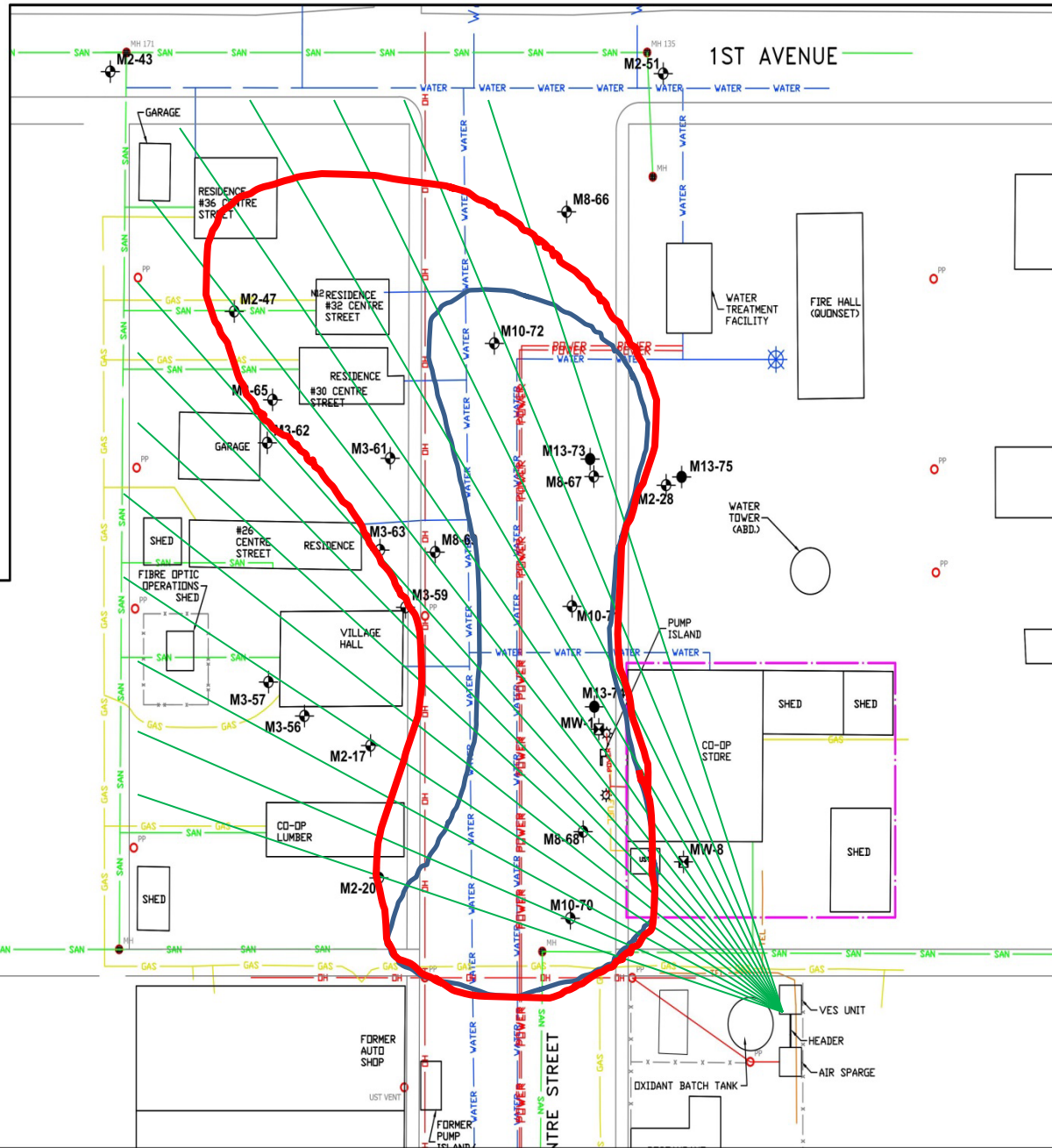


# Comparing Effectiveness of Activated vs. Un-activated $\text{Na}_2\text{S}_2\text{O}_8$ During In-Situ Remediation of PHCs

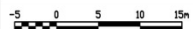


Legend:

- MW-1 Monitoring Well (Envirogeo Testing, 2001)
- M2-47 Monitoring Well (NECL: 2002)
- M3-65 Monitoring Well (NECL: 2003)
- M8-69 Monitoring Well (NECL: 2008)
- M10-70 Monitoring Well (NECL: 2010)
- M13-73 Borehole (Nichols)
- PP Power Pole
- LP Light Pole
- MH Manhole
- Approximate Property Boundary
- X Fence
- TEL Communication Line
- FD Fibre-Optic Communication Line
- GAS Gas Line
- DH Overhead Power Line
- POWER Underground Power Line
- WATER Underground Water Line
- SAN Sanitary Sewer Line



NICHOLS ENVIRONMENTAL (CANADA) LTD.



CLIENT  
 Arrowwood Co-op Association Ltd.

PROJECT  
 Baseline Groundwater Monitoring and Sampling Program  
 Arrowwood Co-op Gas Bar  
 17 Centre Street, Arrowwood, Alberta

DRAWING TITLE  
 Site Detail, Borehole, and Sample Locations

BASE/SITE PLAN PROVIDED BY  
 Nichols Environmental (Canada) Ltd.

