TELESTO
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TECHNICAL MEMORANDUM

DATE:	March 20, 2006	Telesto #	305100 Task 2
TO:	Paul Michalak, NRC/Uranium Processing Section		
FROM:	David Levy, Telesto Solutions, Inc. Tom Gieck, Umetco Minerals Corporation		
SUBJECT:	Umetco Minerals Corporation Gas Hills Site: Sensitivity Analysis of the Effect of Increasing Sulfate on Modeled Lead-210 Concentrations in Ground Water.		

1.0 INTRODUCTION

The Umetco Minerals Corporation (Umetco) proposal to amend License SUA-648, authorizing the use of Alternate Concentration Limits (ACLs) at the East Gas Hills Site, was approved by the U.S. Nuclear Regulatory Commission (NRC) on March 29, 2002 (Umetco, 2001). In 2005, however, the NRC suggested that Umetco propose a revised ^{210}Lead (^{210}Pb) ACL in ground water for the East Gas Hills Southwestern Flow Regime (SWFR). A revised ^{210}Pb ACL was recommended to avoid future exceedences of the current SWFR ^{210}Pb ACL (46.7 pCi/L) which have recently occurred in Monitoring Well GW7. A technical evaluation of ground water elevation and water quality trends have shown that fluctuation of ground water levels in mineralized zones can produce naturally-elevated concentrations of ^{210}Pb which exceed the current ACL for ^{210}Pb (Telesto Solutions, Inc., 2005a).

Umetco has proposed to use the highest historical observed ^{210}Pb concentration of 189 pCi/L from Monitoring Well GW3 as the revised ^{210}Pb ACL for the SWFR. The ground water model was revised accordingly in 2005, and the results indicated that the proposed ^{210}Pb ACL of 189 pCi/L would be protective of human health and the environment at the Point of Exposure (POE) (Telesto, 2005b). However, due to recent increases in sulfate concentrations at the Point of Compliance (POC) Well GW8, the NRC has requested that the sensitivity of

modeled ^{210}Pb concentrations to increasing sulfate be evaluated. Because sulfate forms aqueous metal complexes and may also compete with metal adsorption sites, increasing sulfate concentrations could potentially result in increased mobilization of ^{210}Pb.

2.0 SENSITIVITY ANALYSIS

The sensitivity analysis was performed in three steps based on discussions with NRC. First, the ground water represented by the model (MW-74 with 24.1 mg/L sulfate) was replaced with another ground water containing a higher sulfate concentration (MW-72 with 1,190 mg/L sulfate) to improve the representation of existing conditions. Second, the composition of ground water modeled in the vicinity of POC Well GW8 was revised with 2005 data to reflect recent increases in sulfate (3,020 mg/L) at Well GW8. Third, model output for ^{210}Pb were generated for a series of increasing sulfate concentrations, which were used as input to the decreasing source term and for existing ground water in the vicinity of GW8. All model simulations used a conservative ground water velocity of 0.28 feet/day (Umetco, 2001).

The sulfate concentrations used in the sensitivity analysis were increased to 6,000 mg/L, 9,000 mg/L, 12,000 mg/L, and 15,000 mg/L. The upper limit of the modeled sulfate concentrations (15,000 mg/L) was chosen to bracket the highest historical sulfate concentration of 13,200 mg/L in Well GW3, located in the general vicinity of POC Well GW8. To account for the modeled increase in sulfate concentrations, charge balance was artificially maintained by increasing calcium (10%), magnesium (25%), sodium (10%), potassium (5%), and ferrous iron (25%) to maintain an overall charge balance of $\leq$15% (Table 1). The original mixing model used to determine the composition of the decreasing source term (Umetco, 2001) was then revised and input into the model (Table 2). An example model input file (sulfate = 6,000 mg/L) is provided in Attachment A.

