Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manual for the 2018 Reporting Cycle

Prepared by:

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I. INTRODUCTION

The *Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manual* describes the data evaluation procedures used to assess water quality conditions of surface waters in the state, the process used to identify causes and sources of impairment(s), and the reporting of this information to EPA and the public in the form of an *Integrated List of Waters* report (IR). Included in this CALM Guidance Manual are: a brief summary of the Massachusetts Surface Water Quality Standards (SWQS) at 314 CMR 4.00 that define water quality goals (MassDEP 2013); the requirements for assessing the quality of data to be used for reporting pursuant to the Federal Water Pollution Control Act (33 U.S.C. 1251 et seq.), otherwise known as the Clean Water Act (CWA) and the associated Water Quality Standards regulation (40 Code of Federal Regulation (CFR) section 131); the methods for evaluating water quality data and information used by the Massachusetts Department of Environmental Protection (MassDEP) Division of Watershed Management's (DWM) Watershed Planning Program (WPP) analysts to make designated use-assessment decisions; and a description of the use of the federal Environmental Protection Agency's (EPA) new database, the Assessment and Total Maximum Daily Load Tracking and Implementation System (ATTAINS), for storing assessments and generating the IR (Figure 1).

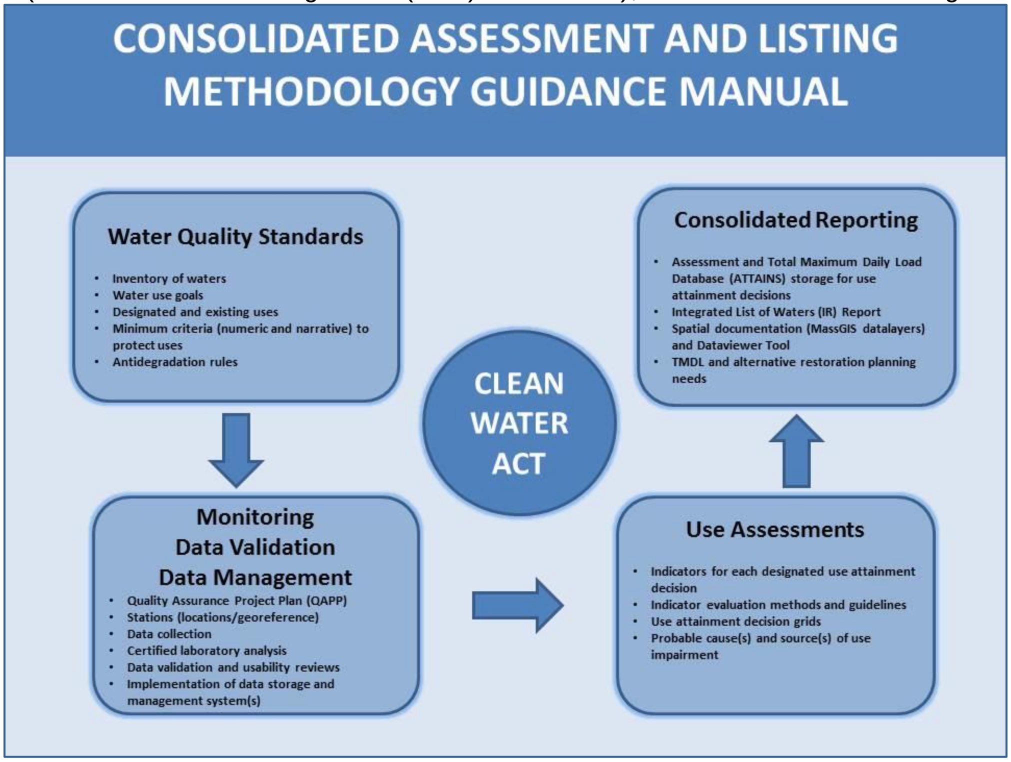


Figure 1 Components of Consolidated Assessment and Listing Methodology Guidance Manual

The Clean Water Act and Water Quality Assessment

The objective of the CWA is to restore and maintain the chemical, physical, and biological ntegrity of the Nation's waters. As one step toward meeting this goal, the CWA directs states to monitor and report on the condition of their water resources. This water quality reporting process is an essential aspect of the Nation's water pollution control effort and is the principal means by which the EPA, Congress, and the public evaluate existing water quality, assess progress made in maintaining and restoring water quality, and determine the extent of remaining problems. The directives of the CWA and the process by which the MassDEP analysts assess and report on the status of Massachusetts' waters are illustrated in Figure 2 and described in more detail in this document.

The CWA §305(b) mandates that states prepare a water quality inventory report every two years that summarizes the status of their waters with regard to the attainment of designated use goals/criteria as defined in the SWQS. The designated uses include suitable habitat for *Fish, other Aquatic Life and Wildlife* (hereafter referred to as *Aquatic Life)*, *Fish Consumption*, *Public Water Supply*, *Shellfish Harvesting*, *Primary* (e.g., swimming) and *Secondary* (e.g., boating) *Contact Recreation*, *Aesthetics, Agricultural, and Industrial* (MassDEP 2013). The CWA distinguishes causes of impairments as either "pollutants" such as nutrients, metals, pesticides, solids and pathogens or "pollution" such as low flow, habitat alterations or non-native species infestations. Section 303(d) of the CWA and the implementing regulations at 40 CFR 130.7 require states to identify those water bodies impaired by "pollutants" that are not expected to meet SWQS after the implementation of technology-based controls and to prioritize and schedule them for the development of total maximum daily loads (TMDL). A TMDL establishes the maximum amount of a pollutant that may be introduced into a water body and still ensure attainment and maintenance of water quality standards. The formulation of the 303(d) *List of Impaired Waters* (303(d) List) includes a more rigorous public review process than does reporting under §305(b), and the final version of this list must be formally approved by the EPA. Restoration of waters impaired by "non-pollutants" requires measures other than TMDL development and implementation such as dam removal, habitat restoration, and/or implementation of Best Management Practices (BMPs).

Prior to 2002 states prepared and submitted to the EPA both a biennial *Summary of Water Quality Report* in accordance with the requirements of §305(b) as well as a separate 303(d) List. On November 19, 2001 the EPA released guidance for the preparation of an optional IR that would combine reporting elements of both sections 305(b) and 303(d) of the CWA. This integrated format allows states to provide the status of all their assessed waters and identify their impaired waters requiring restoration in a single report, multi-part list. Since 2002, MassDEP has adopted the IR format to report on waters for CWA §305(b)/§303(d) purposes.

Massachusetts' rivers, lakes and coastal waters are partitioned into discrete segments or assessment units (AUs) that are defined and maintained in the EPA-developed ATTAINS database. The 305(b) assessment process entails evaluating existing water quality conditions in each AU against the applicable criteria established in the SWQS and this CALM Guidance Manual for each designated use, and identifying wherever possible, causes and sources of use impairment.

Through the 2012 reporting cycle the MassDEP documented assessment decisions and the data used to make them in individual watershed assessment reports (https://www.mass.gov/service-details/water-quality-assessments). For the 2010 through 2014 reporting cycles the assessment decisions themselves were stored in the Assessment Database (ADB V2.3.1) developed by EPA. MassDEP used this tool to both produce the IR and to provide the assessment data electronically to the EPA. For the 2018 reporting cycle the assessment and listing decisions will be done concurrently. The listing decisions for each AU (river, lake, or estuarine area) and a summary statement regarding the use assessment decision will be stored in ATTAINS. A separate "repository" document containing all of the data and the decisions will be kept on file at the MassDEP. ATTAINS IR data will be made available to the public and EPA in fulfillment of the CWA reporting requirements (see Figure 2). A MassGIS 2018 Integrated List Data – 305(b)/303(d) geodatabase with its supporting shape files and database tables will also likely be developed.

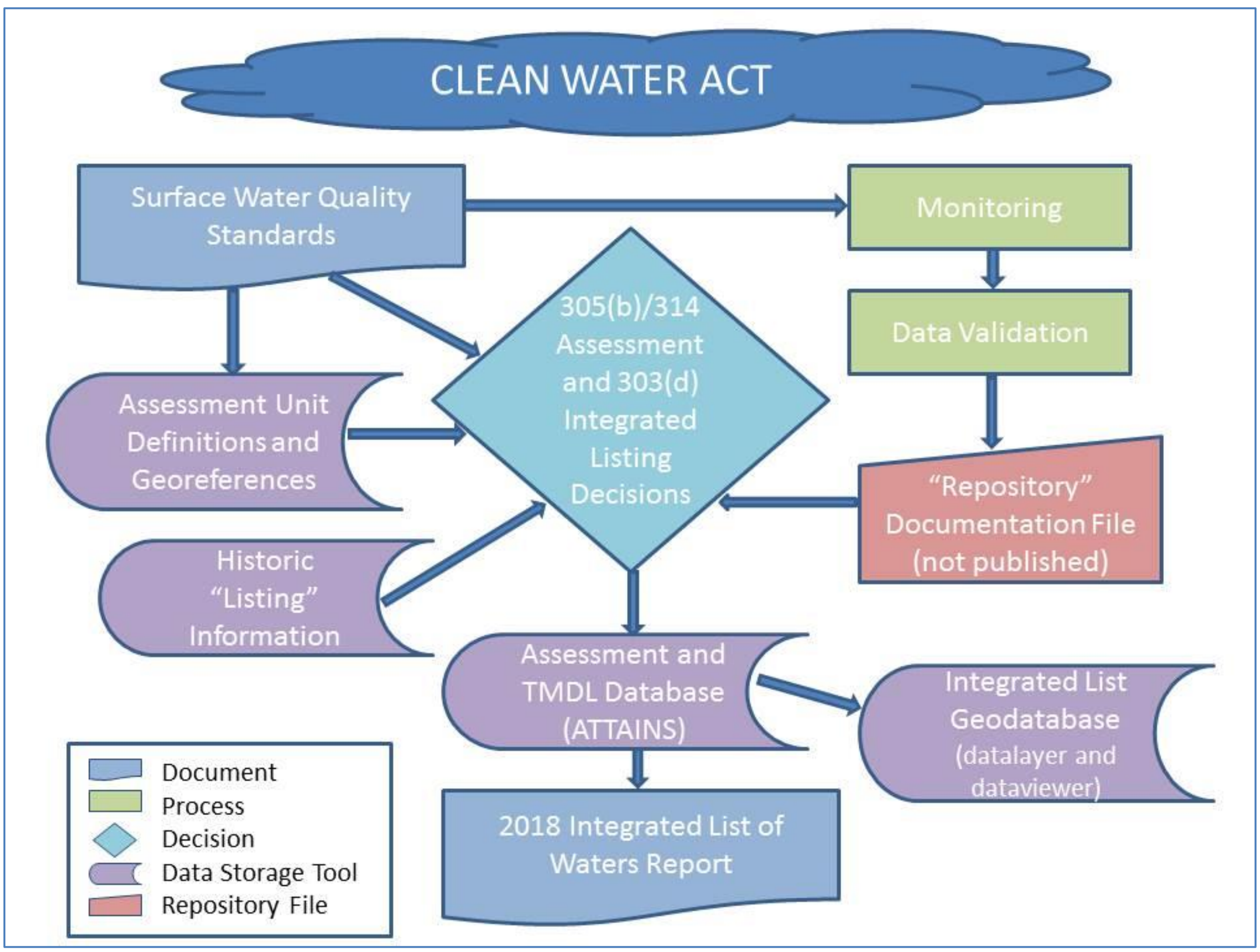


Figure 2. MassDEP, Consolidated Reporting Process Schematic

Notable Guidance Updates for 2018

The first CALM Guidance Manual, published in 2012, provided the methods and rationale for making the assessment decisions embodied in the IRs up to and including the 2014 report (MassDEP 2012). The CALM Guidance Manual underwent a substantial revision in 2016 that included the development of more comprehensive protocols for identifying, protecting and/or restoring cold water fisheries in Massachusetts and guidance for interpreting longer-term, continuous datasets for dissolved oxygen and temperature (MassDEP 2016). Some of the more noteworthy enhancements of the CALM Guidance Manual for 2018 are highlighted below.

New Section

- **Assessment Unit (AU) Definitions:** A section has been added that presents the process and rationale for defining AUs for reporting and listing the use-attainment status of Massachusetts' surface waters (see Section III. Assessment Unit (AU) Definitions for Massachusetts).

New Appendices

- **Chloride Estimator:** A new Appendix entitled *"Development of a Linear Regression Tool for Estimating Chloride Concentrations in Freshwaters of Massachusetts"* has been added. MassDEP analysts developed and validated a linear regression model to estimate chloride concentrations from specific conductance (SC) measurements. Because continuous SC data are available from probes deployed by MassDEP staff, chronic exposures of aquatic organisms to chlorides can be predicted from those data and compared with EPA aquatic life criteria (see *Aquatic Life Use* – Toxic pollutants – *Chloride* and Appendix F).
- **Data Reduction and Analysis Guidance:** A new Appendix entitled *"Standard Practices for Water Data Reduction and Analysis"* has been included. This appendix provides detailed information on how environmental data are reduced and analyzed by WPP for the purposes of assessing and listing waters in accordance with the requirements of the CWA (see Appendix G).

Guidance Updates

*Denotes addition of many AUs

- **EPA ATTAINS database**: All references to the retired ADB database have been replaced with reference to the new EPA ATTAINS database system for storing assessments and generating the IR.
- **Harmful Algal Blooms:** Clarification on the use of the Massachusetts Department of Public Health (DPH) harmful algae bloom (HAB) advisories for assessing recreational and aesthetic uses has been made (see *Primary Contact Recreational Use* – Harmful algal blooms).
- **Toxics:** Clarification regarding the evaluation of toxic pollutants has been updated to be more consistent and transparent with respect to wording in the SWQS and the application of EPA criteria. References to criteria development models (e.g., the Copper Biotic Ligand Model) have been included and hardness dependent criteria formulas and conversion factors between total and dissolved forms have been added for clarity (see *Aquatic Life Use* – Toxic pollutants and Appendix E, Table E1). Aluminum criteria will not be evaluated nor will recent (2016) updates for cadmium and selenium criteria be utilized for this reporting cycle. EPA-approved site-specific copper criteria in the SWQS are also clearly identified in Appendix E (Table E2). Guidance to evaluate acute and chronic chloride criteria exceedances using long term continuous SC datasets as well as to evaluate chronic criteria for metals using grab and/or composite samples has been added.
- **Mainstem River Target Fish Community:** Utilization of the Massachusetts Department of Fish & Game (DFG), Division of Fisheries & Wildlife (*MassWildlife*) Targeted Fish Community model was made, where appropriate, in the assessment of the Aquatic Life Use in selected mainstem rivers (see *Aquatic Life Use* – Fish community data).
- **Cold Waters*:** MassDEP is continuing to develop an evaluation protocol to identify, protect, enhance, and/or restore cold water fishery habitat. For the 2016 reporting cycle, all of the designated Cold Water streams in the SWQS were described as AUs and added to the ADB. For the 2018 reporting cycle, Cold Water Fishery Resource streams proposed by *MassWildlife* biologists for designation as Cold Waters will also be added as AUs to watersheds scheduled for the assessment of the Aquatic Life Use. Cold Water habitat evaluations will be made as part of the evaluation of temperature data (see Section V. *Aquatic Life Use* – Water Quality Data – Temperature). A decision flowchart used to evaluate fish and temperature data for cold waters has also been added.
- **Diadromous Fish Habitat***: New assessment guidance was developed by MassDEP analysts who worked closely with the DFG, Division of Marine Fisheries (*MarineFisheries*) biologists. The analysts refined the *Aquatic Life Use* - habitat and flow data assessment methodology to include the status of fish passage and availability of diadromous fish habitat in coastal streams. Given the important functions that diadromous fish serve in aquatic

ecosystems, as well their cultural value in providing sustenance, fishing opportunities, and the appreciation of wildlife to Massachusetts citizens, MassDEP is initiating an effort, with the 2018 reporting cycle, to add and assess river and lake AUs where documented diadromous fish runs exist (see the *Aquatic Life Use* – Habitat and flow data section for information and context for addressing diadromous fish habitat-related impairments). A diadromous fish habitat assessment decision flowchart with population status and passage score definitions was also included.

II. WATER QUALITY STANDARDS

The Massachusetts SWQS regulation (MassDEP 2013) serves as the foundation for the state's water quality management program. The program includes water quality assessments (305(b)), lists of impaired waters (303(d)), TMDL development, National Pollutant Discharge Elimination System (NPDES) permits, and nonpoint-source management measures. The SWQS regulation: 1) defines the goals for the surface waters of the Commonwealth by designating the most sensitive uses for which they shall be enhanced, maintained and protected; 2) prescribes minimum water quality criteria (both numeric and narrative) required to sustain the designated uses; 3) includes provisions to restore uses, and 4) includes provisions to maintain and protect existing uses and high quality waters (314 CMR 4.04 Antidegradation Provisions), which may include the prohibition of discharges (MassDEP 2013). The federal water quality regulation (40 CFR Part 131.20), requires that state water quality regulations undergo public review at least once every three years.

Water Use Goals

314 CMR Sections 4.05 and 4.06 identify and classify certain surface waters or segments of surface waters, and describe and assign qualifiers which define further the designated uses of those surface waters or segments (MassDEP 2013). The six classes of surface waters (A, B, and C for freshwater and SA, SB, and SC for coastal and marine waters), described below, are identified by the most sensitive, governing water uses to be achieved and protected. Tables 1 through 27 of the SWQS list specific water bodies or groups of water bodies by classification and/or qualifiers, however, not all waters in the State are included. The default classifications for waters not specifically listed in tables 1 through 27, as specified in 314 CMR 4.06(4) under "Other Waters", are Class B for inland waters and Class SA for coastal and marine waters. Additional use goals are applied to surfaces waters through qualifiers that indicate special considerations and uses applicable to specified segments (see 314 CMR 4.06(1)(d)). The qualifiers that affect assessment decisions include public water supply (PWS), cold water, warm water, and combined sewer overflow (CSO). Further discussion of these qualifiers and uses and how they are applied in the assessment decision-making process can be found in Section V, Use Assessment Decision Process. Inland cold water and warm water fisheries and coastal and marine shellfishing qualifiers are applied to unlisted waters as existing uses (those attained in waterbody on or after November 28, 1975) on a case-by-case basis, as necessary. Wetlands generally adopt the class and qualifiers of the surface water they border or are otherwise designated Class B for inland waters and Class SA for coastal and marine waters; vernal pools are designated Class B outstanding resource waters or ORWs (see 314 CMR 4.06(2)). Surface waters may be suitable for other beneficial uses, but shall be regulated by MassDEP to protect and enhance both existing and designated uses.

CLASSIFICATION OF MASSACHUSETTS SURFACE WATERS – RIVERS, LAKES, ESTUARIES
INLAND WATER CLASSES
CLASS A *- These waters include waters designated as a source of public water supply and their tributaries. They are designated as excellent habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation, even if not allowed. These waters shall have excellent aesthetic value. These waters are protected as Outstanding Resource Waters.*
CLASS B *- These waters are designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. Where designated in 314 CMR 4.06, they shall be suitable as a source of public water supply with appropriate treatment ("Treated Water Supply"). Class B waters shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value.*
CLASS C *- These waters are designated as a habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for secondary contact recreation. These waters shall be suitable for the irrigation of crops used for consumption after cooking and for compatible industrial cooling and process uses. These waters shall have good aesthetic value.*
COASTAL AND MARINE CLASSES
CLASS SA *- These waters are designated as an excellent habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, excellent habitat for fish, other aquatic life and wildlife may include, but is not limited to, sea grass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting without depuration (Approved and Conditionally Approved Shellfish Areas). These waters shall have excellent aesthetic value.*
CLASS SB *- These waters are designated as a habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting with depuration (Restricted and Conditionally Restricted Shellfish Areas). These waters shall have consistently good aesthetic value.*
CLASS SC *- These waters are designated as a habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for secondary contact recreation. They shall also be suitable for certain industrial cooling and process uses. These waters shall have good aesthetic value.*

Water Quality Criteria

The SWQS minimum criteria to sustain existing and designated uses and the classes of surface water to which they apply are summarized in Table 1. Table 1 also summarizes bacteria criteria from MA Department of Public Health (MA DPH 2014a) at public bathing beaches and from the United States Food and Drug Administration (USFDA 2015) in shellfishing areas. Criteria for certain pollutants, such as nutrients, are only described in a narrative format. Numerical and narrative criteria for each class of water are outlined in Section 4.05 of the SWQS. In addition, those surface waters that are assigned a qualifier may have unique criteria applied to them. For example, surface waters or segments and their tributaries that are qualified as cold water are evaluated using cold water fishery criteria. If a segment is not a designated or an existing use Cold Water or a tributary to such water, it is assumed to be warm water and warm water fishery criteria are applied. Surface waters exhibiting excursions from criteria due to natural background conditions are not interpreted as violations of standards (per 314 CMR 4.03(5)) (see also guidance provided in Appendix A).

It should also be noted that the SWQS contain site-specific criteria listed in 314 CMR 4.00 Table 28 that were developed for select river segments, lakes, coastal and marine segments. These criteria are only applied after EPA approval. The total phosphorus (TP) criteria for lakes, zinc criteria, and several copper criteria for river segments, although listed in Table 28 have not been approved by EPA; therefore, these criteria have not been used for assessment decisions. The site-specific copper criteria in Table 28 that have been approved are listed in Appendix E (Table E2). Site-specific total nitrogen criteria for several Cape Cod coastal and marine segments have also been approved by EPA.

The SWQS also describe the hydrological conditions at which water quality criteria must be applied (314 CMR 4.03(3), MassDEP 2013). In rivers, water quality criteria for the aquatic life use must be applied at or above the lowest mean flow for seven consecutive days to be expected once in ten years (7Q10). In waters where flows are regulated by dams or similar structures, aquatic life criteria must be applied when flows are equal to or exceeded 99% of the time on a yearly basis or when another minimum flow condition, as determined by MassDEP, is exceeded. In coastal and marine waters and for lakes and ponds the MassDEP will determine on a case-by-case basis the most severe hydrological condition for which the aquatic life criteria must be applied.

It should be noted that waterbodies affected by combined sewer overflow (CSO) discharges are qualified in the standards; however, unless a variance has been granted that states otherwise, excursions from criteria are not allowed during storm events (designated uses still need to be sustained).

Table 1. Summary of Massachusetts Surface Water Quality Standards.

Parameter	Criteria based on surface water classification*
Dissolved Oxygen	Class A Cold Water Fishery (CWF) and Class B Cold Water Fishery (BCWF) and Class SA: ≥6.0 mg/l Class A and Class B Warm Water Fishery (BWWF) and Class SB: ≥5.0 mg/l Class C: Not <5.0 mg/l at least 16 hours of any 24-hour period and not <3.0 mg/l at any time. Class SC: Not <5.0 mg/l at least 16 hours of any 24-hour period and not <4.0 mg/l anytime. *For all classes, where natural background conditions are lower than the criteria stated for each class, DO shall not be less than natural background conditions. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall also be maintained.*
Temperature	Class A CWF: ≤68°F (20°C) based on the mean of the daily maximum temperature over a seven day period in cold water fisheries, unless naturally occurring and ΔT due to a discharge ≤1.5°F (0.8°C). Class A WWF: ≤83°F (28.3°C) and ΔT due to a discharge ≤1.5°F (0.8°C). Class BCWF: ≤68°F (20°C) based on the mean of the daily maximum temperature over a seven day period in all cold water fisheries, unless naturally occurring, and ΔT due to a discharge ≤Δ3°F (1.7°C) Class BWWF: ≤83°F (28.3°C) and ΔT due to a discharge ≤5°F (2.8°C) in rivers (based on the minimum expected flow for the month) and ΔT due to a discharge ≤3°F (1.7°C) in the epilimnion (based on the monthly average of maximum daily temperatures) in lakes Class C and Class SC: ≤85°F (29.4°C) and ΔT due to a discharge ≤5°F (2.8°C) Class SA: ≤85°F (29.4°C) nor a maximum daily mean of 80°F (26.7°C) and ΔT due to a discharge ≤1.5°F (0.8°C) Class SB: ≤85°F (29.4°C) nor a maximum daily mean of 80°F (26.7°C) and Δ T due to a discharge ≤1.5°F (0.8°C) between July and September and ≤4.0°F (2.2°C) between October and June. *For all classes, natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. There shall be no changes from natural background conditions that would impair any uses assigned to each class, including those conditions necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms.*

Table 1. Summary of Massachusetts Surface Water Quality Standards.

Parameter	Criteria based on surface water classification*
	For CWF waters, where a reproducing cold water aquatic community exists at a naturally higher temperature, the temperature necessary to protect the community shall not be exceeded and natural daily and seasonal temperature fluctuations necessary to protect the community shall be maintained. Class B, C, SA, SB, and SC: See MassDEP 2013 for language specific to alternative effluent limitations relating to thermal discharges and cooling water intake structures.
pH	Class A, Class BCWF and Class BWWF: 6.5 - 8.3 SU and Δ0.5 outside the natural background range. Class C: 6.5 - 9.0 SU and Δ1.0 outside the natural background range. Class SA and Class SB: 6.5 - 8.5 SU and Δ0.2 SU outside the natural background range. Class SC: 6.5 - 9.0 SU and Δ0.5 SU outside the natural background range. There shall be no change from natural background conditions that would impair any use assigned to each class.
Solids	All Classes: *These waters shall be free from floating, suspended, and settleable solids in concentrations or combinations that would impair any use assigned to each class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.*
Color and Turbidity	All Classes: *These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use.*
Oil and Grease	Class A and Class SA: *Waters shall be free from oil and grease, petrochemicals and other volatile or synthetic organic pollutants.* Class SA: *Waters shall be free from oil and grease and petrochemicals.* Class B, Class C, Class SB and Class SC: *Waters shall be free from oil, grease, and petrochemicals that produce a visible film on the surface of the water, impart an oily taste to the water or an oily or other undesirable taste to the edible portions of aquatic life, coat the banks or bottom of the water course, or are deleterious or become toxic to aquatic life.*
Taste and Odor	Class A and Class SA: *None other than of natural origin.* Class B, Class C, Class SB and Class SC: *None in such concentrations or combinations that are aesthetically objectionable, that would impair any use assigned to each class, or that would cause tainting or undesirable flavors in the edible portions of aquatic life.*
Aesthetics	All Classes: *All surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life.*
Bottom Pollutants or Alterations	All Classes: *All surface waters shall be free from pollutants in concentrations or combinations or from alterations that adversely affect the physical or chemical nature of the bottom, interfere with the propogation of fish or shellfish, or adversely affect populations of non-mobile or sessile benthic organisms*.
Toxic Pollutants	All Classes: *All surface waters shall be free from pollutants in concentrations or combinations that are toxic to humans, aquatic life or wildlife. For pollutants not otherwise listed in 314 CMR 4.00, the National Recommended Water Quality Criteria: 2002, EPA 822-R-02-047, November 2002 published by EPA pursuant to Section 304(a) of the Federal Water Pollution Control Act, are the allowable receiving water concentrations for the affected waters, unless the Department either establishes a site specific criterion or determines that naturally occurring background concentrations are higher. The Department shall use the water quality criteria for the protection of aquatic life expressed in terms of the dissolved fraction of metals when EPA's 304(a) recommended criteria provide for use of the dissolved fraction and any metal criteria expressed as total recoverable metal shall be converted to dissolved metal using EPA's published conversion factors* (see 314 CMR 4.05(5)(e) for more detail regarding permit limits, conversion factors, and site specific criteria).
Nutrients	*Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site specific criteria developed in a TMDL or as otherwise established by the Department pursuant to these Standards.*
Radioactivity	*All surface waters shall be free from radioactive substances in concentrations or combinations that would be harmful to human, animal or aquatic life or the most sensitive designated use; result in radionuclides in aquatic life exceeding the recommended limits for consumption by humans; or exceed Massachusetts Drinking Water Regulations as set for in 310CMR22.09*.
Bacteria Note: Class A criteria	Class A: *At water supply intakes in unfiltered public water supplies:* either fecal coliform shall not exceed 20 organisms/100 ml in all samples taken in any six month period, or total coliform shall not exceed 100 organisms/ 100 ml in 90% of the samples taken in any six month period. If both total and fecal coliform are measured, then only the fecal coliform criterion must be met.

Table 1. Summary of Massachusetts Surface Water Quality Standards.

Parameter	Criteria based on surface water classification*
apply to the *Public Water Supply Use and Primary Contact Receational Use*. Class B and SB criteria apply to *Primary Contact Recreational Use* Class C and SC criteria apply to *Secondary Contact Recreational Use*.	<u>Class A other waters, Class B</u>: Where *E.* coli is the chosen indicator at public bathing beaches as defined by MA DPH: The geometric mean of the five most recent *E. coli* samples taken within during the same bathing season shall not exceed 126 colonies/ 100 ml and no single sample taken during the bathing season shall exceed 235 colonies/ 100 ml (these criteria may be applied on a seasonal basis at the Department's discretion). Where Enterococci are the chosen indicators at public bathing beaches*:* The geometric mean of the five most recent samples taken during the same bathing season shall not exceed 33 colonies /100 ml and no single *Enterococci* sample taken during the bathing season shall exceed 61 colonies /100 ml. For other waters and, during the non bathing season, for waters at public bathing beaches: The geometric mean of all *E. coli* samples taken within the most recent six months shall not exceed 126 colonies/ 100 ml typically based on a minimum of five samples and no single sample shall exceed 235 colonies/ 100 ml. These criteria may be applied on a seasonal basis at the Department's discretion. The geometric mean of all *Enterococci* samples taken within the most recent six months shall not exceed 33 colonies/ 100 ml typically based on a minimum of five samples and no single sample shall exceed 61 colonies/ 100 ml. These criteria may be applied on a seasonal basis at the Department's discretion. <u>Class C:</u> *The geometric mean of all E. coli samples taken within the most recent six months shall not exceed 630 E. coli/ 100 ml, typically based on a minimum of five samples and 10% of such samples shall not exceed 1260 E. coli/ 100 ml.* This criterion may be applied on a seasonal basis at the discretion of the Department. <u>Class SA:</u> Waters designated for shellfishing: *Fecal coliform bacteria shall not exceed a geometric mean (Most Probable Number (MPN) method) of 14 organisms/100 ml, nor shall more than 10% of the samples exceed an MPN of 28 organisms/100 ml, or other values of equivalent protection based on sampling and analytical methods used by the Massachusetts Division of Marine Fisheries and approved by the National Shellfish Sanitation Program in the latest revision of the Guide for the Control of Molluscan Shellfish Areas (more stringent regulations may apply, see 314 CMR 4.06(1)(d)(5)).* <u>Class SB:</u> Waters designated for shellfishing: *Fecal coliform median or geometric mean MPN shall not exceed 88 organisms/100 ml, nor shall more than 10% of the samples exceed an MPN of 260 organisms/100 ml or other values of equivalent protection based on sampling and analytical methods used by the Massachusetts Division of Marine Fisheries and approved by the National Shellfish Sanitation Program in the latest revision of the Guide for the Control of Molluscan Shellfish Areas (more stringent regulations may apply, see 314 CMR 4.06(1)(d)(5)).* <u>Class SA and Class SB</u>: At public bathing beaches, as defined by MA DPH: No single *Enterococci* sample taken during the bathing season shall exceed 104 colonies /100 ml and the geometric mean of the five most recent *Enterococci* samples taken within the same bathing season shall not exceed 35 colonies /100 ml. At public bathing beaches during the non-bathing season and in non bathing beach waters: No single *Enterococci* sample shall exceed 104 colonies/ 100 ml and the geometric mean of all samples taken within the most recent six months, typically a minimum of five samples, shall not exceed 35 colonies/ 100 ml. These criteria may be applied on a seasonal basis at the discretion of the Department). <u>Class SC:</u> *The geometric mean of all Enterococci samples taken within the most recent six months shall not exceed 175 colonies/ 100 ml, typically based on the five most recent samples, and 10% of such samples shall not exceed 350 colonies/ 100 ml. This criterion may be applied on a seasonal basis at the discretion of the Department.*

Note: *Italics are direct quotations.*

* Excursions from criteria due to solely natural conditions shall not be interpreted as violations of standards and shall not affect the water use classifications adopted by the Department.

Antidegradation Policy

The third component of the SWQS is the antidegradation provisions (314 CMR 4.04) designed to preserve and protect the existing uses and to minimize degradation of the state's high quality waters, outstanding resource waters (ORW), and special resource waters. These provisions restrict or prohibit the authorization of wastewater discharges to these waters. The ORW waters exhibit exceptional socio-economic, recreational, ecological and/or aesthetic qualities. ORWs include, but are not limited to, Class A public water supplies and their bordering vegetated wetlands and vernal pools certified as such by the Massachusetts Division of Fish and Game. Other waters designated as ORWs may include those protected by special legislation, as well as selected waters found in national parks, national wildlife refuges, state forests, parks, and sanctuaries, or areas of critical environmental concern (ACECs).

III. ASSESSMENT UNIT (AU) DEFINITIONS FOR MASSACHUSETTS

When defining AUs (sometimes referred to as "segments") for reporting and listing the use-attainment status of its surface waters, Massachusetts takes into consideration any of the following:

- Water body inventory systems for rivers/streams, lakes/ponds, and coastal/marine features
- Water body type (lotic, lentic, estuarine)
- SWQS classification
- Features that affect water quality (wastewater discharges, dams, river confluences, etc.)
- Availability of recent water quality and/or biological monitoring data
- Development of TMDLs

The SWQS classification is the primary source for defining AUs used for CWA reporting requirements, and water bodies must be broken into smaller AUs to reflect differences in SWQS Class (e.g., B, SA, etc.) and/or qualifiers (e.g., Cold Water resource, Shellfishing, etc.). Furthermore, because each AU is generally assumed to be fairly homogeneous in water quality, AUs are established to account for changes in water quality conditions that may be expected (i.e., at the confluence of a major tributary, at a dam, or at the site of a NPDES discharge).

To aid in monitoring, assessing and managing the water quality of Massachusetts' surface waters, the MassDEP (in conjunction with other agencies and institutions) developed water body inventory systems for rivers, lakes, and estuaries, where each water body was assigned a unique identifying code number tied to the watershed where it was located. The Stream and River Inventory System (SARIS) (Halliwell et al. 1982) was created to describe all Massachusetts' perennial streams that were named on U.S. Geological Survey (USGS) topographic maps (unnamed tributaries were originally excluded from SARIS). The SARIS numbering system was built around a nested stream hierarchy within each watershed with lower numbers corresponding to the main stem river and higher numbers corresponding to headwater tributaries. Each SARIS code is a seven-digit number starting with the two-digit number assigned to each of the 33 major watersheds in Massachusetts (see Figure 3). Each number was originally incremented by units of 25 to allow for the future addition of tributary streams. For example, the Ipswich River, located within the Ipswich River Watershed (92), was assigned a SARIS code of 9253500, and all tributaries to the Ipswich River have larger SARIS numbers. To accommodate new AUs where no SARIS number exists, new SARIS numbers are added as needed to the original inventory system (MassDEP unpublished a). Likewise, approximately 3,000 lakes, ponds, reservoirs, and impoundments were included in the Pond and Lake Information System (PALIS), a numbering system originally developed by Godfrey et al. (1979) and later adopted by the MassDEP's Clean Lakes Program (Ackerman et al. 1984, Ackerman 1989). Each PALIS code is a five-digit number starting with the two-digit watershed number (e.g., 82109 is Walden Pond, located in the Concord River Watershed (82)). PALIS codes are maintained for defining AUs by the DWM-WPP. Finally, the Coastal and Marine Inventory System (CAMIS) (MassDEP unpublished b) has been utilized to organize coastal waters, estuaries, and harbors based on their respective drainage areas as described in SARIS, and for which no SARIS or PALIS numbers have been assigned. Each five-digit CAMIS number begins with the two-digit watershed number followed by a 9 to indicate CAMIS water bodies (e.g., 94906 is Plymouth Harbor; portions of the South Shore coastal drainage system (94) drains to this water body). Note that Boston Harbor (proper) (70) was added as a "watershed" for assessment purposes and is utilized within CAMIS, but was not included as one of the original 32 Massachusetts watersheds described under the SARIS and PALIS systems.

Massachusetts defines AUs using the following three water body types represented by the SARIS/PALIS/CAMIS inventories described above (units given in parentheses): rivers (miles), lakes (acres), and estuaries (square miles). However, AUs were never universally established for every water body in these inventories. Rather, AUs were (and continue to be) created over time, as actual assessments of those water bodies are carried out for the first time. Therefore, the complete inventory of all of Massachusetts' water bodies is not represented by the AUs presented in the IR. When creating AUs, names are adopted directly from the associated SARIS, PALIS or CAMIS water body, although some exceptions do occur. Descriptions also help to identify the location of the AU. For lakes, the town where the AU is located is noted in the description. For rivers, the start and end point of the AU is described in terms of such features as tributaries, headwaters, outlets from ponds, and roads/bridges. Estuarine AUs may be described either way. Unlike lakes and ponds, a river or estuary represented by a single SARIS or CAMIS number may be divided into two or more AUs (see below). Therefore, AU identifiers (AUIDs) are assigned using two formats: 1) prefix "MA" followed by the five-digit PALIS code (lakes); or 2) prefix "MA" followed by "WW-XX" (rivers and estuaries), where WW is the two-digit watershed identification number and XX is a unique number beginning with "01". Unlike the SARIS coding system there is no hierarchical numbering system used for an AUID. Each new AUID for a river or an estuary is incremented by one as it is added during a reporting cycle.

Prior to the use of geographic information systems, AUs were defined using USGS topographic maps, with sizes determined by map wheels (rivers) and planimetry (lakes and estuaries). AUs were first depicted using GIS in 2000 using two feature classes, one for linear features (rivers and a few estuaries) and one for polygon features (lakes and estuaries). Lake and river AUs were georeferenced using the 1:25,000 USGS hydrography dataset (later modified by MassDEP), which depicts water bodies based on USGS topographic quadrangle maps. Today, Massachusetts Geographic Information System (MassGIS) color orthophotos, rasterized USGS topographic base maps, and professional judgment are used to help interpret and define individual river and lake AUs. Estuaries are defined using the USGS 1:25,000 topographic maps, National Oceanic and Atmospheric Administration (NOAA) nautical charts at several scales, and the original inventory and planimetry of Gil (1985) and Maietta (1984), respectively. In addition, coastal boundary definitions, landmarks (such as lighthouses), rock outcroppings, the extent of shellfishing beds, and professional expertise inform the creation of estuarine AUs.

With the completion of the 2016 IR, MassDEP analysts concluded a major effort to clarify AU designations and descriptions and eliminate cases where AUs overlapped. Specifically, since many of Massachusetts' lakes and ponds are impounded stream reaches, several were included in earlier IR reporting cycles as both lake and stream AUs. To avoid this "double-counting" in future IRs, MassDEP analysts began, with the 2008 reporting cycle, to review pertinent morphometric and hydrological data from impoundments as part of the watershed assessment process to determine whether they should continue to be defined and assessed as lake AUs or incorporated into stream AUs. As a general rule, those impoundments formerly identified as lake AUs, but exhibiting unidirectional flow and estimated average retention times of less than fourteen days, were eliminated and merged with their respective stream AUs, whether or not they were named lakes depicted on USGS topographic quadrangle maps and/or had been assigned PALIS numbers. The general approach used by MassDEP to calculate the retention times of impoundments is presented in Appendix G.

When a watershed is scheduled for an assessment update during a new CWA reporting cycle, new AUs may be established due to the availability of a sufficient amount of recent water quality or biological data, as a result of a TMDL study, or as a result of public comment. Furthermore, as SWQS are updated, new information may become available that requires geospatial changes to existing AUs, such as new data that indicate support of an existing use (e.g., Cold Water resource), or changes in public water supply/ORW status. Geospatial changes may require deleting an entire AU, splitting an AU into two or more segments, or joining all or part of one AU with another AU. Whenever an AU is resegmented, the former AU identifiers are listed within the AU description.

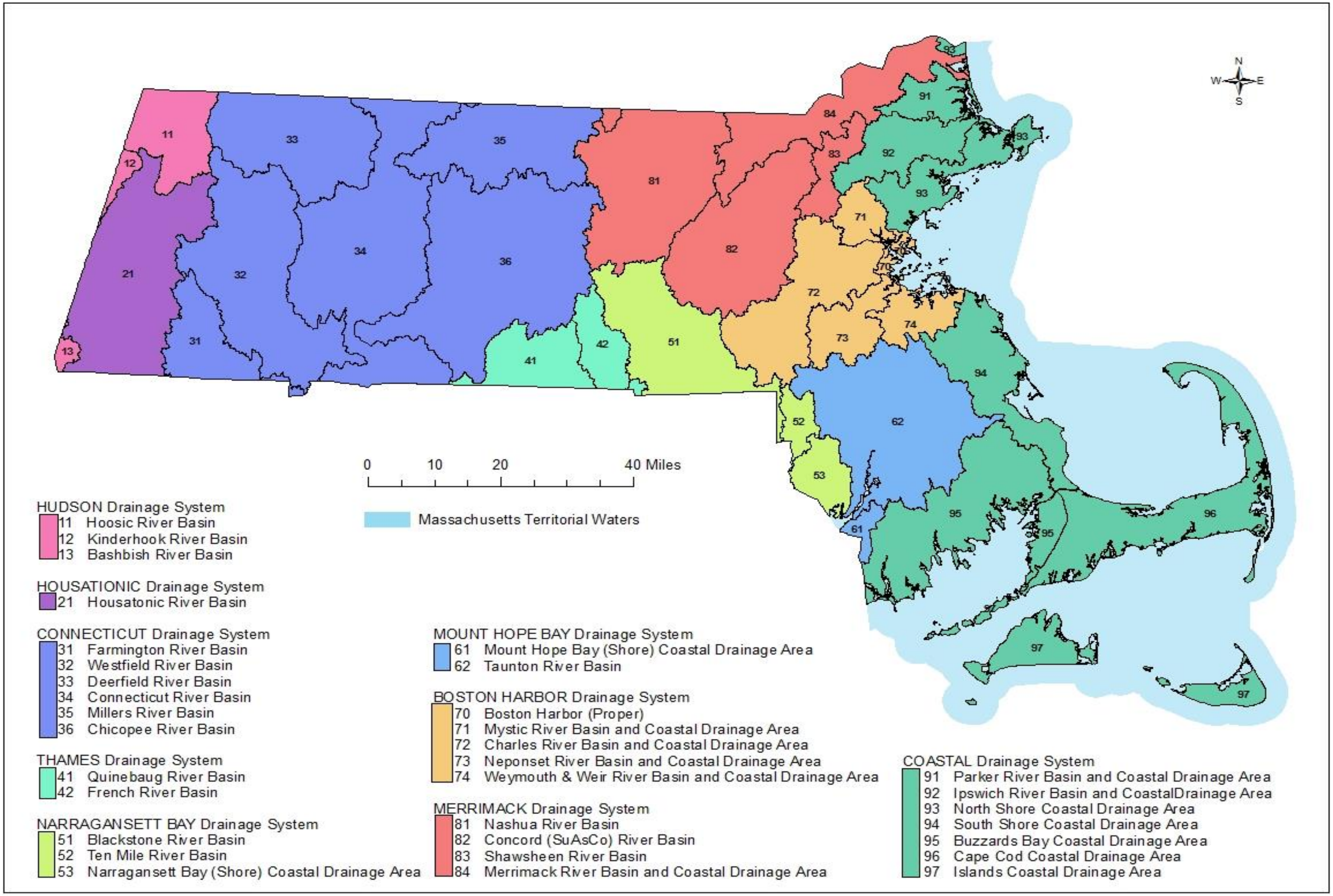


Figure 3. Major drainage systems, river basins (i.e., watersheds) and coastal drainage areas of Massachusetts with their unique Stream and River Inventory System (SARIS) code numbers, as assigned by Halliwell et al. 1982. These river basins and coastal drainage areas serve as the fundamental planning units of MassDEP's surface water monitoring, assessment and management programs.

IV. DATA ACCEPTABILITY

The availability of appropriate and reliable scientific data and technical information is fundamental to the 305(b) reporting and 303(d) listing process. It is EPA policy (EPA Classification No. CIO 2106.0) that any individual or group using EPA funding for any part of any work effort that results in generating data must establish a quality system to support the development, review, approval, implementation, and assessment of data collection operations. The MassDEP's Quality Management Plan ensures that environmental data used by the Department are of known and documented quality and are suitable for their intended use. Although the MassDEP relies most heavily on data collected as part of its ambient water quality monitoring program, "external" data from other state and federal agencies, local governments, drinking water utilities, volunteer organizations and other sources are also solicited and often considered when making assessment decisions. Results of the MassDEP's monitoring efforts, combined with all data deemed acceptable from other sources, constitute the basis for making water quality assessments in accordance with the requirements set forth in Section 305(b) and 303(d) of the CWA.

Each year, MassDEP staff monitor selected surface waters throughout the Commonwealth for chemical, physical and biological parameters of interest (e.g., nutrients, *E. coli* bacteria, dissolved oxygen, temperature, benthic macroinvertebrates, chlorophyll a, algae, fish tissue contaminants and fish communities). These data are collected by trained staff following a programmatic monitoring Quality Assurance Project Plan (QAPP) (MassDEP 2005c, MassDEP 2010b), including field and laboratory Standard Operating Procedures (SOPs). MassDEP water quality monitoring program has ranged from a minimum of three rounds of water quality sampling during the summer months, to a more intensive effort (a minimum of five rounds of water quality data collection augmented with probe deployments). Grab, composite, continuous, depth- integrated sampling techniques, among others, are utilized depending on the monitoring plan and the stated objectives. In addition to MassDEP's Wall Experiment Station laboratory, contract labs may also be used for sample analysis. All labs are evaluated for analytical accuracy and precision using double-blind QC samples, proficiency testing (PT) materials and/or inter-laboratory comparison testing. Resulting water quality data are evaluated against the data quality objectives (DQOs) specified in the QAPPs. Data validation procedures involve detailed analysis of all available information, such as field notes, survey conditions, field and lab QC data and audit results that could affect data quality. Following QC-level and project-level reviews, water quality data are accepted, accepted with qualification, or censored. Through a separate review process biological data (benthic macroinvertebrate, algae, periphyton, fish communities) are evaluated in light of QAPP DQOs, as well as best professional judgment regarding the quality of the data. For fish toxics data, MassDEP also relies on QC review at the state laboratory to assess usability. The MassDEP's goal is to use the most recently validated data for making the use assessment decisions. Ideally these data are five years old or less.

Section B.9 of the DWM-WPP's programmatic monitoring QAPP addresses the use of secondary or external data. External data are categorized into three general levels, which are related to the monitoring objectives (i.e., why the data were collected):

1) Educational/Stewardship-level
2) Screening-level, and
3) Regulatory/Assessment-level

While extremely important, data collected primarily for educational and/or stewardship purposes generally do not meet the rigor (i.e., accuracy, precision, frequency, comparability, overall confidence, etc.) required for use in waterbody assessments or TMDL development. Although these data can be submitted, it is unlikely this type of data would be used for 305(b)- and/or 303(d)-related decision-making. Screening-level-type data are also very important and welcome, but generally fail to meet one or more of MassDEP's criteria required for direct use in assessments or TMDLs. Screening-level data may meet the data quality objectives in the submitter's QAPP, but not those in the MassDEP's monitoring program QAPP approved by the EPA. Screening-level data are typically used to direct future sampling efforts and as supporting evidence only. Assessment-level data have been deemed by MassDEP, based on the external data review procedures, to be directly usable for 305(b) and 303(d) decision-making. These data are typically the result of extensive planning, attention to detail, relatively stringent data quality objectives, training, standard field and lab procedures, metadata collection, project organization and data verification---all of which contribute to data that are scientifically sound and legally-defensible. Contingent on review and approval, these data can help determine if a waterbody is meeting water quality standards or is impaired.

