Synthesis Element 1: Water Temperature Effects on Fisheries and Stream Health in Nontidal Waters

ADDENDUM

Temperature Water Quality Criteria in
CBP Jurisdictions' Water Quality Standards and
Information on Warmwater Species

Synthesis Element 1 emphasizes the effects of rising water temperatures on the species in the Chesapeake Bay watershed's nontidal tributaries which are most sensitive, and therefore vulnerable – that is, coldwater species like brook trout and sculpin, and other aquatic life in cold- and cool-water habitats. As described, jurisdictions in the watershed and scientific agencies are paying close attention to water temperature increases in these habitats.

However, water temperature affects all aquatic species. Thus, temperature rises will affect warmwater species as well. At a certain level, temperature rises will impair species' life stages, and at higher levels, cause lethality. (Temperature rises will also affect the habitat of some indigenous fisheries by increasing algal blooms and may encourage invasive species.)

All jurisdictions have adopted long-standing legal requirements - Water Quality Standards (WQS) - to protect their fisheries from the effects of heating in the aquatic environment, and these have been approved by U.S. EPA. Established under the Clean Water Act (CWA), the national goal – and the object of the standards -- is to protect beneficial water uses, including a balanced, indigenous population of aquatic life.

Scientific guidance for temperature water quality criteria to protect aquatic species was first published by the federal government in 1968. Despite refinements over the years, today's regulatory WQS follow that framework. The standards all include maximum temperature criteria limits (in degrees C or F), based on "naturally-occurring" temperature regimes. Some standards also explicitly limit the rate and amount of increases above ambient temperature. The standards of every jurisdiction specify the "water uses" for its streams, rivers and lakes. For aquatic life protection, maximum temperature limits are applied for naturally-reproducing "coldwater fisheries" and "warmwater fisheries" – and, where applicable, for waterbodies with stocked fisheries. All criteria are designed to protect the designated uses.

ORSANCO's work on temperature criteria for aquatic life protection contributed to the first federal criteria guidance. ORSANCO's updated 2005 compilation of temperature limits for a number of aquatic species can be viewed via a link in Attachment 1.

Attachment 2 presents the temperature water quality criteria associated with designated water uses for aquatic life protection (fisheries) in the WQS of the District of Columbia, Maryland, Pennsylvania and Virginia. (The temperature criteria excerpts do not include all the regulatory provisions pertaining to their use, which can be viewed in each jurisdiction's WQS.)

To meet CWA obligations, states are required to monitor their waters to determine whether the designated water uses in their WQS are being protected, and publish a biennial report (CWA

305(b)). They must publish a list under CWA 303(d) every two years of "impaired waters" necessitating follow-up action. Follow-up will generally include more detailed study, and may lead to allocations (limitations) of Total Maximum Daily Load (TMDL) and guidance for measures to restore the established water uses.

When the WQS for temperature were adopted, the focus was to regulate discharges of heated wastewater from thermal power plants and other sources. The possibility that water temperatures would be rising to harmful levels because of climate change is not yet explicitly discussed in the standards. The limited review for this paper found some early instances where Chesapeake Bay watershed jurisdictions have focused on climate-induced water temperature rises that would cause their WQS for aquatic life protection to be exceeded.

- The Maryland Departments of Natural Resources (DNR) and the Environment (MDE) have performed monitoring and modeling related to water temperature rises in naturally-reproducing trout waters. Not only has Maryland's analysis focused on climate-induced water temperature increases, but also on the exacerbating effects of deforestation, agriculture and impervious runoff from developed areas in the same watersheds.

Maryland has identified numerous thermal impairments in streams with a coldwater fisheries designated use on its 303(d) list of impaired waters (focusing on brook trout). To address these impairments, MDE has been working on developing TMDL methodologies and an implementation guidance for use by local jurisdictions. Maryland hopes to develop its first temperature TMDL and publish the associated implementation guidance sometime in the near future.

Maryland DNR provided a modeling study design for investigating brook trout presence and likelihood of reintroduction success. The work is ongoing, and results are preliminary, but the study shows the kinds of analyses involved to (1) identify key land use, habitat and thermal features associated with brook trout streams; (2) identify the key aquatic insect taxa; and (3) evaluate relationships between air and stream temperature data. Linked here. Also see Maryland's new Brook Trout Conservation Plan in the 2020 Maryland Statewide Brook Trout Patch Assessment: Linked here.

