ICON
ENVIRONMENTAL SERVICES
Environmental Services, Inc
2049 Commercial Drive • Port Allen, LA 70767 • (225) 344-8490 • fax (225) 344-6654

October 14, 2022

Mr. Matt Keating
Mudd, Bruchhaus, & Keating, LLC
422 E. College Street, Suite B
Lake Charles, LA 70605

Subject: **Comments to the Chevron Most Feasible Plan for Site Evaluation and Remediation Under R.S. 30:29**
Henning Management, LLC v Chevron USA, Inc et al;
Docket No. 73318; 31st JDC; Divison "C", Jefferson Davis Parish, LA
Hayes Oil Field, Calcasieu and Jefferson Davis Parish, LA

Dear Mr. Keating,

ICON Environmental Services, Inc. (ICON) is pleased to present these general comments to the Chevron MFP dated August 05,2022.

1. General Overview

Chevron states upfront in their plan in the Overview of Findings that "no active remediation of soil or groundwater is required at the Property to comply with La. R.S. 30:29". Chevron admitted that environmental damage, as defined by Act 312, exists in the soil and groundwater within Areas 2, 4 and 5, and admitted that environmental damage exists in soil in Areas 6 and 8. Environmental Damage is defined in Act 312 as "*any actual or potential impact, damage, or injury to environmental media caused by contamination resulting from activities associated with oilfield sites or exploration and production sites*". Contamination is defined as "*the introduction of substances or contaminants into a groundwater aquifer, a USDW or soil in such quantities as to render them unusable for their intended purposes*". Thus, Chevron is admitting in their MFP that they intend to leave substances or contaminants in a groundwater aquifer or soil on the property in such quantities to render them to be unusable. This is clearly a violation of La. R.S. §30.29(A), "*to ensure that damage to the environment is remediated to a standard that protects the public interest*".

2. Geology

Chevron describes the shallow soils to a depth of 78 feet bls as primarily clay and silty clay with a highly variable and discontinuous shallow water-bearing zone that consists primarily of clayey silt and silt with varying amounts of sand that are poorly interconnected but generally behave as a single water-bearing unit. As stated in RECAP, a Conceptual Site Model shall be implemented and shall illustrate the known or potential sources, routes of constituent migration, exposure media and pathways and receptors. Exposure pathways and potential pathways are to be identified based on anticipated receptor activities at current or future exposure points. The defendants have omitted the geological characterization in their assessment, and even failed to provide correlations on their cross sections. Chevron made no attempt at correlating core data on cross sections, or developing a conceptual site model that incorporates a model to properly evaluate contaminant fate and transport. Thus, they have no means to evaluate the most likely location for a future water supply well.

3. Aquifer Classification

Both ICON and ERM/Chevron generated hydraulic conductivity data that confirms a sustained aquifer yield in excess of 800 gpd (RECAP Class GW2) at various locations within both the A-Bed and B-Bed of the Shallow Aquifer. RECAP defines a Class 2 aquifer as *"groundwater within an aquifer that could potentially supply drinking water to **a** domestic water supply. The aquifer should be sufficiently permeable to transmit water to **a** well at a maximum sustainable yield of greater than or equal to 800 gpd and less than 4800 gpd.."* Nowhere in the RECAP document does it state that the geometric mean of multiple well yield calculations has to meet this definition.

The RECAP document does state in Appendix F (page F6) that "*when averaging a number of hydraulic conductivity results from a site, the geometric mean shall be used*". The geometric mean of the hydraulic conductivity of the B-Bed of the Shallow Aquifer is 2.13 ft/day. The average thickness is 3.24 feet (H9=7'; H18=5.7'; H27=0.5'; MW1=4'; MW2=4'; MW4=2.5'; MW8=0.2'; MW9d=2'). Average confining head is 36 feet. This data applied to the Cooper and Jacob Approximation to the Theis Non-Equilibrium Equation results in a yield of 1131 gpd, confirming the GW2 classification.

4. Leachability of Salts

SPLP

The Synthetic Precipitation Leaching Procedure (SPLP) utilizes extraction procedure Method 1312 in which a 20:1 ratio (by weight) of extraction fluid to solid sample is employed, and is allowed to extract for 18 hours in a rotary extraction device. For samples east of the Mississippi River, the extraction fluid is made using reagent grade water and sulfuric/nitric acid to a pH of 4.2 +/-0.05. For samples west of the Mississippi, the pH is 5 +/- 0.05. The extraction mixture is filtered of solids and the extract is analyzed using SW846 Method 9253, which is a silver nitrate titration method for chloride content. Interferences with Method 9253 include bromide, iodide and sulfide (all of which are titrated along with chlorides).

LDEQ's application of the Synthetic SPLP to predict the concentrations of salts in soil that pose a threat of leaching to groundwater is to:

- For GW2 groundwater classification, compare SPLP results to the groundwater standard (250 mg/L) x 20 x DF2. = [5000 mg/L x DF2].

Again, the SPLP test utilizes a 20:1 reagent water to solid ratio, providing a 20 fold dilution during the testing. The way that LDEQ and LDNR apply the SPLP test to address salt-contaminated soils is guaranteed to indicate a "no leaching threat" conclusion each and every time because:

- In comparing SPLP data to 5000 mg/L, a 400 fold dilution is effected (20 used in the DAF x 20 used in testing).
- The proposed target soil leaching concentration of 5000 mg/L x 20 = 100,000 mg/L [lowest concentration that could possibly exceed the target soil leaching value]. Typical produced water chloride concentrations typically are less than 70,000 mg/L.

In hundreds of samples throughout Louisiana, I have never seen a single "failure" of the SPLP chloride result evaluated in this manner.

The Wisconsin DNR's guidance on the use of leaching tests (October 2003) states with bold emphasis: "*It should be noted that the SPLP test inherently has a 20:1 dilution factor. This dilution factor is the only dilution that should be used, unless a much more extensive scientific analysis of the controlling mechanisms of leachability phenomena is conducted at the specific contaminated site*". Many other states refer to this guidance policy.

The 20-fold dilution being utilized is based on a default assumed dilution factor from the Summer's leaching model. RECAP provides for calculating a site-specific soil/water partition coefficient in their MO-2 Soil_{GW} Method 4. This method utilizes site specific data including soil concentrations and adjacent groundwater concentrations, actual size of the contaminated mass of leaching soil, and most importantly the actual source thickness (Sd) and the very low soil:water partitioning coefficient (Kd) of chlorides (0.1). ICON used site-specific data in the MO-2 Soil_{GW} Method 4 models for Limited Admission Areas 2 and 4 (**Attachment A**), with the following $\text{DF}_{\text{Summers}}$ results:

- Limited Admission Area 2 $\text{DF}_{\text{Summers}}$: 2.28
- Limited Admission Area 2 $\text{DF}_{\text{Summers}}$: 2.5

The relatively large mass of contaminated soil and the relatively thin Sd provides little geometry for dilution of the mass of leaching contaminant.

