Alexco Keno Hill Silver District

Development of treatment alternatives for moderate flow, moderate loading adit drainages

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Philosophy

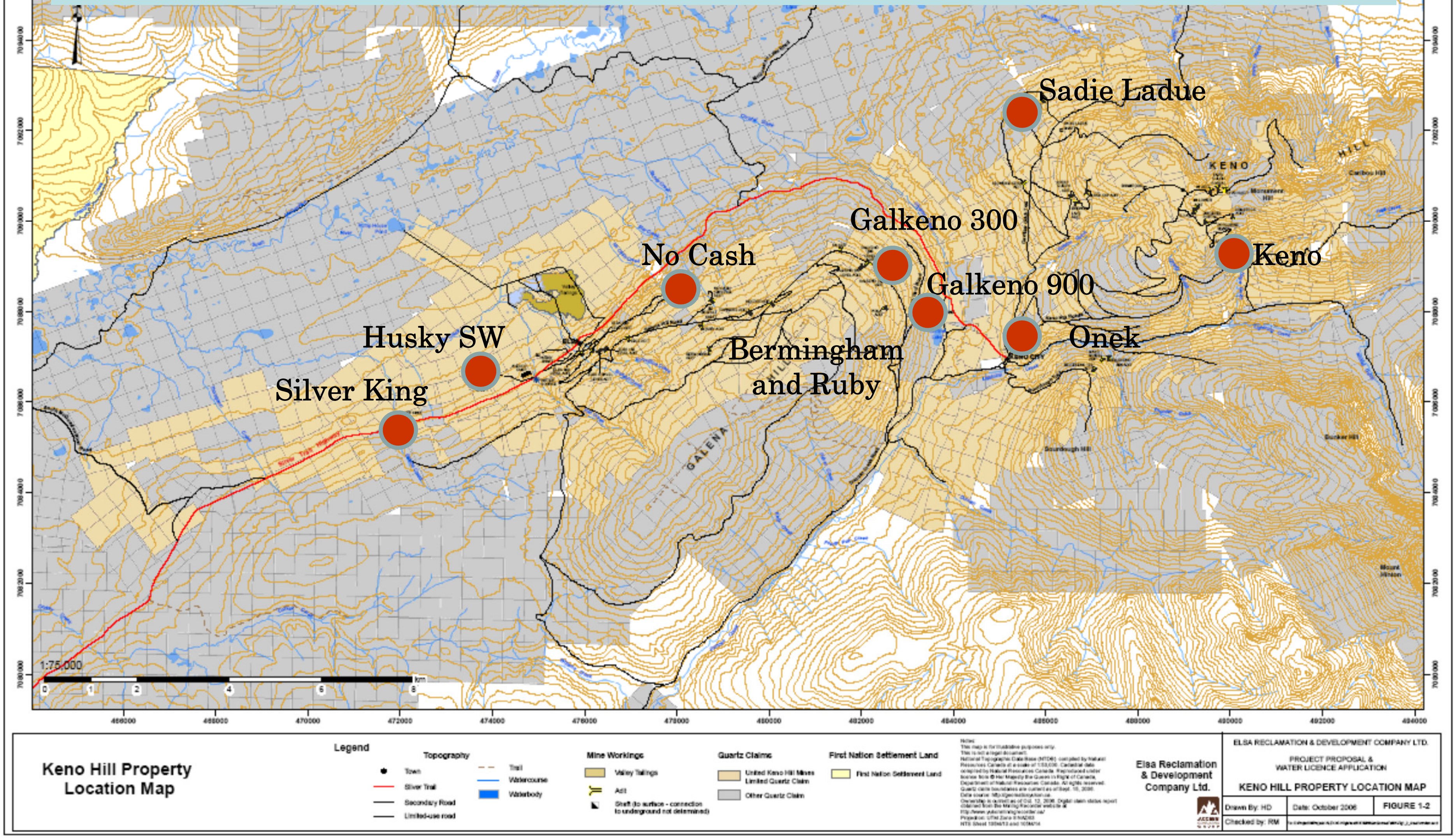
Where possible, treat the source not the symptom (sustainability, lifecycle cost)

Utilize local mine setting to implement cost effective solutions (mine voids, natural wetlands processes, local materials)

Who is Alexco?

Alexco Resource Corp. is a precious metals exploration company with a silver focus and a growing environmental services business.

Major Adit Drainages, Keno District



Adit Loading Summary

Site	Zn (kg/yr)	Flow (m^3/yr)	Zn (mg/L)
Galkeno 300	41,600	394,000	110
Onek	5800	72,500	80
No Cash	2407	137,000	17.6
Galkeno 900	677	217,000	3.1
Bellekeno	523	71,000	7.36
LES-66 Spring	395	79,000	5
Keno	328	266,000	1.23
Bermingham	273	62,000	4.11
Silver King	260	205,000	1.26
Ruby	200	48,000	1.67
Sadie Ladue	112	156,000	0.7
Husky SW	98	104,000	0.94

Desirable Technology Features

1. Located near adit, avoid piping if possible
2. Year-round water handling, avoid power consumption
3. Demonstrate robustness, sustainability
4. Demonstrate aquatic life suitability, absence of toxicity
5. Streamline monitoring
6. Lower cost, avoid mechanical systems if possible

Technology Range Considered

1. Mechanical systems
   - Alkaline reagent
   - Sulfide reagent
2. Passive systems
   - SRB Bioreactor (contained)
   - SRB process in natural system
     - Mine pool
     - Infiltration gallery
   - Natural Attenuation
   - Wetland / Bog (natural or constructed)

Criteria for Natural Attenuation Closure

- Proximity to surface water
- Loading rate from source
- Acceptable monitoring locations
- Available locations for oxidation, peat sorption, and reduction (system geometry and morphology)

- Sites that fit the criteria:
  - Silver King
  - Husky
  - Bermingham
  - Ruby
  - No Cash
  - Sadie Ladue
  - LES-66 Spring (?)

