STATE OF NEW MEXICO

PROCEDURES FOR ASSESSING STANDARDS ATTAINMENT FOR THE INTEGRATED §303(d) /§305(b) WATER QUALITY MONITORING AND ASSESSMENT REPORT:

ASSESSMENT PROTOCOL

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Appendices

1.0 ASSESSMENT PROCESS OVERVIEW

Pursuant to Section 106(e)(1) of the Federal Clean Water Act (CWA), the SWQB has established appropriate monitoring methods, quality assurance/ quality control (QA/QC) procedures, and assessment methodologies in order to compile and analyze data on the quality of the surface waters of New Mexico. In accordance with the *New Mexico Water Quality Act* (NMSA 1978), the SWQB has developed and implemented a comprehensive water quality monitoring strategy for the surface waters of the State. The monitoring strategy establishes methods of identifying and prioritizing water quality data needs, specifies procedures for acquiring and managing water quality data, and describes how these data are used to progress toward three basic monitoring objectives: to develop water quality-based controls, to evaluate the effectiveness of such controls, and to conduct water quality assessments.

Similar to most other states, SWQB utilizes a rotating basin system approach to water quality monitoring. Using this approach, a select number of watersheds are intensively monitored each year with an established return frequency of approximately every seven years. Revisions to the schedule may be occasionally necessary based on staff and monetary resources that fluctuate on an annual basis. It should also be noted that a watershed is not necessarily ignored during the years in between intensive sampling. The rotating basin program will be supplemented with other data collection efforts such as the funding of long-term USGS water quality gaging stations for long-term trend data.

SWQB maintains current quality assurance and quality control plans that cover all monitoring activities. This document called the *Quality Assurance Project Plan* (QAPP) is updated and certified annually by EPA Region 6. When an intensive surveys is completed, all data are checked against QA/QC measures identified in the QAPP and assessed to determine whether or not designated uses detailed in the current *State of New Mexico Standards of Interstate and Intrastate Surface Waters* (20.6.4 NMAC) are being met. In New Mexico, surface water data are assessed according to this document -- *State of New Mexico Procedures of Assessing Standards Attainment for the Integrated §303(d) /§305(b) Water Quality Monitoring and Assessment Report* (otherwise known as the "assessment protocol"). The United States Environmental Protection Agency (USEPA) does not officially approve individual state's assessment protocols, but they do provide review and comment and consult the document when reviewing the state's draft integrated list. The assessment protocol is periodically updated and is generally based on current EPA assessment guidance.

All summary assessment data is housed in the USEPA-developed Assessment Database version 2 (ADB v.2). Use attainment decisions are then summarized in the *Integrated CWA §303(d)/305(b) Water Quality Monitoring and Assessment Report*. This report is prepared every even numbered calendar year as required by the CWA. Category 5 assessment units on this integrated list (see Section 4.0) constitute the *CWA §303(d) List of Impaired Waters*. The integrated list portion of the report is opened for a minimum 30-day public comment period. Response to Comments are prepared by SWQB and submitted to USEPA Region 6 for review and approval. SWQB also submits the Record of Decision (ROD) document. The ROD is an additional, non-required document that SWQB provides to USEPA and the public, which explains why, and when a particular AU was added and, if applicable, why and when it was removed from Category 5 of the integrated list. An outline of the basic assessment process that SWQB Project Leaders and the §303(d) Coordinator follow when performing assessments is contained in Appendix B. All the above-mentioned documents developed and maintained by the SWQB are available on the SWQB web page: http://www.nmenv.state.nm.us/swqb/swqb.html.

1.1 Monitored Data Assessments

The most rigorous level of assessment is the **Monitored Data Assessment**. It forms the basis of designated use support decisions. Monitored assessments are based on data that reasonably reflect current ambient surface water quality conditions. These data are compared to current USEPA-approved water quality standards (WQS) for the state of New Mexico (NMAC 20.6.4). SWQB intensively surveys watersheds in the state on an approximately 7-year rotational basis. Data types may include chemical/physical, biological, habitat, or toxicological data. In general, data collected by SWQB during these intensive water quality surveys is combined with all readily available data collected the same year by other entities partially listed below, provided the organizations' sampling methods meet state QA/QC requirements as detailed in the *Quality Assurance Project Plan* (QAPP) (SWQB/NMED 2004). This collated data set forms the basis of impairment decisions.

Additional current data will be considered in the analysis, particularly available data from the critical condition of the individual parameter of concern, because the CWA requires water quality standards be protective of designated uses during critical conditions such as years with below average stream flow. This distinction is important to mention because it would not meet the intent of the Clean Water Act to use data collected in non-drought conditions to draw a conclusion of no impairment when available data collected during low flow conditions indicates impairment. SWQB arbitrarily defines current data as data less than five calendar years old. Additional data between 5 and 10 years old may also be considered for large mainstem rivers, such as the San Juan River, Rio Grande, and Pecos River, which tend to have greater amounts of outside data, so that the entire range of hydrologic conditions can be examined.

Outside sources of available data are solicited via public notice of a minimum 30-day period before the draft integrated list of surface waters is prepared. Although SWQB specifically solicits data for watersheds that SWQB sampled since the last assessment and listing cycle, all submitted data will be considered. Submitted data must include sufficient QA/QC information to ensure the data meets state QA/QC requirements. Data packages submitted after the solicitation period and/or related to other watersheds in the state may be considered for subsequent integrated lists.

Data sources could include, but are not limited to:

- New Mexico Environment Department (NMED) SWQB chemical/physical, biological, habitat, or toxicological monitoring data collected during intensive watershed surveys using approved or otherwise accepted quantitative methods;

- Chemical/physical data from recent studies by NMED or other organizations, contractors, or individuals;

- United States Geological Survey (USGS) water quality data that has met USGS QA/QC requirements (i.e., provisional data shall not be used to make use determinations);

- Benthic macroinvertebrate, fish community, and/or fish tissue data collected by NMED or other organizations, contractors, or individuals;

- General Aquatic Wildlife Survey (GAWS), Rapid Bioassessment Protocols (RBP), Thalweg-Watershed Area Link (T-WALK), or other biological/habitat data collected by NMED and other qualified organizations, contractors, or individuals;

- National Pollutant Discharge Elimination System (NPDES) Discharge Monitoring Report (DMR) data and in-stream monitoring data collected during NMED effluent monitoring efforts;

- NPDES storm water permit compliance monitoring data;
- In-stream water quality data from other NMED bureaus such as the Drinking Water, Ground Water, and/or DOE Oversite bureaus;
- Citizen or volunteer monitoring data from a program with a state approved QA/QC plan.

1.2 Documented Observed Effects

Even if water quality data are limited or not available, it is possible to conduct an evaluated assessment based on information other than current site-specific monitoring results. Sources of data could include, but are not limited to:

- Documentation of narrative surface water quality standards non-compliance that may include photographs, video, and results of qualitative assessments that can be definitively linked to a standard exceedence;
- Monitoring data between five and ten years old for streams/lakes and between ten and fifteen years old for large rivers;
- Advisories currently in effect related to fishing, swimming, or drinking water.

These types of information will be housed under the "Observed Effects" field in the Assessment Database version 2 (ADB v.2). An observed effect can be any parameter that the state monitors, but that is not defined as an impairment to a designated use in the state's water quality standards (RTI 2002). One example would be a fish kill whose cause was indeterminate.

2.0 DATA USABILITY AND QUALITY DETERMINATIONS

2.1 Data Management Rules

2.1.1 Data qualifiers and validation codes

SWQB has developed an in-house water quality database to house ambient water quality data as it is collected in the field and/or received from the State Laboratory Division (SLD). This database also contains data qualifiers received from SLD as well as internal validation codes that are added during the data validation process (SWQB/NMED 2004). Chemical/physical data collected by SWQB are eventually uploaded to the national STORET database. The current version of STORET does not have a standard lab remark code field. Per suggestion of the STORET user's group, SWQB will put user-defined information on data qualifiers and internal validation codes into STORET field entitled "Results Comments." Any data with a qualifier code or data validation code that is used in an assessment should be noted. Refer to the current version of the QAPP (SWQB/NMED 2004) for the current definition of all data qualifier and data validation codes as they periodically may change.

- Qualifier codes (lab) – In the past, sets of qualifier codes have varied between the individual sections at State Laboratory Division (SLD) and these codes have changed between years. SWQB is working with SLD to determine a unified set of codes that will be reported consistently by all SLD sections. Standards SWQB data validation codes are defined in the QAPP (SWQB/NMED 2004). All data flagged as "rejected" during internal laboratory QA procedures will not be used for assessment purposes. Other flagged results are usable provided the appropriate caveats are documented and uncertainties in the data are discussed.

  When a value is reported as "less than" the minimum quantification limit (ML) and a statistic such as a mean must be calculated to determine impairment, the ML for this result will be multiplied by 0.5 (Gilbert 1987). This calculated value shall be used in the statistical calculation for non-detects. Sometimes, data are marked with a data qualifier that means the data were off the high end of the scale. These data should be used for assessment purposes. Concentrations detected below ML but above the method detection limit (MDL) are typically flagged with a "J" qualifier that indicates the reported concentration is estimated. The concentration is reported as estimated because the concentration being detected is below the lowest concentration on the calibration curve. There is certainty as to the identification of the chemical but uncertainty as to the reported concentration. These values may be used in an assessment.

- Data validation codes (internal) – SWQB validates data after all data for a particular intensive water quality survey is received from SLD. Internal data validation procedures are detailed in Appendix E of the QAPP (SWQB/NMED 2004). All data with internal SWQB validation codes will still be used for assessment purposes except data flagged as "rejected" (R1, R2, R3, or R4).

  Results from samples that are flagged by the laboratory as "exceeded holding time" will be considered estimates and will be used during the assessment process unless the result is deemed "rejected" based on professional judgment. Method holding times are different for different sample parameters. Sample analysis after the allowed holding time for a sample or sample set may be a result of laboratory oversight, delayed sample shipment, need for reanalysis, or poor planning. The data validator will evaluate the impact of utilizing results from analytical tests where the allowable holding time was exceeded, taking into account the nature of the analysis, the extent of the noncompliance (for example, considering the method holding time limit and whether the holding time was exceeded for one day vs. one month), the sample matrix, any supporting data and the purpose and goals of the sampling and analysis program (USEPA 2002d). From USEPA's perspective, the time and expense associated with the sample collection and processing is forfeited when data exceeding the holding time is rejected even though the analytical results may in fact be accurate and usable (USEPA 2002e).

2.1.2 Duplicates and compliance monitoring sampling data

There may be cases where there are multiple data values on the same day. For example, compliance monitoring of human health criteria requires that three samples be consecutively collected (separated by at least 15 minutes) during the same sampling event at the same location (SWQB/NMED 2003 Work Element 10). Results that indicate two or three exceedences of data taken in this manner will be counted as one exceedence of the criterion for use attainability determinations.

Regarding numeric chemical/physical data with field duplicates, variability between duplicates will first be determined (and flagged if outside of pre-defined precision limits) using the methods detailed in section entitled *Quality Objectives and Criteria for Measurement Data* and Appendix E of the QAPP (SWQB/NMED 2004). The results from field duplicates will be averaged into one value for designated use attainment decisions.

2.1.3 Continuous recording equipment (thermographs and sondes)

Prior to 1998, water temperature was measured once during each site visit and designated use support status related to temperature criteria was determined by applying a percent-of-exceedences formula to these instantaneous temperature data. Periodic instantaneous temperature data do not provide information on maximum daily temperatures, duration of excessive temperatures, or the diurnal and seasonal fluctuations of water temperature. These aspects of temperature are pertinent to aquatic life use. Continuously recording temperature data loggers (i.e., thermographs) are now readily available and provide an extensive multiple-day record of hourly temperatures over the critical time period when temperatures are generally highest. The percent-of-exceedences formula previously used with instantaneous temperature data is inappropriate for assessment of thermograph data and was not designed for that purpose.

The SWQB has been deploying thermographs and applying the temperature assessment protocol since the 2000-2002 CWA §303(d) listing cycle (see Appendix C). This protocol developed by a multi-agency workgroup is more technically sound than simply applying percentages to limited instantaneous temperature data and better addresses the intent of the Clean Water Act to use best available technology and to incorporate magnitude and duration concerns into water quality monitoring, assessment, and standards development. This protocol addresses biases introduced when using instantaneous data to assess water quality parameters with significant diurnal fluctuation. Based on the success of this effort, the SWQB plans to formally incorporate these changes into the water quality standards and has drafted large data set protocols to address other parameters with known diurnal fluxes, such as pH and dissolved oxygen (see Appendices F and G).

2.1.4 Limited data sets

SWQB does not require a minimum number of data points to make use attainment decisions. USEPA does not recommend the use of rigid, across the board, minimum sample size requirements in the assessment process. Target sample sizes should not be applied in an assessment methodology as absolute exclusionary rules (USEPA 2003). The use of limited data sets is acceptable to USEPA and commonly used in other states as limited financial resources, and both limited field and laboratory staff resources, often dictate the number of samples that can be collected and analyzed (USEPA 2002a). The situation of limited data sets for physical/chemical and fecal coliform parameters is addressed in the assessment tables (Section 3). If there are fewer than seven data points, the assessment is made based on the number of exceedences versus the percent-of-exceedence rate. In New Mexico, SWQB is allocated a specific number of "WTUs" from the State Laboratory Division (SLD) each year. SLD performs all of the chemical analyses for SWQB. They have a limited capacity because they support several state agencies that require water and soil analyses. Therefore, laboratory capacity, staff resources, and financial resources (for items such as field supplies and travel expenses) often result in limited sample size.

2.1.5 Application of WQS during low flow conditions

Data collected during all flow conditions, including low flow conditions (i.e., flows below the 4Q3), will be used to determine designated use attainment status during the assessment process. 4Q3 values are to be utilized as minimum dilution assumptions for developing discharge permit effluent limitations. In terms of assessing designated use attainment in ambient surface waters, WQS apply at all times under all flow conditions. The intent of the Clean Water Act would not be met if some entity would suddenly be allowed to dump pollutants into a stream in violation of the WQS simply because the stream was currently below some pre-established low flow value.

2.1.6 Assessing chronic WQS when composite data is unavailable

During the 2000 and 2001 SWQB intensive watershed surveys, the sampling regime consisted of two consecutive days of sampling in the spring, three days in the summer, and three days in the fall in order to gather consecutive day data. Starting with the 2002 SWQB intensive watershed survey, the sampling regime was adjusted to sample once per month over an eight-month period in order to 1) better characterize the waterbody throughout most of the hydrograph, and 2) acquire data points that are statistically independent with respect to time. Because of this sampling scheme, consecutive-day data is usually not available to calculate 4-day averages. Few states and tribes are obtaining composite data over a 4-day sampling period for comparison to chronic criteria due primarily to budgetary and staff time constraints. USEPA believes that 4-day composites are not an absolute requirement for evaluating whether chronic criteria are being met when determining use attainment status. Therefore, USEPA affords states and tribes the flexibility to define how they will assess use attainment when 4-day composite data are not available (USEPA 1997). If consecutive day data are not available, a chronic screening level of 1.5 times the chronic criterion will first be calculated. The multiplier of 1.5 was also derived as a way of addressing small data sets (USEPA 1991). This chronic screening level value will then be compared to individual grab sample results as explained in the assessment tables (Section 3.0).

2.2 Data Quality Levels

2.2.1 Aquatic life use data types

It is recognized that not all data of a certain type are of equal quality or rigor. The following tables describe defined levels of data quality or confidence for each type of data recognized for use in making aquatic life support determinations. These tables are adapted from the *Consolidated Assessment and Listing Methodology: Towards a Compendium of Best Practices* guidance document (USEPA 2002a). Tables for determining the level of confidence for biological, habitat, chemical/physical, and toxicological data types are presented. It is necessary to evaluate data quality when assessment performed with more than one data type result in conflicting use attainment decisions (see Section 3.1.4 for more detail). These tables are included only for aquatic life use determinations because it is the only use for which multiple data types are currently recognized. While data quality tables are not available for other designated uses, it is possible to apply the general guidelines to other data to determine if they are of sufficient quality to support use designations. For example, the table for chemical/physical determinations may be used to assign a level of confidence to data used for making a determination of drinking water supply use attainment.

Tables 2.1 through 2.4 classify the data level or rigor of a data type by its technical components and describe the level of effort (spatial or temporal coverage) necessary to achieve each level. Level 4 represents data of the highest rigor and the highest level of confidence while Level 1 represents the lowest acceptable level of confidence. Information of data confidence is housed in ADB v.2.

Table 2.1 Hierarchy of bioassessment approaches for evaluation of aquatic life use attainment

LEVEL OF INFO	TECHNICAL COMPONENTS	SPATIAL/TEMPORAL COVERAGE	DATA QUALITY
1 LOW	Visual observation of biota; reference conditions not used; simple documentation	Limited monitoring; extrapolation from other sites	Unknown or low precision and sensitivity; professional biologist not required.
2 FAIR	One assemblage (usually invertebrates); reference conditions pre-established by professional biologist; biotic index or narrative evaluation of historical records	Limited to a single sampling; limited sampling for site-specific studies; identifications to family level	Low to moderate precision and sensitivity; professional biologist may provide oversight
3 GOOD	Single assemblage usually the norm; reference conditions may be site specific, or composite of sites; biotic index (interpretation may be supplemented by narrative evaluation of historical records)	Monitoring of targeted sites during a single season*; may be limited sampling for site-specific studies; may include limited spatial coverage for watershed-level assessments; identifications to genus and species level	Moderate precision and sensitivity; professional biologist performs survey or provides training for sampling; professional biologist performs assessment
4 EXLNT	Generally two assemblages, but may be one if high data quality; regional (usually based on sites) reference conditions used; biotic index (single dimension or multi metric index)	Monitoring during 2 sampling seasons*; broad coverage of sites for either site-specific or watershed assessments; identifications to genus and species level; conducive to regional assessments using targeted or probabilistic design	High precision and sensitivity; professional biologist performs survey and assessment

NOTES: *Seasons are defined as October – December, January – March, April – June, and July – September.

Table 2.2 Hierarchy of habitat assessment approaches for evaluation of aquatic life use attainment

LEVEL OF INFO	TECHNICAL COMPONENTS	SPATIAL/TEMPORAL COVERAGE	DATA QUALITY
1 LOW	Visual observation of habitat characteristics; no true assessment; documentation of readily discernable land use characteristics that might alter habitat quality; no reference conditions	Sporadic visits; sites are mostly from road crossings or other easy access	Unknown or low precision and sensitivity; professional scientist not required.
2 FAIR	Visual observation of habitat characteristics and simple assessment; use of land use maps for characterizing watershed condition; reference conditions pre-established by professional scientist	Limited to annual visits non-specific to season; generally easy access; limited spatial coverage and/or site-specific studies	Low precision and sensitivity; professional scientist not involved, or only by correspondence
3 GOOD	Visual-based habitat assessment using standard operating procedures (SOPs); may be supplemented with quantitative measurements of selected parameters; conducted with bioassessment; data on land use may be compiled and used to supplement assessment	Assessment during single season usually the norm; spatial coverage may be limited sampling or broad and commensurate with biological sampling; assessment may be regional or site-specific	Moderate precision and sensitivity; professional scientist performs survey or provides oversite and training
4 EXLNT	Assessment of habitat based on quantitative measurements of instream parameters, channel morphology, and floodplain characteristics; conducted with bioassessment; data on land use compiled and used to supplement assessment; reference condition used as a basis for assessment	Assessment during 1-2 seasons; spatial coverage broad and commensurate with biological sampling; assessment may be regional or site-specific	High precision and sensitivity; professional scientist performs survey and assessment

Table 2.3 Hierarchy of chemical/physical data levels for evaluation of use attainment

LEVEL OF INFO	TECHNICAL COMPONENTS	SPATIAL/TEMPORAL COVERAGE	DATA QUALITY
1 LOW	Any one of the following: • Water quality monitoring using grab sampling • Water data extrapolated from up stream or downstream station where homogeneous conditions are expected • BPJ based on land use data, location of sources	Low spatial and temporal coverage: • Quarterly or less frequent sampling with limited period of record (e.g., 1 day) • Limited data during key periods or at high or low flow (critical hydrological regimes) • Data are >5 years old and likely not reflective of current conditions	Approved QA/QC protocols are not followed or QA/QC results are inadequate Methods not documented Inadequate metadata
2 FAIR	Any one of the following: • Water quality monitoring using grab sampling • Rotating basin surveys involving single visits • Synthesis of existing or historical information on fish tissue contamination levels • Screening models based on loadings data (not calibrated or verified) • Verified volunteer monitoring data	Moderate spatial and temporal coverage: • Bimonthly or quarterly sampling at fixed stations • Sampling during a key period (e.g. fish spawning seasons, high and/or low flow) • Stream basin coverage, multiple sites in a basin	Low precision and sensitivity QA/QC protocols followed, QA/QC results adequate Approved SOPs used for field and lab; limited training Adequate metadata
3 GOOD	Any one of the following: • Water quality monitoring using grab sampling • Rotating basin surveys involving multiple visits or automatic sampling • Calibrated models (calibration data <5 years old) • Limited use of continuous monitoring instrumentation	Broad spatial and temporal coverage of site with sufficient frequency and coverage to capture acute events: • Monthly sampling during key periods (e.g. critical hydrological regimes and fish spawning seasons), multiple samples at high and low flows • Period of sampling adequate to monitor for chronic concerns* • Lengthy period of record for fixed station sites (sampling over a period of months)	Moderate precision and sensitivity QA/QC protocols followed, QA/QC results adequate Approved SOPs used for field and lab Adequate metadata
4 EXLNT	All of the following: • Water quality monitoring using composite samples, series of grab samples, and continuous monitoring devices • Limited follow-up sediment quality sampling or fish tissue analyses at sites with high probability of contamination	Broad spatial coverage (several sites) and temporal (long-term, e.g. 5-years) coverage of fixed sites with sufficient frequency and coverage to capture acute events, chronic conditions, and all other potential chemical/physical impacts: • Monthly sampling during key periods (e.g., spawning, critical hydrological regimes) including multiple samples at high and low flows • Continuous monitoring (e.g. use of thermographs, sondes, or similar devices)	High precision and sensitivity QA/QC protocols followed, QA/QC results adequate Approved SOPs used for field and lab; samplers well trained Adequate metadata

NOTE: *See section 2.1.6 for additional information.

