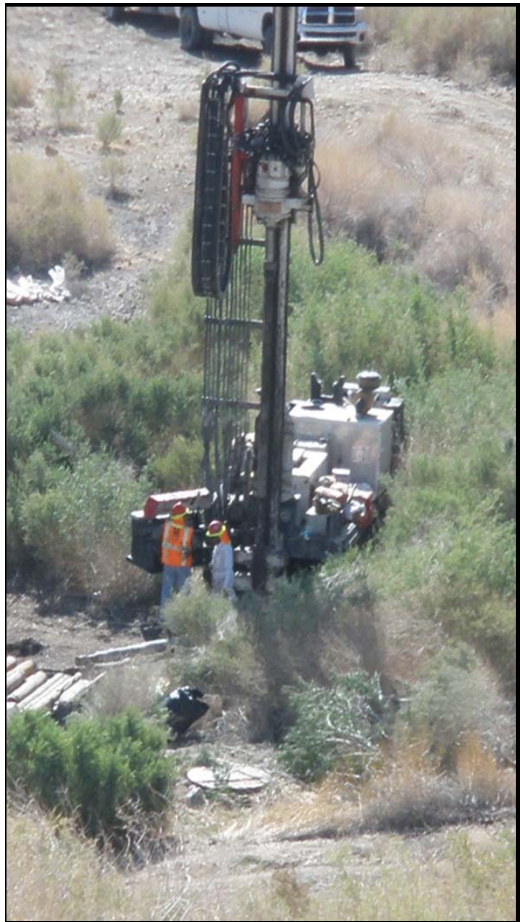
THE ROLE OF NATURAL ATTENUATION FOR ARSENIC IN HEAP LEACH DRAINAGE

RJ Bowell J Declercq R Warrender A Prestia
JR Barber JV Parshley

srk consulting



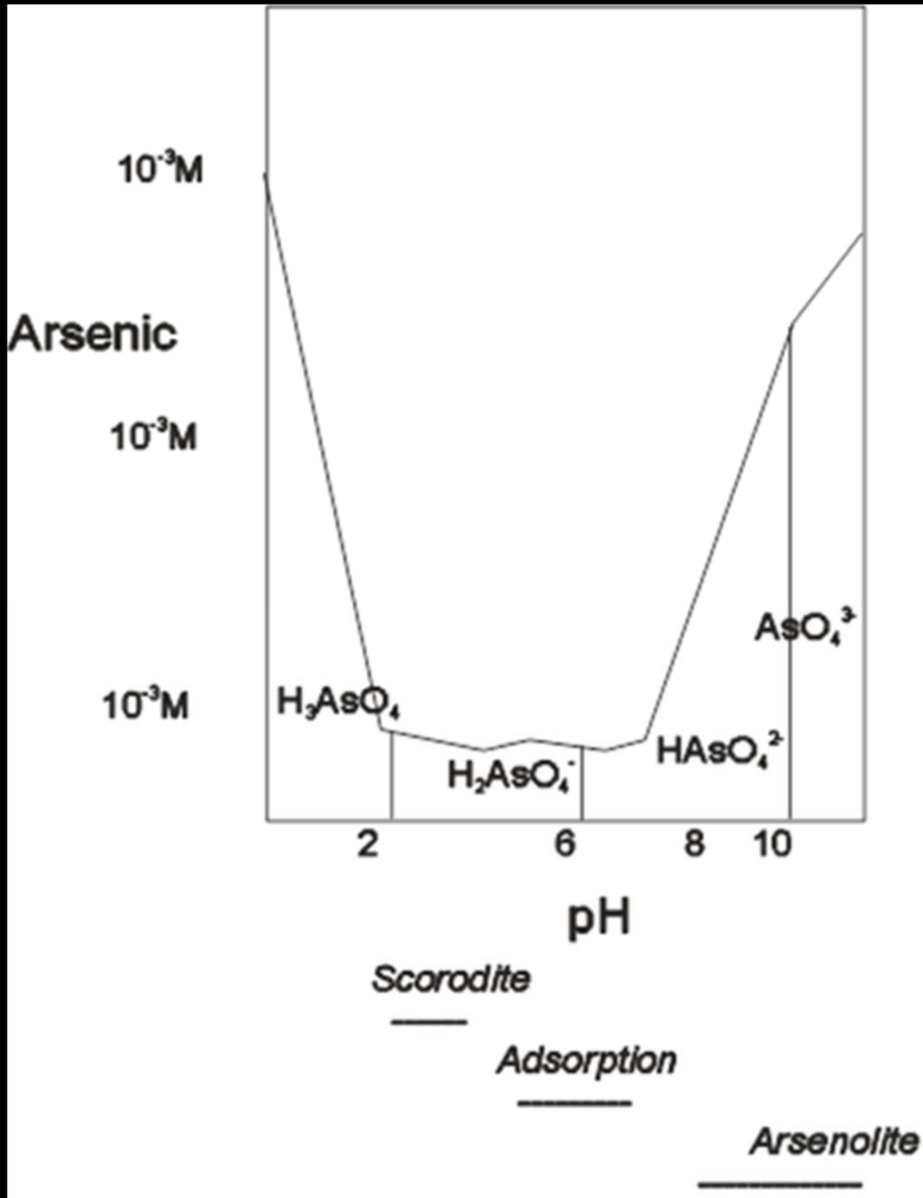
Introduction

- Assess the potential for attenuation of arsenic and other constituents from infiltrated process fluids in evapotranspiration field
- Study focused on the Oxide Heap Leach facility, Daisy Mine, Nevada
- Numerical predictions basis for evaluation of closure options
