Evaluation of Potential Impacts of Hydraulic Fracturing Flowback Fluid Additives on Microbial Processes in Publicly-Owned Treatment Works (POTWs)

> Prepared for Halliburton Energy Services, Inc. (HESI) P.O. Box 42806 Houston, TX 77242-2806

> > December 31, 2009



www.gradientcorp.com • 20 University Road • Cambridge, MA 02138

HESI302159

Table of Contents

1	Intro	oduction	1
2	Hyd	raulic Fracturing Flowback Fluid Disposal to a POTW	2
3		essment of Potential Impacts of Hydraulic Fracturing Flowback Fluid itives on POTW Biological Processes Exposure Analysis Effects Analysis Risk Characterization	3 4
4	Con	clusion	6
Refe	rences		7

Page

List of Tables

Table 1	HF Flowback Disposal to a POTW – Operational Assumptions
Table 2	HF Flowback Disposal – Acute Risks to Microorganisms Based on Model dSGEIS Fluid
	Concentrations
Table 3	HF Flowback Disposal – Acute Risks to Microorganisms Based on Measured Flowback
	Fluid Concentrations from PA and WV

List of Abbreviations

BOD	Biochemical Oxygen Demand
dSGEIS	Draft Supplemental Generic Environmental Impact Statement
HESI	Halliburton Energy Services, Inc.
HF	Hydraulic Fracturing
HQ	Hazard Quotient
MGD	Million Gallons Per Day
NYSDEC	New York State Department of Environmental Conservation
PA	Pennsylvania
POTW	Publicly-owned Treatment Works
QSAR	Quantitative Structure-Activity Relationship
RBC	Risk-Based Concentration
SPDES	State Pollutant Discharge Elimination System
TSS	Total Suspended Solids
WV	West Virginia

Gradient POTW Report-Final

Gradient

1 Introduction

The New York State Department of Environmental Conservation (NYSDEC) published a Draft Supplemental Generic Environmental Impact Statement (dSGEIS), dated September 2009, which contains generic permit requirements for the development of natural gas production wells in the Marcellus Shale formation using horizontal drilling and high-volume hydraulic fracturing techniques (NYSDEC, 2009). This memorandum evaluates potential risks of upsetting microbial processes in a wastewater treatment plant from exposure to typical additives likely to be present in hydraulic fracturing (HF) flowback fluid. Gradient has prepared this report on behalf of Halliburton Energy Services, Inc. (HESI).

1

Gradient POTW Report-Final

2 Hydraulic Fracturing Flowback Fluid Disposal to a POTW

Several options exist or are being developed for treatment, recycling or reuse of flowback water generated during HF operations.¹ One option is treatment of flowback water at publicly-owned treatment works (POTWs), which typically discharge effluent to surface waters, and are regulated in New York State by the State Pollutant Discharge Elimination System, commonly referred to as SPDES. The POTW's permit defines whether it can accept non-domestic waste and includes specific discharge limitations and monitoring requirements. A POTW must have a State-approved "pretreatment" program in order to accept industrial wastewater (such as HF flowback water). POTWs must also notify NYSDEC of any new industrial waste or of substantial changes in the volume or character of pollutants they plan to receive at their facility. NYSDEC must then determine if the SPDES permit needs to be modified.

In addition to an approved pretreatment program, a headworks analysis is required for a POTW to be able to accept HF flowback water. The data required for conducting a headworks analysis are specified in the dSGEIS (pp. 7-58 and 7-59) and include: general chemistry and aquatic toxicity. The POTW will utilize these data to determine whether the volumes and concentrations of chemicals present in the HF flowback water can be accepted by the facility and the changes needed to the facility's permit. One of the key objectives of a headworks analysis is to determine whether HF additives could adversely affect the POTW's microorganisms resulting in disruption of the POTW operation and diminished effluent quality. Therefore, this report presents such an analysis to predict the likely impact of HF additives in flowback water, if any, on microorganisms at a POTW.

¹ Information summarized in Section 2 of this memo is based upon information presented in the dSGEIS (NYSDEC, 2009).

3 Assessment of Potential Impacts of Hydraulic Fracturing Flowback Fluid Additives on POTW Biological Processes

Typically, microorganisms are used in the secondary treatment of wastewater to decompose organic matter at a POTW. As such, conditions in this secondary (biological) wastewater treatment step need to be conducive to microorganism survival. Failure to meet such conditions can cause an upset of the wastewater treatment process and can result in effluents that are not sufficiently treated for discharge to surface water.

3.1 Exposure Analysis

As discussed in Section 2, POTWs operate under permitting programs to ensure that upset conditions and discharges of inadequately treated wastewater are avoided under typical conditions. To evaluate the risk of flowback fluid from Marcellus Shale hydraulic fracturing operations causing disruption of POTW biological treatment processes, we used typical HF operations described in the dSGEIS, and operational information provided by HESI to Gradient, and assessed the potential impacts on POTW microorganisms for the operating conditions listed in Table 1.