Possible Natural Attenuation Sites

Site	Zn (kg/yr)	Flow (m^3/yr)	Zn (mg/L)
Galkeno 300	41,600	394,000	110
Onek	5800	72,500	80
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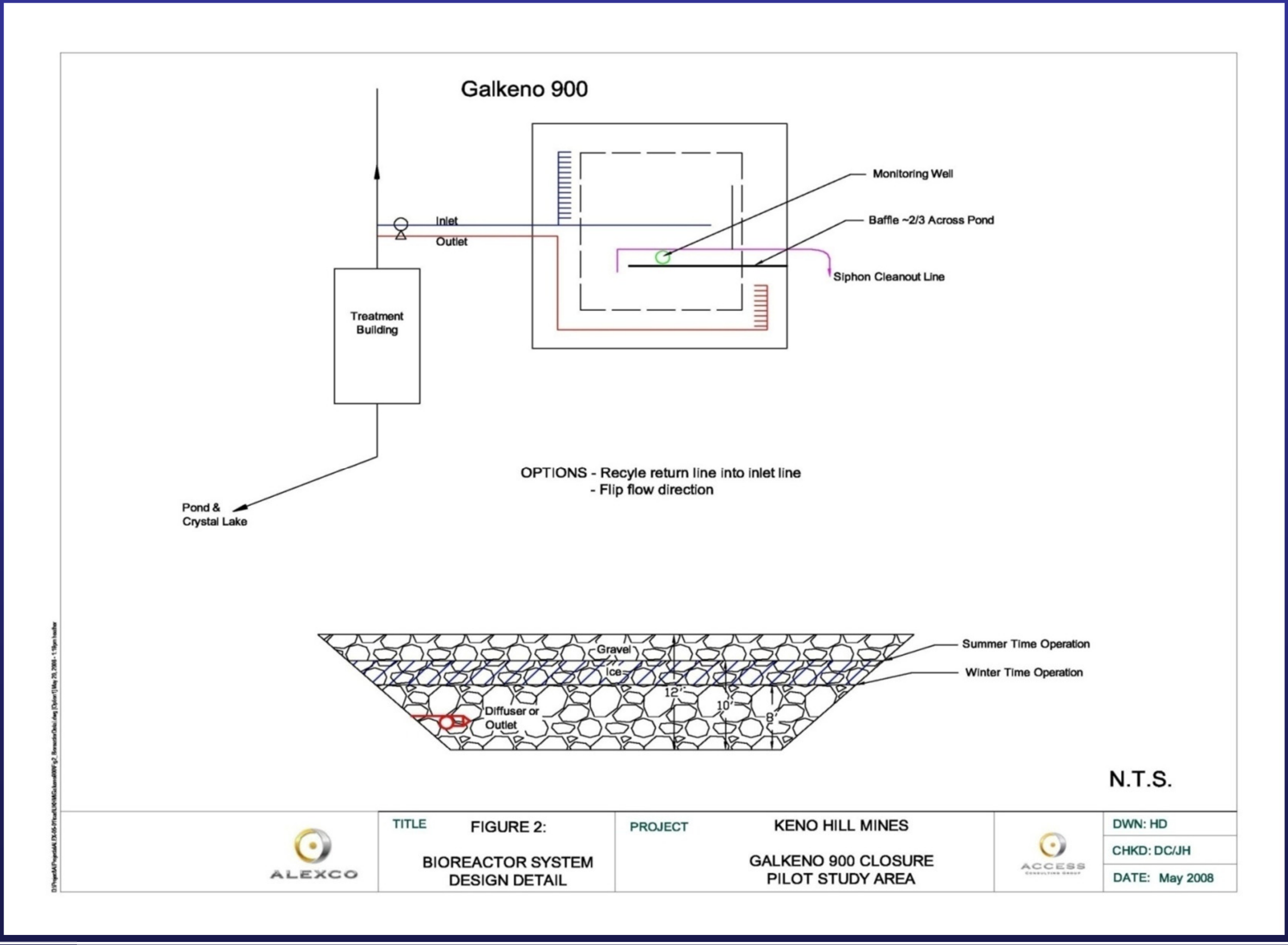
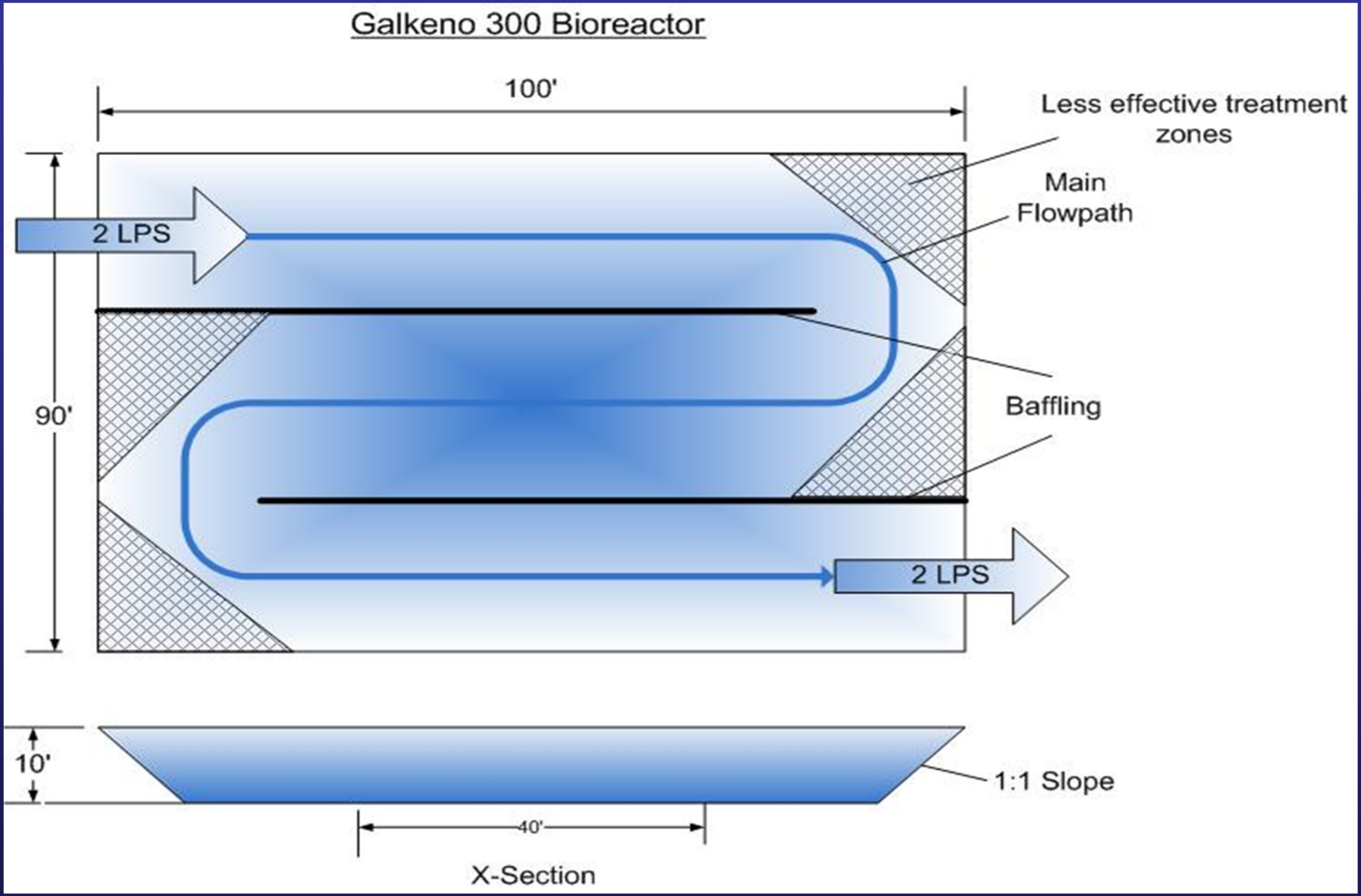
Possible Bioreactor Sites

