Water Quality Standards Academy

Aquatic Life Criteria

March 24, 2021

EPA Region 9 Tribal WQS Academy

Disclaimer

- This Presentation does not:
  - Impose any binding requirements
  - Determine the obligation of the regulated community
  - Change or substitute for any statutory provision or regulation requirement
  - Represent, change or substitute for any Agency policy or guidance
  - Control in any case of conflict between this discussion and statute, regulation, policy, or guidance

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What are Aquatic Life Criteria?

What is an aquatic life criterion?

The highest instream concentration of a toxicant to which organisms can be exposed for a period of time without causing an unacceptable adverse effect.

What is it intended to protect?

Aquatic animals (e.g., fish, invertebrates, crustaceans) and plants from acute and chronic exposure to a toxicant or condition. More to the point, it is protection of the ecosystem so that it retains its “fishable, swimmable” designated use(s).

National Recommended Water Quality Criteria

Human Health Criteria (Fish consumption)

Aquatic Life Criteria

Acute (Criterion Maximum Concentration)

Chronic (Criterion Continuous Concentration)

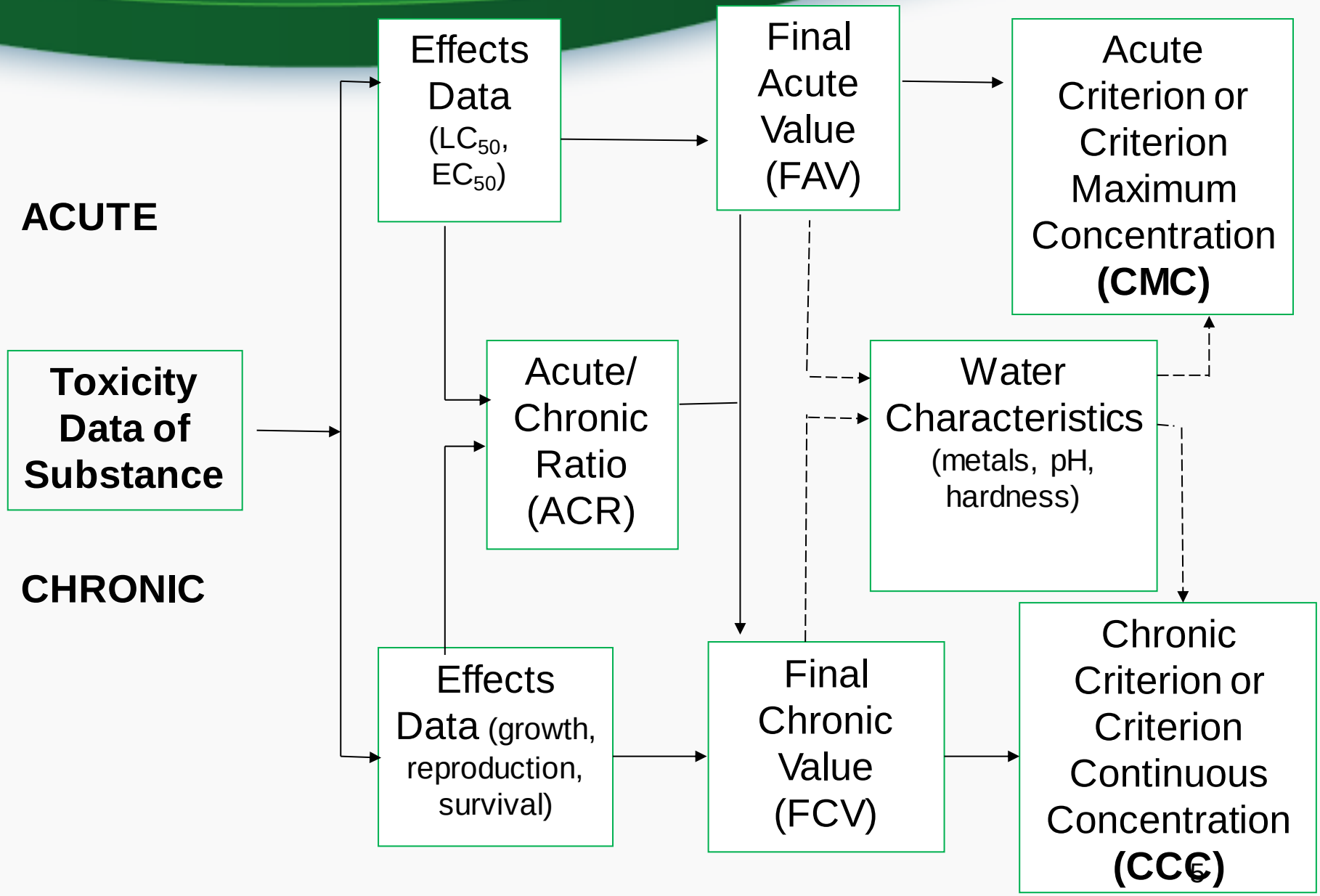
Freshwater and Saltwater

National Recommended Water Quality Criteria for Arsenic

		Freshwater		Saltwater		Human Health for the consumption of	
Priority Pollutant	**CAS Number**	**CMC**	**CCC**	**CMC**	**CCC**	**Water + Organism**	**Organism Only**
Arsenic	7440382	340	150	69	36	0.018	0.14

https://www.epa.gov/wqc

Criteria Derivation Overview



Minimum Data Requirements (MDRs) Freshwater

SALMONID

SECOND FISH FAMILY

CHORDATA

PLANKTONIC CRUSTACEAN

BENTHIC CRUSTACEAN

INSECT

ROTIFERA, ANNELIDA, MOLLUSCA

OTHER INSECT OR MOLLUSC

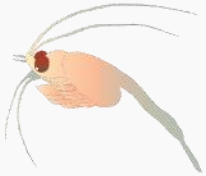
Minimum Data Requirements (MDRs)(Saltwater)

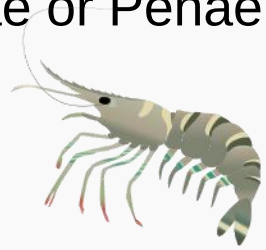
Images:http://ian.umces.edu/imagelibrary/

Two families in the phylum Chordata:

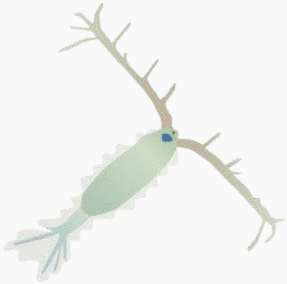
A family in a phylum other than Arthropoda or Chordata:

Either the Mysidae or Penaeidae family:





Three other families not in the phylum Chordata



Any other saltwater aquatic family.

Acute Toxicity Testing

Acute toxicity - 96 hour (4 day) toxicity test for fish or other invertebrates (or 48 for *Daphnia*)

- Measured as LC_{50} or EC_{50} (immobilization)

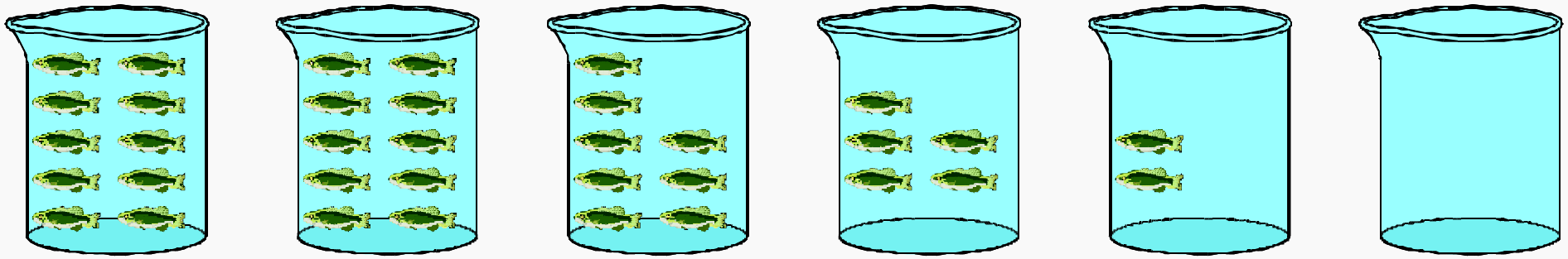
- Lethal concentration [effects concentration] in which 50% of tested organisms display lethality/effect

Acute Test Data Handling

96-hour LC_{50} values from the literature

Concentration:

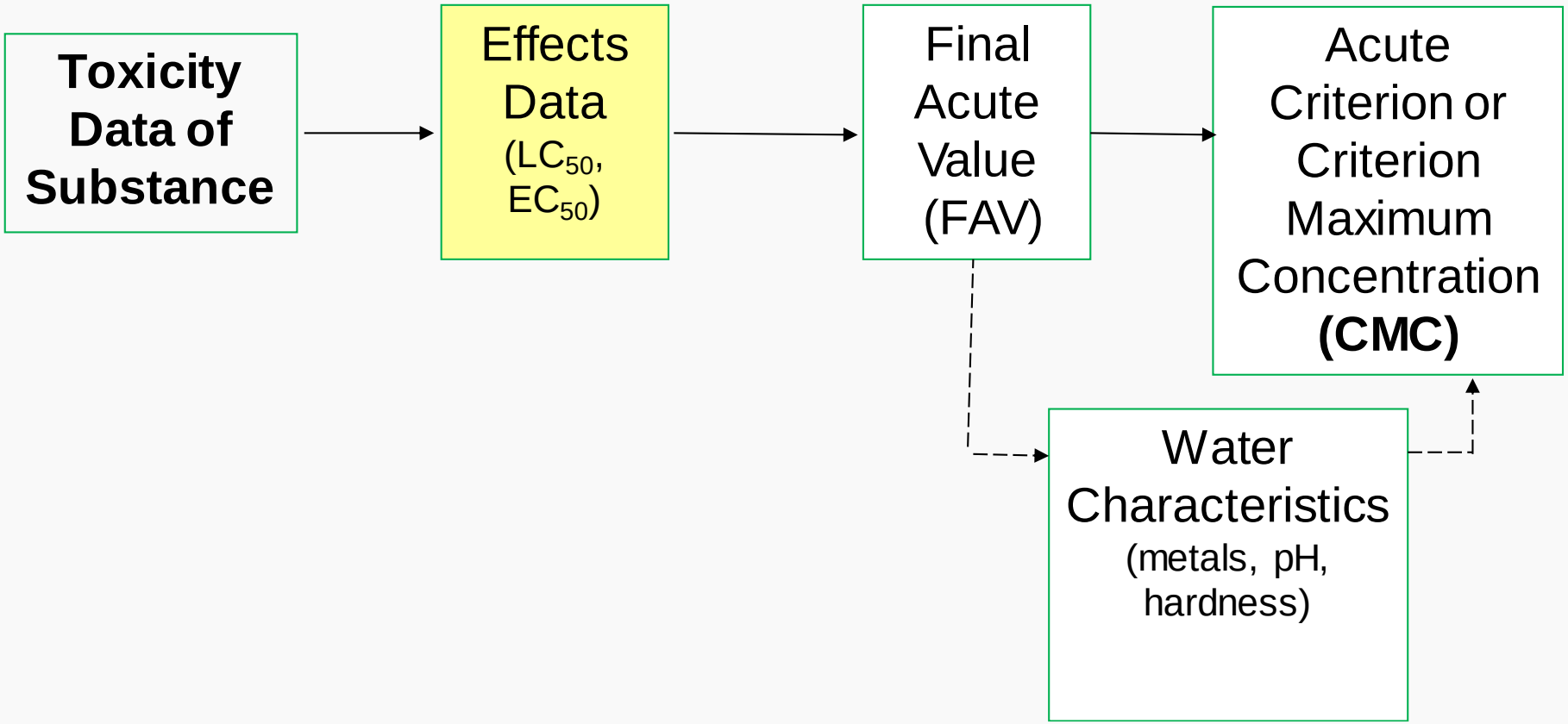
0.0 µg/L	13 µg/L	25 µg/L	50 µg/L	100 µg/L	200 µg/L



Control	1	2	3	4	5
(10)	*(10)*	*(8)*	*(5)*	*(2)*	*(0)*

96-hr LC_{50} = 50 µg/L

Acute Method - Step 1: Toxicity Data of Substance



Data Sources and Endpoints

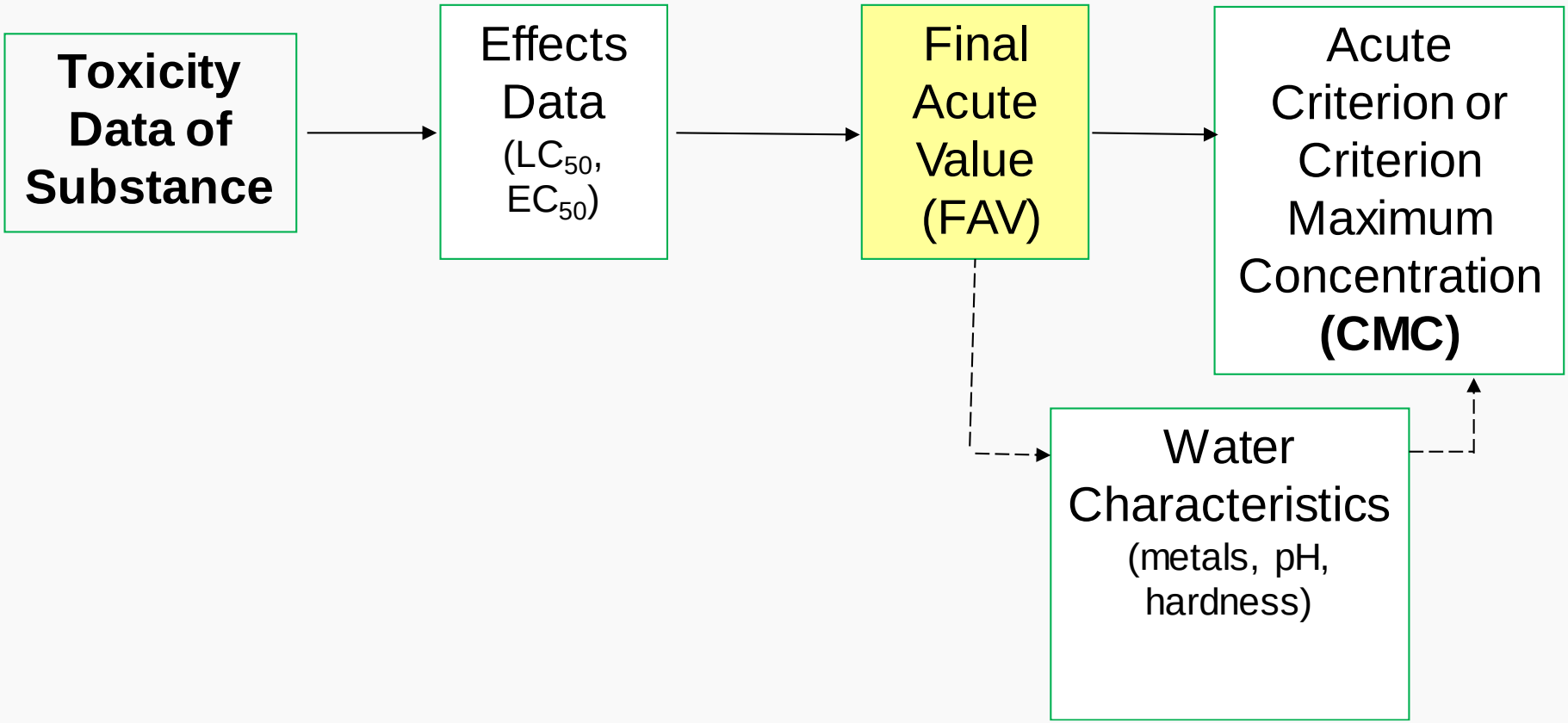
Data is collected from ecological toxicity database (ECOTOX, maintained by EPA). This is periodically updated, on a compound specific basis, from open peer-reviewed literature.

ECOTOX is a comprehensive, publicly available knowledgebase providing single chemical environmental toxicity data on aquatic life, terrestrial plants and wildlife (https://cfpub.epa.gov/ecotox/).

The database contains single chemical exposures using ecologically relevant species.

Main data limitations include reporting effects, concentration or dose, and exposure duration.

Acute Method (cont'd)



FAV Calculation Overview

Step 1. Calculate Species Mean Acute Values (SMAVs)
- geometric mean of all acceptable acute values for species

Step 2. Calculate Genus Mean Acute Values
- geometric mean of all SMAVs for genus

Step 3. Rank Genus Mean Acute Values
- from most sensitive (#1 = lowest concentration to see an effect) to least sensitive (n)

Step 4. Calculate Final Acute Value Using 4 Lowest GMAVs (or those GMAVs closest to the 5^{th} percentile)

FAV Calculation - SMAV

Step 1 – Species Mean Acute Value

Daphnia magna EC_{50}	25 µg/L
Daphnia magna EC_{50}	30 µg/L
Daphnia magna EC_{50}	35 µg/L
Daphnia magna EC_{50}	28 µg/L

SMAV = 29 µg/L

FAV Calculation Overview

Step 1. Calculate Species Mean Acute Values (SMAVs)
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- geometric mean of all SMAVs for genus

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Step 4. Calculate Final Acute Value Using 4 Lowest GMAVs (or those GMAVs closest to the 5th percentile)

FAV Calculation - GMAV

Step 2 – Genus Mean Acute Value

Daphnia magna	SMAV	29 µg/L
Daphnia pulex	SMAV	38 µg/L
Daphnia ambigua	SMAV	42 µg/L

GMAV = 36 µg/L

Summary of steps 1 and 2

Step 1 – Calculate each SMAV (*Daphnia magna*)

Daphnia magna EC_{50}	25 µg/L
Daphnia magna EC_{50}	30 µg/L
Daphnia magna EC_{50}	35 µg/L
Daphnia magna EC_{50}	28 µg/L

SMAV = 29 µg/L

Step 2 – Calculate the GMAV (*Daphnia*)

Daphnia magna	SMAV	29 µg/L
Daphnia pulex	SMAV	38 µg/L
Daphnia ambigua	SMAV	42 µg/L

GMAV = 36 µg/L

FAV Calculation Overview

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FAV Calculation - Ranking

Step 3 – Rank (Percentile) Ordering by Sensitivity

RANK	GMAV	Species	SMAV
4	100	*Oncorhynchus mykiss*	100
3	36	*Daphnia ambigua*	42
		Daphnia pulex	38
		Daphnia magna	29
2	25	*Gammarus pseudolimnaeus*	25
1	19	*Hyalella azteca*	19