Table 2.4 Hierarchy of toxicological approaches and levels for evaluation of aquatic life use attainment

LEVEL OF INFO	TECHNICAL COMPONENTS	SPATIAL/TEMPORAL COVERAGE	DATA QUALITY
1 LOW	Any one of the following: • Acute or chronic WET for effluent dominated channel • Acute ambient • Acute sediment	1 ambient or sediment sample tested in an assessment unit or site	Unknown/Low; minimal replication used; laboratory quality or expertise unknown
2 FAIR	Any one of the following: • Acute or chronic ambient • Acute sediment • Acute and chronic WET for effluent dominated channel • Chronic ambient or acute or chronic sediment	2 ambient or sediment sample tested in an assessment unit or site on 2 different dates	Low/moderate; little replication used within a site; laboratory quality or expertise unknown or low
3 GOOD	Any one of the following: • Acute and chronic WET for effluent dominated system • Chronic ambient or acute or chronic sediment	3 ambient or sediment sample tested in an assessment unit or site on 3 different dates	Moderate/high; replication used; trained personnel and good laboratory quality
4 EXLNT	Both of the following: • Acute and chronic ambient and • Acute or chronic sediment	$\geq$ 4 tests in total based on samples collected in a assessment unit or site on 4 different dates	High; replication used; trained personnel and good lab quality

2.2.2 Contact use data type

Pathogen data is used to make determine use support for Primary Contact and Secondary Contact designated uses. ADB v.2 also houses information on pathogen data quality levels. Pathogen data typically consists of fecal coliform and/or E. coli data. The CALM guidance does not contain any examples of data quality criteria to discern low to excellent data quality (USEPA 2002a). In reality, there is no need to evaluate pathogen data quality because there cannot be conflicting contact use attainment conclusions from various types of data as there can in aquatic life use attainment decisions. The only data type used to make contact use attainment decisions in New Mexico is pathogen data because there are no contact use water quality standards for non-pathogen data.

3.0 INDIVIDUAL DESIGNATED USE SUPPORT DETERMINATIONS

Water Quality Standards (WQS) are actually a triad of elements that work in concert to provide water quality protection. These three elements are: designated uses, numerical and narrative criteria, and an antidegradation policy. Designated uses are the defined the uses of a particular surface water body. Each water body has several designated uses. For example, Domestic Water Supply is a designated use. Designated use definitions and their assignment to various stream segments in New Mexico can be found in the *Standards for Interstate and Intrastate Surface Waters* (20.6.4 NMAC). Numeric and narrative criteria have been adopted to protect these designated uses. There are both site-specific criteria and use-specific criteria in New Mexico's WQS document. All references to criteria throughout this document refer to these state-adopted, USEPA-approved numerical limits found in 20.6.4. NMAC. The antidegradation policy ensures that existing uses and levels of water quality necessary to protect these uses will be maintained and protected (NMAC 20.6.4.8).

WQS segments defined in NMAC 20.6.4 are further divided into assessment units (AUs) for use impairment determination and linked to the National Hydrographic Dataset (NHD) for national electronic reporting requirements. AUs are stream reaches, lakes, or reservoirs defined by hydrologic boundaries, WQS, geology, topography, incoming tributaries, surrounding land use/ land management, etc. As stated in Section 1.0, data collected at representative stations during SWQB intensive surveys along with outside data form the basis of use support determinations for each AU. Stations are chosen to reflect current ambient conditions. The following subsections provide guidelines used to interpret available data. These guidelines will be used to make determinations of use support for each designated use in each AU, utilizing the previously described data sets. Some level of flexibility is built into these guidelines to account for uncertainties such as the natural variability of water quality, the lack of extensive data necessary to make more definitive assessments, and the transitory nature of many pollutants. Each designated use has one or more tables with specific requirements for determining use attainment based on the type of data being evaluated. Each type of data is first evaluated separately when determining aquatic life use support. Guidance on how to reconcile two or more data types with differing use attainment determinations is found in Section 3.1.4. In addition to the following subsections, several specific assessment protocols for temperature, sedimentation/siltation (stream bottom deposits), nutrients, dissolved oxygen, and pH have been developed. These protocols are included in appendices C through G.

In previous New Mexico §305(b) reports and §303(d) lists, five designated use determinations were possible according to earlier versions of the SWQB assessment protocol: Full Support, Full Support Impacts Observed, Partial Support, Not Supported, or Not Assessed. These determinations were modified from recommendations in the §305(b) report guidance (USEPA 1997). The most recent guidance from USEPA recommends the following use attainment categories (USEPA 2001, USEPA 2002a, USEPA 2003): **Fully Supporting, Not Supporting, Insufficient Information, and Not Assessed.** For every assessment unit, one of these four categories is assigned to every designated use applicable to that given assessment unit.

No determination of Fully Supporting or Not Supporting may be made in the absence of monitored data. It is understood that any assessment, particularly when using biological and/or habitat data, may involve some level of best professional judgment (BPJ). However, evaluations based solely on professional judgment, literature statements, or public comments without reliable data to support the decision shall not be the only basis for a listing or de-listing. For segments where there are no monitored data but for which reliable and documented evaluated data that suggest impairment, the potential impairment will be noted in the "Observed Effects" portion of ADB v.2. To those AUs for which there are no reliable monitored data for any criteria within an applicable designated use, a designation of Not Assessed will be assigned that designated use.

3.1 Assessing Aquatic Life Use Support

Use assessment decisions should consider and integrate, whenever possible and appropriate, results of various monitoring data types. These include biological, habitat/stream channel condition, chemical/physical, and toxicological monitoring data. Data quality associated with these types can be found in Section 2.1.1.

3.1.1 Biological and habitat data

Table 3.1 explains how interpret biological and habitat data to assess aquatic life use support. Currently benthic macroinvertebrate sampling is the primary form of biomonitoring utilized by the state of New Mexico. SWQB also monitors fish assemblages and algae in a limited number of streams. Expanded assessment protocols for sedimentation/siltation (stream bottom deposits) and plant nutrient narrative criteria that incorporate benthic macroinvertebrate sampling can be found in Appendices D and E, respectively. To determine impairment due to excessive sedimentation, the assessment approach is based on the concept of comparing the actual conditions of a specific stream with the expected conditions (i.e., reference stream) to determine use attainment of the narrative stream bottom deposit standard. This rapid bioassessment protocol (RBP) approach is consistent with USEPA guidance.

When the RBP method was first introduced, the concept of reference condition was typically limited to pristine streams (Plafkin et al. 1989). This concept was updated to acknowledge the reality of a wider range of aquatic conditions that reflect more than minimal impacts, including historic and dominate land and water use activities (Barbour et al. 1999). This broader definition of reference condition still allows for the definition of reasonable and attainable targets or goals to assess potential impairment to the aquatic community. Full utilization of this updated approach requires state and tribes to develop their own region-specific biocriteria. SWQB is in the process of reassessing and refining current biomonitoring and habitat assessment protocols to better determine reference conditions in New Mexico surface waters and to eventually determine numeric biocriteria. The process of developing biocriteria began in 2002 with assistance from USEPA Region 6 and TetraTech.

While biocriteria is not yet developed to assess numeric criteria, we continue to utilize benthic macroinvertebrate data to determine attainment of certain narrative criteria, such as excessive sedimentation (i.e., bottom deposits) (Appendix D). Until biocriteria development is complete, we will continue to utilize the guidance percentage listed in the original RBP document (Plafkin et al. 1989) and will limit the use of benthic macroinvertebrates in use support determinations to assessing stream bottom deposits, nutrients, and cases of marginal turbidity exceedences where the exceedences are temporary and due to natural causes (i.e., snowmelt runoff or high intensive summer thunderstorms).

Table 3.1 Interpreting biological and habitat data to assess Aquatic Life Use Support

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
•**Biological assemblages**	Reliable data indicate functioning, sustainable biological assemblages not modified significantly beyond the natural range of reference condition (>83% of reference condition).*	At least one biological assemblage indicates moderate to severe impairment when compared to reference condition (≤79% of reference conditions). *	Currently, these percentages are applied to benthic macroinvertebrates data only. Reference condition is defined as the best situation to be expected within an ecoregion (watershed reference site). Reference sites have balanced trophic structure and optimum community structure (composition & dominance) for stream size and habitat quality.
•**Habitat Measurements**	• Data indicate channel morphology, substrate composition, bank/riparian structure, and flow regime are similar to reference reach. • The stream has riparian vegetation approaching that of reference reach. • Measurements indicate that the stream geomorphology is similar to reference condition.	• Moderate to severe habitat alteration by channelization and dredging, bank failure, heavy watershed erosion, or alteration of flow. • Removal of riparian vegetation widespread; substantial encroachment of undesirable, non-indigenous species. • Measurements indicate that the stream is extremely unstable -- Type F, G, or D) (Rosgen 1996).	Vegetation may include desirable, non-indigenous species.

NOTE: *Percentages are based on Plafkin et al (1989). The 4% gap allows for some best professional judgment.

3.1.2 Chemical/physical data

Table 3.2 explains how to interpret chemical/physical data to assess aquatic life use support. Refer to Sections 20.6.4.900.J, 20.6.4.900.M, and 20.6.4.900.N of the Water Quality Standards for the numeric standards for metals, chlorine, and ammonia, respectively, and Sections 20.6.4.900.M for chronic and acute values. Refer to the appropriate stream segment number and the appropriate aquatic life use category in Section 206.4.900 of the Water Quality Standards for numeric standards for conventional chemical/physical parameters. Conventional parameters monitored to determine aquatic life use support include: temperature, turbidity, pH, dissolved oxygen, specific conductance, and total phosphorus. Expanded assessment protocols for temperature when thermograph data is available, and draft large data set protocols for dissolved oxygen (DO), and pH, are found in Appendices C, F, and G respectively. Until the draft protocols are finalized, Table 3.1 will be applied to large dissolved oxygen and pH data sets to determine potential impairment.

Table 3.2 Interpreting chemical/physical data to assess Aquatic Life Use Support

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
•**Conventional parameters** (e.g., pH, temperature, DO, specific conductance, turbidity, total phosphorus) **A)** 1 to 7 samples **B**) > 7 samples	**A**) For any one pollutant, no more than one exceedence of the criterion. **B**) For any one pollutant, criterion exceeded in <15% of measurements.	**A**) For any one pollutant, more than one exceedence of the criterion. **B**) For any one pollutant, criterion exceeded in ≥ 15% of measurements.	Biases in DO, pH, and temperature sampling (such as diurnal flux) should be addressed by sampling with continuously-recording sondes and thermographs whenever possible.* Turbidity exceedence attributable to natural causes are not considered exceedences of the criteria.[a] Reference NMAC 20.6.4.12.J for narrative turbidity criteria.
•**Toxic substance** (e.g., priority pollutants, ammonia, chlorine, metals)	For any one pollutant, no more than one exceedence of the acute criterion, and no more than one exceedence of the chronic criterion or chronic screening level in three years.	For any one pollutant, more than one exceedence of the acute criterion, or more than one exceedence of the chronic criterion or chronic screening level in three years.	The **chronic criterion** shall be applied to the arithmetic mean of the analytical results of consecutive-day samples. Consecutive-day samples are often not available. When this is the case, the **chronic screening level** of 1.5 times the chronic criterion shall be first be calculated and then compared to individual grab sample result to determine whether an exceedence has occurred (see Section 2.1.6).

NOTE: *See appendices C, F, and G.
[a]When available, benthic macroinvertebrate data is used to verify that aquatic life is not impaired according to Table 3.1.

3.1.3 Toxicological data

Table 3.3 explains how to interpret toxicological data to assess aquatic life use support. Refer to NMAC 20.6.4.12.F for the narrative general standards which states "Surface waters of the state shall be free of toxic pollutants from other than natural causes in amounts, concentrations or combinations which affect the propagation of fish…" Toxicity is a valuable indicator for assessing and protecting against impacts on water quality and designated uses caused by the aggregate toxic effect of pollutants. Contaminants may flow directly from industrial and municipal waste dischargers, may come from polluted runoff in urban and agricultural areas, or may collect in the sediments. Toxicity evaluations can be used to assess the type and extent of degraded water quality (USEPA 2002a). Acute toxicities of substances are determined using at least two species tested in whole effluent and/or ambient stream water as well as a series of dilutions.

Table 3.3 Interpreting toxicological data to assess Aquatic Life Use Support

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
•**Acute and/or chronic toxicity testing**	Significant effect noted in no more than one acute tests as compared to controls or reference conditions, and in no more than one chronic test in three years as compared to controls or reference conditions.	Significant effect noted in more than one acute tests as compared to controls or reference conditions, or in more than one chronic test in three years as compared to controls or reference conditions.	Significant effect refers to a statistically significant difference as defined in the latest USEPA procedures documents for acute and chronic toxicity testing (USEPA 2002b, 2002c). Reference controls will be used to compensate for possible toxic effects from naturally occurring conditions (i.e. high salinity).

3.1.4 Conflicting aquatic use support determinations

For aquatic life use assessments, it is possible that data of differing types may lead to differing use attainment determinations for the same assessment unit. For example, there may be chemical/physical data that indicate **Not Supporting** and biological data that indicate **Fully Supporting**. If more than two data types are available for assessment, a weight-of-evidence approach will be adopted. This approach will consider data type and data quality in reaching a final aquatic life use determination. Generally, data types with higher data quality will be given more weight. Once biocriteria are fully developed for the state of New Mexico, biological data will be given greater weight than other data types in making use support determinations when data quality levels are comparable, with the exception of toxic chemical data (see Figure 3.1). Biological assessments provide an integrated assessment of ecological health, are not as subject to transient variability as chemical assessments, and provide a direct measure of the designated goal of providing for the protection and propagation of fish, shellfish, and wildlife as stated in the CWA.

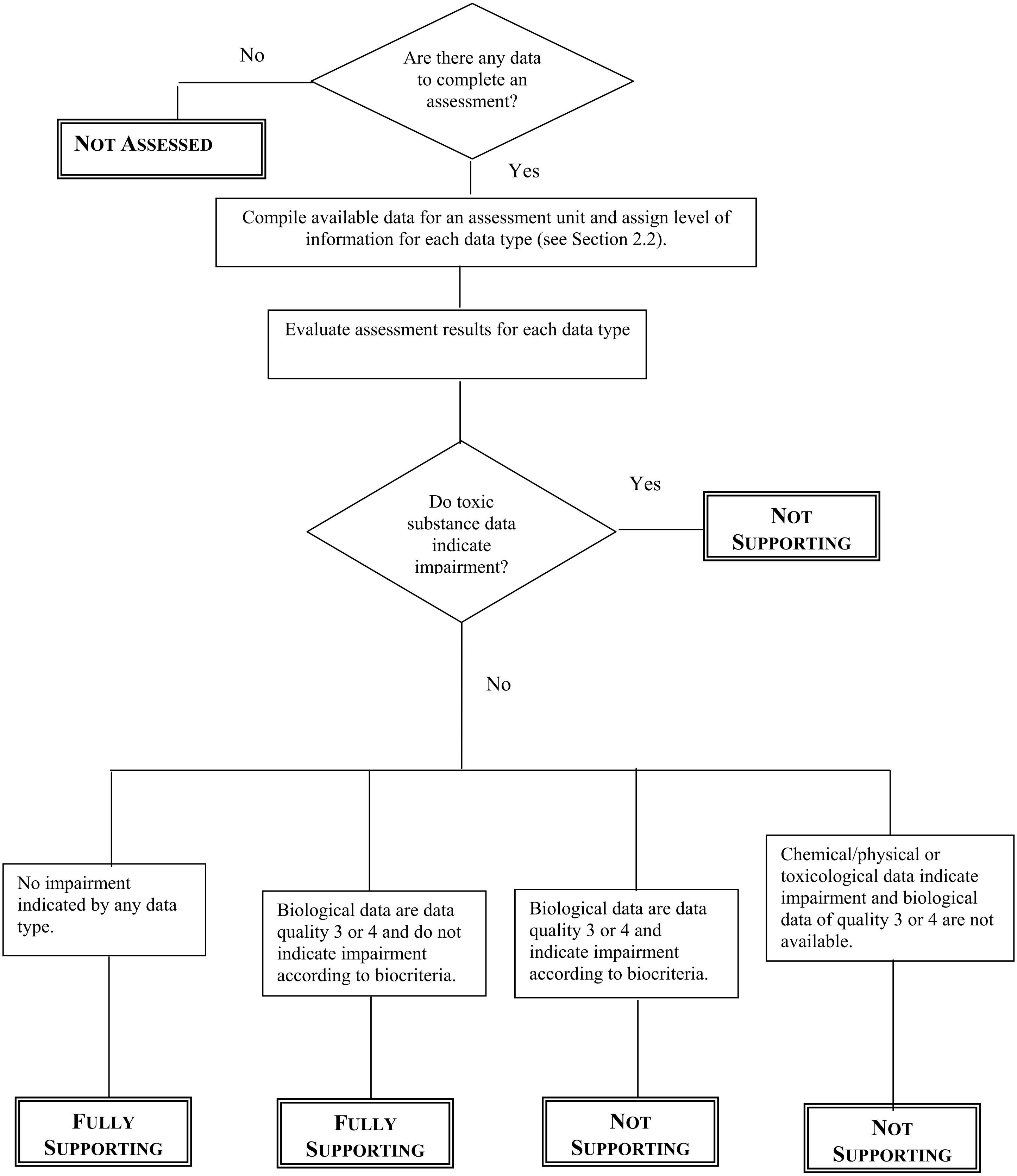

Figure 3.1 General flowchart for determining Aquatic Life Use Support

3.2 Assessing Domestic Water Supply Use Support

Table 3.4 explains how to interpret chemical/physical data to assess domestic water supply use support Refer to Section 20.6.4.900.B and Section 20.6.4.900.M of the Water Quality Standards for the numeric standards for domestic water supply.

Table 3.4 Interpreting chemical/physical data to assess Domestic Water Supply Use Support

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
•Toxic substance (e.g., radionuclides, priority pollutants, metals)	For any one pollutant, no exceedence of the criterion.	For any one pollutant, one or more exceedence of the criterion.	
•Nitrate	No exceedence of the criterion.	One or more exceedences of the criterion.	