POTW Treatment	
HF Disposal (gal/truck)	5,000
Transportation Rate (trucks/day)	10
Disposal Rate (gal/day)	50,000
POTW Flow (gal/day)	$2,000,000^{[a]}$
Flowback Fluid Dilution in POTW	40
(disposal rate/POTW flow)	40
tes:	

Table 1HF Flowback Disposal to a POTW – Operational Assumptions

^[a] Median POTW design flow for POTWs listed in Appendix 21 of the dSGEIS.

Based on the list of POTWs permitted to accept industrial wastewater listed in the dSGEIS, the median POTW flow capacity among these POTWs is 2 million gallons per day (MGD) (see Appendix 21 dSGEIS). It is anticipated that a typical HF flowback disposal rate could be 50,000 gal/day, resulting in a 40-fold dilution of the HF flowback fluid with other influent water. To calculate exposure concentrations to which microorganisms in a typical wastewater treatment plant would be exposed, the 40-fold dilution factor was applied to:

Gradient POTW Report-Final

- <u>Maximum</u> selected representative pollutant concentrations for the model HF fluid listed in Table 6.13 of the dSGEIS (dSGEIS model HF fluid); and
- <u>Maximum</u> measured flowback constituent concentrations,² based on limited data from Pennsylvania and West Virginia listed in Table 6.2, dSGEIS.³

POTW microorganism exposure concentrations for the dSGEIS model HF fluid are presented in Table 2 and exposure concentrations for the flowback fluid based on PA and WV data are presented in Table 3. These exposure concentrations were compared to microbial toxicity effect concentrations to characterize potential risks for disruption of biological treatment processes at a typical POTW.

3.2 Effects Analysis

Traditionally, municipal wastes have been mineralized biologically, employing an assortment of microorganisms. These wastes normally contain readily biodegradable organic substances, however with rapid industrialization, certain synthetic organic chemicals have been shown to cause upset conditions and POTW permit violations. Microbial toxicity data for synthetic organic chemicals are limited. Nonetheless, measured toxicity data were found for three (3) out of the 13 chemicals listed in the dSGEIS HF model fluid (Table 2), and all four (4) synthetic organic chemicals measured in flowback fluid from PA and WV (Table 3). The lowest median inhibitory concentration (IC50),⁴ reported in Trevizo and Nirmalakhandan (1999) or Nirmalakhandan *et al.* (1994), to have an effect on activated sludge, methanogens, nitrobacteria, or two commercial cultures (Polytox and Microtox) was used as the effects concentration [Risk-Based Concentration (RBC)] for POTW microorganisms.

With advances in quantitative structure-activity relationships (QSARs) it has become increasingly possible to derive models using available test results that can reliably predict toxicity for chemicals lacking effects data. For example, aqueous solubility was shown to be a reliable predictor of microbial toxicity by Trevizo and Nirmalakhandan (1999). These authors demonstrated statistically significant correlations between experimental toxicity data [(log (IC50)] and experimental water solubility data [log (solubility)]. An overall correlation was found to be:

² Constituent concentration estimates based on \leq 3 measurements were not considered sufficiently robust and were not further retained in our analysis.

 $^{^{3}}$ As stated in the dSGEIS, characteristics of flowback fluid from the Marcellus shale in New York are expected to be similar to flowback from PA and WV, but not identical (NYSDEC, 2009).

 $^{^4}$ IC50 (the median inhibitory concentration): This is a measure of the effectiveness of a chemical in inhibiting biological or biochemical function. For instance, in the Microtox assay, it is the concentration of a chemical at which 50% reduction in bioluminescence by marine bacteria occurs.

with a correlation coefficient of 0.756 for nearly 200 data points. This correlation was used to predict microbial toxicity values (RBC) for the remaining organic chemicals in the dSGEIS model HF fluid.

3.3 Risk Characterization

The risk characterization for our analysis is presented as an HQ, or hazard quotient, relating the estimated HF flowback constituent concentrations in a typical POTW to the chemical's risk-based concentration, or RBC:

$$HQ = \frac{POTW \ Conc}{RBC}$$

The numerator of this equation (POTW Conc) was calculated using the dSGEIS HF model fluid or measured flowback data (from PA and WV) and applying a dilution factor of 40. The denominator of this equation is the risk-based concentrations that were derived in the previous section. An HQ value of less than 1 indicates that adverse effects on POTW microorganisms are unlikely.

Since all predicted HQs are substantially lower than 1 (Table 2), none of the synthetic organic constituents in the dSGEIS model HF fluid are present at concentrations that are expected to adversely impact biological treatment processes at a typical POTW. Similarly, measured concentrations in HF flowback fluid from PA and WV, after dilution at a typical POTW are more than 3 orders of magnitude below microbial effect concentrations and are therefore not expected to upset plant treatment processes (Table 3).

There are a number of additional constituents listed in Table 3, such as conventional pollutant parameters [*e.g.*, biochemical oxygen demand (BOD), pH, total suspended solids (TSS), oil & grease, *etc.*] and non-conventional parameters (*e.g.*, metals). These additional constituents are commonly treated at POTWs and regulated under the SPDES permitting program to ensure compliance with applicable statutory and regulatory requirements. Therefore, these parameters are not expected to cause microbial toxicity and disrupt biological treatment processes under the conditions specified in a typical POTW facility's permit.