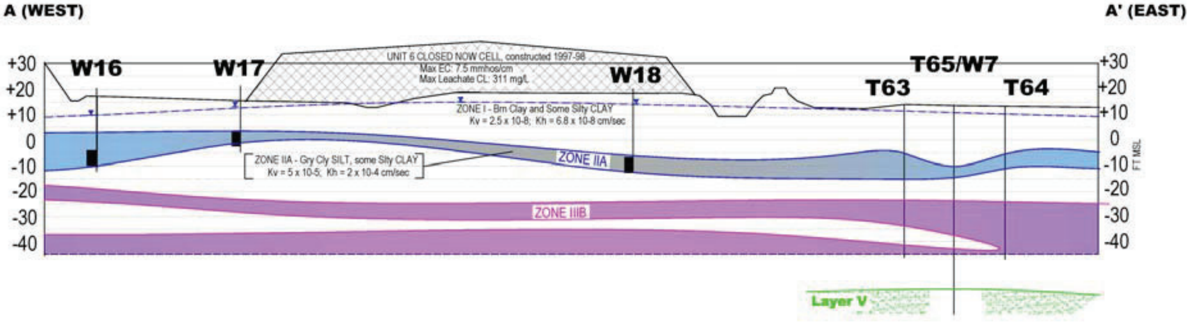
The mass balance evaluations of various leaching methods confirming these opinions was provided to ICON by Dr. Richard Schuhmann, PhD, Principal Consultant at Environmental Systems Evaluations and Assessments, Kennebunkport, Maine, and are included in Attachment B.

Statewide Order 29B Leachate Chlorides

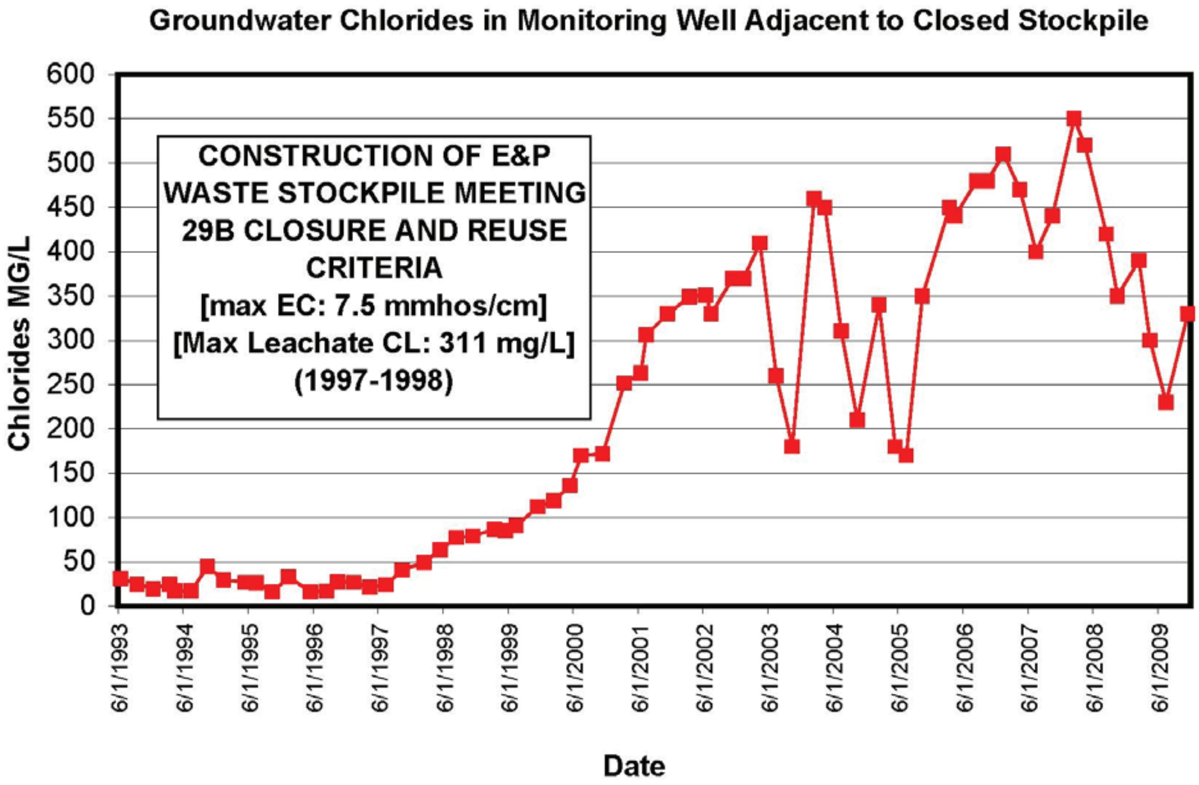
In contrast, for sites under jurisdiction of Statewide Order 29B), the leachability of salts from soils is determined using the 29B Leachate Chloride test (Laboratory Procedures for Analysis of E&P Waste, Revised Nov 2011). This method was designed to simulate water leach effects on treated Exploration and Production Wastes addressed specifically under LAC 43:XIX.Subpart 1. Chapter 3 (Onsite Storage, Treatment and Disposal of E&P Waste) and LAC 43:XIX.565.F (Testing Criteria for Reusable Material). A representative sample of the waste solid is extracted by continuous contact with reagent water (ASTM Type II water) at a 1:4 solid:solution ratio for 7 days "with flask contents swirled on a daily basis to effect gentle, intermittent agitation". After this time period, solids are separated from the mixture by filtration, and chlorides are analyzed using EPA Method SW-846 9056 or 9253. Method 9253 was previously summarized. Method 9056 is an ion chromatography method for determination of inorganic ions including chlorides. The measured concentration of chlorides in the extract are compared to a regulatory standard of 500 mg/L.

It is ICON's direct experience at every site where SPLP Chlorides and Statewide Order 29B Leachate Chlorides are run concurrently, the 29B lab result averages five times higher in magnitude than the SPLP chloride lab result. This is simply a result of sample dilution: Statewide Order 29B utilizes a 4:1 extraction ratio, and SPLP utilizes a 20:1 extraction ratio (five times more dilution). Chlorides do not react with or sorb to the soil matrix, making them the most leachable constituent around. This is why chlorides are often used as a conservative tracer in groundwater tracing studies.

I had the opportunity to evaluate actual leaching of salts into groundwater from a commercial E&P waste treatment facility to compare to the predicted leaching of the 29B Leachate Chlorides test. Quarterly groundwater monitoring began in mid-1993 for monitoring well W18 at a commercial E&P waste treatment facility. The facility shut down for a number of years, and closure of the remaining waste left onsite began in the late 1990's. Closure included mixing waste with clean soil to achieve commercial closure criteria including soil EC of 10 mmhos/cm, SAR of 12, ESP of 15%, and Leachate Chlorides of 500 mg/L. Once sampling confirmed that all target COCs met closure criteria, the treated soil/waste was placed into a compacted stockpile. Unit 6 stockpile was 8.5 acres in plan view, and approximately 20 feet tall. Monitoring well W18 was located on the east center side adjacent to Unit 6. Testing during closure showed a maximum EC of 7.5 mmhos/cm, and a maximum Leachate Chlorides of 311 mg/L.



