Animas River
Arrastra Gulch to Bakers Bridge

Ecological Risk Assessment

Overview

- Ecological Risk Assessment (ERA) Process
- Ecological Risk Assessment Tools
- Results
  - Benthic Macroinvertebrates
  - Fish
  - Wildlife; Not discussed in detail today
- Conclusions

Ecological Risk Assessment (ERA)

- Evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to site contamination.
- ERA is designed to support decision making to mitigate risk where needed.
- Risks may include survival, reproductive impairment, growth impairment and loss of habitat.
- Risks are estimated at the population level (populations on site).

Exposure Units

- Cement Creek

    Not discussed in detail today

- Mineral Creek

    Not discussed in detail today

- Animas Upstream of Cement Creek to Arrastra

    Data averaged across entire reach

- Animas from Cement Creek to Mineral Creek

    Not discussed in detail today

- Animas downstream of Cement Creek

    Data evaluated at individual stations due to distance between each location.

Exposure Point Concentrations

- Reasonable Maximum Exposure (RME)
  - 95% upper confidence level of the mean if dataset allows
  - Otherwise maximum value is used
  - Hardness dependent metals use 95% *lower* confidence limit of the mean.
- Central Tendency (CT)
  - Arithmetic or geometric mean

Measurement Endpoints or Lines of Evidence

- HQ Approach
- Site Specific Toxicity Testing
- Community or Population Surveys

Hazard Quotient (HQ)

HQ = Exposure / Benchmark

HQ<1 = Acceptable risk

HQ>1 = Further evaluation warranted *or* unacceptable risk

Toxicity Testing

Community Surveys

Community Surveys-Habitat

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 11	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE 18	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 9 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE 9 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 10 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE 10 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE 7 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE 9 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Total Score 107

Upper Animas Assessment and Measurement Endpoints

- *Maintain a stable and healthy benthic invertebrate community.*
  - *Hazard Quotient (effect and no effect)*
  - *Toxicity Tests*
  - *Community Survey*
- *Maintain a stable and healthy fish community.*
  - *Hazard Quotient*
  - *Toxicity Tests*
  - *Community Survey*
- *Maintain stable and healthy insectivorous, omnivorous, piscivorous bird populations.*
  - *Hazard Quotient-Food Chain modelling*
- *Maintain stable and healthy herbivorous mammal populations*
  - *Hazard Quotient-Food Chain modelling*

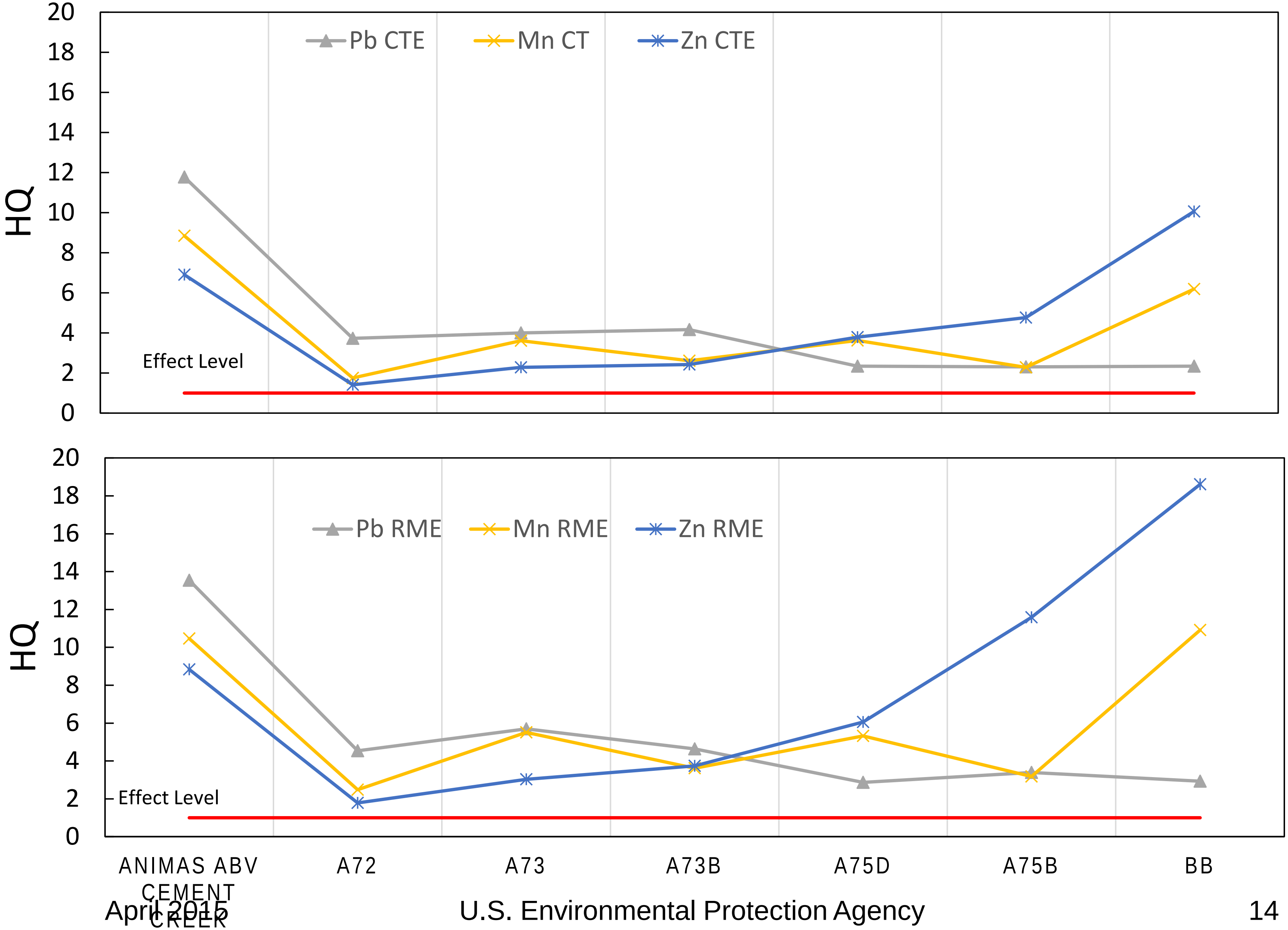
Results

- *Maintain a stable and healthy benthic invertebrate community.*
  - *Hazard Quotient (effect and no effect)*
    - *Sediment and Porewater*
  - *Toxicity Tests*
  - *Community Survey*
- *Maintain a stable and healthy fish community.*
  - *Hazard Quotient*
  - *Toxicity Test*
  - *Community Survey*

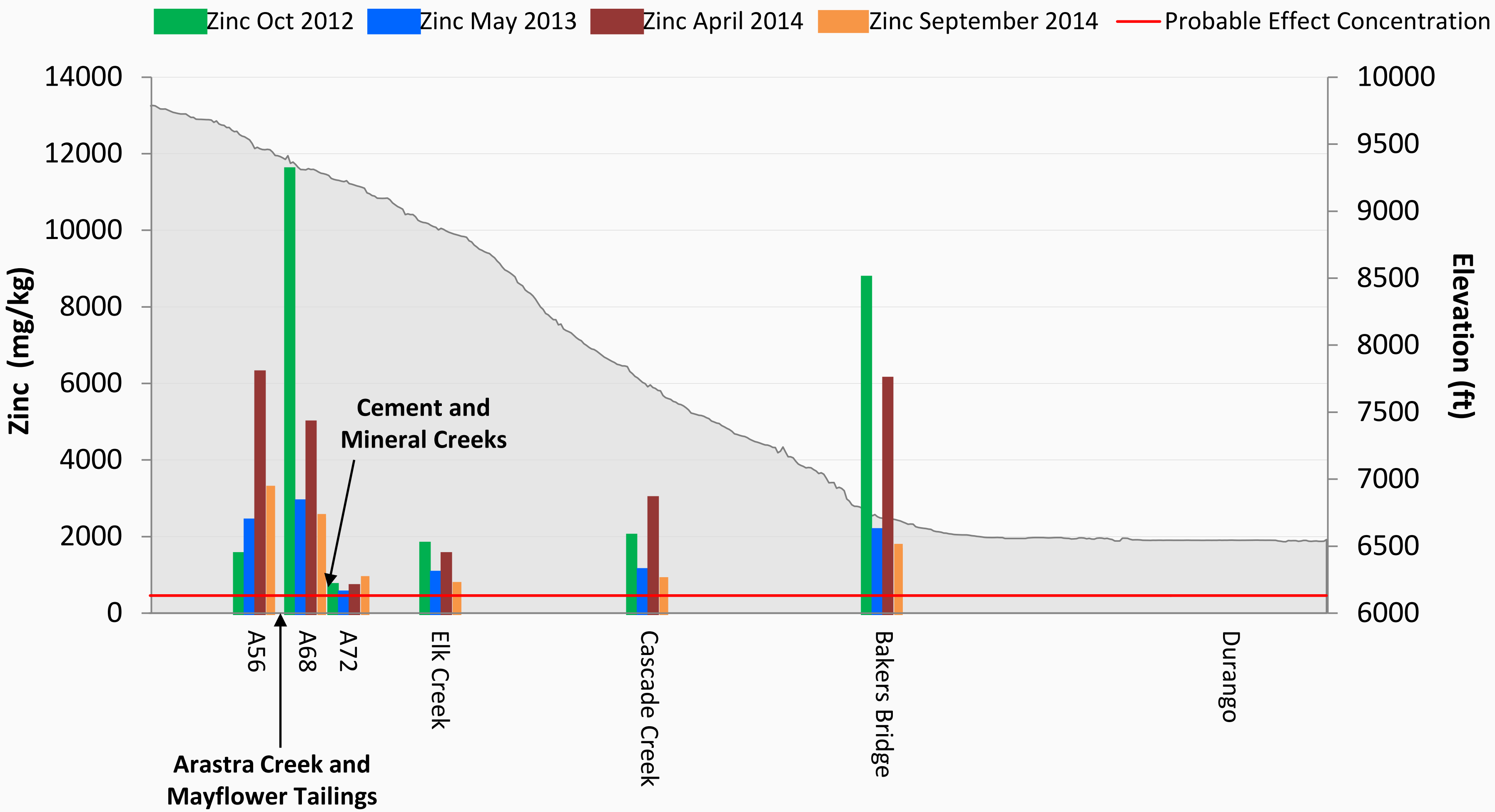
Sediment Data Evaluation

- Organized by river reach (EU)
- Not enough data to organize by flow regime
- No effect and effect benchmarks
- Sediment concentrations evaluated as RME and CTE.

CTE and RME Sediment Effect HQs Results



Zinc Sediment Concentrations and Animas River Elevation Profile



Sediment HQ Conclusions

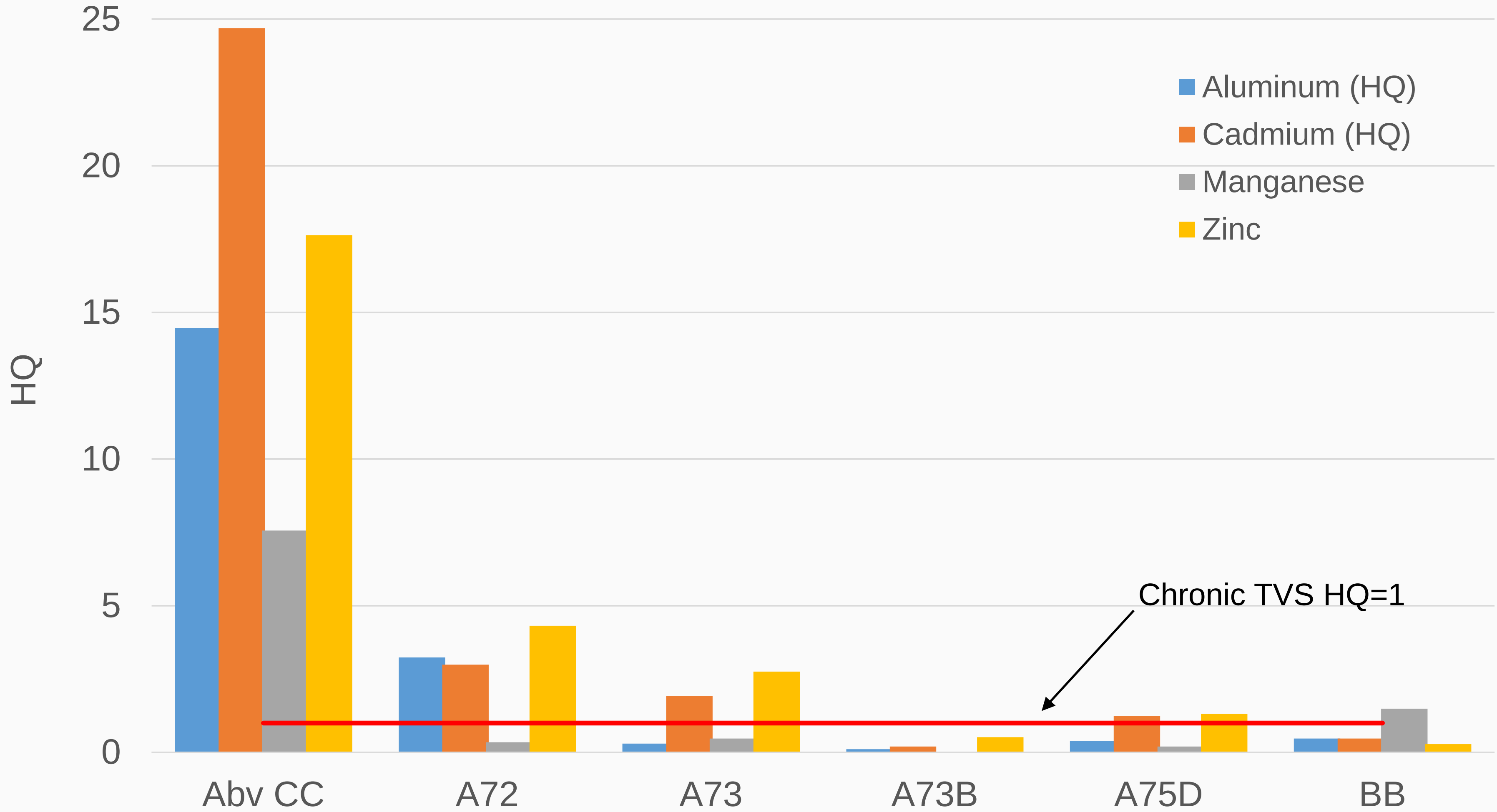
- Primary Risk Drivers to benthic community
  - Lead, Manganese and Zinc
  - Elevated risk in all reaches of the mainstem
- Secondary Risk Drivers
  - Cadmium and Copper
  - Varies by reach
- Some metals increase thru canyon
- Bulk metals concentrations highly variable

Pore Water Data Evaluation

- Organized by river reach (EU)
- Not enough data to organize by flow regime
  - 11 samples upstream, 1 or 2 samples/station downstream of Cement Creek
- Hardness evaluated at mean and 95% LCL
- Compared to chronic water quality standards (TVS)
  - Aluminum, pH, dissolved

Sediment Porewater HQs

Average Concentration and Average Hardness



Porewater HQ Conclusions

- Risks generally low to moderate
- Risk drivers Al, Cd, Mn and Zn
  - Variable by location
- Upstream risks are substantially higher
  - Driven largely by A61
- Uncertainties
  - Data set is small
  - Aluminum results uncertain (dissolved, no pH)

