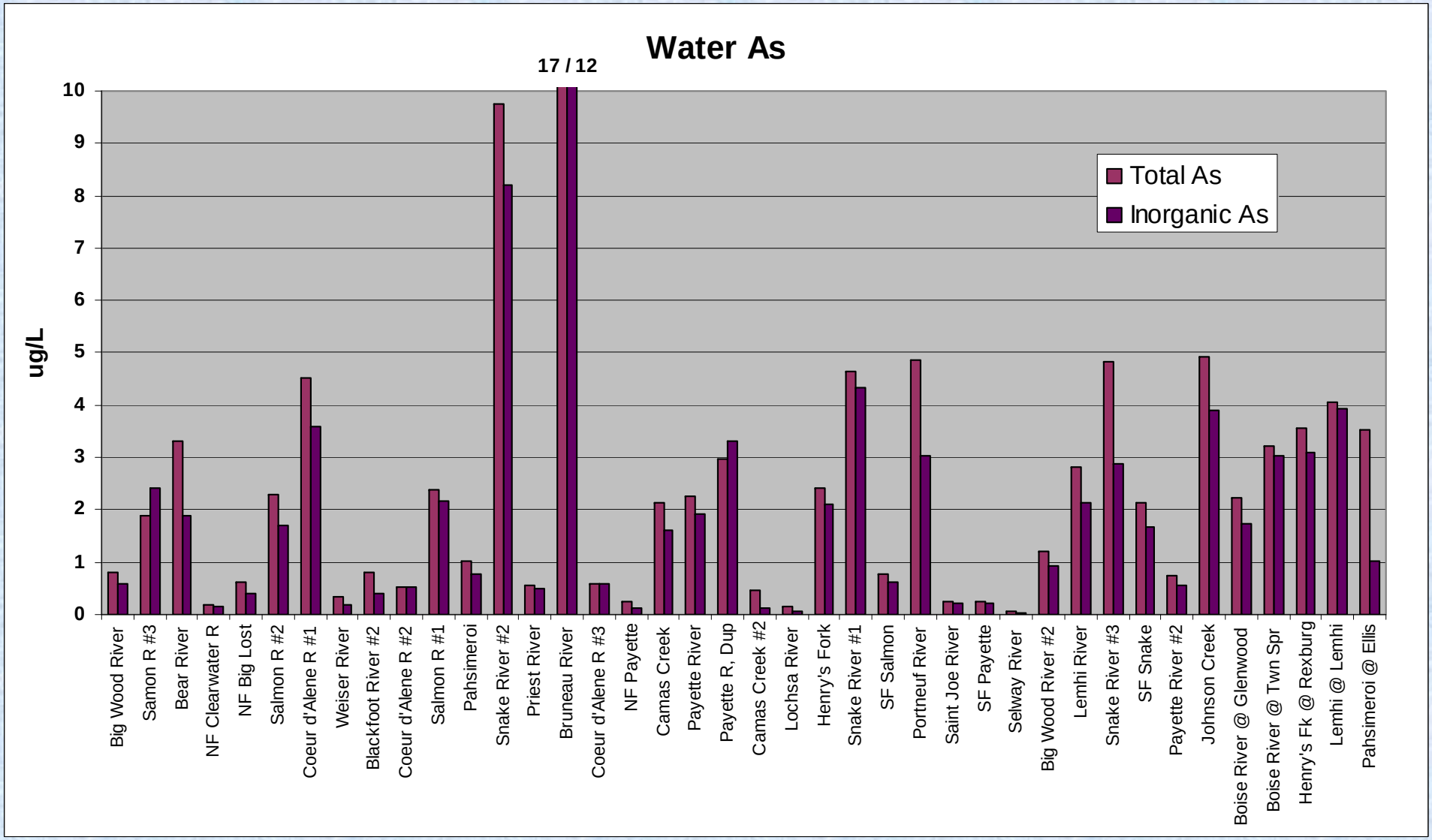
Appendix A

2008 Arsenic in Water from 40 Large River Sites



Appendix B

Location of Targeted Surface Water and Probabilistic Fish Tissue Monitoring Stations

Table B-1 presents the identification number, drainage basin, and waterbody of each of the 40 targeted surface water monitoring stations. Figure B-1 shows the 40 stations on a map. Table B-2 presents the identification number and waterbody of each of the 24 probabilistic fish tissue sampling locations. Figure B-2 shows the 24 locations on a map.

Table B-1
Location information for targeted surface water monitoring stations.

Sample Location ID	Stream/River ID	Basin Name	Nearby Municipalities	Longitude	Latitude
AST001	Kootenai River	Panhandle	Bonners Ferry	-116.312039	48.699232
AST002	SF Coeur d'Alene River	Panhandle	Pinehurst, Kellogg, Osburn, Wallace	-115.785178	47.468986
AST003	Priest River	Panhandle	Priest River, Newport	-116.872210	48.284265
AST004	NF Coeur d'Alene River	Panhandle	Coeur d'Alene, Dalton Gardens, Hayden, Post Falls	-116.253050	47.569764
AST005	St. Maries River	Panhandle	Santa, Fernwood, St. Maries	-116.393277	47.105580
AST006	Palouse River	Clearwater	Harvard, Potlatch	-116.740897	46.915199
AST007	Potlatch River	Clearwater	Bovill, Deary, Kendrick, Juliaetta	-116.399840	46.857178
AST008	Paradise Creek	Clearwater	Moscow, Troy, Genesee	-116.962972	46.748297
AST009	Snake River	Salmon	Lewiston	-117.040041	46.395370
AST010	MF Clearwater River	Clearwater	Kooskia, Kamiah	-115.979384	46.146504
AST011	Threemile Creek	Clearwater	Grangeville, Winchester, Craigmont, Cottonwood	-116.117289	45.930786
AST012	NF Payette River	Southwest	McCall	-116.118594	44.912159
AST013	Little Salmon River	Salmon	New Meadows	-116.295267	44.973071
AST014	Gold Fork River	Southwest	Cascade	-116.052167	44.698826
AST015	Weiser River	Southwest	Council, Cambridge	-116.449595	44.731802
AST016	Mann Creek	Southwest	Weiser	-116.867454	44.241789
AST017	Squaw Creek	Southwest	Emmett, Fruitland, New Plymouth	-116.348164	43.951156
AST018	Deadwood River	Southwest	Garden Valley, Lowman, Horseshoe Bend	-115.659290	44.080173
AST019	MF Boise River	Southwest	Boise	-115.743884	43.649955
AST020	Mores Creek	Southwest	Idaho City, Robie Creek	-115.810086	43.821864
AST021	Bruneau River	Southwest	Bruneau	-115.817776	42.880298
AST022	Big Wood River	Upper Snake	Ketchum, Hailey, Bellevue, Sun Valley	-114.373205	43.687710
AST023	Rock Creek	Upper Snake	Twin Falls, Kimberly, Hansen, Jerome	-114.399756	42.489201
AST024	Salmon River	Salmon	Stanley	-114.886549	44.163196
AST025	Salmon River	Salmon	Salmon, Challis	-113.898119	45.177334
AST026	Snake River	Upper Snake	Burley, Ruperty, Paul, Declo	-113.761888	42.545283
AST027	Portneuf River	Upper Snake	Pocatello, Lava, Inkom, McCammon	-112.012207	42.620393
AST028	Bear River	Bear River	Montpelier, Paris, Grace, Soda Springs	-111.345377	42.308780
AST029	Blackfoot River	Upper Snake	Blackfoot, Pocatello, Shelley, Fort Hall	-112.359577	43.176103
AST030	Bitch Creek	Upper Snake	Rexburg, Driggs, Victor, Tetonia	-111.178947	43.939383
AST031	Henrys Fork	Upper Snake	Ashton, Island Part, St. Anthony	-111.446944	44.111396
AST032	Big Lost River	Upper Snake	Mackay, Arco, Carey	-113.617192	43.903079
AST033	EF Salmon River	Salmon	Challis, Stanley	-114.325582	44.267479
AST034	NF Clearwater River	Clearwater	Orofino, Pierce, Weippe	-116.321485	46.503872
AST035	Snake River	Upper Snake	Idaho Falls, Rigby, Ammon, Shelley, Menan	-112.067627	43.626237
AST036	Camas Creek	Upper Snake	Dubois, Mud Lake	-112.214341	44.014972
AST037	Boise River	Southwest	Boise, Eagle, Meridian, Star, Caldwell	-116.132432	43.565392
AST038	Salmon River	Salmon	Riggins	-116.311452	45.445100
AST039	Snake River	Southwest	Weiser, Payette	-116.981846	44.244351
AST040	Snake River	Southwest	Grand View, Glenns Ferry, Hagerman, Buhl, Bliss	-115.536420	42.943647

