APPENDIX G

SEDIMENTATION/SILTATION LISTING METHODOLOGY FOR WADEABLE, PERENNIAL STREAMS

NEW MEXICO ENVIRONMENT DEPARTMENT
SURFACE WATER QUALITY BUREAU

SEPTEMBER 3, 2019

Purpose and Applicability

This document establishes a listing methodology for determining impairment due to excessive sedimentation/siltation (otherwise referred to as stream bottom deposits or SBD) in wadeable, perennial streams. This assessment is only conducted in wadeable, perennial streams at this time because the research used to develop this listing methodology is based upon data and information collected in perennial streams. The Surface Water Quality Bureau (SWQB) will include other waterbody types as additional information becomes available and applicable assessment thresholds are developed.

This protocol was developed to support an interpretation of the *State of New Mexico Standards for Interstate and Intrastate Surface Waters* narrative standard for bottom deposits found at 20.6.4.13 NMAC (https://www.env.nm.gov/surface-water-quality/wqs/):

> ***A. Bottom Deposits and Suspended or Settleable Solids:***
> *(1) Surface waters of the state shall be free of water contaminants including fine sediment particles (less than two millimeters in diameter), precipitates or organic or inorganic solids from other than natural causes that have settled to form layers on or fill the interstices of the natural or dominant substrate in quantities that damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.*

In 2008, the SWQB Sediment Workgroup was formed to review the previous sedimentation/siltation listing methodology and recommend an approach for revision. As a result of workgroup discussions, the SWQB and the U.S. Environmental Protection Agency (EPA) Region 6 contracted with Tetra Tech, Inc. to develop sediment translators or thresholds. Tetra Tech, Inc. generally followed the steps provided in EPA's Framework for developing suspended and bedded sediment (SABS) water quality criteria (EPA 2006). To address the "*from other than natural causes*" portion of the criterion, Level IV ecoregions were used to classify and group sites to examine distributions and define reference conditions that account for New Mexico's varied associated geological and physiographic characteristics around the state. Several staff from Tetra Tech, Inc., EPA Region 6, and the SWQB worked as a team to complete this effort.

This effort included the identification of sediment characteristics that are expected under the range of environmental settings in New Mexico, especially in undisturbed or best available reference streams. The goal of this characterization was to enable the SWQB to identify situations where sedimentation/siltation expectations are not met, using sediment indicators that show responsiveness to disturbance. Examining the relationships between biological measures and sediment indicators helped to identify where disturbance caused sediment imbalance and biologically-relevant habitat degradation. The results of these analyses led to quantitative, sedimentation indicator threshold recommendations for New Mexico perennial streams.

The 100+ page report (Jessup et al. 2010) detailing this effort, plus information on additional bedded sediment indictors as well as suspended sediment indicators, is available at https://www.env.nm.gov/surface-water-quality/sedimentation/. The SWQB also generated a Sedimentation/ Siltation Thresholds Development Plan (NMED/SWQB 2011), which summarizes the seven steps taken to develop recommended bedded sediment thresholds, available at the same web site. For historical purposes, this plan includes an abbreviated description of the previous sedimentation listing methodology utilized during the 1998 – 2010 listing cycles as Attachment A.

Exclusions

This protocol is not applicable to the following water body types because the necessary research and assessment methods are not yet developed for New Mexico:

- Lakes or reservoirs
- Large rivers (non-wadeable)
- Intermittent streams which includes water bodies under 20.6.4.98 or 20.6.4.128 NMAC
- Ephemeral streams which includes water bodies under 20.6.4.97 or 20.6.4.128 NMAC
- Wetlands or playas

The SWQB is distinguishing rivers from streams by defining systems that cannot be monitored effectively with the biological and habitat methods developed for wadeable streams. These rivers also generally meet the Simon and Lyons (1995) definition of great rivers as those having drainage areas greater than 2,300 square miles (mi^2). There are many systems is in New Mexico that meet the great river definition but are usually suitable to wadeable stream monitoring methods due to the arid nature of the region. For sedimentation monitoring and assessment purposes, the systems included in the "Large Rivers" water body type, and consequently exempt from this protocol, are the non wadeable portions of the:

1. San Juan River from below Navajo Reservoir to the Navajo Nation boundary near Four Corners,
2. Animas River from the Colorado border to the San Juan River,
3. Rio Grande in New Mexico,
4. Pecos River from below Sumner Reservoir to the Texas border,
5. Rio Chama from below El Vado Reservoir to the Rio Grande,
6. Canadian River below the Cimarron River, and
7. Gila River below Mogollon Creek.