- Objective of the study was to predict geochemistry of solutes in groundwater upon interaction with draindown
- Determine the potential of chemical constituents in heap solutions particularly arsenic and salts to attenuate in the unsaturated alluvium and not degrade groundwater beyond an NDEP reference value

Arsenic Mobility in the Environment

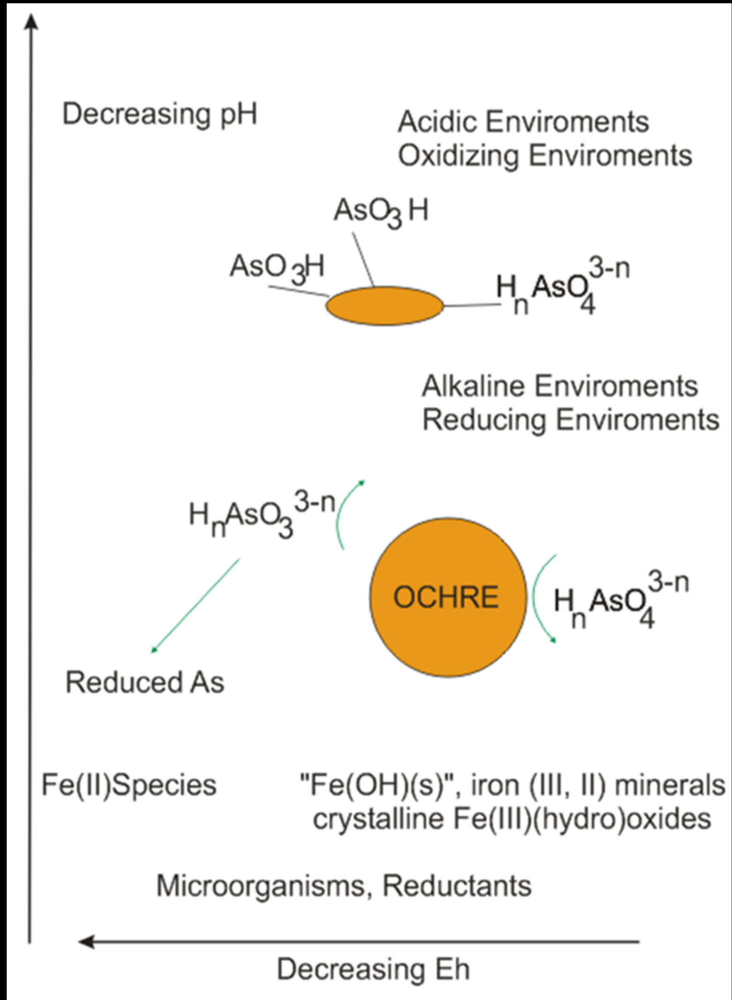
- Arsenic mobility
  - Reducing low Al/Fe
  - Acidic (pH <2) or alkaline (pH > 8.5)

