Draft National 304(a) Aluminum Aquatic Life Criteria

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- Attendees who are members of the media can submit any questions to the press office: Trisha Lynn (202) 564-2615

Overview

- Background
- 2017 Recommended Criteria
- Status

Sources of Aluminum

- Aluminum is found in most rocks and minerals and can enter the environment through natural weathering
- Aluminum's solubility increase under acidic (pH <6) or basic (pH >8) water conditions
- Aluminum is actively mined from bauxite, used in industrial processes, and alum (potassium aluminum sulfate) is used in the clarification process at drinking water facilities

Current 1988 Aluminum Criteria

- The current 1988 criteria account for the:
  - Influence of pH on toxicity (solely by limiting criteria application range)
  - Similarity of acute toxicity of fish and invertebrates
  - The greater sensitivity of invertebrates in chronic toxicity tests

Current 1988 Aluminum Criteria

- The final 1988 criteria document recommended:
  - An acute criterion of 750 µg/L total aluminum when the pH is between 6.5 and 9.0
  - Chronic criterion of 87 µg/L total aluminum when the pH is between 6.5 and 9.0
  - The 1988 freshwater chronic criterion of 87 µg/L was lowered based on two tests (brook trout and striped bass)
  - The studies were not pH adjusted and all the data were not normalized for hardness. The 1988 existing criteria did not take hardness and DOC into account

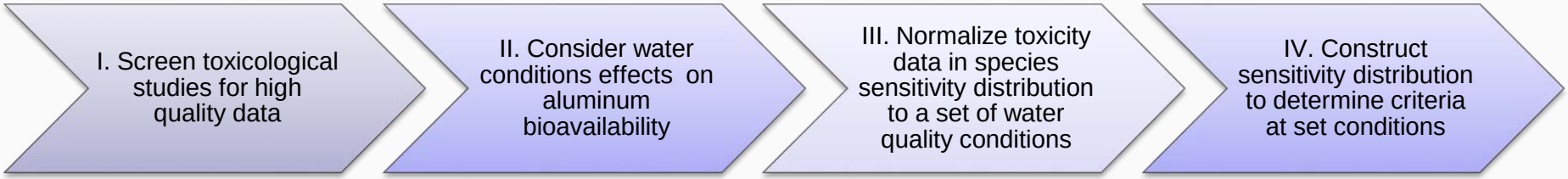
Aluminum Standards

- Aluminum Standards
  - About 20 states have numeric criteria for aluminum for aquatic life
    - Most are based on EPA's 1988 values, and two are hardness-based equations (CO and NM)
    - There are numerous site-specific criteria that involve the Biotic Ligand Model (BLM) or a Water Effects Ratio (WER) -adjusted 1988 aluminum criteria
  - Aluminum is not a priority pollutant

Criteria Development Process

- All EPA Aquatic Life Criteria for Toxics undergo rigorous scientific development and review process
  - Develop criteria document draft
  - Intra-agency peer review process
  - Independent external peer review
  - Revisions based on external peer review
    - Intra-agency review of draft criteria document
  - Release to the public in draft form to obtain scientific views
    - Revisions considering public comments
    - Intra-agency review of final criteria document
  - Publication of final criteria document
- States may then consider recommended criteria in development and adoption of state water quality standards

Framework for Updated Draft Aluminum Criteria



I. Screen toxicological studies for high quality data

- First step in all criteria development
  - Data are evaluated based on the data quality objectives outlined in the 1985 Guidelines methodology and other toxicity testing recommendations (i.e., EPA, ASTM)
  - High quality data are used quantitatively to develop criteria magnitudes
  - Lower quality data are used qualitatively, if appropriate
  - Lowest quality data are considered unacceptable and not used
- Data are grouped into acute and chronic exposures

Aluminum Toxicity Data

- The updated freshwater aluminum criteria meets the acute and chronic minimum data requirements outlined in EPA's 1985 Guidelines

	Invertebrate Species	Fish Species	Amphibian Species	Total Genera
	Acute			
1988 AWQC	8	7	-	14
2017 Draft AWQC	11	8	1	18
	Chronic			
1988 AWQC	2	1	-	3*
2017 Draft AWQC	7	4	-	11

* 1988 AWQC Chronic CCC based on two studies for the striped bass and brook trout

Aluminum Toxicity Data

- Freshwater mussels have been suggested to be potentially sensitive to aluminum
- EPA worked collaboratively with USGS's Columbia Environmental Research Center (CERC) to have acute and chronic aluminum toxicity tests conducted with a unionid mussel (fatmucket *Lampsilis siliquoidea*) in water-only exposures to obtain additional data on invertebrates.
  - New data on amphipod (*Hyalella azteca*) were collected to confirm laboratory conditions.