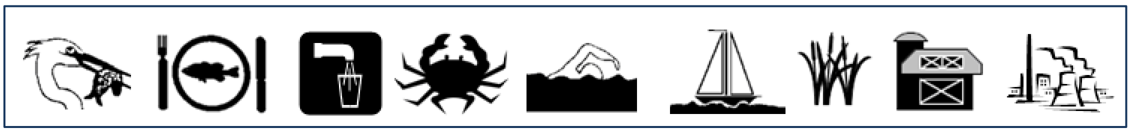
External data can be submitted to MassDEP using guidelines found on the Department's web site here: external-data-submittals. All submitted external data are reviewed using a consistent procedure. Once data are received, a standard data review spreadsheet is used to facilitate and document the MassDEP staff review. Each potential secondary data source is evaluated using the following preliminary criteria: 1) adherence to an acceptable QAPP, including a laboratory Quality Assurance Plan (QAP) and associated SOPs for field sampling and laboratory analyses; 2) use of a state-certified (or as otherwise acceptable to the MassDEP) analytical laboratory; and 3) availability of quality control (QC) data supporting the validity of the data. Meeting these criteria provides a basic level of confidence that the data were generated using appropriate field sampling and analytical methods and that the data were assessed by the group for accuracy, precision, and representativeness. External data meeting these criteria are then further reviewed by one or more MassDEP staff to verify that the group's DQOs were met based on the QC data provided. These DQOs are then compared to the MassDEP DWM-WPP's DQOs to look for any large discrepancies that could affect acceptability. In cases where additional information is needed, the external data group is contacted for the information. If available information is deemed insufficient to complete the review, the data are not used. Data can also be considered unusable due to poor or undocumented QAPP implementation, lack of project documentation, incomplete reporting of data or information, poor quality control results and/or project monitoring objectives unsuitable for MassDEP assessment purposes. Best professional judgment is used to make the final determination regarding data validity and usability for assessment purposes. External data are not qualified in any way but considered either acceptable for use or not (as a whole or in part). External data greater than five years old, with few exceptions, are generally considered unusable for assessment decisions.

V. USE ASSESSMENT DECISION PROCESS

The Massachusetts SWQS designate the most sensitive uses for which the surface waters of the Commonwealth shall be enhanced, maintained and protected. The determination of whether or not a waterbody supports each of the uses designated in the SWQS is a function of the type(s), quality and quantity of available current information. The EPA provides guidelines to states for making their use support determinations and recommends that states prepare their 2018 Integrated Reports (IRs) (available at http://www.epa.gov/tmdl/integrated-reporting-guidance) consistent with previous guidance including the EPA's 2006 IR Guidance (Keehner 2011), which supplements earlier EPA IR memoranda and guidance (EPA 2002, Grubbs and Wayland III 2000, Regas 2003, 2005, 2006, Schwartz 2009, and Wayland III 2001). While the SWQS (Table 1) prescribe minimum water quality criteria to sustain the designated uses, numerical criteria are not available for every indicator of pollution. Where necessary, best available guidance from available literature and/or MassDEP guidance and policies may be applied in lieu of actual numerical criteria (e.g., freshwater sediment data may be compared to *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* 1993 by D. Persaud, R. Jaagumagi and A. Hayton). Excursions from criteria due solely to "naturally occurring" conditions (e.g., slightly low pH in some areas) do not constitute violations of the SWQS.

The designated uses of Massachusetts surface waters are described below (MassDEP 2013).

DESIGNATED USES OF MASSACHUSETTS SURFACE WATERS



Fish, other aquatic life and wildlife *(AQUATIC LIFE)* - suitable habitat for sustaining a native, naturally diverse, community of aquatic flora and fauna, including, but not limited to, wildlife and threatened and endangered species and for their reproduction, migration, growth and other critical functions. Two subclasses of aquatic life are also designated in the SWQS for freshwater bodies: *Cold Water Fishery* - capable of sustaining a year-round population of cold water aquatic life, such as trout; *Warm Water Fishery* - waters that are not capable of sustaining a year-round population of cold water aquatic life. In certain [estuarine] waters, excellent habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass.

FISH CONSUMPTION - pollutants shall not result in unacceptable concentrations in edible portions of marketable fish or for the recreational use of fish, other aquatic life or wildlife for human consumption.

PUBLIC WATER SUPPLY - used to denote those waters used as a source of public drinking water. They may be subject to more stringent regulation in accordance with the Massachusetts Drinking Water Regulations (310 CMR 22.00). These waters are designated for protection as Outstanding Resource Waters under 314 CMR 4.04(3).

SHELLFISH HARVESTING (in SA and SB segments) – Class SA waters where designated shall be suitable for shellfish harvesting without depuration (Approved and Conditionally Approved Shellfish Areas); Class SB waters where designated shall be suitable for shellfish harvesting with depuration (Restricted and Conditionally Restricted Shellfish Areas).

PRIMARY CONTACT RECREATION - suitable for any recreation or other water use in which there is prolonged and intimate contact with the water with a significant risk of ingestion of water. These include, but are not limited to, wading, swimming, diving, surfing and water skiing.

SECONDARY CONTACT RECREATION - suitable for any recreation or other water use in which contact with the water is either incidental or accidental. These include, but are not limited to, fishing, including human consumption of fish, boating and limited contact incident to shoreline activities. Where designated, secondary contact recreation also includes shellfishing, including human consumption of shellfish. Human consumption of fish and shellfish are assessed as the *Fish Consumption* and *Shellfish Harvesting* uses, respectively.

AESTHETICS - all surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life.

AGRICULTURAL - suitable for irrigation or other agricultural uses

INDUSTRIAL – suitable for compatible industrial cooling and process uses.

As part of the 305(b) reporting process, each designated use (*see exception note below*) of the surface waters in the state for each waterbody segment (called an assessment unit or AU in the assessment database) is individually assessed as ***supporting*** or ***not supporting***. When too little current data/information exist the use is identified as having ***insufficient information***. When no reliable data are available the use is ***not assessed***. However, if there is some indication of water quality impairment, which is not "naturally-occurring", the use is identified with an Alert Status. It is important to note that not all waters are assessed. Many small and/or unnamed ponds, rivers, and estuaries have never been assessed. The status of their designated uses has never been reported to the EPA in the Commonwealth's 305(b) Report or the IR nor is information on these waters maintained in ATTAINS. These are considerd ***not assessed other waters.***

Exception Note: There are three uses - *Public Water Supply, Agricultural,* and *Industrial* - not assessed for 305(b) reporting purposes by MassDEP analysts. The *Public Water Supply Use* denotes those waters used as a source of public drinking water. These waters may be subject to more stringent regulation in accordance with the Massachusetts Drinking Water Regulations (310 CMR 22.00). They are designated for protection as Outstanding Resource Waters in 314 CMR 4.04(3). The MassDEP's Drinking Water Program (DWP) has primacy for implementing the provisions of the Federal Safe Drinking Water Act (SDWA). Except for suppliers with surface water sources for which a waiver from filtration has been granted (these systems also monitor surface water quality), all public drinking water supplies are monitored as finished water (tap water). Monitoring includes the major categories of contaminants established in the SDWA: bacteria, volatile and synthetic organic compounds, inorganic compounds and radionuclides. The DWP maintains current drinking supply monitoring data. The suppliers currently report to the MassDEP and the EPA on the status of the supplies on an annual basis in the form of a consumer confidence report (http://water.epa.gov/lawsregs/rulesregs/sdwa/ccr/index.cfm). While the EPA does provide guidance to assess the status of the *Public Water Supply Use* (impairment decision if there is one or more advisories, more than conventional treatment is required, or there is a contamination-based closure of the water supply), this use is currently not assessed. Rather, information on the drinking water source protection and finished water quality can/should be obtained at https://www.mass.gov/drinking-water-program and from local public water suppliers. The *Agricultural* and *Industrial* uses have never been assessed or reported on to date.

The guidance used to assess the *Aquatic Life, Fish Consumption, Shellfish Harvesting, Primary* and *Secondary Contact Recreation* and *Aesthetics* uses are provided in the following pages of this guidance manual. For each of these designated uses the background and context information on the data /indicators used for making the use assessment decision are provided. Depending on the waterbody type, assessment decision trees for the use assessment indicator(s) are also given. When too little data or information are available the use is identified as having insufficient information or not assessed.

To evaluate whether the *Aquatic Life Use* should be assessed as impaired, the analyst must determine whether or not the condition is natural. Excursions from temperature and DO criteria deemed to be the result of natural background conditions are not evaluated as impairment (see Appendix A guidance). Best professional judgment is always the final arbitrator however, several GIS datalayers (published date as noted) are typically utilized in some manner:

- USGS Color Ortho Imagery (2008/2009)
- Impervious Surface (February 2007**)**
- Land Use (2005) (June 2009)
- Dams (February 2012)

The anthropogenic influence can be screened through an ArcMap analysis as follows:

1. The contributing drainage area to each AU is delineated and saved as a shapefile. These shapes as well as further refinements of this spatial scale (described in Appendix A) can then be used to "clip" the land-use, imperious surface polygon coverages, dams or other coverages for each AU's drainage area.
2. The MassGIS Land Use 2005 (40 codes) coverage was grouped into four categories:
   Natural: forest, water, saltwater sandy beach, new ocean, and brushland/successional
   Wetland: wetland, salt water wetland, and forested wetland
   Agriculture: crop land, pasture, cranberry bog, orchard, and nursery
   Developed: mining, open land, participation recreation, spectator recreation, water-based recreation multi-family residential, high density residential, medium density residential, low density residential, commercial, industrial, urban open, transportation, waste disposal, powerline, golf course, marina, urban public, cemetery, very low density residential, and junkyards.
3. The percentages of anthropogenic influences can be calculated at the various spatial scales (e.g., impervious cover (IC)>4%, developed <10%). This type of analysis can provide a quantitative evaluation tool to conclude that an exceedance is in fact due to anthropogenic influence(s).

Note: The percent open water in the contributing drainage area, the percent IC in the contributing drainage area, and the percent forest in the contributing drainage area have all been identified as factors affecting brook trout relative abundance (Armstrong et al. 2011).

Aquatic Life Use

Waters supporting the *Aquatic Life Use* should be suitable habitat for sustaining a native, naturally diverse, community of aquatic flora and fauna. This use includes reproduction, migration, growth and other critical functions. Two subclasses of aquatic life are designated in the SWQS for freshwater bodies -- *Cold Water Fishery* - capable of sustaining a year-round population of cold water stenothermic aquatic life, such as trout, and *Warm Water Fishery* - waters that are not capable of sustaining a year-round population of cold water stenothermic aquatic life. In estuarine waters, excellent habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass (MassDEP 2013).

Weight-of-evidence approach

Results from biological (and habitat), toxicological, physico-chemical, sediment, and body burden investigations are all considered in assessing the *Aquatic Life Use*. The sampling technique (e.g., grab, composite, continuous, depth-integrated, etc.), as well as the type, quality, and amount of data generated for each of these indicators are first evaluated to determine if they are appropriate for use in the assessment decision-making process. Very often only one of the indicators is represented in the available data set or data from one indicator is obviously superior to the others. In these cases use support decisions are made based solely or mostly on one indicator. However, in cases where data are available from multiple indicators and the data are of equal quality the biological community data generally carry more weight in the decision-making process because they are considered an integration of the effects of pollutants and other conditions over time. Under these circumstances the biological community data, particularly those generated by a Rapid Bioassessment Protocol (RBP) III multi-metric analysis (Plafkin et al. 1989) or, in the case of Cold Water Fisheries the fish community data, are usually considered by the MassDEP to be the best and most direct measure of the *Aquatic Life Use*. Additionally, monitoring of the primary producers (algal, macrophyte, and eelgrass community data) also provide good indicators for evaluating the *Aquatic Life Use*. Since toxicological testing data also measure biological response to environmental stressors in the absence of biological community data they are given more weight than direct measurements of physico-chemical stressors. In the evaluation of chemical data, concentrations of toxic pollutants in surface water, sediment and fish tissue are evaluated against EPA's ambient water quality criteria for aquatic life, any sediment screening thresholds available, and whole-fish tissue criteria, respectively. It should be noted that in developing ambient water quality criteria for toxic pollutants, EPA either conducts its own toxicity tests or relies upon test information from the literature. Many of these laboratory tests are conducted using water low in organic carbon or other constituents that can bind to toxicants and make them less "bioavailable". In contrast, when pollutants are released into the natural environment, carbonaceous compounds (e.g., dissolved organic carbon) are more prevalent, rendering the toxicity of some pollutants less than predicted by laboratory tests. On the other hand, certain properties of natural waters, such as low pH, can increase the toxicity of certain pollutants. MassDEP and EPA recognize that natural conditions vary with location, and these variations necessitate evaluating data and information that more accurately reflect site conditions first, followed by those techniques that are less site-specific, in a weight-of evidence approach. Thus, assuming all data are of equal quality, the weight-of-evidence approach used by MassDEP WPP analysts follows this continuum: biological (including habitat) data first, followed by toxicological data, followed by chemical (physico-chemical, sediment chemistry data, whole-fish tissue residue) data.

The background and context information for the indicators used in the *Aquatic Life Use* assessment decision process are provided below in the order of the weight-of-evidence approach used by MassDEP. Within each indicator a summary decision tree (i.e., support decision and impairment decision) is provided. When too little data or information are available, the *Aquatic Life Use* is identified as having insufficient information or is not assessed. An overall summary of the indicators and the decision process used by the MassDEP analysts for making the *Aquatic Life Use* assessment decisions can be found in Table 4 (see end of the *Aquatic Life Use* assessment guidance).

Benthic macroinvertebrate data

Rivers

The benthic macroinvertebrate sampling data generated by MassDEP biologists are usually from 100-organism subsamples, which are analyzed by a multimetric approach based on a modification of the RBP III metrics and scoring (Plafkin et al. 1989). [Note: occasionally other sampling regimes are employed (e.g., in deep rivers or where kick sampling is inappropriate or impractical, multi-plate samplers may be used).] Sampling takes place during the months of July through September when baseflows are at their lowest of the year and levels of stress to aquatic organisms are presumed to be at its peak. The sampling index for a specific watershed also approximates historical sampling periods for that watershed, when possible. Metric values for each station are scored based on comparability to a reference station, and scores are totaled. The percent comparability of total metric scores for each study site to those for a pre-selected least impaired reference station (i.e. "best attainable" condition) yields an impairment score for each site. The RBP III analysis separates sites into four categories (% of reference condition): non-impaired (>83%), slightly impaired (54 – 79%), moderately impaired (21 – 50%), and severely impaired (<17%). Reference station sites and sites determined to be non-impaired or slightly impaired based on the RBP III analysis are assessed as supporting the *Aquatic Life Use*. Moderately and severely impaired RBP III sites are assessed as non-support. Occasionally, sample attributes may be noted by MassDEP biologists that influence an assessment decision (e.g., biologists note extreme [>40%] hyperdominance by a pollution tolerant species even though the RPB III analysis indicated only slight impairment. In this case a determination of "impaired" may be made --a result of best professional judgment (BPJ)).

The MassDEP benthic macroinvertebrate monitoring results are typically summarized in a technical memorandum by watershed. These memoranda combine habitat assessment information and the analysis of multi-metric benthic community characteristics for comparison to previously established reference station data (RBPIII analyses). Quality- assured external sources of benthic macroinvertebrate survey reports are occasionally available from outside parties (e.g., other state/federal agencies, consultants, watershed associations, NPDES permittees).

Use is Supported	Use is Impaired
Non-impaired/most slightly impaired (without caveat) RBP III analysis, reference sites	Moderately impaired/severely impaired RBP III analysis, slightly impaired RBP III analysis with caveat (e.g., hyperdominance by pollution tolerant sp.) as noted by MassDEP biologists

Lakes

Not currently utilized to evaluate *Aquatic Life Use* of lentic waters.

Estuaries

MassDEP analysts occasionally utilize external sources of benthic macroinvertebrate data combined with other water quality monitoring data when making *Aquatic Life Use* assessments of estuarine waterbodies. While no standardized multi-metric analysis is currently employed, some quantitative benthic sampling has been conducted in Massachusetts estuaries (e.g., Massachusetts Water Resources Authority (MWRA) and Massachusetts Estuaries Project (MEP) projects). Sample attributes typically reported include number of species, number of individuals, diversity (H'), evenness (E), and organism-sediment relationship (e.g., opportunistic, deep burrowers, etc.) (Howes et al. 2003). The overall analyses reported by these external data sources are utilized to make *Aquatic Life Use* attainment decisions.

Use is Supported	Use is Impaired
Relatively high number species, high number individuals, good diversity and evenness, moderate to deep burrowing, tube dwelling organisms present, as reported from external data sources.	Relatively low number species, low number individuals, poor diversity and evenness, presence of shallow dwelling opportunistic species, near absence of benthos, thin feeding zone, as reported from external data sources.

Background/context: MassDEP Benthic Macroinvertebrate Biomonitoring Quality Assurance Project Plan (MassDEP 2005a)

The biological sampling methodology is described in an SOP (MassDEP 2007) and is based on the USEPA Rapid Bioassessment Protocols (RBPs) (Plafkin et al. 1989). The main objectives of biomonitoring are: (a) to determine the biological health of streams within the watershed by conducting assessments based on aquatic macroinvertebrate communities; and (b) to identify problem stream segments so that efforts can be focused on developing or modifying NPDES and Water Management Act permits, storm water management, and control of other nonpoint source (NPS) pollution.

A regional reference station approach is currently used for comparisons to site data…this is useful in assessing nonpoint source (NPS) pollution impacts (e.g., physical habitat degradation), including NPS pollution at upstream sites as well as suspected impacted sites downstream from known point source stressors…benthic data from some stations are not compared to a regional reference station due to considerable differences in stream morphology, flow regimes, and drainage area, or simply lack of a suitable reference site.

A site-specific sampling approach (downstream study site compared to an upstream reference site) is occasionally employed for an assessment of a known impact site (e.g., point source discharge), provided that the stations being compared share basically similar instream and riparian habitat characteristics…

Background/context: MassDEP DWM Fish Collection Procedures for Evaluation of Resident Fish Populations Standard Operating Procedures (MassDEP 2011)

Monitoring of the fish assemblage is an integral component of the Massachusetts DEP water quality management program, and its importance is reflected in state stream class and use-support designations. Fish community information provides a valuable measure of the overall structure and function of the ichthyofaunal community and is indicative of biological integrity and surface water resource quality. This information is a key component used in the process to evaluate surface water resources in Massachusetts.

Species composition classifications:
***Tolerance Classification* – Tolerant (T), Moderately Tolerant (M), Intolerant (I)** Classification of tolerance to environmental stressors similar to that provided in Plafkin *et al.* (1989), Barbour *et al.* (1999), and Halliwell *et al.* (1999). Final tolerance classes are those provided by Halliwell *et al.* (1999).

***Macrohabitat Classification* - Macrohabitat Generalists (MHG), Fluvial Specialists (FS), Fluvial Dependents (FD)** Classification by common macrohabitat use as provided in Armstrong et al. 2011.

Temperature Classification: Classification of temperature tolerance provided in Halliwell *et al.* (1999).
Note: To exclude potential stocked trout when evaluating the presence of multiple age classes size should be $\leq$140 mm (~5.5").

There are two Cold Water "Existing Use" tiers:
Tier 1: brook trout $\leq$140mm and slimy sculpin
Tier 2: brook trout, brown trout, rainbow trout and tiger trout $\leq$140mm; landlocked salmon <200mm; and any size range of the following fish species: American brook lamprey, Atlantic salmon, lake chub, lake trout, longnose sucker, and slimy sculpin

See Appendix B for a complete list of species and their associated classifications -- habitat use, tolerances to environmental perturbations, and temperature.

Fish community data

Rivers MassDEP biologists use electrofishing gear (i.e., backpack or barge shockers) to sample fish from 100 m reaches of wadeable streams. Typically one survey is conducted per sampling site. Specimens that can be identified in the field are counted, examined for external anomalies, (i.e., deformities, eroded fins, lesions, and tumors) and this information is recorded on field data sheets. The procedures generally follow the protocols outlined in the RBP V (Plafkin et al. 1989 and Barbour et al*.* 1999), however, the RBP V protocols call for the analysis of the data generated from fish collections using an established Index of Biotic Integrity (IBI) similar to that described by Karr et al. (1986). Since no formal fish IBI for Massachusetts currently exists, the data provided by the MassDEP's (or others) sampling efforts, once evaluated for sample quality and collection efficiency, are used to semi-quantitatively assess the general condition of the resident fish community as a function of the overall richness (number of species) and abundance (number of individuals) and species composition classifications (see inset for more detail) (MassDEP 2011). MassDEP analysts also utilize fish community sampling data available from the *MassWildlife* biologists (MassWildlife 2014) as the goals, objectives, and sampling protocols are similar between the two groups.

When evaluating the status of the *Aquatic Life Use* in lotic waters based on fish community information, the data are evaluated using the following approach as developed by the MassDEP fisheries biologists: For waters designated as a Class B Cold Water Fishery or for those waters on MA DFG's Coldwater Fishery Resource List, the fish community should contain multiple age classes or young of the year (YOY) of any cold water fish excluding stocked trout (see Appendix B). An impairment decision is made if cold water fish are absent or, in some cases, where their numbers are dramatically reduced when compared to historic data. For waters designated as a Class B Warm Water Fishery, or those waters otherwise undesignated: in moderate to high gradient streams (riffle/run prevalent streams) the fish community should include two or more fluvial specialist/dependent species (see Appendix B) or at least one fluvial specialist/dependent species in moderate abundance to fully support the *Aquatic Life Use*. The absence of fluvial fish in these streams will result in an impairment decision. In low gradient streams (glide/pool prevalent streams) the fish community should include at least one fluvial specialist/dependent species or macrohabitat generalist species which are intolerant or moderately tolerant to environmental perturbations to fully support the *Aquatic Life Use*. If fish are absent in these streams, or if only tolerant macrohabitat generalist species are present, the *Aquatic Life Use* will be assessed as impaired. The presence of external anomalies (i.e., deformities, eroded fins, lesions, tumors [DELTS]) are noted and, if found in >10% of the sample, follow-up histology may be conducted to evaluate pollution-related conditions. If it is determined that pollutants are the cause of these anomalies then an impairment decision will be made.

For rivers where *MassWildlife* biologists developed a Target Fish Community (TFC) model, and fish sampling data temporally and spatially represent the AUs being assessed, comparison of fish sample data to the TFC model may be used for the assessment of fish community data. This analysis "measures, on a scale of zero (no similarity) to 100 percent (complete similarity), the degree to which the current and TFCs coincide based on species presence and relative abundance" (Kashiwagi and Richards 2009). For rivers where similarity scores are 50% or greater, the fish community will be assessed as supporting the *Aquatic Life Use*. For rivers where similarity scores are less than 50%, the fish community will be assessed as impaired. Usually, sampling data from the entire mainstem will be compared to the TFC model but under certain circumstances data from one or more AU(s) may be compared to the TFC model individually or as a group.

Fish community data are valuable for assessing the *Aquatic Life Use* and in many cases are all that is needed as described in the weight-of-evidence approach. In some cases, however, additional data are reviewed prior to making an assessment decision, including historic fisheries information, current water quality, and/or habitat evaluation data, potential pollution sources, etc. Even considering these other data sources, however, additional sampling may be needed before an assessment decision is made.

Use is Supported **Cold Water Fishery**	**Use is Impaired** **Cold Water Fishery**
Presence of cold water fish indicative of reproducing populations (e.g., multiple age classes of any cold water fish or YOY cold water fish), or fish community ≥ 50% similarity with TFC.	Absence of cold water fish indicative of reproducing populations, dramatic population reductions relative to historical samples, presence of DELTS (>10% sample) associated with pollutant(s), or fish community < 50% similarity with TFC.
Use is Supported **Warm Water Fishery**	**Use is Impaired** **Warm Water Fishery**
In moderate to high gradient (riffle/run prevalent) streams fish community includes fluvial specialist/dependents species or at least one fluvial species in moderate abundance. In low gradient (glide/pool prevalent) streams, at least one fluvial species, or macrohabitat generalist species which are intolerant or moderately tolerant to environmental perturbations should be present. In either high or low gradient habitat fish community ≥ 50% similarity with TFC.	In moderate to high gradient (riffle/run prevalent) streams fluvial fish are absent. In low gradient (glide/pool prevalent) streams no fish found, absence of fluvial fish, or the presence of only tolerant macrohabitat generalists. In either high or low gradient habitat: presence of DELTS (>10% sample) associated with pollutant(s), and/or fish community < 50% similarity with TFC.

Lakes and Estuaries

Fish community data are not currently utilized to make *Aquatic Life Use* support determination for either lentic or estuarine waters. However, impact evaluations based on studies of site-specific fish community data (e.g., those associated with large power plant type operations relating to impingement and entrainment) and/or the presence of DELTS with abnormal fish histology have been used to determine that the *Aquatic Life Use* is impaired.

Use is Supported	**Use is Impaired**
None made	> 5% population losses estimated, presence of DELTS (>10% sample) associated with pollutant(s)

Primary producer data

Rivers, Lakes, and Estuaries

Cyanobacteria, algae and aquatic vascular plants (macrophytes) represent additional biological communities that may be sampled as part of the MassDEP's biomonitoring efforts. Referred to, collectively, as autotrophs or "primary producers", these organisms contain chlorophyll, a pigment with light absorption properties. Through a process known as photosynthesis, they utilize light energy from the sun to convert inorganic carbon to carbohydrates, the precursors of all of the complex molecules that make up the structure of living cells. As such, the primary producers represent the first trophic level within the intricate food webs of aquatic ecosystems. Freshwater and marine algae, freshwater macrophytes and marine seagrasses are all examples of primary producers.

Freshwater algae are one important autotrophic component of both lake (lentic) and stream (lotic) ecosystems. They may occur as phytoplankton floating freely in the water column or as members of the periphyton community attached to substrata, such as rocks and stones (epilithic), other plants (epiphytic), or even animals (epizoic). Periphytic algae typically appear as a thin film, often green or blue-green, or as a brown floc (loose material without any structure that breaks up when touched or removed) or as green filaments.

Because algae lack true stems, roots, or leaves, they must obtain nutrients directly from the surrounding water. In the presence of excessive levels of available nutrients, such as phosphorus, both phytoplankton and attached algae may exhibit rapid rates of growth and accumulation. Phytoplankton blooms may consist of thousands, or even millions, of algal cells per milliliter of water, resulting in severe turbidity and discoloration of the water. The rapid die-off and decomposition of individual organisms following a bloom can contribute to hypoxia. Harmful algal blooms (HABs) may cause impacts through the production of toxins or by their accumulated biomass, which can affect co-occurring organisms and alter food-web dynamics (US National Office for Harmful Algal Blooms 2013). Impacts include human illness and mortality following consumption of or indirect exposure to HAB toxins and HAB-associated fish, bird and mammal mortalities. The majority of the freshwater HAB problems reported in the United States and worldwide are due to one group of algae, the cyanobacteria (or "blue-green algae") HABs (C-HABs), but other groups of algal blooms can also be harmful (Lopez et al. 2008). Some cyanobacteria produce natural substances that are toxic to other organisms, either during blooming conditions or when the algae cells break down and release these substances to the water.

Attached algae also exhibit abundant growth in response to nutrient enrichment which, under suitable conditions of light and temperature, may lead to nuisance levels. Often a single species population flourishes to the detriment of natural diversity and the loss of critical elements of the food web - vital for *Aquatic Life Use* support - may result from this alteration of community structure. In addition, the decay of large amounts of algal biomass can fill the interstitial spaces of the substrates and limit this habitat for benthic invertebrates, further compromising aquatic life.

As with other aquatic communities, MassDEP biologists assess the periphyton community in shallow streams, or the phytoplankton in deeper rivers and lakes, in an effort to determine the degree of enrichment exhibited by these waterbodies, and as another indicator of whether or not the *Aquatic Life Use* is supported. These assessments may employ an indicator species approach whereby inferences pertaining to water quality conditions are drawn from knowledge of the environmental preferences and tolerances of the individual species present. Alternatively, more quantitative methods may be used to estimate the amount of biomass present. The percent cover of duckweed (*Lemna* sp.) or other non-rooted forms of macrophytes in lakes and chlorophyll concentration are useful indicators of the trophic status of lakes, ponds, and impoundments. Likewise, estimates of periphyton coverage in shallower waters provide information with regard to nutrient effects on aquatic life and recreational use support. However, because the algal community typically exhibits dramatic spatial and temporal shifts in species composition throughout a single growing season, the information gained from the algal community assessment is more useful as a supplement to assessments of other communities that serve to integrate conditions over a longer time period.

Changes in the spatial extent of the seagrass community are indicators of water quality conditions in coastal waters. Eelgrass is considered a sentinel species for embayment health and is an important species in the ecology of shallow coastal systems providing habitat structure and sediment stability. Losses of bed area and/or thinning of beds (decreases in density) are generally both linked to nutrient enrichment. The MassDEP Wetlands Conservancy Program's Eelgrass Mapping Project routinely maps eelgrass beds statewide for comparison to historic records for determination of the stability of this resource and to measure temporal trends in habitat quality. The Massachusetts Estuaries Project (MEP) incorporates eelgrass mapping information into their assessment of nutrient-related health of coastal embayments in southeastern Massachusetts (Howes et al. 2003). The MEP also uses the presence and degree of accumulation of nuisance species of macroalgae as an indication of nutrient impairment in coastal embayments.

Benthic Algae (rivers)

> ***Background/context: Percent Periphyton Cover/Benthic Algae: Micro and Macro Identifications (MassDEP 2002 and MassDEP undated):*** *Benthic algae are useful biological indicators of water quality. The fast growing algae are sessile and take-up their entire nutrient and mineral needs from the water column. They are important primary producers in streams and are critical in oxygen production as well as carbon dioxide use and have been used by many to examine changes in nutrient (nitrogen and phosphorus) levels since they integrate nutrient concentrations over time… algal cover can be estimated by a trained biologist with the use of a viewing bucket. Along with macroinvertebrate and habitat assessments, the benthic algae provide another biological community to help evaluate the condition of aquatic life as well as the impacts from toxicity or nutrient enrichment. Exposure to low nutrient concentrations over time will result in algal populations represented by genera that can utilize nutrients at those levels. These sites are also likely to have reduced algal biomass. Higher algal biomass is often found in streams exposed to elevated nutrient levels.*

In wadeable rivers, MassDEP biologists currently conduct attached benthic algae surveys that include, at a minimum, scraping of substrates for taxonomic identifications. Samples are usually collected in the stream's riffle/run area. Identifications are currently only being performed on the "soft-bodied" algae, and not the diatoms, to determine the community assemblage. Where potential problem locations are found, based upon an estimate of the percent filamentous algal cover and abundance, they are noted and the information is evaluated in context with other habitat assessment information, such as canopy cover.

Sampling is typically conducted three times during the summer growth period with the level of sampling intensity dependent on the project objectives. Currently, when the filamentous algal cover is estimated to be >40% in a sampling reach more than once during a survey season it is considered by MassDEP analysts to be indicative of increased productivity. Sites exceeding this threshold are considered to be indicative of enriched conditions. The relative abundance of genera that appear most frequently in the algae samples may also help to inform the analysts whether or not the taxa indicate nutrient enrichment or some other environmental impact.

Chlorophyll *a* (rivers, lakes , estuaries)

> ***Background/Context: Measures of Biomass*** **(MassDEP 2004)**
> *Chlorophyll is a pigment found in plants that allows them to use radiant energy to convert carbon dioxide into organic compounds through a process called photosynthesis. Several types of chlorophyll exist and these and other pigments are used to characterize the algae. One type, chlorophyll a, is most widely used for biomass estimates since it is found in all algae. A knowledge of chlorophyll a concentrations provides qualitative and quantitative estimations of phytoplanktonic and periphytic biomass for comparative assessments of geographical, spatial and temporal variations (APHA 1981). Chlorophyll a is an indicator of algal biomass since it constitutes approximately 1-2% of the dry weight of organic material. Chlorophyll a measurements are made from both phytoplankton and periphyton samples from lakes, streams, rivers, and estuarine waters.* Excerpt from Wise *et al*. (2009) "*Algae The level of algal biomass depends on the physical, chemical, and biological characteristics of a stream, including water velocity, water temperature, light availability, and nutrient concentrations (Biggs and Close, 1989; Steinman, 1996). Hydrologic conditions also may affect algal biomass through physical scouring, especially during high flow events, and grazing by benthic invertebrates and herbivorous fish also can reduce algal biomass (Steinman, 1996).*"

Either grab and or depth-integrated samples are commonly collected by MassDEP staff for chlorophyll and phytoplankton analysis following procedures in MassDEP (2004). Chlorophyll *a* samples from the periphyton (attached algae) can be collected in different ways, but most are collected by scraping clean a known area of natural substrate (rocks, vegetation etc.). The loosened material is subject to chlorophyll *a* analysis (MassDEP 2002).

MassDEP analysts currently are using chlorophyll *a* thresholds of 16 µg/L for phytoplankton and 200 mg/m^2 for periphyton at benthic algae sites. If either of these thresholds is exceeded more than once during a survey season the waterbodies are considered to be at risk of increased productivity. Sites exceeding these thresholds warrant additional scrutiny for all indicators of enrichment (see nutrients).

Estuaries: According to the MEP critical indicators report when chlorophyll *a* concentrations are $\leq$ 5 µg/L the overall health of the system is generally good to excellent (Howes et al. 2003). Higher concentrations (>10 µg/L) are typically associated with systems experiencing enrichment and degraded overall health.

Aquatic Macrophytes (lakes, estuaries)

Background/context: Visual Surveys Ponds and Impoundments: Percent Cover of Floating, Non-rooted Vegetation (MassDEP 2014a) and Aquatic Plant Mapping (MassDEP 2006): *Aquatic plants represent an important part of the biota of lakes and the density, diversity, and growth patterns of aquatic plants are unique to each lake. MassDEP has established a standard set of procedures for identifying and semi-quantitatively mapping the aquatic macrophytes of a lake or impoundment. The maps can be used over time to document changes in species composition and the density and extent of plant beds as well as non-rooted forms that may impair designated uses. Mapping percent cover gives a semi-quantitative assessment of the general density of plants. The species distribution map is used for determining the type of plant community and for tracking changes in species dominance or expansion of beds across the lake over time. Excerpt from Wise et al. (2009) "Light availability, rather than nutrient availability, is a common factor limiting macrophyte growth (Madsen and others, 2001)—turbidity levels, phytoplankton abundance, and water depth all affect light availability (Barko and others, 1986; U.S. Environmental Protection Agency, 2000a). Rooted macrophytes obtain nitrogen and phosphorus either through roots in the bed sediment or through shoots in the water column, and macrophytes with extensive root systems are able to meet their nutrient needs predominantly from the bed sediment (Carignan, 1982; Chambers and Prepas, 1989; Barko and others, 1991)." Like algae the non-rooted forms are able to obtain their nutrient supply directly from the water column. Therefore the percent cover of non-rooted forms such as Wollfia and Lemna sp. are also noted on lake survey fieldsheets during DWM surveys when water quality samples are being collected.*

Field staff record visual observations made during lake water quality monitoring surveys (via boat or shoreline vantage points) on lake survey field sheets. Visual observations are made of both the open water areas and the bank/littoral areas. Lake surveys are typically carried out monthly during the summer index period. During these surveys the percent coverage of floating non-rooted aquatic macrophytes (i.e., *Lemna* sp. and *Wollfia* sp.) and algal films/clumps are visually estimated in both open water and littoral areas and recorded as a percentage of the whole-lake area covered (MassDEP 2014a). When more rigorous data collection efforts are required detailed methods currently being utilized by staff are available (e.g., the Long-Term Duckweed Monitoring on the Assabet River Impoundments [MassDEP 2014b]). Field staff also occasionally conduct more detailed plant surveys of lakes yielding information on species distribution, dominant species, frequency of occurrence of species, percent cover, and percent biovolume during the height of the growing season (MassDEP 2006).

Lakes: When the total surface area of a lake is estimated to be >25% covered by non-rooted macrophyte(s) and/or algal mats/films/clumps during more than one survey per season it is considered by MassDEP analysts to be exhibiting symptoms of increased productivity. Lakes exceeding this threshold warrant additional scrutiny for all indicators of enrichment (see nutrients).

Estuaries: According to the MEP critical indicators report macroalgae is one of the biological habitat indicators of ecological embayment health and nitrogen assimilative capacity. In nitrogen overloaded systems, eelgrass distribution tends to be much less wide spread across an embayment and macroalgae presence typically increases. The MEP uses the following categories of visual observations of macroalgae as one of a suite of indicators to evaluate nitrogen enrichment: macroalgae absent to present in limited amounts is considered supportive of fair to excellent habitat health; and a range of some macroalgae accumulations present to large and pervasive accumulations is considered an indication of moderately to significantly impaired habitat health (Howes et al. 2003). Certain marine macroalgae species including *Ulva*, *Enteromorpha*, (greens) (both sheet formers), *Pilayella* (brown), and *Porphyra* (red) may be particularly good indicators of enrichment. Nuisance growths of these indicator macroalgae can occur both in the northern rocky estuaries as well as the southern sandy coastline (personal communication Beskenis 2014).

Algal Blooms (rivers, lakes, estuaries)

An algal bloom is a rapid accumulation of algae that often occurs in response to a surplus of nutrients combined with abundant light and other variables that promote their growth. Algal blooms are typically indicative of over-enrichment that, in addition to altering algal community structure, may cause changes in water quality (e.g., turbidity, oxygen depletion) and/or habitat conditions (e.g., siltation). Blooms caused by cyanobacteria (C-HAB) may result in the presence of toxins that can negatively affect aquatic organisms. Counts and IDs of cyanobacteria are used to provide a means of determining if toxins may be present in potentially harmful amounts. Sources of information and data related to the magnitude, frequency, and duration of blooms include notes on MassDEP field sheets, technical memoranda, C-HAB counts and MA DPH advisories. Because waterbodies experiencing frequent and/or prolonged algal and/or C-HAB blooms are likely to be adversely affected (enrichment, habitat degradation, and/or toxicity) the presence of such blooms is an indication of stress and the waters affected will likely be assessed as not supporting the *Aquatic Life Use*.

Eelgrass bed mapping data (estuaries)

Background/context: MassDEP Eelgrass Mapping Project (MassGIS 2017b and Costello and Kenworthy 2011)
Seagrass beds are critical components of shallow coastal ecosystems. They provide food and cover for important fauna and their prey, their leaf canopy calms the water, filters suspended matter and together with extensive roots and rhizomes, stabilizes sediment. Eelgrass, Zostera marina, is the most common seagrass present on the Massachusetts coastline. The other species found in embayments is Ruppia maritima, widgeon grass, which is present in areas of less salinity along the Cape Cod and Buzzards Bay coast.

Often considered a sentinel species for evaluating ecosystem health, the distribution and abundance of eelgrass beds can be documented with aerial photographs, digital imagery and field verification. Much of the Massachusetts coast has a sandy substrate which provides a useful color contrast to map the darker seagrass photo signatures. Accuracy estimates of this quantitative mapping project were reported to be >85% in the 1994 to 1996 effort, 94% in 2006 to 2007, 90% in 2010, and 95% in 2012. These eelgrass data layers are currently the best available information on general eelgrass extent in Massachusetts.

With appropriate temporal and spatial scaling, monitoring environmental quality and mapping the changes in seagrass distribution and abundance can provide scientists and managers with a sensitive tool for detecting and diagnosing environmental conditions responsible for the loss or gain of seagrasses. For example, unlike situations where degraded optical water quality reduces light penetration and threatens plants mostly in the deeper water, the effects of multiple stressors associated with eutrophication cause more widespread losses of eelgrass which are not just confined to the deepest edges of the seagrass beds.

The primary biological information used to make assessment decisions for the *Aquatic Life Use* in marine or estuarine waters is obtained from eelgrass bed maps based on surveys conducted by the MassDEP, Wetlands Conservancy Program (WCP), as part of the Eelgrass Mapping Project. Currently the best available information on the general eelgrass extent along the Massachusetts coastline come from these various eelgrass (seagrass) mapping efforts, which are available as data layers through the MassGIS. The statewide seagrass mapping project has been conducted in phases beginning in 1994 (note here that the 1994 – 1996 mapping effort is referred to as 1995 dataset) and has continued through 2017. Data acquisition and image interpretation are detailed in Costello and Kenworthy (2011) and are available online at https://www.mass.gov/guides/eelgrass-mapping-project. The first statewide mapping phase as part of this project was conducted between 1994 and 1996. The most recent data available are from 2010 to 2013 (MassGIS 2017b).

Eelgrass Mapping along Massachusetts River Basins and/or Coastal Drainage Areas*	Datalayer Years of Mapping Effort (indicated by X)	
	1995	2010-2013
Boston Harbor (Proper)	X	X
Boston Harbor: Weymouth & Weir	X	X
Buzzards Bay	X	X
Cape Cod	X	X
Islands	X	X
North Coastal	X	X
South Coastal	X	X

[*Note: mapping efforts did not include Merrimack, Mount Hope Bay (Shore) and Taunton]

Assessment decisions for the 2018 reporting cycle will be based on a comparison between the data derived from the first phase of the Eelgrass Mapping Project (1995) with the most recent available data (2010-2013) to determine whether or not the eelgrass beds within the AU are stable or are being lost. If the areal coverage of the beds is fairly stable or increasing (i.e., minimal {<10%} or no loss) the AU is considered to be supporting the *Aquatic Life Use*. Loss of eelgrass beds equal to or exceeding 10% is considered to be a "substantial decline" and the *Aquatic Life Use* is not supporting. For example, if the percentage of the AU area determined to be eelgrass was 50% in 1995, but only 40% in 2010-2013 [the percent loss is calculated by (50-40)/50 = 0.2 or 20%]. Loss of the deeper water edge of the eelgrass beds is indicative of declining water quality conditions (personal communication Costello 2015). [Note here: while the earliest *estimated* eelgrass data are available from 1951, these data were only anecdotally validated and, therefore, these data will no longer be used as the baseline. Rather, the current assessment methods require the eelgrass data evaluations to be made with data generated from the standardized eelgrass mapping protocols (Costello and Kenworthy 2011).]

The following summary provides the Primary Producer Biological Screening Guidelines for the three waterbody types. These are the current biological response indicators used by MassDEP in the nutrient criteria development process (Appendix C). These screening guidelines will likely be refined in the future.

Use is Supported			**Use is Impaired**		
Rivers	***Lakes***	***Estuaries***	***Rivers***	***Lakes***	***Estuaries***
Wadeable rivers: benthic chlorophyll *a* samples ≤200 mg/m^2*, filamentous algal cover ≤40%*, occasional non-harmful ephemeral algal blooms* Deep rivers: phytoplankton Chlorophyll a <16 µg/L*, occasional non-harmful ephemeral algal blooms*	phytoplankton Chlorophyll *a* ≤16 µg/L*, ≤25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps*, occasional non-harmful ephemeral algal blooms*	Eelgrass bed habitat in AU area is increasing or fairly stable (i.e., no or minimal loss), Chlorophyll *a* ≤5 µg/L*, little to no macroalgae accumulations*	Wadeable rivers: benthic chlorophyll *a* samples >200 mg/m^2*, filamentous algal cover >40%*, recurring and/or prolonged algal and/or C-HAB blooms* Deep rivers: phytoplankton Chlorophyll a >16 ug/L*, recurring and/or prolonged algal and/or C-HAB blooms*	phytoplankton Chlorophyll *a* >16 µg/L*, >25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps*, recurring and/or prolonged algal and/or C-HAB blooms*. **These indicators may also be applied to impounded reaches of River AUs**	Substantial decline in AU (= or exceed 10% of eelgrass bed area), Chlorophyll *a* >10 µg/L*, some macroalgae accumulations*, recurring and/or prolonged algal and/or C-HAB blooms*

*Denotes that an *Aquatic Life Use* assessment decision is not made based on these indicators alone. If exceedances(s) of any threshold indicators are found, an additional evaluation of other water quality monitoring data (see nutrients) is required to make an assessment decision.

Habitat and flow data

Rivers, Lakes, and Estuaries

Most often evaluations of instream habitat support the biological survey results and enhance the interpretation of the biological data. Habitat qualities are scored using a modification of the evaluation procedure in Plafkin et al. (1989). Most parameters evaluated are instream physical attributes often related to overall land use and are potential sources of limitation to the aquatic biota. Key physical characteristics of the waterbody and surrounding land use include the following: instream cover, epifaunal substrate, embeddedness, sediment deposition, velocity/depth combinations, channel flow status, right and left bank vegetative protection, right and left bank stability, right and left bank riparian vegetative zone width. Habitat parameters are scored, totaled, and compared to a regional reference station and/or a site-specific control (upstream reference) station to provide a final habitat ranking. When biological communities are determined to be impaired from RBP analyses obvious habitat stresses (e.g., sedimentation) are evaluated as possible causes of the impairment. Occasionally, however, the habitat perturbations themselves are severe enough to warrant an impairment decision. These situations include absence of visible streamflow and/or dewatered streambed in a perennial stream or dewatered lake due to artificial regulation, extreme deviation from expected flows (e.g., channel status for all but one stream during a survey noted as full but the one stream had little flow), and lack of natural habitat structure (e.g., concrete channel, underground conduit).

River surveys were historically conducted by MassDEP analysts during low-flow, dry-weather conditions which generally represented the worst-case scenario with respect to the assessment of impacts on receiving water quality from point discharges. Today, increased attention is given to the identification and control of nonpoint pollution, and survey methods are changing to reflect this shift in emphasis. For example, wet-weather sampling may provide the most reliable information pertaining to nonpoint pollutant loadings from stormwater runoff and, when compared with dry-weather survey data, may further distinguish the effects of point and nonpoint pollution sources (MassDEP 2005b).

MassDEP analysts can evaluate habitat quality and streamflow conditions using the habitat assessment field sheets and scores (usually reported in technical memoranda), observations recorded on the water quality monitoring field sheets (water quality technical memoranda or the DWM-WPP's open files), USGS real-time and historical streamflow data (http://waterdata.usgs.gov/ma/nwis/current/?type=flow), and the occasional site-specific flow data collected during DWM-WPP surveys. Up through the 2016 reporting cycle information contained in *MarineFisheries* technical reports on surveys of anadromous fish passage in coastal Massachusetts (https://www.mass.gov/service-details/marine-fisheries-technical-reports) were also utilized.

In November 2016, *MarineFisheries* biologists provided MassDEP staff with their most recent Diadromous Fish Restoration Priority List which documents the status of the State's diadromous fish passageways and barriers, and prioritizes waters for fish passage restoration projects using a scoring system made up of 13 valuation parameters and 15 location attributes (Chase 2016). This list is being utilized by MassDEP staff to document surface waters with diadromous fish runs and to identify habitat impediments that limit the use of migratory habitat by diadromous fish and/or exclude these fish from reaching spawning and nursery habitats. The process by which

Background/context: Diadromous Fish Habitat

Diadromous fish are migratory and spend part of their life cycle in both fresh and salt water. In Massachusetts these fishes include alewives and blueback herring (collectively known as river herring), American shad, rainbow smelt, sea lamprey, and American eel. These fish used to be highly abundant, compared to today's numbers, occurring in most coastal rivers and streams in Massachusetts. Diadromous fish are important prey for a wide range of fish and wildlife, including important recreational and commercial marine fish such as Atlantic cod, bluefish and striped bass. The migrations and habits of striped bass, one of the most valuable fish in Massachusetts' marine waters, reflect a dependence on diadromous fish for forage. Additionally, river herring, shad, American eel and rainbow smelt historically represented important commercial fisheries of their own.

River herring populations along the eastern seaboard are presently at or near historic low levels (ASMFC 2012) with some populations estimated to be less than 10% of historical abundance (Limburg and Waldman 2009). Declines in the Gulf of Maine have been associated with the collapse of near-shore commercial fishes such as Atlantic cod and pollock and other large predatory marine species that feed on river herring (Ames and Lichter 2013). Factors affecting the decline of diadromous fish in the Gulf of Maine are complex; however, the influences of dams on coastal streams (and related losses of inland spawning and nursery habitat), overfishing, and pollution are considered significant across the region. Additional causes include the impingement and entrainment of fish and larvae at power plants and other water intakes, disease, invasive and non-native species infestations, and climate change (Limburg and Waldman 2009). Recent declines of river herring in Massachusetts prompted the MarineFisheries to impose a moratorium on their harvest and sale throughout the state beginning in January 2006. That moratorium is still in effect today. Moreover, the National Marine Fisheries Service has listed both species of river herring as "Species of Concern" within their Endangered Species Act review process.

According to Limburg and Waldman (2009), dam removal, wherever possible, is the single broadest and most useful recovery action in the effort to restore the decimated diadromous fish populations, and where dams cannot be removed installation and/or maintenance of fish passage structures is recommended. In addition to fish passage, other improvements with regard to water quality and/or quantity may also need to be addressed. MarineFisheries staff, with the help of local citizens and watershed groups, actively monitor many of the runs and, in some cases, have reported modest and steady improvement since the moratorium, although diadromous fish populations, overall, remain at drastically reduced levels compared to times past. MarineFisheries staff continue to monitor and maintain fish passage structures, where present, and advocate for dam removals or installation of fish passage structures when appropriate.

the *MarineFisheries* priority list is used to make *Aquatic Life Use* support decisions is illustrated in Figure 4 and described below.