5

Gradient POTW Report-Final

4 Conclusion

We evaluated potential risks of upsetting microbial processes in a wastewater treatment plant from exposure to typical organic additives likely to be present in Marcellus Shale HF flowback fluid. Our analysis demonstrates that organic additives in the dSGEIS HF model fluid and measured flowback fluid data from PA/WV are not expected to cause microbial toxicity and upset conditions at POTWs that would treat such discharges in New York. Conventional (*e.g.*, BOD, pH, TSS, oil & grease, *etc.*) and nonconventional pollutants (*e.g.*, metals) present in HF flowback fluid are commonly treated at POTWs and regulated under the SPDES permitting program to ensure compliance with applicable statutory and regulatory requirements using pre-treatment approaches. They are therefore not expected to cause microbial toxicity and disrupt biological treatment processes under the conditions specified in the POTW's permit. Based on the analysis presented herein, it can be concluded that the organic HF fluid additives listed in the dSGEIS (both in the dSGEIS HF model fluid and in measured flowback data) are present at concentrations substantially below those that might result in disruption of biological treatment processes at typical POTWs treating HF flowback fluids in New York and therefore the possibility that these HF fluid additives might cause an upset condition is *de minimis*.

References

New York State, Dept. of Environmental Conservation (NYSDEC). 2009. "Well Permit Issuance for Horizontal Drilling and High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and other Low-Permeability Gas Reservoirs (Draft)." Division of Mineral Resources, Bureau of Oil & Gas Regulation / Supplemental Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program. September.

Nirmalakhandan, N; Arulgnanendran, V; Mohsin, M; Sun, B; Cadena, F. 1994. "Toxicity of mixtures or organic chemicals to microorganisms." *Water Research* 28(3):543-551.

Trevizo, C; Nirmalakhandan, N. 1999. "Prediction of microbial toxicity of industrial organic chemicals." *Water Science and Technology* 39(10-11):63-69.

7

Gradient POTW Report-Final

Chemical	CasNo	Purpose	Flowback Conc (ug/L) ¹	Flowback Conc (ug/L) ¹ POTW Conc (ug/L) ²	Water Solubility (ug/L) ³	RBC (ug/L) ⁴ Source ⁵	Source ⁵	НQ
Acrylamide	79-06-1	Friction Reducer	10,000	250	640,000,000	19,532,667	Μ	1.28E-05
Benzene	71-43-2	Corrosion Inhibitor	0.01	0.00025	2,000,000	74,986	н	3.33E-09
Diammonium Peroxidisulphate	7727-54-0	Breaker	100,000	2,500	559,000,000	25,876,231	Μ	9.66E-05
Ethylene Glycol	107-21-1	Crosslinker/Breaker/Scale Inhibitor	180,000	4,500	1,000,000,000	25,335,072	Μ	1.78E-04
Formaldehyde	50-00-0	Corrosion Inhibitor	500	13	400,000,000	10,770,069	Μ	1.16E-06
Glutaraldehyde	111-30-8	Biocide	90,000	2,250	709,980,000	23,389,127	Μ	9.62E-05
Hydrochloric Acid	7647-01-0	Acid	385,000	9,625	720,000,000	2,467,612	Μ	3.90E-03
Methanol	67-56-1	Surfactant/Cross Linker/Scale Inhibitor	984,000	24,600	1,000,000,000	20,000,000	ы	1.23E-03
Monoethanolamine	141-43-5	Crosslinker/Corrosion Inhibitor	18,000	450	1,000,000,000	25,205,057	Μ	1.79E-05
Heavy Naphtha	64742-48-9	Gelling Agent	275,000	406	406	1,439	Μ	2.82E-01
Propargyl Alcohol	107-19-7	Corrosion Inhibitor	1,500	38	1,000,000,000	24,522,739	Μ	1.53E-06
Propylene Glycol	57-55-6	Breaker, Surfactant	500,000	12,500	811,000,000	23,451,858	Μ	5.33E-04
Xylene	1330-20-7	Solvent	3,000	75	106,000	140,144	Э	5.35E-04

Acute Risks to Microorganisms Based on Model dSGEIS Fluid Concentrations HF Flowback Disposal

Table 2

I. - Maximum concentrations in flowback taken from Table 6-13 in dSGEIS (dSGEIS, 2009)
 Concentration in POTW = Flowback concentration/POTW dilution factor (40)
 Water solubility predicted using EPA's Epi Saite Software package (v 4.0)
 REC = Risk-Based Concentration (CS0) from Trevizo and Nitmadakhandan et al., 1994
 RBC = Risk-Based Concentration (CS0) from Trevizo and Nitmadakhandan et al., 1994
 RBC Source = Modeled (M) or Experimental (E) - note, the lowest experimentally-derived RBC using either activated studge, methanogens, nitrobacter or two commercial cultures (Polytox and Microtox) was used 6 - HQ = Hazard Quotient = POTW ConCRBC