Aluminum Toxicity Data

- New data and models examined
  - Data submitted to E.U. REACH program
    - New freshwater aluminum toxicity data generated by Oregon State University
    - 2016 BLM model provided by the European Aluminum Association
  - Saltwater data provided by Australia
    - Insufficient data to develop estuarine/marine acute or chronic criteria at this time
  - Multiple Linear Regression (MLR) model developed by DeForest et al. 2017

- DeForest, D.K., K.V. Brix, L.M. Tear and W.J. Adams. 2017. Multiple Linear Regression (MLR) models for predicting chronic aluminum toxicity to freshwater aquatic organisms and developing water quality guidelines. Environ. Toxicol. Chem. (DOI:10.1002/etc.3922).

Minimum Dataset For Freshwater Criteria Derivation

SALMONID

SECOND FISH FAMILY

CHORDATA

PLANKTONIC CRUSTACEAN

BENTHIC CRUSTACEAN

INSECT

ROTIFERA, ANNELIDA, MOLLUSCA

OTHER INSECT OR MOLLUSCA

Estuarine/Marine Minimum Data Requirements

Family Minimum Data Requirement: Estuarine/Marine	Acute (Phylum / Family / Genus)	Chronic (Phylum / Family / Genus)
Family in the phylum Chordata	-	-
Family in the phylum Chordata	-	-
Either the Mysidae or Penaeidae family	-	-
Family in a phylum other than Arthropoda or Chordata	Mollusca / Ostreidae / Crassostrea	-
Family in a phylum other than Chordata	Annelida / Nereididae / Neanthes	-
Family in a phylum other than Chordata	Annelida / Capitellidae / Capitella	-
Family in a phylum other than Chordata	Annelida / Ctenodrilidae / Ctenodrilus	-
Any other family	Arthropoda / Ameiridae / Nitokra	-

II. Evaluate water quality conditions to determine applicability

- Criteria are often based on one or more water quality conditions (e.g., hardness) that affect toxicity of the material to test organisms
- Aluminum toxicity is highly dependent on the pH of the test water
  - The pH of test waters affects the amount and form of aluminum that is bioavailable to test species
  - Hardness and DOC (Dissolved Organic Carbon) also influence the amount of aluminum that is bioavailable

Multiple Bioavailability Modeling Approaches Underwent External Peer Review

- Biotic Ligand Models
  - Full aluminum BLM (2016 model version) – Temperature, pH, Dissolved organic carbon (DOC), Major cations (calcium [Ca], magnesium [Mg], sodium [Na] and potassium [K]), Major anions (sulfate [SO4] and chloride [Cl]), Alkalinity, and Sulfide
  - Simplified aluminum BLM - pH, hardness, DOC, temperature
- Multilinear Regression Equations
  - pH and Hardness

Accounting for Effects of Water Chemistry on Bioavailability and Toxicity

- Water quality criteria can be modified quantitatively when enough data are available to demonstrate that those conditions similarly affect the results with a variety of species
  - High quality data in the draft aluminum document demonstrated that pH, DOC and hardness affected a variety of species in a similar way when exposed to aluminum concentrations
- Recent publications by Cardwell et al. (2017) and Gensemer et al. (2017) summarized short-term aluminum chronic toxicity data across a range of DOC, pH and hardness values for three species

Multiple Linear Regression (MLR) Models to Account for Effects of Water Chemistry

- MLR models were developed for each species (DeForest et al. 2017)
  - $C.\ dubia\ EC20 = e[-41.026 + [0.525 \times \ln(DOC)] + [2.201 \times \ln(hard)] + (11.282 \times pH) - (0.633 \times pH^2) - [0.264 \times pH{:}\ln(hard)]]$
  - $P.\ promelas\ EC20 = e[-14.029 + [0.503 \times \ln(DOC)] + [3.443 \times \ln(hard)] + (3.131 \times pH) - [0.494 \times pH{:}\ln(hard)]]$
- These models were applied to both the acute and chronic aluminum toxicity data
  - The *C. dubia* model was applied to invertebrate data
  - The *P. promelas* model was applied to vertebrate data