When evaluating the status of the Aquatic Life Use based on diadromous fish habitat, the scoring criteria for two *MarineFisheries* valuation parameters are used: “Population Status” and “Passage”. “Population Status“ scores range from 0 (no run present) to 10 (one of largest local runs). “Passage” scores range from 0 (no obstruction) to 10 (no possible passage). Both scores are primarily based on *MarineFisheries* biologist’s best professional judgment (BPJ); however, in the case of waterbodies with no existing diadromous fish runs, documented historical runs were assigned “Population Status” scores of 1-3. For the 2018 reporting cycle, all diadromous fish runs with “population status” scores of >0 were added as river or lake AUs, as appropriate. For all AUs with a “Population Status” score greater than 0 and a “Passage” score of 4 (restricted passage) or greater, the Aquatic Life Use will be assessed as not supporting due to the presence of one or more fish passage barriers. Where a barrier occurs at the boundary of two AUs and passage scores are ≥4, impairment decisions will be assigned to adjacent/adjoining AUs within the same named stream or to the upstream lake AU and the downstream river AU. Where *MarineFisheries* staff conducted more intensive site-specific habitat assessments, additional stressors identified in their technical reports (available online @ https://www.mass.gov/service-details/marine-fisheries-technical-reports) may be added as appropriate (e.g., water quality, low flow alterations, other flow regime alterations,etc) . For all waters with a “Population Status” score greater than 0, and a “Passage” score of less than or equal to 3 (minor obstruction), additional data/information, such as water chemistry, benthic macroinvertebrates, fisheries population, etc. is needed to assess the *Aquatic Life Use*. In the absence of any additional data the *Aquatic Life Use* is assessed as “Insufficient Information”.

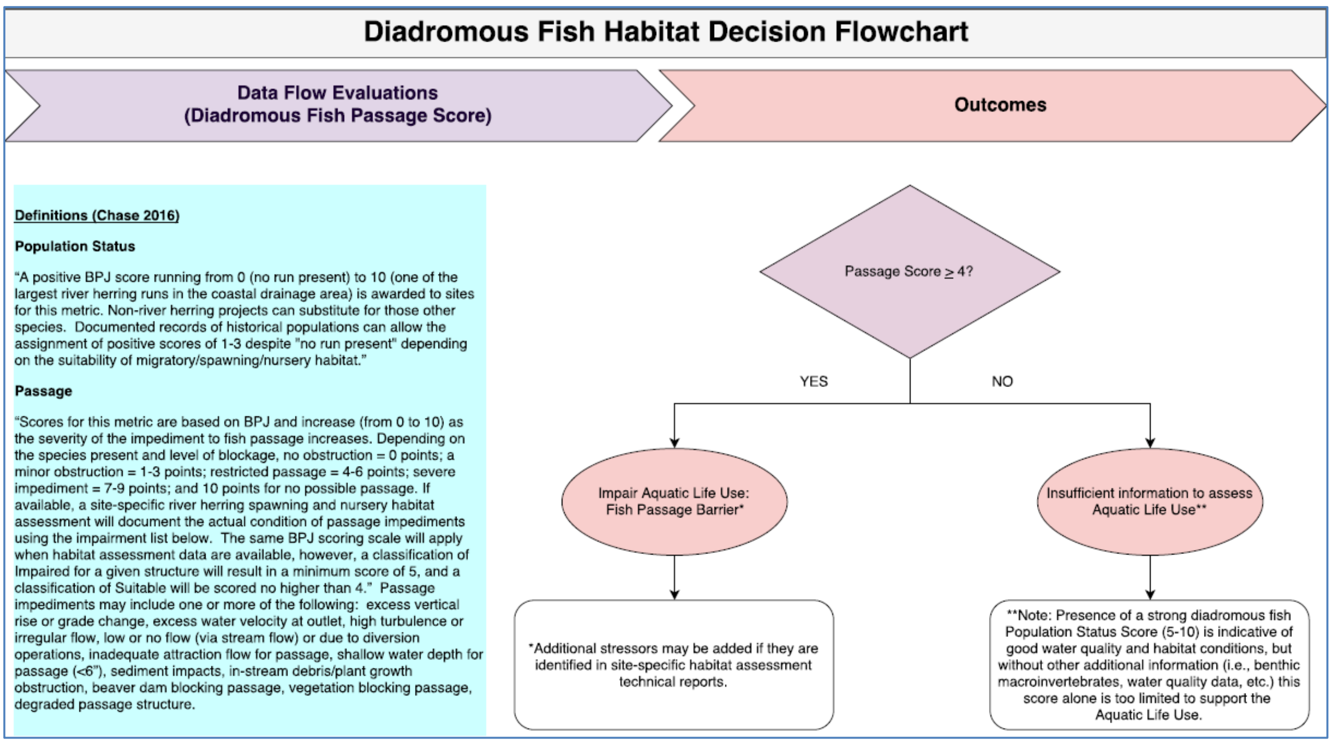


Figure 4. Diadromous fish habitat assessment decision flowchart with population status and passage score definitions.

In the Massachusetts coastal drainage areas, waters listed by *MarineFisheries* with diadromous fish runs identified with anything greater than a minor obstruction to passage limiting the use of migratory habitat by diadromous fish and/or exclude these fish from reaching spawning and nursery habitats (Chase 2016) will be considered an impairment of the *Aquatic Life Use*. [Note: for other waters not on the aforementioned diadromous fish restoration priority list, where impediments to fish passage (such as dams) exist but fish passage structure(s) are absent, no impairment decision is currently made.] Impacts associated with water intakes in rivers, lakes, and estuaries (i.e., power plants, cooling water intake structures) are evaluated on a case-by-case basis by MassDEP biologists by examining impingement, entrainment, and fish returns. Evidence of impact(s) (i.e., determination of unhealthful habitat or community impact) may result in a determination that the *Aquatic Life Use* is impaired.

MassDEP analysts must understand the hydrologic conditions encountered during the surveys and evaluate them against the estimated 7Q10 flow. One of the following methods, in preferential order, may be utilized to estimate the 7Q10: the USGS supported program called StreamStats (provides estimated streamflow statistics for ungaged sites), a drainage area ratio transform method, a flow factor estimate based on drainage area, or DFLOW, a software program used by the EPA permit writers. For lakes and estuaries the extreme hydrologic condition at which the aquatic life criteria must be applied will be established by the MassDEP on a case-by-case basis.

The presence of dams, flood control projects, water supply withdrawals, hydropower projects, and intake structures are considered potential habitat alterations.

Use is Supported	Use is Impaired
No direct evidence of severe physical habitat or stream flow regime alterations	Physical habitat impacted by anthropogenic stressors (e.g., lack of flow, lack of natural habitat -- concrete channel, underground conduit), a lack of passage or restricted fish passage where diadromous fish populations have been documented

Non-native aquatic species data
Rivers, Lakes, not currently used for Estuaries
Waters supporting the *Aquatic Life Use* are suitable for sustaining a native, naturally diverse, community of aquatic flora and fauna. Non-native (or exotic) species, unlike the natural biota, have few or no controls, are often extremely invasive (dominating and/or eliminating native biota), and can displace a healthy and desirable aquatic community and produce economically and recreationally severe impacts even though no other change has occurred in the watershed (Mattson et al*.* 2004). Therefore, the documented presence of an introduced, non-native aquatic species in a waterbody is considered an impairment of the *Aquatic Life Use*.

For the 2018 reporting cycle MassDEP analysts will use the presence of non-native aquatic macrophytes or other aquatic organisms historically noted (as documented in prior listing cycles) and will add any confirmed new infestations documented by field staff based on MassDEP surveys conducted since 2005 or as confirmed/verified by external sources.

The presence of a non-native wetland or semi-terrestrial macrophyte(s) (e.g., *Phragmites* sp., *Lythrum salicaria*) is not usually considered an impairment of the *Aquatic Life Use* unless they have eliminated the open water area of the waterbody. In waterbodies where active aquatic plant management has occurred it is particularly important to have up-to-date information to accurately reflect the conditions during the time period in which the assessment is conducted. In these cases the mere historical presence of a non-native species may not be appropriate for an automatic impairment decision.

Use is Supported	Use is Impaired
Non-native aquatic species absent	Non-native aquatic species present

Background/context: Massachusetts Surface Water Quality Standards (MassDEP 2013) and Guide to Selected Invasive Non-native Aquatic Species in Massachusetts (MA DCR 2007)

The Massachusetts Surface Water Quality Standards (2013) definition of Aquatic Life is "A native, naturally diverse, community of aquatic flora and fauna including, but not limited to, wildlife and threatened and endangered species." Since all waters are designated as habitat for aquatic life, DWM analysts use the presence of non-native aquatic organisms as an impairment of the Aquatic Life Use.

According to the MA DCR (2007), non-native (exotic) species have been introduced to our region in a variety of ways including: hitching rides in ship ballast water, accidental release from aquariums, escape from water gardens and intentional introduction. Exotic species are further spread unintentionally by boaters when plant fragments are tangled on boats, motors, trailers, fishing gear, and dive gear. Some species, including the zebra mussel, have a microscopic larval form that can travel undetected in ballast water, cooling water, live-well water and bait bucket water to new locations. Once an exotic species is established, it is almost impossible to eradicate and very expensive to control. The best way to protect a waterbody is through prevention, education, early detection and rapid response.

Toxicity testing data
Rivers, Lakes, and Estuaries

MassDEP maintains a toxicity testing database (ToxTD) to manage external toxicity testing data (both whole-effluent and ambient upstream sample data) submitted by facilities as part of their National Pollutant Discharge Elimination System *(*NPDES) permits. Validation procedures are implemented prior to uploading final data to the database. Testing frequency varies by facility and is associated with the instream waste concentration of the discharge; many Massachusetts facilities conduct quarterly testing, some conduct tests twice per year, and some conduct tests on an annual basis or a different schedule.

Survival information for test organisms exposed to ambient (rivers, lakes, estuary) water samples utilized as either the dilution water or site control during the whole effluent toxicity test is maintained in the ToxTD database (MassDEP 2018). Survival data for these test organisms are recorded for exposures at 24 and 48 hours and at the end of chronic test (~ 7-days) and are utilized by MassDEP analysts in the *Aquatic Life Use* assessment decision. Survival information is summarized for each test species since the last assessment was completed for a given waterbody AU. The survival data summary should include the number of tests conducted over the time period specified and indicate the time of exposure (e.g., 48 hours, 7 days, etc. depending on the test). MassDEP has concluded that a survival rate of the test organisms exposed to the ambient river water samples should be greater than or equal to 75% to warrant a use assessment decision of support. When survival of test organisms exposed to the river water samples is less than 75% the frequency and magnitude (with respect to temporal patterns) of the low-survival events are considered. The analyst notes any pattern of problems (e.g., seasonal) and reviews associated chemistry data to identify potential cause(s)/source(s). An impairment decision for the *Aquatic Life Use* is typically made when low organism survival (i.e., <75%) occurs in more than 10% of the tests performed since the last assessment was completed. With few data points (n≤10), however, MassDEP analysts will not impair a waterbody unless there is more than one exceedance of the guideline.

Whole effluent toxicity testing results are also typically evaluated for compliance with permit requirements, species sensitivity, and any other patterns that may be of note. For assessment purposes, NPDES facility compliance with whole effluent toxicity test and other limits may be used to identify possible causes/sources of impairment but is not utilized, solely, for assessment decisions.

Other toxicity testing data sources may include EPA investigations or testing carried out as part of waste-site investigations and may also included sediment toxicity testing results. Survival of test controls is always reviewed for data quality assurance. Typically the average survival of organisms exposed to the river water/sediment is calculated and any other test results (e.g., statistically significant change from controls) are also noted but are not utilized for assessment decisions of impairment by themselves.

Use is Supported	Use is Impaired
≥75% survival of test organisms to water column or sediment samples in either 48 hr (acute) or 7-day exposure (chronic) tests.	<75% survival of test organisms to water column or sediment samples in either 48 hr (acute) or 7-day exposure (chronic) tests occurs in >10% of test events or more than once when limited data are available.

Background/context: Whole Effluent Toxicity (EPA 2011)

Whole Effluent Toxicity (WET) is a term used to describe the aggregate toxic effect of an aqueous sample (e.g., whole effluent wastewater discharge) as measured by an organism's response upon exposure to the sample (e.g., lethality, impaired growth or reproduction). WET tests replicate the total effect and actual environmental exposure of aquatic life to toxic pollutants in an effluent without requiring the identification of the specific pollutants. WET testing is a vital component of water quality standards implementation through the NPDES permitting process and supports meeting the goals of the Clean Water Act (Section 402), "maintain the chemical, physical and biological integrity of the nation's waters".

Freshwater organisms used in WET tests include Ceriodaphnia dubia (freshwater flea) and Pimephales promelas (fathead minnow). Estuarine organisms used in WET tests include Americamysis bahia (mysid shrimp), and Menidia beryllina (inland silverside). These species serve as indicators or surrogates for the aquatic community to be protected, and a measure of the real biological impact from exposure to the toxic pollutants. WET tests are designed to predict the impact and toxicity of effluents discharged from point sources into receiving waters. WET limits developed by permitting authorities are included in NPDES permits to ensure that water quality criteria for aquatic life protection (WET) are met.

Background/context:
MassDEP Monitoring Strategy
(MassDEP 2005b)

One of the DWM's main programmatic objectives is to conduct surface water quality monitoring (collection of chemical, physical and biological data) to assess the degree to which designated uses, such as aquatic life, are being met in waters of the Commonwealth (CWA 305(b) purposes) (MassDEP 2005b, MassDEP 2010c). Massachusetts has selected a set of monitoring program elements that utilize a combination of deterministically and probabilistically derived sampling networks. Targeted designs may be used to identify causes and sources of impairments for reporting pursuant to sections 305(b) and 303(d) of the CWA, and to develop and implement control strategies such as TMDLs, NPDES permits, or Best Management Practices (BMPs). Furthermore, targeted monitoring may provide data and information to define new and emerging issues or to support the formulation of water quality standards and policies.

River & stream water quality surveys generally consist of five or six monthly sampling events from April 1 to October 15 (primary contact recreation period). Typical analytes include pH, dissolved oxygen (DO), temperature, conductivity, turbidity, total suspended solids, true color, chloride, nutrients (TP, TN, NH3-N), dissolved metals and indicator bacteria (E. coli for freshwater and Enterococci for coastal areas). Lake surveys typically include such limnological measurements as chlorophyll a and Secchi depth, in-situ measurements using metered probes, and water quality sampling to provide data for the calculation of TMDLs or the derivation of nutrient criteria. Lake surveys are generally conducted during the summer months when productivity is high.

The use of single or multi-probe sondes for physical and chemical monitoring is now also an integral component of the DWM's ambient monitoring program. It allows for the acquisition of short-term, attended data, using hand-held multi-probe units in the field, and long-term, unattended datasets, using stand-alone data loggers deployed for 2-6 days, to collect continuous monitoring data for such analytes as DO and temperature, pH, and specific conductance. Continuous water temperature monitoring units are also available for deployments of three to four months from June through September. Deep-hole profiling for DO and temperature in lakes are usually taken between mid-July and early September to reflect the worse-case conditions.

Water quality data

Rivers, Lakes, and Estuaries

The Massachusetts SWQS include specific numeric physical and chemical water quality criteria adopted to protect aquatic life and human health from the effects of pollution. The standards also contain narrative criteria for other constituents (e.g., nutrients, toxics) that must also be evaluated as part of the *Aquatic Life Use* attainment decision.

The use of water quality monitoring data for evaluating the *Aquatic Life Use* depends, in part, on the data set(s) available. MassDEP analysts rely most heavily on internal monitoring program data to assess use attainment. Over the past 10 years the program has transitioned from a targeted, synoptic survey program, consisting typically of a minimum of three rounds of water quality sampling during the summer months, to a more intensive effort (a minimum of five rounds of water quality monitoring during the sampling season augmented with probe deployments). The quality-assured and validated sampling results of the MassDEP surveys are published in the form of technical memoranda/reports, typically by watershed and/or sampling year. Water quality data published online by the USGS (http://waterdata.usgs.gov/ma/nwis/qw/, http://ma.water.usgs.gov/) are also available for stations across Massachusetts and are utilized for making *Aquatic Life Use* assessment decisions. There are also many other external sources of physico-chemical water quality monitoring data (e.g., environmental consultants, watershed and lake associations, and citizen monitoring programs, etc.). As resources allow, all external data from these and other sources are reviewed for quality/reliability according to the MassDEP's external data validation procedures to determine their acceptability for use in making assessment decisions.

When analyzing datasets for determining use attainment the analyst documents the total number of samples in the data set, the ranges of the data, and, if appropriate, the number of measurements that did not meet the criterion for each analyte. All validated water quality monitoring data are compared to the appropriate criteria, as noted below under individual analytes, in the Massachusetts SWQS (MassDEP 2013). Every attempt is made to consider the frequency, duration and magnitude of exceedances of criteria or guidance in making impairment decisions. However, since the datasets available are usually limited, it is often difficult to have a clear indication of the frequency and/or duration of exceedances. Since a single high or low result can skew the data, an impairment decision is never based on a single sample result.

Assessment guidance is presented below for the following indicators of water quality conditions: dissolved oxygen, pH, temperature, nutrients, and toxic/priority pollutants.

Dissolved oxygen (DO)

DO is a very important indicator of a waterbody's ability to support aquatic life. DO enters water by diffusion directly from the atmosphere, by mechanical aeration (e.g., a spillway or dam), or as a result of photosynthesis by aquatic plants and algae and is generally removed from the water by respiration of aquatic organisms and decomposition of organic matter. Its solubility in water is mainly a function of temperature and pressure and content is reported in terms of concentration (mg/l or ppm) or as a percentage of saturation (% saturation). DO exhibits natural daily and seasonal fluctuations.

The Massachusetts SWQS (MassDEP 2013) criteria for Dissolved Oxygen (DO) in mg/l are as follows:
Class A Cold Water Fishery (CWF) and Class B Cold Water Fishery (BCWF) and Class SA: ≥6.0 mg/l
Class A and Class B Warm Water Fishery (BWWF) and Class SB: ≥5.0 mg/l.
Class C: Not <5.0 mg/l at least 16 hours of any 24-hour period and not <3.0 mg/l at any time.
Class SC: Not <5.0 mg/l at least 16 hours of any 24-hour period and not <4.0 mg/l anytime.
For all classes…where natural background conditions are lower…DO shall not be less than natural background conditions. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall also be maintained. There shall be no changes from natural background conditions that would impair any uses assigned to each class, including those conditions necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms. In cases where a segment has the qualifier "Aquatic Life" added to the class, the Class C DO criteria are applied.

National criteria for DO in freshwater (EPA 1986 and 1988a) were derived using biological production impairment estimates to protect survival and growth of aquatic life below which detrimental effects are expected. The national criteria accommodate an exposure concept (frequency, magnitude and duration of condition). The national criteria daily minima (1.0 mg/l less than the 7-day mean) were set to protect against acute mortality of sensitive species and they were also designed to prevent significant episodes of continuous or regularly recurring exposures to dissolved oxygen at or near the lethal threshold. In 2005, MassDEP's ambient monitoring program for rivers was enhanced by the deployment of single and/or multi-probe sondes for physical and chemical monitoring (e.g., DO, temperature, % saturation, specific conductivity, and/or pH). Sondes which recorded DO were typically deployed three to five separate times during the summer months (June to September) for 3- to 5-day periods. More recently (2012 forward), optic DO/temperature sondes have been deployed for several months. Given the availability of these continuous DO datasets, the 2012 assessment methodology for DO needed revision. Rather than try to develop frequency and duration values for the assessment methodology, MassDEP staff made the decision it would be most appropriate and defensible to apply the 1986 EPA national DO criteria for freshwater aquatic life as the basis for determining assessment/impairment decisions, since both frequency and duration were incorporated into the EPA criterion document. Furthermore, the national criteria include specific protection for early life stages which are absent from the current Massachusetts SWQS. More details pertaining to the derivation of these assessment guidelines can be found in Appendix D.

Rivers: The assessment methodology used by MassDEP analysts is to compare calculated statistics from the available long-term and/or short-term DO datasets, as well as DO minima from any of the available DO data source(s), to the appropriate EPA national dissolved oxygen criteria based on the timing (e.g., presence or absence of early life stages of fish) and frequency of the data measurements (Table 2). It should be noted here that since there was generally very little variation within the daily DO patterns during the 3-5 day deployments at a given site, MassDEP analysts will compare the means from their 3-5 day DO sonde deployments against both the national 7-day mean and mean minimum criteria. In the case of single measurement datasets, a minimum of three, but preferably five, pre-dawn sampling events during the summer sampling season is required.

If all DO data statistics and/or minima meet (i.e., are above) all relevant criteria, DO is considered sufficient to support the *Aquatic Life Use*. When the criterion is not met the analyst must consider whether or not the condition is natural or not as previously described (see also Appendix A). DO is identified as a cause of impairment if excursions from the criterion are not natural.

Lakes: Low DO is considered an impairment if the area exhibiting oxygen depletion is >10% of the lake surface area (the oxygen depleted area is calculated using data from the depth profile along with the lake bathymetry). In deeper, stratified lakes impairment decisions are sometimes made using DO profile data collected from one deep-hole during the later part of the summer growing season. Data requirements for shallow, unstratified lakes follow those described above for rivers.

Table 2 Comparing long-term, short-term, and single measurement datasets to 1986 EPA national dissolved oxygen criteria and quantitative effect levels for the protection of freshwater aquatic life. [Note: this table does not include *early life stage* cold-water criteria since these life stages of cold water species in Massachusetts do not occur during the summer sampling period.]

	Coldwater Criteria	Warmwater Criteria		DO Measurement Types
	Other Life Stages	Early Life Stages* (assume present through July in MA coastal streams)	Other Life Stages	Long-term continuous (LC) Short-term continuous (SC) Single (S)
30-Day Mean	8.0	NA	6.0	LC[1]
7-Day** Mean	NA***	6.5	NA	LC, SC [1,2]
7-Day** Mean Minimum	6.0	NA	5.0	LC, SC[1,2]
1-Day Minimum***	5.0	5.0	4.0	LC, SC, S
* anadromous fish runs present **Continous monitoring data from sondes deployed between 3 to 5 days will also be utilized to evaluate the 7-day mean statistic since MassDEP analysts determined that there was generally very little variation within the daily DO patterns during the 3-5 day deployments at a given site. ***NA (not applicable) ***All minima should be considered as instantaneous concentrations to be achieved at all times.				[1] Exclude the first day of the deployment if it does not contain pre-dawn measurements. [2] A minimum of three continuous (not necessarily consecutive) days with pre-dawn measurements required.

Estuaries: MassDEP analysts compare DO data to the appropriate criteria (depending on a waterbody's classification) for surface water and depth measurements. If all DO data meet (i.e., are above) the criteria, DO is considered sufficient to support the *Aquatic Life Use*. The analyst must evaluate the frequency and duration of excursions (whether or not they exceed 10% of the measurements) as well as the magnitude of any excursions (i.e., >1.0 mg/l below the applicable criterion). DO is identified as a cause of impairment if data indicate frequent, prolonged and/or severe excursion(s) from the appropriate criteria.

Note: DO as an indicator related to nutrient enrichment is discussed later under **Nutrients**.

Use is Supported			**Use is Impaired**		
Rivers	***Lakes***	***Estuaries***	***Rivers***	***Lakes***	***Estuaries***
Deployed (LC, SC) probe datasets: Calculated mean and mean minimum statistics meet EPA criteria Single (S) measurement datasets: No more than one excursion from criteria (minimum three preferably five measurements representing critical --i.e., pre-dawn, conditions)	No/little depletion (the criterion is met in all depths over ≥90% of the lake surface area during summer season)	No/infrequent (≤10%) prolonged or severe excursions from criteria in surface or bottom waters	Deployed (LC, SC) probe datasets: Calculated mean and mean minimum statistics below EPA criterion Single (S) measurement datasets: Frequent (>10%) and/or prolonged or more than one measurement below EPA 1 day minimum criterion	The criterion is not met at all depths for >10% of the lake surface area during periods of maximum oxygen depletion	Frequent (>10%) and/or prolonged or severe excursions (>1.0 mg/l below standards) from criteria

pH

The pH of water is a measure of its hydrogen ion (H^+) concentration on a negative logarithmic scale, which ranges from 0 to 14 standard units (SU). A pH value less than 7 indicates higher H^+ content (acidic solutions), whereas pH values above 7 denote alkaline solutions. Natural waters exhibit a wide range of pH values depending upon their chemical and biological characteristics. Unpolluted river water usually has a pH between 6.5 and 8.5 SU (Hem 1970). In productive segments, diurnal fluctuations in pH may occur as photosynthetic organisms take up dissolved carbon dioxide during the daylight hours reducing the acidity of the water and raising pH. Respiration and decomposition during the night produces CO_2 that dissolves in water as carbonic acid, thereby lowering the pH. The pH of water affects the solubility, reactivity and biological availability of chemical constituents, such as nutrients (e.g., phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.).

The Massachusetts SWQS criteria for pH are as follows:
Class A, Class BCWF and Class BWWF: 6.5 - 8.3 SU and Δ0.5 outside the natural background range.
Class C: 6.5 - 9.0 SU and Δ1.0 outside the natural background range.
Class SA and Class SB: 6.5 - 8.5 SU and Δ0.2 SU outside the natural background range.
Class SC: 6.5 - 9.0 SU and Δ0.5 SU outside the natural background range.
There shall be no change from natural background conditions that would impair any use assigned to each class.

Geographical differences in the acidity of surface waters in Massachusetts have been demonstrated (Walk et al. 1991). The regions with the lowest average pH and acid neutralizing capacity (ANC) are the southeastern and north-central areas of the state, while the highest average pH and ANC are in the west where significant limestone deposits are found. Mattson et al. (1992) used the state map of bedrock formations produced by Zen (1983) to delineate the boundaries between six regions of similar bedrock geology and water quality. According to Portnoy et al. (2001) the seashore kettle ponds are naturally acid (varying between pH 4 and 6 SU).

Rivers and Estuaries: MassDEP analysts compare pH data to the appropriate criteria range. If all pH data are within the range the *Aquatic Life Use* is considered to be supported. When two or more measurements are outside the range analysts must consider whether or not the conditions are natural given the tendency towards acidic conditions described above (e.g., low pH in a wetland dominated sampling area based on field sampling notes and MassGIS topographic maps, orthophotos, and/or land use coverage). The magnitude of the excursion (i.e., >0.5 SU outside the criterion range), and the frequency of the excursions (e.g., non-consecutive vs. consecutive low or high pH measurements) should be considered. pH is identified as a cause of impairment if data indicate frequent, prolonged and/or severe excursion(s) from the criteria. The use may be impaired if criteria are exceeded in >10% of measurements that are not considered to be due to natural conditions.

Lakes: An impairment decision can be made using one deep-hole probe profile during the summer growing season that indicates an extreme excursion from the criteria range.

Use is Supported			Use is Impaired		
Rivers	***Lakes***	***Estuaries***	***Rivers***	***Lakes***	***Estuaries***
No or slight excursions (<0.5 SU) from criteria (minimum five measurements)	No or slight excursions (<0.5 SU) from criteria (minimum one deep-hole profile during summer growing season)	No or slight excursions (<0.5 SU) from criteria (minimum five measurements)	Frequent (>10%) and/or prolonged or severe excursions (>0.5 SU) from criteria	Excursion from criteria (>0.5 SU) summer growing season	Frequent (>10%) and/or prolonged or severe excursions (>0.5 SU) from criteria

Temperature

Most aquatic organisms are unable to internally regulate their core body temperature. Therefore, temperature exerts a major influence on the biological activity and growth of aquatic organisms and the ability of organisms to tolerate certain pollutants. Temperature is also important because of its influence on water chemistry. Temperature affects the solubility of oxygen in water. The rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. Some compounds are also more toxic to aquatic life at higher temperatures.

The Massachusetts SWQS criteria for temperature are as follows (MassDEP 2013):
Class A CWF: <68 F (20°C) based on the mean of the daily maximum temperature over a seven day period in cold water fisheries, unless naturally occurring and ΔT due to a discharge <1.5°F (0.8°C).
Class A WWF: <83°F (28.3°C) and ΔT due to a discharge <1.5°F (0.8°C).
Class B CWF: <68°F (20°C) based on the mean of the daily maximum temperature over a seven day period in all cold water fisheries, unless naturally occurring, and ΔT due to a discharge <Δ3°F (1.7°C).
Class B WWF: <83°F (28.3°C) and ΔT due to a discharge <5°F (2.8°C) in rivers (based on the minimum expected flow for the month) and ΔT due to a discharge <3°F (1.7°C) in the epilimnion (based on the monthly average of maximum daily temperatures) in lakes.
Class C and Class SC: <85°F (29.4°C) and ΔT due to a discharge <5°F (2.8°C).
Class SA: <85°F (29.4°C) nor a maximum daily mean of 80°F (26.7°C) and ΔT due to a discharge <1.5°F (0.8°C).
Class SB: <85°F (29.4°C) nor a maximum daily mean of 80°F (26.7°C) and Δ T due to a discharge <1.5°F (0.8°C) between July and September and <4.0°F (2.2°C) between October and June.
For all classes, natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. There shall be no changes from natural background conditions that would impair any uses assigned to each class, including those conditions necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms. Alternative effluent limitations established in connection with a variance for a thermal discharge issued under 33 U.S.C § 1251 (FWPCA, § 316(a)) and 314 CMR 3.00 are in compliance with 314 CMR 4.00. As required by 33 U.S.C. § 1251 (FWPCA, § 316(a)) and 314 CMR 3.00, for permit and variance renewal, the applicant must demonstrate that alternative effluent limitations continue to comply with the variance standard for thermal discharges.

The definition of "Cold Water Fishery" in the SWQS is *"Waters in which the mean of the maximum daily temperature over a seven day period generally does not exceed 68°F (20°C) and, when other ecological factors are favorable (such as habitat), are capable of supporting a year-round population of cold water stenothermal aquatic life such as trout (salmonidae)"* (MassDEP 2013). While many streams were designated as Cold Water during the 2006 revision of the SWQS, it was recognized that additional information (in particular temperature data) were needed to accurately and systematically identify the many other cold water rivers and streams in the state. However, these streams are, in fact, protected under the "Existing Use" clause in the SWQS. These streams, identified by the Massachusetts Department of Fish and Game's (MA DFG) Division of Fisheries and Wildlife as Cold Water Fishery Resources (CFRs), are identified as having an "Existing Use" which also merits protection.

When MassDEP analysts reviewed the definition for Cold Water Fisheries, the thermal criteria, and the definition of "Existing Use" in the SWQS, they determined that two subcategories of the "Existing Use" would be needed to protect all fish classified as cold water fish by the MA DFG. An evaluation of thermal tolerances of different cold water fish resulted in the development of two cold water "Existing Use" categories: Tier 1 and Tier 2 (see detail below and additional information provided in Appendices B and D). The thermal tolerance evaluation was based on both a literature review as well as on data collected in Massachusetts from fish community samples and data from long-term thermistors that were deployed in areas where the fish community samples were collected. These "paired" datasets were collected by both MassDEP and MA DFG staff. MassDEP staff also reviewed information from shorter-term "sonde" deployments. The two existing uses, and methods of determining these, are listed below:

Tier 1 Cold Water Existing Use: These are waters that have contained at least two fish of either of the following two species and size ranges: *S. fontinalis* (eastern brook trout or EBT) less than or equal to 140 mm (~5.5"), and/or *Cottus cognatus* (slimy sculpin or SC) of any size during a single sampling event (defined as sampling that took place over a single day) during the months of June through October after November 28, 1975. Larger EBT may also qualify in establishing an Existing Tier 1 use if stocking records indicate that the fish (minimum of 2 fish) were not stocked or did not likely come from a stocked waterbody. Both brook trout and slimy sculpin require clean, cold water habitat. The recommended temperature evaluations for the Tier 1 Cold Waters are summarized below.

Tier 2 Cold Water Existing Use: These are waters that have been shown (via sampling) to contain at least two fish from any combination of the following categories and size ranges: brook trout, brown trout, rainbow trout and tiger trout less than or equal to <140mm; landlocked salmon less than or equal to <200mm; and any size range of the following fish species: American brook lamprey, Atlantic salmon, lake chub, lake trout, longnose sucker, and slimy sculpin. These species also require clean, cold water habitat, however, the thermal tolerances of all the species (exclusive of brook trout and slimy sculpin) are slightly higher than those listed in Tier 1. The recommended temperature evaluations for the Tier 2 Cold Waters are summarized below.

In addition, as a rebuttable presumption, MassDEP will assume that any tributary, perennial or intermittent, entering a Tier 1 or Tier 2 segment upstream of the point where the fish sample used to identify a particular cold water fishery "Existing Use" was collected, is of the same Tier as the water into which it flows.

Evaluating thermal impairment of Cold Water streams: Factors influencing water temperature can be both natural and/or anthropogenic. Natural factors include elevation, channel gradient and orientation, surficial geology and groundwater input, air temperature and even the damming of streams by *Castor canadensis* (beaver). Human development disturbances include fragmentation associated with dams or roadways, stormwater runoff resulting in sedimentation, and riparian and/or instream habitat (e.g., stream hardening and/or widening with concrete, flood control manipulation, loss of trees), alterations all of which can result in increased instream temperatures. For the purpose of this reporting cycle, when temperatures are found to exceed the recommended metrics an additional evaluation of natural and/or anthropogenic factors are evaluated through a land-use analysis to identify potential anthropogenic source(s). Waters found to exceed the recommended temperature metrics will be listed as impaired for the *Aquatic Life Use* even if cold water species are present in stream samples when one or more anthropogenic influence(s) are present (see also methods in Appendix A) that are known to increase thermal input to streams. While this assessment procedure is not in line with the weight-of-evidence approach described in the *Aquatic Life Use* assessment guidance, it is deemed necessary and appropriate at this time to protect against any further loss of these cold water habitats where anthropogenic influences can be minimized and/or mitigated. The flowchart used to evaluate fish and temperature data for cold waters is illustrated in Figure 5. It should be noted however that the presence of cold water fish alone may be sufficient to support the *Aquatic Life Use* (see fish community data guidance on pages 19 and 20).

Depending upon the type of data (i.e., large long-term continuous (LC) datasets, shorter-term continuous (SC) datasets, or discrete/infrequent measurements), and the designated or existing use (i.e., cold water, unlisted Tier 1 cold water fish existing use, unlisted Tier 2 cold water fish existing use, warm water, other unlisted water) of the waterbody, the evaluations are made using the decision matrix below. The guidelines for evaluating the temperature data are based on SWQS as well as MassDEP-derived criteria (based on toxicity formulae provided in EPA, 1977 Temperature Criteria for Freshwater Fish: Protocol and Procedures (EPA600/3-77-061), and information from other published and unpublished data sources) for sentinel fish species (see details in Appendix D). An allowed exceedance (~10%) of the chronic criterion has been calculated as up to 11 times within the June 1st through September 15th index period. This allowed exceedance is considered to be a reflection of the term "generally" in the definition of a Cold Water Fishery in the SWQS ("mean of the maximum daily temperature over a seven day period generally does not exceed…") (MassDEP 2013). No exceedances of the 24-hour average (acute) criteria provided below are allowed. For small datasets (occasional discrete measurements), only infrequent or small exceedances from the SWQS are allowed.

Rivers: Waters designated in the Massachusetts SWQS as Cold Water Fisheries (CWF) and unlisted waters for which Tier 1 or Tier 2 Cold Water Existing Uses have been determined, are evaluated using temperature data collected during the summer index period (June through September). Long-term datasets are evaluated against either the SWQS criterion (7-day rolling average of the daily maximum temperatures or 7-DADM) or the MassDEP-derived chronic criterion (7-day rolling average of the daily average temperatures or 7-DADA) and either the Tier 1 or Tier 2 MassDEP-derived criteria (see decision matrix below). The 3-5 day deployed sonde data are also evaluated in the same manner as the rolling 7-day averages; however, these deployed dataset endpoints are expressed as a 3-5 DADM or 3-5 DADA. None of these shorter-term deployments should exceed the SWQS or the MassDEP-derived criteria in the table below; however, an impairment decision will not be made with these shorter datasets relative to chronic criteria. Instead, the exceedance will be identified with an Alert Status and follow-up sampling (long-term deployment data collection) will be recommended. For both the long-term and short-term deployments an evaluation of the acute (24-hour rolling average maximum), will be compared to the Acute (Maximum 24-hour average) criteria in the table below.

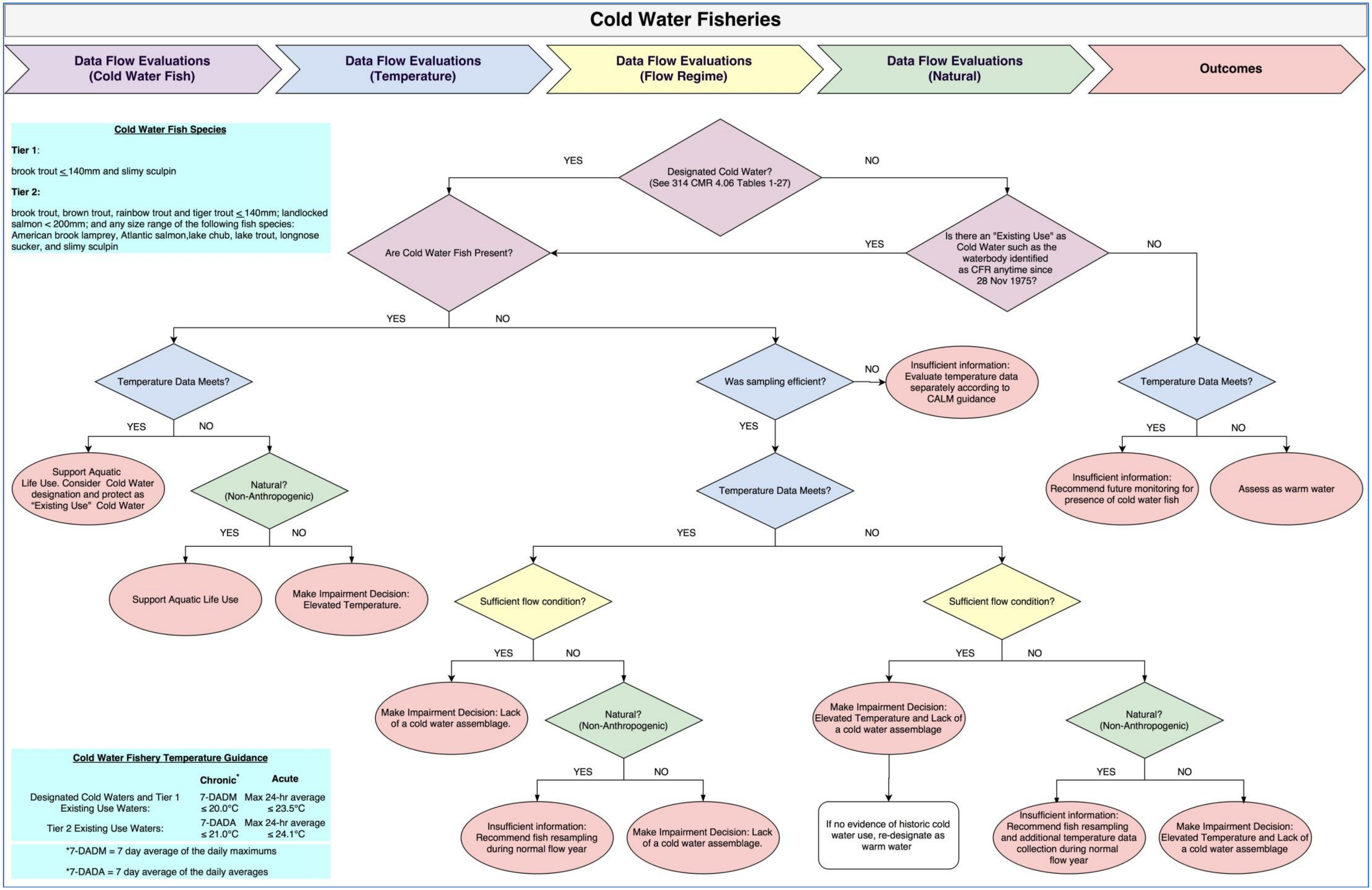


Figure 5. Decision flowchart used to evaluate fish and temperature data for cold waters.

For Warm Water Fisheries (WWF) and other unlisted waters not identified as having a Tier 1 or Tier 2 existing use, the analyst evaluates the temperature datasets collected during the summer index period (June through September). The long term datasets are evaluated against the MassDEP-derived 7-DADA criterion (or 3-5 day DADA) and the SWQS warm water criterion.

Estuaries: The analyst evaluates the temperature measurements against the acute SWQS criteria (shall not exceed 29.4°C nor a maximum daily mean of 26.7°C). Impact of large thermal discharges: Site-specific evaluations are made with regard to the rise in *in-situ* temperatures due to the discharge. Changes over the ΔT criteria result in impairment decisions.

Data Type	**Use is Supported**			**Use is Impaired***		
	Cold Water Fishery	*Warm Water Fishery*	*Estuarine*	*Cold Water Fishery*	*Warm Water Fishery*	*Estuarine*
Large (>one month usually all summer) Thermistor Datasets (Chronic evaluation):	Designated Cold Waters: 7-DADM ≤20.0°C Tier 1 Existing Use Waters: 7-DADM ≤20.0°C Tier 2 Existing Use Waters: 7-DADA ≤21.0°C (Exceedances** ≤11 times)	Designated Warm Waters and Unlisted Class B Waters not Tier 1 or Tier 2: 7-DADM ≤27.7°C (Exceedances ≤11 times)	24-hour average ≤ 26.7°C (Exceedances ≤11 times)	Designated Cold Waters: 7-DADM >20.0°CTier 1 Existing Use Waters: 7-DADM >20.0°C Tier 2 Existing Use Waters: 7-DADA >21.0°C (Exceedances > 11 times)	Designated Warm Waters and Unlisted Class B Waters not Tier 1 or Tier 2: 7-DADM >27.7°C (Exceedances > 11 times)	24-hour average > 26.7°C (Exceedances > 11 times)
Deployed (3-5 day) Sonde Datasets (Chronic evaluations):	Designated Cold Waters: 3-5-DADM ≤20.0°C Tier 1 Existing Use Waters: 3-5-DADM ≤20.0°C Tier 2 Existing Use Waters: 3-5-DADA ≤21.0°C (No exceedances)	3-5-DADM ≤27.7°C (No exceedances)	Not applicable	No impairment decision made but identify exceedance with an Alert Status and recommend followup sampling	No impairment decision made but identify exceedance with an Alert Status and recommend followup sampling	Not applicable
Large Thermistor and Deployed (3-5 day) Sonde Datasets (Acute evaluations):	Acute (Maximum 24-hour average) Tier 1 fish: ≤ 23.5°C Tier 2 fish: ≤ 24.1°C No exceedances of mean (acute criterion)	Maximum 24-hour average ≤ 28.3°C No exceedances of mean (acute criterion)	No more than one day with exceedance of 29.4°C	Acute (Maximum 24-hour average) Designated Cold Waters: > 23.5°C Tier 1 fish: > 23.5°C Tier 2 fish: > 24.1°C	Maximum 24-hour average > 28.3°C	More than one day above criteria 29.4°C
Small (instantaneous/discrete) datasets:	no/infrequent/small excursions (1 to 2°C) above 20°C	no/infrequent excursions above criteria (28.3°C)	No more than one day with exceedance of 29.4°C	MA SWQS criterion frequently exceeded (>10%) or by >2°C (22°C).	MA SWQS criterion frequently exceeded (>10% measurements) or by >2°C (30.3°C).	More than one day above criteria 29.4°C

*due to anthropogenic influences (see Appendix A for guidance to evaluate if excursions/exceedances from criteria can be considered natural).
**[Note here: MassDEP has adopted a 10% exceedance to reflect the term "generally" in the SWQS. The allowed number of 7-DADM exceedances translates to 11 occurrences during the critical index period June 1st through September 15th. See Appendix D for additional information.

Nutrients The Massachusetts SWQS include both narrative nutrient and aesthetic criteria (see excerpts below) that are applicable to all surface waters (MassDEP 2013).

> *"Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and* [concentrations] *shall not exceed the site specific criteria developed in a TMDL ….Any existing point source discharge containing nutrients in concentrations that would cause or contribute to cultural eutrophication* [defined elsewhere in the SWQS as '*The human induced increase in nutrients resulting in acceleration of primary productivity, which causes nuisance conditions, such as algal blooms or dense and extensive macrophyte growth, in a waterbody.'*], *including the excessive growth of aquatic plants or algae, in any surface water shall be provided with the most appropriate treatment … to remove such nutrients* [point and nonpoint source controls] *to ensure protection of existing and designated uses…"*
>
> *And "All surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance* [growth or amount] *species of aquatic life."*

To evaluate a waterbody for nutrient-related impairment MassDEP analysts rely on *multiple* supporting indicators as evidence of nutrient enrichment. Biological indicators of nutrient enrichment (one or more of which is documented as problematic), include the presence of nuisance growths of primary producers or population changes in certain critical species (see detail in primary producer data). Secondly, indications of high primary productivity are often observed as changes to certain physico-chemical analytes, as well. Taken together, these biological and physico-chemical indicators are utilized for making nutrient-related impairment decisions for the *Aquatic Life Use*. A literature review of the freshwater nutrient enrichment indicators used by MassDEP is provided in Appendix C. The more combinations of these indicators are documented, the stronger the case for the *Aquatic Life Use* to be assessed as not supporting. It should be noted here that while total phosphorus or nitrogen concentration data alone are not currently utilized to determine impairment due to nutrient enrichment, they are used to corroborate indicator data and can help to identify potential sources (e.g., release of phosphorus from anoxic sediments).

Nutrient enrichment is not considered to be problematic when biological response indicator data are below threshold values for primary producer data, even if nutrient concentrations exceed their recommended criteria. However, when multiple biological (particularly primary producer) and physico-chemical response indicators suggest that nutrient enrichment is problematic and concentration data exceed the recommended thresholds, the nutrient (total phosphorus or total nitrogen) is also identified as a cause of impairment. For the 2018 reporting cycle, the seasonal average ($n \geq 3$ samples) of the total phosphorus concentration data will be screened against the 1986 EPA recommended "Gold Book" concentrations for rivers (0.1 mg/l flowing waters, 0.05 mg/l for rivers entering a lake/reservoir) and lakes (0.025 mg/l). For estuarine waters, a seasonal average ($n \geq 3$ samples) of the total nitrogen concentration data collected during an ebb tide will be screened against the MEP critical indicator threshold of >0.5 mg/l for waters where eelgrass habitat has not been documented and >0.4 mg/l for waters where eelgrass habitat has been confidently documented at some point in time. According to the MEP critical indicators report, when total nitrogen concentrations are $\leq$ 0.5 mg/l the overall health of the system is generally good to excellent except in areas of eelgrass loss that may begin to occur at somewhat lower concentrations (~0.4 mg/l) (Howes et al. 2003). Higher concentrations (>0.5 mg/l) are typically associated with systems experiencing degraded overall health.

NUTRIENT CRITERIA DEVELOPMENT STATUS FOR MA

It should be noted here that EPA implemented a strategy to develop ambient water quality nutrient criteria by ecoregions for the US (EPA 2000a, 2000b, and 2001c). Massachusetts is encompassed by two of these freshwater ecoregions – the Eastern Coastal Plain (Ecoregion XIV) and the Nutrient-Poor, Largely Glaciated Upper Midwest and Northeast (Ecoregion VIII) and two Estuarine and Coastal Marine Waters provinces- the Acadian Province (northern Cape Cod) and the Virginian Province (southern Cape Cod). EPA has since published their recommended nutrient criteria documents for both rivers and streams and lakes and reservoirs for each of these ecoregions. They include recommended criteria for total phosphorus, total nitrogen, chlorophyll a, and turbidity or Secchi disk depth intended to address the adverse effects of excess nutrient inputs (EPA 2000c, 2000d, 2001a, and 2001b). EPA has not yet published recommended nutrient criteria documents for either the Acadian or Virginian provinces.

Massachusetts evaluated EPA's approach along with other published literature and is using these to guide the development of its Nutrient Strategy. The ultimate goal of the state's effort is to quantitatively translate its narrative nutrient criterion with both biological response thresholds and recommended nutrient concentrations that will support CWA goals (MassDEP unpublished c) and provide a clean and transparent process for protecting high quality waters, identifying impaired waters, and establishing associated restoration targets for degraded waters.

Screening guidelines for making nutrient-related impairment decisions (rivers, lakes, estuaries)

Rivers: MassDEP analysts do not assess the *Aquatic Life Use* as support based solely on the absence of nutrient enrichment indicators [i.e., no/limited observable nuisance growths of algae in forms such as filamentous coverage, planktonic blooms, or mats, or macrophytes (particularly non-rooted forms) during the summer index period (see primary producer data indicator summary)]. However when excessive growths are observed during more than one site visit during the summer index period the analysts also considers changes in physico-chemical data, such as: dissolved oxygen (concentration and supersaturation), pH, and chlorophyll *a*. If a *combination* of these indicator data strongly suggests high productivity/nutrient enrichment the *Aquatic Life Use* is assessed as impaired. Total phosphorus is included as a cause of impairment if the concentrations exceed EPA's "Gold Book" concentration. For river AUs with impoundments, a conservative evaluation of nutrient related response indicators following the guidance described for lakes may be conducted.

