In the Matter of

PR Spring Tar Sands Project, Ground Water Discharge Permit-by-Rule

No. WQ PR-11-001

PREPARED DIRECT TESTIMONY

OF

WILLIAM P. JOHNSON, Ph.D

ON BEHALF OF

LIVING RIVERS

January 20, 2012

I.   INTRODUCTION AND QUALIFICATIONS

Q.   PLEASE STATE YOUR NAME?

A.   My name is William P. Johnson

Q.   BY WHOM ARE YOU EMPLOYED AND WHAT IS YOUR POSITION?

A.   I am a professor in the department of Geology & Geophysics and an adjunct professor in

the department of Civil & Environmental Engineering at the University of Utah.

Q.   FOR WHOM ARE YOU TESTIFYING IN THIS PROCEEDING?

A.   I am testifying on behalf of Living Rivers.

Q.   WOULD YOU PLEASE SUMMARIZE YOUR EDUCATIONAL AND

PROFESSIONAL BACKGROUND?

A.   Since 1995 I have been a professor conducting research and teaching graduate and

undergraduate courses in the subject of contaminant hydrogeology. I have authored, or served as

corresponding author, on over 75 peer-reviewed publications, including several specifically

regarding organic contaminant solubilization and transport. I serve as a reviewer for more than 15

scientific journal and three panels of the National Science Foundation. My doctoral degree is in

Civil (Environmental) Engineering from the University of Colorado (1993). More detail on my

background is provided in Appendix A.

II.   PURPOSE AND SUMMARY OF TESTIMONY

Q.   WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A.   My testimony will discuss the effect of re-distribution of d-limonene-processed tar sands to the land surface in the area of the PR Spring Mine.

Q.   WOULD YOU PLEASE SUMMARIZE YOUR TESTIMONY?

A.   My testimony will demonstrate that re-distribution of these sands to the land surface in the area of the PR Spring Mine poses an increased risk of exposure to carcinogenic compounds via two mechanisms: 1) order of magnitude or more increases in the aqueous concentrations of carcinogenic compounds; 2) factor of 4 increases in the rate of transport of carcinogenic compounds in groundwater. The increased aqueous concentration for a tar compound such as benzo(a)pyrene is nearly 1500 times greater than its normal water solubility, and is more than 400,000 times greater than the drinking water limit for this compound. Both of these increases (concentration and mobility) result from the mixing of d-limonene with tar compounds. Under natural conditions, the risk of exposure to carcinogenic tar compounds is negligible due to the negligible mobility and low aqueous concentrations of these compounds. However, the combination of tar compounds with d-limonene reverses these characteristics by increasing the aqueous concentration and mobility of the tar compounds. The increase in tar compound concentration and mobility constitutes a significant increase in the risk of exposure, and therefore warrants appropriate down-gradient monitoring for the potential increased concentration and transport of tar compounds emanating from the site.

1   Additionally, I will discuss: 1) why it was inappropriate for DWQ to rely on the MSDS

2   sheets provided by the company in determining the toxicity of the reagent; 2) that DWQ did not

3   require the company to conduct the appropriate tests to assess the potential for leaching of

4   petrochemicals from the processed ore to water; and, 3) that it was inappropriate for DWQ to

5   conclude that the processed sediment is "damp-dry" because it is, in fact, saturated with fluid

6   based on water contents provided by the company.

7

8   Q.   CAN YOU BRIEFLY DESCRIBE D-LIMONENE?

9   A.   Based on the properties listed in Appendix B, d-limonene is a small molecule that is

10   readily transported to air. Therefore d-limonene by itself will likely vaporize/volatilize readily to

11   the atmosphere.

12

13   Q.   CAN YOU DESCRIBE UTAH TAR SANDS COMPOUNDS?

14   A.   Based on information regarding Utah tar sand compounds provided in Appendix C, these

15   compounds likely include polycyclic aromatic hydrocarbons (PAH) which are known human

16   carcinogens. The tar exists as a semi-solid, and so has no significant propensity to migrate into

17   the subsurface as a phase. By themselves, the PAH compounds and aliphatic chains comprising

18   the tar are highly insoluble in water, and so despite the significant carcinogencity of at least some

19   of these component compounds, they are not expected to undergo significant transport in site

20   runoff or site groundwater, greatly limiting the possibility of exposure to these compounds.

21

22   Q.   WHY ARE YOU CONCERNED ABOUT THE CARCINOGENCITY OF UTAH TAR

23   SANDS COMPOUNDS WITH THE PR SPRING MINE?

4

1   A.   Concern arises with the PR Spring Mine because the operator of that mine proposes to

2   separate the bitumen from the tar sands using d-limonene, and my concern is the combination of

3   these Utah tar sands compounds as a mixture, i.e. the d-limonene-solubilized tar compounds.

4   The organic mixture of d-limonene and tar compounds has different properties than the two

5   parent mixtures in terms of vaporization, volatilization, and dissolution, and in terms of whether

6   the mixture acts as a semi-solid or a liquid. These altered physicochemical properties yield novel

7   transport properties relative to the parent compounds.

8

9   Q.   HOW SO?

10   A.   Note that these three properties: 1) the semi-solid phase nature of the tar; 2) the very low

11   solubility of the tar compounds; and 3) the very low mobility of the tar compounds are precisely

12   what allow these compounds, under natural conditions, to be considered relatively benign.

13   However, combining d-limonene with the tar compounds reverses the above attributes.

14   Specifically: 1) the mole fraction of d-limonene in the organic mixture may become sufficiently

15   large that the mixture will act as a liquid rather than semi-solid, thereby increasing the propensity

16   of this liquid mixture to infiltrate directly into the subsurface; 2) mixing with d-limonene will

17   increase the apparent water solubility of the tar compounds by orders of magnitude, far above

18   ambient levels, thereby greatly increasing the potential dose upon exposure for the ecosystem; 3)

19   the solubilization of tar compounds by d-limonene will significantly increase the transport rate of

20   the tar compounds in the pore water underlying the site, thereby greatly increasing the risk of

21   exposure.

