

APPENDIX B

TEMPERATURE LISTING METHODOLOGY



**NEW MEXICO ENVIRONMENT DEPARTMENT
SURFACE WATER QUALITY BUREAU**

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Purpose and Applicability

This document establishes a listing methodology for determining temperature impairment in streams, rivers, lakes, and reservoirs. This protocol is not applicable to streams with limited aquatic life use, wetlands, or other water bodies without applicable temperature criteria because the research and implementation procedures necessary have not been investigated or developed by the Surface Water Quality Bureau (SWQB) or adopted in 20.6.4 NMAC.

1.0 Introduction

Water temperature influences the metabolism, behavior, and mortality of fish and other aquatic organisms. 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° Celsius (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 aquatic community. Such modifications may contribute to changes in geographical distribution of species and their ability to persist in the presence of introduced species. SWQB prepared a comprehensive summary of temperature thresholds for sensitive salmonids found in New Mexico as part of the 2009 triennial review of water quality standards process (NMED/SWQB 2009).

2.0 Data Collection Procedures and Considerations

For rivers and streams, long-term thermograph or other datalogger datasets are used to assess and determine attainment. Grab data can be used to determine non-support. Long-term data are required to confirm temperature impairment determinations prior to TMDL development. Data loggers are deployed and the data reviewed following the guidelines specified in the SWQB's Standard Operating Procedures (SOPs), available at <https://www.env.nm.gov/surface-water-quality/sop/> This includes locating the datalogger in the shade when possible, but the primary consideration is to place the datalogger in a location such that it will remain submerged for the duration of the data recording period while not becoming buried in sediment or covered with debris. Available flow records, temperature change rate, and supportive coincident data (such as specific conductance) can be used to confirm whether the datalogger recorded periods of exposure, burial, or flow isolation. Temperature data from periods where the record indicates that the data logger was exposed, buried, or otherwise not indicative of ambient conditions will be censored and not used for assessment.

Data for temperature assessment will ideally be collected from late May through late September. In order for a lake profile or a stream/river datalogger dataset to be used to determine full support, it must include the portion of the year with the highest temperatures. This usually occurs between early June and early September in New Mexico, depending on the site elevation, aspect, topography, and adjacent vegetation. For SWQB collected data, additional information regarding the preferred timing of sonde deployment is typically provided in applicable Field Sampling Plans or Water Quality

Survey Reports (available at: <https://www.env.nm.gov/surface-water-quality/water-quality-monitoring/>).

Ensuring that the warmest stream temperatures of the year were captured can be easily discerned by plotting the data and observing a seasonal temperature increase from late spring through summer followed by a gradual decrease in temperature towards autumn. For example, if the period of record starts at some low point, rises to a high point and then descends to a low point, the data would be considered assessable for either full or non-support (Figure 1). Alternatively, if the plotted dataset does not capture the summer season maximum temperature, the dataset could only be used to determine non-support because even though the dataset did not cover the entire warm season, additional data would not change the non-support determination (Figure 2).

