



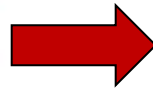
Impact of Coal Mine Reclamation Using Flue Gas Desulfurization (FGD) Materials on Groundwater Quality: Conesville and Cardinal Sites

Chin-Min Cheng¹, Robert Baker¹, Tarunjit Butalia¹, Harold Walker², John Massey-Norton³, William Wolfe¹

¹The Ohio State University, ²American Electric Power



Using FGD Materials for Mine Land Reclamation



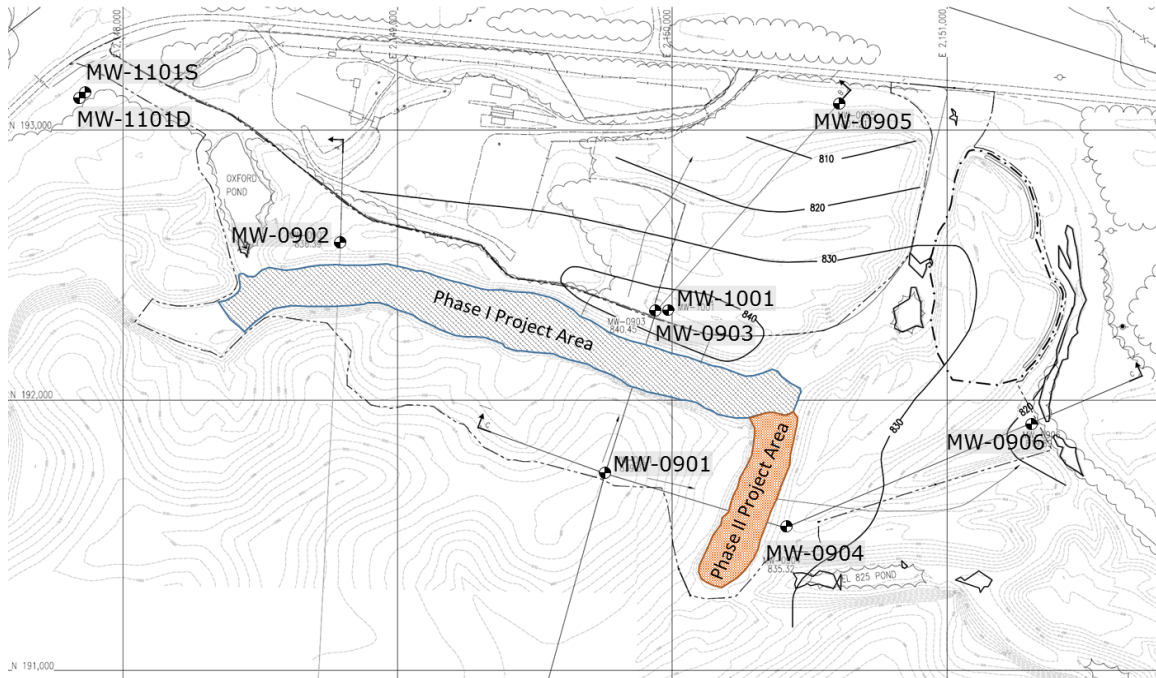
- Flue gas desulfurization (FGD) materials
 - FGD gypsum
 - Stabilized FGD by-product (Sulfite FGD by-product stabilized with fly ash and lime)
- Benefits of Using FGD materials for ML highwall reclamation
 - Re-contour highwalls in surface mines to eliminate dangers to the public's safety
 - Neutralize or encapsulate AMD producing materials
 - Alternative to landfilling
 - More economical than using natural materials

Projects Carried out by OSU on Coal Mine Reclamation

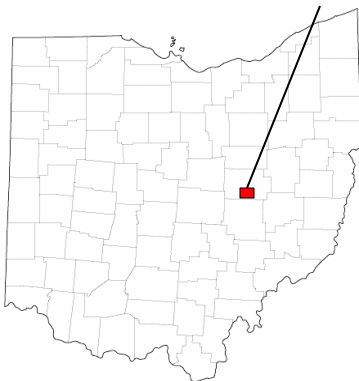
Overall Objective: Demonstrate the potential of **high-volume utilization of FGD materials (**stabilized sulfite FGD and FGD gypsum**) for reclamation at **abandoned and active** Ohio coal mine sites**

- Phase I Study (Reclamation potential, FGD gypsum properties) – completed ([final report online](#))
- Phase II Study (Conesville demo, Cardinal demo, grout pilot project)** – in progress
- Phase III Study (Gavin AMD demo) – in progress
- Impacts of Reclamation and Remining on Watersheds – in progress
- Assessment of Stream Resources at Coal Remining Sites- in progress

Conesville Five Points Reclamation Site



- Reclamation of abandoned highwall (1,200 feet long, 60 to 100 feet in height)
- Large-volume use of Conesville FGD gypsum (about 1.5 million tons) in combination with Conesville fixated FGD by-product and fly ash



Reclamation Progress at Conesville Site



Reclamation Progress at Conesville Site



Reclamation Progress at Conesville Site



8/12/2013

Reclamation Progress at Conesville Site



5/26/2014

Cardinal Star Ridge Reclamation Site



- Star Ridge site near Cardinal landfill (selected in consultation with industrial sponsors and Ohio DNR)
- Reclamation at permitted surface coal mine site of a highwall pit (250 feet long, 10 to 60 feet in height)
- Medium-volume use of Cardinal FGD gypsum (about 0.45 million tons) in combination with onsite spoil