Site	Zn (kg/yr)	Flow (m^3/yr)	Zn (mg/L)
Galkeno 300	41,600	394,000	110
Onek	5800	72,500	80
No Cash	2407	137,000	17.6
Galkeno 900	610	120,000	5.5
Bellekeno	523	71,000	7.4
LES-66 Spring	395	79,000	5
Keno	328	266,000	1.2
Bermingham	273	62,000	4.1
Silver King	260	205,000	1.3
Ruby	200	48,000	1.7
Sadie Ladue	112	156,000	0.72
Husky SW	98	104,000	0.94

Galkeno 900 Bioreactor Schematic



Bioreactor flow path illustration



Bioreactor Fill Media—Coarse Cobbles

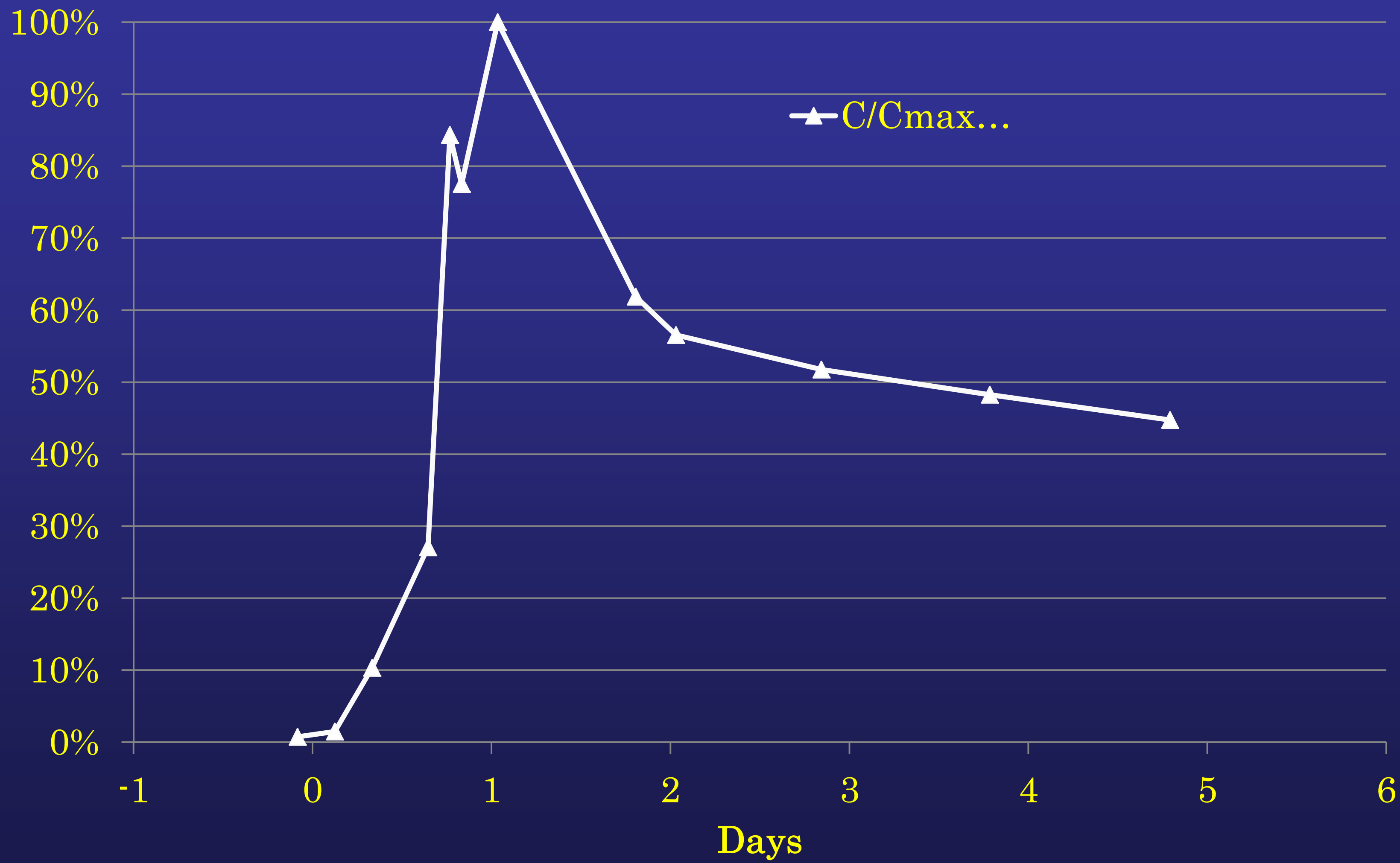
Bioreactor plumbing

Bioreactor Setting

Bioreactor Setting

Downgradient receiving environment

Dye breakthrough 2 l/s



Residence time estimate

Flow rate	Residence time (total porosity)	Residence time (active porosity)
0.5 l/s	21.0 days	9.0
1.0 l/s	10.5 days	4.5
2.0 l/s	5.25 days	2.25