Figure B-1

Map of targeted surface water monitoring stations

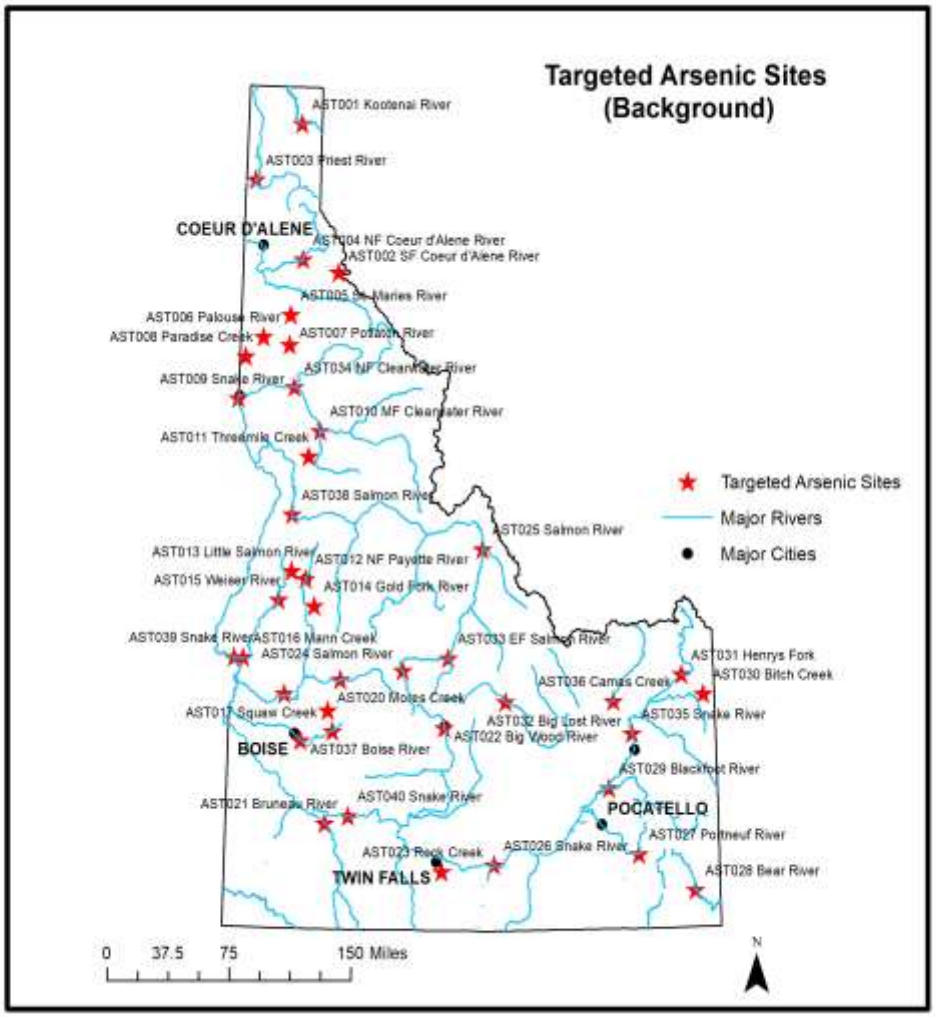
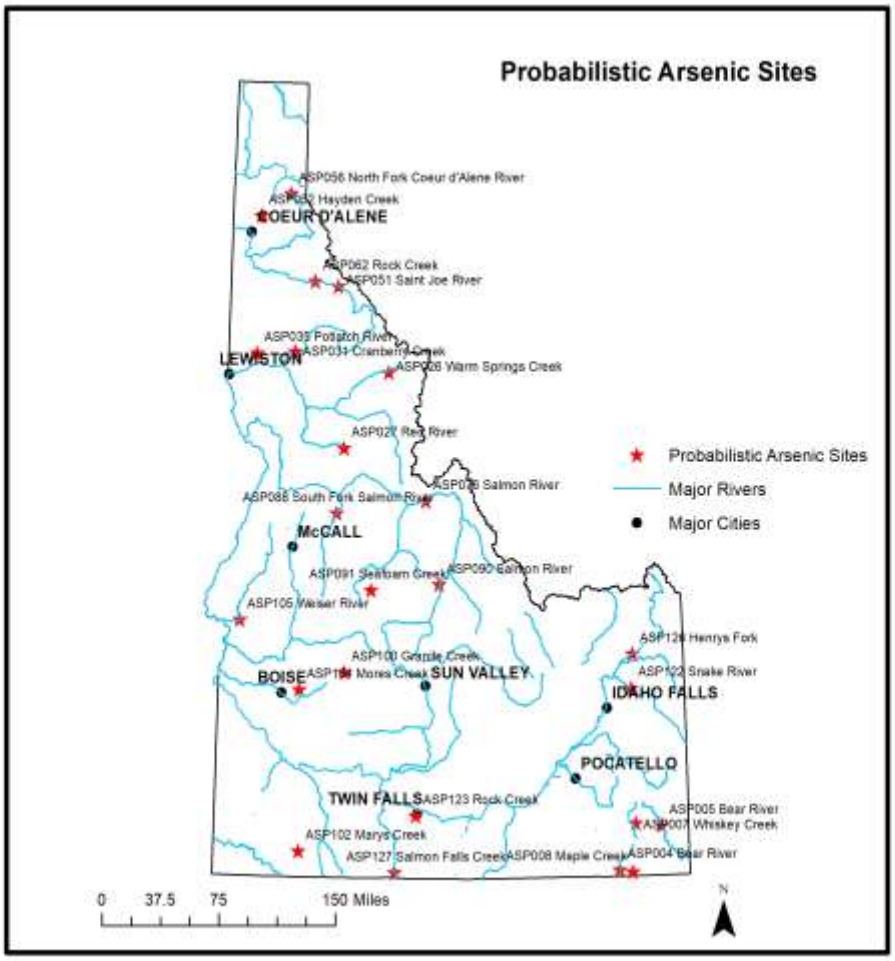


Table B-2.
Location information for probabilistic fish tissue sampling locations.

Sample Location ID	Stream/River ID	Longitude	Latitude
ASP004	Bear River	-111.919	42.058
ASP005	Bear River	-111.381	42.438
ASP007	Whiskey Creek	-111.709	42.465
ASP008	Maple Creek	-111.759	42.035
ASP026	Warm Springs Creek	-114.876	46.466
ASP027	Red River	-115.456	45.792
ASP031	Cranberry Creek	-116.14	46.635
ASP035	Potlatch River	-116.655	46.612
ASP051	Saint Joe River	-115.575	47.219
ASP052	Hayden Creek	-116.654	47.823
ASP056	North Fork Coeur d'Alene River	-116.252	48.026
ASP062	Rock Creek	-115.891	47.259
ASP076	Salmon River	-114.366	45.331
ASP088	South Fork Salmon River	-115.545	45.215
ASP090	Salmon River	-114.189	44.595
ASP091	Seafoam Creek	-115.078	44.542
ASP100	Granite Creek	-115.404	43.813
ASP102	Marys Creek	-115.949	42.227
ASP104	Mores Creek	-115.981	43.651
ASP105	Weiser River	-116.773	44.255
ASP122	Snake River	-111.723	43.661
ASP123	Rock Creek	-114.479	42.551
ASP126	Henrys Fork	-111.694	43.962
ASP127	Salmon Falls Creek	-114.741	42.049

Figure B-2.
<u>Map of probabilistic fish tissue sampling locations</u>.