III. Normalize toxicity data in species sensitivity distribution to a set of water quality conditions

- Just like single parameter hardness models, the MLR models were used to normalize the aluminum toxicity data to a single set of water quality conditions
  - As an illustration for one set of calculations the draft aluminum AWQC set these conditions to pH 7, hardness of 100 mg/L and DOC of 1 mg/L
- This allows for comparisons to be made between species based on their sensitivity to aluminum
  - Apples to apples

IV. Construct sensitivity distribution to determine criteria at set conditions

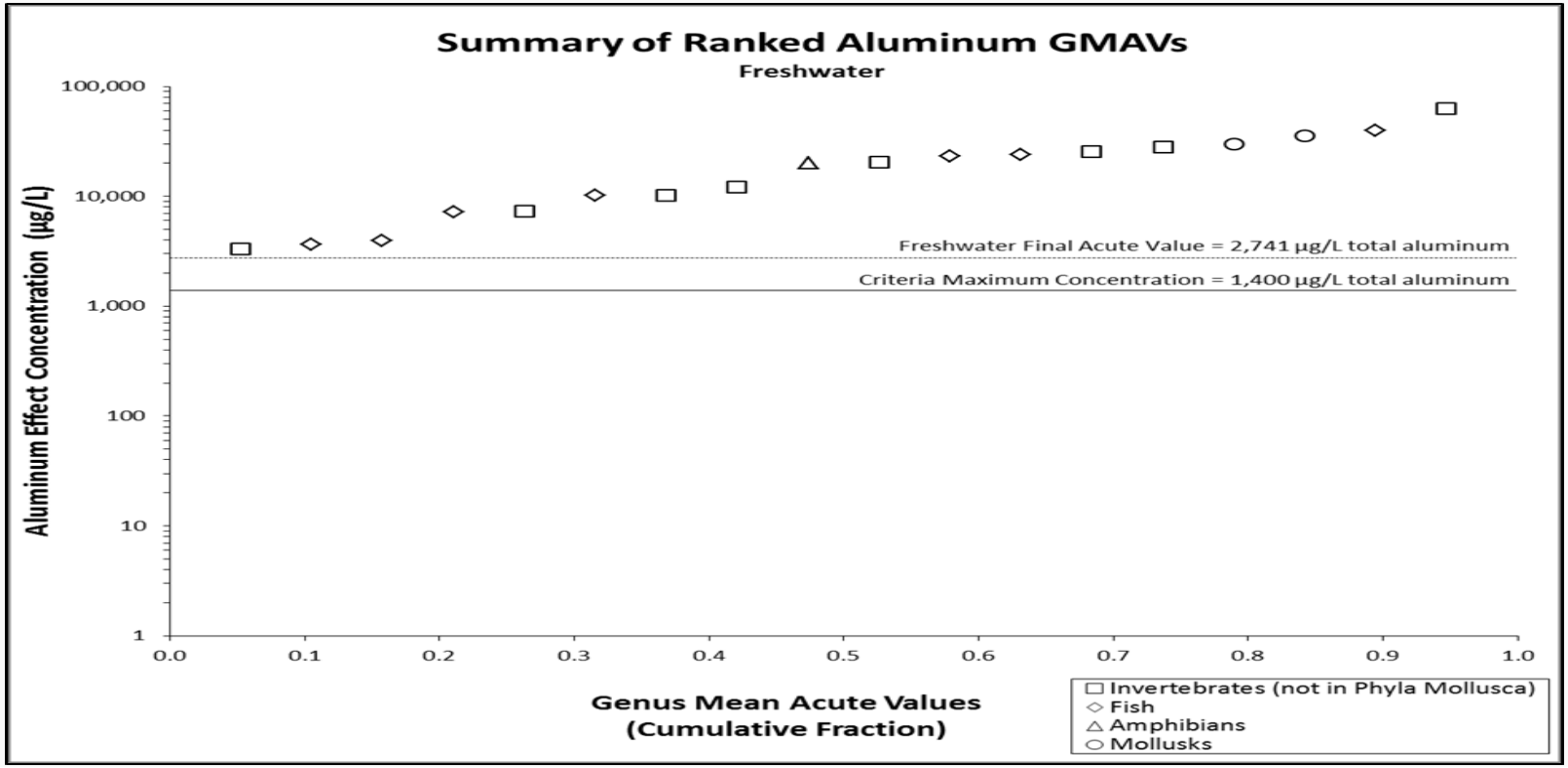


Figure 8. Ranked Summary of Total Aluminum Genus Mean Acute Values (GMAVs) - Freshwater at pH 7, Hardness of 100 mg/L, and DOC of 1 mg/L.

