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August 28, 2014
Kleinfelder Job No. 20151585.000A

Mike Barham
Helis Oil and Gas Company, LLC
1415 Louisiana, Suite 2150
Houston, TX 77002

SUBJECT: POTENTIAL FRACTURE FLUID MIGRATION AND CHEMICAL FATE AND TRANSPORT ANALYSIS
PROPOSED HELIS OIL & GAS WELL
ST. TAMMANY PARISH, LA

Dear Mr. Barham:

Kleinfelder Inc. (Kleinfelder) was contracted by Helis Oil & Gas Company LLC (Helis) to estimate the potential for well stimulation water to migrate a lateral distance from a proposed Helis Oil and Gas Company, LLC (Helis) well located in St. Tammany Parish, Louisiana. Helis requested an evaluation of a hypothetical situation involving a triple casing failure allowing well stimulation water into a shallow aquifer during hydraulic fracturing activities.

We appreciate the opportunity to provide this service for Helis. Should you require additional information or have any questions regarding this analysis please contact Mr. Brad A. Woodard at (303) 297-6601.

Sincerely,

KLEINFELDER, INC.

B. A. Woodard

Brad A. Woodard, CPG, EI
Project Manager III

EXHIBIT
tabbies
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An Analysis Prepared for:

Mike Barham
Helis Oil and Gas Company, LLC
1415 Louisiana, Suite 2150
Houston, TX 7700

POTENTIAL FRACTURE FLUID MIGRATION AND CHEMICAL FATE AND TRANSPORT ANALYSIS
Proposed Helis Oil & Gas Well
St. Tammany Parish, LA

Kleinfelder Job No. 20151585.000A

Prepared by:

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Professional

Reviewed by:

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POTENTIAL FRACTURE FLUID MIGRATION AND CHEMICAL FATE AND TRANSPORT ANALYSIS PROPOSED HELIS OIL & GAS WELL ST. TAMMANY PARISH, LA

1 EXECUTIVE SUMMARY

Helis Oil and Gas Company, LLC (Helis) requested Kleinfelder conduct an evaluation to estimate the lateral distribution and subsequent fate & transport characteristics for a hypothetical situation involving a near-surface triple casing failure allowing well stimulation water into a shallow aquifer during pressurized well stimulation activities.

Kleinfelder employed basic analytical modeling methods to estimate the radial distance that well stimulation water could potentially penetrate the aquifer and subsequently migrate via advective flow with groundwater while being subjected to commonly recognized attenuation processes.

The first analytical model determined the potential radial migration distance of well stimulation water injected under pressure through a presumed breach in the well casings. The model is based on a simple conceptualization of an expanding cylinder (expanding cylinder model), which simulates an expanding cylinder of water through effective porosity that emanates from the proposed oil & gas well. This method has traditionally been used for waste disposal injection well planning, which considers the height of the cylinder to correspond to the thickness of the permeable formation into which the injection occurs. In this instance, the height of the cylinder is conservatively assumed to correspond to the vertical length of a breach in the well casing. The calculated radial migration distances for the hydraulic fracture fluid ranged from 71.5 to 457 feet.

An analytical fate and transport model was used to evaluate the migration of the hypothetical inadvertent well stimulation water injection via a breach in the well casings. The pulse source model simulated a finite mass of select chemicals impacting the groundwater after the casing failure then migrating and attenuating downgradient as a pulse. A pulse source for select chemicals, identified in the well stimulation fluids, is expected to migrate in groundwater via advection while undergoing attenuation via dispersion, sorption, and biodegradation.

Pulse source modeling was conducted for each chemical using the three different calculated radius migration distances from the expanding cylinder model. The use of expanded injection radii from the expanding cylinder model due to dispersion or preferential flow is conservative (protective), because it over estimates the mass of the chemical introduced. The predictive pulse source modeling indicates chemicals with low half-lifes (methanol and ethylene glycol) will degrade to below detectable concentrations within one year. Modeling indicates the more recalcitrant chemical naphthalene (half-life = 4.7 years) will migrate greater distances from the proposed oil & gas well.

Using the most conservative input parameters (i.e. highest porosity, longer half-lifes, larger radii, etc.), the predictive pulse source modeling for naphthalene indicates a downgradient migration ranging from 846 to 1,131 feet. The fate and transport model predicts the time it would take the initial concentration of naphthalene to degrade to the Environmental Protection Agency's Risked-based Screening Level (0.17 µg/L) ranging from 65.7 to 87.9 years.