REVISION DATE  
 December 2013

SCALE 1:550 APPROVED  
 RS/JB

PROJECT NO.  
 13-431-ACA

DRAWING NO.  
 Figure 2

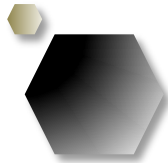
Original drawing in colour. Black and white copies may not interpret property. \\10.0.180\dss\joba\2013\13-431-ACA-Dr-wing\13-431-ACA-ACA\_RS.dwg



# Approach

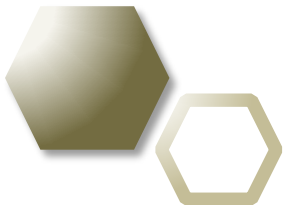
In-situ ChemOx using  
FMC Klozur Persulfate

Persulfate is widely used  
and well documented  
(generation of sulfate  
radical)



# Question

Do we use Activated or Un-  
activated Persulfate



# Activated Persulfate

Higher production of sulfate radicals

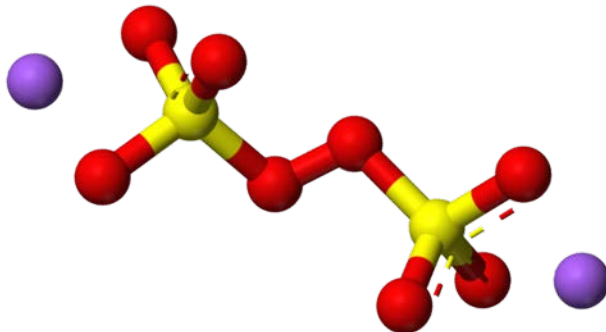
Results in rapid oxidation of PHCs

# Un-Activated Persulfate

Lower production of sulfate radicals  
Degrade into sulfuric acid over time

Promote release of soil-bound phosphate

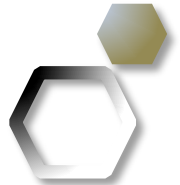
Provide sustained secondary anaerobic biological degradation