Fine sediment benchmarks in representative riffle areas were previously developed for the San Juan and Animas Rivers. In 2002, the SWQB received a grant to develop a protocol for the determination of sedimentation impairment in these rivers. The SWQB contracted with the U.S. Department of Agriculture (USDA) National Sedimentation Lab (NSL) to provide technical support on the project (Heins et al. 2004). The SWQB used the results of this study to develop a repeatable, quantitative assessment procedure for determining whether New Mexico's current narrative sedimentation standard is being attained in the San Juan and Animas rivers. The NSL study resulted in the determination of fine sediment benchmarks for representative riffles areas in Ecoregion 22 as well as various river reaches in the San Juan River basin. The SWQB used these benchmarks to establish one fine sediment threshold for the San Juan and Animas Rivers and compared the measured bed material characteristics of the stream reach of concern to this fine sediment threshold. This procedure was used to assess the San Juan and Animas rivers for development of the 2004-2006 Integrated List, and was applied to subsequent data collected during non-wadeable conditions with comparable sampling methods to determine potential sedimentation impairment in these rivers. This document and the entire NSL report is available at: https://www.env.nm.gov/surface-water-quality/sedimentation/. A hybrid approach was used to assess the San Juan and Animas Rivers for sedimentation on the 2012-2014 Integrated Report following the 2010 watershed survey (see the Assessment Rationale for these assessment units for details). The SWQB hopes to develop a sedimentation listing methodology intended to be applicable to all non-wadeable river reaches listed above in the future.

1.0 Introduction/Background

Stream bottom substrate without excessive fine sediment filling the interstitial spaces provides optimum habitat for many fish and aquatic insect communities. Excessive fine sediment occurs when biologically-important habitat components, such as spawning gravels and cobble surfaces, are physically covered by fines (Chapman and McLeod 1987). Excessive fine sediment can result in decreased inter-gravel oxygen, as well as reduced or eliminated quality and quantity of habitat for fish, macroinvertebrates, 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 can be described as follows: 1) abundance of certain invertebrate taxa is correlated with substrate particle size; 2) fine sediment reduce the abundance of sediment intolerant taxa by reducing interstitial habitat normally available in large-particle substrate (e.g., gravel or cobbles); and 3) community composition changes as substrate particle size changes from large to small (e.g., sand, silt, or clay) (Waters 1995).

Sediment loads that exceed a stream's sediment transport capacity often trigger changes in stream morphology (Leopold et al. 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 can accelerate erosion, reduce habitat diversity (e.g., pools, riffles, etc.), and place additional stress on the designated aquatic life use.

Substrate characteristics may be considered impacted at a site if they are: 1) not similar to expectations for undisturbed sites in the same environmental setting; or 2) detectably affecting the biota. In the first case, substrate may be more fine, more coarse, more unstable, or more stable than expected under broadly-recognized, undisturbed conditions (i.e., reference or best available conditions) for that particular environmental setting. In the second case, biotic responses to disturbed substrates can be variable, but sub-optimal biotic conditions are often associated with unbalanced sediment.

Bedded sediments cannot be treated as introduced pollutants such as pesticides because they are not uniquely generated through human input or disturbance. Rather, bedded sediments are components of natural systems that are present even in pristine settings and to which stream organisms have evolved and adapted. Therefore, the detection of a sediment imbalance is more difficult than detecting an absolute concentration or percentage that represents a clear biological impact (Jessup et al. 2010).