3.0 MODEL RESULTS AND DISCUSSION

Model results showing the predicted concentrations of ^{210}Pb as a function of time at the POE for varying sulfate concentrations are shown on Figure 1. The predicted concentrations of ^{210}Pb as a function of distance between the POC and the POE for the same sensitivity analyses are shown on Figure 2. On each figure, the ^{210}Pb model output from the original ACL application (Umetco, 2001) is shown for comparison on the curve labeled "2001 Model". The curve labeled "2001 Model-Revised GW" shows the results from the first step of the sensitivity analysis, where existing ground water in the original model (MW-74 with 24.1 mg/L sulfate) was replaced with another ground water containing a higher sulfate concentration (MW-72 with 1,190 mg/L sulfate) to improve the representation of existing conditions. The curve labeled "3,020 mg/L sulfate" shows the results from the second step of the sensitivity analysis, where the composition of ground water modeled in the vicinity of POC Well GW8 was revised with 2005 data to reflect recent increases in sulfate at Well GW8. The remaining curves depict the ^{210}Pb results from the additional sensitivity calculations for sulfate concentrations ranging from 6,000 mg/L to 15,000 mg/L.

The results of the sensitivity calculations indicate that concentrations of ^{210}Pb are not expected to exceed the Ground Water Protection Standard (GWPS) of 4.6 pCi/L (Umetco, 2001) at the POE for the 1,000 year compliance period. Although the model predicts that increasing sulfate concentrations will increase the mobility of ^{210}Pb to values which exceed the GWPS, the ^{210}Pb is not expected to reach the POE within the same 1,000 year time frame (Figure 2).

4.0 SUMMARY AND CONCLUSION

A model sensitivity analysis was conducted to examine the effects of increasing sulfate on predicted ground water concentrations of ^{210}Pb in the East Gas Hills SWFR. The results of this analysis show that concentrations of ^{210}Pb are not expected to exceed the GWPS of 4.6 pCi/L (Umetco, 2001) at the POE for the 1,000 year compliance period.

5.0 REFERENCES

Telesto Solutions, Inc. 2005a. Gas Hills ACL Action Plan for Point of Compliance Well GW7. Technical Memorandum to Umetco Minerals Corporation, January 28.

Telesto Solutions, Inc. 2005b. Proposed Revised ACL for Pb-210 in the Southwestern Flow Regime, East Gas Hills, Wyoming. Technical Memorandum to Umetco Minerals Corporation, April 1.

Umetco Minerals Corporation. 2001. Final Application for Alternate Concentration Limits for Gas Hills, Wyoming. November.

ATTACHMENT A

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TITLE  A-9 area (SW flow regime). FILE: SWFR2d_sulfate2.in
#Concentration vs Distance between POE and POE
#Using flow rate of 0.28 ft/d - DECREASING SOURCE TERM TO 90% REDUCTION
#Dispersivity = 50
#SOLID PHASES ALLOWED
#Revised in 2005 for Pb-210
#Revised in 2006 for solutions in cells 1-54/ Sulfate = 6000 mg/L
KNOBS
      -iterations 100
      -tolerance 1.00E-13
      -step_size 100
      -pe_step_size 10
      -diagonal_scale TRUE
      -debug_prep FALSE
      -debug_set FALSE
      -debug_model FALSE
      -debug_inverse FALSE
      -logfile FALSE

SOLUTION 0 # Initial Source Term
      units      ppm
      pe         8
      pH         4.33
      Th         2.22e-6
      Pb         2.44e-9    #Revised ACL 2005/2006
      Be         1.7
      Ca         800 #Increased to achieve reasonable charge balance with SO4.
      Mg         356 #Increased to achieve reasonable charge balance with SO4.
      Na         221 #Increased to achieve reasonable charge balance with SO4.
      K          151 #Increased to achieve reasonable charge balance with SO4.
      Fe(2)      576 #Increased to achieve reasonable charge balance with SO4.
      Cl         161
      As         1.36
      Ni         9.34
      Se         0.53
      Si         56.4
      U          34.1
      Alkalinity 2.44 as HCO3
      S(6)       6000 #Recent GW-8 data
      Ra         3.57e-7

