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Bureau of Abandoned Mine Reclamation

# TREATMENT PLANT OPTIMIZATION AND COST REDUCTION STRATEGIES AT SELECTED BANKRUPTCY MINE SITES IN PENNSYLVANIA

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## West Virginia Mine Drainage Task Force Symposium
## March 29, 2016

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OFFICE OF SURFACE MINING

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Tom Wolf, Governor

John Quigley, Secretary

# Project Background

- Ensuring perpetual treatment of coal mine drainage (CMD), post-bankruptcy, is a challenging task
- DEP assumed treatment responsibilities after the bankruptcy of Barnes and Tucker Coal Company (2001), LTV Steel Corporation (LTV) in 2001, and Mon-View Mining in 2002
- Collectively, these facilities controlled five underground mine pools that encompass 71,000 acres and treat about 20.5 million gallons a day (MGD)
- DEP used historical treatment cost data to calculate the perpetual treatment liability; in all three cases, assets were inadequate
- Cost reduction and performance evaluation of these facilities is essential to maintain operations

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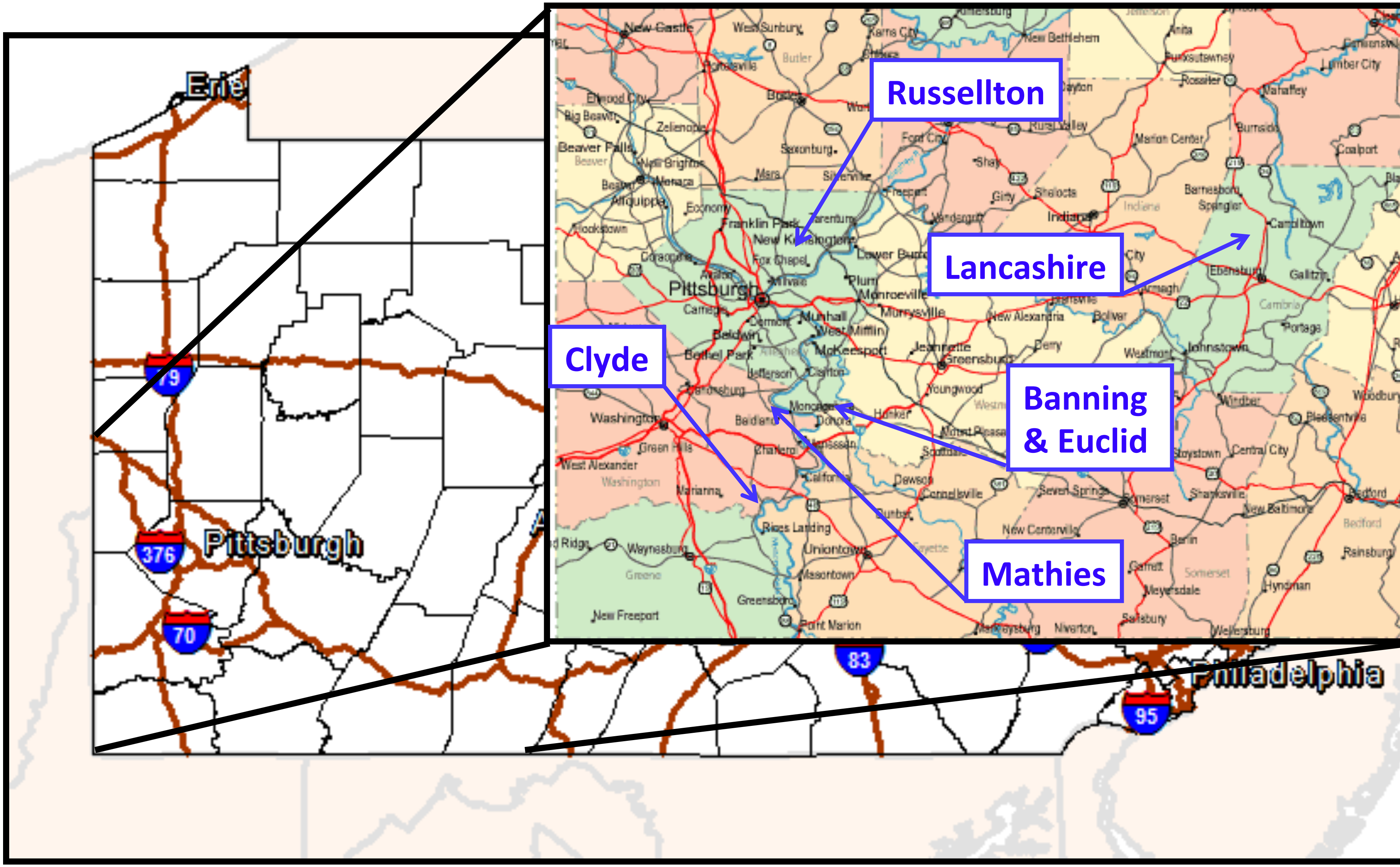
# Project Locations