22

1 Q.   WHY DOES THE D-LIMONENE-SOLUBILIZED TAR COMPOUND HAVE THE

2 PROPENSITY TO INFILTRATE DIRECTLY INTO THE SUBSURFACE?

3 A.   Let me first note that the residual concentration of d-limonene in re-distributed sediment

4 was not provided to me initially. I therefore first assumed that it was reasonable to expect that

5 the d-limonene content in this d-limonene/tar mixture residual was sufficient to cause the

6 mixture to act as a liquid rather than a semi-solid phase that is characteristic of tar. This

7 assumption was confirmed by information provided by the company to Living Rivers' attorneys.

8 This tendency to act as a liquid rather than a semi-solid phase creates a profound change in the

9 mobility of the tar compound phase by way of two mechanisms: a) by changing their phase from

10 an organic semi-solid to an organic liquid, which is potentially more mobile than the semi-solid

11 phase. The high potential mobility of organic liquids is why disposal of non-containerized

12 hazardous liquids is not allowed in RCRA/CERCLA legislation; b) via vast increases in the

13 groundwater solubility and mobility of the tar compounds in response to equilibration with

14 d-limonene, as demonstrated in the calculations substantiating concerns (2) and (3) below.

15

16 Q.   HOW DID YOU GO ABOUT SUBSTANTIATING CONCERN (2) THAT MIXING

17 WITH D-LIMONENE WILL INCREASE THE WATER SOLUBILITY OF THE TAR SANDS

18 COMPOUNDS BY ORDER OF MAGNITUDE, AND CONCERN (3) THAT THIS

19 SOLUBILIZATOIN WILL SIGNIFICANLY INCREASE THE TRANSPORT RATE OF THE

20 TAR COMPOUNDS, THUS GREATLY INCREASING THE RISK OF EXPOSURE?

21 A.   To substantiate these two concerns, the following calculations are provided for a

22 representative PAH compound, namely: (2) the factor by which the solubility of PAH is

23 increased in the presence of d-limonene relative to water; and, (3) the factor by which the

1   transport time of PAH over a given distance is decreased in the presence versus absence of

2   d-limonene. The calculations are made using benzo(a)pyrene as a representative PAH. B(a)P has

3   five fused aromatic rings. The choice of this compound is not critical to demonstrate the changes

4   in transport of tar compounds in response to solubilization by d-limonene. Any PAH compound

5   with four or more rings, and any unsubstituted alkane with approximately ten or more carbon

6   atoms, will show similar effects. Such sizes of compounds (and larger) are expected to dominate

7   the tar (Appendix B).
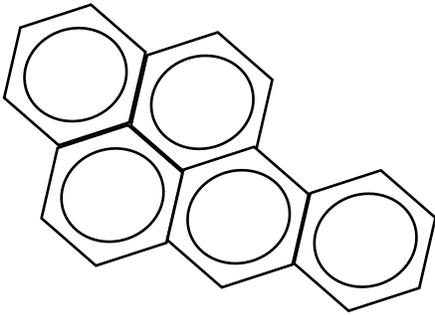
8
9   Benzo(a)pyrene data (from reference 5):
10
11   Molecular weight   = 252.3 gmol^{-1}

12   Melting temperature   = 176.5 $^\circ$C

13   C^{sat}_w (s,25^{0}C) = 1.52 µgL^{-1}

14   C^{sat}_w (L,25^{0}C) = 49.19 µgL^{-1}

15

16   Q.   HOW DID YOU CALCULATE THE FACTOR BY WHICH THE SOLUBILITY OF

17   PERYLENE IN WATER IS INCREASED?

18   A.   I calculated that factor as follows:

19   The normal solubility of B(a)P dissolving from solid tar in water (C^{sat}_w) at room temperature is

20   1.5 µgL^{-1}. When d-limonene is added to the water, it creates a liquid organic mixture, and this

21   rises the solubility of B(a)P since it is dissolving not from solid tar, but from liquid d-limonene.

1   The solubility of B(a)P dissolving from an organic liquid is 49.2 μgL^{-1}, which is more than 30

2   times greater than that dissolving from solid tar. However, this effect is small relative to the

3   further increase in B(a)P concentrations in water that result from d-limonene dissolving into

4   water. Since d-limonene has a strong affinity for B(a)P, and since d-limonene has a much

5   higher water solubility (13,800 μgL^{-1}) than B(a)P, the dissolved d-limonene essentially coaxes

6   the B(a)P into the aqueous phase, raising the apparent solubility of B(a)P in the aqueous phase

7   (C^{*}_{w}). The extent to which the apparent water solubility of B(a)P is raised relative to its

8   normal water solubility is directly proportional to: 1) the concentration of d-limonene in

9   solution (C^{dl}_{w}); and, 2) the affinity of B(a)P for d-limonene, as measured by the distribution

10   coefficient for B(a)P between water and d-limonene $K^{B(a)P}_{dl}$. The corresponding equation is:

11     $$C^{*}_{w} = C^{sat}_{w} + C^{sat}_{w} K^{B(a)P}_{dl} C^{dl}_{w}$$

12

13   The concentration of d-limonene expected in water will vary depending on scenario.

14   Upon re-distribution of the residual tar sand to the land surface, it is reasonable to expect

15   residual d-limonene to dissolve into pore water to a concentration representing its normal water

16   solubility. Solubilities vary with temperature; however, temperature corrections are not made

17   here since the comparison between presence versus absence of d-limonene will be similar

18   regardless of which temperature (e.g. 25 versus 5 Celsius) is used. The room temperature

19   solubility of d-limonene in water is herein used to represent C^{dl}_{w} (13.8 mg/L).