Cardinal Construction Progress



Cardinal Construction Progress



11/29/2012

Cardinal Construction Progress



8/01/2013

Cardinal Construction Progress

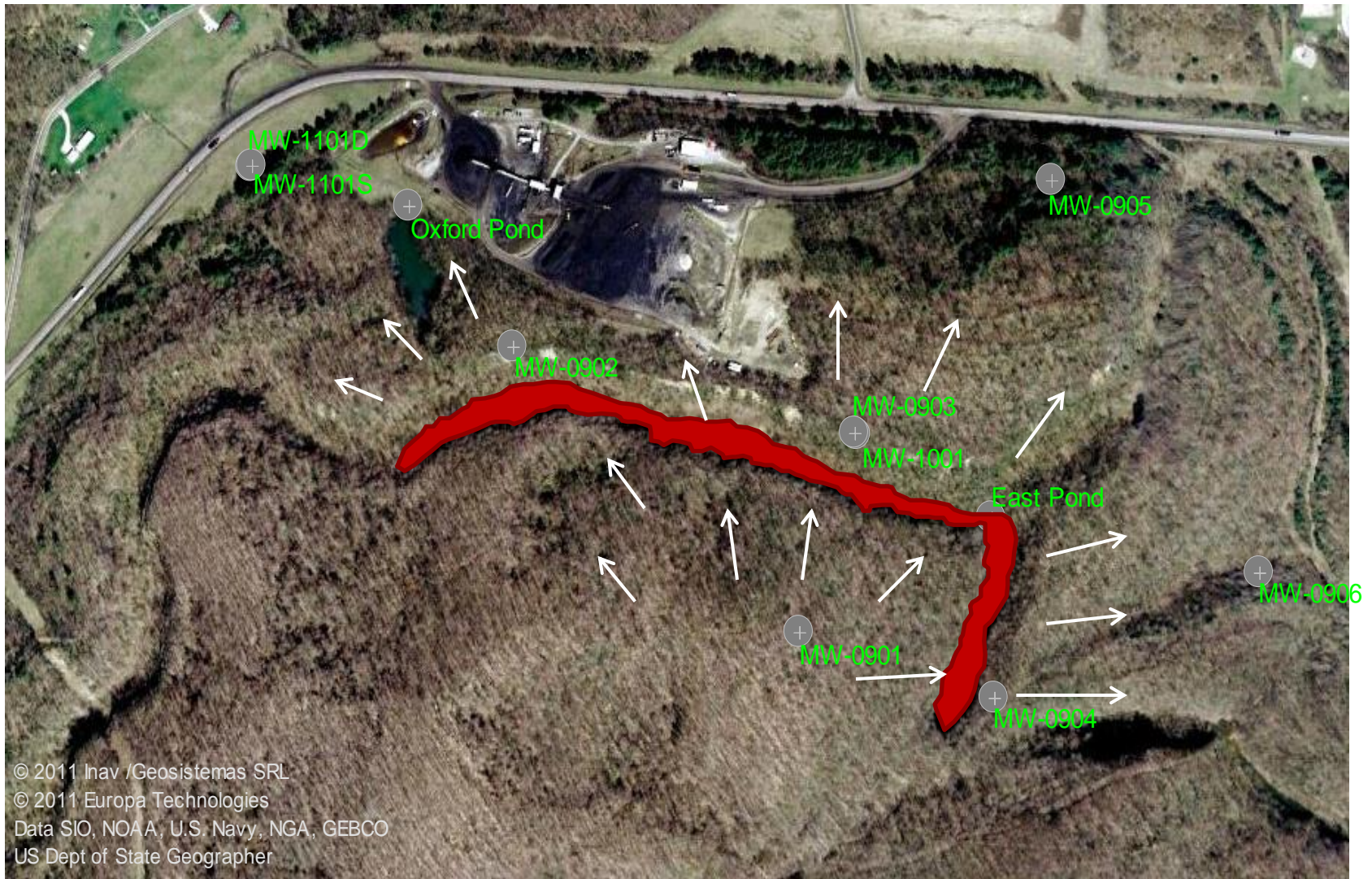




Water Quality Monitoring

- The primary objective is to evaluate the impact of reclamation on the water quality of the uppermost aquifers underlying the sites
- Approaches
 - Collecting monthly groundwater samples from monitoring wells installed around the reclamation sites using a low-flow purging and sampling procedure
 - Monitoring the water quality of surface water bodies within or adjacent to the project sites
 - Assessing the leaching properties of the backfilling FGD materials

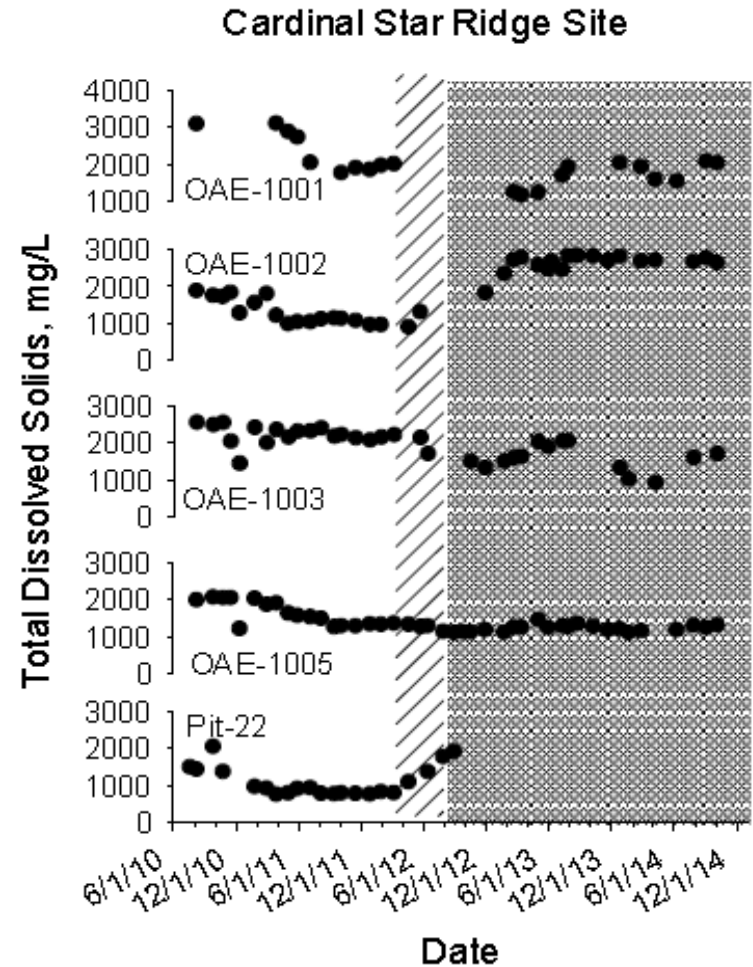
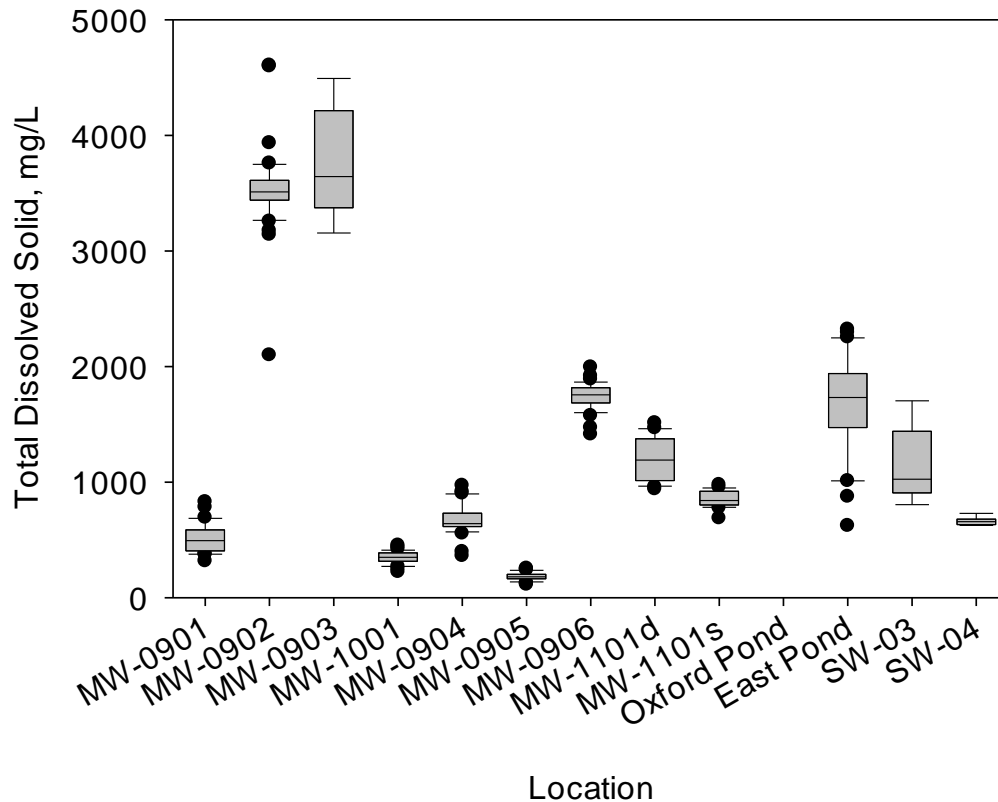
Conesville Five Points Sampling Sites



Cardinal Star Ridge Sampling Sites



Spatial and Temporal Variations



- Baseline monitoring
- Site preparation
- Backfilling Started



Sampling

■ Pre-reclamation

- Conesville: 11/2009 to 7/2011 (18 months)
- Cardinal: 7/2010 to 3/2012 (21 months)
- Establishing background water quality data

■ Site preparation

- Conesville: 8/2011 to 12/2011 (5 months)
- Cardinal: 4/2012-8/2012 (5 months)

■ Reclamation

- Conesville: 1/2012 to present
- Cardinal: 9/2012-present
- The water monitoring at both sites continues throughout the reclamation stage, as well as after the reclamation is completed



Background Water Quality

- More than 18-month worth of monitoring data for establishing background water quality
 - Provides sufficient sample size to estimate variations of background water quality
 - Establishes upper prediction limit (UPL), a “not-to-exceed” threshold value, for each of the 34 monitoring parameters, used for evaluating if significant changes occur during and after reclamation.
 - Concentration levels of As, Be, Cd, Co, Cr, Tl, Zn, and V were frequently below the limits of detection.
 - Concentration levels of Al, Cu, Se, and Pb were always below the limits of detection in all water samples.

