Decarbonating at the St. Michael Treatment Plant: Effect on Cost, Sludge, and Sedimentation

Brad Parker: Rosebud Mining

Brent Means: Office of Surface Mining

Rich Beam: Pa Bureau of Abandoned Mine Reclamation

Presentation Topics

1. **Background on Decarbonation**
2. **St. Michael decarbonation retrofit**
3. **Calculating CO_2 gas transfer coefficients for decarbonation units**
4. **Use gas transfer coefficients to predict decarbonation at St. Michael**
5. **Compare predictions to actual decarbonation performance at St. Michael**
6. **Decarbonation Cost Savings**

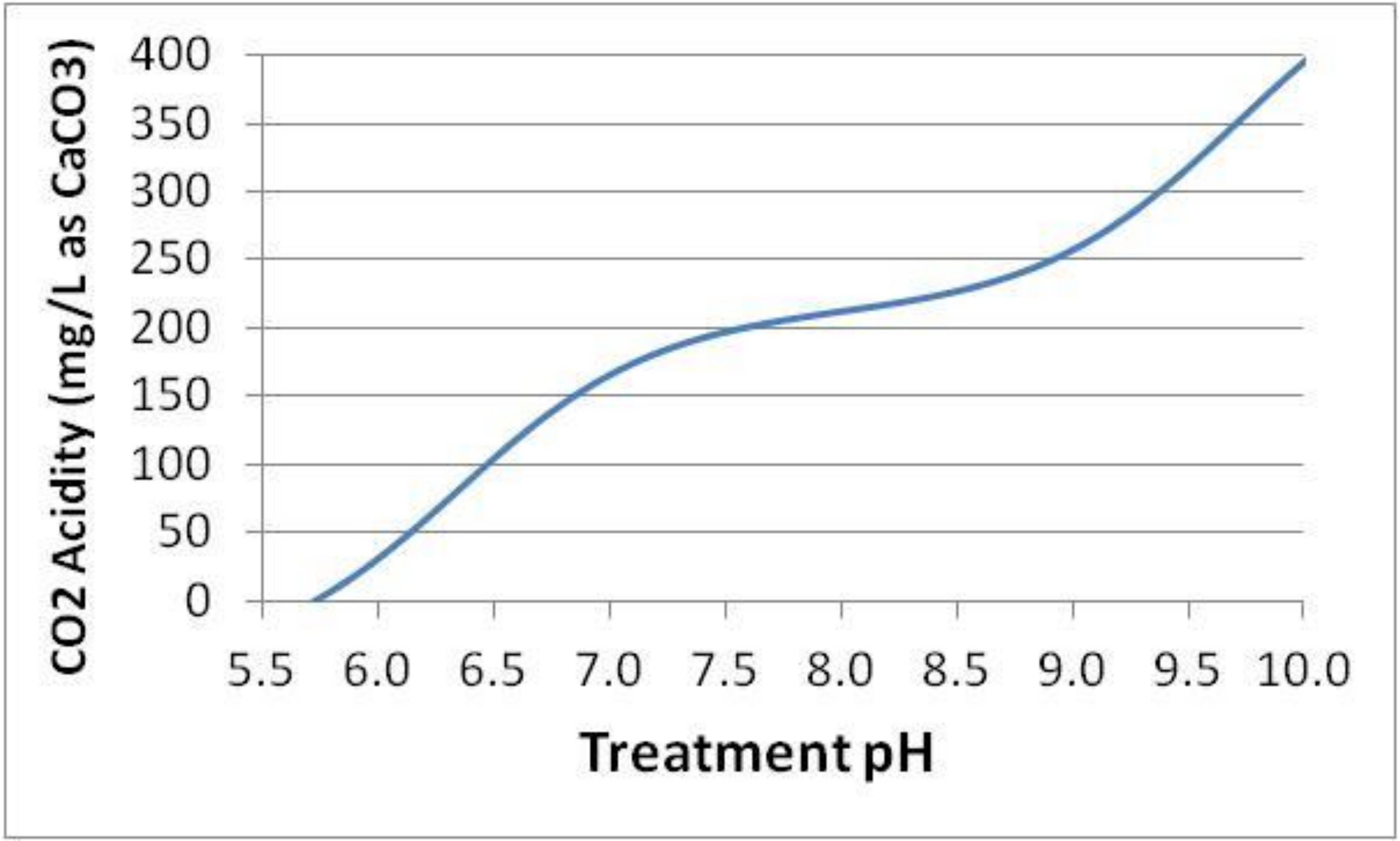
Background on Decarbonation

- **Goal of decarbonation is to exsolve dissolved carbon dioxide from water to lessen alkali consumption**