2 INTRODUCTION

Kleinfelder conducted an evaluation to estimate the lateral distribution and subsequent fate & transport characteristics for a hypothetical situation involving a near-surface triple casing failure allowing well stimulation water into a shallow aquifer during pressurized well stimulation activities.

The hypothetical situation posed to Kleinfelder assumes that 50 barrels per minute (bbls/min) of well stimulation water would enter a shallow groundwater aquifer under pressurized well stimulation activities for approximately 10 minutes, and that fluid would subsequently flow with the direction of groundwater.

Basic analytical modeling methods were utilized to estimate the radial distance that well stimulation water could potentially penetrate the aquifer and subsequently migrate via advective flow with groundwater while being subjected to commonly recognized attenuation processes.

3 FORMATION CHARACTERISTICS

According to Louisiana Department of Natural Resources, SONRIS database, the shallow aquifers located in the vicinity of the proposed oil & gas well range from 10 to 20 feet thick. Based on literature research and an open-hole bore log for a nearby oil & gas well, the shallow aquifers consist predominately of sand. Published values for effective porosity in a sandy aquifer range from 0.10 to 0.35. For modeling purposes, the most conservative value (higher porosity) of 0.35 was used.

A client-supplied potentiometric surface map for southeastern Louisiana indicates a groundwater flow direction south toward Lake Pontchartrain. Based on potentiometric surface and distance data, the gradient was determined to be 0.00089 feet/feet.

4 ANALYSIS

3.1 EXPANDING CYLINDER ANALYTICAL MODEL

The potential radial migration distance of well stimulation water injected under pressure through a presumed breach in the well casing is based on a simple conceptualization of an expanding cylinder (expanding cylinder model), which simulates an expanding cylinder of water through effective porosity that emanates from the oil & gas well. The dimensions of the cylinder are related to the total volume of fluid injected (injection rate multiplied by duration), average effective porosity, and height of the cylinder corresponding to the thickness of the injected fluid penetrating the formation. This method has traditionally been used for waste disposal injection well planning, which considers the height of the cylinder to correspond to the thickness of the permeable formation into which the injection occurs. In this instance, the height of the cylinder is conservatively assumed to correspond to the vertical length of a breach in the well casing. This is conservative, because a shorter cylinder height corresponds to a greater radius of penetration. This model is represented mathematically by the following equation:

$$r = \sqrt{\frac{V}{\pi b \Phi}}$$

Where,

- r = radial distance of waste water front from well
- V = cumulative volume of "injected" water
- b = effective aquifer thickness
- Φ = average effective porosity.

The following equation adjusts for the effects of dispersion of the expanding cylinder of fluid, which acts to extend the migration distance:

$$r' = r + 2.3\sqrt{Dr}$$

Where,

- r' = radial distance of travel with dispersion
- D = dispersion coefficient.

3.2 FATE AND TRANSPORT ANALYTICAL MODEL

An analytical fate and transport model was used to evaluate the migration of the hypothetical inadvertent well stimulation water injection via a breach in the well casing. A pulse source model simulates a finite mass of select chemicals identified in the well stimulation water impacting the groundwater after casing failure then migrating and attenuating downgradient as a pulse.

A pulse source for each chemical is expected to migrate in groundwater via advection while undergoing attenuation via dispersion, sorption, and biodegradation. These processes for a pulse source scenario can be modeled according to the following equation:

$$c(x,y,t)=\frac{coA}{4\pi t\left(D_xD_y\right)^{1/2}}\exp\left[-\frac{\left(x-v_xt\right)^2}{4D_xt}-\frac{y^2}{4D_yt}-\lambda t\right]$$

Where,

- c = Modeled Concentration (mg/L)
- c_o = Source Concentration (mg/L)
- v_x = Contaminant Velocity (ft/yr)
- D_x = Longitudinal Dispersion (ft^2/yr)
- D_y = Transverse Dispersion (ft^2/yr)
- A = Ground Surface Area of Release (ft^2)
- t = Time (years)
- x = Longitudinal Distance (ft)
- y = Transverse Distance (ft)
- λ = First-Order Decay Coefficient (1/yr)

In broad terms, the fate and transport modeling consisted of two parts. The first part was to establish a maximum concentration and travel distance for select chemicals typically found in stimulation fluids for a specific time.