Constituents Exceeding UPLs

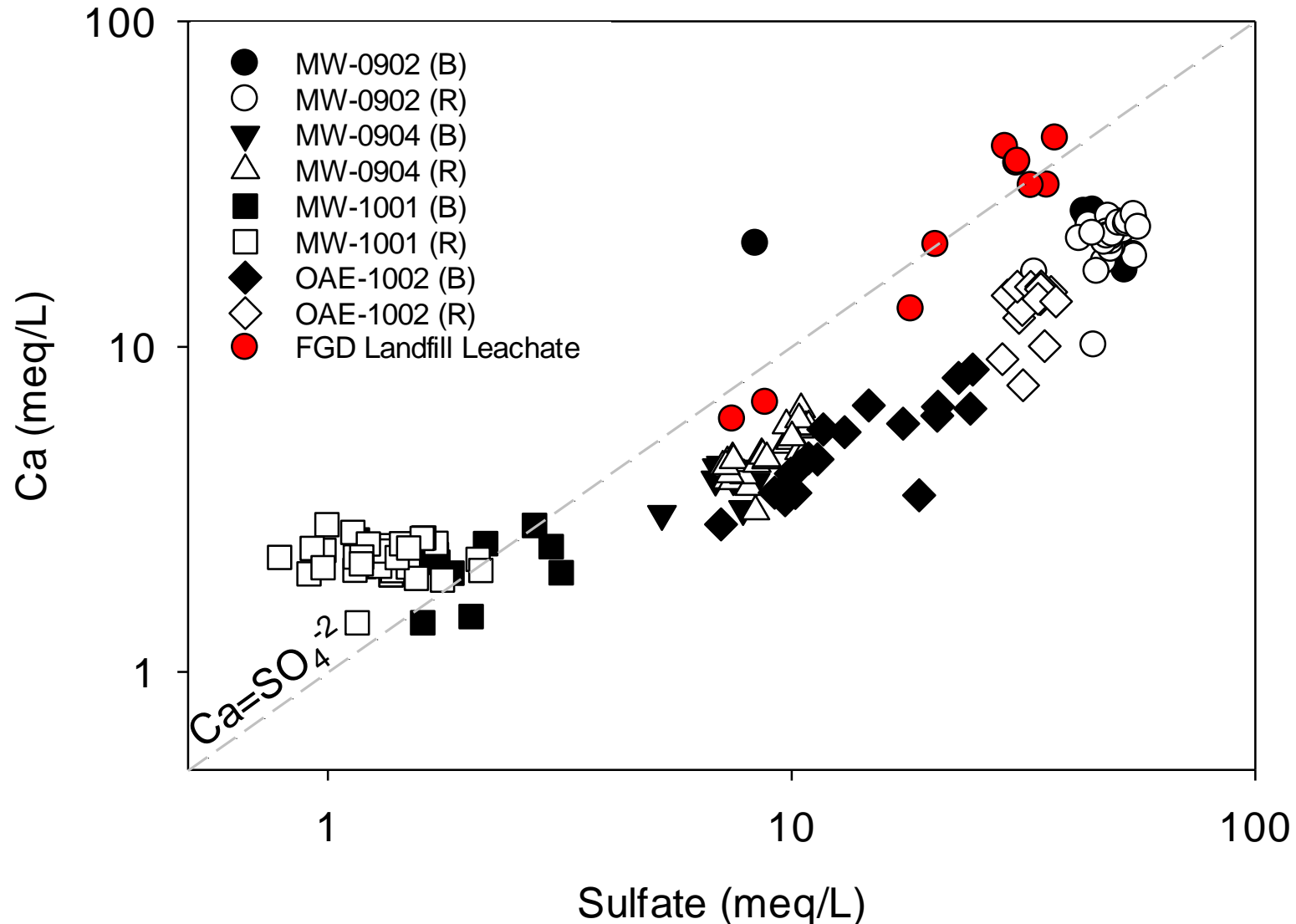
■ Conesville Five Points site

- MW-0901: Si
- MW-0902: P, B, Si, and Tl, Na, and Cl
- MW-1001: Alkalinity, Ba, and Si,
- MW-0904: Conductivity, TDS, sulfate, Ca, Mg,
B, Fe, Mn, Na, Ba, Cd, Sb, Si, and Sr,
- MW-0905: Si,
- MW-0906: Conductivity, sulfate, B, Ba, Co, Si, and
Tl
- Oxford Pond: Na, Ba, Si, and Cl

Constituents Exceeding UPLs

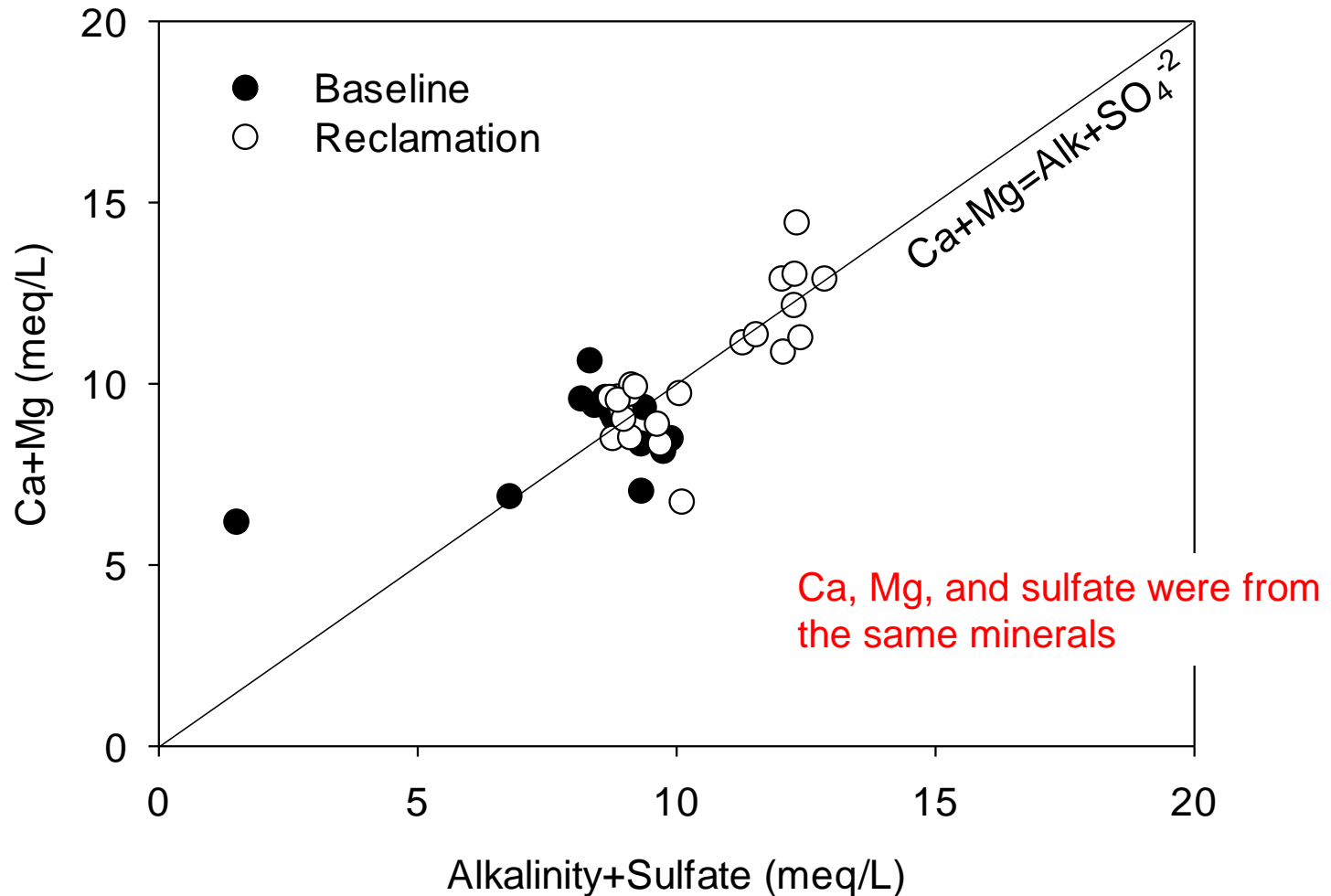
- Cardinal Star Ridge site
 - OAE-1001: B.
 - OAE-1002: TDS, sulfate, K, Ca, Mg, Mn, Ba, Cr, Si, Sr, and Tl.
 - OAE-1003: pH, K, B, Mo, As, Li, and Sr.
 - OAE-1005: K, Na, and Li

Seepage of leachate from FGD materials?