Lakes: Unlike the rivers, the *Aquatic Life Use* for lakes is assessed primarily with the primary producer biological data. The use is assessed as support for lakes when the nutrient enrichment indicator thresholds based on survey data are not exceeded. The *Aquatic Life Use* for lakes is assessed as impaired when there is more than one nutrient enrichment indicator present more than once during the survey season (i.e., the occurrence of planktonic blooms particularly blue-greens, extensive cover of non-rooted aquatic macrophytes -- particularly duckweed or water meal covering >25% of the surface, decreased Secchi disk transparency <1.2 m, oxygen supersaturation $\geq$125%, elevated pH values >8.3 SU, and elevated chlorophyll *a* concentrations >16 µg/L). Total phosphorus is included as a cause of impairment if the concentrations exceed EPA's "Gold Book" concentration.

Estuaries: MassDEP analysts currently utilize areal coverage of seagrasses or other submerged aquatic vegetation and, when available, the MEP habitat health indicator analysis. Assessment decisions are based on whether or not the eelgrass beds within the AU area are stable or are being lost. For embayments in Southeastern Massachusetts the MEP has also generated a significant amount of enrichment indicator data based on a weight-of-evidence approach that includes several response variables (e.g., eelgrass, infauna, macroalgae, chlorophyll *a*, DO, Secchi disk, TN concentrations). Since this project is intended to develop site-specific nutrient (nitrogen) thresholds for these systems, their overall analysis of habitat health are utilized to make *Aquatic Life Use* attainment decisions. The *Aquatic Life Use* of an estuarine AU is assessed as support if eelgrass bed habitat is found to be increasing or fairly stable or the MEP analysis provided in a site-specific technical report indicates excellent to good/fair health. Conversely, the *Aquatic Life Use* is assessed as impaired if there is a substantial decline (>10%) of eelgrass bed habitat or the MEP analysis provided in a site-specific technical report indicates moderate to severe impairment. Total nitrogen is listed as a cause of impairment in MEP project sites evaluated as moderately to severely impaired.

Use is Supported			Use is Impaired		
Rivers	***Lakes***	***Estuaries***	***Rivers***	***Lakes***	***Estuaries***
Primary Producer Biological Screening Guidelines					
Wadeable rivers: benthic chlorophyll *a* samples ≤200 mg/m^2*, filamentous algal cover ≤40%*, occasional non-harmful ephemeral algal blooms* Deep rivers: phytoplankton Chlorophyll a <16 µg/L*, occasional non-harmful ephemeral algal blooms*	phytoplankton Chlorophyll *a* ≤16 µg/L*, ≤25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps*, occasional non-harmful ephemeral algal blooms*	Eelgrass bed habitat in AU area is increasing or fairly stable (i.e., no or minimal loss), Chlorophyll *a* ≤5 µg/L*, little to no macroalgae accumulations*	Wadeable rivers: benthic chlorophyll *a* samples >200 mg/m^2*, filamentous algal cover >40%*, recurring and/or prolonged algal and/or C-HAB blooms* Deep rivers: phytoplankton Chlorophyll a >16 ug/L*, recurring and/or prolonged algal and/or C-HAB blooms*	phytoplankton Chlorophyll *a* >16 µg/L*, >25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps*, recurring and/or prolonged algal and/or C-HAB blooms*. **These indicators may also be applied to impounded reaches of River AUs**	Substantial decline in AU (= or exceed 10% of eelgrass bed area), Chlorophyll *a* >10 µg/L*, some macroalgae accumulations*
Physico-chemical Screening Guidelines					
Small diel changes in oxygen/saturation/pH (Δ <3 mg/l, < 125% saturation, <8.3 SU, respectively), seasonal summer average (n≥3) total phosphorus concentrations below EPA Gold Book concentrations. (≤0.1 mg/l flowing waters, ≤0.05 mg/l for rivers entering a lake/reservoir)	Secchi disk transparency ≥1.2 m, seasonal average Phosphorus (Total) below EPA Gold Book concentrations ≤0.025 mg/l	MEP analysis provided in a site-specific technical report indicates support (overall health evaluated between excellent to good/fair health) seasonal average mid-ebb (outgoing) tide total nitrogen concentration generally ≤0.4 mg/l*	Large diel changes in oxygen/saturation/pH (Δ ≥3 mg/l, ≥ 125% saturation,≥8.3 SU, respectively), elevated seasonal summer average (n≥3) Phosphorus (Total) above EPA Gold Book concentrations >0.1 mg/l flowing waters, >0.05 mg/l for rivers entering a lake/reservoir	Secchi disk transparency <1.2 m, in combination with secondary indicators high oxygen super-saturation, elevated pH, elevated seasonal average (n≥3) Phosphorus (Total) above EPA Gold Book concentrations >0.025 mg/l. **These indicators may also be applied to impounded reaches of River AUs.**	MEP analysis provided in a site-specific technical report indicates moderately to severely degraded health due to nitrogen enrichment, seasonal average mid-ebb tide total nitrogen concentration generally >0.5 mg/l*

* Denotes that an *Aquatic Life Use* assessment decision not made based on the Primary Producer Biological Screening Guideline indicator thresholds alone. If exceedances(s) are found, the Physico-chemical Screening Guidelines are also evaluated in order to make an assessment/listing decision. Site-specific MEP analyses may supersede the screening guidelines above.

Toxic pollutants

Rivers, Lakes, and Estuaries

Pollutants, such as metals, ammonia, chlorine, polycyclic aromatic hydrocarbons, and chlorinated organics, are considered toxic to humans, wildlife, and aquatic life when concentrations exceed criteria in the Massachusetts SWQS. The SWQS require that EPA's 2002 National Recommended Water Quality Criteria (NRWQC, EPA-822-R-02-047 or referred to here as EPA's 2002 Criteria) be applied for those pollutants that do not have listed criteria within the SWQS (see excerpt in text box below) (MassDEP 2013). However, the statement that "all surface water shall be free from pollutants...that are toxic to…aquatic life or wildlife" allows flexibility in applying EPA criteria recommendations issued after 2002 when evaluating any toxic pollutant. Therefore, to evaluate the potential for adverse effects on aquatic life, the water quality data for toxic pollutants are compared to their respective aquatic life water quality criteria as of August 2014 as described below (EPA 2014 available at https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table). In general, the EPA recommends both acute (typically expressed as one-hour averages) and chronic (typically expressed as four-day averages) criteria to protect against short- and long-term effects. For most toxicants the EPA also recommends that the criteria should not be exceeded more than once every three years on the average.

> *"All surface waters shall be free from pollutants in concentrations or combinations that are toxic to humans, aquatic life or wildlife. For pollutants not otherwise listed in 314 CMR 4.00, the National Recommended Water Quality Criteria: 2002, EPA 822-R-02-047, November 2002 published by the EPA pursuant to Section 304(a) of the Federal Water Pollution Control Act, are the allowable receiving water concentrations for the affected waters, unless the Department either establishes a site specific criterion or determines that naturally occurring background concentrations are higher. The Department shall use the water quality criteria for the protection of aquatic life expressed in terms of the dissolved fraction of metals when the EPA's 304(a) recommended criteria provide for use of the dissolved fraction. The EPA recommended criteria based on total recoverable metals shall be converted to dissolved metal using EPA's published conversion factors "*(see 314 CMR 4.05(5)(e) , MassDEP 2013 for more detail regarding permit limits, conversion factors, site specific criteria).

Toxic pollutant data are evaluated against their respective criterion maximum concentration (CMC or acute criterion) and criterion continuous concentration (CCC or chronic criterion). MassDEP analysts develop the ratios of the toxic pollutant concentrations measured in the water column against their respective acute and chronic criteria values (referred to as a "Toxic Unit" or TU calculation) for samples collected at each monitoring station. When the TU is greater than 1.0 the toxicant concentration exceeds its criterion. Exceedance can be defined as a result (i.e., a concentration; an average concentration, or other appropriate statistically derived concentration as applicable) that does not meet the criterion as specified in the SWQS (MassDEP 2013). The TU calculation provides the relative magnitude of the exceedance which, together with its frequency and duration, are important factors in evaluating toxicants.

Water quality samples for toxicants may be collected using either grab or composite techniques (see inset). A single grab is considered to be representative of an acute exposure period (typically one-hour) and its pollutant concentrations are therefore compared directly against acute criteria. Composite sample pollutant concentrations can also be compared directly to acute criteria. A minimum of two exceedances (TU>1.0) of an acute criterion within a three-year time period must be found prior to making an impairment decision.

> ***Background/context: Water quality sampling field techniques (MassDEP 2009):*** *Discrete instantaneous grab samples are collected manually at a representative location in the waterbody (wade-in samples preferred for stream sampling or collected off of a bridge or boat in deeper rivers) or collected via a Kemmerer, Van Dorn or other sampling device. Composite samples may be obtained using flow-weighted, time-composited (e.g., 1-hour, 24-hour, four-day, etc.) or other approved/accepted collection techniques.*

Chronic toxicant criteria evaluations require additional considerations based on both sample type and the toxicant's CCC exposure period (e.g., a 4-day period for most metals, a 30-day period for ammonia, etc.). To evaluate against chronic criteria, samples (grab or composite) should be collected under relatively stable flow conditions (i.e., excluding samples collected during major storm events or flow conditions below 7Q10). Multiple grab and/or composite samples are needed to evaluate whether or not two or more chronic criterion exceedances have occurred within the three-year time period. Independent samples are defined as those separated in time by more than a toxicants' CCC exposure period and these include both grab or composite samples that do not represent a CCC exposure period. Additional guidance for chronic criteria evaluations can be found in Appendix G. Where toxicant concentrations are documented with TUs >1 but the data are insufficient to make an impairment decision, these sites will be targeted for additional data collection. Sampling scenarios for determining chronic criteria impairments for toxic pollutants can be found in Table 3.

Table 3 Toxic pollutant sample scenarios used to evaluate chronic criteria exceedances.

Chronic criteria exceedance evaluations within a three year period for determination of impairment	
Grab sample scenarios	a. Out of 3 independent* samples all 3 have TUs > 1
	b. Out of 4 or more independent* samples >50% have TUs >1
	c. 2 or more sets of averaged** samples have TUs >1
Composite sample scenarios	a. 2 or more composite*** samples have TUs >1
Combination of grab and composite sample scenarios	a. 1 composite*** sample has TU > 1 and 2 independent* samples have TUs > 1
	b. 1 composite*** sample has TU > 1 and $\geq$ 50% of 3 or more independent* samples have TUs >1
	c. 1 composite*** sample has TU > 1 and at least one set of averaged** samples has a TU > 1

* Independent samples are defined as those separated in time by more than a toxicants' CCC exposure period and these include both grab or composite samples that do not represent a CCC exposure period.

** Samples collected during two or more days within a four day CCC exposure period will be averaged to best represent the exposure period; sample size and type for toxicants with longer CCC exposure periods will be evaluated on a case-by-case basis.

*** Composite samples that best represent the toxicant's CCC exposure period are preferred.

Metals. Since 2007 WPP staff have utilized clean sampling techniques for gathering instream metals data. While this dataset is very limited (typically three samples collected per site), validated data collected using clean sampling techniques will be used in the *Aquatic Life Use* assessment decisions for the 2018 reporting cycle. In addition, these data will be used to evaluate whether or not historical impairment decisions, based on older metals data not collected using clean sample techniques, were appropriate.

Evaluation of WPP metals data, typically collected as grab samples, is conducted according to the TU method described above and further detailed in Appendix G. Other usable external data sources may also be evaluated. The metals data evaluated for the 2018 reporting cycle based on the dissolved fraction include cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), silver (Ag), zinc (Zn). Arsenic (As) and Selenium (Se) are evaluated using total recoverable concentration data. For metals with hardness-based criteria (Cd, Cr, Cu, Pb, Ni, Ag, Zn), the actual instream hardness (calculated from calcium and magnesium concentration data) is used. The criteria and hardness-dependent formulas can be found in Table E1 of Appendix E. It should be noted that for Cu, its hardness-based criteria are used unless the 10 other parameters required as in-puts for the biotic ligand model (BLM) (EPA 2007) are available. In addition, for specific waterbodies site specific copper criteria may apply (see details below in exceptions and in Table E2 of Appendix E).

Exceptions.

- Although EPA updated their recommended cadmium and selenium criteria in 2016, these updated criteria have not yet been fully evaluated by MassDEP staff and, therefore, were not utilized for the 2018 reporting cycle. Instead, data comparisons were based on the criteria in effect as of August 2014. The updated criteria will be considered for use in the 2020 cycle.
- No evaluations will be made for aluminum (Al) for several reasons. In 2017, EPA issued draft recommended freshwater aluminum criteria that use dissolved organic carbon (DOC), pH, and hardness as inputs to a multiple linear regression (MLR) model. The input parameters, DOC, pH, and hardness all affect aluminum toxicity. The draft document indicates that aluminum criteria calculated using the MLR model can increase significantly above the current acute (750 ug/L) and chronic (87 ug/L) criteria, depending on site chemistry. MassDEP, working with USGS, is currently evaluating the effect of DOC concentrations (6 and 10 mg/L), hardness (20 and 35 mg/L as $CaCO_3$), and pH (6 SU) on aluminum toxicity. Further evidence that the current aluminum criteria are likely not reflective of actual toxicity in Massachusetts waters is that largemouth bass, shown by EPA to be sensitive to aluminum at levels near or below the 87 ug/l chronic value are found in the state's waters where aluminum levels greatly exceed that value (see Appendix E in MassDEP 2016). MassDEP has also collected information demonstrating that natural background aluminum concentrations may exceed the chronic ambient water quality criterion (87 ug/L). Again, Massachusetts' SWQS state that EPA's 2002 Criteria shall be used "*unless the Department either establishes a site specific criterion or determines that naturally occurring background concentrations are higher.*" For these reasons regarding

both the applicability of the current aluminum criteria and the implications of the proposed criteria, no evaluations will be made for aluminum for this reporting cycle.

- Lastly, site-specific criteria for Cu adopted in the state's SWQS that are approved by EPA can be found in Appendix E, Table E2. For these waters only, the Cu data are compared to the dissolved site-specific Cu acute and chronic criteria of 25.7 and 18.1 µg/L, respectively. These site-specific copper criteria are higher than EPA's 2002 Criteria, and are only considered when the 2002 criteria have been exceeded.

Ammonia. According to the EPA (2013) the freshwater acute and chronic criteria for ammonia are dependent on pH and temperature. At lower temperatures (<15.7 ^{o}C) the recommended acute criterion is also dependent on the presence or absence of the Genus *Oncorhynchus* (rainbow trout). The acute criterion duration represents a one-hour average. The chronic criterion duration represents a 30-day rolling average with the additional restriction that the highest 4-day average within the 30 days be no greater than 2.5 times the chronic criterion magnitude. These values are not to be exceeded more than once in three years on average. Because the ammonia criterion is a function of pH and temperature the analyst *screens* for acute and chronic criteria exceedances using the highest pH and temperature measurements taken at each sampling location during the course of the surveys to determine the most conservative acute and chronic ammonia criteria. The concentration data are then compared to these conservative ammonia criteria values. Where screening exeedances are found, sample-specific acute and chronic criteria are calculated and the data are compared to these criteria. Alternatively analysts can omit the screening approach and can calculate sample-specific acute and chronic ammonia criteria and compare them directly to all the ammonia data. A minimum of two exceedances of acute ammonia criteria must be found prior to making an impairment decision. In the absence of sample-specific temperature and pH data, a sample-specific criterion cannot be calculated, therefore an impairment decision is not made.

> EPA (1999) *"regarding the dependence of the toxicity of ammonia to aquatic organisms on various physicochemical properties of the test water, especially temperature, pH, and ionic composition… in aqueous solution, ammonia primarily exists in two forms, un-ionized ammonia (NH3) and ammonium ion (NH4 +)…the individual fractions vary markedly with temperature and pH…ammonia speciation also depends on ionic strength, but in fresh water this effect is much smaller… These speciation relationships are important to ammonia toxicity because un-ionized ammonia is much more toxic than ammonium ion…it was observed that increased pH caused total ammonia to appear to be much more toxic… because it is a neutral molecule and thus is able to diffuse across the epithelial membranes of aquatic organisms much more readily than the charged ammonium ion…ammonia is unique among regulated pollutants because it is an endogenously produced toxicant that organisms have developed various strategies to excrete, which is in large part by passive diffusion of un-ionized ammonia from the gills…high external un-ionized ammonia concentrations reduce or reverse diffusive gradients and cause the buildup of ammonia in gill tissue and blood".*

It is notable that of the two principal variables that determine chronic ammonia toxicity, pH plays a larger role than does temperature (see ammonia as a toxicant in MassDEP 2016). Although the MassDEP water quality monitoring program staff often deploy thermistors to collect continuous temperature data at many sites, pH is usually measured during the water quality sampling survey when the nutrient (including ammonia) samples are being collected (typically~5 samples collected between April and October). Given the long CCC exposure period for ammonia (i.e., 30-day) the typical monthly grab sample data are insufficient to evaluate chronic ammonia criteria exceedances. If, however, sufficient datasets are available containing more than one grab sample or one or more representative composite samples within the thirty-day averaging period, comparisons against chronic criteria and impairment determinations may be made according to the guidance in Table 3 above.

Chloride

While chloride occurs naturally in aquatic environments, elevated levels of chloride often result from anthropogenic sources. Road deicing salts, urban and agricultural runoff, discharges from municipal wastewater and industrial plants, and drilling of oil and gas wells are the major anthropogenic sources of chloride (EPA 1988b). The EPA-recommended acute criterion for chloride is 860 mg/L (one-hour average) and the chronic criterion is 230 mg/L (four-day average). Neither value is to be exceeded more than once every three years.

For the 2018 reporting cycle MassDEP analysts developed and validated a linear regression model to estimate chloride concentrations from specific conductance (SC) measurements (see Appendix F). Model validation testing also proved it to be sufficiently accurate and robust to reliably predict chloride concentrations using SC as a surrogate in Massachusetts freshwaters according to the following equation:

$$Y = 0.2753X - 18.987 \quad (R^2 = 0.9445, P < 0.001),$$

where Y is chloride concentration and X is specific conductance at 25°C.

For the purpose of evaluating chloride toxicity data used to make assessment decisions data can be either discrete laboratory results for chloride and/or estimated discrete/continuous chloride values based on the above equation. Instantaneous exceedances of the acute and chronic chloride criteria are estimated to occur at SC readings greater than 3,193 and 904 µS/cm, respectively.

Chlorine Chlorine is primarily used as a biocide to disinfect municipal wastewater effluents, to control fouling organisms in cooling water systems, as a bleaching agent in textile mills and paper-pulping facilities, and in cyanide destruction in electroplating and other industrial operations. The freshwater ambient water quality criteria for this toxicant are expressed as total residual chlorine (TRC) which is the sum of the concentrations of free and combined residuals as measured by amperometric titration or an equivalent method. The 1986 EPA recommended acute criterion for TRC is 0.019 mg/l (one-hour average), and the chronic criterion for TRC is 0.011 mg/l (four-day average). Neither criterion is to be exceeded more than once every three years. The most recent minimum quantification level for TRC in NPDES permits and WET testing guidelines is 0.02 mg/l, and concentrations reported at or below this level are considered by EPA to be meeting the criteria.

Toxic pollutant assessment guidance summary:

Use is Supported	Use is Impaired
For any toxic pollutant there is no more than a single exceedance of the acute or chronic criterion (i.e., analyte-specific TU$\leq$1 using the applicable exposure period) within a 3-year period.	For any toxic pollutant there is more than one exceedance of the acute or chronic criterion (i.e., analyte-specific TU > 1 using the applicable exposure period) within a 3-year period.

Background/context:
Sediment and tissue chemistry
(CCME 1999a)

Highly persistent, bioaccumulative compounds, such as PCBs, dichlorodiphenyltrichloroethane (DDT), toxaphene, dioxin and furans, and mercury, are not often detectable in water because they readily partition into other environmental media, including sediment and biota (CCME 1999a).

Organochlorine compounds, which include insecticides and PCBs, had been in widespread use since World War II but have since been restricted or banned because of their toxic effects on wildlife and human health. According to Coles (1998) "They are resistant to biochemical degradation…which contributes to excessive buildup in aquatic environments…they are prone to atmospheric transport…have a high affinity for sediment organic matter…tend to partition strongly into the lipid component of aquatic organisms…they can be passed up the food chain to higher trophic feeders through bioaccumulation…the National Academy of Science/National Academy of Engineering's (NAS/NAE) recommended guidelines for the protection of fish-eating wildlife apply to whole fish tissue. These guidelines were based on experimental studies showing induction of eggshell thinning in birds by DDT and metabolites. More conservative guidelines for other organochlorines were set by analogy to DDT, based on their greater toxicity to wildlife."

Sediment quality data

Rivers, Lakes, and Estuaries

The Massachusetts SWQS do not currently contain numeric sediment quality criteria. To evaluate the potential for adverse biological effects, surficial sediment quality data for heavy metals, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs),and pesticides are compared to the Canadian Interim Sediment Quality Guidelines (ISQL), which represent the concentration below which adverse biological effects are expected to rarely occur and to the Probable Effect Levels (PEL), which represent the levels for which adverse biological effects are expected to frequently occur (CCME 2002).

For those analytes measured in surficial sediment samples where ISQL and PEL guidance are available a matrix of analytes and their respective guidance values is developed. Ratios of the sediment concentration for each analyte to its respective ISQL and PEL are then calculated. When the ratio of the contaminant to the guideline exceeds a value of 1.0 the concentration is considered to be of concern. To assess the overall quality of the sediment at a site all of the ratios that exceed a value of 1.0 are added together. This sum is noted as the total factor over the ISQL and/or PEL.

Sediment quality data alone are not typically used to assess the *Aquatic Life Use* as impaired. However, when there are exceedances of sediment screening values (ISQLs and/or PELs) along with other indicators of impairment (e.g., fish tissue contamination or impaired biological community) the analyst will use best professional judgment (BPJ) and likely add the sediment screening value exceedances as a cause of impairment for the *Aquatic Life Use*. It should be noted here that for areas in Massachusetts where the sediments are known to be severely contaminated and are undergoing remedial actions (e.g., Housatonic River or Inner New Bedford Harbor.) sediment contamination is identified as one source of the impairment.

Use is Supported	Use is Impaired
No/infrequent excursions of ISQL/PEL guidelines and no other indicators of impairment.	Frequent excursions over ISQL/PEL guidelines along with other evidence of impairment, waterbody known to have sediment contamination undergoing remedial actions.

Tissue residue data

Rivers, Lakes, and Estuaries

Body burdens of chemicals in aquatic organisms (i.e., fish, shellfish and other invertebrates, and plants) also provide a mechanism to evaluate risk to wildlife consumers of aquatic biota. According to Coles (1998) the National Academy of Science/National Academy of Engineering (NAS/NAE) guidelines based on whole fish for the protection of fish-eating wildlife are as follows:

Total PCBs: $\leq$ 500 µg/kg (ppb) wet weight

Total DDT, DDE, DDD: $\leq$ 1,000 µg/kg (ppb) wet weight

Chlordane and Heptachlor epoxide: $\leq$ 200µg/kg (ppb) wet weight (also applies to total residues of aldrin, benzene hexachloride (BHC), chlordane, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, and toxaphene either singly or in combination).

Residues of contaminants in whole body samples of fish are compared to the NAS/NAE recommended guidelines based on whole fish for the protection of fish-eating wildlife. If the concentration of contaminants is below the guideline(s) (e.g., [total PCB] $\leq$ 500 µg/kg (ppb) wet weight) then no impairment decision for the *Aquatic Life Use* is made. However, if whole body burden residue(s) exceed the recommended guideline(s), best professional judgment is used by the analyst to evaluate whether or not an impairment decision is warranted. While an impairment decision will not be made on one or two samples, an impairment decision will be made based on several samples exceeding NAS/NAE guidelines combined with any other data types that corroborate an impairment decision (see DELTS/abnormal fish histology in Fish Community Section).

Use is Supported	Use is Impaired
Residue of contaminants in whole body samples do not exceed NAS/NAE guidelines	Residue of contaminants in whole body samples frequently exceed NAS/NAE guidelines, DELTS with abnormal fish histology.

Background/context:
Body Burdens
(CCME 1999b, 1999c, 2000 and 2001)

DDT*, a chlorinated hydrocarbon insecticide, was used world-wide since the 1940s to control insects (CCME1999b). "DDT, as well as its breakdown products, is highly lipophilic and presents serious problems for wildlife that feed at high trophic levels in the food chain…for aquatic-based wildlife species, food resources provide the main route of exposure…exposure to DDT and its metabolites [DDD and DDE] is known to reduce longevity and alter cellular metabolism, neural activity and liver function…mutagenic and carcinogenic effects, as well as adverse effects on reproduction, growth, and immunocompetence."*

Toxaphene *"(chlorinated camphenes known as campheclor, chlorocamphene, or polychlorocamphene (PCC)) was developed in 1946 and used as a contact insecticide for crops, as an herbicide and to control ectoparasites on livestock… also applied to lakes and streams in Canada and the northern US to eliminate undesirable fish, lamprey, and invertebrate communities…exposure to toxaphene is known to induce adverse effects on cardiovascular, hepatic, renal, endocrine, immunological, and neurological systems, and to decrease longevity in birds and mammals…while contamination of surface waters may continue to occur as a result of erosion of toxaphene-contaminated soils, atmospheric deposition is a main source"* (CCME 1999c).

Dioxin and Furans *"(polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurnas (PCDFs) are planar tricyclic aromatic compounds…while they have never been intentionally produced they are byproducts formed as a result of anthropogenic activities including waste incineration, chemical manufacturing, petroleum refining, wood burning, metallurgical processes, fuel combustion (autos), residential oil combustion, and electric power generation…natural sources include forest fires and volcanic activity…the 2,3,7,8-substituted PCDD/Fs are thought to elicit most of their toxicity via the aryl hydrocarbon (Ah) receptor, a protein present in mammals, birds, and fish…by binding however linkages between enzyme induction and specific organ toxicity are unclear"* (CCME 2001). Mortality and a multitude of sublethal effects on organisms were described.

Methyl mercury*, "the most toxicologically relevant form, is a potent neurotoxicant for animals and humans…It is produced through the biological and chemical methylation of inorganic mercury…Methyl mercury is not very lipid soluble but it binds strongly with sulfhydryl groups in proteins and is therefore readily accumulated and retained in biological tissues".(CCME 2000).*

Aquatic Life Use Assessment Summary

Table 4 Aquatic Life Use assessment decision indicator summary by weight-of-evidence approach.

Indicator for *Aquatic Life Use* Assessment	Use is Supported	Use is Impaired
BIOLOGICAL MONITORING INFORMATION		
Benthic macroinvertebrate data (rivers)	Non-impaired/most slightly impaired (without caveat) RBP III analysis, reference sites	Moderately impaired/severely impaired RBP III analysis, slightly impaired with special condition with caveat (e.g., hyperdominance by pollution tolerant species), as noted by MassDEP biologists
Benthic macroinvertebrate data (estuaries)	Relatively high # species, high # individuals, good diversity and evenness, moderate to deep burrowing, tube dwelling organisms present, as reported from external data sources	Relatively low # species, low # individuals, poor diversity and evenness, presence of shallow dwelling opportunistic species or near absence of benthos, thin feeding zone, as reported from external data sources
Fish community data (rivers)	**Cold Water Fishery** Presence of cold water fishes, multiple age classes (indicative of reproducing populations) of any salmonid, presence of YOY salmonids. **Warm Water Fishery** In moderate to high gradient (riffle/run prevalent) streams the fish community should include fluvial specialist/dependents species or at least one fluvial species in moderate abundance. In low gradient (glide/pool prevalent) streams, at least one fluvial species, or species which are intolerant or moderately tolerant to environmental perturbations should be present. In either high or low gradient habitat: fish community $\geq$ 50% similarity with TFC	**Cold Water Fishery** Absence of cold water fishes, or dramatic population reductions relative to historical samples, DELTS with abnormal fish histology. **Warm Water Fishery** In moderate to high gradient (riffle/run prevalent) streams fluvial fish are absent. In low gradient (glide/pool prevalent) streams no fish found or the absence of fish which are intolerant or moderately tolerant to environmental perturbations. In either high or low gradient habitat presence of DELTS (>10% sample) due to pollutant(s), and/or fish community < 50% similarity with TFC.
Fish community data (lakes, estuaries)	None made	> 5% population losses estimated , DELTS with abnormal fish histology
Primary Producer Data* (rivers, lakes, estuaries) *Note: An *Aquatic Life Use* assessment decision generally not made based on these indicators alone, if exceedances(s) of any threshold indicators found, additional evaluation of other water quality monitoring data (see nutrients) is required to make an assessment decision. **Lake impairment indicator levels may also be applied to impounded reaches of river AUs.**	**Benthic Algae** Wadeable rivers: benthic chlorophyll *a* samples $\leq$200 mg/m^2, filamentous algal cover $\leq$40% **Chlorophyll a** Deep rivers: phytoplankton Chlorophyll *a* $\leq$16 µg/L, Lakes: phytoplankton Chlorophyll *a* $\leq$16 µg/L Estuaries:Chlorophyll *a* $\leq$5 µg/L **Aquatic Macrophytes** Lakes: $\leq$25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps Estuaries: little to no macroalgae accumulations **Algal Blooms** Rivers, lakes, estuaries: occasional non-harmful ephemeral algal blooms **Eelgrass bed mapping data** Estuaries: Eelgrass bed habitat in AU area is increasing or fairly stable (i.e., no or minimal loss) between 1994 – 1996 and 2010 – 2013 mapping efforts	**Benthic Algae** Wadeable rivers: benthic chlorophyll *a* samples >200 mg/m^2, filamentous algal cover >40% **Chlorophyll a** Deep rivers: phytoplankton Chlorophyll *a* >16 ug/L Lakes: phytoplankton Chlorophyll *a* >16 µg/L, Estuaries: Chlorophyll *a* >10 µg/L **Aquatic Macrophytes** Lakes: >25% of the total lake area covered by non-rooted macrophyte(s) and/or algal mats/films/clumps Estuaries: some macroalgae accumulations **Algal Blooms** Rivers , lakes, estuaries: recurring and/or prolonged algal and/or C-HAB blooms* **Eelgrass bed mapping data** Estuaries: Substantial decline in AU (= or exceed 10% of eelgrass bed area between 1994 – 1996 and 2010 – 2013 mapping efforts
Habitat and flow data (rivers, lakes, estuaries)	No direct evidence of severe physical habitat or stream flow regime alterations	Physical habitat structure impacted by anthropogenic stressors (e.g., lack of flow, lack of natural habitat structure such as concrete channel, underground conduit), a lack of or restricted fish passage where diadromous fish populations have been documented
Non-native aquatic species data (rivers, lakes)	Non-native aquatic species absent	Non-native aquatic species present

Table 4 (continued). *Aquatic Life Use* assessment decision indicator summary by weight-of-evidence approach.

Indicator for *Aquatic Life Use* Assessment	Use is Supported	Use is Impaired
TOXICOLOGICAL MONITORING INFORMATION		
Toxicity testing data (rivers, lakes, estuaries)	≥75% survival of test organisms to water column or sediment samples in either 48-hr (acute) or 7-day exposure (chronic) tests.	<75% survival of test organisms to water column or sediment samples in either 48-hr (acute) or 7-day exposure (chronic) tests occurs in >10% of test events or more than once when limited data are available.
PHYSICO-CHEMICAL WATER QUALITY INFORMATION		
Water quality data - DO (rivers)	Deployed (LC, SC) probe datasets: Calculated mean and mean minimum statistics meet EPA criterion (cold or warm water dependent) Single (S) measurement datasets: No more than one excursion from criteria (minimum three preferably five measurements representing critical --i.e., pre-dawn, conditions)	Deployed (LC, SC) probe datasets: Calculated mean and mean minimum statistics below EPA criterion (cold or warm water dependent) Single (S) measurement datasets: Frequent (>10%) and/or prolonged or more than one measurement below EPA 1 day minimum criterion
Water quality data - DO (lakes)	No/little depletion (the criterion is met in all depths over ≥90% of the lake surface area during summer season)	The criterion is not met at all depths for >10% of the lake surface area during periods of maximum oxygen depletion
Water quality data - DO (estuaries)	No/infrequent prolonged or severe (≤10%) excursions from criteria in surface or bottom waters	Frequent (>10%) and/or prolonged or severe excursions (>1.0 mg/l below standards) from criteria
Water quality data - pH (rivers)	No or slight excursions (<0.5 SU) from criteria (minimum five measurements)	Frequent (>10%) and/or prolonged or severe excursions (>0.5 SU) from criteria
Water quality data - pH (lakes)	No or slight excursions (<0.5 SU) from criteria (minimum one deep-hole profile during summer growing season)	Excursion from criteria (>0.5 SU) summer growing season
Water quality data - pH (estuaries)	No or slight excursions (<0.5 SU) from criteria (minimum five measurements)	Frequent (>10%) and/or prolonged or severe excursions (>0.5 SU) from criteria
Water quality data - temperature (rivers, lakes, estuaries) [Note here: Allowed (~10%) exceedance up to 11 times June-September (reflects the term "generally" in the SWQS).]	**Cold Water Fishery** Chronic evaluation large thermistor dataset: Designated Cold Water:7-DADM ≤20.0°C Tier 1 Existing Use Waters: 7-DADM ≤20.0°C Tier 2 Existing Use Waters: 7-DADA ≤21.0°C (Exceedances ≤11 times) Chronic evaluation 3-5 day sonde deployment: Designated Cold Waters: 3-5-DADM ≤20.0°C Tier 1 Existing Use Waters: 3-5-DADM ≤20.0°C Tier 2 Existing Use Waters: 3-5-DADA ≤21.0°C (No exceedances) Acute evaluation thermistor / sonde deployment: Acute (Maximum 24-hour average), Tier 1 fish: ≤ 23.5°C, Tier 2 fish: ≤ 24.1°C No exceedances of mean (acute criterion) Small dataset: no/infrequent/small excursions (1 to 2°C) above 20°C **Warm Water Fishery** Chronic evaluation large thermistor dataset: Designated Warm Waters and Unlisted Class B Waters not Tier 1 or Tier 2: 7-DADM ≤27.7°C (Exceedances ≤11 times) Chronic evaluation 3-5 day sonde deployment: 3-5-DADM ≤27.7°C (No exceedances) Acute evaluation thermistor /sonde deployment: Maximum 24-hour average ≤ 28.3°C No exceedances of mean (acute criterion) Small dataset: no/infrequent excursions above criteria (28.3°C)	**Cold Water Fishery** Chronic evaluation large thermistor dataset: Designated Cold Waters: 7-DADM >20.0°C Tier 1 Existing Use Waters: 7-DADM >20.0°C Tier 2 Existing Use Waters: 7-DADA >21.0°C (Exceedances > 11 times) Chronic evaluation 3-5 day sonde deployment: No impairment decision made but identify exceedance with an Alert Status and recommend followup sampling Acute evaluation thermistor / sonde deployment: Acute (Maximum 24-hour average) Designated Cold Waters: > 23.5°C, Tier 1 fish: > 23.5°C, Tier 2 fish: > 24.1°C Small dataset: criterion frequently exceeded (10%) or by >2°C (22°C) **Warm Water Fishery** Chronic evaluation large thermistor dataset: Designated Warm Waters and Unlisted Class B Waters not Tier 1 or Tier 2: 7-DADM >27.7°C (Exceedances > 11 times) Chronic evaluation 3-5 day sonde deployment: No impairment decision made but identify exceedance with an Alert Status and recommend followup sampling Acute evaluation thermistor/sonde deployment: Maximum 24-hour average > 28.3°C Small dataset: MA SWQS criterion frequently exceeded (>10% measurements) or by >2°C (30.3°C).

Table 4 (continued). *Aquatic Life Use* assessment decision indicator summary by weight-of-evidence approach.

Indicator for *Aquatic Life Use* Assessment	Use is Supported	Use is Impaired
	Estuary Chronic evaluation large thermistor dataset: 24-hour average ≤ 26.7°C (Exceedances ≤11 days) Acute evaluation of large thermistor /deployed sonde (3- 5 day) dataset: No more than one day with exceedance of 29.4°C Small dataset: No more than one day with exceedance of 29.4°C	**Estuary** Chronic evaluation large thermistor dataset: 24-hour average > 26.7°C (Exceedances > 11 times) Acute evaluation of large thermistor/deployed sonde (3- 5 day) dataset: More than one day above criteria 29.4°C Small dataset: More than one day above criteria 29.4°C Other: rise due to discharge exceeds ΔT standards
Physico-chemical nutrient screening guidelines (rivers)	Small diel changes in oxygen/saturation/pH (Δ <3 mg/l, < 125% saturation, <8.3 SU, respectively), seasonal summer average (n≥3) total phosphorus concentrations below EPA Gold Book concentrations. (≤0.1 mg/l flowing waters, ≤0.05 mg/l for rivers entering a lake/reservoir) with primary producer biological response indicators (as described above) generally minimal	Combination of primary producer biological screening guidelines present (more than one site visit) as mentioned above as well as some combination of physicochemical screening guidelines including: Large diel changes in oxygen/saturation/pH (Δ ≥3 mg/l, ≥ 125% saturation, ≥8.3 SU, respectively), elevated seasonal summer average (n≥3) Phosphorus (Total) above EPA Gold Book concentrations >0.1 mg/l flowing waters, >0.05 mg/l for rivers entering a lake/reservoir
Physico-chemical nutrient screening guidelines (lakes)	Secchi disk transparency ≥1.2 m, seasonal average Phosphorus (Total) below EPA Gold Book concentrations ≤0.025 mg/l with primary producer biological response indicators (as described above) generally minimal	Combination of primary producer biological screening guidelines present (more than one site visit) as mentioned above as well as some combination of physicochemical screening guidelines including: Secchi disk transparency <1.2 m, in combination with secondary indicators high oxygen super-saturation, elevated pH, elevated seasonal average (n≥3) Phosphorus (Total) above EPA Gold Book concentrations >0.025 mg/l. **These indicators may also be applied to impounded reaches of River AUs.**
Physico-chemical nutrient screening guidelines (estuaries)	MEP analysis provided in a site-specific technical report indicates support (overall health evaluated between excellent to good/fair health) seasonal average mid-ebb (outgoing) tide total nitrogen concentration generally ≤0.4 mg/l with primary producer biological response indicators (as described above) generally minimal	Combination of primary producer biological screening guidelines present (more than one site visit) as mentioned above as well as some combination of physicochemical screening guidelines including: MEP analysis provided in a site-specific technical report indicates moderately to severely degraded health due to nitrogen enrichment, seasonal average mid-ebb tide total nitrogen concentration generally >0.5 mg/l
Water quality data Toxic and other pollutants (rivers, lakes, estuaries)	For any toxic pollutant there is no more than a single exceedance of the acute or chronic criterion (i.e., analyte-specific TU≤1 using the applicable exposure period) within a 3-year period.	For any toxic pollutant there is more than one exceedance of the acute or chronic criterion (i.e., analyte- specific TU > 1 using the applicable exposure period) within a 3-year period.
SEDIMENT AND TISSUE RESIDUE INFORMATION		
Sediment quality data (rivers, lakes, estuaries)	No/infrequent excursions of ISQL/PEL guidelines and no other indicators of impairment.	Frequent excursions over ISQL/PEL guidelines along with other evidence of impairment, waterbodies known to have sediment contamination undergoing remedial actions.
Tissue residue data (rivers, lakes, estuaries)	Residue of contaminants in whole body samples do not exceed NAS/NAE guidelines	Residue of contaminants in whole body samples frequently exceed NAS/NAE guidelines, DELTS with abnormal fish histology.

Fish Consumption Use

The definition of "Secondary Contact Recreation" in the Massachusetts Surface Water Quality Standards (SWQS) includes the statement that waters supporting the *Secondary Contact Recreational Use* are suitable for "…*Any recreation or other water use in which contact with the water is either incidental or accidental. These include but are not limited to fishing, including human consumption of fish, boating and limited contact incident to shoreline activities*." (MassDEP 2013). For the purpose of assessment and 305(b)/303(d) IR reporting, however, the status of the *Fish Consumption Use* (human consumption of fish) is reported as its own use rather than part of the *Secondary Contact Recreational Use*. The SWQS also state that "*pollutants shall not result in unacceptable concentrations in edible portions of marketable fish or for the recreational use of fish, shellfish, other aquatic life or wildlife for human consumption*" (see 314 CMR4.05(5)(e)3b in MassDEP 2013).

Use Assessment Decision-Making Process:

MassDEP biologists have been conducting fish toxics monitoring, mostly in freshwaters, since 1983. As the years passed, it became increasingly clear that the major problems in Massachusetts (as in the other New England states) were related to the widespread atmospheric deposition of mercury and/or to the historic use and disposal of PCBs (MassDEP 2010c). Currently, freshwater fish tissue contaminant testing in Massachusetts is conducted by the MassDEP in cooperation with the MA Department of Public Health (MA DPH) and the Department of Fish and Game (MA DFG). The three agencies work together as the Interagency Committee on Freshwater Fish Toxics Monitoring and Assessment, through a Memorandum of Understanding (MOU) established in 1994, to facilitate the communication, coordination, and dissemination of information pertaining to contaminants in freshwater fish (MassDEP 2010c). The collaborative efforts of the MassDEP, the MA DPH, and the MA DFG ensure the state's ability to conduct limited testing and evaluation of contaminants in fish tissue for purposes of protecting public health and the environment. Each of the three agencies named in this MOU has responsibilities unique to their mission. While the MassDEP provides much of the field and analytical support (refer to background/context inset on next page for the MassDEP DWM-WPP Fish Toxics Monitoring Program), all data are submitted to the MA DPH and the MassDEP Office of Research and Standards (ORS) for risk assessment and issuance of advisories, if appropriate. Ultimately, the MA DPH is responsible for decisions regarding the need for and/or implementation of public health advisories.

MA DPH provides a guide to eating fish safely in Massachusetts (MA DPH 2017a):

Fish Consumption Advisory for Marine and Fresh Water Bodies (MA DPH 2017a)

Fish is good for you and your family. It may also protect you against heart disease. It is a good source of protein and it is low in fat. A varied diet, including safe fish, will lead to good nutrition and better health. If you may become pregnant or are pregnant or nursing, you and your children under 12 years old may safely eat 12 ounces (about 2 meals) per week of fish or shellfish not covered in this advisory. This recommendation includes canned tuna, the consumption of which should be limited to 12 ounces per week. Very small children, including toddlers, should eat less. Consumers may wish to choose to eat light tuna rather than white or chunk white tuna, the latter of which may have higher levels of mercury. Otherwise, it is important to follow the Safe Eating Guidelines included in this advisory.

Safe eating guidelines for pregnant women, women who may become pregnant, nursing mothers and children under 12 years old: **(contaminants of concern in parenthetical as noted by MA DPH and MassDEP analysts)**

Do Not Eat: *Freshwater fish caught in streams, rivers, lakes, and ponds in Massachusetts** **(Hg)**
Safe To Eat: *Fish that are stocked in streams, rivers, lakes, and ponds in Massachusetts*
Safe To Eat: *Cod, haddock, flounder and pollock in larger amounts*
Do Not Eat: *Lobster from New Bedford Harbor* **(PCB)**
Do Not Eat: *Bluefish caught off the Massachusetts coast* **(PCB)**
Do Not Eat: *Lobsters, flounder, soft-shell clams and bivalves from Boston Harbor* **(PCB and other contaminants)**. ***This Boston Harbor advisory is also recommended for people with weakened immune systems.*** **NOTE: For assessment purposes Boston Harbor is broadly defined to include all coastal waters that drain into it.**

Safe eating guidelines for everyone

Do Not Eat: *Fish, shellfish, or lobsters from Area I of New Bedford Harbor, Lobsters or bottom feeding fish from Area II of New Bedford Harbor, Lobsters from Area III of New Bedford Harbor* **(PCB)**
Do Not Eat: *Lobster tomalley* **(PCB)**

In 2017, the federal government issued additional advice about safe fish consumption. Please visit: www.fda.gov/fishadvice and www.epa.gov/fishadvice

*More specific consumption advice is available for certain freshwater bodies that have been tested at: http://www.mass.gov/dph/fishadvisories or by calling the Massachusetts Department of Public Health, Bureau of Environmental Health at 617-624-5757.

In addition to these statewide fish advisories, the MA DPH periodically (every one to three years) updates their **Freshwater Fish Consumption Advisory List**. The most recent list was made available in August 2017 (MA DPH 2017b). This list provides specific consumption advice for individual water bodies that is to be considered in addition

Background/context
MassDEP DWM Fish Toxics Monitoring Program (MassDEP 2010c)

"Originally, monitoring was conducted either in the vicinity of known or suspected waste sites or in conjunction with much larger watershed surveys to attempt to assess the potential for bioaccumulative effects of past or present wastewater treatment plant or other discharges…the objective of DWM's sampling is primarily to screen edible fillets of fishes for a variety of contaminants (i.e. mercury, polychlorinated biphenyls (Aroclors), and organochlorine pesticides). Due to the highly variable concentrations of bioaccumulative contaminants in fish tissue and the wide range of environmental conditions which affect bioaccumulation (bioconcentration, bioaccumulation, and biomagnification), screening is conducted in an effort to sample as many of the Commonwealth's waters as possible during a given sampling season. Although screening may not accurately predict bioaccumulation patterns among a full range of year classes of any given fish species, sampling a three fish composite of average sized individuals answers the questions with regard to the presence/absence of any given analyte and its relative concentration. All screening analyses are performed at the Senator William X. Wall Experiment Station (WES). All data are sent to the MDPH and the MassDEP Office of Research and Standards (ORS) for assessment and advisory issuance if appropriate…"

"In order to assess the level of contamination present in fish of different trophic guilds and habitat types, screening involves the collection of three to five fish composites representing fishes of three trophic groups (i.e. predators, water column feeders, bottom feeders). Fish species targeted include at a minimum; largemouth bass, Micropterus salmoides, and/or chain pickerel, Esox niger, (predators); yellow perch, Perca flavescens, and/or white perch, Morone americana, (water column invertivores/omnivores); and bullhead, Ameiurus sp. and/or common carp, Cyprinus carpio, (bottom feeding omnivores). Average-sized fish (above legal length limit when applicable) are analyzed as composite samples. Additional species or substitute species are chosen on a site-by-site basis."

to the statewide advisories (MA DPH 2017a). This list identifies the waterbody, the town(s), the fish consumption advisory language, and the hazard (see https://www.mass.gov/lists/fish-consumption-advisories).

EPA considers a fish or shellfish consumption advisory to be existing and readily available data and information that demonstrates non-attainment of the "fishable" use when the advisory is based on fish and shellfish tissue data collected from the specific water body in question (Grubbs and Wayland 2000).

The assessment of the *Fish Consumption Use* relies on the most recent fish consumption advisory lists issued by the MA DPH Bureau of Environmental Health Assessment (MA DPH 2017a, MA DPH 2017b). For those waters covered by site-specific MA DPH advisories the *Fish Consumption Use* is assessed as impaired due to the hazard(s) identified (e.g., mercury, PCB, etc.), and the waters are listed in the integrated report, accordingly. Due to the statewide fish edibility advisories targeting sensitive populations (i.e., women who may become pregnant or are pregnant or nursing, and children under 12 years of age), the *Fish Consumption Use* of all waters in Massachusetts can be considered impaired. However, based on the EPA guidance (Grubbs and Wayland 2000), waters are not individually listed as impaired in the integrated report unless site-specific advisories based on actual fish tissue data apply to them. MA DPH has removed a few waterbodies from their advisory list where fish have tested high for mercury but fishing is not permitted for various reasons. MassDEP analysts will continue to assess these waters as impaired until such a time as the concentration of mercury in the fish tissue meets the human health criterion of 0.3 ppm or less. The guidance used to assess the *Fish Consumption Use* is summarized below.

***Fish Consumption Use* Assessment**

Use is Supported	Use is Impaired
Not applicable in Massachusetts, precluded by statewide advisories (Hg and/or PCBs)	Waterbody has site-specific MA DPH Fish Consumption Advisory with hazard (e.g., mercury, PCBs, pesticides, DDT, etc.)

