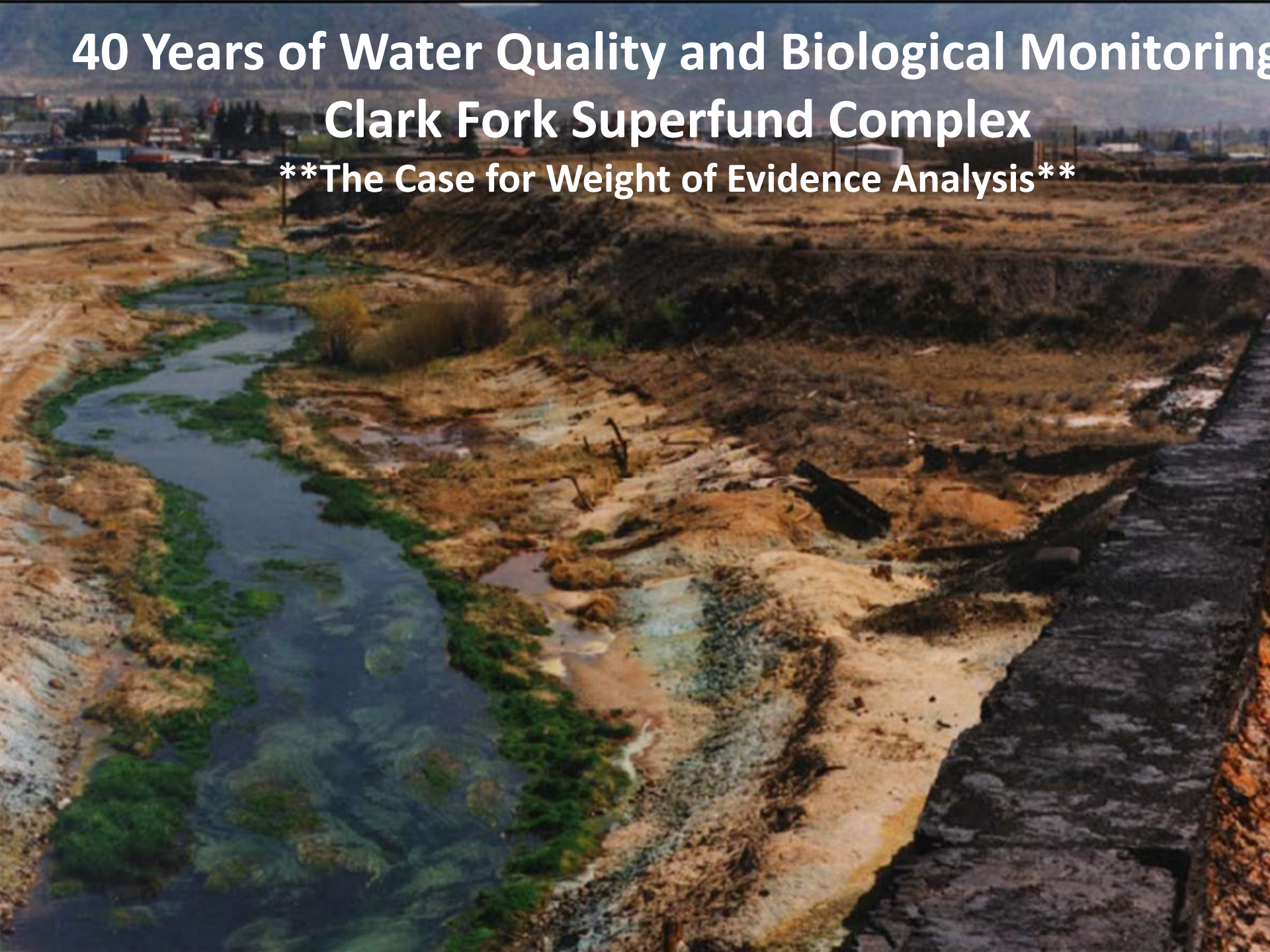
40 Years of Water Quality and Biological Monitoring
Clark Fork Superfund Complex
The Case for Weight of Evidence Analysis



MEASURES OF SUCCESS

Numeric Standards VS Biological Integrity

Long-Term Spatially Distributed Data Sets

NOT FISH BUT MACROINVERTEBRATES – 1986 to Present

Three Superfund Mega-Sites

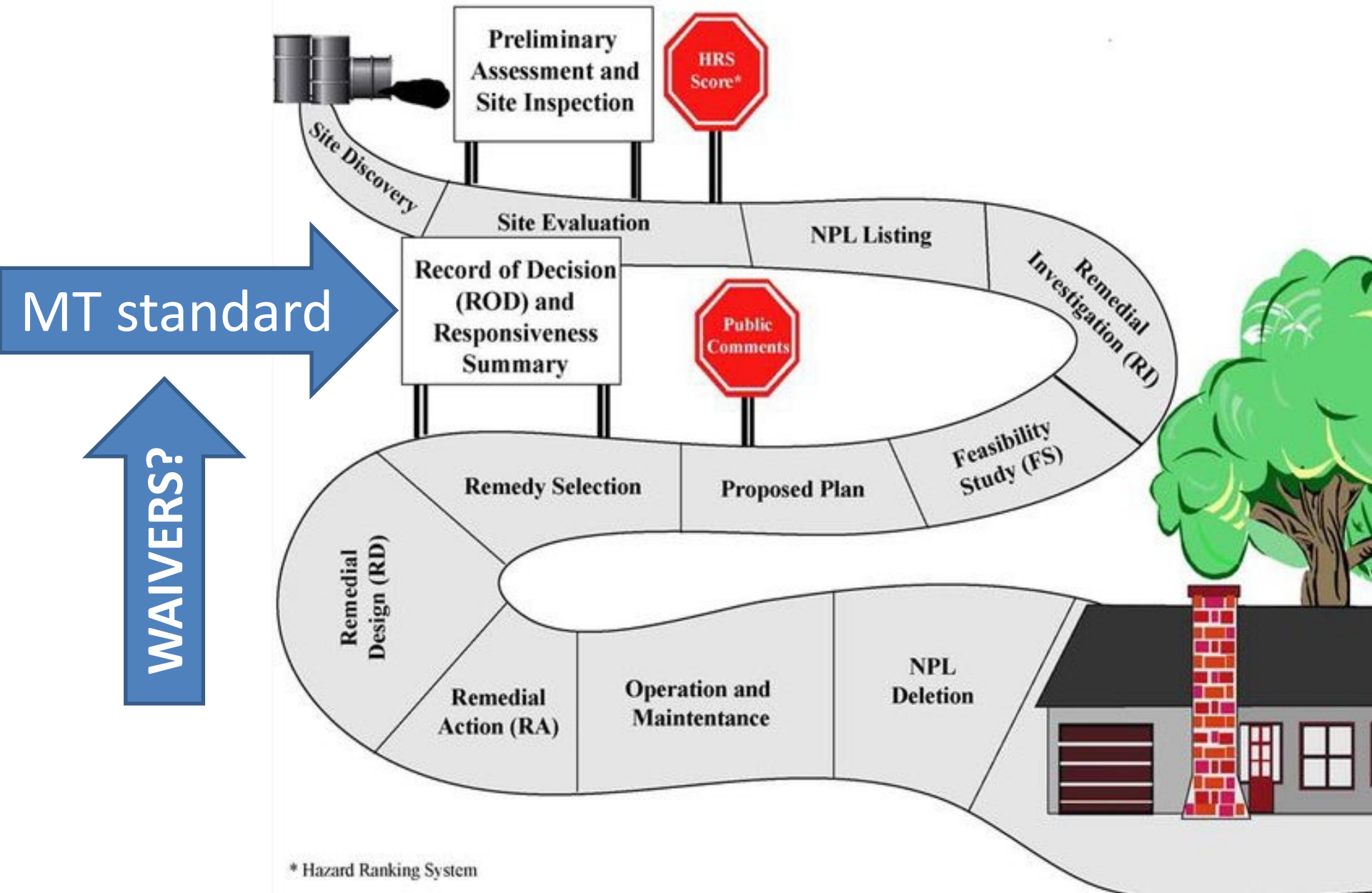
13 OPERABLE UNITS

Each with its own remedy

Three Superfund Mega-Sites

But It's a Watershed!

The Superfund Process

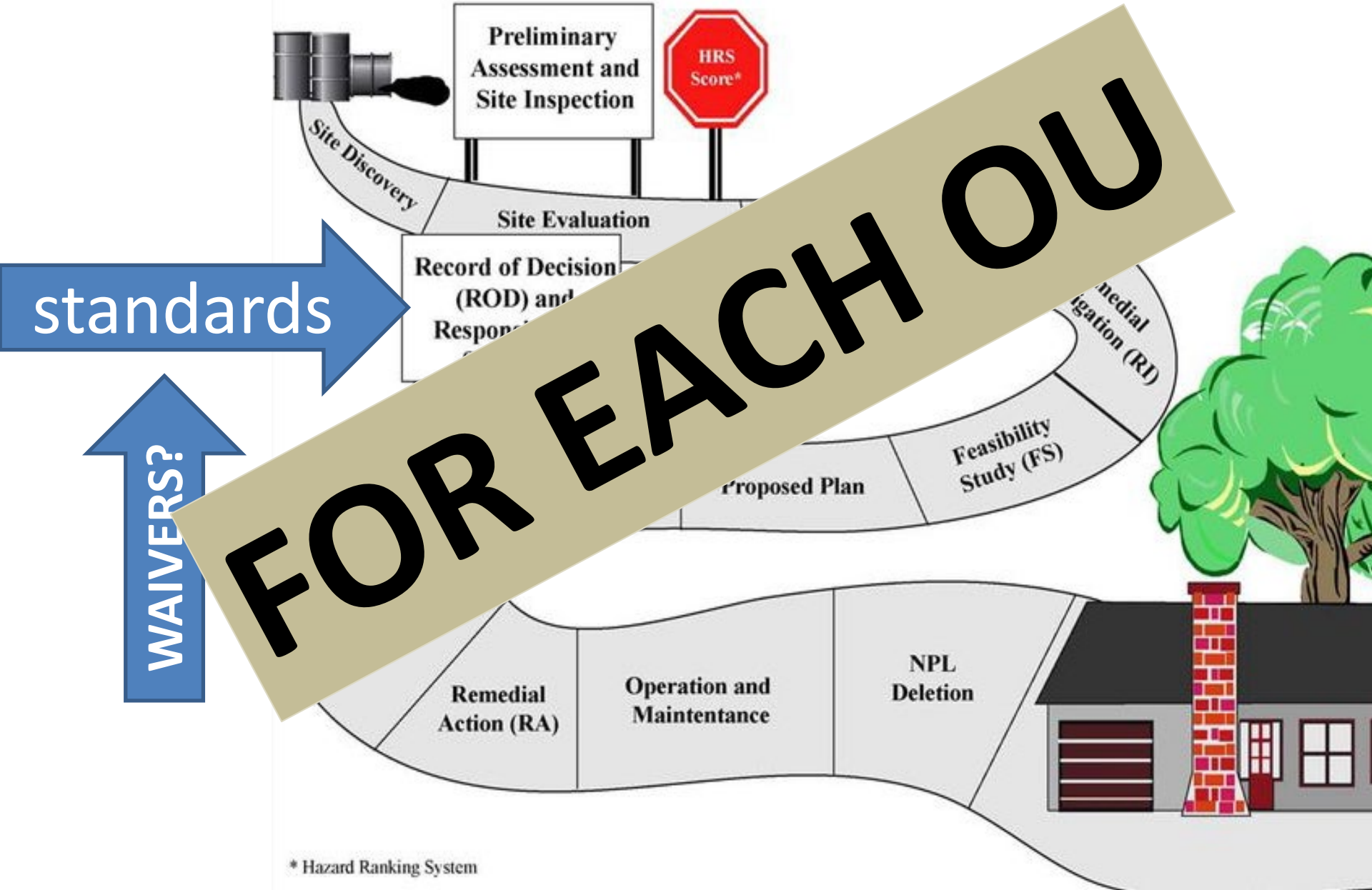


MT standard

WAIVERS?