SOLUTION 1-5 GW8 #2005 data replaces January 2001 data
      units      ppm
      pe         7
      pH         4.41 #Aug-05
      S(6)       6000 #May-05
      Cl         97
      #Alkalinity 2.0  as HCO3
      Ca         800 #Increased to achieve reasonable charge balance with SO4.
      Na         221 #Increased to achieve reasonable charge balance with SO4.
      Mg         356 #Increased to achieve reasonable charge balance with SO4.
      K          151 #Increased to achieve reasonable charge balance with SO4.
      Fe(2)      576 #Increased to achieve reasonable charge balance with SO4.
      As         0.0272 #May-05
      Be         0.22 #May-05
      Th         5.46e-8 #May-05
      Pb         2.32e-10 #May-05
      Ra         2.63e-7 #Aug-05
      Ni         3.2 #May-05
      Se         0.05 #May-05
      U          22.9 #May-05

SOLUTION 6-54 MW-72 #Replaces MW-74 January 2001
      units      ppm
      pe         6
      pH         6.48  #Jun-04
      S(6)       1190 #Jun-04
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```
      Cl          115 #Jun-04
      Alkalinity 400 as HCO3      #Jan-01
      Ca          580 #Jan-01
      Na          25 #Jan-01
      Mg          63 #Jan-01
      K           17 #Jan-01
      Fe(2)       4 #Jan-01
      As          0.0081 #Jun-05
      Be          0.0001      # Jun-05
      #Th         3.77e-8 negative value reported
      Pb          2.97e-11 #Jan-01
      Ra          2.42e-8 #Jan-01
      Ni          0.0179 #Jun-05
      Se          0.017 #Jun-05
      U           0.609 #Jun-05
      #S(-2)            0.033 not measured

EQUILIBRIUM_PHASES 1-54
      Calcite           0.0         0.0
      Gypsum            0.0         0.0
      Uraninite         0.0         0.0
      USiO4(c)          0.0         0.0
      Ferroselite       0.0         0.0
      Se(A)             0.0         0.0
      RaSO4             0.0         0.0
      NiSe              0.0         0.0
      Anglesite         0.0         0.0

SURFACE 1-5
      -equilibrate 1
      Hfo_wOH     0.086       600      45.9
      Hfo_sOH     0.0021

SURFACE 6-54
      -equilibrate 6
      Hfo_wOH     0.086       600      45.9
      Hfo_sOH     0.0021

EXCHANGE 1-5
      -equilibrate 1
      X     1.2

EXCHANGE 6-54
         -equilibrate 6
      X        1.2

TRANSPORT
      -lengths          54*30.5
      -dispersivities   54*50
      -cells            54
      -shifts           6

PRINT
      -reset      false
END

SOLUTION 0 #33% REDUCTION

      units       ppm
      pe          5.6
      pH          4.47
      Th          1.47e-6
      Pb          1.63e-9     #Revised ACL 2005/2006
      Ra          2.41E-07
      U           22.62
      Be          1.13
      Ca          632
```

```
      Mg          258
      Na          164
      K           107
      Fe(2)       386
      Cl          114.6
      As          0.90
      Ni          6.20
      Se          0.35
      Si          37.4
      Alkalinity 4.0 as HCO3
      S(6)        4218

TRANSPORT
      -lengths         54*30.5
      -dispersivities  54*50
      -cells           54
      -shifts          3

END

SOLUTION 0 #50% Reduction

      units       ppm
      pe          5.5
      pH          4.57
      Th          1.12e-6
      Pb          1.24e-9          #Revised ACL 2005/2006
      Ra          1.86E-07
      U           17.16
      Be          0.85
      Ca          550
      Mg          211
      Na          136
      K           85.4
      Fe(2)       295
      Cl          92.5
      As          0.68
      Ni          4.7
      Se          0.27
      Si          28.31
      Alkalinity 4.73 as HCO3
      S(6)        3356