Results

- *Maintain a stable and healthy benthic invertebrate community.*
  - *Hazard Quotient (effect and no effect)*
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  - *Community Survey*
- *Maintain a stable and healthy fish community.*
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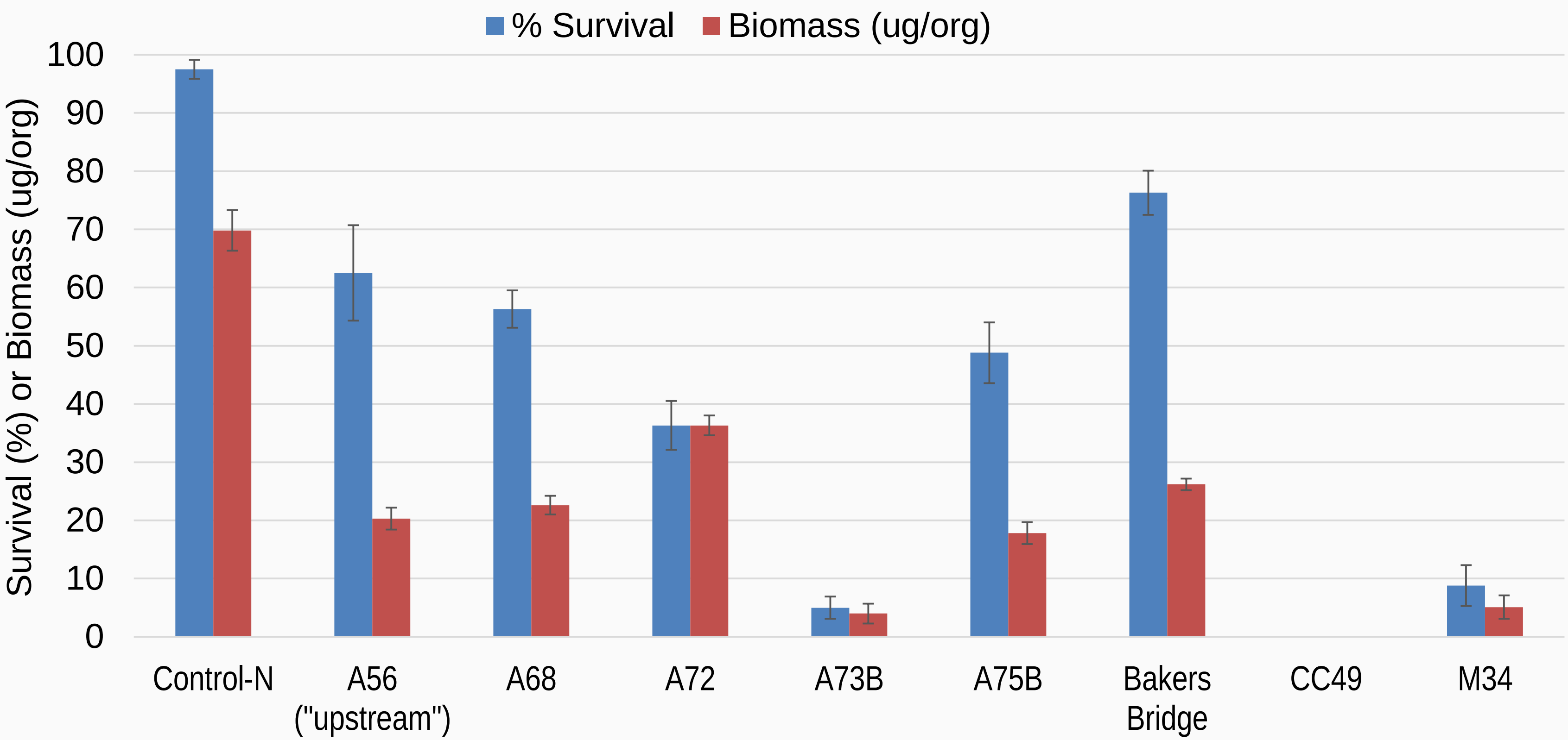
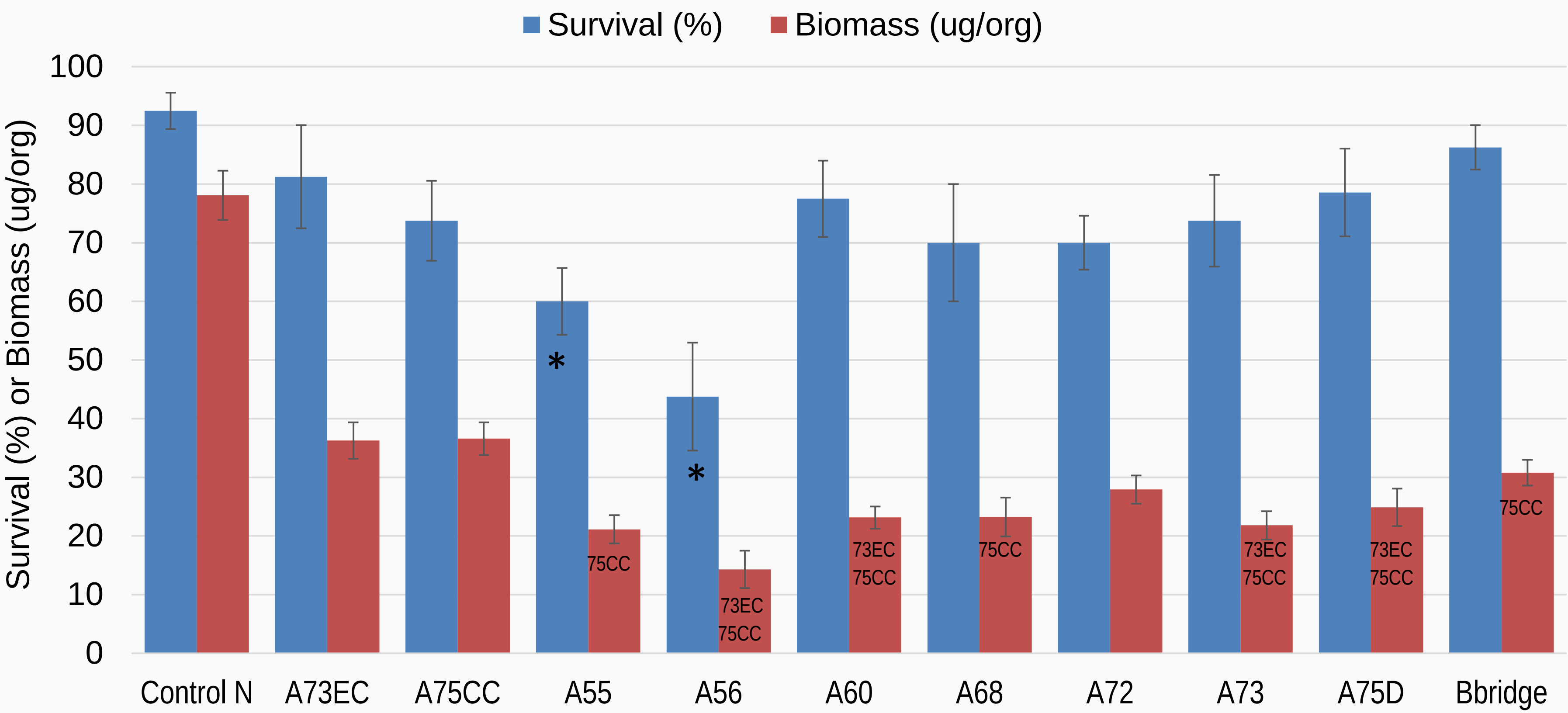
2012 Sediment Toxicity Test Results



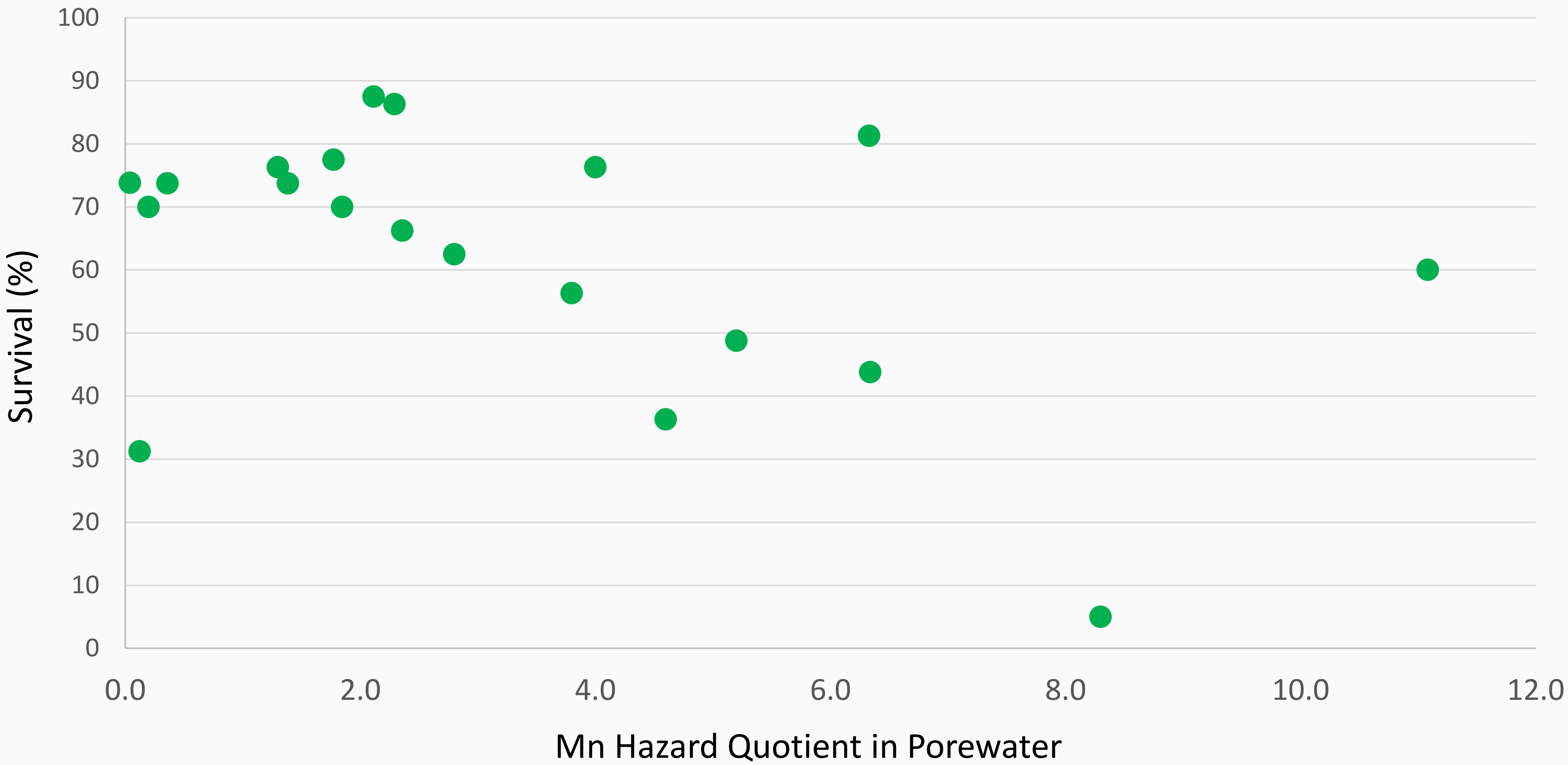
All locations statistically different from Control-N

2014 Sediment Toxicity Test Results



*statistically different from Control-N for Survival results. All Biomass results statistically less than Control-N.
73EC-statistically different than station A73EC
75CC- statistically different that station A75CC

Survival vs Mn HQs in Porewater ?



Sediment Toxicity Test Conclusions

- Survival results variable between 2012 and 2014
  - 2012:
    - All locations showed low survival and biomass compared to lab control.
  - 2014:
    - Upstream locations had low survival compared to lab control.
    - Most locations had low biomass compared to Elk and Cascade creek locations
    - All locations had low biomass compared to lab control
- Responses not obviously correlated to bulk metals
- Responses *suggest* Mn playing a role in toxicity

Results

- *Maintain a stable and healthy benthic invertebrate community.*
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- *Maintain a stable and healthy fish community.*
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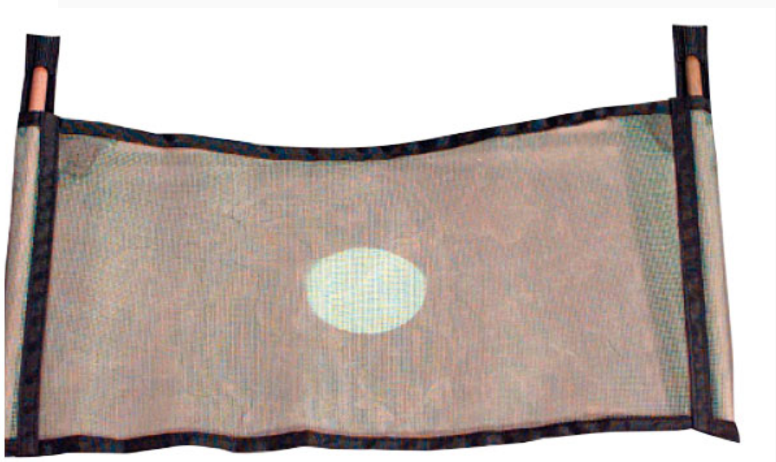
Benthic Community Survey Methods



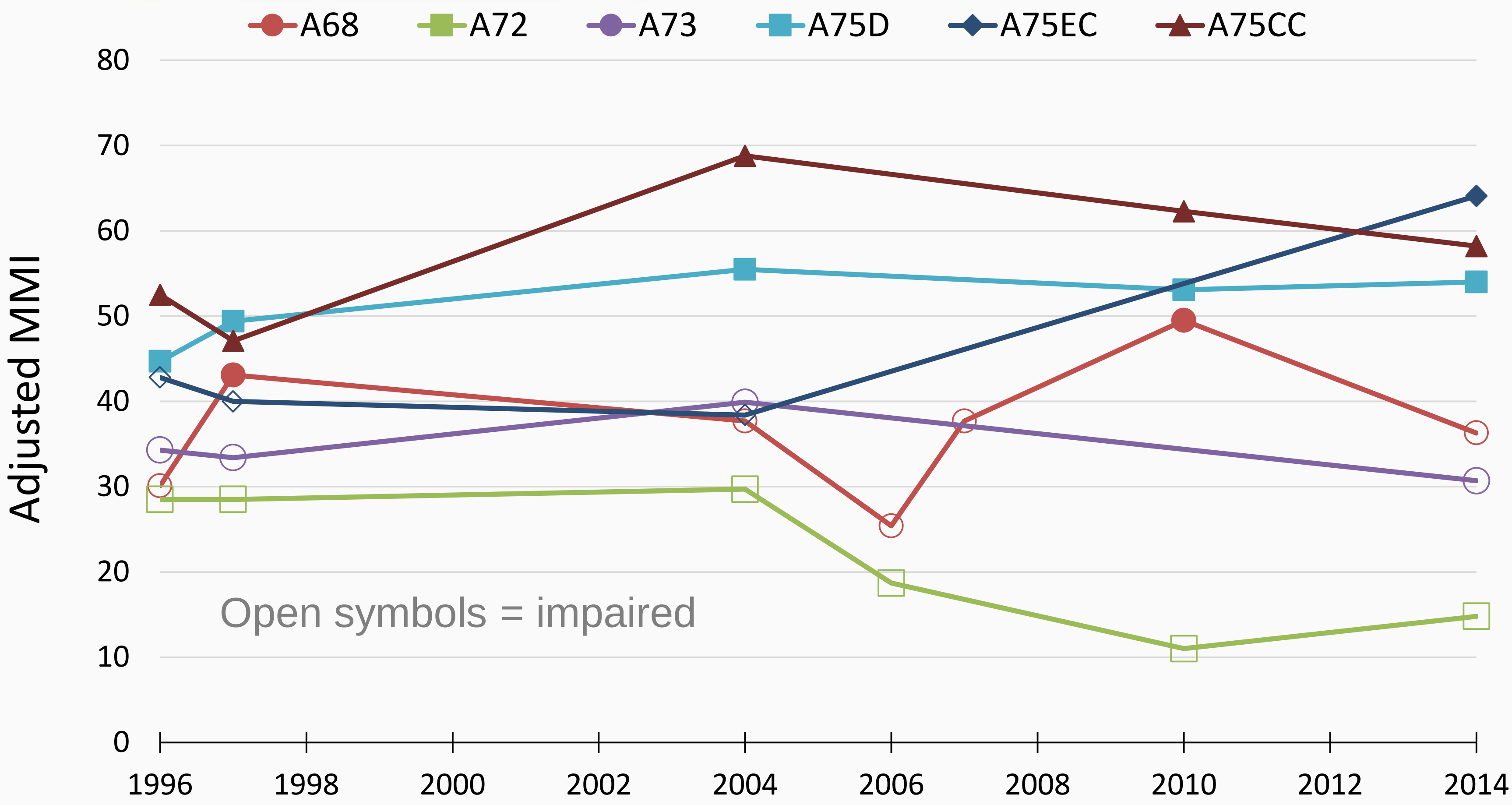
Historic Data Uncertainty

- Multiple methods listed in the datasheets and reports
- CO Multi-Metric Index (MMI) recalibrated
  - Comprised of different metrics
  - Different identification requirements
  - Different classification of organisms
- Comparisons with historic data
  - 2014 calculated to match historic data
  - Historic data reclassified to match current requirements where possible
- Consider as qualitative estimates