- Virginia has an extensive water temperature monitoring network, and its 2020 305(b) report lists a number of waters – over 100 stream/river segments, lakes and tidal areas – where spot sampling found that temperature water quality criteria were exceeded. Almost all of these segments is a coldwater fishery stream or a managed trout fishery. The Department of Environmental Quality (DEQ) has prioritized 40 sites for investigation of site conditions and a continuous monitoring study. As the current monitoring requirements for WQS attainment and the 305(b) report entail one grab sample at a location, at a random time of the day, there may be stream temperature issues, even with warmwater fisheries, that have not yet been detected.

Thus far, DEQ has done temperature TMDL studies yielding eight TMDL equations, in conjunction with TMDLs for other impairments in the listed waters but has not yet prepared implementation guidance for temperature impairments.

- The District of Columbia Department of Energy and Environment has implemented several stream restoration projects to improve warmwater aquatic life habitat, especially in National Park

areas and the National Arboretum. The most obvious habitat damages to be corrected were extreme bank erosion and pollution associated with flashy urban stormwater runoff, but temperature protection has also been incorporated into the restoration projects. The District emphasized controlling stormwater runoff first, through "LID" infiltration practices. The stream restoration design incorporated thermal refugia for aquatic life (e.g. deeper channels where fish could go to cooler water), and preserving/planting riparian trees to shade and cool the stream. Post-project monitoring is showing fish population improvements, such as largemouth bass and sunfish.

The District of Columbia example is illustrative of several things:
– the importance of protecting warmwater fish species and their habitats. These are, after all, the most common species and habitats in the watershed. They are also an important source of fishing for minority and poor communities;
– the need to understand and address the relationship between water temperature rises due to increases in air temperature, and the exacerbating effects of heated stormwater runoff from impervious surfaces;
– the value of cooling stormwater runoff through use of stormwater management practices that infiltrate the runoff; and
– the value of incorporating thermal refugia* and riparian tree protection/shade in stream restoration.
(*A recent U.S. Forest Service white paper, "Climate Change Refugia"/Climate Change Resource Center (usda.gov) discussed "climate change refugia", and defined them as "areas that remain relatively buffered from contemporary climate change over time and enable persistence of valued physical, ecological, and socio-cultural resources.")

Attachment 1

ORSANCO Temperature Criteria Re-evaluation, March 31, 2005. Appendix Table Z-1: Database of temperature endpoints for 125 fish species and 28 macroinvertebrate taxa
Linked here
For information about notable warmwater species, see the following pages: striped bass, white perch, white bass (35-36), largemouth bass (41), smallmouth bass (44-45), bluegill (46-49), pumpkinseed sunfish (49), yellow perch (52).

Attachment 2

WATER QUALITY STANDARDS - TEMPERATURE CRITERIA

All Water Quality Standards (WQS) adopted by the jurisdictions and approved by U.S. EPA are accessible on the web, either through epa.gov or the water quality agency websites. See below the temperature-related provisions contained in the WQS of the three jurisdictions mentioned above: the District of Columbia, Maryland, and Virginia. Also here are the temperature provisions of Pennsylvania's WQS, which has a table of maximum temperature limits by time-period. Note that all WQS contain provisions to allow mixing zones, provide for low flow exceptions, and specify stream segments where different criteria may be allowed while still protecting the use. (All excerpts from epa.gov.)

DISTRICT OF COLUMBIA MUNICIPAL REGULATIONS
Chapter 11, Water Quality Standards

1104.5
Class C streams shall be maintained to support aquatic life and shall not be placed in pipes.

1104.8 Unless otherwise stated, the numeric criteria that shall be met to attain and maintain designated uses are as follows (Tables 1 through 3).
Excerpt from Table 1:

	Temperature (°C)
Maximum	32.2
Maximum change above ambient	2.8

4 At temperatures greater than 29°C, in tidally influenced waters, an instantaneous minimum dissolved oxygen concentration of 4.3 mg/L shall apply.

Annotated Code of MARYLAND
Title 26, Department of the Environment
Subtitle 08 : Water Pollution

26.08.02.03-3
.03-3 Water Quality Criteria Specific to Designated Uses.