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# Methodology

- A DEP/OSM team formed in 2011 to evaluate these facilities and identify potential cost saving strategies while preserving system effluent performance
- 5-Step Approach
  1. Determine current dosing rates
  2. Quantify chemical consumption
  3. Develop alternative strategies
  4. Pilot test alternatives
  5. Perform cost and performance comparison evaluation

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# Project Background

| Evaluation Year | Treatment Facility | Year Constructed | Average Dsg. (GPM) | Original System Configuration | Treatment Trust |
|---|---|---|---|---|---|
| 2011 | Monview | 2002 | 700 | NaOH Pond Clarification | Mathies Trust |
| 2012 | Banning | 1966 | 2,500 | $CaOH_2$ Clarifier | LTV Trust |
| 2012 | Euclid | 1970 | 4,000 | $CaOH_2$ Clarifier | LTV Trust |
| 2013 | Russellton | 1966 | 1,000 | $CaOH_2$Pond Clarification | LTV Trust |
| 2013 | Lancashire | 1974<br>2011 | 5,000 | HDS<br>$CaOH_2$ Clarifier & Polishing Pond | Barnes & Tucker Trust |
| 2014 | Clyde | 1997 | 1,000 | HDS<br>CaO/Slaker Clarifier | LTV Trust |

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# Mon-View Mathies Site

- **60% Flooded Pittsburgh Seam Deep Mine**
- **Mined by Mon-View Mining Corp & Predecessors 1944 - 2002**
- **Gravity discharge from drift varies from 500 to 3,000 gpm seasonally**

- **NaOH treatment**
- **Injected in to 500 ft long conveyance pipeline**
- **Flows into two oxidation/ settling ponds**
- **Treatment sludge hauled off-site**
- **Initially (2002) net acidic, now net alkaline**

# Banning Site

- Flooded Pittsburgh Seam Underground Mine
- Operated by LTV Steel Corp & Predecessors 1889 - 1982
- Pumping and treatment required to prevent pool breakout into the Youghiogheny River in the town of West Newton PA

- Originally constructed in the mid 1960's
- Hydrated lime treatment w/ clarifier settling Constant inflow 2,300 gpm
- Sludge re-injected into mine

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# Euclid Site

- Operated in conjunction with the Banning Site
- Treats approx. 2 times the volume of Banning
- Similar influent water quality

- Originally constructed in the mid 1960's
- Hydrated lime treatment w/ clarifier settling only
- Constant inflow 4,500 gpm
- Sludge re-injected into mine