Groundwater chlorides in W18 averaged ~25 mg/L before the Unit 6 stockpile was constructed. After construction, quarterly data began to show increasing chloride concentrations in W18 samples. The chlorides peaked at 550 mg/L in 2008, approximately 10 years after construction of Unit 6, the then leveled off at ~ 325 mg/L.



The accuracy of the 29B Leachate Chloride test in this case is remarkable, predicting a concentration of 311 mg/L that would leach to groundwater containing 25 mg/L chlorides (predicting 335 mg/L to be measured in groundwater), compared to ~325 mg/L final chloride concentration in groundwater from W18.

5. Barium Extraction

ERM suggests that the barium results of ICON's soil samples were more than five times higher on average for barium, and they attributed that to the "dry and grind" preparation of the soil samples for analysis to be reported on a dry weight basis. They assert that because their data was subjected to a validation process, that their results are more accurate. All of the soil samples analyzed by Element were prepared for acid digestion using Method 3050B. That method provides (Section 2.0) that a representative 1-2 gram (wet weight) or 1 gram (dry weight) sample is digested with repeated additions of nitric acid and hydrogen peroxide. ERM's samples would have been prepared as per the wet weight, and ICON's as per the dry weight. The method however makes the following definitive statements:

- (Section 1.2) This method is not a total digestion technique for most samples. It is a very strong acid digestion that will dissolve almost all elements that could become "environmentally available". By design, elements bound in silicate structures are not normally dissolved by this procedure as they are not usually mobile in the environment.

- (Section 6.4) It can be difficult to obtain a representative sample with wet or damp materials. Wet samples may be dried, crushed, and ground to reduce subsample variability as long as drying does not affect the extraction of the analytes of interest in the sample.

Data validation includes evaluation of the sample extracts as they are carried through the various steps of the analytical process, i.e. compared to laboratory control samples, etc. Data validation typically does not evaluate the precision or accuracy of the extraction process. It is quite likely, as stated in Method 3050B, that it is easier and more efficient to extract a dry sample as compared to a wet or damp sample. Thus, it is likely that the higher barium results of ICON's samples represent a more accurate result of the true barium concentration of the sample.

6. Wet Weight v Dry Weight

It is generally accepted and required by the scientific community that exposure assessment from inorganic chemical soil ingestion and dermal absorption rely upon the dry weight concentrations of the contaminants of concern. We once again submit an opinion provided to ICON by Dr. Richard Schuhmann, PhD, included in **Attachment C** in support of this statement. In much more general terms, ICON submits that dry weight data eliminate the bias introduced to a sample by variability of the sample's moisture content. This variability is most likely in surface soil samples, where surface soil during drought conditions can have highly variable moisture content. A sample with 50% moisture would have half the contaminant concentration of a dry sample.

7. Remediation Within the Current Effective Root Zone

Chevron opined the current effective root zone to be 10 inches and does not propose any remediation of salts below one foot. Chevron stated that the historical use of properties in the area have been used to grow rice which they state has an effective root zone less than 10 inches. Limiting the remediation of salt constituents to one foot to would restrict the future use of the property and not allow the owners to grow other crops with deeper rooting depths or recontour elevation of property by digging ponds and using that dirt as fill for residential development.

The opinions and interpretations listed herein are based on the referenced sources and are subject to change upon receipt of additional data. If you have any questions concerning this report, please feel free to contact me at (225) 344-8490.

Sincerely,
ICON Environmental Services, Inc.

LOUISIANA BOARD OF PROFESSIONAL GEOSCIENTISTS
GREGORY W. MILLER
LICENSE NUMBER 939
Est. 2011

Gregory W Miller

Gregory W. Miller
Principal Hydrogeologist, LBOPG License # 939

Wayne Prejean

Wayne Prejean, P.E.
Senior Engineer,
Louisiana P.E. License #32502

Jason S. Sills
Senior Engineer EI No. 20568

ATTACHMENT A

MO-2 SOIL$_{GW}$ METHOD 4

ed to develop a site-specific) groundwater concentrations indicate the GW_1, GW_2, or oundwater RECAP Standard 2.10).

ns (GW_{conc} and $Soil_{conc}$) that he COC between soil and hould be: (1) from the same and at equilibrium and /or

rd based on the current or ction 2.10 for groundwater in Table 3, determine the on H2.2.2, H2.2.3, or H2.2.4. pplied to the GW_2 risk-based lity criterion to define the ter partition equation in Step

sing the site-specific soil and ater RS identified in Step (2)

(EQ37)

	Input Value
er (mg/kg)	site-specific
	refer to Section H2.2
the POC (mg/l)	site-specific
(mg/kg)	site-specific

-specific $DAF_{Domenico}$ (EQ65)

pecific $DF_{Summers}$ (for $Soil_{GW1}$, fic $DAF_{Domenico}$ (for $Soil_{GW2}$, ield the maximum theoretical ause the groundwater RECAP

(EQ34)

(EQ35)

omenico (EQ36)

Area 2

H12		EC (mmhos/cm)	Soluble CL (mg/kg)	GW CL (mg/L)
H12	Soil:	63.7	20349	
H12	GW:			39200

▨ Calculated/Correlated

GW RS: 250 mg/L

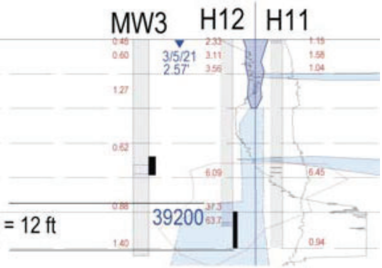
GW2: 250 mg/L
Gw_{conc}: 39200 mg/L
$Soil_{conc}$: 20349 mg/kg

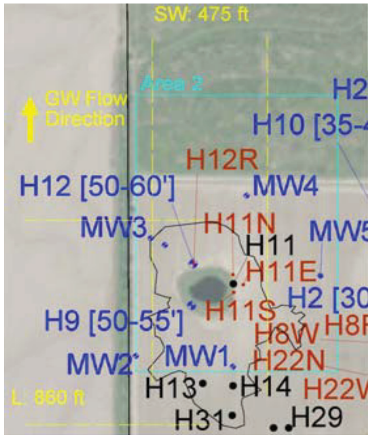
$Soil_{GW}$: **130 mg/kg**

Dfsummers = 2.276

$Soil_{GW}$: **130 mg/kg**

$Soil_{GW2}$ = **295 mg/kg** **0.925 EC (mmhos/cm)**





concentrations in groundwater are estimated using the Summers Model:

$DF_{Summers}$:

$$\frac{(Q_p + Q_a)}{Q_p} = \frac{C_l}{C_{si}} \qquad \textbf{(EQ61)}$$

where:

Parameter	Definition (units)	Input Value
C_{si}	constituent concentration in the groundwater (mg/l or g/m³)	--
Q_p	volumetric flow rate of infiltration (soil pore water) from the AOI into the aquifer (m³/day)	site-specific (refer to EQ61)
Q_a	volumetric flow rate of groundwater (m³/day)	site-specific (refer to EQ62)
C_l	dissolved constituent concentration in the liquid phase (mg/l)	site-specific (refer to EQ63)

The volumetric flow rate of infiltration from the AOI into the aquifer:

Q_p (m³/day):

$$I \times S_W \times L \qquad \textbf{(EQ62)}$$

where:

Parameter	Definition (units)	Input Value (Default Value)
Q_p	volumetric flow rate of infiltration (soil pore water) from the AOI into the aquifer (m³/day)	site-specific
I	infiltration rate (m/yr)	site-specific (0.1) [a]
S_W	source width perpendicular to groundwater flow (m)	site-specific
L	length of impacted area parallel to flow direction of aquifer (m)	site-specific

[a] *Soil Screening Guidance, User's Guide*, EPA 1996.