TRANSPORT
      -lengths         54*30.5
      -dispersivities  54*50
      -cells           54
      -shifts          7
END

SOLUTION 0 #75% Reduction

      units       ppm
      pe          5.1
      pH          4.85
      Th          5.65e-07
      Pb          6.42E-10   #Revised ACL 2005/2006
      Ra          1.0E-07
      U           8.62
      Be          0.43
      Ca          421
      Mg          137
      Na          92.3
      K           52
      Fe(2)       152
      Cl          58
      As          0.34
```

```
      Ni          2.36
      Se          0.13
      Si          14.2
      Alkalinity 5.88 as HCO3
      S(6)        2008

TRANSPORT
      -lengths         54*30.5
      -dispersivities  54*50
      -cells           54
      -shifts          19
END

SOLUTION 0 #90% Reduction

      units       ppm
      pe          4.4
      pH          5.27
      Th          2.33E-07
      Pb          2.80e-10   #Revised ACL 2005/2006
      Ra          4.84e-8
      U           3.5
      Be          0.17
      Ca          344
      Mg          92.2
      Na          66.2
      K           31.9
      Fe(2)       65.7
      Cl          37.3
      As          0.14
      Ni          0.96
      Se          0.05
      Si          5.66
      Alkalinity 6.56 as HCO3
      S(6)        1200

TRANSPORT
      -lengths         54*30.5
      -dispersivities  54*50
      -cells           54
      -shifts          987
      -punch_frequency 987