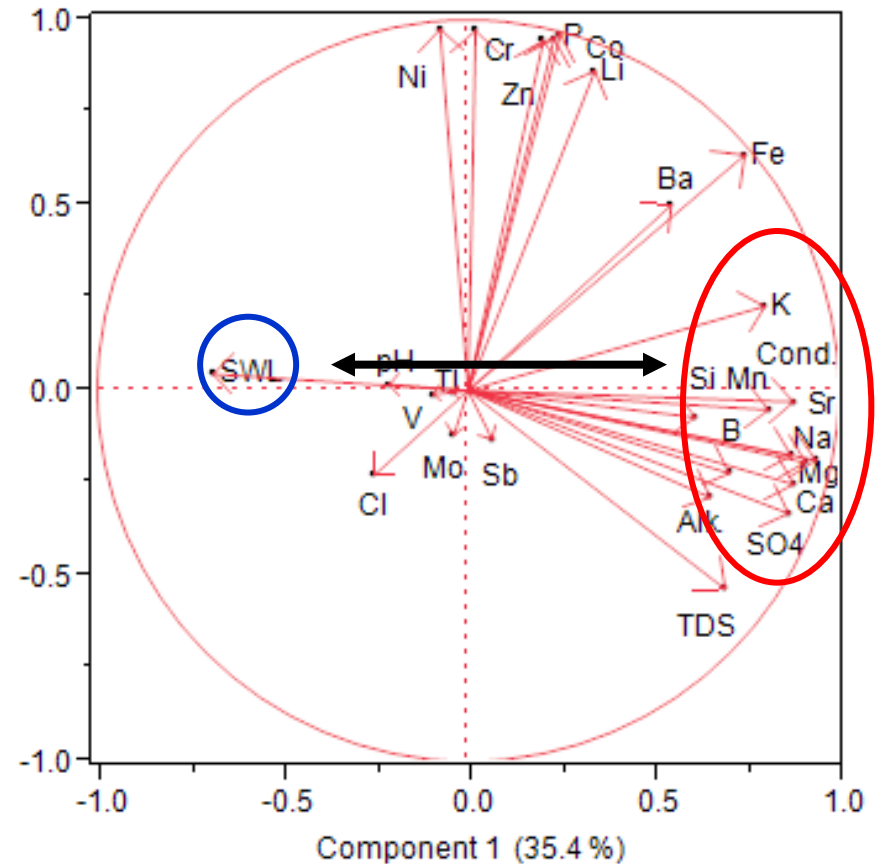
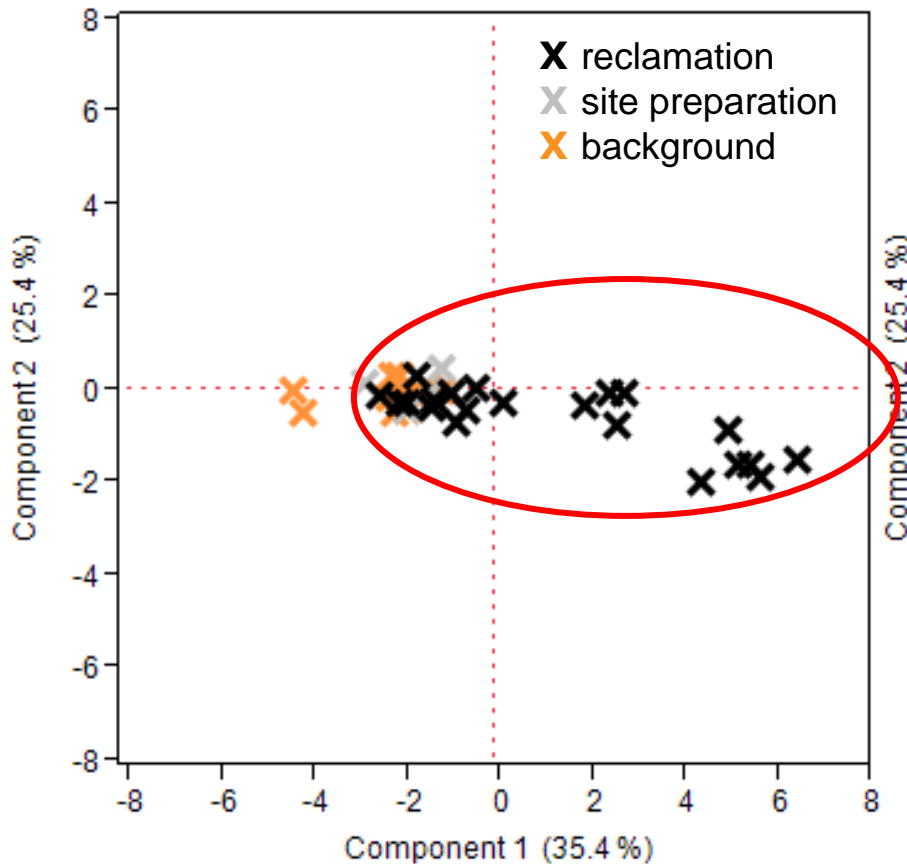
Seepage of leachate from FGD materials?

■ MW-0904



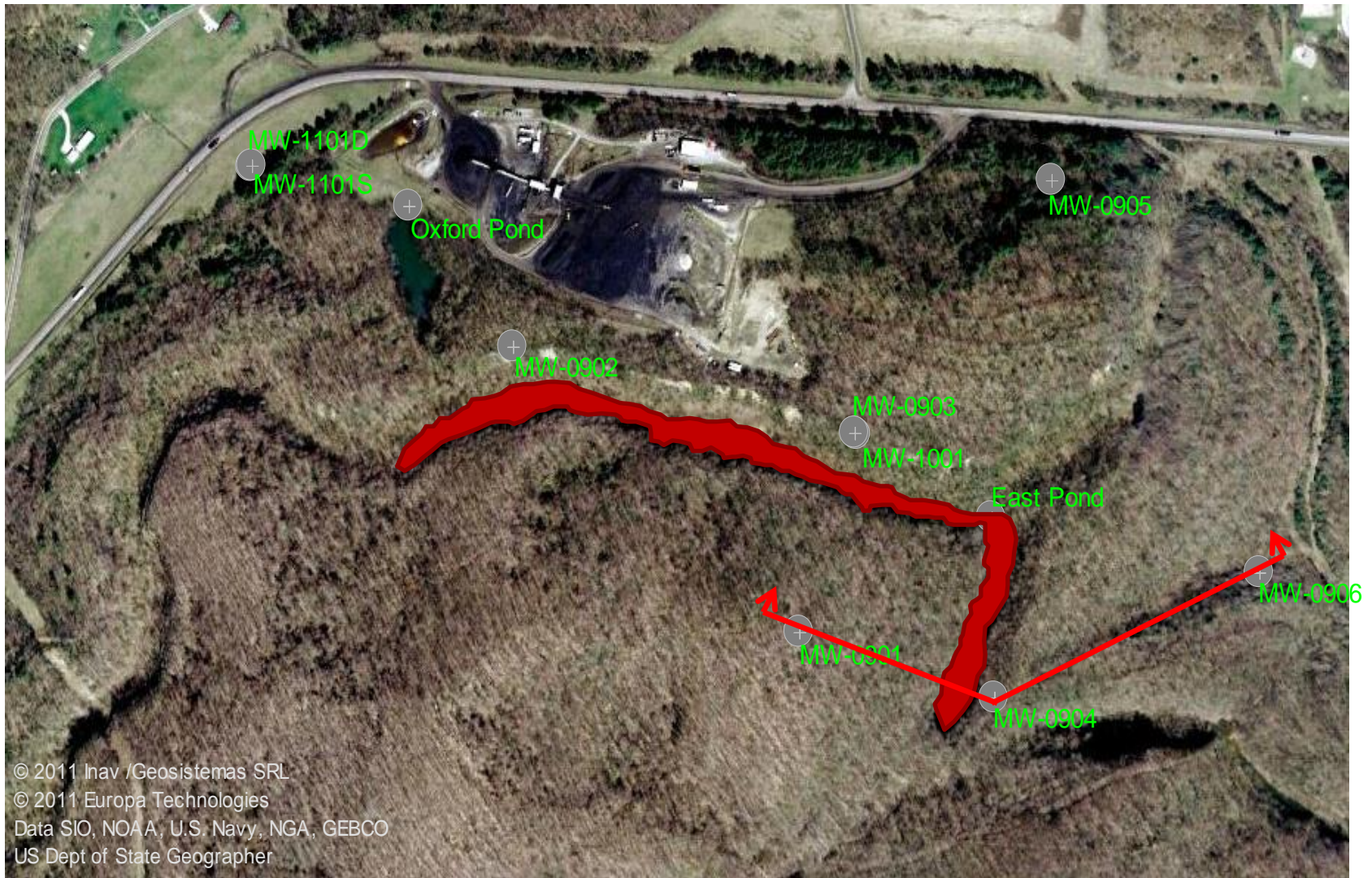
What has caused the changes?

