Fresh Water Aquatic Life Water Quality Criteria for Aluminum: Methodology for Deriving Watershed Default Criteria

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December 2021

CN 561.0

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AWQC	Ambient Water Quality Criteria
CALM	Consolidated Assessment and Listing Methodology
CCC	Criterion Continuous Concentration
CMC	Criterion Maximum Concentration
CMR	Code of Massachusetts Regulations
DOC	Dissolved Organic Carbon
EPA	Environmental Protection Agency
MassDEP	Massachusetts Department of Environmental Protection
MLR	Multiple Linear Regression
NPDES	National Pollutant Discharge Elimination System
NWIS	National Water Information System
SWD	Surface Water Discharge
TOC	Total Organic Carbon
ToxTD	Toxicity Testing Database
USGS	United States Geological Survey

1.0 Introduction

In 2018, the U.S. Environmental Protection Agency (EPA) updated the 1988 national recommended ambient water quality criteria (AWQC) for acute and chronic aluminum aquatic life exposure in fresh water by releasing the *Final Aquatic Life Ambient Water Quality Criteria for Aluminum 2018* (USEPA, 2018b). The recommended AWQC for aluminum are protective of aquatic life in surface waters if a one-hour average concentration does not exceed the acute criterion more than once every three years and a four-day average concentration does not exceed the chronic criterion more than once every three years. The revised guidance is based on multiple linear regression (MLR) models developed using aluminum toxicity studies with variable pH, DOC, and total hardness data. To facilitate the calculation of instantaneous acute and chronic total recoverable aluminum criteria values using the MLR models, the EPA developed the *Aluminum Criteria Calculator V.2.0* ("Aluminum Calculator"; USEPA, 2018a) that uses water chemistry parameters (pH, DOC, and total hardness data) as inputs. Instantaneous aluminum criteria values generated by the Aluminum Calculator will therefore vary by site (i.e., the criteria values are site-dependent).

The Massachusetts Department of Environmental Protection (MassDEP) amended the Massachusetts Surface Water Quality Standards (314 CMR 4.00) in 2021, which included adoption of the Aluminum Calculator for aluminum in fresh water. See MassDEP's guidance for the design and implementation of Quality Assurance Project Plans for generating minimum required data, calculation of instantaneous criteria values, and how final site-dependent aluminum criteria values will be calculated to determine effluent limits in National Pollutant Discharge Elimination System (NPDES) and Massachusetts Surface Water Discharge (SWD) permits (MassDEP, 2021).

In addition, MassDEP adopted *Default Fresh Water Aluminum Criteria by Watershed (River Basin or Coastal Drainage Area)* that are listed in Appendix A to Table 29a, Generally Applicable Aquatic Life Criteria. MassDEP consulted with EPA to develop the methodology used to derive the watershed default aluminum criteria values described in this document.

If appropriate[1] data are not available to generate site-dependent final criteria values for aluminum in fresh water, watershed default criteria values will be used. However, if both final site-dependent criteria values generated from appropriate data and watershed default criteria are available for a waterbody, the site-dependent criteria values supersede the watershed default criteria.

2.0 Methodology

2.1 Data Sources

Data sources used to derive watershed default criteria are listed in **Table 1**. The dataset consisted of long-term (1990-2017) statewide data consisting of 8,143 concurrent measurements of pH, total hardness, and DOC or total organic carbon (TOC). In some cases, previously collected data may have

[1] For water quality assessments pursuant to the Clean Water Act, appropriate data collection will be defined in future Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manuals.

only included TOC and not DOC data, which is required for the Aluminum Calculator. In these scenarios, a TOC-to-DOC conversion was used. The United States Geological Survey (USGS) developed a TOC-to-DOC conversion for surface waters in Massachusetts (**Equation 1**; Armstrong et al., *in-prep*).

Equation 1. TOC-to-DOC conversion.

$$DOC\ (\frac{mg}{L}) = 0.858 * TOC(\frac{mg}{L}) - 0.196$$

Table 1. List of data sources used to derive default watershed fresh water aluminum criteria.

Data Source	Metadata	Number of Samples
MassDEP Toxicity Testing Database (ToxTD)	Ambient water quality data collected upstream of effluent discharge. Concurrent TOC, total hardness, and pH data.	7391
USGS National Water Information System (NWIS) Database	Concurrent DOC or TOC, total hardness, and pH data.	752
		8143

A map of sampling locations used in deriving watershed default fresh water aluminum criteria is provided in Appendix B, and the number of concurrent samples by watershed or watershed group (Section 2.3) is provided in Appendix C. Sections 2.1.1 and 2.1.2 include further information on the data sources used to derive default watershed criteria.