The volumetric flow rate of the groundwater is estimated as:

Q_a (m³/day):

$$D_v \times S_d \times S_W \qquad \textbf{(EQ63)}$$

where:

Parameter	Definition (units)	Input Value (Default Value)
Q_a	volumetric flow rate of groundwater (m³/day)	--
D_v	groundwater darcy velocity in the aquifer (K x i) (m/yr)	site-specific (9.144 m/yr)
S_d	source thickness (i.e., the thickness of the impacted groundwater within the permeable zone) (m)	refer to EQ39
S_W	width of impacted area perpendicular to flow direction of aquifer (m)	site-specific

The aqueous-phase concentration (C_l) is estimated from the total soil concentration (C_{Tw}) as follows:

C_l (mg/l):

$$C_{Tw}\left(\frac{[(\rho_w x \theta_w) + \rho_b]}{\rho_b K_d + \theta_w + (n - \theta_w) x H'}\right) \qquad \textbf{(EQ64)}$$

where:

Parameter	Definition (units)	Input Value (Default Value)
C_l	dissolved constituent concentration in the liquid phase (mg/l)	--
C_{Tw}	total soil concentration on a wet weight basis (mg/kg)	site-specific
ρ_w	density of water (g/cm³)	1.0
ρ_b	dry bulk density of soil (g/cm³)	site-specific (1.7) [a]
ρ_s	soil particle density (g/cm³)	site-specific (2.65) [a]
n	total porosity of soil (L_{pore}/L_{soil})	site-specific ($1 - \rho_b/\rho_s$)
θ_w	water filled soil porosity (L_{water}/L_{soil})	site-specific (0.21) [a]
K_{oc}	soil organic carbon partition coefficient (cm³/g)	chemical specific
f_{oc}	fractional organic carbon in soil = percent organic matter /174 (g/g) (ASTM 2974)	site-specific (0.006) [a]
K_d	soil water partition coefficient = K_{oc} x f_{oc} (cm³/g)	chemical-specific
H'	Henry's Law Constant (dimensionless)	chemical-specific [b]

[a] LDEQ default value.

[b] H' = H x 41 where: H = Henry's Law Constant (atm-m³/mol); R = Universal Law Constant (0.0000821 atm-m³/mole-°K); and T = Absolute temperature of soil (°K) [273 + °C (25°C)].

Qp = **10.39775749 m3/d**
Qa = **13 m3/d**
Cl = **82233 mg/L**

Dfsummers = 2.276

Csi = **36132 mg/L**

I = 0.1 m/yr
Sw = 475 ft 145 m
L = 860 ft 262 m

Qp = **10.4 m3/d**

Dv = 9.144 m/yr
Sd = 12 ft 3.66 m
Sw = 475 ft 145 m

Qa = **13.3 m3/d**

Ctw = 16361 mg/kg-wet 19.6 %moist 2034
ρw = 1 g/cm3
ρb = 1.7 g/cm3 EC = 63
ρs = 2.65 g/cm3
n = 0.36
θw = 0.21
Kd = 0.1 cm3/g

Cl = **82233 mg/L**

Note: For inorganic contaminants with no significant vapor pressure (chloride), H' is a to be equal to zero, eliminating that portion of the equation (EPA Soil Screening Guid Guide, EPA, 1996).

ed to develop a site-specific) groundwater concentrations n indicate the GW_1, GW_2, or oundwater RECAP Standard 2.10).

ns (GW_{conc} and $Soil_{conc}$) that he COC between soil and hould be: (1) from the same and at equilibrium and /or

rd based on the current or ction 2.10 for groundwater in Table 3, determine the on H2.2.2, H2.2.3, or H2.2.4. pplied to the GW_2 risk-based lity criterion to define the ter partition equation in Step

sing the site-specific soil and ater RS identified in Step (2)

(EQ37)

	Input Value
er (mg/kg)	site-specific
	refer to Section H2.2
the POC (mg/l)	site-specific
(mg/kg)	site-specific

-specific $DAF_{Domenico}$ (EQ65)

pecific $DF_{Summers}$ (for $Soil_{GW1}$, fic $DAF_{Domenico}$ (for $Soil_{GW2}$, ield the maximum theoretical ause the groundwater RECAP

(EQ34)

(EQ35)

Domenico **(EQ36)**

Area 4

H16		EC (mmhos/cm)	Soluble CL (mg/kg)	GW CL (mg/L)
H16	Soil:	21.7	6932	
H16	GW:			11900

🟨 Calculated/Correlated

GW RS: 250 mg/L

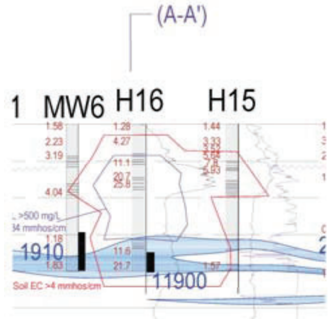
GW2: 250 mg/L
$GW_{conc:}$ 11900 mg/L
$Soil_{conc:}$ 6932 mg/kg

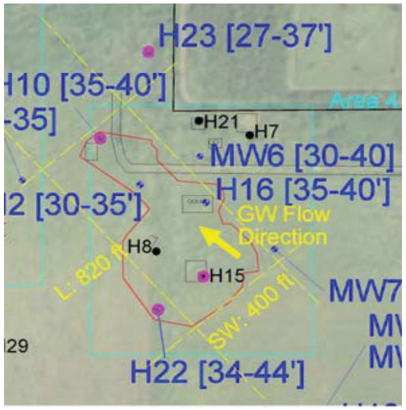
$Soil_{GW:}$ **146 mg/kg**

Dfsummers = 2.504

$Soil_{GW:}$ **146 mg/kg**

$Soil_{GW2}$ = **365 mg/kg** **1.142 EC (mmhos/cm)**





concentrations in groundwater are estimated using the Summers Model:

$DF_{Summers}$:

$$\frac{(Q_p + Q_a)}{Q_p} = \frac{C_l}{C_{si}} \qquad \textbf{(EQ61)}$$

where:

Parameter	Definition (units)	Input Value
C_{si}	constituent concentration in the groundwater (mg/l or g/m³)	--
Q_p	volumetric flow rate of infiltration (soil pore water) from the AOI into the aquifer (m³/day)	site-specific (refer to EQ61)
Q_a	volumetric flow rate of groundwater (m³/day)	site-specific (refer to EQ62)
C_l	dissolved constituent concentration in the liquid phase (mg/l)	site-specific (refer to EQ63)

The volumetric flow rate of infiltration from the AOI into the aquifer:

Q_p (m³/day):

$$I \times S_W \times L \qquad \textbf{(EQ62)}$$

where:

Parameter	Definition (units)	Input Value (Default Value)
Q_p	volumetric flow rate of infiltration (soil pore water) from the AOI into the aquifer (m³/day)	site-specific
I	infiltration rate (m/yr)	site-specific (0.1)[a]
S_W	source width perpendicular to groundwater flow (m)	site-specific
L	length of impacted area parallel to flow direction of aquifer (m)	site-specific

[a] *Soil Screening Guidance, User's Guide*, EPA 1996.