The approach used to identify sedimentation/siltation thresholds for wadeable, perennial streams in New Mexico followed seven basic steps:

1. Review background information
2. Assemble datasets
3. Establish reference sites
4. Classify sites
5. Characterize sediments
6. Describe stressor-response relationships
7. Recommend thresholds or benchmarks

These steps are generally based on the EPA Framework for developing SABS water quality criteria (EPA 2006). The details of each step are available in summary form or in entirety in separate documents available on the SWQB web site (NMED/SWQB 2011 and Jessup et al. 2010, respectively): https://www.env.nm.gov/surface-water-quality/sedimentation/.

Multiple sediment indicators and their responsiveness to site disturbance and effects on benthic macroinvertebrates were analyzed. The analysis used reference distributions, quantile regression, and change-point analysis, and resulted in the threshold recommendations for two bedded sediment indicators (Table 1) – % Sand and Fines (%SaFN) and log Relative Bed Stability calculated without bedrock (LRBS_NOR) – in three sediment site classes, Mountains, Foothills, and Xeric areas (Table 2, Figure 1). The site classes are defined by Level III and IV ecoregions (Griffith et al. 2006) and distinguish sediment expectations across New Mexico. Site classes were identified through a principal component analysis (PCA) of environmental conditions and the bedded sediment indicators. The Foothills and Xeric site class definitions were modified slightly from Jessup et al. 2010 to further divide ecoregion 22 based on site characteristics used in the PCA (see NMED/SWQB 2011 for additional details). Site locations near sediment site class boundaries warrant additional scrutiny. Any study site within approximately twenty kilometers of these boundaries should be compared to the adjacent ecoregion definition within the bordering sediment site class to determine the appropriate ecoregion and associated bedded sediment site class designation for that particular site. Sediment site class assignments that deviate from Table 2 will be documented the SWQB's in-house database (SQUID).

Table 1. Bedded sediment indicators

Sediment Indicator	Description
Percent Sand & Fines (%SaFN)	**The percentage of systematically selected streambed substrate particles that are ≤2.0 mm in diameter from reach-wide pebble count.**
Log Relative Bed Stability (LRBS)	**A measure of the relationship of the median particle size in a stream reach compared to the critical particle size calculated to be mobilized by standardized fluvial stresses in the reach.** Median particle size is determined using a reach-wide pebble count (Peck et al. 2006). Critical particle size is calculated from channel dimensions, flow characteristics, and channel roughness factors (Kaufmann et al. 2008). The measure is expressed as a logarithm of the ratio of geometric mean to critical particle size.
LRBS_NOR	**RBS without bedrock or hardpan (log10).** This measure regards only the potentially mobile streambed particles in determining the geometric mean particle size, and improved associations between the bedded sediment measure and biological responses in the TetraTech analyses (see Jessup et al. 2010 for additional discussion of LRBS_NOR).

Table 2. Definition of bedded sediment site classes

Site Class	Definition
Mountains	Ecoregions 21 and 23, ***except*** *21d, 23a, 23b and 23e*
Foothills	Ecoregions 21d, 22a, 22b, 22f, 23a, 23b, 23e and 79
Xeric	Ecoregions 20, 22, 24, 25, and 26, ***except*** *22a, 22b, 22f*
Ecoregion number	**Ecoregion Name***
20	Colorado Plateaus
21	Southern Rockies
21d	Foothill Woodlands and Shrublands
22a	San Luis Shrublands and Hills
22b	San Luis Alluvial Flats and Wetlands
22f	Taos Plateau
23	Arizona/New Mexico Mountains
23a	Chihuahuan Desert Slopes
23b	Madrean Lower Montane Woodlands
23e	Conifer Woodlands and Savannas
24	Chihuahuan Deserts
25	High Plains
26	Southwestern Tablelands
79	Madrean Archipelago

NOTES: * Additional written descriptions of level 4 ecoregions in New Mexico are available at: http://www.eoearth.org/view/article/51cbed847896bb431f692a14/.