3.3 Assessing Primary and Secondary Contact Use Support

Table 3.5 explains how to interpret bacteriological data to assess contact use support Refer to Paragraph B under the appropriate stream segment number and to Section 20.6.4.900.G of the Water Quality Standards for standards to determine use support for primary and secondary contact recreation.

Table 3.5 Interpreting bacteriological data to assess Contact Use Support

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
•Fecal coliform			
A) 1 to 7 samples	**A**) No more than one exceedence of the single sample criterion.	**A**) More than one exceedence of the single sample criterion.	SWQB proposes replacing fecal coliform criteria with *E. coli* criteria during the next triennial review (proposed under 20.6.4.900).
B) > 7 samples	**B**) Single sample criterion is exceeded in <15% of samples and geometric mean criterion is met	**B**) Single sample criterion exceeded in ≥ 15% of measurements and/or geometric mean criterion is not met.	USEPA guidance recommends a 10% exceedence rate to determine impairment (USEPA 2002a). Because short holding times often lead to a small total number of samples, USEPA Region 6 believes a 25% exceedence rate is acceptable.

3.4 Assessing Irrigation Use Support

Table 3.6 explains how to interpret chemical/physical and bacteriological data to assess irrigation use support Refer to Section 20.6.4.900.D and 20.6.4.900.M of the Water Quality Standards for the numeric standards for the protection of irrigation use.

Table 3.6 Interpreting chemical/physical and bacteriological data to assess Irrigation Use Support

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
•Toxic substance (e.g., radionuclides, priority pollutants, metals)	For any one pollutant, no more than one exceedence of the criterion.	For any one pollutant, more than one exceedence of the criterion.	
•Fecal coliform **A)** 1 to 7 samples	**A**) No more than one exceedence of the single sample criterion.	**A**) More than one exceedence of the single sample criterion.	SWQB proposes replacing fecal coliform criteria with *E. coli* criteria during the next triennial review (proposed under 20.6.4.900).
B) > 7 samples	**B**) Single sample criterion is exceeded in <15% of samples and geometric mean criterion is met.	**B**) Single sample criterion exceeded in ≥ 15% of measurements and/or geometric mean criterion is not met.	USEPA guidance recommends a 10% exceedence rate to determine impairment (USEPA 2002a). Because short holding times often lead to a small total number of samples, USEPA Region 6 believes a 25% exceedence rate is acceptable.

3.4 Assessing Livestock Watering Support

Table 3.7 explains how to interpret chemical/physical data to assess livestock watering use support Refer to Section 20.6.4.900.K and 20.6.4.900.M of the Water Quality Standards for the numeric standards for the protection of livestock watering.

Table 3.7 Interpreting chemical/physical data to assess Livestock Watering Use Support

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
•**Toxic substance** (e.g., radionuclides, priority pollutants, metals)	For any one pollutant, no more than one exceedence of the criterion.	For any one pollutant, more than one exceedence of the criterion.	

3.5 Assessing Wildlife Habitat Use Support

Table 3.8 explains how to interpret chemical/physical data to assess wildlife habitat use support. Refer to Section 20.6.4.900.L of the Water Quality Standards for narrative criteria and 20.6.4.900.M for numeric standards for the protection of wildlife habitat use.

Table 3.8 Interpreting chemical/physical data to assess Wildlife Habitat Use Support

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
•**Toxic substance** (e.g., PCBs, DDT, cyanide, chlorine, metals)	For any one pollutant, no more than one exceedence of the acute criterion, and no more than one exceedence of the chronic criterion or chronic screening level in three years.	For any one pollutant, more than one exceedence of the acute criterion, or more than one exceedence of the chronic criterion or chronic screening level in three years.	The **chronic criterion** shall be applied to the arithmetic mean of the analytical results of consecutive-day samples. Consecutive-day samples are often not available. When this is the case, the **chronic screening level** of 1.5 times the chronic criterion shall be first be calculated and then compared to individual grab sample result to determine whether an exceedence has occurred (see Section 2.1.6).

3.6 Assessing Human Health Use Support

Table 3.9 explains how to interpret chemical/physical data to assess human health use support. Refer to Section 20.6.4.900.M of the Water Quality Standards for the numeric standards for protection of human health.

Table 3.9 Interpreting chemical/physical data to assess Human Health Use Support

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
•**Toxic substance** (e.g., cyanide, PAHs, pesticides, PCBs, metals)	For any one pollutant, no more than one exceedence of the criterion.	For any one pollutant, more than one exceedence of the criterion.	

3.7 Assessing Non-Use Specific Criterion

Table 3.9 explains how to interpret chemical/physical data to assess segment-specific numeric criteria. Refer to Sections 20.6.4.101 through 20.6.4.805 of the Water Quality Standards for segment-specific numeric criterion not expressly related to any particular use.

Table 3.9 Interpreting chemical/physical data to assess segment-specific numeric criteria

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
•**Total dissolved solids, sulfate, chloride**			
A) 1 to 7 samples	**A**) For any one pollutant, no more than one exceedence of the criterion.	**A**) For any one pollutant, more than one exceedence of the criterion.	
B) > 7 samples	**B**) For any one pollutant, criterion exceeded in <15% of measurements.	**B**) For any one pollutant, criterion exceeded in ≥ 15% of measurements.	

4.0 ASSESSMENT UNIT CATEGORY DETERMINATIONS FOR INTEGRATED LIST

The determination of use support using Section 3.0 and other specified protocols are then combined to determine the overall water quality standard attainment category for each AU (USEPA 2001). The unique assessment categories for New Mexico are described as follows (see also Figure 4.1):

1. **Attaining the water quality standards for all designated and existing uses.** AUs are listed in this category if there are data and information that meet all requirements of the assessment and listing methodology and support a determination that the water quality criteria are attained.

2. **Attaining some of the designated or existing uses based on numeric and narrative parameters that were tested, and no reliable monitored data is available to determine if the remaining uses are attained or threatened.** AUs are listed in this category if there are data and information that meet requirements of the assessment and listing methodology to support a determination that some, but not all, uses are attained based on numeric and narrative water quality criteria that were tested. Attainment status of the remaining uses is unknown because there is no reliable monitored data with which to make a determination.

3. **No reliable monitored data and/or information to determine if any designated or existing use is attained.** AUs are listed in this category where data to support an attainment determination for any use are not available, consistent with requirements of the assessment and listing methodology.

4. **Impaired for one or more designated uses, but does not require development of a TMDL because:**

   A. **TMDL has been completed.** AUs are listed in this subcategory once all TMDL(s) have been developed and approved by USEPA that, when implemented, are expected to result in full attainment of the standard. Where more than one pollutant is associated with the impairment of an AU, the AU remains in Category 5A (see below) until all TMDLs for each pollutant have been completed and approved by USEPA.

   B. **Other pollution control requirements are reasonably expected to result in attainment of the water quality standard in the near future**. Consistent with the regulation under 130.7(b)(i),(ii), and (iii), AUs are listed in this subcategory where other pollution control requirements required by local, state, or federal authority are stringent enough to implement any water quality standard (WQS) applicable to such waters.

   C. **Impairment is not caused by a pollutant.** AUs are listed in this subcategory if a pollutant does not cause the impairment. For example, USEPA considers flow alteration to be “pollution” vs. a “pollutant.”

5. **Impaired for one or more designated or existing uses**. The AU is not supporting one or more of its designated uses because one or more water quality standards are not attained according to current water quality standards and assessment methodologies. **This category constitutes the *CWA §303(d) List of Impaired Waters*.** In order to relay additional information to stakeholders including SWQB staff, Category 5 is further broken down into the following categories:

   A. **A TMDL is underway or scheduled.** AUs are listed in this category if the AU is impaired for one or more designated uses by a pollutant. Where more than one pollutant is associated with the impairment of a single AU, the AU remains in Category 5A until TMDLs for all pollutants have been completed and approved by USEPA.

   B. **A review of the water quality standard will be conducted.** AUs are listed in this category when it is possible that water quality standards are not being met because one or more current designated use is inappropriate. After a review of the water quality standard is conducted, a Use Attainability Analysis (UAA) will be developed and submitted to USEPA for consideration, or the AU will be moved to Category 5A and a TMDL will be scheduled.

   C. **Additional data will be collected before a TMDL is scheduled.** AUs are listed in this category if there is not enough data to determine the pollutant of concern or there is not adequate data to develop a TMDL. For example, AUs with biological impairment will be listed in this category until further research can determine the particular pollutant(s) of concern. When the pollutant(s) are determined, the AU will be moved to Category 5A and a TMDL will be scheduled. If it is determined that the current designated uses are inappropriate, it will be moved to Category 5B and a UAA will be developed. If it is determined that "pollution" is causing the impairment (vs. a "pollutant"), the AU will be moved to Category 4C.

This change in reporting was developed in response to a recent National Research Council (NRC) report and a desire to provide a clearer summary of the nation's water quality status and management actions necessary to protect and restore them (NRC 2001, USEPA 2001). With a few additions and minor changes in terminology, the information requested in the *Integrated Listing* guidance (USEPA 2001) and CALM guidance (USEPA 2002a) were previously suggested in earlier 305(b) reporting guidance (USEPA 1997). The earlier guidance formed the basis of previous SWQB assessment protocols.

Assessment information is housed in ADB v.2 (RTI 2002). This database was designed to help states implement suggestions in the Integrated Listing guidance (USEPA 2001). The database is first populated with AU information, associated designated uses, comments, and any supporting documentation. Individual designated use attainment decisions (i.e., Full Support, Non Support, Not Assessed) are then entered for each AU. ADB v.2 then automatically determines the water quality standards attainment category for each AU based on the information entered for each applicable designated use.

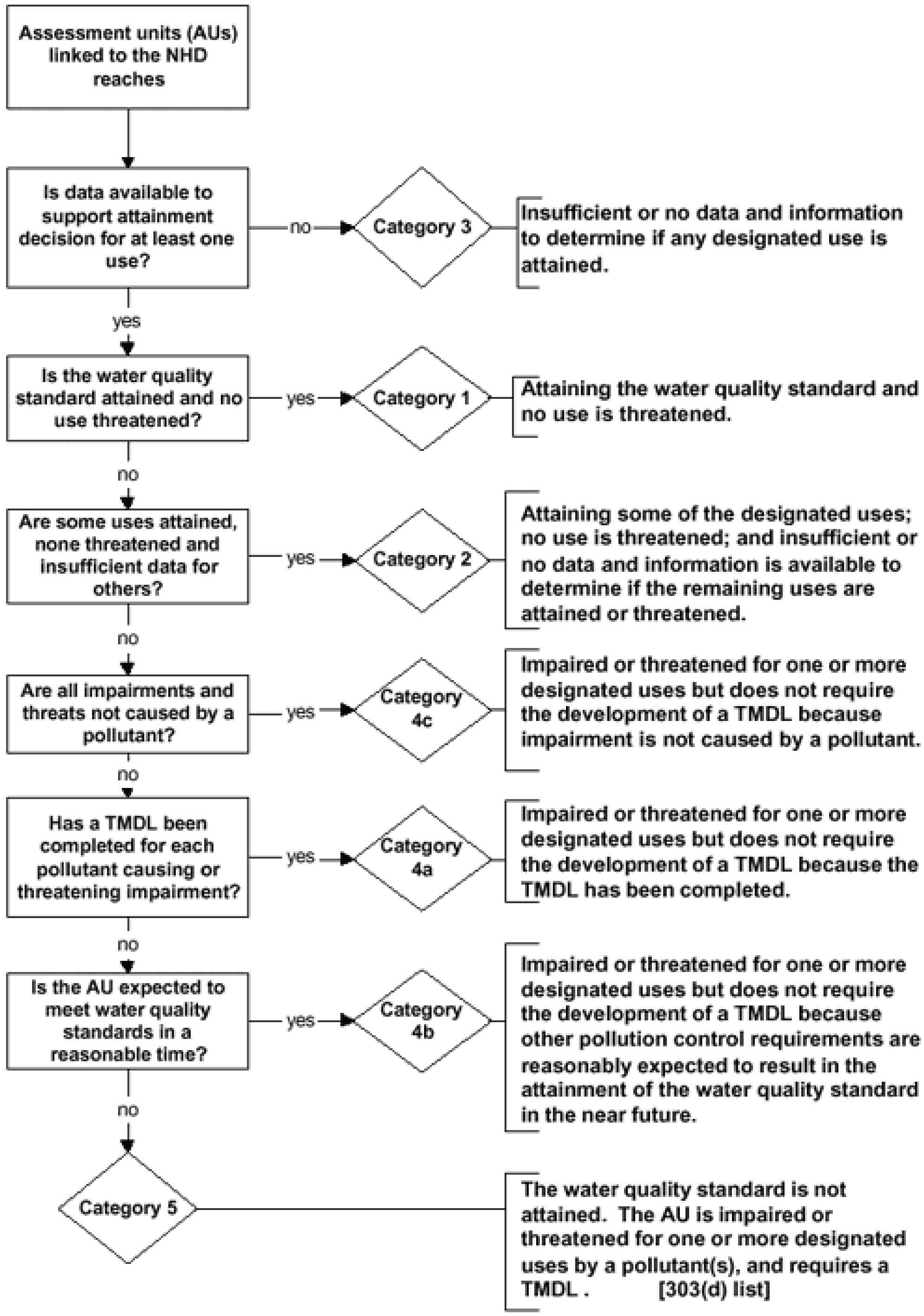

Figure 4.1. Generalized summary of logic for attainment categories (USEPA 2001). Category 5 was further expanded into categories 5A, 5B, and 5C.

5.0 PUBLIC PARTICIPATION

The assessment protocols are periodically revised based on new USEPA guidance, changes to the New Mexico Water Quality Standards, and the need to clarify various assessment procedures for staff. When the protocols are revised, a preliminary draft is first sent to USEPA Region 6 for review and comment. After appropriate changes are made, a public notice announces a 30-day comment period on the draft revised Assessment Protocol. A draft of this version of the assessment protocol was opened for a 45-day public comment period on June 16, 2003. Since the assessment protocols are not formally approved by USEPA, SWQB does not prepare a formal response to comments. The majority of comments received during the comment period were considered and incorporated into the final version.

The final version of this protocol is provided to USEPA Region 6. They consider the assessment protocols in their review and approval of Category 5 waters in the integrated report. The assessment protocol is also posted on the SWQB website: http://www.nmenv.state.nm.us/swqb/swqb.html.

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APPENDIX A

List of acronyms

4Q3	4-Day, 3-Year Low Flow
ADB	Assessment Database
AU	Assessment Unit
CALM	Consolidated Assessment and Listing Methodology
CWA	Clean Water Act
DO	Dissolved Oxygen
MDL	Method Detection Limit
NHD	National Hydrographic Dataset
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMSA	New Mexico Statues Annotated
NPDES	National Pollutant Discharge Elimination System
PAH	Poly Aromatic Hydrocarbon
PCBs	Polychlorinated Biphenyls
PQL	Practical Quantification Limit
QA	Quality Assurance
QC	Quality Control
QAPP	Quality Assurance Protection
RBP	Rapid Bioassessment Protocols
ROD	Record of Decision
SLD	State Laboratory Division
STORET	Storage and Retrieval System
SWQB	Surface Water Quality Bureau
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
UAA	Use Attainability Analysis
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WET	Whole Effluent Toxicity
WQCC	Water Quality Control Commission
WQS	Water Quality Standard

APPENDIX B

Outline of Data Assessment Procedure

New Mexico Environment Department
Surface Water Quality Bureau

DRAFT
January 2004

Introduction:

After completion of an intensive watershed survey, comprehensive assessments to determine designated use attainment status on an assessment unit basis are performed after all data have been received. In general, the Project Lead from the Chemical Team performs the chemical/physical and toxicological data assessments while a member of the Bio&Habitat Team performs the biological data assessments and the large dataset assessments (i.e., assessments using sonde and/or thermograph data).

Chemical/Physical Data

A. Pre-assessment steps (QA):

1. Ensure that all field data has been correctly entered, and that all SLD data have been received and uploaded into the in-house water quality database.
2. Perform the Data Validation steps detailed in Appendix E of the *Quality Assurance Project Plan* (SWQB/NMED 2004). Enter any necessary data validation codes into the database. Report any changes/problems/erroneous data, etc., to the QA Officer by completing the QA Checklist (Appendix D of the QAPP).
3. After the QA Officer and Database Manager have made any necessary changes to the database based on the QA Checklist and all Data Validation codes have been entered into the database, inform the Database Manager that the dataset is ready for upload to STORET and move on to Phase 2.

B. Assessment steps:

1. Search for any readily available sources of outside data (such as recent water quality from active USGS stream gages, USFS data, etc.) to incorporate into the assessment.
2. Start an electronic Administrative Record file by creating a directory on your hard drive to house all assessment documentation (Ex: Dry Cim 2000 Assessment)
3. If no one else is on the database, run the Exceedence Report for your study and save as an *.RFT (rich text format) file in the newly created directory. If others are using the database, ask the Database Manager to run the exceedence reports for you and send you the *.RFT file to avoid locking up the database. ***NOTE****: This report is a record of the data used to make your final assessment decisions. If data is changed (as a result of QA), if assessment units are split, if stations are re-assigned to a different assessment unit, etc., the report must be re-run and re-saved.*
4. Review the Exceedence Report to ensure that the data is being evaluated against the correct water quality criteria. Report any errors to the Database Manager. ***NOTE:*** *This will be particularly important while preparing assessments for the 2006-2008 list because SWQB is a triennial review year.*
5. Print a copy of final Exceedence Report for assessment hardcopy packet that will be submitted to the 303(d) Coordinator.
6. Fill out a Chemical/Physical Assessment Form for any AUs with any exceedences **AND** any AUs that are on the most recent 303(d) list (the most recent 303(d) list is on the SWQB web site). Determine use attainment status based on the most recent version of the *State of New Mexico Procedures of Assessing Standards Attainment for the Integrated §303(d) /§305(b) Water Quality Monitoring and Assessment Report*. Include comments and notes regarding extraordinary field conditions that may have influenced results, Data Validation flags, the need for AU splits, questionable designated uses, etc., in the Comments section of this form. Add these sheets to the hardcopy packet that will be submitted to the 303(d) Coordinator. ***HINT****: Much of the data at the top of the form is repeated. Just fill out the top part of one and make photocopies.*

7. Submit the hardcopy packet and email electronic copies of the Exceedence Report and any other supporting information (such as USGS flow data) to the 303(d) Coordinator for the Administrative Record.

Toxicological Data

1. Download the most recent New Mexico toxicological data at http://www.epa.gov/earth1r6/6wq/ecopro/watershd/monitrng/toxnet/nm.pdf.
2. If there were any significant effects noted in any acute or chronic water or sediment tests in any AUs in your study, fill out an Ambient Toxicity Monitoring Assessment Form. Determine use attainment status based on the most recent version of the *State of New Mexico Procedures of Assessing Standards Attainment for the Integrated §303(d) /§305(b) Water Quality Monitoring and Assessment Report*. Include comments and notes regarding extraordinary field conditions that may have influenced results, etc., in the Comments section of this form.
3. Submit any forms and supporting data to the 303(d) Coordinator for the Administrative Record.

Biological/Habitat Data (sedimentation determination)

1. Locate available benthic macroinvertebrate data, associated metrics, and pebble count data.
2. Determine appropriate reference station and locate associated data.
3. Determine %fines (% of pebble count with intermediate axis < 2mm) for both stations.
4. Fill out Stream Bottom Deposit Assessment form. Determine use attainment status using the most recent version of the **Protocol for the Assessment of Stream Bottom Deposits** in *State of New Mexico Procedures of Assessing Standards Attainment for the Integrated §303(d) /§305(b) Water Quality Monitoring and Assessment Report*. Include comments and notes regarding extraordinary field conditions that may have influenced results, Data Validation flags, the need for AU splits, questionable designated uses, etc., in the Comments section of this form.
5. If there is more than one station in the Assessment unit, repeat steps 1-4 and fill out a new form.
6. Submit any forms and supporting data (such as pebble count graphics, USGS flow data, etc) to the 303(d) Coordinator for the Administrative Record.