FAV Calculation Overview

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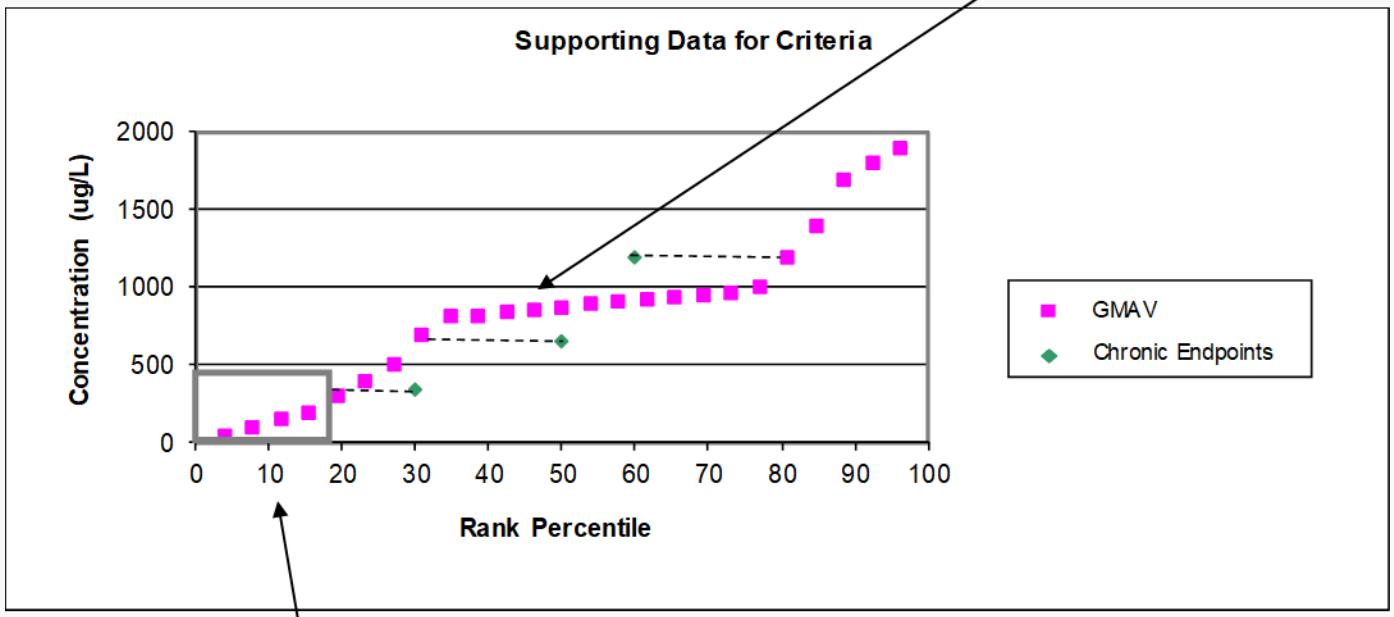
- geometric mean of all SMAVs for genus

Step 3. Rank Genus Mean Acute Values
- from most sensitive (#1 = lowest concentration to see an effect) to least sensitive (n)

Step 4. Calculate Final Acute Value Using 4 Lowest GMAVs (or those GMAVs closest to the 5th percentile)

FAV Calculation

GMAV and Calculate the Percentile of each rank (100 R/(N+1))

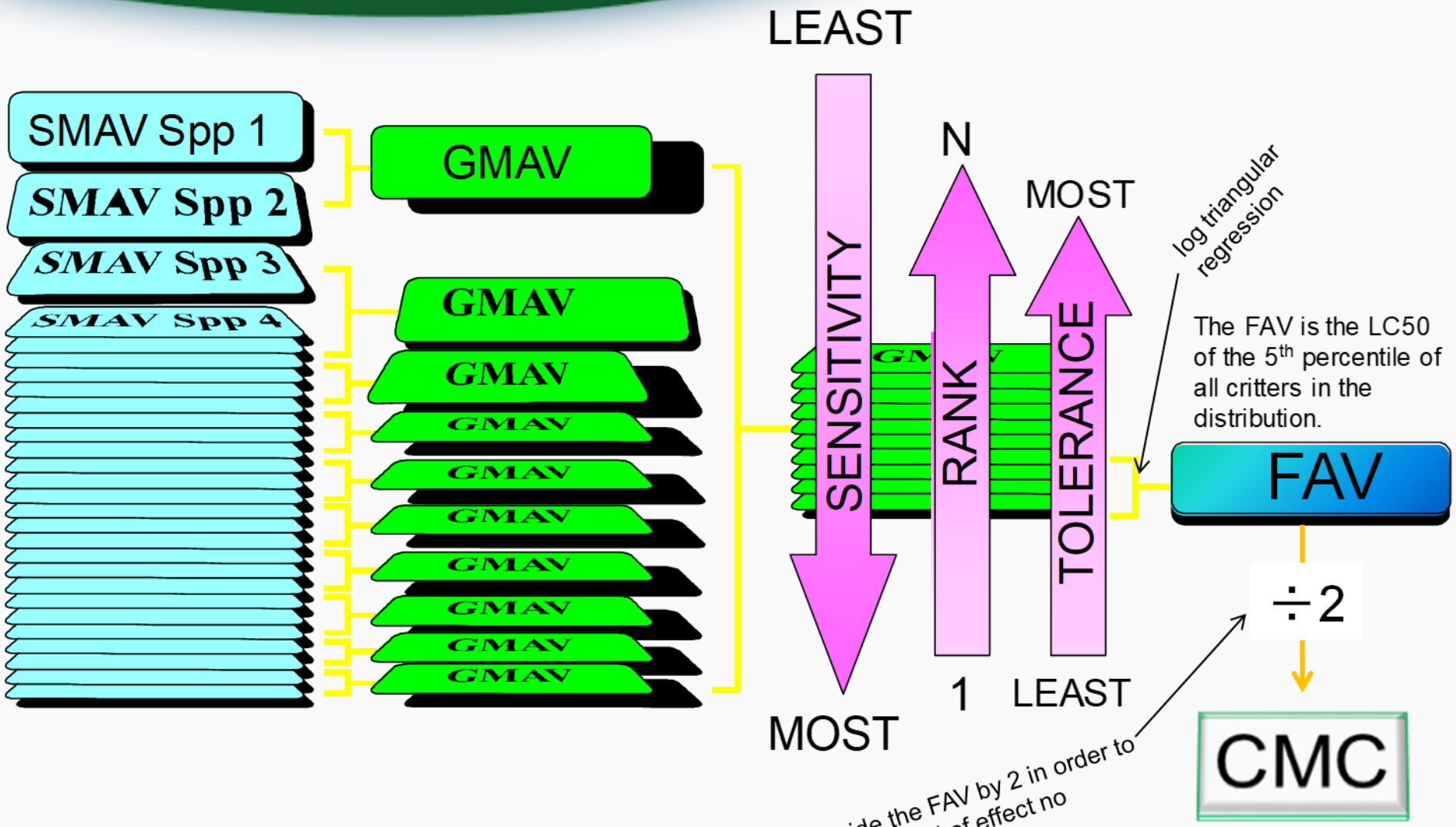


Using the 4 Most Sensitive Genera, Perform a Log Triangular Regression of the GMAV (log values) on the Percentile Ranks (square roots) to generate an HC_5 = FAV