- **Dissolved $CO_{2(aq)}$ species release acidity when pH is increased via alkali addition – leads to increased chemical consumption**

Background on Decarbonation

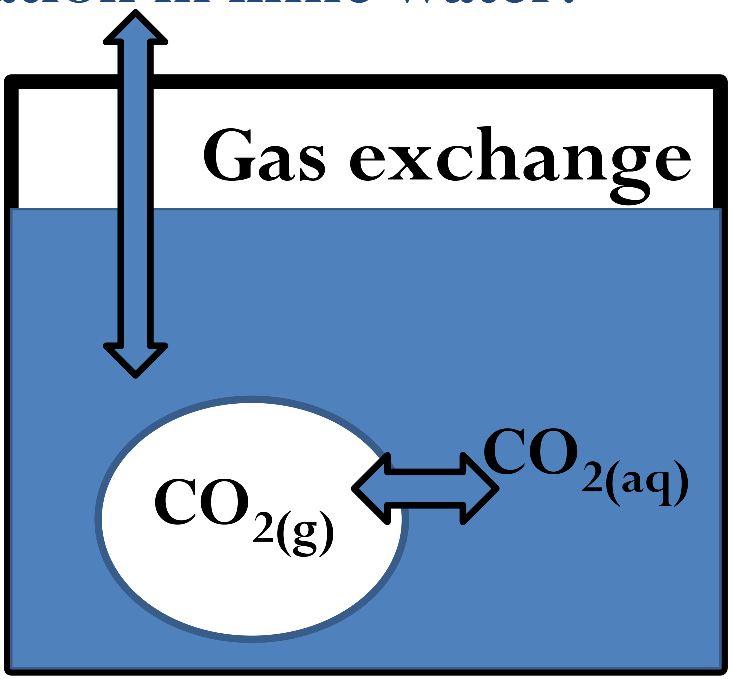
- The amount of CO_2 acidity released is strongly dependent on the change in pH caused by alkali addition
  - E.g. Consider pH 5.7, Alkalinity 48 mg/L as CaCO3, TIC 61 mg/L



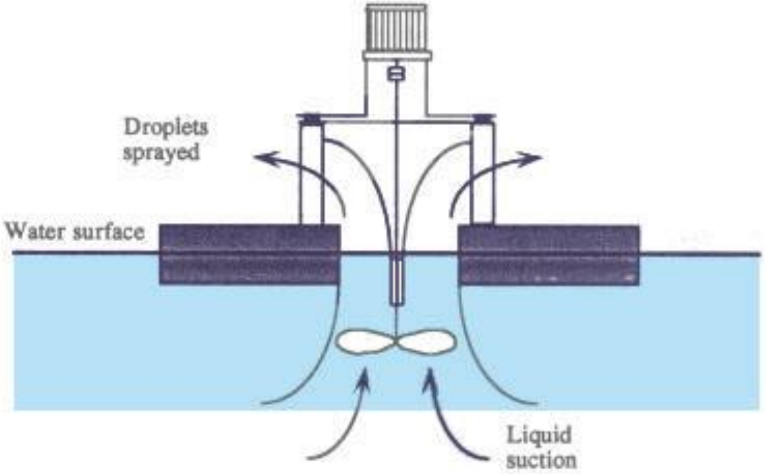
Background on Decarbonation/Aeration

- The process of Decarbonation is conducted before any other treatment process to remove CO_2 before pH is increased

- Decarbonation is the process of mixing water and air to remove $CO_{2(aq)}$
- Two common methods of decarbonation in mine water:
  1. Forcing water through air (e.g. Surface Aerators)
  2. Forcing air through water (e.g. Diffused Aeration)



Methods of Decarbonation: Surface Aerators



Aka Mechanical Aeration

Methods of Decarbonation: Diffused Aerators

Background

- **Mine Drainage contains elevated concentrations of $CO_{2(aq)}$**
- **Recognized by Kostenbader (1970) and Jagman (1988)**
- **Pa AML interested in improving decarbonation for new treatment plants**
- **Rosebud Mining interested in retrofitting St. Michael Treatment Plant for decarbonation**
- **Formed an evaluation team to study decarbonation options**

3-Step Methodology.