When waters are assessed as impaired for the *Fish Consumption Use* due to elevated mercury and no source of mercury other than atmospheric deposition is identified, atmospheric deposition is listed as the source since it is anticipated that the waterbody will be restored in accordance with the Northeast Regional Mercury TMDL (Northeast States 2007). This TMDL is mandated by the CWA and identifies the pollutant load reductions necessary for regional waterbodies to meet and maintain compliance with state and federal water quality standards. The TMDL document was prepared by the New England Interstate Water Pollution Control Commission (NEIWPCC) for the six New England States and New York and was approved by the EPA in December 2007. The TMDL target for Massachusetts is 0.3 ppm or less of methyl mercury in fish tissue. The TMDL also called for a 75% reduction of in-region and out-of-region atmospheric sources by 2010 and a 90% or greater reduction in the future (NEIWPCC 2007). The TMDL will be reassessed in the future based on an evaluation of new, on-going monitoring and air deposition data. Final targets will be determined at a later time. Waters for which MA DPH mercury advisories have been issued since the approval date of the TMDL are considered on a case-by-case basis for coverage under that document.

Shellfish Harvesting Use

The definition of "Secondary Contact Recreation" in the Massachusetts SWQS includes the statement that "*Waters supporting the Secondary Contact Recreational Use are suitable for any recreation or other water use in which contact with the water is either incidental or accidental….Where designated, secondary contact recreation also includes shellfishing, including human consumption of shellfish*" (MassDEP 2013). For the purpose of assessment and 305(b)/303(d) IR reporting, however, the status of the *Shellfish Harvesting Use* (human consumption of shellfish) is reported as its own use rather than part of the *Secondary Contact Recreational Use*. In 314 CMR 4.05(5)(e)3b the SWQS state that "pollutants shall not result in unacceptable concentrations in edible portions of marketable fish or for the recreational use of fish, shellfish, other aquatic life or wildlife for human consumption" (MassDEP 2013).

Use Assessment Decision-Making Process:
Grubbs and Wayland (2000) provided states the following guidance for 305(b)/303(d) reporting: "*For purposes of determining whether a waterbody is impaired and should be included on a section 303(d) list, EPA considers a shellfish consumption advisory, a NSSP classification, and the supporting data, to be existing and readily available data and information that demonstrates non-attainment of a section 101(a) "fishable" use when: 1. the advisory is based on fish and shellfish tissue data. 2. a lower than "Approved" NSSP classification is based on water column and shellfish tissue data (and this is not a precautionary "Prohibited" classification or the state water quality standard does not identify lower than "Approved" as attainment of the standard) 3. the data are collected from the specific waterbody in question*".

The Massachusetts DFG, Division of Marine Fisheries (*MarineFisheries*), is responsible for implementing the Shellfish Sanitation and Management Program (see inset). Based on the results of their sanitary surveys, triennial evaluations and annual reviews the *MarineFisheries* biologists assign a sanitary classification to each shellfish growing area. DFG's designated shellfish growing area is an area of potential shellfish habitat. Growing areas are managed with respect to shellfish harvest for direct human consumption, including commercial shellfishing. The DFG classifications range from Approved (shellfish taking permitted) to Prohibited (no shellfish taking permitted) (see descriptions in inset on next page). Administrative or Management Closure's may be assigned by DFG if sufficient work has not been done to properly classify a growing area or if the associated risks to the fishery cannot be managed in a manner that ensures public health.

According to the SWQS (MassDEP 2013), the shellfish harvesting goals for SA and SB waters are as follows:

- Class SA waters, where designated, shall be suitable for shellfish harvesting without depuration (Approved and Conditionally Approved Shellfish Areas);
- Class SB waters, where designated, shall be suitable for shellfish harvesting with depuration (Restricted and Conditionally Restricted Shellfish Areas).

MarineFisheries Shellfish Sanitation and Management Overview (MA DFG undated and USFDA 2015)

The Shellfish Program has two primary missions, public health protection and both direct and indirect management of the Commonwealth's molluscan shellfish resources. Public health protection is afforded through the sanitary classification of overlying waters within the states territorial sea in accordance with the provisions of the National Shellfish Sanitation Program (NSSP). The NSSP is the federal/state cooperative program recognized by the U.S. Food and Drug Administration (FDA) and the Interstate Shellfish Sanitation Conference (ISSC) for the sanitary control of shellfish produced and sold for human consumption.

Public health protection is achieved as a result of sanitary surveys of shellfish growing areas to determine their suitability as shellfish sources for human consumption. The principal components of a sanitary survey include: 1) an evaluation of pollution sources that may affect an area, 2) evaluation of hydrographic and meteorological characteristics that may affect distribution of pollutants, and 3) an assessment of water quality.

Each growing area must have a complete sanitary survey every twelve years, a triennial evaluation every three years and an annual review in order to maintain a classification which allows shellfish harvesting. Minimum requirements for sanitary surveys, triennial evaluations, annual reviews and annual water quality monitoring are established by the ISSC and set forth in the NSSP. As of April 2017 there are 304 growing areas in Massachusetts' coastal waters (MassGIS 2017a). DMF also reports a total of ~2,700 sampling station locations associated with their designated growing areas (MassGIS 2000). Water and shellfish samples are tested for fecal coliform bacteria at two *MarineFisheries* laboratories located in Gloucester and New Bedford using a Most Probable Number (MPN) method (American Public Health Association) for classification purposes and a membrane filtration technique (usually M-tec) for pollution source identification.

MarineFisheries Shellfish Growing Area Classifications (MA DMF undated, USFDA 2015)

Approved - *"...open for harvest of shellfish for direct human consumption subject to local rules and regulations..." An approved area is open all the time and closes only due to hurricanes or other major coastwide events."*

Conditionally Approved - *"...subject to intermittent microbiological pollution..." During the time the area is open, it is "...for harvest of shellfish for direct human consumption subject to local rules and regulations…" A conditionally approved area is closed some of the time due to runoff from rainfall or seasonally poor water quality. When open, shellfish harvested are treated as from an approved area."*

Restricted – *"…area contains a "limited degree of pollution." It is open for "harvest of shellfish with depuration subject to local rules and state regulations" or for the relay of shellfish. A restricted area is used by DMF for the relay of shellfish to a less contaminated area."*

Conditionally Restricted - *"...subject to intermittent microbiological pollution..." During the time area is restricted, it is only open for "the harvest of shellfish with depuration subject to local rules and state regulations." A conditionally restricted area is closed some of the time due to runoff from rainfall or seasonally poor water quality. When open, only soft-shell clams may be harvested by specially licensed diggers (Master/Subordinate Diggers) and transported to the DMF Shellfish Purification Plant for depuration (purification)."*

Prohibited – "*Closed for harvest of shellfish*."

MassDEP analysts assess the *Shellfish Harvesting Use* using the most recent *MarineFisheries* classification of the shellfish growing areas available at the time that the assessments are made. While no updates are planned for this use for the 2018 reporting cycle, the Shellfish Growing Areas GIS datalayer dated 8 January 2014 was used for the 2016 cycle. The guidance used by MassDEP analysts to assess the *Shellfish Harvesting Use* is summarized below. Shellfish growing areas under administrative or management closures are not assessed (see note below).

Shellfish Harvesting Use Assessment

Use is Supported	Use is Impaired
SA Waters: Approved SB Waters: Approved,' Conditionally Approved, or Restricted	SA Waters: Conditionally Approved, Restricted, Conditionally Restricted SB Waters: Conditionally Restricted

An impairment decision for this use presumes that the cause is the result of elevated fecal coliform bacteria in the water column and, therefore, in shellfish. The source(s) of impairment may be identified based on *MarineFisheries* reports and information, TMDL reports, and/or BPJ of MassDEP analysts using orthophotos, land-use, and urbanized area MassGIS datalayers.

Note: Information pertaining to whether or not a shellfish growing area was classified as prohibited based on water quality data or as a precautionary measure (e.g., proximity of wastewater treatment discharge, marina) is not readily available to the MassDEP analysts. For previous assessment cycles, impairment decisions were made based on the prohibited classification alone when, in fact, no impairment decision should have been made for precautionary prohibitions. Therefore, for the 2016 assessment cycle the "Prohibited" classification areas will not be used to make an impairment decision since there is insufficient information available to determine whether or not a particular closure is due to poor water quality conditions.

Aesthetics Use

The narrative aesthetics criterion in the Massachusetts SWQS states that surface waters should be "*free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life*" (MassDEP 2013). Waters supporting the *Aesthetics Use* are pleasing to the senses for both active and passive activities: to look upon, to walk or rest beside, to contemplate, to recreate on, and should enhance the visual scene wherever it appears (Federal Water Pollution Control Administration 1968).

Use Assessment Decision Making Process:
Aesthetic observations
Rivers, Lakes, and Estuaries MassDEP field staff note aesthetically objectionable and abnormal conditions encountered at sampling stations. Based on these notes, an evaluation is made regarding the aesthetic quality of a waterbody. The field sheets provide documentation of conditions that exist at a site which may be indicative of nutrient enrichment (e.g., algal growth/blooms) or other aesthetically objectionable conditions (e.g., deposits, sheens, odors, unnatural color, turbidity (clarity), trash/debris, etc.). Field data are recorded at each site during each survey so analysts can later determine the general magnitude and frequency of any objectionable conditions over the course of the sampling period. Therefore, the *Aesthetics Use* is assumed to be supported unless field notes indicated otherwise. While the aesthetic assessments are somewhat subjective, issues of concern (e.g., the presence of trash/debris, one very dense algal bloom noted during the summer survey season) *may* be identified with an Alert Status to flag the need for more detailed information gathering, whereas gross-level aesthetic impairments are identified as not supporting. It should be noted that a waterbody will not be assessed as impaired for the occasional presence of litter or debris, but rather for persistent and/or other more serious indicators of aesthetic degradation. External sources of information related to aesthetic quality include volunteer stream team/shoreline surveys and lake reports. Additional guidelines for interpreting aesthetic observations are provided below.

Algal blooms
Rivers, Lakes, and Estuaries The visual presence of planktonic blooms/mats/scums are associated with aesthetically objectionable conditions. Depending on the severity of a bloom, water may appear only slightly colored or it may resemble pea soup or green paint. Rivers and streams with greater than 40% percent cover of benthic algae (filamentous green) may also exhibit aesthetic impairment (Barbour et al*.* 1999). MassDEP analysts currently utilize this general guideline of 40% cover of the substrata in a stream reach with visible filamentous forms of algae to evaluate whether or not the aesthetics of a stream AU is supported. When more than 40% of the stream bottom is covered by filamentous algae, the *Aesthetics Use* (and also the recreational uses of the waterbody) is generally considered to be impaired. The *Aesthetics Use* for a waterbody is assessed as impaired as a result of the harmful algal blooms when MA DPH C-HAB advisories exceed 20 days in a year (for more detail see *Primary Contact Recreational Use*). Marine and/or estuarine HABs involving microalgae are addressed on a case-by-case basis.

Macroalgae
Estuaries Certain marine macroalgae species including *Ulva*, *Enteromorpha* (greens), *Pilayella* (brown), and *Porphyra* (red) may form nuisance growths. The presence of objectionable growths of these and/or other species may result in an impairment of the *Aesthetics Use*.

Macrophyte cover
Lakes and the impounded reaches of river AUs Determining whether recreational uses are impaired due to overabundant (i.e., undesirable or nuisance) growths of aquatic macrophytes or algae requires some judgment decisions. In the case of macrophytes, a combination of factors may be considered, including: the area of the lake that is covered, the percentage of biovolume that is filled (if those data are available), the growth habit and overall species composition, and the dominance of the species within the plant community. Areal coverage is considered excessive if more than 25% of the lake is affected, particularly if the area encompasses bathing areas. Within the areas covered by plant populations/communities the biovolume would need to be dense (>50 – 75%) or very dense (>75 – 100%) to be considered impaired. There are certain species with growth habits that tend to grow from the bottom to the surface in close proximity and, thus, fill the biovolume and cause a safety hazard for extended or incidental contact with the water, as well as undesirable aesthetic conditions. Among the species that exhibit this growth habit are the non-native *Myriophyllum heterophyllum*, *M. spicatum*, and *Cabomba caroliniana,* but also native species, such as *Ceratophyllum demersum* or *Elodea* sp. Note that there are often cases where dense/very dense macrophyte populations/communities are found in lakes whose natural morphometry typically include extensive shallow areas that provide ideal habitat for the proliferation of aquatic

plants. Unless accompanied by notes of algae and/or turbidity, lakes with >25% dense/very dense macrophytes are assessed as impaired with Aquatic Plant (Macrophytes), a “non-pollutant” noted as the cause of impairment. There are also cases where algae or certain floating macrophyte species, like *Lemna* sp. or *Wollfia* sp., can “bloom” to cause unsafe and aesthetically undesirable conditions, almost always as a result of increased enrichment. In these cases, Nutrient/Eutrophication Biological Indicators, a “pollutant” will be noted as the cause of impairment and will require the development of a TMDL.

Aesthetics Use Assessment

Use is Supported	Use is Impaired
No aesthetically objectionable conditions; waterbodies are generally “*free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life”*	Aesthetically objectionable conditions frequently observed [e.g., blooms, scums, water odors, discoloration, taste, visual turbidity highly cloudy/murky, excess algal growth (>40% filamentous cover in rivers, nuisance growths >25% dense/very dense macrophytes* or blooms in lakes (or the impounded reaches of a river AU), nuisance growths of marine macroalgae)], Secchi disk transparency < 4 feet at least twice during survey season, MA DPH cyanobacteria advisories for >20 days in a year *Note: Cause identification can be either Aquatic Plant (Macrophyte) non-pollutant or Nutrient/Eutrophication Biological Indicators (pollutant)

Primary Contact Recreational Use

Waters supporting the *Primary Contact Recreational Use* are suitable for any recreation or other water uses in which there is prolonged and intimate contact with the water with a significant risk of ingestion of water during the primary contact recreation season. These include, but are not limited to: wading, swimming, diving, surfing and water skiing (MassDEP 2013). For purposes of 305(b) reporting the "bathing season" each year is defined as 1 April to 15 October.

Use Assessment Decision Making Process:
The assessment of the *Primary Contact Recreational Use* is based on sanitary/health (i.e., bacteria, harmful algal blooms), safety (e.g., Secchi depth) considerations, and/or aesthetics of the waters. MassDEP analysts assess this use as support when sanitary, safety, and aesthetic (i.e., desirability) conditions are suitable (e.g., low bacteria densities, low turbidity, infrequent beach closures/postings for bacteria or harmful algal blooms) and when aesthetics are good (e.g., narrative aesthetics criteria are met – see *Aesthetics Use* assessment guidance for details). While the current bacteria criteria for Massachusetts surface waters include both a geometric mean and a single sample maximum, the assessment decisions are based on whether or not the geometric mean of bacteria samples collected within the "bathing season" meet the criterion for primary contact recreation (i.e., *E. coli* and/or *Enterococci* bacterial indicators for Class A, B, SA, SB waters) (MassDEP 2013). Occasionally, site-specific health risk assessments performed by consultants, the MA DPH, and/or MassDEP's ORS are utilized to evaluate dangers posed to organisms and humans by contaminants in the aquatic environment. Routes of exposure can include ingestion, dermal contact, or inhalation. When risk is calculated to be greater than acceptable (e.g., total hazard index value exceeds a threshold of 1) some or all of the designated use(s) may be assessed as impaired for the contaminant of concern.

Bacteria Standards for Recreation (EPA 2003)

"Fecal bacteria have been used as an indicator of the possible presence of pathogens in surface waters and the risk of disease, based on epidemiological evidence of gastrointestinal disorders from ingestion of contaminated surface water or raw shellfish. Contact with contaminated water can lead to ear or skin infections, and inhalation of contaminated water can cause respiratory diseases. The pathogens responsible for these diseases can be bacteria, viruses, protozoans, fungi, or parasites that live in the gastrointestinal tract and are shed in the feces of warm-blooded animals… concentrations of fecal bacteria, including fecal coliforms enterococci, and Escherichia coli, are used as the primary indicators of fecal contamination. The latter two indicators are considered to have a higher degree of association with outbreaks of certain diseases than fecal coliforms and were recommended as the basis for bacterial water quality standards in the 1986 Ambient Water Quality Criteria for Bacteria document (both for fresh waters, enterococci for marine waters). The standards are defined as a concentration of the indicator above which the health risk from waterborne disease is unacceptably high".

An overview of the data types and the decision process used by MassDEP analysts to make assessment decisions for the *Primary Contact Recreational Use* is as follows.

Aesthetics
Rivers, Lakes, and Estuaries
It should be emphasized here that, because of the narrative aesthetics criteria, which are applicable to all surface waters (see *Aesthetics Use* assessment guidance for details) MassDEP analysts assess the *Primary Contact Recreational Use* as impaired when the *Aesthetics Use* of a waterbody is assessed as impaired.

Bacteria data
Rivers, Lakes, and Estuaries
For freshwater AUs (rivers and lakes) the primary source of bacteria data is the results of the MassDEP water quality surveys. The validated (quality-assured) bacteria data from these surveys are usually published in technical memoranda/reports. There are also many other external sources of bacterial quality monitoring data (e.g., environmental consultants, watershed and lake associations, and citizen monitoring programs, etc.). As resources allow, data from these external sources are reviewed for quality/reliability according to MassDEP DWM-WPP's external data validation procedures and, when approved, can also be utilized for assessment decisions.

E. coli bacteria	*Enterococci* bacteria
Geo mean ≤126 colonies/100 ml Class A, B	Geo mean ≤33 colonies/100 ml Class A, B Geo mean ≤35 colonies/100 ml Class SA, SB

[Note: Single sample maximum bacteria criteria are also in the SWQS, however, the geometric mean criterion is considered by MassDEP analysts to be a more robust and appropriate measure for making the *Primary Contact Recreational Use* assessment decision, while the single sample maximum value is more appropriate for determining the need to close beaches because of an immediate risk.]

The geometric mean of either *E. coli* and/or *Enterococci* data (minimum of five or more samples) during each "bathing season" (1 April through 15 October) is calculated for each sampling station/site by year. The geometric mean is then compared directly to the SWQS (provided above). Geometric mean calculation used the Method Detection Limit (MDL) and the Upper Quantification Limit (UQL) for "<MDL" and ">UQL" results, respectively; however, the geometric mean is flagged when an MDL or UQL is used. It should be noted here that if a UQL is used to calculate the geometric mean, the result can be utilized to make a decision of impairment but not a decision of support since the actual count is not known. [Note: An occasional exception will be made that allows for an assessment decision to be based on a geometric mean of only four samples.]

Presence of active CSO discharges

Rivers, Lakes, and Estuaries Other than in Boston Inner Harbor (the Class SB waters described as westerly inside a line from the southern tip of Governors Island to Fort Independence including the Charles, Mystic, Island End and Chelsea (Creek) Rivers, and Reserved, Fort Point and Little Mystic Channels), the Mystic River from the Amelia Earhart Dam to the confluence with the Chelsea River, and the Muddy River in the Charles River Basin, where limited CSO discharges are authorized, the presence of an active (i.e., open to discharge at some point) CSO discharge will be utilized by MassDEP analysts to make a presumptive impairment decision for the *Primary Contact Recreational Use* for *E. coli* (fresh waters) or *Enterococcus* (saline waters).

Secchi disk depth

Lakes The MassDEP analysts apply the 4-foot (1.2 m) Secchi disk transparency guideline as BPJ to indicate when conditions are unsafe for recreational use. When waters fail to meet this guideline it is felt that hazardous objects are not visible to someone diving (or falling) into the water and rescuers are unable to easily locate a possible drowning victim. Currently, three Secchi disk transparency readings are considered to be a minimum acceptable number of sampling events taken during the summer months when productivity is high. MassDEP analysts will not impair a waterbody unless there is more than one exceedance of the guideline. This approach applies to cases where low Secchi disk transparency results from algal or non-algal turbidity but does not include highly tannic, tea-stained waters with high color that may result in low Secchi readings. This is considered to be a naturally-occurring condition resulting from associated wetland influence.

According to the "Green Book" (Federal Water Pollution Control Administration 1968) *"For primary contact waters, clarity should be such that a Secchi disc is visible at a minimum depth of 4 feet. In "learn to swim" areas, the clarity should be such that a Secchi disc on the bottom is visible. In diving areas, the clarity shall equal the minimum required by safety standards, depending on the height of the diving platform or board"*.

Harmful algal blooms

Rivers, Lakes, and Estuaries

Background/Context: Harmful BlueGreen Blooms (MassDEP 2010a). *Blooms of cyanobacteria can be toxic to humans, wildlife, and to pets. Anabaena, Nostoc, Microcystis and Nodularia may contain the hepatotoxin microcystin, which can damage the liver. Others, like Aphanizomenon flos-aquae, Anabaena circinalis and Cylindrospermopsis raciborskii, may carry neurotoxins such as saxitoxin or anatoxin a. Freshwater cyanobacteria blooms often occur in lakes and ponds, but slow moving rivers like the Charles River can also be sites where blooms occur. In the summer of 2006, the lower basin of the Charles River experienced a massive bloom of Microcystis sp. and counts carried out on samples collected from sites in the lower basin indicated that the risk potential for long-term illness as a result of ingesting the water during contact recreation was moderate. Thus, in order to determine what level of risk existed, a method was developed to count the cyanobacteria present.*

Cyanobacteria counts are performed in order to determine if the amount present would be enough to indicate a moderate level of risk to the public using the waterbody. The World Health Organization (WHO 1999) has found that when cyanobacteria cell counts exceed 100,000 cells/ml the risk is then considered moderate. Massachusetts Dept. of Public Health (MA DPH undated) used the WHO cell count and developed a relationship between cyanobacteria cell counts and associated toxin levels based upon modified average weights and amount of ingestion and determined that a cell count of 70,000 cells/ml would correspond to a toxin level of approximately 14 ppb which is the current guideline for contact recreational waters. The MA DPH has developed guidelines regarding harmful algal blooms that occur in fresh waterbodies (https://www.mass.gov/files/documents/2016/07/qk/protocol-cyanobacteria.pdf).

"Harmful algal blooms, or HABs, occur when colonies of algae — simple plants that live in the sea and freshwater — grow out of control and produce toxic or harmful effects on people, fish, shellfish, marine mammals and birds. The human illnesses caused by HABs, though rare, can be debilitating or even fatal" (noaa.gov/what-is-harmful-algal-bloom). The MA DPH (undated) recommends an advisory or closure of a waterbody to avoid contact with the water when a visible scum or mat layer is present, cyanobacteria cell counts exceed 70,000 cells/ml, or when the microcystin level of lysed cells exceeds 14 parts per billion (ppb) in order to protect public health). MA DPH guidelines for evaluating potential health concerns regarding cyanobacteria in fresh waterbodies in Massachusetts can be found online at (https://www.mass.gov/guides/cyanobacterial-harmful-algal-blooms-

cyanohabs-water). MassDEP uses MA DPH cyanobacteria advisories when assessing primary, secondary, and aesthetics uses for HAB presence. In 2015/2016 MA DPH initiated work to manage data and information related to HAB advisories in a database which they made available for the 2016 assessment cycle. The issuance of a MA DPH cyanobacteria advisory does not, in and of itself, lead to the decision that a water body is impaired because an advisory is posted for a cyanobacteria bloom regardless of its duration. MassDEP does not consider occasional or ephemeral algae blooms to be indicative of overall use impairment and, therefore, the frequency and duration of cyanobacteria blooms are always considered before making a use-attainment determination. MassDEP considers HABs to be "frequent" or "prolonged" if they are subject to MA DPH advisories for >20 days in a calendar year. This threshold is based, in part, on the MA DPH *Guidelines For Cyanobacteria In Freshwater Recreational Water Bodies In Massachusetts* (MA DPH undated) which states that "advisories may be lifted after two successive and representative sampling rounds one week apart demonstrate cell counts or toxin levels below those at which an advisory would be posted". In light of MA DPH's policy, waters exhibiting one extended-length advisory or two or more advisories of any duration would be considered by MassDEP to be impaired for HABs. While MA DPH guidelines specifically pertain to freshwater HABs, marine and/or estuarine HABs involving microalgae are addressed on a case-by-case basis.

Beach postings

Estuaries and Freshwater DCR beaches The Beaches Bill monitoring program is a major source of bacteria data and beach posting/closing information. Pursuant to this legislation, the MA DPH requires communities to report monitoring data from their beaches (most beaches sampled weekly) and decisions to post/close their beaches over the course of the beach season (see inset for details). MA DPH publishes annual reports of these data (MA DPH 2014b) and, approximately every two years, provides MassDEP analysts with a copy of their database (MA DPH 2014c). It should be noted here that the MA DPH has expressed that more uncertainty exists with the reporting accuracy of *freshwater* beach posting information than with coastal beaches, and, with one notable exception, this has precluded MassDEP analysts from making assessment decisions based on the information from freshwater beaches. The exception is the posting information from inland beaches managed by the DCR. To date, rather than using the actual bacteria data, MassDEP analysts have utilized the beach closing/posting information as a surrogate indicator of water quality conditions when assessing the recreational use for waters governed by the Beaches Bill. This surrogate was chosen for use by MassDEP analysts until such a time as all data quality assurance considerations (e.g., QAPP, QA/QC, sample collection, analysis, data quality and validation procedures) for the bacteria data are in place. When considering beach closure information for making assessments, MassDEP contends that postings/advisories at public bathing beaches should be neither frequent nor prolonged during the swimming season (i.e., the number of days posted or closed should not, or rarely exceed 10% during the locally operated swimming season). MassDEP analysts calculate the number of days and the percentage of time during each beach season that each marine and DCR freshwater beach is posted/closed. While no updates are planned for this use for the 2018 reporting cycle, the analysis for the 2016 cycle included beach posting data from 2005 through

> ***Beaches Bill (MA DPH 2014b):*** *"There are over 1,100 public and semi-public bathing beaches in Massachusetts, both freshwater and marine…bathing beach water quality is regulated by the Massachusetts Department of Public Health (MDPH) under Massachusetts General Law and the Code of Massachusetts Regulations. These require that all public and semi-public bathing beaches (e.g., beaches at camps, campgrounds, hotels, condominiums, country clubs) in the state be monitored for bacterial, and on occasion other environmental contamination during the bathing beach season. The exact dates of a given bathing season vary from beach to beach, and are determined by the operators of each individual beach. Some beaches open as early as Memorial Day, but the majority begin operation when the school year ends in mid-June, and most close for the season during the week of Labor Day. Most freshwater samples are analyzed at private laboratories hired by beach operators or boards of health, while a small number are analyzed at municipal laboratories. The vast majority of beach water sampling in Massachusetts is conducted by local boards of health, the Barnstable County Department of Health and the Environment, and the Massachusetts Department of Conservation and Recreation (MDCR). Most marine beach samples are analyzed at laboratories under contract with MDPH's Bureau of Environmental Health (BEH). BEH utilizes federal Environmental Protection Agency (USEPA) funds to support these costs. Bathing water samples that are found to contain levels of bacterial contamination in excess of regulatory standards are termed exceedances. If water samples from a beach are found to be in exceedance of regulatory standards, the beach waters must be closed. When this happens signs must be posted at access points to the beach notifying the public that swimming is unsafe due to bacterial contamination. For marine beaches, the public is also notified via the Beach Water Quality Locator, on the MDPH/BEH website, which is operated in collaboration with local health officials and MDPH contract laboratories. Local health officials and MDPH/BEH contract laboratories collect and analyze the samples and perform a majority of the data entry onto the website. MDPH/BEH is notified of exceedances within 24 hours (105 CMR 445.040). Beaches are to remain closed until their bacteria counts decrease to levels below the applicable standard, at which point the postings can be removed and MDPH/BEH is notified of the beach reopening."*

2013. Postings due to the 2011 tropical cyclones "Bob" and "Irene" were excluded from the calculations because they were preemptive severe weather postings and not based on bacteria sampling. The pathogen indicator used for marine beach monitoring as well as the DCR fresh water beach monitoring (the rare exception being DCR beaches sampled by local municipalities) is *Enterococci* bacteria.

The *Primary Contact Recreational Use* is assessed as support if marine beaches and DCR freshwater beaches are rarely posted for more than 10% of the swimming season. If postings often exceed 10% of the swimming season(s) the *Primary Contact Recreational Use* will be assessed as impaired. More weight is given to the more recent years of posting data by the MassDEP analyst when an improvement or decline in posting at a beach occurred. Data for multiple beaches located along the shoreline of an AU that may lead to conflicting assessment decisions are handled on a case-by-case basis by the MassDEP analysts.

Approved shellfish growing area classification

Estuaries Although the bacteria indicator species are different (i.e., fecal coliform bacteria for shellfish and *Enteroccoci* for bathing beach areas) an "*approved*" shellfish growing area classification is indicative of excellent water quality ("Approved" areas are "*open for harvest of shellfish for direct human consumption subject to local rules and regulations. An approved area is open all the time and closes only due to hurricanes or other major coastwide events*" (see additional detail in *Shellfish Harvesting Use*). MassDEP analysts consider water quality to be excellent in terms of bacterial quality and, therefore, supportive of the *Primary Contact Recreational Use* when the *MarineFisheries* Shellfish Growing Area Classification is "Approved" (MA DFG 2014). However, when the shellfish classification is anything less than "approved" no use assessment determination for the *Primary Contact Recreational Use* can be made.

Primary Contact Recreational Use Assessment

Use is Supported		Use is Impaired	
Rivers, Lakes	***Estuaries***	***Rivers, Lakes***	***Estuaries***
No aesthetic use impairment, geometric mean bacteria meets criterion, Secchi disk transparency ≥4 feet, beach postings at DCR freshwater beaches generally ≤10% season	No aesthetic use impairment, geometric mean bacteria meets criterion, beach postings generally ≤10% season, *MarineFisheries* "Approved" Shellfish Growing Area Classification	Aesthetic use impairment, geometric mean bacteria exceeds criterion, risk calculation exceeds hazard threshold for contaminant of concern, MA DPH cyanobacteria advisories for >20 days in a year, Secchi disk transparency < 4 feet at least twice during survey season, beach postings at DCR beaches often >10% season presence of CSO outfall in waterbody without an approved variance	Aesthetic use impairment, geometric mean bacteria exceeds criterion, beach postings often >10% season, risk calculation exceeds hazard threshold for contaminant of concern, presence of CSO outfall in waterbody without an approved variance

Secondary Contact Recreational Use

Waters supporting the *Secondary Contact Recreational Use* are suitable for any recreation or other water use in which contact with the water is either incidental or accidental. These include, but are not limited to: fishing, including human consumption of fish, boating and limited contact incident to shoreline activities. Where designated, secondary contact recreation also includes shellfishing, including human consumption of shellfish. [Note: For the purpose of assessment and 305(b) reporting the status of the consumption of fish and shellfish are reported as the *Fish Consumption* and *Shellfish Harvesting* uses, respectively, and are not reported as part of the *Secondary Contact Recreational Use*.] For purposes of 305(b) reporting the *Secondary Contact Recreational Use* is assumed to occur year-round. Since water quality conditions during the *Primary Contact Recreational* season are often considered representative of worse-case (e.g., higher temperatures, increases in population density at bathing beaches) data collected during that season are considered appropriate for making *Secondary Contact Recreational Use* assessment decisions.

Use Assessment Decision Making Process:
Similar to the *Primary Contact Recreational Use* assessment guidance, the assessment of the *Secondary Contact Recreational Use* is based on sanitary (i.e., bacteria), safety (e.g., Secchi depth) considerations, and/or aesthetic/practical usability of the waters. While the current bacteria criteria for Massachusetts surface waters include both a geometric mean and a single sample maximum, the assessment decisions are based on whether or not the geometric mean of bacteria samples collected meet the following criteria for *Secondary Contact Recreation* (i.e., *E. coli* and/or *Enterococci* bacterial indicators for Class C, SC waters) (MassDEP 2013):

E. coli bacteria	*Enterococci* bacteria
Geo mean ≤630 colonies/100 ml applies to all inland freshwaters	Geo mean ≤175 colonies/100 ml applies to all coastal/marine waters

[Note: While single sample maximum bacteria criteria are also ascribed in the SWQS, they are utilized for making short-term closure/posting decisions. The geometric mean criterion is considered by MassDEP analysts to be a more robust and appropriate measure for making the *Secondary Contact Recreational Use* assessment decision.]

An overview of the data types and the decision process used by MassDEP analysts to make assessment decisions for the *Secondary Contact Recreational Use* is as follows:

Aesthetics
Rivers, Lakes, and Estuaries It should be emphasized here that because of the narrative aesthetics criterion, which is applicable to all surface waters (see *Aesthetics Use* assessment guidance for details), MassDEP analysts assess the *Secondary Contact Recreational Use* as impaired when the *Aesthetics Use* of a waterbody is assessed as impaired.

Bacteria data
Rivers, Lakes, and Estuaries For freshwater AUs (rivers and lakes) the primary source of bacteria data is the results of the DWM-WPP's water quality surveys. The validated (quality-assured) bacteria data from these surveys are usually published by the MassDEP in technical memoranda/reports. There are also many other external sources of bacterial quality monitoring data (e.g., environmental consultants, watershed and lake associations, and citizen monitoring programs, etc.). As resources allow, all external data from these and other sources are reviewed for quality/reliability according to the MassDEP's external data validation procedures and, when approved, can also be utilized for assessment decisions.

The geometric mean of either *E. coli* and/or *Enterococci* data (minimum of five sampling events) each year is calculated for each sampling station by year. The results are then compared directly to standards (provided above). [Note: Geometric mean calculations included the Method Detection Limit (MDL) and the Upper Quantification Limit (UQL) for "<MDL" and ">UQL" results, respectively; however, the geometric mean is flagged when an MDL or UQL is used. It should be noted here that if a UQL is used to calculate the geometric mean, the result can be utilized to make an impairment decision but not a decision of support since the actual count is not known.]

Presence of active CSO discharge
Rivers, Lakes, and Estuaries Other than in Boston Inner Harbor (the Class SB waters described as westerly inside a line from the southern tip of Governors Island to Fort Independence including the Charles, Mystic, Island End and Chelsea (Creek) Rivers, and Reserved, Fort Point and Little Mystic Channels), the Mystic River from the Amelia Earhart Dam to the confluence with the Chelsea River, and the Muddy River in the Charles River Basin,

where limited CSO discharges are authorized, the presence of an active (i.e., open to discharge at some point) CSO discharge will be utilized by MassDEP analysts to make a presumptive impairment decision for the *Secondary Contact Recreational Use.*

Harmful algal blooms
Rivers, Lakes, and Estuaries Waters exhibiting one extended-length advisory (i.e., >20 days) or two or more advisories of any duration would be considered by MassDEP to be impaired for HABs (for more detail see *Primary Contact Recreational Use*). While MA DPH guidelines specifically pertain to freshwater HABs, marine and/or estuarine HABs involving microalgae are addressed on a case-by-case basis.

Beach postings
Estuaries and Freshwater DCR beaches The *Secondary Contact Recreational Use* is assessed as support if marine beaches and DCR freshwater beaches are rarely, if ever, posted for more than 10% of the swimming season. If postings exceed 10% of the swimming season(s) the *Secondary Contact Recreational Use* is not assessed using this indicator data.

Approved shellfish growing area classification
Estuaries MassDEP analysts consider water quality to be excellent in terms of bacterial quality and, therefore, supportive of the *Secondary Contact Recreational Use* when the *MarineFisheries* Shellfish Growing Area Classification is “Approved” (MA DFG 2014). However, when the shellfish classification is anything less than “approved” no use assessment determination for the *Secondary Contact Recreational Use* can be made.

Secondary Contact Recreational Use Assessment

Use is Supported		Use is Impaired	
Rivers, Lakes	***Estuaries***	***Rivers, Lakes***	***Estuaries***
No aesthetic use impairment, geometric mean bacteria meets criterion, beach postings at DCR freshwater beaches generally ≤10% season	No aesthetic use impairment, geometric mean bacteria meets criterion, beach postings generally ≤10% season, *MarineFisheries* “Approved” Shellfish Growing Area Classification	Aesthetic use impairment, geometric mean bacteria exceeds criterion, presence of CSO outfall in waterbody without an approved variance, MA DPH cyanobacteria advisories for >20 days in a year	Aesthetic use impairment, geometric mean bacteria exceeds criterion , presence of CSO outfall in waterbody without an approved variance

Causes and Sources of Use Impairments

When a waterbody is assessed as **not supporting** for a particular designated use the 305(b) reporting process requires that the pollutant(s)/pollution causing the impairment and the source(s) of the pollutants/pollution be identified, if possible. EPA maintains lists of cause codes (CAUSE_LUT) and source codes (SOURCE_LUT) used within ATTAINS.

The typical cause(s) of impairment used by MassDEP analysts for each designated use are based on the indicator(s) used to make an impairment decision as described in the preceding use assessment guidance. As an example, Figure 6 illustrates the decision process for identifying whether nutrient enrichment is present in lakes and, if so, the causes of impairment.

Sources are the discharges or activities that contribute pollutants or stressors resulting in impairment of designated uses in a waterbody. Sources of impairments may include both point sources and nonpoint sources of pollution. Point sources discharge pollutants directly into surface waters from a conveyance and include, but are not limited to: industrial facilities, municipal sewage treatment facilities, CSO discharges, and storm sewers. Nonpoint sources deliver pollutants to surface waters from diffuse origins. Nonpoint sources include: urban runoff that is not captured in a storm sewer, agricultural runoff, leaking septic tanks, and landfills. The source(s) of impairment may be identified based on *MarineFisheries* reports (e.g., sanitary surveys) and information and/or BPJ of MassDEP analysts using MassGIS datalayers (e.g., orthophotos, land-use, urbanized areas) for example, but in general the actual sources of impairment are not confirmed until a TMDL or similar analysis is conducted on the waterbody.

A summary of the typical cause(s) associated with the impairment decisions (based on the indicator(s) as appropriate) and the typical source(s) of the impairment for each designated use used by MassDEP analysts can be found in Appendix F.

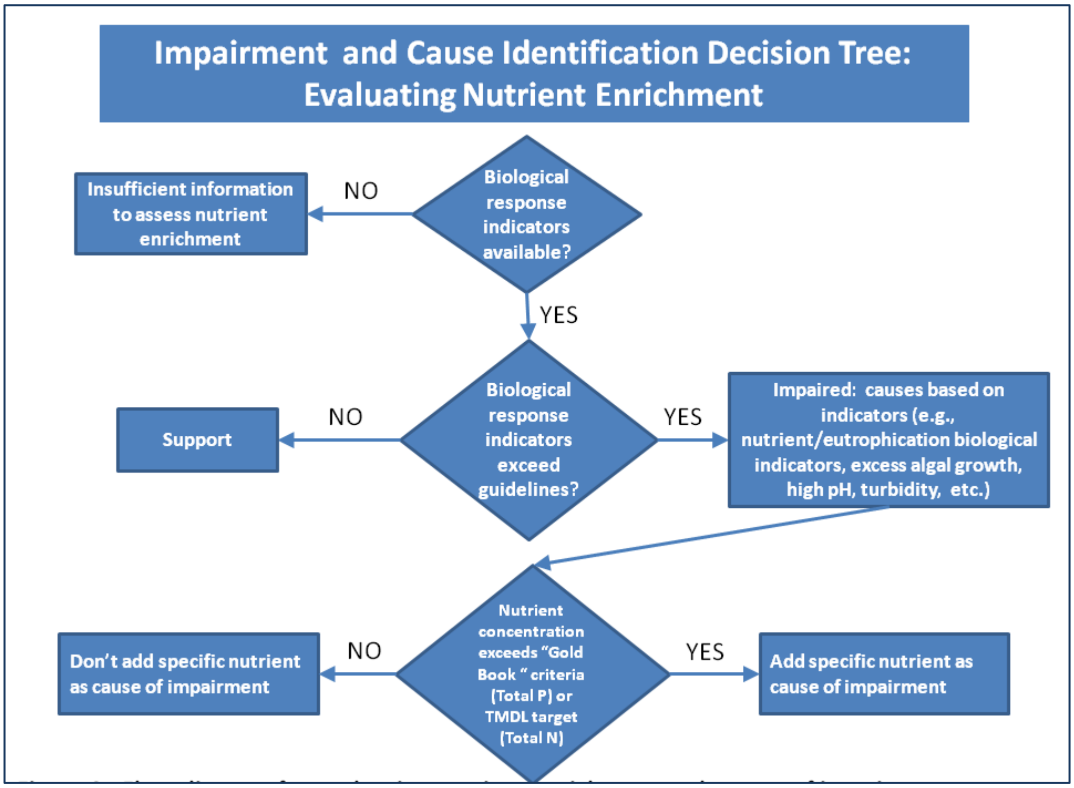


Figure 6. Impairment and cause identification decision tree for evaluating nutrient enrichment in lakes.

VI. CONSOLIDATED REPORTING

Since 2001, the EPA has recommended that states combine their 305(b) and 314 water quality assessment reporting elements with their 303(d) List of Impaired Waters into a consolidated IR report. The IR is submitted to the EPA every two years for review and, in the case of waters identified pursuant to Section 303(d), EPA approval.

The Section 305(b) reporting process entails determining the attainment status of each of the designated uses, where applicable, for rivers, lakes and coastal waters in the state, and identifying, wherever possible, causes and sources of any use impairment. Use assessment determinations are made for each waterbody AU for which adequate data and information are available. However, many waters are not assessed for one or more uses in any given assessment cycle, and many small and/or unnamed streams and ponds have never been monitored and/or assessed. Similarly, Section 314 of the CWA provides for cooperative agreements between federal, state and local entities to restore publicly-owned freshwater lakes and ponds and protect them against degradation. During the late 1970s through the early 1990s diagnostic and feasibility (D&F) studies were completed for many lakes and ponds throughout Massachusetts and were used in earlier 305(b) assessments and 303(d) listing decisions. Information from these studies continues to carry over into new assessment and listing cycles unless new monitoring information results in a change in their assessment and listing status. It should also be mentioned that information contained in the nonpoint source assessment report, prepared in 1989 in accordance with the requirements of Section 319, is also reflected in 305(b) and 303(d) reporting elements unless more recent information has resulted in a modification of the original assessment.

Under Section 303(d) of the Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters. These are waters that are too polluted or otherwise degraded to meet the state's water quality standards. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop TMDLs for these waters. The formulation of the 303(d) List includes a more rigorous public review and comment process than does reporting under Section 305(b), and the final version of the list must be formally approved by the EPA.

The new ATTAINS Database

The EPA-developed ATTAINS database is a relational database designed for tracking water quality assessment decision data, including use attainment status and causes and sources of impairment, for reporting required by sections 305(b), 314 and 303(d) of the CWA. ATTAINS also integrates the former National TMDL Tracking System (NTTS) database within its structure. ATTAINS is designed to make the assessment and listing process accurate, straightforward and user-friendly for states, tribes and other water quality reporting agencies. Massachusetts will utilize ATTAINS for the 2018 reporting cycle.

The Integrated List of Waters

ATTAINS is used to generate output files, which are then assembled into an IR in a single, multi-part list. Each AU is listed in one of five categories (see Table 5 for brief description of each List Category). ATTAINS and its precursor databases never contained an entry for every surface water in Massachusetts; rather, AUs represent only those waters for which assessments of one or more designated uses were actually completed at some time in the past. As assessments are carried out in new waters they are added to ATTAINS, resulting in greater representation of Massachusetts' surface waters in the IR with subsequent reporting cycles. The MassDEP acknowledges that with the multi-part listing format, all surface waters could be categorized whether or not they have ever been assessed. However, time and resources are currently not available to define all Massachusetts surface waters as AUs in ATTAINS. Therefore, it is acknowledged that many of the Massachusetts surface waters that have never been assessed are missing from the IR. By definition, they would all be listed as Category 3 (Not Assessed).

Table 5. Brief description of the five list categories of assessed waters used by MassDEP for the IR.

The Integrated List of Waters -- categories of assessed waters	
Category 1	Support and not threatened for all designated uses
Category 2	Support for some uses and not assessed for others
Category 3	Insufficient information to make assessments for any uses
Category 4	Impaired for one or more uses, but not requiring the calculation of a Total Maximum Daily Load (TMDL); (impairment due to "pollution" such as low flow, habitat alterations or non-native species infestations).
Category 5	Impaired for one or more uses and requiring a TMDL (impairment due to pollutant(s) such as nutrients, metals, pesticides, solids and pathogens). This constitutes **the 303(d) List.**

***Integrated List of Waters*.**

List Categories 1 - 3

IR categories 1-3 include those waters that are either unimpaired or not assessed with respect to their attainment of designated uses. Often insufficient data and information exist to assess all designated uses of any particular waterbody or AU. Furthermore, no Massachusetts waters are listed in Category 1 because a statewide Department of Public Health advisory pertaining to the consumption of fish precludes any waters from being in full support of the *Fish Consumption Use* as described previously in the use assessment decision process. Waters listed in Category 2 were found to support the uses for which they were assessed, but other uses were not assessed. Finally, Category 3 contains those waters for which insufficient or no information was available to assess any uses. Waters for which assessments were determined to be insufficient for 303(d) listing were also included in Category 3.

List Category 4

Waters exhibiting impairment for one or more uses are placed in either Category 4 (impaired but not requiring TMDLs) or Category 5 (impaired and requiring one or more TMDLs) according to the EPA guidance. Category 4 is further divided into three sub-categories – 4a, 4b and 4c – depending upon the reason that TMDLs are not needed. Category 4a includes waters for which the required TMDL(s) has already been completed and approved by the EPA. However, since the MassDEP chooses to list each AU in only one category, waters that have an approved TMDL for some pollutants but not others remain in Category 5 until TMDLs are approved for all of the pollutants. The CWA distinguishes between “pollutants” such as nutrients, metals, pesticides, solids and pathogens that all require TMDLs and “pollution” such as low flow, habitat alterations or non-native species infestations that do not require TMDLs. Non-pollutant stressors are marked with an asterisk in the IR report to distinguish them from pollutants requiring TMDLs. Waterbodies impaired solely by “pollution” are included in Category 4c. The restoration of these waters requires measures other than TMDL development and implementation. Waters that have one or more approved TMDLs, but also continue to be impaired by non-pollutants, are listed in Category 4a.

List Category 5 – The 303(d) List of Impaired Waters Requiring Development of TMDL

While the EPA guidance provides the overall framework for a five-part list of waters, the development, submittal, and review of Category 5 remains subject to the prevailing regulation governing the implementation of Section 303(d) of the CWA. This regulation requires states to identify and list those waterbodies that are not expected to meet surface water quality standards after the implementation of technology-based controls and, as such, require the development of TMDLs. Specific cause(s) of the impairment (if known) are included in the 303(d) List. On some occasions biological impairment is found but the cause of the impairment is unclear or unknown. In these cases the waterbody AU is placed, by default, into Category 5 until further evidence can better define the cause.

Reporting on impaired waters as required by Section 303(d) includes a more rigorous public review and comment process than does reporting under Section 305(b), and the final version of the list must be formally approved by the EPA. Once a waterbody is identified as impaired by a pollutant, the MassDEP is required, based on Section 303(d) of the CWA and the implementing regulations at 40 CFR 130.7, to develop a pollutant budget designed to restore the health of the impaired waterbody. The process of developing this pollutant budget, generally referred to as a Total Maximum Daily Load (TMDL), includes: identifying the cause (type of pollutant) and source (where the pollutant comes from), determining how much of the pollutant is from direct discharges (point sources) or indirect discharges (non-point sources), determining the maximum amount of the pollutant that can be discharged to a specific waterbody to meet water quality standards, and developing a plan to meet that goal. In short, a TMDL is a clean-up plan that is required under the CWA to restore water quality and enable waters to attain designated uses. The EPA tracks the states’ progress with completing TMDLs in its Assessment and Total Maximum Daily Load Tracking and Implementation System (ATTAINS), which can be accessed at http://ofmpub.epa.gov/waters10/attains_state.control?p_state=MA. This system assigns a unique identification number to each approved TMDL. This number is included for reference in categories 4a and 5 of the *Massachusetts* IR reports.

Waterbodies, or AUs thereof, can be removed from Category 5, or delisted, when a TMDL is approved by the EPA for that waterbody or AU. Waters with approved TMDLs move into Category 4a until it is determined that they are no longer impaired. In addition, there are some instances when a previously listed waterbody can be removed from the 303(d) List without calculating a TMDL; for example, when a new assessment reveals that the waterbody is now meeting all applicable water quality standards.

Spatial Documentation

Another component of consolidated reporting is the spatial georeferencing of the river, lake, and estuary AUs (as illustrated in Figure 7). MassDEP analysts maintain geospatial information for each waterbody AU stored in ATTAINS. Two georeferenced ArcMap shapefiles contain the geospatial documentation delineating these waterbody AUs. These two feature classes include an arc (primarily river) shapefile and a polygon (primarily lake and estuary areas) shapefile. The geo-referencing of individual AUs relied on linework derived from the MassGIS 1:25,000 hydrography based on USGS topographic maps. Additional on-screen editing was performed as needed using USGS topographic quadrangles and/or MassGIS color orthophotos as a base map for all river AUs. Occasionally National Oceanic and Atmospheric Administration nautical charts at several scales and the "Planimetry of Harbors for the 1984 305(b) Report" were utilized. Where definitions were still ambiguous after using these references, DWM-WPP staff members were consulted to define and geo-reference individual waterbody AUs. No two river AUs overlap nor do any two lake features nor do any two estuary features. In addition to the georeferenced AU locations, data from ATTAINS can be related to each shape and spatially displayed. This allows mapping to display the Massachusetts IR by category (Figure 7) as well as the ability to obtain more detailed information for each AU (Figure 8). A table generated from ATTAINS containing the support status for each individual use with associated cause(s) and source(s) of impairment, as well as approved TMDL information, can be linked and displayed through the waterbody AU shapefiles. An additional tool was also developed to access this information without the need for ArcMap. The link to this interactive map can be found here: https://www.mass.gov/lists/integrated-lists-of-waters-related-reports.