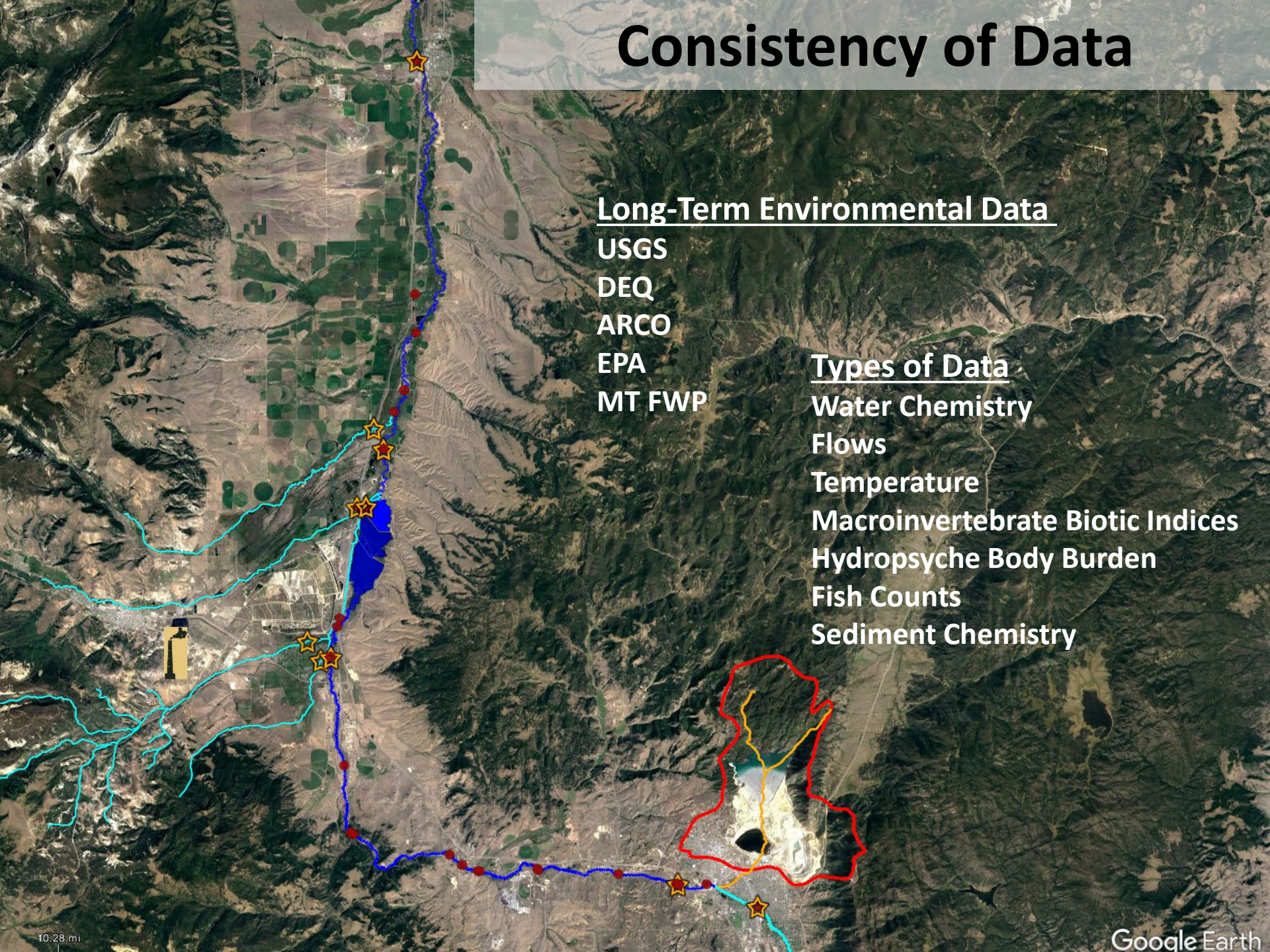
* Hazard Ranking System

The Superfund Process

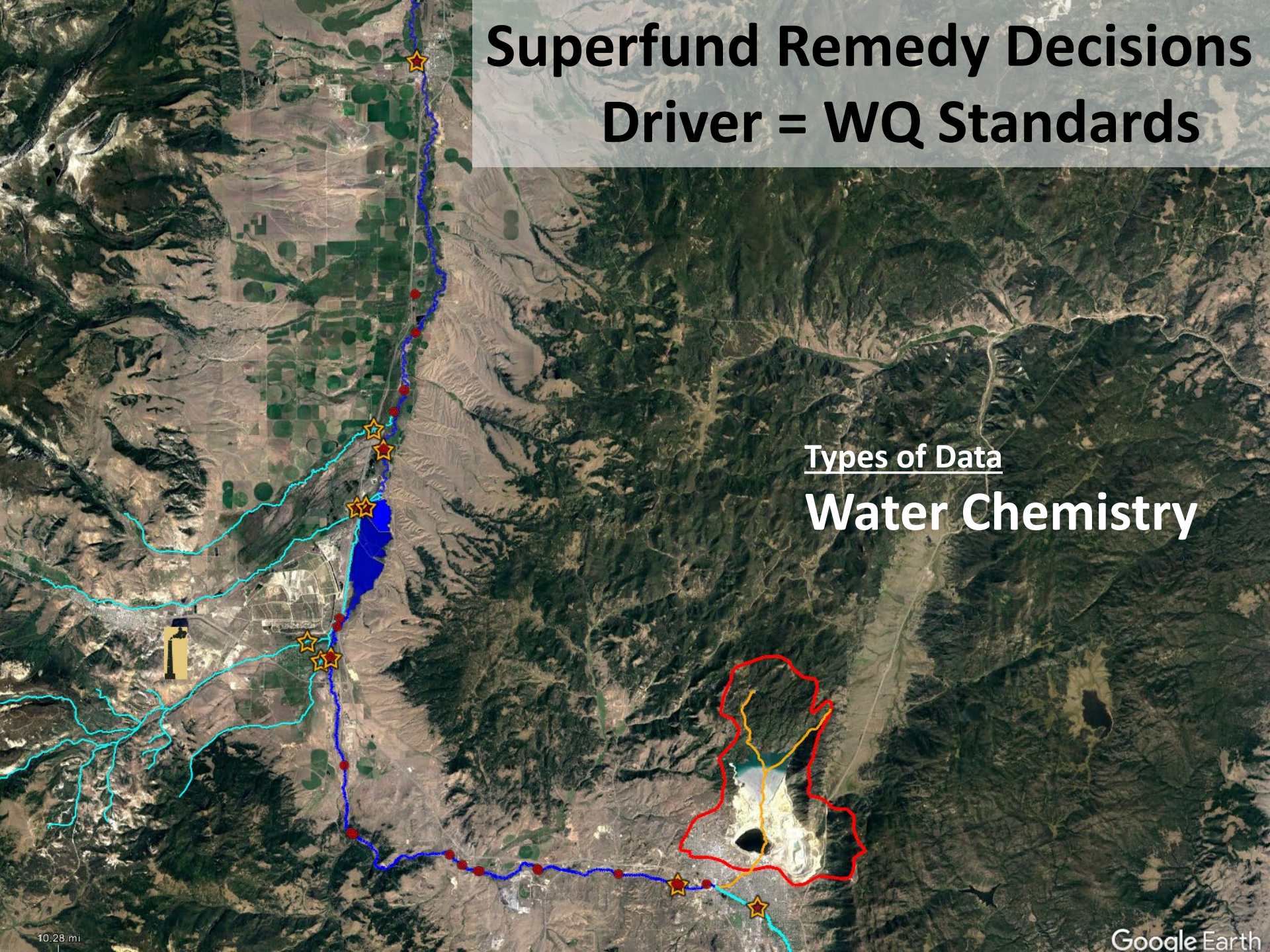


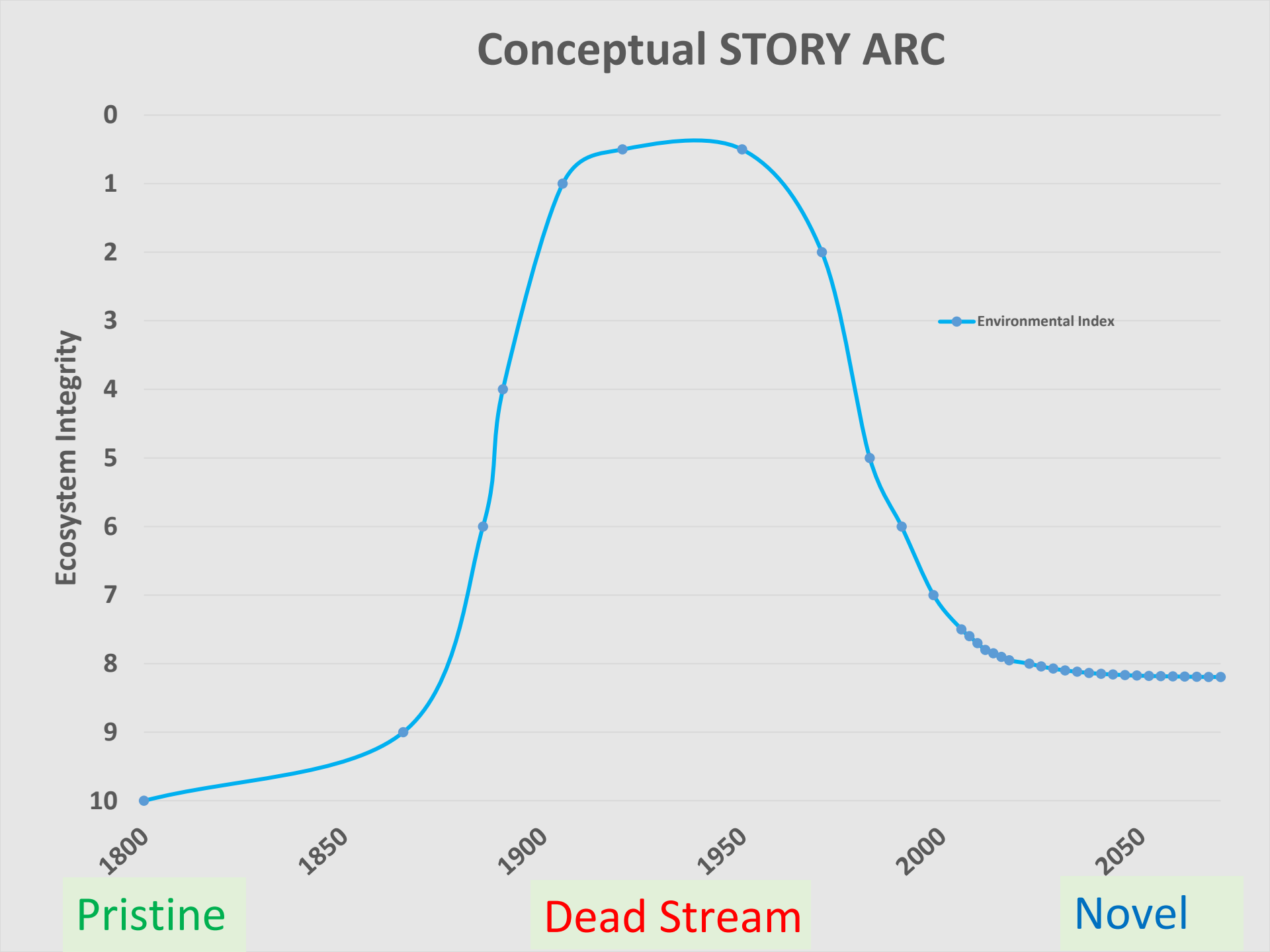
* Hazard Ranking System

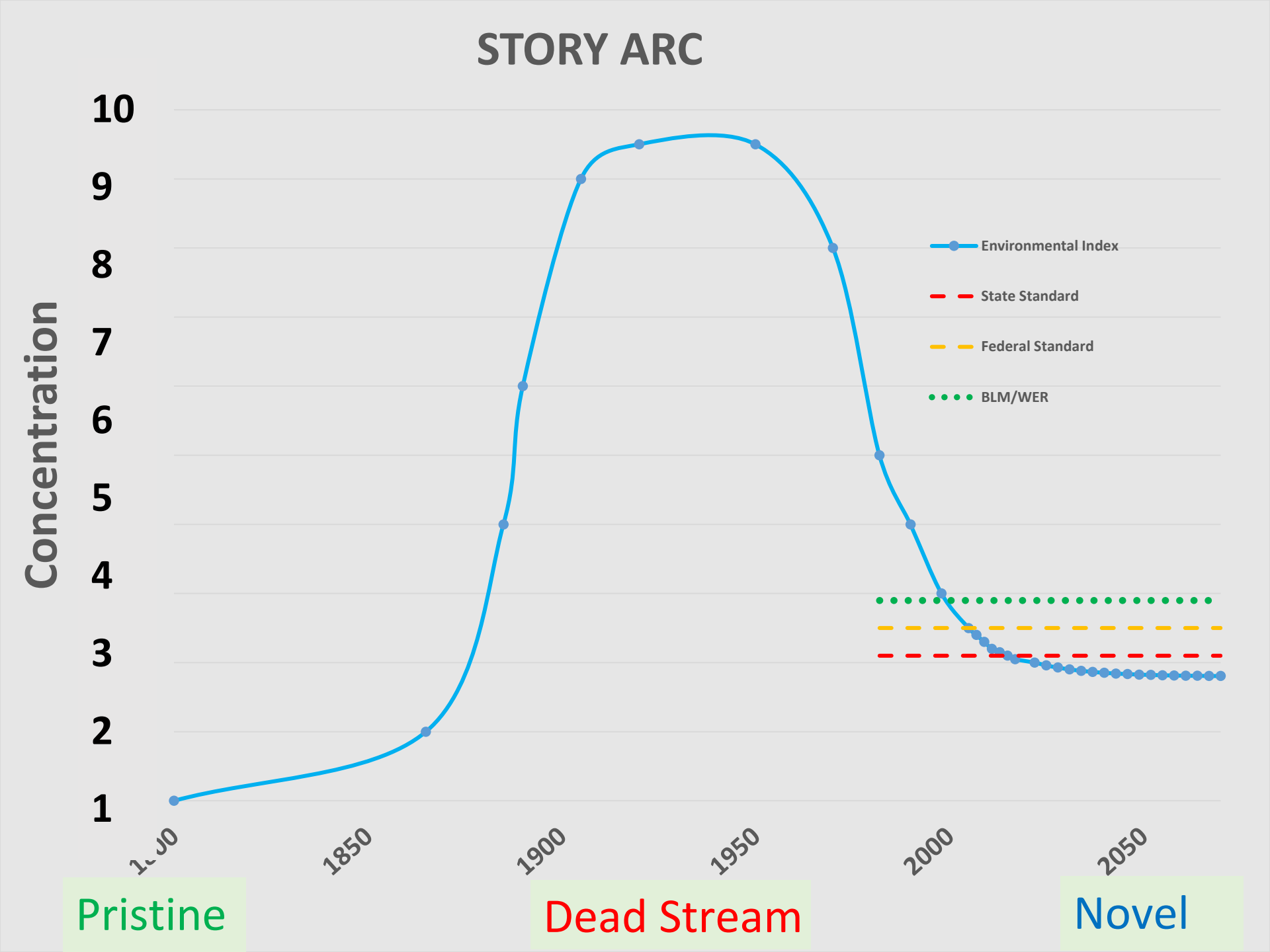
Consistency of Data



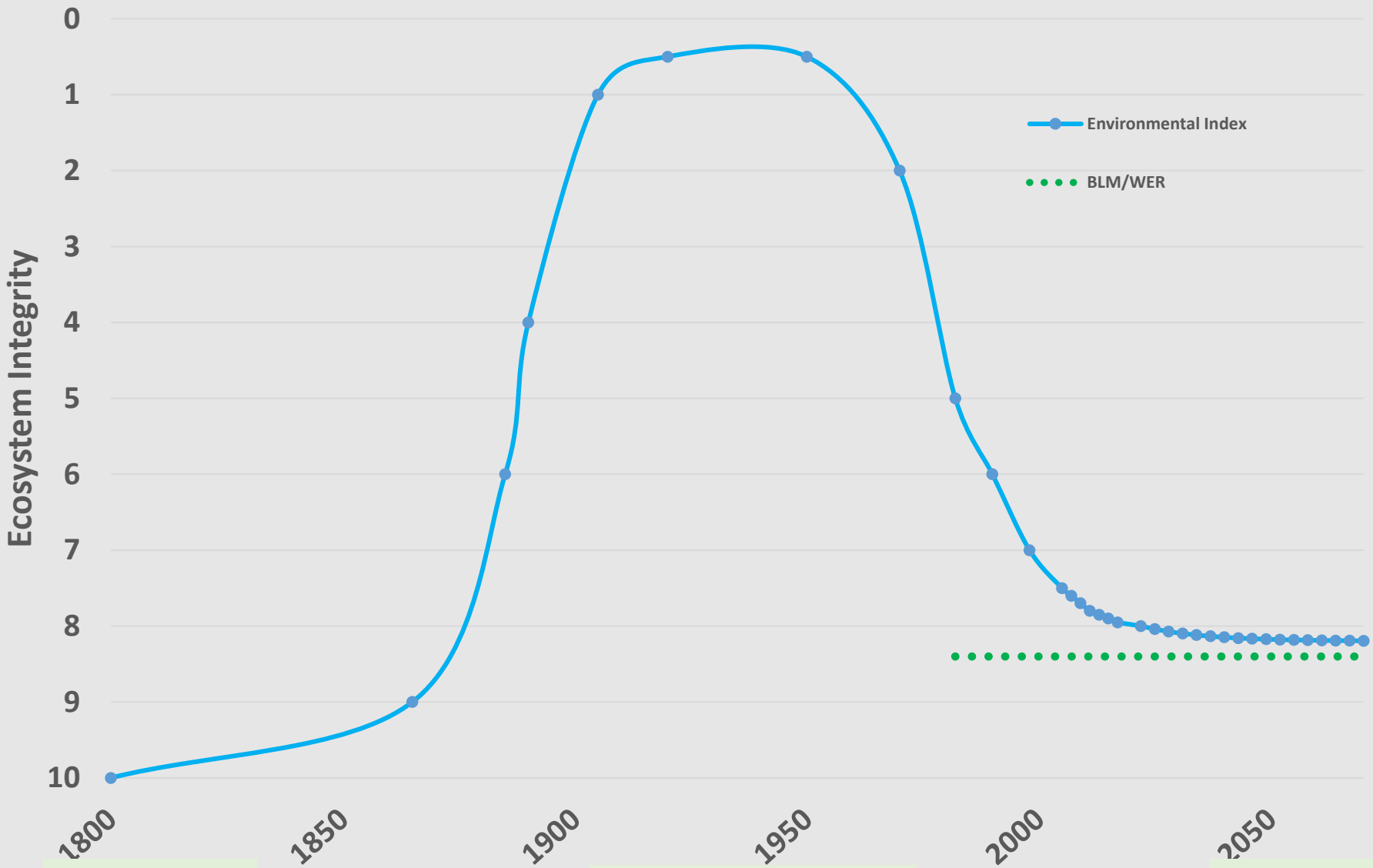
Superfund Remedy Decisions
Driver = WQ Standards




Conceptual STORY ARC
Ecosystem Integrity
0
1
2
3
4
5
6
7
8
9
10
1800
1850
1900
1950
2000
2050
Environmental Index
Pristine
Dead Stream
Novel


STORY ARC
Concentration
10
9
8
7
6
5
4
3
2
1
1850
1900
1950
2000
2050
Environmental Index
State Standard
Federal Standard
BLM/WER
Pristine
Dead Stream
Novel

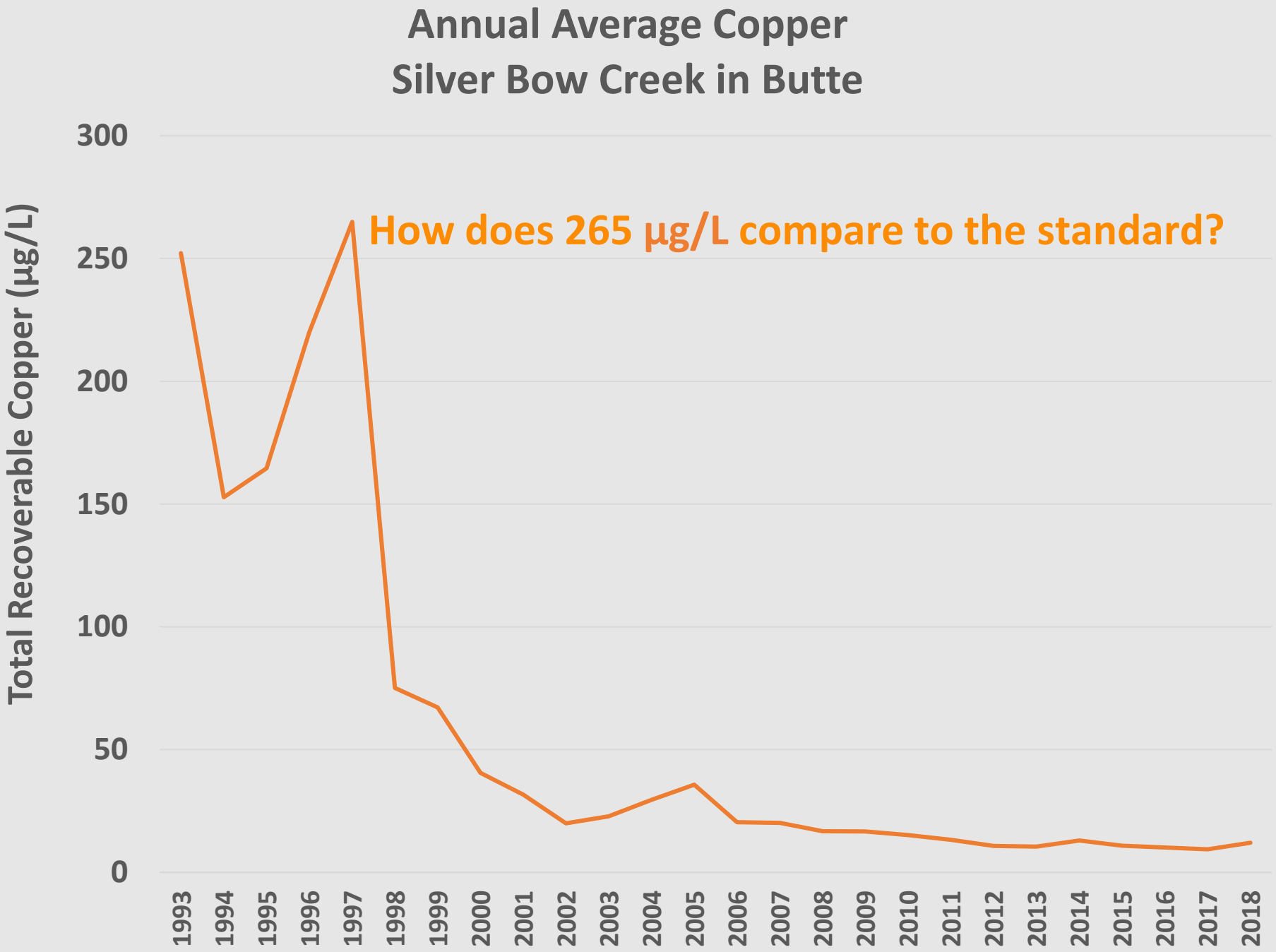
STORY ARC



Pristine

Dead Stream

Novel


Annual Average Copper
Silver Bow Creek in Butte
How does 265 µg/L compare to the standard?
Total Recoverable Copper (µg/L)
300
250
200
150
100
50
0
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018

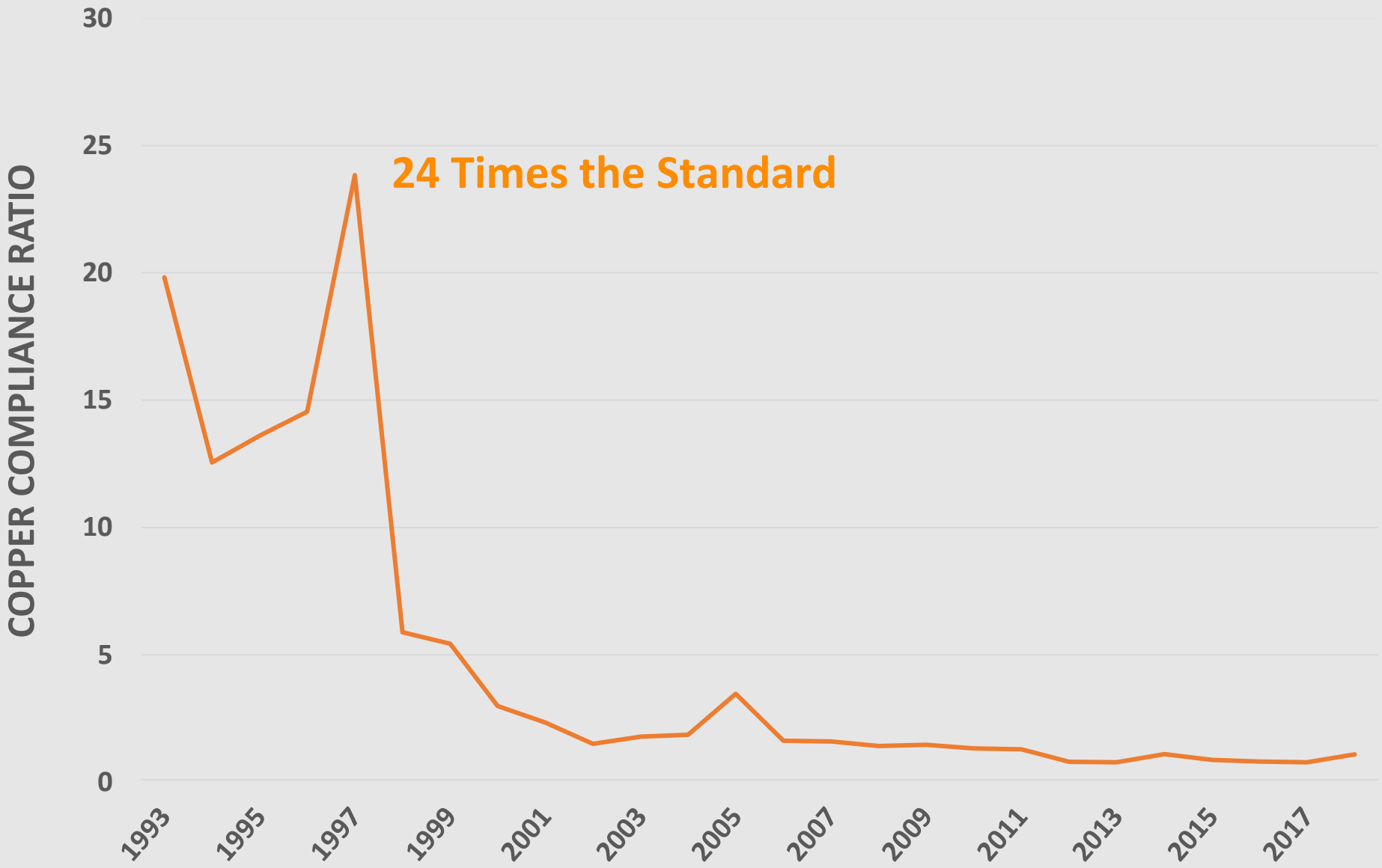
STANDARD = exp{m[ln(hardness)]+b}

	M	B	HARDNESS	STANDARD (µg/L)
Copper Chronic	0.8545	-1.702	141	12.5

State Standard = Unfiltered (Total Recoverable)