A. Criteria for Class I Waters -- Water Contact Recreation and Protection of Nontidal Warmwater Aquatic Life.

(3) Temperature.
(a) The maximum temperature outside the mixing zone determined in accordance with Regulation .05 of this chapter or COMAR 26.08.03.03.--.05 may not exceed 90 degrees F (32 degrees C) or the ambient temperature of the surface waters, whichever is greater.
(b) A thermal barrier that adversely affects aquatic life may not be established.
(c) Ambient temperature is the water temperature that is not impacted by a point source discharge.
(d) Ambient temperature shall be measured in areas of the stream representative of typical or average conditions of the stream segment in question.
(e) The Department may determine specific temperature measurement methods, times, and locations.

D. Criteria for Class III Waters — Nontidal Cold Water.
(3) Temperature.

(a) The maximum temperature outside the mixing zone determined in accordance with Regulation .05 of this chapter or COMAR 26.08.03.03—.05 may not exceed 68°F (20°C) or the ambient temperature of the surface waters, whichever is greater.

(b) Ambient temperature — Same as Class I.

(c) A thermal barrier that adversely affects salmonid fish may not be established.

(d) It is the policy of the State that riparian forest buffer adjacent to Class III waters shall be retained whenever possible to maintain the temperatures essential to meeting this criterion.

E. Criteria for Class III-P Waters — Nontidal Cold Water and Public Water Supplies.

(1) Exception. Authorized operation of the Little Seneca Creek Dam means that all operational activities permitted are met under the conditions of a dam operating permit issued by the Department of Natural Resources under Natural Resources Article, §§8-801-8-814, Annotated Code of Maryland, and COMAR 08.05.03. Injury resulting from the authorized operation of Little Seneca Creek Dam to the Class III natural trout fishery recognized in the stream use designation assigned to Little Seneca Creek in Regulation .08 of this chapter is not considered a violation of this chapter.

(2) The following criteria apply:

The criteria for Class HI waters in §D(1)—(7); and....

F. Criteria for Class IV Waters — Recreational Trout Waters.

(3) Temperature.

(a) The maximum temperature outside the mixing zone determined in accordance with Regulation .05 of this chapter or COMAR 26.08.03.03—.05 may not exceed 75°F (23.9°C) or the ambient temperature of the surface waters, whichever is greater.

(b) Ambient temperature — Same as Class I.

© A thermal barrier that adversely affects salmonid fish may not be established.

(d) it is the policy of the State that riparian forest buffer adjacent to Class IV waters shall be retained whenever possible to maintain the temperatures essential to meeting this criterion.

Criteria Critical Use*

Maximum temperatures in the receiving waterbody resulting from heated waste sources regulated under Chapters 92a, 96 and other sources where temperature limits are necessary to protect designated and existing uses.

Temp (°C)	**Cold Water Fisheries**	**Warm Water Fisheries**	**Trout Stocked Fisheries**
January 1-31	38	40	40
February 1-29	38	40	40
March 1-31	42	46	46
April 1-15	48	52	52
April 16-30	52	58	58
May 1-15	54	64	64
May 16-31	58	72	68
June 1-15	60	80	70
June 16-30	64	84	72
July 1-31	66	87	74
August 1-15	66	87	80
August 16-30	66	87	87
September 1-15	64	84	84
September 16-30	60	78	78
October 1-15	54	72	72
October 16-31	50	66	66
November 1-15	46	58	58
November 16-30	42	50	50
December 1-31	40	42	42

Critical Use: The designated or existing use the criteria are designed to protect. More stringent site-specific criteria may be developed to protect other more sensitive, intervening uses.

(b) For naturally reproducing salmonids, protected early life stages include embryonic and larval stages and juvenile forms to 30 days after hatching. The DO standard for naturally reproducing salmonid early life stages applies October 1 through May 31. The DO1 standard for naturally reproducing salmonid early life stages applies unless it can be demonstrated to the
Department's satisfaction, that the following conditions are documented: 1) the absence of young of the year salmonids measuring less than 150 mm in the surface water; and 2) the absence of multiple age classes of salmonids in the surface water. These conditions only apply to salmonids resulting from natural reproduction occurring in the surface waters. Additional biological information may be considered by the Department which evaluates the presence or absence of early life stages.

(c) The list of specific water quality criteria does not include all possible substances that could cause pollution. For substances not listed, the general criterion that these substances may not be inimical or injurious to the existing or designated water uses applies....
(d) If the Department determines that natural quality of a surface water segment is of lower quality than the applicable aquatic life criteria in Table 3 or 5, the natural quality shall constitute the aquatic life criteria for that segment....