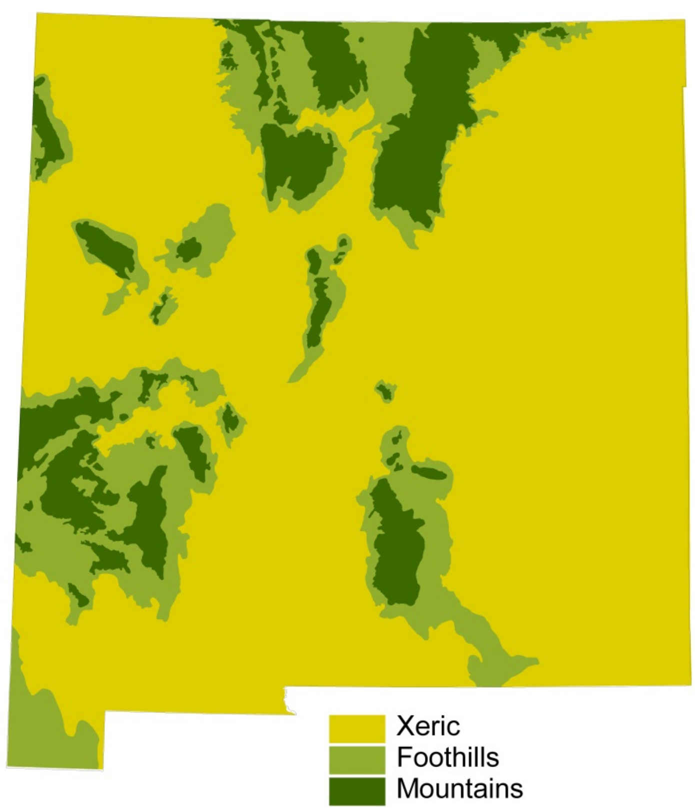

Figure 1. New Mexico Mountain, Foothills, and Xeric site class map

The recommended thresholds by site class resulted from a weight-of-evidence approach that considered multiple analytical approaches and the strength of each analysis. Corroborating evidence for selection of thresholds from reference conditions was found in the analysis of relationships between sediment and biological indicators. Biological effects are less direct indicators of required sediment conditions because the biota is affected by other environmental conditions, not just sediments (Jessup et al. 2010).

2.0 Assessment Procedure

To determine if there is excessive sedimentation/siltation in the study stream reach, two levels of assessment are performed in sequential order (Figure 2). The first level considers the simpler indicator of biological impairment, and the second level considers geomorphic impairment, as needed, when the first level threshold is exceeded.