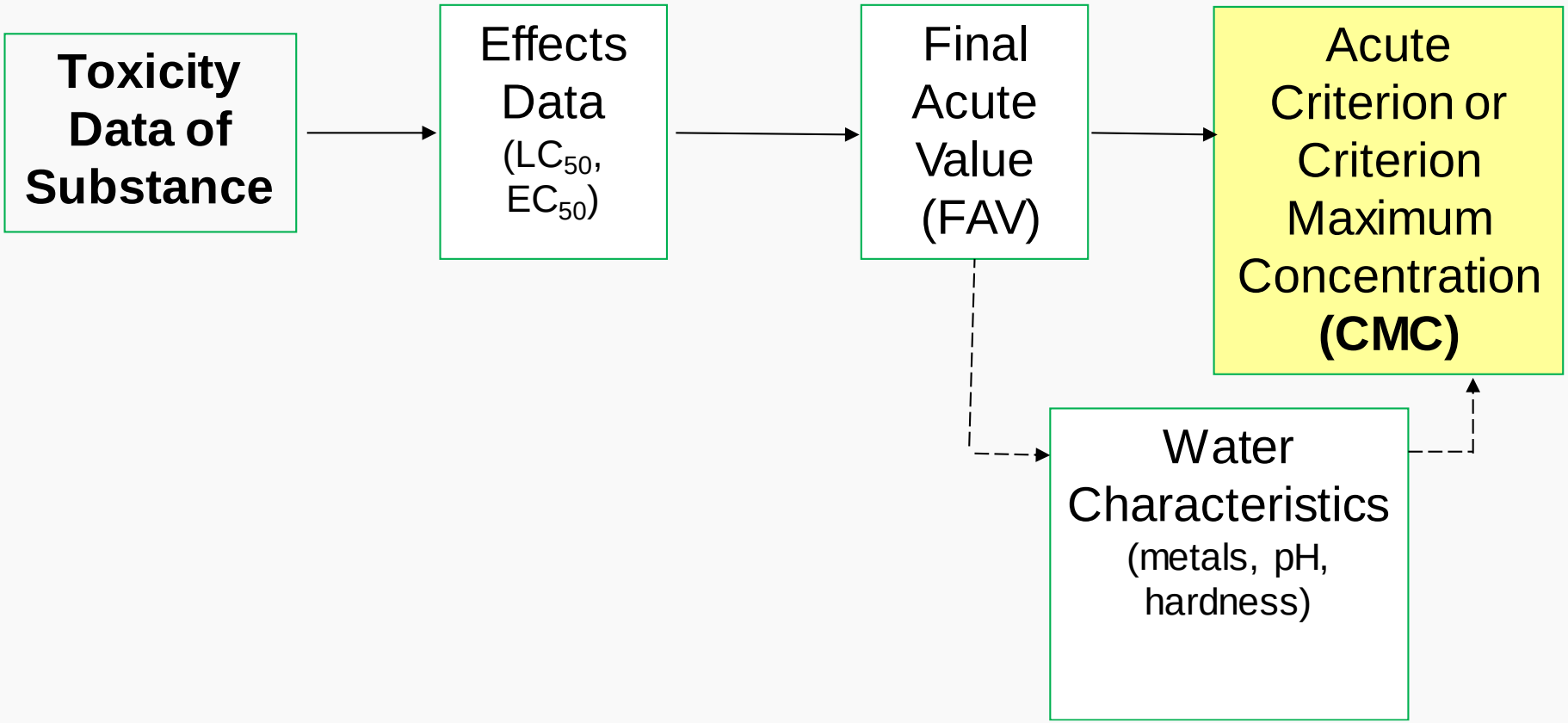
Log Triangular Distribution

- Assume the available GMAVs follow a log-triangular distribution.
- Rank Order the GMAVs – least to most sensitive
- Assign Ranks (1 to N); Calculate Cumulative Probability $P = R/(N+1)$
- Select the 4 GMAVs closest to 0.05 (often the lowest 4 GMAVs) – those are used to define the slope of the toxic response

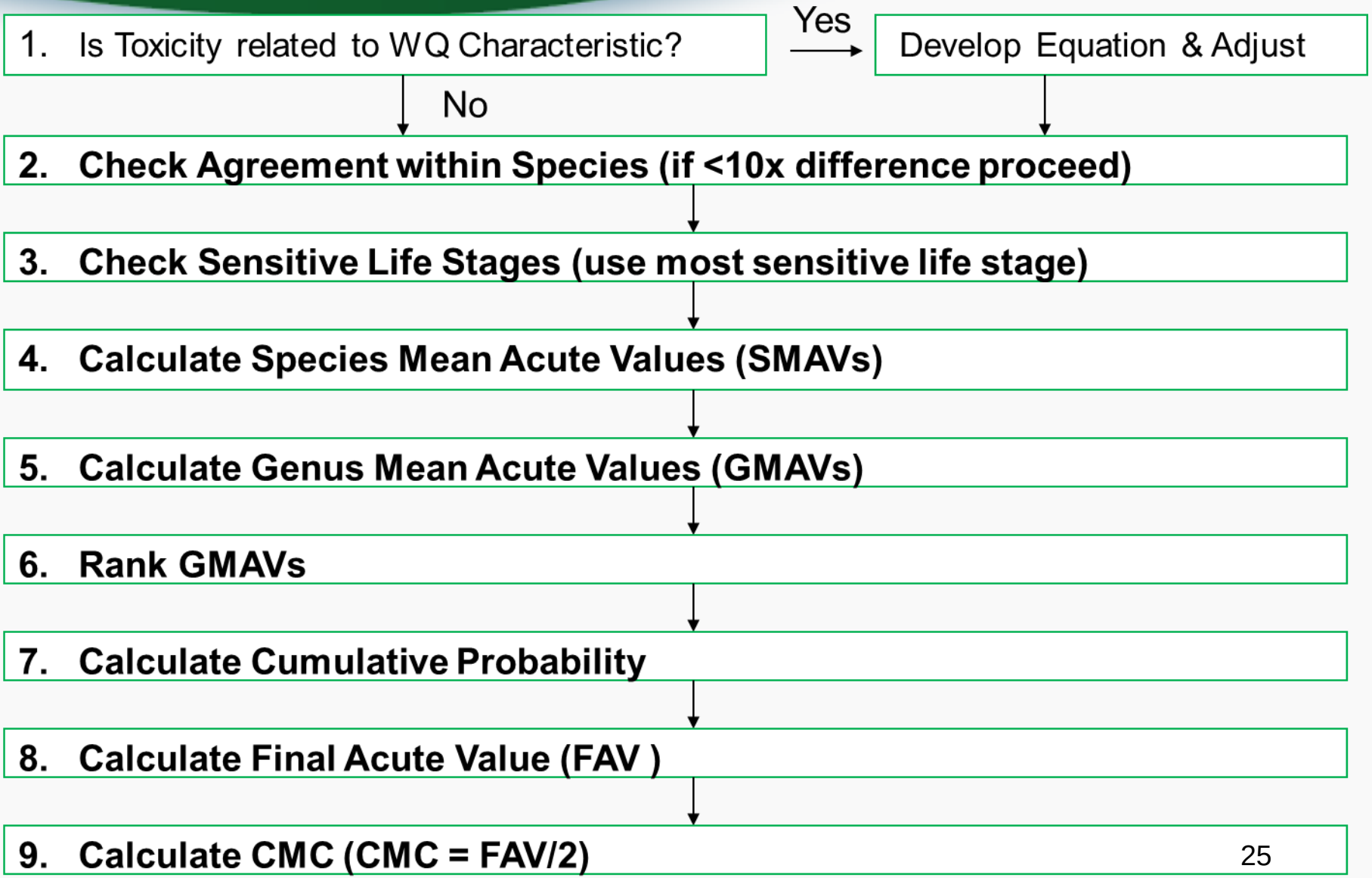
FAV Calculation Overview



Criterion Maximum Concentration (CMC)

