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July 17th, 2020

Dave Rozeboom
West Central Region Team Supervisor
Remediation and Redevelopment Program
Wisconsin Department of Natural Resources

Subject: Human Health Risk Assessment for Arsenic in Soil at Hi-Crush LLC site in Whitehall, WI

Dear Mr. Rozeboom,

The purpose of this letter is to: (1) summarize arsenic test results from soil samples collected in segments 1, 2, and 3 of the creek at the Hi-Crush site in Whitehall, WI; (2) assess the potential risks to human health; and (3) provide recommendations to protect the health of anyone that may come into contact with the soil on the property. Overall, DHS concludes that the arsenic levels for soil in segments 1, 2, and 3 at the Hi-Crush site do not pose a human health risk.

Background

On May 21, 2018, a contractor's bulldozer accidently slid into a 12-15 feet deep temporary settling pond located at the Hi-Crush sand mine in Whitehall, Wisconsin. The bulldozer operator was trapped inside the airtight cab as rescuers tried to reach him. After several attempts by first responders to locate and rescue the bulldozer operator, the first responders recommended lowering the water level of the pond. Hi-Crush workers used two excavators to dig through the earthen berm of the settling pond. Approximately 10 million gallons of water/soil solids (e.g., sediment) were released from the pond into a nearby tributary of the Trempealeau River, known locally as the Poker Coulee Creek. The contents of the settling pond were primarily water, with silt, clay, and find sand. The pond is used to settle out the silt and clay sized particles, and to recover the water for subsequent reuse at the sand processing plant.

Segments 1, 2, and 3 have had soil samples evaluated for arsenic concentrations and additional site specific background soil samples have been evaluated for arsenic concentrations. At the request of the Wisconsin Department of Natural Resources (DNR), the Wisconsin Department of Health Services (DHS) has conducted a human health risk assessment of the arsenic concentrations in the soil present in Segments 1, 2, and 3 at the Hi-Crush site.

Site Description
From May 2018 through the summer of 2019, Hi-Crush investigated impacts to the affected areas and subsequently removed the majority of newly deposited overbank material and in-stream sediments in segments 4 through 14 along unnamed tributary WBIC 1791400. For the purposes of site investigation, and the evaluation and selection of remedial alternatives, the site addressed for the purposes of this memo are segments 1, 2, and 3 on Hi-Crush property. There are no residences located near the site or with access to the site.

Data Review
On behalf of Hi-Crush, LLC, TRC has conducted soil testing on segments 1, 2, and 3 on the Hi-Crush site and has taken additional site-specific samples of background arsenic concentrations in the area. A summary of the arsenic test results from the soil is shown below in **Table 1** with corresponding sampling locations in **Appendix D**.

Table 1. Soil Test Results for Arsenic in Site Specific Background Levels and Segments 1, 2, and 3 at the Hi-Crush site.

	Site Specific Background (mg/kg)	**Segments 1, 2, and 3 (mg/kg)**
Minimum	<0.84	1.3
Maximum	5.1	5.9
Mean	2.6	4.5
Sample size	10	12
95% UCL[a]		5.14
ATSDR CV[b]		16

Mg/kg=milligrams per kilograms
[a]95% of the upper confidence level based on 12 individual site specific samples taken from arsenic contaminated soil
[b]ATSDR soil comparison value (CV)

Discussion
Oral ingestion of arsenic has been shown to cause stomach irritation, nausea, vomiting, and diarrhea.[1] Little information is available on the effects of direct dermal contact with inorganic arsenic but several studies indicate that the main effect is local irritation and dermatitis, with little risk of other adverse effects.[1]