- Arsenic attenuation
  - Precipitation- scorodite/arsenates
  - Precipitation – As(III) oxides
  - Precipitation – As (III) sulfides
  - Adsorption onto mineral surfaces

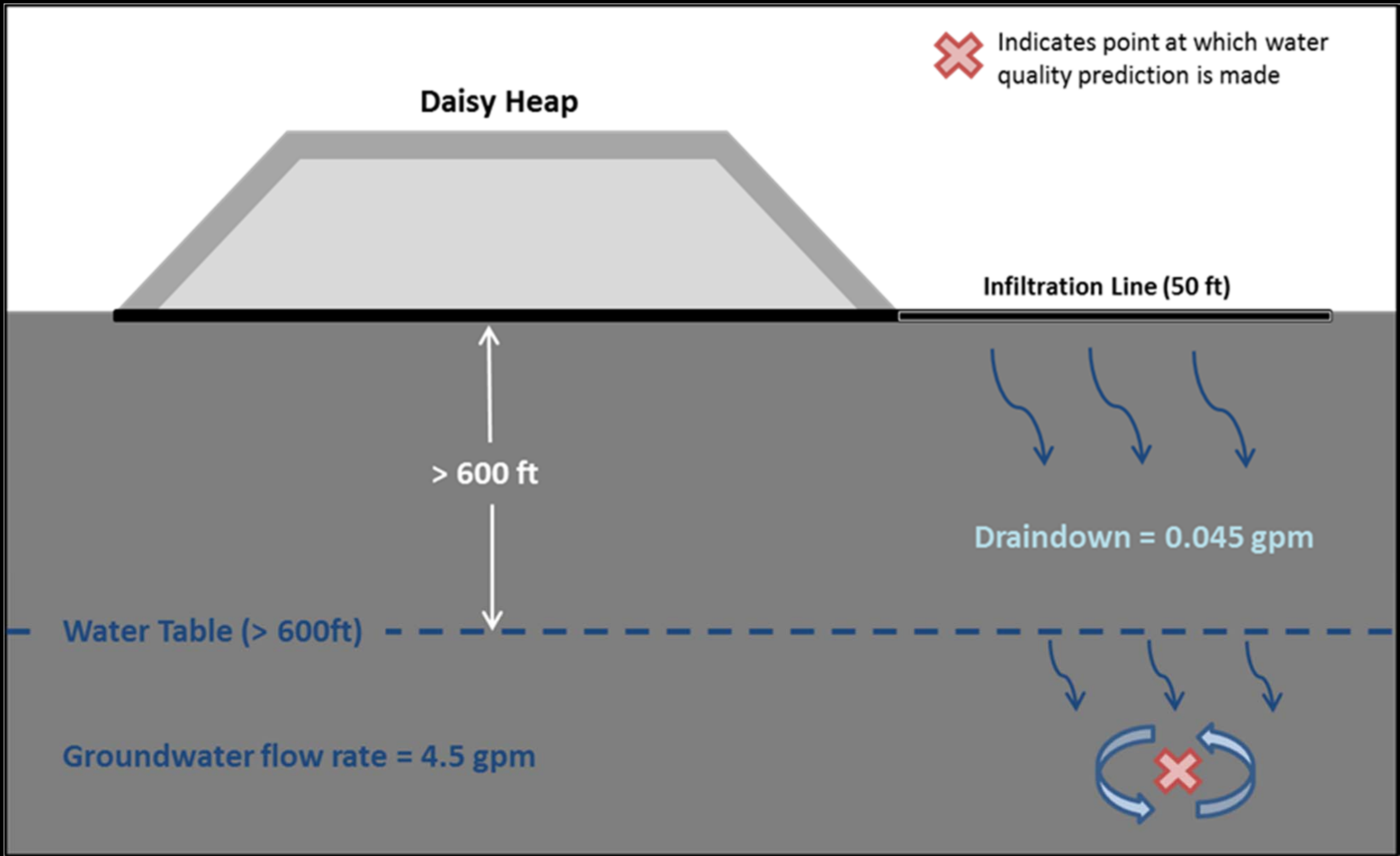


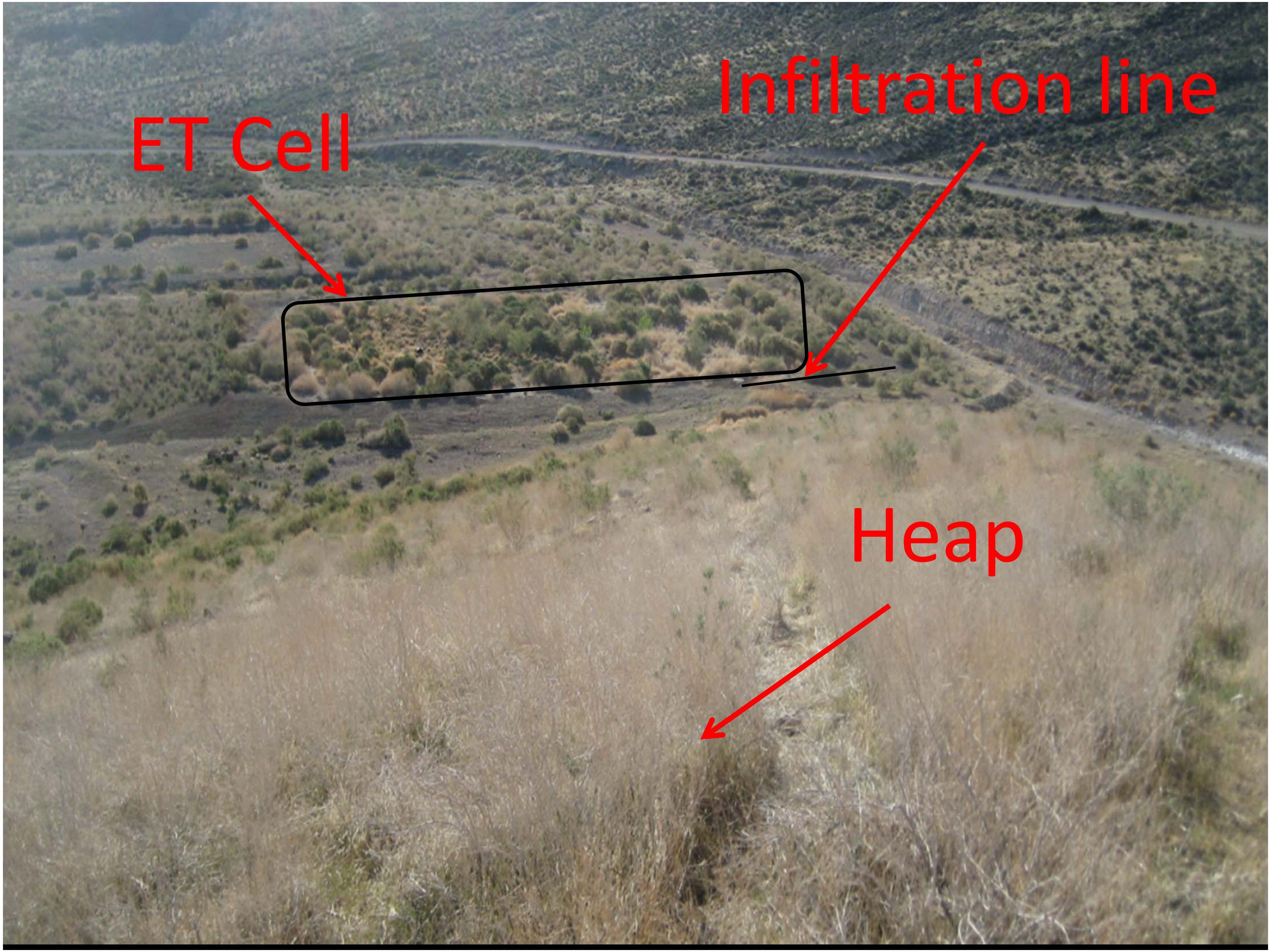
Arsenic Attenuation

- As pH increases ferric hydroxide (or hydrous ferric oxide, HFO) solubility decreases with a minimum at around pH 6.
- At low pH, precipitated HFO tends to scavenge negatively charged oxyanions as the surface of the HFO is positively charged in the Helmholtz layer (Deng and Stumm 1994).
- In low-pH environments these HFO particles are usually colloidal sized and have a high reactivity proportional to surface area
- Point of change for HFO for attracing anions to repelling – point of zero charge around pH 5-8 (goethite ~ 6.8)