2014 MMI


70
60
50
40
30
20
10
0
MMI
Red bars indicate impairment
M34
CC49
A53
A55
A56
A60
A68
A72
A73
A75D
BB
James Ranch
A75EC
A75CC

Adjusted MMI



Benthic Community Survey Conclusions

- 2014 results scored as impaired at several locations.
  - Impairment greatest below Cement Creek
  - Recovery evident downstream
  - Upstream not consistently or severely impaired
- Historic trends
  - Results are uncertain
  - A72,A73 consistently impaired
  - A68 inconsistently and moderately impaired

Benthic Invertebrate Risk Conclusions

- Evidence shows strong likelihood of risk to invertebrates in the Animas River.
- Severity decreases downstream.
- Chemistry variable by location.
- Effects not obviously attributable to single metal.
- Chemistry vs Effect not consistent across lines of evidence

Results

- *Maintain a stable and healthy benthic invertebrate community.*
  - *Hazard Quotient (effect and no effect)*
    - *Sediment and Porewater*
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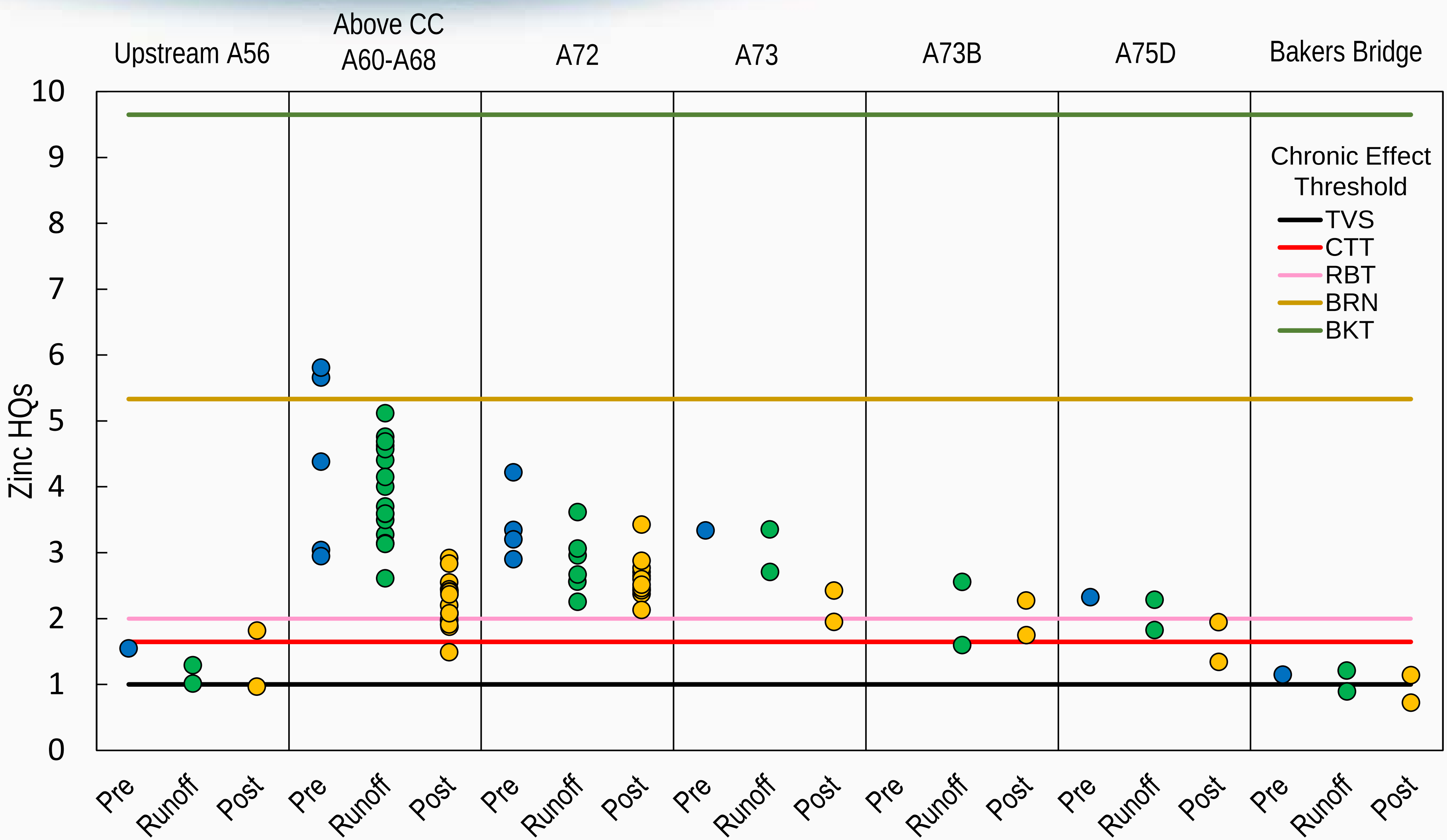
  - *Community Survey*
- *Maintain a stable and healthy fish community.*
  - *Hazard Quotient*
  - *Toxicity Test*
  - *Community Survey*

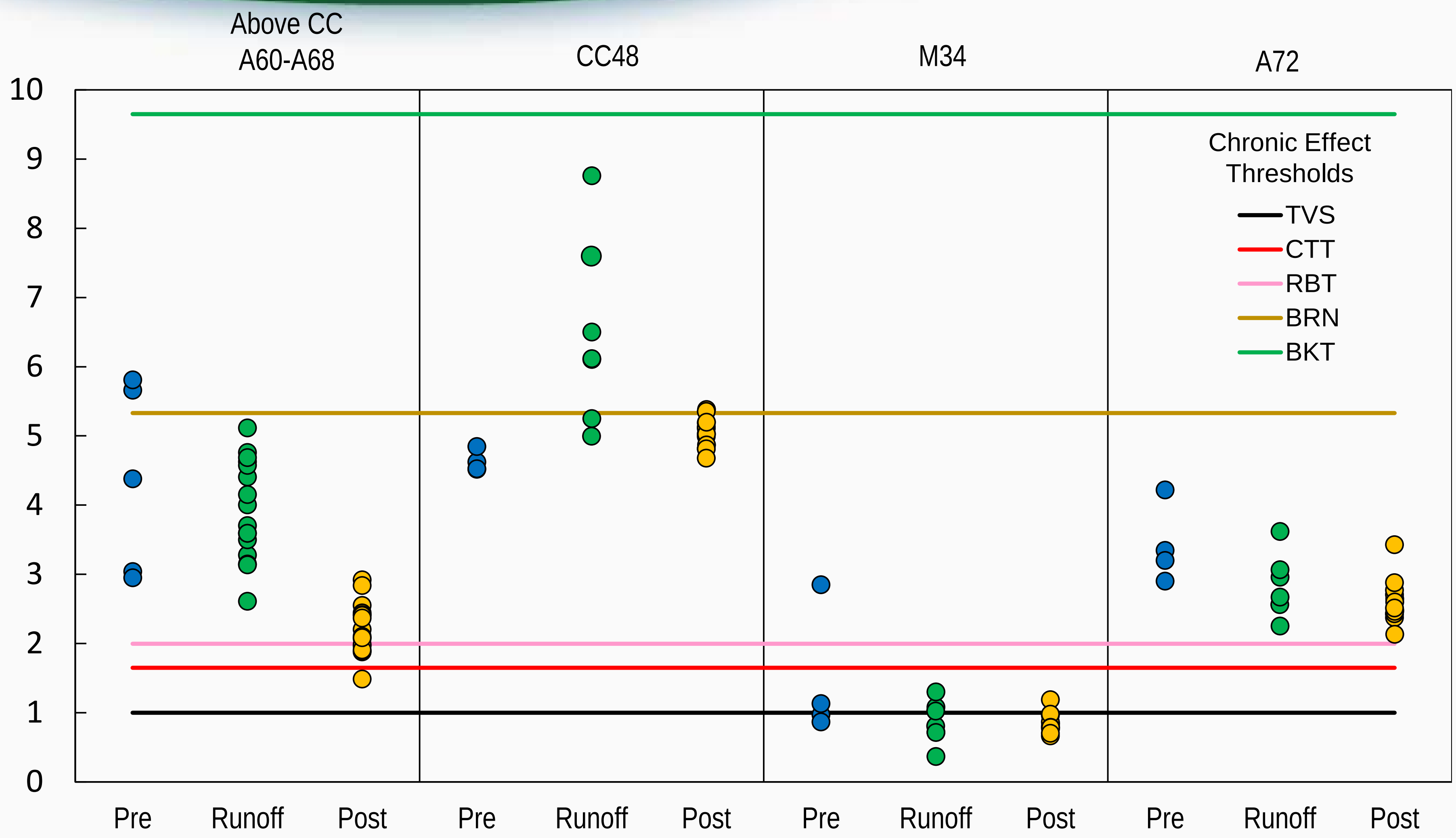
Surface Water HQ Assessment

- Two approaches
  1) Averaging over a reach *and* flow regime
     - Metals concentrations-95%UCL (or maximum) and mean
     - Hardness-95%LCL (or minimum) and mean
     - RME and CTE for both mean and low hardness
  2) Scatter plot across reach *and* flow regime
     - HQs from paired hardness and metal concentration
     - Benchmark normalized to sample hardness
- Flow regime (where data is adequate)
  - Pre-runoff (Feb-April), Runoff (May-June), Post-runoff (July-Nov)