SELECTED_OUTPUT

      -file C:\SWFR2d_sulfate2.dat

USER_PUNCH
            -headings As Be Cl Pb U Ni Se SO4 Th Ra sOPb+
      -headings wOPb+ PbX2 Anglesite sOHUO2+2
      -headings wOUO2+ USiO4(C) Uraninite sONi+ wONi+
      -headings NiSe sOHRa+2 wORa+ RaX2 RaSO4 wSeO4-
      -headings wOHSeO4-2 wSeO3- wOHSeO3-2 Se(A)
      -headings FeSe2 sSO4- wSO4- sOHSO4-2 wOHSO4-2
      -headings gypsum wOTh+3 wOTh(OH)+2 wOTh(OH)2+
      -headings wOTh(OH)3 wOTh(OH)4- sH2AsO3 wH2AsO3
      -headings sH2AsO4 wH2AsO4 sHAsO4- wHAsO4- sAsO4-2
      -headings wAsO4-2 sOHAsO4-3 wOHAsO4-3 sOBe+ wOBe+
      -headings Calcite Ca Mg Na K HCO3 SO4 Cl TDS
      -start
      10  REM Convert to ppm and show molalities
      20  PUNCH TOT("As")*74.9216*1000
      30  PUNCH TOT("Be")*9.0122*1000
      40  PUNCH TOT("Cl")*35.453*1000
      50  PUNCH TOT("Pb")*207.19*1000/1.29e-11
      60  PUNCH TOT("U")*238.029*1000
      70  PUNCH TOT("Ni")*58.71*1000
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80  PUNCH TOT("Se")*78.96*1000
90 PUNCH TOT("S(6)")*96.0616*1000
100 PUNCH TOT("Th")*232.038*1000/4.96e-8
110 PUNCH TOT("Ra")*226*1000/1.01e-9
120 PUNCH MOL("Hfo_sOPb+")
130 PUNCH MOL("Hfo_wOPb+")
140 PUNCH MOL("PbX2")
150 PUNCH EQUI("Anglesite")
160 PUNCH MOL("Hfo_sOHUO2+2")
170 PUNCH MOL("Hfo_wOUO2+")
180 PUNCH EQUI("USiO4(C)")
190 PUNCH EQUI("Uraninite")
200 PUNCH MOL("Hfo_sONi+")
210 PUNCH MOL("Hfo_wONi+")
220 PUNCH EQUI("NiSe")
230 PUNCH MOL("Hfo_sOHRa+2")
240 PUNCH MOL("Hfo_wORa+")
250 PUNCH MOL("RaX2")
260 PUNCH EQUI("RaSO4")
270 PUNCH MOL("Hfo_wSeO4-")