Conceptual Model




Infiltration line
ET Cell
Heap

Heap Draindown

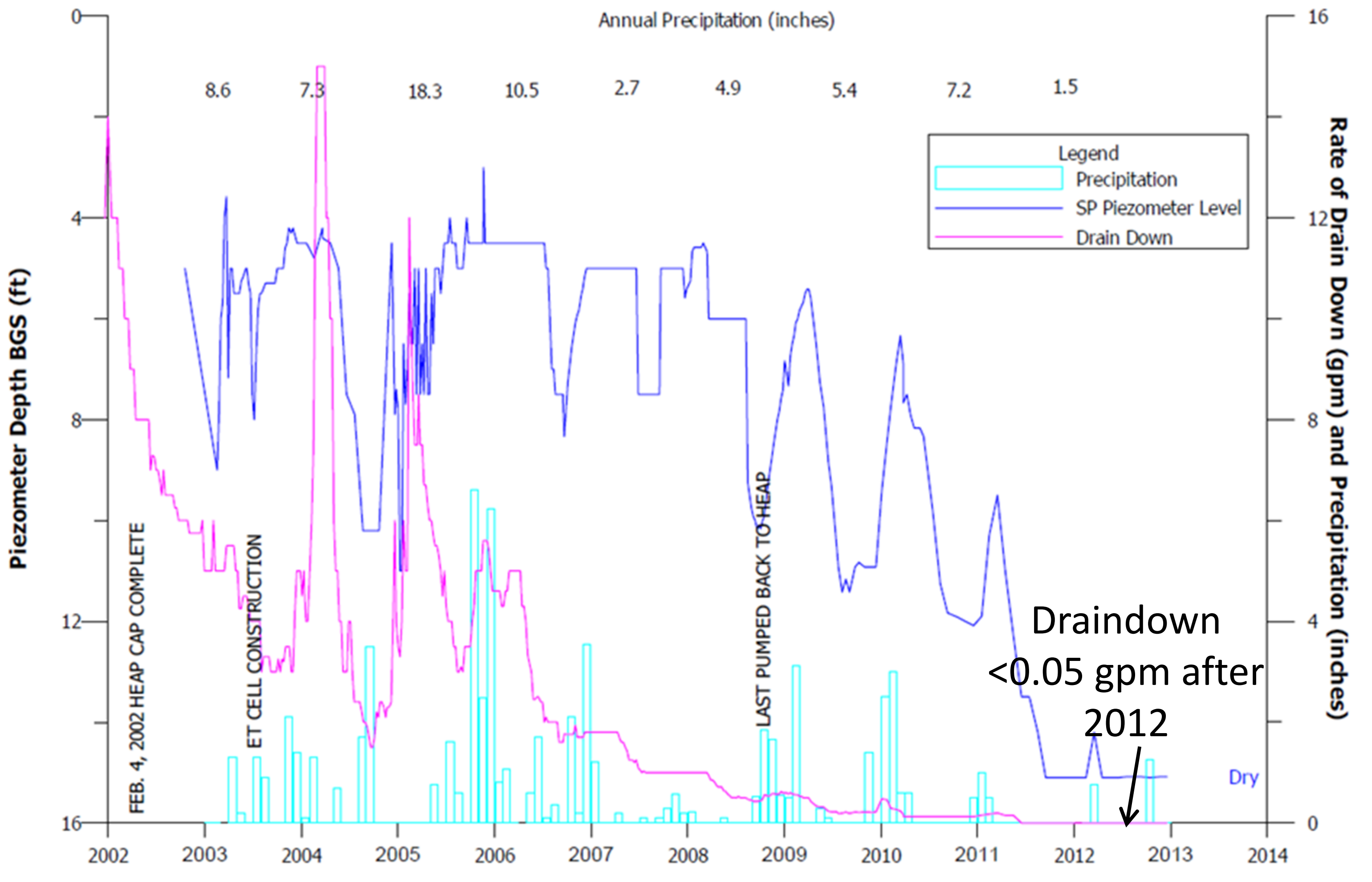


Figure 1. Daisy Heap Drain Down, Monthly Precipitation, and Piezometer Levels

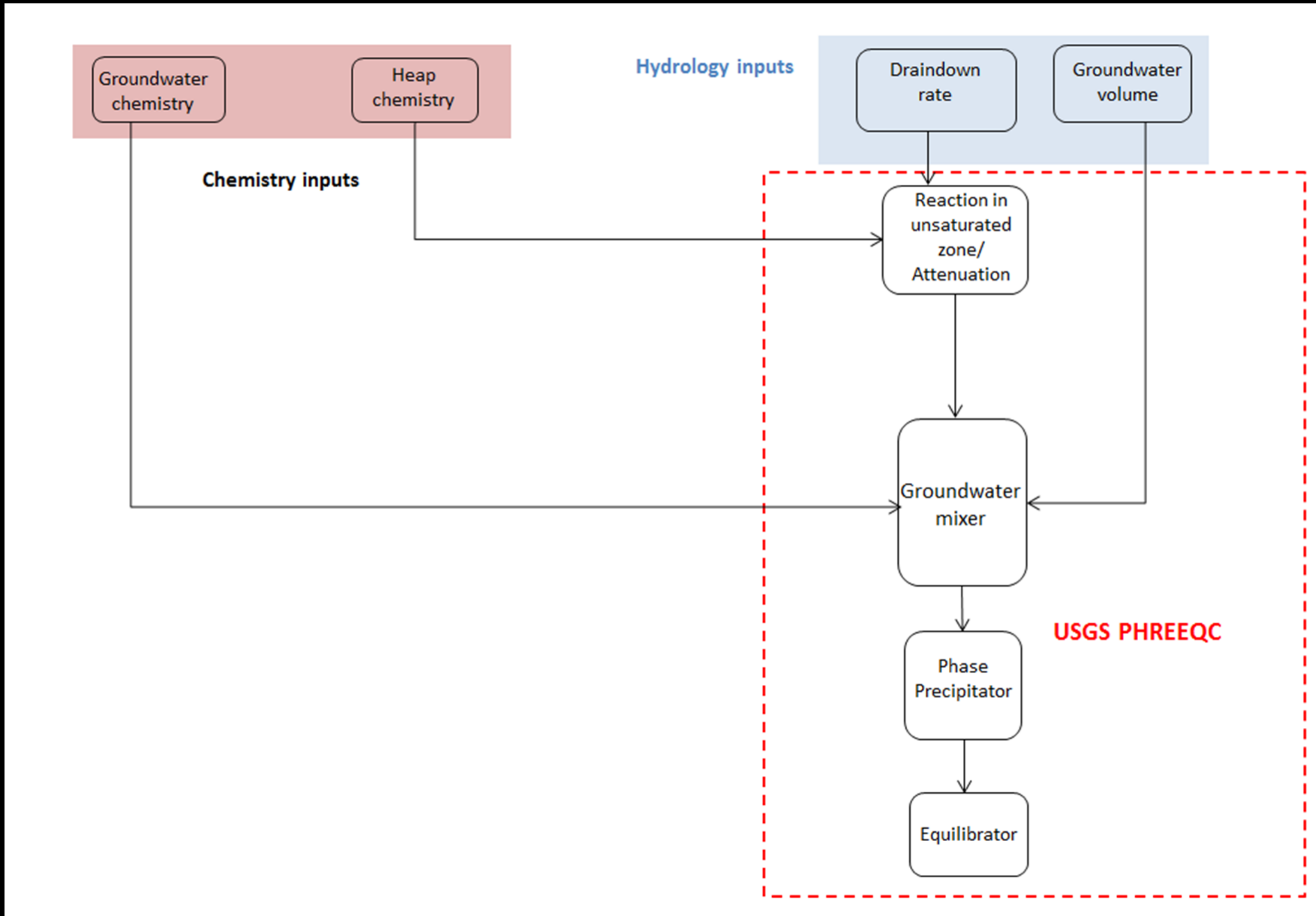
Results, Heap Draindown chemistry

Parameter	NDEP Value	Min	Max	Average	Standard Deviation
Alkalinity (Total)	--	95	160	130	17
Aluminum	0.2	0.03	0.22	0.067	0.048
Antimony	0.006	0.0057	0.011	0.0072	0.0012
Arsenic	0.01	0.27	0.613	0.52	0.062
Barium	2.0	0.016	0.05	0.02	0.0067
Cadmium	0.005	<0.001	<0.005	<0.001	0.0011
Chloride	400	82	120	96	11
Fluoride	4	0.29	8.7	1.8	1.6
Gallium	--	<0.02	<0.5	<0.1	0.12
Manganese	0.1	0.005	0.23	0.085	0.069
Mercury	0.002	0.0023	0.02	0.0089	0.0046
Molybdenum	--	0.01	0.05	0.033	0.013
Nickel	0.1	0.01	0.05	0.012	0.0078
Nitrate + Nitrite	10.0	48	230	160	30
pH	6.5- .5	6.89	8.01	7.7	0.3
Selenium	0.05	0.047	0.074	0.056	0.0067
Sulfate	500	2160	3100	2400	190
Total Dissolved Solids	1000	3500	5400	4500	380
WAD Cyanide	0.2	0.023	0.28	0.086	0.063
Zinc	5.0	0.01	0.1	0.028	0.033

Groundwater Chemistry

Parameter	NDEP Value	Min	Max	Mean	Standard Deviation