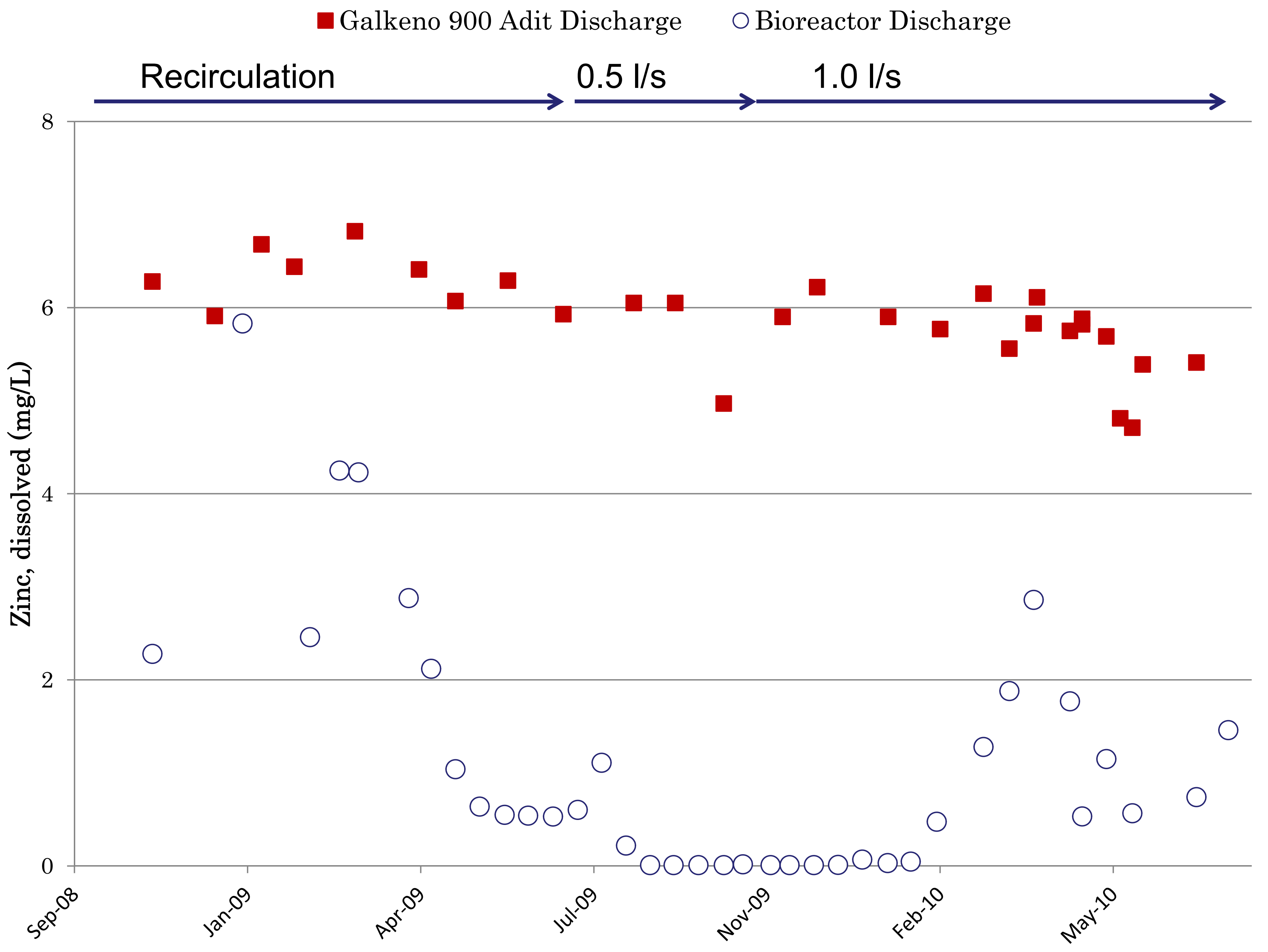
Temperature and pH in Bioreactor

Sulfate Reduction Rate

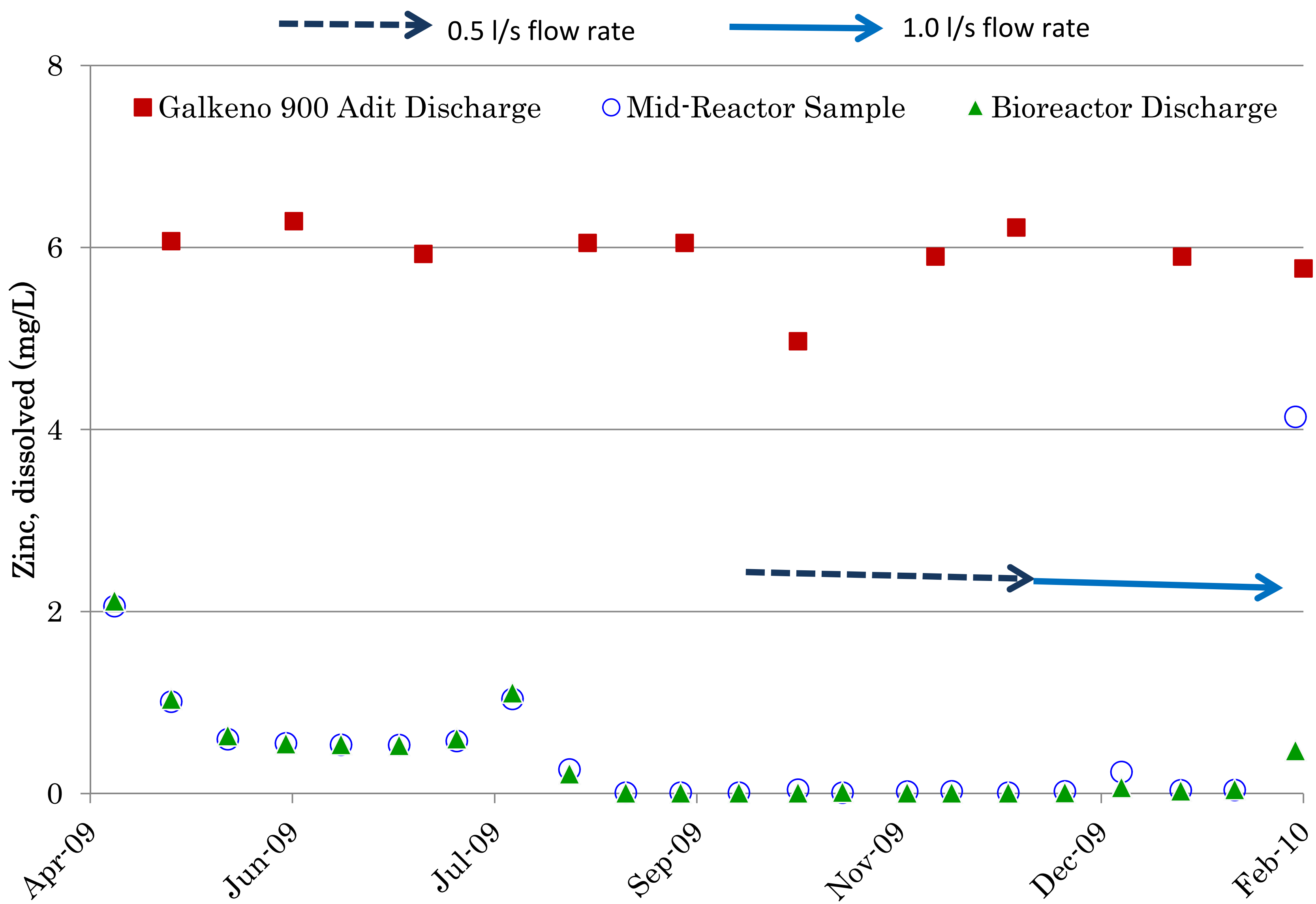
	Change SO_4	Change SO_4	Change SO_4	SRR
	(mg/L)	(mM)	(per day)	(mM/m^3/day)
Recirculation (Avg)	110.00	1.15		
Reduction Onset (Avg)	196.00	2.04		
Throughflow (Avg)	128.00	1.33	115,200	45.23
Total Period (Avg)	159.87	1.67		
Constants				
Flow Rate (liter/sec)	1			
All Volume in pond (ft^3)	90,000			
All Volume in pond (m^3)	2,547			