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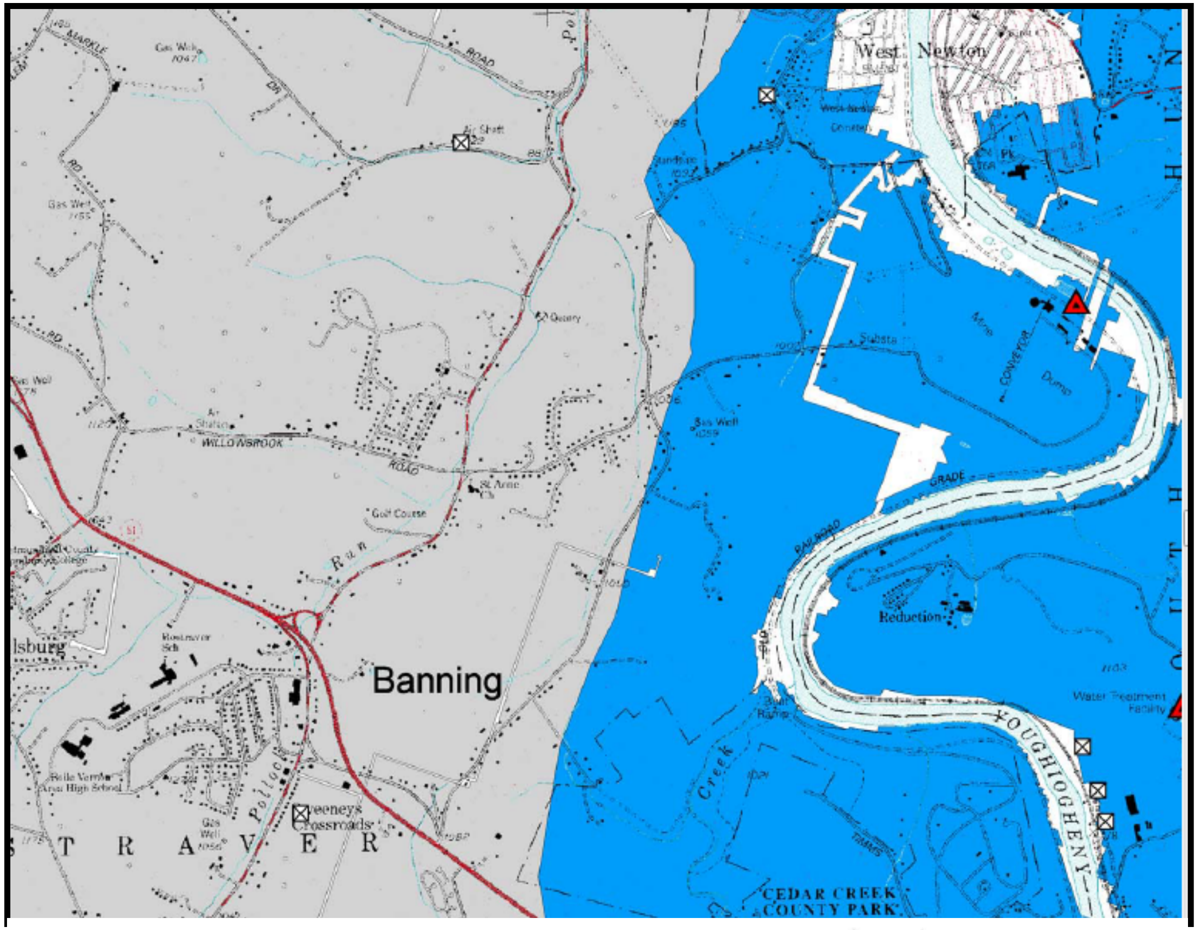
# Banning Mine Pool




Legend:

- water treatment plant
- mine discharge
- sealed shaft
- Pittsburgh coal outcrop

28,000 acres mined

43% percent flooded

Republic Steel initiated treatment operations in 1966


West Virginia University
West Virginia Water Research Institute
Hydrology Research Center



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# Russellton Site

- **Flooded Upper Freeport Underground Mine Operated by Republic Steel Corp & Predecessors 1904 - 1982**
- **Average pumping rate of 1,000 to 1,200 gpm is required to control the mine pool elevation**

- **Hydrated lime treatment**
- **Dry Hydrate ($Ca(OH)_2$) addition directly into pumped influent**
- **50 foot long mixing channel**
- **Flows into a single large oxidation/settling pond**
- **Treatment sludge periodically re-injected into mine**

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# Lancashire Site

- **Multiple interconnected underground mines (~ 15,000 acres) on the Lower Kittanning and Lower Freeport Coal Seams.**
- **Yearly average pumping rate of 4,500 to 5,000 gpm is required to control the mine pool elevation and prevent breakout into the West Branch Susquehanna River.**

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# Lancashire Site

- **In 2011, a new hydrated lime treatment facility was constructed to replace the original Barnes and Tucker system.**
- **The treatment process includes:**
  - preaeration to exsolve $CO_{2(aq)}$ from raw mine water
  - dense sludge recirculation
  - Polymer addition