****Federal Standard = Filtered 0.45 microns****

Annual Average Copper
Silver Bow Creek in Butte



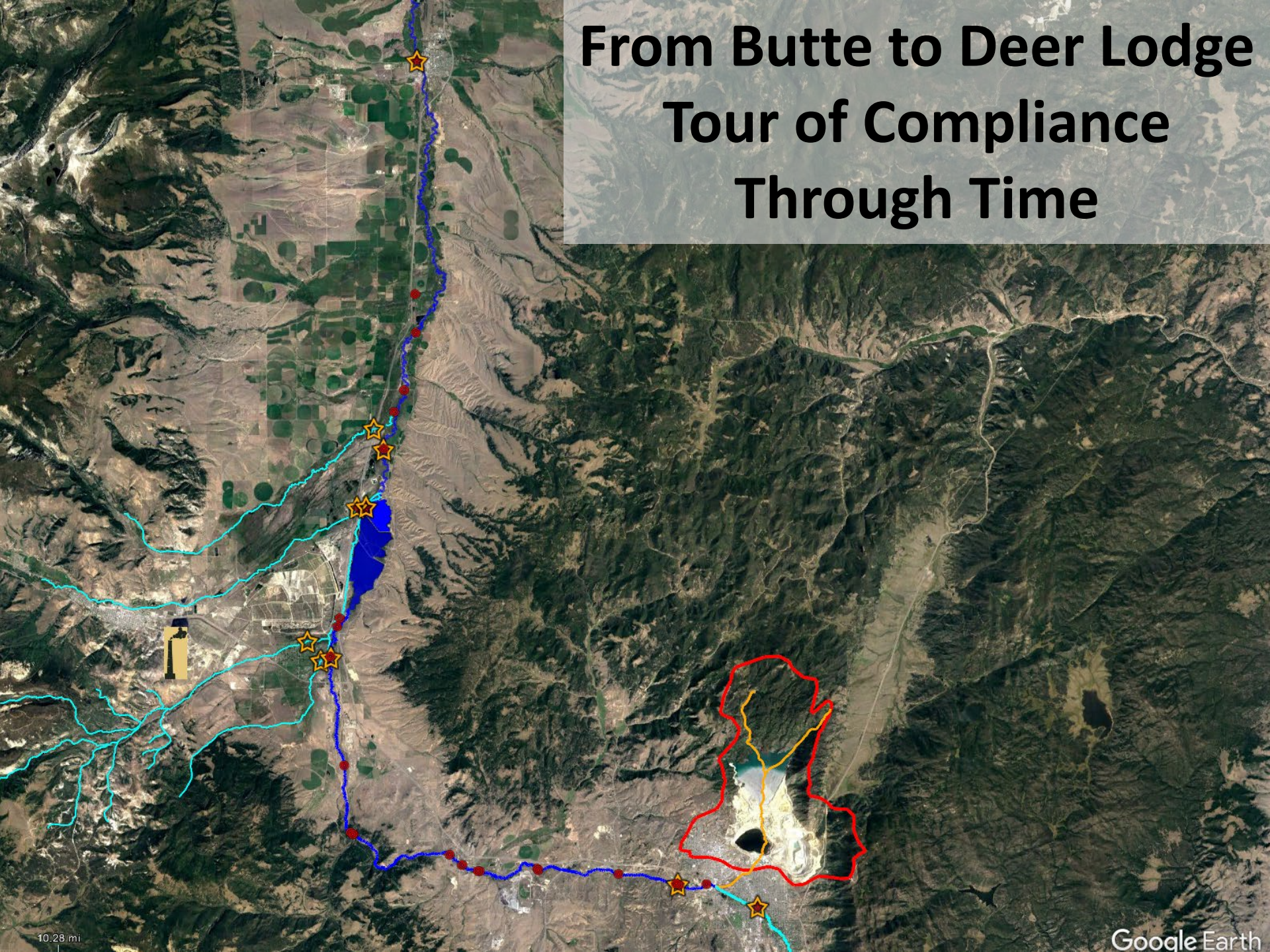
STANDARD = exp{m[ln(hardness)]+b}

	M	B	HARDNESS	STANDARD (µg/L)
Copper Chronic	0.8545	-1.702	141	12.5

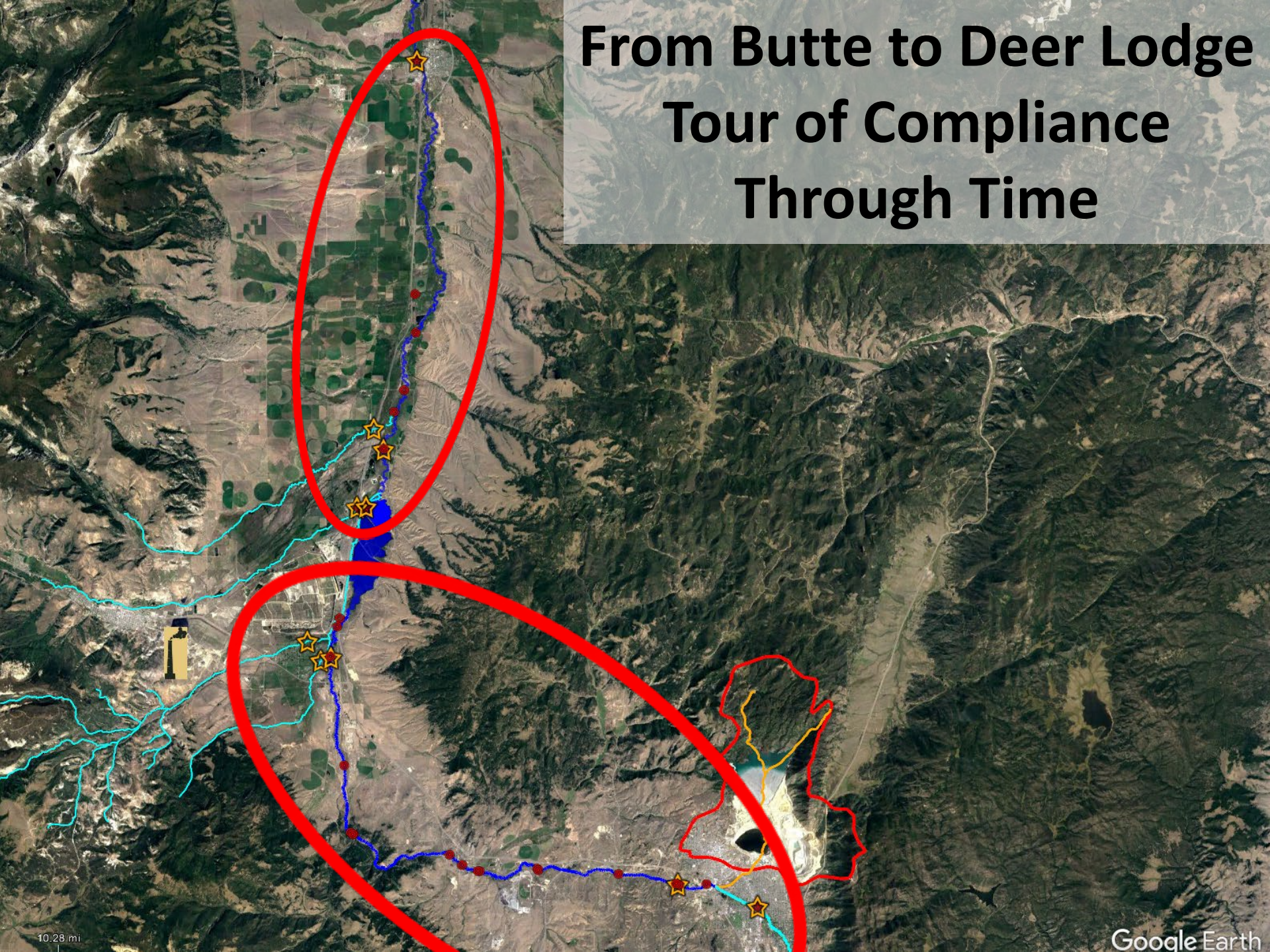
State Standard = Unfiltered (Total Recoverable)
Federal Standard = Filtered 0.45 microns
Federal Water Effects Ratio
Biotic Ligand Model

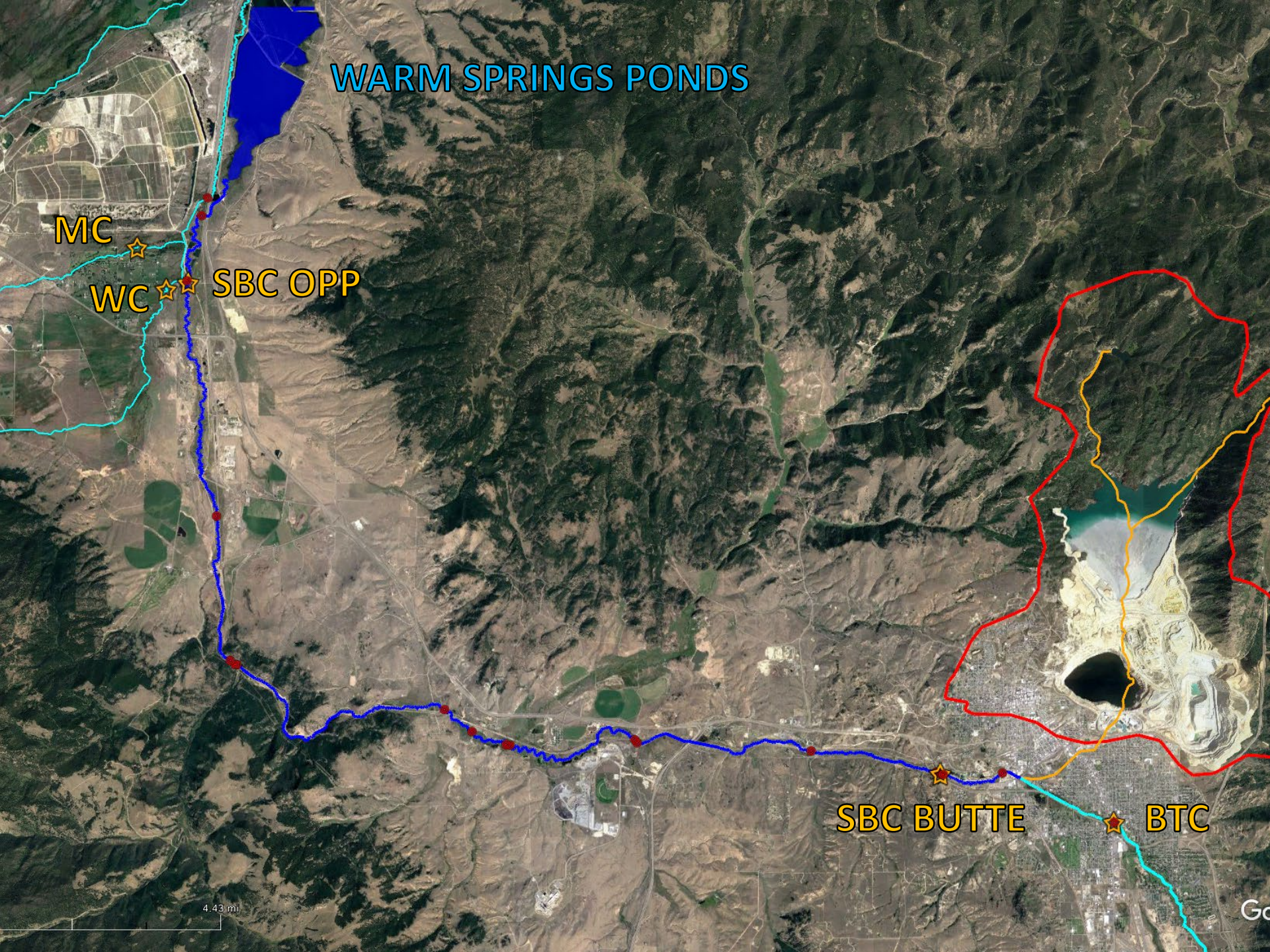

ARSENIC
CADMIUM
COPPER
LEAD
ZINC

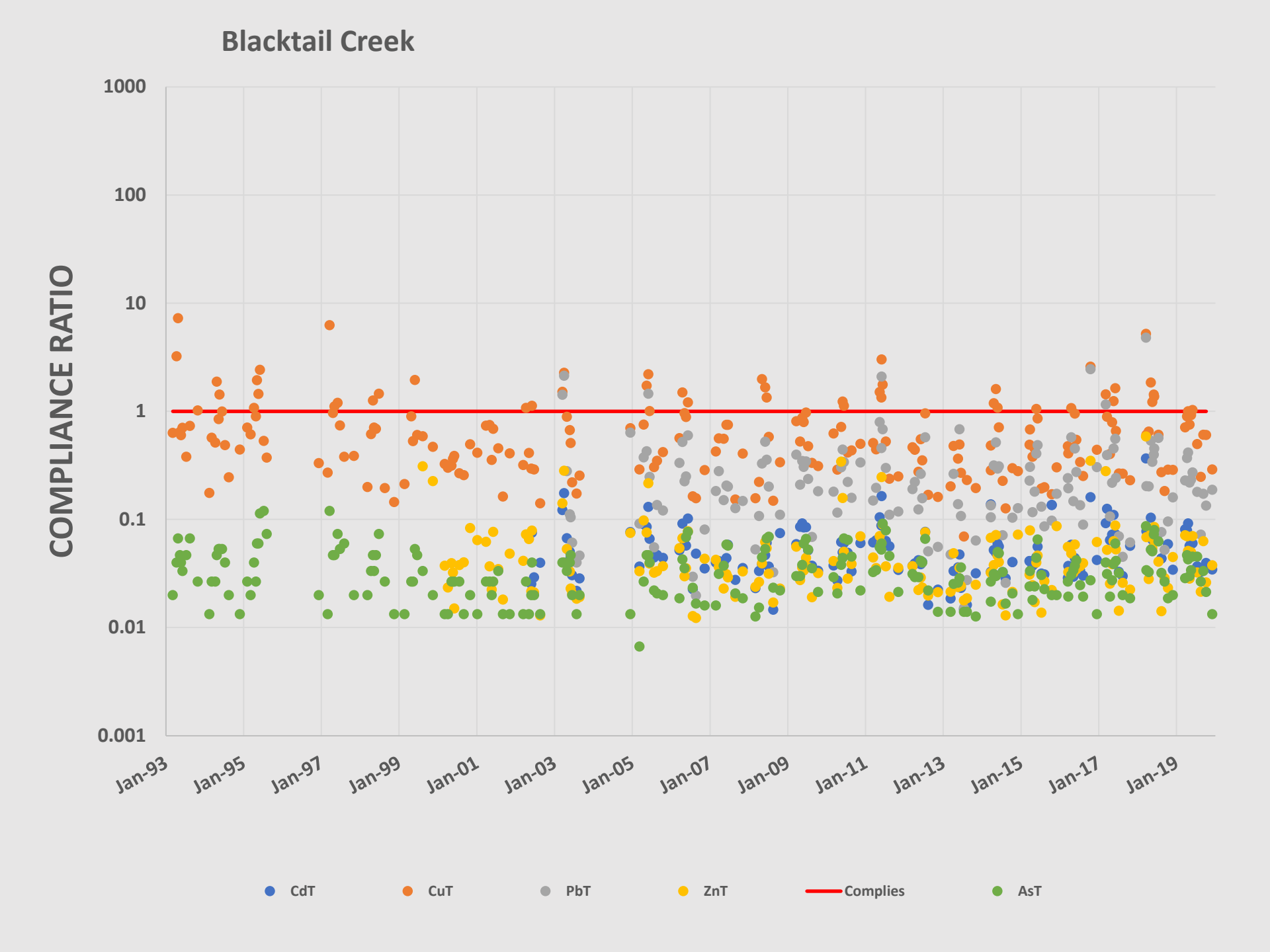
From Butte to Deer Lodge
Tour of Compliance
Through Time

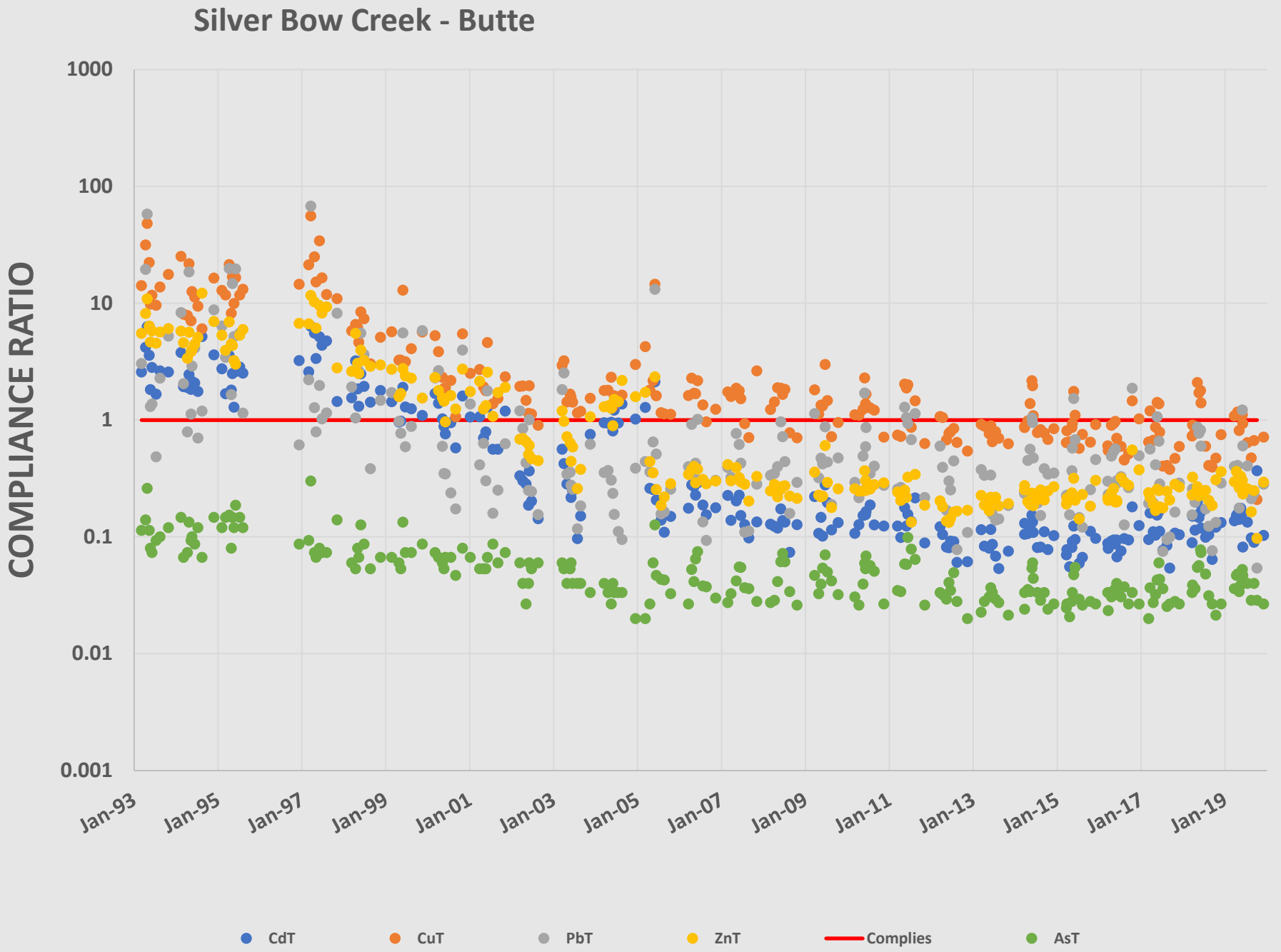


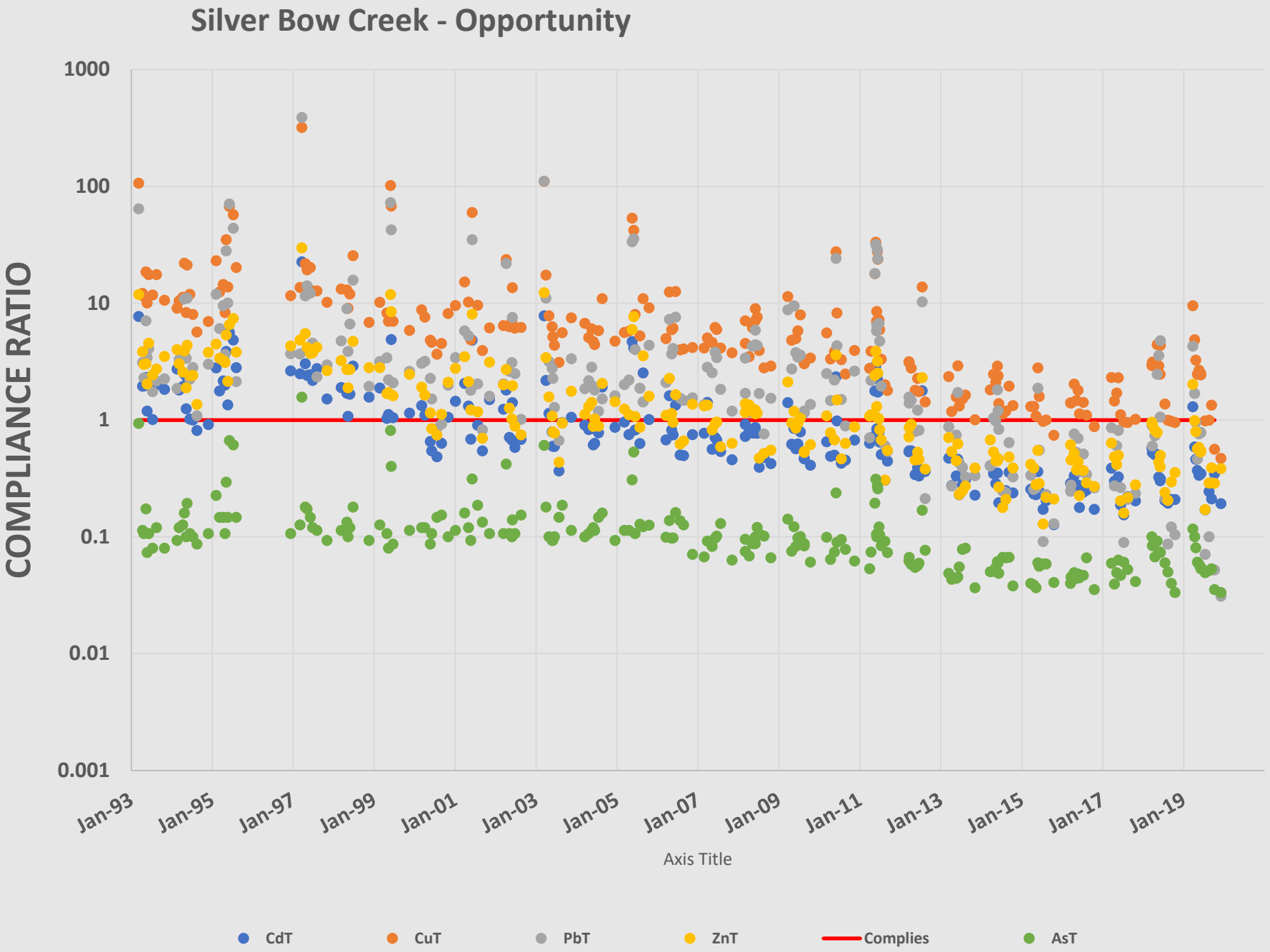
From Butte to Deer Lodge
Tour of Compliance
Through Time