Appendix C

J.R. Simplot Company
Simplot Headquarters
1099 W. Front Street
Boise, Idaho 83702
P.O. Box 27
Boise, Idaho 83707

April 10, 2020

Sent via email to: paula.wilson@deq.idaho.gov
Docket: 58-0102-1801
Human Health Water Quality Criteria for Arsenic

Ms. Paula Wilson
Idaho Department of Environmental Quality
1410 N. Hilton, Boise, ID 83706

Dear Ms. Wilson:

The Department of Environmental Quality (Department) is conducting a negotiated rulemaking to revise the arsenic human health water quality criteria. The J.R. Simplot Company (Simplot) has participated in past meetings on this rulemaking and retained Arcadis U.S. Inc. (Arcadis) to review and analyze technical information that have been gathered during this rulemaking.

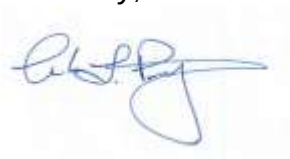
The Department has undertaken a very robust program to characterize arsenic, including inorganic arsenic concentrations, in fish tissues and surface waters. The data gathered by the Department is very important so that the arsenic human health water quality criteria for Idaho reflects Idaho's natural environment.

Arcadis has reviewed the data gathered by the Department. Their analysis of the data is provided in the attached report. As this report shows, the existing data set (which is extensive) indicates that the inorganic arsenic concentration in fish tissue is independent of the total arsenic concentration in surface water. A similar non relationship exists with the inorganic arsenic concentration in surface water. The attached report does provide some thoughts for the Department to consider in the upcoming field system.

As to how this data should be utilized in the development of a "new" human health arsenic water quality criteria, the lack of a definitive relationship suggests that the ingestion of just water (no ingestion of fish tissues) might be the best technical approach to establish a human health arsenic water quality criteria.

We appreciate the ability to provide this analysis and input to the Department. Please contact me at (208) 780-7365 or the Arcadis staff if you have any questions.

Sincerely,



Alan L. Prouty
Vice President, Environmental & Regulatory Affairs

Attachment

P. Anderson	Arcadis
A. LaBeau	IACI
B. Davenport	IMA
B. Adams	NAMC

TECHNICAL MEMO

Arcadis U.S., Inc.
1 Executive Drive
Suite 303
Chelmsford
Massachusetts 01824
Tel 978 937 9999

To:

Alan Prouty
J.R. Simplot Company

Copies:

None

From:

Paul Anderson
Emily Morrison

Date:

April 10, 2020

Arcadis Project No.:

30039729

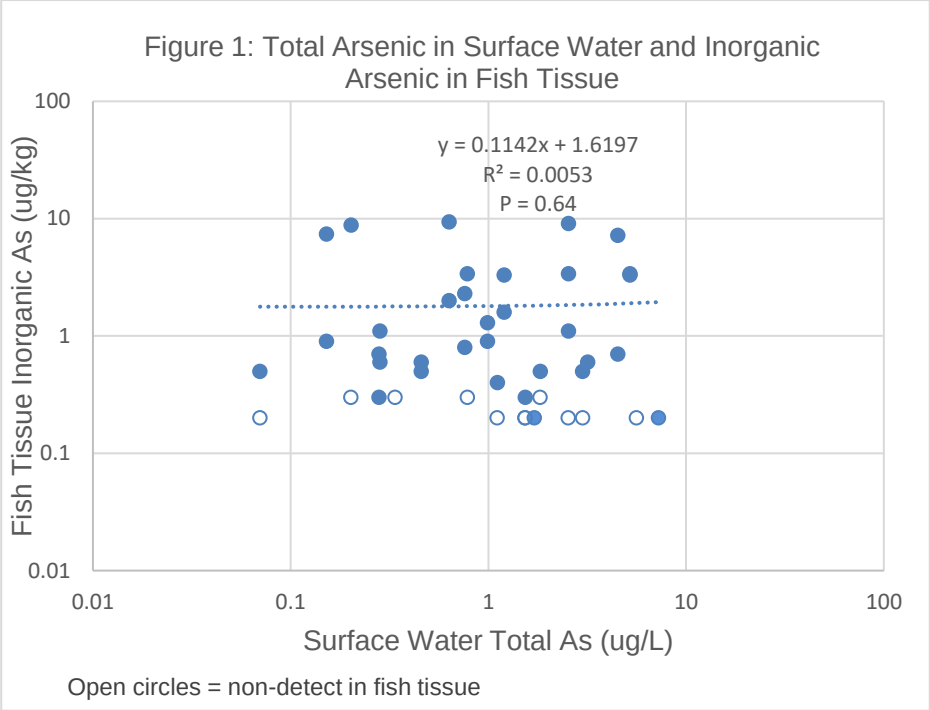
Subject:

IDEQ 2019 Preliminary Monitoring Findings

This technical memorandum provides an initial evaluation of the results of the Idaho Department of Environmental Quality (IDEQ) 2019 arsenic paired fish tissue and surface water sampling program summarized in 2019 Arsenic Accumulation in Fish Tissue Preliminary Monitoring Results dated March 2020 (IDEQ 2020) and how the results might be used to establish a bioaccumulation factor (BAF) for arsenic in Idaho surface waters.

IDEQ is to be commended for undertaking a comprehensive state-wide sampling program to better understand the relationship between concentrations of arsenic in surface water and concentrations of arsenic in fish tissue, the results of which can be used to inform development of a BAF for use in establishing water quality criteria (WQC) for arsenic in Idaho waters. The 2019 dataset is exceptionally robust and, to Arcadis' knowledge, represents a one-of-a-kind study given the large number of sampling locations and their geographic coverage. We focused our review on the interpretation of the 2019 results and not the sampling approach and methods as those were consistent with the approach and methods presented and discussed at previous rulemaking meetings.

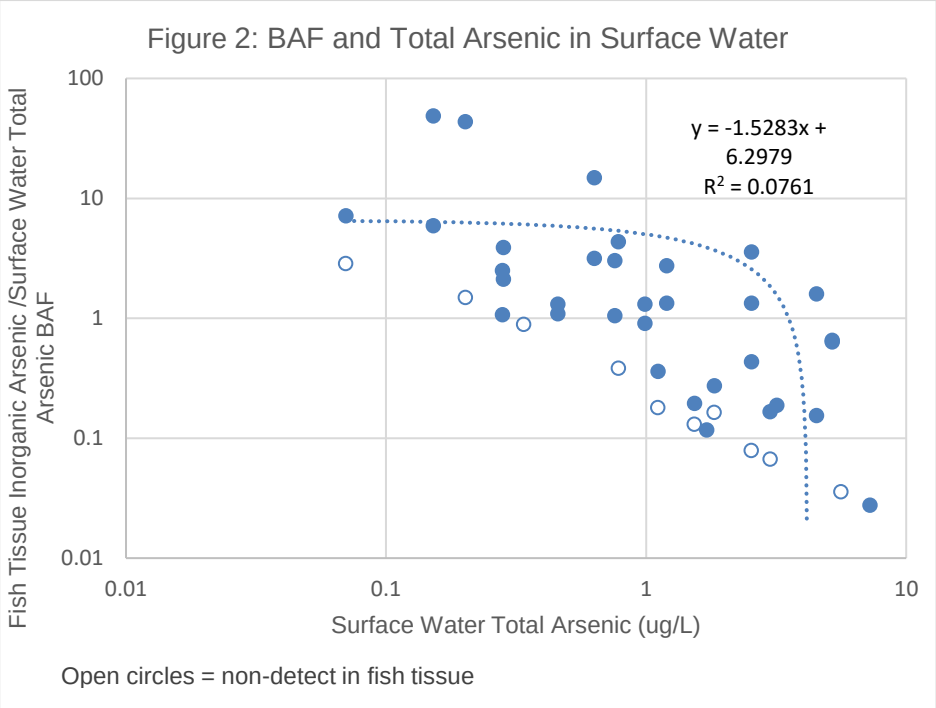
Arcadis' confirmed the key finding presented by IDEQ (2020). Namely that that the concentration of inorganic arsenic (iAs) in fish tissue is not related to the concentration of iAs in surface water. We also confirmed that a relationship does not exist between total arsenic (tAs) in fish tissue and tAs in surface water (results not shown). More importantly, because our understanding is that the state-wide arsenic WQC that IDEQ is developing will be for tAs in surface water, Arcadis evaluated the relationship between iAs in fish tissue (the form of arsenic in fish tissue that is assumed to be toxic) and tAs in surface water. A direct relationship between iAs in fish tissue and tAs in surface water was also absent (Figure 1).