20   The value for $K^{B(a)P}_{dl}$ can be approximated by the distribution coefficient for B(a)P

21   between water and octanol ($K^{B(a)P}_{ow}$). This value will underestimate the solubility

22   enhancement of B(a)P by d-limonene, since octanol is a somewhat more polar solvent than d-

1   limonene, which makes octanol slightly less ideal than d-limonene for solubilization of the

2   non-polar compound B(a)P.   The value of $K^{B(a)P}_{ow}$ is available in reference 5, hence:

3   $$K^{B(a)P}_{dl} \approx K^{B(a)P}_{oct} = 10^{6.50} = 3{,}162{,}278$$

4   Inserting the above values into the equation, the apparent solubility in water is calculated:

5   $$C^*_w = \frac{49.2\ \mu g_{B(a)P}}{L_w} + \frac{49.2\ \mu g_{B(a)P}}{L_w} \left[\frac{3{,}162{,}278 L_w}{Kg_{dl}}\right]\left[\frac{13.8 mg_{dl}}{L_w}\right]\frac{1 kg_{dl}}{10^6 mg_{dl}}$$

6   $$C^*_w = \frac{2196\ \mu g_{B(a)P}}{L_w} = \frac{2.2\ mg_{B(a)P}}{L_w}$$

7   Hence, the concentration of B(a)P in water will increase in the presence of d-limonene by a

8   factor of over 1440, from 1.5 to 2200 µg/L.

9

10 Q.   WHAT IS THE SIGNIFICANCE OF THIS INCREASED CONCENTRATION?

11 A.   To understand the significance of this concentration, a simple risk-based cleanup level in

12 groundwater can be determined (Appendix C). The groundwater concentration supporting a

13 1E-6 excess risk of contracting cancer as a result of drinking groundwater from the site

14 contaminated with benzo(a)pyrene is 0.00479 µg/L. The expected 2200 µg/L concentration is

15 a factor of 458,455 greater than this risk-based concentration. If a 1E-5 risk of contracting

16 cancer were used, the concentration limit would be 0.0479 µg/L and the expected

17 concentration would be a factor of 45,845 above this limit. If a 1E-4 risk of contracting cancer

18 were used to define the concentration limit, the concentration limit would be 0.479 µg/L and

19 the expected concentration would be a factor of 4,584 above this limit. Therefore, even limited

20 ingestion, or ingestion of diluted groundwater from the site, would be expected to carry

21 significant carcinogenic risk.

1   If no groundwater supply wells exist down-gradient of the site, or if no ingestion of site

2   groundwater by humans is expected, the concern for ecosystem health remains significant since

3   PAHs bioaccumulate through the food chain because they are retained in lipophilic tissues (for

4   the same reason they are solubilized in d-limonene). The result strongly suggests a need for

5   monitoring of site groundwater for elevated PAH concentrations in response to redistribution

6   of sediments containing the d-limonene/tar mixture.

7

8   Q.   HOW DID YOU CALCULATE THE FACTOR BY WHICH THE TRANSPORT TIME

9   OF B(A)P IS DECREASED IN THE PRESENCE OF D-LIMONENE?

10   A.   The factor by which the transport time of B(a)P is decreased in the presence versus

11   absence of d-limonene is calculated based on the so-called retardation factor for B(a)P

12   transport. The retardation factor represents the ratio of the velocity of an average water

13   molecule relative to the velocity of the average B(a)P molecule in groundwater. For the

14   system with no d-limonene, the retardation factor reflects the partitioning of B(a)P and other

15   PAH compounds between water and sediment (sand). As groundwater moves through the

16   subsurface, B(a)P dissolved in the groundwater partitions between the water and the

17   surrounding sediment according to a distribution constant between water and sediment (K_d).

18   The distribution process is often considered to be near local equilibrium in groundwater

19   because of the relatively slow velocities involved in groundwater flow. Because the tar sands

20   are rich in organic carbon (including tar), and these compounds provide a compatible

21   environment for non-polar compounds such as PAH, the partitioning of PAH between water

22   and sand is driven by the affinity of the PAH compounds for the organic compounds (K_{om}),

1 and the fraction of sediment mass comprised by organic compounds (f_{om}). As a result, the

2 equilibrium constant for distribution of PAH between water and sediment can be calculated as:

3 $K_d = K_{om} f_{om}$

4 The value of f_{oc} will be taken to equal 0.1%, i.e., 1 g tar per 1 kg sand. The specific value

5 used for f_{om} will not greatly affect the analysis since the goal is to examine the effect of d-

6 limonene on the retardation of PAH, using B(a)P as an example.

7 The value for K_{om} is obtainable using free energy relationships given in reference 5, for

8 example:

9 $Log K_{om} = 0.81 Log K_{ow} - 0.25$

10 $Log K_{om} = 0.81(6.60) - 0.25$

11 $K_{om} = 124,738$

12 Therefore:

13 $K_d = \dfrac{124,738 L_w}{Kg_{om}} \dfrac{1 g_{om}}{1 Kg_{sand}} \dfrac{1 Kg_{om}}{1000 g_{om}}$

14 $K_d = 124.7 \dfrac{L_w}{Kg_{sand}}$

15 The retardation factor (R) is obtained from:

16 $R = 1 + \dfrac{\rho_b}{\theta} K_d$

17 Where ρ_b and θ are the bulk density and the porosity, respectively, of the sand. Using

18 representative values of ρ_b and θ equal to 1.7 and 0.35, respectively, yields:

19 $R = 1 + \dfrac{1.7\, Kg_{sand}}{L_{aquifer}} \left[\dfrac{1 L_{aquifer}}{0.35 L_w} \right] \left[\dfrac{124.7 L_w}{Kg_{sand}} \right]$

20 $R = 607$

21

1   Q.   WHAT IS THE SIGNIFICANCE OF THIS CALCULATION?

2   A.   The significance is that B(a)P will take a factor of 607 times longer than the average

3   water molecule to achieve a given travel distance in groundwater due to partitioning of the

4   B(a)P between sediment tar and groundwater. In other words, if the water takes 1 year to

5   travel 1000 meters, the B(a)P will take 607 years to travel the same distance. This is precisely

6   why the tar compounds do not move appreciable distances from their source in groundwater,

7   and why they are not considered problematic despite their significant carcinogenicities.