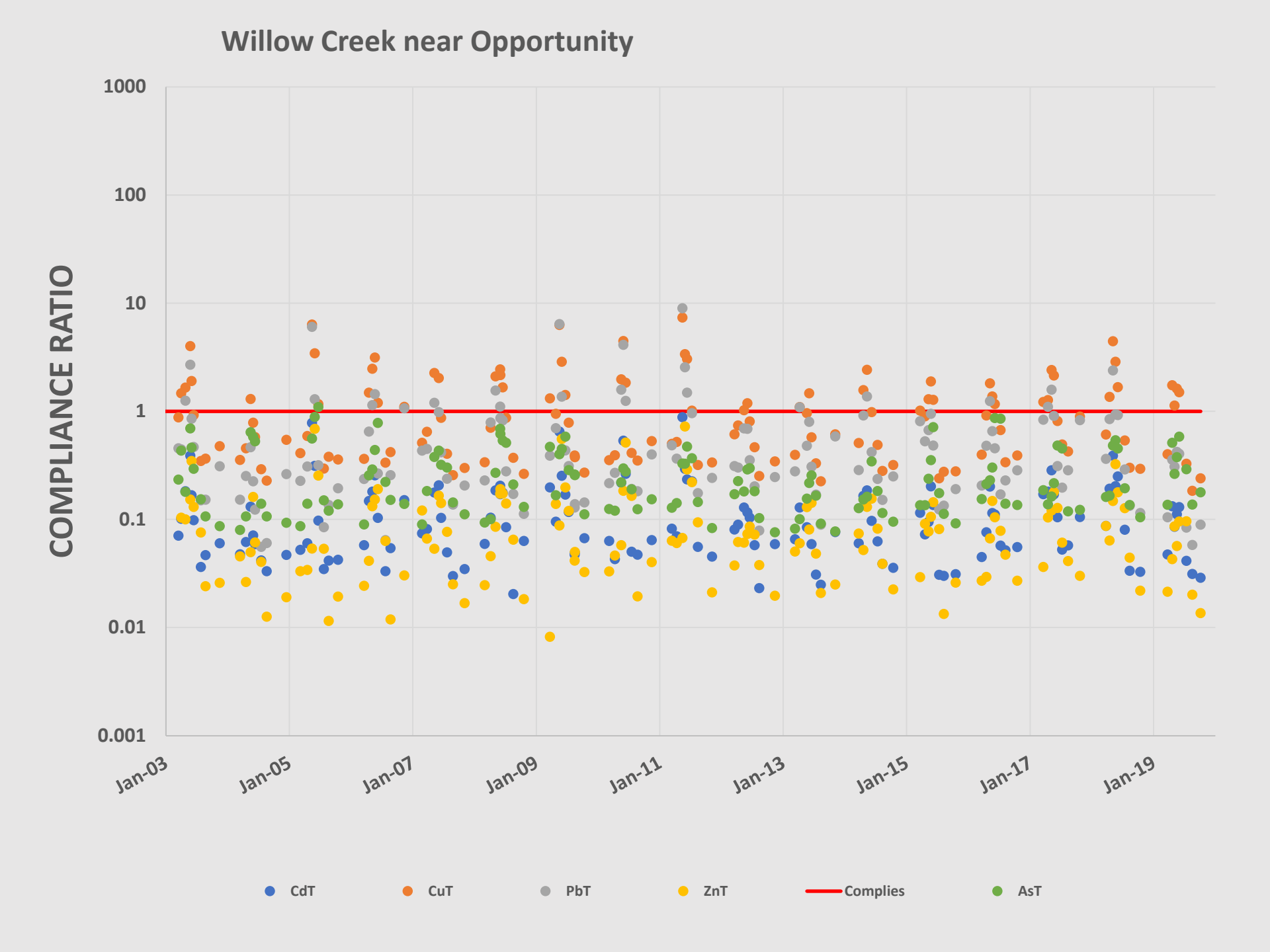


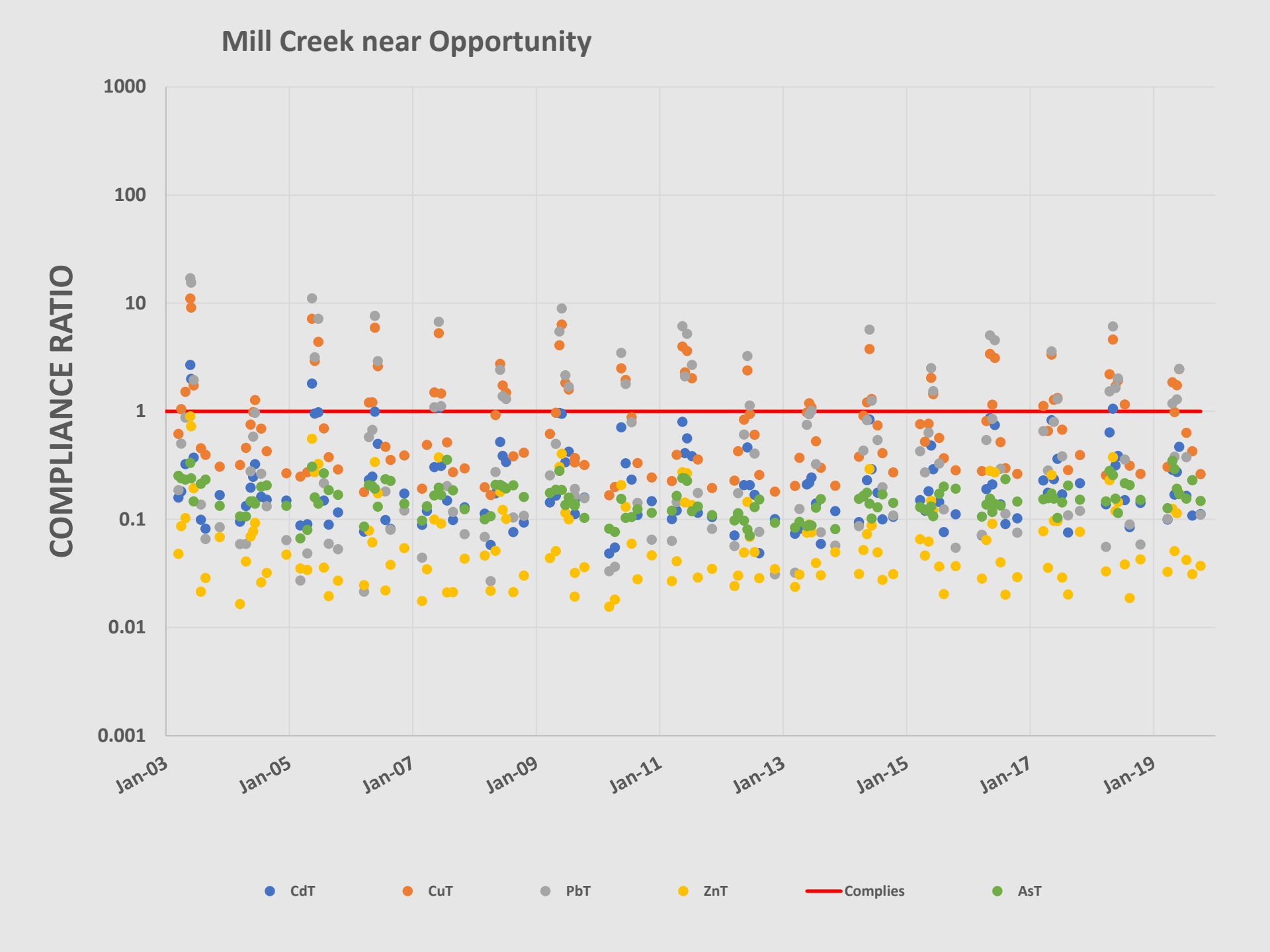

WARM SPRINGS PONDS
MC
WC
SBC OPP
SBC BUTTE
BTC
4.43 mi


Blacktail Creek
COMPLIANCE RATIO
1000
100
10
1
0.1
0.01
0.001
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
CdT
CuT
PbT
ZnT
Complies
AsT

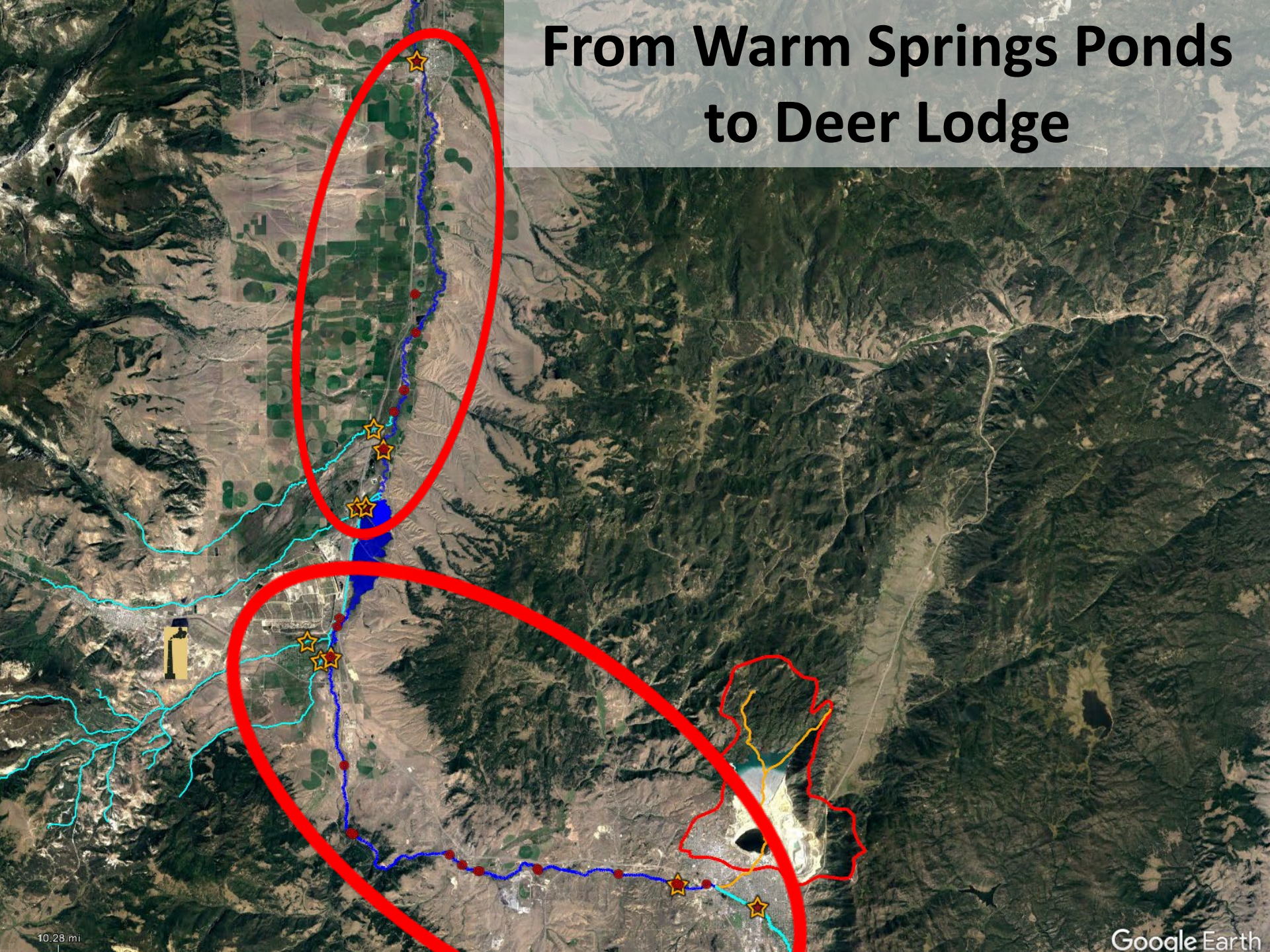

Silver Bow Creek - Butte
COMPLIANCE RATIO
1000
100
10
1
0.1
0.01
0.001
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
CdT
CuT
PbT
ZnT
Complies
AsT

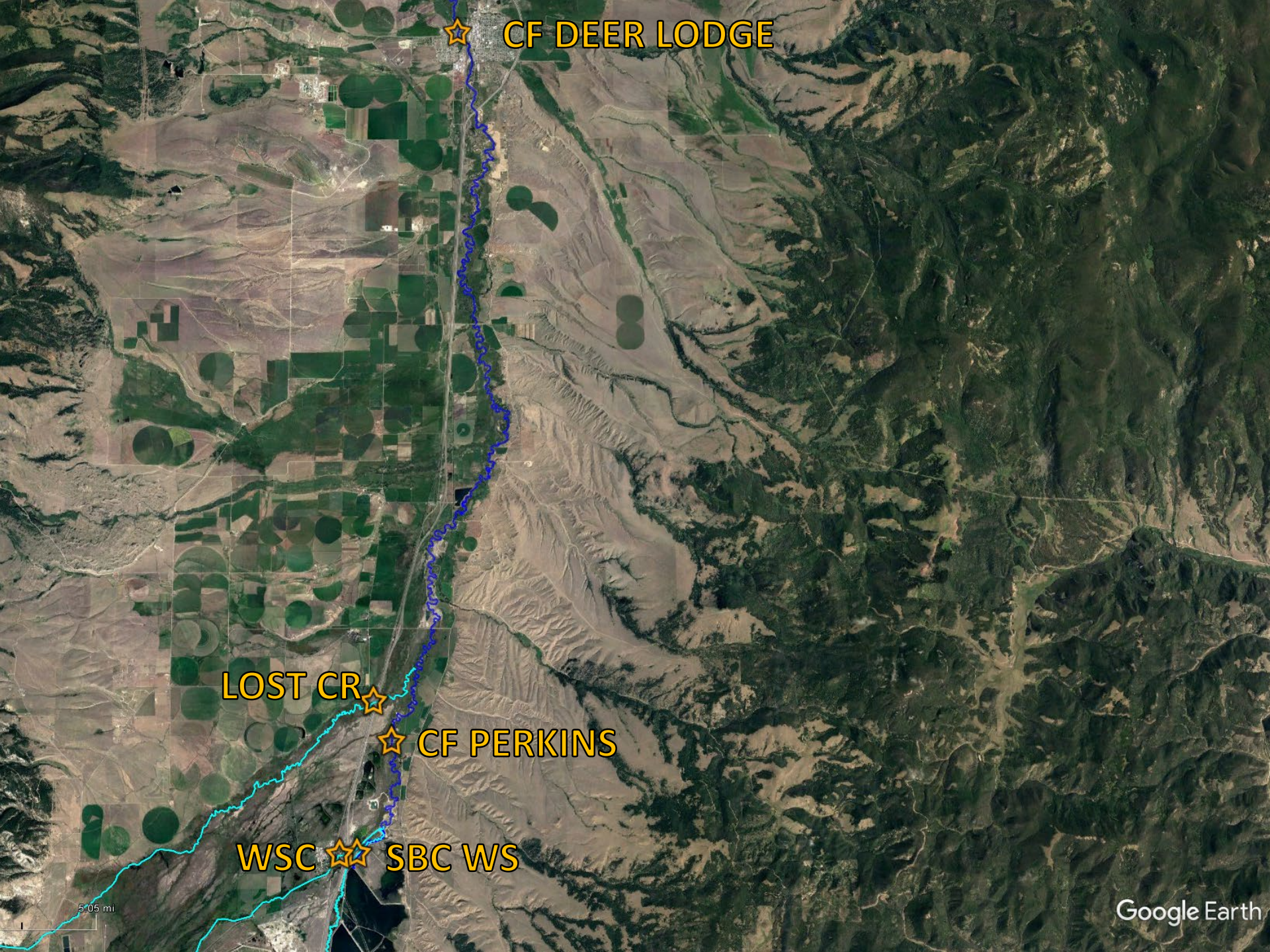

Silver Bow Creek - Opportunity
COMPLIANCE RATIO
1000
100
10
1
0.1
0.01
0.001
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Axis Title
CdT
CuT
PbT
ZnT
Complies
AsT

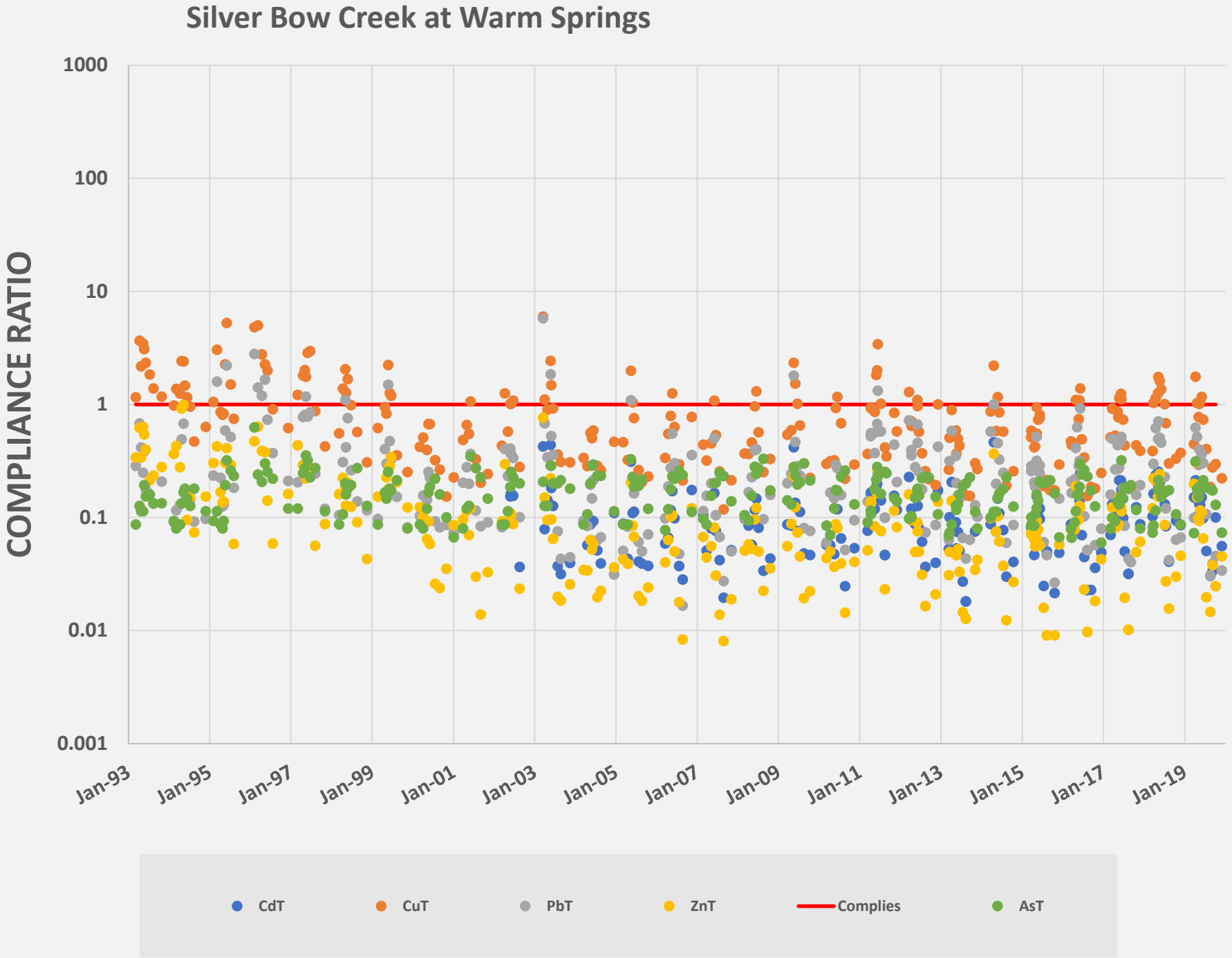

Willow Creek near Opportunity
COMPLIANCE RATIO
1000
100
10
1
0.1
0.01
0.001
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
CdT
CuT
PbT
ZnT
Complies
AsT

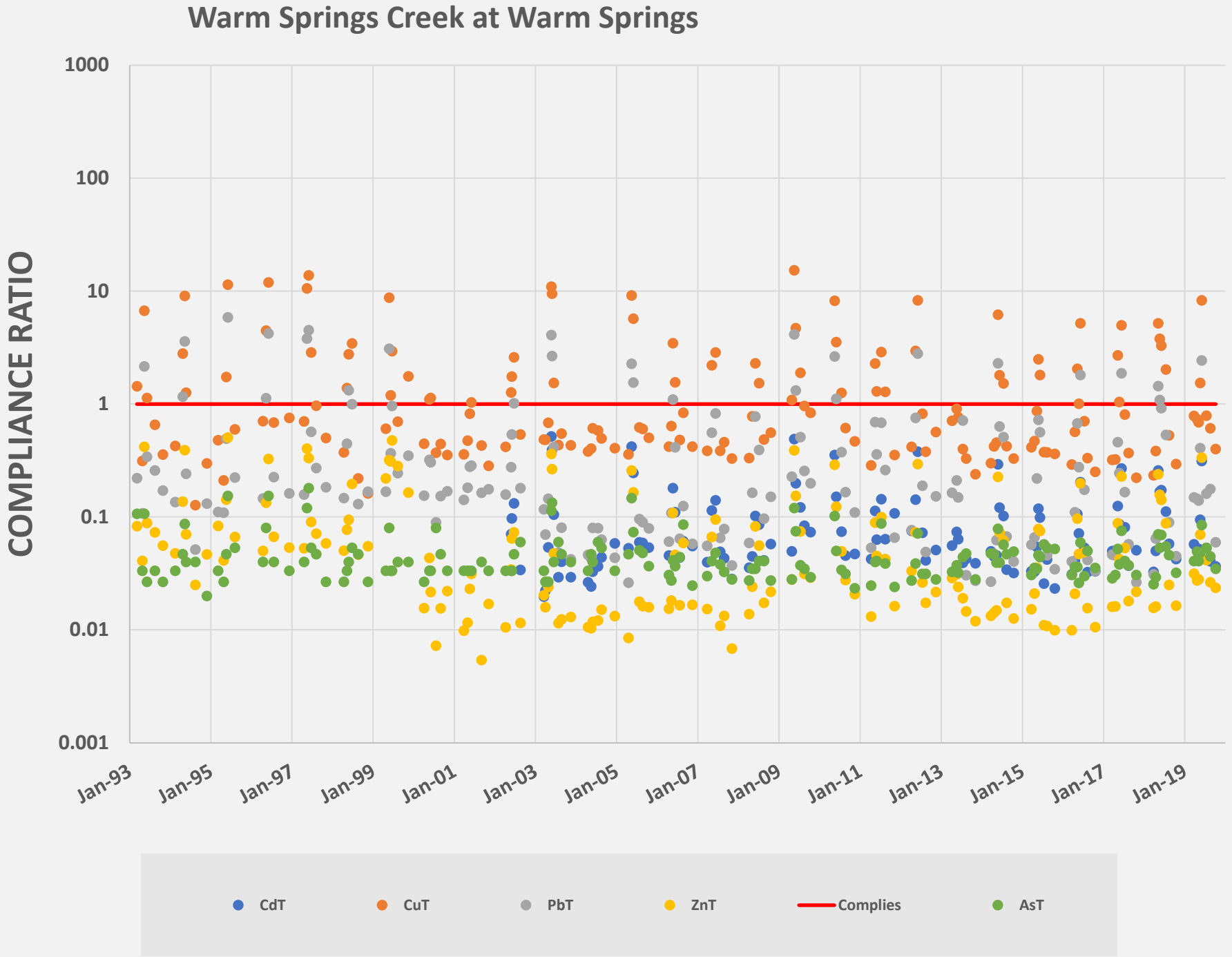

Mill Creek near Opportunity
COMPLIANCE RATIO
1000
100
10
1
0.1
0.01
0.001
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
CdT
CuT
PbT
ZnT
Complies
AsT