Nutrient Data

1. See the most recent **Nutrient Assessment Protocol** and associated forms in the *State of New Mexico Procedures of Assessing Standards Attainment for the Integrated §303(d) /§305(b) Water Quality Monitoring and Assessment Report* to determine impairment status

<u>Temperature, Dissolved Oxygen, and pH Large Data Sets</u>

A. Thermograph data:

1. Locate available thermograph MS Excel files in /SWQB-elibrary/thermographs/.
2. Fill out Thermograph Assessment form. Use the “Conditional Formatting” option, other MS Excel functions, and the most recent **Temperature Assessment Protocol** in the *State of New Mexico Procedures of Assessing Standards Attainment for the Integrated §303(d) /§305(b) Water Quality Monitoring and Assessment Report* to determine impairment status.
3. Submit impairment conclusions and supporting electronic thermograph files to the 303(d) coordinator for the Administrative Record.

B. Sonde data

1. Locate available thermograph MS Excel files in /SWQB-elibrary/sondes/.
2. Fill out Large Data Set Assessment form. Use the most recent protocols in the appendices of the *State of New Mexico Procedures of Assessing Standards Attainment for the Integrated §303(d) /§305(b) Water Quality Monitoring and Assessment Report* to determine impairment status.
3. Submit impairment conclusions and supporting electronic thermograph files to the 303(d) coordinator for the Administrative Record.

Evaluator: __________________
Date: ___________

Chemical/ Physical Data Assessment Form

Study Year/Study Name____

1. Name of assessment unit (stream reach) in the SWQB WQ database or 303d/305b list:

   ____

2. Segment number from NM WQ standards:____________________________________

3. Parameter: ____

4. Designated use and associated criterion:__________________________________

5. Evaluation of data, expressed as a ratio of exceedences/number of samples:

Station(s) used in assessment	Spring	Summer	Fall	Outside source #1	Outside source #2	Exceedence Ratio

6. Outside data source #1: ____

7. Outside data source #2: ____

8. What is the use support designation according to the SWQB Assessment Protocol:

   ☐ Full support

   ☐ Not supported

Additional comments about the assessment:

Evaluator: __________________
Date: ___________

Stream Bottom Deposit Assessment Form

Study Year/Study Name____

1. Name of assessment unit (stream reach) in the SWQB WQ database or 303d/305b list:

   ____

2. Station location: ____

3. Reference location:____

% Fines at Station:_________ % Fines at Reference: ___________**%Increase in fines**:______

Bio Score at Station:________ Bio score at Reference:_________ **Bio Score % of Ref**:______

Physical \ **Biological**	**Impaired (Non Support)** 0-79%	**Non-impaired (Full Support)** 84-100%
Non-Support Fines or Embeddedness >28% increase	Non-Support	Full Support
Full Support Fines or embeddedness <27% increase[2]	Non-Support[1]	Full Support

[1] Reduction in the relative support level for the aquatic life use in this particular matrix cell is probably not due to sediment. It is most likely the result of some other impairment (temperature, D.O., pH, toxicity, etc.), alone or in combination with sediment. Label as Category 5C on the Integrated §303(d)/305(b) list to indicate that further study is needed.

[2] Raw percent values of ≤20% fines (pebble counts) and ≤ 33% embeddedness at a study site should be evaluated as fully supporting regardless of the percent attained at the reference site.

4. What is the use support designation according to the SWQB Assessment Protocol:

   ☐ Full support ☐ Not supported

Additional comments about the assessment:

*Attach associated flow, pebble count, and metric graphics and documentation.

Evaluator: ___________________
Date: ___________

Ambient Toxicity Monitoring Assessment Form

Study Year/Study Name____

1. Name of assessment unit (stream reach) in the SWQB WQ database or 303d/305b list:

____

2. Segment number from NM WQ standards:____________________________________

3. List all ambient toxicity monitoring test with significant differences compared to control:

Station Location*	Date of test	Acute or chronic[a] test?	Sample type (sediment or water)	Number of tests with significant difference

5. What is the use support designation according to the SWQB Assessment Protocol:

☐ Full support

☐ Not supported

Additional comments about the assessment:

[a]Chronic test durations are 5 days or greater, while acute tests are 4 days or later according to USEPA Region 6.
*Attached printout of data related to this assessment unit from
http://www.epa.gov/earth1r6/6wq/ecopro/watershd/monitrng/toxnet/nm.pdf
Draft 27 January 2004

Evaluator: __________________
Date: ___________

Thermograph Assessment Form

Year/Watershed ____

1. Name of assessment unit (stream reach) as in the SWQB database (or 303d list):

   ____

2. Segment number from stream standards: ______________________________

3. What designated use: ______________________________

4. Temperature criterion in WQS: ______ºC

   Absolute Temperature Maximum according to Temperature Protocol and Use: ______ºC

Station(s) used in assessment	**Deployment Dates**	**Max temp recorded (incl date)**	**If max allowable not exceeded, list consecutive dates when criterion was exceeded for ≥ 4 (HQCWF) or 6 (CWF) hours**

List thermograph filename(s) on SWQB-elibrary:

____

What is the use support designation: ☐ Full support ☐ Not supported

Additional comments about the assessment:

Evaluator: ________________
Date: __________

Large Data Set Assessment Form

Year/Watershed ____

1. Name of assessment unit (stream reach) as in the SWQB database (or 303d list):

   ____

2. Segment number from stream standards: ________________________________

3. What designated use: ____

4.

Station used in assessment	Elevation in meters	Deployment Date and Duration

pH Assessment

What criterion was used: Range_______________________Absolute Maximum____________

Percent Outside Range	Hours at + 0.5 are >24 (T or F)	Max pH	Percent exceedences from grab samples

What is the use support designation: ☐ Full support ☐ Not supported

Dissolved Oxygen Assessment

Assessment for what life stage (circle one): early like stage other life stages

What criterion was used: 7 day mean (only early life stages) ________ 7 day mean minimum (only other life stages) ________ Daily minimum (all life stages) _________

7 day mean	7 day minimum	minimum	Percent exceedences from grab samples

What is the use support designation: ☐ Full support ☐ Not supported

Additional comments about the assessment:

APPENDIX C

Temperature Assessment Protocol

New Mexico Environment Department
Surface Water Quality Bureau

Revised December 2003

RATIONALE FOR DEVELOPMENT OF TEMPERAURE ASSESSMENT PROTOCOL:

Prior to 1998, water temperature was measured once during each site visit and designated use support status related to temperature criteria was determined by applying a percent-of-exceedences formula to these instantaneous temperature data. Periodic instantaneous temperature data do not provide information on maximum daily temperatures, duration of excessive temperatures, or the diurnal and seasonal fluctuations of water temperature. These aspects of temperature are pertinent to aquatic life use. Continuously recording data loggers (thermographs) are now readily available and provide an extensive multiple-day record of hourly temperatures over the critical time period when temperatures are generally highest. The percent-of-exceedences formula previously used with instantaneous temperature data is inappropriate for assessment of thermograph data and was not designed for that purpose.

In 1998, the New Mexico Environment Department Surface Water Quality Bureau (SWQB) initiated an effort to review current temperature criteria and to determine the most appropriate method to monitor and assess potential aquatic life use impairment due to elevated water temperature. This effort involved: 1) convening an interdisciplinary multi-agency workgroup to review existing scientific literature and EPA guidance in order to recommend methods to assess current temperature criteria, and 2) development of a standard operating procedure for deployment of thermographs in each assessment unit during intensive water quality surveys.

The SWQB has been deploying thermographs and applying the following temperature assessment protocol since the 2000-2002 CWA §303(d) listing cycle. This protocol is more technically sound than simply applying percentages to limited instantaneous temperature data and better addresses the intent of the Clean Water Act to use best available technology and to incorporate magnitude and duration concerns into water quality monitoring, assessment, and standards development. This protocol addresses biases introduced when using instantaneous data to assess water quality parameters with significant diurnal fluctuation. Based on the success of this effort, the SWQB plans to formally incorporate these changes into the water quality standards and to initiate additional efforts to address other parameters with known diurnal fluxes, such as pH and dissolved oxygen.

Introduction

Water temperature influences the metabolism, behavior, and mortality of fish and other aquatic organisms that affect fish. Natural temperatures of a waterbody fluctuate daily and seasonally. These natural fluctuations do not eliminate indigenous populations, but may affect existing community structure and geographical distribution of species. In fact, such temperature cycles are often necessary to induce reproductive cycles and may regulate other aspects of life history (Mount, 1969). Behnke and Zarn (1976), in a discussion of temperature requirements for endangered western native trout, recognized that populations cannot persist in waters where maximum temperatures consistently exceed 21-22°C, but they may survive brief daily periods of higher temperatures (25.5-26.7°C). Anthropogenic impacts can lead to modifications of these natural temperature cycles, often leading to deleterious impacts on the fishery. Such modifications may contribute to changes in geographical distribution of species and their ability to persist in the presence of introduced species.

Historical Background

The Surface Water Quality Bureau (Bureau) of the New Mexico Environment Department convened a multi-agency workgroup to evaluate current temperature criteria and how the Bureau could best incorporate these criteria into its management activities. This exercise was undertaken as a result of changes in temperature monitoring procedures initiated by the Bureau in 1998, and the resulting data.

Prior to 1998, temperature monitoring by the Bureau was limited to instantaneous streamside measurements taken by a staff member conducting a water quality survey. This resulted in limited information concerning actual dynamics of temperature in New Mexico streams. During 1998, stream sampling surveys used a new device, the continuously recording thermograph, to collect more complete temperature data. These devices may be deployed in streams for extended periods of time, and collect data at preset intervals. Bureau protocols for use of these devices (Attachement A) call for deployment during the critical summer period of May through September, with a data collection interval of one hour. These devices were first deployed in mid-July 1998.

Following deployment, devices were collected and data were downloaded and interpreted. Data review indicated only one stream (Sulphur Creek) of more than 20 evaluated in 1998 had no exceedences of the 20°C standard. Many of these monitoring sites were established on what were considered to be minimally impacted stream reaches. These preliminary results seemed to indicate that the streams evaluated had temperatures that may not support their coldwater fishery designated use.

Procedures for assessing designated use support were conducted using 1997 Bureau protocols. Under these protocols, all physical parameters, including temperature, were evaluated based on a percent-of-exceedences formula. Review of data generated by thermographs brought into question the usefulness of this method of evaluation, as it did not recognize a maximum allowable temperature. In response, the Bureau convened the Temperature Workgroup.

The Workgroup was comprised of representatives from the US Environmental Protection Agency (EPA) Region 6, the US Department of Interior, Fish and Wildlife Service – New Mexico Ecological Services Field Office, New Mexico Department of Game and Fish – Conservation Services and Fisheries Management Divisions, and the Bureau. The Workgroup held four meetings beginning in December 1998. The Workgroup's task was to develop an assessment protocol that would evaluate designated use support status of New Mexico streams using detailed temperature data collected by the Bureau. The Workgroup was informed of implementation of new sampling procedures and given a general summary of preliminary results. It was the Bureau's wish that the Workgroup develop an assessment protocol independent of any data or *a priori* beliefs that could have been developed from a review of data collected. For this reason, the Workgroup was not given any specific thermograph data, nor were members made aware of specific data collection sites.

The Workgroup decided to conduct a literature review, and to base any recommendations on results of this review and internal discussions held with other agency or department staff. Information collected, that formed the basis for recommendations, is summarized below.

Review of the EPA Criteria Document for Temperature

Following is a summary of temperature information from EPA's September 1988 document "*Water Quality Standards Criteria Summaries: A Compilation of State/Federal Criteria*."

Preamble: Temperature standards are set to control thermal pollution, or the amount of heated wastes discharged into a waterbody. The following guidelines were developed by the EPA and published in *"Quality Criteria for Water, 1986"* (Gold Book).

<u>Freshwater Aquatic Life</u>

For any time of year, there are two upper limiting temperatures for a location (based on the important sensitive species found there at that time):

1. One limit consists of a maximum temperature for short exposures that is time and species dependent, and

2. The second value is a limit on weekly average temperature that:

    a. In the cooler months, will protect against mortality of important species if the elevated plume temperature is suddenly dropped to the ambient temperature, with the limit being the acclimation temperature minus two °C when the lower lethal threshold temperature equals ambient water temperature;

or

    b. In the warmest months, is determined by adding to the physiological optimum temperature (for growth) a factor calculated as 1/3 of the difference between the ultimate upper incipient lethal temperature and the optimum temperature for the most sensitive species that are normally present at that location and time;

or

    c. During reproductive seasons, the limit is the temperature that meets site-specific requirements for successful migration, spawning, egg incubation, fry rearing, and other reproductive functions of important species. These local requirements should supersede all other requirements when applicable;

or

    d. There is a site-specific limit that is found necessary to preserve normal species diversity or prevent appearance of nuisance organisms.

Upper and lower limits have been established for many aquatic organisms. Tabulations of lethal temperatures for fish and other organisms are available. Factors such as diet, activity, age, general health, osmotic stress, and even weather contribute to the lethality of temperature. Aquatic species, thermal acclimation state, and exposure time are considered critical factors.

Effects of sublethal temperatures on metabolism, respiration, behavior, distribution and migration, feeding rate, growth, and reproduction have been summarized by De Sylva (1969). Brett (1960) illustrated that inside the tolerance zone, there is a more restrictive temperature range in which normal activity and growth occur, and an even more restrictive zone inside that in which normal reproduction occurs.

The upper incipient lethal temperature and the LT50 (the highest temperature at which 50% of a sample of organisms can survive) for any given species are determined at that species' highest sustainable acclimation temperature. Generally, the lower end of temperature accommodation for aquatic freshwater species is 0°C.

The following requirements are currently considered necessary and sufficient for development of a protective temperature criteria definition:

1. Maximum sustained temperatures are consistent with maintaining desirable levels of primary and secondary productivity.

2. Maximum levels of metabolic acclimation to warm temperatures that permit return to ambient winter temperatures should artificial sources of heat cease.

3. Time-dependent temperature limitations for survival of brief exposures to temperature extremes, both upper and lower.

4. Restricted temperature ranges for various states of reproduction, including (for fish) gametogenesis, spawning migration, release of gametes, development of embryo, commencement of independent feeding (and other activities) by juveniles, and temperature required for metamorphosis, emergence, or other activities of lower forms.

5. Thermal limits for diverse species composition of aquatic communities, particularly where reduction in diversity creates nuisance growth of certain organisms, or where important food sources are altered.

6. Thermal requirements of downstream aquatic life (in rivers) where upstream diminution of a coldwater resource will adversely affect downstream temperature requirements.

The temperature-time duration for short-term maximum (STM) exposure, such that there is 50% survival, is expressed mathematically by fitting experimental data with a straight line on a semi-logarithmic plot. Time is shown on the log scale; temperature is on the linear scale. To provide for safety, an experimentally derived safety factor of 2°C is applied. In equation form this is:

Equation 1. STM = (log(time)-a)/b

Where: STM = short-term maximum temperature
$\log_{10}$ = logarithm to base 10 (common log)

a	=	intercept on "y" axis (or logarithmic axis) of the line fitted to experimental data that is available for some species from Water Quality Criteria 1972, Appendix II-C (US EPA, 1972).
b	=	Slope of the line fitted to experimental data and available for some species from Water Quality Criteria 1972, Appendix II-C (US EPA, 1972).
time	=	minutes.

For extensive exposure, the maximum weekly average temperature (MWAT) is expressed as:

Equation 2. MWAT = OT + ((UUILT - OT)/3)

Where:

MWAT	=	maximum weekly average temperature.
OT	=	a reported optimum temperature for the particular life state or function.
UUILT	=	ultimate upper incipient lethal temperature (the upper temperature at which tolerance does not increase with increasing acclimation temperature).

One caveat in determining maximum weekly average temperature is that the limit for short-term exposure must not be exceeded. Some calculated values are available in the literature for species considered important in New Mexico.

EPA Calculated Values for Maximum Weekly Average Temperatures for Growth and Short-term Maxima for Survival of Juveniles and Adults During Summer Months are given in the following table.

Species	Growth[a]	Maxima[b]
Rainbow trout	19	24
Brook trout	19	24
Brown trout	--	25

[a]Calculated according to the maximum weekly average formula (Equation 2).
[b]Based on the short term maximum formula (Equation 1), with acclimation at the weekly average temperature for summer growth (does not indicate exposure period).

Other Literature References

Numerous literature references (Armour, 1991; US EPA, 1986) also recognize the concept of using short-term maxima and weekly average temperatures to protect for temperature effects on fisheries. Of primary importance are protections necessary to support reproducing populations of salmonids in stream segments designated as high quality coldwater fisheries.

Armour (1991) cited the following findings for the calculated short-term maxima (STM) = (log of time - *a*)/*b*. Values for *a* and *b*, intercept, and slope of a line from experimental data, are taken from National Academy of Sciences, Water Quality Criteria (1972) for juvenile brook trout (*Salvelinus fontinalis*), where time = 120 min. This yields a calculated STM of 25.6°C (25.5°C for juvenile brown trout, *Salmo trutta*). To provide a margin of safety for all organisms, this value was reduced by 2°C, resulting in a calculated STM of 23.6°C.

This calculated STM value is consistent with data found in other literature. US EPA (1986) short-term lethal threshold for brook trout and rainbow trout (*Oncorhynchus mykiss*) is given as 24°C, after reduction by the 2°C safety factor. Grande and Andersen (1991) experimentally determined in controlled studies a LT50 for brook trout, brown trout, and rainbow trout to be 25.2°C, 26.2°C, and 26.6°C, respectively. Applying a safety factor of 2°C results in 23.2°C, 24.2 °C, and 24.6°C, respectively, which are similar to US EPA findings. Eaton (1995) developed a Fish Temperature Database Matching System (FTDMS) to document temperatures at which various species were found in natural settings. He reported a 95th percentile temperature (i.e. 95% of all individuals collected were found at temperatures below this value) of 22.3°C for brook trout, 24.1°C for brown trout, and 24.0°C for rainbow trout.

Workgroup Recommendations

Given the broad literature support for temperature evaluations employing a concept of short-term thermal maximum and long-term average value, the Workgroup recommended such an approach be applied in New Mexico. Because the current criterion is 20°C, this value was used as the basis of the assessment protocol.

The specific recommendations from the Workgroup are as follows:

Temperature in High Quality Coldwater Fisheries (HQCWF)

Full Support Instantaneous (hourly) temperatures do not exceed 3.0°C greater than the applicable temperature criterion, <u>and</u> temperatures do not exceed the applicable criterion for more than four consecutive hours in a 24-hour cycle for more than three consecutive days.

Non Support Instantaneous (hourly) temperatures exceed 3.0°C greater than the applicable temperature criterion, <u>or</u> temperatures exceed the applicable criterion for more than four consecutive hours in a 24-hour cycle for more than three consecutive days.

During reproductive seasons, temperatures must not impede successful migration, egg incubation, fry rearing, and other reproductive functions of target species.

Temperature in Coldwater Fisheries (CWF)

Full Support Instantaneous (hourly) temperatures do not exceed 4.0°C greater than the applicable temperature criterion, <u>and</u> temperatures do not exceed the applicable criterion for more than six consecutive hours in a 24-hour cycle for more than three consecutive days.

Non Support Instantaneous (hourly) temperatures exceed 4.0°C greater than the applicable temperature criterion, <u>or</u> temperatures exceed the applicable criterion for more than six consecutive hours in a 24-hour cycle for more than three consecutive days.

Sampling for assessment of these criteria will be accomplished using continuously recording thermographs with a maximum interval of one hour. Data will be collected from May through September.

Other Recommendations

Additional recommendations by the Workgroup:

- Language should be included in any future standard indicating temperature limits are established to protect the entire aquatic community, not just fish species.
- Additional data should be collected on varying stream types, thought to be representative of least impacted streams, to establish an expected or reference range of temperatures.
- Fish population data should be collected on reference streams in order to evaluate appropriateness of designated uses.
- The need for a regionalized temperature standard should be reviewed.
- This proposal should be evaluated over time, and a new standard criterion should be developed from this review that will eventually be proposed to replace the single-value temperature criterion currently specified in the New Mexico Surface Water Quality

Standards.

References

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* The date on the publication that DM Tarzwell edited is 1960, Brett's title conflicts.