The absence of a direct relationship between the concentration of arsenic in water and fish tissue is a key finding. It indicates that the concept of a single state-wide BAF is not applicable to arsenic in Idaho surface waters. While it is true that a BAF can be calculated for every paired fish tissue and surface water sample (as summarized in Table 3 of IDEQ 2020) the large range of those iAs BAFs from 0.02 to 97 L/kg (nearly 5,000-fold)[1] reinforces that a meaningful relationship between the concentration of arsenic in water and fish tissue is absent.

Additionally, BAFs (calculated as the iAs fish tissue concentration divided by the tAs surface water concentration for each individual paired sample) tend to decrease with increasing surface water concentration (Figure 2) though the relationship is not statistically significant[2]. Such a trend is expected given the lack of a relationship between fish tissue and surface water concentrations; because fish tissue concentrations are essentially identical across the entire range of surface water concentrations, dividing a constant range of tissue concentrations by an increasing surface water concentration results in lower BAFs at higher surface water concentrations. Thus, the existing data set (which is extensive) indicates that the iAs concentration in fish tissue is independent of the tAs concentration in surface water.

[1] Inorganic arsenic in fish tissue to tAs in surface water BAFs range from 0.03 to 49 L/kg, about 1,700-fold (results not shown).
[2] A similar, but not statistically significant, trend of decreasing BAF with increasing iAs concentration in surface water also observed (results not shown).



Arcadis also investigated whether a relationship exists between arsenic in fish tissue and arsenic in water for individual species (Table 1). None of the relationships were statistically significant and no consistent trends were apparent. Tissue concentrations increase with increasing concentrations for some species and decrease for other species. Notably, in trout species, the concentration of iAs in tissue tended to decrease with increasing iAs or tAs concentration in water.

Table 1. Summary of Surface Water to Fish Tissue Regression Results of Individual Species

Species	Sample Size	Regression Equation	R^2	p
Tissue iAs to Water tAs				
Brown Trout	5	iAs(ug/kg) = -0.08(tAs(ug/L)) + 0.65	0.48	0.2
Cutthroat Trout	9	iAs(ug/kg) = -0.01(tAs(ug/L)) + 1.82	0.00	0.99
Northern Pikeminnow	5	iAs(ug/kg) = 0.02(tAs(ug/L)) + 0.39	0.01	0.88
Rainbow Trout	6	iAs(ug/kg) = -0.81(tAs(ug/L)) + 4.59	0.12	0.26
Sculpin sp.	7	iAs(ug/kg) = 0.81(tAs(ug/L)) + 1.62	0.25	0.26
Tissue tAs to Water tAs				
Brown Trout	5	tAs(ug/kg) = 4.97(tAs(ug/L)) + 42.2	0.08	0.64
Cutthroat Trout	9	tAs(ug/kg) = 66.7(tAs(ug/L)) + 47.4	0.28	0.14
Northern Pikeminnow	5	tAs(ug/kg) = 0.66(tAs(ug/L)) + 20.6	0.001	0.96
Rainbow Trout	6	tAs(ug/kg) = 21.3(tAs(ug/L)) + 79.3	0.33	0.23
Sculpin sp.	7	tAs(ug/kg) = 6.81(tAs(ug/L)) + 53.3	0.06	0.59
Tissue iAs to Water iAs				
Brown Trout	5	iAs(ug/kg) = -0.06(iAs(ug/L)) + 0.56	0.31	0.33
Cutthroat Trout	9	iAs(ug/kg) = 0.26(iAs(ug/L)) + 1.63	0.006	0.85
Northern Pikeminnow	5	iAs(ug/kg) = 0.06(iAs(ug/L)) + 0.35	0.06	0.7
Rainbow Trout	6	iAs(ug/kg) = -0.88(iAs(ug/L)) + 4.60	0.13	0.49
Sculpin sp.	7	iAs(ug/kg) = 1.18(iAs(ug/L)) + 1.26	0.36	0.15

Notes:
Non-detects were equal to the detection limit.

As part of collecting fish tissue samples, IDEQ field teams recorded the length and weight of fish comprising each tissue sample. For all species combined there was a very slight, not statistically significant, trend for iAs concentration in fish tissue to decline with increasing weight of fish comprising the sample (Figure 3). This trend was observed in cutthroat trout, rainbow trout, northern pikeminnow and sculpin sp., while an increasing trend was observed in brown trout (Table 2). None of the relationships within individual species were statistically significant.