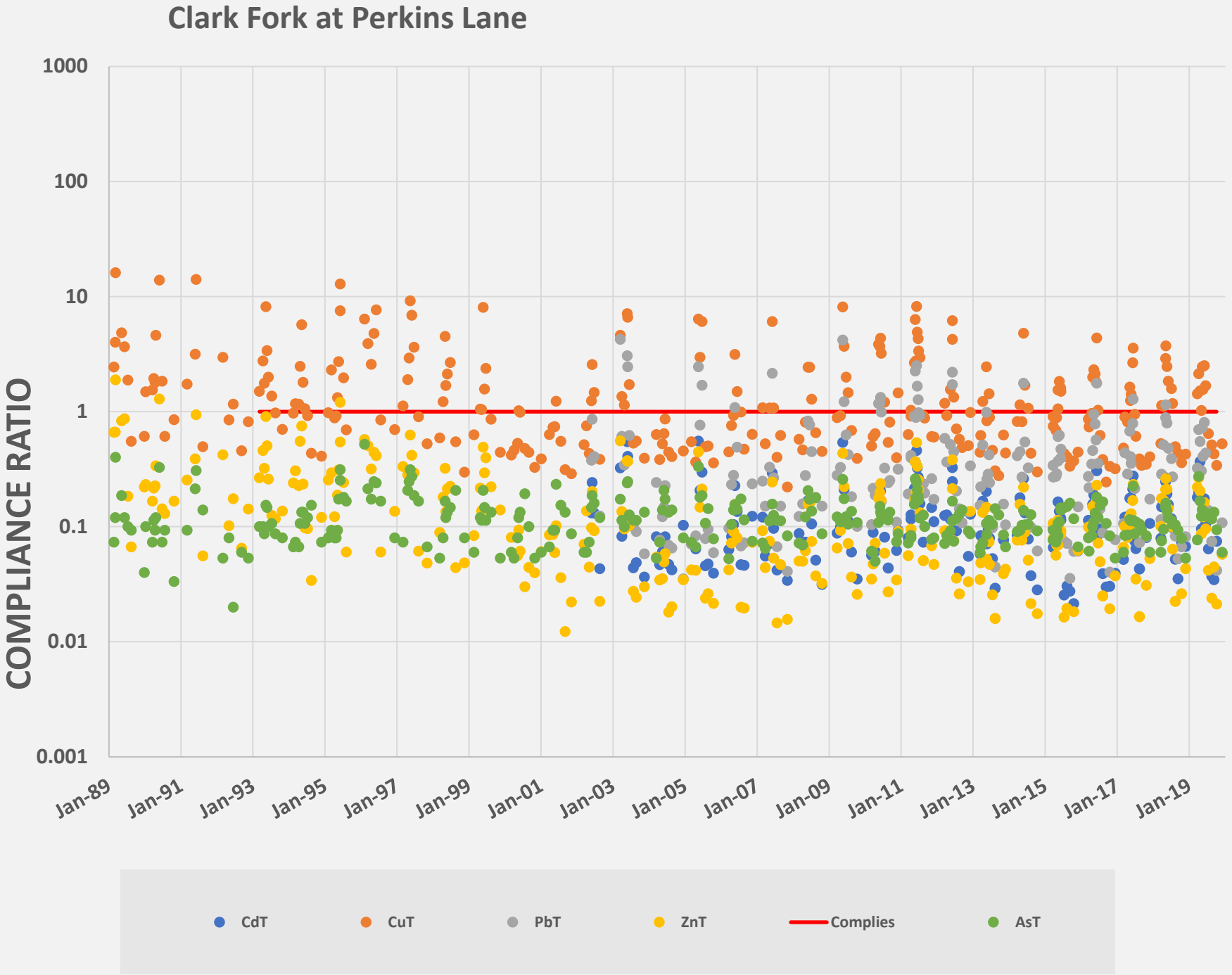
From Warm Springs Ponds to Deer Lodge

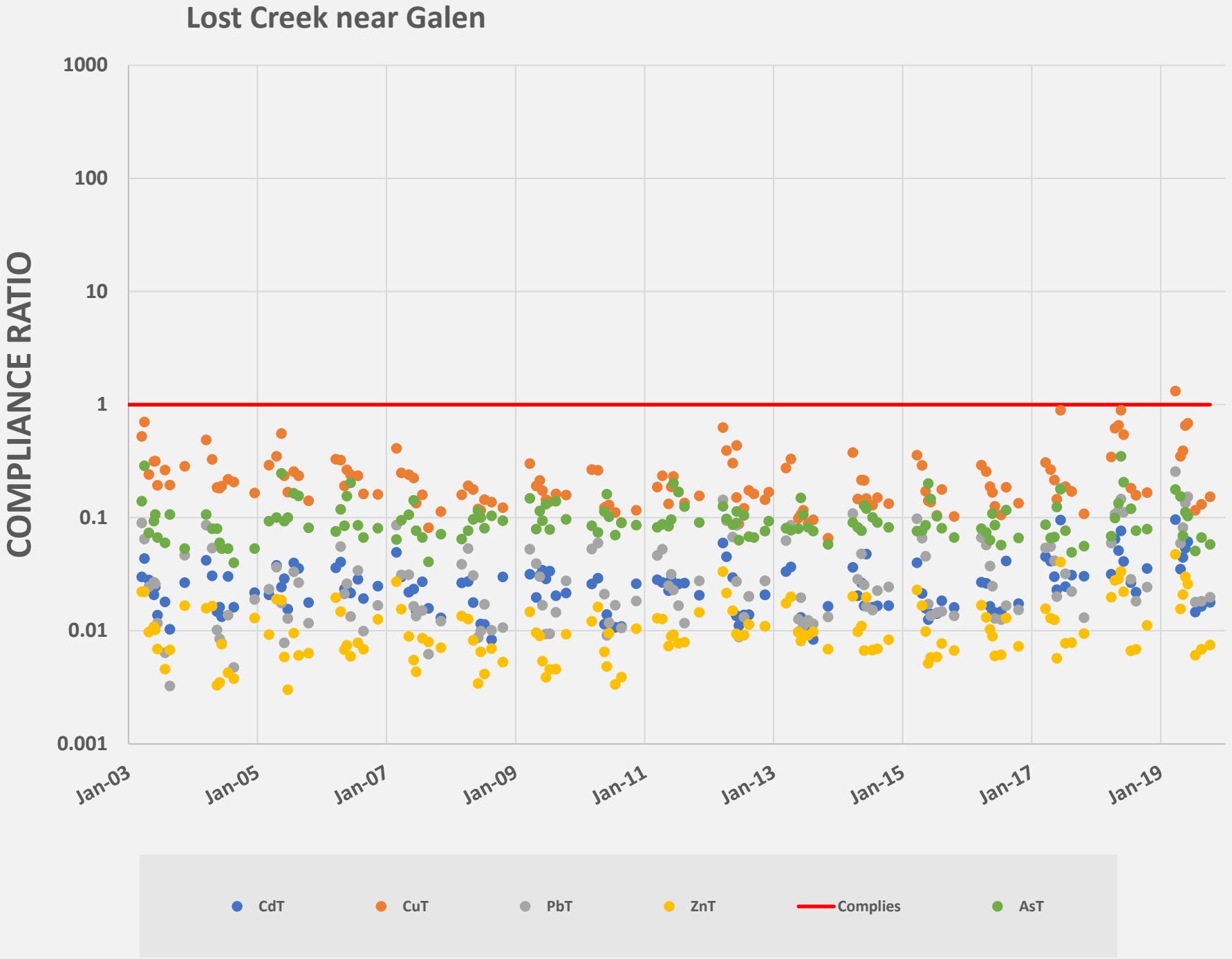


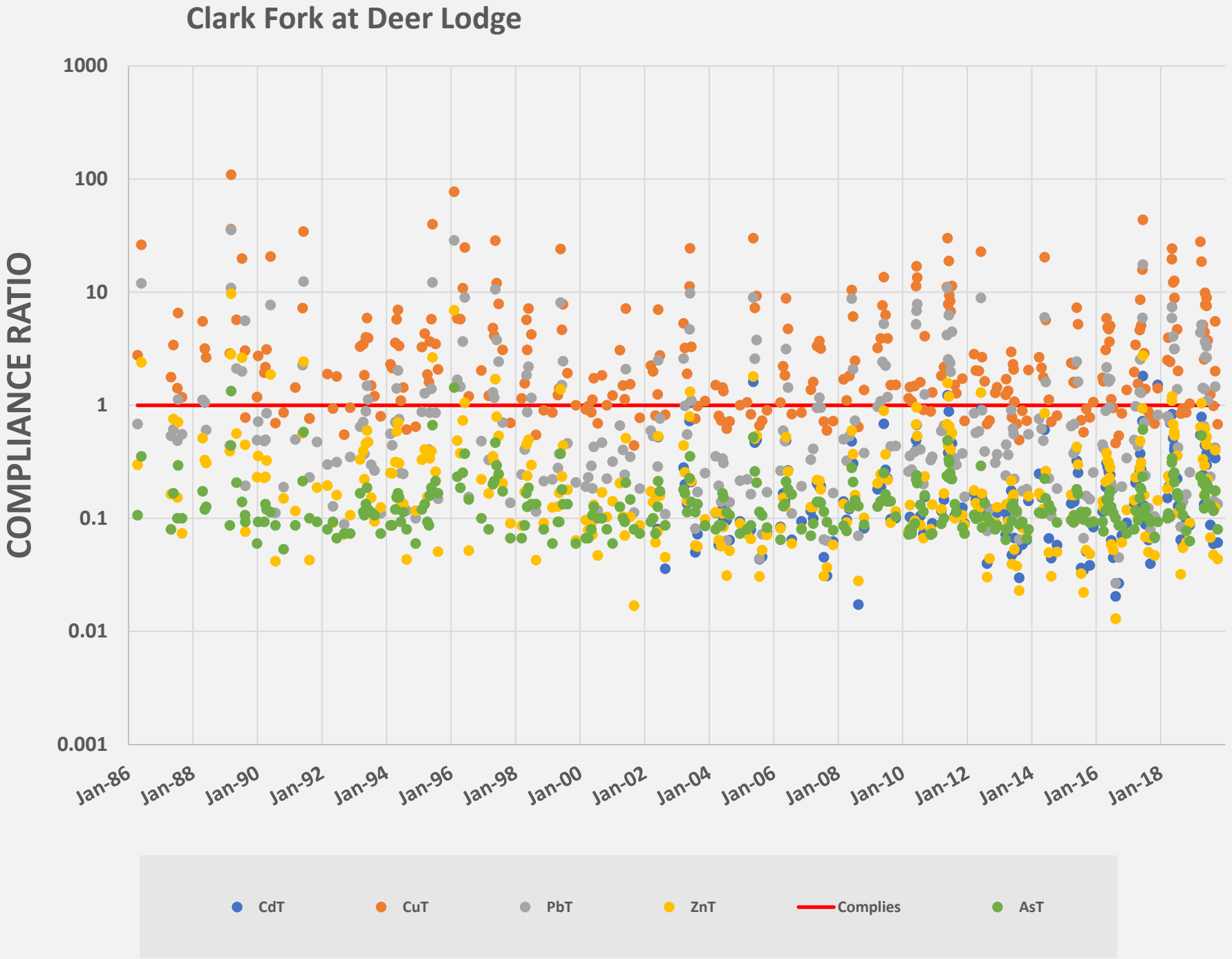

CF DEER LODGE
LOST CR
CF PERKINS
WSC
SBC WS
5.05 mi
Google Earth


Silver Bow Creek at Warm Springs
COMPLIANCE RATIO
1000
100
10
1
0.1
0.01
0.001
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
CdT
CuT
PbT
ZnT
Complies
AsT


Warm Springs Creek at Warm Springs
COMPLIANCE RATIO
1000
100
10
1
0.1
0.01
0.001
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
CdT
CuT
PbT
ZnT
Complies
AsT


Clark Fork at Perkins Lane
COMPLIANCE RATIO
1000
100
10
1
0.1
0.01
0.001
Jan-89
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
CdT
CuT
PbT
ZnT
Complies
AsT


Lost Creek near Galen
COMPLIANCE RATIO
1000
100
10
1
0.1
0.01
0.001
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
CdT
CuT
PbT
ZnT
Complies
AsT


Clark Fork at Deer Lodge
COMPLIANCE RATIO
1000
100
10
1
0.1
0.01
0.001
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
CdT
CuT
PbT
ZnT
Complies
AsT

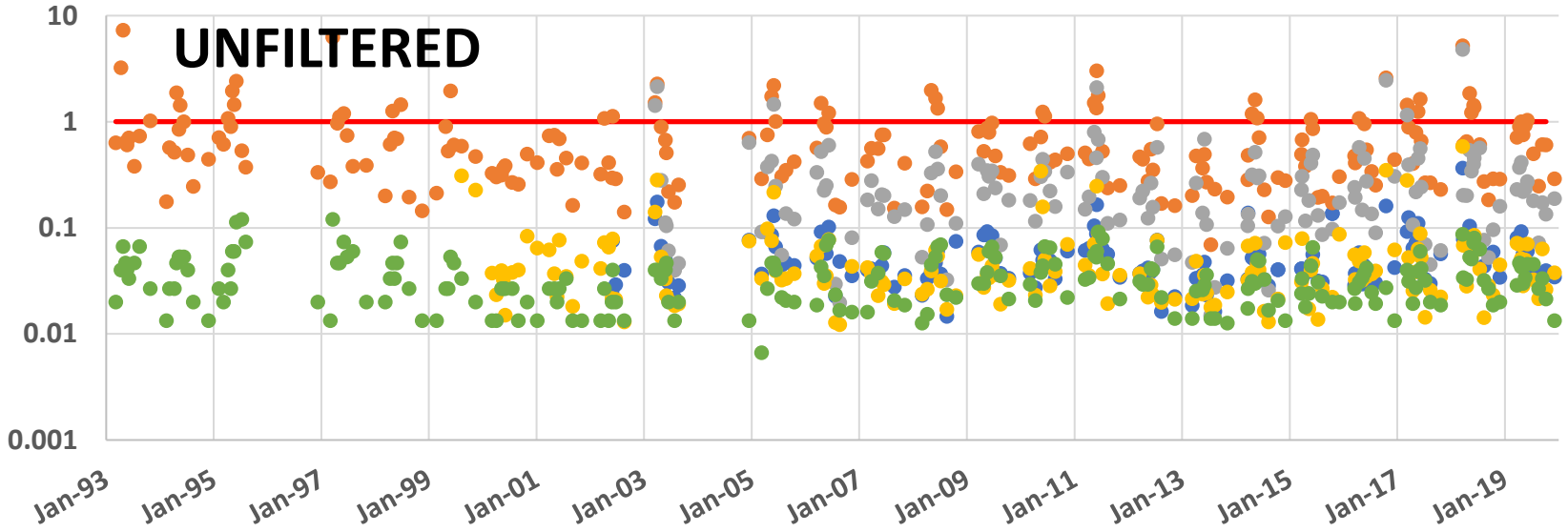
Numeric Standards VS Biological Integrity