Bioreactor Performance for Key Parameters

	As	Sb	Cd	Co	Fe	Mg	Mn	Ni	SO_4	Zn
Recirculation (% reduction)	97%	79%	69%	99%	99%	-2%	99%	88%	10%	91%
Reduction Onset (% reduction)	-5%	69%	57%	8%	-233%	-6%	-107%	82%	21%	96%
Flow 0.5 l/s (% reduction)	58.8%	78.0%	93.2%	79.2%	-503.1%	-0.8%	-13.4%	97.5%	19.0%	99.8%
Flow 1.0 l/s (% reduction)	82.0%	80.0%	93.2%	64.0%	-376.2%	6.5%	-1.7%	83.7%	5.4%	97.8%



Galkeno 900 Adit Discharge
Bioreactor Discharge
Recirculation
0.5 l/s
1.0 l/s
Zinc, dissolved (mg/L)
8
6
4
2
0
Sep-08
Jan-09
Apr-09
Jul-09
Nov-09
Feb-10
May-10



0.5 l/s flow rate
1.0 l/s flow rate
Galkeno 900 Adit Discharge
Mid-Reactor Sample
Bioreactor Discharge
Zinc, dissolved (mg/L)
8
6
4
2
0
Apr-09
Jun-09
Jul-09
Sep-09
Nov-09
Dec-09
Feb-10

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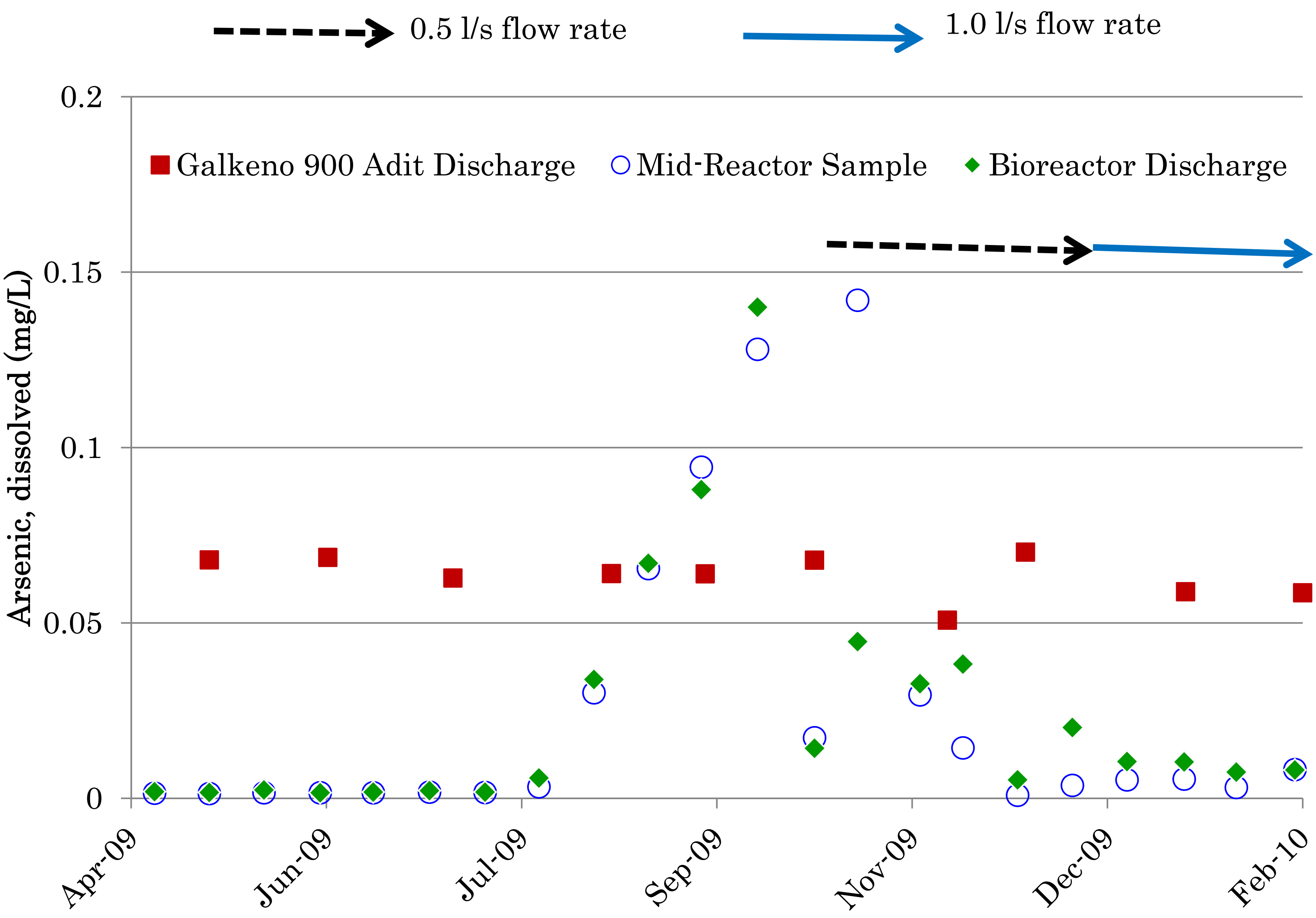
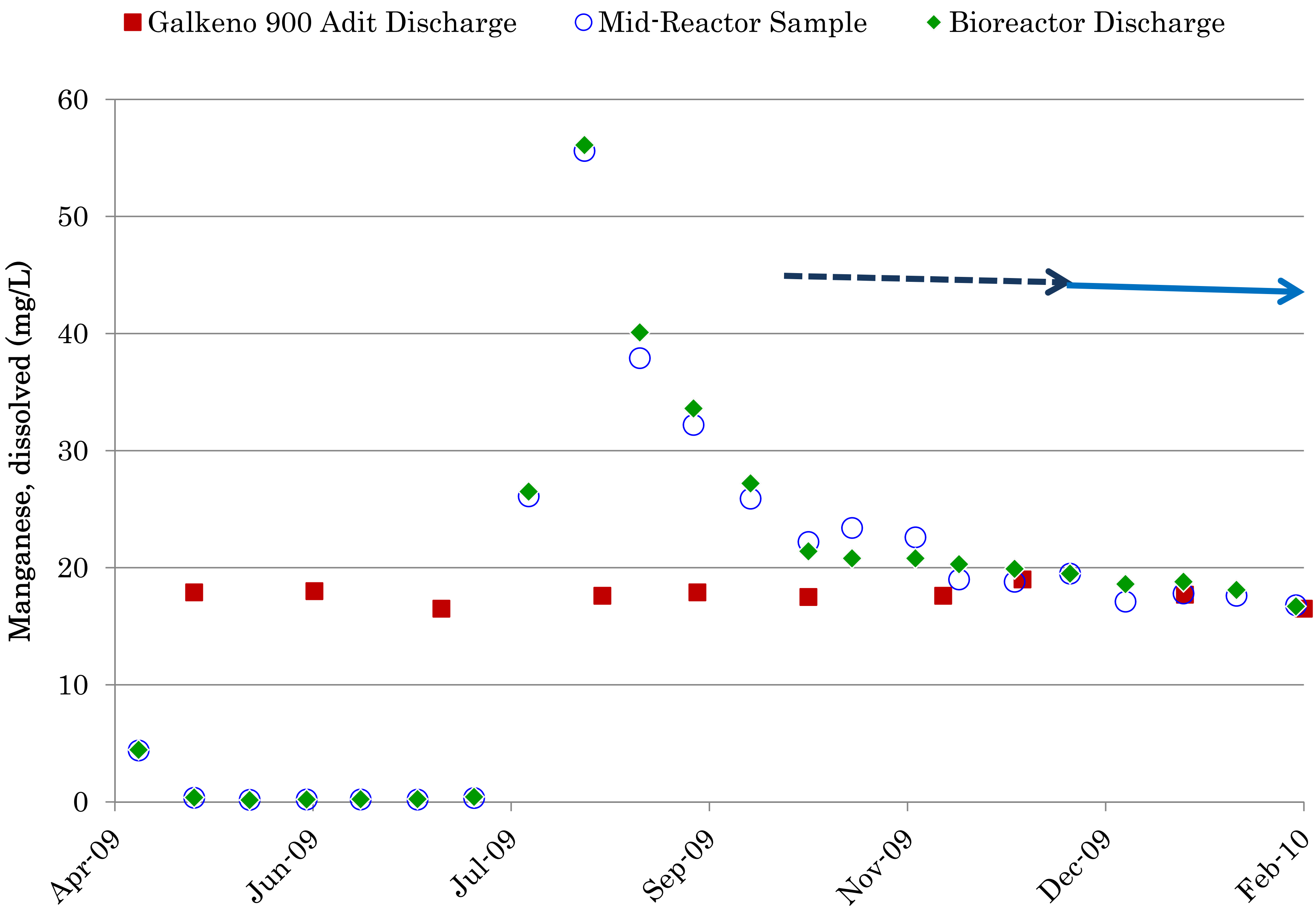
Bioreactor Zinc Removal Performance