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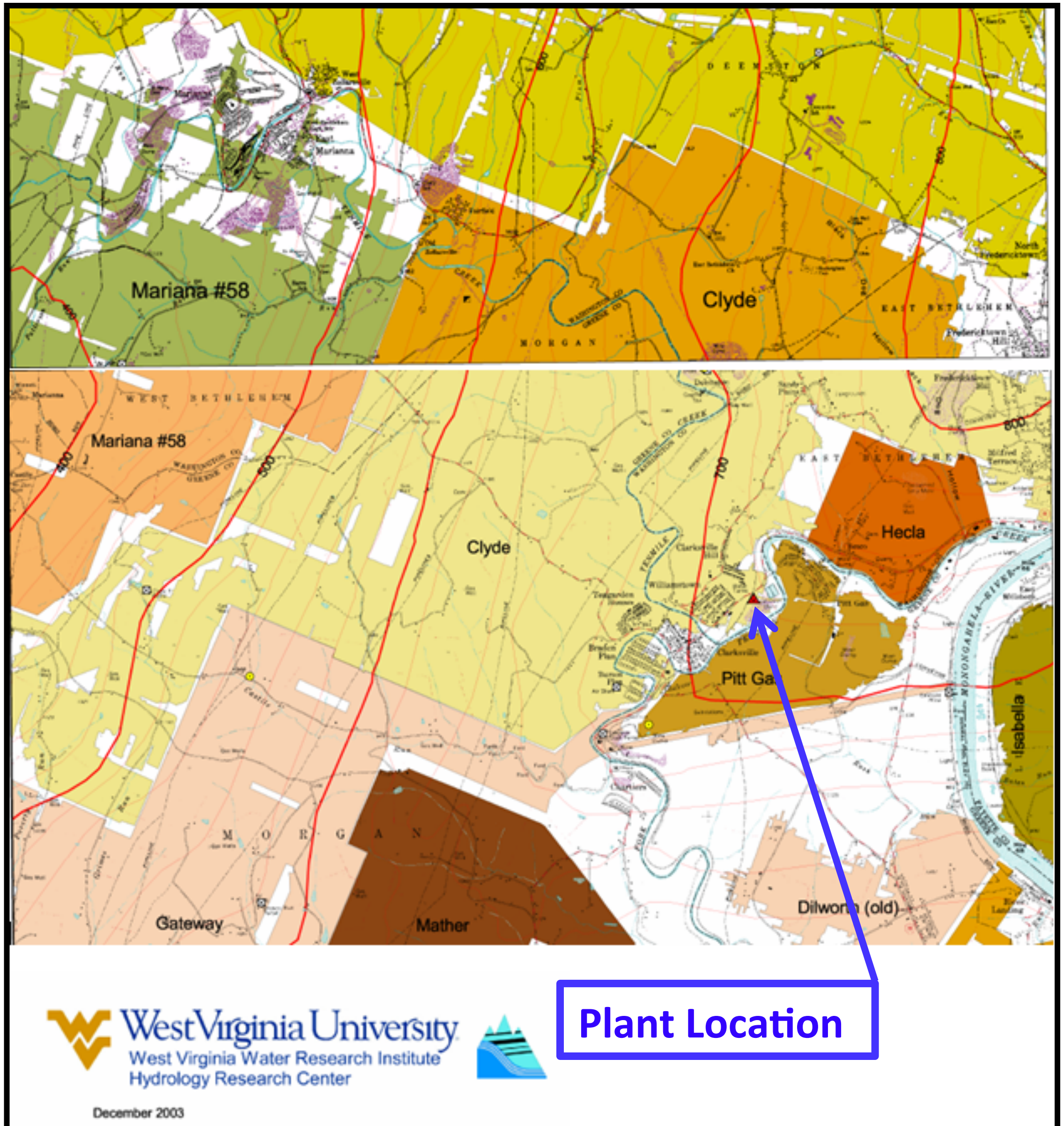
# Clyde Site

- **Flooded Pittsburgh Seam underground mine**
- **Mined by LTV Steel Corp and predecessors from 1920 through 1992**
- **Pumping required to prevent breakouts into the Tenmile Creek watershed**
- **Quicklime treatment (CaO) with an onsite slaker system producing $CaOH_2$ slurry**

# Clyde Site




- 34,000 acres mined
- 87.5 percent flooded
- LTV Steel initiated pumping and treatment operations in 1997

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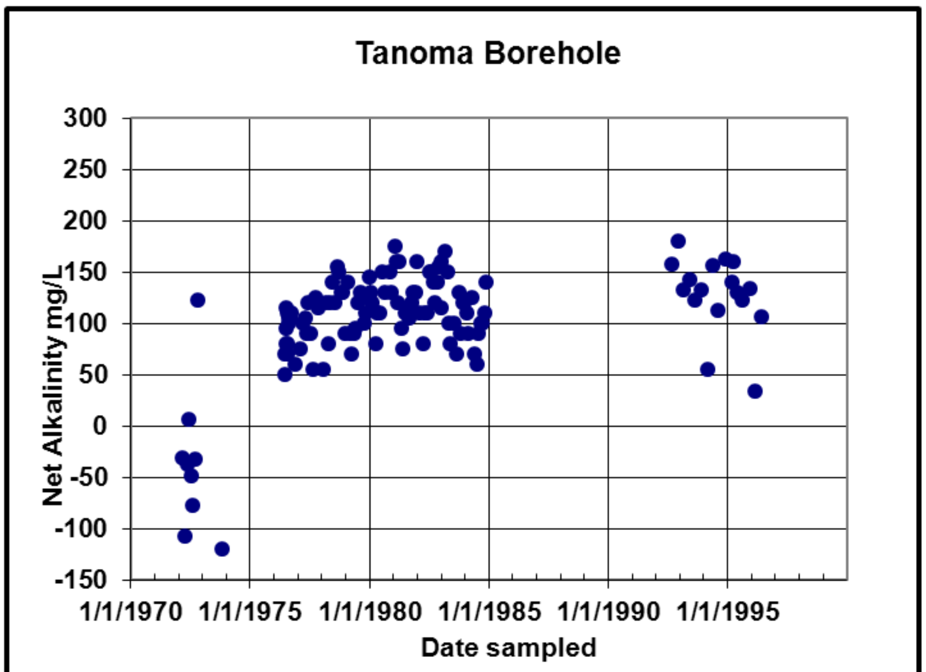
# Project Background