2.1.1 Toxicity Testing Database (ToxTD)

MassDEP maintains a toxicity testing database (ToxTD) to manage external toxicity testing data submitted by facilities as part of their NPDES and SWD permits, which include water quality monitoring requirements for whole effluent toxicity (WET). Each NPDES and SWD permit requiring WET testing includes detailed sample collection and analysis procedures. Data maintained in the ToxTD database includes data on the survival of test organisms in the ambient river water, lab water, and whole effluent samples and the toxicity test endpoints (LC_{50}[2], ANOEC[3], CNOEC[4]). Physico-chemical data for the initial water sample are also included for both the whole effluent and the ambient river water. All data undergo MassDEP quality assurance review and validation procedures prior to inclusion in the database.

MassDEP and EPA NPDES staff use ToxTD data for water quality assessments pursuant to Clean Water Act reporting, NPDES and SWD permit development and modification requests, toxics policy evaluation, site-dependent criteria development, and review and development of Total Maximum Daily Loads.

[2] Lethal Concentration for 50% of the population
[3] Acute No Observed Effect Concentration
[4] Chronic No Observed Effect Concentration

2.1.2 National Water Information System (NWIS) Database

The USGS collects water quality and water-use data at approximately 1.9 million sites across the United States at both surface water and groundwater sites. Data collected by the USGS include site characteristics, streamflow, precipitation, and water quality data (e.g., pH, nutrients, temperature, and organic compound concentrations). The USGS also performs chemical analyses for water, sediment, and biological samples. The USGS processes, reviews, uploads, and maintains this data in the National Water Information System (NWIS) database. Data are publicly available for viewing and download through the USGS Water Data for the Nation website (https://waterdata.usgs.gov/nwis).

2.2 Procedures

ToxTD ambient freshwater data includes TOC, total hardness, and pH. The USGS NWIS database includes two types of data: (1) concurrent DOC, total hardness, and pH data and (2) concurrent TOC, total hardness, and pH data. MassDEP converted all available surface water TOC data in freshwater environments from ToxTD and NWIS to DOC using the USGS conversion equation (**Equation 1**). MassDEP then calculated 8,143 instantaneous total recoverable aluminum criteria values (Table 1) for each set of input parameters (i.e., pH, total hardness, and DOC) using EPA's Aluminum Calculator (USEPA, 2018a). **Figure 1** illustrates the process for deriving the watershed defaults using the MLR models, and Appendix D is a detailed flowchart on the procedures used to derive the watershed default criteria.

Figure 1. Conceptual model for calculating instantaneous freshwater aluminum criteria values.

2.3 Combining Watersheds

Watershed groups were established for watersheds in the same ecoregions that satisfied either of the following conditions:

a) Default aluminum criteria for adjacent individual watersheds in the same Level III ecoregion were similar.
b) Watersheds with either limited or no ambient freshwater data were adjacent to watersheds in the same Level III ecoregion with sufficient data to derive default aluminum criteria.

Based on the conditions listed above, seven watershed groups were established:

1. Boston Harbor Drainage Area and Charles River Basin
2. Buzzards Bay Coastal Drainage Area, Narragansett Bay / Mount Hope Bay Drainage Area, and Ten Mile River Basin
3. Farmington River Basin and Westfield River Basin
4. French River Basin and Quinebaug River Basin
5. Housatonic River Basin and Hudson River Basin

6. Ipswich River Basin, North Coastal Drainage Area, and Parker River Basin
7. Merrimack River Basin and Shawsheen River Basin

Nine watersheds had sufficient data to derive default aluminum criteria but could not be grouped with other watersheds based on the conditions outlined above. These watersheds were analyzed separately:

1. Blackstone River Basin
2. Chicopee River Basin
3. Connecticut River Basin
4. Deerfield River Basin
5. Millers River Basin
6. Nashua River Basin
7. South Coastal Drainage Area
8. Sudbury, Assabet, and Concord (SuAsCo) River Basin
9. Taunton River Basin

The Cape Cod and Islands Coastal Drainage Areas had insufficient data to derive default aluminum criteria. A map of the watershed groups and individual watersheds is provided in Appendix A, and the number of concurrent samples by watershed grouping is provided in Appendix C.

