



# Passive Treatment System for Arsenic, Manganese, & Iron

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# Agenda

- Site Background
- Passive Treatment System (PTS) Design
- PTS Performance
- Conclusions
- Future Work
- Questions





# Background - Empire Mine State Historic Park

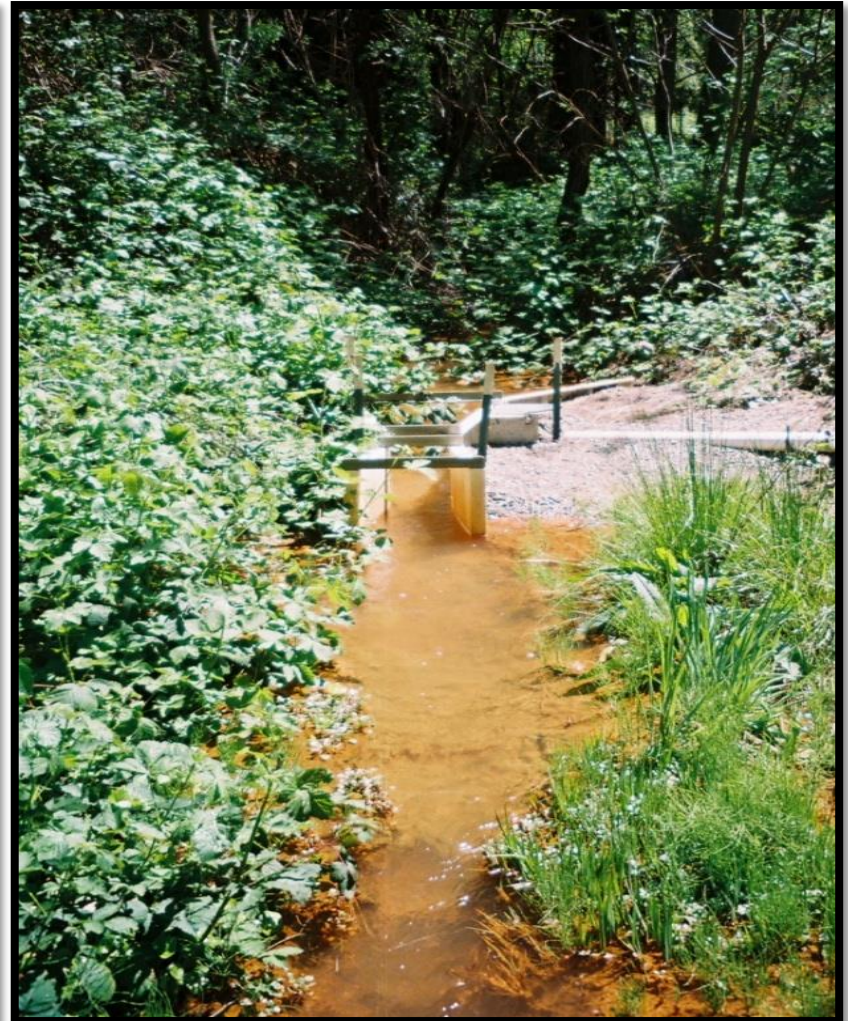


- Oldest, largest, and richest gold mine in California
- Produced 5.6 million ounces of gold (~\$6.6 billion today) from 1850-1956
- 367 miles of underground workings
- 845 acre park with 12 miles of trails
- Magenta Drain portal drains portions of the underground workings – neutral pH





## Background – Legacy: MIW 24-7





## Design – Constituents of Concern

Parameter	Influent Average (Maximum)	Interim Limit <sup>1,2</sup>	Final Limit <sup>1,2</sup>
pH	7	--	6.5 - 8.5
Arsenic (µg/L)	69 (240)	400	10
Iron (µg/L)	5,500 (14,000)	11,000	300
Manganese (µg/L)	2,360 (4,100)	3,000	50