DHS examined the levels of arsenic levels in segments 1, 2, and 3 to determine if they are a health risk at the request of the DNR to assist in determining if further remediation is needed. The arsenic concentrations range from 1.3 to 5.9 mg/kg with an average of 4.5 mg/kg in the soil in segments 1, 2, and 3. Site-specific soil background levels ranged from <0.84 to 5.1 mg/kg. All values were below the Agency for Toxic Substances and Disease Registry's (ATSDR) child chronic environmental media evaluation guide (EMEG) of 16 mg/kg for arsenic in soil indicating that the estimated contaminant concentrations are not expected to result in adverse non-carcinogenic health effects based on ATSDR evaluation.[2,3] EMEGs are based on ATSDR's minimal risk level (MRL) and conservative assumptions about exposure, such as intake rate, exposure frequency and duration, and body weight.[3] MRLs are exposure levels posing minimal

risk to humans and is defined as an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (non-carcinogenic) over a specified duration.[1] The hazard quotient is the calculated daily dose divided by the MRL to determine if the dose exceeds the effect level. If the hazard quotient exceeds 1, than the effect level is exceeded indicating that the substance may pose a health threat. Overall, DHS determined that the arsenic concentrations in soil segments 1, 2, and 3 do not pose a risk to human health through oral ingestion and/or dermal contact.

In Wisconsin, background arsenic naturally occurs in the soil at concentrations ranging from less than the laboratory detection limit (<1 mg/kg) to 39 mg/kg.[4] The Wisconsin DNR utilizes a soil clean up standard known as the residual contaminant level (RCL) of 0.677 mg/kg for non-industrial properties and 3 mg/kg for industrially zoned properties. These values are in accordance with chapter NR 720 of the Wisconsin Administration Code. People are exposed to arsenic in soil through oral ingestion or dermal contact.[6]

ATSDR's Public Health Assessment Site Tool (PHAST) was used to evaluate the risk for acute and chronic non-cancer and cancer health effects associated with exposures among seven age ranges by comparing the estimated arsenic exposures from soil to ATSDR's acute MRL (0.005 mg/kg/day) and chronic MRL (0.0003 mg/kg/day).[1] The ATSDR chronic MRL is the same value as the US Environmental Protection Service's (USEPA) chronic reference dose (RfD).[7]

Estimated exposure doses are expressed as the amount of contaminant that a person takes in daily per unit of body weight. The unit is expressed as milligram chemical per kilogram body weight per day (mg/kg/day). In this case, we estimated how much arsenic people are exposed to from accidentally ingesting arsenic-containing soil particles and from absorbing arsenic through skin by touching the contaminated soil.

Total estimated dose (mg/kg/day) = Ingestion dose + Dermal absorption dose

Conservative assumptions and parameters were included in our analysis; the assumptions and parameters used for the calculations are presented in detail in Appendix B. Calculation formulas are described in Appendix A. The health effects of the estimated doses were then evaluated by comparing them to established guidelines from EPA and the ATSDR for both non-cancer risk and cancer risk.

Short term Exposure

For the acute ATSDR's reasonable maximum exposure (RME) scenario, 1 to 2-year-olds consistently had higher acute dose estimates compared to age 2 through adulthood. Infants through <1 year old had higher estimated daily exposure rates but did not take a pica exposure of 5 grams into consideration. Therefore, even though it is highly unlikely for a 1 to 2-year-old to wander onto private property, we used the estimate for a 1 to 2 year-old for a conservative estimate since this age group has the highest estimated intake and could have a one-time exposure that is high (see **Appendix C** for doses by age group).

Health risks associated with a one-time episode in which a 1 to 2-year-old child is assumed to ingest either the daily amount of spoil in ATSDR's RME scenario (200 milligrams per day) or an

unusually large amount of soil (5 grams, representing pica behavior[*]) were evaluated (**Table 2**). In each scenario, the soil concentration used to estimate the exposure dose is assumed to be 5.14 mg/kg which is the 95% upper confidence level of the mean (UCL) for segments 1 through 3 on the Hi-Crush property.

Calculations considered the arsenic concentration in the soil to be the 95% UCL value of 5.14 mg/kg based on site-specific sampling of arsenic in soil. A single ingestion event of the RME soil ingestion rate (200 milligrams per day) for a 1 to 2-year old child (non-pica) or a single ingestion event for a 1 to 2-year old (pica) with a soil ingestion rate of 5 grams did not exceed the ATSDR's acute MRL of 0.005 mg/kg/day (indicated by a hazard quotient less than 1, **Table 2**). Exposure to arsenic in soil on this non-residential, private property shown in Table 2 and 3 indicates no elevated risk for the short-term non-cancer arsenic health effects.

Table 2. Acute risk assessment for dermal and ingestion exposure to arsenic in soil in 1 to 2-year olds.