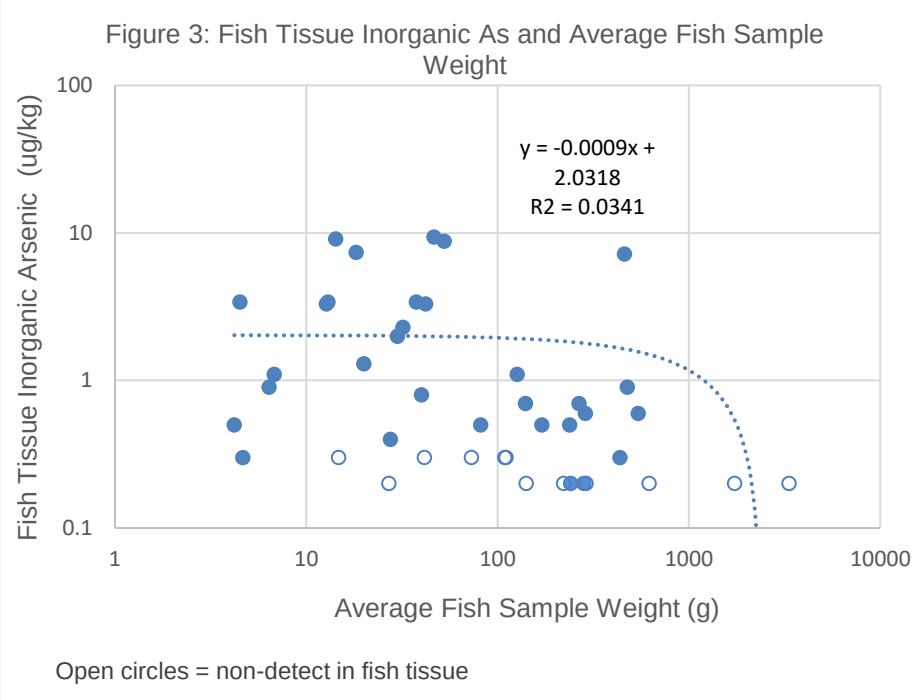


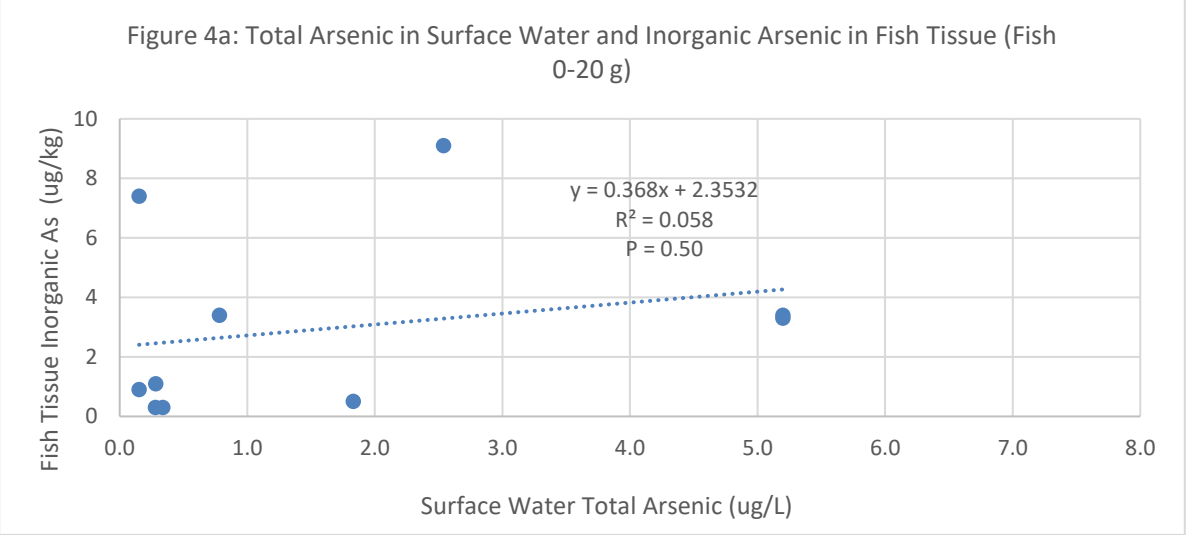
Table 2. Summary of Inorganic Fish Tissue Concentration Regressions by Species

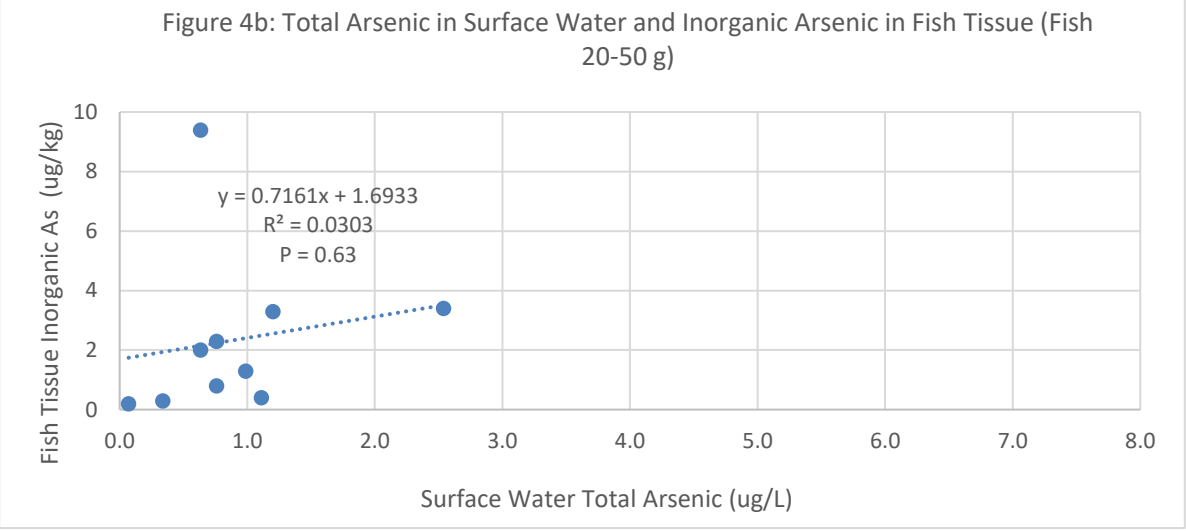
Species	Sample Size	Regression Equation	R^2	p
Brown Trout	5	iAs(ug/kg) = -0.075(tAs(ug/L)) + 0.65	0.48	0.2
Cutthroat Trout	9	iAs(ug/kg) = -0.011(tAs(ug/L)) + 1.82	0.00	0.99
Northern Pikeminnow	5	iAs(ug/kg) = 0.022(tAs(ug/L)) + 0.39	0.008	0.88
Rainbow Trout	6	iAs(ug/kg) = -0.813(tAs(ug/L)) + 4.59	0.12	0.5
Sculpin sp.	7	iAs(ug/kg) = 0.805(tAs(ug/L)) + 1.62	0.24	0.26
All Fish Combined[a]	45	iAs(ug/kg) = 0.039 (tAs(ug/L)) + 1.72	0	0.86

Notes:
Non-detects were equal to the detection limit
[a] Includes species other than those listed in the table

Given that fish move and may be exposed to surface water and habitats beyond the reach from which surface water samples were collected, we evaluated whether a relationship between fish tissue and surface water may be more evident in smaller size classes of fish, under the assumption that smaller fish

may have more limited movement than larger fish. None of the regressions within specific size classes were statistically significant though a trend of increasing iAs concentration in fish tissue with increase tAs concentration in surface water was more apparent in small sized fish (0-20g and 20-50g) than in larger size fish (50-200g, 200-500g and >500g) (Figures 4a-4e).





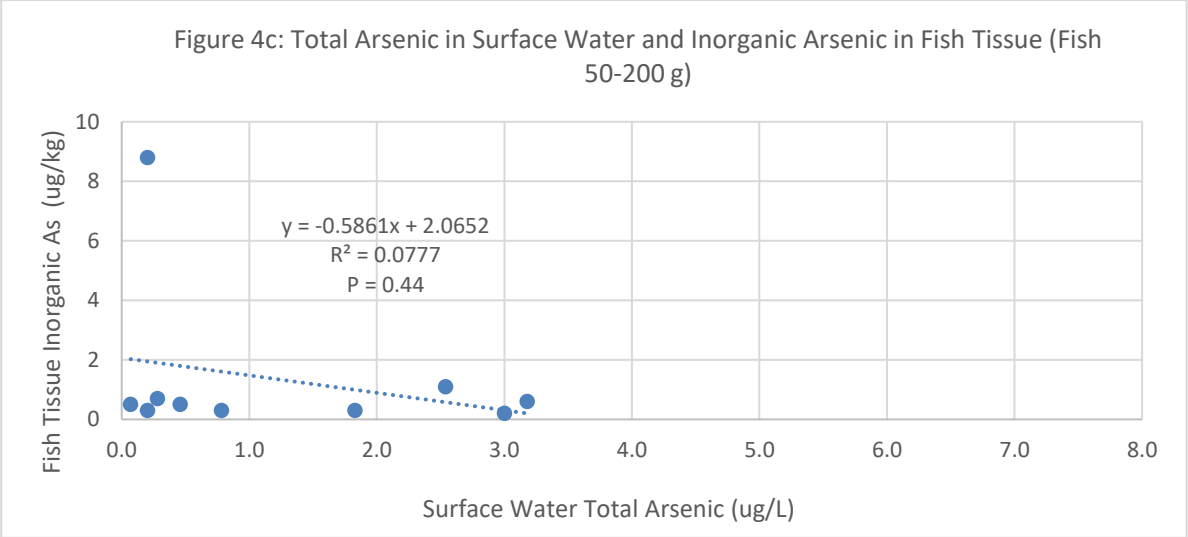


Figure 4c: Total Arsenic in Surface Water and Inorganic Arsenic in Fish Tissue (Fish 50-200 g)
Fish Tissue Inorganic As (ug/kg)
Surface Water Total Arsenic (ug/L)
y = -0.5861x + 2.0652
R² = 0.0777
P = 0.44
0
2
4
6
8
10
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0