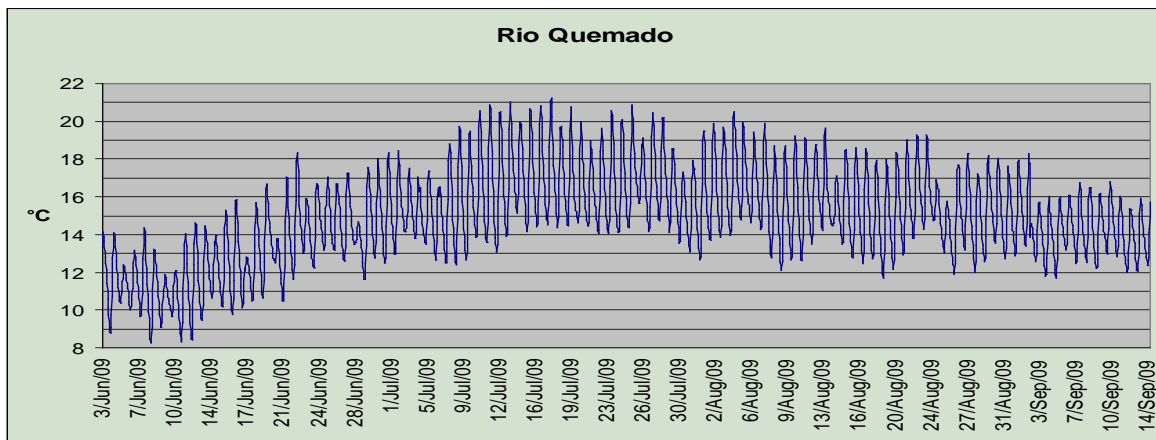


Figure 1. Example of assessable dataset for full support determination (adequate duration and includes summer season maximum temperature less than applicable maximum criterion of 23°C)

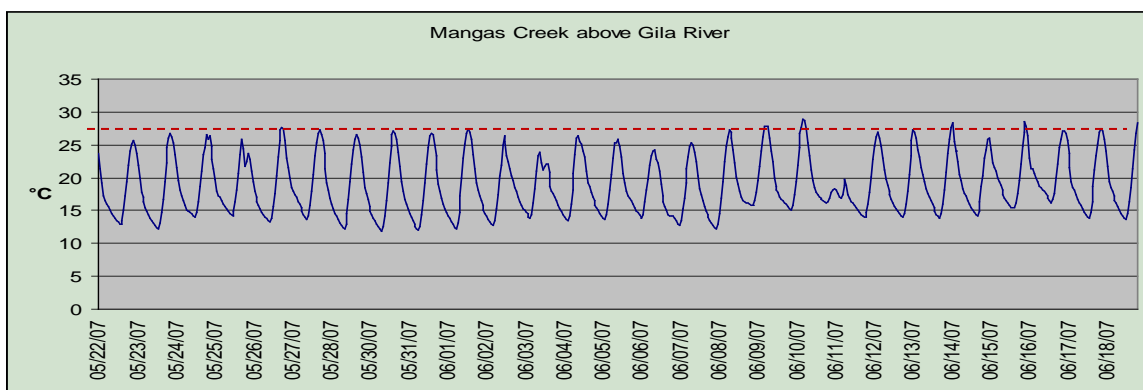


Figure 2. Example of assessable dataset for non-support determination (applicable segment-specific maximum criterion of 28°C is exceeded on more than one day in this limited duration dataset)

For lakes and reservoirs, data are collected at one-meter intervals as specified in the SWQB SOP for lentic sampling (SOP 12.0). Measurements are taken at the surface to within one meter of the bottom of the lake or to the maximum depth allowed by current equipment.

3.0 Assessment of Temperature Data to Determine Aquatic Life Use Support

Numeric temperature criteria per aquatic life use (ALU) are summarized in Table 1, and detailed in 20.6.4.900.H NMAC (<https://www.env.nm.gov/surface-water-quality/wqs/>). “4T3 temperature” is defined as the temperature not to be exceeded for four or more consecutive hours in a 24-hour period on more than three consecutive days, and the “6T3 temperature” is defined as the temperature not to be exceeded for six or more consecutive hours in a 24-hour period on more than three consecutive days (20.6.4.7.A NMAC).

Table 1. New Mexico’s temperature criteria by ALU (from 20.6.4.900.H NMAC)

AQUATIC LIFE USE	MAXIMUM TEMPERATURE (°C)	4T3 ^(a) (°C)	6T3 ^(a) (°C)
High Quality Coldwater (HQCWAL)	23	20	
Coldwater (CWAL)	24		20
Marginal Coldwater (MCWAL)	29		25 ^(b)
Coolwater (CoolWAL)	29		
Warmwater (WWAL)	32.2		
Marginal Warmwater (MWWAL)	Routinely exceeds 32.2		
Limited	No default established		

NOTES: ^(a)Default 4T3 and 6T3 values are not applicable in cases where segment-specific maximum temperature criteria exist in 20.6.4.97 - 20.6.4.899 NMAC per 20.6.4.900.H(1)(2)(3).

^(b) With the exception of segment 20.6.4.114 NMAC, which contains a segment-specific 6T3 of 22°C.