Duration	**95% UCL (mg/kg)**	**Acute[a] dose (mg/kg/day)**		**Acute[b] Hazard Quotient**	
Ingestion		RME	Pica	RME	Pica
Acute	5.14	5.4E-05	0.00097	0.011	0.19
Dermal					
Acute	5.14	6.2E-06		0.0012	
Dermal + Ingestion		RME	Pica	RME	Pica
Acute	5.14	6.0E-05	0.00097	0.012	0.19

Mg/kg=milligrams of arsenic per kilogram of soil; mg/kg/day = milligrams of arsenic per kilogram of body weight per day; RME=reasonable maximum exposure (assumes 200 milligrams per day); 95% UCL= 95% of the upper confidence level based on 12 individual site specific samples taken from arsenic contaminated soil

[a]Acute Dose: Exposure estimates are for 1 to 2-year-old child weighing 11.4 kg who ingests 5,000 milligrams (pica) or 200 milligrams (RME) of soil per episode.[8] Acute is considered less than 14 days with an exposure factor of 1 and a bioavailability factor of 0.6.[8]
[b]The hazard quotient is calculated by dividing the estimated contaminant exposure by the ATSDR acute arsenic MRL (0.005 mg/kg/day)[1]

<u>Long term exposure--non-cancer risk</u>

For calculations of risk, the long-term exposure was assumed to occur 5 days a week for 50 weeks with the RME assumption that an infant from birth to 1 year of age consumed 150 mg per day, 5 days a week, 50 weeks a year, over a 70 year period (see **Appendix C** for doses by age group). An infant from birth to 1 year of age was used due to this age range having the highest daily chronic dose exposure compared to the 6 other age ranges evaluated. However, we acknowledge that it is unlikely that a person this age would trespass 5 days a week for 50 weeks for over 70 years and that this is a conservative estimate in order to estimate a potential maximum exposure to evaluate risk. The estimated long-term exposure dose did not exceed the ATSDR chronic MRL[†] of 0.003 mg/kg/day.[1,7] In **Table 3**, the hazard quotient is <1 indicating

[*] pica behavior is defined as an abnormal craving for and eating of substances not normally eaten
[†] MRL is the same as the USEPA arsenic RfD level

that the chronic MRL and RfD were not exceeded for ingestion, dermal, and ingestion with dermal exposures.

Long term exposure--Cancer Risk

Current toxicological practice assumes there is no "safe dose" of a carcinogen (chemical that can cause cancer). In other words, exposure to any amount of a carcinogen causes some additional cancer risk. Because of this, EPA and ATSDR use a theoretical cancer risk approach to evaluate potential health risk from exposure to carcinogens.[9] This approach does not provide a yes or no answer to cancer risk but shows the chance of additional risk. The US EPA's generally acceptable risk for environmental exposure ranges from 1 in 10,000 to 1 in 1,000,000 with a risk above 1 in 10,000 considered high enough to recommend that remediation is needed.[10,11] ATSDR estimates lifetime cancer risks by multiplying the estimated exposure by the USEPA arsenic cancer potency factor.[12] The cancer potency factor is a numerical estimate of the carcinogenic strength (potency) of a contaminant (see **Appendix B** for calculations).

Cancer risk was determined assuming exposure from birth to <1-year-old to adulthood for 5 days a week for 50 weeks for 70 years (see **Appendix C**). The arsenic contamination rate in the soil was assumed to be 5.14 mg/kg. The cancer risk (**Table 3**) ranged from 1.0×10^{-6} to 6.3×10^{-6} for a 70-year exposure which was greater than the background cancer risk of 10^{-6}. Stated another way, if one million people were exposed to the same level of arsenic over the same amount of time (70 years), we estimate that 1 to 6 additional cases of cancer might occur.

Several conservative exposure assumptions were applied for the risk calculation. First, we assumed that arsenic is present in surface soil across segments 1, 2, and 3 of the Hi-Crush site. We also assumed that during each visit, people will always be exposed to contaminated soils by disturbing the covered area (grass or snow) and touching the underneath soil. In addition, we assumed that the exposure frequency would be 5 days a week for 50 weeks a year consistently for 70 consecutive years. It is unlikely to see an infant to 1 year old's activity fulfilling all of these assumptions in a realistic scenario particularly since being present in segments 1, 2, and 3 would be trespassing. Thus, the calculations are very conservative dose estimates and we expect actual exposures and corresponding risk to be lower than the calculated results.