- CMD from flooded underground coal mines is notably different than other Pennsylvania CMD
- Infiltration of alkaline groundwater results in varying degrees of in-situ treatment of mine drainage
- Flooding also limits and isolates mine atmosphere development and alkaline conditions slows $FeS_2$ oxidation




**Lancashire #15 Mine**

| Date | pH | Alk | Acid | Fe | $SO_4$ |
|---|---|---|---|---|---|
| **12/4/1974** | 4.2 | 0 | 626 | 326 | 1,750 |
| **6/20/2013** | 6.1 | 100 | -68 | 34 | 380 |

pH S.U. All other values mg/l

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# Clyde Influent Water Quality

| Date | pH | Alkalinity | Acidity | Fe | Mn | Al | Sulfate |
|---|---|---|---|---|---|---|---|
| **1/24/2000** | 6.4 | 500 | 154 | >300 | 8.47 | 0.56 | 6,085 |
| **5/15/2002** | 6.4 | 514 | - 42 | 248 | 4.61 | 0.48 | 5,400 |
| **6/21/2005** | 6.3 | 519 | - 23 | 213 | 4.32 | < 0.2 | 4,350 |
| **1/6/2011** | 6.4 | 520 | - 203 | 194 | 3.34 | < 0.2 | 4,010 |
| **10/6/2014** | 6.4 | 550 | -200 | 190 | 3.5 | <0.2 | 4,000 |
| **5/15/2015** | 6.6 | 510 | -240 | 154 | 2.6 | <0.2 | 3,989 |
| **1/19/2016** | 6.6 | 520 | -260 | 148 | 2.6 | <0.2 | 3,593 |

All values except pH expressed as mg/l

- From 2000 to 2016
  - ~ 50 percent reduction in dissolved iron
  - ~ 70 percent reduction in dissolved manganese
  - ~ 40 percent reduction sulfate

# Influent Water Quality

| Site | pH | Alkalinity | T. Fe | D. Fe | Mn | Al | Sulfate | TDS |
|---|---|---|---|---|---|---|---|---|
| **Euclid** | 6.6 | 400 | 15 | 14.5 | 0.28 | <0.2 | 850 | 1,900 |
| **Russellton** | 6.7 | 390 | 18.5 | 18.3 | 0.35 | <0.2 | 165 | 750 |
| **Mathies** | 6.9 | 350 | 42 | 31 | 1.2 | <0.2 | 960 | 1,500 |
| **Banning** | 6.6 | 410 | 13.1 | 13 | 0.33 | <0.2 | 825 | 1,850 |
| **Lancashire** | 6.1 | 100 | 30.5 | 29.6 | 1.35 | <0.2 | 400 | 725 |
| **Clyde** | 6.0 | 520 | 150 | 148 | 2.6 | <0.2 | 3,593 | 7,100 |
| All values except pH expressed as mg/l | | | | | | | | |

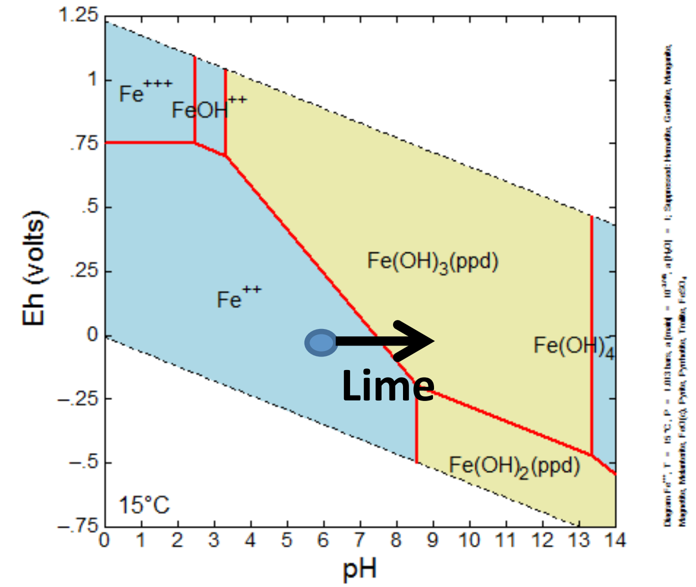
- All the treatment facilities used a pH adjustment strategy to achieve effluent goals
  - Russellton, Banning, Euclid, Clyde and the Lancashire site used Hydrated Lime systems
  - The Mathies site utilized Sodium Hydroxide
- Influent water quality had “evolved” at each site – Treatment strategy had not