2.4 Deriving Final Criteria Values

When determining the watershed default acute and chronic criteria, the values must be protective of the waterbody (i.e., its designated use for aquatic life) under a variety of circumstances (e.g., flow differences, seasonal variation, etc.), and must not be exceeded more than once every three years. MassDEP determined that the percentile approach is protective of aquatic life and is consistent with 314 CMR 4.05(5)(e): *Toxic Pollutants* ("All surface waters shall be free from pollutants in concentrations that are toxic to humans, aquatic life or wildlife."). The 5th percentile value is warranted to ensure protective conditions in watersheds with known endangered species (e.g., freshwater mussels, Atlantic Sturgeon) and is also consistent with recommendations from the Massachusetts Division of Fisheries & Wildlife (MassWildlife).

The 10th percentile of acute and chronic instantaneous criteria values generated from the Aluminum Calculator were used to calculate the final watershed default acute and chronic aluminum criteria. If there are endangered species (as defined in the federal Endangered Species Act or Massachusetts Endangered Species Act) within the watershed, then the 5th percentile was used. Endangered freshwater mussels or Atlantic Sturgeon are known to occur in the Chicopee River Basin, Connecticut River Basin, Farmington River Basin, Merrimack River Basin, Nashua River Basin, and Taunton River Basin. For grouped watersheds, the 5th percentile was used for (1) the Farmington River Basin and Westfield River Basin and (2) the Merrimack River Basin and Shawsheen River Basin. The 5th percentile was also used to calculate the final watershed default criteria for the Chicopee, Connecticut, Nashua, and Taunton river basins.

3.0 Results

Final default freshwater aluminum criteria by watershed or watershed group are listed in **Table 2**. A watershed map for the Commonwealth is in Appendix A.

Table 2. Default freshwater aluminum criteria by watershed or watershed group.

Default Fresh Water Aluminum Criteria by Watershed (River Basin or Coastal Drainage Area)[5]		
River Basin or Coastal Drainage Area	**CMC (Acute) µg/L**	**CCC (Chronic) µg/L**
Blackstone	532	262
Boston Harbor/Charles	978	380
Buzzards Bay/Mt Hope Bay/Narragansett Bay/Ten Mile	451	230
Cape Cod Coastal	**	**
Chicopee (5th percentile)	290	170
Connecticut (5th percentile)	600	290
Deerfield	440	220
Farmington/Westfield (5th percentile)	299	169
French/Quinebaug	570	270
Housatonic/Hudson	1400	515
Ipswich/North Coastal/Parker	932	396
Islands Coastal	**	**
Merrimack/Shawsheen (5th percentile)	460	249
Millers	329	200
Nashua (5th percentile)	368	200
South Coastal	1200	460
Sudbury, Assabet, and Concord (SuAsCo)	940	394
Taunton (5th percentile)	300	190
** Insufficient data are available to calculate watershed-based default criteria.		

4.0 Discussion

For the Cape Cod and Islands Coastal Drainage Areas, default criteria for aluminum are not included in the Massachusetts Surface Water Quality Standards. There were insufficient data available to derive default criteria using the methodology described in Section 2.0; see Appendix B, Appendix C, and Appendix D for additional information. For water quality assessment and permitting purposes in the Cape Cod and Islands Coastal Drainage Areas, appropriate water quality data must be collected to calculate site-dependent aluminum criteria values. For all other watersheds, if there are applicable

[5] Defaults are based on 10th percentile criteria calculated from concurrent pH, DOC, and total hardness data, except watersheds marked as 5th percentile to protect state and federal endangered species.

default watershed aluminum criteria, and the Aluminum Calculator can be used to derive appropriate final site-dependent criteria values, then the site-dependent criteria values shall be used for the site (see MassDEP, 2021).

5.0 References

Armstrong, D.S., Savoie, J.G., DeSimone, L., Laabs, K., and R.O. Carey. *In-prep*. Surface Water-Quality Data to Support Implementation of Revised Freshwater Aluminum Water-Quality Criteria in Massachusetts, 2018-19. United States Geological Survey (USGS).