The volumetric flow rate of the groundwater is estimated as:

Q_a (m³/day):

$$D_v \times S_d \times S_W \qquad \textbf{(EQ63)}$$

where:

Parameter	Definition (units)	Input Value (Default Value)
Q_a	volumetric flow rate of groundwater (m³/day)	--
D_v	groundwater darcy velocity in the aquifer (K x i) (m/yr)	site-specific (9.144 m/yr)
S_d	source thickness (i.e., the thickness of the impacted groundwater within the permeable zone) (m)	refer to EQ39
S_W	width of impacted area perpendicular to flow direction of aquifer (m)	site-specific

The aqueous-phase concentration (C_l) is estimated from the total soil concentration (C_{Tw}) as follows:

C_l (mg/l):

$$C_{Tw}\left(\frac{[(\rho_w x\theta_w)+\rho_b]}{\rho_b K_d + \theta_w + (n-\theta_w)xH'}\right) \qquad \textbf{(EQ64)}$$

where:

Parameter	Definition (units)	Input Value (Default Value)
C_l	dissolved constituent concentration in the liquid phase (mg/l)	--
C_{Tw}	total soil concentration on a wet weight basis (mg/kg)	site-specific
ρ_w	density of water (g/cm³)	1.0
ρ_b	dry bulk density of soil (g/cm³)	site-specific (1.7)[a]
ρ_s	soil particle density (g/cm³)	site-specific (2.65)[a]
n	total porosity of soil (L_{pore}/L_{soil})	site-specific (1 - ρ_b/ρ_s)
θ_w	water filled soil porosity (L_{water}/L_{soil})	site-specific (0.21)[a]
K_{oc}	soil organic carbon partition coefficient (cm³/g)	chemical specific
f_{oc}	fractional organic carbon in soil = percent organic matter /174 (g/g) (ASTM 2974)	site-specific (0.006)[a]
K_d	soil water partition coefficient = K_{oc} x f_{oc} (cm³/g)	chemical-specific
H'	Henry's Law Constant (dimensionless)	chemical-specific[b]

[a] LDEQ default value.
[b] H' = H x 41 where: H = Henry's Law Constant (atm-m³/mol); R = Universal Law Constant (0.0000821 atm-m³/mole-°K); and T = Absolute temperature of soil (°K) [273 + °C (25°C)].

Qp = **7.35 m3/d**
Qa = **11.1 m3/d**
Cl = **26794 mg/L**

Dfsummers = 2.504

Csi = **10701 mg/L**

I =	0.1 m/yr	
Sw =	361 ft	110 m
L =	800 ft	244 m
Qp =	**7.35 m3/d**	

Dv =	9.144 m/yr	
Sd =	10 ft	3.05 m
Sw =	475 ft	145 m
Qa =	**11.1 m3/d**	

Ctw =	5331 mg/kg-wet	23.1 %moist		693
ρw =	1 g/cm3			
ρb =	1.7 g/cm3		EC =	21
ρs =	2.65 g/cm3			
n =	0.36			
θw =	0.21			
Kd =	0.1 cm3/g			
Cl =	**26794 mg/L**			

Note: For inorganic contaminants with no significant vapor pressure (chloride), H' is a to be equal to zero, eliminating that portion of the equation (EPA Soil Screening Guid Guide, EPA, 1996).

ATTACHMENT B

Dr. Richard Schuhmann, PhD Leaching Method Evaluation

Application of Field Method for Leaching of Contaminants of Concern from Soil

The LDEQ allows the use of SPLP results to quantify the leaching of contaminants of concern (CoCs) from soil within RECAP.[1] The LDNR has a different laboratory leaching procedure within 29B, the results of which are required for calculating leaching from soil. The US EPA and multiple states instead use first principles (*i.e.* equilibrium partitioning) to calculate a site specific value for CoCs leaching from soil; that equation (for inorganic, non-volatile CoCs) is as follows:[2]

$$C_T = [(C_L)(K_d)] + \left[(C_L)\left(\frac{\theta_w}{\rho_b}\right)\right]$$

The New Jersey Department of Environmental Protection published a critique of applying SPLP results to represent the soil-to-groundwater leaching process [*emphasis added*]:

> "Leachate concentrations measured under the conditions of the SPLP test *do not necessarily represent* leachate concentrations that would be observed in the field because the water to soil ratio affects the resulting leachate concentration. For *chemicals that are not strongly adsorbed*, a large percentage of the initial contaminant mass desorbs from soil during the SPLP extraction because of the large volume of extracting solution relative to soil."[3]
>
> "Leachate concentrations under *field conditions* are the *relevant data needed to compare against the leachate criteria or to calculate site-specific impact to ground water remediation standards.* These can be determined using the SPLP results, the known initial total soil concentration, and the assumptions underlying the basis of the USEPA soil water partition equation."[4]

Other states that have rejected SPLP results in favor of the US EPA partitioning equation for determining site-specific leaching-to-groundwater include: Georgia (Equation 2),[5] Montana (refers to NJ DEP guidance).[6]

---

[1] RECAP, 2003, Appendix H

[2] US EPA, Soil Screening Guidance – Users Guide, 1996, Equation 10, page 29, Soil Screening Level Partitioning Equation for Migration to Ground Water; US EPA, Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites, 2002, page 4-28, Equation 4-10 Soil Screening Level Partitioning Equation for Migration to Ground Water

[3] Guidance Document – Development of Site-Specific Impact to Ground Water Soil Remediation Standards using the Synthetic Precipitation Leaching Procedure, Version 3.0 - November 2013, Appendix C, New Jersey Department of Environmental Protection, Trenton, New Jersey

[4] Ibid

[5] Georgia Department of Natural Resources, Frequently Asked Questions for Evaluating the Soil-to-Groundwater Migration Pathway, Technical Guidance Document, October 18, 2019, page 9

[6] Montana Department of Environmental Quality, Montana Risk-Based Corrective Action Guidance for Petroleum Releases, May 2018, page 31

Essentially, the goal of all these methods is to quantify as accurately as possible the amount of a CoC moving from contaminated soil, percolating through the vadose zone, and entering underlying groundwater. Conservation of mass informs us that the total mass of a CoC in a soil sample is that residing within pore water and that adsorbed to soil particles. The relative mass of CoC within pore water is a function of that CoCs ability to partition into water; some CoCs are hydrophobic, while others are hydrophilic.