**Injected north half of site  
with alkaline activated  
persulfate**

**Injected south half of site  
with un-activated  
persulfate**







← 3 MBG →

← 4 MBG →

← 5 MBG →

← 6 MBG →



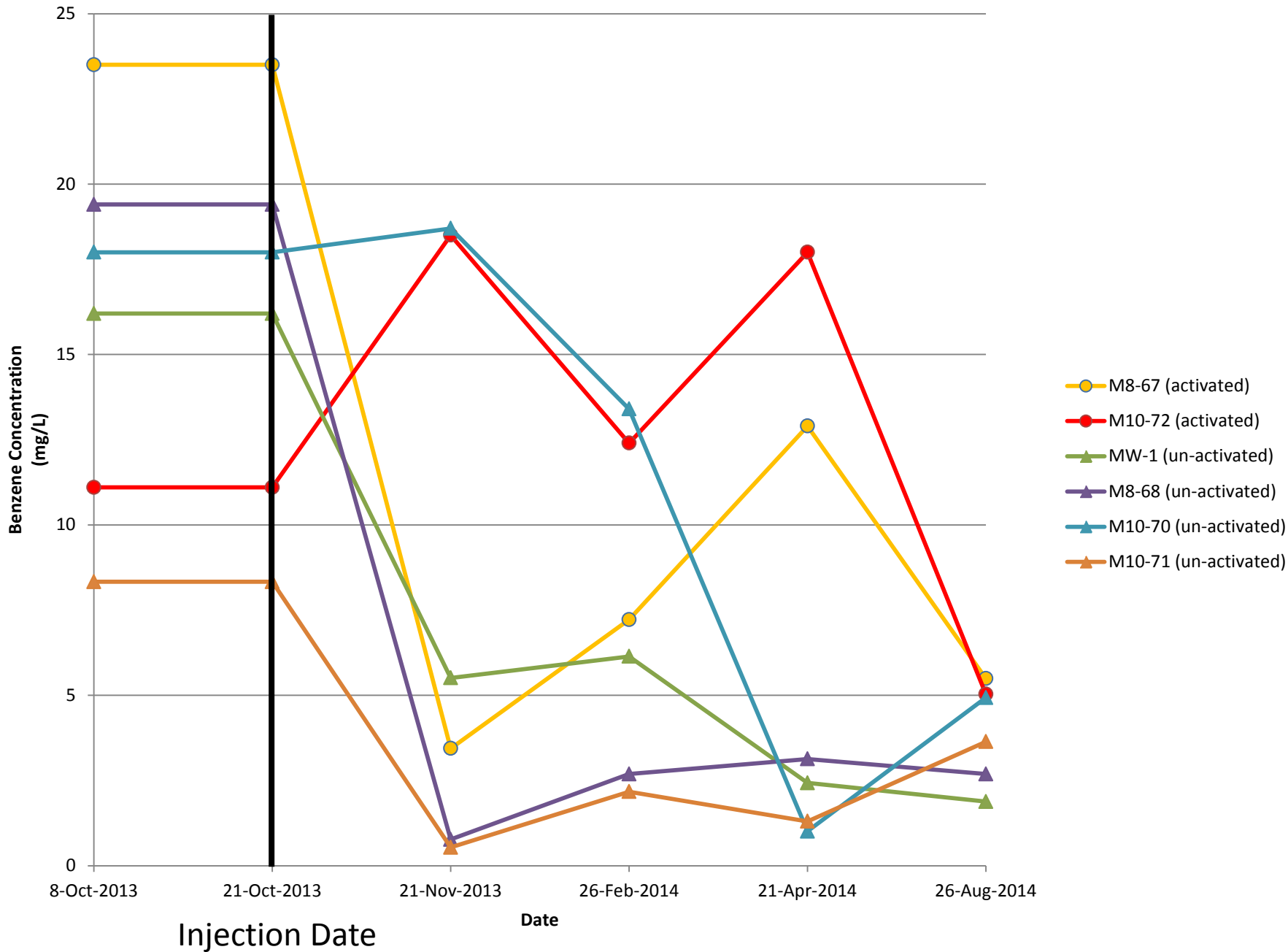
# Results

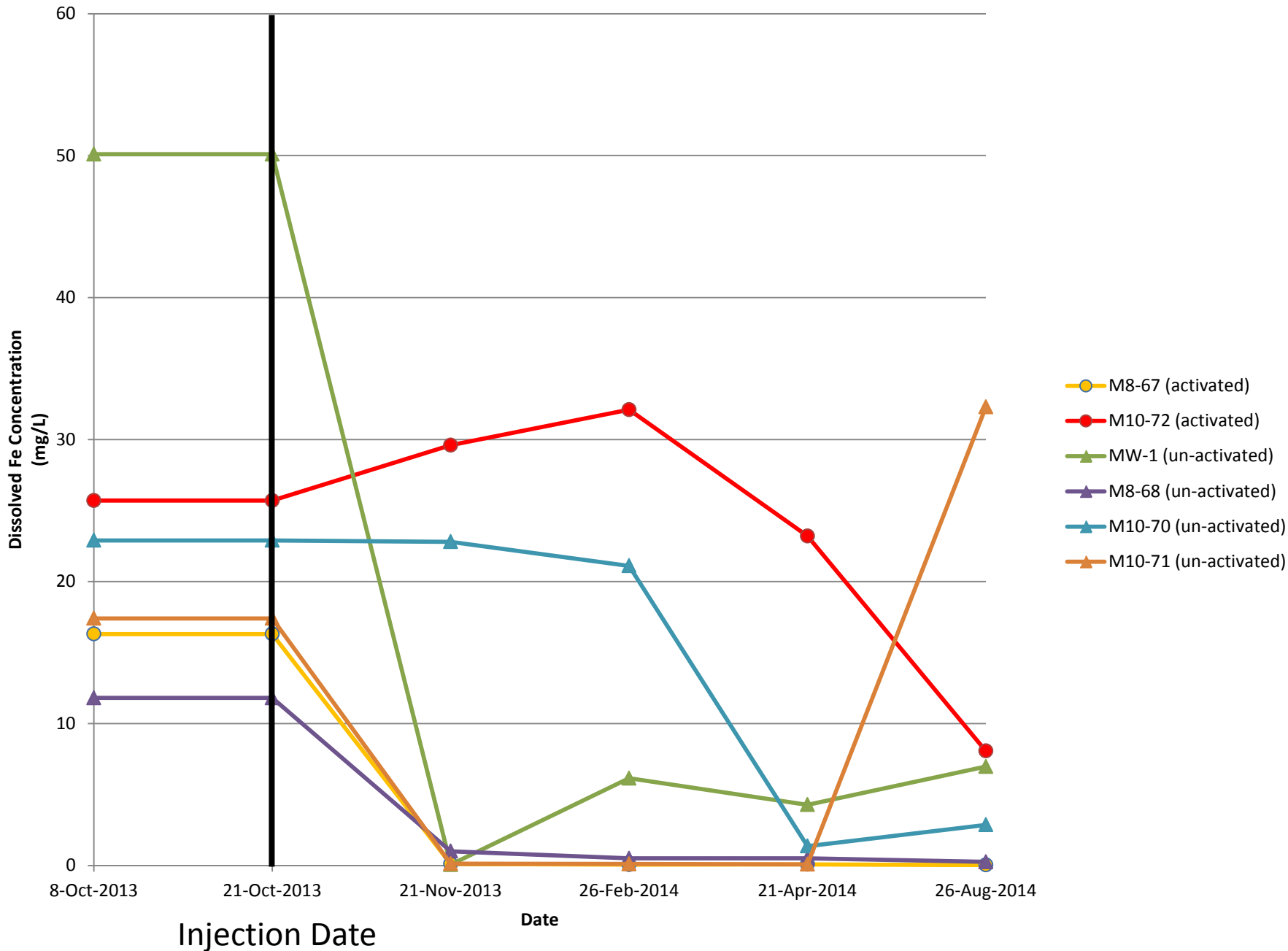
Success?