Alkalinity (Total)	--	119	123	120	2.1
Aluminum	0.2	<0.02	<0.037	<0.03	0.0089
Antimony	0.006	0.002	0.003	0.0023	0.00058
Arsenic	0.01	0.014	0.017	0.016	0.0015
Barium	2.0	0.024	0.025	0.024	0.00058
Cadmium	0.005	<0.002	<0.0024	<0.002	0.00023
Calcium	--	10.9	11.6	11	0.35
Chloride	400	10	10.6	10	0.32
Fluoride	4	3.1	3.3	3.2	0.1
Iron	0.6	<0.019	<0.02	<0.02	0.00058
Manganese	0.1	0.002	0.004	0.0027	0.0012
Mercury	0.002	<0.0002	<0.0002	<0.0002	0
Nickel	0.1	<0.005	<0.023	<0.01	0.0091
Nitrate + Nitrite	10.0	0.03	0.41	0.26	0.2
pH	6.5 - 8.5	8.1	8.2	8.1	0.051
Selenium	0.05	<0.001	<0.002	<0.002	0.00058
Silver	0.1	<0.005	<0.006	<0.006	0.00058
Sulfate	500	43.8	45.8	45	1
Total Dissolved Solids	1000	237	307	260	39
WAD Cyanide	0.2	<0.01	<0.01	<0.01	0
Zinc	5.0	0.003	0.039	0.016	0.02

Prediction Mechanism



Results (10% $Fe(OH)_3$)

Parameter	Units	Baseline groundwater (MW4)	*NDEP reference value*	Draindown rate (gpm)				
				0.045	**0.1**	**0.25**	**0.5**	**0.75**
pH	-	8.1	*6.5 - 8.5*	8.49	8.45	8.36	8.27	8.20
Alkalinity	mg/L	120	*-*	102	94.7	78.5	63.9	56.2
Aluminium	mg/L	0.03	*0.2*	0.03	0.03	0.03	0.02	0.02