The second part was to determine the time it would take for the most recalcitrant chemical (naphthalene) to degrade from the initial concentration to the Environmental Protection Agency (EPA) risk screening level (RSL) for naphthalene. In addition, the distance the plume traveled from the oil & gas well before reaching the RSL concentration was calculated.

5 INPUT DATA

4.1 EXPANDING CYLINDER ANALYTICAL MODEL

Constants and variables selected for input into the radial distance calculations are tabulated and described as follows:

TABLE 1
EXPANDING CYCLINDER ANALYTICAL MODEL PARAMETERS

VARIABLE	UNITS	VALUE	DESCRIPTION	NOTES
Q	ft^3/yr	147,550,194	Volumetric Flow Rate	Based on 500 bbl "injection" which occurred for 10 min (50 bbl/min)
t	years	1.9026E-05	Duration of Injection	10 min
V	ft^3	2,807	Cumulative Volume Injected	Calculated based on Q and t
b	feet	0.5	Effective aquifer Thickness	Assume a 6-inch break or thin rupture in pipe.
Φ	unitless	0.35	Average effective porosity	LMNO Engineering Website
D	feet	65	Dispersion Coefficient	Literature values range from 3 feet (sandstone) and 65 feet for limestone and dolomite per Warne and Lehr (1981). Most conservative value selected.

4.2 FATE AND TRANSPORT ANALYTICAL MODEL

Fate and transport model input parameters are summarized as follows:

- *Source Concentration (c_o)* – The starting source concentration is chemical specific. A variety of chemicals (naphthalene, methanol, ethylene glycol, and isopropanol) with differing fate, transport, and toxicological properties were modeled to simulate a range of potential migration scenarios in groundwater. Source concentrations of these chemicals, obtained from Appendix E of the Environmental Protection Agency's Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources, are listed as follows:

- Naphthalene: 14 mg/L
- Methanol: 236,070 mg/L
- Ethylene Glycol: 286 mg/L
- Isopropanol: 39,510 mg/L

- *Contaminant Velocity (V_x) (ft/yr)* – Contaminant velocity is calculated as the seepage velocity (Ki/n) divided by the retardation factor (R). The calculated contaminant velocity is based on the following parameters:

  - *Hydraulic Conductivity (K) (ft/yr)* – A hydraulic conductivity of **23,725 ft/yr** is based on a literature value for a sand aquifer presented in Remediation Hydraulics (Payne, Quinnan, and Potter, 2008).

  - *Hydraulic Gradient (i) (ft/ft)* – A hydraulic gradient of **0.000894 ft/ft** was determined from a regional groundwater data collected from the SONRIS Database.

  - *Effective Porosity (n) (decimal fraction)* – An effective porosity of **0.35** was used in the model, found in LMNO Engineering, Reference data, http://www.lmnoeng.com/.

  - *Retardation Factor* (R) - The model calculates the retardation of the groundwater flow through the formation using the following equation: 1+(ρb/n)*Koc*foc.

    - *Soil Bulk Density* (ρb) (g/cm^3) – A soil bulk density value of **1.3 g/cm^3** was selected from published literature, Remediation Hydraulics (Payne, Quinnan, and Potter, 2008).

    - *Partition Coefficient* (Koc) (L/Kg) – Is a chemical-specific parameter. Values for each chemical modeled are based on literature values presented in Remediation Hydraulics (Payne, Quinnan, and Potter, 2008), by Exponent / the Methanol Institute, the ATDSR, and the HSDB. Chemical-specific Koc values are listed as follows:

- Naphthalene: 100 L/Kg
- Methanol: 8 L/Kg
- Ethylene Glycol: 1 L/Kg
- Isopropanol: 25 L/Kg

- *Fraction of Organic Carbon* (foc) – A fraction of organic carbon value of **0.01** was selected based on United States Geological Survey, Lake Pontchartrain Basin: Bottom Sediments and Related Environmental Resources.

Contaminant velocities are summarized as follows:

- Naphthalene: 12.85 ft/yr
- Methanol: 46.72 ft/yr
- Ethylene Glycol: 58.43 ft/yr
- Isopropanol: 55.45 ft/yr

- *Longitudinal Dispersion (D_x)* – Longitudinal dispersion is the product of the contaminant velocity and the longitudinal dispersivity (a_x). The longitudinal dispersivity (a_x) is calculated according to the method of Xu and Eckstein (1995). This method is scale dependent, and is estimated based on the length of the plume. Consequently, the plume length input is adjusted iteratively until it matches the plume output length.