VIRGINIA Administrative Code, Title 9
Environment 25-26- et seq.

9VAC25-260-40. Stream flow.

Man-made alterations in stream flow shall not contravene designated uses including protection of the propagation and growth of aquatic life.

9VAC25-260-50. Numerical criteria for dissolved oxygen, pH, and maximum temperature**.

	DO Min.	EN (mg/I)**** Daily Avg.	pH	Max. Temp. (°C)
Open Ocean	5.0		6.0-9.0	
Tidal Waters in the Chowan Basin and the Atlantic Ocean Basin	4.0	5.0	6.0-9.0	
Tidal Waters in the Chesapeake Bay and its tidal tributaries	see 9VAC25-260-185		6.0-9.0	
Nontidal Waters (Coastal and Piedmont Zones)	4.0	5.0	6.0-9.0	32

Mountainous Zones Waters	4.0	5.0	6.0-9.0	31
Stockable Trout Waters	5.0	6.0	6.0-9.0	21
Natural Trout Waters	6.0	7.0	6.0-9.0	20
Swamp Waters			3.7-8.0*	**

**Maximum temperature will be the same as that for Classes I through VI waters as appropriate.

***The water quality criteria in this section do not apply below the lowest flow averaged (arithmetic mean) over a period of seven consecutive days that can be statistically expected to occur once every 10 climatic years (a climatic year begins April 1 and ends March 31). See 9VAC25-260-310 and 9VAC25-260-380 through 9VAC25-260-540 for site specific adjustments to these criteria.

****For a thermally stratified man-made lake or reservoir in Class III, IV, V or VI waters that are listed in 9VAC25-260-187 these dissolved oxygen and pH criteria apply only to the epilimnion of the waterbody. When these waters are not stratified, the dissolved oxygen and pH criteria apply throughout the water column.

9VAC25-260-60. Rise above natural temperature.

Any rise above natural temperature shall not exceed 3°C except in the case of Class VI waters (natural trout waters), where it shall not exceed 1°C. However, the board can, on a case-by-case basis, impose a more stringent limit on the rise above natural temperature. Natural temperature is defined as that temperature of a body of water (measured as the arithmetic average over one hour) due solely to natural conditions without the influence of any point-source discharge.

9VAC25-260-70. Maximum hourly temperature change.

The maximum hourly temperature change shall not exceed 2°C, except in the case of Class VI waters (natural trout waters) where it shall not exceed 0.5°C. These criteria shall apply beyond the boundaries of mixing zones and are in addition to temperature changes caused by natural conditions.

9VAC25-260-80. Thermal discharges into lakes and impoundments.

In lakes and impoundments receiving thermal discharges, the temperature of the epilimnion, or surface water when there is no stratification, shall not be raised more than 3°C above that which
existed before the addition of heat of artificial origin. The board may, on a case-by-case basis, impose a more stringent limit on temperature rise. The increase shall be based on the monthly average of the maximum daily temperature. The temperature of releases from these lakes and impoundments shall be consistent with standards established for the receiving waters. When an applicant for a permit proposes either a discharge of heated effluent into the hypoliinnion or the pumping of water from the hypolimnion for return back into the same body of water, such practice shall not be approved unless a special study shows that the practice will not produce adverse effects.

9VAC25-260-90. Thermal variances.

The temperature limits set forth in 9VAC25-260-50 through 9VAC25-260-80 may be superseded in certain locations where a thermal variance demonstration is performed in accordance with § 316(a) of the Clean Water Act.

B. Basin descriptions. The tables that follow divide the state's surface waters into 10 river basins, some with subbasins: Potomac River Basin (Potomac and Shenandoah Subbasins), James River

Basin (Appomattox River Subbasin), Rappahannock River Basin, Roanoke River Basin, Yadkin River Basin, Chowan and Dismal Swamp Basin (Chowan and Albemarle Sound Subbasins), Tennessee and Big Sandy Basins (Big Sandy, Clinch and Holston Subbasins), Chesapeake Bay, Atlantic Ocean and Small Coastal Basin, York River Basin and New River Basin. (See Figure 2.)

Each basin is further divided into sections. Each section is assigned a class, represented by Roman Numerals I through VII, based on its geographic location or, in the case of trout waters, on its use. Descriptions of these classes are found in 9VAC25-260-50.