IV. Construct sensitivity distribution to determine criteria at set conditions

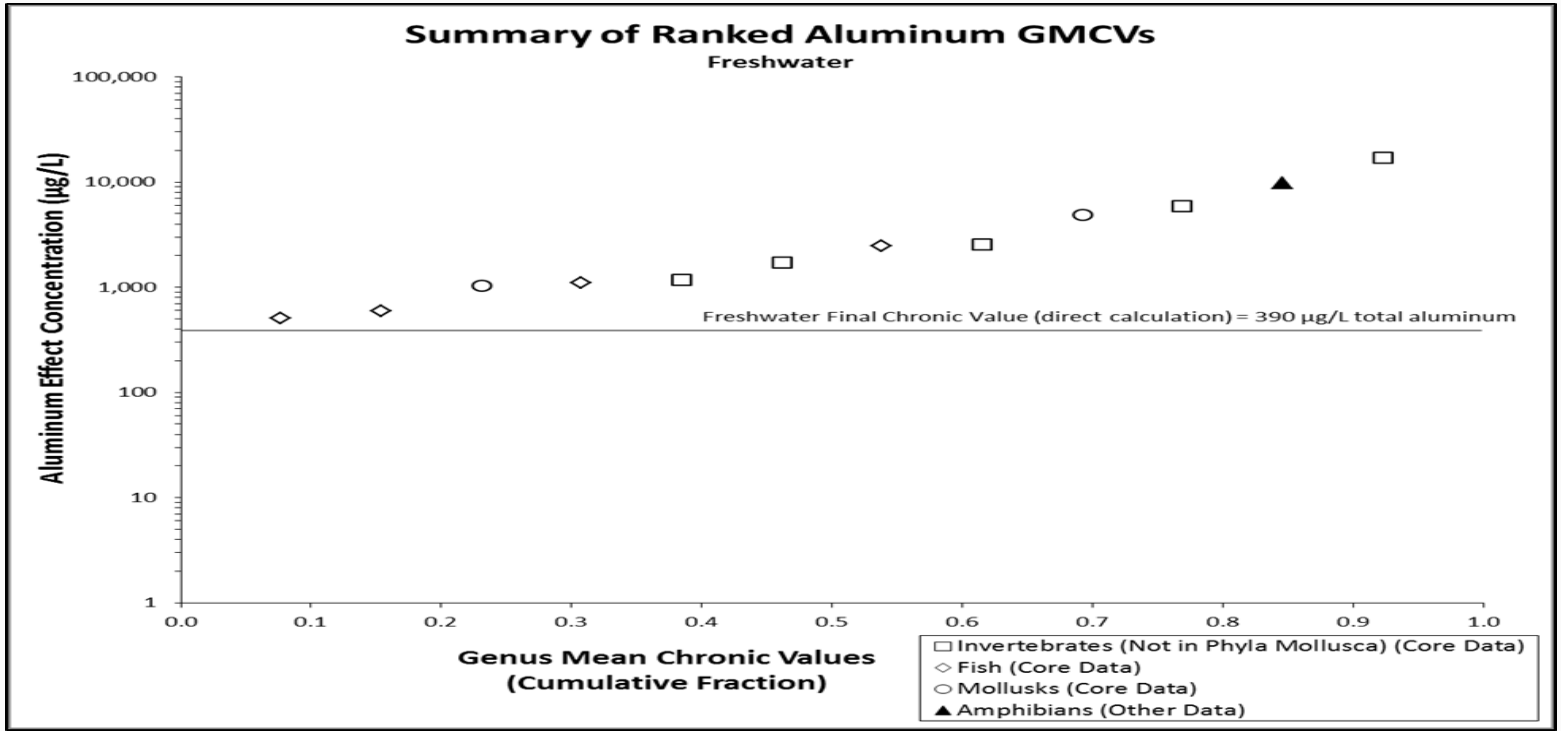


Figure 10. Ranked Summary of Total Aluminum Genus Mean Chronic Values (GMCVs) – Freshwater Supplemented with Other Data to Fulfill Missing MDRs at pH 7, Hardness of 100 mg/L, and DOC of 1 mg/L.