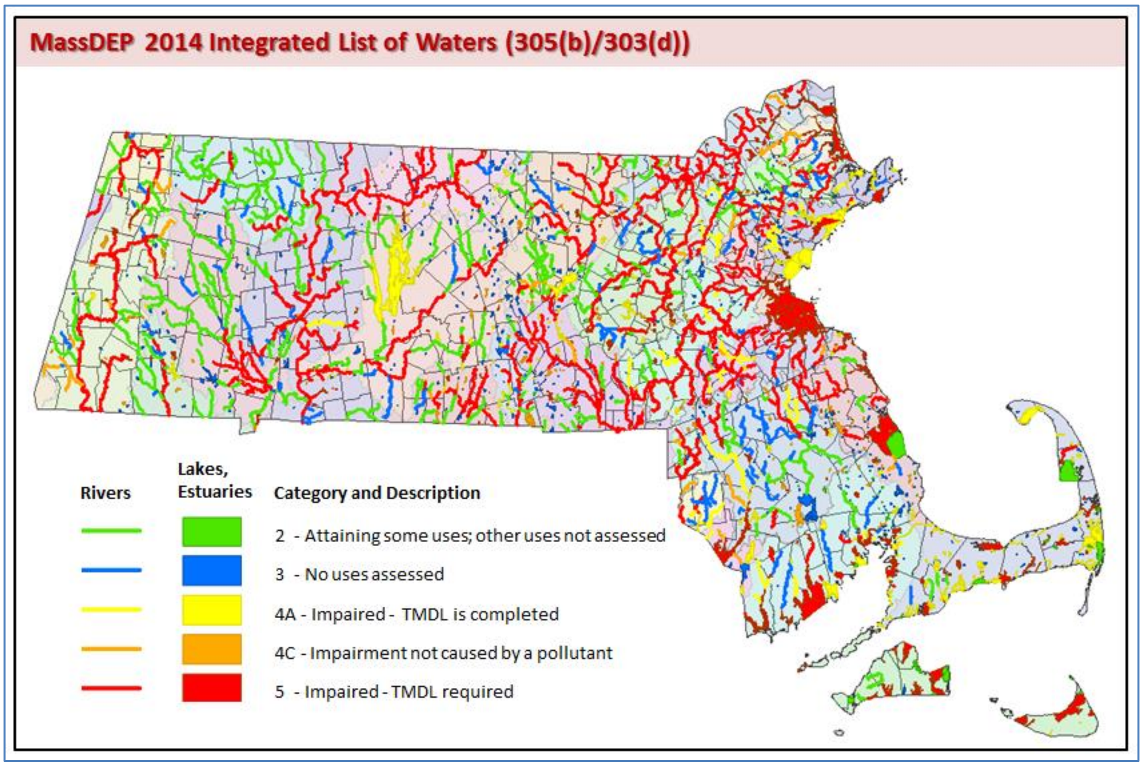


Figure 7. MassDEP geo-referenced waterbody assessment unit (AU) locations and 2014 listing category.

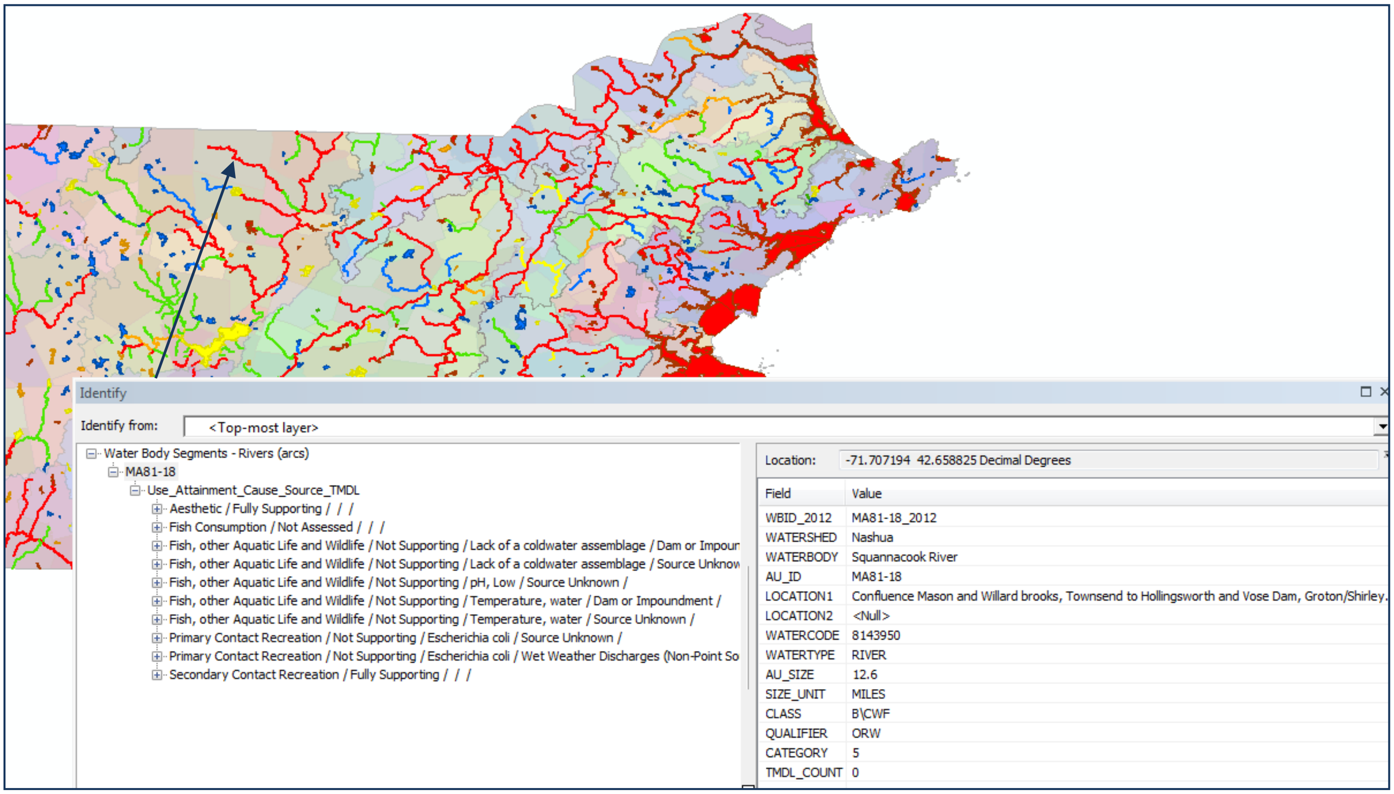


Figure 8. MassDEP Assessment Database (ATTAINS) data associated with geo-referenced waterbody assessment unit (AU) locations.

The Massachusetts 2014 Integrated List of Waters (305(b)/303(d)) data layers and all of the data elements (including metadata) are available at the Commonwealth of Massachusetts' Office of Geographic Information (MassGIS) website (MassGIS datalayer 2014 IR). The datalayers for the 2018 IR will be developed by MassDEP analysts once the 2018 303(d) list (Category 5 waters) is approved by EPA.

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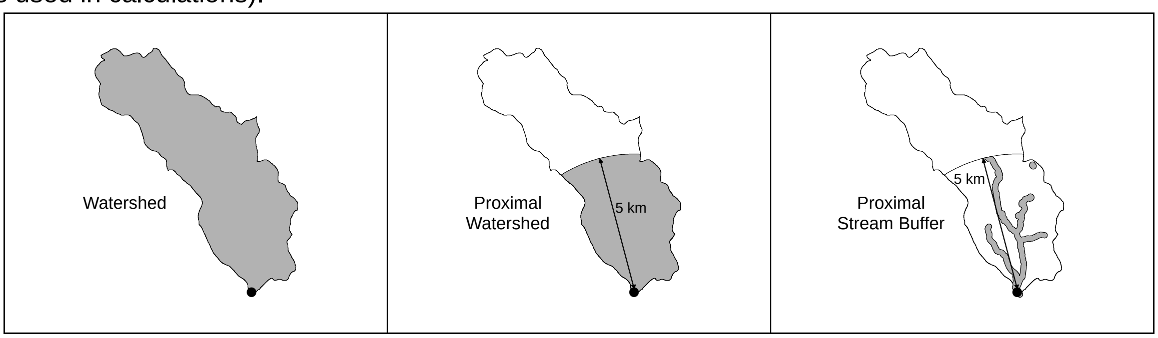
Appendix A Evaluation Methods for Natural Condition

Temperature

Violations of temperature criteria will NOT be considered natural under the following circumstances:

1. Determine which temperature criteria were violated, the warm water or cold water. If the warm water criteria were violated, the temperature violations will not be considered natural.
2. Determine the general nature of the temperature criteria violations. If the violation is the result of isolated spike(s), the temperature violations will not be considered natural.
3. Delineate a complete watershed, proximal (5 km) watershed, and proximal (5 km) 100 m stream buffer (Figure 1) on either side for the assessment unit (AU) and calculate the percent of natural land, and impervious cover within those delineations (Schiff and Benoit 2007). If the percentages fail to meet the criteria outlined in Table D1, the temperature violations will not be considered natural.
4. Determine the presence of dams along the AU and in its contributing watershed and their potential to be the source of the observed temperature criteria violations. If they cannot be reasonably eliminated as the source of the violations, the temperature violations will not be considered natural.
5. Determine the presence of point source discharges (wastewater treatment plants (WWTP), non-contact cooling water, stormwater, etc.) and/or water withdrawals along the AU and in its contributing watershed and their potential to be the source of the observed temperature criteria violations. If they cannot be reasonably eliminated as the source of the violations, the temperature violations will not be considered natural.
6. Determine the presence of any localized human disturbances within the riparian area of the AU from recorded fieldsheet observations and GIS. If the present localized human disturbances cannot be reasonably eliminated as the source of the violations, the temperature violations will not be considered natural.
7. Determine if there are any other potential sources of the temperature violations not considered above. If there are any other potential sources, the temperature violations will be not be considered natural.

Figure 1. Illustration of the different spatial scales used to evaluate the landscape criteria (grey shaded area clips used in calculations).



If not screened out in any of the above steps, the temperature violations will be considered natural.

Table D1. Landscape criteria used to evaluate thermal excursions

Land Cover	**Complete and Proximal Watersheds**	**Complete[2] or Proximal Stream Buffer**
Natural Land[1]	>80%	>90%[3]
Impervious Cover	<4%	<2%

[1]Includes forest, brushland/successional, wetland, and water.
[2]Watersheds <25 mi^2
[3]This is best professional judgment of DWM-WPP biologists

Dissolved Oxygen (DO)

Violations of the DO criteria may be due to natural conditions, especially in areas where wetlands contribute low DO water to the stream. A study relating natural wetlands and predawn dissolved oxygen in Massachusetts streams reported that wetland areas exceeding 4 percent of the subwatershed within a mile of the sample site was related to a marked drop to 60% dissolved oxygen saturation (Mattson et al., 2007). The study recommended a limit of 7 percent proximal wetland area as a threshold for natural conditions to meet the state's water quality standards. Furthermore the cause and effect is likely confounded by the co-correlation between impervious cover and stream slope (Waite et al., 2006) where the cause of the low dissolved oxygen may be due to the low gradient hydrologic setting.

Violations of DO criteria will NOT be considered natural under the following circumstances:

1. Determine the general nature of the DO criteria violations. If the violation is the result of isolated spike(s), the DO violations will not be considered natural.
2. Determine the diurnal shift in DO concentration. If the diurnal shift is ever greater than 3mg/l, the DO violations will not be considered natural.
3. Delineate a complete watershed, proximal (5 km) watershed, 100 m stream buffer on both sides including both the intermittent and perennial streams, and proximal (5 km) 100 m stream buffer (Figure 1) on both sides for the assessment unit (AU) and calculate the percent of natural land, and wetland within those delineations. If the percentages fail to meet the criteria outlined in Table D2, the DO violations will not be considered natural.
4. Determine the presence of dams within the AU and upstream of the AU and their potential to be the source of the observed DO criteria violations. If the present dams cannot be reasonably eliminated as the source of the violations, the DO violations will not be considered natural.
5. Determine the presence of point sources (wastewater treatment plants (WWTP), non-contact cooling water, stormwater, etc.) and water withdrawals to the AU and upstream of the AU and their potential to be the source of the observed DO criteria violations. If the present point sources cannot be reasonably eliminated as the source of the violations, the DO violations will not be considered natural.
6. Determine the presence of any localized human disturbances within the riparian area of the AU from fieldsheets and GIS. If the present localized human disturbances cannot be reasonably eliminated as the source of the violations, the DO violations will not be considered natural.
7. Determine if there are any other potential sources of the DO violations not considered above (e.g., spill). If there are any other potential sources, the DO violations will be not be considered natural.

If not screened out in any of the above steps the DO violations will be considered natural.

Table D2. Landscape criteria used to evaluate DO excursions.

Land Cover	Complete Watershed	Proximal Watershed	Complete[2] or Proximal Stream Buffer
Natural Land[1]	>80%	>80%	>90%[3]
Wetland	NA	>7%	NA

[1]Includes forest, brushland/successional, wetland, and water.
[2]Watersheds <25 mi^2
[3]This is best professional judgment of DWM-WPP biologists

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Appendix B Fish Species of Massachusetts and their associated classifications

Table B1. Fish Species of Massachusetts and their associated classifications -- habitat use, tolerances to environmental perturbations, and temperature.

Scientific Name	Common Name	Fish Code	Family	Habitat Use Classification[1]	Tolerance Classification[2]	Temperature Classification[3]
Lampetra appendix	American Brook Lamprey	BL	Petromyzontidae		I	C
Petromyzon marinus	Sea Lamprey	SL	Petromyzontidae		M	W
Amia calva	Bowfin	BF	Amiidae	MG	T	W
Anguilla rostrata	American eel	AE	Anguillidae	MG	T	W
Alosa aestivalis	Blueback herring	BBH	Clupeidae	FS	M	W
Alosa sapidissima	American shad	S	Clupeidae		M	W
Alosa pseudoharangus	Alewife	A	Clupeidae	MG	M	W
Notropis hudsonius	Spottail shiner	SS	Cyprinidae	MG	M	W
Rhinichthys atratulus	Blacknose dace	BND	Cyprinidae	FS	T	W
Notropis bifrenatus	Bridle shiner	BM	Cyprinidae	MG	I	W
Cyprinus carpio	Common carp	C	Cyprinidae	MG	T	W
Rhinicthys cataractae	Longnose dace	LND	Cyprinidae	FS	M	W
Pimephales notatus	Bluntnose Minnow	BNM	Cyprinidae	MG	T	W
Luxillus cornutus	Common shiner	CS	Cyprinidae	FD	M	W
Hybognathus regius	Eastern Silvery Minnow	ESM	Cyprinidae	MG	I	W
Exoglossum maxillingua	Cutlips Minnow	CLM	Cyprinidae	FS	I	W
Semotilus atromaculatus	Creek chub	CRC	Cyprinidae	FS	T	W
Pimephales promelas	Fathead Minnow	FM	Cyprinidae	MG	T	W
Semotilus corporalis	Fallfish	F	Cyprinidae	FS	M	W
Carassius auratus	Goldfish	G	Cyprinidae	MG	T	W
Notemigonus crysoleucas	Golden shiner	GS	Cyprinidae	MG	T	W
Couesius plumbeus	Lake chub	LC	Cyprinidae	MG	M	C
Catostomus catostomus	Longnose Sucker	LNS	Catostomidae	FD	I	C
Catostomus commersoni	White sucker	WS	Catostomidae	FD	T	W
Erimyzon oblongus	Creek chubsucker	CCS	Catostomidae	FS	I	W
Ameiurus nebulosus	Brown bullhead	BB	Ictaluridae	MG	T	W
Ameiurus natalis	Yellow bullhead	YB	Ictaluridae	MG	T	W
Ameiurus catus	White catfish	WC	Ictaluridae	MG	M	W
Ictalurus punctatus	Channel catfish	CC	Ictaluridae	MG	M	W
Noturus gyrinus	Tadpole Madtom	TMT	Ictaluridae	FS	M	W
Noturus insignis	Margined Madtom	MM	Ictaluridae		M	W
Esox lucius X Esox masquinongy	tiger muskellunge	TM	Esocidae	MG		W
Esox niger	Chain pickerel	CP	Esocidae	MG	M	W
Esox americanus americanus X Esox niger	Hybrid Redfin/Chain Pickerel	RPXCP	Esocidae	MG		W
Esox lucius	Northern pike	NP	Esocidae	MG	I	W
Esox americanus americanus	Redfin pickerel	RP	Esocidae	MG	M	W
Umbra limi	Central Mudminnow	CM	Umbridae		T	W

Scientific Name	Common Name	Fish Code	Family	Habitat Use Classification[1]	Tolerance Classification[2]	Temperature Classification[3]
Osmerus mordax	Rainbow smelt	RS	Osmeridae		I	C
Salmo trutta	Brown trout	BT	Salmonidae	FS	I	C
Salvelinus fontinalis X Salmo trutta	Tiger Trout	TT	Salmonidae	FS		C
Salvelinus fontinalis	Brook trout	EBT	Salmonidae	FS	I	C
Salvelinus namaycush	Lake trout	LT	Salmonidae	MG	I	C
Salmo salar	Atlantic salmon	AS	Salmonidae	FS	I	C
Oncorhynchus mykiss	Rainbow trout	RT	Salmonidae	FS	I	C
Salmo salar	Landlocked salmon	LLS	Salmonidae	FD	I	C
Fundulus heteroclitus	Mummichog	M	Fundulidae		T	W
Fundulus diaphanus	Banded killifish	K	Fundulidae	MG	T	W
Gambusia affinis holbrooki	Eastern Mosquitofish	EM	Poeciliidae	MG	T	W
Pungitius pungitius	Ninespine Stickleback	NSS	Gasterosteidae		M	W
Gasterosteus aculeatus	Threespine stickleback	TSS	Gasterosteidae		M	W
Apeltes quadracas	Fourspine stickleback	FSS	Gasterosteidae		M	W
Cottus cognatus	Slimy sculpin	SC	Cottidae	FS	I	C
Morone americana	White perch	WP	Moronidae	MG	M	W
Morone saxatilis	Striped bass	SB	Moronidae	FD	I	W
Lepomis cyanellus	Green sunfish	GSF	Centrarchidae	MG	T	W
Lepomis auritus	Redbreast sunfish	RBS	Centrarchidae	MG	M	W
Micropterus salmoides	Largemouth bass	LMB	Centrarchidae	MG	M	W
Lepomis macrochirus X Lepomis gibbosus	Hybrid Bluegill/Pumpkinseed	BXP	Centrarchidae	MG		W
Lepomis gibbosus	Pumpkinseed	P	Centrarchidae	MG	M	W
Pomoxis annularis	White crappie	WR	Centrarchidae	MG	T	W
Lepomis macrochirus	Bluegill	B	Centrarchidae	MG	T	W
Ambloplites rupestris	Rock bass	RB	Centrarchidae	MG	M	W
Enneacanthus obesus	Banded sunfish	BS	Centrarchidae	MG	I	W
Pomoxis nigromaculatus	Black crappie	BC	Centrarchidae	MG	M	W
Micropterus dolomieu	Smallmouth bass	SMB	Centrarchidae	MG	M	W
Stizostedion vitreum	Walleye	W	Percidae	MG	M	W
Perca flavescens	Yellow perch	YP	Percidae	MG	M	W
Etheostoma fusiforme	Swamp Darter	SD	Percidae	MG	I	W
Etheostoma olmstedi	Tesselated darter	TD	Percidae	FS	M	W
Channa sp.	Snakehead	SH	Channidae	MG	T	W

[1] Habitat Use Classification codes: FD = fluvial dependent species, FS = fluvial specialist species, MG=macrohabitat generalist species
[2] Tolerance Classification Codes: I = Intolerant, M = Moderately Tolerant, T = Tolerant
[3] Temperature Classification Codes: C = Cold Water, W = Warm Water

Appendix C MemorandumLiterature Review of Freshwater Nutrient Enrichment Indicators

To: DWM-WPP Program Managers
From: Anna Mayor, DWM-WPP Water Quality Standards Committee Member
Date: September 2, 2015
Subject: Literature Review of Freshwater Nutrient Enrichment Indicators

1.0 Introduction

Nutrients, such as total phosphorus (TP) in freshwaters, have been identified as the primary causes of anthropogenic (cultural) eutrophication in Massachusetts (MassDEP 2012). The addition of nutrients to freshwater systems often stimulates rapid growth of primary producing autotrophs containing chlorophyll (e.g., cyanobacteria, algae, non-rooted macrophytes, etc.). Anthropogenic enrichment can lead to impairment of the designated uses of Massachusetts surface waters including public water supply, aesthetics, recreation, as well as aquatic life.

Massachusetts to date has relied on narrative statements in its water quality standards to regulate unacceptable nutrient impacts on surface waters from anthropogenic sources. To better implement their water use impairment guidelines, MassDEP has increasingly applied quantitative rather than narrative screening guidelines for freshwater nutrient enrichment response indicators, along with TP concentrations, in a weight-of-evidence approach. Because a combination of surface water depth, substrate type, shading, color, grazing, herbivory, the nature of inputs, and hydrology all play a role in the degree of nutrient response, the preferred approach has been to use field measurements of the primary producers' responses as the first indicators for assessing surface waters for impairment in compliance with Section 305(b) of the CWA. Massachusetts currently follows the "Designated Use Approach" (USEPA, 2000a), establishing nutrient enrichment response indicator screening guidelines to evaluate whether or not designated uses such as aquatic life, recreation, and aesthetics are being met.

Biological indicators of nutrient enrichment include the presence of nuisance growths of primary producers, such as cyanobacteria, algae and aquatic vascular plants (macrophytes). Physico-chemical indicators of high primary productivity include low clarity (as Secchi depth), elevated pH, elevated TP, elevated dissolved oxygen saturation and significant diel fluctuation in dissolved oxygen. Total phosphorus concentration data alone are not used to determine impairment due to nutrient enrichment; rather, they are used to corroborate indicator data and can help to identify potential sources. This Appendix provides the supportive literature and basis for the nutrient enrichment indicator screening guidelines used in the 2016 Consolidated Assessment and Listing Methodology (CALM) Guidance Manual.

2.0 Summary of Massachusetts Nutrient Enrichment Indicator Screening Guidelines

To assess nutrient enrichment, Massachusetts has grouped its inland waterbodies into three categories: 1. wadeable rivers and streams; 2. non-wadeable rivers and streams, and 3. lakes, ponds, and impoundments generally greater than two meters in depth. The surface waters are grouped in this way because each is distinct in the sampling methodology applied (e.g., wading vs. boat), the exhibition of biological responses (benthic growth vs. planktonic growth), the retention times, and in hydraulic conditions such as scouring.

For wadeable rivers and streams, the selected nutrient enrichment indicators include:

- benthic filamentous algae percent visual coverage,
- benthic algae as chlorophyll-*a*,

- diel changes in and saturation of dissolved oxygen,
- elevated pH, and
- elevated TP.

The indicators used for non-wadeable rivers are:

- non-rooted vegetation percent visual coverage,
- planktonic chlorophyll-*a*,
- diel changes in and saturation of dissolved oxygen,
- elevated pH,
- elevated TP, and
- the frequency and duration of cyanobacteria blooms.

For lakes, ponds and impoundments, the indicators include:

- secchi disk transparency,
- non-rooted vegetation percent visual coverage,
- planktonic chlorophyll-*a*,
- dissolved oxygen saturation,
- elevated pH,
- elevated TP, and
- the frequency and duration of cyanobacteria blooms.

MassDEP has selected its nutrient enrichment indicators and their respective numeric screening guidelines based on historical precedent, best professional judgment (BPJ) and the scientific literature. MassDEP's response indicator guidelines for each waterbody type, the literature reviewed for each indicator, along with the thresholds mentioned or recommended by the literature are provided in Table 1.

Table 1

Recommended Nutrient Enrichment Indicator Screening Guidelines and Literature Sources for Various Surface Water Types

Waterbody Type	Nutrient Enrichment Indicator	Recommended Indicator Screening Guideline(s)	Water Use Goal Potentially Impacted	Reference	Literature Thresholds
Wadeable Rivers	Benthic Filamentous Algae % Visual Coverage	>40%	Aquatic Life/ Recreation/ Aesthetics	Welch et al., 1988	20% (Aquatic Life no effect level*)
				USEPA, 2000a	Variable (Aesthetic)
				Biggs and Price, 1987	>40% (Visual)
				Zurr, 1992	>40% (Primary recreation)
	Benthic Algae as Chlorophyll-*a*	> 200mg/m^2	Aquatic Life/ Recreation/ Aesthetics	Dodds et al., 1997	>200 mg/m^2 (Nuisance)
				Welch et al., 1988	>100 - 150 mg/m^2 (Nuisance)
				USEPA, 2000a	>100 - 200 mg/m^2 (Nuisance)
	Diel Changes in DO Concentration	Δ>3 mg/l	Aquatic Life	Gower, 1980	Δ 2.5 mg/l (generally nutritionally balanced) Δ 10 mg/l (generally nutritionally imbalanced)
				Mathews, 1998	Δ> 3.6 - 6 mg/l
	DO Saturation	≥125%	Aquatic Life	USEPA,1986a	>110-120% (total dissolved gas)
				MassDEP BPJ	≥125% (Oxygen)
	Elevated pH	>8.3 SU	Aquatic Life/ Recreation	USDI, 1968	>8.3 SU (human eye irritation)
				USEPA, 1976	>9 SU (freshwater organisms)
	Elevated TP-seasonal avg: used to confirm nutrient enrichment	>.1 mg/l flowing waters >.05 mg/l entering a lake/reservoir (n≥3 samples)	See preceeding indicators for potential impacts	Mackenthun, 1973 USEPA, 1986a	>0.1 mg/l flowing waters >0.05 mg/l entering a lake/reservoir
				USEPA, 2002	>0.010 mg/l - 0.031 mg/l (range within Massachusetts Ecoregions)
Non-Wadeable Rivers	Non-rooted Vegetation % Visual Coverage	>25%	Aquatic Life/ Recreation/ Aesthetics	Wolverton, 1986; Landolt 1986, cited in Ozbay, 2002; Leng et al., 1995;	100% cover results in anoxia and suppression of algae and submerged plant growth.
				Gee et al., 1997	>25% (for O_2 saturation, swimming and aesthetics)
	Phytoplankton Chlorophyll-*a*	>16 µg/l	Aquatic Life	Dodds, et al., 1998	>30 µg/l (mesotrophic-eutrophic rivers)
				USEPA, 2000/2001	0.63 - 3.75 ug/l (rivers + streams)

Waterbody Type	Nutrient Enrichment Indicator	Recommended Indicator Screening Guideline(s)	Water Use Goal Potentially Impacted	Reference	Literature Thresholds
	Diel Changes in DO Concentration	Δ>3 mg/l	Aquatic Life	Gower, 1980	Δ 2.5 mg/l (generally nutritionally balanced) Δ 10 mg/l (generally nutritionally imbalanced)
				Mathews, 1998	Δ> 3.6 - 6 mg/l
	DO Saturation	≥125%	Aquatic Life	USEPA,1986a	>110-120% (total dissolved gas)
				MassDEP BPJ	>125% (DO)
	Elevated pH	>8.3 SU	Aquatic Life/ Recreation	USDI, 1968	>8.3 SU (human eye irritation)
				USEPA, 1976	>9 SU (freshwater organisms)
	Cyanobacteria Blooms	Recurring and/or Prolonged, Resulting in Advisories	Aquatic Life/ Recreation/ Aesthetics	WHO, 1999; MassDPH, 2007	Advisory = a cell count of 70,000 cells/mL or more corresponding to a toxin level of approx. 14 ppb
	Elevated TP-Seasonal Average: Used to confirm nutrient enrichment	>.1 mg/l flowing waters >.05 mg/l entering a lake/reservoir (n≥3 samples)	See preceeding indicators for potential impacts	Mackenthun, 1973; USEPA, 1986a	>.1 mg/l flowing waters >.05 mg/l entering a lake/reservoir
				USEPA, 2002	>0.010 mg/l - 0.031 mg/l (range within Massachusetts Ecoregions)
Lakes, Ponds and Impoundments (Generally >2m Depth)	Secchi Disk Transparency	≤ 1.2 m	Aesthetics/ Recreation	USDI, 1968; MassDPH; BPJ	≤ 4' (1.2 m) (swimming safety)
				USEPA 2000 a,b, c,d; USEPA 2001 a,b	≤4.50-4.93 m (range within Massachusetts Ecoregions)
	Non-Rooted Vegetation % Visual Coverage	>25%	Aquatic Life Recreation/ Aesthetics	Wolverton, 1986; Landolt, 1986, cited in Ozbay, 2002; Leng et al., 1995	<100% cover (anoxia, suppression of algae and submerged plant growth)
				Gee et al., 1997	>25% (for O_2 saturation, swimming and aesthetics)
	Planktonic Chlorophyll-*a*	> 16 μg/l	Aquatic Life/ Recreation/	USEPA, 2000/2001	>2.43-2.90 ug/l (25th Percentile range within Massachusetts Ecoregions)

Waterbody Type	Nutrient Enrichment Indicator	Recommended Indicator Screening Guideline(s)	Water Use Goal Potentially Impacted	Reference	Literature Thresholds
			Aesthetics	Wetzel, 2001.	14.3 µg/l (mean, eutrophic) 42.6 µg/l (max, eutrophic) 16.1 µg/l (max, mesotrophic)
	DO Saturation	≥125%	Aquatic Life	USEPA, 1986a	>110-120% (total dissolved gas)
				MassDEP BPJ	>125%
	Elevated pH	>8.3 SU	Aquatic Life/ Recreation	USDI, 1968	>8.3 SU (human eye irritation)
				USEPA, 1976	>9 SU (freshwater organisms)
	Cyanobacteria Blooms	Recurring and/or Prolonged, Resulting in Advisories	Aquatic Life/ Recreation/ Aesthetics	WHO, 1999; MassDPH, 2007.	Advisory= a count of 70,000 cells/mL or more corresponding to a toxin level of approx. 14 ppb
	Elevated TP-Seasonal Average: Used to confirm nutrient enrichment	>0.025 mg/l (n≥3 samples)	See preceeding indicators for potential impacts	USEPA, 1986a	>0.025 mg/l
				USEPA, 2000b	>0.008 mg/l (within Massachusetts Ecoregions)
				Gower, 1980	>0.01 mg/l
				Hutchinson, 1957	>0.01-0.03 mg/l

Notes:

mg/m^2	= milligrams per square meter	cells/mL	= bacteria cells per milliliter
mg/l	= milligrams per liter	m	= meter
SU	= standard units	T	= total
µg/L	= micrograms/L	DO	= dissolved oxygen
ppb	= parts per billion	*	= No apparent effects on DO, pH, or benthic invertebrates

These basic nutrient enrichment screening guidelines represent thresholds that shall not be exceeded in more than one site visit (generally visit per month) during the summer index period. If the guidelines are exceeded repeatedly, MassDEP uses a weight-of-evidence approach to assess impairment of the surface water, outlined as follows:

- In the assessment of rivers and streams, MassDEP analysts evaluate both excessive primary-producer growths observed two or more times, and also consider changes in the physico-chemical data (e.g., dissolved oxygen concentration and supersaturation, pH, and chlorophyll-a). If a combination of these indicator data suggests nutrient enrichment the guidelines will be used to determine whether or not the condition of the surface water supports its designated uses.

- Lakes are assessed and potentially impaired using mostly primary producer biological data (i.e., planktonic blooms, cover of non-rooted aquatic macrophytes); and, the evaluation may also include physicochemical data such as oxygen saturation, pH, chlorophyll-a, and Secchi disk transparency. These surface waters would be impaired when more than one of these indicators exceed guidelines more than once during the survey season.

- If the surface water is impaired using biological and/or physicochemical indicators, total phosphorus is then included as a cause of impairment if the concentrations exceed EPA's "Gold Book" criteria.

The proposed guidelines apply to freshwaters but exclude darkly colored waters, as well as marine or brackish waters that have salinity greater than 0.5 ppt.
To define appropriate guidelines, MassDEP conducted a detailed literature review of biological and physical characteristics related to nutrient enrichment that support attainment of each surface water's designated uses.

3.0 Literature Summaries

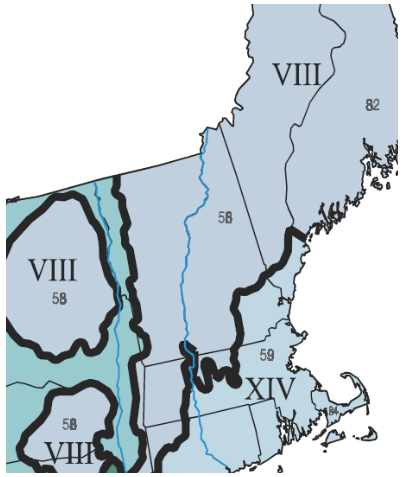
Over the last decade a wealth of research has been generated to help identify appropriate nutrient criteria for protection and restoration of water resources. MassDEP reviewed EPA's technical support and guidance documents, scientific literature and the extensive surface water sampling data collected by MassDEP.

3.1 USEPA General Nutrient-Related Background Information

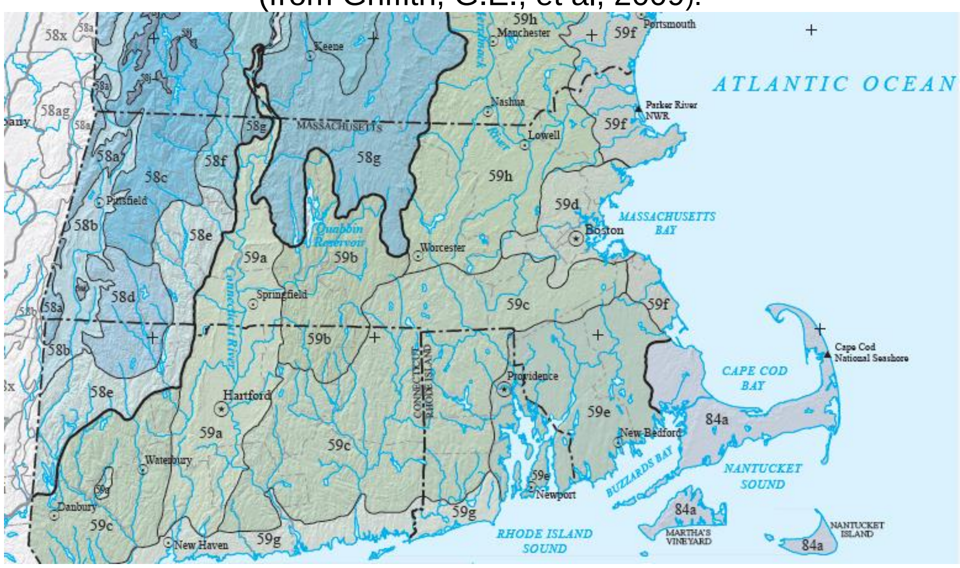
The United States Environmental Protection Agency (USEPA) has published technical support documents to help guide efforts for numeric nutrient criteria development by waterbody type (e.g., estuarine and coastal waters, lakes and reservoirs, rivers and streams and wetlands). In addition USEPA conducted studies that divided the US into 14 distinct ecoregions and finalized reports that derive numeric nutrient criteria by waterbody type and region (USEPA, 2001a and 2001b). Massachusetts is within two major Ecoregions, dividing the state roughly in half vertically. The western portion of the state, approximately along the Connecticut river valley and to the west, is within Ecoregion VIII. The eastern portion of the State is within Ecoregion XIV. The State also contains three subregions, the Northeastern Highlands (58), the Northeastern Coastal Zone (59), and the Atlantic Coastal Pine Barrens (84). EPA has published their recommended nutrient criteria documents for both rivers and streams and lakes and reservoirs for each of these ecoregions. They include recommended criteria for total phosphorus, total nitrogen, chlorophyll a, and turbidity or Secchi disk depth intended to address the adverse effects of excess nutrient inputs (USEPA 2000c, 2000d, 2001a, and 2001b). Massachusetts evaluated EPA's approach along with other published literature to establish its nutrient enrichment screening guidelines for freshwater systems. See Figure 1 for the EPA Ecoregions within Region 1, and the Sub-Ecoregions specific to Massachusetts.

Figure 1

EPA Ecoregions for the National Nutrient Strategy



Massachusetts lies within two major Ecoregions: VIII and XIV (see above map), and three Sub-Ecoregions: 58, 59 and 84, as indicated below (from Griffith, G.E., et al, 2009).



EPA provides a description of the characteristics of the Sub-Ecoregions in its Nutrient Guidance documents. Information pertaining to the ecoregions within Massachusetts, as defined in the EPA guidance documents, is paraphrased below.

(a) Ecoregion 58 - Northeastern Highlands
The Northeastern Highlands comprise a relatively sparsely-populated region characterized by nutrient-poor soils blanketed by northern hardwood and spruce fir forests. Land-surface form in the region grades from low mountains in the southwest and central portions to open high hills in the northeast. Many of the numerous glacial lakes in this region have been acidified by atmospheric sulfur depositions.

(b) Ecoregion 59 - Northeastern Coastal Zone
Like the Northeastern Highlands, the Northeastern Coastal Zone contains relatively nutrient-poor soils and has concentrations of continental glacial lakes, some of which are sensitive to acidification; however, this Ecoregion contains considerably less surface irregularity and much greater concentrations of human population. Current land use consists mainly of forests and residential development.

(c) Ecoregion 84 - Atlantic Coastal Pine Barrens
This Ecoregion is distinguished by its coarser grained soils and oak-pine potential natural vegetation, as compared to forests including hickory. Appalachian Oak forests and northern hardwoods were found in the northern portion of this Ecoregion. This Ecoregion is not as irregular as that of the Northeastern Coastal Zone.

3.2 MassDEP Literature Review by Waterbody Type

The following are brief synopses of the literature and field data that support the selected quantitative nutrient enrichment screening guidelines.

(a) Wadeable Streams and Rivers

(1) Benthic Filamentous Algae % Visual Coverage

Benthic algal biomass can be measured as percent cover by filamentous algae. Filamentous algae are the most commonly-noted nuisance growth in nutrient-enriched wadeable streams and various threshold values have been proposed by a number of scientists. Welch et al. (1988) studied 22 streams in northwestern United States and Sweden. The Welch et al. (1988) study noted that when benthic chlorophyll was lower than 100-150 mg/m^2, filamentous algae covered less than 20 percent of the stream bottom. A survey of New Zealand rivers found that when filamentous algae exceeded 40 percent the algal community became very conspicuous from shore (Biggs and Price, 1987). Streambed coverage by filamentous algae of <20 percent had no apparent effects on DO or benthic invertebrates (Welch et al. 1988). New Zealand Ministry for the Environment has established guidelines to protect contact recreational use of streams, and recommended that the seasonal maximum cover by filamentous algae should not exceed 40% (Zurr, 1992). Based on the above and the general recommendations in the USEPA rivers nutrient guidance document (USEPA 2000a), the proposed maximum screening guideline for filamentous macroalgae is set at 40 percent coverage in streams.

MassDEP Guideline: to support the designated uses of aquatic life, recreation, and aesthetics, visible filamentous periphyton exceeding 40% coverage in the streambed in more than one monthly site visit during the summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(2) Benthic Algae as Chlorophyll-*a*

In most cases, aesthetic and recreational nuisance algal growth in wadeable streams is associated with benthic growths. The Welch et al. (1988) study suggested nuisance conditions occur when benthic chlorophyll exceeds 100-150 mg/m^2. However, the same study concluded that other measures of water quality related to the aquatic life designated use such as dissolved oxygen and benthic macroinvertebrates were unaffected by either benthic chlorophyll or filamentous algae. In a study of a trout fishery, Montana's Clark Fork River, Dodds et al. (1997) used a benthic chlorophyll mean of 100 mg/m^2 to define nuisance conditions and suggested a maximum benthic chlorophyll-*a* screening guideline of 200 mg/m^2.

The studies of Dodds et al. (1998) and Welch et al. (1988) and recommendations of a number of studies compiled in USEPA (2000a) suggest a benthic algae chlorophyll-*a* threshold at a maximum of 200 mg/m^2 for recreational and aesthetic use in streams. Levels of benthic algae chlorophyll-*a* can vary significantly within single segments depending on the physical conditions at each sampling location; therefore, case-by-case decisions need to be made as to whether conditions can represent the entire segment.

MassDEP Guideline: to support the designated uses of recreation and aesthetics, benthic chlorophyll-a exceeding 200mg/m^2 in more than one monthly site visit during the summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(3) Diel Changes in Dissolved Oxygen Concentration

Generally, for warm-water organisms, the optimum DO concentration is 6 mg/l, and it is best that levels not decrease below 5 mg/l (USDI 1968). Only in very favorable conditions is it considered tolerable for the DO to fall to between 4 and 5 mg/l, and then only for brief periods (USDI 1968). For cold water fish, the lowest tolerable in favorable condition is between 5 and 6 mg/l, with the optimum oxygen concentration of 7 mg/l (USDI 1968).

Daytime photosynthetic activities of algae and macrophytes can increase dissolved oxygen (DO) levels, and continued decomposition and respiration at night can significantly decrease DO, particularly in slow-moving streams and rivers (Wetzel 2001). If the biomass of algae and macrophytes is very high, this diel swing in DO may be severe (USEPA 1998, Sharpley et al. 2000). Such large daily swings in DO can be harmful to aquatic animal life (Jones 2011).

Studies have shown that growth of largemouth bass under any DO fluctuation is reduced compared to growth under steady DO concentrations (USEPA 1986b). Similar results were exhibited in studies with yellow perch and channel catfish (USEPA, 1986b). Spawning of mature black crappies was not successful when DO fluctuated between 1.8 mg/l and 4.1 mg/l (a fluctuation of 2.3 mg/l) (USEPA 1986b).

Quantification of the diel changes in DO in defined river sections has been used as a measure of photosynthetic production (Wetzel 2001). Gower (1980) depicts that DO levels in a “nutritionally balanced” stream fluctuate by approximately 2.25 to 2.5 mg/l of DO; whereas a eutrophic stream can exhibit diel DO fluctuations of 10 mg/l. This is supported by a 1977 study reviewed by Mathews (1998). The study indicated that in August, after measurement of DO at 13 sites within a 1 kilometer segment of a stream in Norman, Oklahoma, a mean morning-afternoon increase of 3.6 mg/l DO was observed. Yet, at individual “backwaters with algae” locations, DO increased by 6 mg/l or more.

MassDEP Guideline: to support the designated use of aquatic life, the diel change in dissolved oxygen greater than 3 mg/l during the summer growing season (April 1 to October 31), is considered an indicator of nutrient enrichment.

(4) Dissolved Oxygen Saturation

Percent saturation is the amount of dissolved oxygen in a water sample compared to the maximum amount that could be present (at the same temperature). For example, a water sample that is 50 % saturated only has half the amount of oxygen that it could potentially hold at that temperature. Dissolved oxygen (DO) in surface waters can exceed expected saturations when photosynthetic processes by algae or rooted aquatic plants produce oxygen more quickly than it can diffuse into the atmosphere. Algal blooms often accompany an increase in water temperature and this higher temperature further contributes to supersaturation (USEPA 1986a).

To protect aquatic life, EPA (1986a) recommends a total dissolved gas concentration in water not to exceed 110 percent of the saturation value for gases at existing atmospheric and hydrostatic pressures. Water at this level of saturation and above may lead to fish mortalities when dissolved gases in their circulatory system form emboli which block the capillary flow of blood. This condition is commonly referred to as "gas bubble disease”. Studies have also shown, however, that it is high nitrogen and carbon dioxide (CO_2) saturation that is potentially harmful to fish due to gas bubble disease, and not high oxygen saturation (Weitkamp and Katz 1980). Therefore, MassDEP is applying the 125% saturation level of DO as simply an additional indicator of high primary producer photosynthesis levels. However, DO saturation is not recommended as a primary variable to assess nutrient enrichment in some cases because the supersaturation may not be apparent due to surface turbulence and/or other non-nutrient-related factors (USEPA 2000a).

MassDEP Guideline: to support the designated use of aquatic life, a dissolved oxygen saturation exceeding 125% in more than one site visit during the summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(5) Elevated pH

According to EPA, pH in surface water in the range of 6.5-9 standard units (SU) is protective of freshwater fish and benthic organisms (USEPA 1976). Very few organisms tolerate pH above 10 SU (USDI 1968). In aquatic systems, during the day photosynthesis usually exceeds respiration, and as carbon dioxide is extracted from the water pH increases (Tucker and D'Abramo 2008). This photosynthetic activity can be represented by the following chemical equation: $CO_2 + H_2O \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$. The system is in equilibrium under constant conditions, but when these conditions are disrupted, the reactions flow to the left or the right to maintain equilibrium. Removing carbon dioxide shifts the equation to the left, thereby removing hydrogen ions and causing pH to increase. The degree of variation from the initial pH depends on the amount of carbon dioxide removed and alkalinity, which tends to buffer, or reduce, the effect of changes in carbon dioxide concentrations (Tucker and D'Abramo 2008). The amount of bicarbonate and carbonate (CO_3^{2-}) are the anions contributing the most to a water's capacity to neutralize acid, or its alkalinity (Tucker and D'Abramo 2008).

When primary producers are growing rapidly, more carbon dioxide is removed each day by photosynthesis than is added each night by respiration, causing pH to rise to abnormally high levels during the afternoon and may even remain high through the night (Tucker and D'Abramo 2008). This cycle means that pH can be a useful indicator of unusually high primary productivity and hence a nutrient enrichment indicator; however, in surface waters with high alkalinity ("buffering capacity"), pH is not as useful a nutrient indicator (MassDEP BPJ).

Elevated pH can also affect the toxicity of other constituents in the water column which then may impact aquatic life, but these effects are not relevant to pH as a nutrient enrichment indicator and are therefore discussed briefly in other sections of the CALM document.

For primary contact, the recommended pH of surface water is 6.5-8.3 to protect the human eye from irritation (USDI 1968).

MassDEP Guideline: to support the designated uses of recreation and aquatic life, a pH of >8.3 SU during the summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(6) Elevated Total Phosphorus (TP)

Phosphorus is commonly the initial limiting nutrient to algae (Wetzel 2001). In addition to point sources, there are three major sources of TP to surface waters: atmospheric precipitation, groundwater and land runoff (Wetzel 2001). The effects of phosphorus vary by region and are dependent on physical factors such as the size, hydrology, and depth of rivers and lakes.

According to the EPA frequency analysis of surface water data collected in Massachusetts, the aggregate recommended TP criterion level for rivers and streams is .010 mg/l for Ecoregion VIII (Western Mass), and .031 mg/l for Ecoregion XIV (Eastern Mass) (USEPA 2002).

However, because many biological, chemical and physical characteristics influence whether a river or stream responds to certain levels of TP, MassDEP uses phosphorus concentrations as a confirming measurement when the weight of evidence points to nutrient enrichment. Specifically, when multiple biological and physico-chemical nutrient enrichment indicator thresholds are exceeded, then the seasonal average (greater than three samples) of the TP concentration data are screened against the 1986a EPA recommended “Gold Book” TP concentrations. As noted in the Gold Book, for prevention of primary producer over-abundance in streams, it is recommended that TP be maintained at 0.05 mg/l where streams are entering lakes, ponds, or impoundments, or 0.1 mg/l in streams or other flowing waters (EPA 1986a).

MassDEP Guideline: When multiple biological and physico-chemical nutrient enrichment indicator screening guidelines are exceeded, the seasonal average for TP exceeding 0.1 mg/l in flowing waters, or exceeding 0.05 mg/l for rivers entering a lake or reservoir during the summer growing season (April 1 to October 31), is considered additional confirmation that there is a condition of nutrient enrichment.

(7) Application of the Wadeable Streams and Rivers Screening guidelines

More information is needed on applicability of benthic and filamentous algae screening guidelines to cold water streams. Future guidance may have to be revised as additional water quality information is collected for cold water streams in Massachusetts in what has been called Phase II of the MassDEP nutrient-related guidance documents.