- *Transverse Dispersion (D_y)* - Transverse dispersion is the product of the contaminant velocity and the transverse dispersivity (a_y). Transverse dispersivity (a_y) is calculated as 0.1 times the longitudinal dispersivity.

- *Ground Surface Area of Release (A)* – The ground surface area used was **16,052 ft^2**, **163,000 ft^2**, and **653,000 ft^2** which corresponds to the area of circle centered on the oil & gas well. The radius of the circle corresponds to the lateral migration distance calculated in the expanding cylinder model.

- *Time (t)* – The time value was adjusted to simulate future migration and determine the travel distance to reach the EPA RSL for naphthalene. A one year and thirty year time value were used to calculate maximum concentrations for isopropanol and naphthalene, respectively.

- *First-Order Decay Coefficient (λ) (1/yr)* – The first order decay coefficient corresponds to 0.693/half-life. Published half-lives for each chemical, found in the ATSDR, Saba, T., Mohsen, F., Michael, G., Murphy, B., and Hilbert, B. (January 2012), Dobson, S., (2000), and Bodehagen, D. (May 2010) were used for the simulation to determine the first-order decay coefficient.
    - Naphthalene: 4.66 years
    - Methanol: 7 days
    - Ethylene Glycol: 56 hours
    - Isopropanol: 14 days

6 SIMULATION RESULTS

The radial migration distance was estimated using an Excel spreadsheet presented in Attachment A. The calculated radial distance for the hydraulic fracture fluid without dispersion was 71.5 feet. Based on a very conservative dispersion coefficient (one for limestone), the radial distance with dispersion increased to 228 feet. To account for the possibility of preferential flow pathways the radial distance with dispersion is increased by a factor of two, resulting in a distance of 457 feet.

Pulse source modeling was conducted for each chemical using the three different calculated radius migration distances from the expanding cylinder model. The predictive pulse source modeling indicates chemicals with low half-lifes (methanol and ethylene glycol) will degrade to below detectable concentrations within one year. Modeling indicates the more recalcitrant chemical naphthalene (half-life = 4.7 years) will migrate greater distances from the proposed oil & gas well. Table 2 below summarizes the results for the pulse source modeling. Attachment B contains charts of the pulse source model runs.

TABLE 2

PULSE SOURCE MODEL RESULTS SUMMARY

Run Without Dispersion			
Chemical	Time (years)	Distance from Well (feet)	Peak Concentration (mg/L)
Isopropanol	1	56	0.02
Naphthalene	30	386	0.108
Naphthalene*	65.7	846	0.17 (µg/L)
Run With Dispersion			
Chemical	Time (years)	Distance from Well (feet)	Peak Concentration (mg/L)
Isopropanol	1	56	0.206
Naphthalene	30	386	1.09
Naphthalene*	79.4	1,021	0.17 (µg/L)
Run with Factor of Safety of 2			
Chemical	Time (years)	Distance from Well (feet)	Peak Concentration (mg/L)
Isopropanol	1	56	0.821
Naphthalene	30	386	4.38
Naphthalene*	87.7	1,131	0.17 (µg/L)

*During the model run time was adjusted until the Peak Concentration matched the EPA RSL (0.17 µg/L).

Note, the use of expanded injection radii due to dispersion or preferential flow is conservative (protective), because it over estimates the mass of the chemical introduced. This occurs because a constant source concentration is assumed for each radius; however, dilution of the source concentration would occur due to dispersion, or a lesser source volume would be associated with preferential flow.

Both analytical models indicate minor to moderate downgradient migration of chemicals from the oil & gas well during this hypothetical situation using conservative assumptions and input parameters; however at distances much less than the nearest receptor.

7 LIMITATIONS

The analyses and simulations presented in this report are based on simple analytical calculations of a hypothetical scenario and are intended to illustrate potential outcomes that could reasonably occur. Information presented herein is not represented as a prediction of results, which would require more detailed knowledge of field conditions, sophisticated numerical flow modeling, and knowledge of the actual release mechanisms and circumstances.