9VAC25-260-370. Classification column.

> A. DO, pH and temperature criteria. The classification column defines the class of waters to which the basin section belongs in accordance with the class descriptions given in 9VAC25-260-50. 9VAC25-260-50 defines the state's seven classes (I through VTI) and the dissolved oxygen (DO), pH and maximum temperature that apply to each class. By finding the class of waters for a basin section in the classification column and referring to 9VAC25-260-50 the DO, pH and maximum temperature criteria can be found for each basin section.

> B. DGIF trout waters. The Department of Game and Inland Fisheries (DGIF) has established a classification system for trout waters based on aesthetics, productivity,

resident fish population and stream structure. Classes i through iv rate wild trout habitat; Classes v through viii rate cold water habitat not suitable for wild trout but adequate for year-round hold-over of stocked trout. The DGIF classification system is included in this publication with the board's trout water classes (Class V— Stockable trout waters and Class VI—Natural trout waters) in the class column of the River Basin Section Tables 9VAC25-260-390 et seq.

DGIF trout water classifications which are not consistent with board classifications for stockable trout waters or natural trout waters are shown with a double asterisk (**) in the class column of the River Basin Section Tables 9VAC25-260-390 et seq. These trout waters have been identified for reevaluation by the DGIF. Those trout waters which have no DGIF classification are shown with a triple asterisk (***). The DGIF classes are described below. Inclusion of these DGIF classes provides additional information about specific streams for permit writers and other interested persons. Trout waters classified as classes i or ii by the DGIF are also recognized in 9VAC25-260-1I 0.

DGIF STREAM CLASS DESCRIPTIONS.

Wild natural trout streams.

Class i. Stream of outstanding natural beauty possessing wilderness or at least remote characteristics, an abundance of large deep pools, and excellent fish cover.

Substrate is variable with an abundance of coarse gravel and rubble. Stream contains a good population of wild trout or has the potential for such. Would be considered an exceptional wild trout stream.

Class ii. Stream contains a good wild trout population or the potential for one but is lacking in aesthetic quality, productivity, and/or in some structural characteristic. Stream maintains good water quality and temperature, maintains at least a fair summer flow, and adjacent land is not extensively developed. Stream would be considered a good wild trout stream and would represent a major portion of Virginia's wild trout waters.

Class iii. Stream which contains a fair population of wild trout with carrying capacity depressed by natural factors or more commonly man-related land use practices. Land use activities may result in heavy siltation of the stream, destruction of banks and fish cover, water quality degradation, increased water temperature, etc. Most streams would be considered tube in the active state of degradation or recovery from degradation. Alteration in land use practices would generally improve carrying capacity of the stream.

Class iv. Stream which contains an adequately reproducing wild trout population but has severely reduced summer flow characteristics. Fish are trapped in isolated pools where they are highly susceptible to predators and fishermen. Such streams could quickly be over-exploited and, therefore, provide difficult management problems.

Stockable trout streams.

Class v. Stream does not contain an adequately reproducing wild trout population nor does it have the potential for such. However, water quality is adequate, water temperature is good, and invertebrate productivity is exceptional. Pools are abundant with good size and depth and fish cover is excellent. Stream would be good for stocked trout but may offer more potential for a fingerling stocking program.

Class vi. Stream does not contain a significant number of trout nor a significant population of warmwater gamefish. Water quality is adequate and water temperature good for summer carryover of stocked trout. Summer flow remains fair and adjacent land is not extensively developed. All streams in this class would be considered good trout stocking water.

Class vii. Stream does not contain a significant number of trout nor a significant population of warmwater gamefish. Water quality and temperature are adequate for trout survival, but productivity is marginal as are structural

characteristics. Streams in this class could be included in a stocking program but they would be considered marginal and generally would not be recommended for stocking.

Class viii. Stream does not contain a significant number of trout nor a significant population of warmwater gamefish. Water quality and temperature are adequate for trout but summer flows are very poor (less than 30% of channel). Streams in this class can provide good trout fishing during spring and early summer but would not be recommended for summer or fall stocking.

Other. Remaining streams would be considered unsuitable for any type of trout fishery. Streams would be considered unsuitable under any of the following conditions:

- summer temperatures unsuitable for trout survival;
- stream contains a significant population of warmwater gamefish;
- insufficient flow; or
- intolerable water quality.