Antimony	mg/L	0.0023	*0.006*	0.002	0.002	0.003	0.003	0.003
Arsenic	mg/L	0.016	*0.01*	0.015	0.014	0.014	0.013	0.013
Barium	mg/L	0.024	*-*	0.02	0.02	0.02	0.01	0.01
Berllyium	mg/L	0.002	*-*	0.002	0.002	0.001	0.001	0.001
Cadmium	mg/L	0.002	*0.005*	0.002	0.002	0.002	0.002	0.002
Chloride	mg/L	10	*400*	10.9	11.9	14.6	18.8	22.6
Chromium	mg/L	0.006	*0.1*	0.006	0.006	0.006	0.005	0.005
Copper	mg/L	0.003	*1*	0.003	0.003	0.003	0.003	0.003
Fluoride	mg/L	3.2	*4*	3.18	3.17	3.12	3.05	2.98
Iron	mg/L	0.02	*0.6*	0.00004	0.00004	0.00004	0.00004	0.00004
Lead	mg/L	0.001	*0.015*	0.001	0.001	0.0009	0.0009	0.0008
Manganese	mg/L	0.0027	*0.1*	0.003	0.003	0.003	0.003	0.003
Nitrate (total)	mg/L	0.26	*10*	6.40	12.5	29.1	54.3	77.4
Mercury	mg/L	0.0002	*0.002*	0.0003	0.0004	0.0007	0.001	0.001
Selenium	mg/L	0.002	*0.05*	0.002	0.002	0.002	0.002	0.002
Silver	mg/L	0.006	*-*	0.006	0.006	0.006	0.006	0.006
Sulfate	mg/L	45	*500*	68.3	93.8	164	270	368
Thallium	mg/L	0.001	*0.002*	0.001	0.001	0.001	0.001	0.001
Cyanide (total)	mg/L	0.01	*-*	0.01	0.01	0.01	0.009	0.009
Zinc	mg/L	0.016	*5*	0.016	0.016	0.015	0.014	0.014