Attachment A

New Mexico Environment Department/Surface Water Quality Bureau Protocol for Deployment and Evaluation of Long-term Thermographs

Monitoring Timing, Frequency and Duration

Monitoring for temperature should generally be conducted from May through September to be consistent with periods when incident solar radiation angles are high and ambient air temperatures are most likely to be at maximums. Knowledge of regional patterns is important if monitoring duration must be limited to periods shorter than the interval described above. Monitoring should always include the period of critical maximum expected temperatures.

When monitoring data are to be used to make assessments of designated use support maximums, duration and rate of temperature increase must be collected. For these purposes, the recording thermograph is the most useful tool. For a recording thermograph, monitoring frequency should be adequate to provide a realistic estimate of the maximum temperature and duration of criteria exceedences. If data are collected at too large an interval, maximum temperatures and durations are likely to be missed. **The SWQB maximum interval for monitoring for standards attainment, with a recording thermograph, is one hour.** Obviously, shorter intervals provide a more precise estimate of the duration of daily maximums. For this reason, shorter intervals may be used with no impact to data quality. However, this is a trade-off against data storage limitations. One approach to this problem is use of a pilot period of monitoring, with at least thirty-minute monitoring intervals, to determine how rapidly stream temperature may change. The need for a shorter monitoring interval is more important on smaller, coldwater streams than larger streams.

Monitoring Equipment

Thermographs must be waterproof and have a temperature range that is appropriate for the applicable standard. Devices should have a minimum temperature range of –5°C to 40°C, with minimum resolution and accuracy of ±0.5°C within this range. They should be capable of recording at a wide range of intervals with a minimum of no more than fifteen minutes and a maximum greater than two hours. The thermograph must be capable of direct download to a PC, creating a file that is exportable to currently available spreadsheet software.

Where to Monitor

Thermographs should be placed in stream locations that are representative of ambient stream conditions. For this reason, thermographs should not be placed in shallow riffles or in deep pools. Generally, the thermograph should be deployed in a transition between a riffle/run and a pool. If possible, the thermograph should be placed at the toe of a pool as it becomes more shallow, prior to entering a run or riffle. The thermograph should be placed such that under expected flow conditions it will be continuously submerged. If possible, the thermograph should be located under shading to eliminate direct solar gain.

Field Equipment

Actual situations encountered during thermograph deployment will vary. Consequently, this protocol offers only very general recommendations for thermograph deployment. Consideration should be given to the list of conditions in the section entitled “Where to Monitor.”

Typical equipment that should be available includes:

- plastic zip ties
- surveyors marking tape
- iron rebar stakes (minimum 18 inches)
- sledge hammer
- wire cutters and knife
- portable computer and interface, as needed by your equipment
- auditing thermometer
- timepiece
- field book or data sheets
- camera and film

Precautions against vandalism, theft, and accidental disturbance should be considered when deploying equipment. In areas frequented by the public, it is advisable to secure or camouflage equipment. Visible tethers are not generally advisable, since they attract attention. If such tethers are deemed necessary, they should be buried or hidden.

Quality Assurance and Quality Control

The following procedures must be followed to ensure that temperature data are of acceptable quality. These procedures document instrument accuracy, test for proper functioning during the deployment period, and set criteria for data acceptance.

Accuracy Testing and Recording

A National Institute of Standards and Technology (NIST) traceable thermometer, with a resolution and accuracy of 0.1°C or better, should be used to test thermograph accuracy prior to deployment. The NIST thermometer should be calibrated annually, with a minimum of two temperatures. If a NIST thermometer is not available, a good quality thermometer calibrated against an NIST thermometer may be used. This thermometer should also be calibrated annually, with a minimum of two temperatures.

Accuracy of the thermograph must be tested pre- and post-deployment, at a minimum of two calibration temperatures between 0°C and 25°C. Testing is done using a stable thermal mass, such as an ice water bath or other controlled water bath. The stable temperature of the insulated water mass allows direct comparison of the unit’s readout with that of the certified or calibrated thermometer. Accuracy should be within ±0.5°C. A logbook must be kept that documents each unit’s calibration date, test result, and the reference thermometer used.

Field Auditing of Instrument Performance

In addition to laboratory calibrations, temperature monitoring equipment may be audited during deployment. A field audit is a comparison between the temperature of the field probe and a properly calibrated mercury thermometer. The purpose of this procedure is to ensure thermograph accuracy. Two field audits are recommended: one at the time of deployment, after the instrument has reached thermal equilibrium, and one at the time of recovery. Other periodic audits are recommended to assure proper functioning and to minimize data loss.

Thermometers for audits should have an accuracy and resolution of ±0.5 °C. The audit is performed by placing a thermometer as close as possible to the thermograph's sensor. The audit value is recorded when the temperature stabilizes. If the thermograph allows for the auditor to view real-time temperature data without interfering with sampling, it is possible to do a "real-time" audit. If the thermograph does not allow this feature, the audit must necessarily be conducted by "post-processing" of recorded data. In this case, recorded data are off-loaded and compared later to recorded audit values. For this type of audit, recording times of the device and recorded auditing times should be as synchronous as possible. The thermograph will have a date and time based on the set-up computer's internal clock. The timepiece used for the audit should be synchronized with the computer's clock to reduce time-induced error.

Data Review and Reduction

Data will be retained in raw form without post-processing. Only data that meet quality control requirements may be used for comparison to numeric temperature criteria. Data are considered valid if they pass pre- and post- calibration and field audits.

All data will be reviewed for any obvious anomalies. Since these devices are left for long periods of time without supervision, they may be subject to external forces or conditions that may render some of the data questionable. Examples of such conditions may include being picked up by persons other than sampling personnel or being exposed to ambient air temperature as water levels drop below the sensor. These problems can be minimized through proper deployment of the devices and a complete data review to document anomalous or apparently unnatural data.

APPENDIX D

Protocol for the Assessment of Stream Bottom Deposits (Sedimentation/Siltation) On Wadeable Streams

New Mexico Environment Department
Surface Water Quality Bureau

Revised
January 28, 2004

Introduction

Clean stream bottom substrates are essential for optimum habitat for many fish and aquatic insect communities. The most obvious forms of degradation (other than diminished stream flows and higher water temperatures) occurs when critical habitat components, such as spawning gravels (Chapman and McLeod, 1987) and cobble surfaces, are physically covered by fines thereby decreasing intergravel oxygen and reducing or eliminating the quality and quantity of habitat for fish, macro invertebrates, and algae (Lisle, 1989; Waters, 1995). Chapman and Mcleod (1987) found that bed material size is related to habitat suitability for fish and macroinvertebrates and that excess sediment decreased both density and diversity of aquatic insects. Specific aspects of sediment-invertebrate relationships may be described as follows: 1) invertebrate abundance is correlated with substrate particle size; 2) fine sediment reduces the abundance of original populations by reducing interstitial habitat normally available in large-particle substrate (gravel, cobbles); and 3) species type, species richness, and diversity all change as substrate particle size changes from large (gravel, cobbles) to small (sand, silt, clay) (Waters, 1995).

In addition, sediment loads that exceed a stream's sediment transport capacity often trigger changes in stream morphology (Leopold and Wolman, 1964). Streams that become overwhelmed with sediment often go through a period of accelerated channel widening and streambank erosion before returning to a stable form (Rosgen, 1996). These morphological changes tend to accelerate erosion, thereby reducing habitat diversity (pools, riffles, etc.) and placing additional stress on the designated water use.

This protocol was developed to support an interpretation of the New Mexico State Water Quality Standards (NMWQCC, 2000) narrative standard for stream bottom deposits. The current standard for the deposition of material on the bottom of a stream channel is listed in the *State Of New Mexico Standards for Interstate and Intrastate Surface Waters*, Section 1105.A General Standards:

> Bottom Deposits: Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

The following protocol is similar to the approach proposed by the State of Colorado (CDPH&E, 1998) and represents a simple, but quantitative, three-step assessment procedure for determining whether the above narrative standard is being attained in a particular stream reach or segment by: 1) comparing changes or differences, if any, between the site of concern and a reference site; 2) directly evaluating instream habitat by measuring either of two stream bottom substrate parameters or indicators, namely substrate size (mainly fines, 2 mm or less) abundance or cobble embeddedness, and; 3) verifying or confirming results obtained in number 2 by assessing and comparing benthic macroinvertebrate communities (or fish) at the same sites. **This protocol is not designed to determine sources, locations, quantities, or causes of excess stream bottom sediment**.

1. <u>Reference and Study Site</u>

In order to properly assess a study site or stream reach for impairment(s) due to stream bottom deposits, a proper reference site must be selected and classified for comparison. Once this is accomplished, selected "indicators" such as percent fines, embeddedness, and biological integrity can be measured and compared between the two sites. Under this protocol, the reference site or condition serves as a quantitative and/or qualitative control or yardstick to which a study (or impacted site) may be statistically compared and evaluated. Reference conditions are used to scale the assessment to the "best attainable" situation. This approach is critical to the assessment because stream characteristics vary dramatically across different regions (Barbour *et al.*, 1996), watersheds, or even stream segments. **The ratio between the score for the study site and the reference site (or condition) provides a percent comparability measure for each station**. The station of interest is then classified on the basis of its similarity to expected conditions (reference condition) and its apparent potential to support an acceptable level of biological health (Barbour *et al.*, 1999).

Ideally, the reference and study sites should share similar or common characteristics such as elevation, geology, hydrology, hydraulics, watershed size, in-stream habitat (pools, substrate, etc), and riparian vegetation. However, if the study site is impaired, such things as channel hydraulics, habitat, and streamside vegetation may be different from the reference site simply because the differences observed may either be a cause or a result of a possible departure from the reference condition. Characteristics that cannot change over time should be used as primary attributes of similarity between reference and study sites. Examples of similar attributes are elevation, geology, and hydrology (precipitation, etc.). These three characteristics of similarity between a reference and study site can be ensured through the use of ecoregion designations. Simply put, **the study site and the reference site need to be in the same ecoregion**. Currently, the Surface Water Quality Bureau recognizes and/or uses two different ecoregion classifications. The first is a terrestrial system (Omernik, 1987) developed for the United States Environmental Protection Agency (USEPA) while the second is an evolving aquatic classification scheme based primarily on altitude and developed exclusively for New Mexico by its Department of Game and Fish (NMDGF) (Cowley *et al*., 1997). To ensure that enough similarity exists between a reference and study site so that a valid comparison can be made, both sites should be in the same terrestrial and aquatic ecoregion. For example, sampling site A could be used as a reference for study site B if both sites are located in Omernik ecoregion 21 and NMDGF ecoregion 1. If, however, only one ecoregion classification scheme can be matched between the reference and study site, it should be the aquatic ecoregion classification. For instance, if sites A and B are in NMDG&F ecoregion 1, but site A is located in Omerick ecoregion 21 while site B is in ecoregion 22, the two sites can still be compared.

Additional or secondary characteristics that can be used to supplement and further fine tune the ecoregion similarity between reference and study sites are those that can be readily measured at each site such as stream type (Rosgen, 1996) and channel cross-sectional area. In other words, reference and study sites in the same ecoregion, having the same stream type (McGarrell, 1998) and cross-sectional area are extremely similar and can be readily compared. Use of these secondary characteristics in evaluating similarities for pairing of sampling sites needs further study. However, their use as an additional tool for evaluation of sites is encouraged (Barbour et al, 1999). At a minimum, these data can be entered into a database that can later be used in a statistical analysis to determine whether use of these characteristics is valid in site selection protocols.

It should be pointed out that relative quality of every reference site is not equal based on location in a watershed. A tiered approach (CDPH&E, 1998) to establishing the reference condition is based on the quality of reference sites, and is consistent with USEPA technical guidance (Barbour *et al.*, 1996).

Tier 1. Reference sites are acceptable and are minimally disturbed or "natural" and described by EPA as the "biological integrity expectation." The following characteristics should be considered in selecting this group of reference sites: a) no upstream impoundments or diversions; b) no point discharges, spills, or hazardous waste sites; c) low human, agricultural, and road density, and; d) minimal nonpoint source impacts. An example would be a headwater mountain stream.

Tier 2. Reference sites are acceptable, but are more than minimally disturbed. Where no "natural" site or condition exists, the best available sites are sampled for determination of reference condition or selected based on best professional judgment for the best available site in the ecoregion. USEPA describes these sites as the "interim expectation" because of the potential for restoration to a minimally disturbed or "natural" condition listed in Tier 1.

Tier 3. Reference sites are not acceptable or no reference site exists. Reference conditions would be based on models, historical data, data from neighboring states, ecological information, and/or expert opinion as appropriate.

In summary, the classification of streams based on geographic region (ecoregions) and stream type (Rosgen 1994, 1996) is to reduce the complexity of biological information and improve the resolution or sensitivity of biological surveys by partitioning or accounting for variation between sites. Furthermore, the best classification variables are those that are readily obtained from maps or regional water characteristics such as ecoregion, gradient, alkalinity, and hardness. Stream characteristics that are readily affected by human activities or occur as a biological response to physical conditions (i.e., land use, habitat condition, or nutrient concentrations) should not be used as classification variables (McGarrell, 1998; Barbour *et al;* 1999).

2. **Physical Assessment**

In order to assess the stream bottom for contaminants (mainly sediment) that may damage or impair aquatic life and significantly alter the physical properties of the bottom, physical measurements of the stream bottom substrate must be made alongside measurements being made of the biological component. Physical measurements (or indicators) of the stream bottom need to take into account those attributes or characteristics that potentially promote the best physical habitat or environment for aquatic life independent of water quality. This concept can best be seen in Figure 1 (Plafkin *et al.*, 1989), which shows the relationship between habitat and biological quality. More specifically, substrate that is plentiful, sufficiently large and varied, and is not surrounded or buried by fines appears to offer the best attributes for habitat suitability for many aquatic organisms adapted to such conditions.

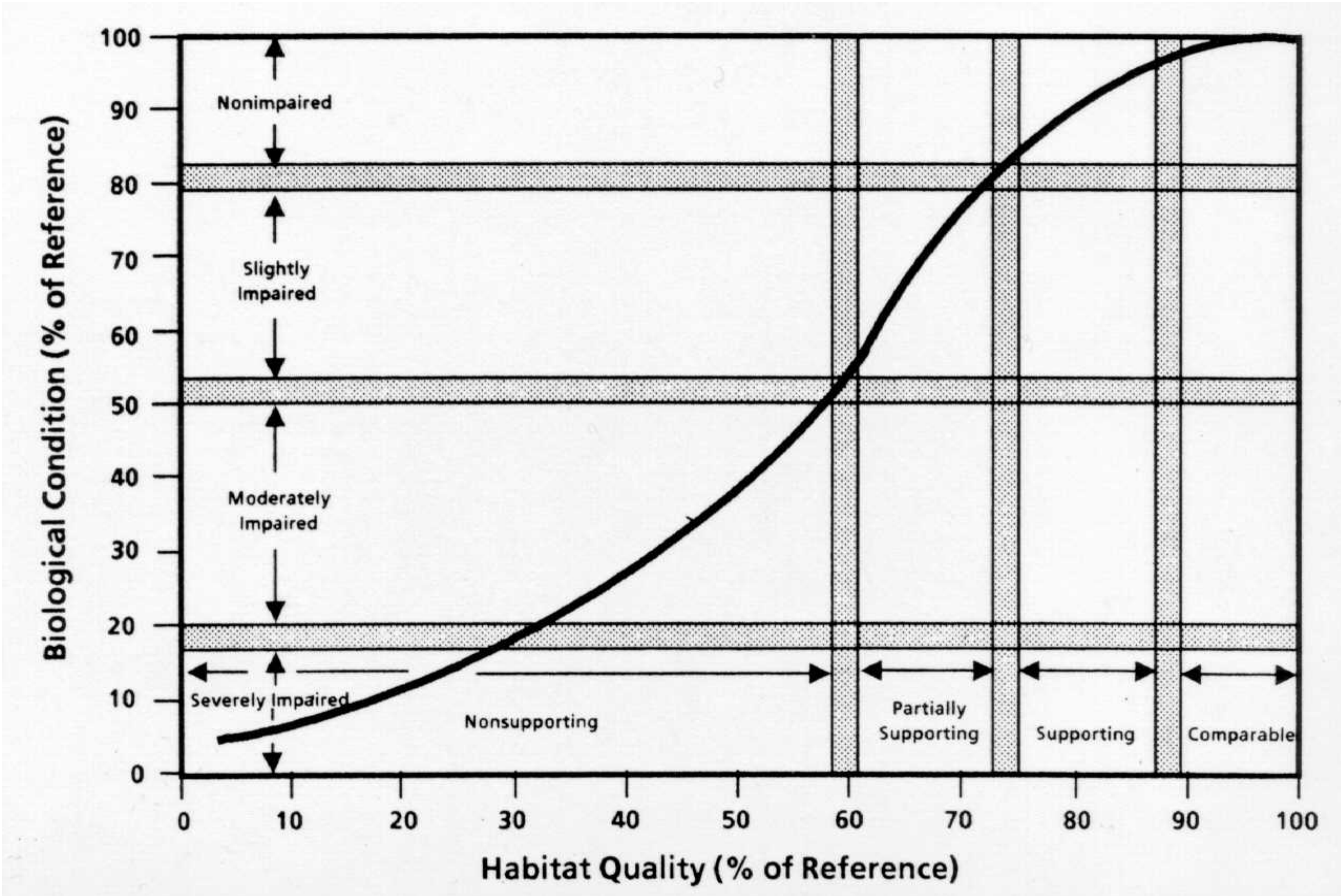

Figure 1. The relationship between habitat and biological condition (Plafkin *et al.*, 1989).

In a study of 562 streams located in four northwestern states, Relyea *et al.* (2000) suggested **that changes to invertebrate communities as a result of fine sediment (2mm or less) occur between 20-35% fines**. Chapman and McLeod (1987) suggest that geometric particle size and percent of the bed surface covered by fines should both be used to define habitat quality. These two criteria can be ascertained by performing a **pebble count**. The pebble count procedure provides not only particle size distributions (D50, D84, etc.) and percent class sizes (% sand, % cobble, etc.), but offers a relatively fast and statistically reliable method for obtaining this information. In addition, relatively rapid temporal and spatial comparisons can be made at a number of sites within a watershed.

Although sufficient and varied sizes of stream bottom substrate are necessary for biological colonization, protection, and reproduction, its full potential may not be realized if the substrate surfaces are surrounded by fine sediment. In streams with a large amount of sediment, the coarser particles become surrounded or partially buried by fine sediment. **Embeddedness** quantitatively measures the extent to which larger particles are surrounded or buried by fine sediment (Mc Donald *et al*., 1991). Studies by Bjorn *et al.* (1974, 1977) concluded **that approximately one-third embeddedness (33%) or less is probably the normal condition in proper functioning streams**. Above this condition, however, insect populations decline substantially as habitat spaces become smaller and filled. By performing a **pebble count** and/or measuring **cobble embeddedness**, the stream bottom can be characterized as an aquatic habitat, compared to a reference site, and then tentatively evaluated for impairment due to stream bottom deposits. **Confirmation** of impairment takes place when a stream site is **biologically assessed**.

A. Pebble Count

The pebble count (Wolman, 1954) may be performed separately or as part of a larger stream inventory and assessment study (Rosgen, 1996). **It is recommended that biological sampling and pebble counts be performed concurrently**. The intermediate axis of particles should be measured **within the wetted perimeter of the channel** and tallied using standard Wentworth size classes (Bunte and Abt, 2001) from 10 equidistant transects (10 particles/transect as a minimum) selected along a longitudinal stream section of the **specific habitat type** being biologically sampled (riffle, run, pool) or evaluated. Pebble counts may be recorded, tallied, and represented either by using forms provided by Rosgen in the *Reference Reach* field book (Rosgen, 1998) or on a computer laptop at streamside using the *Reference Reach* (channel materials) software package (Mecklenberg, 1998) which can be downloaded from the State of Ohio Department of Natural Resources website (http://www.dnr.state.oh.us/soilandwater/streammorphology.htm).

From the raw data, D35, D50, and D84 values can then be calculated along with percent composition values for six classes of channel materials ranging from fines (silt, clay, and sand) to bedrock. If a “Rosgen” Level II classification is being performed in addition to the sediment protocol assessment, a separate pebble count analysis should be done to account for the larger bankfull widths, increased longitudinal distances, and multiple habitats used in various “Rosgen” protocols.