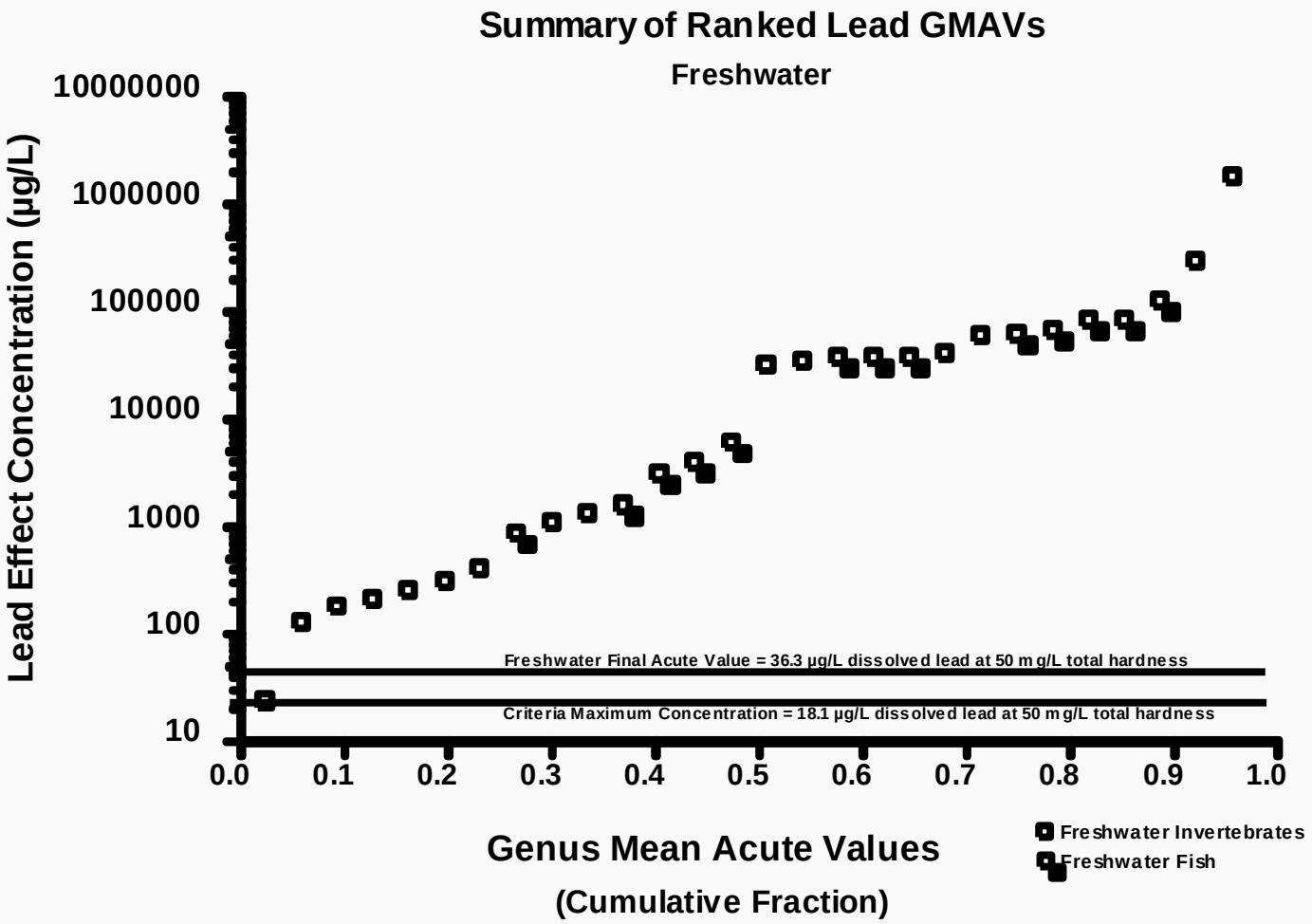


Aquatic Life Criteria: Final Overview

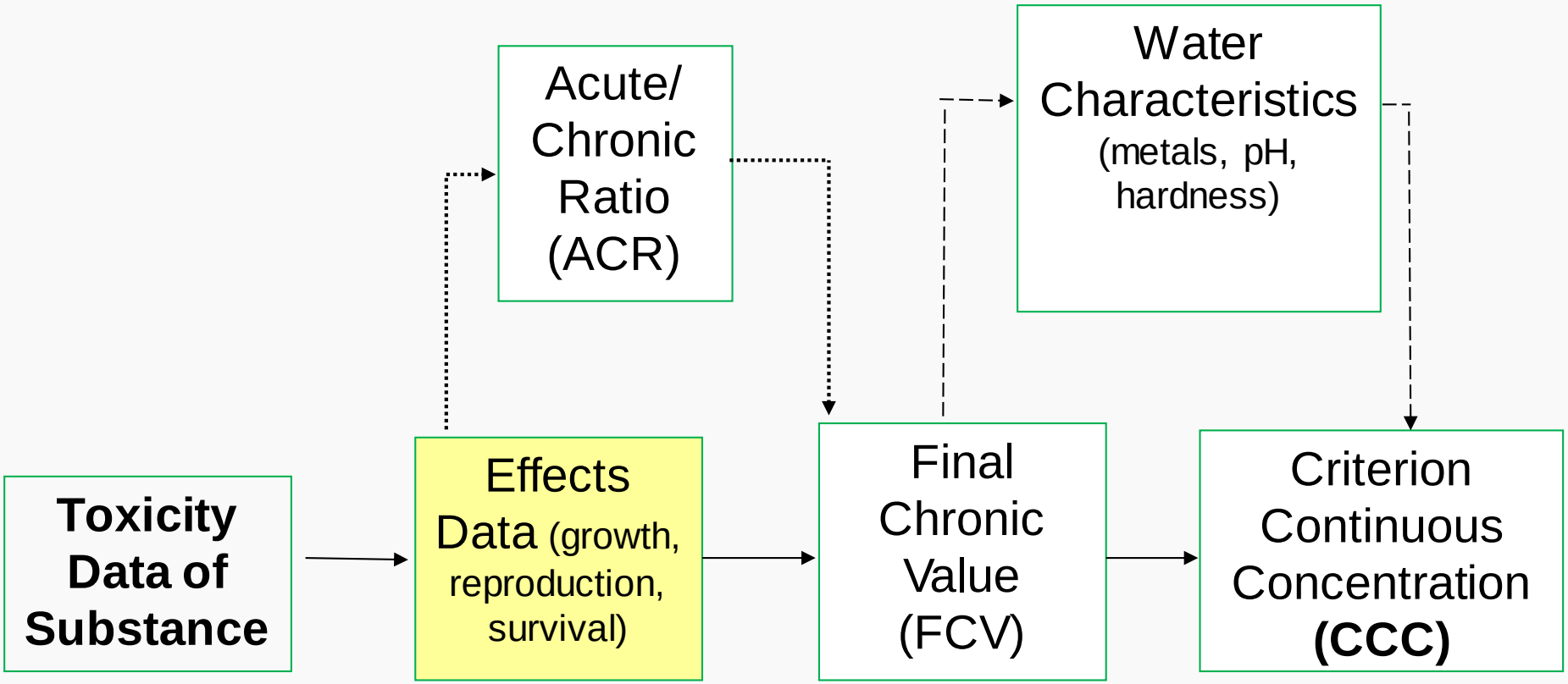


Species Sensitivity Distribution

Species Sensitivity Distribution (SSD)



Chronic Criteria Derivation Overview



Chronic Criteria Test Endpoints

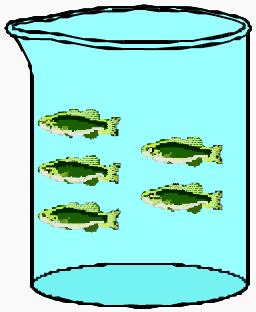
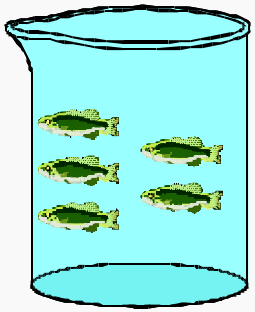
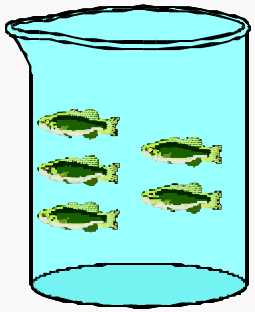
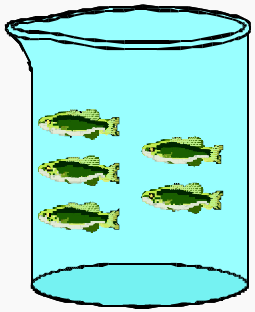
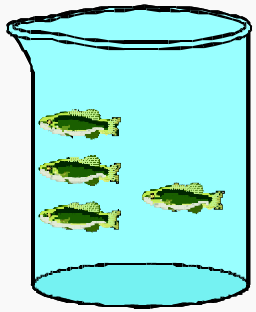
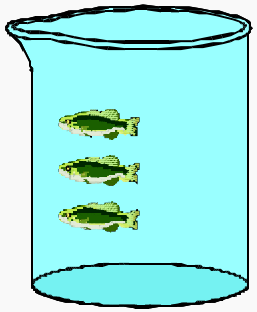
- Species-appropriate test durations
  - Including full life cycle, early-life stage tests, etc as appropriate
- Endpoints include long term mortality, growth and reproduction
  - Or other endpoints that can be linked to those apical responses quantitatively
- Test endpoints include NOECs, LOECs, and EC20s

Chronic Criteria Test Endpoint Calculation

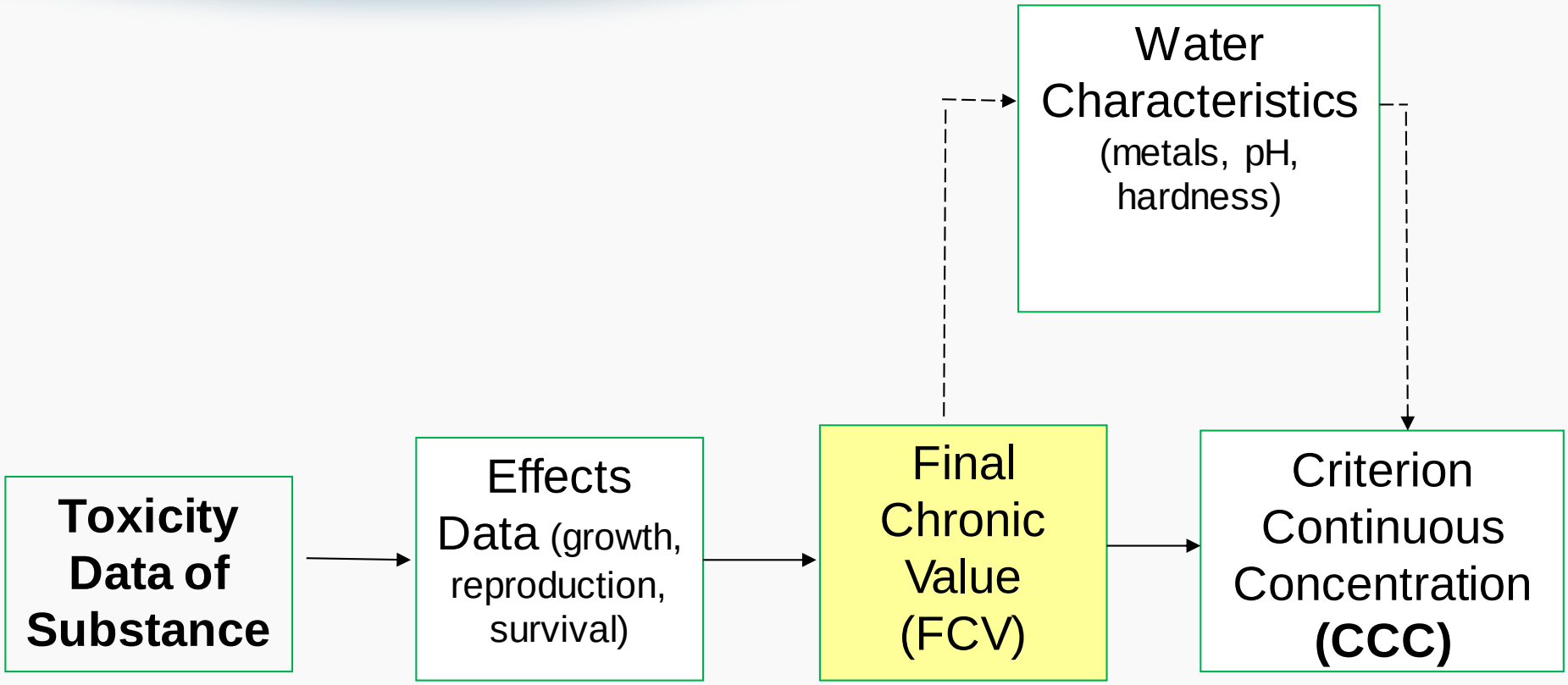
Fathead Minnow Early Life Stage Test: Growth Measured as Length