G:/Projects/209135_HESI_NYSDECU eliverables/POTW/Gradient POTW Report - Final

Chemical CasVo Dender Conc (egL) ¹ POTV Conc (egL) ¹ Vac Soubling (egL) ¹ Ref (egL) ¹		THE OF SUSINE WINNE						
$^{\circ}$	Chemical	CasNo	Flowback Conc (ug/L) ¹	POTW Conc (ug/L) ²	Water Solubility (ug/L) ³	RBC (ug/L) ⁴	Source ⁵	нQ ⁶
(1.433) 3.190 80 25600 27700 E 1.432 1.930 <	Phenols ⁷	64743-03-9	440	11	8,470	17,881	Ĥ	6.15E-04
(1-4) $(1-4)$ <	Toluene	108-88-3	3,190	80	526,000	207,000	н	3.85E-04
mene 100414 164 41 169000 129515 E 5 2670 2670 677 100000 140144 E 5 13929575 3101000 76750 810000 140144 E 74395954 310000 76750 816 816 81 1439565 161000 76750 816 816 818 1439565 161000 76750 816 816 818 1439565 1430000 75750 816 818 818 84412 3190000 75750 816 818 818 844126 784000 75750 816 818 818 844128 784000 9550 8160 816 818 818 8441000 75750 816 816 816 818 818 844250 $7440-56$ 7381000 95500 8	Benzene	71-43-2	1,950	49	2,000,000	74,900	н	6.51E-04
($130, 120, 1$ $2,670$ $2,670$ $6,7$ $106,000$ $14,14$ E $130, 20, 7$ $3,70,000$ $5,750$ $3,70,000$ $5,750$ NE NE NA $1490, 20, 2$ $3,07,000$ $2,05, 2$ NE NE NE NA $1490, 20, 2$ $3,10,000$ $2,0,20$ NE NE NE NA $1490, 20, 2$ $3,10,000$ $2,0,20$ NE NE NA NA $1490, 24, 2$ $3,10,000$ $2,47,500$ NE NE NA NA m $1490, 26, 3$ $3,10,000$ $2,47,500$ NE NB NA m $1490, 26, 3$ $3,10,000$ $2,47,500$ NE NB NA m $1490, 26, 3$ $1,200, 0$ $3,570$ NE NB NA m $1490, 28$ $1,200, 0$ $2,30, 000$ NE NB NA m $1490, 28$ $1,200, 0$	Ethyl Benzene	100-41-4	164	4.1	169,000	129,515	Щ	3.17E-05
c $2495.67.9$ $3.070.000$ $7.67.90$ NENENENANA $744.02.0$ 137 2.035 NENENENENANA $744.02.9$ 101000 $2.0.250$ NENENENANA 749.954 101000 $2.0.250$ NENENENANA 866 749.965 149000 9.0250 NENENENANA 866 749.965 149000 9.5700 9.7500 NENENANA 866 749.465 149000 9.5700 9.7500 NENENANA 749.965 149000 9.5700 9.7500 NENENANA 749.466 140.923 149000 195.200 195.200 NENENANA m 7440.429 140.923 1570000 195.200 NENENANA m 7440.429 1570000 195.200 NENENANA m 7440.429 1570000 97.500 NENENANA m 7440.429 1570000 97.500 NENENANA m 7440.429 1570000 97.500 NENENANA m 7440.429 117000 97.500 NENENANA m 140.929 117000 97.500 NENENANA m 140.420	Xylenes	1330-20-7	2,670	67	106,000	140,144	ш	4.76E-04
1440.02 137 34 NENENENA 1249.924 $10,000$ $20,230$ NENENENA 1249.924 $10,000$ $20,230$ NENENENA 1249.924 $31,00,000$ $20,230$ NENENENA 1249.924 $31,90,000$ $25,730$ NENENENA 1249.924 $31,90,000$ $2417,500$ NENENENA 1249.924 $34,0000$ $2417,500$ NENENENA 1249.235 $96,700,000$ $2417,500$ NENENENA 1249.245 $3841,000$ $195,230$ NENENENA 1249.245 $3541,000$ $195,230$ NENENENA 1249.245 $3541,000$ $392,500$ NENENENA 1249.245 $3541,000$ $392,500$ NENENENA 1249.245 $350,000$ $32,500$ NENENENA 1249.245 $31,7000$ $32,500$ NENENENA 1249.245 $11,70000$ $32,500$ NENENENA 1249.245 $11,70000$ $31,750$ NENENENA 1249.245 $11,70000$ $31,750$ NENENENA 1249.245 $11,70000$ $31,750$ NENENENA 1249.245 1249.242 $11,70000$ $31,750$ NENE	Bromide	24959-67-9	3,070,000	76,750	NE	NE	NA	NE