In order to ascertain and/or evaluate increases in fines by pebble count methodology and its potential effect on aquatic life at the study (or impacted) site relative to the reference site, the following steps should be taken. First, download a copy of the pebble count software tool *Size-Class Pebble Count Analyzer V1 2001.xls* (651KB) by John Potyondi and Kristin Bunte from the US Forest Service's Stream System Technology Center (aka "Stream Team") website (www.stream.fs.fed.us) under their Download PDF Documents and Software Tools menu. Specific information concerning its use, application, sample size, data input, statistical analysis, and case studies are included in **various document sections of the software** and **should be read** prior to setting up a study and collecting any data. Next, select a reference site for each group of study sites being assessed or evaluated. Visit each reference site and collect the necessary biological samples (benthic macroinvertebrates) along with a pebble count (n≈200-300) from the same habitat unit(s) that the biological samples were collected. Using the USFS pebble count software (preferably streamside at the reference site) calculate the percent fines (< 2 mm) encountered at the reference site under the **data input tab**. The percent fines can be also calculated using the *Reference Reach* channel materials software (Mecklenberg, 1998) package. Using the percent fines value at the reference site, determine the increase in percent fines needed at the study site to classify them as non-supporting (28% increase) according to Figure 1 and Table 1. This can be accomplished by multiplying the percent fines at the reference site by 1.28. Under the **sample size tab** in the software package, the sample sizes of both the reference and study sites can be estimated for statistical significance by filling in the worksheet provided which requires the following fields to be filled: **1)** Type 1 error probability (use 0.1), **2)** Type 2 error probability (use 0.2), **3)** ratio of study site sample size to reference site sample size (1 is recommended, but unequal sample sizes can be used), **4)** reference site percent fines or proportion (entered as a decimal percent i.e. 0.1 for 10%) , **5)** and the study site percent fines or proportion (reference site fines plus 28%). Finding the sampling number to cover a 28% increase. **If the percent value for fines at the reference site is determined to be 20% or less, calculate the percent fines to be used in step 5 (study site fines or proportion) by choosing the greater value between either a 28% increase (reference fines multiplied by 1.28) or the percent increase obtained by using 21% as a raw fines percent at the study site(s).** The program will then calculate an estimated reference and study site sample size necessary to determine whether an increase in fines of 28% is statistically valid at the 10% level of significance (90% confidence level). Once the statistical sampling size(s) of both the reference and study site has been determined, the data can be collected, entered, and compared under the analysis section of the software and then subsequently used according to Tables 1 and 3.

Study sites showing fines of **20% or less should be considered non-impaired (fully supporting)** regardless of the percent fines determined at the reference site. If the percent fines at the study site are lower than that of the reference site, one might consider using the study site as a new reference site provided that the other criteria mentioned previously for reference site nomination are equal or better.

B. Embeddedness (State of Idaho Procedure)

This method (Burton and Harvey, 1990) along with its accompanying software **should be used only on cobble-bottom or cobble-dominated streams** (D50 $\geq$64 mm or the greatest % fraction of any group is cobble). **Because this methodology is labor intensive, its use is recommended only when data from the pebble count and biological sampling does not provide a satisfactory answer as to the degree of impairment.** From the pebble count data, determine the D50 value of the stream bottom substrate. If it is found to be 64 mm or greater (or if the highest % fraction is cobble), proceed with the methodology described in the Idaho embeddedness protocol (Burton and Harvey, 1990). Embeddedness measurements should be performed on the same stream reach where the pebble count was performed. However, to avoid processing substrate previously disturbed from the pebble count, it is recommended that cross-sectional transects for the embeddedness measurements be located in between those used for the pebble count. For example, if the pebble count measurements were performed at cross-sectional transects listed as 0, 20, and 40 feet, etc. along the longitudinal profile of the river, the embeddedness measurements should be done at the distances of 10, 30, and 50 feet, etc. If a laptop computer is not used for field data entry and statistical determination of sample size adequacy, it is recommended that the substrate content of ten hoops (1/transect) be measured. After performing embeddedness measurements at both the reference and study site(s), the data should be entered and analyzed using computer program software developed for this procedure by the State of Idaho. The embeddedness derived from this procedure and subsequent analysis is termed a "weighted" embeddedness because it factors in percent fines along with the percent embeddedness of cobble within the hoop (Burton and Harvey, 1990; McDonald *et al.*, 1991). An additional calculation generated by this program is the interstitial-space index (ISI), which is a measure of unembedded substrate. This number should be used for inclusion in any database that statistically evaluates potential physical "indicators" of sedimentation and their relationship to biological integrity. As previously mentioned, studies by Bjornn indicate that approximately 33% embeddedness appears to be a "normal" stream condition. Therefore, **embeddedness percents of 33% or less encountered at a study site should be assessed as fully supporting** regardless of the values measured at the reference site. At values above 33%, a comparison of percent embeddedness between the reference and study sites can be performed using a T-test for significance in which the null hypothesis is s=s. If the hypothesis is accepted, then the percent mean embeddedness at both the reference and the study sites is similar and the aquatic life use is therefore supported or not impaired. If, however, the hypothesis is rejected (s≠s) then the study site mean should be divided by the reference mean (as mentioned previously with the pebble count) and multiplied by 100 to determine the percent increase in embeddedness at the study site. The increase in embeddedness and its effect on aquatic life use may be evaluated as follows: full support (comparable to reference), 0 to 27% and non-support $\geq$ 28% (Table 1).

Table 1 **Degree of aquatic life use support affected by stream bottom deposits (sediment) evaluated by increases in either fines or embeddedness, relative to a reference site.[1] Adapted and modified from Figure 1, i.e. 100 - 90% = 0 - 10%).**

Pebble Count Fines ≤ 2 mm (% increase over reference)[2]	**Embeddedness (% increase over reference)[2]**	**Degree of Aquatic Life Use Support (Presumptive[1])**
0 – 27%	0 – 27%	Full Support, Comparable to Reference [1,3]
≥ 28%	≥ 28%	Non-Support[1]

[1] Biological assessment is necessary for confirmation and statistical database.
[2] Raw data values used for these percent comparisons between reference and study sites needs to meet adequate sampling size requirements.
[3] Raw percent values of ≤20% fines (pebble counts) and ≤ 33% embeddedness at a study site should be evaluated as fully supporting regardless of the percent attained at the reference site.

3. Biological Assessment (Macroinvertebrates)

Since the narrative standard for stream bottom deposits is centered around a biological component, any assessment or evaluation of a stream bottom using physical criteria, such as pebble count and embeddedness, needs to be confirmed using some type of bioassessment. A biological assessment using EPA's Rapid Bioassessment Protocol (Plafkin *et al,* 1989; Barbour *et al.*, 1999) for macroinvertebrates must be included at the reference and study sites in which the pebble count and/or embeddedness procedures were performed to confirm the evaluations and to provide a database in which to infer or provide a statistical relationship between the physical and biological components. Prior to collection of macroinvertebrates, a habitat assessment (Plafkin *et al.*, 1989; Barbour *et al.*, 1999) of the site should be performed using both visual observation and measurements made in association with any other studies (pebble counts, embeddedness, Rosgen Level II or III, longitudinal profiles, etc.). This can be compared later with the habitat assessment at the reference site to yield additional information as to other potential sources of use impairment other than sediment. Habitat assessment categories are based on percentages derived from dividing the study site score by the reference site score. Assessment categories and the percent comparability to the reference site (Plafkin *et al.*, 1989) are as follows: comparable to reference and fully supporting, > 83%; and community structure less than expected to few species present and non-supporting, ≤79%. The missing 4% value between categories allows adjustments between categories based on best professional judgment.

Macroinvertebrates for analysis should be collected in a riffle area and may consist of either three quantitative samples using a Hess sampler or three composited kick samples (semi-quantitative) covering an area of approximately one meter for one minute. For valid comparisons and analysis, sampling procedures must be identical between the reference and study site(s). Procedures for preservation, sorting, enumeration, identification, and analysis need to follow standard Surface Water Quality Bureau and USEPA procedures (Barbour *et al.*, 1999; NMED, 2000).

Application of the biological assessment or degree of impairment is a percentage comparison of the sum of selected metric scores at the study site compared to a selected reference condition (site). Biological groupings will be the same as those defined in the 1998 Surface Water Quality Bureau's document "Procedures for Assessing Standards Attainment" (NMED, 1998) and EPA guidance (Plafkin *et al.,* 1989). In Table 2, those sites achieving a biological assessment score greater than 83 percent of the reference condition will be termed non-impaired (full-support) and scores less than or equal to 79 percent will be determined to be impaired (non-support). Percentage values obtained that are in between the above ranges will require best professional judgment as to the correct placement (Plafkin *et al.*, 1989).

Table 2. Biological Integrity Attainment Matrix

% Comparison to Reference	Biological Condition Category	Attributes[1]
>83%	Non-impaired	Comparable to best situation to be expected within ecoregion (watershed reference site). Balanced trophic structure. Optimum community structure (composition & dominance) for stream size and habitat quality.
79 – 54%	Slightly Impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
50– 21%	Moderately Impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<17	Severely Impaired	Few species present. Densities of organisms dominated by one or two taxa.

[1] Biological attributes from EPA's *Rapid Bioassessment Protocols for Use in Stream and Rivers, (*Plafkin *et al.*, 1989*)*. The Surface Water Quality Bureau has initiated a program of reassessing and refining the biomonitoring protocols and percentages used in this table to better reflect conditions in New Mexico waters. New Mexico has lumped all but the "non-impaired" category into "Non Support" per USEPA Region 6 suggestion.

Final Assessment: Combined Application of Physical and Biological Assessments

Upon completion of physical and biological assessments for stream bottom deposits (sediments), a final assessment can be determined from the following matrix table (Table 3). This is accomplished by taking the increases between percent fines or embeddedness and matching it with the appropriate physical assessment use support category in the far left column. The physical assessment use category can then be matched with the biological assessment use category located on the top row to obtain a use support category for aquatic life use based on biological and physical indicators of increased stream bottom sediment. **It is noteworthy that under certain situations, the physical indicators (fines and/or embeddness) may indicate full support, while the biological assessment may indicate non support. In these cases, factors other than sediment alone, such as extremes in pH, low oxygen, temperature, lack of stream flow, and toxicity, etc. may be responsible for a reduction in biological integrity at a particular site. In this case, the assessment unit should be listed under Category 5C with an impairment of "Benthic-Macroinvertebrate Bioassessments (Streams)" on the Integrated Clean Water Act §303(d)/305(b) list until the exact cause of impairment is determined. Potential causes of impairment such as those listed above will then be quantified by examining such things as chemical and physical data collected at or near the site in question.**

Table 3. Final assessment matrix for determining aquatic life use support categories by combining physical (% fines & embeddedness) and biological assessments as sediment indicators[1]

Physical \ Biological	**Impaired (Non Support)** 0-79%	**Non-impaired (Full Support)** 83-100%
Non-Support Fines or Embeddedness >28% increase	Non-Support	Full Support
Full Support Fines or embeddedness <27% increase[3]	Non-Support[2]	Full Support

1 In previous New Mexico §305(b) reports and §303(d) lists, New Mexico also had categories entitled Full Support Impacts Observed (Supporting) and Partial Support. The most recent guidance from USEPA recommends the following use attainment categories (USEPA 2001): Fully Supporting, Not Supporting, Insufficient Information, and Not Assessed. Also, UPEPA Region 6 requested that New Mexico lump all but the "Non Impaired" category in Plafkin et al. 1989 into the Non Support attainment category. Therefore, Full Support and Supporting terminology related to percent fines or embeddedness in previous versions of this protocol were condensed into Full Support, while Partial Support and Non Support were condensed into Non Support. Regarding terminology based on Plafkin et al. 1989, "Non Impaired" terminology related to benthic macroinvertebrates remains Full Support while "Slightly Impaired," "Moderately Impaired," and "Severely Impaired" were condensed into Non Support per USEPA Region 6's request.

2 Reduction in the relative support level for the aquatic life use in this particular matrix cell is probably not due to sediment. It is most likely the result of some other impairment (temperature, D.O., pH, toxicity, etc.), alone or in combination with sediment. These waters will be labeled as Category 5C on the Integrated §303(d)/305(b) list to indicate that further study is needed to determine the exact cause of impairment.

3 Raw percent values of ≤20% fines (pebble counts) and ≤ 33% embeddedness at a study site should be evaluated as fully supporting regardless of the percent attained at the reference site.

Step by step procedure for evaluating whether sediment is impairing the aquatic life use at a stream site.

1. Select study site(s) along with a comparable reference site.

2. Perform a bioassessment on the benthic macroinvertebrate community at each reference in which a pebble count and/or embeddedness procedure is to be performed.

3. Do a pebble count and/or embeddedness evaluation at the reference sites. Pebble counts should be done in the same habitat unit(s) where the macroinvertebrates were collected. When doing pebble count evaluations, it is important to determine the necessary sample size (see page7) needed at each study site based on the evaluated sample size and determined percent fines at each reference site. This calculation should preferably be done streamside at the reference site using the pebble count analyzer software so that sufficient data can be collected with one visit. However, it is acceptable to do the calculations in the office, but realize that an additional visit to the stream may be required if your sample size is inadequate.

4. Perform a bioassessment of the benthic macroinvertebrate community at each study site, accompanied by collection of either pebble count and/or embeddedness data of sufficient size to be statistically significant.

5. Compare the physical and biological data between the study and reference sites by dividing the results obtained at the study site by that of the reference site to obtain percent "comparability."

6. Using the final assessment matrix (Table 3), locate the proper support cells for both the physical and biological percentages calculated in step 5, and determine the final degree of support for the aquatic life use that is affected by sediment.

Data collection and interpretation

The various support categories along with the ranges of percents used to quantify the various categories are based on slight modifications of those used in EPA's Rapid Bioassessment Protocols (Plafkin *et al.*, 1989) and the State of Colorado Sediment Task Force (CDPH&E, 1998). **They are intended to provide an initial base or reference point from which to proceed in the collection and interpretation of data regarding the adverse effects of sediment on biological communities in the State of New Mexico.** As this guidance is applied and data from various sites are collected, it will be necessary to adjust the standards attainment matrices in terms of the percentage of reference conditions for physical stream bottom substrate "indicators" and biology. It is imperative to the validity, growth, and evolution of this document that the Surface Water Quality Bureau establishes a proper database from which the valid statistical treatment may be employed to strengthen and adjust the matrix tables when deemed necessary through the addition of data generated from this protocol. Also, it is critical that the metrics (EPT, diversity, standing crop, shredders/total, etc.) used for evaluating the macroinvertebrate communities also undergo review in order to select those metrics that are most sensitive to changes or increases in stream bottom sediment. In addition, it may be prudent to engage the services of a statistician to review and strengthen these endeavors.

Sandy Bottom Streams

Sandy bottom streams or **stream bottom channels consisting mostly of fines (D84 <2mm) will require different methodologies** for proper analysis **not described in this document**. For instance, the necessary data needed for comparison of the physical component (stream bottom substrate size and distribution) between reference and study sites may require sieving (using 2.0mm, 1.0mm, 0.5mm, 0.25mm, 12.5mm and 0.063mm sieve sizes) of a standardized weight of dry stream bottom fines (Bunte and Abt 2001) while the biological component (benthic macroinvertebrates) may require the combined use of both artificial substrate samplers and multihabitat sampling by kicking and jabbing using a D-frame dip net (Barbour *et al.*, 1999*).* At present, **the bureau does not have a methodology or protocol that it can use for either detecting or assessing the effect of stream bottom deposits on sandy bottom streams**. Instead, it is seeking input and guidance from outside sources for specific methods and protocols that are not only scientifically sound but also time and cost effective to address this specific assessment problem.

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APPENDIX E

NUTRIENT ASSESSMENT PROTOCOL FOR STREAMS

New Mexico Environment Department
Surface Water Quality Bureau

July 2002

Purpose

The purpose of this document is to establish an assessment protocol for the determination of nutrient enrichment of streams. There is no numeric standard for nutrients in New Mexico. The narrative standard reads, plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the state (NMWQCC 2000). This protocol will be used to assess the need for a TMDL on a reach that is listed on the State of New Mexico's 303 (d) list as impaired by plant nutrients.

Background

The presence of some aquatic vegetation is normal in streams. Algae and macrophytes provide habitat and food for all stream animals. However, an excessive amount of aquatic vegetation is not beneficial to most stream life. The level of nutrient enrichment is often reflected by the types and amounts of aquatic vegetation in the water. High levels of nutrients (especially nitrogen and phosphorus) may promote an overabundance of algae and floating and rooted macrophytes.

Plant respiration and decomposition of dead vegetation consume dissolved oxygen in the water. Lack of dissolved oxygen creates stress for all aquatic organisms and can cause fish kills. A landowner may have seen fish gulping for air at the water surface during warm weather, indicating a lack of dissolved oxygen (DO). Increases in primary productivity can increase invertebrates and fish in streams. However, excessive plant growth and decomposition can limit aquatic populations by decreasing dissolved oxygen concentrations. Nocturnal respiration can cause oxygen depletion in waters with high primary productivity and low reaeration rates. Even relatively small reductions in dissolved oxygen can have adverse effects on both invertebrate and fish communities (EPA 1991). Saturation levels of greater than 115% have been shown to be harmful to aquatic life (Behar 1996). Development of anaerobic conditions will alter a wide range of chemical equilibria, and may mobilize certain pollutants and generate noxious odors (EPA 1991).

Assessment Procedure

The primary question to be answered is: Is this reach nutrient impaired, and is the area of impairment large enough to cause undesirable water quality changes?. A nutrient impaired reach occurs where algal and macrophyte growths interfere with beneficial uses such as primary contact recreation, and high quality coldwater fishery etc. Algal biomass is the most important indicator of nutrient enrichment. Algae are either the direct (excessive, unsightly periphyton mats or surface plankton scums) or indirect (high/low DO and pH and high turbidity) cause of most problems related to excessive nutrient enrichment.

Algal and macrophyte growths may be determined to be a nuisance when there is 1) rotting algae and macrophytes in the stream, 2) substrate in the stream are choked with algae, 3) there are diurnal fluctuations in DO and pH, and/or 4) a release of sediment bound toxins. The EPA criteria for levels of periphyton biomass that are a nuisance are 150 mg^2/m^2 chlorophyll *a*. This protocol should be applied in the field during critical seasons; especially during low flow periods such as summer (before the monsoons), and early fall.

Standard field deployment of a sonde.

Normally, during this time there is more potential to have higher concentrations of plant nutrients in the stream, higher water and air temperatures, decreased periods of scouring, and maximum solar gain. This protocol consists of three levels, which range from a visual to analytical assessments. The different levels of assessment are used in sequential order to determine occurrence of nutrient over enrichment. Nutrient enrichment can be determined following a Level 1 analysis. In most cases, a level II-III analysis will be used to confirm this conclusion. Level I focuses on visual observations of a system and will usually provide enough information to determine whether a reach is impaired by plant nutrients, although it is often useful to continue with a Level II analysis. A Level II assessment combines analysis of chemical and biological samples to characterize the benthic community and water chemistry. If these measures contain exceedances of surface water quality standards, indicators of excessive primary production (i.e. large D.O. and pH fluctuation and/or high chlorophyll a concentration) or there is an unhealthy benthic community a Level III analysis can be performed. Level III analysis involves more quantitative measures and focuses on the algal and macrophyte community dynamics.

If it is determined that a stream reach is nutrient enriched, a TMDL will be written for that reach.

<u>**Level I: Observational with Limited Measures**</u>

The following measurement and observations should be made to assess for nutrient enrichment. If any of the measures are apparent, then there would be a strong indication of nutrient enrichment, and the analysis would move to a level II. If a reach is considered "borderline" a more intensive level II-III assessment would be made to further verify.

Location: Please take photos of the reach being studied with the date, time, and personnel.

Field Notes:

- Observe the presence of algae and/or macrophytes. Record a visual estimate of percent of each algal and macrophyte coverage. Look for lush and deep green thick mats of algae, and dense stands of macrophytes. Coverages of greater than 70% may indicate excessive nutrient enrichment. Note the presence of algae and macrophytes in the stream, substrate that is choked with algae and/or macrophytes, and where in the stream the growth is occurring (i.e. only on low flow areas, on fine substrate, or large stable substrate etc).