# Project Background

- The increase in pH affects Fe(III) and Al(III) solubility and causes precipitation
- Fe(II) remains stable and pH evolves to between ~6.0 and ~7.0
- The ensuing mine drainage requiring treatment is either net alkaline or slightly net acidic, near neutral pH containing elevated concentrations of Fe(II)
- Alkaline reagents ($Ca(OH)_2$, NaOH, etc.) are often selected to treat both water types, but for different reasons
- The alkaline reagent dosage requirement to achieve a desired target treatment pH is a function of the total hydroxyl-consuming reactions that occur when pH is adjusted

# Sources of Alkali Chemical Consumption

- Fe(II) Removal
  - $Fe^{2+} + 2OH^- = Fe(OH)_2$
- Calcite Formation
  - $Ca^{2+} + OH^- + CO_{2(aq)} = CaCO_{3(s)} + H^+$
  - $Ca(OH)_{2(s)} + CO_{2(aq)} = CaCO_{3(s)} + H_2O$
- Hydroxylation
  - Reaction with OH- ion with aqueous species to form $H_2O$ and other species
  - $HCO_3^- + OH^- = CO_3^{2-} + H_2O$

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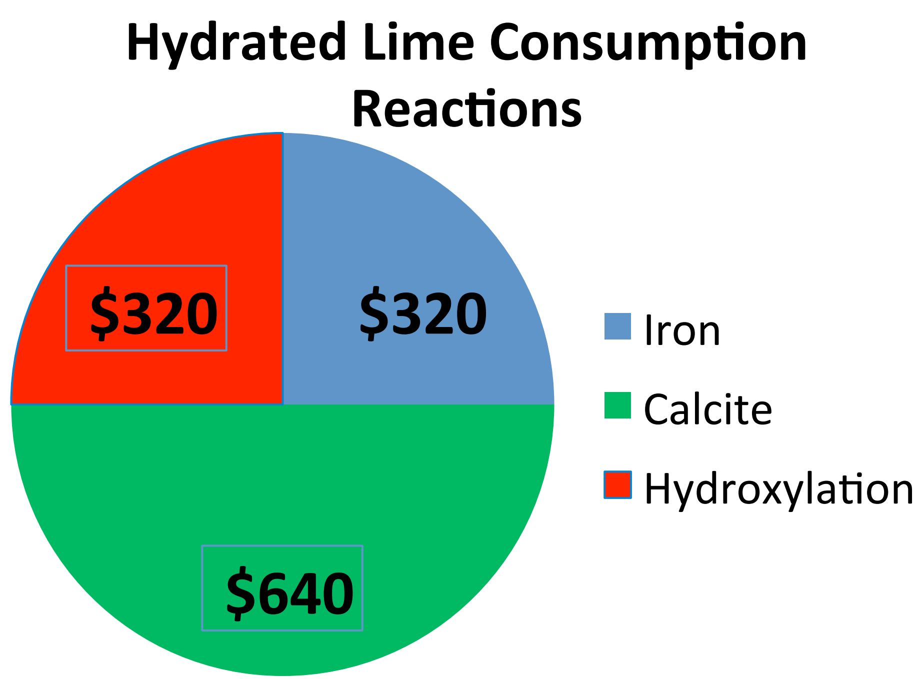
# Alkali Chemical Consumption Analysis

## Clyde Site - What is consuming Hydrated Lime?

- **Under "normal" flow conditions (1,000 gpm) Treatment pH ~8.5**
  - **8 Tons/day of CaO (Calcium Oxide) were needed to meet plant effluent goals**
  - **Current Quick lime (CaO) cost is $160.00/ton**



# Alkali Chemical Consumption Analysis

| Site | Treatment Chemical | Avg. Daily Chemical Dose Rate | Iron Removal | Calcite Formation | Hydroxylation Reactions |
|---|---|---|---|---|---|
| **Mathies** | **NaOH** | 122 gal/day | 50% | 4.3% | 45.7% |
| **Banning** | **$CaOH_2$** | 3.7 tons | 9% | 58% | 33% |
| **Russellton** | **$CaOH_2$** | 1 ton | 14% | 31% | 55% |
| **Lancashire** | **$CaOH_2$** | 5 tons | 36% | 29% | 35% |
| **Clyde** | **CaO** | 8 tons | 25% | 50% | 25% |