8

9   Q.   WHAT HAPPENS WHEN YOU ADD D-LIMONENE TO THE SYSTEM?

10   A.   However, the addition of d-limonene to the system causes a major change in the transport

11   characteristics of B(a)P and other hydrophobic compounds, and this is discerned in the so-

12   called modified retardation factor (R^*). The modified retardation factor accounts not only for

13   the distribution of B(a)P between water and sediment, but also for the distribution of B(a)P

14   between water and d-limonene (K^{peryl}_{dl}), as well as the distribution of d-limonene between

15   water and sediment (K^{dl}_{d}), as follows:

16

$$R^* = \frac{1 + \frac{\rho_b}{\theta} K_d + K_{dl}^{B(a)P} C_w^{dl} + K_{dl}^{B(a)P} K_d^{dl} C_w^{dl} \frac{\rho_b}{\theta}}{1 + K_{dl}^{B(a)P} C_w^{dl}}$$

17   An approximate value for K^{dl}_{d} is obtained by applying the linear free energy relationship

18   to determine the partition coefficient for d-limonene between water and sediment organic

19   matter (tar):

20     $LogK^{dl}_{om} = 0.81LogK_{ow} - 0.25$

21     $LogK^{dl}_{om} = 0.81(4.2) - 0.25$

22     $K^{dl}_{om} = 1419$

1   Therefore:

2    $$K_d^{dl} = \frac{1419 L_w}{Kg_{om}} \frac{1 g_{om}}{1 Kg_{sand}} \frac{1 Kg_{om}}{1000 g_{om}}$$

3    $$K_d^{dl} = 1.42 \frac{L_w}{Kg_{sand}}$$

4   An approximate value for $K^{B(a)P}{}_{dl}$ is obtained using linear free energy relationships using

5   the conservative but reasonable assumption that the affinity of B(a)P for d-limonene is similar

6   to the affinity of B(a)P for sediment organic matter:

7    $$Log K_{dl}^{B(a)P} = 0.81 Log K_{ow} - 0.25$$

8    $$Log K_{dl}^{B(a)P} = 0.81(6.50) - 0.25$$

9    $$K_{dl}^{B(a)P} = 124{,}738$$

10   However, the solubilizing capacity of dissolved organic matter tends to be somewhat

11   greater relative to equivalent sorbed organic matter due to conformational effects. Schlautman

12   and Morgan 1990, found the difference to be approximately a factor of two (Reference 6),

13   hence:

14    $$K_{dl}^{B(a)P} = 249{,}476$$

15   Hence:

16    $$R^* =$$

17    $$\frac{R + \left(\frac{249{,}476 L_w}{Kg_{dl}}\right)\left(\frac{1.38E - 5\ Kg_{dl}}{L_w}\right) + \left(\frac{124{,}738 L_w}{Kg_{dl}}\right)\left(\frac{1.42 L_w}{Kg_{sand}}\right)\left(\frac{1.38E - 5\ Kg_{dl}}{L_w}\right)\left[\frac{1.7\ Kg_{sand}}{L_{aquifer}}\right]\left[\frac{1 L_{aquifer}}{0.35 L_w}\right]}{1 + \left(\frac{249{,}476 L_w}{Kg_{dl}}\right)\left(\frac{1.38E - 5\ Kg_{dl}}{L_w}\right)}$$

18    $$R^* = 140$$

19

20   Q.   WHAT DOES THIS DEMONSTRATE?

1   A.   This demonstrates that d-limonene can be expected to increase the rate of transport of tar

2   compounds by more than a factor of four ($R/R^* = 607/140 = 4.3$). This factor-of-four increase

3   in the transport rate, along with the factor-of-1440 increase in the aqueous concentration of tar

4   compounds in the presence of d-limonene, constitutes a major increase in the potential for

5   exposure to these compounds via groundwater as a result of interaction with d-limonene

6   residual.

7

8   Q.   ARE THERE MEASUREMENTS PROVIDED BY THE COMPANY THAT

9   CORROBORATE YOUR CALCULATIONS?

10   A.   The reported reagent (TAI) content in the produced fines (averaging 1.8%) (provided to

11   Living Rivers' attorneys by the company) and the reported water content in the produced fines

12   (15.25%) yield a reagent concentration in the fluid equal to 118 mg of reagent per liter of fluid.

13   This concentration is nearly ten times higher than the solubility of d-limonene in water (13.8

14   mg/L) assumed in the calculations above. This discrepancy suggests that the actual increase in

15   tar compound solubility in water as result of mixing with the reagent will be ten times greater

16   than the calculated factor of 1400, i.e, 14,000. Assuming that the reported % bitumen content

17   of the "water" that is mixed with the ore is equivalent to the bitumen content of the residual

18   fluid in produced waste sediment, the bitumen concentration of the residual fluid in the

19   produced waste sediment is 900,000 µg/L. Using the normal water solubility (49.2 µg/L) of

20   B(a)P, this represents a factor of 18,290 increase in the solubility of the tar compounds due to

21   mixing with the reagent. This is a similar value to the expected factor of 14,000 increase

22   observed in the "water" mixed with the ore. This agreement indicates that solubilization of tar

14

1   compounds by reagent occurs as expected, and therefore the mobility of the tar compounds will

2   increase as calculated.

3

4   Q.   WHAT DID YOU CONCLUDE BASED ON YOUR CALCULATIONS?

5   A.   The calculations show clearly that d-limonene enhances the solubility, and facilitates the

6   transport, of tar compounds. It does so because the d-limonene is more soluble than the tar

7   compounds; whereas, the tar compounds have a strong affinity for d-limonene. Although the

8   specific partition coefficients can potentially be refined, the overall finding is correct: the

9   residual d-limonene in the sand creates the potential for increased transport of carcinogenic tar

10   compounds at higher concentrations.