	Average total zinc concentration (mg/L)	Average dissolved zinc concentration (mg/L)	% total zinc that is dissolved
Recirculation phase	0.64	0.65	100%
Reduction onset phase	0.32	0.27	86%
0.5 l/s treatment phase	0.28	0.012	4%
1.0 l/s treatment phase	0.74	0.13	17%

Average influent concentration ~ 6 mg/L



0.5 l/s flow rate
1.0 l/s flow rate
Galkeno 900 Adit Discharge
Mid-Reactor Sample
Bioreactor Discharge
Arsenic, dissolved (mg/L)
0.2
0.15
0.1
0.05
0
Apr-09
Jun-09
Jul-09
Sep-09
Nov-09
Dec-09
Feb-10



Galkeno 900 Adit Discharge
Mid-Reactor Sample
Bioreactor Discharge
Manganese, dissolved (mg/L)
0
10
20
30
40
50
60
Apr-09
Jun-09
Jul-09
Sep-09
Nov-09
Dec-09
Feb-10

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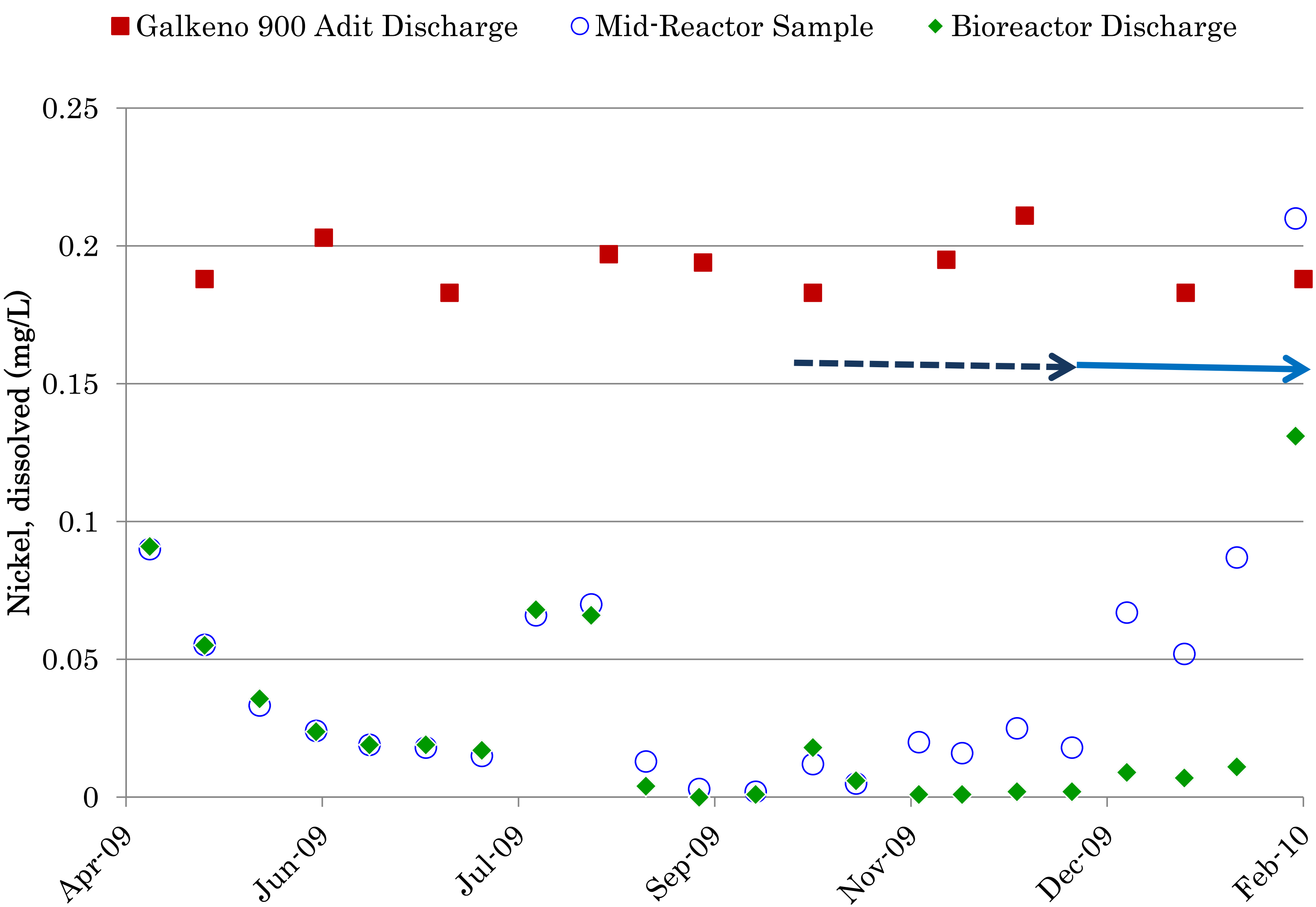