- **Its important to understand what reactions are consuming chemical so cost-reduction strategies can be identified**

| Clyde Site Calcite Solubility | |
|---|---|
| Influent @ pH 6.4 | pH increased to 8.4 |
| -0.3268 | 1.5565 s/sat |

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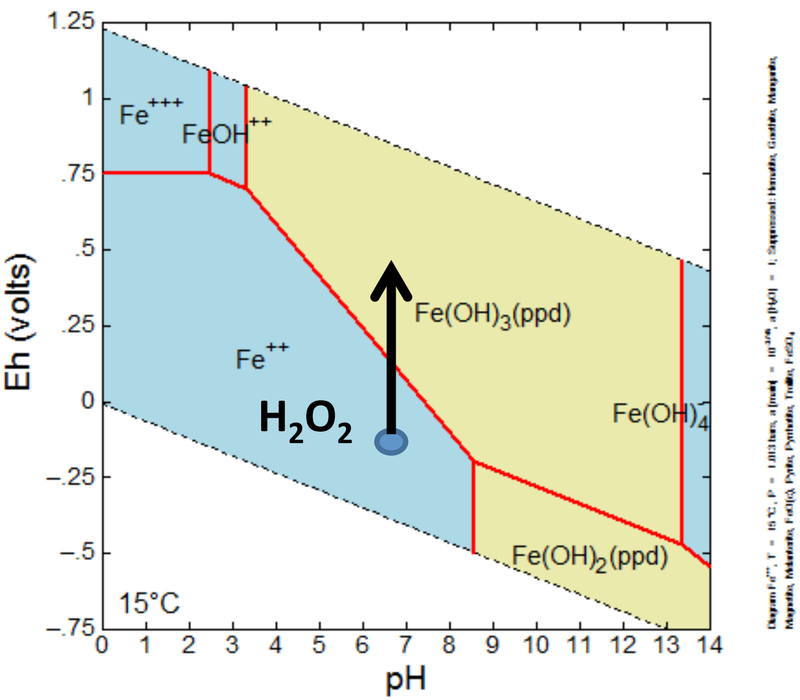
# Alternative Treatment Hydrogen Peroxide ($H_2O_2$)

- Near instantaneous iron oxidation without pH adjustment
- No nuisance reactions
- Only minor plant modifications required
- Additional electrical & sludge disposal savings

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# Russellton Site Performance Comparison

| $CaOH_2$ | $H_2O_2$ |
| --- | --- |
| pH - 8.45 | pH - 7.21 |
| Total Fe - 2.18 mg/l | Total Fe – 0.94 to 2.4 mg/l |
| Total Mn – 0.044 mg/l | Total Mn – 0.25 mg/l |

| Chemical cost | |
| --- | --- |
| Lime | Peroxide |
| $160.00/day | $37.00/day |
| **Lime cost = $160.00/ton** | **50% peroxide cost = $2.42/gal** |

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# Clyde Site Performance Comparison

| | Lime Treatment | Peroxide Treatment |
|---|---|---|
| Flow (GPM) | 1,000 | 1,000 |
| Influent/Effluent Field pH (mg/l) | 6.62/8.58 | 6.84/6.47 |
| Influent/Effluent Field Alkalinity (mg/l) | 550/199 | 560/260 |
| Influent/Effluent Total Iron (mg/l) | 166/1.5 | 194/0.69 |
| Influent/Effluent Total Manganese (mg/l) | 3.48/0.32 | 3.02/2.76 |

| Chemical cost | |
|---|---|
| Lime | Peroxide |
| $1,280.00/day | $460.00/day |
| Lime cost = $160.00/ton | 50% peroxide cost = $2.42/gal |

# Clyde Site


- The addition of an aerobic wetlands polishing pond, similar to the recent Flight 93 system re-design, has a probability of reducing both iron and manganese effluent concentrations
 http://www.arcc.osmre.gov/programs/tdt/flight93.shtm