280 PUNCH MOL("Hfo_wOHSeO4-2")
290 PUNCH MOL("Hfo_wSeO3-")
300 PUNCH MOL("Hfo_wOHSeO3-2")
310 PUNCH EQUI("Se(A)")
320 PUNCH EQUI("Ferroselite")
330 PUNCH MOL("Hfo_sSO4-")
340 PUNCH MOL("Hfo_wSO4-")
350 PUNCH MOL("Hfo_sOHSO4-2")
360 PUNCH MOL("Hfo_wOHSO4-2")
370 PUNCH EQUI("gypsum")
380 PUNCH MOL("Hfo_wOTh+3")
390 PUNCH MOL("Hfo_wOTh(OH)+2")
400 PUNCH MOL("Hfo_wOTh(OH)2+")
410 PUNCH MOL("Hfo_wOTh(OH)3")
420 PUNCH MOL("Hfo_wOTh(OH)4-")
430 PUNCH MOL("Hfo_sH2AsO3")
440 PUNCH MOL("Hfo_wH2AsO3")
450 PUNCH MOL("Hfo_sH2AsO4")
460 PUNCH MOL("Hfo_wH2AsO4")
470 PUNCH MOL("Hfo_sHAsO4-")
480 PUNCH MOL("Hfo_wHAsO4-")
490 PUNCH MOL("Hfo_sAsO4-2")
500 PUNCH MOL("Hfo_wAsO4-2")
510 PUNCH MOL("Hfo_sOHAsO4-3")
520 PUNCH MOL("Hfo_wOHAsO4-3")
530 PUNCH MOL("Hfo_sOBe+")
540 PUNCH MOL("Hfo_wOBe+")
550 PUNCH EQUI("Calcite")
560 PUNCH TOT("Ca")*40.08*1000
570 PUNCH TOT("Mg")*24.312*1000
580 PUNCH TOT("Na")*22.9898*1000
590 PUNCH TOT("K")*39.102*1000
600 PUNCH TOT("C(4)")*61.018*1000
610 PUNCH TOT("S(6)")*96.0616*1000
620 PUNCH TOT("Cl")*35.453*1000
630 A = (TOT("Ca")*40.08*1000)+(TOT("Mg")*24.312*1000)
640 B = (TOT("Na")*22.9898*1000)+(TOT("K")*39.102*1000)
650 C = TOT("C(4)")*61.018*1000
660 D = TOT("S(6)")*96.0616*1000
670 E = TOT("Cl")*35.453*1000
680 PUNCH A+B+C+D+E
-end
END
```

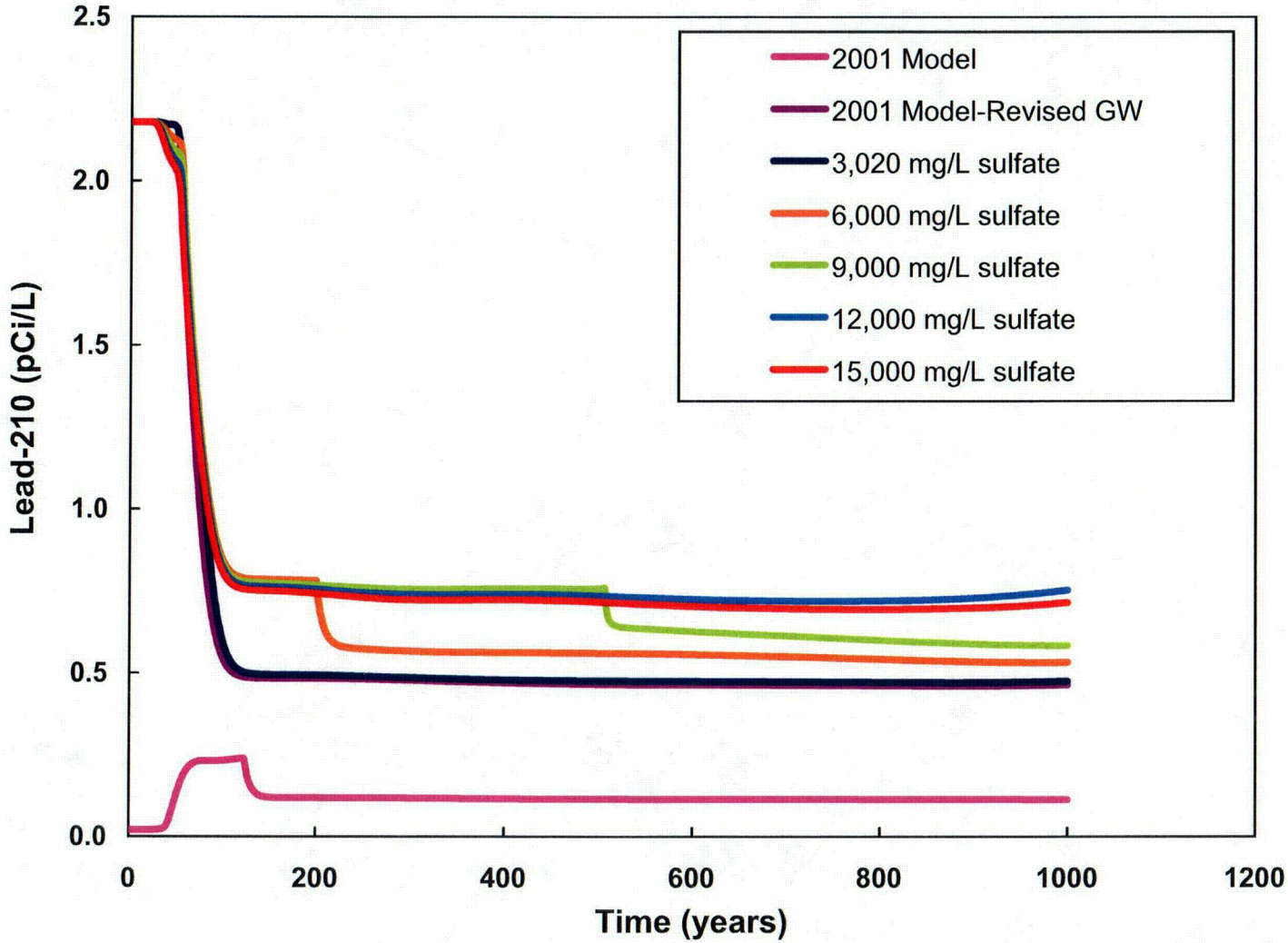
Table 1: Cation-Anion Balance for Sulfate Sensitivity Runs.

Sulfate 1	(3,020 mg/L)	me/L	Sulfate 2	(6,000 mg/L)	me/L	Sulfate 3	(9,000 mg/L)	me/L	Sulfate 4	(12,000 mg/L)	me/L	Sulfate 5	(15,000 mg/L)	me/L