In addition, it is important to consider the goal of the assessment when applying the above thresholds. If the intent is to judge the frequency, duration and magnitude (or extent) of a periphyton bloom as it impacts designated uses over a 5-20 mile stretch of river segment over a given period of time, then careful selection of a sampling design is needed to avoid bias. Blooms may develop preferentially in areas without tree canopy (increased light), in areas of cobble, shallow riffles, moderate flow velocities and when rare periods of low flow and a lack of scouring allow excessive biomass accrual. Extreme low-flow conditions have the potential to produce bloom conditions in reference streams and these may be considered natural events. Likewise, high flow events and high velocity sites have the potential to scour benthic algal growth (Biggs 2000, Biggs 2012).

The USEPA Nutrient Criteria Guidance suggests that light, cobbles, flow velocity, and accrual time be considered and to determine the degree to which these are “common in the stream or reach” (USEPA 2000a). If the sampling plan focuses on such times and places that favor blooms the data will be biased high, and if such conditions are avoided the data may be biased low. With random sampling or representative sampling the goal is to produce an unbiased estimate of the mean biomass of the segment that represents the mean biomass of the time interval. Given the year to year variability in climate it is suggested that if rare hydrologic conditions were present during sampling, the sampling should be repeated in following year(s) to confirm the impairment was not a spurious result.

(b) Non-Wadeable Rivers

The biological response to excessive nutrients in non-wadeable rivers occurs primarily within the water column and surface rather than at the bottom of the river. There are fewer instances and published reports of impairments caused by excessive planktonic algae or surface accumulations of algae or floating macrophytes in such systems, presumably because the short water residence time results in flushing of algae and floating plants out of the systems.

(1) Non-Rooted Vegetation % Visual Coverage

Floating non-rooted macrophytes such as *Lemna* sp. or *Wolfia* sp., or algal scums formed by either green algae or bluegreen algae (cyanobacteria) may impair aquatic life, recreation, and aesthetic designated uses of non-wadeable rivers; however, this is unlikely unless there are eutrophic impoundments upstream. Again, the short residence times within flowing rivers usually preclude large biomass accumulations of duckweed or algae. Because these impairments are usually associated with impoundments, the threshold to be applied to rivers will be the same as for impoundments, discussed below in Section 3.2(c)(2).

MA Guideline: to support the designated uses of recreation and aesthetics, floating duckweed/scum exceeding 25 % of surface coverage in more than one site visit within the index period April 1-October 31 is considered an indicator of nutrient enrichment.

(2) Planktonic Chlorophyll-*a*

The MassDEP threshold for planktonic chlorophyll-a was developed to differentiate between mesotrophic (unimpaired) and eutrophic (impaired) waterbodies. Trophic levels and associated chlorophyll-*a* concentrations have been well defined for lakes. Researchers have cited ranges of chlorophyll-*a* of 2-15 for mesotrophic freshwater lakes (Wetzel 2001). Although trophic levels are not well defined for rivers, Dodds et al. (1998) suggests a reasonable mesotrophic-eutrophic boundary of 30 µg/l sestonic chlorophyll-*a* in the water column based on a large number of reported rivers. A maximum water quality screening guideline of 16 µg/l is proposed here based on the above literature and MassDEP experience. This value falls between the Dodds et al. (1998) value and the USEPA-derived value of 0.63-3.75 µg/l reported in Table 2 below.

Table 2
Summary of USEPA Statistically-Derived Nutrient Criteria for Massachusetts
By Ecoregion and Waterbody Type (USEPA 2000 a,b,c,d; 2001 a,b).

Parameter	**USEPA Ecoregion VIII* Western Massachusetts**	**USEPA Ecoregion XIV* Central & Eastern Massachusetts**
Rivers and Streams		
Chlorophyll a (µg/l) (planktonic)	0.63	3.75
*All values based on 25th percentile all data		

As noted previously, the USEPA criteria are based on a frequency distribution and presumably include wadeable streams that are often very low in planktonic chlorophyll-*a*. Historically, such low levels of chlorophyll-*a* in the water column are not associated with impairments of uses in Massachusetts.

MassDEP Guideline: to support the designated uses of recreation and aesthetics, water column chlorophyll-a >16 µg/l in more than one monthly site visit during the growing season from April 1-October 31 is considered an indicator of nutrient enrichment.

(3) Diel Changes in Dissolved Oxygen Concentration
See Section 3.2(a)(3) for the discussion of diel changes in dissolved oxygen.

MassDEP Guideline: to support the designated use of aquatic life, the diel change in dissolved oxygen greater than 3 mg/l during the summer growing season (April 1 to October 31), is considered an indicator of nutrient enrichment.

(4) Dissolved Oxygen Saturation
See 3.2(a)(4) for the discussion of DO saturation.

MassDEP Guideline: to support the designated use of aquatic life, a dissolved oxygen saturation equal to or greater than 125% in more than one site visit during the summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(5) Elevated pH
See 3.2(a)(5) for discussion of pH.

MassDEP Guideline: to support the designated uses of recreation and aquatic life, a pH of >8.3 SU during the summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(6) Elevated Total Phosphorus (TP)
See 3.2(a)(6) for discussion of elevated TP.

MassDEP Guideline: When multiple biological and physico-chemical nutrient enrichment indicator screening guidelines are exceeded, the seasonal average for TP exceeding 0.1 mg/l in flowing waters, or exceeding 0.05 mg/l for rivers entering a lake or reservoir during the summer growing season (April 1 to October 31) is considered additional confirmation of a condition of nutrient enrichment.

(7) Frequency and Duration of Cyanobacteria Blooms
MassDEP does not provide a specific numerical screening guideline for detection of cyanobacteria blooms within surface waters. Instead, MassDEP tracks the frequency of cyanobacteria advisories placed on surface waters by the Massachusetts' Department of Public Health (MDPH). In 2007 MDPH issued a guidance outlining monitoring procedures for cyanobacteria and/or the toxins they produce designed to prevent adverse health effects before they reach levels of concern.

Cyanobacteria blooms occur most often in late summer or early fall. The most common types of blooming cyanobacteria are *Microcystis* and *Anabaena*, which may produce toxins called microcystin and anatoxin, respectively. If these cyanobacteria are ingested, the cell walls break down and the toxin may be released.

MDPH guidelines are designed to encourage action to be taken prior to exposure, thereby mitigating possible health concerns. The guidelines recommend various combinations of three monitoring methods, while cautioning that the measurement of the toxin is less feasible than conducting cell counts:

1. Observation of visible algae layer;
2. Total cell count of cyanobacteria (units of total cells/mL water); and/or
3. Concentration of cyanobacteria toxin (units of µg toxin/L of water).

Using World Health Organization's (WHO) research on cell counts and toxin levels, MassDPH determined that a cell count of 70,000 cells/mL would correspond to a toxin level of approximately 14 ppb which is the current guideline for contact recreational waters (MDPH 2007).

MassDEP Guideline: to support the designated uses of aquatic life, recreation and aesthetics, a surface water containing cyanobacteria at levels where the MDPH issues an advisory (i.e.,at a cell count of 70,000 cells/mL or more, corresponding to a toxin level of approximately 14 ppb) generally more than once during the summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(c) Lakes, Ponds and Impoundments (Generally >2m Depth)

Massachusetts is somewhat unusual for New England in that impoundments dominate the 'lake' types. Impoundments are differentiated from rivers by having standing water behind a dam, a lack of unidirectional flow, and an estimated detention time greater than 3 days. According to the state records of registered dams (MassGIS 2012) there are 2979 dams in the state and at least 1487 are located on 'lakes' listed among the 2951 lakes of the Pond and Lake Information System database (Ackerman 1989). Most of the natural, groundwater-fed seepage lakes are located in glacial outwash plains characterized by sandy areas along the coast and on Cape Cod, while impoundments and lakes with inlets are more frequently found farther inland.

The discussion in this section mentions data collected by USEPA as a part of its Ecoregion sampling program. Combined for the ecoregions that include Massachusetts, EPA collected samples from 2,881 lakes and reservoirs from a total of 4,656 stations. Table 3 lists the total number of samples for each region.

Table 3
Lake Records for Aggregate Ecoregions VIII and XIV

	Aggregate Ecoregion VIII	Sub ecoRegion 58	Aggregate Ecoregion XIV	Sub ecoRegion 84	Sub ecoRegion 59
# of Lakes / Reservoirs	2,234	849	647	92	485
# of Lake Stations	3,746	1,898	910	100	602
# of records* for Secchi depth	82,656	24,451	14,581	79	13,174
# of records* for Chlorophyll *a* (all methods)	21,223	11,478	5,977	73	4,548

*Note: # of records refers to the total count of observations for that parameter over the entire decade (1990-1999) for that particular aggregate or subecoregion. These are counts for all seasons over that decade. # of lake stations refers to the total number of lake and reservoir stations within the aggregate or subecoregion from which nutrient data were collected. Since lakes and reservoirs can cross ecoregional boundaries, it is important to note that only those portions of a lake or reservoir (and data associated with those stations) that exist within the Ecoregion are included within this table. (USEPA 2001a and 2001b). Aggregate Ecoregion and SubecoRegions may include data from multiple states.

(1) Secchi Disk Transparency

Particulate matter suspended in the water column (total suspended solids or TSS) attenuates light and reduces transparency. The suspended matter could consist of algae, algal detritus or inorganic sediment. Surface water may also have high concentrations of light-absorbing dissolved compounds that originate from wetland areas that border the waterbody. This type of surface water is often referred to as "tea-stained".

Historically, Massachusetts has used the 1.2 meter (4 foot) transparency standard for swimming beaches to assess primary contact recreation use. This visibility standard originated from the "Green Book" (USDI 1968) which stated that *"clarity in recreational waters is highly desirable [to provide] for visual appeal, recreational enjoyment, and safety".* For primary recreation*, "clarity should be such that a Secchi disc is visible at a minimum depth of 4 feet."* This threshold was used at the Massachusetts Department of Health (MassDPH) to reduce risk of injury from swimming. Because swimming is a designated use in nearly all waters, the 1.2 m Secchi disk was selected as a screening guideline for all lakes, ponds and impoundments where swimming is a use. This guideline is less than the 4.50-4.93 m proposed by the USEPA based on the cumulative transparency frequency of lakes in the Ecoregions (see Table 4).

Table 4
Summary of USEPA Statistically-Derived Secchi Disk Transparency for Massachusetts By Ecoregion and Waterbody Type (USEPA 2000a,b,c,d; 2001a,b).

Parameter	**USEPA Ecoregion VIII* Western Massachusetts**	**USEPA Ecoregion XIV* Central & Eastern Massachusetts**
Lakes and Impoundments		
Secchi Disk Transparency (m)	4.93*	4.50*
*Transparency based on 75th percentile of all data.		

The USEPA Ecoregions include the natural deep lakes found in Maine, Vermont and New Hampshire, whereas a large proportion of lakes in Massachusetts are shallow lakes and impoundments, with correspondingly higher trophic conditions (i.e., more eutrophic) and lower transparencies.

Where surface water inflows dominate, impoundments tend to be much shallower and smaller than natural lakes, with large watersheds and large surface area drainage ratios resulting in median retention times of only 8 days. Impoundments have lower Secchi disk transparencies than natural lakes of any type except for highly colored, tea stained/bog-type lakes.

Because of the prevalence of shallow lakes and impoundments that tend toward eutrophic conditions, a Secchi depth of 1.2 meters is appropriate for Massachusetts as an initial water quality guideline with regard to swimming use and as a potential indication of nutrient enrichment.

The use of the 1.2 meter Secchi screening guideline will not be effective in protecting the conditions of surface waters such as lakes with inlets and clear seepage lakes. The Antidegradation section of the Surface Water Quality Standards that relates to High Quality Waters (314 CMR 4.04(2)) and the associated Antidegredation Implementation Policy (10-21-2009) serves to protect these surface water types.

MassDEP Guideline: to support the designated uses of recreation and aesthetics for lakes, ponds and impoundments, if transparency is less than or equal to 1.2 meters during more than one site visit within the index period April 1-October 31, it is considered an indicator of nutrient enrichment.

Note: Natural conditions exemptions to the 1.2 meter Secchi threshold apply to highly colored, humic waters. A site-specific screening guideline for these types of surface waters may be developed. A single exceedance of this threshold in a given site visit should not be enough to place the surface water on the impaired waters list.

(2) Non-Rooted Vegetation % Visual Coverage

Mats of non-rooted vegetation **("**scums") may form on lakes, ponds, and impoundments as a result of high nutrient concentrations. These scums may be due to floating, non-rooted macrophytes such as duckweed (*Lemna* sp. or *Wolfia* sp.) or may be due to algal scums formed by either green algae or bluegreen algae (cyanobacteria) or some combination of the above. Impairment may be aesthetic or recreational, if for example, the lake is oligotrophic or mesotrophic, and duckweed cover is not expected nor desired. Some waterfowl such as ducks and geese use naturally eutrophic ponds, impoundments and wetlands as important feeding sites, and as such, the presence of duckweed or patches of floating algae on such waters is not necessarily an impairment.

Dense continuous (100 percent) cover of duckweed is known to inhibit the growth of algae and submersed plants and may result in anoxia (Wolverton, 1986; Landolt 1986, cited in Ozbay, 2002; Leng et al., 1995). The minimum percent oxygen saturation in waters is known to be correlated negatively with percent cover of floating unattached plants and one study (Gee et al., 1997) suggests a coverage of 25% or less is associated with relatively high oxygen saturation. Impairment to aquatic life support may occur if the scum significantly inhibits oxygen exchange across the water surface and results in low dissolved oxygen.

MassDEP Guideline: to support the designated uses of recreation and aesthetics, if non-rooted vegetation exceeds 25% surface coverage in more than one site visit within the index period April 1-October 31, it is considered an indicator of nutrient enrichment.

Note: Impairment of uses may occur at levels lower than 25 percent coverage if the lake is a coldwater fishery (typically oligotrophic), or if swimming is impaired or if the scum consists of toxic bluegreen algae (cyanobacteria) in which case the waterbody could be considered impaired under the existing narrative standard. In the case of cyanobacteria blooms, swimming and contact recreation may be impaired if surface scum is present in the area of contact. The aesthetic screening guideline may be exceeded in some site-specific cases where duckweed accumulates on the downwind shorelines.

(3) Plankton as water column Chlorophyll-*a*

Chlorophyll-*a* is a commonly used indicator of algal biomass. The uses impaired by high chlorophyll-*a* (a measure of algal biomass) in the water column are likely to be swimming, aesthetics and biotic integrity. Unlike other uses, assessment of biotic integrity depends on the natural trophic conditions expected in the lake, and Massachusetts has a wide range of natural trophic conditions ranging from oligotrophic to eutrophic.

According to the general trophic classification, eutrophic lakes have mean chlorophyll-*a* of 14.3 µg/l and maxima of 42.6 µg/l, while mesotrophic lakes are expected to have chlorophyll-*a* maxima of 16.1 µg/l according to experienced investigators (Wetzel 2001). A threshold of 16 µg/l is proposed as an upper boundary for Massachusetts lakes as this would agree with typical eutrophic lakes and also roughly correspond to the Secchi disk transparency threshold of 1.2 m noted above.

The proposed threshold is higher than the 2.43-2.90 µg/l proposed by the cumulative frequency approach of the USEPA (see Table 5).

Table 5

Summary USEPA Statistically-Derived Chlorophyll-*a* Criteria for Massachusetts By Ecoregion and Waterbody Type (USEPA 2000a,b,c,d; 2001a,b).

Parameter	**USEPA Ecoregion VIII* Western Massachusetts**	**USEPA Ecoregion XIV* Central & Eastern Massachusetts**
Lakes and Impoundments		
Chlorophyll-*a* (µg/l) (planktonic)	2.43	2.90
*All values based on 25th percentile all data		

While such low chlorophyll concentrations may be applicable to oligotrophic lakes (see Table 13-18 in Wetzel, 2001), they are not appropriate as a limit to maintain designated uses in shallow water impoundments commonly found in Massachusetts. The designated uses in Massachusetts include warm water fisheries that are inconsistent with such low chlorophyll-*a* levels. Future studies are planned to evaluate thresholds that may be needed for oligotrophic waters.

MA Guideline: to support the designated uses of recreation and aesthetics, if planktonic chlorophyll-a exceeds 16 µg/l in surface waters in more than one site visit within the index period April 1-October 31, it is considered an indicator of nutrient enrichment.

(4) Dissolved Oxygen Saturation

See 3.2(a)(4) for discussion of DO Saturation.

MassDEP Guideline: to support the designated use of aquatic life, a dissolved oxygen saturation exceeding 125% in more than one site visit during the summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(5) Elevated pH

See 3.2(a)(5) for discussion of pH.

MassDEP Guideline: to support the designated uses of recreation and aquatic life, a pH of >8.3 SU in more than one site visit during the summer growing season (April 1 to October 31) is considered an indicator of nutrient enrichment.

(6) Elevated Total Phosphorus (TP)

Phytoplankton blooms can occur in lakes having concentration as low as 0.01 mg/l TP (Gower 1980). Relatively uncontaminated lake districts contain water with TP concentrations ranging from .01-.03 mg/l (Hutchinson, G.E. 1957). More recently, EPA guidance states that there is a general consensus that an ambient TP concentration of greater than 0.01 mg/l is likely to predict blue-green algal bloom problems during the growing season; however, because both soil enrichment and precipitation are variable across the U.S., EPA has taken an Ecoregion frequency approach to the TP criterion (USEPA 2000b). EPA recommends a TP criterion of 0.008 mg/l for lakes in both of the Massachusetts Ecoregions.

However, because many biological, chemical and physical characteristics influence whether a lake responds to certain levels of TP, MassDEP uses phosphorus concentrations as a confirming measurement when the weight of evidence points to nutrient enrichment. Specifically, when multiple biological and physico-chemical nutrient enrichment indicator thresholds are exceeded, then the seasonal average (greater than three samples) of the TP concentration data are screened against the 1986a EPA recommended “Gold Book” TP concentrations. As noted in the Gold Book, for prevention of primary producer over-abundance in lakes, it is recommended that TP be maintained at 0.025 mg/l (EPA 1986a).

MassDEP Guideline: When multiple biological and physico-chemical nutrient enrichment indicator screening guidelines are exceeded, if the seasonal average for TP exceeds 0.025 mg/l for lakes, ponds and impoundments during the summer growing season (April 1 to October 31), it is considered additional confirmation of nutrient enrichment.

(6) Frequency and duration of Cyanobacteria Blooms

See discussion of cyanobacteria blooms in section 3.2(b)(6).

MassDEP Guideline: to support the designated uses of aquatic life, recreation and aesthetics, a surface water containing cyanobacteria at levels where the MDPH issues an advisory (i.e., a cell count of 70,000 cells/mL or more, corresponding to a toxin level of approximately 14 ppb) generally more than once during the summer growing season (April 1 to October 31) it is considered an indicator of nutrient enrichment.

<u>4.0 Potential Future Data and Indicators not used in the 2016 CALM:</u>

MassDEP used in-house data and that collected by the USGS and the Cape Cod Commission (CCC), to generate a lakes and impoundment data set consisting of 211 locations sampled between 1999-2004. Data were collected during the summer index period beginning in mid-June and ending in mid-September. MassDEP is currently undertaking a detailed evaluation of the data, potentially applying it in the future to re-evaluate its water quality nutrient enrichment screening guidelines to increase their specificity to waterbody type (MassDEP 2012a).

Guidelines for rooted aquatic plants as nutrient enrichment indicators were not developed. This is because the relationship between nutrients and plant abundance and biomass is influenced by many factors, some of which are natural. A key influence on the growth rate of rooted aquatic plants is the nutrient content in bottom sediments rather than the water column. As a result, rooted aquatics do not respond readily to fluctuation of phosphorus concentrations in the water column.

Secondary variables and response indicators that were considered but not included in the literature review were turbidity and predawn dissolved oxygen (DO). In addition, confounding variables such as canopy, flow, depth, hydrology and color, should be considered in the sub-classification of waters. Trout space is a cold water characteristic for lakes, ponds, and impoundments that is monitored by MassDEP in selected waterbodies. MassDEP is developing physical and chemical thresholds for the management of lakes that may be designated as cold water in the future. In these lakes MassDEP may recommend the maintenance of a minimum depth of trout space, level of dissolved oxygen and a maximum temperature.

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Appendix D Derivation of Temperature and Dissolved Oxygen (DO) Assessment Criteria for use in MassDEP/WPP 305b Assessments

Memorandum for the Record

By:	Gerald M. Szal, Aquatic Ecologist, Surface Water Quality Standards Section, MassDEP, Watershed Planning Program (WPP), Worcester, MA
Date:	September 16, 2015
Subject:	**Derivation of Temperature and Dissolved Oxygen (DO) Assessment Criteria for use in MassDEP/WPP 305b Assessments**

Background: At this point in time there has been so much research on the effects of temperature and dissolved oxygen (DO) on aquatic organisms that it is "common knowledge" that these two variables play vital roles in determining the distribution of aquatic life in surface waters. Researchers have found that not only are there certain fish that need cold, well-oxygenated water to successfully move through their lifecycle, but other organisms also require these conditions. The latter includes certain macroinvertebrates. Although the documentation for this group is not as voluminous, it is building and others developing criteria for DO and temperature in the future should ensure that they familiarize themselves with this literature. Because there is so much research available for fish, this memo primarily utilizes that body of research.

In the past, temperature and DO criteria listed in the MA Surface Water Quality Standards (SWQS: 314 CMR 4.00) were used by WPP in 305b Assessments to evaluate impairment. These criteria were established during a time when sampling equipment for these variables was limited to hand-held thermometers and bottles. Technological advances now allow for the deployment of measurement and recording equipment that can provide DO and temperature measurements many times per hour, can be left in place for months and the information can be downloaded from this equipment at the end of the deployment period, although it is important to verify that the equipment was submerged during the deployment. Information from these devices provides analysts with a fairly "continuous" dataset over an entire sampling season that allows for an evaluation of magnitude, duration and frequency of high-temperature and low-oxygen events, both of which can be detrimental to aquatic life.

The Assessment Criteria for DO and temperature are, in some cases, different than the criteria in 314 CMR 4.00. New, longer-term datasets allow WPP staff to evaluate both acute (short-term) and chronic (longer-term) toxic events. The current SWQS criteria for these two variables are, in most cases, inadequate for this task. New criteria are needed to allow for such assessments.

The assessment criteria presented in this document were vetted by a group of WPP staff that met on a regular basis to review and improve the Consolidated Assessment and Listing Methods (CALM) used to conduct 305b assessments. This group consisted of Christine Duerring, Kimberly Groff, Arthur Johnson, Laurie Kennedy, Richard McVoy and me. This group is referred to as the CALM Committee in the discussion below. We were assisted with specific tasks by Dan Davis, Robert Maietta and James Meek.

Cold Water Temperature Criteria

Regulatory Considerations: There is a range of tolerance with regard to increasing summertime water temperatures among the different fish species considered to be "cold water fish". The MA Dept. of Fish and Game has a list of cold water fish that it uses to develop its "cold water fishery resources", a list of streams considered by that agency to be important surface-water resources for cold water fisheries. The surface waters on that list that are not already designated as "Cold Water" in 314 CMR 4.00 are protected as cold water "Existing Uses" (see the definitions of Cold Water Fishery and Existing Uses at 314 CMR 4.02 and the description of Cold Water at 314 CMR 4.06 (1)(d) 7). The protection of Cold Water Existing Uses extends to both the populations of fish found in those waters *as well as the protection of their habitat*. Thus, there does not need to be any determination that a population has deteriorated over time, only that the habitat does not meet criteria needed to support a Cold Water Fishery. If fish have to move from that habitat, the habitat would only meet a "partial use" as cold water habitat. These habitats would be considered to be degraded for the Cold Water Use. The same applies to "designated" (i.e., under 314 CMR 4.00) Cold Water surface waters. Moreover, *any* surface water that has held a population of cold water fish at any time since November 28, 1975, *even if that population has been extirpated since that time*, is protected as a Cold Water Existing Use under 314 CMR 4.00.

As a result of the considerations above, those conducting 305b Assessments needed to consult:

1. GIS maps provided by Mass Fish and Game that depicted cold water fishery resources;
2. Tables 1-27 in the 314 CMR 4.00 which list and describe streams designated as Cold Water; and
3. fish sampling data from collections made on or after November 28, 1975

to determine which waterbodies should undergo 305b Assessments for Tier 1 and Tier 2 Cold Water fish as described below. The reader should know also that both cold water fishery resources and designated Cold Waters receive protection under the stormwater section of 310 CMR 10.0 (the MA Wetlands Protection Act: see definitions for Cold Water Fisheries and Critical Areas in section 10.04 of that Act). Because so many cold water streams have been lost due to:

a) dams which slow water velocity and widen streams allowing for much greater solar input per unit of stream volume and per mile of stream length;
b) agricultural practices which remove shade from streamsides;
c) non-point runoff from impervious surfaces such as roads, parking lots, roofs and other surfaces impervious to rain which introduce heated water during rain events; and
d) point discharges,

much of the focus in developing temperature criteria for streams is the protection and restoration of existing Cold Waters . High temperature events considered to be "natural" (e.g., those resulting from the damming of waters caused by beaver activities) are not considered to be "impairments".

Tier 1 and Tier 2 Cold Water Fish: The CALM Committee developed different Temperature Assessment Criteria for each of two different groups of cold water fish. Because the Cold Water classification in 314 CMR 4.00 only applies to streams and rivers but not to lakes or ponds, we considered only the *fluvial* cold water fish species and assigned these to one of the following two categories based on their tolerance to high-temperature events:

Tier 1 cold water fish: brook trout (*Salvelinus fontinalis*); and slimy sculpin (*Cottus cognatus*); these are fluvial cold water fish species that need the coldest summertime temperatures for survival;

Tier 2 cold water fish: brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*) and all other species classified by MassDFG as cold water fish; these fish can survive slightly warmer temperatures than brook trout and slimy sculpin but still need cold summertime temperatures for survival.

A procedure for determining which MA-designated Cold Water streams and Existing Use Cold Water streams (further defined in the CALM) would be considered Tier 1 and Tier 2 was developed by the CALM Committee. Basically, if we had fish-community information from any stream to demonstrate that at some time after the Clean Water Act "Existing Use" clause took effect (i.e., after November 28, 1975) there were reproducing brook trout and/or slimy sculpin at the site in question, the site became a Tier 1 designated (if already designated as Cold Water in the SWQS) or Existing Cold Water Use stream. All other streams where there was evidence of reproducing cold water fish of any species other than brook trout or slimy sculpin were considered to be Tier 2 designated (if already designated as Cold Water in the SWQS) or Existing Cold Water Use streams. Streams were assessed according to the assessment criteria in the category into which they fell.

Acute and chronic assessment criteria, used to evaluate thermal habitat impairment, were developed for the two tiers of cold water fish and are discussed below. To calculate the acute criteria, I used formulae developed by EPA (1977) and listed by species in Appendix B (Thermal Tables) of that document. EPA's basic formula for the TL50 (50% kill of exposed organisms) is:

Log10(time in minutes) = a +b (Temperature as °C)

Where: **a** and **b** are constants (provided in the 1977 document referenced above, that were derived from multiple toxicity tests on the organism in question); and

Temperature (as °C) is the temperature that will kill 50% of the organisms exposed for the **time in minutes** listed.

The time estimates in minutes provided for each TL50 apply only to the particular Acclimation Temperature chosen, and EPA warns that its species-specific formulae in Appendix B should only be used within the

Temperature Data Limits listed (in EPA, 1977) for those species. EPA based its acute toxicity formulae on laboratory toxicity tests in which fish were first acclimated to a certain temperature and then stressed with higher temperatures. The 24- hr. (i.e., 24-hr. exposure) No Effect Level (NOEL, i.e., just below the point where toxicity is expected) was estimated by subtracting 2°C from the approximate 24-hr. TL50 as recommended by EPA (1977).

In developing the cold-water chronic criteria EPA (1977) looked at growth of exposed fish and compared this growth to fish kept at optimal-growth temperatures. We used EPA's results and other information for the chronic criteria below.

Tier 1 Acute Criterion = 23.5°C as a 24-hr. average not to be exceeded: This criterion was taken from data and formulae relating to brook trout (from a hatchery in PA) in EPA (1977). Exposures to temperature/duration combinations beyond those specified by this criterion are expected to be toxic to juvenile brook trout. As a result, even a one-time occurrence of this criterion should result in a judgment of "impairment" to cold water habitat in 305b assessments if the high-temperature event is thought to be due to un-natural (i.e., anthropogenic) sources.

Tier 1 Chronic Criterion = **20°C as a 7-day average of the daily maximum temperatures (allowable exceedances ≤11)**. This criterion is the same as the criterion for Cold Water found in 314 CMR 4.00 and applies to Tier 1 cold water habitat unless the high-temperature events are deemed to be due to natural causes. The number of allowable exceedances was based on considerations outlined below.

The MA SWQS uses the following phrase to define the temperature regime for Cold Water:

> *Cold Water Fishery. Waters in which the mean of the maximum daily temperature over a seven day period generally does not exceed 68°F (20°C) and, when other ecological factors are favorable (such as habitat), are capable of supporting a year-round population of cold water stenothermal aquatic life such as trout (salmonidae).*

Note the term "generally". This term implies that a Cold Water Fishery does not *always* have to meet the 20°C maximum. The CALM group reviewed how other states handled assessment data relative to their SWQS criteria. Many of those reviewed allow 10% exceedances of their criterion prior to making a judgment of "impaired". This approach would make little sense with reference to temperature, however, if the analyst were to review data for an entire year, and the CALM Committee had to determine what period of time was reasonable to evaluate in assessing impairment. We reviewed our long-term temperature datasets from a subset of streams considered to be high-quality Cold Water streams (based on fish population surveys) and found that if exceedances occurred, they primarily took place in July and August but some also occurred in early June and into the first couple of weeks in September. Based on this information, we decided to calculate 7-day rolling average temperatures (one for each 7-day period: i.e., day 1-7, day 2-8, day 3-9, etc.) for each 7-day period over the June 1-Sept. 15 time period and to use a 10% exceedance threshold for making impairment decisions. This threshold (and, for that matter, all the thresholds described in this document) may change in the future based on new information and/or new considerations.

Tier 2 Acute Criterion = 24.1°C as a 24-hr. average not to be exceeded: Based on our literature review, brown trout (*Salmo trutta*) is the fish species that is the most sensitive to high water temperatures of all the fluvial cold water fishes in MA exclusive of brook trout and slimy sculpin. Although brown trout are not native to Massachusetts, and stocking of streams with brown trout by MA Fish and Game is controversial for this reason, they have become important to fishermen in MA and are one of the species used by MA Fish and Game to delimit its "cold water fishery resources". The acute criterion listed above was developed from EPA (1977) as described above using that document's formula for 24-hr. acute toxicity to brown trout at an acclimation temperature of 20°C. Any temperature/duration exposures in combinations greater than the 24.1°C value as a 24-hr. average are expected to be acutely toxic to brown trout. As a result, even a one-time occurrence of this criterion should result in a judgment of "impairment" to Tier 2 cold water fish habitat in 305b assessments if the high temperature event is considered to be due to un-natural (i.e., anthropogenic) sources.

Tier 2 Chronic Criterion = 21.0°C as a 7-day average of the daily average temperatures; allowable exceedances ≤11. This criterion was based on best-professional judgment after a review of EPA 1973, EPA 1977 and an un-published collection of published literature values used by the state of Colorado in setting their criteria for Tier II Cold Water Streams. The allowable number of exceedances of this criterion was based on the ideas expressed for the Tier 1 Chronic Criterion. As with other criteria, the assessment of "impairment" only applies when the high temperature events are considered to be due to non-natural causes.

Warm Water Temperature Criteria

The CALM committee reviewed thermal toxicity information for five fluvial fish species found in MA: common shiner (*Luxilus cornutus*), long-nose dace (*Rhinichtys cataractae)*, creek chubsucker (*Erimyzon oblongus*), redfin pickerel (*Esox americanus americanus*) and white sucker (*Catostomus comersoni*). Based on literature reviewed, white sucker is the most thermally-sensitive fluvial fish species of those above. None of these fish species is listed as a cold water species by MA Fish and Game. By default these species fall into the warm water fish category. White suckers are a native species and are fairly ubiquitous in Massachusetts. We set our criteria to be protective of this species. As more thermal-toxicity information becomes available for other MA fluvial fish not found to be cold water species, WPP should review that information to ensure that the criteria developed using this species are protective for other fluvial warm-water species in MA.

Acute Criterion = 28.3°C as a 24-hr. average not to be exceeded: This criterion was developed using the EPA (1977) formula and an acclimation temperature of 25°C. Based on these specifications, an NOAEL of 28.4 would have resulted from a 23-hour exposure, so we subtracted 0.1°C from that value to yield an approximate NOAEL for a 24-hr. exposure. As with the other acute criteria described above, even one-time exposures to temperature/duration combinations above this criterion are expected to result in acute toxicity to adult white suckers and should result in a judgment of "impairment" in 305b assessments of warm-water streams if the high-temperature event is judged to be due to un-natural (i.e., anthropogenic) causes.

Chronic Criterion = 27.7°C as a 7-day average of the daily maximum temperatures (allowable exceedances = ≤11. EPA (1977) provides a maximum weekly average temperature value of 27.8°C for white sucker. The state of Colorado (unpublished) provided a number of additional references beyond that of EPA and arrived at a temperature of 27.7°C for a maximum weekly average temperature which we chose for this application. The number of allowable exceedances was based on considerations outlined in the Tier 1 cold water chronic criterion discussion.

Dissolved Oxygen (DO) Criteria

Tables 1 and 2 and text from EPA's 1986 water quality criteria document (section on dissolved oxygen, EPA, 1986) were used to develop DO-assessment criteria for MA streams. The 2016 CALM assessment criteria for DO are listed below:

	Cold Water Criteria	**Warm Water Criteria**	
	Other Life Stages	Early Life Stages* (assume present through July in MA coastal streams)	Other Life Stages
30 Day Mean	8.0	NA	6.0
7 Day Mean	NA**	6.5	NA
7 Day Mean Minimum	6.0	NA	5.0
1 Day Minimum***	5.0	5.0	4.0

* anadromous fish runs present
**NA (not applicable)
***All minima should be considered as instantaneous concentrations to be achieved at all times.

Oxygen saturation in water varies with temperature and high temperature events in streams typically result in low oxygen concentrations. Because of this link between these two variables, the CALM committee decided to use the June 1- Sept. 15 index period for evaluating low DO in streams as this was the period found most likely to result in high temperature events. EPA (1986) reviewed information from "early life stages" (i.e., eggs and larvae) of fish and from "other life stages" (i.e., juveniles and adults) and developed criteria for each. Eggs and larvae of brown trout, rainbow trout and brook trout are not typically found in MA streams over the June-Sept. 15 period. As a result, cold water DO criteria for "early life stages" were not developed for the cold water DO assessment criteria. In the future, WPP should review egg/larval seasonal presence for other species besides those mentioned to ensure that cold water criteria should not also be considered for early life stages in the summer months. The term "production impairment" used in text below, the studies that were used to develop this term and the DO values associated with it are described fully in EPA 1986a.

Cold Water Criteria

A 30-day mean of 8.0 mg/l for "other life stages" (i.e., life stages other than early life stages) was chosen after considering the information in EPA's (1986) Table 2 which notes that both salmonids and invertebrates had "no production impairment" at DO levels of 8.0 mg/l and above. The CALM committee also reviewed DO information from streams in the Deerfield River Basin, which contains many cold water streams known to produce fairly high-quality fish and invertebrate samples. Long-term DO concentrations from cold water streams in that basin rarely fell below 8.0 mg/l.

The 7-day mean minimum (mean of each day's minimum DO value) criterion **for "other life stages"** (see above) chosen **was 6.0 mg/l**. Invertebrates showed some production impairment at a DO of 5 mg/l and none at DO of 8 mg/l; salmonids were not impaired at a DO near 8 mg/l and showed "moderate production impairment" at a DO around 5 mg/l or less. Unpublished information from MA fish population records showed that the highest densities of cold water fish were typically found in water with DO values >6 mg/l.

A 1-day minimum criterion of 5 mg/l was chosen **for "other life stages"** (see above) based EPA's (1986) use of this figure in Table 1 and on information in Table 2 of that document. Table 2 (EPA, 1986) notes that "some" production impairment of invertebrates" and "moderate" production impairment of salmonids" were found at DO values around 5 mg/l.

Warm Water Criteria

Early life stages of certain warm water fish are found during the June 1-Sept. 15 period prompting the need to develop DO assessment criteria for both "early" and "other" life stages.

The 7-day mean for early life stages of warmwater fish chosen for a criterion **is 6.5 mg/l**. This is slightly higher than the criterion (6.0 mg/l) recommended by EPA (Table 1; EPA, 1986). EPA's Table 2 lists "no production impairment" at DO near 6.5 mg/l. EPA did not have a recommendation for the 30-day mean category for early life stage warmwater fish, and the CALM committee felt that, absent any 30-day average recommendation from that agency, at least one of the criteria categories should reflect a "no impairment" status.

A 1-day minimum for early, warmwater life stages of 5 mg/l is the same as that in EPA's Table 1 (EPA, 1986) for this category. Moderate production was found at DO levels around 5 mg/l and below and slight production impairment was found at DO values around 5.5 mg/l. "Some" production impairment to invertebrates was found at DO values near 5 mg/l.

A 30-day mean criterion for "other" life stages of warmwater fish of 6.0 mg/l is 0.5 mg/l higher than that in EPA's Table 1 (EPA, 1986) for this category. We chose this value to correspond to a "no production impairment" value (as we had for the cold water 30-day mean criterion) which is supported by EPA's Table 2 (EPA, 1986) recommendation for this category.

A 7-day mean minimum criterion for "other life stages" of warmwater fish of 5.0 mg/l is 1.0 mg/l higher than EPA's recommendation. EPA's Table 2 (EPA, 1986) shows "slight" production impairment to "other life stages" of warmwater fish at DO values near 5.0 mg/l and "some" production impairment to invertebrates at DO values near 5.0 mg/l. EPA's recommendation of 4.0 mg/l for this category appeared to be much too low to the CALM Committee as it was listed as the "Acute Mortality Limit" for invertebrates in EPA's Table 2.

The 1-day minimum value for warmwater fish of "other life stages" is 4.0 mg/l. EPA (Table 2, EPA 1986) found "moderate production impairment" to warmwater fish of "other life stages" at this DO concentration and, as mentioned above, this is the Acute Mortality Limit (EPA, 1986, Table 2) for invertebrates.

Literature Citations:

EPA. 1973. Ecological Research Series; Water Quality Criteria, 1972. EPA/R3/73/033/March 1973.

EPA. 1977. Temperature Criteria for Freshwater Fish: Protocol and Procedures. EPA600/3-77-061. May 1977.

EPA. 1986. Quality Criteria for Water. EPA 440/5-86-001. May 1, 1986.

EPA. 1986a. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003. April 1986.

Appendix E Metals data comparisons to water quality criteria

There are a few notes to keep in mind related to the Toxic Metals.
The following definitions are given by EPA for their Criteria Maximum Concentration and Criterion Continuous Concentration:

- ***The Criteria Maximum Concentration (CMC)*** *is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect.*
- ***The Criterion Continuous Concentration (CCC)*** *is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect.*

The CMC and CCC are just two of the six parts of an aquatic life criterion; the other four parts include the following:

- *acute averaging period,*
- *chronic averaging period,*
- *acute frequency of allowed exceedance, and*
- *chronic frequency of allowed exceedance.*

Because 304(a) aquatic life criteria are national guidance, they are intended to be protective of the vast majority of the aquatic communities in the United States.

WPP analysts use an Excel spreadsheet (CN101.6 SOP_MetalsCriteriaCalculations.xls February 2017) with embedded formulas to calculate hardness-dependent criteria for certain metals. These formulas, where applicable, and conversion factors used to calculate total-to-dissolved criteria are provided in Table E1 below. Formulas for conversion factors that are hardness dependent are also included in Table 1. For metals with criteria expressed as total, both the total criteria and the estimated dissolved criteria are provided. For illustrative purposes only a hardness of 10 mg/l was used to calculate the hardness dependent criteria in Table 1 below. Sample-specific hardness data are used to calculate the actual CMC and CCC criteria.

Toxic Units (TUs) are developed using the ratio of the pollutant concentration to the calculated criterion. The TU calculation also provides the relative magnitude of the exceedance, which together with frequency and duration of exceedances, are important factors in evaluating toxicants.

Site-specific copper criteria (acute 25.7 µg/L, chronic 18.1 µg/) have been approved by EPA in the SWQS for certain waterbody segments (see Table E2). Where copper exceedances (i.e., TUs >1) have been calculated in these waters, concentration data will be compared directly to the EPA approved site-specific copper criteria prior to making an impairment decision.

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Table E1. Freshwater Metals Aquatic Life Criteria (as dissolved fraction, unless otherwise stated)[1] (for illustrative purposes only criteria shown at a hardness of 10 mg/l as $CaCO_3$)					Use best-available hardness data (no lower limit)		HARDNESS (mg/l as CaCO3)=	2.497*Ca + 4.118*Mg
Feb-17	*italics = not hardness dependent*				HARDNESS max=400		*Example:*	**Where Ca (mg/l) = 1.9 and Mg (mg/l) = 1.2**
via USEPA "National Recommended Water Quality Criteria--Correction (EPA 822-Z-99-001), April, 1999; and subsequent updates							**HARDNESS=**	9.8
Step1: Enter Hardness value		Step 2: Use calculated CMC and CCC values						
Metal	**Enter Hardness**	CMC (Criterion Maximum Concentration) Hardness dependent formulas	CMC Conversion Factor (CF) necessary for total-to-dissolved criterion	CMC (Criterion Maximum Concentration), µg/l	CCC (Criterion Continuous Concentration) Hardness dependent formulas	CCC Conversion Factor (CF) necessary for total-to-dissolved criterion	CCC (Criterion Continuous Concentration), µg/l	notes
	mg/l as CaCO3			*Acute (1 hour average not to be exceeded more than once in three years on the average unless otherwise noted)*			*Chronic (4-day average not to be exceeded more than once in three years on the average unless otherwise noted)*	
Cadmium	10	(EXP(1.0166* LN(Hardness)-3.924))	(1.136672-LN(Hardness)*0.041838)	**0.21 (24 hour average)**	(EXP(0.7409*LN(Hardness)-4.719))	(1.101672-LN(Hardness)*0.041838)	**0.05**	The hardness dependent formulas used here and for the 2018 reporting cycle are based on the 2001 criteria not the updated 2016 revised criteria Link to the 2016 updated freshwater and marine criteria for information only can be found here: https://www.epa.gov/sites/production/files/2016-03/documents/cadmium-final-report-2016.pdf
Chromium III	10	EXP((LN(Hardness))*(0.819)+3.7256)	0.316	**86.44**	EXP((LN(Hardness))*(0.819)+0.6848)	0.86	**11.24**	
Copper[2]	10	EXP((LN(Hardness))*(0.9422)-1.7)	0.96	**1.54**	EXP((LN(Hardness))*(0.8545)-1.702)	0.96	**1.25**	The hardness dependent formulas used here and for the 2018 reporting cycle are based on the 1995 updated copper criteria. EPA's 2007 criteria revision recommends use of Biotic Ligand Model (BLM). The BLM will only be used if all 10 inputs (see [2]below) are available. Link to the 2007 recommended freshwater copper criteria: https://nepis.epa.gov/Exe/ZyPDF.cgi/P1000PXC.PDF?Dockey=P1000PXC.PDF
Lead	10	(EXP((LN(Hardness))*(1.273)-1.46))	(1.46203-(LN(Hardness)*0.145712))	**4.91**	EXP((LN(Hardness))*(1.273)-4.705)	(1.46203-(LN(Hardness)*0.145712))	**0.19**	
Nickel	10	EXP((LN(Hardness))*(0.846)+2.255)	0.998	**66.75**	EXP((LN(Hardness))*(0.846)+0.0584)	0.997	**7.41**	CMC=470 @100hardness (EPA)
Silver	10	EXP((LN(Hardness))*(1.72)-6.59)	0.85	**0.06**	*NA*	NA	**NA**	
Zinc	10	EXP((LN(Hardness))*(0.8473)+0.884)	0.978	**16.66**	EXP((LN(Hardness))*(0.8473)+0.884)	0.986	**16.79**	CMC and CCC=120 @100hardness (EPA)
Arsenic (as total)	*NA*	*NA*	*1.000*	***340 (total) 340 (dissolved)***	*NA*	*1.000*	***150 (total) 150 (dissolved)***	To compare dissolved data to criteria expressed as total, total criteria must be converted to dissolved criteria using the CF
Mercury (as total)	*NA*	*NA*	*0.850*	***1.694 (total) 1.4 (dissolved)***	*NA*	*0.850*	***0.9081 (total) 0.77 (dissolved)***	To compare dissolved data to criteria expressed as total, total criteria must be converted to dissolved criteria using the CF
Chromium VI	*NA*	*NA*	*0.982*	***16***	*NA*	*0.962*	***11***	Compare dissolved data directly to the dissolved criteria
Selenium (as total)[3]	*NA*	*NA*	*NA*	***NA***	*NA*	*0.922*	***5 (total) 4.61 (dissolved)***	Criterion is total recoverable selenium; using CF from Great Lakes Initiative to convert this criterion to dissolved form is acceptable (EPA 2002). Link to the 2016 updated freshwater criteria for information only can be found here: *https://www.epa.gov/sites/production/files/2016-07/documents/aquatic_life_awqc_for_selenium_-_freshwater_2016.pdf*

[1] EPA has issued draft recommended freshwater aluminum criteria that use dissolved organic carbon (DOC), pH, and hardness as inputs to a multiple linear regression (MLR) model. DOC, pH, and hardness can all affect aluminum toxicity and the MLR model normalizes these input parameters to derive aluminum criteria based on site chemistry. The tables provided in the draft document, and the associated EPA Aluminum Calculator available for download, indicate that aluminum criteria calculated using the MLR model can increase significantly above the current acute (750 ug/L) and chronic (87 ug/L) criteria, depending on site chemistry. MassDEP, working with USGS, is currently evaluating the effect of DOC concentrations (6 and 10 mg/L), hardness (20 and 35 mg/L as CaCO3), and pH (6 SU) in an initial aluminum toxicity study. MassDEP has also collected information demonstrating that natural background aluminum concentrations may exceed the chronic ambient water quality criterion (87 ug/L). For these reasons regarding both the applicability of the current aluminum criteria and the implications of the proposed criteria, no evaluations will be made for aluminum for this reporting cycle.

[2] The ten freshwater copper BLM input values (temperature, pH, dissolved organic carbon, alkalinity, calcium, magnesium, sodium, potassium, chloride and sulfate), as specified in section 3.2 of EPA-822-R-07-001, shall be considered as an input parameter dataset that ideally consists of concurrently measured water chemistry data.

[3] For the selenium acute criteria, the equation to calculate the CMC requires that both fractions be measured (selenate and selenite). Since these fraction data are neither available nor advised, no evaluations of acute selenium toxicity will be made as part of 2018 reporting cycle. Use of the water column chronic criteria for selenium should be used with caution.

Table E2. EPA-Approved Site-Specific Copper Criteria in the SWQS: acute 25.7 µg/L, chronic 18.1 µg/L

Watershed	Waterbody Name	Waterbody description
BLACKSTONE RIVER BASIN	Blackstone River	From the Upper Blackstone POTW discharge to the MA-RI state line (river mile 45.2 to 20.0)
	Mumford River	From the Douglas POTW discharge to confluence with the Blackstone River (river mile 9.0 to 0.0)
	West River	From the Upton POTW discharge to confluence with Blackstone River (river mile 8.8 to 0.0)
BUZZARDS BAY COASTAL DRAINAGE AREA	Unnamed Brook	River mile 0.75 to 0.0 (confluence with Aucoot Cove)
CHARLES RIVER BASIN	Charles River	From the Milford POTW discharge to the Watertown Dam (river mile 73.4 to 9.8)
	Stop River	From MCI-Norfolk Water Pollution Control Facility discharge to confluence with Charles River (river mile 4.4 to 0.0)
CONNECTICUT RIVER BASIN	Bachelor Brook	River mile 12.4 to 0.0 (confluence with Connecticut River)
FRENCH RIVER BASIN	French River	River mile 27.3 to 7.0 (MA-CT state line)
HUDSON RIVER BASIN	Hoosic River (South Branch Hoosic River)	From Adams POTW discharge to confluence with the North Branch Hoosic River (river mile 15.4 to 10.3)
HOUSATONIC RIVER BASIN	Housatonic River	From Pittsfield POTW discharge to the MA-CT state line (river mile 50.9 to 0.0)
IPSWICH RIVER BASIN	Unnamed tributary (Greenwood Creek)	From Ipswich POTW discharge to confluence with the Ipswich River (river mile 0.7 to 0.0)
NASHUA RIVER BASIN	North Branch, Nashua River	River mile 36.5 to 0.0 (confluence with the Nashua River)
	Nashua River (South Branch)	River mile 3.3 to 0.0 (confluence with the Nashua River)
QUINEBAUG RIVER BASIN	Cady Brook	From the Charlton POTW discharge to confluence with the Quinebaug River (river mile 5.1 to 0.0)
	Quinebaug River	River mile 19.7 to 7.9 (MA-CT state line)
SOUTH COASTAL DRAINAGE AREA	French Stream	River mile 19.0 to 15.7 (confluence with the Drinkwater River)
SUASCO RIVER BASIN	Assabet River	River mile 30.4 to 0.0 (confluence with the Sudbury River)
TAUNTON RIVER BASIN	Nemasket River	River mile 5.5 to 0.0 (confluence with Taunton River)
	Salisbury Plain	River mile 2.0 to 0.0 (confluence with Taunton River)
	Three Mile River	River mile 6.0 to 0.0 (confluence with Mill River)
	Town River	River mile 2.2 to 0.0 (confluence with Taunton River)
TEN MILE RIVER BASIN	Ten Mile River	River mile 14.0 to 0.0 (MA-RI state line)
WESTFIELD RIVER BASIN	Westfield River	River mile 10.8 to 0.0 (confluence with Connecticut River)

References:

EPA. 2002. *National Recommended Water Quality Criteria: 2002*. EPA-822-R-02-047. November 2002. USEPA Office of Water and Office of Science and Technology. Washington, DC.