(139.89.6) (139.89.6) (130.00) (20.2) (NE) (NE) (NE) (NA) mm (139.95.2) (1000) (20.2) (NE) (NE) (NE) (NE) (NE) (NA) esc (139.96.5) (1000) (20.5) (NE) (NE) (NE) (NE) (NE) (NE) (NE) (NA) summonia (139.96.5) (145.00) (247.500) (NE) (NE) (NE) (NE) (NE) (NE) (NA) m (140.243) (340.000) (241.500) (NE) (NE) (NE) (NE) (NE) (NE) (NE) (NA) m (140.245) (341.000) (195.200) (NE) (NE) (NE) (NE) (NA) m (140.55) (157.0000) (195.200) (NE) (NE) (NE) (NE) (NA) m (140.55) (157.0000) (195.200) (196.000) (110.000) (110.000) (110.000) (110.000) (11	Nickel	7440-02-0	137	3.4	NE	NE	NA	NE
memonia1439-9.2161,0004.0.25 NE NENANAese7439-95431,90,00095,750NENENBNANAese7439-95431,90,0009,550NENENBNANAese7439-95431,90,0009,550NENENBNANAese7439-95438,0009,550NENENBNANAm7440-9245,841,00014,6025NENENBNANAm7440-9245,841,00014,6025NENENBNANAm7440-9245,841,00014,6025NENENANANAm7440-9245,841,000992,500NENENANANAm7440-9245,841,000992,500NENENANANAm7440-9245,80090,000850,000NENANANAm7440-92434,00000850,000850,000NENANANAm7440-92434,0000095,750NENENANANAm7440-92434,0000095,750NENENANANAm7440-92434,0000095,750NENENANANAm7440-92434,0000095,750NENENANANAm7440-92810,000 <td< td=""><td>Iron</td><td>7439-89-6</td><td>810,000</td><td>20,250</td><td>NE</td><td>NE</td><td>NA</td><td>NE</td></td<>	Iron	7439-89-6	810,000	20,250	NE	NE	NA	NE
imm 1439.954 $3190,000$ 72750 NENENENANAsee 7439.956 $14,500$ 9.563 NENENENANAsamonia 764.916 $31,000$ 9.563 NENENENANAsamonia 764.912 $32,0000$ 9.570 NENENENANAm 7440.246 $5,31,000$ $195,250$ NENENENANAm 7440.266 $5,31,000$ $146,025$ NENENANAm 7440.566 9.0 30 NENENBNANAm 7440.566 9.0 30 NENENANAm 7440.566 9.0 30 NENENANAm 7440.566 9.0 30 NENENANAm 7440.566 9.0 30 NENENANAm 7440.456 390000 3000 900 NENENAm 7440.456 9.0000 31700 NENENANAm 7440.456 9.0000 31700 NENENANAm 7440.456 9.0000 31700 NENENANAm 7440.456 9.00000 31700 NENENANAm 7440.456 9.00000 31700 NENENANAm <td< td=""><td>Lithium</td><td>7439-93-2</td><td>161,000</td><td>4,025</td><td>NE</td><td>NE</td><td>NA</td><td>NE</td></td<>	Lithium	7439-93-2	161,000	4,025	NE	NE	NA	NE
ese 1439.6-5 1430.00 363 NE NE NE NA samonia 764-41-7 382.000 9,550 NE NE NE NA samonia 746-41-7 581.0000 247.500 NE NE NE NA m 7440-3-5 5.841.000 195.1250 NE NE NE NA m 7440-3-46 5.841.000 195.250 NE NE NA NA m 7440-3-45 5.841.000 146.025 NE NE NA NA m 7440-3-5 15.700.000 392.50 NE NE NA NA m 7440-32 15.700.000 392.50 NE NE NA NA m 7440-45 5.840.000 31.750 NE NE NA NA m 7440-45 5.800 6.70 NE NE NA NA m 7440-75 7440-75 <td< td=""><td>Magnesium</td><td>7439-95-4</td><td>3,190,000</td><td>79,750</td><td>NE</td><td>NE</td><td>NA</td><td>NE</td></td<>	Magnesium	7439-95-4	3,190,000	79,750	NE	NE	NA	NE
sammonia $7664-1$ $382,000$ $9,550$ NE NE NA NA sammonia $740-23-5$ $9,670,000$ $9,541,000$ $9,550$ NE NE NA NA m $7440-24-6$ $5,41,000$ $19,520$ NE NE NE NA NA m $7440-54-6$ $5,41,000$ $19,520$ NE NE NE NA NA m $7440-54-6$ $5,41,000$ $19,520$ NE NE NE NA NA $7440-54-7$ $5,41,000$ $9,520$ NE NE NA NA NA $7440-54-8$ $1,570,000$ $9,2,30$ NE NE NA NA $1740-54-8$ $1,570,000$ $9,2,30$ NE NE NA NA $1740-54-8$ $1,570,000$ $9,2,30$ NE NE NA NA $1740-54-8$ $1,270,000$ $3,2,500$ NE NE NA NA $1440-54-8$ $1,270,000$ $3,1,500$ NE NE NA NA $1440-44-9$ $1,270,000$ $3,1,500$ NE NE NA NA $1440-44-9$ $1,240,000$ $3,1,500$ NE NE NA NA $1440-44-9$ $1,270,000$ $3,1,500$ NE NE NA NA $1440-44-9$ $1,270,000$ $1,4,700$ $1,4,700$ NE NA NA $1440-44-9$ NA $1,270,000$ NE NE NA NA 1460	Manganese	7439-96-5	14,500	363	NE	NE	NA	NE