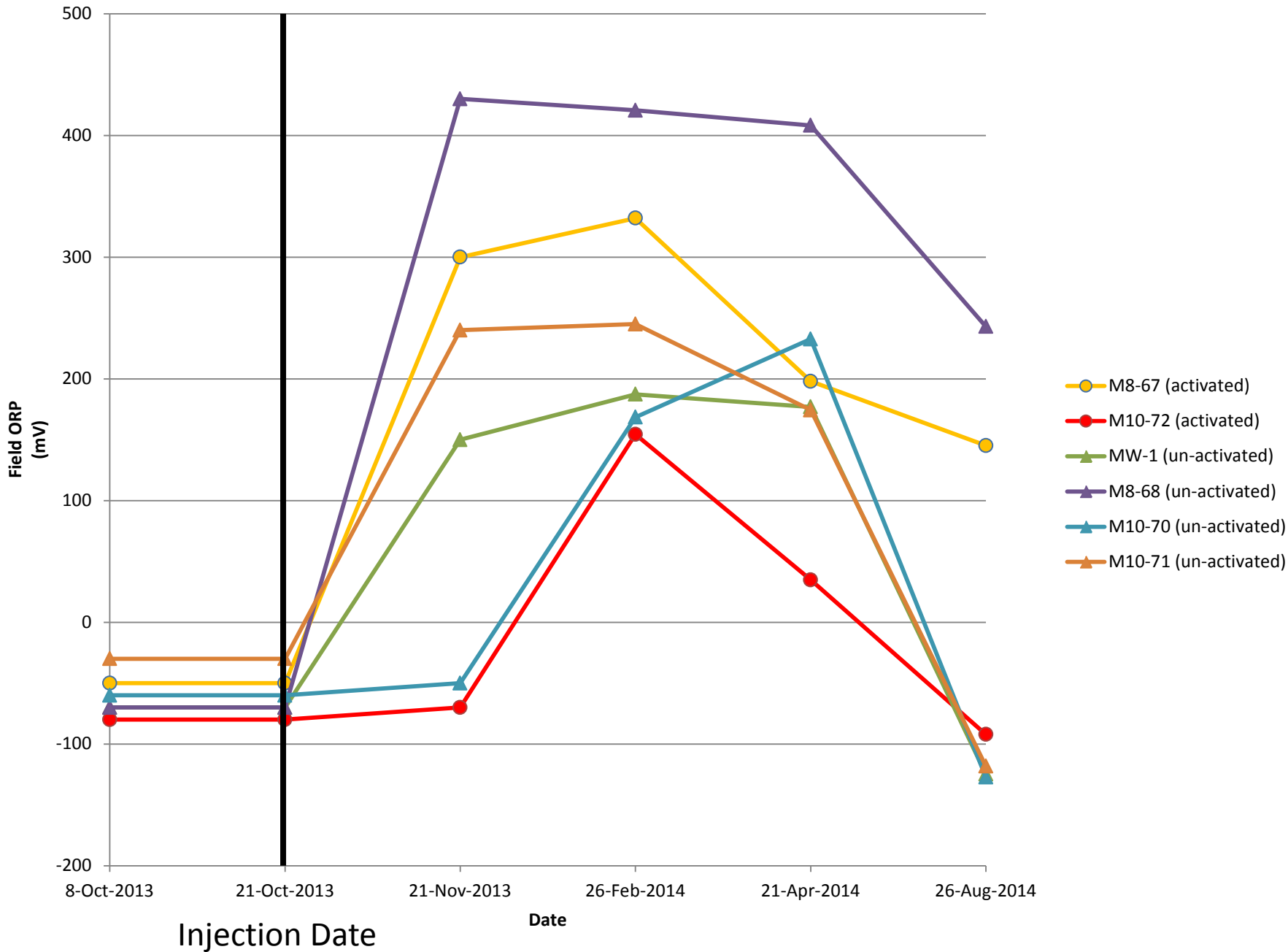
I think so!

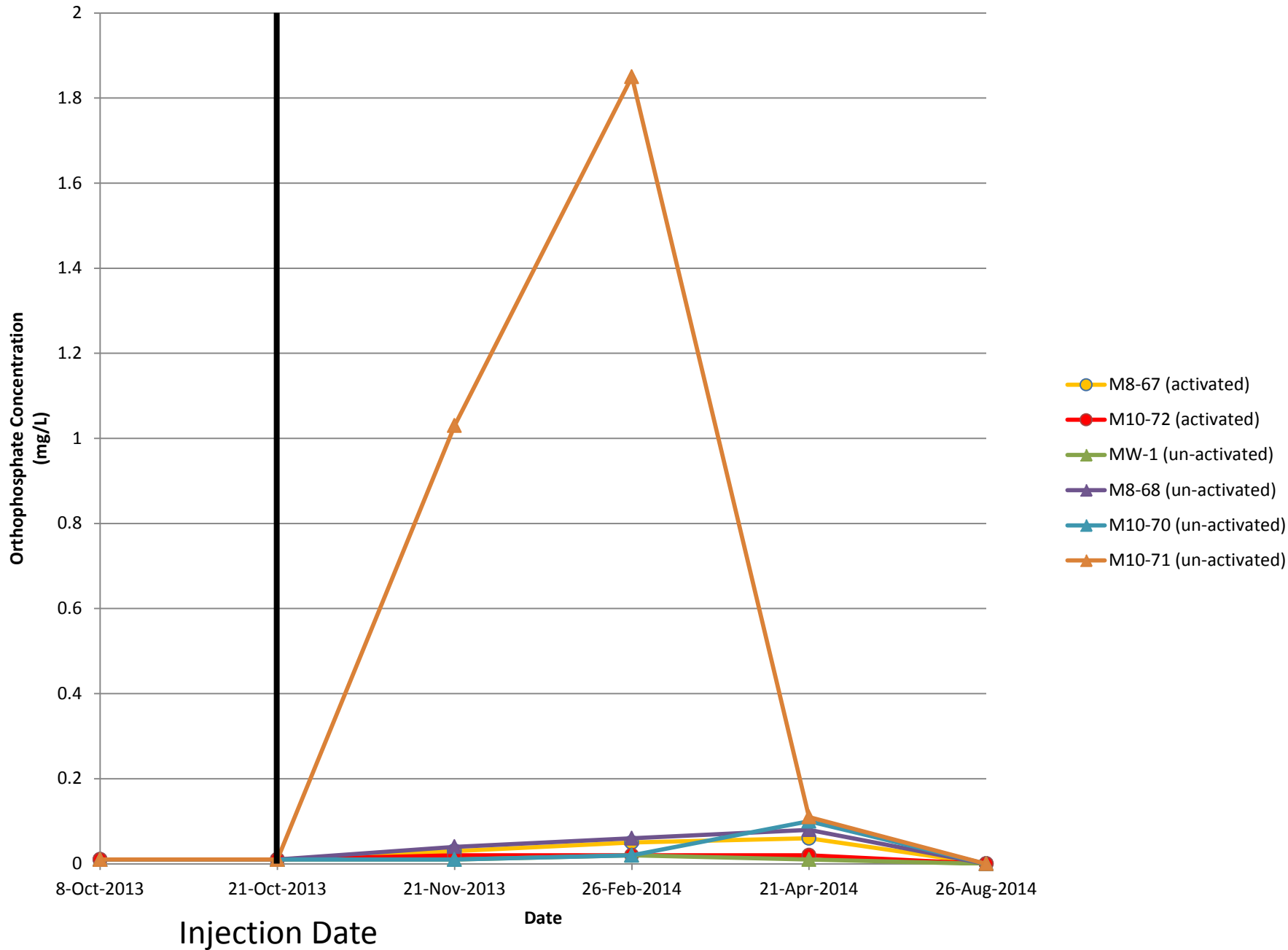
But what about activated v  
unactivated?