11

12   Q.   IS DWQ'S RELIANCE ON THE MSDS SHEETS FOR THE REAGENT

13   APPROPRIATE?

14   A. The two MSDS sheets (d-limonene) provided to DWQ have information pertaining to

15   workplace exposure, and are not specifically intended for assessment of environmental

16   toxicity. However, there is sufficient concern expressed in these MSDS sheets regarding

17   environmental dispersion of the reagent ("may be toxic to aquatic organisms") that additional

18   investigation of potential deleterious consequences of environmental disposal should be

19   investigated.

20

21

1   Q.   HAVE THE APPROPRIATE TESTS BEEN CONDUCTED TO ASSESS THE

2   POTENTIAL FOR LEACHING OF PETROCHEMICALS FROM THE PROCESSED ORE?

3   A. Tests should be performed to assess the potential for leaching of tar and terpene compounds

4   into water from the produced sediment. The test that was performed was extraction of non-

5   volatile compounds from ore using hexane, which only assesses how much tar compound can

6   be extracted using a non-polar solvent, and in no way addresses the question of how much tar

7   compound would dissolve into water in contact with produced sediment. In the 2008

8   Demonstration, on page 10, the company makes the curious statement that "the absence of

9   volatile or semi-volatile constituents in the processed material indicates that the organic

10   compounds in the residual material are likely to be no more mobile than the *in situ* tar sands

11   themselves." This statement completely ignores the fact that the addition of reagent terpenes

12   alters the properties of the tar, as described above.

13

14   Q.   WOULD YOU CHARACTERIZE THE PROCESSED SEDIMENT AS "DAMP-DRY"?

15   A. A comparison of the % water content in produced sands and fines (provided to Living

16   Rivers by the company) indicates that approximately 511 tons of produced fluid exists in

17   approximately 2763 tons of produced sediment (combined sand and fines). This ratio yields a

18   volumetric ratio of 28.5% of fluid in the sediment, assuming a fluid specific gravity near unity

19   and a sediment bulk density of 1.5 g/mL (reasonable values). This volumetric ratio is close to

20   the expected 30% porosity of the sediment, indicating that the produced rock is saturated and

21   will drain fluid to underlying soil, particularly with additional water added by precipitation.

22

23

1   Q.   DOES THIS CONCLUDE YOUR TESTIMONY FOR NOW?

2   A.   Yes.

3

4

5   _____

6   William P. Johnson

7   Professor

8   Geology & Geophysics

9   University of Utah

10   115 South 1460 East

11   Salt Lake City, Utah 84112

12   801-664-8289

13

14

Appendix A – Curriculum Vitae

2 William Paul Johnson, Professor

3 Geology and Geophysics

4 Civil & Environmental Engineering Adjunct Professor

5 University of Utah, 135 South, 1460 East, Salt Lake City, Utah, 84112-1183. (801) 664-8289,
6 william.johnson@utah.edu.

7 <u>**EXPERIENCE**</u>

8	1995-present	University of Utah	Professor (since 2007)
9		Department of Geology and Geophysics	Assoc. Professor (2001-2007)
10			Asst. Professor (1995-2001)
11			
12	1994-1995	University of Arizona at Tucson	Research Assoc.
13		Department of Hydrology and Water Resources	
14		Department of Chemical and Environmental Engineering	
15			
16	1993	Water Science, Inc.	Consultant
17			
18	1990-1993	University of Colorado at Boulder	Research Assistant
19		Civil, Environmental & Architectural Engineering	
20			
21	1987-1990	United States Geological Survey	Hydrologist
22		Water Resources Division	
23			
24	1984-1986	Dartmouth College	Research Assistant
25		Department of Earth Sciences	Teaching Assistant
26			

27 <u>**EDUCATION**</u>

28	1990-1993	Ph.D. in Civil and Environmental Engineering. University of Colorado,
29		Boulder, CO. Dissertation entitled: Facilitated Transport and Enhanced
30		Desorption of Polycyclic Aromatic Hydrocarbons by Natural Organic Matter in
31		Aquifer Sediments.
32	1984-1986	M.S. degree in Geology. Dartmouth College, Hanover, NH. Thesis entitled:
33		The physical and magnetic polarity stratigraphy of the Bunthang Sequence,
34		Skardu intermontane basin, northern Pakistan.
35	1980-1983	B.A. degree in Geology. Whitman College, Walla Walla, WA.

HONORS AND AWARDS

Leeds Prize in Geology, Whitman College, 1983

Dartmouth Fellowship, Dartmouth College, 1984-1986

Outstanding Faculty Research Award, Department of Geology & Geophysics (U of U), 2000

Outstanding Faculty Research Award, Department of Geology & Geophysics (U of U), 2010

PROFESSIONAL AFFILIATIONS

Association of Environmental Engineering and Science Professors

American Geophysical Union

American Chemical Society

CURRENT FUNDED PROJECTS

The Ability for Impounded Wetland Sediment to Mobilize Metals, Ammonia and Sulfides and Their Potential Toxicity to Submerged Aquatic Vegetation and Macroinvertebrates, Central Davis Sewerage Improvement District, **05/2011-11/2012**, $40,000, sole PI.

Spatial variation of mercury methylation in the sediment and the deep brine layer of the Great Salt Lake, Utah Department of Wildlife Resources, Division of Forestry, Fire, and State Lands, **09/2011-08/2012**, $28,600, sole PI

Influence of Cell Surface Properties and Structures on Microbial Deposition in Porous Media in the Absence and Presence of Energy Barriers, American Chemical Society Petroleum Research Fund, **01/2011-01/2013**, $100,000, sole PI.

SPLITT-FFF-based detection and monitoring of engineered nanomaterials in aquatic systems, National Science Foundation Chemical, Biological, and Environmental Transport Program and Hydrology Program, **09/2010-08/2013**, $427,500, lead PI of three.

MRI Acquisition: An ICP-MS Facility at the University of Utah, National Science Foundation, EAR-MRI Program, **9/2009-08/2012**, $1,323,400, co-PI of five.

New Filtration Theory via Incorporation of Pore Scale Mechanisms Operating in the Presence of an Energy Barrier, National Science Foundation Chemical, Biological, and Environmental Transport Program and Hydrology Program, **09/2009-08/2012**, $426,000, sole PI.