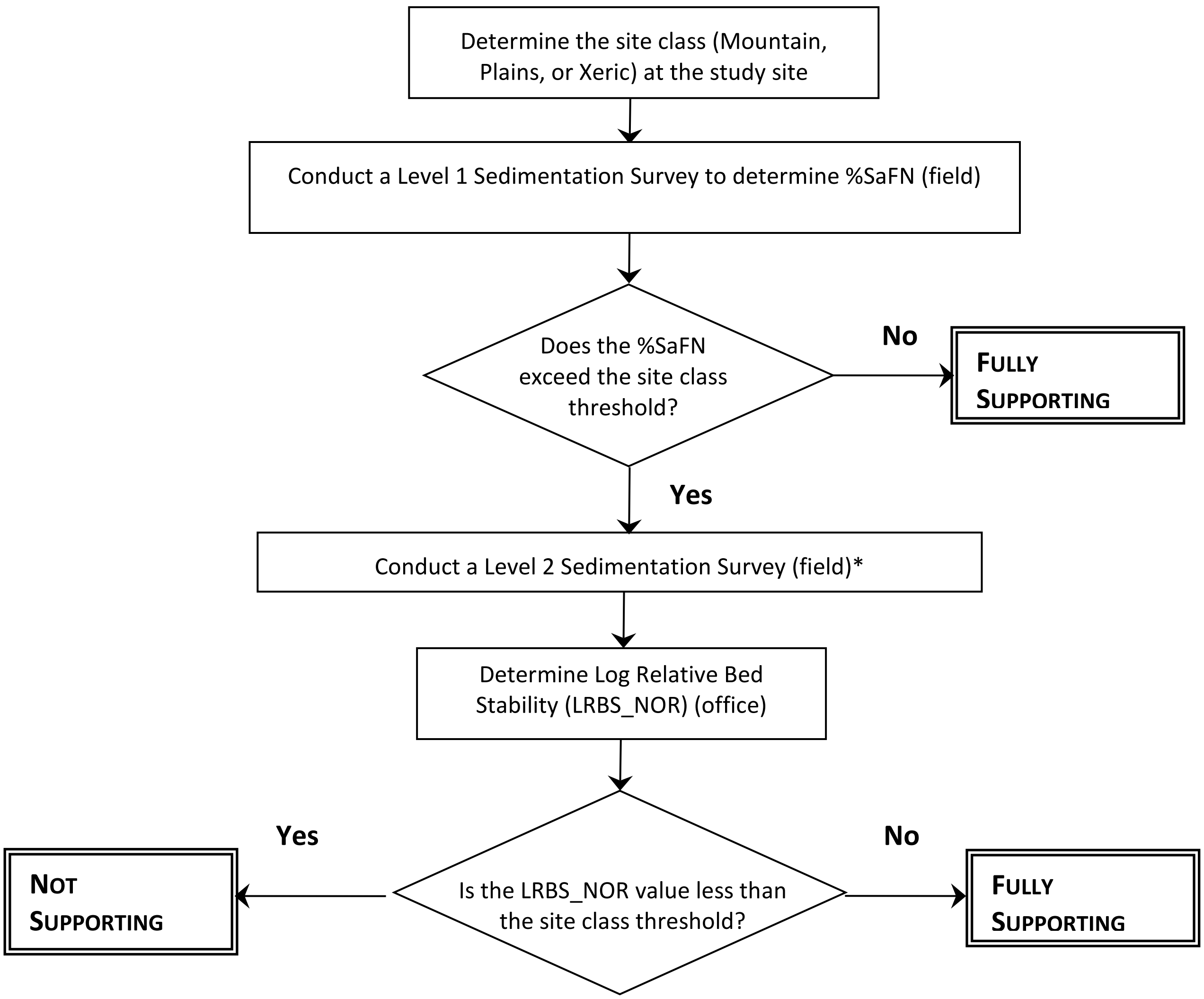

Figure 2. Generalized flowchart for determining sedimentation/siltation impairment

NOTES: * As described in the SWQB's Physical Habitat SOP (https://www.env.nm.gov/surface-water-quality/sop/) or equivalent. Level 1 and Level 2 sedimentation surveys should be performed during the same site visit to reduce the influence of seasonal variability, including flood/scouring events, large reservoir releases, etc.

The %SaFN sediment indicator is used in the Level 1 assessment because it is easily measured and correlated strongly with biological metrics. If the %SaFN indicates excessive fine sediment in the stream bed, a Level 2 assessment is performed to collect the data necessary to calculate the LRBS_NOR value. This sediment indicator is a calculation that considers site-specific hydraulic potential for moving bed sediments, so that the observed amounts of sand and fine sediments are only considered impaired when the streambed is more easily mobilized and transported than expected. The LRBS_NOR measure is appropriate as a second-tier indicator because it is scaled to hydro-geomorphic factors of the individual sites, as well as to the broader site classes, thus allowing evaluation of the potential of the specific site in terms of retaining or flushing fine sediments. When used as a second-tier sediment indicator, LRBS_NOR helps explain whether high %SaFN were expected for a given site or are a result of disturbed conditions (Jessup et al. 2010). Sediment condition relative to the fluvial potential is a better estimate of system stability and imbalance than absolute measures of fine sediment concentration alone, because they intrinsically account for site-specific natural settings. In contrast to LRBS_NOR, the %SaFN measure is an absolute quantity, which is more susceptible to spatial and temporal variations (Jessup et al. 2010) exceeding the natural variability captured by site classification.

Another way to present how the two indicators are applied in a tiered approach is to consider the quadrants when the two indicators are graphed against one another (Figure 3).