### Notes:

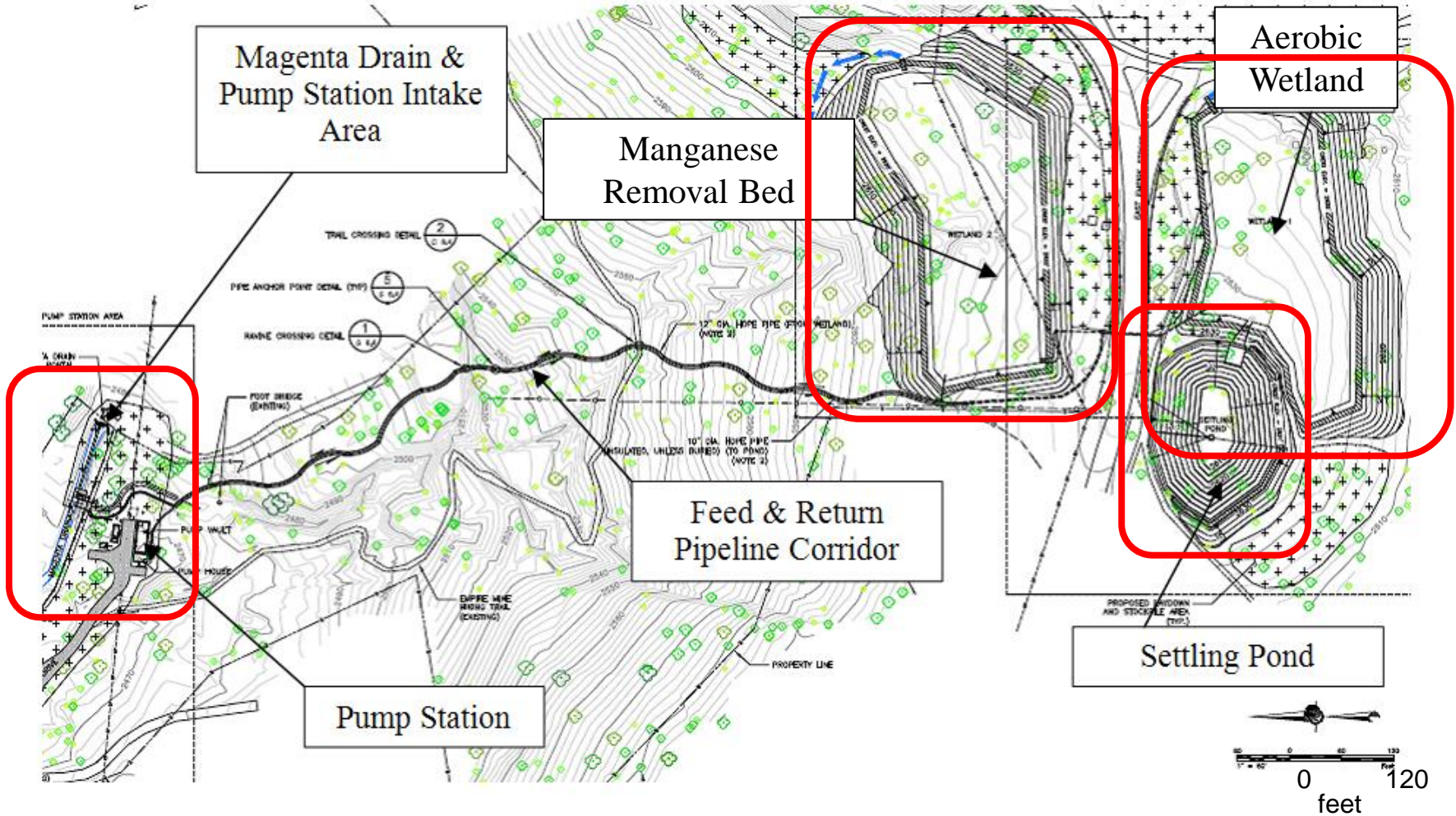
1 – As defined by NPDES Permit and Time Schedule Order

2 – Interim limits in effect from startup through June 1, 2015





# Design – Layout





# PTS Design – Treatment Mechanisms

- **Settling Pond:** *Iron and Arsenic Treatment*
  - Oxidation of ferrous iron to ferric iron oxy-hydroxide
  - Adsorption/Co-precipitation of arsenic and ferric iron oxy-hydroxides
- **Aerobic Wetland:** Iron, Arsenic, and Manganese Treatment
  - Further oxidation, settling, and retention of Fe/As complexes
- **Manganese Removal Bed:** Manganese Treatment
  - Biotic and abiotic removal, catalyzation, and precipitation of manganese oxide (Pyrolusite/ $MnO_2$ )