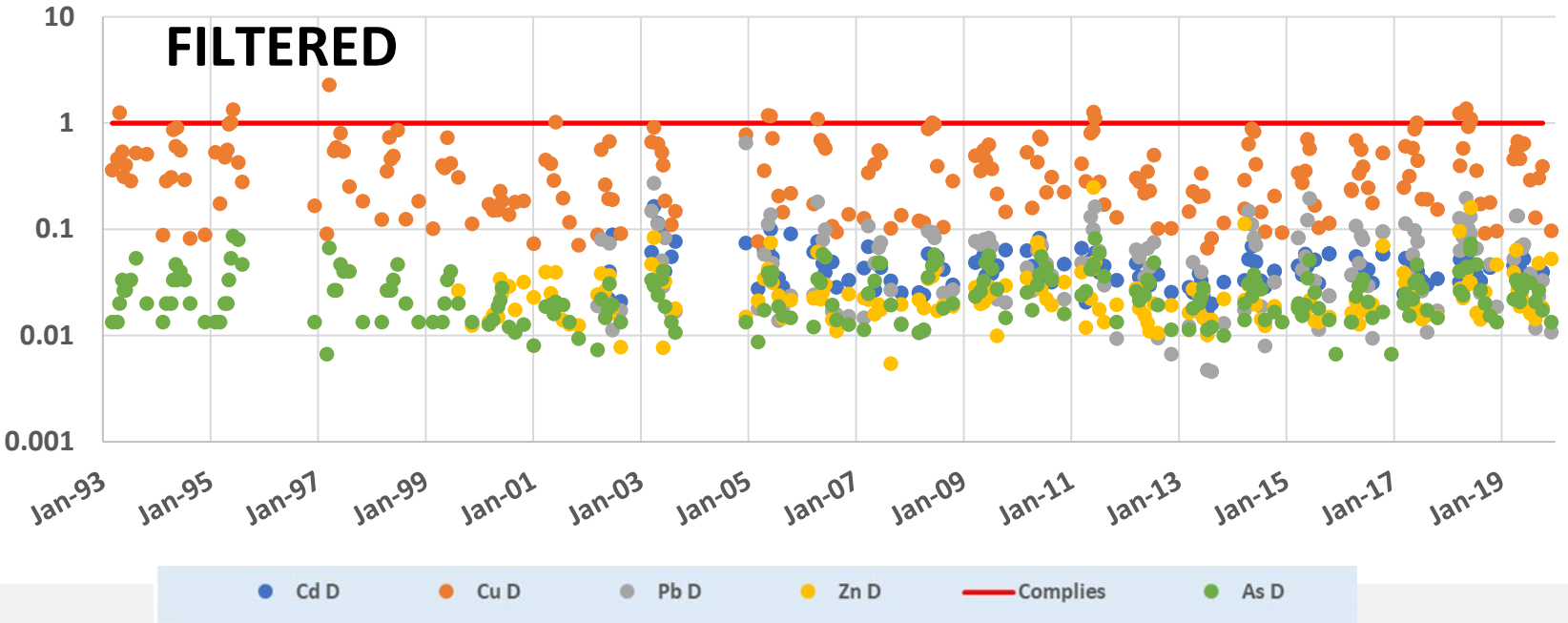
Case for Reference Stream Analysis

REFERENCE STREAM

Blacktail Creek

BLACKTAIL CREEK

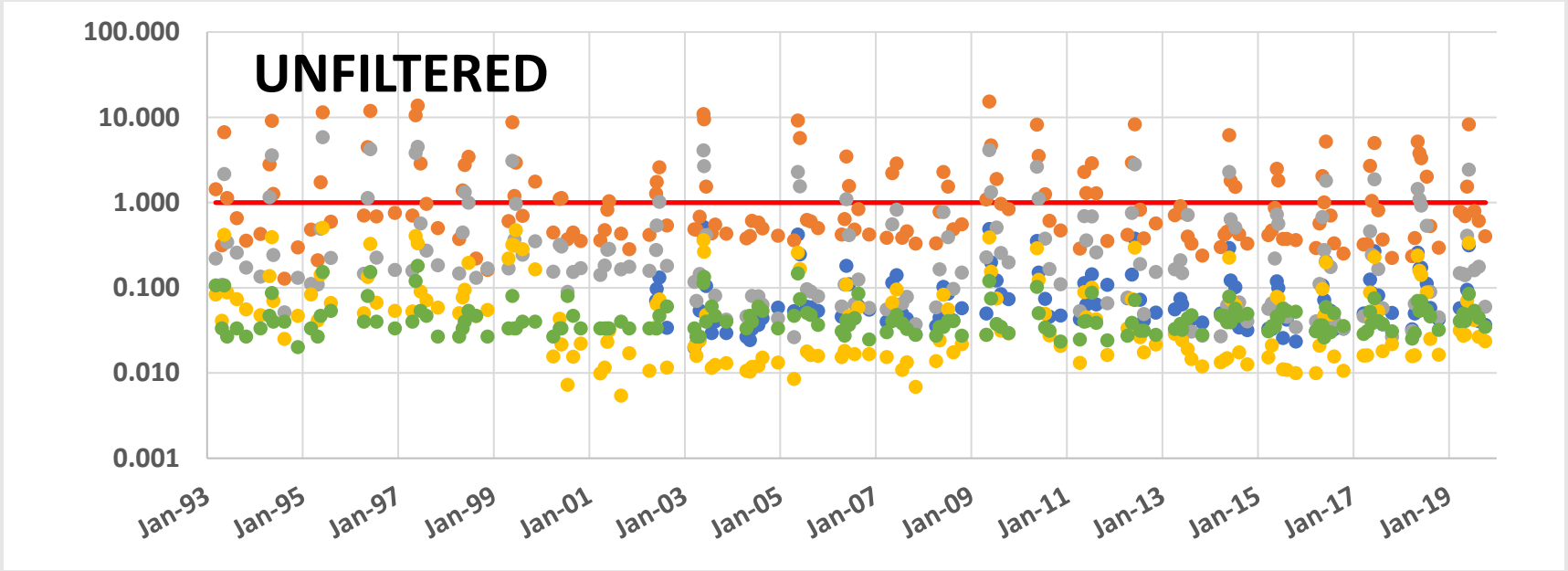


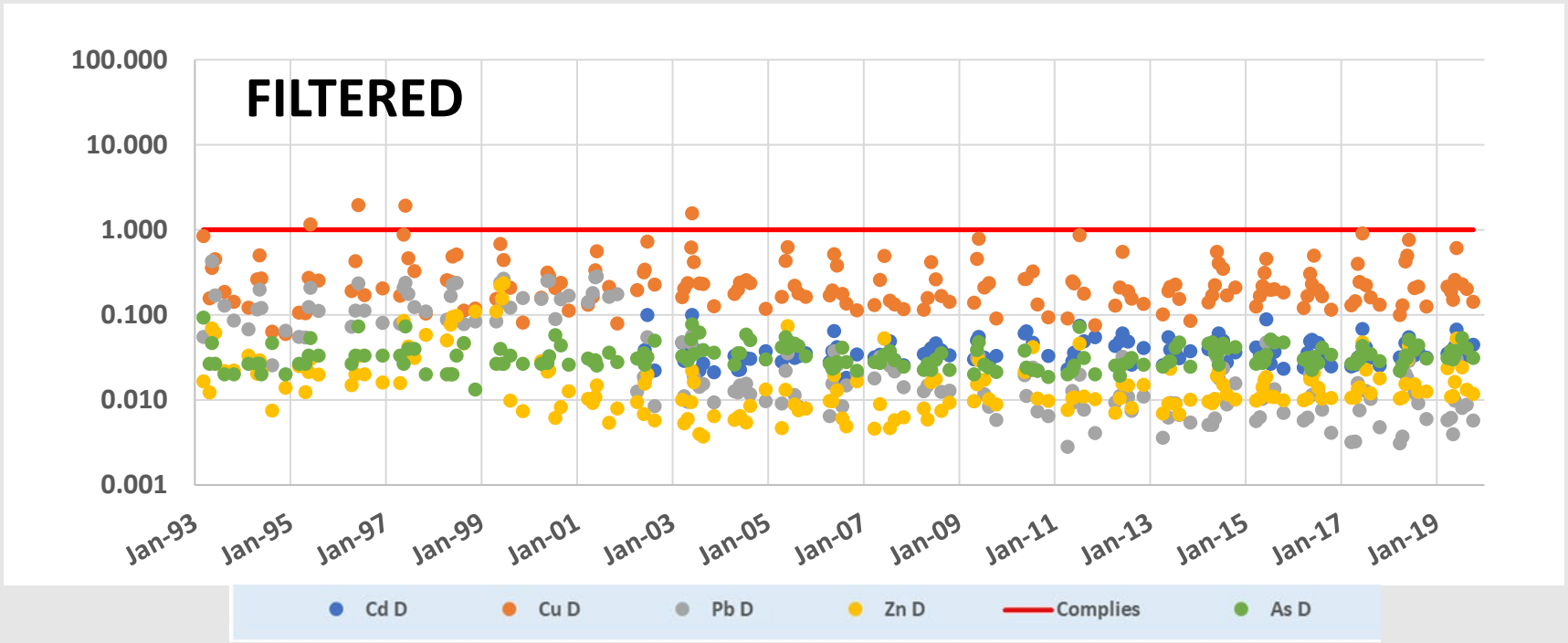


REFERENCE STREAM

Warm Springs Creek

WARM SPRINGS CREEK





2013 Copper Bioavailability Testing in Silver Bow Creek and Anaconda Tributaries (Warm Springs Creek, Mill Creek, Willow Creek, Lost Creek)

Winter, Spring, and Summer/Fall Sampling

For:

Atlantic Richfield Company

Butte, Montana, USA

Prepared by:

TRE

TRE Environmental Strategies, LLC.
4303 West LaPorte Avenue
Fort Collins, Colorado

ARCADIS
Infrastructure · Water · Environment · Buildings

ARCADIS U.S., Inc.
1687 Cole Blvd, Suite 200
Lakewood, CO, 80401

October 14

DRAFT

WATER EFFECTS RATIO

2013 Copper Bioavailability Testing in Silver Bow Creek and Anaconda Tributaries (Warm Springs Creek, Mill Creek, Willow Creek, Lost Creek)

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Lakewood, CO, 80401

October 14

DRAFT

WATER EFFECTS RATIO

BLM

Site[a]	Round	Type of copper concentration[b]	Copper LC_{50} (µg/L)		WER
			Site water	Lab water	
WSC	Winter	TR	277.7	145.1	**1.914**
		Diss	255.5	119.8	**2.133**
	Spring	TR	360.3	62.71	**5.745**
		Diss	216.6	56.21	**3.853**
	Summer/ Fall	TR	233.7	121.3	**1.927**
		Diss	176.1	99.28	**1.774**
MC	Winter	TR	131.4	59.65	**2.203**
		Diss	106.5	50.15	**2.124**
	Spring	TR	138.8	29.41	**4.719**
		Diss	114.7	24.81	**4.623**
	Summer/ Fall	TR	117.5	43.10	**2.726**
		Diss	101.1	37.96	**2.663**
WC	Winter	TR	253.7	71.12	**3.567**
		Diss	177.4	62.33	**2.846**
	Spring	TR	403.4	73.79	**5.467**
		Diss	263.9	65.50	**4.029**
	Summer/ Fall	TR	207.8	103.5	**2.008**
		Diss	169.7	94.41	**1.797**
LC	Winter	TR	292.3	261.3	**1.119**
		Diss	250.7	225.7	**1.111**
	Spring	TR	107.6	46.22	**2.328**
		Diss	96.28	42.89	**2.245**
	Summer/ Fall	TR	117.7	67.47	**1.744**
		Diss	112.3	64.46	**1.742**
BTC					**3.090**
		Diss	206.2	71.46	**2.886**
	Spring	TR	287.7	56.55	**5.088**
		Diss	212.6	51.51	**4.127**
	Summer/ Fall	TR	161.8	87.64	**1.846**
		Diss	123.7	76.30	**1.621**

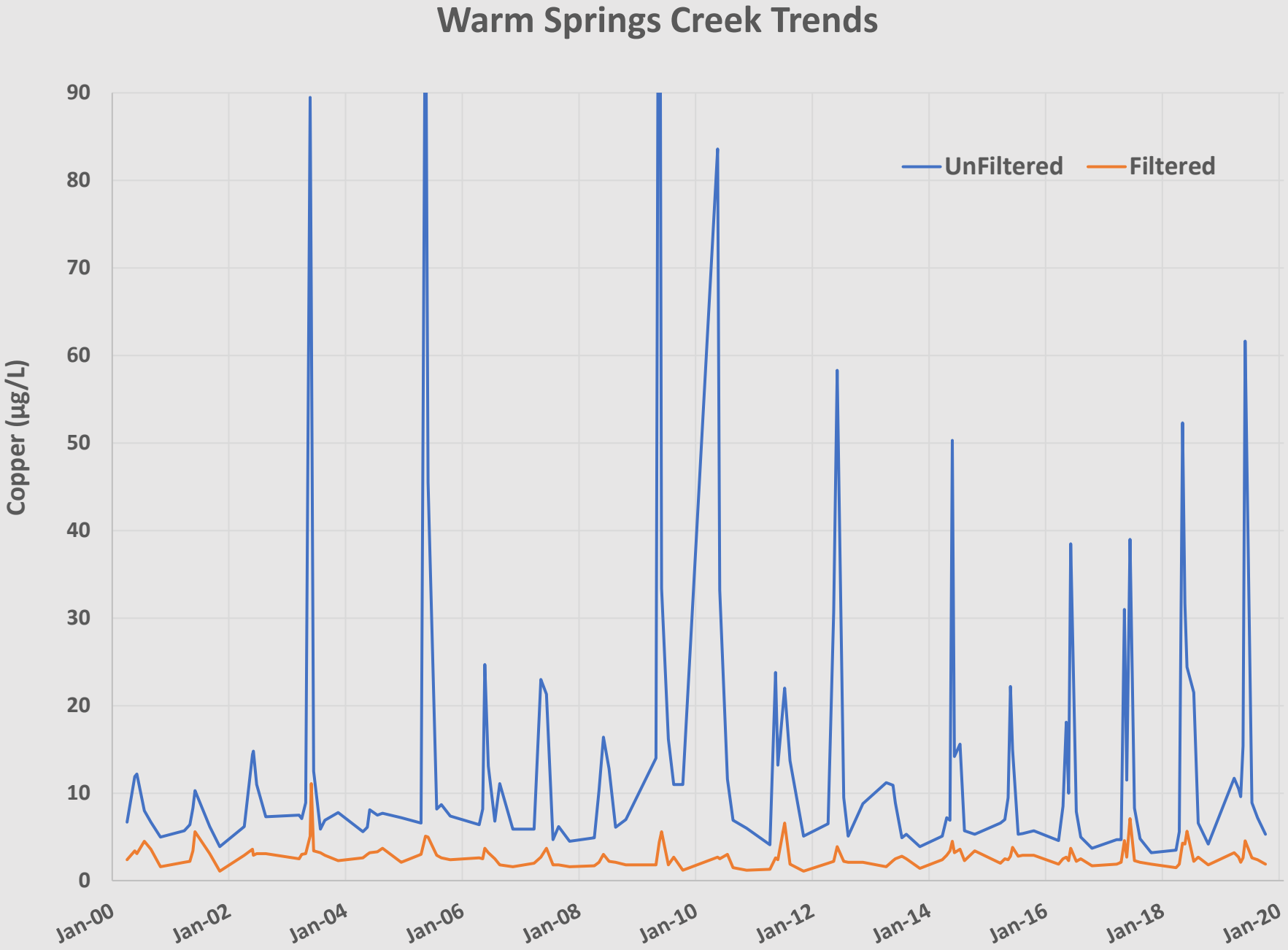
WARM SPRINGS CREEK

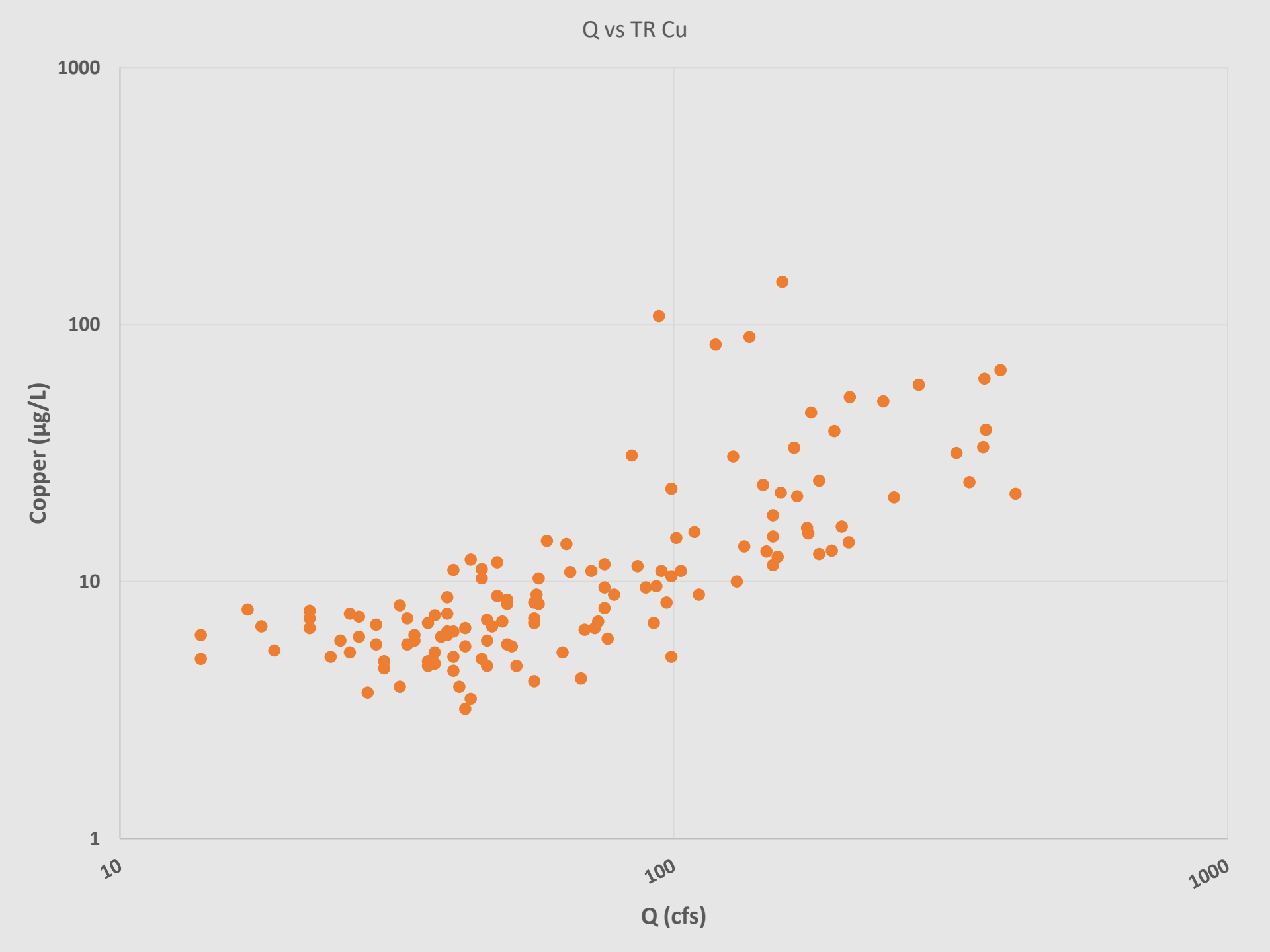
Site	Season	Unfiltered Filtered	Copper LC_{50} (µg/L) Site water	Lab water	WER
WSC	Winter	UF	277.7	145.1	1.914
		F	255.5	119.8	2.133
	Spring	UF	360.3	62.71	5.745
		F	216.6	56.21	3.853
	Summer/ Fall	UF	233.7	121.3	1.927
		F	176.1	99.28	1.774

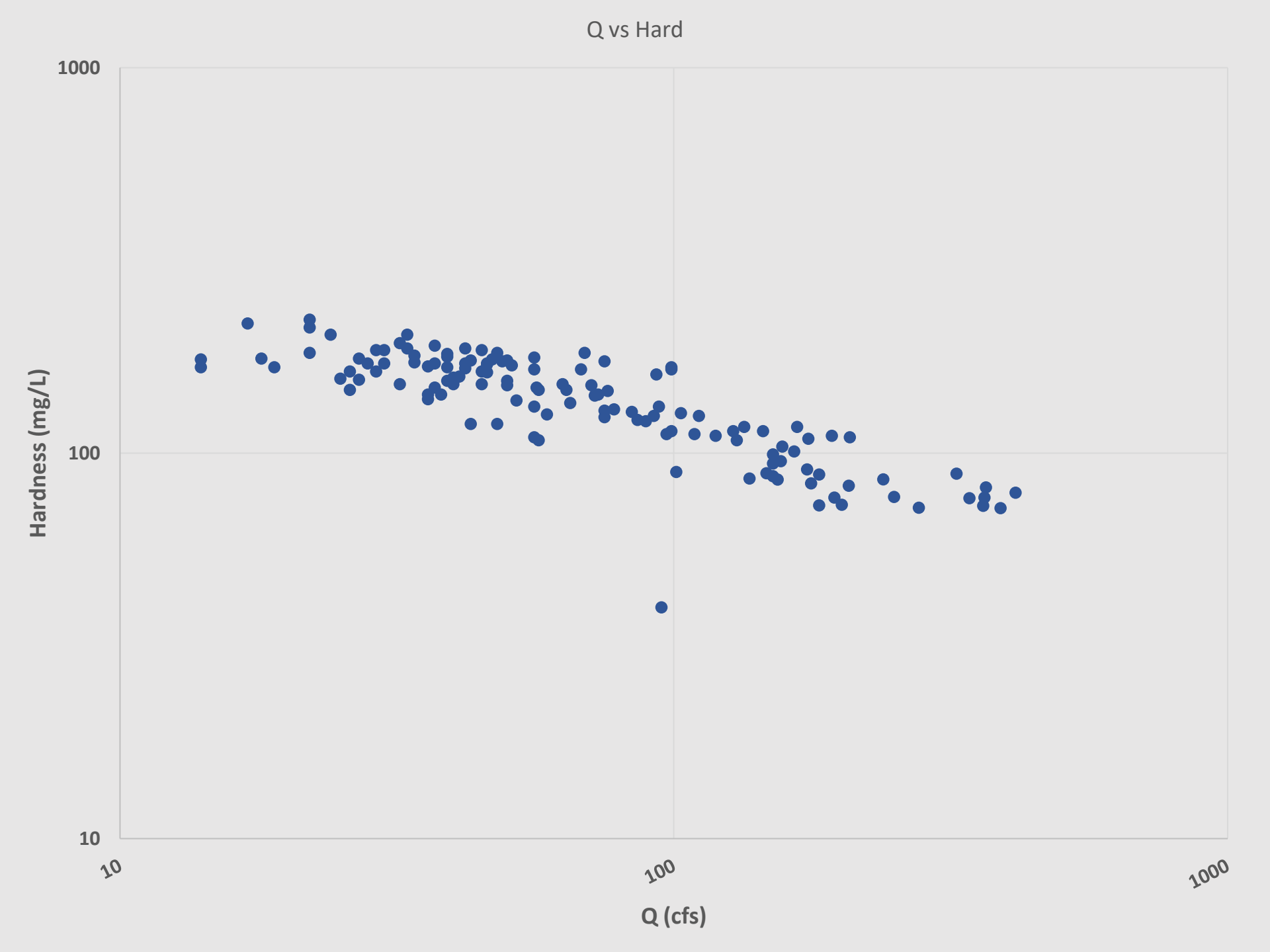
WARM SPRINGS CREEK

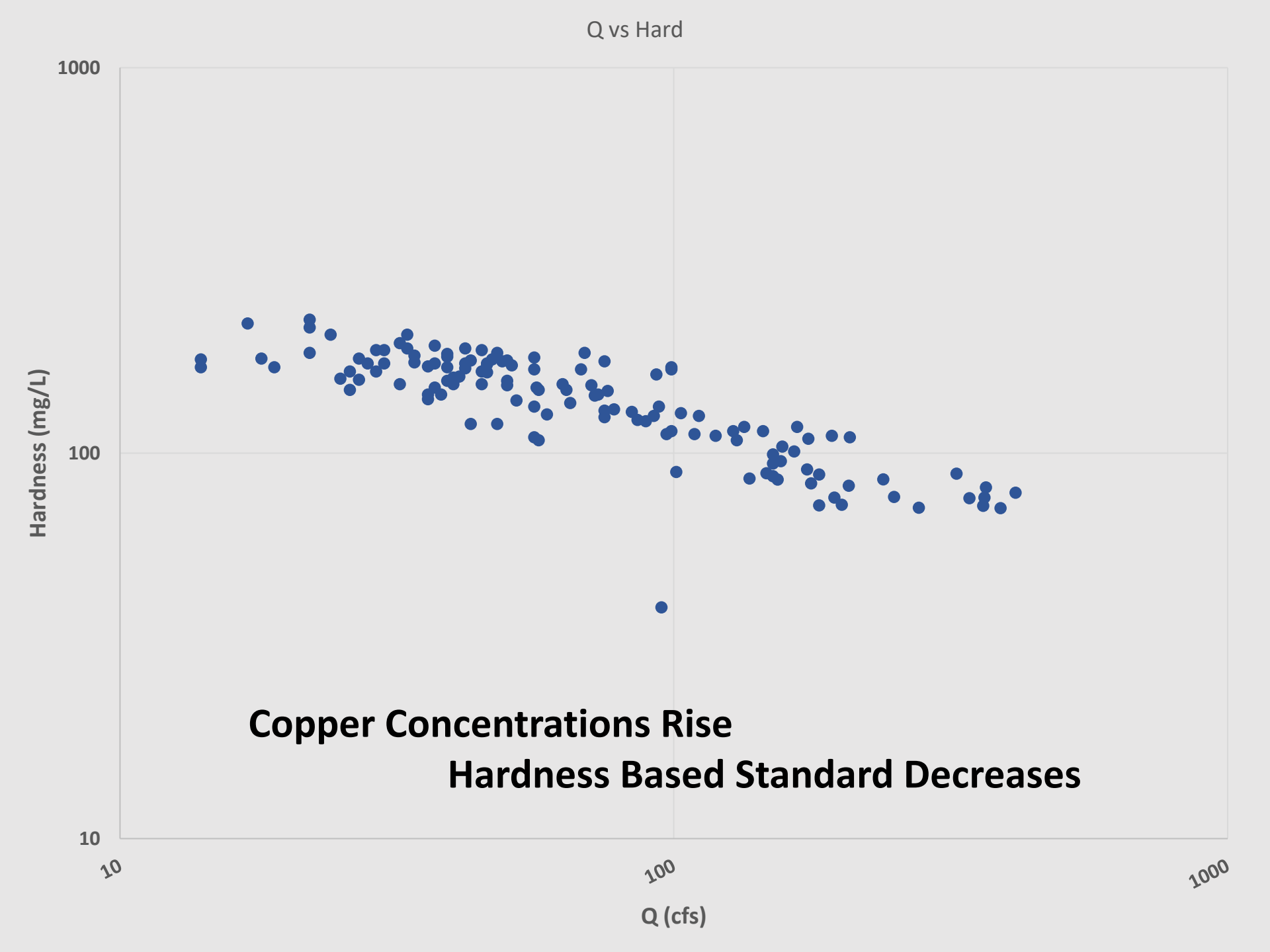
Site	Season	Unfiltered Filtered	Copper LC_{50} (µg/L) Site water	Lab water	WER
WSC	Winter	UF	277.7	145.1	1.914
		F	255.5	119.8	2.133
	Spring	UF	360.3	62.71	5.745
		F	216.6	56.21	3.853
	Summer/ Fall	UF	233.7	121.3	1.927
		F	176.1	99.28	1.774