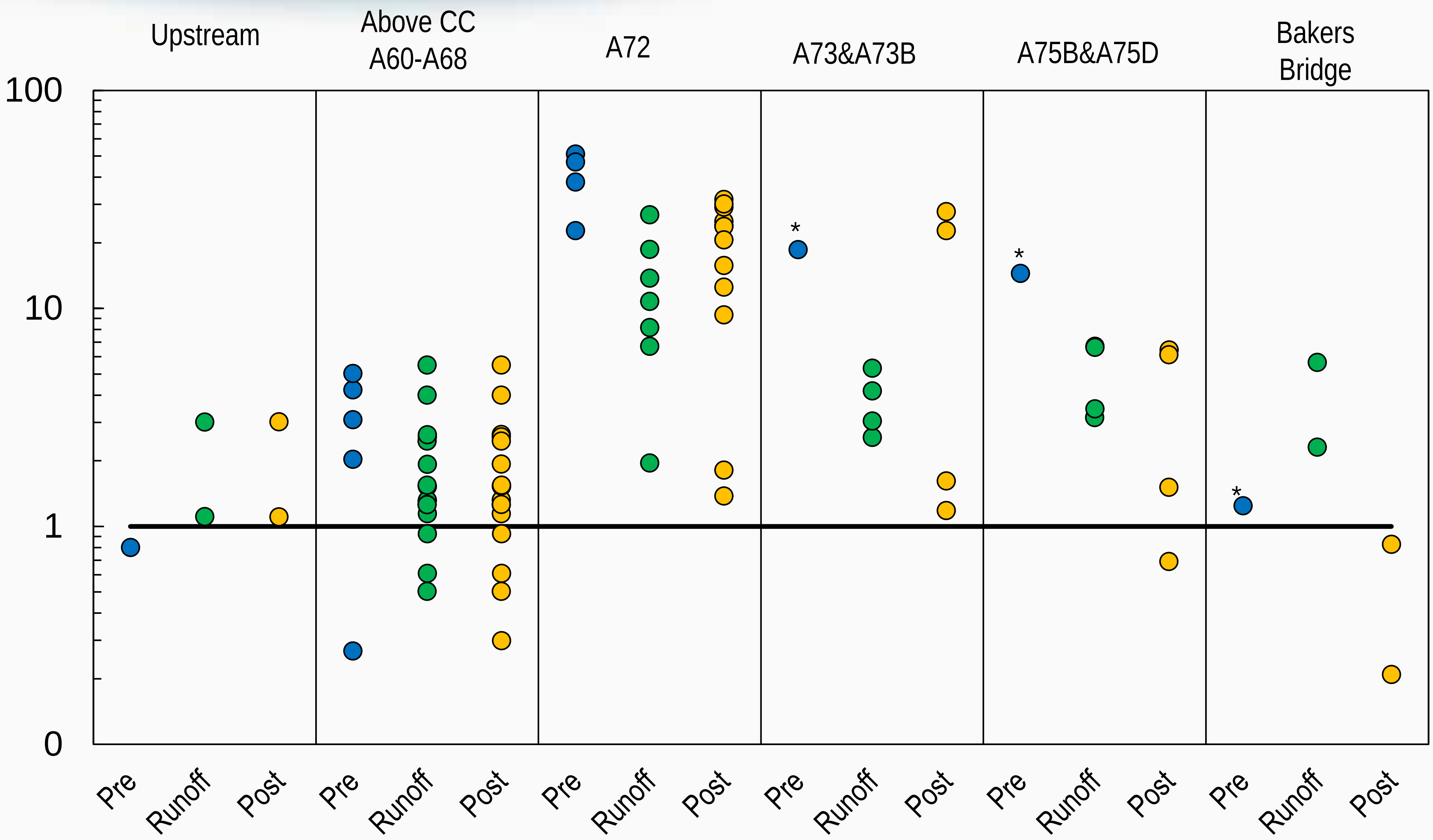
Zinc Surface Water HQs



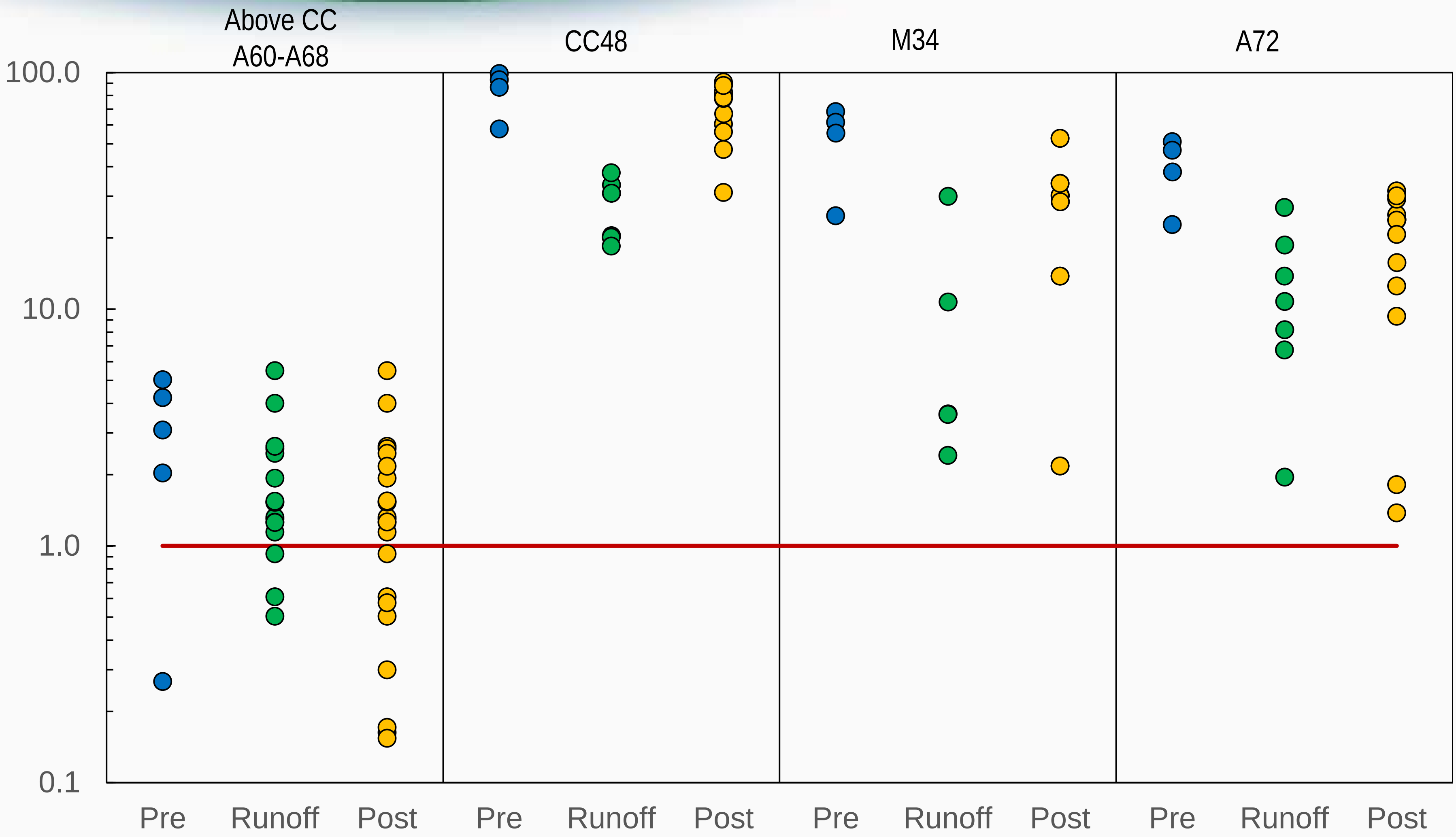
Zinc Surface Water HQs



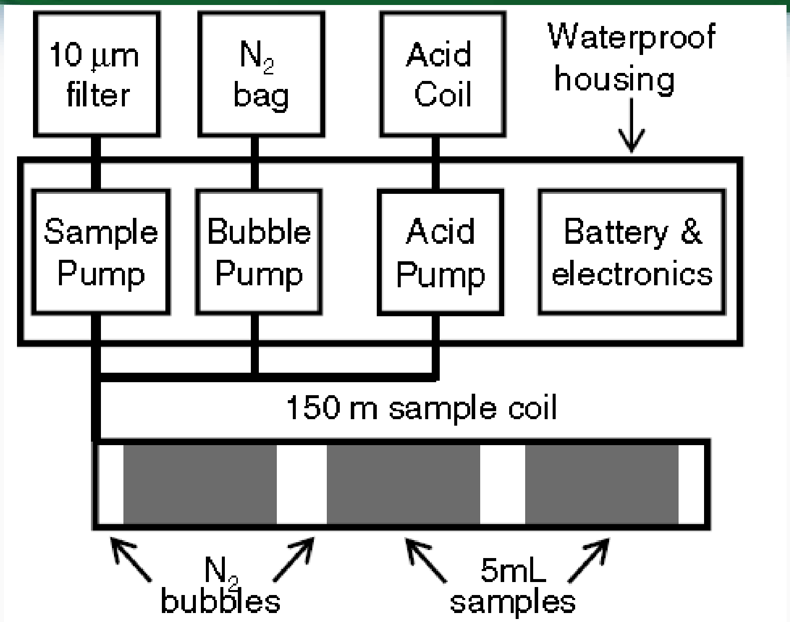
Aluminum Surface Water HQs

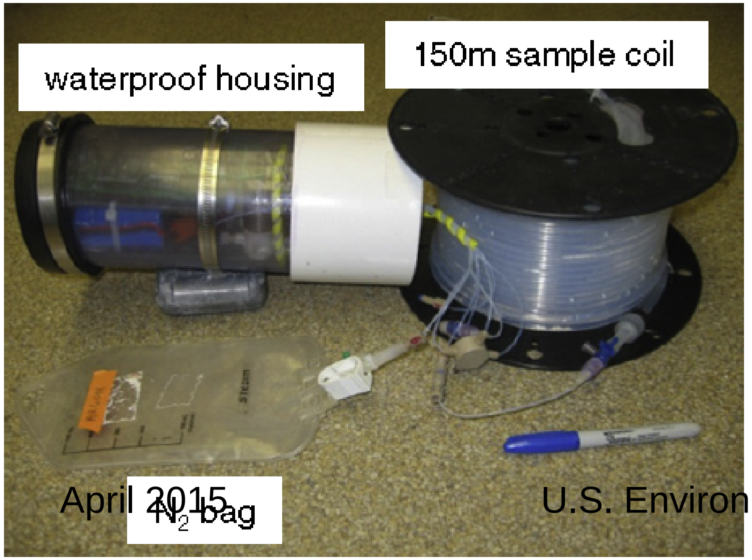


Aluminum Surface Water HQs



Mini-Sipper





- Thomas Chapin, USGS

  MiniSipper: A new in situ water sampler for high-resolution, long-duration acid mine drainage monitoring.

Science of the Total Environment 439 (2012) 343–353

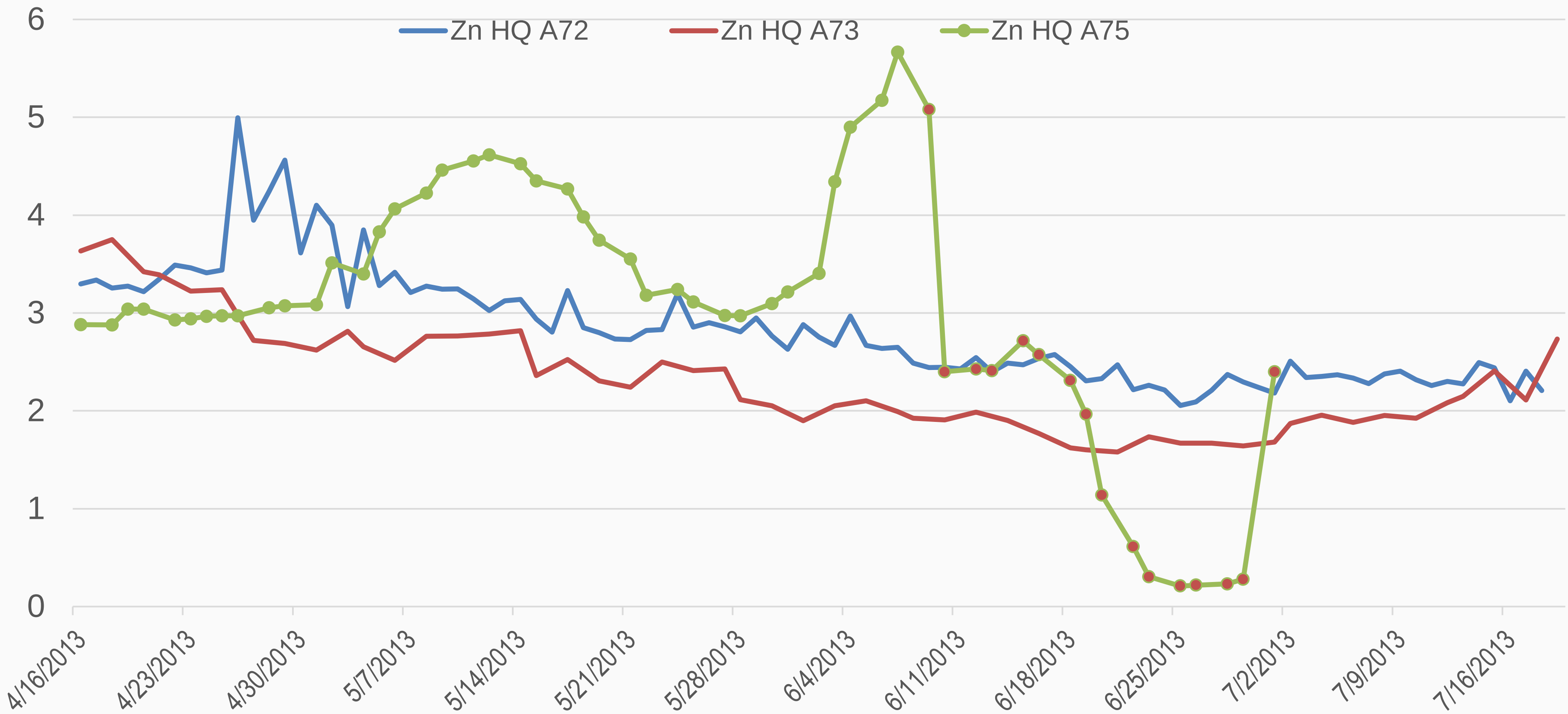
Mini-Sipper Data

- 2013 (mid April-July)
  - A72, A73, A75D
- 2014 (mid April-July)
  - A55, A56, A68, A72, A73, A75D, BB
- 2015 (mid Nov-mid April)
  - LA2, A45, A55, A68, A72, BB

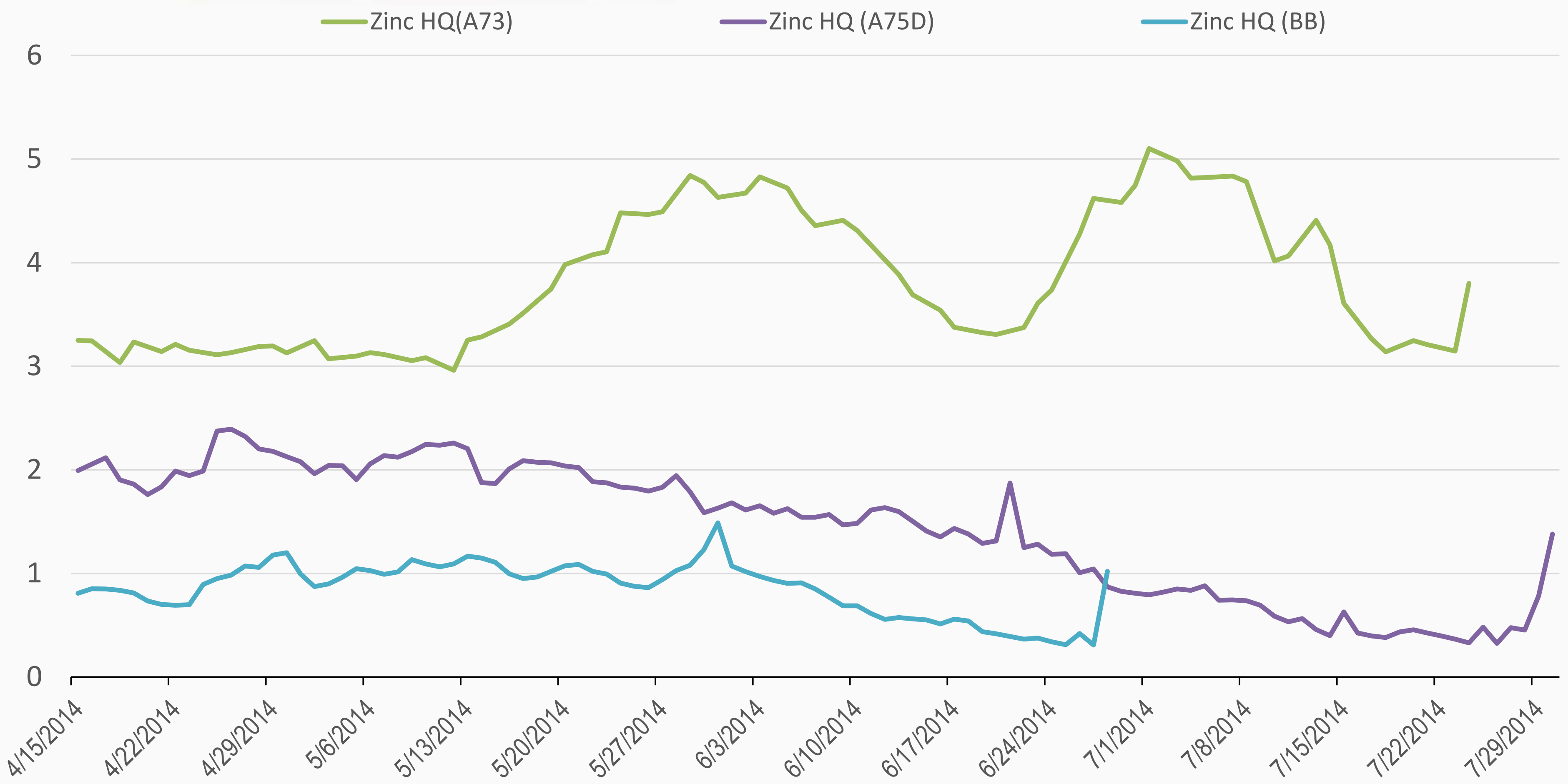
Use of Mini-Sipper data in BERA

- Several limitations
  - 10um filter
  - Limited QA
  - Subject to smearing
- Screening level data
- Consistent with grab samples trends?

2013 Mini-Sipper data (Zn HQ)



2014 Mini-Sipper data (Zn HQ)



Surface Water HQs Conclusions

- Animas Upstream of Cement Creek
  - Elevated risk most flow regimes
  - Risk driven by Al, Cd and Zn
  - Seasonally (pre-runoff) significant risk from primarily Zn
- Animas downstream of Cement Creek
  - High HQs during almost all flow regimes
  - Risk driven by Aluminum and to a lesser degree by Zinc
  - Effects expected down to at least Bakers Bridge
  - Effects lessen downstream
- Mini-sipper results are consistent with grab samples.

Results

- *Maintain a stable and healthy benthic invertebrate community.*
  - *Hazard Quotient (effect and no effect)*
    - *Sediment and Porewater*
  - *Toxicity Tests*
  - *Community Survey*
- *Maintain a stable and healthy fish community.*
  - *Hazard Quotient*
  - *Toxicity Tests*
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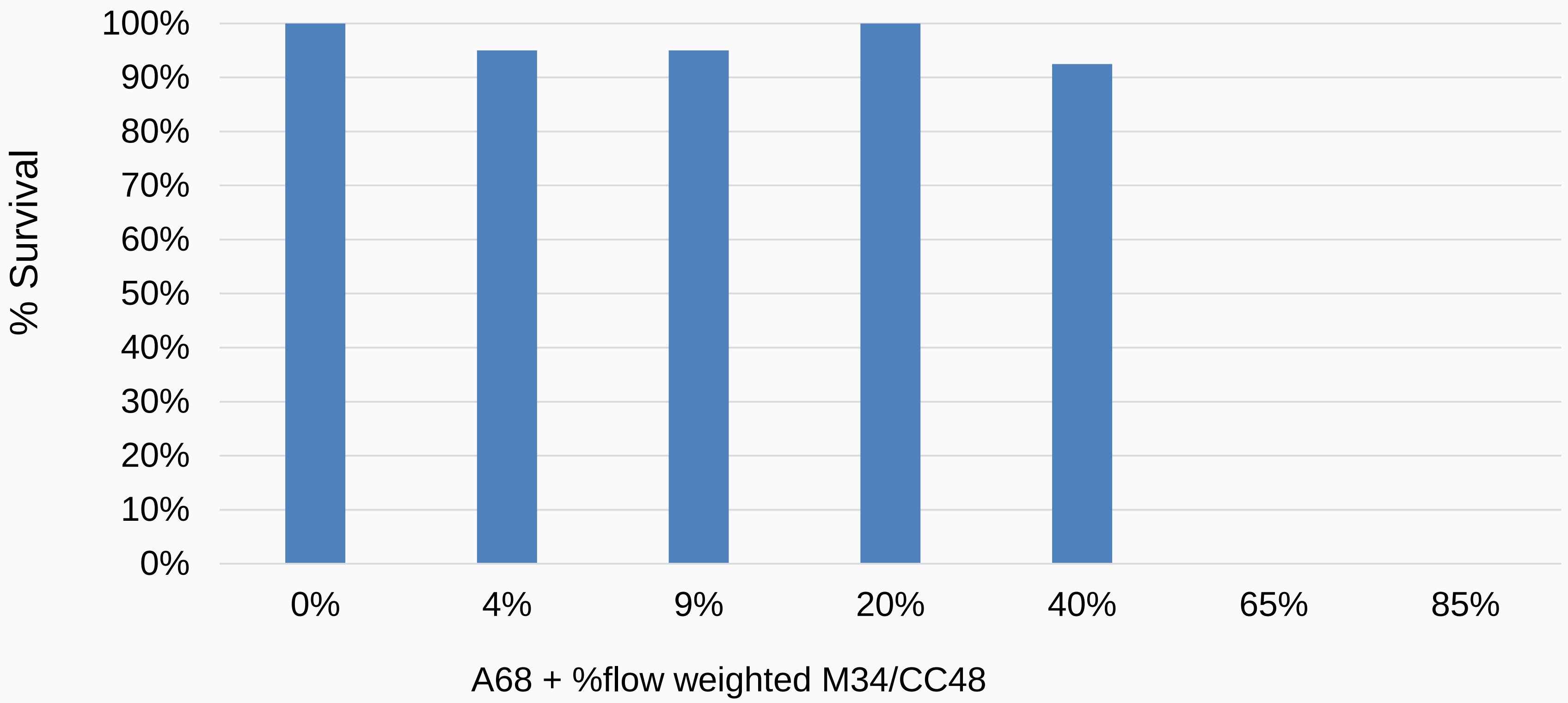
Toxicity Tests