Aluminum Criteria Calculator

- The relative ranking of genera in the sensitivity distribution to which the toxicity data are normalized will change based on the set of water chemistry conditions (i.e., pH, hardness and DOC)
- To make calculating aluminum criteria easier, EPA developed an Aluminum Criteria Calculator
  - Automated so that user only needs to enter water chemistry conditions of interest
  - Allows quick calculations for a variety of conditions
  - Limits calculations to the recommended conditions for which the MLR models were developed were specified for hardness and DOC
    - No extrapolation beyond hardness and DOC empirical data bounds

Aluminum Criteria Calculator SD Example

Chronic Ranked GMCV				
Rank		**GMCV**	**Genus**	
12		17,098	Aeolosoma	Invert
11	>	9,746	Rana	Amphib - Other Data
10		5,908	Chironomus	Invert
9		4,877	Lymnaea	Mollusk
8		2,555	Brachionus	Invert
7		2,488	Pimephales	Fish
6		1,713	Hyalella	Invert
5		1,182	Ceriodaphnia	Invert
4		1,102	Danio	Fish
3		1,042	Lampsilis	Mollusk
2		591	Salvelinus	Fish
1		509	Salmo	Fish

Chronic Ranked GMCV				
Rank		**GMCV**	**Genus**	
12	>	2,131	Rana	Amphib - Other Data
11		1,710	Aeolosoma	Invert
10		591	Chironomus	Invert
9		544	Pimephales	Fish
8		488	Lymnaea	Mollusk
7		255	Brachionus	Invert
6		241	Danio	Fish
5		171	Hyalella	Invert
4		129	Salvelinus	Fish
3		118	Ceriodaphnia	Invert
2		111	Salmo	Fish
1		104	Lampsilis	Mollusk

FCV = 394.0 µg/L total aluminum

pH=7, Hardness=100, DOC=1

FCV = 98.7 µg/L total aluminum

pH=6, Hardness=25, DOC=1

Boundaries of the Criteria Outputs

- MLR models were developed using data that encompass:
  - DOC range of 0.08-5 mg/L
  - Hardness range of 9.8-127 mg/L (as $CaCO_3$)
  - pH range of 6-8.1
- MLR criteria outputs are bounded at:
  - Maximum of 150 mg/L total hardness (as $CaCO_{3)}$
  - DOC of 5.0 mg/L
  - pH range of the model is 5.0 to 9.0

Aluminum Criteria Look-Up Tables

- EPA also provided criteria look-up tables in Appendix K

Hardness	CCC (µg/L total aluminum) (DOC=0.5 mg/L)																	
	pH 5.0		pH 5.5		pH 6.0		pH 6.5		pH 7.0		pH 7.5		pH 8.0		pH 8.5		pH 9.0	
25	2.3	a	14	b	69	c	160	f	350	f	620	i	540	b	410	a	230	a
50	4.3	a	24	b	100	d	170	f	310	f	630	f	670	j	400	a	200	a
75	6.1	a	33	b	130	e	180	f	290	f	530	f	730	i	390	a	190	a
100	7.8	a	41	b	150	e	190	f	280	g	460	f	770	c	390	a	180	a
150	11	a	55	b	180	f	200	g	270	h	390	g	650	f	430	b	170	a
200	11	a	55	b	180	f	200	g	270	h	390	g	650	f	430	b	170	a
250	11	a	55	b	180	f	200	g	270	h	390	g	650	f	430	b	170	a
300	11	a	55	b	180	f	200	g	270	h	390	g	650	f	430	b	170	a
350	11	a	55	b	180	f	200	g	270	h	390	g	650	f	430	b	170	a
400	11	a	55	b	180	f	200	g	270	h	390	g	650	f	430	b	170	a