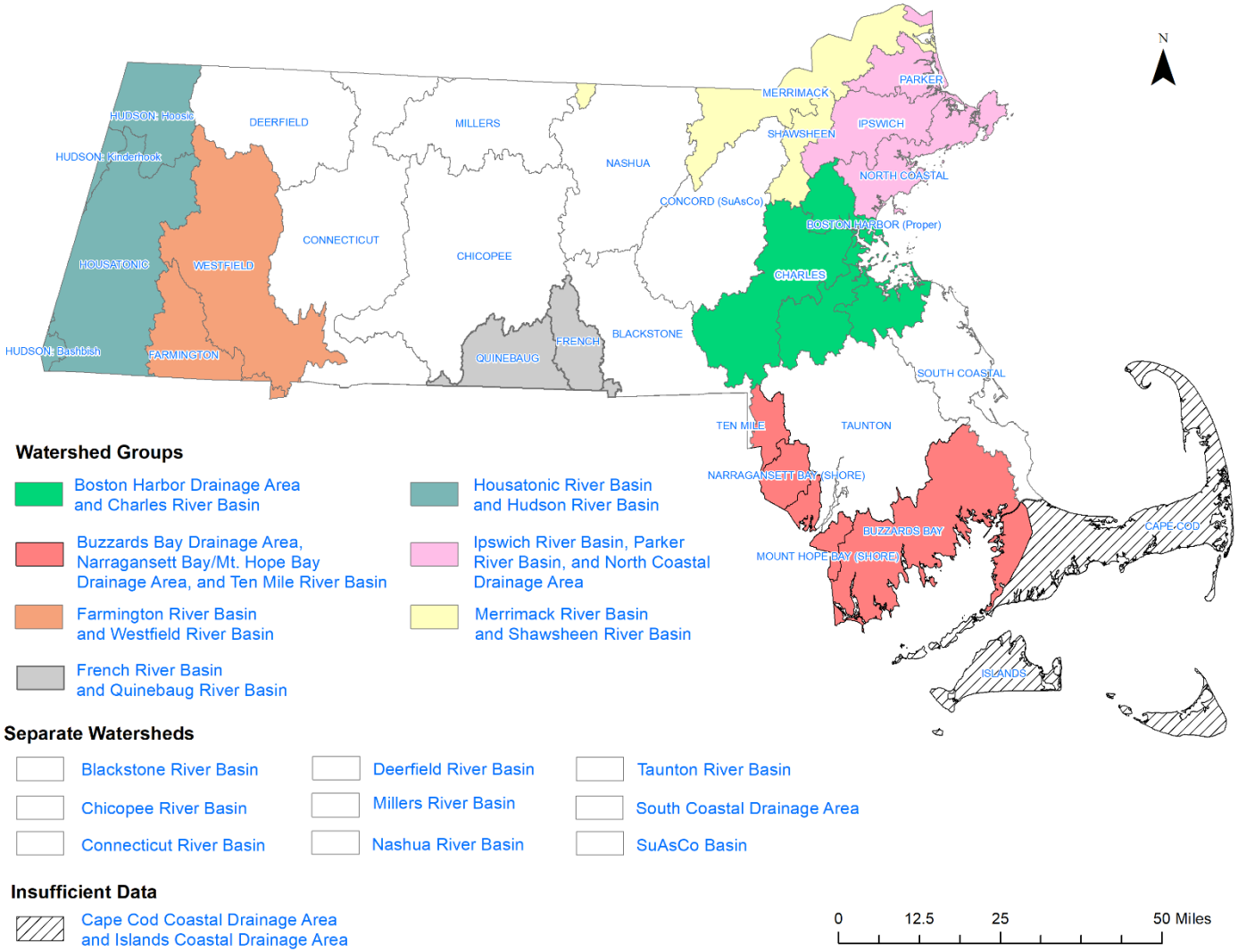
MassDEP. 2021. Fresh Water Aquatic Life Water Quality Criteria for Aluminum: Application of the Aluminum Criteria Calculator for National Pollutant Discharge Elimination System (NPDES) and Massachusetts Surface Water Discharge (SWD) Permits. CN 560.0. Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

United States Environmental Protection Agency (USEPA). 2018b. Aluminum Criteria Calculator V2.0 (Excel). Online: https://www.epa.gov/sites/production/files/2018-12/aluminum-criteria-calculator-v20.xlsm.

United States Environmental Protection Agency (USEPA). 2018a. Final Aquatic Life Ambient Water Quality Criteria for Aluminum 2018. EPA-822-R-18-001. Washington, D.C. Office of Water.