■ MW-0904 at the Coneville site



Change of hydrological Condition

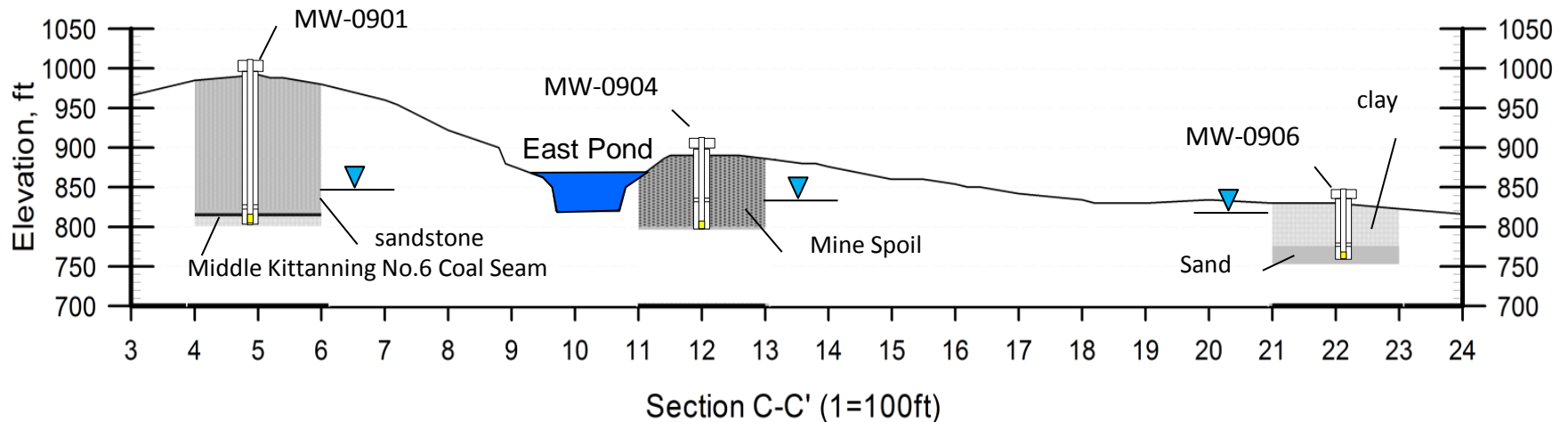
Conesville Five Points Sampling Sites



Effect of East Pond Recharge

■ MW-0904

- Collects water from minespoil layer
- Has similar dominating cations and anions as waters from minespoil layers (MW-0902 and MW-0903) but with lower concentrations
- Recharge from East Pond
- Concentrations of TDS and major ions are higher in MW-0906 than in MW-0904, indicating dissolution process as groundwater moving downstream

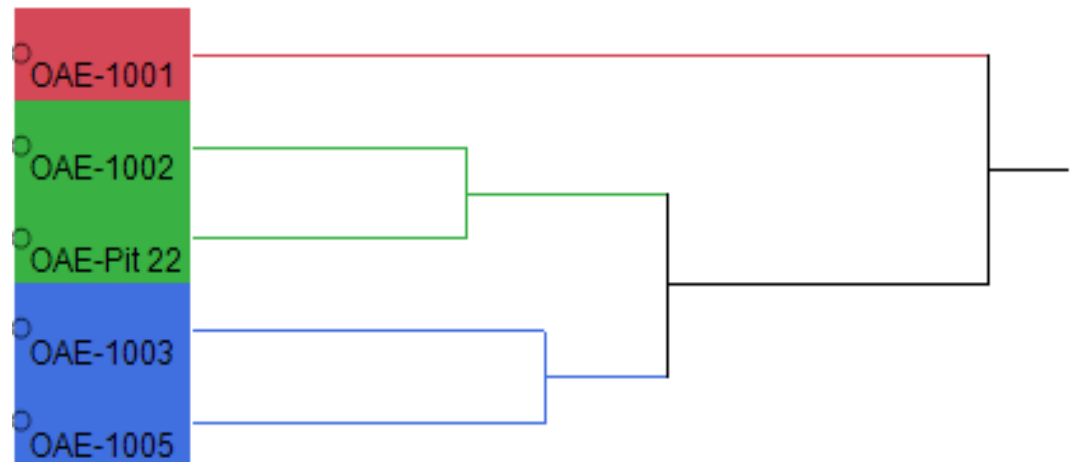


Pit 22 and OAE-1002



■ Hierarchical cluster analysis

- Group water samples into classes on the basis of 16 parameters, i.e., pH, conductivity, alkalinity, TDS, Cl⁻, SO₄⁻², K, Ca, Mg, B, Fe, Mn, Na, Ba, Si, Sr
- Water in OAE-1002 was similar to the surface water accumulated in Pit 22 before reclamation start





Summary

- High volume FGD materials have been placed since the reclamation started
 - Conesville: over 1,400,000 tons as of 5/2015
 - Cardinal: over 450,000 tons
- Changes of water qualities at both sites were statistically significant after reclamation started.
 - Ca, sulfate, Mg, Ba, Co, Fe, Mn, Na, Ba, Cd, Sb, Si, and/or Sr, exceeded the upper prediction limits (UPLs) in one or more of the sampling locations
 - In addition, significant incline or decline trends in the concentrations of major monitoring parameters during the reported reclamation period had also been identified



Summary (continued)

- Current observed changes in water quality are unlikely due to seepage of FGD leachates (i.e., FGD gypsum and/or fixated FGD material).
- Change of hydrogeological condition might play more significant role.
- Reclamation progress
 - Conesville: ~90% of capacity
 - Cardinal: backfilling and capping have been completed. The site is ready for revegetation.



Future Work

- American Electric Power/OSU will continue to monitor/analyze the surface and groundwater quality around the reclamation sites
- Establish geochemical model to better describe the change of hydrochemical properties of groundwater
- Stable isotope analysis
 - Monitoring wells have been installed in the middle of fill to collect water samples from the bottom of the well and the aquifer underneath of the fill.



Acknowledgement

- Ohio Coal Development Office
- Ohio Department of Natural Resources
- Ohio American Energy

Coal Combustion Products Program

Ohio State's Coal Combustion Products Program focuses on sustainable, high-volume beneficial uses of coal combustion products (CCPs), primarily from sulfur dioxide scrubbing processes, in construction, reclamation, infrastructure rehabilitation, manufacturing and agricultural applications. This program advances the beneficial uses of CCPs from sulfur dioxide scrubbing processes as well as more traditional byproducts, including fly ash, bottom ash, boiler slag and fluidized-bed combustor ash. Re-use of CCPs provides a low-cost raw construction material; extends the life of landfills, and lessens the need for new ones; and helps keep energy production costs in check.



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Funded by the Ohio Coal Development Office, Ohio State University, Ohio coal-fired utilities, ash marketers, private businesses and trade and farming organizations, the Coal Combustion Products Program Improves and discovers technically sound, environmentally friendly and commercially competitive uses of CCPs in many interdisciplinary sustainable applications.

The program aids the CCP industry through research, education, technology transfer and outreach in its efforts to:

- expand uses in proven areas, such as highway and agricultural applications;
- remove or reduce regulatory and perceptual barriers to use;
- develop new or under-used large-volume market applications, such as mine land reclamation; and
- place greater emphasis on sulfate and sulfite flue gas desulfurization byproducts utilization.