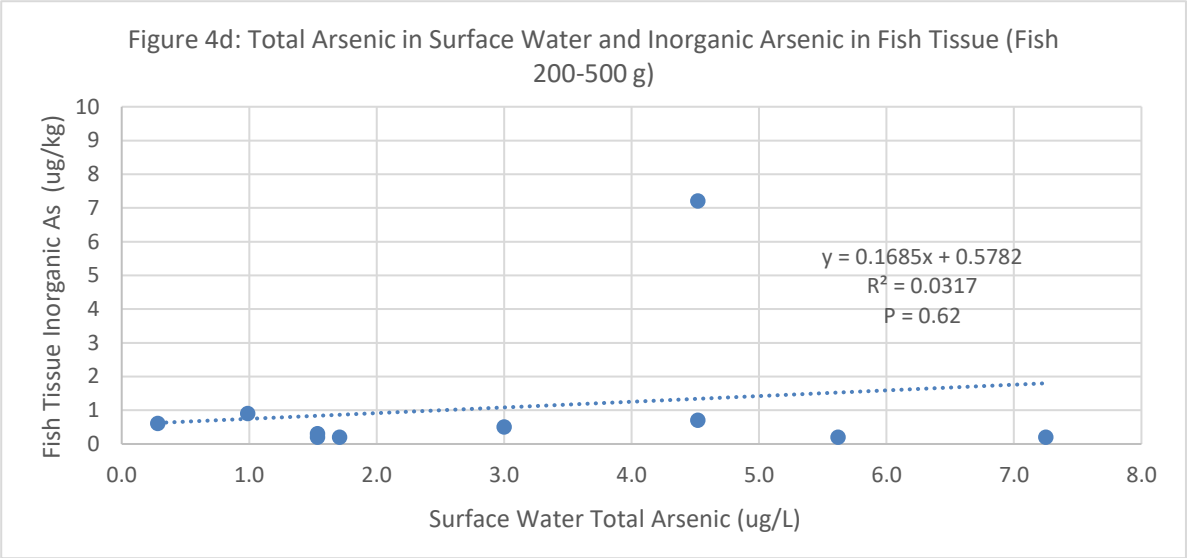


Figure 4d: Total Arsenic in Surface Water and Inorganic Arsenic in Fish Tissue (Fish 200-500 g)
Fish Tissue Inorganic As (ug/kg)
Surface Water Total Arsenic (ug/L)
y = 0.1685x + 0.5782
R² = 0.0317
P = 0.62
0
1
2
3
4
5
6
7
8
9
10
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0

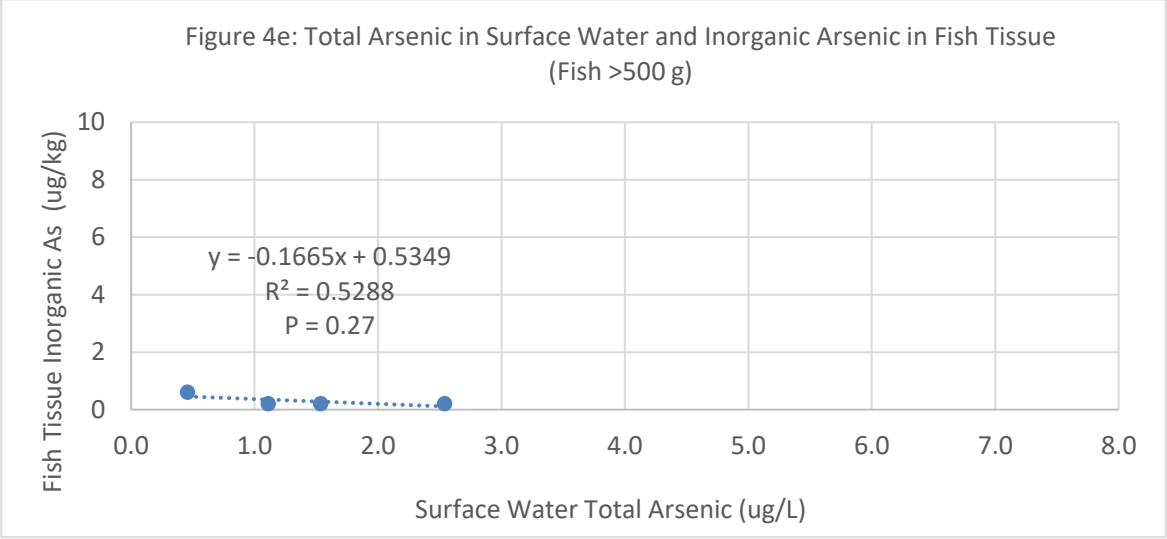


Figure 4e: Total Arsenic in Surface Water and Inorganic Arsenic in Fish Tissue (Fish >500 g)
Fish Tissue Inorganic As (ug/kg)
Surface Water Total Arsenic (ug/L)
y = -0.1665x + 0.5349
R² = 0.5288
P = 0.27
0
2
4
6
8
10
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0

Combined, these evaluations indicate that the concentration of iAs in fish tissue samples is independent of the concentration of arsenic in water and that the iAs concentrations measured in fish tissue collected in 2019 cannot be explained by, and are largely independent of, the various parameters measured by IDEQ during the 2019 field effort.

With regard to additional sampling in 2020, IDEQ (2020) lists four potential options. Which of those four options to undertake, or other option, would seem to depend upon the goal of the 2020 monitoring program. The 2019 sampling is very robust and indicates that a direct relationship between concentrations of arsenic in surface water and fish tissue is absent. Given the robustness of the 2019 sampling effort, it is not clear it needs to be repeated (i.e., the first of the listed options) unless the goal is to reinforce the likely absence of a relationship.

The second option is to target sites with more robust iAs water column data (IDEQ 2020). To the extent the arsenic concentration in surface water varies and is not well characterized by a one-time sample, collecting fish from the vicinity of the targeted monthly locations would help refine the concentration of arsenic in the water column. Review of the available 2019/2020 monthly monitoring data (posted on the Rulemaking Website on April 3, 2020) indicates that variation in water column concentration over the seven months of sampling (August 2019 through February 2020) is less than 2-fold at most sampling locations and is between 4- and 6-fold at only six of 40 locations. These results suggest that one-time surface water concentrations, like those collected as part of the 2019 paired surface water tissue sampling program, are likely to be reasonably representative of long-term concentrations at most sampling locations. Thus, it is not clear additional refinement of the water concentration will help explain the variation observed in fish concentrations. That said, we see no harm in collecting fish tissue samples at some of the monthly water column monitoring locations as it will help refine surface water concentrations, though IDEQ should not expect such refinement to greatly improve the relationship between arsenic concentration in fish tissue and surface water.

The third option is to target sampling locations with relatively high or low ambient iAs concentrations. Because ambient iAs concentrations in Idaho surface waters span a large range, it is not clear focusing on just the upper or lower end of that range will provide insight about tissue concentrations in the remaining waters. If a more focused approach to sampling is ultimately chosen, it will be important to collect data from the entire “cloud of 2019 points”, including the edges and corners, not just one portion of that “cloud”.

The fourth option is to collect individual fish rather than composites to better understand variability between fish species (IDEQ 2020). The fish tissue data collected in 2019 already provide strong indication that concentrations of iAs (and tAs) can be quite variable between species at a given sampling location and the duplicate results (Table 2 in IDEQ 2020) provide strong indication of substantial variability between individual fish within a species at a given sampling location. It is unclear how a finding of similar or greater variability between individual fish would be used when establishing a BAF for a WQC. Such data would seem to provide only further indication that the concentration of arsenic in fish tissue is independent of the arsenic concentration in water and that whatever factors determine the fish tissue concentration, the concentration in water plays a small, if any, part in that process.