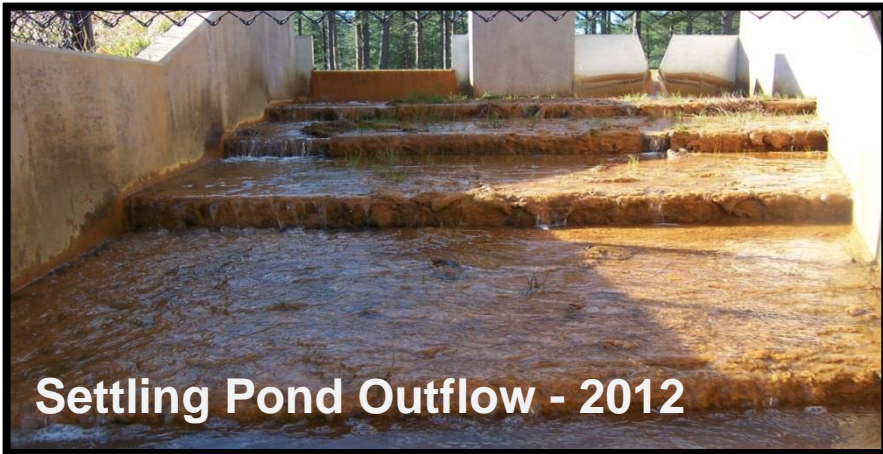


# Design – Settling Pond



Settling Pond

- Average HRT: 88 hours
- Minimum HRT: 18 Hours
- Surface Area: 0.5 acres



Settling Pond Outflow - 2012



Settling Pond Outflow - 2015



# Design – Aerobic Wetland

Aerobic Wetland - 2012



Aerobic Wetland - 2015



- **Surface area:** 1.1 acres
- Arroyo willow (*Salix lasiolepis*) (primary)
- Sandbar willow (*Salix exigua*) (secondary)
- Common rush (*Juncus effuses*) Baltic rush (*Juncus balticus*).



## Design – Manganese Removal Bed (MRB)



- **Surface Area:** 1.2 acres
- **Media:** 8 inches crushed limestone rock
- **Design Mn Removal:** 0.9 g/m<sup>2</sup>/day