Chronic Value = 26.8 µg/L

(NOEC = 15; LOEC = 30)

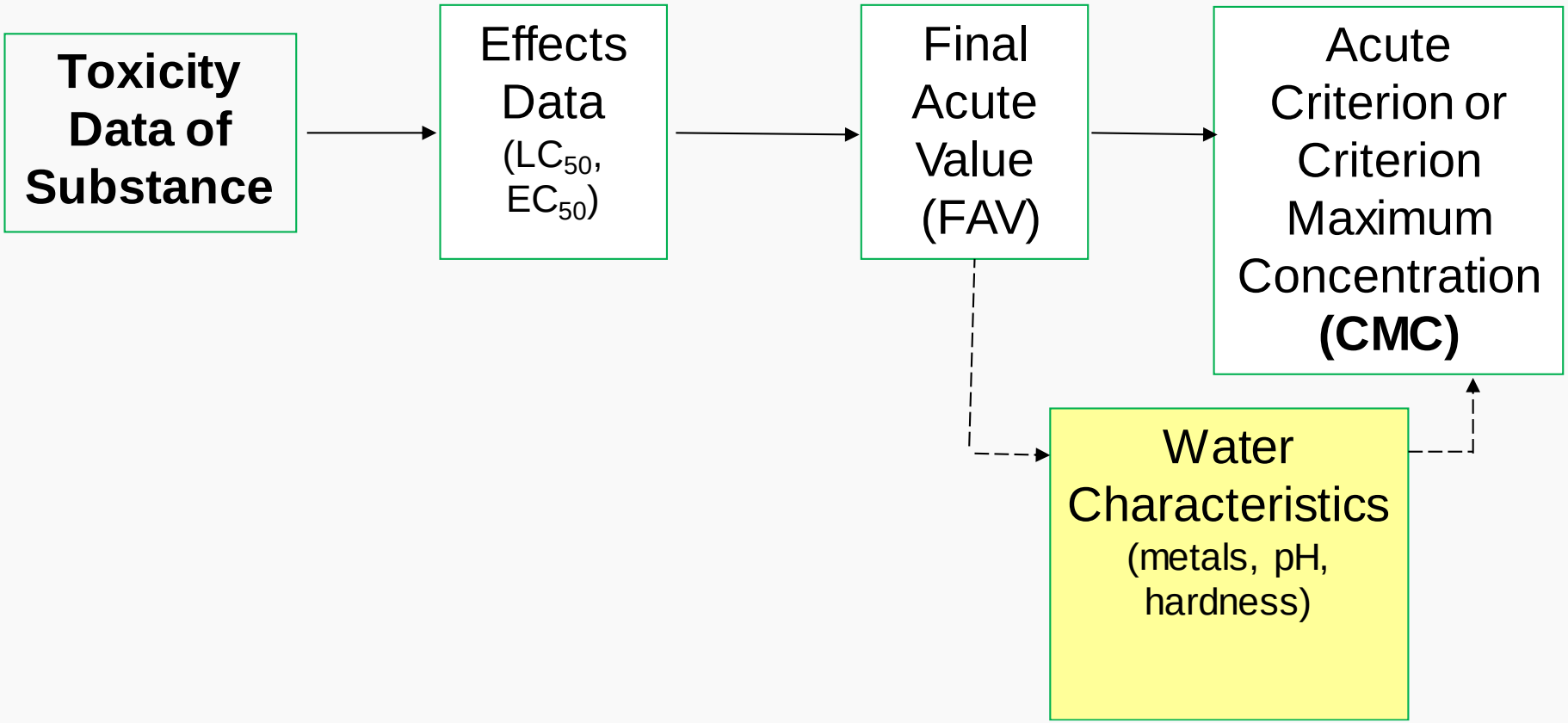
Concentration:	Control					
	0.0 µg/L	**3.8 µg/L**	**7.5 µg/L**	**15 µg/L**	**30 µg/L**	**60 µg/L**
						
Length:						
	40 mm	**41 mm**	**38 mm**	**36 mm**	**20 mm**	**5 mm**

Final Chronic Value



FCV is calculated in the same manner as with acute criteria: values are ranked in sensitivity and then a regression is performed on the 4 most sensitive genera.

Water Characteristics Affecting Criteria



Water Chemistry Dependency

Example: Cadmium Criteria Equation*

$= e^{(0.9789 \times (\ln \text{Hardness}) - 3.866)} \times CF,$

where CF (conversion factor from Total to Dissolved)

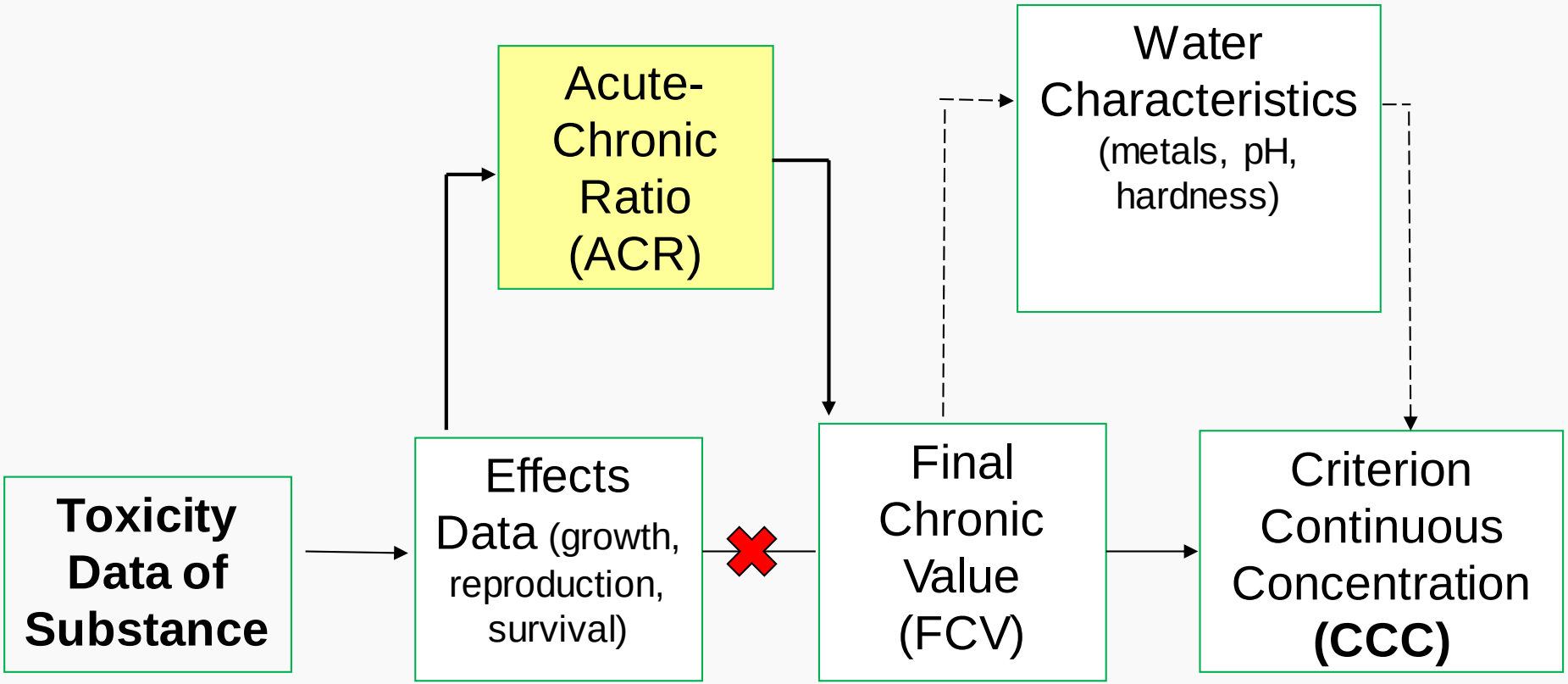
$= 1.136672 - [(\ln \text{hardness}) \times (0.041838)]$

Hardness (mg/L)	Criteria Value (µg/L dissolved)
25	0.49
50	0.94
100	1.8
200	3.4

** Based on dissolved concentration, 2016 Final Cd criteria document*

Derivation of FCV when Insufficient Data

… OR …



Acute-Chronic Ratio

Calculating and Applying the ACR

1. Acute & chronic tests using same species in same dilution water *(guidance on test matching and requirements in 1985 Guidelines)*

2. Use results of tests to calculate Acute-Chronic Ratios (ACR)

$$ACR = \frac{\text{Acute Value}}{\text{Chronic Value}}$$

3. Develop a Final Acute-Chronic Ratio (FACR) by taking a geometric mean of the appropriate ACRs *(3 minimum)*

4. Calculate the Final Chronic Value (FCV) using the FACR

$$FCV = \frac{\text{Final Acute Value}}{FACR}$$

Site Specific Criteria (1)

Why would you develop a site-specific criterion?

The sensitivities of the site-specific species differ from the national data set (e.g., that in the criteria document).

and/or

The physical/chemical characteristics of the site alter the bioavailability/toxicity of the pollutant.