An alternate goal of the 2020 sampling might be to collect information to help identify the causes of the large range of arsenic fish tissue concentrations observed in 2019. Such information would likely continue to include collection of paired fish tissue and water column samples but IDEQ might add collection of sediment and/or porewater samples, or of multiple species of different sizes at a single location to better understand if food web complexity is driving the observed differences between species and individuals, or

perhaps, if sufficient mass can be collected, of components of the diet. Collecting other water quality and fish tissue parameters might also improve understanding of the causes of the iAs concentrations in fish tissue. For example, is there a parallel for arsenic to the role of organic carbon in sediments or lipid in fish when predicting fish tissue concentrations of non-ionized organic compounds. For organic compounds a relationship was typically evident from paired water and tissue samples; it was further refined using lipid and carbon data. The 2019 paired arsenic data are unique in the absence of any apparent relationship between tissue and surface water making it more difficult to identify which other parameters might need to be included in a sampling program.

With respect to selecting any (or several) of these 2020 monitoring options, the key question remains: how will IDEQ use the results when developing a WQC for arsenic? If the 2020 results reinforce the 2019 finding of no direct relationship between concentrations of arsenic in the water column and fish tissue, will a BAF and, therefore, fish consumption exposures, be excluded from the arsenic WQC? If the 2020 results confirm the 2019 findings, does this support continuing with the existing 10 micrograms per liter standard (which is based on consumption of water for drinking water purposes). If a BAF will continue to be included, what additional information is needed to inform selection of a state-wide BAF?

We are available to discuss the above results and other aspects of our initial review and evaluation at your convenience.

References

IDEQ 2020. 2019 Arsenic Accumulation in Fish Tissue. Preliminary Monitoring Results. 14 pp. March.

Appendix D

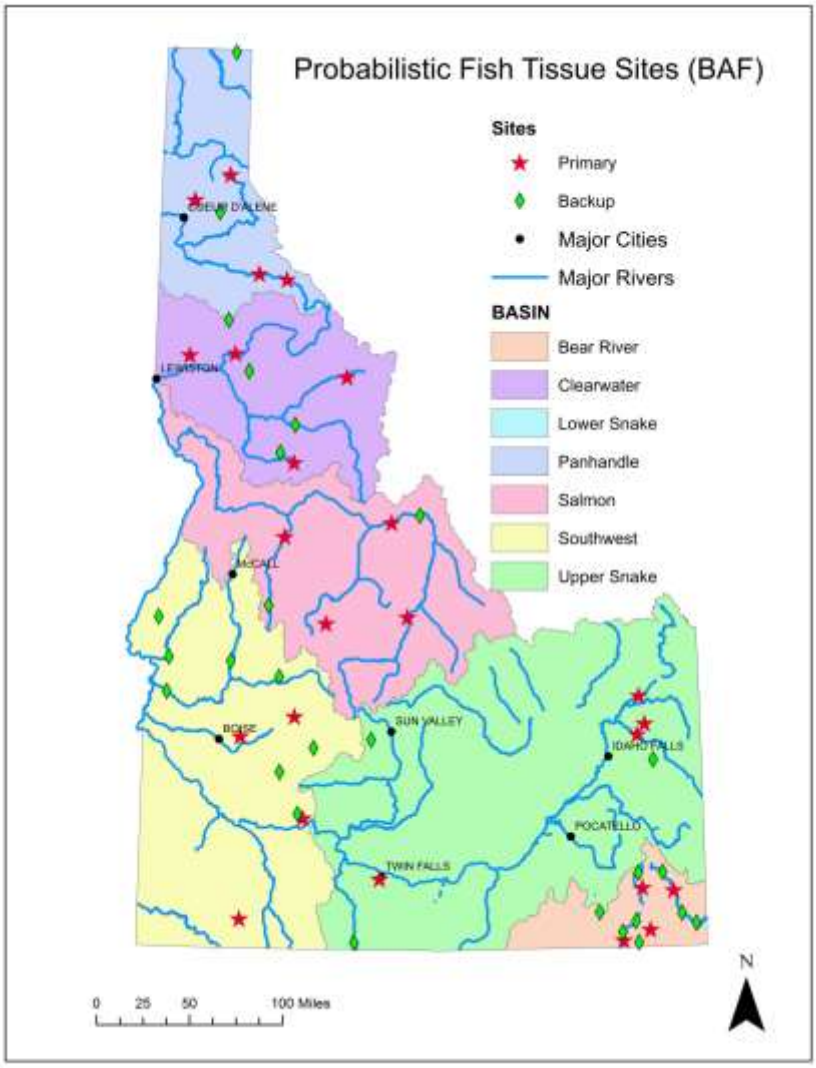
Summary of Inorganic and Total Arsenic Surface Water Concentrations by Basin

Background concentrations between basins vary substantially, where basins are defined as those used by DEQ to present the results of the probabilistic fish tissue monitoring program (Figure D-2). The arithmetic mean iAs concentration in the Clearwater basin is 0.18 ug/L while the arithmetic mean iAs concentration in the Southwest basin is 3.0 ug/L, more than ten times higher (Table D-1). Background concentrations also vary substantially within basins. The minimum detected concentrations range from about 2 to 60 times lower than the arithmetic mean concentration within a basin (Table D-1). The maximum detected concentrations range from about 2 to 6 times higher than the arithmetic mean concentration within a basin (Table D-1). The basin-specific data indicate that variation in iAs concentrations within a basin makes it challenging to establish a basin-specific background concentration, though it may be possible to do so with further refinement of the monitoring data taking into account information about the causes of the variation within a basin (e.g., varying geologic formations).

Table D-1. Summary of inorganic arsenic concentrations by basin.

Basin	Sample Size	Detects	Non-Detects	Min Detected	Max Detected	Mean	Coefficient of Variation	10th Percentile	90th Percentile
Bear River	4	4	0	0.507	2.25	1.201	0.627	0.612	1.932
Clearwater	48	44	4	0.044	1.11	0.182	1.008	0.0461	0.36
Panhandle	40	40	0	0.044	1.67	0.318	1.011	0.106	0.607
Salmon	48	48	0	0.089	3.55	1.514	0.675	0.223	3.37
Southwest	94	93	1	0.047	19.8	3.048	1.289	0.0807	7.693
Upper Snake	75	75	0	0.101	4.82	1.841	0.562	0.604	3.352

Figure D-2. Basins as defined by DEQ's probabilistic fish monitoring program


Probabilistic Fish Tissue Sites (BAF)
Sites
Primary
Backup
Major Cities
Major Rivers
BASIN
Bear River
Clearwater
Lower Snake
Panhandle
Salmon
Southwest
Upper Snake
COEUR D'ALENE
LEWISTON
McCALL
BOISE
SUN VALLEY
IDAHO FALLS
POCATELLO
TWIN FALLS
0 25 50 100 Miles
N

Appendix E

Use of Arithmetic and Harmonic Mean in Human Health Water Quality Criteria

Summary. Estimates of potential risk developed in human health risk assessments require estimating that arithmetic mean daily dose. When the concentration of a substance in a receiving water is known (e.g., measured concentrations are available as is the case for inorganic arsenic in Idaho surface waters) the arithmetic mean concentration, not the harmonic mean concentration, should be used to estimate exposures in a human health risk assessment. In situations where the concentration of a substance in a receiving water is unknown and needs to be predicted (e.g., and effluent discharging the substance to a receiving water), the harmonic mean of the receiving water flow, not the arithmetic mean flow, should be used. The example below demonstrates the difference.

Example. The example presented in the table below is hypothetical. It is based on a monthly flow regime that is typical of many rivers in the United States that receive runoff from spring snow melt. The example includes an effluent with a constant flow and a constant concentration of a substance discharging into the receiving water.