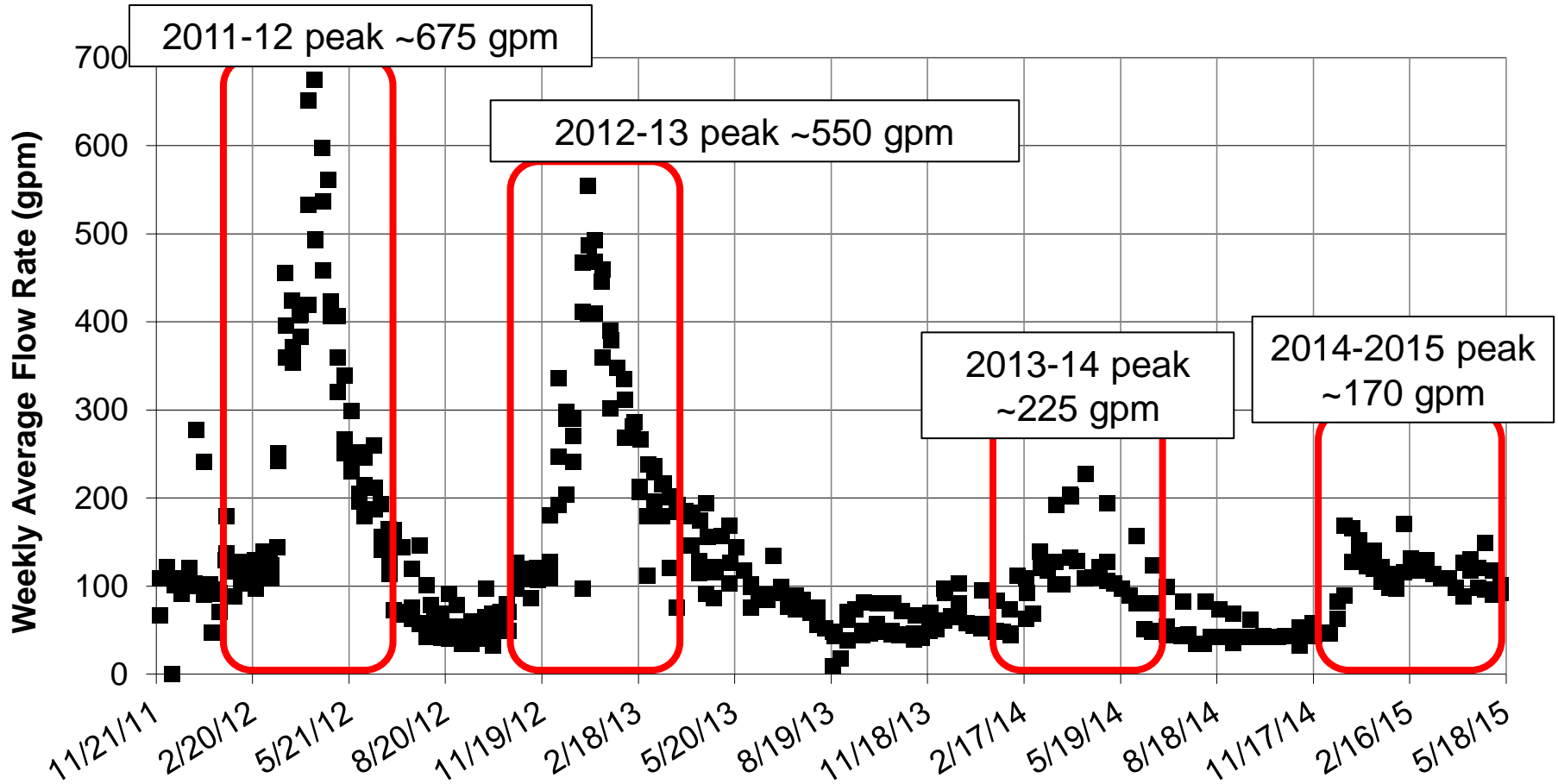


## Design – PTS Influent

- Main influent source is the Empire Mine pool, via the Magenta Drain
- Significant seasonal flow variation, correlated with precipitation
- Design hydraulic flow capacity: 1,200 gpm
- Average measured discharge flow rate: 150 gpm
- Peak measured discharge flow rate: 675 gpm