delta SO4	370	7.70	delta SO4	2980	62.0	delta SO4	3000	62.5	delta SO4	3000	62.5	delta SO4	3000	62.5
Mg increase	23.4	1.93	Mg increase	188.5	15.5	Mg increase	189.7	15.6	Mg increase	189.7	15.6	Mg increase	189.7	15.6
Ca increase	15.4	0.77	Ca increase	124.3	6.2	Ca increase	125.2	6.2	Ca increase	62.6	3.1	Ca increase	62.6	3.1
Na increase	17.7	0.77	Na increase	142.6	6.2	Na increase	143.6	6.2	Na increase	143.6	6.2	Na increase	143.6	6.2
K increase	15.1	0.39	K increase	121.3	3.1	K increase	122.1	3.1	K increase	122.1	3.1	K increase	122.1	3.1
Fe increase	53.7	1.93	Fe increase	432.8	15.5	Fe increase	435.7	15.6	Fe increase	435.7	15.6	Fe increase	435.7	15.6
Magnesium	167.4	13.8	Magnesium	355.9	29.3	Magnesium	545.6	44.9	Magnesium	735.3	60.5	Magnesium	925.0	76.1
Calcium	675.4	33.7	Calcium	799.8	39.9	Calcium	924.9	46.2	Calcium	987.5	49.3	Calcium	1050.1	52.4
Sodium	78.7	3.4	Sodium	221.4	9.6	Sodium	364.9	15.9	Sodium	508.5	22.1	Sodium	652.1	28.4
Potassium	30.1	0.8	Potassium	151.3	3.9	Potassium	273.4	7.0	Potassium	395.5	10.1	Potassium	517.6	13.2
Iron	142.7	5.1	Iron	575.5	20.6	Iron	1011.2	36.2	Iron	1446.8	51.9	Iron	1882.5	67.5
Chloride	161	4.5	Chloride	161.0	4.5	Chloride	161.0	4.5	Chloride	161.0	4.5	Chloride	161.0	4.5
Sulfate	3020	62.9	Sulfate	6000	124.9	Sulfate	9000	187.4	Sulfate	12000	249.8	Sulfate	15000	312.3
Cations (me/L)	56.8		Cations (me/L)	103.3		Cations (me/L)	150.2		Cations (me/L)	193.9		Cations (me/L)	237.6	
Anions (me/L)	67.4		Anions (me/L)	129.5		Anions (me/L)	191.9		Anions (me/L)	254.4		Anions (me/L)	316.8	
% Difference	-8.6		% Difference	-11.2		% Difference	-12.2		% Difference	-13.5		% Difference	-14.3	