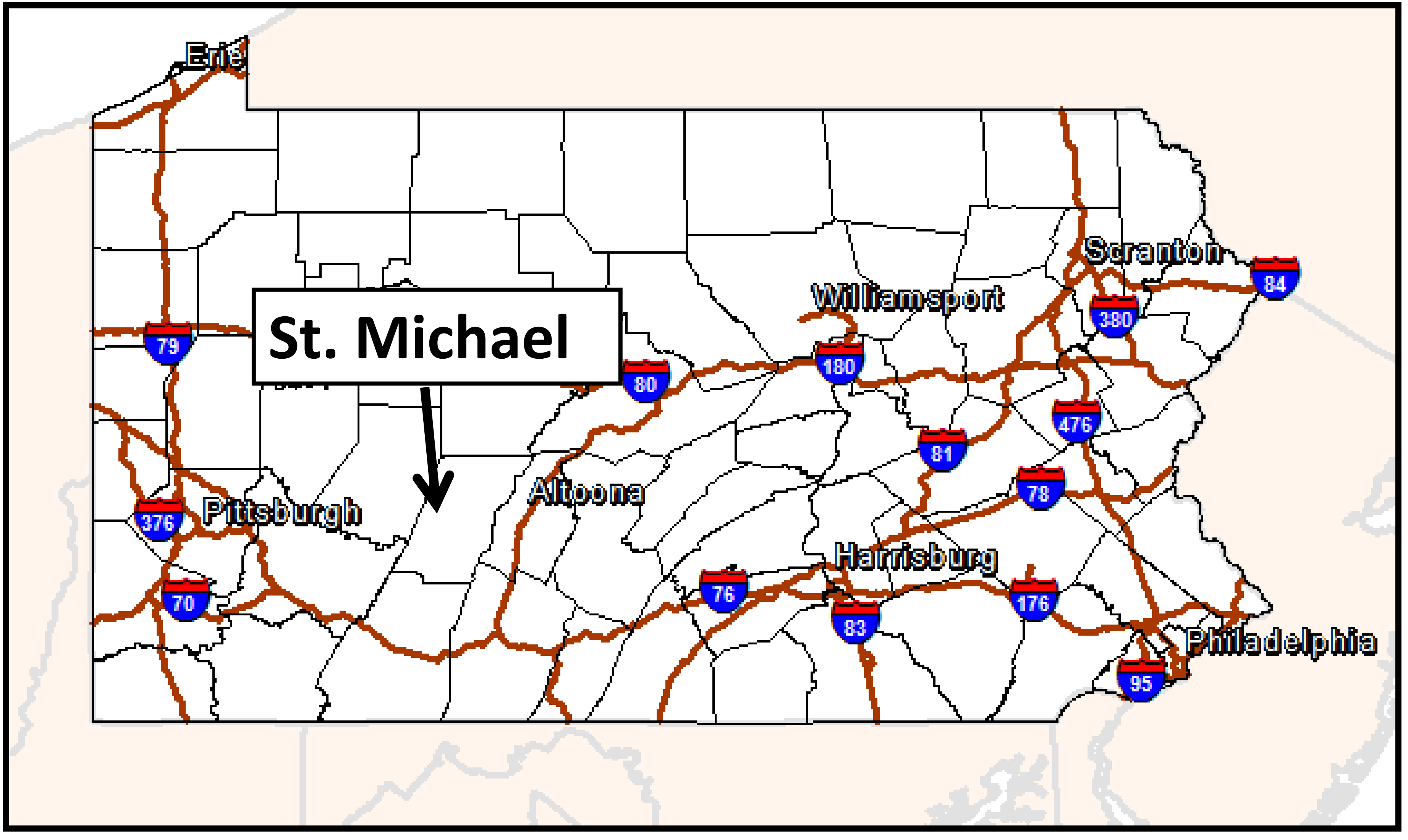
- **Evaluation Team used a 3-Step Methodology to evaluate decarbonation systems:**