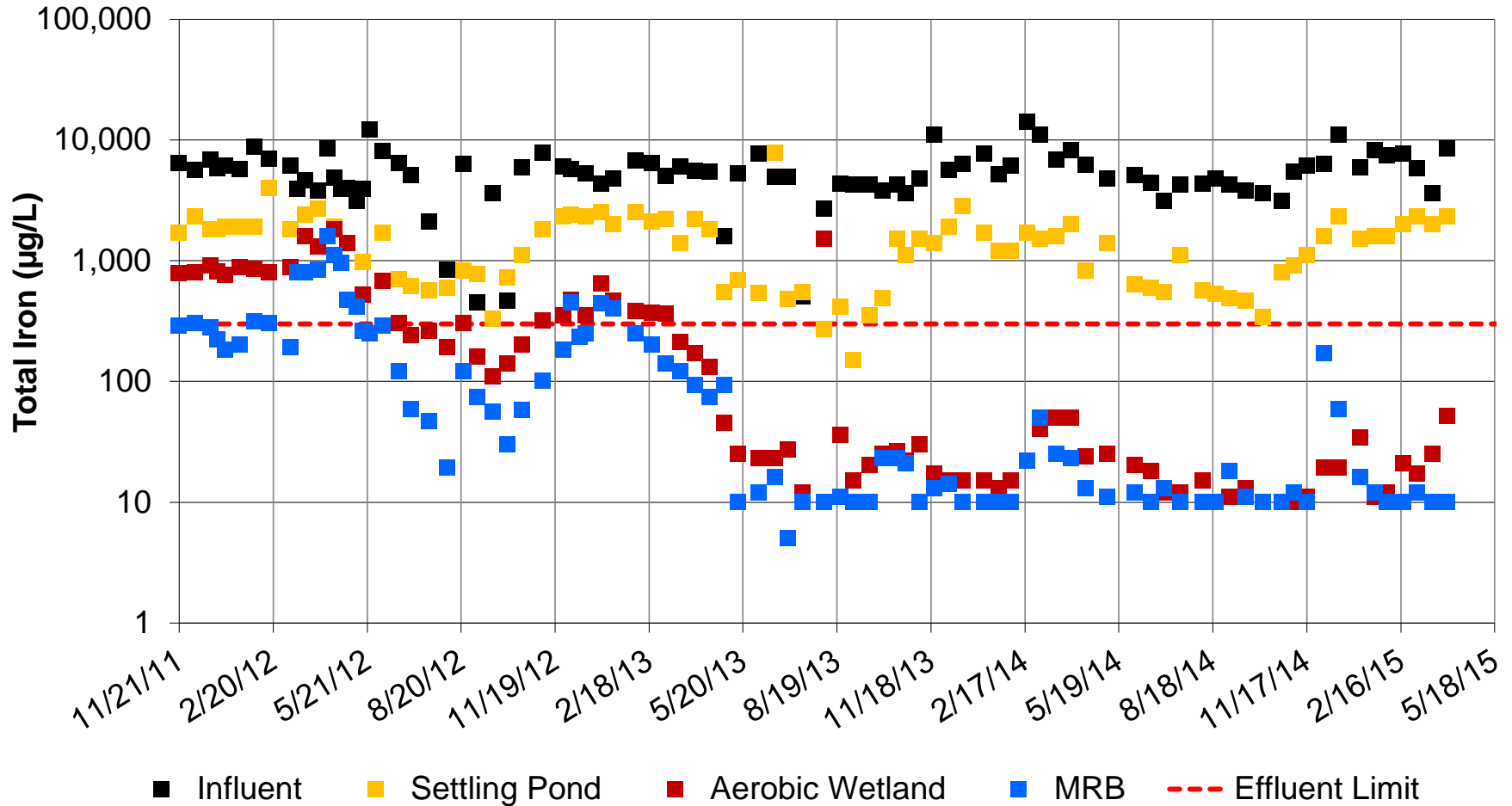


# Design – PTS Influent



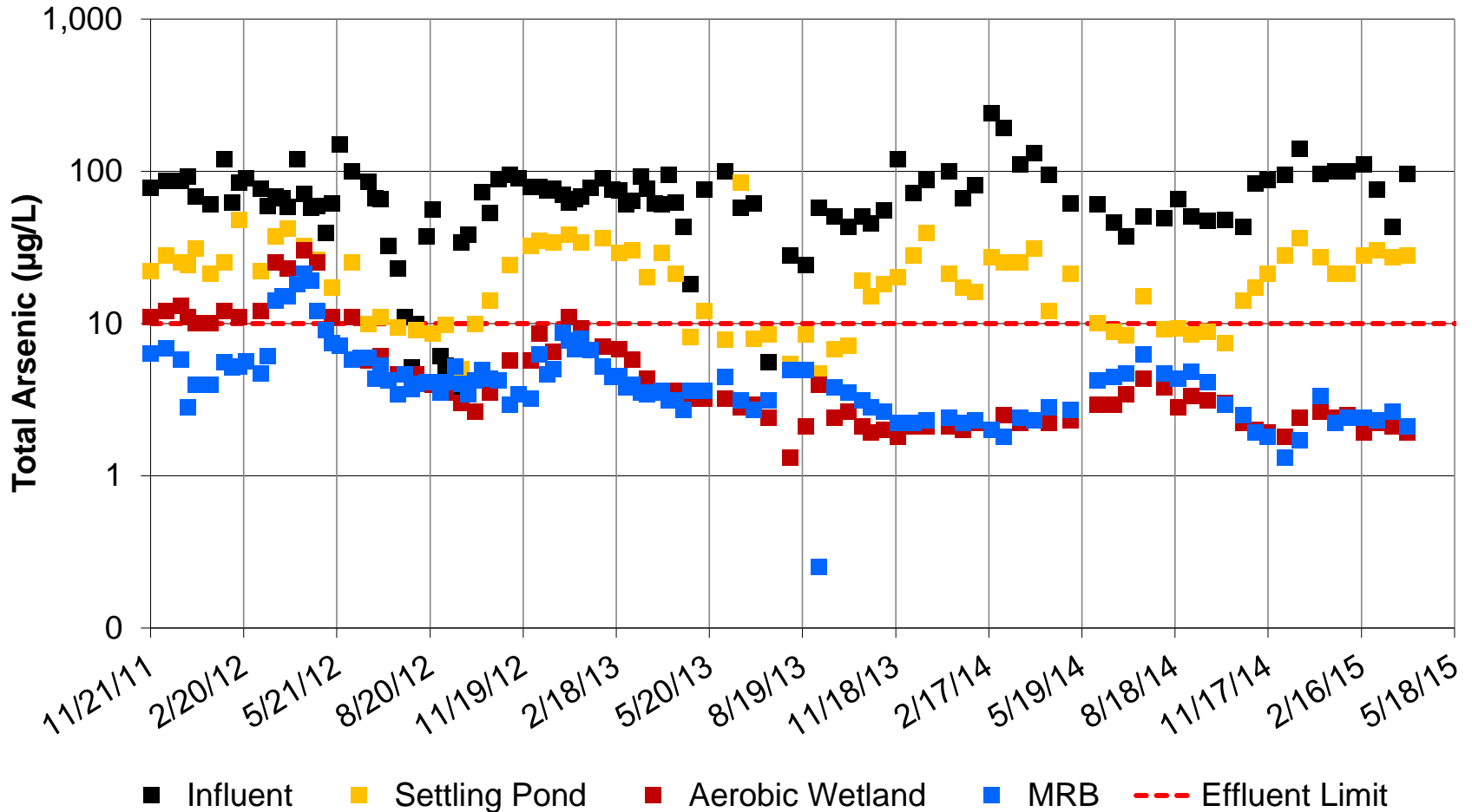


# PTS Performance – Total Iron



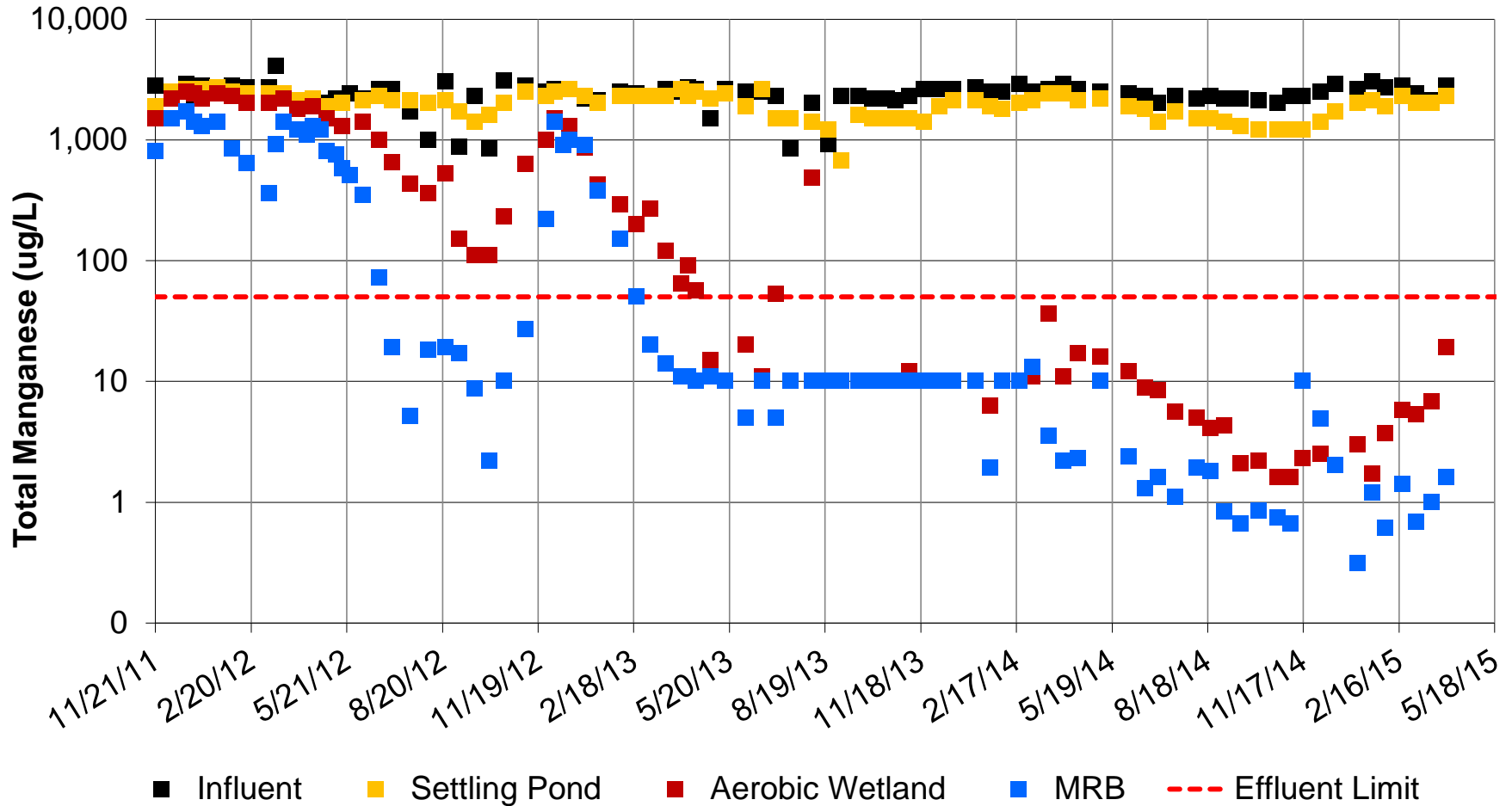


# PTS Performance – Total Arsenic





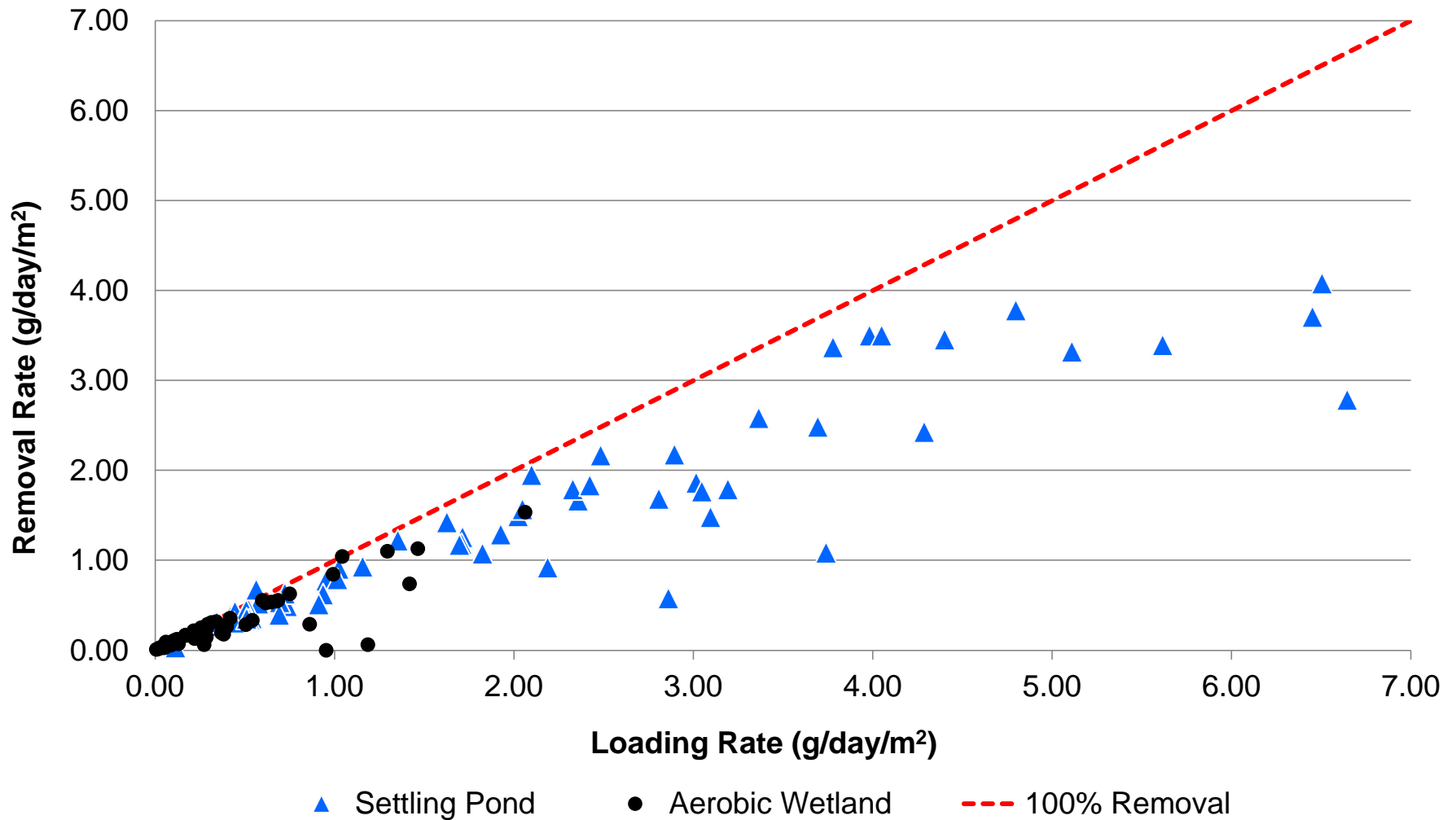
# PTS Performance – Total Manganese





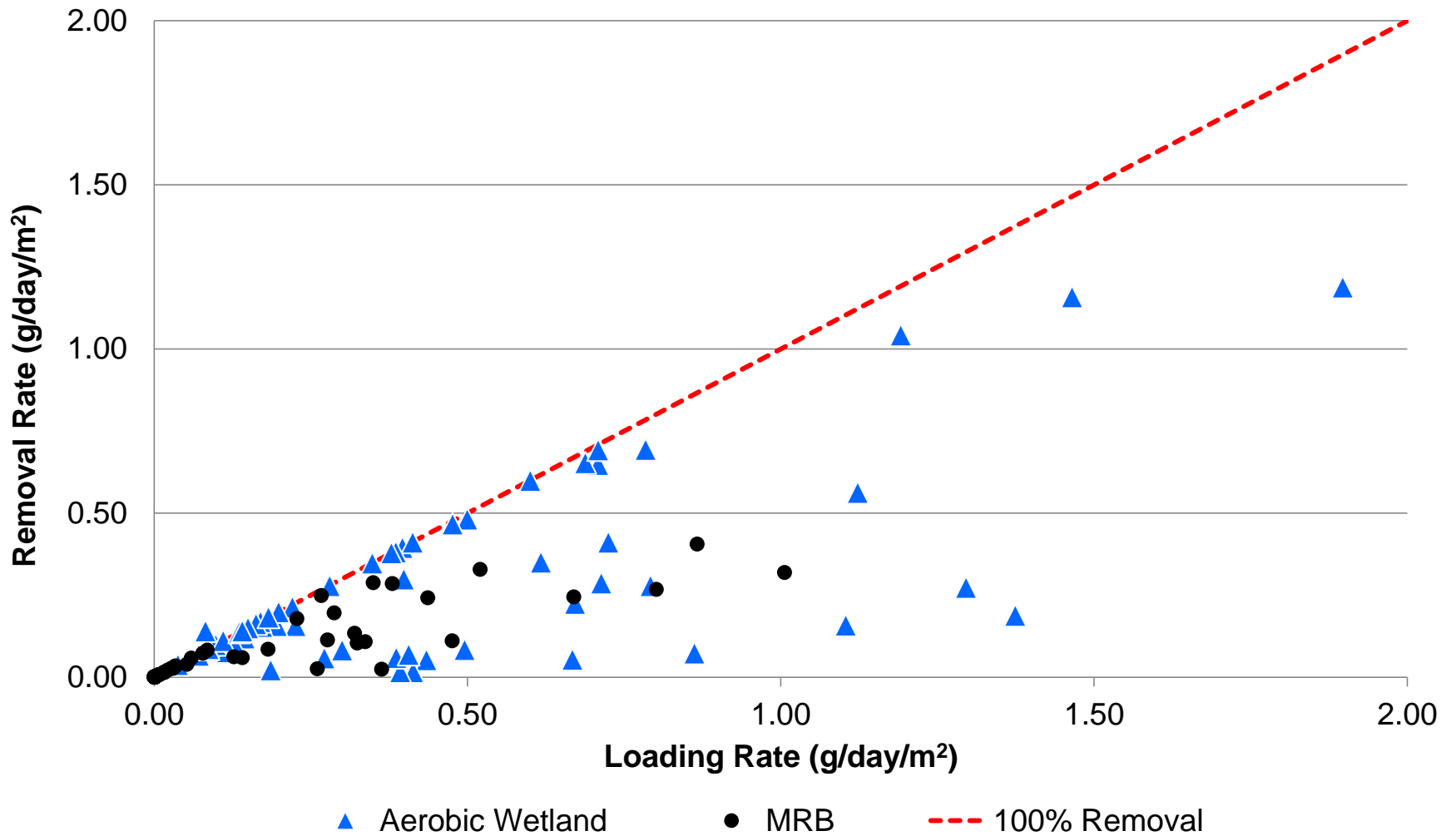


# PTS Performance – Fe Loading and Removal





# PTS Performance – Mn Loading and Removal





# PTS Performance – Mn Loading and Removal

- **Aerobic Wetland**
  - **Magenta PTS:** Near complete removal up to 0.71 g/day/m<sup>2</sup>