Galkeno 900 Adit Discharge
Mid-Reactor Sample
Bioreactor Discharge
Nickel, dissolved (mg/L)
0.25
0.2
0.15
0.1
0.05
0
Apr-09
Jun-09
Jul-09
Sep-09
Nov-09
Dec-09
Feb-10

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Preliminary Conclusions

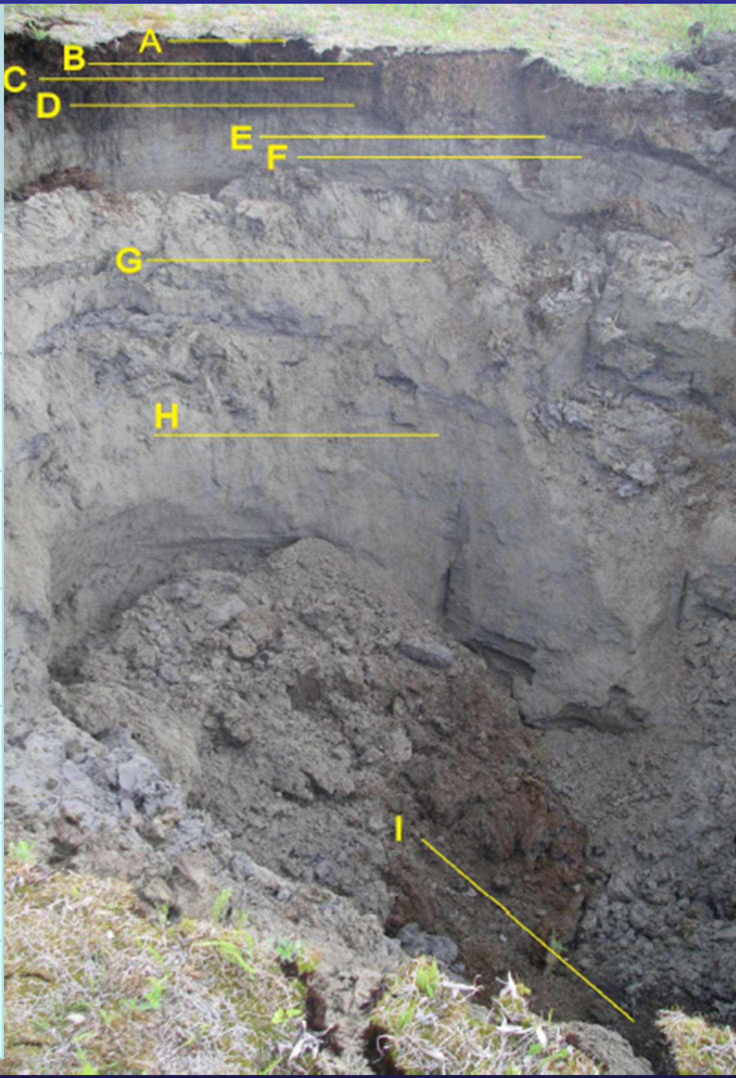
1. Alcohol-fed bioreactor can perform in all seasons in Keno weather
   – 2009-2010 winter failure related to power failure
2. Cd/Zn removal at 0.5 l/s superior to lime treatment
3. This specific configuration has acceptable performance at 0.5 l/s, 1.0 l/s uncertain due to pump failure
4. Sulfate reduction rate, carbon substrate loading rate, and specific metals removal capacity have been determined
5. Subsequent filtration required in short residence time bioreactor configuration (natural media such as porous substrate, bog or wetland)

Attenuation in Keno Silver District

- Broadly studied
- Neutral alkaline water
- High manganese concentrations
- Extensive peat
- Wetland bogs with psychrophilic SRB

Attenuation below Valley Tailings

Concentration (mg/L)	In Tailings (Well H4S)	Below Tailings (Wells H4D)	% Attenuation
Arsenic	0.727	0.0089	98.78%
Cadmium	1.34	0.00058	99.96%
Copper	0.04	0.003	92.50%
Lead	0.583	0.0031	99.47%
Nickel	0.192	0.0076	96.04%
Silver	0.0005	<0.0001	>80.00%
Zinc	194	0.032	99.98%



Summary

- ❑ **Attenuation processes are effective are reducing metals**
  - Zinc – 100-fold decrease
  - Cadmium - 100 to > 1000-fold decrease
  - Manganese - 20 to 10,000-fold decrease
- ❑ **Attenuation processes consistent with previous studies**
- ❑ **System is stable**
  - Adit chemistry is at steady-state or improving
  - Mineral precipitation products are stable under ambient conditions
    - Oxides and carbonates in oxic surface water & sediments
  - Metal sulfides in organic-rich, water-saturate sediments

No Cash 500 Adit

No Cash Creek

Oxidation & CO_2 degassing

- Fe & Mn oxide precipitation
- Metal adsorption to Fe & Mn oxides
- Cd, Mn, & Zn carbonate precipitation

Particulate Deposition

- Fe & Mn oxides with adsorbed metals
- Other mineral precipitates

Sulfide Generation

- Cd, Zn sulfide precipitation
- Mn, Fe partial release

Long-Term Stability Natural Attenuation

Surface Water Attenuation Processes

Aeration ➔ Oxic conditions

- ❑ Oxide mineral precipitation
  - Ferrihydrite – $Fe(OH)_3$
  - Manganese oxides – MnOOH, MnO_2
- ❑ Adsorption (Cd, Zn)