Based on the calculation and site-specific evaluation, we concluded that exposure to arsenic in surface soil at Hi-Crush through trespassing is not expected to cause harm and has no apparent public health hazard due to its inaccessibility and because it does not cause an unacceptable increased risk of cancer.

Table 3. Chronic health risk assessment for dermal and ingestion exposure to arsenic in soil over a 70-year lifetime exposure

Duration	95% UCL (mg/kg)	Chronic[a] dose (mg/kg/day)	Chronic[b] Hazard Quotient	Cancer Risk
Ingestion		RME	RME	RME
Chronic	5.14	4.1E-05	0.14	5.3E-06
Dermal				
Chronic	5.14	4.8E-06	0.016	1.0E-06
Dermal + Ingestion		RME	RME	RME
Chronic	5.14	4.5E-05	0.15	6.3E-06

Mg/kg=milligrams of arsenic per kilogram of soil; mg/kg/day = milligrams of arsenic per kilogram of body weight per day; RME=reasonable maximum exposure (assumes 200 milligrams per day); 95% UCL= 95% of the upper confidence level based on 12 individual site specific samples taken from arsenic contaminated soil

[a]Chronic Dose: Exposure estimates are exposed for a 78-year lifetime (70 year continuous exposure) for 5 days a week for 50 weeks consuming milligrams per day as indicated in Appendix C and with an exposure factor of 0.68 and a bioavailability factor of 0.6.[8]
[b]The hazard quotient calculated by dividing the estimated contaminant exposure by the USEPA reference dose (RfD) for oral exposure of 0.0003 mg/kg/day.[7] The USEPA RfD and ATSDR MRL[1] are the same value (0.0003 mg/kg/day).

Conclusions

The risk assessment based on site-specific arsenic levels in the soil indicate that the levels are elevated compared to site-specific background arsenic concentrations (<0.84 to 5.1 mg/kg); however, there is no increased risk associated with ingestion or dermal exposure to arsenic levels found in soils onsite. These concentrations are within the normal range of arsenic that is naturally found within Wisconsin soil (< 1 mg/kg to 39 mg/kg) and are below the DNR's background threshold level (8 mg/kg) for arsenic in soil.[4,5] Furthermore, the location is on private property, is not actively used for recreation or public use. Therefore, potential exposures are expected to be minimal and it is unlikely that a child (birth to <2 years old) which has the highest potential for exposure to the soil, would regularly venture onto this private property given there are no residences in the immediate area. DHS concludes that the arsenic levels for soil in segments 1, 2, and 3 at the Hi-Crush site do not pose an unacceptable increase in human health risk.

Recommendations

DHS concludes that the health risks due to arsenic exposure at concentrations observed in soil in segments 1, 2, and 3 at the Hi-Crush site are minimal. DHS has the following recommendations to reduce potential human health risks by avoiding dermal and ingestion exposure to soil:

- Implementing best practices to avoid unnecessary exposure to arsenic in the soil by avoiding oral ingestion through proper sanitation procedures such as washing hands, clothing, etc. that come into contact with the soil.
- Using signage acknowledging that this area is private property and/or no trespassing to avoid unnecessary exposures through recreational use and/or trespassing in the area.

If you have any questions regarding the information or conclusions contained in this letter, please contact me at the number or email address below.

Sincerely,

Brita Kilburg-Basnyat, PhD
Toxicologist
Bureau of Environmental and Occupational Health

Cc:
Barb Barczak, Health Officer, Trempealeau
Kevin Lien, DNR, Trempealeau

Appendices

Appendix A:	**Estimated dose calculations**
Appendix B:	**Exposure assumptions and parameters used for risk assessments**
Appendix C:	**Acute and chronic doses by age group**
Appendix D:	**Scope of the site including sampling locations**

Appendix A. Estimated dose calculations

Soil Ingestion Exposure Dose Equation

D = (C x IR x EF x CF) / BW

D=exposure dose (mg/kg-day), C=contaminant concentration (mg/kg), IR=intake rate (mg/day), EF=exposure factor (unitless), CF=conversion factor (10^{-6} kg/mg), BW=body weight (kg)