A Quantitative Assessment of Mercury Influx to the Great Salt Lake, Regional Applied Research Effort (RARE) Program (USEPA Region 8), **09/2010-08/2012**, $200,000, co-PI with three.

REVIEWER FOR

Professional Journals

1   Colloid & Surfaces
2   Chemical Geology
3   Chemosphere
4   Environmental Engineering Science
5   Environmental Pollution
6   Environmental Science & Technology
7   Geochimica et Cosmochimica Acta
8   Journal of Contaminant Hydrology
9   Journal of Colloid & Interface Science
10   Journal of Environmental Engineering
11   Journal of Environmental Monitoring
12   Journal of Environmental Quality
13   Journal of Geophysical Research
14   Langmuir
15   Separation and Purification Technology
16   Vadose Zone Journal
17   Water Research
18   Water Resources Research
19
20   Funding agency proposal, panel, and center reviews
21
22   National Science Foundation
23   Hydrologic Sciences Panel 2008-2011
24   Chemical, Biological, and Environmental Transport Panel 2010
25   External reviewer for National Center for Environmental Implications of Nanotechnology (CEINT)
26   2009 to present
27   Department of Energy 1997
28   American Chemical Society Petroleum Research Fund
29
30   **COURSES CREATED AND TAUGHT**

31   Environmental Conflict: Mining and Water Quality in Ecuador, Study Abroad May 2012

32   Sustainability Practicum

33   Aqueous Geochemistry for Engineers & Scientists

34   Subsurface Remediation and Hazardous Waste Management

35   Contaminant Partitioning for Engineers & Scientists

36   Architecture of the Earth

37   **STUDENTS/ASSOCIATES ADVISED (Primary Advisor)**

1 2005 to present:

2 Post-doctoral associates:

3 Dr. Huilian Ma, Degree: Chemical Engineering, Subject: New filtration theory for colloid
4 retention under unfavorable conditions

5 Ph.D. recipients/candidates:

6 Mr, Eddy Pazmino, Degree: Chemical Engineering, Expected completion 2014, Subject: New
7 filtration theory for colloid retention under unfavorable conditions

8 Mr. Greg Carling, Degree: Geology, Expected completion 2012, Subject: Mercury cycling in the
9 Great Salt Lake Basin

10 Ms. Wenjie Huang, Degree: Chemical Engineering, Expected completion 2012, Subject:
11 Nanoparticle characterization via field flow fractionation.

12 Dr. Ximena Diaz, Degree: Environmental Engineering, Completed 2008, Subject: Selenium cycling
13 in the Great Salt Lake, Utah. Present position: Associate Professor of Extractive Metallurgy at
14 the National Polytechnic University, Quito, Ecuador.

15 Dr. Xiqing Li, Degree: Environmental Engineering, Completed 2006, Subject: Role of fluid drag
16 and energy barrier on colloid retention. Present position: Associate Professor in Resource and
17 Environmental Science, at Peking University, Beijing, China

18 Dr. Meiping Tong, Degree: Environmental Engineering, Completed 2007, Subject: Role of pore
19 domain geometry and energy barrier on colloid retention in porous media. Present position:
20 Associate Professor in Environmental Science and Engineering, Peking University, Beijing, China

21 Dr. Pengfei Zhang, Degree: Geological Engineering, Completed 2000, Subject: Immunomagnetic
22 methods for bacterial detection in groundwater and role of fluid velocity and predation on
23 bacterial transport. Present position: Professor at City College of New York, New York.

24 M.S. recipients/candidates

25 Mr. Brooks Black, Degree: Geology, 2013, Subject: Mercury and Trace Element Cycling

26 Mr. Joel Pierson, Degree: Geology, 2013, Subject: Mercury and Trace Element Cycling

27 Mr. Neil Swanson, Degree: Geology, 2013, Subject: Mercury and Trace Element Cycling

28 Ms. Eliana Manangon, Degree: Geological Eng., 2012, Subject: Environmental Nanoparticles

29 Mr. Eddy Pazmino, Degree: Geological Engineering, 2011, Subject: Colloid transport

30 Ms. Abigail Rudd, Degree: Geological Engineering, 2010, Subject: Mercury methylation

1   Ms. Kimberley Beisner, Degree: Geology, 2008, Subject: Selenium cycling in the Great Salt Lake

2   Mr. Wade Oliver, Degree: Geology, 2008, Subject: Selenium sedimentation in the Great Salt Lake

3   Ms. Mary Ellen Potter, Degree: Civil Eng., 2008, Subject: Phosphorous accum. in Farmington Bay

4   Ms. Christina Brow, Degree: Environmental Eng., 2004, Subject: Colloid Transport

5   Mr. Michael Koch, Degree: Public Health, 2004, Subject: Cholera detection in ship ballast

6   Ms. Margaret McGriff, Degree: Geology, 2002, Subject: Surfactant solubilization of PCE and PAH

7   Mr. William McIntosh, Degree: Geology, 2002, Subject: Bacterial transport in groundwater

8   Mr. Ryan Rowland, Degree: Geology, 2002, Subject: U treatment in permeable reactive barrier

9   Mr. Gaobin Bao, Degree: Geology, 2000, Subject: Surfactant solubilization of PCE and PAH

10   Mr. Phillip Schmitz, Degree: Geol. Eng., 2000, Subject: Au extraction from carbonaceous ore

11   Mr. Wynn John, Degree: Geol. Eng., 1999, Subject: PAH solubilization by surfactants and NOM

12   Mr. Jorn Stenebraten, Degree: Geol. Eng., 1998, Subject: Au extraction from carbonaceous ore

13

14   **PROFESSIONAL ACTIVITIES**

15   • Symposium co-convener American Chemical Society Colloids & Surfaces Meeting, Johns Hopkins
16   University, June 2012

17   • Utah Statewide Mercury Workgroup

18   • Symposium co-convener, American Geophysical Union, San Francisco, CA, December, 2011

19   • UNESCO IHE Invited Research Director in Kampala, Uganda, Fall 2009

20   • National Nanotechnology Initiative Environmental Health and Safety Panel for Research Directions,
21   Fall 2009.