Month	Receiving Water Flow (L/d)	Effluent Flow (L/d)	Effluent Concentration (mg/L)	Receiving Water Concentration (mg/L)	Water Exposure (mg/kg-day)
January	20,000	2,000	1	0.100	0.0030
February	30,000	2,000	1	0.067	0.0020
March	20,000	2,000	1	0.100	0.0030
April	50,000	2,000	1	0.040	0.0012
May	100,000	2,000	1	0.020	0.0006
June	80,000	2,000	1	0.025	0.0008
July	50,000	2,000	1	0.040	0.0012
August	30,000	2,000	1	0.067	0.0020
September	20,000	2,000	1	0.100	0.0030
October	10,000	2,000	1	0.200	0.0060
November	40,000	2,000	1	0.050	0.0015
December	20,000	2,000	1	0.100	0.0030
Arithmetic Mean	39,167	2,000	1	0.076	0.0023
Harmonic Mean	26,422	2,000	1	0.051	0.0015

The first column of the table lists the month. The second column lists the receiving water flow rate for each month. For purposes of the example, flow is presented in units of liters per day (L/d). The third column is the effluent flow rate for each month also in L/d. The fourth column is the concentration of the substance in units of milligrams per

liter (mg/L). The fifth column is the monthly concentration of the substance in the receiving water. The monthly concentration is estimated by multiplying the effluent concentration by the effluent flow and then dividing that product by the monthly receiving water flow (e.g., for January; 1 (mg/L) x 2,000 (L/d) ÷ 20,000 (L/d) = 0.1 (mg/L)). The sixth column in the daily exposure to the substance associated with use of the receiving water as drinking water. Drinking water exposure is estimated by multiplying the receiving water concentration by the drinking water consumption rate (2.4 liters per person per day) and dividing that product by bodyweight (80 kilograms per person). Using January as an example; 0.1 (mg/L) x 2.4 (L/d) ÷ 80 (kg) = 0.003 (mg/kg-d). The assumed drinking water consumption rate and bodyweight are identical to those used by IDEQ when setting water quality criteria protective of human health (WQC).

The last two rows of the table present the arithmetic mean and harmonic mean for each of the columns. For parameters that do not vary (e.g., the effluent flow and effluent concentration) the harmonic mean and arithmetic mean are identical. For all the other parameters, the harmonic mean is smaller than the arithmetic mean.

In human health risk assessment we are interested in the long-term daily exposure or dose. In non-cancer risk assessment that dose is referred to as the average daily dose (ADD). In cancer risk assessment it is referred to as the ifetime average daily dose (LADD). The relevant average turns out to be the arithmetic mean dose. Perhaps the best way to understand why it is the arithmetic mean dose and not some other mean dose (e.g., geometric or harmonic) is to consider how a person is exposed. In the above hypothetical example, a person is exposed to the substance every day through drinking water. His or her total lifetime exposure is the sum of each day's exposure. His or her lifetime average daily dose is equal to his or her total lifetime exposure divided by the days of his or her lifetime. That daily dose is equal to the arithmetic mean daily dose. In the case of the hypothetical example, assuming it represents monthly receiving water and effluent flows over a lifetime, the LADD is equal the arithmetic mean of the monthly exposures (0.0023 mg/kg/d) and is the relevant dose to use in risk assessment.

When receiving water concentration data are available for many months (as they are for inorganic arsenic in Idaho surface waters), the arithmetic mean concentration of the substance in receiving water, not the harmonic mean concentration, needs to be used to estimate the LADD. In the case of the hypothetical example, the arithmetic mean receiving water concentration is 0.076 mg/L. When that concentration is multiplied by a drinking water consumption rate of 2.4 L/d and divided by a bodyweight of 80 kg, the resulting LADD is equal to 0.0023 mg/kg-d, the same LADD estimated by taking the arithmetic mean of the monthly exposures. When the harmonic mean concentration of 0.051 mg/L is used, the resulting LADD (0.0015 mg/kg-d) is smaller than the LADD based on the arithmetic mean receiving water concentration.

The harmonic mean becomes relevant when receiving water concentrations need to be predicted based on receiving water and effluent flows and concentrations. Arithmetic

mean annual flows are readily available for many receiving waters and have, in the past, been used to estimate the annual average concentration of substances in receiving water. However, when arithmetic mean flows are used to estimate the average concentration of a substance in receiving waters that has been discharged in an effluent, they underestimate the arithmetic mean of the daily concentration of the substance in the receiving water.

In the hypothetical example, the arithmetic mean annual flow is 39,167 L/d. When that annual mean flow is used to estimate a mean receiving water concentration, the resulting mean concentration is 0.051 mg/L (2,000 (L/d) x 1 (mg/L) ÷ 39,167 (L/d) = 0.051 (mg/L)). That mean concentration is lower than the arithmetic mean of monthly concentrations (i.e., 0.076 mg/L) and will lead to an underestimate of the LADD. When the harmonic mean annual flow is used to estimate a mean receiving water concentration, the resulting mean concentration is 0.076 mg/L (2,000 (L/d) x 1 (mg/L) ÷ 26,422 (L/d) = 0.076 (mg/L) which his equal to the arithmetic mean of monthly concentrations and leads to an appropriate estimate of the LADD.

In summary, the arithmetic mean of receiving water concentrations should be used for human health risk assessment and for comparison to WQC developed for the protection of human health from long-term exposures to substances in receiving waters. When long-term receiving water concentrations are unknown and need to be predicted, the harmonic mean flow should be used to estimate the average concentration of a substance in a receiving water.

Appendix F

CONTRIBUTORS

The Idaho Association of Commerce and Industry (IACI) is solely responsible for the content of these comments, but does want to acknowledge the following contributors to these comments:

Dr. Paul Anderson has over 30 years of experience in human health and ecological risk assessment. He has been involved in evaluating the potential effects of pharmaceuticals in the environment as well as constituents of emerging concern (CEC). Dr. Anderson has managed the development of a watershed based model that predicts environmental concentrations of pharmaceuticals and related compounds in United States surface waters. Dr. Anderson serves as one of seven national experts on a Science Advisory Panel established by the California State Water Resources Control Board to provide recommendations for monitoring of chemicals of emerging concern in recycled water and surface water. He has conducted human health and ecological risk assessments in support of the air and water permitting required for large industrial facilities and has prepared comments on the scientific basis of many Federal and State regulations including Ambient Water Quality Criteria. Dr. Anderson is also currently an Adjunct Assistant Professor in the Department of Earth and Environment at Boston University.

Mr. Ben Latham has over 25 years of experience in technical lead capacities on a diverse range of environmental and water resources projects both in the United States and internationally. He specializes in watershed and surface water hydrology, groundwater and surface water quality, contaminant loading and mitigation, geospatial analysis, and US Clean Water Act (CWA) related regulations. Mr. Latham has over 14 years of experience leading and implementing stream assessment projects including hydrologic and water quality analysis, stream surveys, sediment studies, and stream biologic analysis.

Dr. Emily Morrison is an Environmental Scientist at Arcadis, Inc. She has a PhD in biology from Michigan State University and 10 years of experience conducting ecological and human health risk assessments including the development of conceptual site models, data analyses, selection and development of toxicity reference values and exposure point concentrations, food web modeling, and evaluation of weight of evidence for risk assessment. She is experienced in the application of population ecology and probabilistic modeling approaches for natural resource damage assessments and risk assessments.

Mr. Alan Prouty has been involved in natural resource and environmental work for over 35 years. This work has included large scale river and regional stream studies on water quality and impacts from point and non-point sources. This work has included looking at biological transfer and toxicity of metals and organochlorine compounds to fish. He currently leads the Environmental and Regulatory Affairs organization for the J.R. Simplot Company.