Field Notes:

- Please note if watercress is in the stream. It may be an indicator of springs in the area that is naturally occurring. Watercress can be identified by the following: (1) it has small whitish flowers, several arranged closely and (2) has roots from stem nodes (ADEQ 1996).

Field Notes:

- Measure dissolved oxygen (D.O); field measurement should be measured in the late afternoon. Determine if the D.O. concentration is above 110% saturation. Only algal production will cause supersaturated DO and high pH during the day. If a D.O. measurement can be taken at night, determine if the concentration exceeds surface water quality standards for that reach. Nocturnal respiration can cause oxygen depletion in waters with high primary productivity and low reaeration rates.

Field Notes:

- Measure the pH during the late afternoon. High pH is indicative of eutrophic conditions. Determine if the pH exceeds 9 or the standard for the stream reach.

Field Notes:

- Look at the landscape patterns (such as an alluvium to bedrock transition, open basin to canyon transition)? (ADEQ 1996).

Field Notes:

- ♦ Note the channel characteristics, width to depth ratios, bank stability etc.

Field Notes:

- ♦ Evaluate the coarse substrata (cobbles, boulders, gravel, and sand). Note the dominance and subdominant size classes. Look for the presence of slime on the coarse substrate. Note the occurrence and character of the slime (i.e. which substrate it occurs on, its thickness and color etc.). This slime is periphyton and may develop in response to nutrient enrichment.

Field Notes:

- ♦ Identify possible known sources of plant nutrients (i.e., septic, point source, confined animal feeding operations, residential development, fertilizers on agricultural land etc.) utilizing the Draft Pollutant Source Documentation Protocol (SWQB/NMED 1996b), Note observations of land use and other sources. Some elevated nutrient levels may also be natural from springs, wetlands, (Synder and Morace 1997), and upwelling areas (groundwater). Please note this information as well.

Field Notes:

- Is there any evidence of scouring of the stream from recent rainstorm or flooding events? Look at meteorological data if available for the area.

Field Notes:

- Gather existing data. Compile data on water quality, aquatic communities, land use, etc. for the reach of concern and associated watershed. Determine if the existing data (chemical, biological, land use, etc.) substantiates observational findings?

Field Notes:

- Observe the color and clarity of the water. Measure the turbidity and TSS values. Green colored water can indicate the presence of phytoplankton and high levels of total suspended solids (TSS) and turbidity. TSS attenuates light and decreases transparency. These variables affect the response of algae to nutrients due to light attenuation and scouring. TSS in the range of 10-32 mg/L and turbidity in the range of 7-23 NTU may reduce abundance and diversity of benthic macroinvertebrates that graze on the algae (EPA Guidance 1998).

Field Notes:

- Note if black fly larvae or other diptera occur in high numbers and dominate benthic community.

Field Notes:

- Estimate the extent of the impacted area (i.e. the distance of the stream that is impaired). Note where the indicators of nutrient enrichment change.

Field Notes:

- Determine if the stream discharges to an impoundment.

Field Notes:

- Note if there are any significant tributaries (wet or dry), which may be contributing to the nutrient problem in the stream.

Field Notes:

- Note the dominant velocity of the flow. The flow velocity influences algal growth. High flow events can scour the stream channel and reduce algal biomass. Reduced flows may produce drought conditions leading to low levels of algal biomass. Stable, moderate flows that provide plant nutrients may increase eutrophication problems. If possible, record the flow on-site, or from a nearby USGS gage station.

Field Notes:

- ♦ Observe the riparian corridor. Record the character of the riparian area noting the height, density and removal of streamside vegetation (rivers need adequate light to develop and maintain high levels of algal biomass). An assessment of streamside vegetation will help to determine if there is sufficient light to support an algal bloom. Take photos.

Field Notes:

Level II: Limited Quantitative Measures Taken

Before selecting locations for sampling, walk a couple of hundred meters of the stream to ensure the sampling stations are representative (i.e. are not atypical) of the reach being characterized. The following data should be collected from each site:

- ♦ Three to fourteen days of continuous sonde data of dissolved oxygen, pH, conductivity, temperature, and turbidity. Observe predawn measurements for diurnal minimum dissolved oxygen concentrations and afternoon hours for maximum pH. Aquatic organisms are affected most by maximum pH and minimum DO rather than by daily means for those variables. The sonde should be placed upright in the stream in area with significant flow, and secured to a T-post, with nylon straps or hose clamps (see photo attached). The sonde should be placed in PVC pipe, which is secured to the T-post. The PVC should have holes in it to protect the sonde from debris, while allowing water to flow past the probe membranes. Also, the sonde should not be touching the bottom of the stream. In addition, the sonde should be further secured with a chain or cable and padlocked to a tree or other stable object on shore, and should be placed where it is not easily detectable. If it is feared the sonde cannot be safely deployed for unattended logging due to potential vandalism, the sonde should not be deployed for long term unattended logging.

Field Notes:

- ♦ Water samples should be collected for analysis of total and dissolved nutrient concentrations including total phosphorus and nitrogen. Dissolved nitrogen and phosphorus (especially orthophosphate) should also be taken. Nutrient sampling should be conducted monthly to bimonthly during the season of greatest nutrient loading and during the season of greatest algal growth. Some nutrient sampling should also occur during the season of lowest algal biomass levels. If possible, the nutrient assessment should also be conducted in the spring or during high flow events, as nitrogen and phosphorus concentrations may increase due to sediment inputs into the stream. Soluble reactive phosphorus and dissolved inorganic nitrogen are the forms available for algal uptake, and are the forms determined (after digestion) for total nitrogen and total phosphorus. Generally, dissolved nitrogen is the more readily available form for biological uptake. Orthophosphate is the only form readily available for plant uptake. Ortho phosphorus samples should be filtered immediately through a 0.45um filter, and cooled to 4ºC with a maximum holding time of 48 hours. Plastic or glass can be used for the dissolved samples, although glass is preferred as low levels of phosphorus may adsorb onto the container, if not frozen. A comparison of inorganic particulate and dissolved phosphorus may help determine whether the primary source is due to erosion or to other factors.

Field Notes:

- ♦ Characterize the aquatic vegetation in the reach using the attached form (Evan Horning, USGS). Walk a zig-zag pattern upstream approximately 20 times the bankfull width or 2 meander lengths of the channel. At 10 randomly selected steps pick up or feel the substrate. Rate the periphyton thickness on the substrate using the following scale:

    - 0 indicates substrate is rough with no apparent growth;

    - 0.5 indicates substrate is slimy, but biofilm is not visible (tracks cannot be drawn in the film with the back of your fingernail; endolithic algae can appear green but will not scratch easily from the substratum);

- 1 indicates a thin layer of microalgae is visible (tracks can be drawn in the film with the back of your fingernail);
- 2 indicates accumulation of microalgae to a thickness of 0.5-1 mm;
- 3 indicates accumulation of microalgae from 1 mm to 5 mm thick;
- 4 indicates accumulation of microalgae from 5 mm to 20 mm and
- 5 indicates layer of microalgae is greater than 2 cm.

Also at the randomly selected step observe a cross section transect and rate the algal and macrophyte cover separately using the following scale:

- 0 indicates no macrophytes or macro-algae present;
- 1 indicates some (but < 5% coverage) macrophytes or macro-algae present;
- 2 indicates 5-25% cover of substratum by macrophytes or macro-algae;
- 3 indicates greater than 25-50% cover of substratum by macrophytes or macro-algae;
- 4 indicates greater than 50-75% cover of substratum by macrophytes or macro-algae and
- 5 indicates greater than >75% cover of substratum by macrophytes or macro-algae

Field Notes:

♦ If the stream observations indicate that algal biomass (suspended or filamentous) seems to be a problem in the stream, a limiting nutrient analysis and algal growth potential test should be performed. Currently, researchers at the University of New Mexico (UNM) are conducting this work for the SWQB. Please check with the Financial Section in the SWQB to find out funding levels for these analyses before proceeding. Two one-gallon samples of water (no acidification) should be taken at each site in the river and stored on ice at 4ºC immediately. The samples should be taken to UNM Biology Department within two days of collecting the samples. Please call Dr. Barton @ UNM before taking the samples to his lab.

The procedures for determining limiting nutrients and algal growth potential is outlined in an EPA publication EPA-600/9-78-018 entitled *The Selenastrum Capricornutum* Prinz Algal Assay Bottle Test and the EPA-660/3-75-034 publication entitled Biostimulation and Nutrient Assessment Workshop. The amount of chlorophyll for each site is determined using fluorescence measurements. The fluorescence values are then converted to dry weight values using a standard the researchers construct. The results are given in dry weight measurements in accordance with the EPA procedure. The researchers at UNM then further study the effects of nitrogen and phosphorus additions on algal growth potential in the stream.

Field Notes:

♦ If the algal bioassay and limiting nutrient analysis cannot be done, chlorophyll a concentration should be measured by collecting a sample from a known area of substrate or from an artificial substrate (i.e. slides). Chlorophyll *a* concentration is used as a surrogate for algal biomass. **An algal indicator such as chlorophyll *a* is generally the most appropriate monitoring technique (**EPA 1991). Chlorophyll *a* values < 50 mg/m^2 are typical of unenriched or light scoured streams (EPA Guidance 1998). EPA (1998) guidance states that British Columbia developed algal biomass criteria for small wadeable streams: 50 mg/L of chlorophyll a to protect aesthetics, and 100 mg/L to protect against undesirable changes in stream communities. Chlorophyll a is specific to algae, while Ash Free Dry Mass (AFDM) and turbidity includes living and non-living organic matter. **AFDM/Chlorophyll a is an autotrophic index for periphyton productivity, which can distinguish the relative response to inorganic nitrogen, phosphorus and biological oxygen demand (BOD) enrichment.** Streams enriched with inorganic nutrients that have eutrophication problems have ratios of AFDM/chlorophyll a >250, values > 400 indicate organically polluted conditions (EPA 1998).

Field Notes:

- Samples of benthic macroinvertebrates should be collected from the reach being characterized and a suitable reference site if possible. The benthic community can be assessed using the 1999 EPA Rapid Bioassessment Protocols (RBP). This index of biological integrity (B-IBI) for macroinvertebrates uses a number of metrics that are non-specific to waste type and can evaluate effects of nutrient enrichment (e.g. Number of taxa, percent EPT-mayflies, stoneflies, and caddisflies, percent predators etc.). The advantages of the B-IBI include: low variability and high sensitivity, and absolute background values for a no effect condition (EPA Guidance 1998). In areas where other stressors such as sediment are not shown to be causing an impairment to the biological community, an assessment using metrics specific to organic enrichment such as the Hilsenhoff Biotic Index, or others as appropriate, should be conducted. **Indices employing macroinvertebrates as indicators of nutrient pollution have great potential. They are the most reliable and frequently used organisms to assess water quality (EPA 1998).** Macroinvertebrates are highly sensitive to changes in water quality and disturbance and are relatively immobile. They are also long lived and easy to sample, and are an important food supply for fish. Karr developed a 10 metric B-IBI index for macroinvertebrates to evaluate the effects of nutrient enrichment.

Field Notes:

- The ideal sampling procedure to survey the biological community would be to **sample each change of season (if possible), and then select appropriate sampling periods that accommodate seasonal variation (EPA 1996).** This ensures sources of ecological disturbance will be monitored and trends documented, and additional information will be available in the event of spills etc. Therefore, the response of the biological community to eposodic events can be assessed (EPA 1996).

Field Notes:

- ♦ If possible, collect samples for microbial analysis, especially for *Escherichia coli* (E. Coli) (ADEQ 1996).

Field Notes:

Level III: Extensive Quantitative Measures Taken (Diatoms, Phytoplankton, IBA)

Level III analysis uses information gathered in Level I and II assessments combined with additional information that provides a more quantitative measure of over enrichment. In streams benthic algae production and biomass are the most useful of all aquatic flora parameters in monitoring changes in water quality (EPA 1991). Periphyton algal biomass above nuisance levels often produces wide diurnal swings in water quality variables. The use of models such as CE-QUAL-RIV1, QUAL2E, and FORTRAN can be very useful to assess aspects of nutrient overenrichment. CE-QUAL-RIV1 simulates water quality conditions with the highly unsteady flows that can occur in regulated rivers. QUAL2E allows simulation of diurnal variations in temperature or algal photosynthesis and enrichment. FORTRAN simulates water quality and quantity for a wide range of organic and inorganic pollutants from agricultural watersheds (EPA Guidance 1998)

Identify a reference reach for the test reach and compare the characteristics of the sites including algal biomass, algal community composition, benthic community composition and associated environmental conditions (such as nutrient concentrations, canopy cover, substrate, DO and pH). In streams, benthic algae production and biomass are the most useful of all aquatic flora parameters to monitor changes in water quality (EPA 1991). Periphyton algal biomass above nuisance levels often produces wide diurnal swings in water quality variables due to metabolism.

Field Notes:

- ♦ **For benthic algae, biomass, species richness, diversity, and productivity can be measured from natural or artificial substrates.** To reduce variability, algae should be sampled from the same habitat (the midpoint of a glide), or in the part of the stream where algae is most likely to conflict with beneficial uses. **Generally, sampling once a month from June to September is adequate to assess algal biomass**. Two samples of algae should be collected from a known area of natural or artificial substrates and filtered onto 2 glass filter fibers for analysis of chlorophyll a concentration and biomass. A sample should also be preserved with formalin for identification. **An autotrophic index can be obtained by measuring the accumulation of organic material (ie. Biomass) on artificial substrates over a period of one to two weeks.** Until more is known about the natural variability of these parameters, the Chlorophyll a concentration, biomass, and algal composition should be compared to the reference site(s) as well as EPA guidance.

Field Notes:

Other Comments:

References:

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ATTACHMENTS

Site and Date:
Riffle A
Transect 1

Step	Depth (cm)	Velocity Rank (0-3)	Rock max diam-mm)	Macro phyte (0-3)	Moss (0-3)	Macro algae (0-3)	Periphyton (0-5)
13							
15							
23							
38							
59							
60							
70							
72							
99							

Macrophyte, Moss, and Macroalgae Indices:
0: none present
1: < 5% cover
2: 5% to 25% cover
3: < 25% cover

Periphyton Index:
0: rough surface with no apparent growth
0.5: slimy surface and may appear grean, but biofilm not visible (and tracks in the film cannot be drawn or scratched with the back of a fingernail
1: thin layer of periphyton is visible and tracks can be drawn in this film with the back of a fingernail
2: accumulation of periphyton evident, up to 1 mm thickness
3: periphyton 1 mm to 5 mm thick
4: periphyton 5 mm to 20 mm thick
5: periphyton > 2 cm thick

Site and Date:
Riffle B
Transect 1

Step	Depth (cm)	Velocity Rank (0-3)	Rock max diam-mm)	Macro phyte (0-3)	Moss (0-3)	Macro algae (0-3)	Periphyton (0-5)
1							
3							
14							
26							
35							
40							
62							
84							
91							

Macrophyte, Moss, and Macroalgae Indices:
0: none present
1: < 5% cover
2: 5% to 25% cover
3: < 25% cover

Periphyton Index:
0: rough surface with no apparent growth
0.5: slimy surface and may appear grean, but biofilm not visible (and tracks in the film cannot be drawn or scratched with the back of a fingernail
1: thin layer of periphyton is visible and tracks can be drawn in this film with the back of a fingernail
2: accumulation of periphyton evident, up to 1 mm thickness
3: periphyton 1 mm to 5 mm thick
4: periphyton 5 mm to 20 mm thick
5: periphyton > 2 cm thick

Site and Date:
Riffle C
Transect 1

Step	Depth (cm)	Velocity Rank (0-3)	Rock max diam-mm)	Macro phyte (0-3)	Moss (0-3)	Macro algae (0-3)	Periphyton (0-5)
6							
8							
34							
46							
54							
60							
66							
71							
91							

Macrophyte, Moss, and Macroalgae Indices:
0: none present
1: < 5% cover
2: 5% to 25% cover
3: < 25% cover

Periphyton Index:
0: rough surface with no apparent growth
0.5: slimy surface and may appear grean, but biofilm not visible (and tracks in the film cannot be drawn or scratched with the back of a fingernail
1: thin layer of periphyton is visible and tracks can be drawn in this film with the back of a fingernail
2: accumulation of periphyton evident, up to 1 mm thickness
3: periphyton 1 mm to 5 mm thick
4: periphyton 5 mm to 20 mm thick
5: periphyton > 2 cm thick

Site and Date:
Riffle D
Transect 1

Step	Depth (cm)	Velocity Rank (0-3)	Rock max diam-mm)	Macro phyte (0-3)	Moss (0-3)	Macro algae (0-3)	Periphyton (0-5)
20							
35							
53							
56							
60							
61							
66							
75							
87							

Macrophyte, Moss, and Macroalgae Indices:
0: none present
1: < 5% cover
2: 5% to 25% cover
3: < 25% cover

Periphyton Index:
0: rough surface with no apparent growth
0.5: slimy surface and may appear grean, but biofilm not visible (and tracks in the film cannot be drawn or scratched with the back of a fingernail
1: thin layer of periphyton is visible and tracks can be drawn in this film with the back of a fingernail
2: accumulation of periphyton evident, up to 1 mm thickness
3: periphyton 1 mm to 5 mm thick
4: periphyton 5 mm to 20 mm thick
5: periphyton > 2 cm thick

Site and Date:
Riffle A
Transect 2

Step	Depth (cm)	Velocity Rank (0-3)	Rock max diam-mm)	Macro phyte (0-3)	Moss (0-3)	Macro algae (0-3)	Periphyton (0-5)
10							
26							
41							
67							
72							
78							
81							
92							
93							

Macrophyte, Moss, and Macroalgae Indices:
0: none present
1: < 5% cover
2: 5% to 25% cover
3: < 25% cover

Periphyton Index:
0: rough surface with no apparent growth
0.5: slimy surface and may appear grean, but biofilm not visible (and tracks in the film cannot be drawn or scratched with the back of a fingernail
1: thin layer of periphyton is visible and tracks can be drawn in this film with the back of a fingernail
2: accumulation of periphyton evident, up to 1 mm thickness
3: periphyton 1 mm to 5 mm thick
4: periphyton 5 mm to 20 mm thick
5: periphyton > 2 cm thick

Site and Date:
Riffle B
Transect 2

Step	Depth (cm)	Velocity Rank (0-3)	Rock max diam-mm)	Macro phyte (0-3)	Moss (0-3)	Macro algae (0-3)	Periphyton (0-5)
12							
19							
39							
49							
62							
84							
88							
91							
100							

Macrophyte, Moss, and Macroalgae Indices:
0: none present
1: < 5% cover
2: 5% to 25% cover
3: < 25% cover

Periphyton Index:
0: rough surface with no apparent growth
0.5: slimy surface and may appear grean, but biofilm not visible (and tracks in the film cannot be drawn or scratched with the back of a fingernail
1: thin layer of periphyton is visible and tracks can be drawn in this film with the back of a fingernail
2: accumulation of periphyton evident, up to 1 mm thickness
3: periphyton 1 mm to 5 mm thick
4: periphyton 5 mm to 20 mm thick
5: periphyton > 2 cm thick

Site and Date:
Riffle C
Transect 2

Step	Depth (cm)	Velocity Rank (0-3)	Rock max diam-mm)	Macro phyte (0-3)	Moss (0-3)	Macro algae (0-3)	Periphyton (0-5)
17							
36							
60							
61							
67							
68							
69							
76							
92							

Macrophyte, Moss, and Macroalgae Indices:
0: none present
1: < 5% cover
2: 5% to 25% cover
3: < 25% cover

Periphyton Index:
0: rough surface with no apparent growth
0.5: slimy surface and may appear grean, but biofilm not visible (and tracks in the film cannot be drawn or scratched with the back of a fingernail
1: thin layer of periphyton is visible and tracks can be drawn in this film with the back of a fingernail
2: accumulation of periphyton evident, up to 1 mm thickness
3: periphyton 1 mm to 5 mm thick
4: periphyton 5 mm to 20 mm thick
5: periphyton > 2 cm thick