4T3/6T3 criteria have only been established for HQCWAL, CWAL, and MCWAL. Continuous data are needed to determine the 4T3/6T3 in streams and rivers. A determination of non-support is made if the measured 4T3 or 6T3 exceeds the applicable temperature criteria.

The “maximum temperature” is defined as the maximum instantaneous temperature, unless otherwise identified in a segment-specific temperature criterion. A determination of non-support is made if the maximum temperature criterion is exceeded on more than one day during the same calendar year and the daily maximum temperatures are not statistical outliers from the maximum daily temperatures measured during the calendar year. A potential outlier is defined as a temperature greater than the 75th percentile (Q3) of the measured daily maximum temperatures plus three times the inter-quartile range (IQR). The IQR is defined as the difference between the 25th percentile (Q1) and Q3 (Tukey 1977, Seo 2006). This approach is intended to 1) reduce the influence from autocorrelation of continuous data, 2) demonstrate the repeatability of an observation and 3) take into consideration potential anomalies in the thermograph data set due to extreme air temperatures deviating from seasonal norms, other anomalous events such as runoff from catastrophic fire areas, or instrument errors. Potential statistical outliers are determined in the either the 15 min or 1 hour SWQB Long-term Dataset (LTD) Data Management Spreadsheet based on the sampling interval¹. Non-assessable data are removed in order to generate the final assessment dataset. A generalized flowchart for assessing thermograph data in rivers and streams is provided in Figure 3.

For lakes and reservoirs, the SWQB generally does not deploy thermographs and 20.6.4.14.C(3) NMAC dictates assessment of lake data. The assessor examines the profile for the presence of a thermocline (greater than 1°C change per meter). If present, temperature measurements taken

¹ For a copy of this spreadsheet, please <https://www.env.nm.gov/surface-water-quality/sop/>.

within the epilimnion (above the thermocline) are averaged. If absent (i.e., the lake is well mixed), measurements taken from the upper one-third of the depth profile are averaged. Therefore, the “grab” sample used to assess is actually an average value. This average value is assumed equivalent to and compared against the 4T3/6T3 criterion as opposed to the applicable ALU maximum criterion (unless there is a segment-specific maximum) to be the most protective of aquatic life. In addition, the upper one-third of a lake is usually considered well-mixed and fish and other aquatic life have potential refugia. For example, they can move deeper if surface temperatures are higher depending on depth and conditions of the lake.

The assessment procedures for each ALU with applicable temperature criteria for both water types are detailed in Tables 2 – 6 below.

Table 2. Assessing temperature data to determine HQCWAL Use Support

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
•Instantaneous (grab) temperature data A) Rivers or streams B) Lakes or reservoirs	A) Not assessable (cannot determine fully supporting with grab data only) B) No temperature measurement greater than 20.0°C^(b) (or the segment-specific maximum temperature).	A) More than one temperature measurement greater than 23.0°C (or the segment-specific maximum temperature) ^(a) B) One or more temperature measurements greater than 20.0°C^(b) (or the segment-specific maximum temperature).	^(a) IR Category 5C – needs thermograph data to confirm. ^(b) Because lake temperature measurements are averaged over the epilimnion or the upper 1/3 of the water column, the measured value is assumed be equivalent to the 4T3 value and thus this criterion is used when there is not a segment-specific maximum. See 20.6.4.14.C(3) NMAC for additional information regarding lake sampling.
•Thermograph data (≤one-hour frequency interval)	Maximum daily temperatures, excluding outliers ^(d) , do not exceed 23.0°C (or the segment-specific maximum temperature), on more than one day during the calendar year <u>and</u> 4T3 does not exceed 20.0°C if there is no segment-specific maximum temperature. ^(c)	Maximum daily temperatures exceed 23.0°C (or the segment-specific maximum temperature) on more than one day during the calendar year and are not outliers ^(d) , <u>or</u> 4T3 exceeds 20.0°C if there is no segment-specific maximum temperature.	^(c) Plotted dataset must capture the summer season maximum temperature. ^(d) Statistical outliers are identified prior to assessment via the SWQB LTD Data Management Spreadsheet.