- Test Dates
  - Oct 2012, Nov 2012 and April 2013
- Dilution Series
  - Establish dose response
- Profile Tests
  - Test individual stations
- Rainbow trout
- 96hr-standard methods

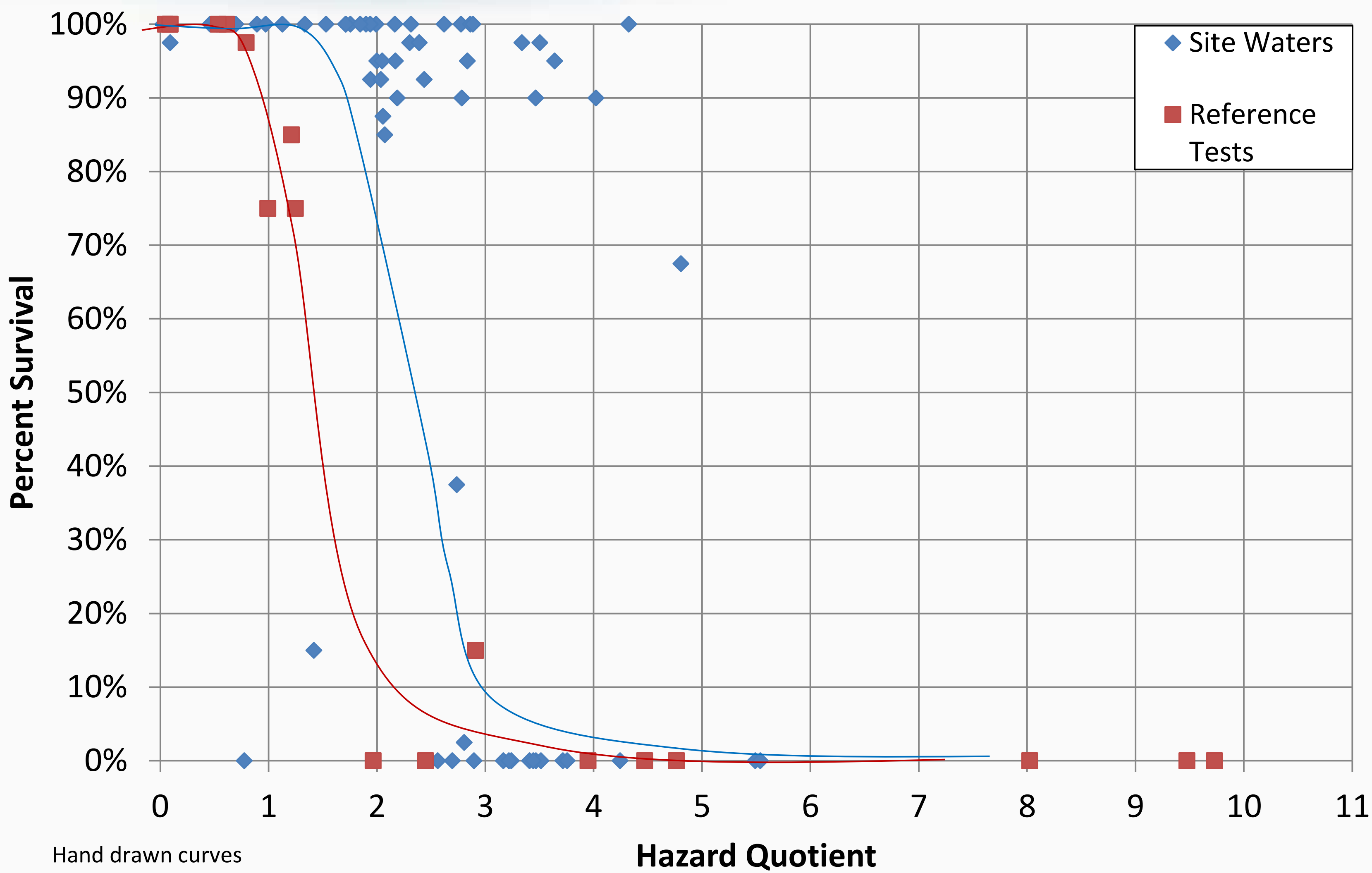
Example SW Toxicity Test Results



SW Toxicity Test Results

- Acute toxicity observed
  - M34, CC48, A72 (~0% survival)
- Acute toxicity observed seasonally
  - A68 (67.5% survival)
- No acute toxicity observed downstream of A72
  - A73, A73B, A75B, Bakers Bridge

Trout Survival vs Zinc HQs
pooled toxicity test data



Hand drawn curves

Results

- *Maintain a stable and healthy benthic invertebrate community.*
  - *Hazard Quotient (effect and no effect)*
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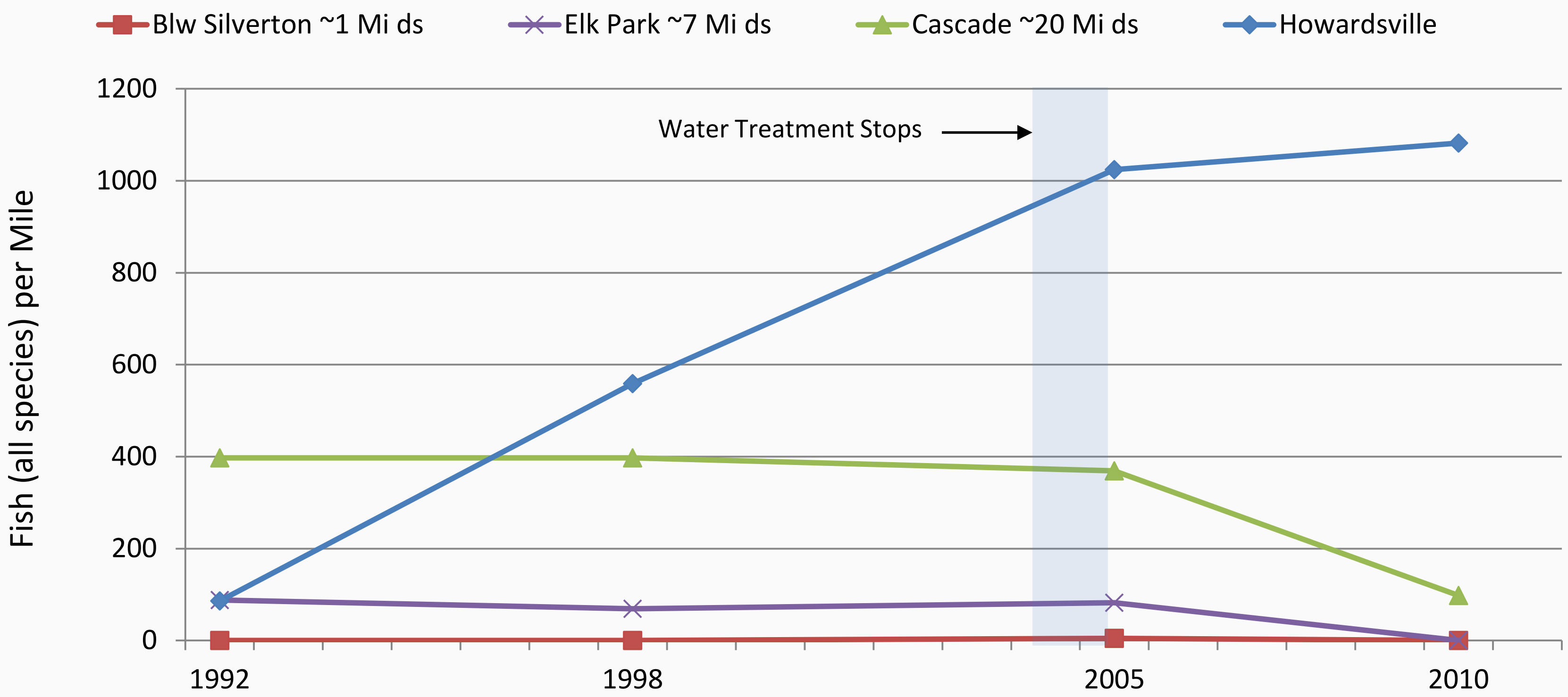
Fish Community Survey Results

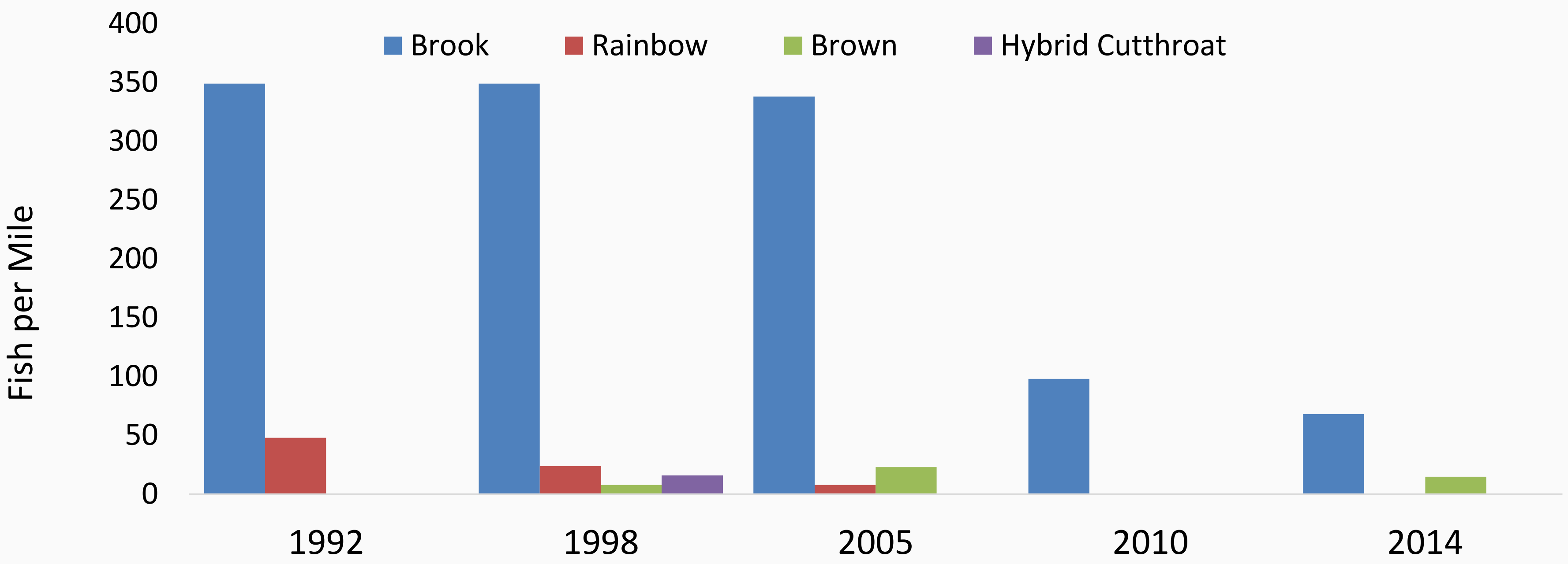
Colorado Parks and Wildlife Data



ds=downstream, us =upstream

2014 Fish Survey Results

Animas at Cascade Creek (Tefts Spur)

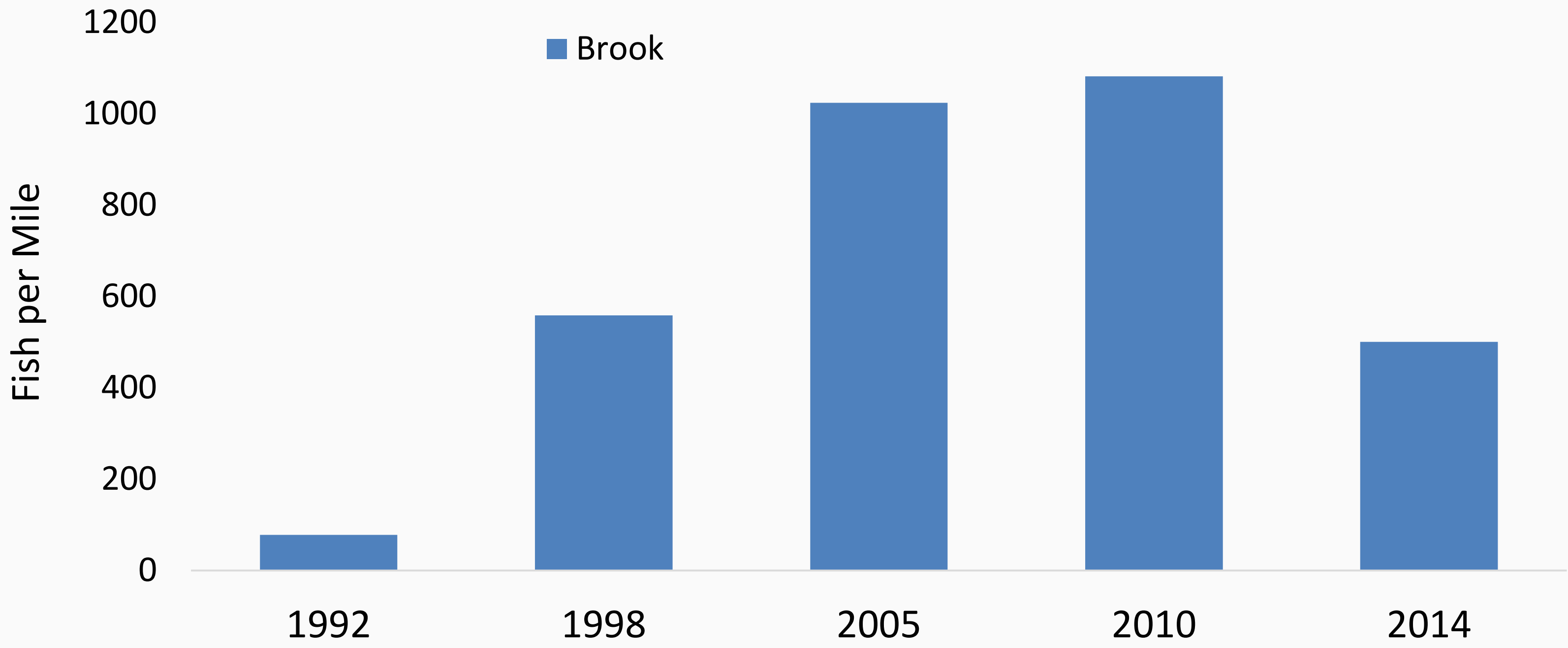


2014

- 9 brook trout and 2 brown trout (~2.4 lbs/acre)
- 1 juvenile and 10 adults
- Brook trout Wr = 96%, brown trout Wr = 100%

2014 Fish Survey Results

Animas at Howardsville above Cunningham Creek



2014

- 162 brook (~17 lbs/acre)
- Multiple age classes
- Brook trout Wr = 102%, up from 85% in 2010