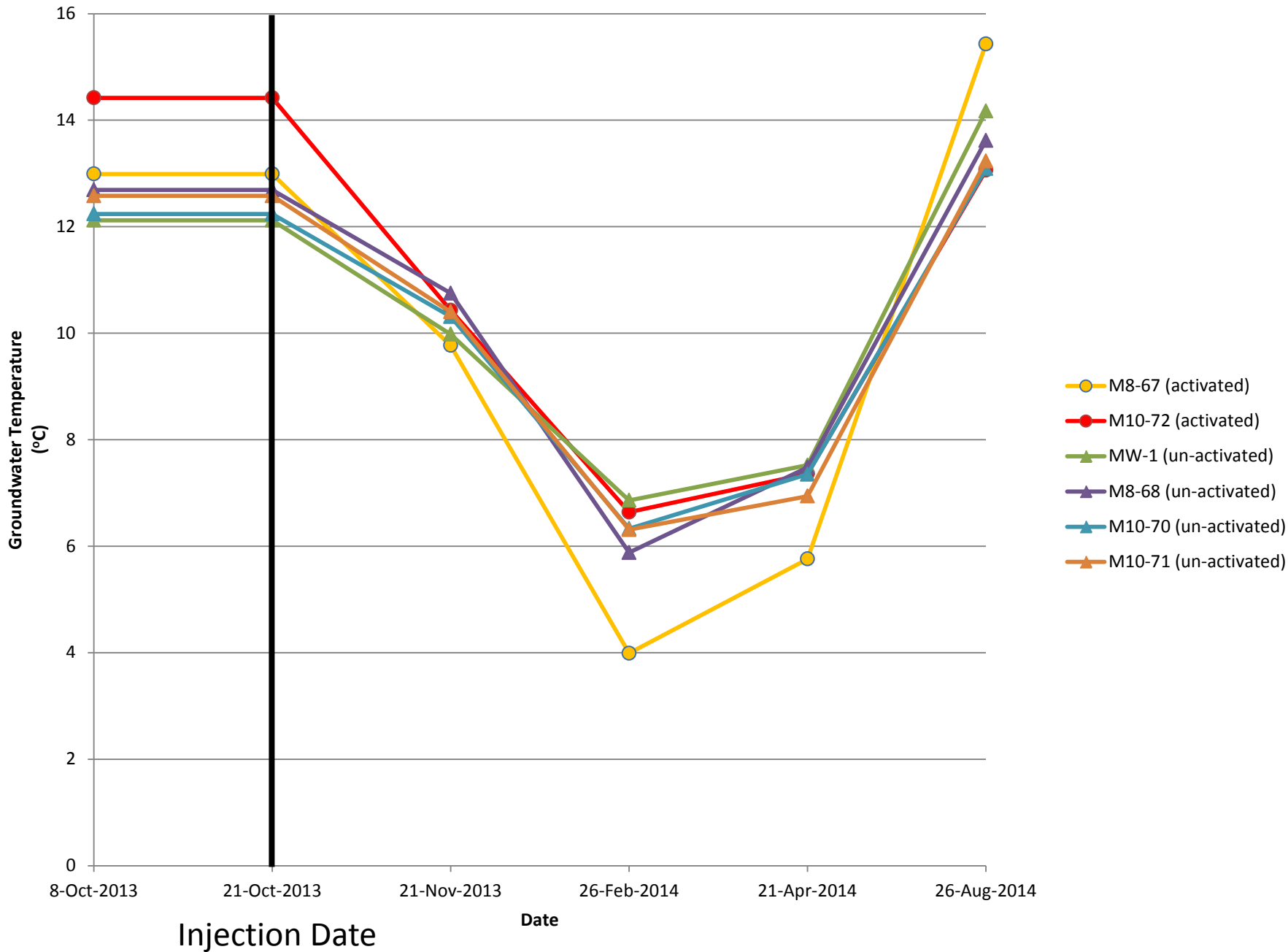


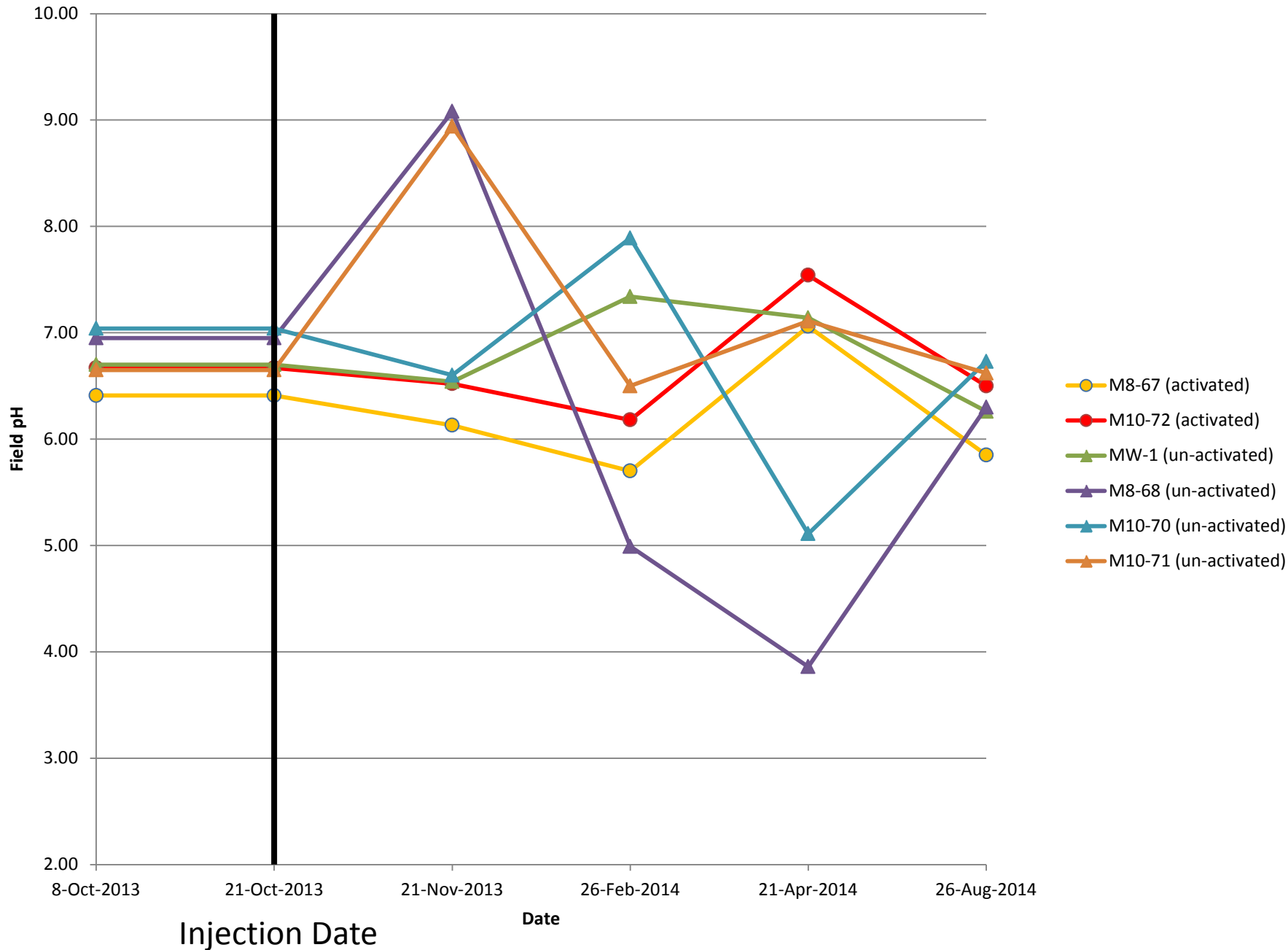


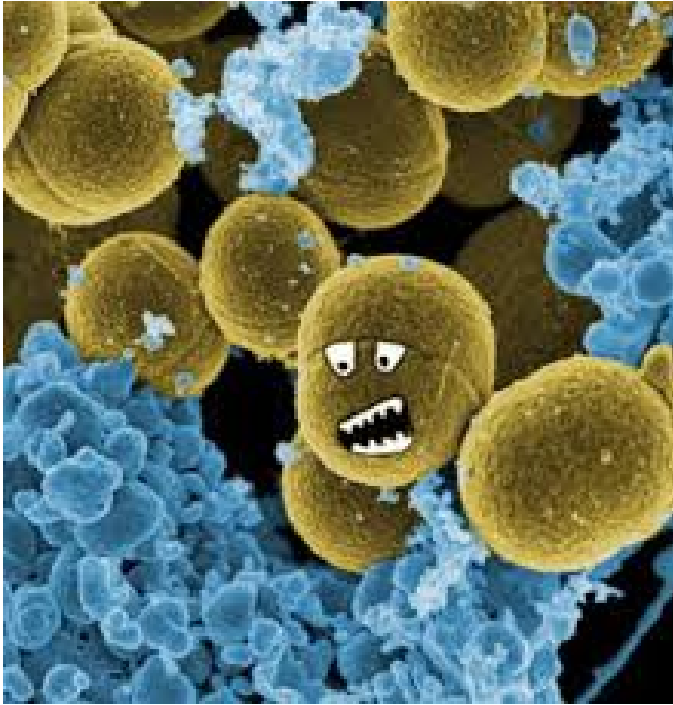












# Bacteria

Groundwater samples collected from both treatment zones and submitted for laboratory analyses of:

Sulfate Reducing Bacteria

Heterotrophic Aerobic Bacteria

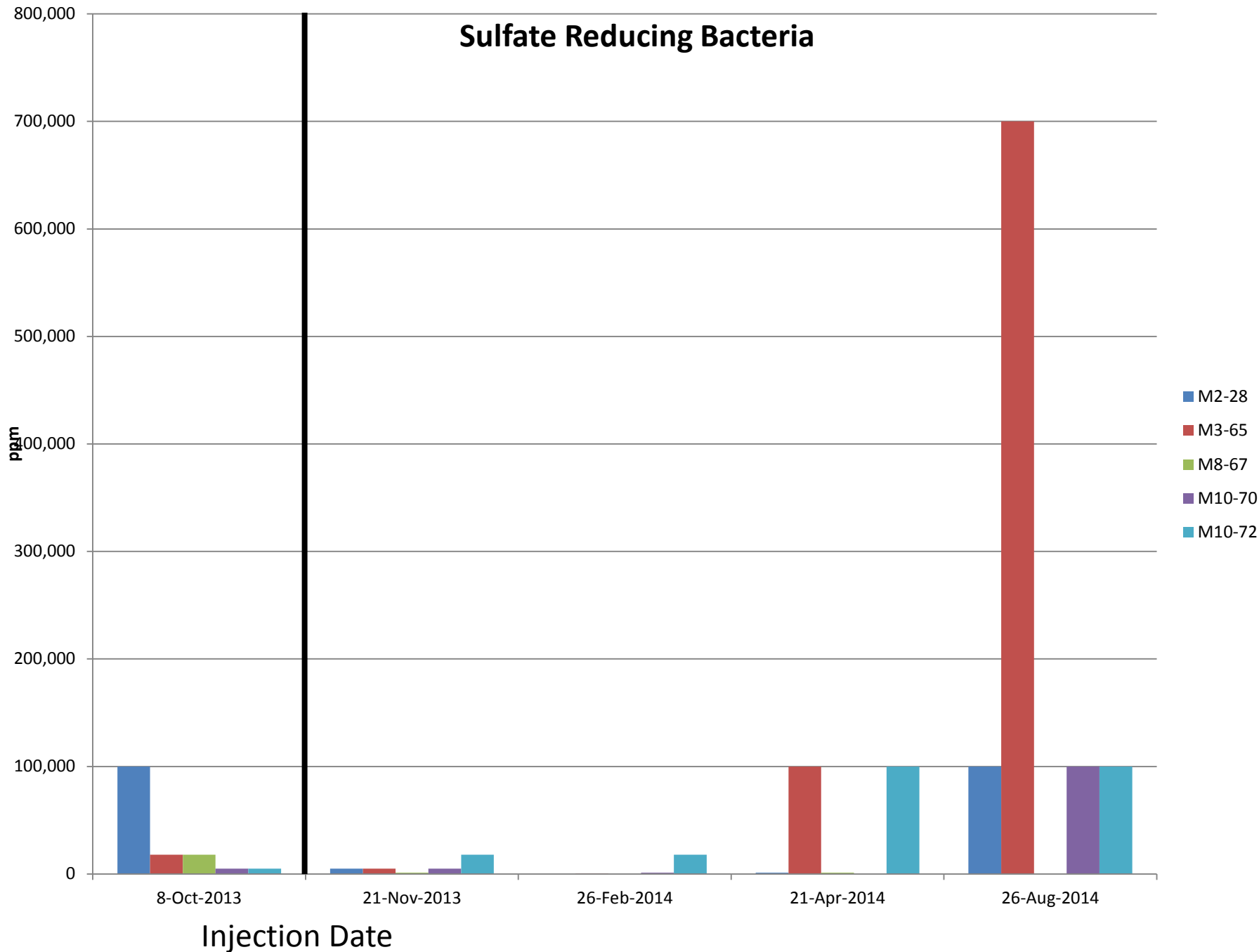
Iron Reducing Bacteria

Slime Forming Bacteria

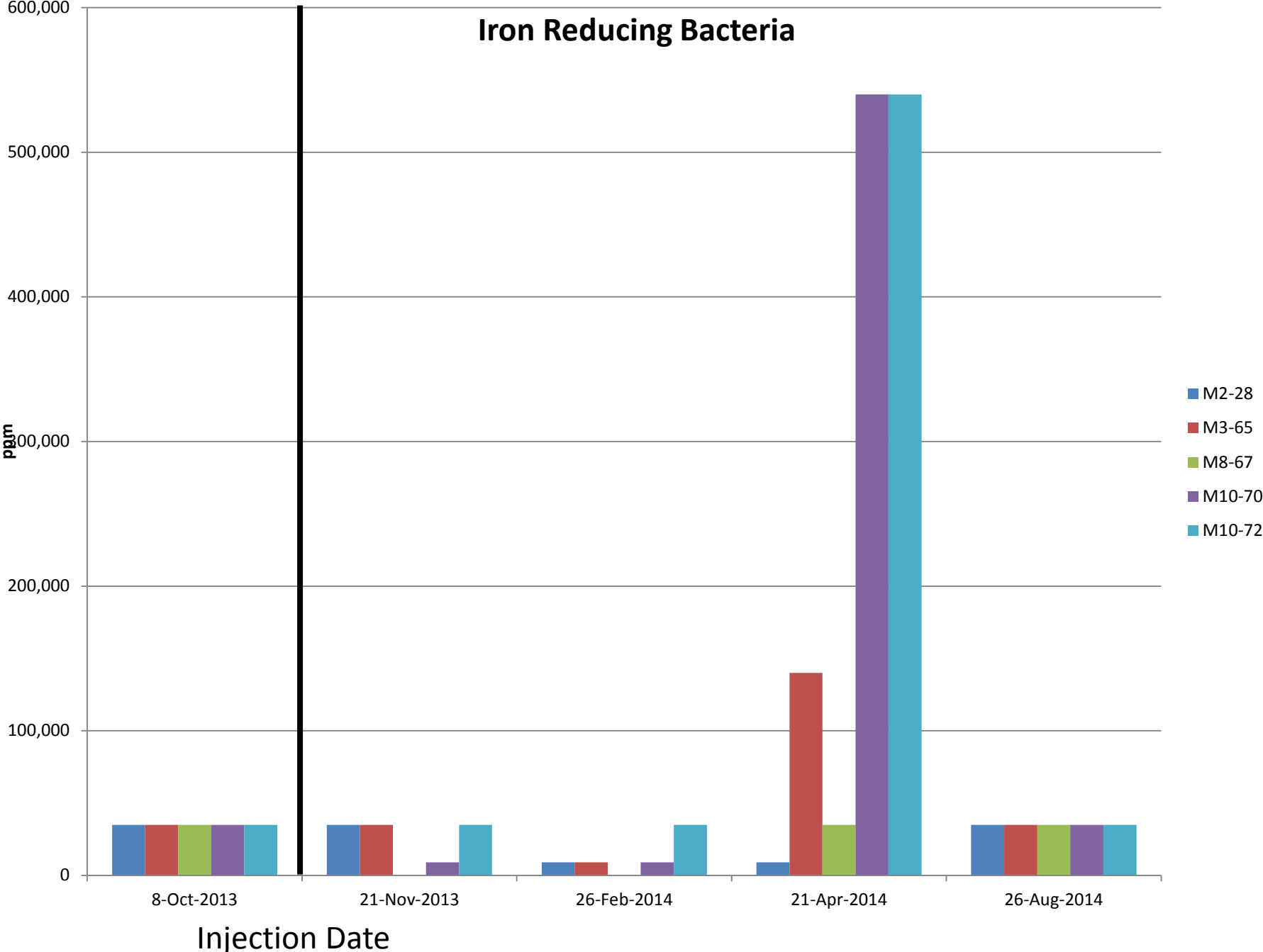




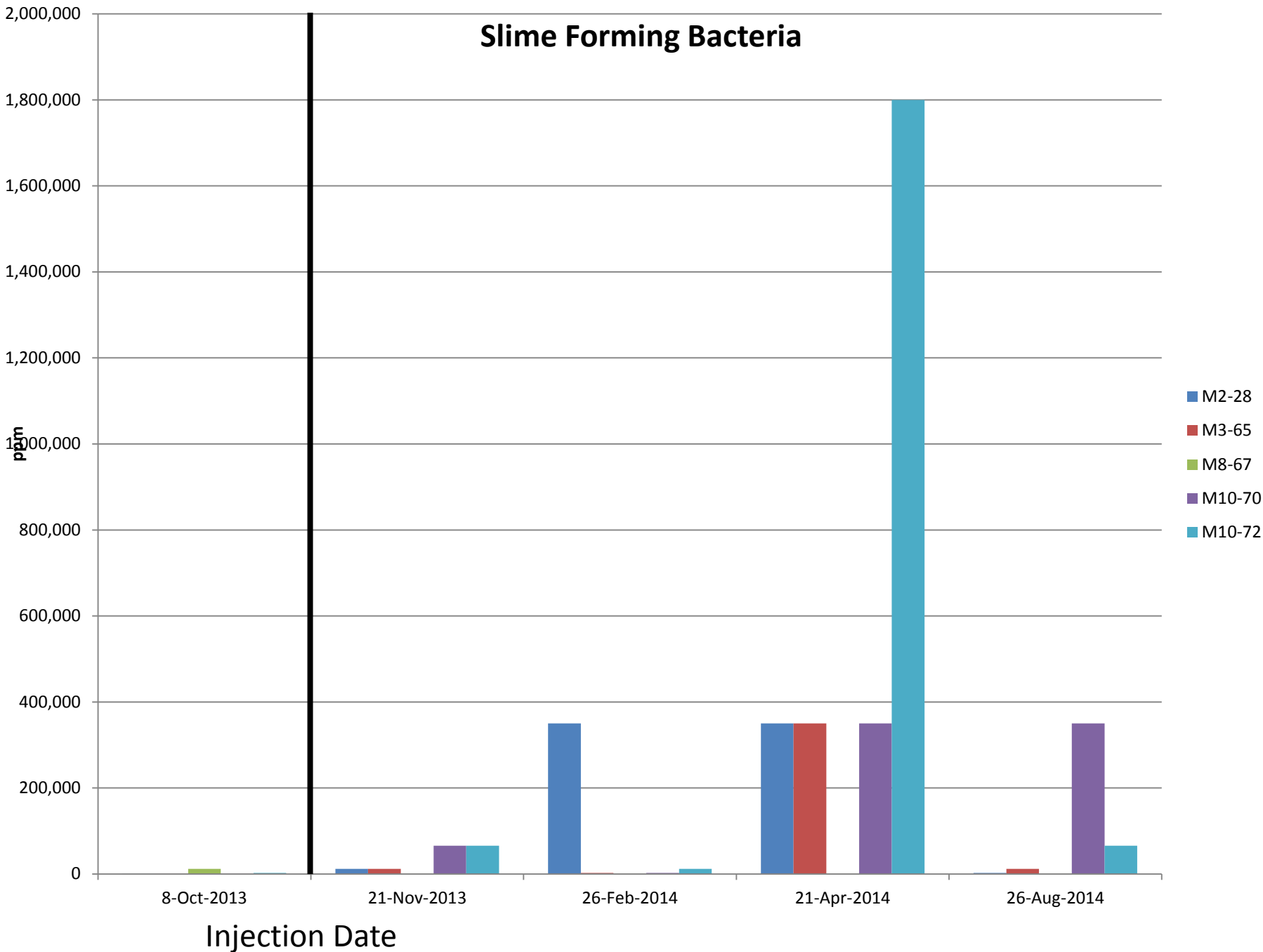
# Sulfate Reducing Bacteria



# Iron Reducing Bacteria



# Slime Forming Bacteria



# CONCLUSIONS

- Hydraulic fracturing → introduced preferential pathways for persulfate delivery
  - May explain variance in results throughout treatment areas
  - Valuable mechanism for persulfate delivery into fine-grained soils
- The recalcitrant benzene concentrations were greatly reduced in multiple wells
  - Some rebound (expected)
  - Less rebound in un-activated versus activated treatment zones
- No difference in efficacy of benzene degradation
  - using either NaOH activated versus un-activated persulfate
  - Natural activation may have occurred (elevated Fe)
- Large increase in bacterial population
  - Indicates orthophosphate was available
  - Being consumed immediately after release from the lithology

# QUESTIONS?