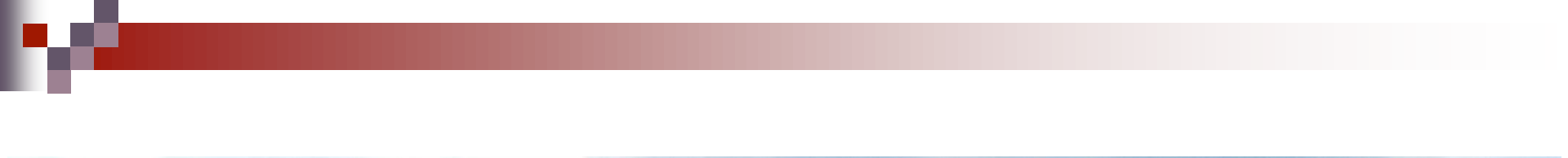


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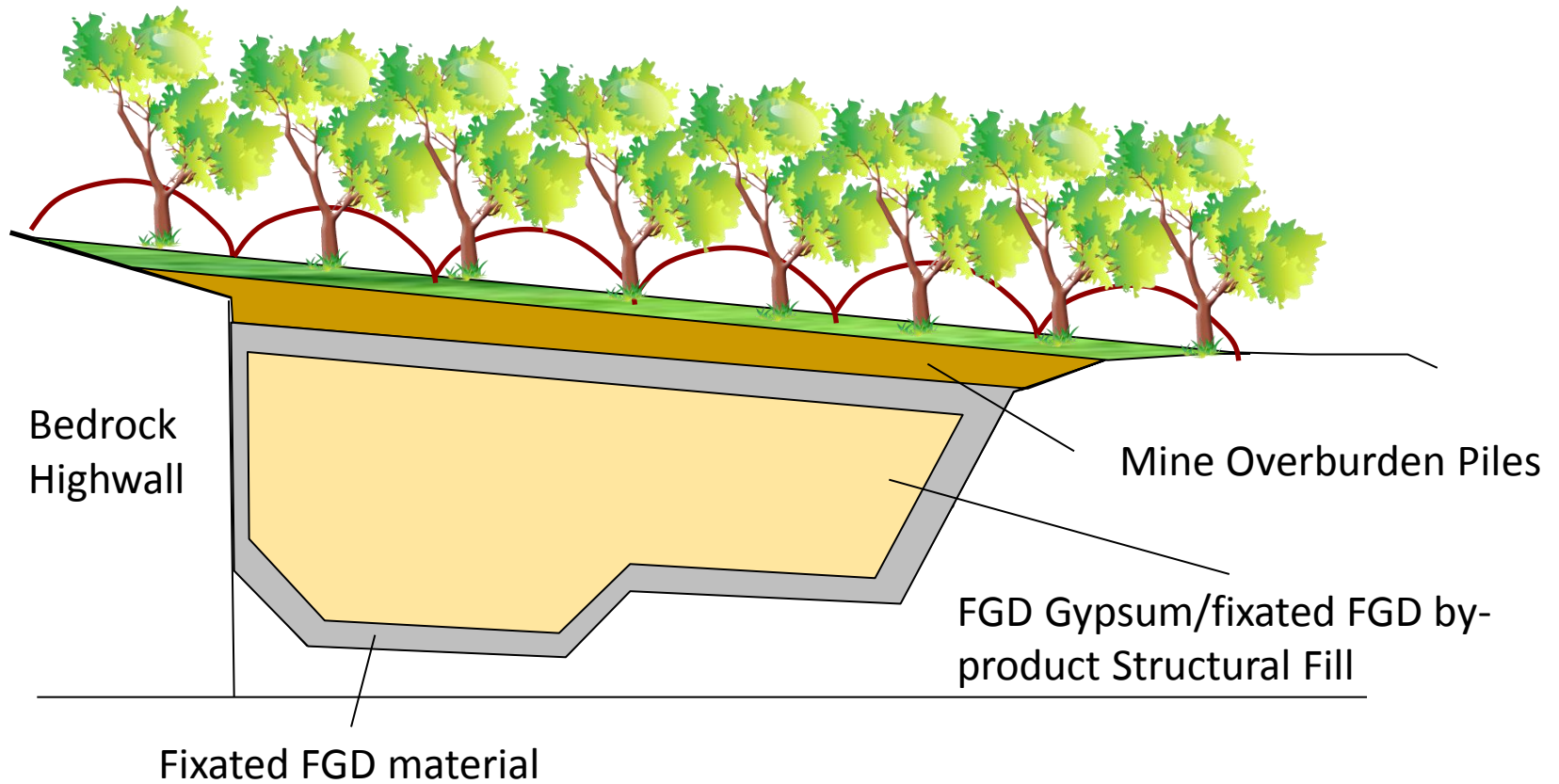
Coal Combustion Products Program
470 Hitchcock Hall
2070 Neil Ave.
Columbus, OH 43210

Program Coordinator: Tarunjit Butalia
Email: butalia.1@osu.edu
Phone: 614-688-3408
To learn more, visit ccp.osu.edu.