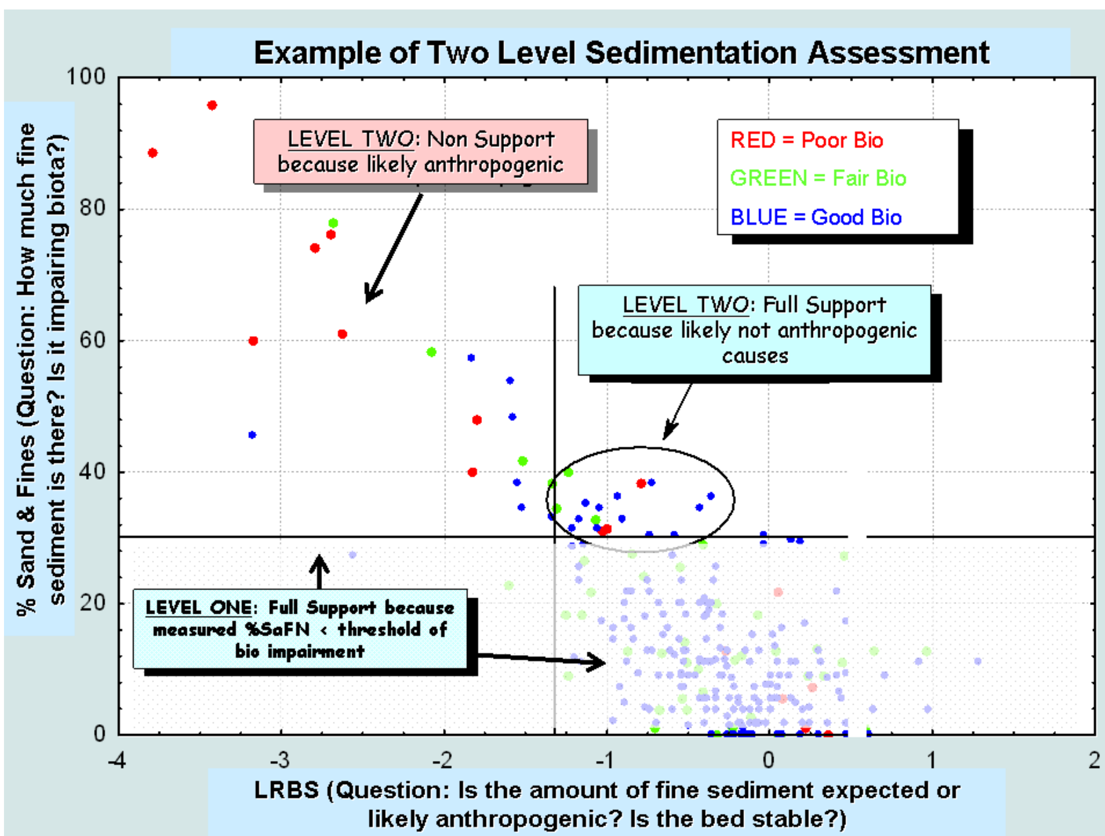

Figure 3. Graphical example of two indicator tiered assessment approach

For example, sites falling in the upper left quadrant represent **Non Support** (impaired) for sedimentation/siltation because they fail both the Level 1 and Level 2 thresholds (i.e., have both high %SaFN and low LRBS_NOR values). Sites in the other three quadrants are considered **Full Support** (unimpaired).

Specifically, sites that fall in the lower quadrants are considered unimpaired because they have low %SaFN (passing the Level 1 threshold). These sites are considered unimpaired because the measured %SaFN values from the Level 1 survey are below the threshold for biological impairment. Observations in the upper right quadrant indicate potential impairment using the Level 1 (%SaFN) threshold, but are considered unimpaired based on the Level 2 (LRBS_NOR) threshold because LRBS_NOR values greater than the threshold suggests that the higher %SaFN values may be natural and therefore expected for those sites.