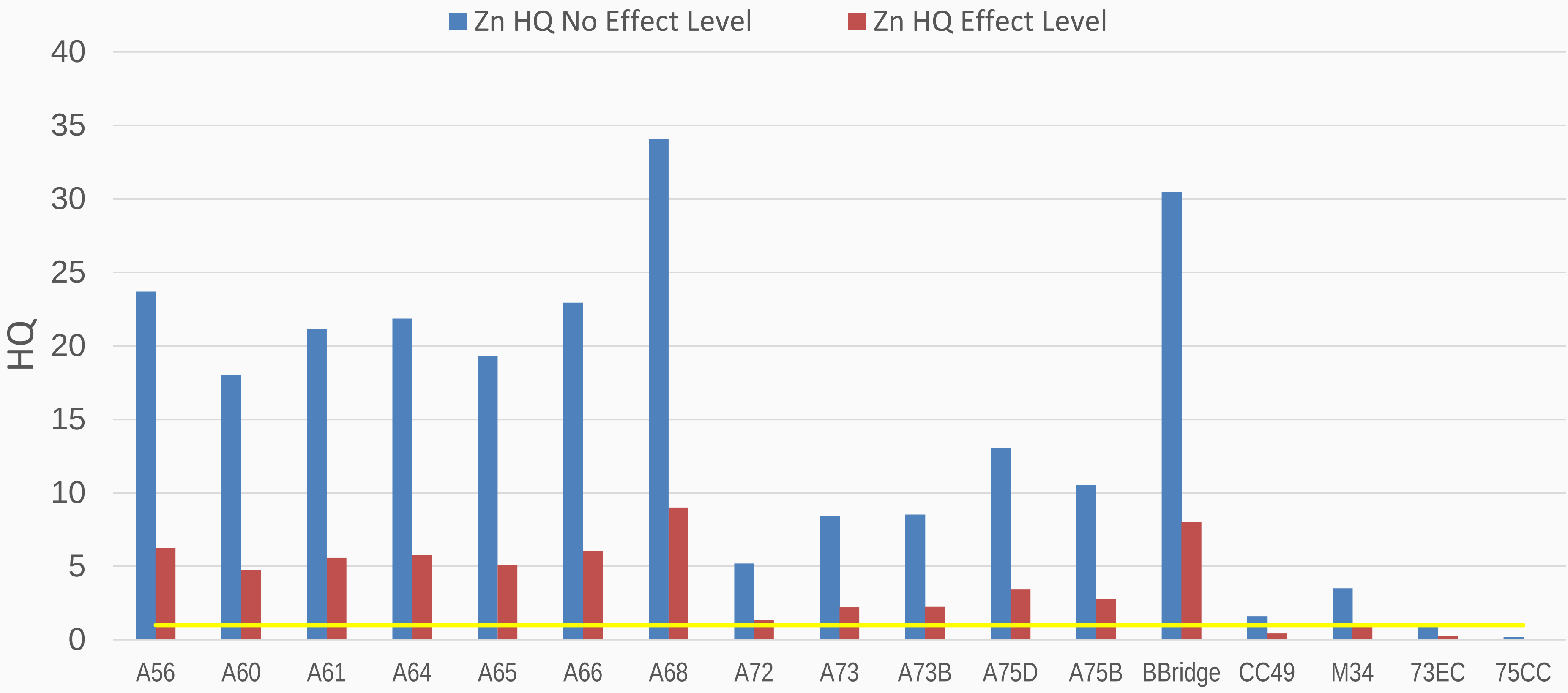
Fish Survey Results

- 2014 Survey Results at Cascade Creek
  - Fishery significantly impaired
  - 30% reduction from 2010
  - Poor age class structure, low body condition
  - 2 Brown trout present
- 2014 Survey Results above Howardsville
  - Less fish than 2010 but biomass is about the same
  - Good body condition
- Time trend
  - Animas fishery below Cement Creek has dramatically declined since 2005

BERA Conclusions

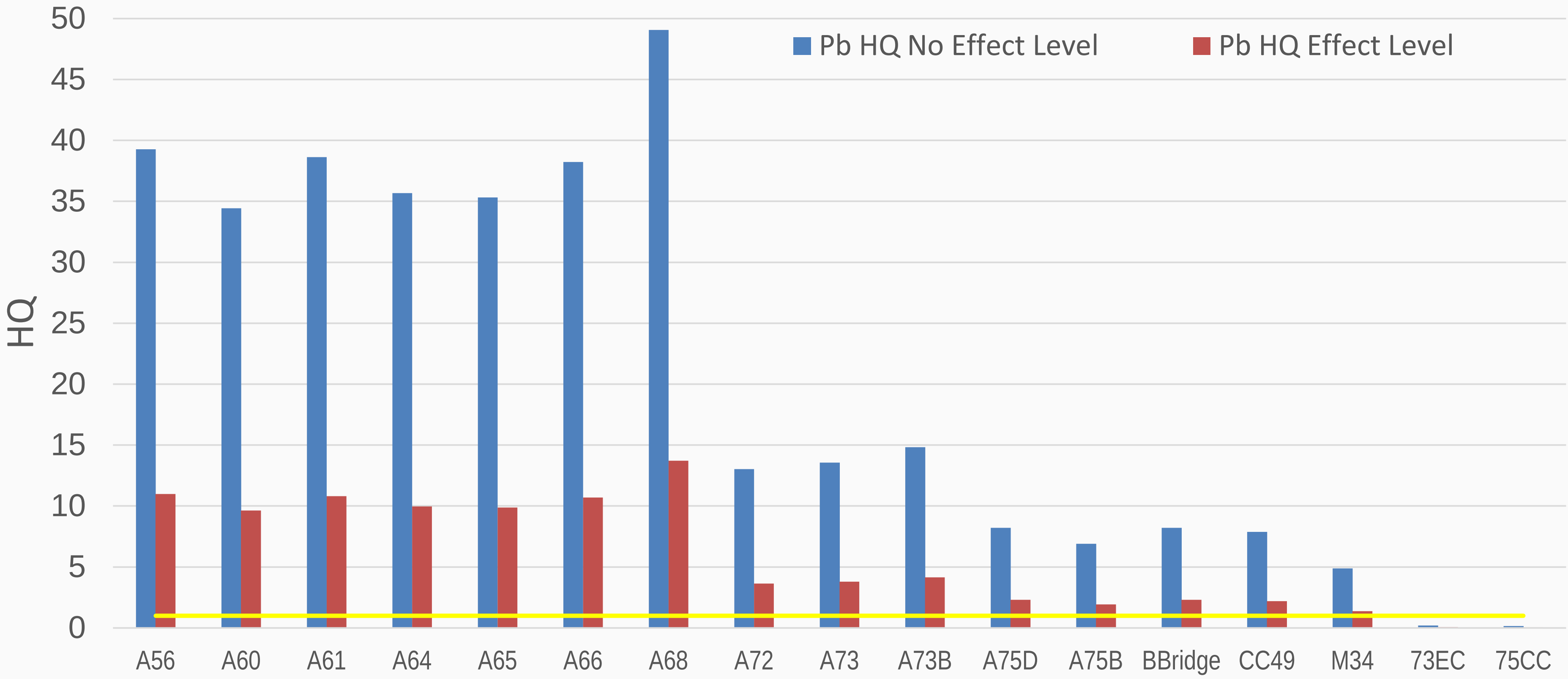
- Aquatic community is impaired from Cement Creek to Bakers Bridge.
  - Surface water and sediment
  - Aluminum, zinc, cadmium, manganese, pH
- Elevated risk upstream
  - Surface water and sediment
  - Seasonally influenced
  - Aluminum, zinc and cadmium
- Risks to wildlife using Animas River is low

Zinc Hazard Quotients in Sediments*



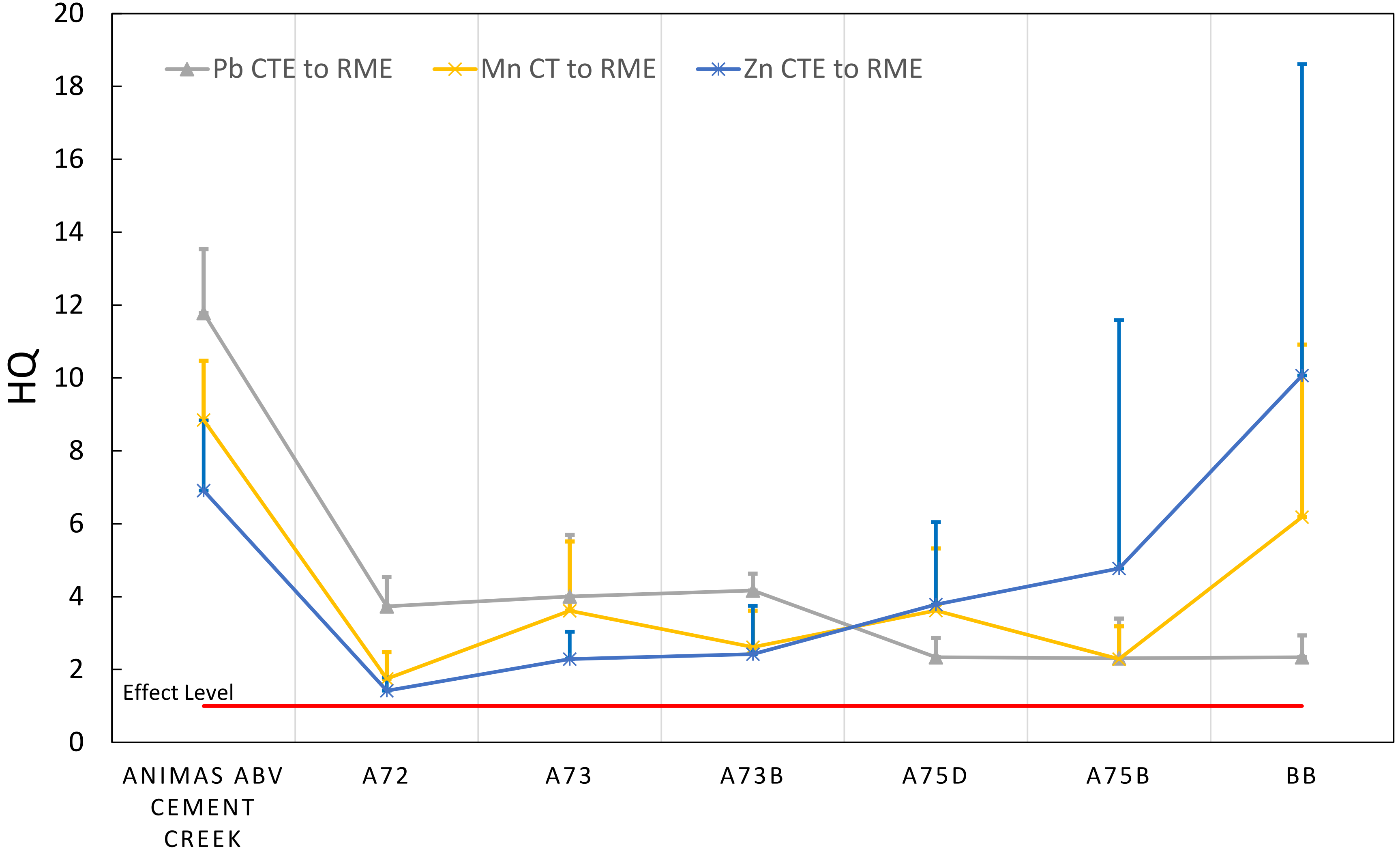
*geometric means. High seasonal variability at some locations.

Zinc Hazard Quotients in Sediments*

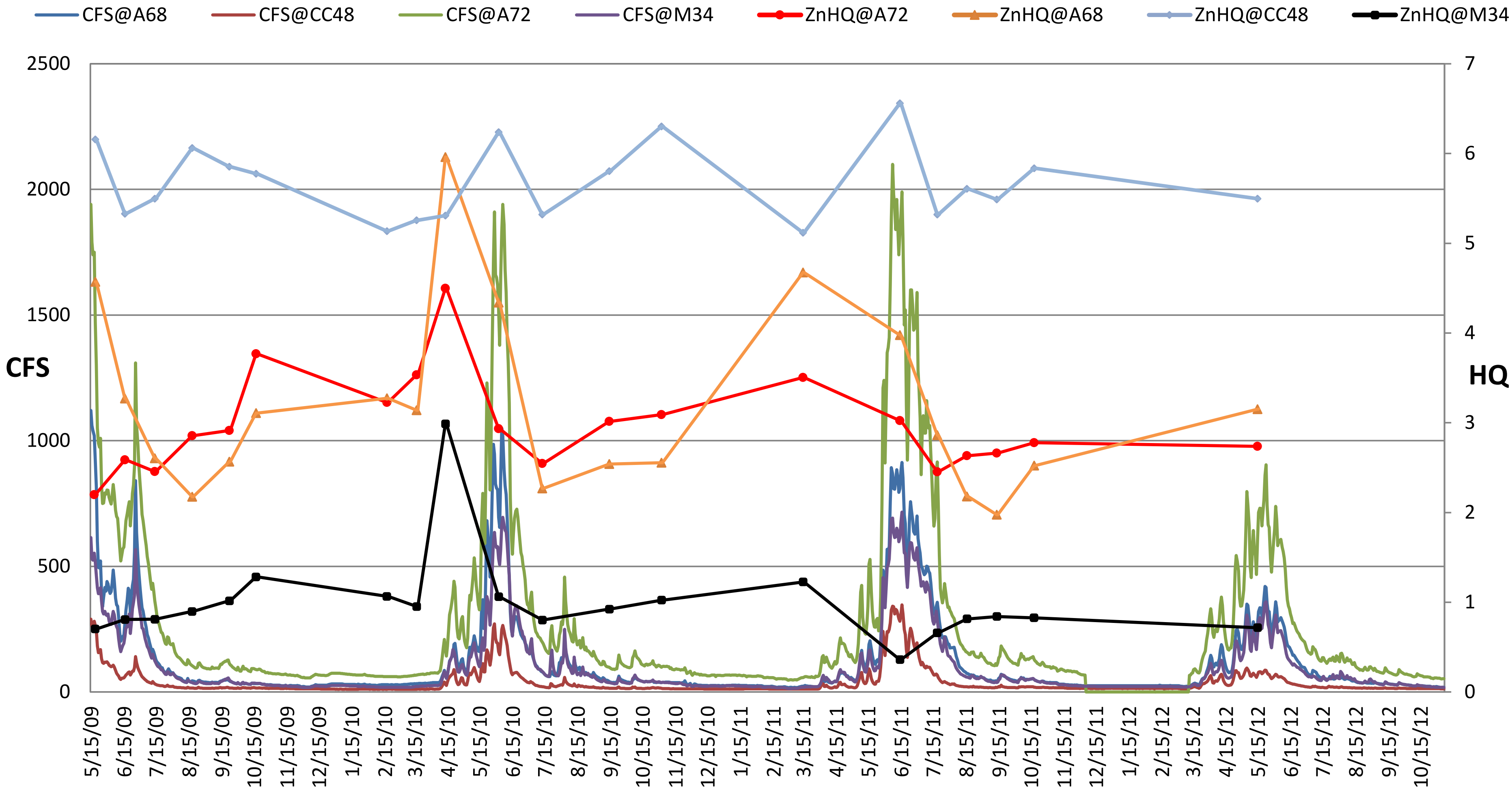


*geometric means. High seasonal variability at some locations.