Aluminum Criteria Look-Up Tables

- EPA also provided criteria look-up tables in Appendix K

Hardness	CCC (µg/L total aluminum) (DOC=1.0 mg/L)																	
	pH 5.0		pH 5.5		pH 6.0		pH 6.5		pH 7.0		pH 7.5		pH 8.0		pH 8.5		pH 9.0	
25	3.3	a	21	b	99	c	220	f	490	f	900	i	780	b	590	a	330	a
50	6.1	a	35	b	150	e	250	f	440	f	890	f	960	j	580	a	290	a
75	8.8	a	47	b	180	e	260	f	410	f	740	f	1,100	i	570	a	270	a
100	11	a	59	b	210	e	270	f	**390**	g	650	f	1,100	c	560	b	260	a
150	16	a	80	b	250	f	280	g	380	h	540	g	910	f	620	b	240	a
200	16	a	80	b	250	f	280	g	380	h	540	g	910	f	620	b	240	a
250	16	a	80	b	250	f	280	g	380	h	540	g	910	f	620	b	240	a
300	16	a	80	b	250	f	280	g	380	h	540	g	910	f	620	b	240	a
350	16	a	80	b	250	f	280	g	380	h	540	g	910	f	620	b	240	a
400	16	a	80	b	250	f	280	g	380	h	540	g	910	f	620	b	240	a

Aluminum Criteria Look-Up Tables

- EPA also provided criteria look-up tables in Appendix K

Hardness	CCC (µg/L total aluminum) (DOC=2.5 mg/L)																	
	pH 5.0		pH 5.5		pH 6.0		pH 6.5		pH 7.0		pH 7.5		pH 8.0		pH 8.5		pH 9.0	
25	5.4	a	34	b	160	c	350	f	770	f	1,500	i	1,300	b	960	a	540	a
50	9.9	a	57	b	230	e	390	f	690	f	1,400	f	1,600	j	930	a	470	a
75	14	a	77	b	290	e	410	f	640	f	1,200	f	1,700	i	920	a	440	a
100	18	a	96	b	330	e	420	f	620	g	1,000	f	1,800	d	920	b	420	a
150	26	a	130	b	390	f	450	g	590	h	860	g	1,400	f	1,000	b	390	a
200	26	a	130	b	390	f	450	g	590	h	860	g	1,400	f	1,000	b	390	a
250	26	a	130	b	390	f	450	g	590	h	860	g	1,400	f	1,000	b	390	a
300	26	a	130	b	390	f	450	g	590	h	860	g	1,400	f	1,000	b	390	a
350	26	a	130	b	390	f	450	g	590	h	860	g	1,400	f	1,000	b	390	a
400	26	a	130	b	390	f	450	g	590	h	860	g	1,400	f	1,000	b	390	a

Aluminum Criteria Look-Up Tables

- EPA also provided criteria look-up tables in Appendix K

Hardness	CCC (µg/L total aluminum) (DOC=5.0 mg/L)																	
	pH 5.0		pH 5.5		pH 6.0		pH 6.5		pH 7.0		pH 7.5		pH 8.0		pH 8.5		pH 9.0	
25	7.7	a	49	b	230	c	500	f	1,100	f	2,100	c	1,900	b	1,400	a	770	a
50	14	a	82	b	330	e	540	f	970	f	2,000	f	2,200	j	1,300	a	680	a
75	20	a	110	b	410	e	570	f	900	f	1,600	f	2,500	i	1,300	a	640	a
100	26	a	140	b	460	f	590	f	880	g	1,400	f	2,500	d	1,300	b	600	a
150	38	a	190	b	550	f	630	g	840	h	1,200	g	2,000	f	1,500	b	560	a
200	38	a	190	b	550	f	630	g	840	h	1,200	g	2,000	f	1,500	b	560	a
250	38	a	190	b	550	f	630	g	840	h	1,200	g	2,000	f	1,500	b	560	a
300	38	a	190	b	550	f	630	g	840	h	1,200	g	2,000	f	1,500	b	560	a
350	38	a	190	b	550	f	630	g	840	h	1,200	g	2,000	f	1,500	b	560	a
400	38	a	190	b	550	f	630	g	840	h	1,200	g	2,000	f	1,500	b	560	a

Status

- Draft Document Released to the Federal Register on 7/28/17
  - Public comment period of 60 days
  - Due Date for Comments is 9/26/17
- Revisions will be made considering public comments
- Subsequent EPA intra-agency review of final criteria document will then be conducted
- Publication of final criteria document planned for Late Fall 2017

Federal Register Webpage

https://www.federalregister.gov/documents/2017/07/28/2017-15968/request-for-scientific-views-draft-updated-aquatic-life-ambient-water-quality-criteria-for-aluminum

Aluminum Criteria Webpage

https://www.epa.gov/wqc/2017-draft-aquatic-life-criteria-aluminum-freshwater-documents

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