(Pink) Indicates value is above the NDEP reference value

Results (100% $Fe(OH)_3$)

Parameter	Units	Baseline groundwater (MW4)	*NDEP reference value*	Draindown rate (gpm)				
				0.045	0.1	0.25	0.5	0.75
pH	-	8.1	*6.5 - 8.5*	8.51	8.50	8.46	8.42	8.38
Alkalinity	mg/L	120	*-*	108	104.8	97.8	88.9	82.2
Aluminium	mg/L	0.03	*0.2*	0.03	0.03	0.03	0.03	0.03
Antimony	mg/L	0.0023	*0.006*	0.002	0.002	0.002	0.003	0.003
Arsenic	mg/L	0.016	*0.01*	0.015	0.014	0.014	0.013	0.012
Barium	mg/L	0.024	*-*	0.02	0.02	0.02	0.02	0.02
Berllyium	mg/L	0.002	*-*	0.002	0.002	0.001	0.001	0.001
Cadmium	mg/L	0.002	*0.005*	0.002	0.002	0.002	0.002	0.002
Chloride	mg/L	10	*400*	10.6	11.3	13.2	16.1	18.7
Chromium	mg/L	0.006	*0.1*	0.006	0.006	0.006	0.005	0.005
Copper	mg/L	0.003	*1*	0.003	0.003	0.003	0.003	0.003
Fluoride	mg/L	3.2	*4*	3.18	3.16	3.09	3.00	2.91
Iron	mg/L	0.02	*0.6*	0.00004	0.00004	0.00004	0.00004	0.00004
Lead	mg/L	0.001	*0.015*	0.001	0.001	0.0009	0.0009	0.0008
Manganese	mg/L	0.0027	*0.1*	0.003	0.003	0.003	0.002	0.002
Nitrate (total)	mg/L	0.26	*10*	4.90	9.3	21.4	39.8	56.7
Mercury	mg/L	0.0002	*0.002*	0.0002	0.0002	0.0003	0.000	0.000
Selenium	mg/L	0.002	*0.05*	0.002	0.002	0.002	0.002	0.002
Silver	mg/L	0.006	*-*	0.006	0.006	0.006	0.005	0.005
Sulfate	mg/L	45	*500*	56.8	69.7	105	159	208
Thallium	mg/L	0.001	*0.002*	0.001	0.001	0.001	0.001	0.001
Cyanide (total)	mg/L	0.01	*-*	0.01	0.01	0.01	0.009	0.009
Zinc	mg/L	0.016	*5*	0.016	0.016	0.015	0.014	0.014

(pink) Indicates value is above the NDEP reference value

Conclusions

- Draindown rates for the Daisy Heap are declining
- Approaching steady state conditions ~ 0.05 gpm
- Geochemical assessment indicates that the interaction of Daisy Heap draindown with groundwater will not alter baseline groundwater chemistry
- Arsenic is naturally elevated in groundwater above the NDEP value of 0.01 mg/L prior to and after interaction with heap draindown
- At predicted draindown rates no other parameters exceed NDEP target values and no salt build up is predicted within the infiltration channel- no wildlife risk