CTE/RME Range of Sediment HQs



Vertical line represents high end


CFS@A68
CFS@CC48
CFS@A72
CFS@M34
ZnHQ@A72
ZnHQ@A68
ZnHQ@CC48
ZnHQ@M34
CFS
HQ
2500
2000
1500
1000
500
0
7
6
5
4
3
2
1
0
5/15/09
6/15/09
7/15/09
8/15/09
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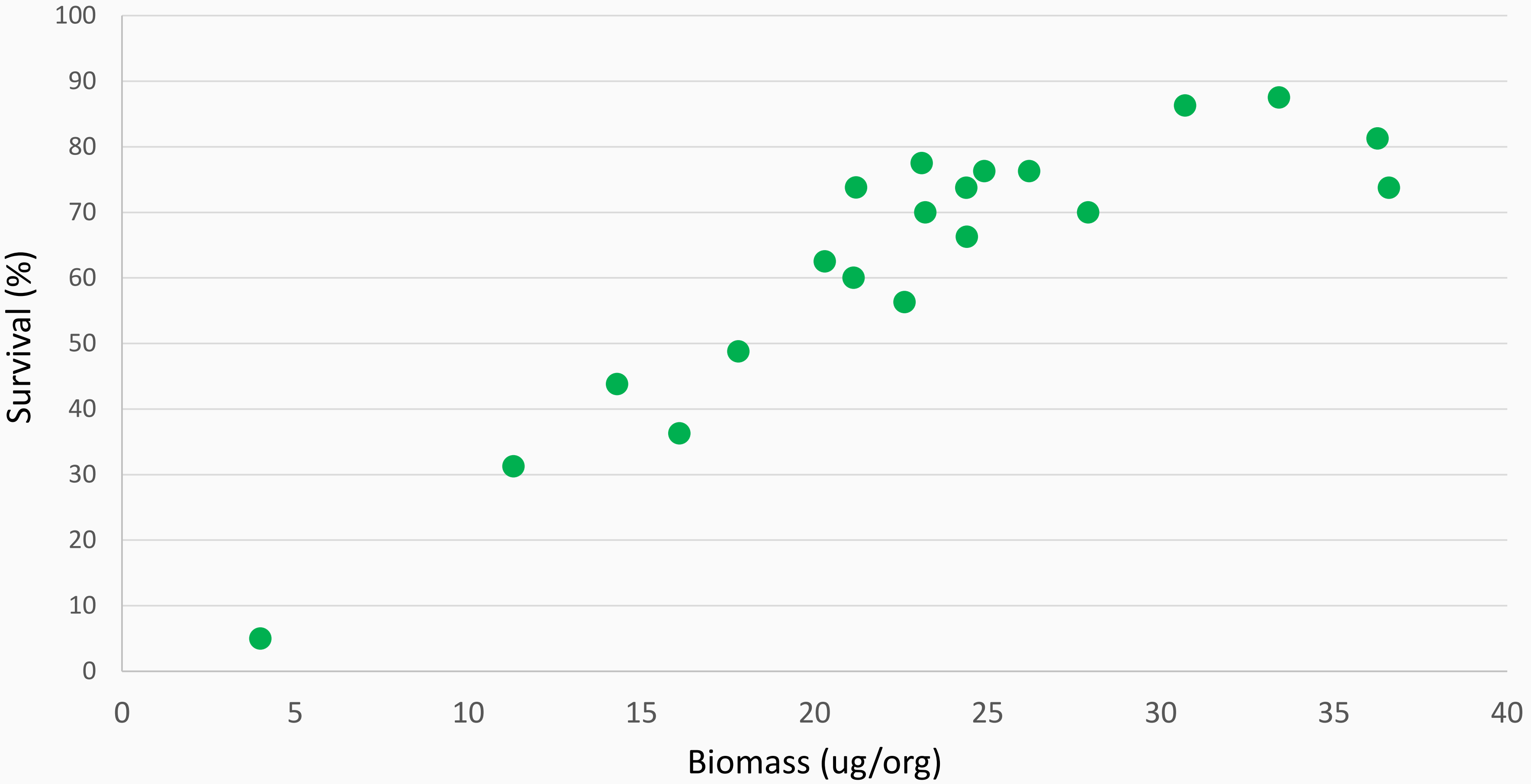
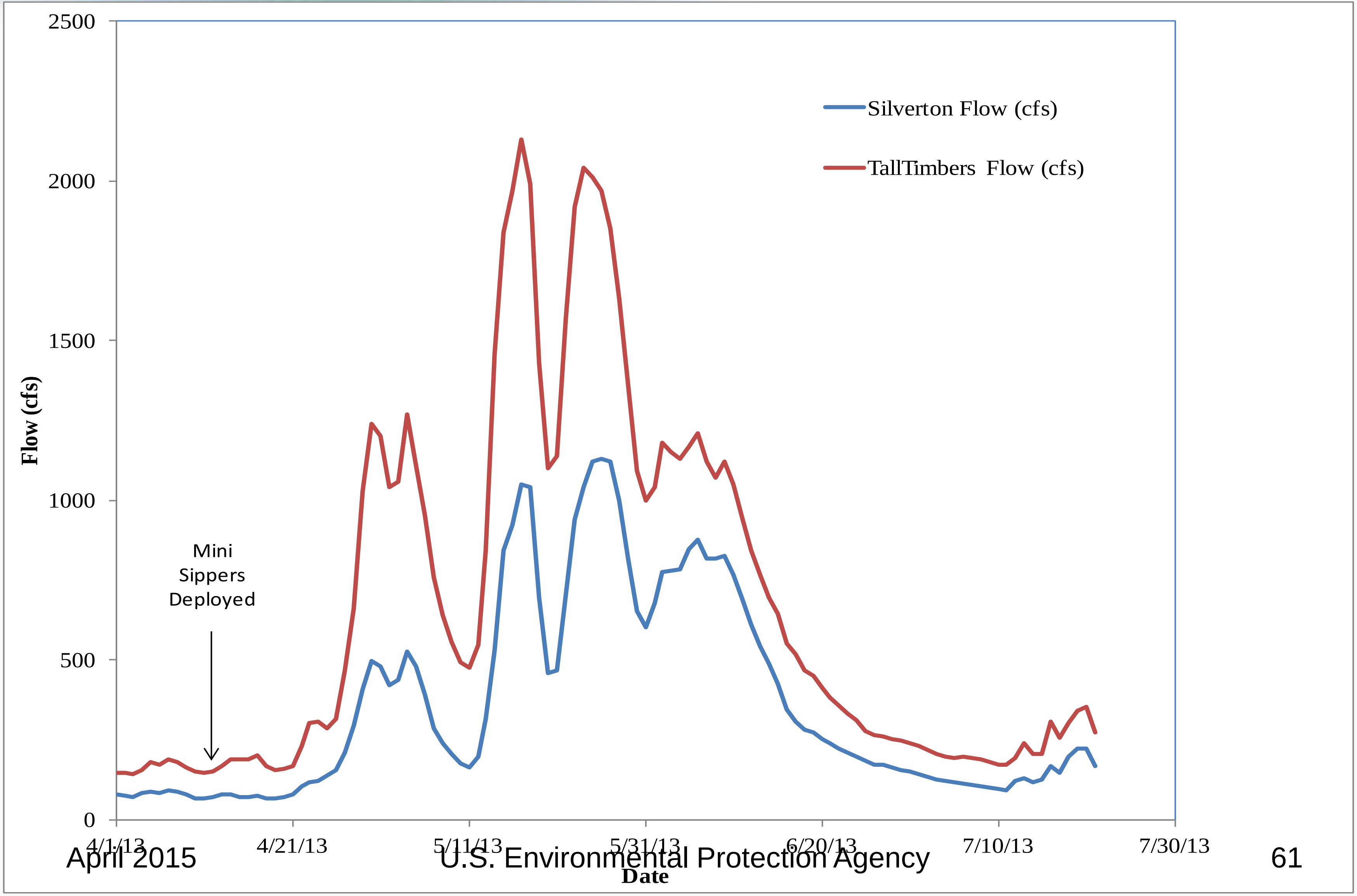
10/15/12

Survival v Biomass

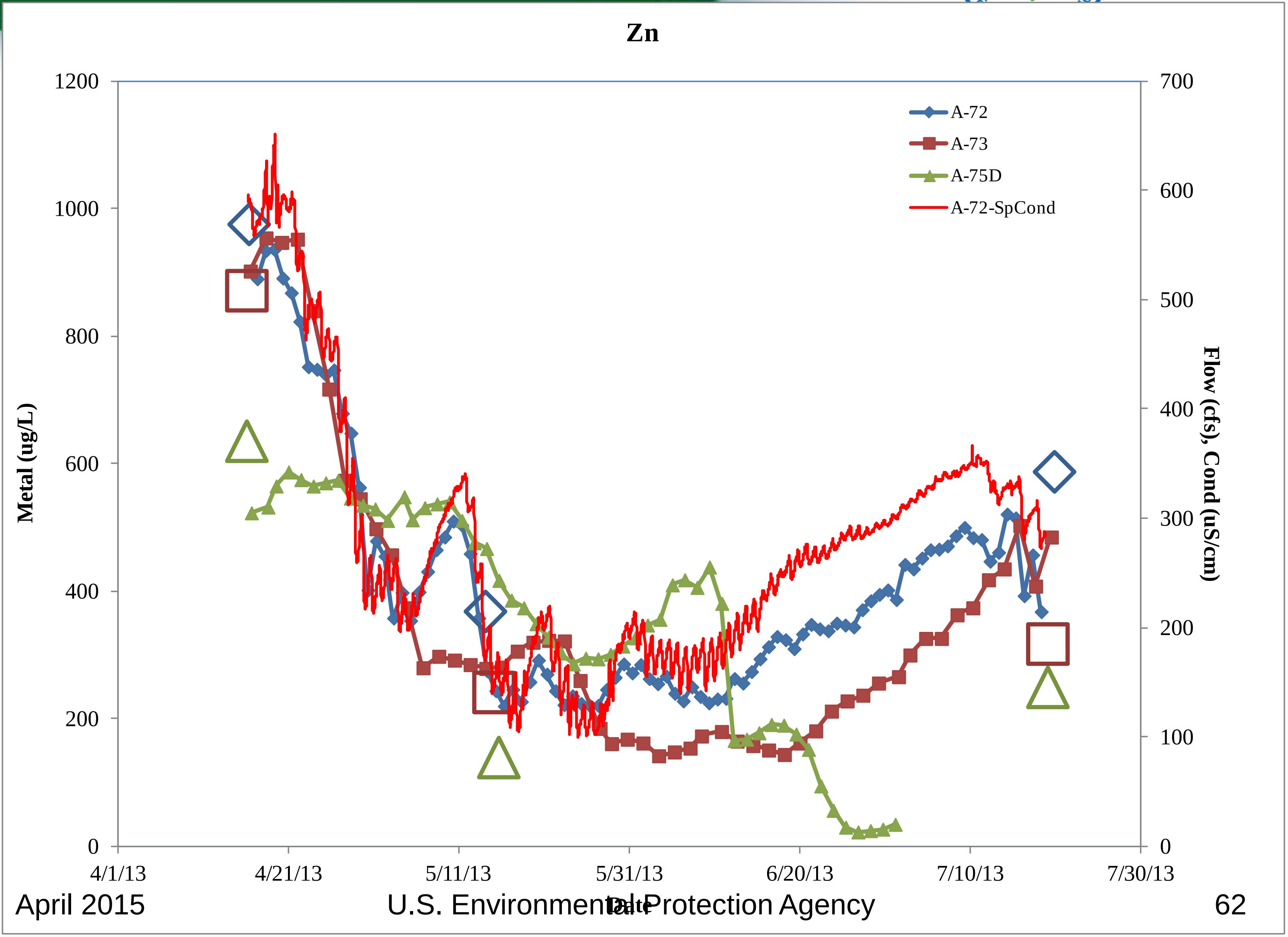


2013 Flows

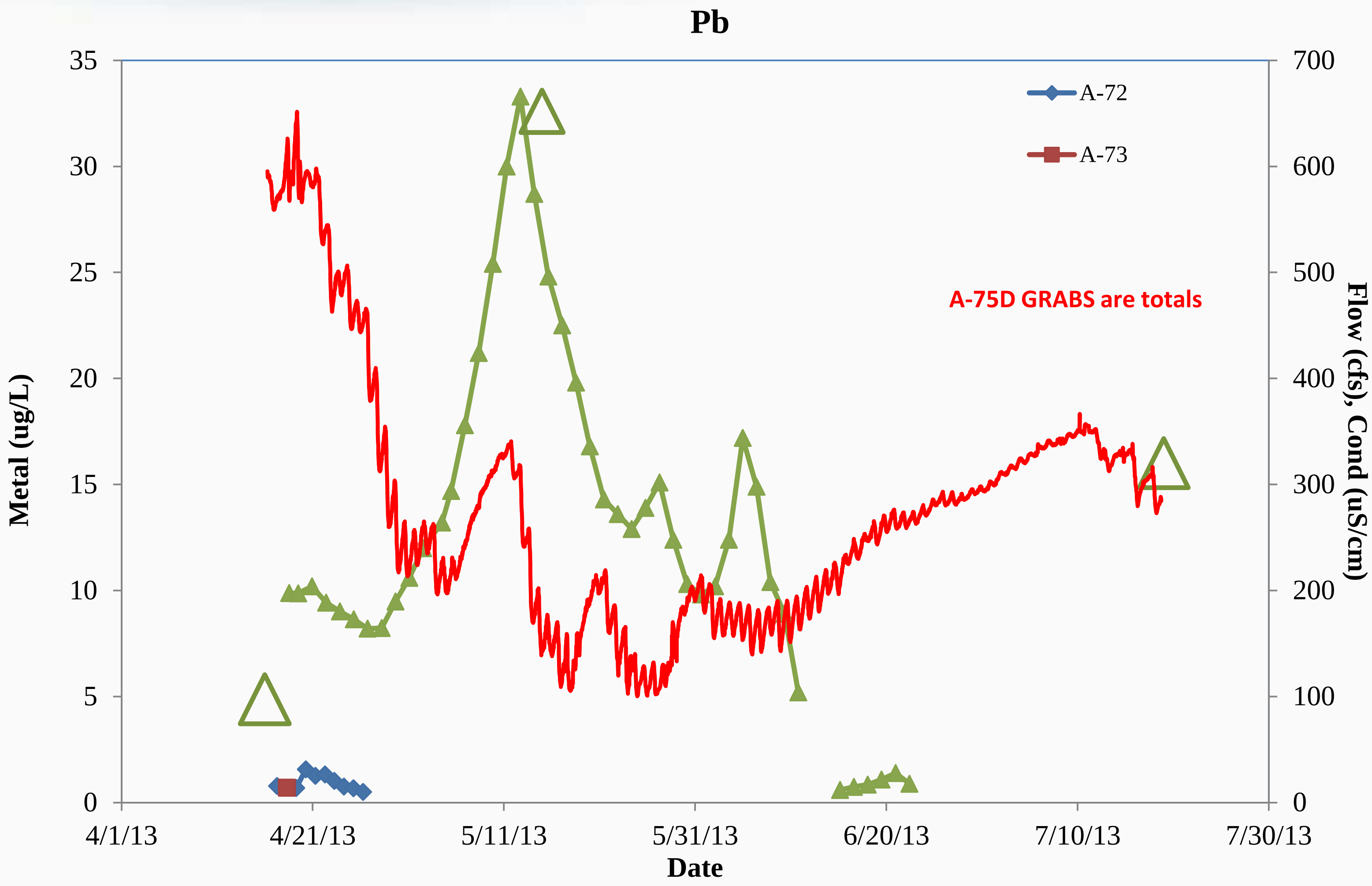


Silverton Flow (cfs)
TallTimbers Flow (cfs)
Flow (cfs)
2500
2000
1500
1000
500
0
Mini
Sippers
Deployed
4/1/13
4/21/13
5/11/13
5/31/13
6/20/13
7/10/13
7/30/13
Date