General Equation

$$Mass_{Total\ in\ sample} = Mass_{on\ solids} + Mass_{in\ liquid}$$

A review of the three methods (LDEQ RECAP, LDNR 29B, and US EPA Partitioning) appears below.

SPLP Method

$$C_T = [(C_{SPLP})\,(K_d)] + \left[(C_{SPLP})\left(\frac{V_L}{M_S}\right)\right]$$

Physical meaning: the total concentration of (*e.g.*) chloride (C_T) 0s equal to the concentration of chloride adsorbed to soil particles (C_{SPLP}*K_d) plus the concentration of chloride dissolved in laboratory leaching water (C_{SPLP}*(V_L/M_S).

2 Liters of extracting leachate solution (V_L) are added to 100 grams of soil (M_s).

$$\frac{V_L}{M_S} = \frac{2\ L}{100\ g} = \frac{0.02\ L}{g} = \frac{20\ mL}{g}$$

Physical meaning: In the SPLP Method there are 20 mL of water added for every gram of soil sample.

Assume C_{SPLP} is GW_1 target concentration of 5,000 mg/L (20*250 mg/L)

$$C_{SPLP} = \frac{5000\ mg}{L}$$

Assume K_d consistent with 2002/2006 BC studies

$$K_d = 0.1\left(\frac{\frac{mg}{kg}}{\frac{mg}{L}}\right)$$

Solving for C_T

$$C_T = C_{SPLP}\left[K_d + \left(\frac{V_L}{M_S}\right)\right]$$

$$C_T = 100{,}500\left(\frac{mg}{kg}\right)$$

C_T is the allowable concentration of chloride in soil to ensure groundwater does not exceed 5,000 mg/L

29B Method

In the LDNR 29B method, a representative sample of treated waste is extracted by continuous contact with water at a 1:4 solid:solution ratio.[7]

0.4 Liters of extracting leachate solution (V_L) are added to 100 grams of soil (M_s).

$$\frac{V_L}{M_S} = \frac{0.4\ L}{100\ g} = \frac{0.004\ L}{g} = \frac{4\ mL}{g}$$

Physical meaning: In the 29B Method there are only 4 mL of water added for every gram of soil sample.

Assume C_{SPLP} is GW_1 target concentration of 5,000 mg/L (20*250 mg/L)

$$C_{SPLP} = \frac{5000\ mg}{L}$$

Assume K_d consistent with 2002/2006 BC studies

$$K_d = 0.1\left(\frac{\frac{mg}{kg}}{\frac{mg}{L}}\right)$$

Solving for C_T

$$C_T = C_{SPLP}\left[K_d + \left(\frac{V_L}{M_S}\right)\right]$$

$$C_T = 20{,}500\left(\frac{mg}{kg}\right)$$

C_T is the allowable concentration of chloride in soil to ensure groundwater does not exceed

---

[7] LDNR, Laboratory Procedures for Analysis of Exploration & Production Waste, 1988, page 30

US EPA Method

$$C_T = C_L\left[K_d + \left(\frac{\theta_w}{\rho_b}\right)\right]$$

$$C_T = [(C_L)\,(K_d)] + \left[(C_L)\left(\frac{\theta_w}{\rho_b}\right)\right]$$

Physical meaning: the total concentration of (*e.g.*) chloride (C_T) in a soil sample is equal to the concentration of chloride adsorbed to soil particles (C_L*K_d) plus the concentration of chloride dissolved in pore water (C_L*(θ_w/ρ_b)).

$$\frac{\theta_W}{\rho_b} = \frac{0.3\ \dfrac{mL_{water\ voids}}{mL_{soil}}}{1.5\ g_{soil}/mL_{soil}} = \frac{0.2\ mL_{water}}{g_{soil}}$$

Physical meaning: there is 0.2 mL of water present in every gram of soil.

Assume C_L is GW_1 target concentration of 5,000 mg/L (20*250 mg/L)

$$C_L = \frac{5000\ mg}{L}$$

Assume K_d consistent with 2002 BC study

$$K_d = 0.1\left(\frac{\frac{mg}{kg}}{\frac{mg}{L}}\right)$$

Solving for C_T

$$C_T = C_L\left[K_d + \left(\frac{\theta_w}{\rho_b}\right)\right]$$

$$C_T = 1{,}500\left(\frac{mg}{kg}\right)$$

Allowable concentration of chloride in soil to protect groundwater to 1,500 mg/L

Why do these three method results differ?

(1) The SPLP Method relies upon 20 mL of water (dilution) for every gram of soil.

(2) The 29B Method relies upon 4 ml of water (dilution) for every gram of soil.

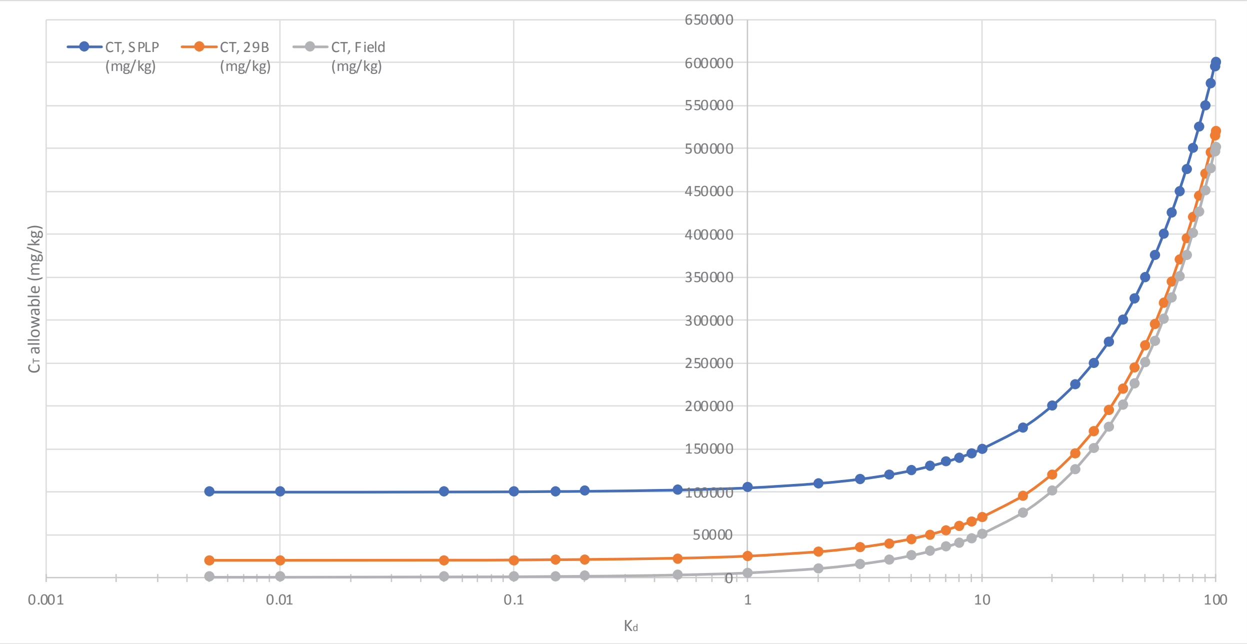
(3) The Field Method relies on first principles to calculate the presence of only 0.2 mL of pore water is present in each gram of soil.