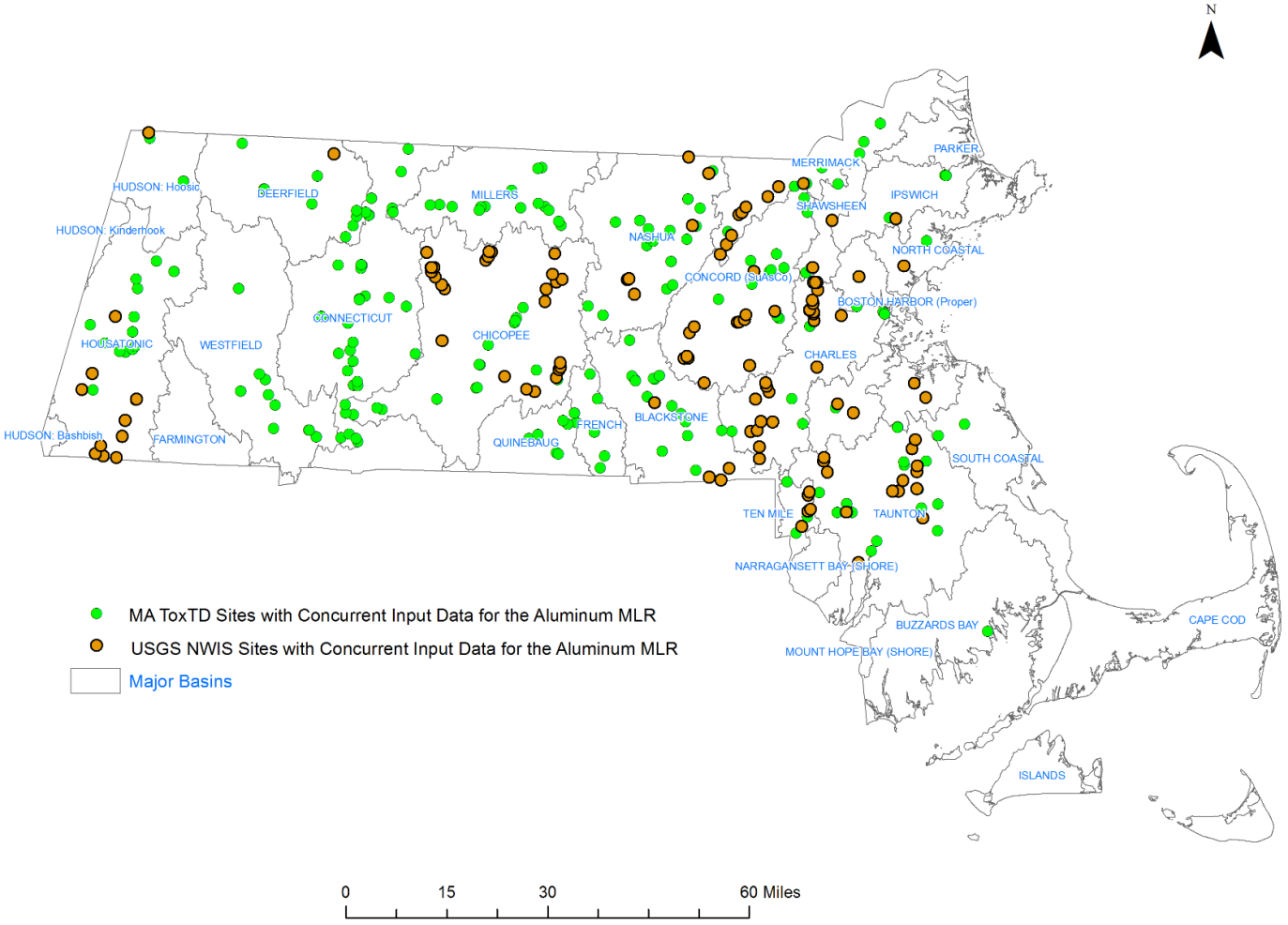
Appendix A: Map of Watersheds and Watershed Groups

Figure 2. Watersheds and watershed groups for default aluminum criteria.



Appendix B: Sample Locations Used to Derive Watershed Default Aluminum Criteria

Figure 3. Sample locations used in derivation of watershed fresh water default criteria for aluminum.



Appendix C: Number of Concurrent Samples by River Basin or Coastal Drainage Area

Table 3. Number of concurrent samples by river basin or coastal drainage area.

River Basin or Coastal Drainage Area	Start Year	End Year	Number of Concurrent Samples
Blackstone	1990	2017	493
Boston Harbor/Charles	1991	2017	470
Buzzards Bay/Mt Hope Bay/Narragansett Bay/Ten Mile	1992	2017	202
Cape Cod Coastal	--	--	--
Chicopee	1990	2017	583
Connecticut	1990	2017	973
Deerfield	1990	2017	326
Farmington/Westfield	1991	2017	259
French/Quinebaug	1991	2017	515
Housatonic/Hudson	1990	2017	1406
Ipswich/North Coastal/Parker	1992	2016	97
Islands Coastal	--	--	--
Merrimack/Shawsheen	1990	2017	359
Millers	1990	2017	650
Nashua	1990	2017	497
South Coastal	1991	2017	95
Sudbury, Assabet, and Concord (SuAsCo)	1991	2017	605
Taunton	1990	2017	613
All Watersheds (1990-2017)	1990	2017	8143

Appendix D: Process Flowchart Used to Derive Watershed Default Aluminum Criteria

Figure 4. Methodology used to derive fresh water watershed default criteria for aluminum.