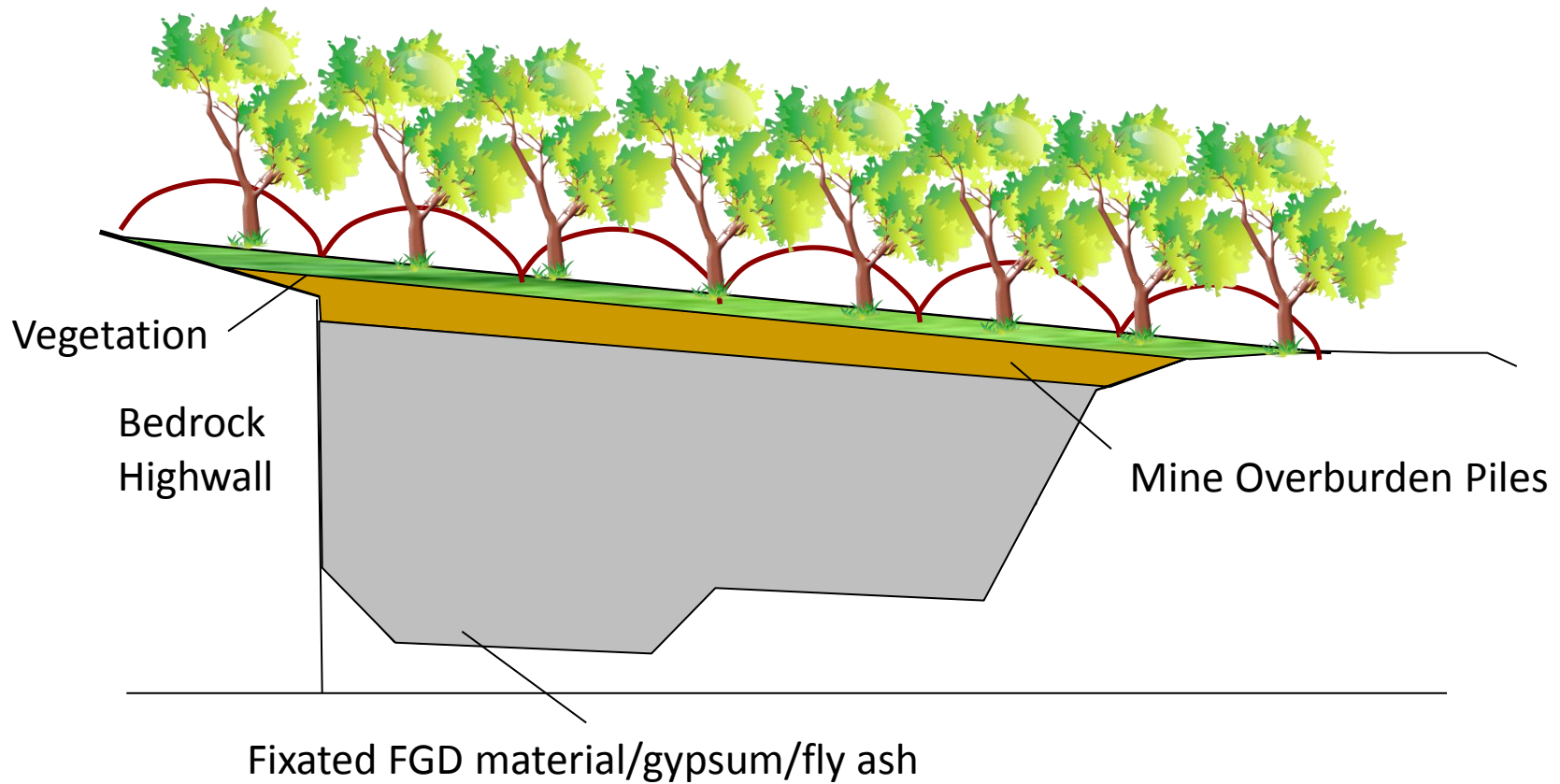
Thank you

Mine Reclamation with FGD Materials



Phase I

Mine Reclamation with FGD Materials



Phase II

Leachates of FGD Materials

	Conesville Five Points Site		Cardinal Star Ridge Site	3745-82-02 Ohio Secondary Maximum Contaminant Levels/Drinking Water Standards (DWS), mg/L	3745-81-11(B) Ohio Primary Maximum Contaminant Levels/Drinking Water Standards (DWS), mg/L	Maximum Acceptable Leachate Concentration, mg/L
	Fixated FGD	FGD Gypsum	FGD Gypsum			
Number of Samples	11	10	7			
Alkalinity	260±180	31±11	21±3	No Standard		
Arsenic	0.05±0.03	< 0.009	0.032±0.019		0.01	0.3
Aluminum	1.3±1.8	0.07±0.05	< 0.05	0.05-0.2		
Barium	0.21±0.12	0.12±0.05	0.14±0.06		2.0	60.0
Beryllium	0.0004	< 0.0004	< 0.004			
Boron	1.0±0.5	0.6±0.8	0.05±0.02	No Standard		
Cadmium	0.0005	0.0008±0.0005	0.00075±0.00012		0.005	0.150
Chloride	27±21	14±10	4±4	250		
Chromium	0.0038±0.0013	0.0046±0.0010	0.0040±0.0016		0.1	3.0
Copper	0.018	< 0.002	< 0.002	1.3		
Fluoride	1.7±1.4	6±3	1.6±0.9	2		
Iron	0.006±0.006	< 0.001	0.00370±0.00004	0.3		
Lead	< 0.004	0.005	< 0.004		0.015*	0.450*
Magnesium	1.1±2.4	2±2	0.39±0.05	No Standard		
Manganese	0.475	0.10±0.10	0.04±0.02	0.05		
Mercury	0.0003±0.0007	0.0009±0.0013	0.0001±0.0003		0.002	0.060
Nickel	0.006±0.005	0.0028±0.0009	0.003±0.002			
pH	10.9±1.2	7.6±0.7	8.1±0.9	7.0-10.5		
Silver	< 0.001	< 0.001	< 0.001	0.1		
Selenium	0.026	0.034±0.008	< 0.012		0.05**	1.00**
Sodium	20±32	1.2±0.9	0.5±0.2	No Standard		
Sulfate	300±500	1520±30	1200±500	250		
TDS	1000±800	2260±60	2230±70	500		
Zinc	0.006±0.003	0.007±0.004	0.005±0.002	5		

* This is an action level for lead, not a primary maximum contaminant level.

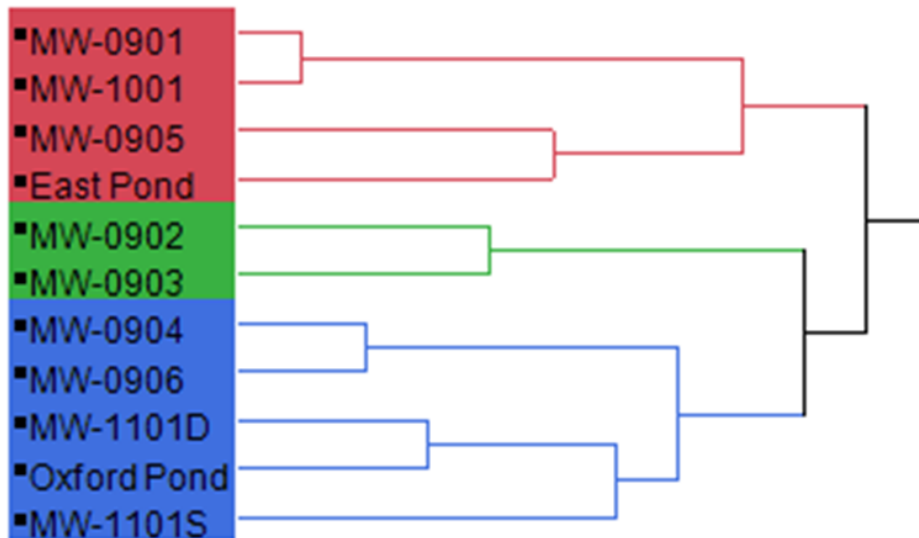
For the purposes of CEPA policy 0400.007, this number will be referenced as a drinking water standard (DWS)