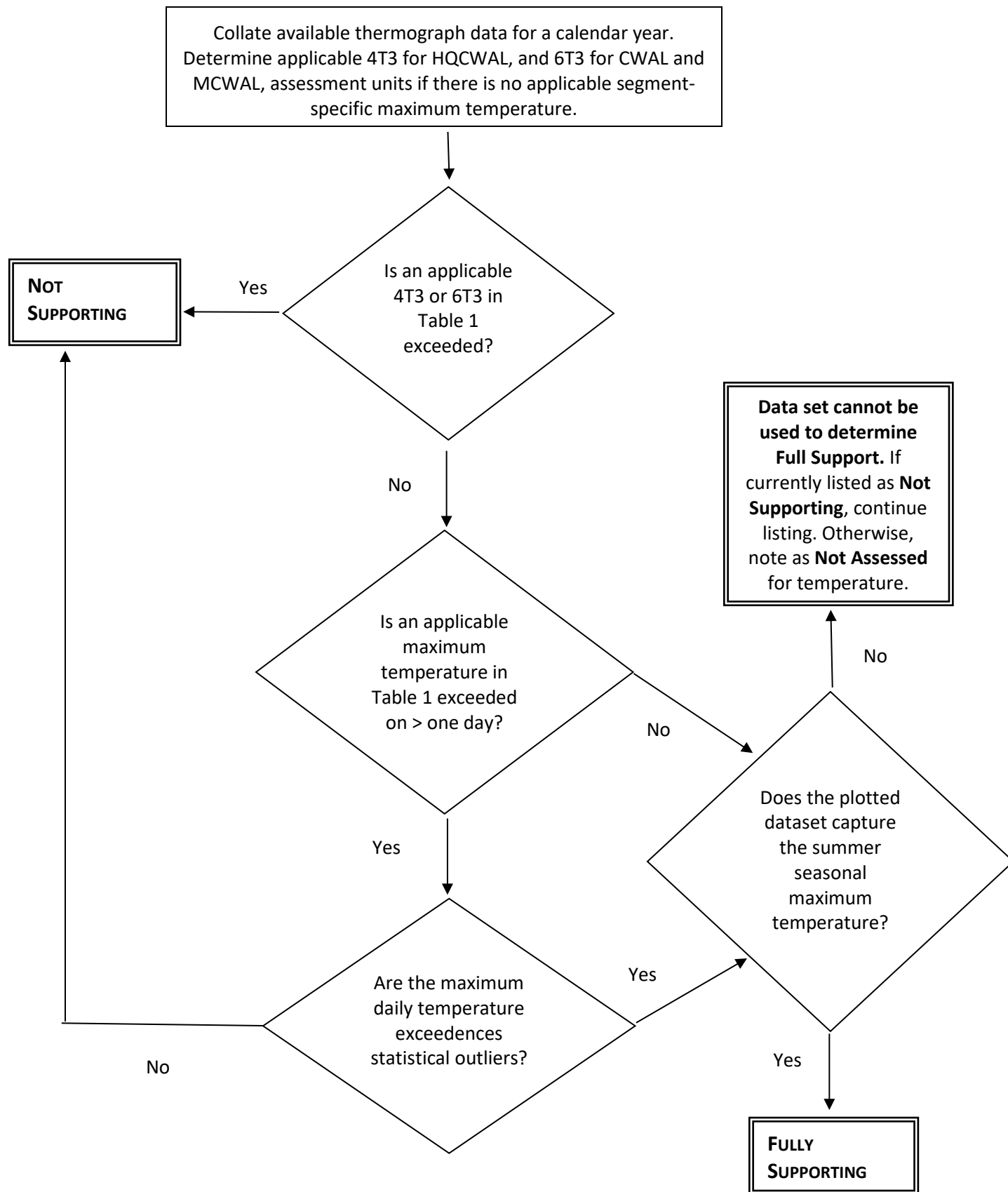


Figure 3. Generalized flowchart for assessing thermograph data in rivers and streams