Table 2: Mixing Model Results for Decreasing Source Term.

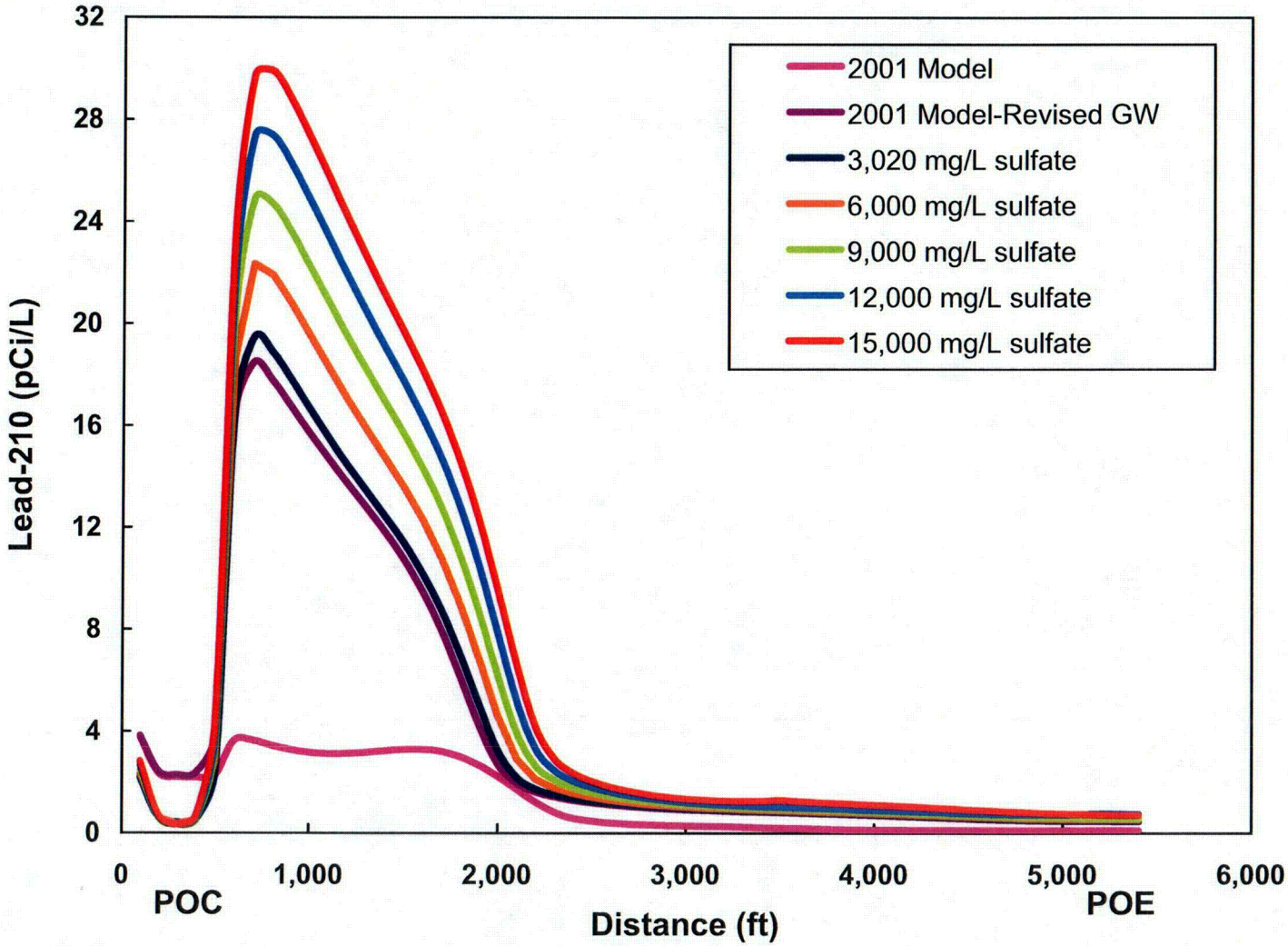
Sulfate (mg/L)	% Reduction	33	50	75	90
3,020	Calcium	547	485	389	331
	Magnesium	132	115	88.9	73.1
	Sodium	68.7	63.9	56.3	51.8
	Potassium	26.2	24.3	21.4	19.7
	Chloride	115	92.6	58.0	37.3
	Sulfate	2227	1847	1254	898
	Iron	97.7	76.0	42.2	21.9
6,000	% Reduction	33	50	75	90
	Calcium	632	550	421	344
	Magnesium	258	211	137	92.2
	Sodium	164	136	92.3	66.2
	Potassium	107	85	52.0	31.9
	Chloride	115	92.9	58.2	37.3
	Sulfate	4218	3356	2008	1200
	Iron	386	295	152	66
9,000	% Reduction	33	50	75	90
	Calcium	718	614	453	357
	Magnesium	386	308	185	112
	Sodium	261	209	129	80.8
	Potassium	189	147	83.0	44.3
	Chloride	116	93.2	58.3	37.4
	Sulfate	6239	4887	2774	1506
	Iron	678	516	262	110
12,000	% Reduction	33	50	75	90
	Calcium	762	648	470	364
	Magnesium	514	405	234	131
	Sodium	358	283	166	95.6
	Potassium	272	211	115	56.9
	Chloride	116	93.6	58.5	37.5
	Sulfate	8276	6430	3545	1815
	Iron	974	740	374	155
15,000	% Reduction	33	50	75	90
	Calcium	807	682	487	370
	Magnesium	644	503	283	151
	Sodium	456	357	203	110
	Potassium	355	274	146	69.5
	Chloride	116	93.9	58.7	37.5
	Sulfate	10330	7986	4323	2126
	Iron	1271	965	487	200

Figure 1: ^{210}Pb Concentration vs Time at the East Gas Hills SWFR POE. Modeled Sulfate Sensitivity for Revised ^{210}Pb ACL (189 pCi/L)



C01

Figure 2: ^{210}Pb Concentration vs Distance Between the East Gas Hills POC and POE.
Modeled Sulfate Sensitivity for Revised ^{210}Pb ACL (189 pCi/L)



C02