This report was prepared in substantial accordance with the generally accepted hydrogeologic practice as it exists in the site area at the time of our study. The scope of work was limited to preliminary analytical modeling. It should be recognized that definition and evaluation of subsurface conditions are difficult. Judgments leading to conclusions and recommendations are generally made with incomplete knowledge of the subsurface conditions present. The conclusions of this assessment are based on geologic information provided by others, analytical modeling assumptions, and literature values for hydrogeologic properties. More extensive studies may further reduce the uncertainties associated with this assessment. Kleinfelder should be notified for additional consultation if the client wishes to reduce the uncertainties beyond the level associated with this report. No warranty, express or implied, is made.

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Kleinfelder offers various levels of investigative and engineering services to suit the varying needs of different clients. Although risk can never be eliminated, more detailed and extensive investigations yield more information, which may help understand and manage the level of risk. Since detailed investigation and analysis involves greater expense, our clients participate in determining levels of service, which provide adequate information for their purposes at acceptable levels of risk.

8 REFERENCES

1 Bedient, P.B., Rifai, H.S., Newell, C.J., 1994, *Ground Water Contamination, Transport & Remediation*, Englewood Cliffs, N.J., PTR Prentice Hall, 541 p.

2 Roberts, E.P., June 23, 2009, Observed Contaminant Half-Lives – Will Natural Attenuation Achieve the Goal?

3 Xu, M. and Eckstein, Y., 1995, *Use of Weighted Least-Squares Method in Evaluation of the Relationship Between Dispersivity and Scale*: Ground Water, v. 33, p. 905-908.

4 EPA Office of Research and Development, November 2011, Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources, US Environmental Protection Agency, Washington, D.C., APPENDIX E.

5 Louisiana Dept. of Natural Resources, SONRIS Database. http://sonri www.dnr.state.la.us/gis/agsweb/IE/JSViewer/index.html?TemplateID=181.

6 Payne, F.C., Quinnan, J.A., Potter, S.T., 2008, *Remediation Hydraulics*, Boca Raton, Florida, CRC Press, 34 p.

7 United States Geological Survey, Lake Pontchartrain Basin: Bottom Sediments and Related Environmental Resources.

8 Warner, D.L. and Lehr, J.H., 1981, *Subsurface Wastewater Injection: The Technology of Injecting Wastewater into Deep Wells for Disposal,* Premier Press, Berkley, CA, 344 p.

9 LMNO Engineering, Reference data, http://www.lmnoeng.com/.

10 Hazardous Substances Data Bank, U.S. National Library of Medicine.

11 Agency for Toxic Substances and Disease Registry (ATSDR). http://www.atsdr.cdc.gov/.

12 Saba, T., Mohsen, F., Michael, G., Murphy, B., Hilbert, B., January 2012, Methanol Use in Hydraulic Fracturing Fluid, Exponent, 3-17 p.

13 Dobson, S., 2000, Ethylene Glycol: Environmental Aspects, World Health Organization, http://www.who.int/ipcs/publications/cicad/en/cicad22.pdf.