(4) Because K_d is very small (0.1) as compared with the SLPL leachate volume (2 L) and 29B leachate volume (0.4 L) but not when compared with the volume of water present in a natural soil (0.02 L), the equation is sensitive to this dilution discrepancy for chloride.

(5) This sensitivity results in a K_d value of 0.1 returning a final C_T value for the SPLP Method that is 67 times greater than that calculated for the Field Method, and a final C_T value for the 29B Method that is 14 times greater than that calculated for the Field Method.

K_d (L/kg)	**$C_{T,\ SPLP}$ (mg/kg)**	**$C_{T,\ 29B}$ (mg/kg)**	**$C_{T,\ Field}$ (mg/kg)**	**$C_{T,\ SPLP}/C_{T,\ Field}$**	**$C_{T,\ 29B}/C_{T,\ Field}$**
0.005	100025	20025	1025	97.6	20
0.01	100050	20050	1050	95.3	19
0.05	100250	20250	1250	80.2	16
0.1	100500	20500	1500	67.0	14

(6) As the K_d value increases (*e.g.* different soil or other chemicals) the discrepancy between the SPLP, the 29B, and the Field Methods decreases.



(7) Although the discrepancy between methods decreases, it "never" reaches zero (*e.g.* assuming 99% of chemical remains sorbed to soil particles, the SPLP Method still predicts a C_T 20% greater than that resulting from the Field Method).
(8) For chemicals with <u>extremely</u> large K_d values, there is the opportunity for leaching approximation using SPLP results (*e.g.* K_d = 1000, 2% discrepancy with Field Method; K_d = 5000 (DDT), 0.4% discrepancy with Field Method); however, this appears to be an exception rather than a rule.

Conclusions
(1) The SPLP can be used to measure a site specific K_d for some chemicals of concern.
(2) Because chloride has such a low K_d, it is difficult to analytically quantify, even with approaches much more sensitive (*e.g.* greater soil sample to leachate ratio) than the SPLP Method); therefore, the SPLP is not an effective method for the determination of chloride K_d.
(3) The SPLP test results can be used to directly represent soil leachate under field conditions if the chemicals of concern have very large Kd values (e.g. >>1000).
(4) Given its low K_d (0.1), the SPLP test results cannot be used to directly represent soil leachate under field conditions for chloride.

ATTACHMENT C

Dr. Richard Schuhmann, PhD Wet Weight v Dry Weight

Wet Weight vs. Dry Weight Relevant Literature and Appropriate Applications

It is generally accepted and required by the scientific community that exposure assessment from inorganic chemical soil ingestion and dermal absorption rely upon the dry weight concentrations of the contaminants of concern and not wet weight.

The exposure pathways of incidental ingestion and dermal contact with inorganic chemicals in soil are considered in the equations used to calculate the LDEQ RECAP SS_{ni} and MO-1 $Soil_{ni}$ standards for a non-industrial (residential) receptor. Dermal absorption is a less significant pathway because the absorption coefficient for inorganics (excluding Arsenic and Cadmium) is zero.

The equations and inputs for the direct contact soil ingestion pathway are based upon the following definitions and principles (*emphasis added*):

> **Soil**
> "Particles of unconsolidated mineral and/or organic matter from the earth's surface that are located outdoors, or are used indoors to support plant growth. *It includes* particles that have settled onto outdoor objects and surfaces (*outdoor settled dust*)."[1]
>
> **Outdoor Settled Dust**
> "Particles that have settled onto outdoor objects and surfaces due to either wet or dry deposition. Note that it may not be possible to distinguish between soil and outdoor settled dust because outdoor settled dust *generally is present on the uppermost surface layer of soil*."[2]
>
> **Indoor Settled Dust**
> "Particles in building interiors that have settled onto objects, surfaces, floors, and carpeting. These particles *may include soil particles* that have been tracked or blown into the indoor environment *from outdoors*, as well as organic matter."[3]
>
> **Ingestion**
> "For the purposes of this handbook, soil ingestion includes both soil and *outdoor settled dust*, and dust ingestion includes *indoor settled dust only*."[4]
>
> **Soil Ingestion**

---

[1] USEPA, 2017, Update for Chapter 5 of the Exposure Factors Handbook, Soil and Dust Ingestion, EPA/600/R-17/384F, page 5-2

[2] USEPA, 2017, Update for Chapter 5 of the Exposure Factors Handbook, Soil and Dust Ingestion, EPA/600/R-17/384F, page 5-2

[3] USEPA, 2017, Update for Chapter 5 of the Exposure Factors Handbook, Soil and Dust Ingestion, EPA/600/R-17/384F, page 5-2

[4] USEPA, 2017, Update for Chapter 5 of the Exposure Factors Handbook, Soil and Dust Ingestion, EPA/600/R-17/384F, page 5-2

"Soil ingestion is the consumption of soil. This may result from various behaviors including, but not limited to, mouthing, contacting dirty hands, eating dropped food, or consuming soil directly."[5]

Dust Ingestion

"The *dust ingestion* recommendations in Table 5-1 *include soil tracked into the indoor setting*, indoor settled dust, and air-suspended particulate matter that is inhaled and swallowed. "Dust" recommendations are provided in the event that assessors need recommendations for an indoor or inside a transportation vehicle scenario in which dust, but not outdoor soil, is the exposure medium of concern."[6]

Soil + Indoor Dust Ingestion

"The soil + dust recommendations would include soil, either from outdoor or containerized indoor sources, *dust* that is a combination of outdoor settled *dust*, indoor settled *dust*, and *air-suspended particulate matter* that is inhaled, subsequently trapped in mucous and moved from the respiratory system to the gastrointestinal tract, and a soil-origin material located on indoor floor surfaces that was tracked indoors by building occupants."[7]

"*The soil ingestion* recommendations in Table 5-1 are *intended to represent ingestion of a combination of soil and outdoor settled dust*, *without distinguishing between these sources*. The source of the soil in these recommendations could be outdoor soil, indoor containerized soil used to support growth of indoor plants, or a combination of both outdoor soil and containerized indoor soil. The inhalation and subsequent swallowing of soil particles is accounted for in these recommended values; therefore, this pathway does not need to be considered separately. These recommendations are called "soil.""[8]

"The recommended values for soil ingestion only and dust ingestion only are based on the assumption that *45% of the soil + dust ingestion can be attributed to soil and 55% can be attributed to dus*t."[9]

"Soil", "Dust" and "Soil+Dust" Ingestion Rate Values

USEPA and LDEQ soil, dust and soil+dust ingestion rates are compared below to illustrate their relationship: the USEPA soil+dust ingestion rate is identical to the LDEQ soil ingestion rate.