** For CCB Material leachate, the Maximum Acceptable Leachate Concentration for selenium cannot exceed 1 mg/L

Background Water Quality

■ Hierarchical cluster analysis

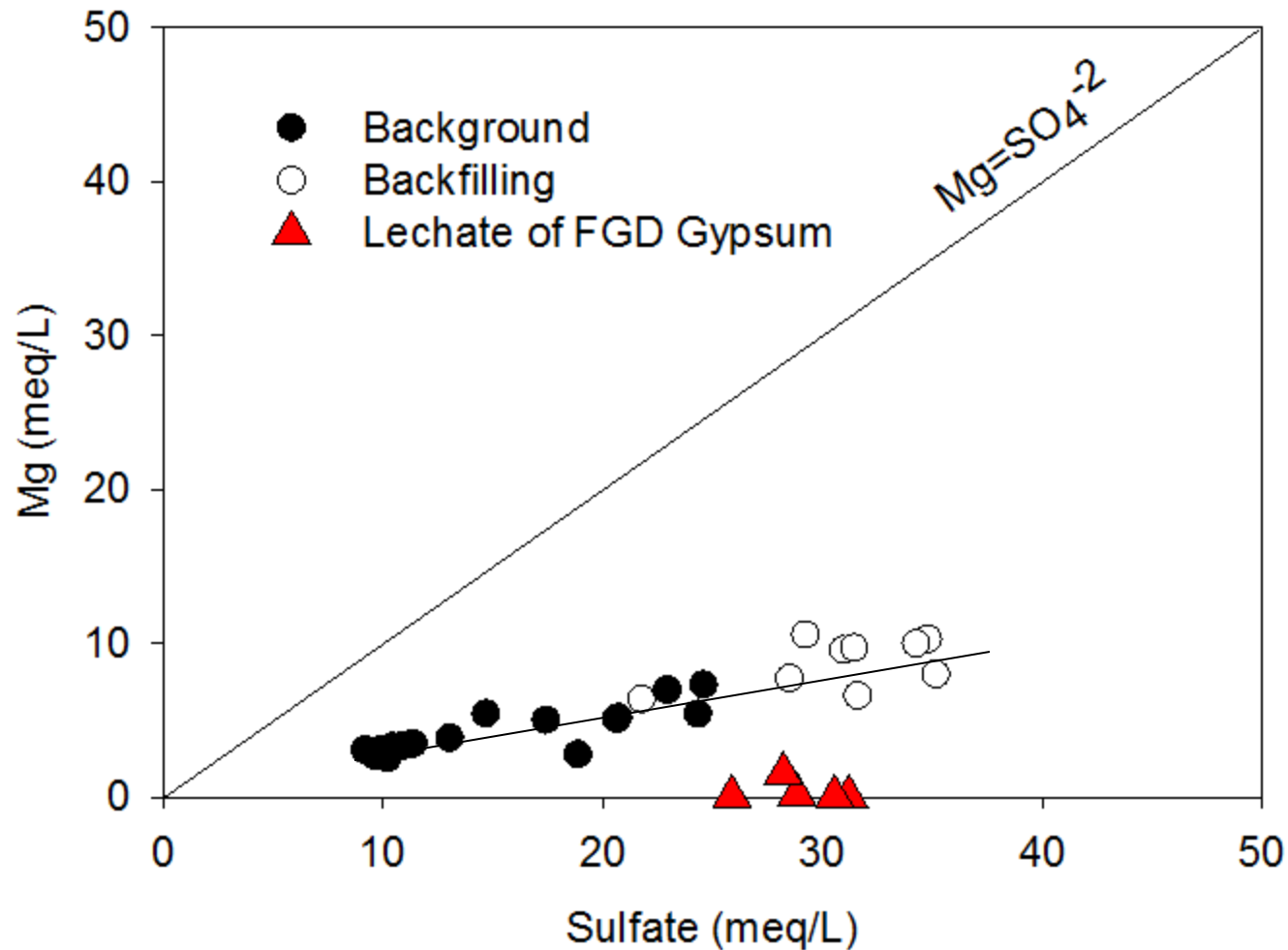
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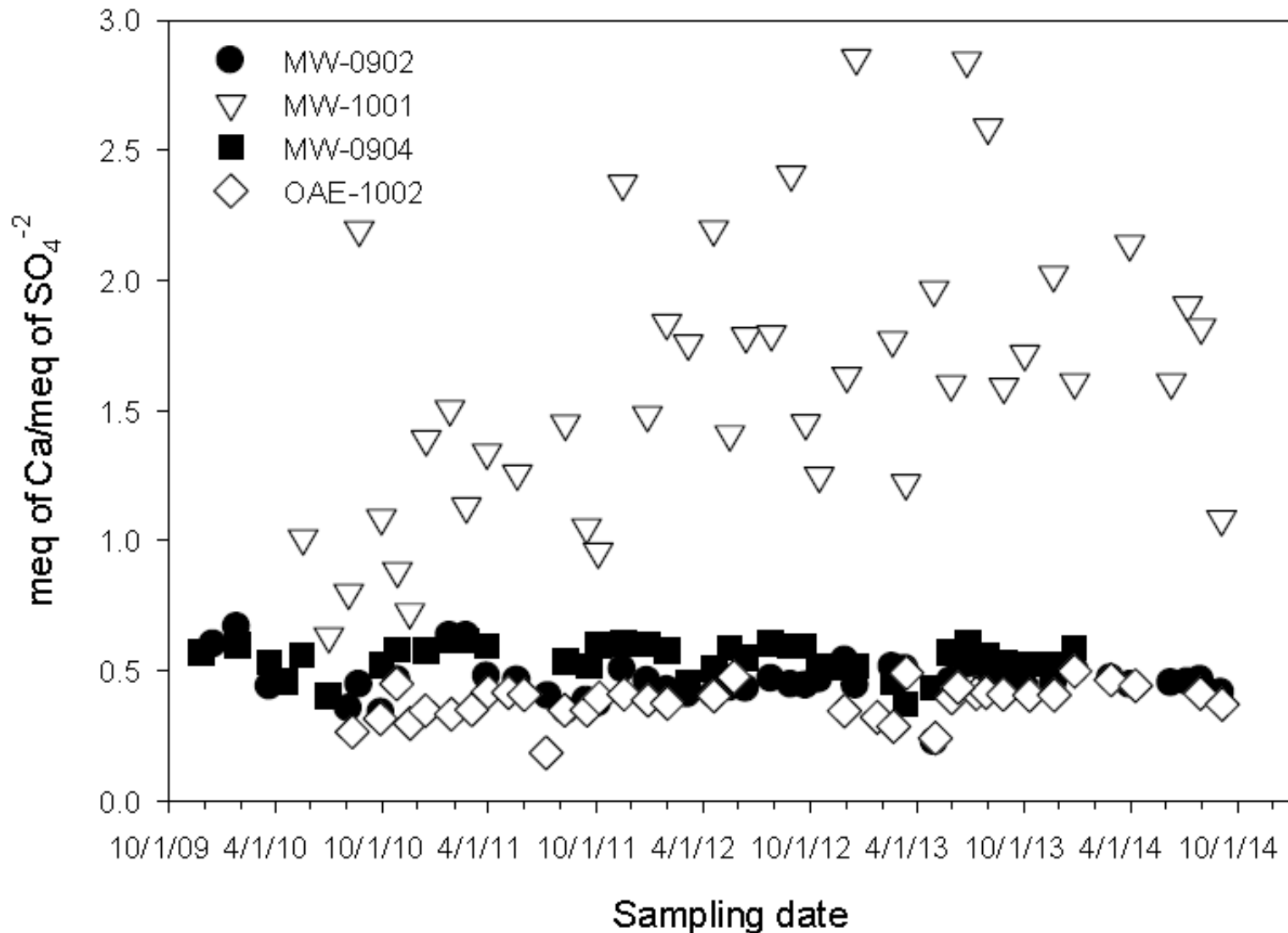
- MW-0901, MW-1001, and MW-0905: coal, clay shale and/or sandstone layers.
- MW-0902 and MW-0903: minespoil layers
- MW-0904, MW-0906, MW-1101D and MW-1101S: similar to MW-0902 and MW-0903 with diluted concentrations

Leakage of leachate from FGD materials?

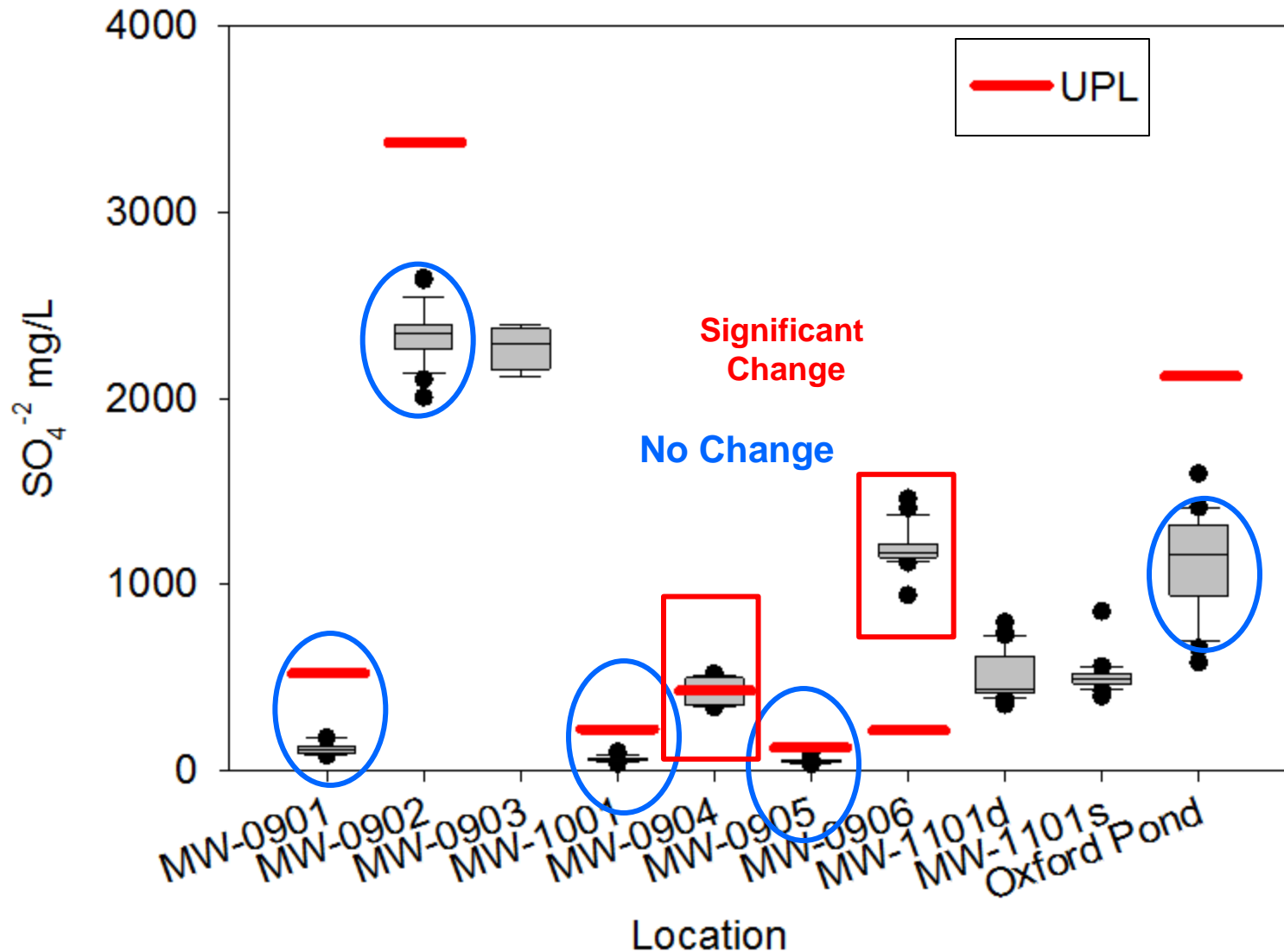
■ OAE-1002



Seepage of leachate from FGD materials?



Impact of Reclamation on Water Quality



Data collected after 8/2012 when reclamation start