2.1 Level 1 Sedimentation Assessment

Level 1 sedimentation surveys[1] are conducted during regular SWQB watershed surveys according to the SWQB's Standard Operating Procedure (SOP) 5.0 Physical Habitat (https://www.env.nm.gov/surface-water-quality/sop) or equivalent. The SWQB's physical habitat surveys are completed during stable low flow conditions, between August 15 and November 15 if concurrent biological monitoring is planned because this is the SWQB's historic biomonitoring index period. If no biological monitoring is planned or needed at a particular site, physical habitat surveys may be conducted during baseflow conditions post snowmelt runoff and prior to the monsoon season (generally mid-May through early-July), or late- fall to early-winter depending on location and weather patterns. The %SaFN is calculated on-site based on the 105 particle count and recorded on the appropriate field sampling sheet.

The %SaFN is an appropriate sediment indicator because it is essentially equivalent to New Mexico's definition of "…fine sediment particles (less than two millimeters in diameter)…" found at 20.6.4.13 NMAC. In a slight deviation from 20.6.4.13 NMAC, this listing methodology includes particles that are 2mm in diameter to be conservative, and to match EPA's definition and TetraTech, Inc.'s analyses (Peck et al. 2006, Jessup et al. 2010).

Table 3. Percent Sand & Fines (Level 1) thresholds

Site Class	Measured % Sand & Fines	Number of particles ≤ 2mm diameter based on an 105 particle count
Mountain	< 20% Sand & Fines	< 21 particles
Foothill	< 37% Sand & Fines	< 39 particles
Xeric	< 74% Sand & Fines	< 78 particles

Level 1 Analysis & Interpretation

If the measured %SaFN is less than the applicable site class threshold in Table 3, the sediment survey and assessment is complete and the assessment unit is considered to be **Full Support** with respect to New Mexico's narrative sedimentation/siltation standard found at 20.6.4.13 NMAC. If the measured %SaFN is greater than the applicable site class threshold in Table 3, the assessment is inconclusive and a Level 2 sedimentation survey is conducted according to the procedures in SWQB's SOPs. As stated in the SOPs, Level 1 and Level 2 surveys should be performed during the

[1] Although the terms "Level 1" and "Level 2" were removed from the SOP in 2019, they are still being used in this version of the CALM because 2017-2018 sedimentation data assessed for the draft 2020-2022 Integrated Listing cycle were collected under the previous physical habitat SOP that made this distinction.

same site visit whenever possible to reduce the influence of seasonal variability, including flood/scouring events, large reservoir releases, etc.

2.2 Level 2 Sedimentation Assessment

Data from the Level 2 sedimentation survey are used to calculate LRBS_NOR. Because fluvial site conditions are major determinants of the substrate conditions in stream channels, the critical particle size calculated from fluvial characteristics is a predictor of dominant and stable substrate conditions. In essence, the LRBS_NOR calculation is used to predict the expected sediment particle size that would be moved during a bankfull flow event. This expected or "critical" particle size is calculated from channel dimensions, roughness factors, and shear stresses (Kaufmann et al. 2008). The logarithm ratio of the measured particle size to the expected particle size is a measure of the relative stability of the stream bed.

In minimally disturbed streams, the measured geometric mean stream bottom particle size should trend towards the expected particle size (i.e., the size a stream is capable of moving as bedload at bankfull). Thus, LRBS_NOR values near zero indicate a stable stream bed, whereas increasingly negative values indicate excess fine sediment. For example, a LRBS_NOR value of -1 means that the measured geometric mean bedded sediment particle size is ten times (10X) finer than the expected particle size moving during bankfull flow events. Calculated LRBS values less than -3 indicate that the bed substrate may be moving even during low flow events.

LRBS_NOR was selected to be a sediment impairment indicator because this measure regards only the potentially mobile streambed particles in determining the geometric mean particle size and produces improved associations between the bedded sediment measure and biological responses when compared to the LRBS calculated with bedrock (Jessup et al. 2010). LRBS_NOR threshold values by site class are listed in Table 4.

Table 4. LRBS_NOR (Level 2) thresholds

Site Class	LRBS_NOR Units
Mountain	> -1.1
Foothill	> -1.3
Xeric	> -2.5

<u>Level 2 Analysis & Interpretation</u>

If the calculated LRBS_NOR is greater than the applicable site class threshold in Table 4, the assessment unit is regarded as **Full Support** with respect to New Mexico's narrative sedimentation/siltation standard found at 20.6.4.13 NMAC. If the calculated LRBS_NOR is less than or equal to the applicable site class threshold, the assessment unit is considered **Non Support**.