740.23.5 $96,70,000$ $2.417,500$ NENENANAm $740.23.5$ $96,70,000$ $195,250$ NENENANAm $7440.90.7$ $7,810,000$ $195,250$ NENENENA $7440.50.8$ $15,70,000$ $195,250$ NENENENA $7440.50.8$ $15,70,000$ $302,500$ NENENENA $7440.42.8$ $15,700,000$ $302,500$ NENENANA $7440.42.8$ $12,00,000$ $302,500$ NENENANA $7440.42.9$ $1,200,000$ $302,500$ NENENANA $7440.42.9$ $1,200,000$ $302,500$ NENENANA $7440.42.9$ $1,200,000$ $302,500$ NENENANA $7440.42.9$ $1,200,000$ $30,700$ NENENANA $7440.42.9$ $1,200,000$ $31,750$ NENENANA $7440.70.2$ $34,00,000$ $36,700$ NENENANA $7440.70.2$ $34,00,000$ $36,700$ NENENANA $7440.70.2$ $140,700$ $36,700$ NENENANA $7440.70.2$ $1,7000$ $36,700$ NENENANA $7440.70.2$ $1,7000$ $36,700$ NENENANA $7440.70.2$ $1,70000$ $36,700$ NENENANA 740.4000 $1,90000$	Aqueous ammonia	7664-41-7	382,000	9,550	NE	NE	NA	NE
m $1440.09.7$ $7.810,000$ $195,250$ NENENENANAm 7440.246 $5.841,000$ $146,025$ NENENENENANA $1740.50.8$ 157 3.9 NENENENENANA $1740.50.8$ 1570.000 $3.92,000$ NENENENANA $1740.52.8$ 1570.000 $392,500$ NENENENANA $1740.42.8$ $26,800$ 670 NENENENANA $1740.42.8$ 1270.000 $392,500$ NENENENANA $1740.42.8$ 1270.000 370.000 850.000 NENENANA $1740.42.8$ $1,270.000$ $31,750$ NENENENA $1740.42.8$ $1,270.000$ $31,750$ NENENANA $1480.87.98$ $1,270.000$ $31,750$ NENENA $117,000$ $2,925$ NENENANA $117,000$ $2,7200$ NENENANA $117,000$ $2,700$ NENENANA $117,000$ $2,925$ NENENENA $100,000$ $31,750$ NENENANA $100,000$ $32,700$ NENENANA $100,000$ $32,700$ NENENANA $100,000$ $14,000$ $14,000$ $14,60$ NENENA	Sodium	7440-23-5	96,700,000	2,417,500	NE	NE	NA	NE
m $146,025$ $5,841,000$ $16,025$ NE NE NE NA NA $140,026$ 157 3.9 NE NE NE NA NA $140,056$ 157 3.9 NE NE NE NA NA $140,056$ $1570,000$ $32,23$ NE NE NE NA $140,128$ $1570,000$ $32,00$ NE NE NE NA $140,128$ $1570,000$ $30,000$ $31,750$ NE NE NA $1440,428$ $1,270,000$ $31,750$ NE NE NA $1440,428$ $1,240,428$ $1,270,$	Potassium	7440-09-7	7,810,000	195,250	NE	NE	NA	NE
(4, 10, 10) $(4, 10, 10)$ $(1, 11, 20)$ $(1, 10, 10)$ $(1, 11, 20)$ $(1, 11, 10)$ $(1, 11, 10)$ $(1, 11, 10)$ $(1,$	Strontium	7440-24-6	5,841,000	146,025	NE	NE	NA	NE
1440.666 90 2.3 NE NE NA NA 7440.428 $15.700,000$ 392.500 NE NE NE NA NA 7440.428 $15.700,000$ 392.500 NE NE NE NA NA m 7440.428 $1.5.00,000$ 3070 NE NE NE NA NA m 7440.428 $1.20,000$ $850,000$ NE NE NE NA NA 1740.702 $340,0000$ $850,000$ NE NE NE NA NA 7440.84 5.80 $1.270,000$ $850,000$ NE NE NE NA $1480.79.8$ NA $1.270,000$ 31.750 NE NE NA NA $1480.79.8$ NA $1.740,000$ 31.750 NE NE NA NA MA NA $1.740,000$ 2.925 NE NE NA NA MA NA $1.708,000$ $2.700,000$ NE NE NA NA MA NA NA NA NA NE NA NA NE NA MA NA NA NA NA NE NE NA NA MA NA NA NA NA NE NA NA NA MA NA NA NA NA NE NA NA NA MA NA NA NA NA NA NA </td <td>Copper</td> <td>7440-50-8</td> <td>157</td> <td>3.9</td> <td>NE</td> <td>NE</td> <td>NA</td> <td>NE</td>	Copper	7440-50-8	157	3.9	NE	NE	NA	NE
7440.39.3 $15,700,000$ $392,500$ NE NE NA NA $7440.42.8$ $26,800$ 670 NE NE NE NA NA $17440.42.8$ $26,800$ 670 NE NE NE NA NA $17440.42.8$ $7440.42.9$ $1,200$ $850,000$ NE NE NE NA NA $17440.48.4$ $34,000,000$ $850,000$ NE NE NE NA NA $1740.48.4$ $1,270,000$ $31,750$ NE NE NE NA $1740.48.4$ $1,170,000$ $3,1750$ NE NE NA NA $1740.48.4$ $1,170,000$ $3,1750$ NE NE NA NA $1000000000000000000000000000000000000$	Zinc	7440-66-6	90	2.3	NE	NE	NA	NE