Appendix F Development of a Linear Regression Tool for Estimating Chloride Concentrations in Freshwaters of Massachusetts

Summary:
For assessment purposes and to better determine the potential for chloride impairments in fresh surface waters, a linear regression model was developed to estimate chloride concentrations from Specific Conductance (SC) measurements. The model development dataset was developed using 2426 paired chloride and SC data points generated by the Massachusetts Department of Environmental Protection (MassDEP) from 1994 to 2012 at 244 inland stream and river stations across Massachusetts (Figure F1). Model validation was conducted using the USEPA Auburn Project study data (N=37) collected during winter of 2013-2014 (Heath 2014), the MassDEP River Meadow Brook study data (N=54) collected between October 2015 and September 2016, and additional data (N = 96) collected by MassDEP staff from streams and rivers in western Massachusetts in 2013-2014.

The equation for estimating chloride concentrations is:

***Y*=0.2753*X* – 18.987**, where *Y* is chloride concentration and *X* is specific conductance.

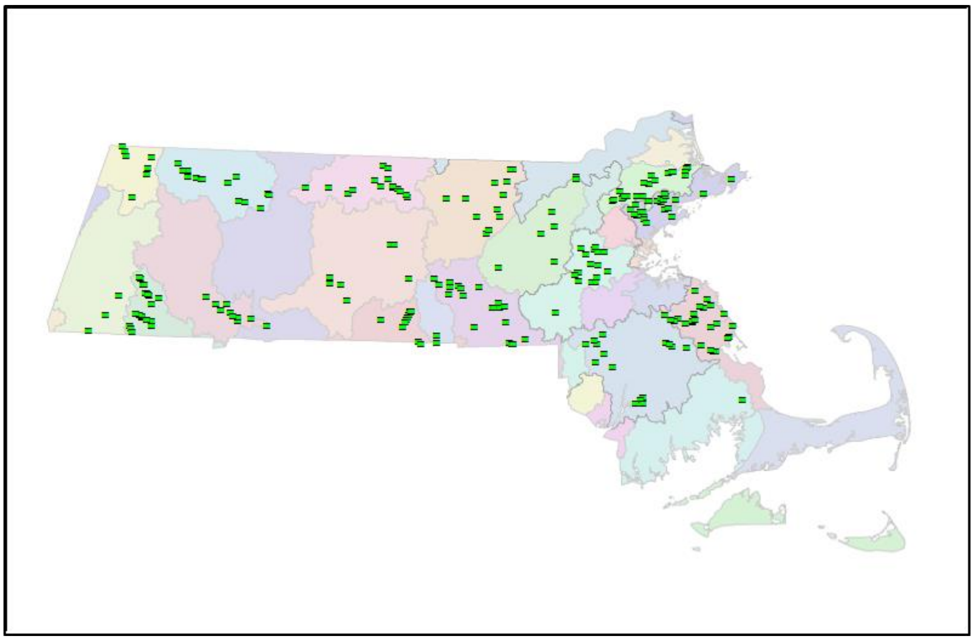

Figure F1. Distribution of the 244 sampling stations where paired chloride-SC data were collected in Massachusetts from 1994 to 2012.

Sample Collection, Chloride Analyses and Specific Conductance Measurements for Model Development
From summer 1994 to fall 2012, water samples for chloride were collected by MassDEP staff at 244 sites across Massachusetts. Grab samples were collected using new sample bottles that were generally rinsed two to three times in ambient water prior to sample collection. In general, samples were collected by plunging the sample containers into the water to about 6 inches below the water surface. Samples were stored in insulated coolers packed with wet ice (<6°C) and transported to the MassDEP Wall Experiment Station (WES) laboratory. When chloride samples were collected in the same bottle as nutrient analytes, multi-parameter samples were preserved with 9-18N H_2SO_4 to pH <2. Samples were analyzed by the WES laboratory for chloride using the argentometric titration method (Standard Methods 4500-Cl^-, B; from 1994 to 2006) and the automated ferricyanide method (Standard Methods 4500-Cl^-, E; from 2007 to 2012) (APHA 2005). All chloride concentration data were reported in units of mg/L.

During the water sample collection surveys, multi-probe sonde instruments (primarily Hydrolab®) were used to measure *in-situ* SC levels (normalized to 25°C). Detailed SOPs for instrument pre-calibration, field use and post-survey instrument check were applied. Typically, multiprobe sonde precalibration for freshwater surveys consisted of a single point calibration at 1,413 µS/cm and a check at 718 µS/cm. For the stations that were not wadable, sondes were lowered from bridges using an anchored guideline and the probes were kept off the bottom sediments at all times. Readings were recorded every 30 seconds for five minutes only after all sonde parameters, including SC, were stable. The last 30 second reading (after approximately 5 minutes) was typically used as the dataset of record for the location, date and time. All SC data were recorded in units of µS/cm.

Quality Assurance and Control

Chloride and SC data generated by MassDEP generally followed approved procedures in place at the time of sampling, including Quality Assurance Program Plans (QAPPs), Sampling & Analysis Plans (SAPs), and Standard Operating Procedures (SOPs). Site conditions and observations, and the use of non-routine sampling techniques, were noted on standard sample collection fieldsheets. Discrete water samples were collected by trained MassDEP water quality monitoring personnel, and efforts were made to ensure sample representativeness, accuracy, and precision. With minor exception, all field surveys and lab analyses included the use of blank and duplicate quality control samples, for approximately 10% of total samples. Data were validated by the MassDEP WES laboratory personnel and by the Principal Investigators and/or Quality Assurance Officers at the MassDEP, Division of Watershed Management, Watershed Planning Program. All data used in model development are considered final. Secondary data used in model validation and related analyses were from verified sources.

Regression Analysis

Freshwater samples for both chloride and SC (N=2426) were used to develop a statewide linear model to estimate chloride concentration using SC data. The model for freshwater (Figure F2; R^2=0.9445, P<0.001) shows a strong linear relationship between SC and chloride concentration:

***Y*=0.2753*X* – 18.987**, where *Y* is chloride concentration and *X* is specific conductance

Development of the freshwater model only included data with SC less than 10,000 µS/cm (n=2426). The lower limit for estimated chloride values using the model is 5 mg/L (i.e., if the model calculates the chloride values <5, these are reported as 5 mg/L for estimation purposes to account for the model error at the extreme lower range. All statistical analysis and model estimation were performed using SAS® (Version 9.4, SAS Institute Inc. Cary, NC).

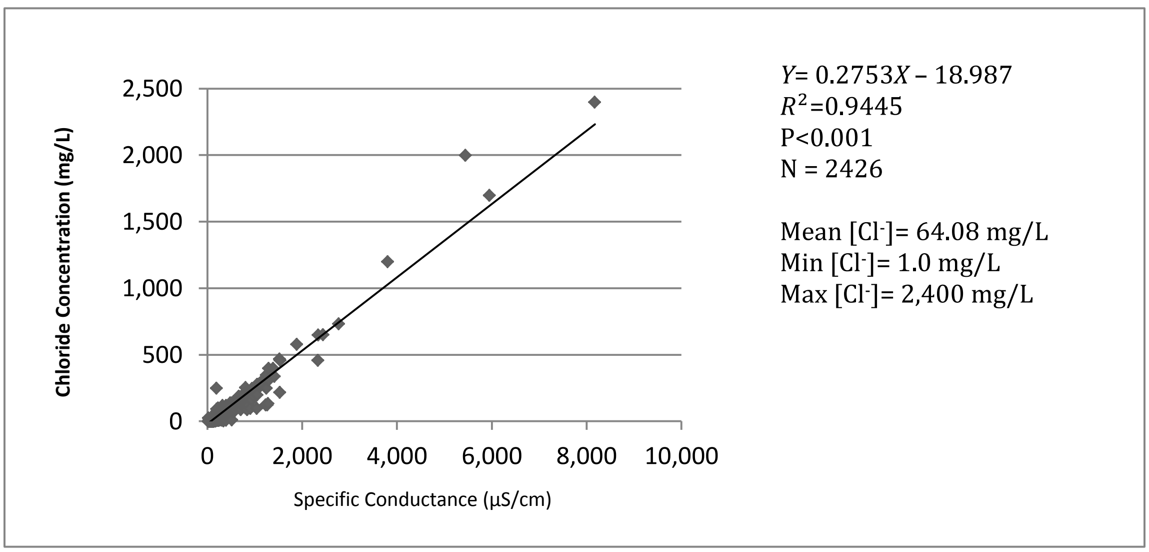

Figure F2. Relationship between chloride and SC for Massachusetts freshwaters.

Model Validations

<u>Initial Model Validation</u>:

The freshwater model was validated using separate data and field observations from the USEPA Auburn Project in Auburn, MA, which was conducted during winter of 2013-2014 (Heath 2014). For the Auburn Project, 37 freshwater samples were collected for SC and chloride by USEPA staff and analyzed for chloride at the USEPA Northeast Regional Laboratory (NERL) in North Chelmsford, MA. Using SC values from the

Auburn Project, predicted chloride concentrations generated by the MassDEP freshwater model were compared with actual chloride data collected from the USEPA Auburn Project using a best fit line.

The regression line demonstrates 99% accuracy of the model (Figure F3; R^2=0.9908, P<0.001) with a slope of 0.9709.

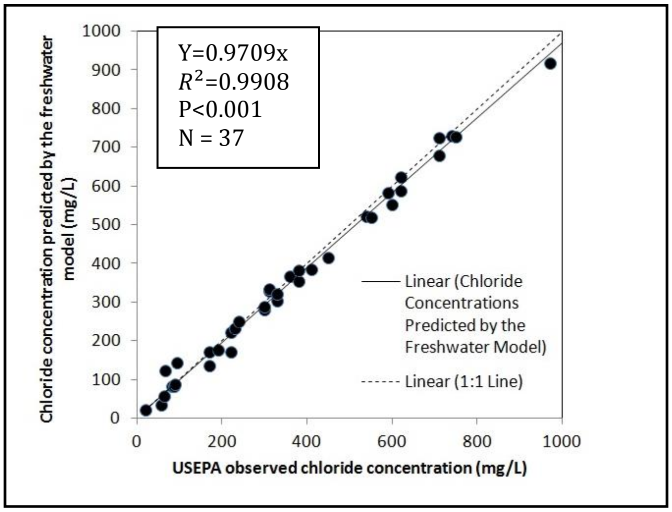

Figure F3. Validation of Freshwater Model using USEPA Data.

Supplemental Validation (River Meadow Brook Study):
An additional validation of the freshwater model was conducted using MassDEP data collected between October 2015 and September 2016 at a total of six stations in the Concord River Watershed in northeastern Massachusetts. Four stations were located on River Meadow Brook and two stations were located in the Concord River bracketing the confluence of River Meadow Brook. Project details are outlined in a Sampling & Analysis Plan (MassDEP 2015). Onset® probes (HOBO U24 conductivity and temperature loggers) were deployed by MassDEP staff at these six sites to collect continuous conductivity and temperature data and grab samples for subsequent chloride analysis were also collected periodically (N=9) at each site throughout the deployment period.

Conductivity/temperature loggers (Onset®) were deployed *in-situ* per manufacturer's directions at each of the six stations at a recording interval of every 30 minutes. Prior to deployment, each logger was checked for conductivity and temperature accuracy using a NIST-traceable thermometer and KCl standards in the lab. Each (Onset®) data logger was housed in a protective plastic (ABS) pipe, mounted vertically on a metal post and completely submerged. On a nearly monthly basis site visits (n=9 during the time of deployments) were made to each sampling location where the (Onset®) data logger had been deployed. During these site visits data files were downloaded from each logger and the conductivity sensor faces were cleaned (after side-by-side multiprobe QC readings were taken). To evaluate the accuracy of deployed continuous conductivity data loggers, co-located multiprobe (Hydrolab®) readings, including SC and temperature, were collected using instruments that were calibrated just prior to the survey and were compared to the (Onset®) data logger data. Both pre-survey calibration and post-survey checks were performed on the Hydrolab® multiprobes for each survey. To check deployed logger accuracy, SC (at 25°C) readings from the Hydrolab® multi-probes were compared to conductivities collected by the Onset loggers at ambient temperatures (the co-located SC readings were converted to conductivity and then compared to logger conductivity readings at the nearest 30-minute recording time). Across all stations during the study, relative percent differences (RPD) for conductivities ranged from 0.4% to 13.8%, with a mean RPD of 6.4% for these QC comparisons. To check for drift during deployment, conductivity readings immediately before and after cleaning the sensor were compared for each site. The majority of data align well between a logger that had been recording data for about one month and for a re-deployed logger just after cleaning, with 77% of readings within +/- 3.0% RPD. Because a temperature change may affect the drift (Barron and Ashton 2005) and temperature is a factor in the SC calculation, measured temperature was also compared before and after cleaning, with 76% of readings found to be within +/- 5.0% RPD. At the completion of the study recorded continuous conductivity and temperature data were reviewed and any outliers investigated. All data were reviewed for acceptability, and individual datum qualified or censored as appropriate (e.g., logger data documented or estimated to have been out-of-water for any length of time). Censored data were excluded from analysis and only accepted and qualified data were used in validating the model.

Grab chloride samples were collected at each of the six sampling stations approximately once a month using standard WPP procedures for wade-in sampling. Chloride samples were iced following collection and were delivered to the USEPA NERL in North Chelmsford, MA for analysis. Chloride samples were analyzed at EPA NERL using a Dionex ICS-3000 Ion Chromatograph following the EPA Region I SOP, and results were reported in units of mg/L. Ambient field blanks and field duplicate samples for chloride were collected at a minimum of one each per survey trip. Laboratory quality control sampling involved analysis of matrix spikes, duplicates and double-blind KCl standards supplied by MassDEP.

In order to utilize the model, the logger conductivity data (µS/cm) recorded at ambient temperatures were transformed to SC (µS/cm at 25°C) using the following equation:

$$\mathrm{SC} = \frac{\text{Measured conductivity}}{1 + r(T - 25)}$$

where r = the temperature coefficient of variation (TCV)
and T = temperature of measured conductivity in °C

A Temperature Coefficient of Variation (TCV) of 0.02, which assumes a 2.0% change in conductivity for every degree (°C) change in temperature (Barron and Ashton 2005), was applied for each station to derive continuous SC readings.

Following transformation of the conductivity data, the derived SC data from the loggers were used to estimate chloride concentrations using the regression equation. Then, the estimated chloride data (nearest-in-time to chloride grab sample collection) was compared to the actual, co-located chloride grab sample (total of 54) concentrations. Across all stations, RPDs ranged from 0.7% to 30.3%, with an average RPD of 8.3%. Grab samples at Station 1 in August and September 2016 were excluded from these summaries because the model predicted chloride concentration below 0. More on lower limits of the model is discussed below under Model Uncertainty.

The linear regression equation developed using only the supplemental River Meadow Brook study data was also compared to the statewide freshwater model. The slopes of the two regression lines were found to be identical ($P > 0.05$) and the intercepts between the two show marginally significant difference ($P=0.034$). The regression equations are as follows:

For Massachusetts, $Y=0.2753X - 18.987$
For River Meadow Brook, $Y= 0.2755X - 19.053$

Where Y = modeled chloride concentration and X = lab-measured chloride concentration

<u>Supplemental Validation (applicability to Western MA region):</u>
To address the concern over the need for regional chloride models, additional data collected in 2013-2014 (N = 96) from basins in western Massachusetts were available to compare to the statewide freshwater model using ANCOVA. No significant difference between the western region and the original statewide model was detected ($P=0.6869$). It was concluded that creation of the statewide model accurately predicts chloride concentrations including the western region of the state.

Model Uncertainty and Applicability

As a result of acceptable validations, the chloride assessment tool for MA freshwaters has been determined to be sufficiently accurate and robust enough to reliably predict chloride concentrations using SC values ranging from approximately 70-10,000 uS/cm. The freshwater model can be applied using both instantaneous and continuous SC measurements. The model is less reliable at SC readings <70 uS/cm. Since the linear regression line in the model is not set at a 0,0 intercept SC levels below about 70 µS/cm result in a negative predicted chloride concentration, which would not be consistent with the actual chloride concentration in the water. Therefore, for the purposes of the tool, a predicted chloride concentration lower limit of 5 mg/L (SC=87 µS/cm) was established to account for this low-level error. The model has greater accuracy at higher SC levels, including near and above EPA ambient criteria-based concentrations. For very high SC readings (>5000 uS/cm), however, caution should be used due to the potential for unique site-specific water chemistry conditions contributing to elevated water conductivity.

Due to the cumulative uncertainty[1] of estimated chloride values, best professional judgment should be applied at all times when using the tool, and especially for values within 10% of criterion values. Careful assessment is also needed to evaluate site-specific issues that may have compromised the accuracy of predictions. While not strictly required for assessment purposes, corroboratory sampling and laboratory analysis for chloride should be performed whenever needed to confirm model accuracy.

Calculated chloride values are used for freshwater assessment purposes. The tool is not applicable for coastal areas with salt water influences (e.g., tides, salt water intrusion, etc.).

Note: Predicted chloride values are not maintained in MassDEP's water quality database.

[1] Factors contributing to the cumulative uncertainty of chloride prediction include conductivity probe accuracy (typically 3% of reading), associated temperature probe accuracy (typ. 0.2 ^{o}C), probe drift (typically <3%/year), sensor fouling in-between cleanings, transformation of conductivity readings at ambient temperatures to SC at 25 ^{o}C using an assumed value for temperature coefficient of variation, and regression model error.

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MassDEP (2015). Sampling & Analysis Plan DEP Intern Project: Monitoirng and Assessment for Chloride 2015-2016. CN#: 458.0. Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA. 7 pages.

Appendix G Standard Practices for Water Data Reduction and Analysis

Some of the standard practices implemented by the MassDEP, Division of Watershed Management (DWM), Watershed Planning Program (WPP) when reducing and analyzing environmental data for the purposes of assessing and listing waters pursuant to sections 305(b) and 303(d) of the Clean Water Act (CWA) are described below. More detailed information on how individual data types are used for each designated use assessment is provided in the main body of the Consolidated Assessment and Listing Methodology (CALM) Guidance Manual. Depending on the specific designated use assessment and data type, practices other than those defined here may be used.

GENERAL:

Age, Status, and Sources of Data Used: Water quality and biological monitoring data used for assessment decisions by MassDEP analysts are ideally five years old or less, although older data (up to ~10 years old) may be utilized. In general, validated final MassDEP data, sister environmental state agency data, federal environmental agency data, and data submitted from outside groups (e.g., including watershed associations, local governments, grantees, etc.) that have been reviewed and considered usable by MassDEP will be utilized for making use assessment and listing decisions.

Data Collected During Extreme Low Flows (<7Q10) or in designated mixing zones:

- 7Q10 low flow: Assessments for waterbodies downstream from wastewater discharges are based on samples taken when river flows were documented or assumed based on best available information to have been at, or above, the seven-day low flow that occurs, on the average, once every ten years (7Q10 low flow). This approach is consistent with the Massachusetts SWQS (specifically, 314 CMR 4.03(3)). Water quality criteria do not apply at flows below the 7Q10 in waters receiving wastewater discharges.
- Mixing Zones: Whenever possible, ambient water quality monitoring conducted downstream from permitted wastewater treatment facility discharges is done at a sufficient distance downstream to allow for mixing of the effluent with the receiving water and for the resulting data to be considered representative of ambient conditions. Mixing zones are formally defined in the MA SWQS Implementation Policy for Mixing Zones (1993) as an area or volume of a waterbody in the immediate vicinity of a discharge where the initial dilution of the discharge occurs. The quality of water within a mixing zone must a) protect public health b) protect aquatic life and c) prevent nuisance conditions. However, excursions from certain water quality standards may be tolerated under certain conditions. Mixing zones shall be limited to an area or volume as small as feasible, should not interfere with migration or free movement of fish or other aquatic life (there should be safe and adequate passage for swimming and drifting organisms with no deleterious effects on their populations), and they shall not create nuisance conditions. Whenever data are determined by MassDEP analysts to represent conditions within a mixing zone, such data may be used with extreme caution or excluded from analysis for the purpose of assessment and listing decisions based on their best professional judgement.

Wet-weather vs. Dry-weather Conditions. For each monitoring survey, hydrologic and climatic conditions up to five days prior to the survey and on the survey date are typically reviewed to determine whether monitoring survey conditions and resulting data are representative of wet-weather or dry-weather conditions. Hydrologic and climatic data from the United States Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA) and other sources are used for the evaluation. Criteria for what defines defines wet- and dry-weather data can vary by project. The documentation and evaluation of survey conditions and wet/dry determinations are typically contained in WPP technical memoranda presenting project-specific data.

Retention Time Calculations for Impoundments. In order to identify lake segments vs. run-of-the-river impoundments, estimated water retention times are calculated using best available information. When the estimated retention time calculations of the dammed waterbody are ≥14 days, the waterbody is evaluated as a lake AU. Estimated retention times <14 days are generally considered run-of-the-river impoundments and considered part of a river AU. An exception to this methodology is when the impounded area shape contains lobes (not just a widened river) and does not likely have unidirectional flow. In these situations, the impounded waterbody will be maintained as a lake AU. Other exceptions may be made on a case by case basis. Information used to calculate the estimated retention times in a standardized spreadsheet calculator is gathered from several sources:

- Massachusetts Department of Environmental Management's (now the Department of Conservation and Recreation) Dam Safety Database: nominal storage (acre feet) of the dam's impoundment.
- ArcMap analysis: drainage area to the dam (mi^2) calculated using watershed delineation tools.
- USGS gaging stations: average discharge (ft^3/s) over the period of record and gage drainage area (mi^2). Two USGS gaging stations within a watershed are used to estimate the two most extreme (high and low) flow scenarios. USGS gages are selected within the impounded "waterbody under review" watershed unless stream discharge at a gage is noted as being heavily regulated by industries or municipalities in which case USGS gage station(s) in a nearby watershed are used instead.

CHEMICAL/MICROBIOLOGICAL DATA:

Non-Detects. Historical and current MassDEP data analyses for 305(b) assessments have been based on a simplistic, conservative approach where the lower limit of reference/detection is substituted for the "less than" result. Depending on the laboratory used or the project, the lower limit of reference can be the Method Detection Limit (MDL), Reporting Detection Limit (RDL), Lower Quantitation Limit (LQL) or Minimum Reporting Limit (MRL). *Example: A reported value of "<0.2" becomes "0.2" for calculation purposes.* This approach includes any data reported as zero, where the lower limit is substituted when possible and appropriate. Project-specific variations of this approach (such as substituting ½ the MDL value) or more sophisticated statistical approaches [1] may be used with appropriate documentation.

[1] An alternative approach for analyses involving non-detect results is to apply appropriate statistical techniques that account for the distribution and probability of non-detects in the dataset, rather than substitute values for the "less than" result (i.e., the Detection Limit (DL) value, ½ the DL value or other calculated value). Statistical approaches that account for the distribution and probability of non-detects, such as contingency tables, Robust Order Statistics (ROS), Kaplan-Meier method, the Kruskel-Wallis test, and survival analysis methods (e.g., Maximum Likelihood Estimation (MLE), Generalized Wilcoxon test), avoid the introduction of "invasive data" that are estimated and that can introduce false patterns in the data and poor statistical estimates. These techniques may be more appropriate for datasets containing multiple detection limits. In cases where the percentage of non-detects is greater than approximately 20%, use of Cohen's method, Winsorized mean, or tests for proportions may be more appropriate.

Values exceeding the Upper Quantitation Limit (UQL). For calculation purposes, a simplistic approach is used in cases where results exceed the upper limit, whereby the upper limit of reference (e.g., Upper Quantitation Limit or UQL) is substituted for the "greater than" result. *Example, ">2920" becomes 2920 for* *calculation purposes.* Similarly to the non-detect alternative approaches described above, project-specific variations or more sophisticated statistical approaches may be employed for datasets involving one or more “greater-than” results.

Zero values in calculations. It is generally recommended that zero values be replaced with the lower limit of reference, when available. If the lower limit of reference is not available or does not apply (as in the case of true zero values, e.g. temperature data), the zero value is replaced with a positive, near-zero value, using applicable significant figures, and using the numeral closest to zero (e.g., 0.01, 0.001).

Subtracting blank values from sample results. Sample results are not adjusted by subtracting parameter-specific blank values (e.g., ambient field blanks, equipment blanks, etc.) from associated sample results. Quality control (QC) blank samples are collected for quality assurance (QA) purposes (bias) only, not to “shift” the data.

Correction Factors. The application of correction factors (e.g., adjusting *in-situ* probe readings based on co-located, same-time QC readings) to adjust analytical results is currently not included in WPP’s data validation procedures. Project-specific variations may apply.

Averaging of field duplicate results. Field duplicate results, when collected for QC purposes, are not averaged to attempt to derive more precise estimates for results. QC field duplicate samples, collected during WPP monitoring surveys, are collected at approximately 10-20% of sites visited for QA purposes (field precision) only, and the “first” duplicate is generally reported as the sample result and used to make assessment decisions. In contrast, non-QC sample replicates, when collected, can be averaged to arrive at more precise and representative results.

Outliers. Reviews for outlier values are made during systematic data validation procedures using one or more outlier tests (e.g., Dixon, Barnett-Lewis, standard normal, etc.) and/or best professional judgment. Outliers can also be identified and flagged during data analyses by Principal Investigators. Outliers may be censored (i.e. removed from reporting and analysis) where they have been determined to be invalid during QC review. Outliers are retained if they are determined to most likely represent conditions during known episodic events or for known site conditions at the time of sampling. Suspect (qualified) outlier data may be removed from calculations based on the best professional judgment of MassDEP analysts for assessment related purposes.

Continuous Data --- Summary Statistics. During validation of MassDEP-collected data, continuous datasets (e.g., temperature, dissolved oxygen) are systematically processed to generate standardized file outputs. These standardized files include daily statistics as well as summary statistics for each probe deployment. These data are available for each individual deployment at a station and combined where multiple deployments occured at a station over the course of a sampling season (i.e., station summary statistics). Additional statistics (e.g., amount of time greater than or less than a target surface water quality standard and/or use assessment guideline) are also calculated.

Continuous Data --- Out-of-Water Analyses. When evidence points to a deployed probe having been out of the water for any amount of time, an investigation is conducted to determine which data points need to be censored from the record based on available collective information. This analysis involves examining the temperature “buffering” capacity (i.e., the ability to resist changes in water temperature from air temperature fluctuations) of water compared to air temperatures during the deployment period, identifying aberrant patterns in the data, reviewing fieldsheet notes, etc., in order to make decisions on whether to censor all or portion(s) of a continuous record dataset.

Continuous Data --- Notes for assessment summary purposes. WPP qualified data were utilized without caveat. Unattended data for DO: Deleted all records/days that did not include a predawn measurement. Continuous temperature data: Removed records where all statistics were "--" (i.e., daily statistics not calculated due to incomplete days); 24 hour rolling average calculations did not exclude incomplete days and were calculated based on the "previous" 24 hours (not 12 hours on either side); rolling 7DADM statistics (the rolling 7 day averages of the daily maximum results) and 7DADA (the rolling 7 day averages of the daily average results) excluded non-24-hour days that included the probe deploy and pickup days and calculations were based on 3 days on either side.

Data Procedures:

- Conductivity to Specific Conductance: For standardized data reporting and to estimate chloride values using the regression tool, continuous conductivity readings measured in µS/cm at ambient water temperatures are converted to specific conductance at 25°C using the following equation:

$$Specific\ conductance\ (SC)\ @\ 25°C = \frac{Measured\ conductivity}{1 + r * (T - 25)}$$

  where *r*= the temperature coefficient of variations (TCV), ≈ 2.0% per °C
  and *T*= temperature of measured conductivity in °C

- Data Transformations: For statistical data analyses, logarithmic or other data transformations may be made where necessary to achieve a normal distribution.

- Calculating Water Quality Criteria: For water quality criteria that vary with hardness (e.g., metals), pH, temperature and/or other variables, applicable criteria values must be calculated before direct comparisons with actual sampling data are made. WPP analysts rely on the use of standardized spreadsheet calculator tools that have been tested and verified to be accurate, or other vetted approaches (e.g., use of the EPA Biotic Ligand Model (BLM) for copper in freshwater) to calculate a criterion. Whenever possible, site-specific and contemporaneous data are used to derive applicable criteria. When this type of data is lacking, estimated values for supporting data may be used for criteria calculation purposes using best available information (which may include EPA ecoregional default values).

- Toxic Unit (TU): The ratio of a toxicant concentration to its criterion. This TU calculation provides the relative magnitude of the exceedance.

- Comparing toxicant data to Water Quality Criteria: A single grab or composite sample is considered to be representative of the one-hour average exposure period and is therefore appropriate to compare directly against an acute criterion. Multiple grab or representative composite samples collected within a three-year timeframe are needed to determine exceedances of a chronic criterion. When multiple samples have been collected from the same sampling location within a toxicant's chronic exposure period (e.g., 4-days) then these results will be averaged and used to calculate a single TU. For example, two or more grab samples collected during two or more days will be averaged to better represent the CCC four-day exposure period. The representativeness of composite samples will be evaluated on a case-by-case basis with preference given to those that best represent the toxicant's CCC exposure period. Samples separated by more than the exposure period of the toxicant are considered independent concentrations that are not averaged. Independent samples separated in time by more than a toxicants' CCC exposure period include grab or composite samples that do not represent a CCC exposure period.

- Geometric Mean Calculation for Bacteria Data: Geometric means are typically calculated from data derived from a minimum of five or more samples collected within the "bathing season" (1 April through 15 October). These means are calculated and compared directly to the SWQS for the recreational use assessments. Single sample maxima are not used for use assessment reporting but can be applied for other decision making purposes (e.g., beach closures, etc.). The geometric mean can be flagged when an MDL or UQL is used in the calculation.

Modeled/Estimated Results: With minor exceptions as detailed below, data based on the use of predictive models, conversions and translators are generally not used directly in assessment-related determinations. Exceptions include:

1) Chloride – Specific Conductance regression (freshwater, statewide): Estimates of chloride concentrations are made using a validated regression model between specific conductance (SC) levels and associated chloride concentrations in Massachusetts freshwater streams:

$$Cl = 0.2753*(SC) - 18.987 \quad (R^2=0.9445, P<0.001, N=2426)$$

Estimated chloride values are compared with EPA criteria for assessment purposes (using rolling 4-day averages). It is preferred, but not required, that chloride samples also be collected for each site where the model is applied to confirm the accuracy of model output. At present, there are no site-specific or regional freshwater SC/Cl regressions developed for MA. As more data are generated, WPP plans to refine the model. For more information, see Appendix F.

2) Dissolved-fraction-only results for metals that have EPA criteria expressed as total (i.e., arsenic, mercury, selenium):
   a. Arsenic (As): The EPA-published conversion factor for determining the dissolved criterion from the total recoverable criterion for arsenic is 1.0 (EPA 2002). After converting the total recoverable criterion to a dissolved criterion, the dissolved As concentration may be compared to it (or mean concentration over its acute or chronic criteria's averaging period).
   b. Mercury (Hg): The EPA-published conversion factor for determining the dissolved criteria from total recoverable criteria for mercury is 0.850 (EPA 2002).
   c. Selenium (Se): The EPA-published conversion factor for determining the chronic dissolved criteria from total recoverable criteria for selenium is 0.922 (EPA 2002).

3) Use of the Copper Biotic Ligand Model (BLM) to derive freshwater copper criteria: When evaluating copper data, the EPA BLM for copper will be applied using best available information, including the potential use of default values based on ecoregional statistical estimates. BLM software versions 2.2.3 or 3.1.2.37 will be used to calculate the copper criteria if both the toxicity data and EPA water quality criteria calculations referenced in EPA-822-R-07-001 are applied. Updated BLM versions, such as those that accommodate new operating systems, may also be used if both the toxicity data

and EPA water quality criteria calculations referenced in EPA-822-R-07-001 are retained and applied without modification. Multiple input parameter datasets (using the 10 BLM input values) will be used to run the model. For each input parameter dataset, the BLM calculates Instantaneous Water Quality Criteria (IWQC) that include both a 1-hour acute exposure criterion (criterion maximum concentration, CMC) and a 96-hour chronic exposure criterion (criterion continuous concentration, CCC). Multiple IWQCs are generated and then have to be reduced to single CCC and CMC values using appropriate statistical procedures.

Metals data generated using Clean vs. Non-Clean Techniques. Only metals data collected using documented clean sampling techniques are utilized in the use assessment and listing decision process.

10% Rule: A threshold of >10% of samples violating an applicable criterion (frequency of occurrence) is often used prior to making a judgment of "impaired", under the condition that more than one violation is needed to make an impairment decision. See specific use determinations for more information.

References

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Appendix H List of typical cause(s) and source(s) of designated use impairments

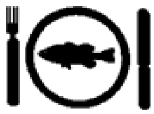
Typical cause(s) and source(s) of use impairments (*Aquatic Life, Fish Consumption, Shellfish Harvesting, Primary Contact Recreation, Secondary Contact Recreation,* and *Aesthetics*) used for the 2012 and 2014 integrated reporting cycles.

***AQUATIC LIFE USE* IMPAIRMENT CAUSES AND SOURCES**			
***Aquatic Life Use* Assessment Indicators**	**Use is Impaired**	**Typical Cause(s) of Impairment**	**Typical Source(s) of Impairment**
BIOLOGICAL MONITORING INFORMATION			
Benthic macroinvertebrate data	**Rivers** Moderately impaired/severely impaired RBP III analysis, slightly impaired with special conditions (e.g., hyperdominance by pollution tolerant sp.) as noted by DWM-WPP biologists **Estuaries** Low #species, low # individuals, poor diversity and evenness, shallow dwelling opportunistic species or near absence of benthos, thin feeding zone, as reported from external data sources	Aquatic Macroinvertebrate Bioassessments Organic Enrichment (Sewage) Biological Indicators Nutrient/Eutrophication Biological Indicators Combined Biota/Habitat Bioassessments	Municipal Point Source Discharges Dam or Impoundment Unspecified Urban Stormwater Impacts from Hydrostructure Flow Regulation/Modification Discharges from Municipal Separate Storm Sewer Systems (MS4) Source Unknown
Fish community data	**Rivers - *Cold Water Fishery*** No fish found or cold water species absent, DELTS with abnormal fish histology **Rivers - *Warm Water Fishery*** No fish found or fluvial fish were absent or relatively scarce (few in number), DELTS with abnormal fish histology **Lakes, Estuaries** > 5% population losses estimated , DELTS with abnormal fish histology	Thermal inadequacies Flow reductions Degraded habitat Competition from pond species or generalists Fish Kills Pathogens or contaminants	Municipal Point Source Discharges Dam or Impoundment Source Unknown
Habitat and flow data	**Rivers, Lakes, Estuaries** Physical habitat structure impacted by anthropogenic stressors (e.g., lack of flow, lack of natural habitat structure such as concrete channel, underground conduit), non-functioning anadromous fishway present	Fish-Passage Barrier Low flow alterations Habitat Assessment (Streams) Other flow regime alterations Other anthropogenic substrate alterations Physical substrate habitat alterations Sedimentation/Siltation Bottom Deposits Alteration in stream-side or littoral vegetative covers Petroleum Hydrocarbons (Oil Spills) Total Suspended Solids Turbidity	Hydrostructure Impacts on Fish Passage Dam or Impoundment Channelization Streambank Modifications/destabilization Flow Alterations from Water Diversions Impacts from Hydrostructure Flow Regulation/Modification Habitat Modification - other than Hydromodification Loss of Riparian Habitat Unspecified Urban Stormwater Source Unknown
Eelgrass bed mapping data	**Estuaries** Substantial decline (more than 10% of the in bed size or total loss of beds no matter their size)	Estuarine Bioassessments	Source Unknown
Non-native aquatic species data	**Rivers, Lakes** Non-native aquatic species present	Non-Native Aquatic Plants Non-native Fish, Shellfish, or Zooplankton Eurasian Water Milfoil, *Myriophyllum spicatum* Zebra mussel, *Dreissena polymorph*	Introduction of Non-native Organisms (Accidental or Intentional) Source Unknown
Periphyton/algal blooms	**Rivers, Lakes, Estuaries** Frequent and/or prolonged algal blooms or growths of periphyton, cyanobacteria blooms result in advisories (recurring and/or prolonged), >25% cover noxious	Excess Algal Growth Nutrient/Eutrophication Biological Indicators	Municipal Point Source Discharges Unspecified Urban Stormwater Internal Nutrient Recycling Discharges from Municipal Separate Storm Sewer

***AQUATIC LIFE USE* IMPAIRMENT CAUSES AND SOURCES**			
***Aquatic Life Use* Assessment Indicators**	**Use is Impaired**	**Typical Cause(s) of Impairment**	**Typical Source(s) of Impairment**
	aquatic plants (e.g. *Lemna* sp.), periphyton cover within stream AU >40%		Systems (MS4) Source Unknown
TOXICOLOGICAL MONITORING INFORMATION			
Toxicity testing data	**Rivers, Lakes, Estuaries** <75% survival of test organisms to water column or sediment samples in either 48 hr (acute) or 7-day exposure (chronic) tests occurs in >10% of test events.	Ambient Bioassays -- Acute Aquatic Toxicity Ambient Bioassays -- Chronic Aquatic Toxicity Sediment Bioassays -- Acute Toxicity Freshwater Whole Effluent Toxicity (occasionally used)	Contaminated Sediments Municipal Point Source Discharges Source Unknown
PHYSICO-CHEMICAL WATER QUALITY INFORMATION			
Water quality data - DO	**Rivers and lake surface waters** Frequent (>10%) and/or prolonged or severe excursions (>1.0 mg/l below standards) from criteria **Lakes** In deep lakes (with a hypolimnion), the criterion is not met in a hypolimnetic area >10% of the lake surface area during maximum oxygen depletion (summer growing season) **Estuaries** Frequent (>10%) and/or prolonged or severe excursions (>1.0 mg/l below standards) from criteria	Oxygen, Dissolved Dissolved oxygen saturation	Municipal Point Source Discharges Discharges from Municipal Separate Storm Sewer Systems (MS4) Unspecified Urban Stormwater Industrial Point Source Discharge Dam or Impoundment Combined Sewer Overflows Impacts from Hydrostructure Flow Regulation/Modification Source Unknown
Water quality data - pH	**Rivers** Frequent (>10%) and/or prolonged or severe excursions (>0.5 SU) from criteria, **Lakes** Excursion from criteria (>0.5 SU) summer growing season, **Estuaries** Frequent (>10%) and/or prolonged or severe excursions (>0.5 SU) from criteria	pH, Low pH, High	Municipal Point Source Discharges Source Unknown
Water quality data - temperature	**Rivers - *Cold Water Fishery*** Criterion frequently exceeded (>10%) or by >2°C **Rivers and Lakes - *Warm Water Fishery*** Criterion frequently exceeded (>10% measurements) or by >2°C. **Estuaries** Criterion frequently exceeded, rise due to discharge exceeds ΔT standards	Temperature, water	Dam or Impoundment Baseflow Depletion from Groundwater Withdrawals Source Unknown
Water quality data nutrient indicators	**Rivers** Combination of indicators present: excessive visible nuisance algae (filamentous, blooms, mats), large diel changes in oxygen/saturation/pH, elevated chlorophyll <u>*a*</u>	Chlorophyll-a Excess Algal Growth Phosphorus (Total) pH, High Secchi disk transparency Turbidity Dissolved oxygen saturation Nutrient/Eutrophication Biological Indicators	Municipal Point Source Discharges Unspecified Urban Stormwater Internal Nutrient Recycling Discharges from Municipal Separate Storm Sewer Systems (MS4) Non-Point Source Urban Runoff/Storm Sewers Source Unknown
	Lakes	Secchi disk transparency	Municipal Point Source

***AQUATIC LIFE USE* IMPAIRMENT CAUSES AND SOURCES**			
***Aquatic Life Use* Assessment Indicators**	**Use is Impaired**	**Typical Cause(s) of Impairment**	**Typical Source(s) of Impairment**
	Combination of indicators present: excessive visible nuisance algal blooms or macrophytes, low Secchi disk transparency, high oxygen super-saturation, elevated pH elevated chlorophyll <u>a</u>	Chlorophyll-a Excess Algal Growth Phosphorus (Total) Turbidity Aquatic Plants (Macrophytes) Secchi disk transparency Dissolved oxygen saturation Nutrient/Eutrophication Biological Indicators	Discharges Unspecified Urban Stormwater Internal Nutrient Recycling Discharges from Municipal Separate Storm Sewer Systems (MS4) Non-Point Source Urban Runoff/Storm Sewers Source Unknown
	Estuaries Substantial decline (> 10% of bed size or total loss of beds no matter their size, MEP analysis indicates moderately to severely degraded health due to nitrogen enrichment	Nitrogen (Total) Nutrient/Eutrophication Biological Indicators Chlorophyll-a Excess Algal Growth	Municipal Point Source Discharges Unspecified Urban Stormwater Internal Nutrient Recycling Discharges from Municipal Separate Storm Sewer Systems (MS4) Industrial Point Source Discharge On-site Treatment Systems (Septic Systems and Similar Decentralized Systems) Septage Disposal Source Unknown
Water quality data toxic and other pollutants	**Rivers, Lakes, Estuaries** Frequent and/or prolonged excursions from criteria (more than a single exceedance of acute criteria or >10% samples exceed chronic criteria).	Ammonia (Un-ionized) Chlorine, Residual (Chlorine Demand) Heavy metals* (e.g., arsenic, mercury) PAHs* (e.g., acenaphthene, naphthalene) chlorinated organic* (e.g., aldrin, heptachlor) Non priority pollutants" (e.g., choride, aluminum, Sulfide-Hydrogen Sulfide)	Municipal Point Source Discharges Highway/Road/Bridge Runoff (Non-construction Related) Combined Sewer Overflows Contaminated Sediments Source Unknown
SEDIMENT AND TISSUE RESIDUE INFORMATION			
Sediment quality data	**Rivers, Lakes, Estuaries** Frequent excursions over PEL guidelines along with other evidence of impairment, waterbodies known to have sediment contamination undergoing remedial actions.	Sediment Screening Value (Exceedence) Arsenic, Cadmium, Chromium (total), Copper, Lead, Mercury, Nickel, Zinc Petroleum Hydrocarbons' Polycyclic Aromatic Hydrocarbons (PAHs) (Aquatic Ecosystems)	Contaminated Sediments CERCLA NPL (Superfund) Sites Inappropriate Waste Disposal
Tissue residue data	**Rivers, Lakes, Estuaries** Residue of contaminants in whole body samples frequently exceed NAS/NAE guidelines, DELTS with abnormal fish histology.	Abnormal Fish deformities, erosions, lesions, tumors (DELTS), Abnormal Fish Histology (Lesions) PCBs (polychlorinated biphenyls), HG, DDT)and it's metabolites DDD and DDE), Chlordane, PAHs, TCDD in Fish Tissue	Contaminated Sediments Inappropriate Waste Disposal Releases from Waste Sites or Dumps Source Unknown

* Asterisk indicates there are many possible contaminants that belong to these classes of pollutants, the cause of impairment however is the individual pollutant (see EPA list of cause codes ((http://iaspub.epa.gov/apex/waters/f?p=ASKWATERS:CAUSE_LUT:0::::P4_OWNER:ATTAINS)) for complete listing.

FISH CONSUMPTION USE IMPAIRMENT CAUSES AND SOURCES			
Indicator for *Fish Consumption* Use Assessment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	Waterbody has site-specific MA DPH Fish Consumption Advisory with hazard (e.g., mercury, PCBs, pesticides, DDT, etc.)	Mercury in Fish Tissue PCB in Fish Tissue Dioxin (including 2,3,7,8-TCDD) (Pentachlorophenol (PCP)* Chlordane DDT and/or it's metabolites DDD and DDE Polycyclic Aromatic Hydrocarbons (PAHs) (Aquatic Ecosystems)	Atmospheric Deposition - Toxics Contaminated Sediments CERCLA NPL (Superfund) Sites Inappropriate Waste Disposal Releases from Waste Sites or Dumps Source Unknown

SHELLFISH HARVESTING USE IMPAIRMENT CAUSES AND SOURCES			
Indicator for *Shellfish Harvesting* Use Assessment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	SA Waters: Conditionally Approved, Restricted, Conditionally Restricted, or Prohibited SB Waters: Conditionally Restricted or Prohibited	Fecal Coliform Polychlorinated biphenyls	Discharges from Municipal Separate Storm Sewer Systems (MS4) Combined Sewer Overflows Marina/boating Pumpout Releases Marina/Boating Sanitary On-vessel Discharges Unspecified Urban Stormwater Municipal Point Source Discharges Illicit Connections/Hook-ups to Storm Sewers Sanitary Sewer Overflows (Collection System Failures) On-site Treatment Systems (Septic Systems and Similar Decentralized Systems) Source Unknown

AESTHETICS USE IMPAIRMENT CAUSES AND SOURCES			
Indicator for *Aesthetics Use* Assessment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	Aesthetically objectionable conditions frequently observed (e.g., blooms, scums, water odors, discoloration, taste, visual turbidity highly cloudy/murky, excess algal growth (>40% filamentous cover in rivers, nuisance growths >25% dense/very dense macrophytes or blooms in lakes), Secchi disk transparency < 4 feet at least twice during survey season.)	Excess Algal Growth Debris/Floatables/Trash Foam/Flocs/Scum/Oil Slicks Turbidity Total Suspended Solids Nutrient/Eutrophication Biological Indicators Organic Enrichment (Sewage) Biological Indicators Secchi disk transparency Taste and Odor Color Oil and Grease Sedimentation/Siltation	Municipal Point Source Discharges Unspecified Urban Stormwater Municipal (Urbanized High Density Area) Combined Sewer Overflows Internal Nutrient Recycling Discharges from Municipal Separate Storm Sewer Systems (MS4) Introduction of Non-native Organisms (Accidental or Intentional) Source Unknown

PRIMARY CONTACT RECREATIONAL USE IMPAIRMENT CAUSES AND SOURCES			
Indicator for *Primary Contact Recreational Use* Assessment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	Geometric mean bacteria above criterion, aesthetic use impairment Beach Postings >10% season	*Enterococcus* *Escherichia coli* Polychlorinated biphenyls** Any applicable aesthetic causes (see list below)	Municipal Point Source Discharges Combined Sewer Overflows Municipal (Urbanized High Density Area) Discharges from Municipal Separate Storm Sewer Systems (MS4) Unspecified Urban Stormwater Wet Weather Discharges (Non-Point Source) Illicit Connections/Hook-ups to Storm Sewers Urban Runoff/Storm Sewers Waterfowl Introduction of Non-native Organisms (Accidental or Intentional) Source Unknown

** Example of risk calculation exceeds hazard threshold for (contaminant of concern)

SECONDARY CONTACT RECREATIONAL USE IMPAIRMENT CAUSES AND SOURCES			
Indicator for *Secondary Contact Recreational Use* Assessment	**Impaired Decision**	**Cause(s)**	**Typical Source(s) of Impairment**
	Geometric mean bacteria above criterion, aesthetic use impairment	*Enterococcus* *Escherichia coli* Any applicable aesthetic causes (see list below)	Municipal Point Source Discharges Combined Sewer Overflows Municipal (Urbanized High Density Area) Discharges from Municipal Separate Storm Sewer Systems (MS4) Unspecified Urban Stormwater Wet Weather Discharges (Non-Point Source) Illicit Connections/Hook-ups to Storm Sewers Urban Runoff/Storm Sewers Waterfowl Introduction of Non-native Organisms (Accidental or Intentional) Source Unknown