USEPA[10]	Soil	50 mg/day[11]

---

[5] USEPA, 2017, Update for Chapter 5 of the Exposure Factors Handbook, Soil and Dust Ingestion, EPA/600/R-17/384F, page 5-1

[6] USEPA, 2017, Update for Chapter 5 of the Exposure Factors Handbook, Soil and Dust Ingestion, EPA/600/R-17/384F, page 5-3

[7] USEPA, 2017, Update for Chapter 5 of the Exposure Factors Handbook, Soil and Dust Ingestion, EPA/600/R-17/384F, page 5-4

[8] USEPA, 2017, Update for Chapter 5 of the Exposure Factors Handbook, Soil and Dust Ingestion, EPA/600/R-17/384F, page 5-3

[9] USEPA, 2017, Update for Chapter 5 of the Exposure Factors Handbook, Soil and Dust Ingestion, EPA/600/R-17/384F, page 5-4

USEPA[12]	Dust	60 mg/day[13]
USEPA[14]	Soil+Dust	100 mg/day[15]
LDEQ[16]	Soil	100 mg/day[17]

Given the LDEQ "RECAP is consistent with the Environmental Protection Agency's (EPA) guidance on risk assessment",[18] as can be seen from the previous definitions and the comparative ingestion rates presented above, the LDEQ appears to use the term "soil" to account for the ingestion of both soil and dust (*i.e.* what the USEPA explicitly calls "soil + dust"). Given that soil and dust is a combination of outdoor settled dust, indoor settled dust, and air-suspended particulate matter that is inhaled, and a soil-origin material located on indoor floor surfaces that was tracked indoors by building occupants, it should be clear why a dry weight concentration is appropriately used in both the USEPA and LDEQ RECAP risk/hazard equations for the soil ingestion pathway and not a wet weight.

The use of dry weight by environmental scientists, practitioners, and regulators is not unusual- it is the accepted norm. Relevant quotes (*emphasis added*) and sources supporting of the use of dry weight and not wet weight for hazard assessments using the equation above[19] from ingestion and dermal absorption of non-industrial inorganic constituents of concern in soil are provided below:

> "The soil SLs are based on *dry weight* because the soil intake rates are based on *dry weight*. Most soil data is typically reported as *dry weight*."
> USEPA (2020)[20]
>
> "Soil and dust recommendations *exclude the soil or dust's moisture content*. In other words, recommended values represent mass of ingested soil or dust that is represented on a *dry-weight* basis."
> USEPA (2011)[21]
>
> "Reporting of *soil and/or sediment data for use in a human health risk assessment* in *dry weight is necessary* to ensure consistency between the

---

[10] USEPA, 2017, Update for Chapter 5 of the Exposure Factors Handbook, Soil and Dust Ingestion, EPA/600/R-17/384FTable 5-1

[11] Adult, General Population Upper Percentile

[12] USEPA, 2017, Update for Chapter 5 of the Exposure Factors Handbook, Soil and Dust Ingestion, EPA/600/R-17/384FTable 5-1

[13] Adult, General Population Upper Percentile

[14] USEPA, 2017, Update for Chapter 5 of the Exposure Factors Handbook, Soil and Dust Ingestion, EPA/600/R-17/384FTable 5-1

[15] Adult, General Population Upper Percentile; note: (f) Estimates of soil and dust were derived from the soil + dust values assuming 45% soil and 55% dust, rounded to one significant figure.

[16] RECAP 2003, Appendix H, Equations, Exposure Parameter Tab, IRS_a,

[17] Adult soil ingestion rate ages 7-31

[18] LDEQ, RECAP, 2003, Preamble

[19] Note: this applies to risk assessment as well; however the fundamental equation differs in that, for example, a cancer slope factor is used and the averaging time is different

[20] https://www.epa.gov/risk/regional-screening-levels-frequent-questions

[21] USEPA (2011). Exposure Factors Handbook, Chapter 5—Soil and Dust Ingestion, page 5-3

> reporting units for the contaminant levels in the environmental medium of concern (soil or sediment) and the exposure factor intake rates."
> Ohio EPA (2012)[22]

The sentence below from RECAP 2003 is somewhat unfortunate as it is non-specific and allows room for misinterpretation:

> "Typically, exposure concentrations (and the risk-based SS and RS) are based on a wet-weight concentration whereas source concentrations (and environmental fate and transport SS and RS) are based on a dry-weight concentration."[23]

Although no portion of the draft RECAP 2019 revision can be used to evaluate or support current site management decisions (including the proposed screening standards and MO-1 standards),[24] it is relevant that the sentence above no longer exists in the 2019 version and in fact the following three very definitive statements are associated with the only three uses of "dry weight" in the document (*emphasis added*):

> "The data shall be presented in units of mg/kg (soil, sediment, and biota), mg/l (water), or ⍰g/m3 (air). *Soil and sediment shall be reported on a dry weight basis unless otherwise approved by the Department* to address site-specific concerns."[25]

> "The AOI concentration (AOIC) is defined as: 1) the concentration of the COC in the soil to which the receptor is, or may be, exposed in the future; and/or 2) the concentration of the COC in soil that may serve as a source for constituent transport and/or transfer to another environmental medium. The AOIC is the concentration of the COC in the soil that is compared to the limiting SS or the MO-1, MO-2, or MO-3 limiting RS. *The soil AOIC shall be based on dry weight*, presented in unit of parts per million (ppm) (mg/kg) and presented with 2 significant digits unless otherwise approved by the Department."[26]

> "The AOIC for sediment shall be determined using the method(s) deemed most appropriate for the environmental fate and transport and/or exposure pathways identified for evaluation at the AOI. The AOIC shall be based on an upper bound estimate of the average COC concentration within the AOI. The methods used to determine the sediment AOIC are dependent on the pathway(s) of concern and are subject to Department approval. *The sediment AOIC shall be presented in units of mg/kg on a dry weight basis* and shall be presented with 2 significant digits unless otherwise approved by the Department."[27]

---

[22] Ohio EPA (2012). Technical Guidance Compendium, VA30007.14.021. Soil and Sediment Sampling: Wet Weight versus Dry Weight

[23] LDEQ, RECAP, 2003, pages 45-46

[24] https://www.deq.louisiana.gov/page/recap-2019

[25] RECAP 2019, page 30

[26] RECAP 2019, page 37

[27] RECAP 2019, page 47

Wet weight concentrations may have a restricted application to risk assessment from direct soil ingestion.

Soil ingestion includes "consuming soil directly",[28] a phenomenon associated with geophagy. Geophagy is the *intentional* consumption of soil and is usually associated with cultural practices. In contrast with Pica behavior, geophagy typically involves the consumption of clay soil from a greater soil depth (*e.g.* greater than 3 inches). In 1979, a community in rural Mississippi reported the occurrence of geophagia in 57% of women and in 16% of children (50,000 mg/day average consumption for children and adults),[29] a percentage similar to those associated with pica behavior. A risk assessor might apply wet weight soil concentrations in a site-specific assessment of geophagy.

---

[28] USEPA, 2017, Update for Chapter 5 of the Exposure Factors Handbook, Soil and Dust Ingestion, EPA/600/R-17/384F, page 5-1

[29] Vermeer, D.E.; Frate, D.A. (1979) Geophagia in rural Mississippi: environmental and cultural contexts and nutritional implications. Am J Clin Nutr 32:21292135.