Table 3. Assessing temperature data to determine CWAL Use Support

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
<p>•Instantaneous (grab) temperature data</p> <p>A) Rivers or streams</p> <p>B) Lakes or reservoirs</p>	<p>A) Not assessable (cannot determine fully supporting with grab data only).</p> <p>B) No temperature measurement greater than 20.0°C ^(b) (or the segment-specific maximum temperature).</p>	<p>A) More than one temperature measurement greater than 24.0°C (or the segment-specific maximum temperature). ^(a)</p> <p>B) One or more temperature measurements greater than 20.0° C ^(b) (or the segment-specific maximum temperature).</p>	<p>^(a) IR Category 5C – needs thermograph data to confirm.</p> <p>^(b) Because lake temperature measurements are averaged over the epilimnion or the upper 1/3 of the water column, the measured value is assumed be equivalent to the 4T3 value and thus this criterion is used when there is not a segment-specific maximum. See 20.6.4.14.C(3) NMAC for additional information regarding lake sampling.</p>
<p>•Thermograph data (≤one-hour frequency interval)</p>	<p>Maximum daily temperatures, excluding outliers^(d), do not exceed 24.0°C (or the segment-specific maximum temperature) on more than one day during the calendar year, <u>and</u> 6T3 does not exceed 20.0°C if there is no segment-specific maximum temperature. ^(c)</p>	<p>Maximum daily temperatures exceed 24.0°C (or the segment-specific maximum temperature) on more than one day during the calendar year and are not outliers^(d), <u>or</u> 6T3 exceeds 20.0°C if there is no segment-specific maximum temperature.</p>	<p>^(c) Plotted dataset must capture the summer season maximum temperature.</p> <p>^(d) Statistical outliers are identified prior to assessment via the SWQB LTD Data Management Spreadsheet.</p>

Table 4. Assessing temperature data to determine MCWAL Use Support

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
<p>•Instantaneous (grab) temperature data</p> <p>A) Rivers or streams</p> <p>B) Lakes or reservoirs</p>	<p>A) Not assessable (cannot determine fully supporting with grab data only)</p> <p>B) No temperature measurement greater than 25.0°C^(b) (or the segment-specific maximum temperature).</p>	<p>A) More than one temperature measurement greater than 29.0°C (or the segment-specific maximum temperature).^(a)</p> <p>B) One or more temperature measurements greater than 25.0°C^(b) (or the segment-specific maximum temperature).</p>	<p>^(a) IR Category 5C – needs thermograph data to confirm.</p> <p>^(b) Because lake temperature measurements are averaged over the epilimnion or the upper 1/3 of the water column, the measured value is assumed be equivalent to the 6T3 value and thus this criterion is used when there is not a segment-specific maximum. See 20.6.4.14.C(3) NMAC for additional information regarding lake sampling.</p>
<p>•Thermograph data (≤one-hour frequency interval)</p>	<p>Maximum daily temperatures, excluding outliers^(e), do not exceed 29.0°C (or the segment-specific maximum temperature) on more than one day during the calendar year, <u>and</u> 6T3 does not exceed 25.0°C if there is no segment-specific maximum temperature. ^(c) ^(d)</p>	<p>Maximum daily temperatures exceed 29.0°C (or the segment-specific maximum temperature) on more than one day during the calendar year and are not outliers^(e), <u>or</u> 6T3 exceeds 25.0°C if there is no segment-specific maximum temperature.</p>	<p>^(c) Plotted dataset must capture the summer season maximum temperature.</p> <p>^(d) With the exception of segment 20.6.4.114 NMAC, which contains a segment-specific 6T3 of 22°C.</p> <p>^(e) Statistical outliers are identified prior to assessment via the SWQB LTD Data Management Spreadsheet.</p>

Table 5. Assessing temperature data to determine CoolWAL Aquatic Life Use Support