22   • National Science Foundation Hydrology Panel Spring and Fall, 2008 to present

23   • Sustainability Practicum leader – coordinating students from four colleges with architects and
24   campus operations staff to design and implement 6 projects to increase the environmental
25   performance of the Frederick Albert Sutton Building, U. of Utah
26   (http://www.earth.utah.edu/news_events/news/green07).

27   • Field trip developer and coordinator for elementary school field trips to Great Salt Lake for Water,
28   Environment, Science & Teaching (WEST) graduate program (http://www.earth.utah.edu/west)

- Director of the Center for Water, Ecosystems, and Climate Science (CWECS) at the University of Utah, 2004 to 2008. Developer of CWECS ICP-MS facility.

- Board of Directors, Consortium of Universities for the Advancement of Hydrologic Science, Inc., May 2002 to December 2004.

- Frederick Albert Sutton Building Design Committee, 2006-2009

- Chair, Geological Engineering Degree Program Committee, 1996-2003

- Executive committee, Environmental Engineering degree program (1996-present)

ADVISORS

Ph.D. advisor: Dr. Gary Amy, U. of Colorado, Civil, Environmental, and Architectural Engineering

Post-doctoral advisor: Dr. Bruce Logan, U. of Arizona, Chemical and Environmental Engineering

REFEREED PUBLICATIONS ([*]**corresponding author)**

Carling G.T., Fernandez D.P., and [*]**Johnson W.P.**, **2012**, Dust-mediated loading of trace and major elements to Wasatch Mountain snowpack, submitted.

Ma H., Pazmino E.F, [*]**Johnson W.P., 2011**, Surface Heterogeneity on Hemispheres-in-Cell Model Yields All Experimentally-Observed Non-Straining Colloid Retention Mechanisms in Porous Media in the Presence of Energy Barriers, *Langmuir*, http://dx.doi.org/10.1021/la203587j.

Pazmino E.F., Ma H., [*]**Johnson W.P.**, **2011**, Applicability of colloid filtration theory in size-distributed, reduced porosity, granular media in the absence of energy barriers, *Environ. Sci. Technol*. http://dx.doi.org/10.1021/es202203m .

Ma H., Pazmino E.F., [*]**Johnson W.P.**, **2011**, Gravitational Settling Effects on Unit Cell Predictions of Colloidal Retention in Porous Media in the Absence of Energy Barriers, *Environ. Sci. Technol*., 45(19), 8306-8312.

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8   Dissolution and nanoparticle generation behavior of Be-associated materials in synthetic lung fluid
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27 **Johnson, W. P.**, X. Li, M. Tong, and H. Ma, **2009**, Comment on "Transport and fate of bacteria in porous
28   media: Coupled effects of chemical conditions and pore space geometry" by Saeed Torkzaban et al.,
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31   interruption of meromixis in the Great Salt Lake, Utah, *Science of the Total Environment*, 407, 5263-
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1   Diaz X, D. Fernandez, D.L. Naftz, [*]**W.P. Johnson**, **2009**, Size and Elemental Distributions of Nano- to
2   Micro- Particulates in the Geochemically-stratified Great Salt Lake, *App. Geochem.*,
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5   Great Salt Lake, Utah, *App. Geochem*, 24 , 936-949.

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12   concentration monitoring of two bacterial strains in an Atlantic Coastal Plain Aquifer in Oyster, VA,
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BOOK CHAPTERS

W.P. Johnson, **2008**, Mechanisms of Retention of Biological and Non-biological Colloids in Porous Media: Wedging and Retention in Flow Stagnation Zones in the Presence of an Energy Barrier to Deposition, in *Structure, Interactions and Reactivity at Microbial Surfaces*, T. Camesano and C. Mello eds., American Chemical Society Symposium Series 984, 339 pp.

REPORTS

Johnson, W.P., D.L. Naftz, X. Diaz, K. Beisner & W. Oliver. 2008. Estimation of Selenium Removal Fluxes from the South Arm of the Great Salt Lake, Utah. Final Report. April 7, 2008. 86 pp.

Naftz, D.L., W.P. Johnson, M. Freeman, K. Beisner & X. Diaz. 2008. Estimation of Selenium Loads Entering the South Arm of Great Salt Lake, Utah. U.S. Geological Survey Scientific Investigations Report. 210 pp.

Johnson W.P., M. Conover, W. Wurtsbaugh, J. Adams, **2006**, Conceptual Model for Selenium Cycling in the Great Salt Lake, Prepared for the Division of Water Quality of the Utah Department of Environmental Quality, 38 pp.

Harte, P.T., and **Johnson, W.P.**, **1993**, Geohydrology and Water Quality of Stratified-drift Aquifers in the Contoocook River Basin, New Hampshire: USGS Water Resources Investigation 92-4154, 120p.

RECENT INVITED PRESENTATIONS (2010)

The Pennsylvania State University Engineering Energy & Environmental Institute (E3I) Fall Graduate Seminar: New filtration theory for predicting retention of *Cryptosporidium* oocysts and other > 2 micron particles in porous media under environmental conditions

The Johns Hopkins University Center for Environmental and Applied Fluid Mechanics Fall Seminar Series: Progress and challenges in developing theory for prediction of micro- and nano-particle transport in porous media under environmental conditions

Utah State University College of Natural Resources Fall Seminar Series: Ongoing research questions regarding Se and Hg in the Great Salt Lake.

University of Utah Global Change and Ecosystem Center Fall Seminar Series: Ongoing research questions regarding Se and Hg in the Great Salt Lake

EPA Symposium on Ground Water-borne Infectious Disease Epidemiology, Etiologic Agents and Indicators, Washington D.C. Winter 2010, New filtration theory for predicting retention of *Cryptosporidium* oocysts and other > 2 micron particles in porous media under environmental conditions.