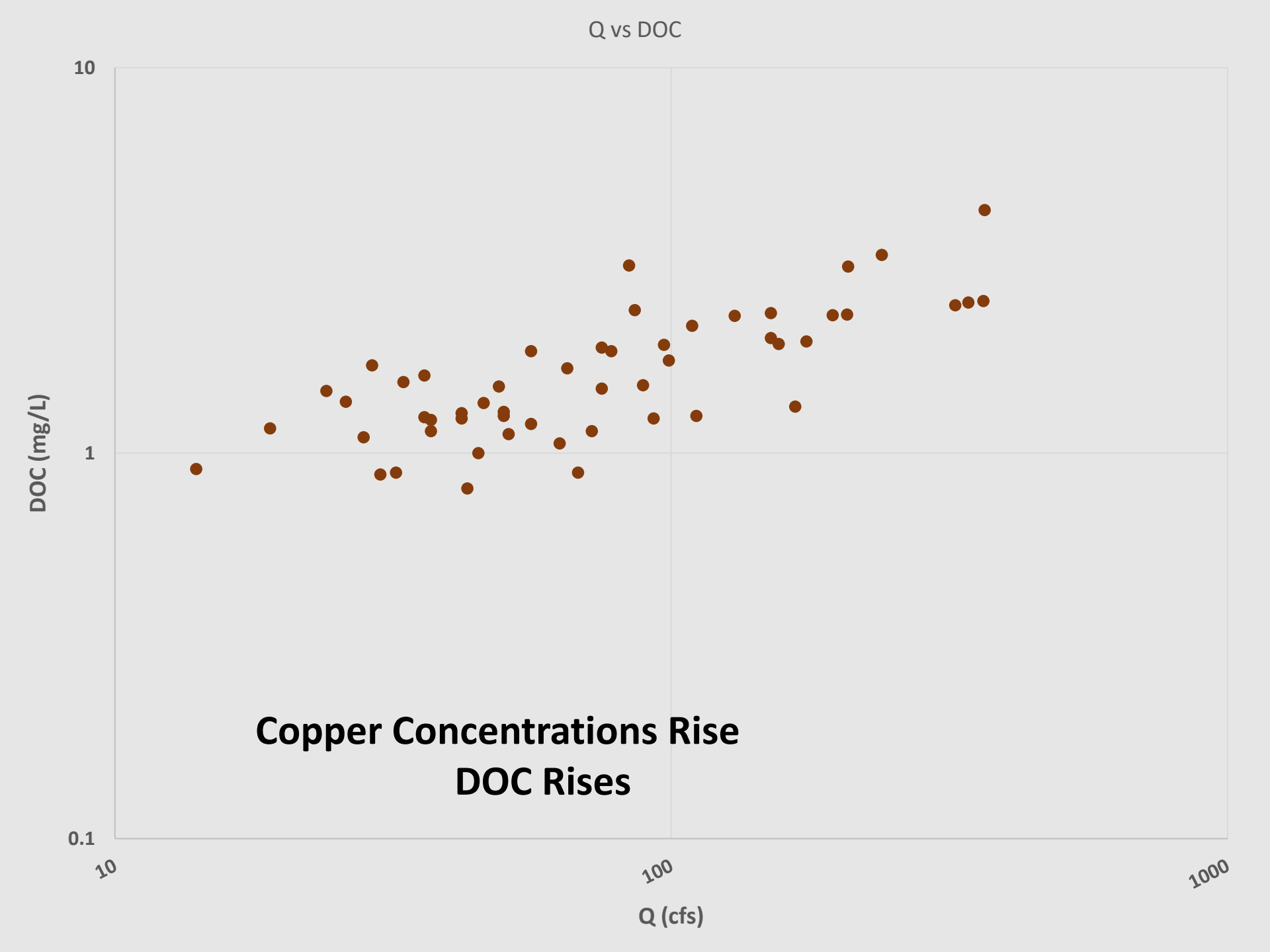
LETS LOOK AT SOME TRENDS


Warm Springs Creek Trends
Copper (µg/L)
90
80
70
60
50
40
30
20
10
0
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20
UnFiltered
Filtered

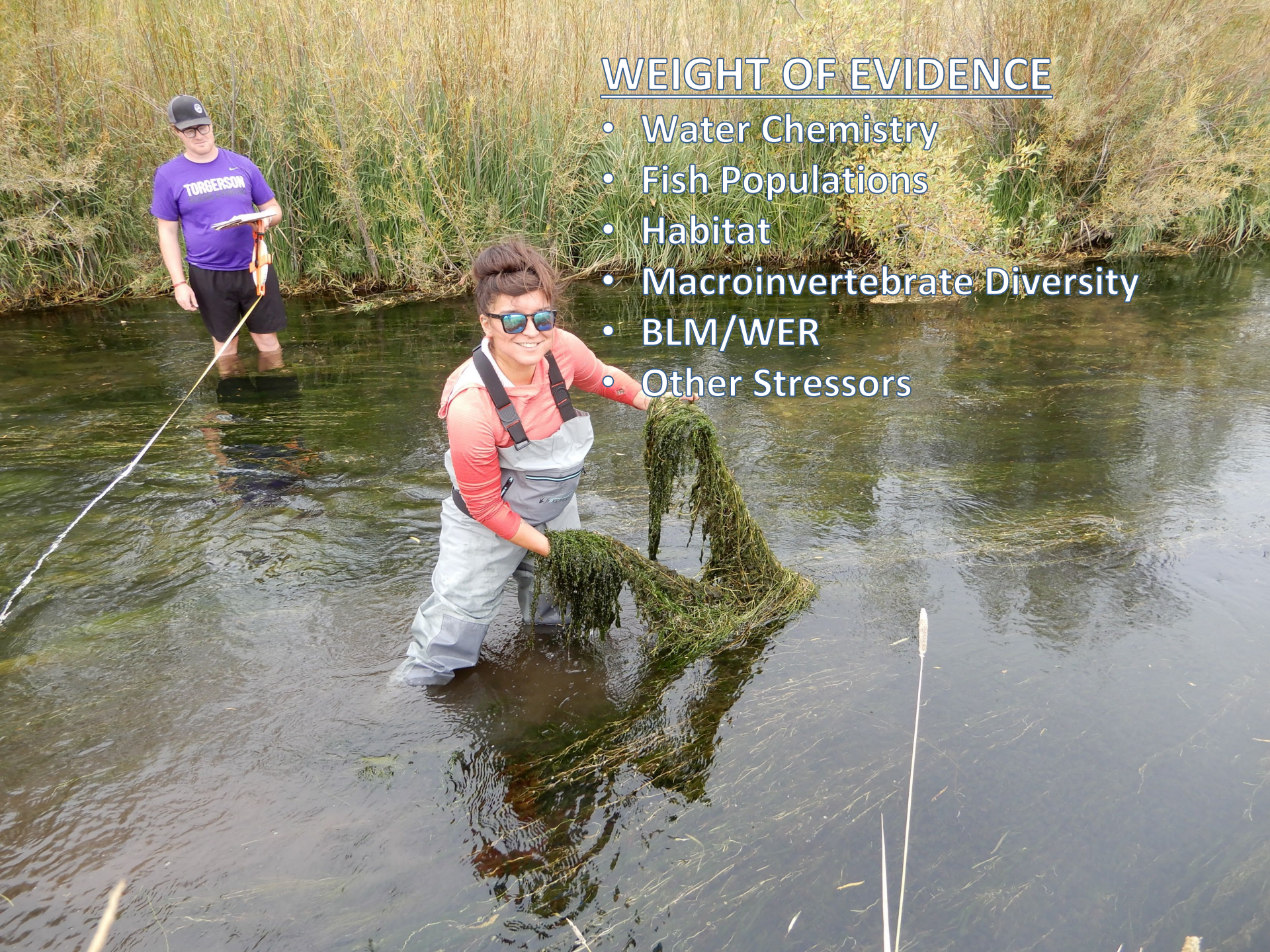

Q vs TR Cu
1000
100
10
1
Copper (µg/L)
10
100
1000
Q (cfs)


Q vs Hard
1000
100
10
Hardness (mg/L)
10
100
1000
Q (cfs)


Q vs Hard
1000
100
10
Hardness (mg/L)
10
100
1000
Q (cfs)
Copper Concentrations Rise
Hardness Based Standard Decreases


Q vs DOC
10
1
0.1
DOC (mg/L)
10
100
1000
Q (cfs)
Copper Concentrations Rise
DOC Rises

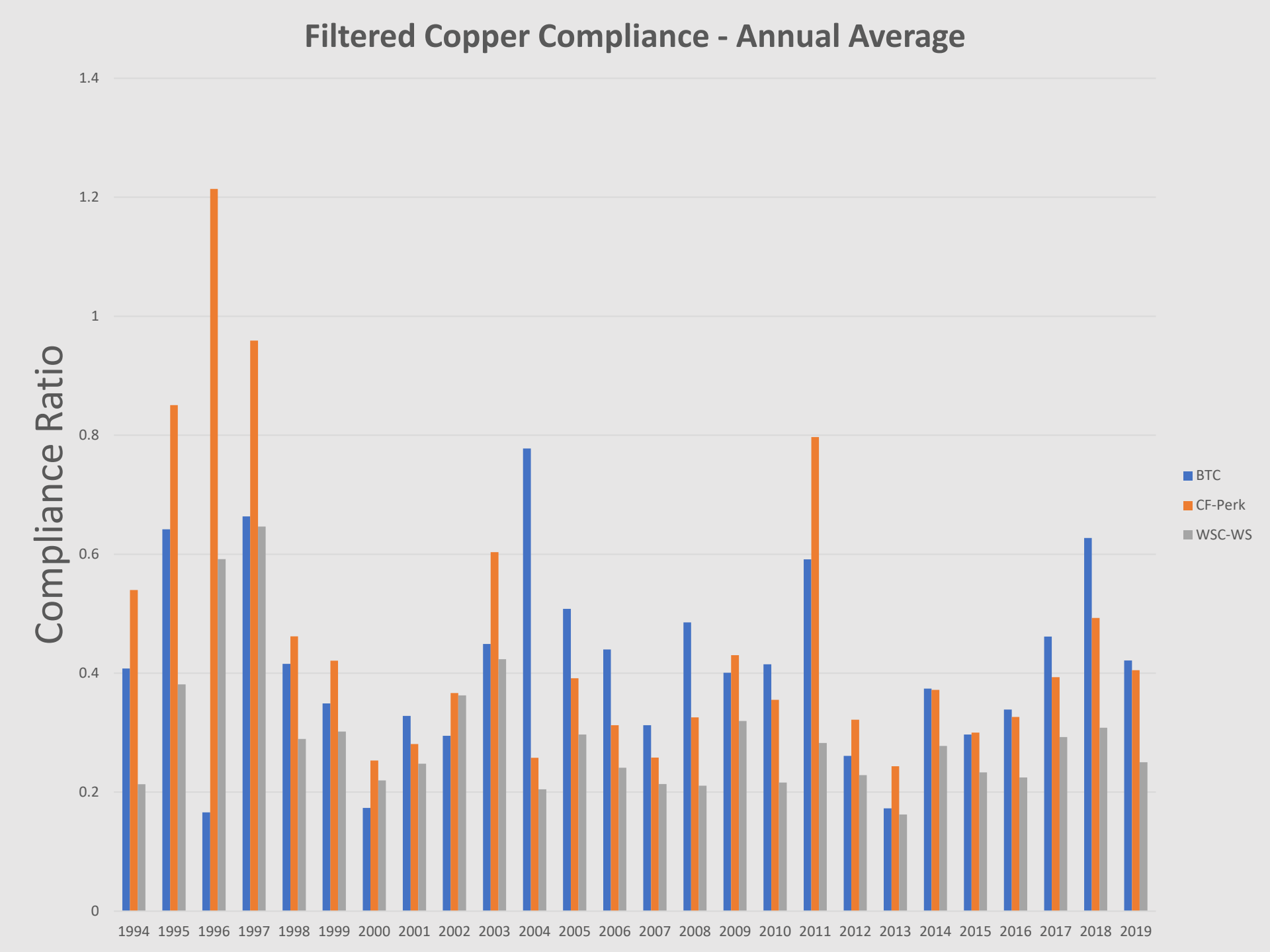
Does BLM Better Describe Copper Toxicity in Warm Springs Creek?

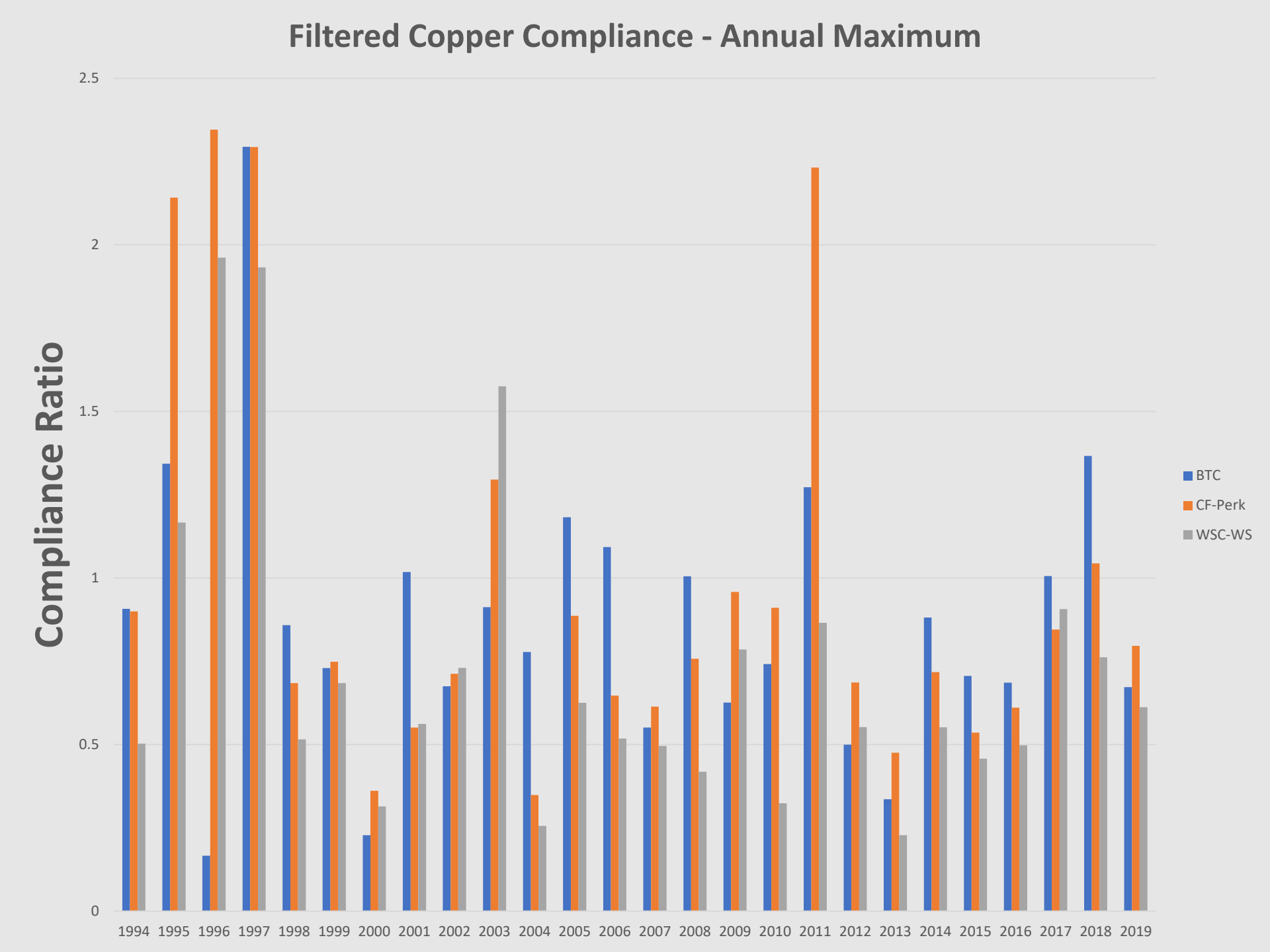


WEIGHT OF EVIDENCE

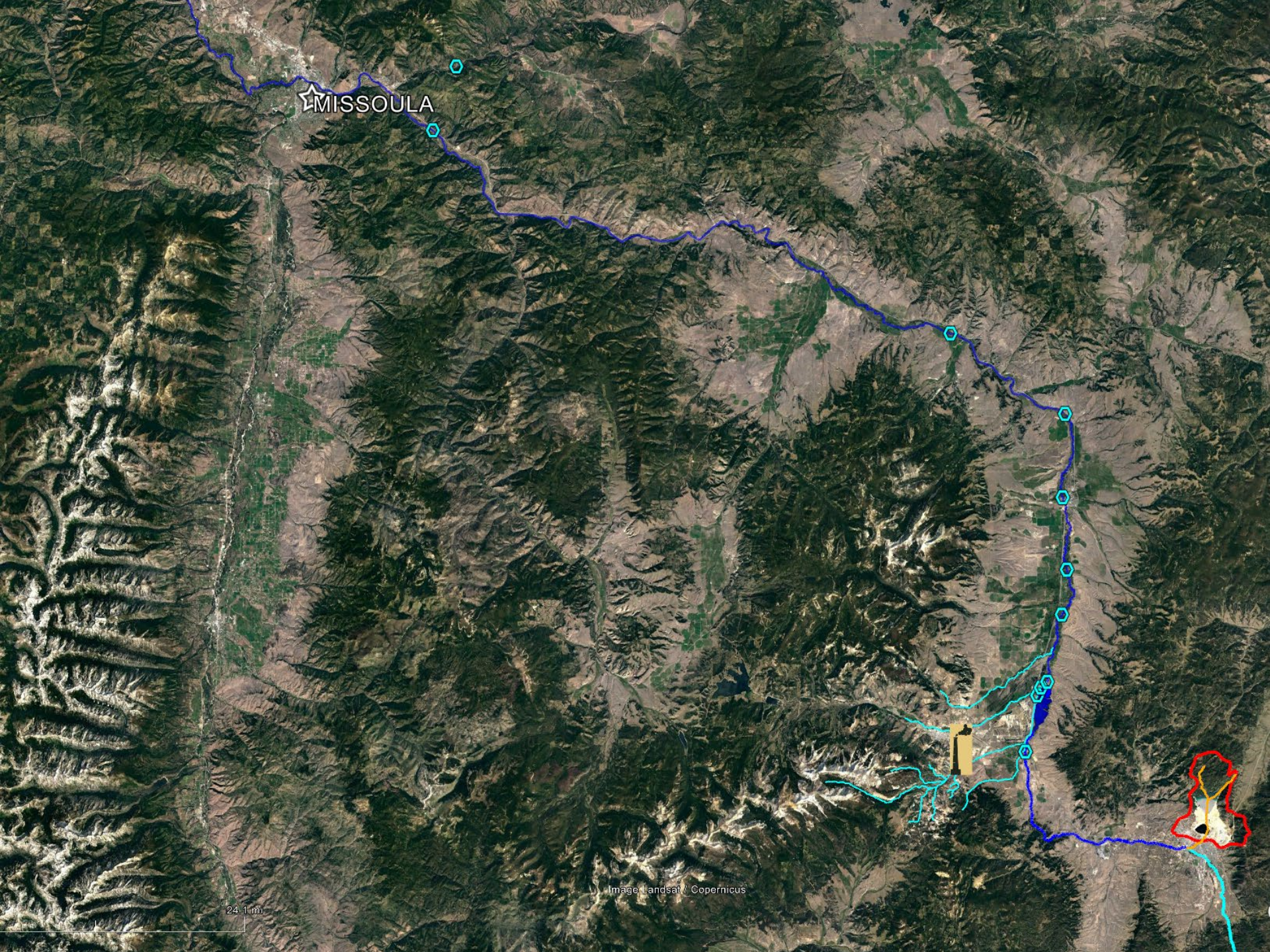
- Water Chemistry
- Fish Populations
- Habitat
- Macroinvertebrate Diversity
- BLM/WER
- Other Stressors