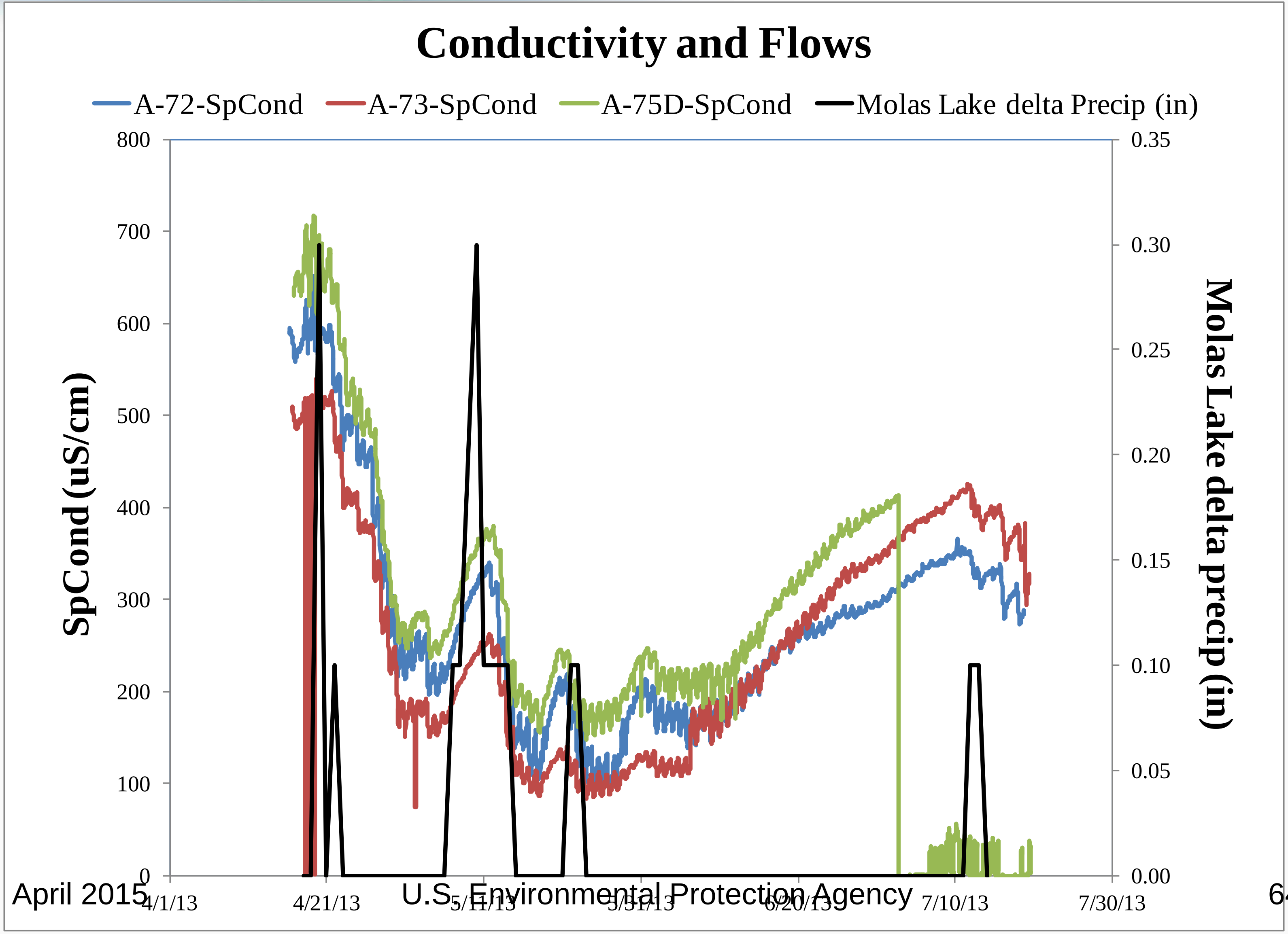
2013 Mini-Sipper Results



Pb 2013


Pb
35
30
25
20
15
10
5
0
700
600
500
400
300
200
100
0
Metal (ug/L)
Flow (cfs), Cond (uS/cm)
A-72
A-73
A-75D GRABS are totals
4/1/13
4/21/13
5/11/13
5/31/13
6/20/13
7/10/13
7/30/13
Date

2013 Mini-Sipper Results



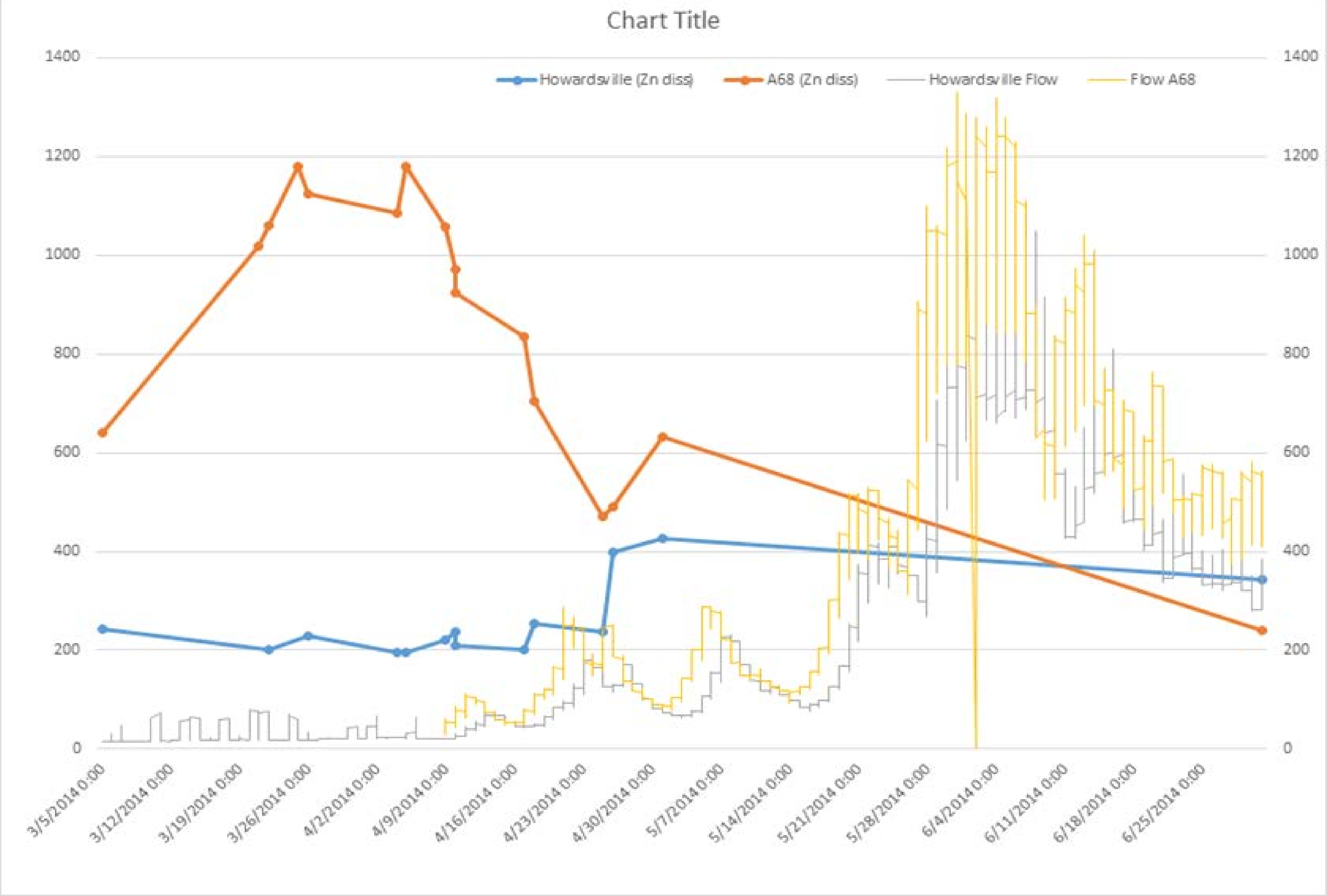
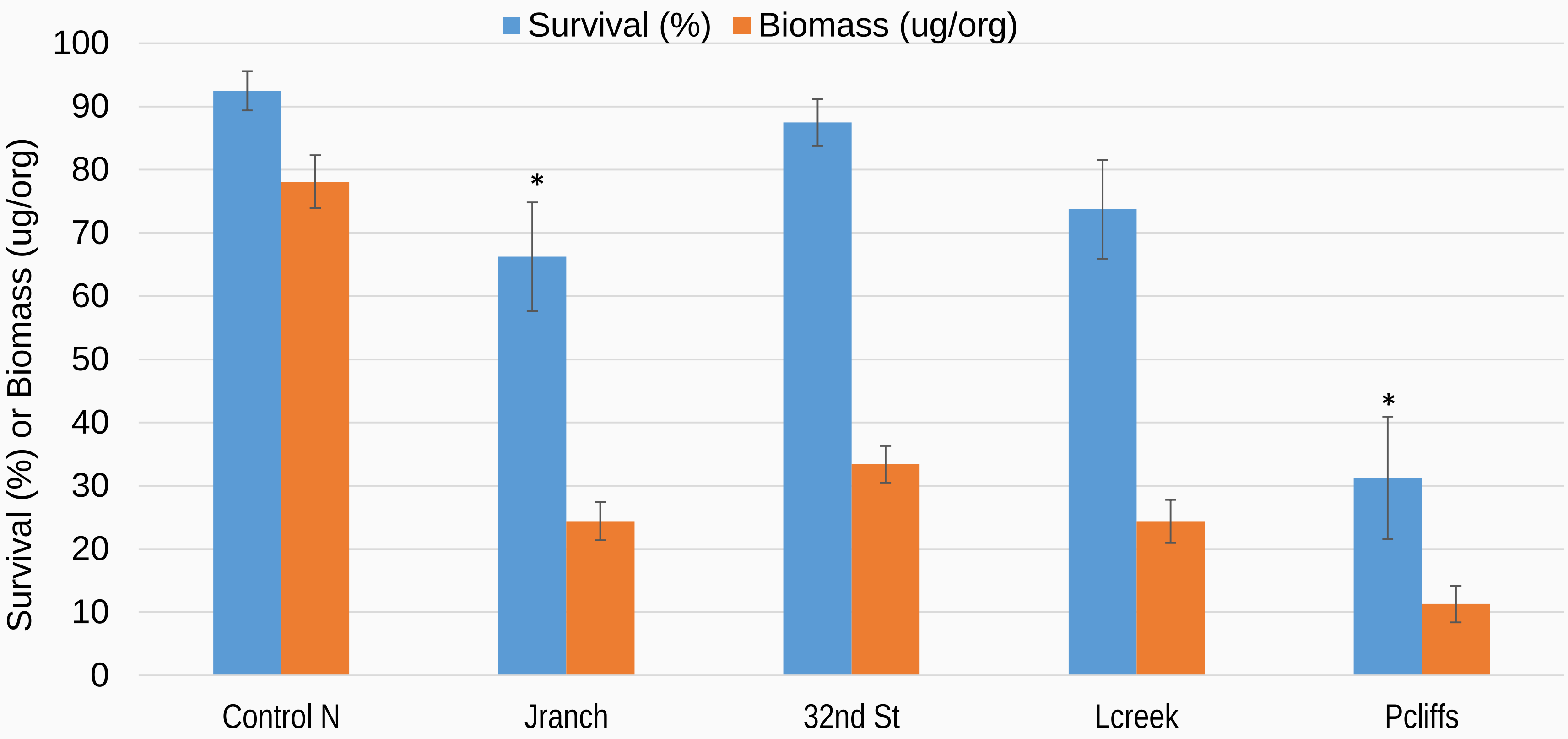


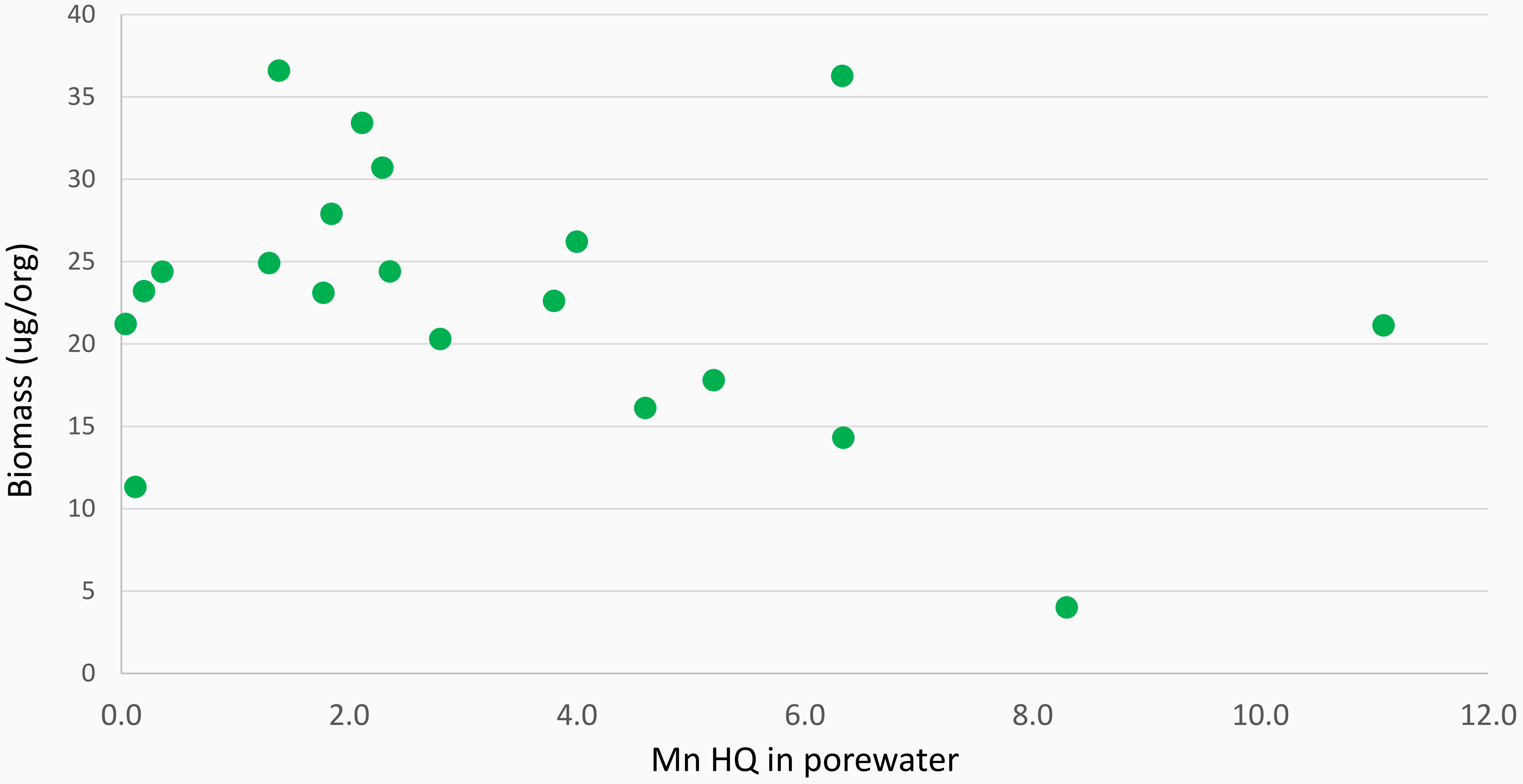
Chart Title
Howardsville (Zn diss)
A68 (Zn diss)
Howardsville Flow
Flow A68
1400
1200
1000
800
600
400
200
0
3/5/2014 0:00
3/12/2014 0:00
3/19/2014 0:00
3/26/2014 0:00
4/2/2014 0:00
4/9/2014 0:00
4/16/2014 0:00
4/23/2014 0:00
4/30/2014 0:00
5/7/2014 0:00
5/14/2014 0:00
5/21/2014 0:00
5/28/2014 0:00
6/4/2014 0:00
6/11/2014 0:00
6/18/2014 0:00
6/25/2014 0:00

2014 Additional Sediment Toxicity Test Results



*statistically different from Control N for Survival results
All Biomass results statistically less than Control N

Biomass v Mn HQs in Porewater ?



Species Sensitivity

Species	Metal	Calculated Values at Hardness of 50 mg/L $CaCO_3$		
		LC50 Toxicity Thresholds (f)	Acute Toxicity Thresholds (g)	Chronic Toxicity Thresholds (h)
Brown Trout	Cadmium	2.43	1.21	0.99
Rainbow Trout	Cadmium	2.67	1.33	1.30
Brook Trout	Cadmium	2.31	1.15	ACR (i)
Brook Trout	Copper	45.44	22.72	ACR (i)
Brown Trout	Copper	36.09	18.05	16.61
Cutthroat Trout	Copper	48.81	24.41	ACR (i)
Rainbow Trout	Copper	26.72	13.36	10.78
Brook Trout	Zinc	1464.91	732.46	627.29
Brown Trout	Zinc	565.83	282.91	346.50
Cutthroat Trout	Zinc	281.93	140.96	107.07
Rainbow Trout	Zinc	242.39	121.19	129.76

- Where the pH is equal to or greater than 7.0 in the receiving water after mixing, the chronic hardness-dependent equation will apply. Where pH is less than 7.0 in the receiving water after mixing, either the 87 µg/l chronic total recoverable aluminum criterion or the criterion resulting from the chronic hardness-dependent equation will apply, whichever is more stringent

Assessment Endpoints

<u>Definition</u>

"……explicit expressions of the environmental values to be protected."

\- EPA 1992

Ecological relevance
Sensitivity
Exposure
Management relevance

Measurement Endpoint

Definition

"……a quantifiable ecological characteristic that reflects....effects on the assessment endpoint."

- EPA 1992

Relevance to assessment endpoints
Ecological relevance
Mechanism of toxicity