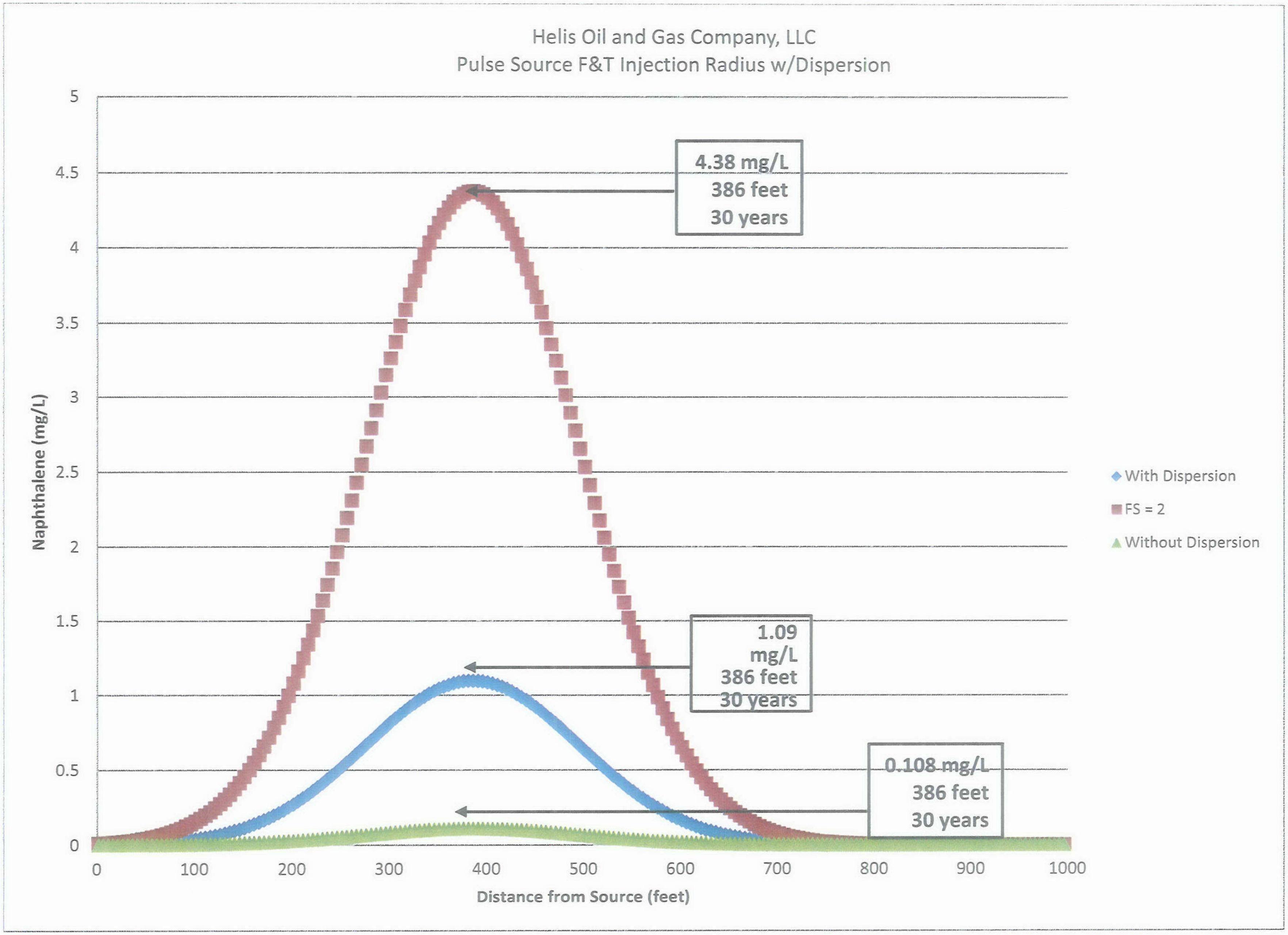
14 Bodehagen, D., May 2010, Measuring Groundwater and Contaminant Flux: Passive Flux Meter Field Applications and Issues with Alcohol Degradability, Air, Soil and Water Research journal.

APPENDIX A
EXPANDING CYLINDER
ANALYTICAL MODEL RESULTS

HELIS OIL GAS COMPANY LLC
POTENTIAL FRACTURE FLUID MIGRATION
Expanding Cylinder Analytical Model

Variable	Units	Value	Description	Notes
Q	ft^3/yr	147,550,194	Volumetric Flow Rate	estimating a 500 bbl "release" (or 50 bbl/min.) - client provided
t	years	1.9026E-05	Duration of Injection	10 minute duration - client provided
V	ft^3	2,807.29	Volume	500 bbl "release"
b	feet	0 5	Effective Reservoir Thickness	Assume a 6-inch break or thin rupture in pipe.
n_e	unitless	0.35	Average effective porosity	Reference data - compiled on LMNO Eng. Website
D	feet	65	Dispersion Coefficient	"65 feet for limestone or dolomite aquifers" Subsurface Wastewater Injection (Warner and Lehr, 1981). Formation characterized by variable transmissivity, solution cavities, fractures and jointing (USGS Water-Supply Paper 2248).
r	**feet**	**71.48**	**Radial distance of hydraulic fracture water front from well**	
r'	**feet**	**228.24645**	**Radial distance of travel with dispersion**	
r'_{prf2}	**feet**	**456.4929**	**Migration distance assuming preferential flow**	**Increased distance by 2.0X from predicted extent with dispersion (safety factor of 2.0).**