m $7440-42.8$ $26,800$ 670 NENENANAm $7440-42.8$ $1,200$ 30 NENENENANAn $7440-43.9$ $1,200$ 30 NENENENANAn $7440-43.9$ $1,200$ 3500 NENENENANA $1740-48.4$ 5.80 $1,450$ NENENENANA $1740-48.4$ 5.80 $1,17,000$ $31,750$ NENENENA $198.79.8$ $1,170,000$ $2,720,000$ $31,750$ NENENANA $198.79.700$ NA $1,170,000$ $2,720,000$ NENENENA $10,80,000$ $2,700$ NE NENENENA $10,80,000$ $36,790$ NENENENANA $10,80,000$ $2,700,000$ $36,700$ NENENA $10,80,000$ $36,700$ NENENENA $10,80,000$ $1,700,000$ $8,425,000$ NENENA $10,80,000$ $14,700$ $14,620,000$ NENENA $10,90,$	Barium	7440-39-3	15,700,000	392,500	NE	NE	NA	NE
mm140-43-91,20030NENENANA $1740-43-4$ $740-43-4$ $3400,000$ $850,000$ NENENENANA $1740-48-4$ 580 14.50 NENENENANA $1740-48-4$ 580 14.50 NENENENANA $1740-48-4$ 580 14.50 NENENENANA $140-48-4$ $1808-79-8$ $117,000$ $31,750$ NENENANA $1490-000$ $31,750$ NENENENANA 1470000 $31,750$ NENENANA 1470000 $27,000$ $31,750$ NENENA 17700 NA $1,708,000$ $42,700$ NENENA $1000000000000000000000000000000000000$	Boron	7440-42-8	26,800	670	NE	NE	NA	NE
1 140-70-2 34,00000 850,000 NE NE NA NA 740-70-2 580 14.50 NE NE NE NA NA tyt 14808-79-8 1,270,000 31,750 NE NE NA NA tyt 14808-79-8 1,270,000 31,750 NE NE NA tyt NA 117,000 2,925 NE NE NA Grease NA 117,000 2,925 NE NE NA agaic Carbon NA 1,708,000 42,700 NE NE NA nates NA 1,080,000 5,700,000 NE NE NA nates NA 1,080,000 5,700,000 NE NE NA e NA 1,080,000 8,425,000 NE NE NA e NA 337,000,000 8,455,000 NE NE NA e NA 31,90	Cadmium	7440-43-9	1,200	30	NE	NE	NA	NE
(14) (14) <th< td=""><td>Calcium</td><td>7440-70-2</td><td>34,000,000</td><td>850,000</td><td>NE</td><td>NE</td><td>NA</td><td>NE</td></th<>	Calcium	7440-70-2	34,000,000	850,000	NE	NE	NA	NE
(i) (i) <td>Cobalt</td> <td>7440-48-4</td> <td>580</td> <td>14.50</td> <td>NE</td> <td>NE</td> <td>NA</td> <td>NE</td>	Cobalt	7440-48-4	580	14.50	NE	NE	NA	NE
alinity, Carbonate, as CaCO3 NA 117,000 2,925 NE NE NA NA and Grease NA 1,470,000 36,750 NE NE NA NA al Organic Carbon NA 1,470,000 36,750 NE NE NA NA al Organic Carbon NA 1,880,000 27,000 NE NE NA NA arbonates NA 1,080,000 27,000 NE NE NA NA arbonates NA 1,980,000 5,700,000 NE NE NA NA arbonates NA 23,700,000 8,425,000 NE NE NA al Dissolved Solids NA 37,700,000 8,425,000 NE NE NA al Kjeldaln Nitrogen NA 37,900,000 8,425,000 NE NE NA al Kjeldaln Solids NA 31,900,000 8,425,000 NE NE NA NA NA NA NA	Sulfate	14808-79-8	1,270,000	31,750	NE	NE	NA	NE
and Grease NA 1,470,000 36,750 NE NE NA NA al Organic Carbon NA 1,870,000 36,750 NE NE NA NA al Organic Carbon NA 1,080,000 27,000 NE NE NE NA arbonates NA 1,080,000 27,000 NE NE NE NA oride NA 1,708,000 5,700,000 NE NE NE NA oride NA 238,000,000 5,700,000 NE NE NA NA oride NA 337,000,000 8,425,000 NE NE NA NA oride NA 337,000,000 8,425,000 NE NE NA NA oride NA 337,000,000 8,425,000 NE NE NA NA oride NA 31,900,000 14,550 NE NE NA NA oride NA	Alkalinity, Carbonate, as CaCO3	NA	117,000	2,925	NE	NE	NA	NE