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
<p>•Instantaneous (grab) temperature data</p> <p>A) Rivers or streams</p> <p>B) Lakes or reservoirs^(c)</p>	<p>A) Not assessable (cannot determine fully supporting with grab data only)</p> <p>B) No temperature measurement greater than 29.0°C ^(b) (or the segment-specific maximum temperature).</p>	<p>A) More than one temperature measurements greater than 29.0°C (or the segment-specific maximum temperature). ^(a)</p> <p>B) One or more temperature measurements greater than 29.0°C^(b) (or the segment-specific maximum temperature).</p>	<p>^(a) IR Category 5C – needs thermograph data to confirm</p> <p>^(b) See 20.6.4.14.C(3) NMAC for additional information regarding lake sampling.</p> <p>^(c) Plotted dataset must capture the summer season maximum temperature.</p>
<p>•Thermograph data (≤one-hour frequency interval)</p>	<p>Maximum daily temperatures, excluding outliers^(d), do not exceed 29.0°C (or the segment-specific maximum temperature) on more than one day during the calendar year. ^(c)</p>	<p>Maximum daily temperatures exceed 29.0°C (or the segment-specific maximum temperature) on more than one day during the calendar year and are not outliers^(d).</p>	<p>^(d) Statistical outliers are identified prior to assessment via the SWQB LTD Data Management Spreadsheet.</p>

Table 6. Assessing temperature data to determine WWAL or MWWAL^(e) Use Support

TYPE OF DATA	FULLY SUPPORTING	NOT SUPPORTING	NOTES
<p>•Instantaneous (grab) temperature data</p> <p>A) Rivers or streams</p> <p>B) Lakes or reservoirs</p>	<p>A) Not assessable (cannot determine fully supporting with grab data only)</p> <p>B) No temperature measurement greater than 32.2°C^(b) (or the segment-specific maximum temperature)</p>	<p>A) More than one temperature measurements greater than 32.2°C (or the segment-specific maximum temperature)^(a)</p> <p>B) One or more temperature measurements greater than 32.2°C^(b) (or the segment-specific maximum temperature)</p>	<p>^(a) IR Category 5C – needs thermograph data to confirm</p> <p>^(b) See 20.6.4.14.C(3) NMAC for additional information regarding lake sampling.</p> <p>^(c) Plotted dataset must have a discernible seasonal peak and must cover the entire recommended deployment period in order to determine Fully Supporting.</p> <p>^(d) Statistical outliers are identified prior to assessment via the SWQB LTD Data Management Spreadsheet.</p>
<p>•Thermograph data (≤one-hour frequency interval)</p>	<p>Maximum daily temperatures, excluding outliers^(d), do not exceed 32.2°C (or the segment-specific maximum temperature) on more than one day during the calendar year. ^(c)</p>	<p>Maximum daily temperatures exceed 32.2°C (or the segment-specific maximum temperature) on more than one day during the calendar year and are not outliers^(d).</p>	<p>^(e) The MWWAL description in 20.6.4.7.M(2) NMAC states “...or historical water quality data routinely exceed 32.2 degrees C.” The associated temperature criterion in 20.6.4.900.H(6) NMAC states “...maximum temperature of 32.2 degrees C.” This inconsistency is under WQS review. Until resolved, any temperature impairments for MWWAL will be noted as IR Category 5B.</p>

REVISION HISTORY:

2014 listing cycle – Clarified data requirements for thermograph datasets to be assessable (removed 72-hour minimum); clarified that no 4T3 or 6T3 applies when segment-specific maximum exists, except for 20.6.4.114 NMAC; various minor word changes and clarifications.

2016 listing cycle – Added temperature criteria table and clarified use of segment-specific maximum temperatures when assessing data. Added additional description of lake data collection and assumption that averaged values are equivalent to 4T3/6T3.

2018 listing cycle – Changed “Assessment Protocol” to “Listing Methodology.” For thermograph data, added provision regarding when there is only one day where the temperature exceeds the applicable maximum temperature criterion to demonstrate repeatability of observation and account for the autocorrelation of time series data. Also, added a provision to test for outliers in a temperature dataset. Added a generalized assessment flowchart for assessing thermograph data in rivers and streams. Clarified that stream/river impairment determinations based on grab data must be confirmed with thermograph dataset prior to TMDL development.

2020 listing cycle – Clarified that other long-term data loggers also record temperature data that can be used for assessment. Added reference to SWQB Field Sampling Plans for additional sonde deployment information. Clarified how statistical outliers in a long-term temperature dataset are identified prior to assessment. Added a note to the MWWAL assessment table to highlight the 20.6.4 NMAC discrepancy.

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