Site Specific Criteria (2)

PROCEDURES

If Physical or Chemical Properties at Site Affect Bioavailability

Use Water-Effect Ratio (WER) Procedure or a Streamlined WER

If Species at Site Are More or Less Sensitive

Use Recalculation Procedure

If Both of These Conditions Exist

Use Recalculation Procedure in Conjunction with Water-Effect Ratio Procedure or Use Resident Species Procedure

BLMs, MLRs, & WERs

- Since the 1990s, the WER has been used to adjust hardness-based criteria for metals.
- In 2007, the biotic ligand model (BLM) was developed for copper.
  - The BLM models the bioavailability of copper based on 10 water chemistry parameters (pH, DOC, temperature, alkalinity and 6 geochemical ions (GI))
  - Implementation issues have slowed its widespread adoption and use
- Recently, a multiple linear regression method (MLR) was developed for aluminum, that simplifies the modeling necessary based on 3-4 water chemistry parameters.
  - EPA published a Final Revised Aluminum (December 2018) based on 3 water chemistry parameters (pH, DOC, and hardness)

BLMs, MLRs, & WERs

- EPA recommends the use of the Biotic Ligand Model (BLM) for copper.
- EPA recommends the use of the Multiple Linear Regression (MLR) approach for aluminum.
- For other metals (Cd, Ni, Pb, Zn), a WER based on appropriately-conducted studies is still a potential approach for adjusting the respective hardness-based criteria at a site, until the criteria are updated to reflect fuller effects of water chemistry through bioavailability modeling (e.g., MLR or BLM).
- EPA has entered into a Cooperative Research and Development Agreement (CRADA) with 8 metals associations to further the development of updated aquatic life criteria for the other metals.
  - https://www.epa.gov/sites/production/files/2018-01/documents/metals-crada-summary-2018.pdf

Criteria Review Process

EPA Review

- Internal Review
  - EPA Peer Review
    - Data quality of studies used in criteria derivation
    - Intra-agency workgroup
- External Review
  - External Peer Review (external experts – multiple views)
- Publication of Draft Recommended 304(a) criteria via the Federal Register
  - Request for scientific views on draft criteria from the public via Federal Register
- Publication of Final Recommended 304(a) criteria via the Federal Register
  - Response to Comments Document (Published with Final)

State/Tribal Review and Adoption Process

- State Triennial Review/Adoption of criteria into WQS
- Public comments on draft WQS according to State/Tribal regulatory adoption process (Administrative Procedure Act)
- EPA approval of WQS
- WQS implementation – permits, TMDLs, monitoring and assessments

Aquatic Life Exercise

See Exercise 6

Data Table for Mineral X

Genus	species	Common name	SMAV (ug/L)	GMAV	ACR	taxa
Bufo	americanus	American toad	9805			chordata
Cragonyx	pseudogracilis	Amphipod	9190			benthic crustacean
Hyalella	azteca	Amphipod	1455			benthic crustacean
Salmo	salar	Atlantic salmon	879			salmonid
Salvelinus	fontinalis	Brook trout	6965			salmonid
Ictalurus	punctatus	Channel catfish	761			fish
Oncorhynchus	tshawytscha	Chinook salmon	11827			salmonid
Ceriodaphnia	dubia	Cladoceran	1718		4.31	planktonic crustacean
Daphnia	magna	Cladoceran	12329			planktonic crustacean
Enallagma		Damselfly	1075			insect
Pimephales	promelas	Fathead minnow	14100		6.06	fish
Lepomis	cyanellus	Green sunfish	52273			fish
Hyla	cinerea	Green tree frog	6171			chordata
Rana	pipiens	Leopard frog	8709			chordata
Tanytarus	dissimilis	Midge	186860		34.08	insect taxa 1
Pisidium	casertanum	Pea cockle	1072			mollusc
Oncorhynchus	mykiss	Rainbow trout	6901			salmonid
Pisidium	compressum	Ridged-beak peaclam	1072			mollusc
Hybognathus	amarus	Rio Grande minnow	25074			fish
Micropterus	dolomieui	Smallmouth bass	1662			fish
Amnicola	limosa	Snail	1080			mollusc
Physa		Snail	32907			mollusc

Question 1

1.Are the required eight taxa represented in this dataset?

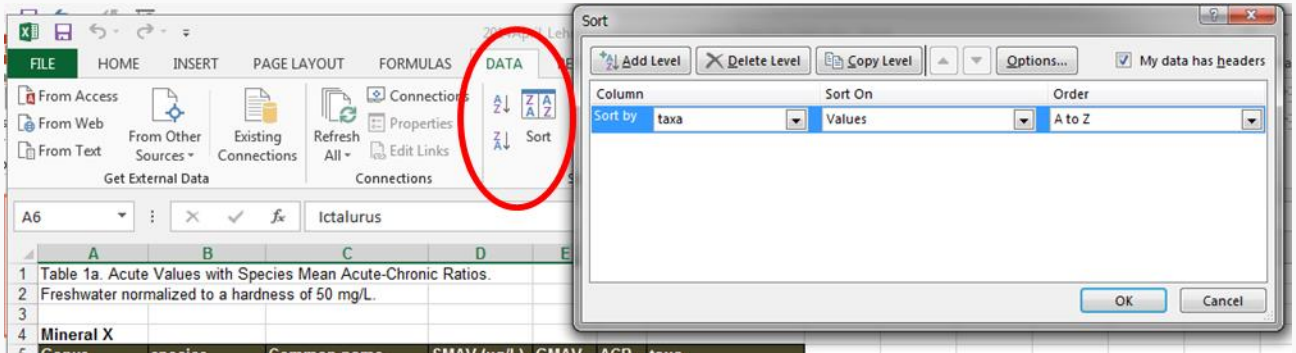


Table 1a. Acute Values with Species Mean Acute-Chronic Ratios.
Freshwater normalized to a hardness of 50 mg/L.

Mineral X

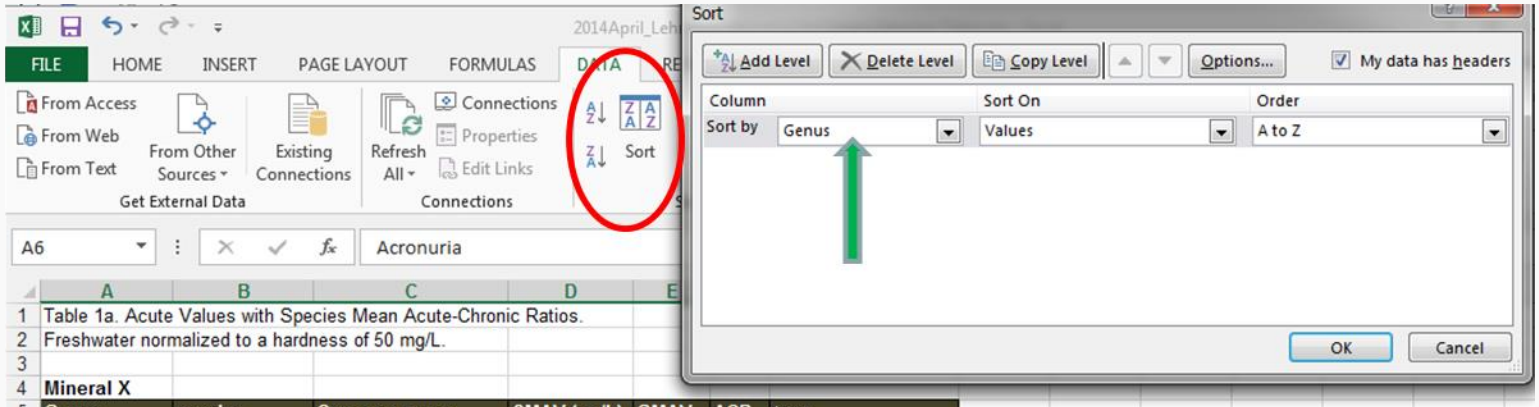
Genus	species	Common name	SMAV (ug/L)	GMAV	ACR	taxa
Ictalurus	punctatus	Channel catfish	761			fish
Salmo	salar	Atlantic salmon	879			salmonid
Pisidium	casertanum	Pea cockle	1072			mollusc
Enallagma		Damselfly	1075			insect
Amnicola	limosa	Snail	1080			mollusc
Pisidium	compressum	Ridged-beak peaclam	1110			mollusc
Hyalella	azteca	Amphipod	1455			benthic crustacean
Micropterus	dolomieui	Smallmouth bass	1662			fish
Ceriodaphnia	dubia	Cladoceran	1718		4.31	planktonic crustacean
Hyla	cinerea	Green tree frog	6171			chordata
Oncorhynchus	mykiss	Rainbow trout	6901			salmonid
Salvelinus	fontinalis	Brook trout	6965			salmonid
Rana	pipiens	Leopard frog	8709			chordata
Cragonyx	pseudogracilis	Amphipod	9190			benthic crustacean
Bufo	americanus	American toad	9805			chordata
Oncorhynchus	tshawytscha	Chinook salmon	11827			salmonid
Daphnia	magna	Cladoceran	12329			planktonic crustacean
Pimephales	promelas	Fathead minnow	14100		6.06	fish
Acronuria		Stonefly	23627			insect
Hybognathus	amarus	Rio Grande minnow	25074			fish
Physa		Snail	32907			mollusc
Lepomis	cyanellus	Green sunfish	52273			fish
Tanytarus	dissimilis	Midge	186860		34.08	insect taxa 1

YES!