Panel Presentation at National Nanotechnology Initiative Meeting on Nanomaterials and the Environment & Instrumentation, Metrology, and Analytical Methods, Developing methods to detect nanomaterials and determine exposure routes, Fall, 2009

|		
1	**Appendix B: Properties of d-limonene**	
2		
3	solubility in water = 13.8 mg/L	ref 1
4	Koc = 1030-4780 ml/g	ref 2
5	Half lives: biotic (aerobic) < 14 days, abiotic (in air) < 2 hours	ref 2
6	Log octanol-water partition coefficient = 4.2	ref 1
7	Formula: $C_{10}H_{16}$	ref 3
8	Molecular weight = 136.24	ref 3
9	Temp melt: -142.4 F	ref 3
10	Vapor Pressure:	
11	2.0 mm Hg	ref 1
12	1.0 mm Hg at 57.0 ° F	ref 3
13	5 mm Hg at 104.7° F	ref 3
14	10 mm Hg at 128.8° F	ref 3
15	Vapor Density: 4.69	ref 3
16	Specific Gravity: 0.8411 at 68.0 ° F	ref 3
17	Boiling Point: 348-349 ° F at 760 mm Hg (NTP, 1992)	ref 3

18

19

20
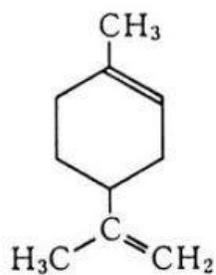
1

Appendix C: Properties of the tar

3 Dr. Nick Dahdah (Energy Geosciences Institute, Utah) states that the Eastern Utah tar sands
4 represent recalcitrant compounds dominated by asphaltenes. They contain negligible unsaturated
5 aliphatics and little of the small polycyclic aromatic hydrocarbons (PAHs) such as naphthalene
6 or phenanthrene. However, they may contain significant larger PAHs such as pyrene, chrysene,
7 benz(a)anthracene, benzo(a)pyrene, etc.

8 Dr. Dahdah says that GC analyses do not resolve the individual compounds in the tar, and so the
9 composition is only generally characterized. He says that Frank Hanson and Milind Deo (UU
10 Chem Eng) examined these compounds prior to retirement.

11 http://www.docstoc.com/docs/46744779/Asphaltenes-and-Polycyclic-Aromatic-Hydrocarbons

12 URL above boils down to: the tar sands are expected to be dominated by asphaltenes.
13 Petroleum-based asphaltenes (as opposed to coal-based) have a significant alkane fraction and
14 contain large aromatic ring systems.

Asphalt component
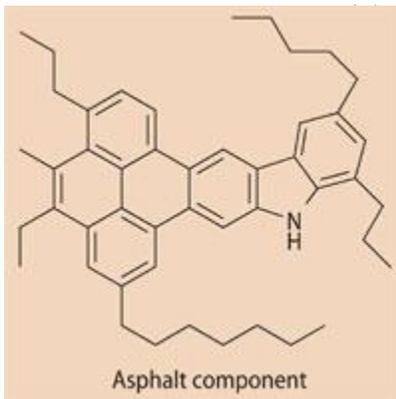
Such molecular structure can be exemplified by the following
structure (figure left).   Such structures dominated by non-polar
bonds characteristically have low water solubilities, e.g. in the
µg/L range or less.

22   Multiple
23 aromatic ring structures in the form of polycyclic
24 aromatic hydrocarbons (PAH) (figure right) are
25 well-known carcinogens, although the alkane
26 substituents on asphaltenes may alter their
27 carcinogenicity relative to PAHs

28 benzo(a)pyrene physical (not necessarily
29 toxicological) properties as an example.

30 (Figure source reference 4)

Chemical compound		Chemical compound	
Anthracene		Benzo[a]pyrene	
Chrysene		Coronene	
Corannulene		Naphthacene	
Naphthalene		Pentacene	
Phenanthrene		Pyrene	
Triphenylene		Ovalene	

31

1

Appendix D - Risk

3   The cleanup level to meet a given excess carcinogenic risk is obtained by the following equation
4   which determines the intake concentration (in this case in groundwater) corresponding to the
5   acceptable excess carcinogenic risk (set to 1E-6 as default regulatory goal).

6   cleanup level $= \dfrac{(R)(BW)(AT)}{(CSF)(CR)(AAF)(EF)(ED)}$

7   where:

8   cleanup level = concentration of compound in groundwater (e.g. mg/L)
9   R = acceptable excess carcinogenic risk (1E-6 regulatory goal)
10   BW = body weight (kg)
11   AT = averaging time (days)
12   CSF = carcinogenic slope factor for the compound (excess risk per mg/(kg-day))
13   CR = contact rate (e.g. L/day)
14   AAF = absorption adjustment factor (usually set equal to unity as default)
15   EF = exposure frequency (days/year)
16   ED = exposure duration (years)
17
18   Despite being a suspected carcinogen, there is no CSF available for perylene. However, a CSF is
19   available for benzo(a)pyrene, which is another 5-ring PAH expected in crude oil and tar.
20
21   The CSF for benzo(a)pyrene via ingestion is: 7.3 (reference 7)

22   cleanup level $= \dfrac{(1E-6)(70kg_{bodyweight})(365\frac{days}{year}\,70\frac{years}{ave\,time})}{(7.3\dfrac{excess\ risk}{\dfrac{mg_{cmpd}}{kg_{bodyweight}-day}})(2\frac{L_w}{day})(1)(365\frac{days}{year})(70\frac{years}{ave\,time})}$

23   cleanup level = 0.00479 µg/L

1

References Cited

3 1. USEPA. Office of Pesticide Programs. Exposure and Risk Assessment on Lower Risk
4   Pesticide Chemicals. D-Limonene.

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15 7. http://www.epa.gov/iris/subst/0136.htm

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CERTIFICATE OF SERVICE

The undersigned hereby certifies that on this 20th day of January, 2012, a true and correct copy of the foregoing Pre-Filed Direct Testimony of Mr. Lips and Dr.Johnson was served via e-mail, as follows:

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