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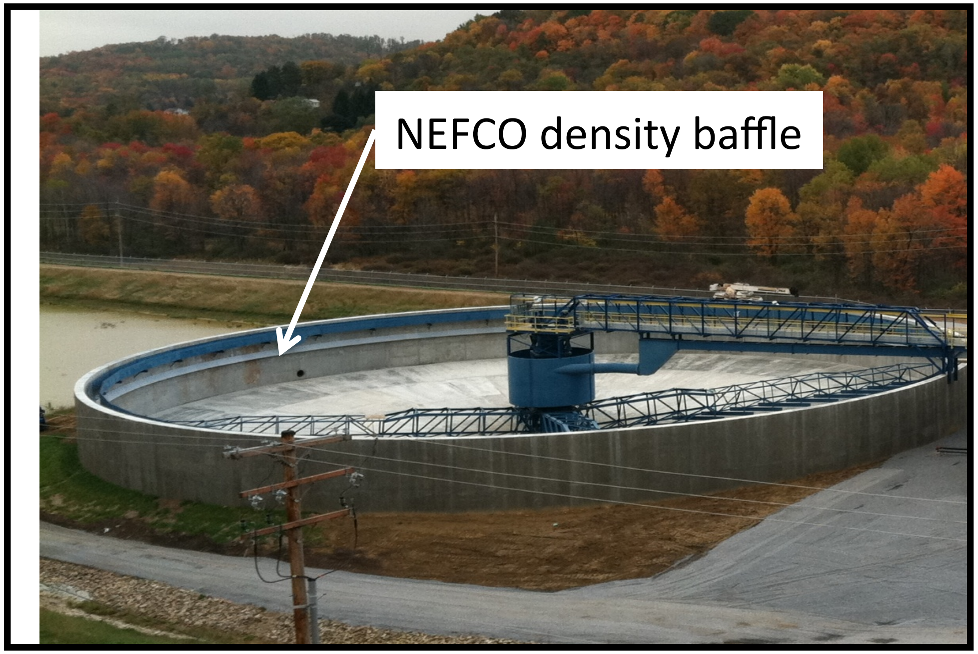
# Lancashire Site Performance Comparison

| Reagent | Dose | $/day | Effluent pH | Effluent T-Fe (mg/L) | Effluent T-Mn (mg/L) | Influent/Effluent Alkalinity(mg/L) |
|---|---|---|---|---|---|---|
| $Ca(OH)_2$ | 5.0 tons/day | $800 | 8.1 | 1.5 - 3.0 | 0.49 | 120/93 |
| 50% $H_2O_2$ | 90 gal/day | $261 | 7.5 | 0.3 – 1.8 | 1.2 | 116/74 |

* $Ca(OH)_2$ = $160/ton, $H_2O_2$ = $2.90/gal

# Lessons Learned – Settling Solids

- **Pond Clarification**
  - **$H_2O_2$ treatment is as good or better than pH adjustment without modifications.**
- **Clarifiers**
  - **HDS / Solids re-circulation systems perform much better than older designs but all require polymer addition to match lime performance**




# Lessons Learned – Storage Equipment

## Stainless vs. Double Wall Poly Tanks

Cost, Life Cycle & Repair

## Storage Volume

Bulk Delivery Benefit

Tank Construction Materials Cost


# Lessons Learned – Provider Options

## Full Service Provider:

- Minimal capital investment
- Technical support and training
- Contractual obligations

## Existing Plant Staff:

- Short term or spot market product pricing
- Equipment maintenance
- Long term cost advantage

# Safety Issues

- Appropriate PPE for all Facility Personnel
- Safety Showers and Eyewash Stations
- Training
- Site Security

http://h2o2.evonik.com/product/h2o2/en/services/Pages/h2O2-safety-training-video.aspx

http://www.h2o2.com/technical-library/default.aspx?pid=66

# Cost Reduction Summary

- Additional Savings
  - **Power Consumption**
    - Lancashire 2012 Electrical Cost (lime only) $181,600
    - Lancashire 2014 Electrical Cost ($H_2O_2$ only) $161,700
    - Lancashire 2015 Electrical Cost ($H_2O_2$ only) $141,700
  - **Sludge Volume**
    - Monview Pond de-sludging reduced from 2 times per year to once per year ~ $30,000 savings
    - Lancashire pumping to sludge disposal borehole reduced from 4 hours per day to 4 hours every fifth day
  - **Recapitalization Costs**

# Project Summary

| Evaluation Year | Treatment Facility | Treatment Trust | Annual Cost Savings |
|---|---|---|---|
| 2014 | Clyde | LTV Trust | $347,000 |
| 2013 | Lancashire | Barnes & Tucker Trust | $213,000 |
| 2013 | Russellton | LTV Trust | $36,000 |
| 2012 | Banning | LTV Trust | $120,000 |
| 2012 | Euclid | LTV Trust | $220,000 |
| 2011 | Monview | Mathies Trust | $26,000 |
| Total Annual Savings | | | $962,000 |
| 10-year savings at 3 percent investment return | | | $11,200,000 |

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