1. Salmonid
2. 2nd Fish
3. Chordate
4. Planktonic crustacean
5. Benthic crustacean
6. Insect
7. Rotifer/annelid/mollusc
8. Other insect/mollusc

Question 2

2. What is the N for this data set?



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Physa		Snail	32907			mollusc
Pimephales	promelas	Fathead minnow	14100		6.06	fish
Pisidium	casertanum	Pea cockle	1072			mollusc
Pisidium	compressum	Ridged-beak peaclam	1110			mollusc
Rana	pipiens	Leopard frog	8709			chordata
Salmo	salar	Atlantic salmon	879			salmonid
Salvelinus	fontinalis	Brook trout	6965			salmonid
Tanytarus	dissimilis	Midge	186860		34.08	insect taxa 1

21

Number (N) is the number of GMAVs.
GMAV = genus mean acute values

Questions 4 and 5

4 & 5. What is the most/least sensitive Genus?

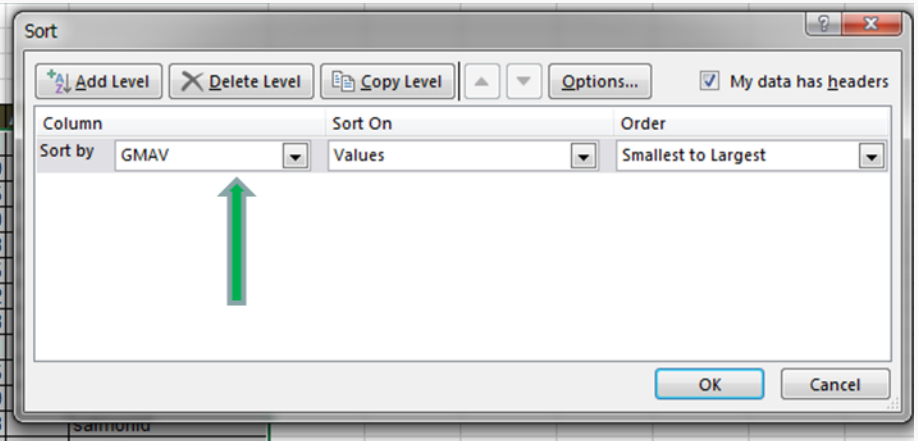
Most = Ictalurus

Least = Tanytarus

Table 1a. Acute Values with Species Mean Acute-Chronic Ratios.
Freshwater normalized to a hardness of 50 mg/L.

Mineral X

Genus	species	Common name	SMAV (ug/L)	GMAV		
Ictalurus	punctatus	Channel catfish	761	761		
Salmo	salar	Atlantic salmon	879	879		
Enallagma		Damselfly	1075	1075		
Amnicola	limosa	Snail	1080	1080		
Pisidium	casertanum	Pea cockle	1072	1090		
Hyalella	azteca	Amphipod	1455	1455		
Micropterus	dolomieui	Smallmouth bass	1662	1662		
Ceriodaphnia	dubia	Cladoceran	1718	1718		
Hyla	cinerea	Green tree frog	6171	6171		
Salvelinus	fontinalis	Brook trout	6965	6965		
Rana	pipiens	Leopard frog	8709	8709		
Oncorhynchus	mykiss	Rainbow trout	6901	9034		
Cragonyx	pseudogracilis	Amphipod	9190	9190		benthic crustacean
Bufo	americanus	American toad	9805	9805		chordata
Daphnia	magna	Cladoceran	12329	12329		planktonic crustacean
Pimephales	promelas	Fathead minnow	14100	14100	6.06	fish
Acronuria		Stonefly	23627	23627		insect
Hybognathus	amarus	Rio Grande minnow	25074	25074		fish
Physa		Snail	32907	32907		mollusc
Lepomis	cyanellus	Green sunfish	52273	52273		fish
Tanytarus	dissimilis	Midge	186860	186860	34.08	insect taxa 1
Pisidium	compressum	Ridged-beak peaclam	1110			mollusc
Oncorhynchus	tshawytscha	Chinook salmon	11827			salmonid



Questions 6 and 7

6 & 7. What are the FAV & CMC?

E10 =GEOMEAN(D10,D27)

	A	B	C	D	E
1	Table 1a. Acute Values with Species Mean Acute-Chronic Ratios.				
2	Freshwater normalized to a hardness of 50 mg/L.				
3					
4	**Mineral X**				
5	**Genus**	**species**	**Common name**	**SMAV (ug/L)**	**GMAV**
6	Ictalurus	punctatus	Channel catfish	761	761
7	Salmo	salar	Atlantic salmon	879	879
8	Enallagma		Damselfly	1075	1075
9	Amnicola	limosa	Snail	1080	1080
10	Pisidium	casertanum	Pea cockle	72	1090.83
11	Hyalella	azteca	Amphipod	1455	1455
12	Micropterus	dolomieui	Smallmouth bass	1662	1662
13	Ceriodaphnia	dubia	Cladoceran	1718	1718
14	Hyla	cinerea	Green tree frog	6171	6171
15	Salvelinus	fontinalis	Brook trout	6965	6965
16	Rana	pipiens	Leopard frog	8709	8709
17	Oncorhynchus	mykiss	Rainbow trout	6901	9034.28
18	Cragonyx	pseudogracilis	Amphipod	9190	9190
19	Bufo	americanus	American toad	9805	9805
20	Daphnia	magna	Cladoceran	12329	12329
21	Pimephales	promelas	Fathead minnow	14100	14100
22	Acronuria		Stonefly	23627	23627
23	Hybognathus	amarus	Rio Grande minnow	25074	25074
24	Physa		Snail	32907	32907
25	Lepomis	cyanellus	Green sunfish	52273	52273
26	Tanytarus	dissimilis	Midge	186860	186860
27	Pisidium	compressum	Ridged-beak peaclam	1110	
28	Oncorhynchus	tshawytscha	Chinook salmon	11827	

Criteria Calculator

Beryllium - 7440417

Red fields are for data entry. Results are in green highlighted boxes after input.

1. Recalculate the FAV & CMC from GMAVs

Instructions: enter N (number of acceptable GMAVs) and the 4 GMAVs that have cumulative probabilities (P) close
If $N < 59$, these are the four lowest GMAVs. N must be ≥ 8 (see User Manual for addional details). Red cells

Input

N	GMAV	Rank	ln(GMAV)	ln(GMAV)²	P=R/(N+1)	sqrt(P)
21	761	1	6.63	44.02	0.045	0.213
	879	2	6.78	45.95	0.091	0.302
	1075	3	6.98	48.72	0.136	0.369
	1080	4	6.98	48.79	0.182	0.426
		Sum:	27.38	187.48	0.45	1.31

$S^2 = 3.42$
$S = 1.85$
$L = 6.24$
$A = 6.65$

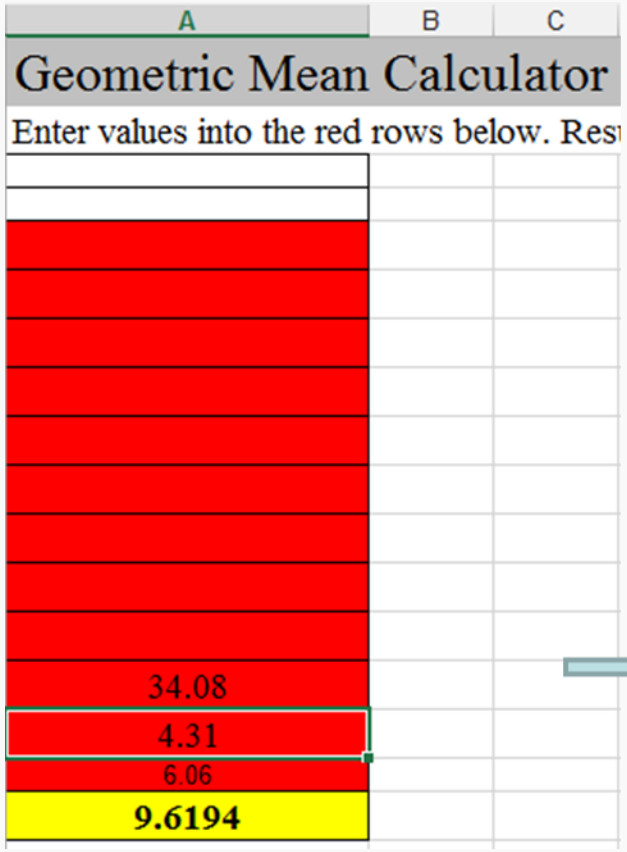
Recalculated FAV and CMC: FAV = 774.5240, CMC = 387.2620

FAV = 775 CMC = 387

Questions 8 and 9

8. What is the FACR? 9. What is the CCC (chronic)?

FACR = 9.6 CCC = 80.5



Input						
N	GMAV	Rank	ln(GMAV)	ln(GMAV)²	P=R/(N+1)	sqrt(P)
21	761	1	6.63	44.02	0.045	0.213
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	1080	4	6.98	48.79	0.182	0.426
		Sum:	27.38	187.48	0.45	1.31

$S^2 = 3.42$
$S = 1.85$
$L = 6.24$
$A = 6.65$

Recalculated FAV and CMC: FAV = 774.5240, CMC = 387.2620

(automatic)

2(b). Recalculate the CCC from the final ACR

Instructions: enter the acute-chronic ratio (ACR) in red colored cell

Input: Final ACR: 9.62

Recalculated CCC: (Estimated as FAV/ACR) CCC = 80.5169