al Organic Carbon NA 1,080,000 27,000 NE NE NE NA NA arbonates NA 1,708,000 42,700 NE NE NE NA NA arbonates NA 1,708,000 42,700 NE NE NE NA arbonates NA 8.0 NA 8.0 NA NE NE NA NA arbonates NA 238,000,000 5,700,000 NE NE NA NA al SigledM Nitrogen NA 337,000,000 14,655 NE NE NA NA al SigledM Nitrogen NA 31,900,000 14,655 NE NE NA NA al Supended Solids NA 31,900,000 14,750 NE NE NA NA al Supended Solids NA 1,910,000 47,750 NE NE NA NA al Supended Solids NA 1,910,000 11,1250 NE	Oil and Grease	NA	1,470,000	36,750	NE	NE	NA	NE
arbonates NA 1,708,000 42,700 NE NE NE NA NA NA NA NB NA NB NB NB NA NB NB NB NB NA NA NA NB NA NA NA NB NB NB NB NB NA NA NA NB NB NA NA <td>Total Organic Carbon</td> <td>NA</td> <td>1,080,000</td> <td>27,000</td> <td>NE</td> <td>NE</td> <td>NA</td> <td>NE</td>	Total Organic Carbon	NA	1,080,000	27,000	NE	NE	NA	NE
NA 8.0 NA NE NE NE NE NA OIL al Dissolved Solids NA 228,000,000 5,700,000 NE NE NA NA al Dissolved Solids NA 337,000,000 8,425,000 NE NE NA NA al Kjeldahl Nitrogen NA 337,000,000 8,425,000 NE NE NA NA al Kjeldahl Nitrogen NA 337,000,000 8,425,000 NE NE NA NA al Stopended Solids NA 31,900,000 797,500 NE NE NA NA al Suspended Solids NA 1,910,000 47,750 NE NE NA NA chemical Oxygen Demand NA 4,450,000 111,250 NE NE NA NA	Bicarbonates	NA	1,708,000	42,700	NE	NE	NA	NE
NA 223,000,000 5,700,000 NE NE NE NA 337,000,000 8,425,000 NE NE NE NA NA 337,000,000 8,425,000 NE NE NA NA 337,000,000 14,625 NE NE NA NA 31,900,000 797,500 NE NE NA NA NB NA NB NA NA NB NA NB NA NB NA NA NA NA NA NA NA NB NA NA NA NA NB NA NB NA	PH	NA	8.0	NA	NE	NE	NA	NE
NA 337,000,000 8,425,000 NE NE NE NA 337,000,000 14,625 NE NE NE NA NA 585,000 14,625 NE NE NA NA 31,900,000 797,500 NE NE NA NA 1,910,000 47,750 NE NE NA NA NA NE NA NA NE NA NA NA NA NE NA N	Chloride	NA	228,000,000	5,700,000	NE	NE	NA	NE
NA 585,000 14,625 NE NE NA NB NA 31,900,000 797,500 NE NE NA NA NA NA NB NA NB NA NB NA NA NA NA NB NA NA NB NA NB NA NA NA NA NA NA NA NB NA NA NA NA NA NA NB NA N	Total Dissolved Solids	NA	337,000,000	8,425,000	NE	NE	NA	NE
NA 31,900,000 797,500 NE NE NA NA 1,910,000 47,750 NE NE NA NA 1,910,000 47,750 NE NE NA NA 4,450,000 111,250 NE NE NA	Total Kjeldahl Nitrogen	NA	585,000	14,625	NE	NE	NA	NE
NA 1,910,000 47,750 NE NE NA NA 4,450,000 111,250 NE NE NA	Chemical Oxygen Demand	NA	31,900,000	797,500	NE	NE	NA	NE
NA 4,450,000 111,250 NE NE NA	Total Suspended Solids	NA	1,910,000	47,750	NE	NE	NA	NE
	Biochemical Oxygen Demand	NA	4,450,000	111,250	NE	NE	NA	NE

HF Flowback Disposal Table 3

Maximum measured concentrations taken from Table 6-2 in dSCEIS (dSCEIS, 2009)
 Concentration in POTW = Flow back concentration/POTW dilution factor (40)
 Rare solubility predicated single FLAs Egits Software production (AO)
 RE Concentration (ECS0) from Thereize on AN inmulability and an et al., 1994
 RE Source = Experimental (E) - note, the lowest experimentaly-derived toxicity value using either activated sludge, methanogens, nitrobacter or no commercial cultures (Polytox and Microtox) was used
 H = Hacard Quotient = POTW ConcRBC

7 - Phenol (CAS 108-95-2) was used as a surrogate NA - Not Applicable NE - Not Evaluated

HESI302170

G:\Projects\209135_HESI_NYSDECUcliverables\POTW\Gradent POTW Report - Final