Site and Date:
Riffle D
Transect 2

Step	Depth (cm)	Velocity Rank (0-3)	Rock max diam-mm)	Macro phyte (0-3)	Moss (0-3)	Macro algae (0-3)	Periphyton (0-5)
1							
2							
11							
17							
29							
49							
62							
67							
71							

Macrophyte, Moss, and Macroalgae Indices:
0: none present
1: < 5% cover
2: 5% to 25% cover
3: < 25% cover

Periphyton Index:
0: rough surface with no apparent growth
0.5: slimy surface and may appear grean, but biofilm not visible (and tracks in the film cannot be drawn or scratched with the back of a fingernail
1: thin layer of periphyton is visible and tracks can be drawn in this film with the back of a fingernail
2: accumulation of periphyton evident, up to 1 mm thickness
3: periphyton 1 mm to 5 mm thick
4: periphyton 5 mm to 20 mm thick
5: periphyton > 2 cm thick

Site and Date:
Riffle A
Transect 3

Step	Depth (cm)	Velocity Rank (0-3)	Rock max diam-mm)	Macro phyte (0-3)	Moss (0-3)	Macro algae (0-3)	Periphyton (0-5)
8							
23							
27							
34							
40							
51							
64							
77							
82							

Macrophyte, Moss, and Macroalgae Indices:
0: none present
1: < 5% cover
2: 5% to 25% cover
3: < 25% cover

Periphyton Index:
0: rough surface with no apparent growth
0.5: slimy surface and may appear grean, but biofilm not visible (and tracks in the film cannot be drawn or scratched with the back of a fingernail
1: thin layer of periphyton is visible and tracks can be drawn in this film with the back of a fingernail
2: accumulation of periphyton evident, up to 1 mm thickness
3: periphyton 1 mm to 5 mm thick
4: periphyton 5 mm to 20 mm thick
5: periphyton > 2 cm thick

Site and Date:
Riffle B
Transect 3

Step	Depth (cm)	Velocity Rank (0-3)	Rock max diam-mm)	Macro phyte (0-3)	Moss (0-3)	Macro algae (0-3)	Periphyton (0-5)
30							
31							
55							
56							
61							
65							
67							
73							
77							

Macrophyte, Moss, and Macroalgae Indices:
0: none present
1: < 5% cover
2: 5% to 25% cover
3: < 25% cover

Periphyton Index:
0: rough surface with no apparent growth
0.5: slimy surface and may appear grean, but biofilm not visible (and tracks in the film cannot be drawn or scratched with the back of a fingernail
1: thin layer of periphyton is visible and tracks can be drawn in this film with the back of a fingernail
2: accumulation of periphyton evident, up to 1 mm thickness
3: periphyton 1 mm to 5 mm thick
4: periphyton 5 mm to 20 mm thick
5: periphyton > 2 cm thick

Site and Date:
Riffle C
Transect 3

Step	Depth (cm)	Velocity Rank (0-3)	Rock max diam-mm)	Macro phyte (0-3)	Moss (0-3)	Macro algae (0-3)	Periphyton (0-5)
2							
7							
29							
38							
61							
65							
87							
89							
99							

Macrophyte, Moss, and Macroalgae Indices:
0: none present
1: < 5% cover
2: 5% to 25% cover
3: < 25% cover

Periphyton Index:
0: rough surface with no apparent growth
0.5: slimy surface and may appear grean, but biofilm not visible (and tracks in the film cannot be drawn or scratched with the back of a fingernail
1: thin layer of periphyton is visible and tracks can be drawn in this film with the back of a fingernail
2: accumulation of periphyton evident, up to 1 mm thickness
3: periphyton 1 mm to 5 mm thick
4: periphyton 5 mm to 20 mm thick
5: periphyton > 2 cm thick

Site and Date:
Riffle D
Transect 3

Step	Depth (cm)	Velocity Rank (0-3)	Rock max diam-mm)	Macro phyte (0-3)	Moss (0-3)	Macro algae (0-3)	Periphyton (0-5)
6							
18							
20							
22							
44							
46							
55							
58							
79							

Macrophyte, Moss, and Macroalgae Indices:
0: none present
1: < 5% cover
2: 5% to 25% cover
3: < 25% cover

Periphyton Index:
0: rough surface with no apparent growth
0.5: slimy surface and may appear grean, but biofilm not visible (and tracks in the film cannot be drawn or scratched with the back of a fingernail
1: thin layer of periphyton is visible and tracks can be drawn in this film with the back of a fingernail
2: accumulation of periphyton evident, up to 1 mm thickness
3: periphyton 1 mm to 5 mm thick
4: periphyton 5 mm to 20 mm thick
5: periphyton > 2 cm thick

APPENDIX F

DRAFT December 2003

Protocol for Assessment of Large Dissolved Oxygen Data Sets

Introduction

The recommendations contained in this document are based primarily on the US Environmental Protection Agency (EPA) document *Ambient Water Quality Criteria for Dissolved Oxygen* (USEPA, 1986). That document is, in turn, based on several summaries of literature on oxygen requirements of freshwater aquatic organisms (mostly fish) and other studies.

Most of the information available concerning oxygen requirements of fish is based on salmonids, although a substantial number of studies also involve warmwater species. The consensus that has emerged from the literature is that salmonids and other coldwater species are generally more sensitive to low levels of dissolved oxygen than warmwater species, and that early life stages (embryos and larvae) of all species have higher dissolved oxygen requirements than their respective adult stages. Although few data are available on the effects of reduced dissolved oxygen on benthic macroinvertebrates, "historical consensus states that, if all life stages of fish are protected, the invertebrate communities, although not necessarily unchanged, should be adequately protected" (USEPA, 1986) although there may be exceptions to this generalization.

Based on the above statements, this protocol recommends criteria based on coldwater vs. warmwater aquatic life uses and early life stages vs. other life stages.

Recommendations

Ideally, dissolved oxygen data should be collected using continuous recording devices (sondes). However, in many cases, grab sample data will be all that are available. In those cases, it will not be possible to determine mean dissolved oxygen concentrations, thus, the minimum recorded concentration will need to be compared against the applicable criterion and associated assessment protocol for grab samples. Grab samples should be taken as near to sunrise as possible to ensure that the lowest concentration for a given day is recorded. Areas where excessive aquatic plant growth is evident should be prioritized for sonde deployment because diurnal fluctuations in dissolved oxygen concentrations will likely be greater due to variation in photosynthetic activity.

Daily mean is calculated as the arithmetic mean of the daily minimum and daily maximum. If the daily maximum concentration exceeds 100% saturation, the concentration that corresponds to 100% saturation should be used in the calculation (see Table 2). For example, if the daily maximum concentration recorded is supersaturated at 12 mg/L, but 11 mg/L corresponds to 100% saturation, the daily mean is calculated using 11 mg/L as the daily maximum concentration. The seven day mean is the arithmetic mean of seven consecutive daily means. The seven day mean minimum is the arithmetic mean of the daily minima for seven consecutive days.

Interstitial dissolved oxygen concentration may be substantially lower than that of the adjacent water column. In order to be protective of fish embryos and larvae that develop in the interstitial environment (e.g., salmonids), early life stages criteria are 3 mg/L higher than the desired interstitial concentration (see Table 1). It is recognized that interstitial oxygen concentration is largely dependent on porosity of the interstitial environment. Since this factor is highly variable, a 3mg/L differential is intended to be protective in the majority of situations. Early life stage criteria do not apply to the marginal coldwater aquatic life use, as this designated use is intended to protect cold season use of warm waters.

Early life stage criteria shall apply to continuously recorded data sets that are collected during the time period when early life stages are likely to occur in a given water body. The period of applicability for early life stages criteria shall be defined for high quality coldwater and coldwater aquatic life uses as 1 November through 31 July for elevations at or above 2750 m and 1 November through 30 June for elevations below 2750 m; for warmwater aquatic life use as 1 March through 31 August.

In Table 1, coldwater criteria apply to high quality coldwater, coldwater, and marginal coldwater aquatic life uses (with the exception, as noted above, that early life stages criteria do not apply to marginal coldwater aquatic life uses). Warmwater criteria include warmwater and limited warmwater aquatic life uses. All criteria are given in mg/L. For water bodies containing only fish species that have early life stages exposed directly to the water column (i.e., not in the interstitial environment), the 3 mg/L differential discussed above is irrelevant, thus, the figures in parentheses apply. In situations where the dissolved oxygen concentration that corresponds to 100% saturation is below the criterion in Table 1, the early life stages criteria shall be defined as 95% saturation and other life stages criteria shall be defined as 90% saturation.

Table 1. Water Quality Criteria for dissolved oxygen (mg/L)

	COLDWATER CRITERIA		**WARMWATER CRITERIA**	
	Early life stages (1 Nov - 31 Jul at ≥ 2750 m; 1 Nov - 30 Jun at < 2750 m)	**Other life stages**	**Early life stages** (1 Mar - 31 Aug)	**Other life stages**
30 Day Mean	Not Applicable	6.5	Not Applicable	5.5
7 Day Mean	9.5 (6.5)	Not Applicable	6.0	Not Applicable
7 Day Mean Minimum	Not Applicable	5.0	Not Applicable	4.0
Daily Minimum	8.0 (5.0)	4.0	5.0	3.0
If the concentration that corresponds to 100% saturation is below the applicable criterion	95% saturation	90% saturation	95% saturation	90% saturation

Table 2. Dissolved oxygen saturation values (mg/L) at given elevations (m) and temperatures (°C)
(Table generated from <http://water.usgs.gov/software/dotables.html>)

°C \ m	812	926	1053	1173	1302	1423	1556	1686	1818	1945	2086	2226	2362	2500	2646	2797	2938	3088	3239	3401
0	13.2	13.0	12.8	12.7	12.5	12.3	12.1	11.9	11.7	11.5	11.3	11.1	10.9	10.7	10.5	10.3	10.1	10.0	9.8	9.6
1	12.9	12.7	12.5	12.3	12.1	11.9	11.7	11.6	11.4	11.2	11.0	10.8	10.6	10.4	10.2	10.1	9.9	9.7	9.5	9.3
2	12.5	12.3	12.2	12.0	11.8	11.6	11.4	11.2	11.1	10.9	10.7	10.5	10.3	10.1	10.0	9.8	9.6	9.4	9.2	9.0
3	12.2	12.0	11.8	11.7	11.5	11.3	11.1	10.9	10.8	10.6	10.4	10.2	10.0	9.9	9.7	9.5	9.3	9.2	9.0	8.8
4	11.9	11.7	11.5	11.3	11.2	11.0	10.8	10.7	10.5	10.3	10.1	10.0	9.8	9.6	9.4	9.3	9.1	8.9	8.7	8.6
5	11.6	11.4	11.2	11.1	10.9	10.7	10.5	10.4	10.2	10.0	9.9	9.7	9.5	9.4	9.2	9.0	8.9	8.7	8.5	8.3
6	11.3	11.1	10.9	10.8	10.6	10.4	10.3	10.1	9.9	9.8	9.6	9.5	9.3	9.1	9.0	8.8	8.6	8.5	8.3	8.1
7	11.0	10.8	10.7	10.5	10.3	10.2	10.0	9.9	9.7	9.5	9.4	9.2	9.1	8.9	8.7	8.6	8.4	8.3	8.1	7.9
8	10.7	10.6	10.4	10.2	10.1	9.9	9.8	9.6	9.5	9.3	9.1	9.0	8.8	8.7	8.5	8.4	8.2	8.0	7.9	7.7
9	10.5	10.3	10.2	10.0	9.8	9.7	9.5	9.4	9.2	9.1	8.9	8.8	8.6	8.5	8.3	8.2	8.0	7.9	7.7	7.5
10	10.2	10.1	9.9	9.8	9.6	9.5	9.3	9.2	9.0	8.9	8.7	8.6	8.4	8.3	8.1	8.0	7.8	7.7	7.5	7.4
11	10.0	9.8	9.7	9.5	9.4	9.2	9.1	9.0	8.8	8.7	8.5	8.4	8.2	8.1	7.9	7.8	7.6	7.5	7.3	7.2
12	9.8	9.6	9.5	9.3	9.2	9.0	8.9	8.7	8.6	8.5	8.3	8.2	8.0	7.9	7.7	7.6	7.5	7.3	7.2	7.0
13	9.5	9.4	9.3	9.1	9.0	8.8	8.7	8.5	8.4	8.3	8.1	8.0	7.8	7.7	7.6	7.4	7.3	7.1	7.0	6.9
14	9.3	9.2	9.0	8.9	8.8	8.6	8.5	8.4	8.2	8.1	7.9	7.8	7.7	7.5	7.4	7.3	7.1	7.0	6.8	6.7
15	9.1	9.0	8.8	8.7	8.6	8.4	8.3	8.2	8.0	7.9	7.8	7.6	7.5	7.4	7.2	7.1	7.0	6.8	6.7	6.6
16	8.9	8.8	8.7	8.5	8.4	8.3	8.1	8.0	7.9	7.7	7.6	7.5	7.3	7.2	7.1	6.9	6.8	6.7	6.5	6.4
17	8.7	8.6	8.5	8.3	8.2	8.1	8.0	7.8	7.7	7.6	7.4	7.3	7.2	7.1	6.9	6.8	6.7	6.5	6.4	6.3
18	8.6	8.4	8.3	8.2	8.0	7.9	7.8	7.7	7.5	7.4	7.3	7.2	7.0	6.9	6.8	6.7	6.5	6.4	6.3	6.1
19	8.4	8.3	8.1	8.0	7.9	7.8	7.6	7.5	7.4	7.3	7.1	7.0	6.9	6.8	6.6	6.5	6.4	6.3	6.1	6.0
20	8.2	8.1	8.0	7.8	7.7	7.6	7.5	7.4	7.2	7.1	7.0	6.9	6.7	6.6	6.5	6.4	6.3	6.1	6.0	5.9
21	8.1	7.9	7.8	7.7	7.6	7.5	7.3	7.2	7.1	7.0	6.9	6.7	6.6	6.5	6.4	6.3	6.1	6.0	5.9	5.8
22	7.9	7.8	7.7	7.5	7.4	7.3	7.2	7.1	7.0	6.8	6.7	6.6	6.5	6.4	6.2	6.1	6.0	5.9	5.8	5.7
23	7.7	7.6	7.5	7.4	7.3	7.2	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.2	6.1	6.0	5.9	5.8	5.7	5.5
24	7.6	7.5	7.4	7.3	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.5	5.4
25	7.5	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.4	5.3
26	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.4	5.3	5.2
27	7.2	7.1	7.0	6.9	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.4	5.3	5.2	5.1
28	7.1	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.3	5.2	5.1	5.0
29	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.2	5.1	5.0	4.9
30	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.0	4.9	4.8
31	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0	4.9	4.8
32	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0	4.9	4.8	4.7
33	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0	4.9	4.8	4.7	4.6
34	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0	4.9	4.8	4.7	4.6	4.5
35	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0	4.9	4.8	4.7	4.6	4.5	4.4

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
•**Dissolved oxygen – continuously recorded data** (e.g., sonde data)	30 day mean, 7 day mean, 7 day mean minimum, or daily minimum is not exceeded.	30 day mean,7 day mean, 7 day mean minimum, or daily minimum is exceeded.	Data from partial 24-hour periods shall not be included in calculations of daily means and mean minima. The only exception to this rule is if there is an exceedence of the daily minimum within the partial day data. When available, biological assessment data shall be considered in determination of support status. When single excursions substantially above the criteria occur; when such excursions occur during critical life cycle period, such as during spawn periods for coldwater fish species; or when severe events lead to fish kills (or other serious water quality impairment), best professional judgment and other available data will be used to determine aquatic life use support status.

References

US Environmental Protection Agency. 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003. Office of Water. Washington, DC.

APPENDIX G

DRAFT December 2003

Protocol for Assessment of Large pH Datasets

Introduction

The pH of a solution is a measure of its hydrogen ion concentration and is calculated as the inverse log of the hydrogen ion concentration ($pH = -\log_{10} [H^+]$). A pH value of 7.0 is considered neutral. That is, at pH 7, the concentration of hydrogen ions ($[H^+]$) is equal to that of hydroxide ions ($[OH^-]$). In natural waters, pH is a measure of the acid-base equilibrium resulting from various dissolved compounds and gases. The principal system regulating pH in natural waters is the carbonate system, composed of carbon dioxide (CO_2), carbonic acid (H_2CO_3), bicarbonate ion (HCO_3), and carbonate ion (CO_3).

There is no absolute pH range outside of which there are detrimental effects to freshwater aquatic life. Rather, gradual deterioration occurs as pH values move away from neutral. A range of pH values from 5.0 to 9.0 is not directly lethal to fish; however, the toxicity of some pollutants (e.g., ammonia) can be substantially affected by pH changes within this range (USEPA, 1986). At pH values above 9.0, fish have difficulty excreting ammonia across the gill epithelium, but they are generally able to survive pH values up to 9.5 for 2-3 days (McKean and Nagpal, 1991). Benthic macroinvertebrates may be more sensitive to lower pH values than fish. A pH range from 6.5 to 9.0 appears to adequately protect both fish and benthic macroinvertebrates (USEPA, 1986).

In New Mexico, typical pH values in surface waters that are largely unaffected by anthropogenic disturbance vary approximately from 7.5 to 8.7. Some streams, depending on local geology, have documented natural background pH values as low as 3.0 (e.g., Sulphur Creek in the Jemez River watershed), but this is atypical on a statewide basis.

An increase in pH values can result from the decrease of carbonic acid when carbon dioxide, carbonate, and bicarbonate are used by plants during photosynthesis. Thus, when high levels of nutrients lead to excessive plant growth, pH values above 9.0 may occur during the daylight hours. During the night, when photosynthesis does not occur, the pH value drops. The result is a diurnal fluctuation of pH values that lags a few hours behind the diurnal fluctuation observed in dissolved oxygen concentrations. For this reason, it is best to use continuous recording devices (sondes) to record pH values where excessive aquatic plant growth is evident. If this is not possible, grab samples should be taken at the end of the day when pH values will be at their highest.

If exceedences of water quality criteria are to be detected, the use of grab samples for recording pH in areas of excessive aquatic plant growth poses a logistic problem when viewed with the need to also detect exceedences of the dissolved oxygen criterion. Dissolved oxygen is at its lowest (i.e., most likely to exceed criteria) in the early morning in areas of excessive aquatic plant growth. This is in contrast to the diurnal pattern of pH values, which are most likely to exceed criteria late in the day. This dilemma underscores the need to use sondes for collecting these kinds of data.

Recommendations

When continuously recorded pH data are available, instantaneous (hourly) pH values shall not be outside the range of the criterion for the water body in question in greater than 15% of the measurements, pH shall not exceed the range of the criterion for the water body in question for more than 24 contiguous hours, and pH shall never exceed 0.5 units above the upper limit of the criterion.

The following table shall be used to determine the degree of aquatic life use support.

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
•**pH – continuously recorded data** (e.g., sonde data)	pH is outside the range of the criterion for the water body in question in <15% of measurements; pH exceeds the upper limit of the range of the criterion by 0 to 0.5 units for less than 24 contiguous hours; and pH is never 0.5 or more units above the upper limit of the criterion at any time.	pH is outside the range of the criterion for the water body in question in ≥ 15% of measurements; pH exceeds the range of the criterion by 0 to 0.5 units for 24 or more contiguous hours; or pH is 0.5 or more units above the upper limit of the criterion at any time.	Assessments shall be based upon floating 24-hour periods; data from partial 24-hour periods shall not be included in assessments in order to avoid skewing the percentage of exceedences. The only exception to this rule is if there is an instantaneous reading that exceeds 0.5 units above the upper limit of the criterion within the partial day data. When available, biological assessment data shall be considered in determination of support status. When single excursions substantially above the criteria occur; when such excursions occur during critical life cycle period, such as during spawn periods for coldwater fish species; or when severe events lead to fish kills (or other serious water quality impairment), best professional judgment and other available data will be used to determine aquatic life use support status.

References

McKean, C. J. and N. K. Nagpal. 1991. Ambient water quality criteria for pH. British Columbia Ministry of Environment, Water Quality Branch, Water Management Division. <http://wlapwww.gov.bc.ca/wat/wq/BCguidelines/pH.html>

U.S. Environmental Protection Agency. 1986. Quality criteria for water 1986. EPA 440/5-86-001. Office of Water, Washington, D.C.