CO_2(g) degassing

- ❑ Carbonate mineral precipitation
  - Hydrozincite - $[Zn_5(OH)_6(CO_3)_2]$
  - Smithsonite – $ZnCO_3$
  - Otavite – $CdCO_3$
  - Rhodochrosite – $MnCO_3$

Sediment Attenuation Processes

Organic rich, Water-saturated ➔ Anoxic conditions

- ❑ Sulfide generation from sulfate-reducing bacteria create reducing conditions in organic rich sediments
  - Metal sulfide mineral precipitation
  - Sphalerite – ZnS
  - Greenockite – CdS
- ❑ Organic sorption of metals provides rapid removal mechanism

These processes will continue to occur naturally as long as ambient conditions are not changed

Attenuation Column Study

- 3 materials evaluated
  - No Cash bog peat
  - Flame and moth peat
  - Flame and moth silty soil
- Two peat flow configurations tested:
  - Unsaturated downflow
  - Saturated upflow
- Flow rate 2 pore volumes/week
- Columns contained ~0.1 m^3 material
- Continuous mine recharge

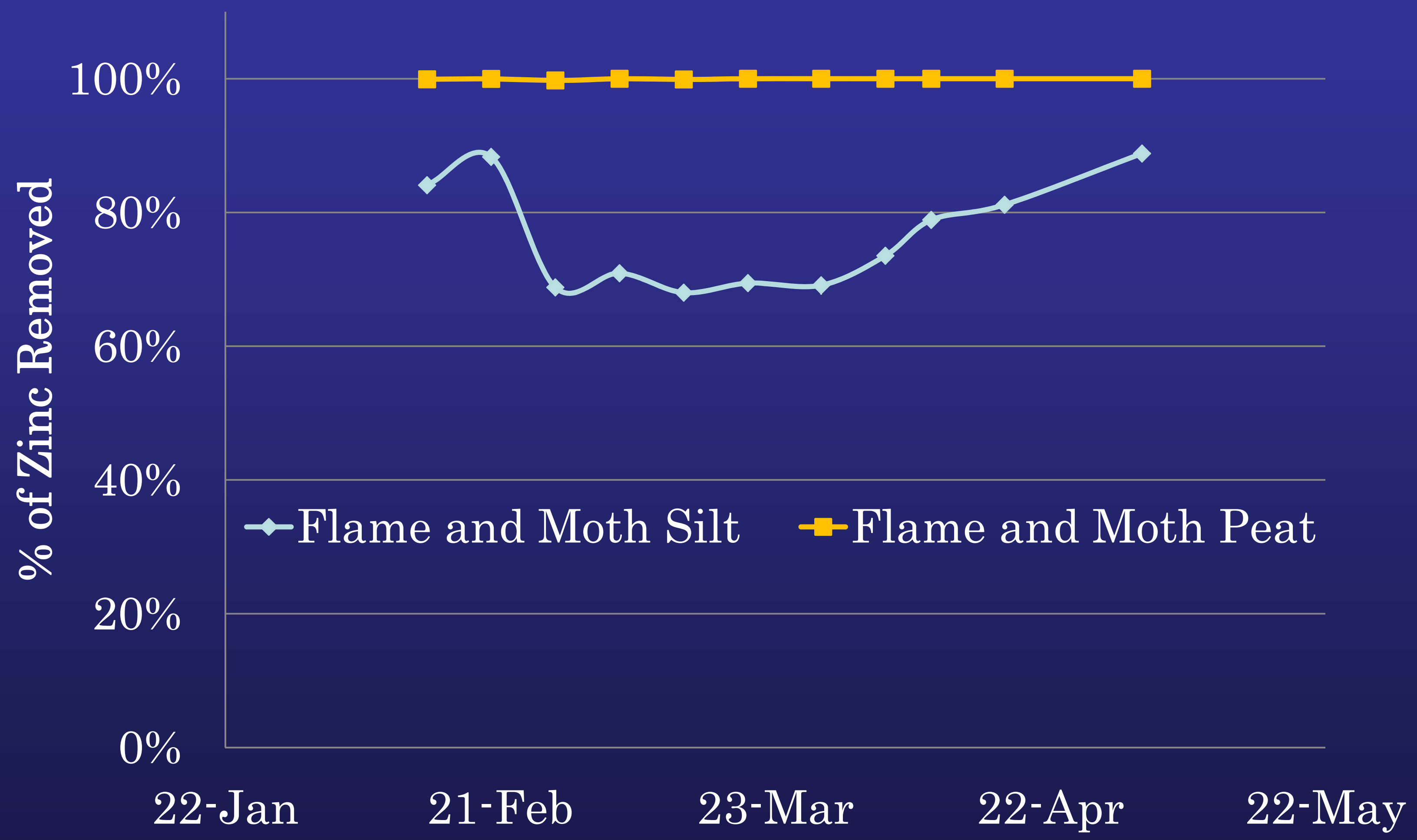
Saturated Peat Removal

Dissolved Metals	Units	Avg. Influent	Avg. Effluent	Avg. (%) Removal
Arsenic (As)	ug/L	59.95	12.925	78.4%
Cadmium (Cd)	ug/L	1.4	0.065	95.4%
Iron (Fe)	ug/L	1935	2395.25	-23.8%
Manganese (Mn)	ug/L	16450	5945	63.9%
Nickel (Ni)	ug/L	191	2.5	98.7%
Zinc (Zn)	ug/L	5790	8	99.9%
Anions				
Sulphate	mg/L	950	897.5	5.6%

Saturated Silty Soil Removal

Dissolved Metals	Units	Avg. Influent	Avg. Effluent	Avg. (%) Removal
Arsenic (As)	ug/L	59.95	2.1	96.4%
Cadmium (Cd)	ug/L	1.4	0.95	32.1%
Iron (Fe)	ug/L	1935	42	97.8%
Manganese (Mn)	ug/L	16450	1183	92.8%
Nickel (Ni)	ug/L	191	55.5	70.9%
Zinc (Zn)	ug/L	5790	1486	74.3%
Anions				
Sulphate (SO4)	mg/L	950	1015	-6.8%

Saturated Peat Removal



Summary

- Alcohol-fed bioreactors can treat metals in Keno district to appropriate levels
- Natural attenuation processes appear sustainable for long-term
- Other in situ sulfate-reducing applications appear feasible
- District-wide, watershed based closure will involve wide array of technologies