Soil Administered Dermal Dose Equation

ADD = (C x EF x CF x AF x ABSd x SA)/ (BW x ABSGI)

ADD=Administered dermal dose (mg/kg-day), C=contaminant concentration (mg/kg), EF=exposure factor (unitless), CF=conversation factor (10^{-6} kg/mg), AF=Adherence factor to Skin (mg/cm^2-event), ABSd= dermal absorption fraction to skin (unitless), SA=skin surface area available for contact (cm^2), BW=body weight (kg), ABSGI=gastrointestinal absorption factor (unitless).

Exposure factor (non-cancer)

EF= (days exposed/days in a week) x (weeks exposed a year/total weeks in a year) x (1 year)

EF dermal: the dermal absorbed dose equation includes a 1 event/day EF parameter

Exposure factor (cancer)

EF= (EF non-cancer) x (age-specific exposure duration (years))/78 years

Cancer Risk Equation

CR=(D x CSF) x (ED/LY)

CR=cancer risk, D=age-specific dose (mg/kg/day), CSF=cancer slope factor ($(mg/kg/day)^{-1}$), ED=age-specific exposure duration (years). LY=lifetime in years (78 years).

Hazard Quotient Equation

HQ= (D/MRL or D/RfD)

HQ=hazard quotient, D=Exposure dose (mg/kg/day), MRL=minimal risk level (mg/kg/day), RfD=reference dose (mg/kg/day)

Appendix B. Exposure assumptions and parameters used for risk assessments

Parameter	Symbol	Value		Unit	Source	Notes
95% Upper Confidence Limit for Arsenic in soil	C	Segment 1, 2, 3 at Hi-Crush site	5.14	mg/kg		
conversion factor	CF	1.00E-06		kg/mg		Converts contaminant concentration from nm to kg
ingestion rate	IR	infant	150	mg/day	EPA	birth to < 1 year old
		Child	200			1 year old to 2 years old
		Adult	100			
exposure frequency	EF	Segment 1, 2, 3 at Hi-Crush site	250	days/year		5 days a week, 50 weeks a year
exposure duration	ED	Childhood	1	years		See Appendix C for assumptions for exposure and duration from childhood to adulthood.
		70-year old adult	70			
body weight	BW	Infant	7.8	kg	ATSDR	Child age 0 to <1
		Child	11.4			Child age 1to <2
		Adult	80			Adult:70 years
cancer slope factor	CSF	1.5		$(mg/kg/day)^{-1}$	EPA	
Combined Skin Surface Area	SA	Child	2299	cm^2	ATSDR	
		Adult	6030			
soil-to-skin adherence factor	AF	Child	0.2	mg/cm^2		
		Adult	0.07			
Dermal absorption factor	ABSd	0.03		unitless	EPA	
Gastrointestinal absorption factor (GI)	ABSGI	1		unitless	EPA	
Exposure factor (dermal)	EF	1		event/day	EPA	
Bioavailability factor	ORAF	0.6		unitless		