APPENDIX B
FATE AND TRANSPORT MODEL RESULTS


Helis Oil and Gas Company, LLC
Pulse Source F&T Injection Radius w/Dispersion
Naphthalene (mg/L)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
4.38 mg/L
386 feet
30 years
1.09
mg/L
386 feet
30 years
0.108 mg/L
386 feet
30 years
0
100
200
300
400
500
600
700
800
900
1000
Distance from Source (feet)
With Dispersion
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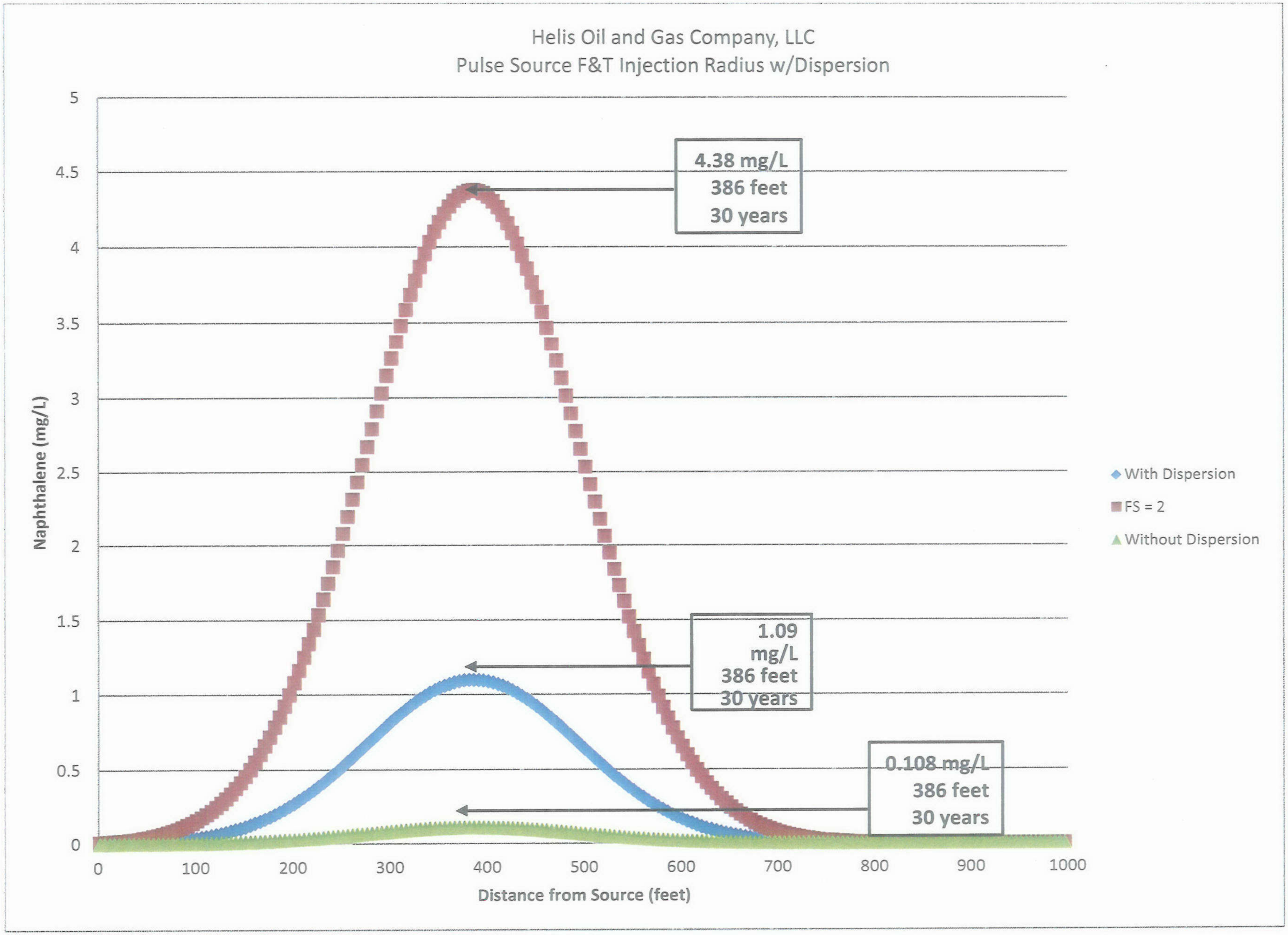
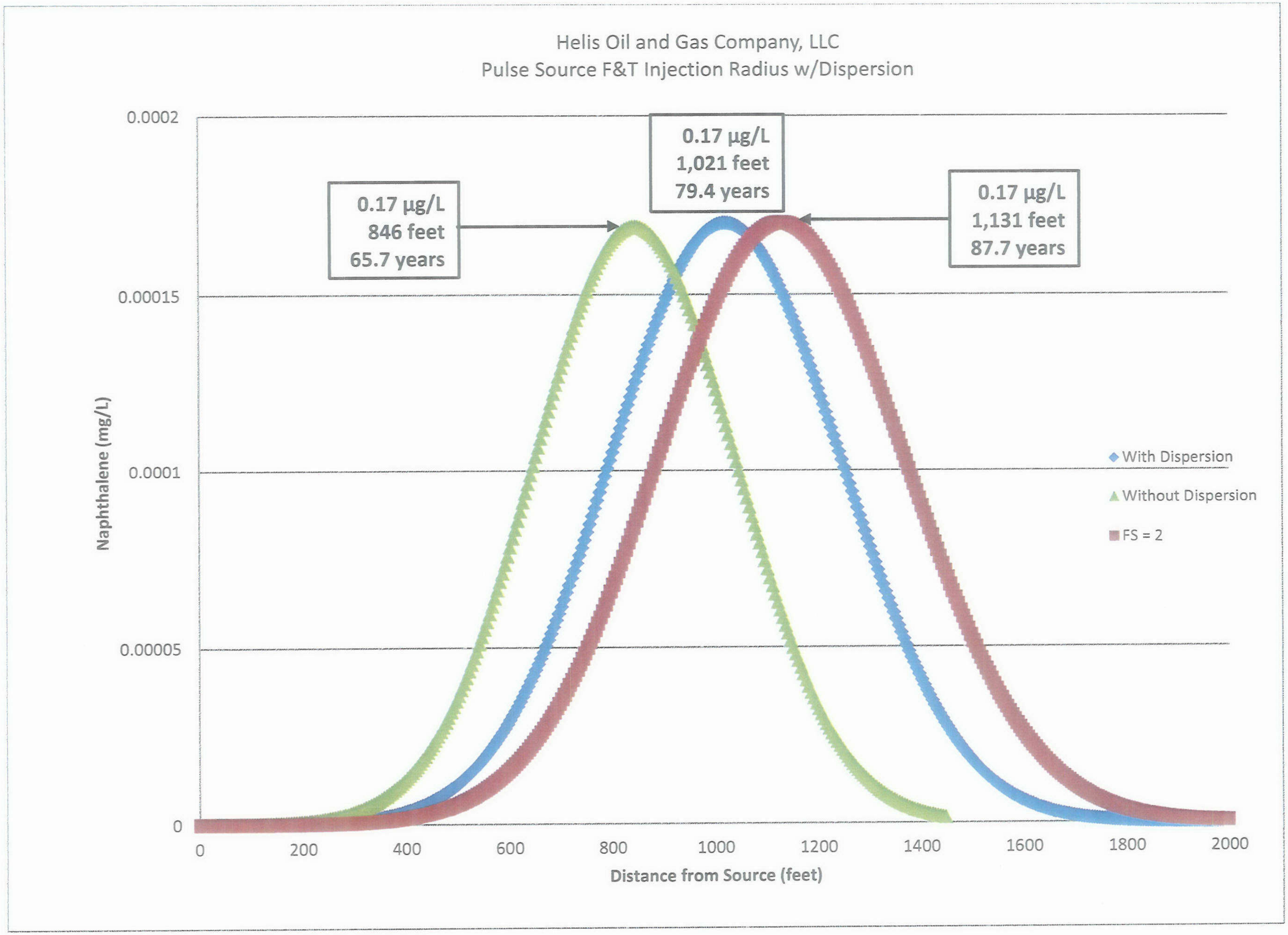
Without Dispersion


Helis Oil and Gas Company, LLC
Pulse Source F&T Injection Radius w/Dispersion
Naphthalene (mg/L)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
4.38 mg/L
386 feet
30 years
1.09
mg/L
386 feet
30 years
0.108 mg/L
386 feet
30 years
0
100
200
300
400
500
600
700
800
900
1000
Distance from Source (feet)
With Dispersion
FS = 2
Without Dispersion


Helis Oil and Gas Company, LLC
Pulse Source F&T Injection Radius w/Dispersion
0.17 µg/L
846 feet
65.7 years
0.17 µg/L
1,021 feet
79.4 years
0.17 µg/L
1,131 feet
87.7 years
Naphthalene (mg/L)
0.0002
0.00015
0.0001
0.00005
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance from Source (feet)
With Dispersion
Without Dispersion
FS = 2