QUESTIONS?
TORGERSON

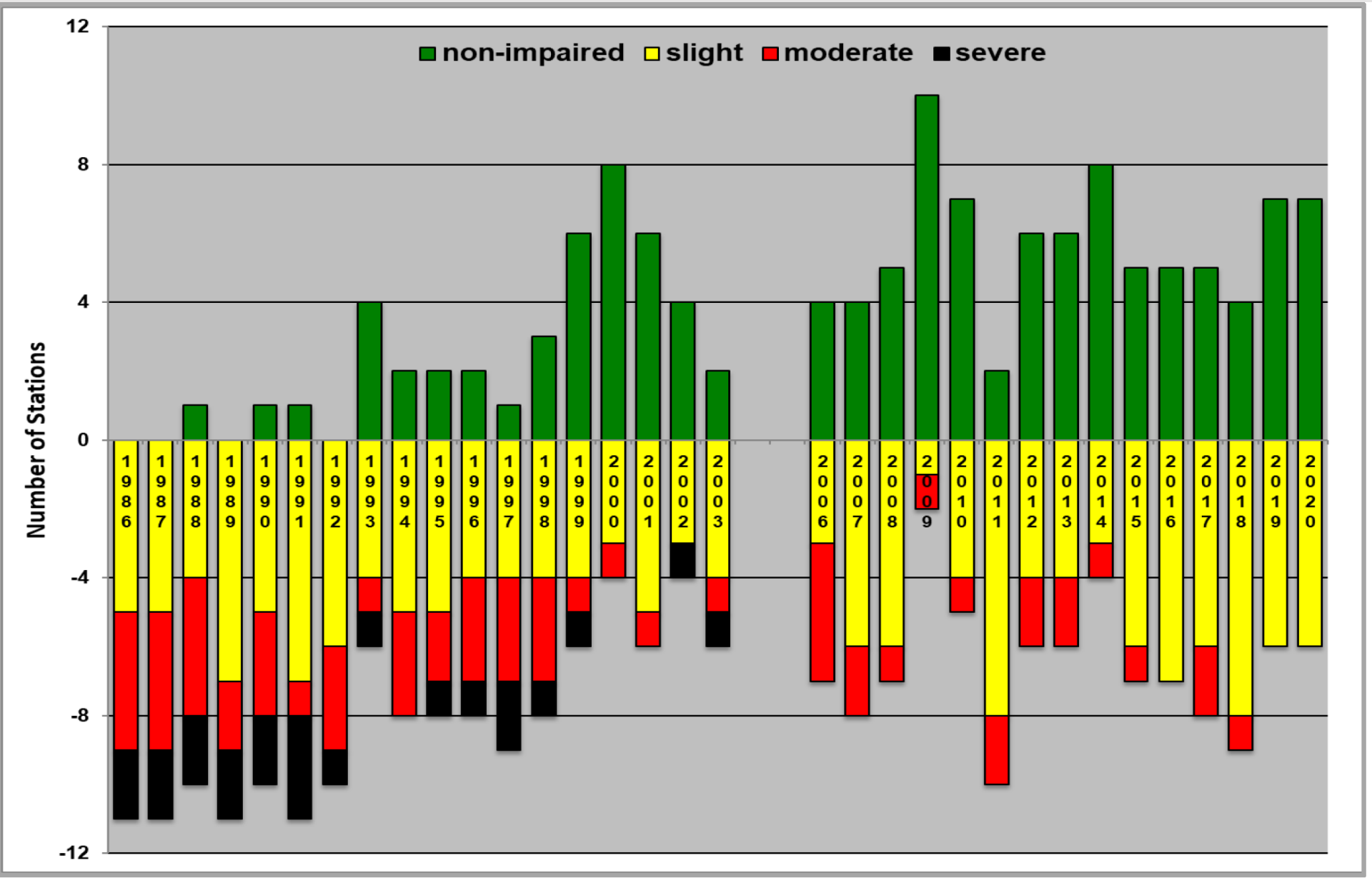

Filtered Copper Compliance - Annual Average
Compliance Ratio
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
BTC
CF-Perk
WSC-WS

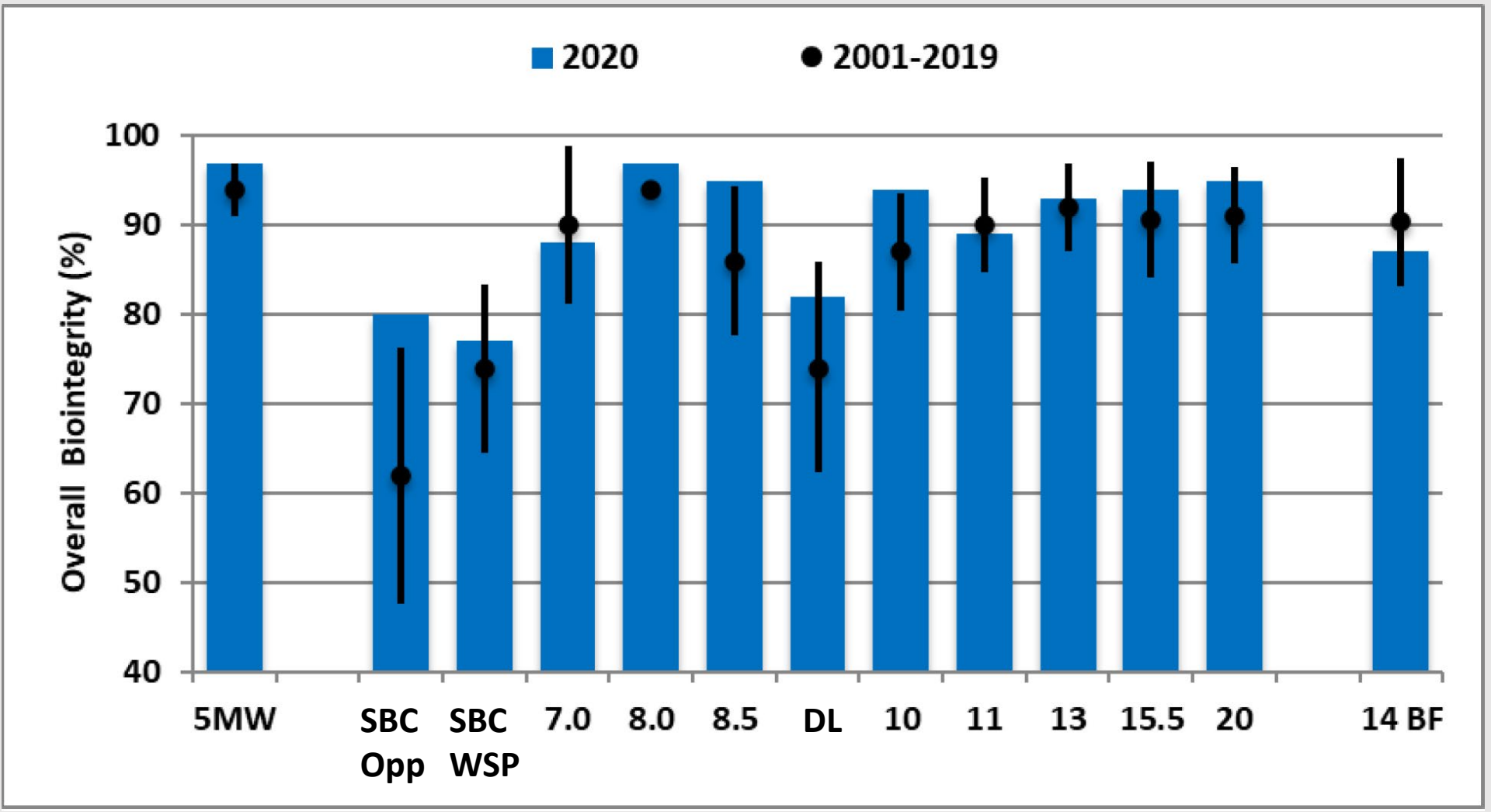

Filtered Copper Compliance - Annual Maximum
Compliance Ratio
2.5
2
1.5
1
0.5
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
BTC
CF-Perk
WSC-WS

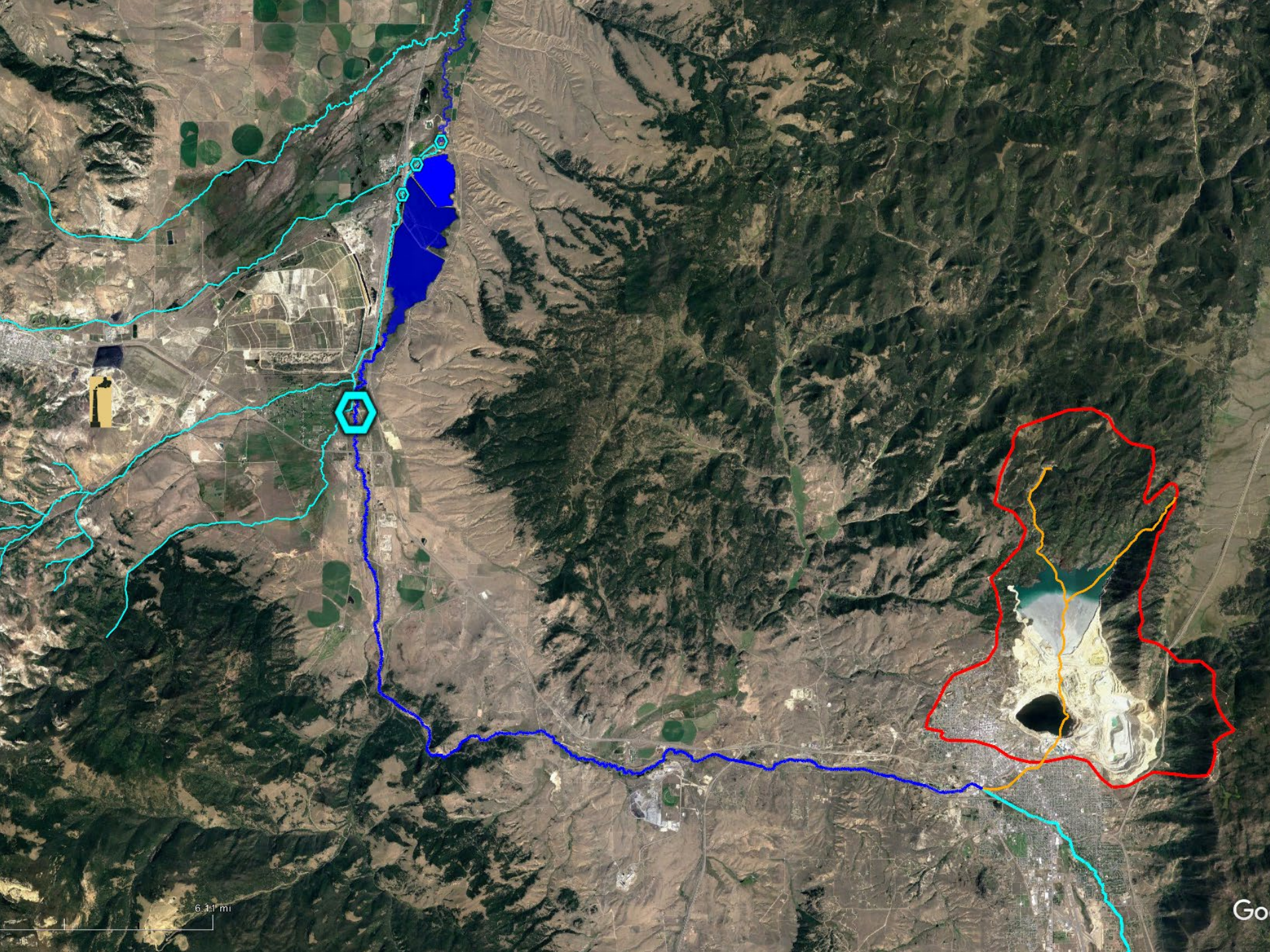
NOT FISH BUT MACROINVERTEBRATES – 1986 to Present

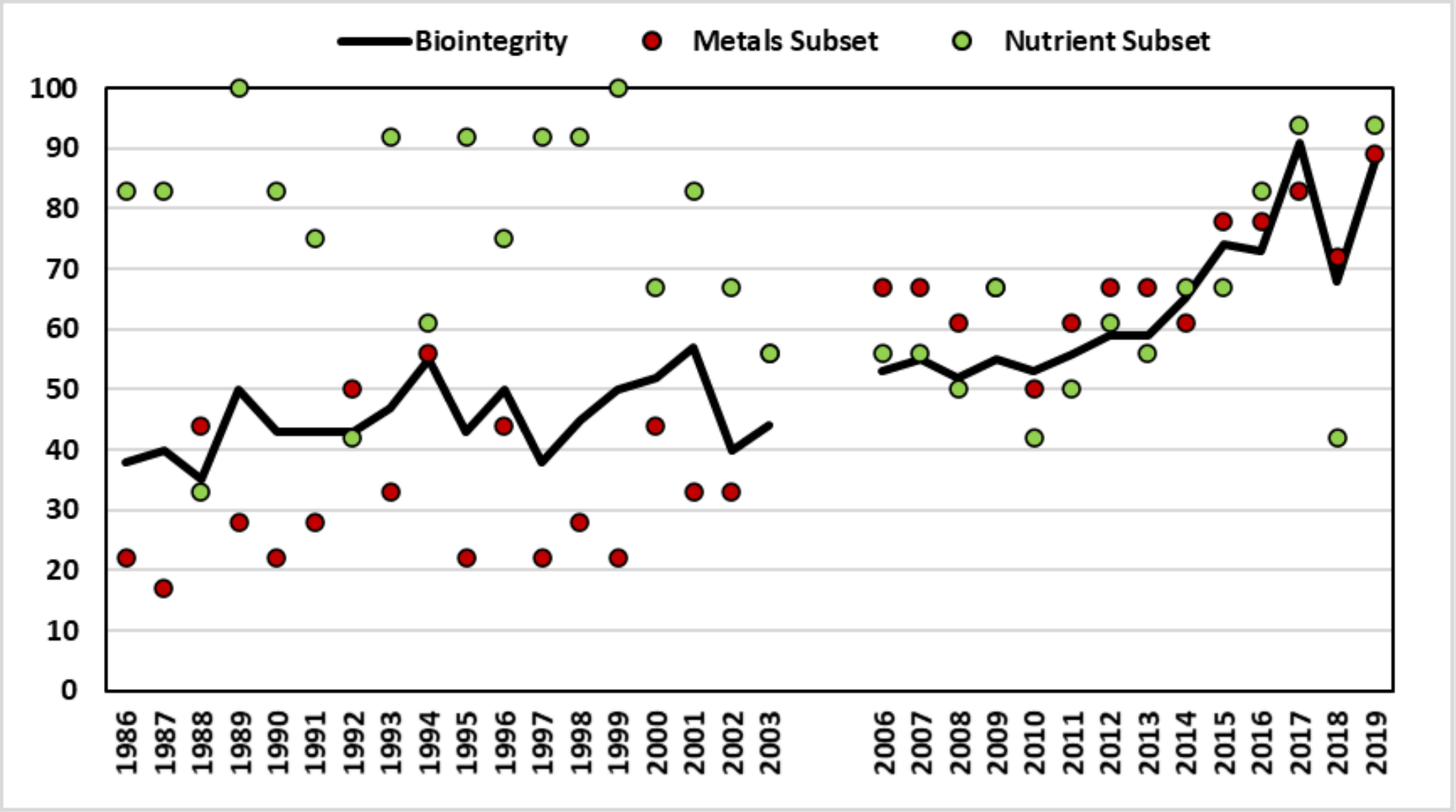

MISSOULA
Image Landsat / Copernicus
24.1 mi

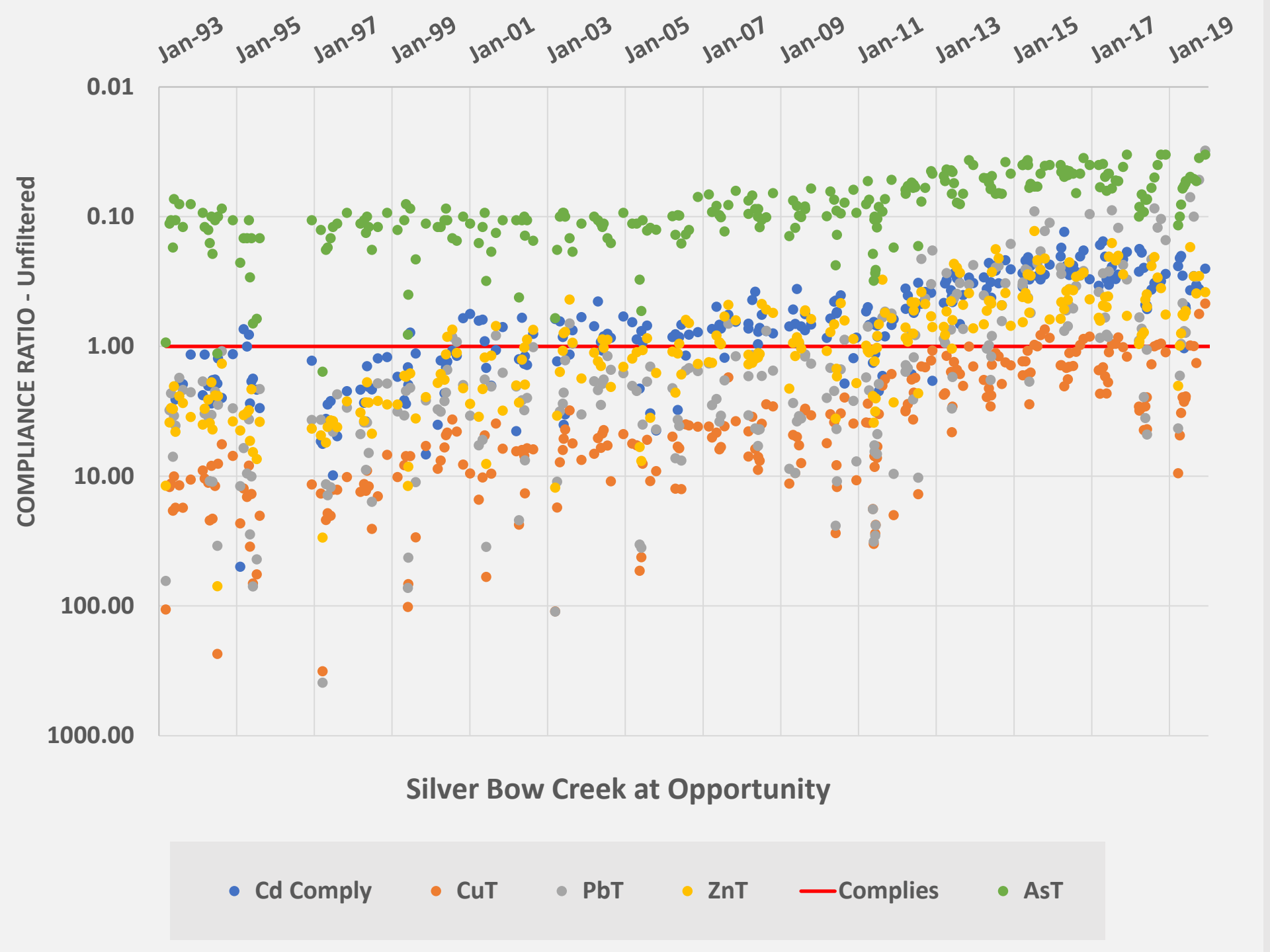
13 Stations From Silver Bow Creek to the Clark Fork below Missoula




2020
2001-2019
Overall Biointegrity (%)
100
90
80
70
60
50
40
5MW
SBC Opp
SBC WSP
7.0
8.0
8.5
DL
10
11
13
15.5
20
14 BF


6.11 mi


Biointegrity
Metals Subset
Nutrient Subset
100
90
80
70
60
50
40
30
20
10
0
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019


Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
0.01
0.10
1.00
10.00
100.00
1000.00
COMPLIANCE RATIO - Unfiltered
Silver Bow Creek at Opportunity
Cd Comply
CuT
PbT
ZnT
Complies
AsT

ABSTRACT

40 Years of Water Quality and Biological Monitoring at the Confluence of the Clark Fork Superfund Complex - The Case for Weight of Evidence Analysis

The upper Clark Fork Superfund Complex is comprised of three gargantuan sites, Silver Bow Creek/Butte Area, Anaconda Smelter and Mill Town Reservoir/Clark Fork River. The Complex is commonly referred to as "the largest in the nation." Major cleanup work in the watershed began in the early 1990s and will continue for at least another decade.

Under Superfund authority and law, the measure of success in that massive cleanup of mining damages to the Clark Fork and its five tributaries is meeting Montana's strict water quality standards based on a total recoverable (unfiltered) fraction. There is an enormous body of water quality data, extending from the early 1990s to the present, that answers the question "where are we now" by that measure of success.

In this presentation, I suggest it is time to recognize the limitations imposed by strict adherence to those standards and turn to a weight-of-evidence and reference-reach approach that also integrates 40 years of biological monitoring with water chemistry data for a more pragmatic and useful measure of success.

SOURCES:

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Under construction

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C:\Users\jgrif\OneDrive\Projects\CF-SBC\SW Analysis\WSC Cu Pb Trends Oct 2023.xlsx