Appendix C. Acute and chronic doses by age group

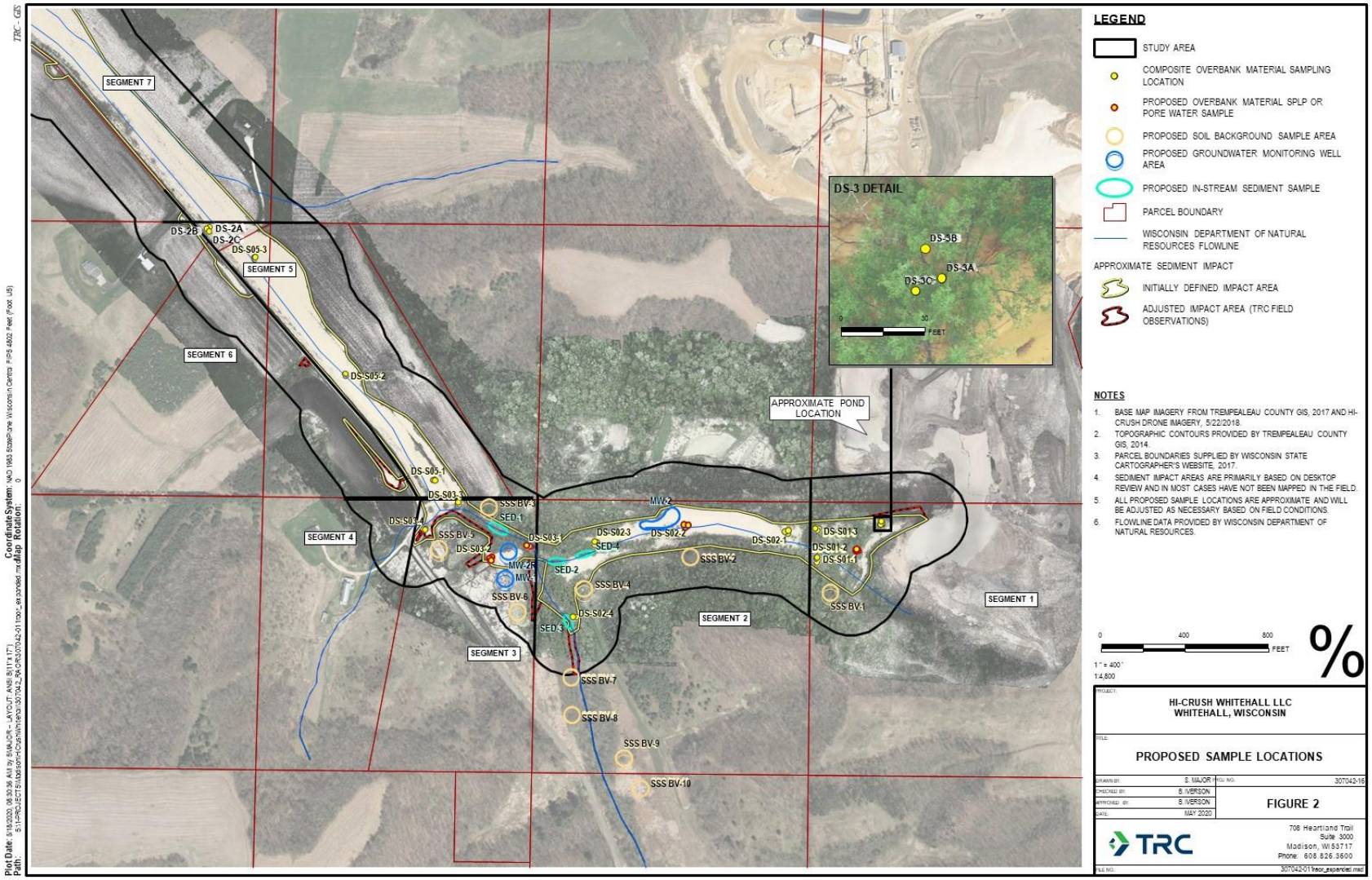
Exposure Group (Dermal + Oral exposure)	Acute Dose[b] (mg/kg/day)	Pica (5 grams)	Chronic Dose[c] (mg/kg/day)	ED (yrs)
Birth to <1 year	6.60E-05	NC[a]	4.50E-05	1
1 to <2 years	6.00E-05	9.70E-04	4.10E-05	1
2 to <6 years	4.00E-05	6.40E-04	2.70E-05	4
6 to <11 years	2.30E-05	NC	1.60E-05	5
11 to <16 years	8.40E-06	NC	5.70E-06	5
16 to <21 years	6.90E-06	NC	4.70E-06	5
Total exposure duration for child cancer risk				21
Adult	4.70E-06	NC	3.20E-06	70

[a]NC=not calculated; based on scientific literature, 30% of children 1 to 3 years of age exhibit pica behavior making this age group most likely to have a pica exposure.[13]

[b]Acute is considered less than 14 days and for pica, it was assumed to be 5 days a week. The exposure factor for acute exposures always equals 1.[8]

[c]Chronic in this specific scenario is a 78-year-old (life expectancy) with a 70 year exposure (5 days a week for 50 weeks starting at birth to < 1 year old).[8]

Appendix D. Arsenic sampling locations in segment 1, 2, and 3 along Poker Creek at the Hi-Crush Sand Mine, Whitehall, Wisconsin



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