- **Manganese Removal Bed**
  - **Literature:** 1.2 – 10.7 g/day/m<sup>2</sup> (Rose, 2003)
  - **Magenta PTS:** Loading has been limited to 1 g/day/m<sup>2</sup>



## Conclusions - Data

- **Continually achieved PPB effluent for As, Mn, and Fe over past 2 years:**
  - Arsenic averaged 3.0 µg/L
  - Manganese averaged 5.9 µg/L
  - Iron averaged 22 µg/L
- **Majority of Fe and As removal occurring in Settling Pond and Aerobic Wetland:**
  - Fe – 97%
  - As – 94%
- **Majority of Mn removal occurring in Aerobic Wetland and MRB:**
  - Mn – 77% in aerobic wetland; 4% in MRB



## Conclusions - Data

- **Maximum removal rates achieved for As, Mn, and Fe as follows:**
  - Aerobic Wetland
    - As – 0.022 g/day/m<sup>2</sup>
    - Mn – 1.2 g/day/m<sup>2</sup>
    - Fe – 1.5 g/day/m<sup>2</sup>
  - MRB:
    - Mn – 0.4 g/day/m<sup>2</sup>
- **Waiting on the Rain:**
  - Higher Mn loading through PTS needed to better characterize MRB removal rates



## Conclusions - Highlights

- **Interim regulatory limits achieved since Startup (November 2012)**
- **Final regulatory limits achieved since February 2013**
- **Few studies have shown passive Mn removal to ppb range at full scale and are permitted to comparably low Mn (50 µg/L) limits**
- **PTS has demonstrated passive Mn removal to <1 µg/L**



## Future Work

- **Ongoing PTS performance monitoring**
  - Regulatory sampling, data evaluation, reporting (ongoing)
  - Systems monitoring, e.g. settling pond sludge level measurement (ongoing)
  - Oxygen profiling (2014 – 2015)
  - Scaled testing (2015)



# Future Work - Oxidation Profile Monitoring







# Future Work – Scaled Testing



**THANK YOU!**



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