REVISION HISTORY:

2012 listing cycle – Protocol was substantially revised based on Jessup et al. (2010).

2014 listing cycle – Minor clarifications and re-formatting.

2016 listing cycle – Minor clarifications.

2018 listing cycle – "Assessment Protocol" changed to "Listing Methodology." Clarified application of Heins et. al 2004 study to waters in the San Juan River basin. Clarified potential re-assignment and documentation of sediment site class for a particular site.

2020 listing cycle – Minor clarifications.

REFERENCES:

Chapman, D.W. and K.P. McLeod. 1987. Development of criteria for fine sediment in Northern Rockies ecoregion. United States Environment Protection Agency Water Division, Report 910/9-87-162. Seattle, WA.

Heins, A., A. Simon, L. Farrugia, and M. Findeisen. 2004. Bed-material characteristics of the San Juan River and selected tributaries, New Mexico: Developing protocols for stream-bottom deposits. USDA-ARS National Sedimentation Laboratory. Research Report Number 47. Oxford, MS. Available at: https://www.env.nm.gov/surface-water-quality/sedimentation/.

Griffith, G.E., J.M. Omernik, M.M. McGraw, G.Z. Jacobi, C.M. Canavan, T.S. Schrader, D. Mercer, R. Hill, and B.C. Moran. 2006. Ecoregions of New Mexico (color poster with map, descriptive text, summary tables, and photographs). U.S. Geological Survey. Reston, VA.

Jessup, B.K., D. Eib, L. Guevara, J. Hogan, F. John, S. Joseph, P. Kaufmann, and A. Kosfiszer. 2010. Sediment in New Mexico streams: Existing conditions and potential benchmarks. Prepared for the U.S. Environmental Protection Agency, Region 6, Dallas, TX and the New Mexico Environment Department. Tetra Tech, Inc., Montpelier, VT. Available at: https://www.env.nm.gov/surface-water-quality/sedimentation/.

Kaufmann, P.R., J.M. Faustini, D.P. Larsen, M. Shirazi. 2008. A roughness-corrected index of relative bed stability for regional stream surveys. Geomorphology. 99:150-170. Available at: https://www.sciencedirect.com/science/article/pii/S0169555X07004916.

Leopold, L.B., M.G. Wolman, and J.P. Miller. 1964. Fluvial Processes in Geomorphology. Dover Publications, Inc. New York, NY.

Lisle, T. 1989. Sediment transport and resulting deposition in spawning gravels, North Coast California. Water Resources Research. 25(6):1303-1319.

New Mexico Environment Department/ Surface Water Quality Bureau (NMED/SWQB). 2011. Sedimentation/siltation thresholds development plan. Santa Fe, NM. Available at: https://www.env.nm.gov/surface-water-quality/sedimentation/

Peck, D.V., A.T. Herlihy, B.H. Hill, R.M. Hughes, P.R. Kaufmann, D.J. Klemm, J.M. Lazorchak, F.H. McCormick, S.A. Peterson, P.L. Ringold, T. Magee, and M. Cappaert, 2006. Environmental monitoring and assessment program-surface waters western pilot study: Field operations manual for wadeable streams. EPA-620-R-06-003. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C. Available at: http://www.epa.gov/wed/pages/publications/authored/EPA620R-06003EMAPSWFieldOperationsManualPeck.pdf.

Rosgen, D.L. 1994. A classification of natural rivers. Catena. 22:169-199. Elsevier Science, B.V. Amsterdam.

U.S. Environmental Protection Agency (EPA). 2006. Framework for developing suspended and bedded sediment (SABS) water quality criteria. Office of Water, Office of Research and Development. EPA-822-R-06-001. Available at: http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=164423.

Waters, T. 1995. Sediment in streams sources: Biological effects and control. American Fisheries Society Monograph 7. Bethesda, MD.