1. **Field-measure $CO_{2(aq)}$ gas transfer coefficients for several operating decarbonation systems**

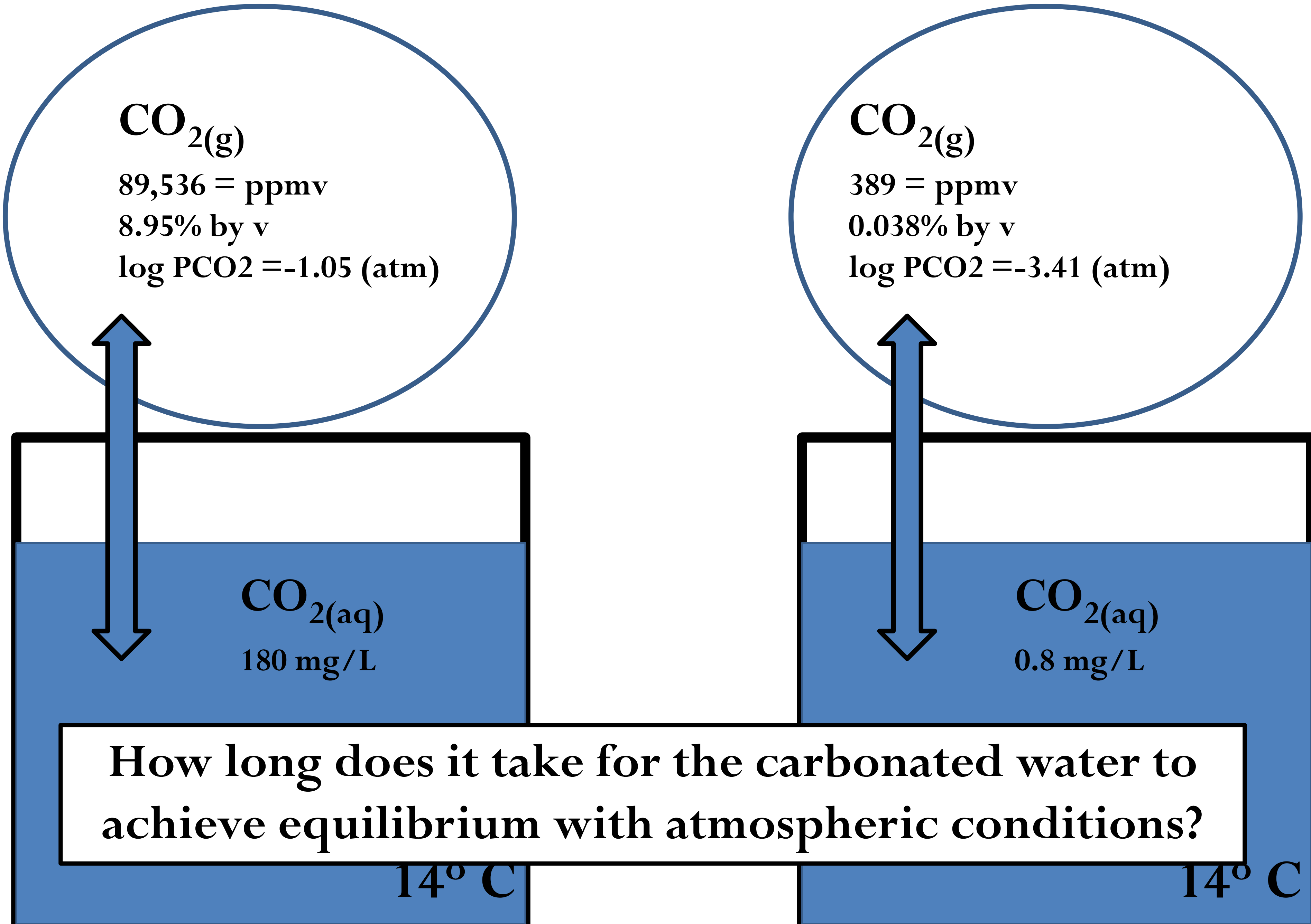
2. **Use the measured gas transfer coefficients to predict the decarbonation performance if the systems were scaled and installed at St. Michael**

3. **Compare the predicted results to the actual results after a decarbonation unit is installed at St. Michael to validate our understanding of decarbonation**

Project Location



St. Michael | Surface Water/atm

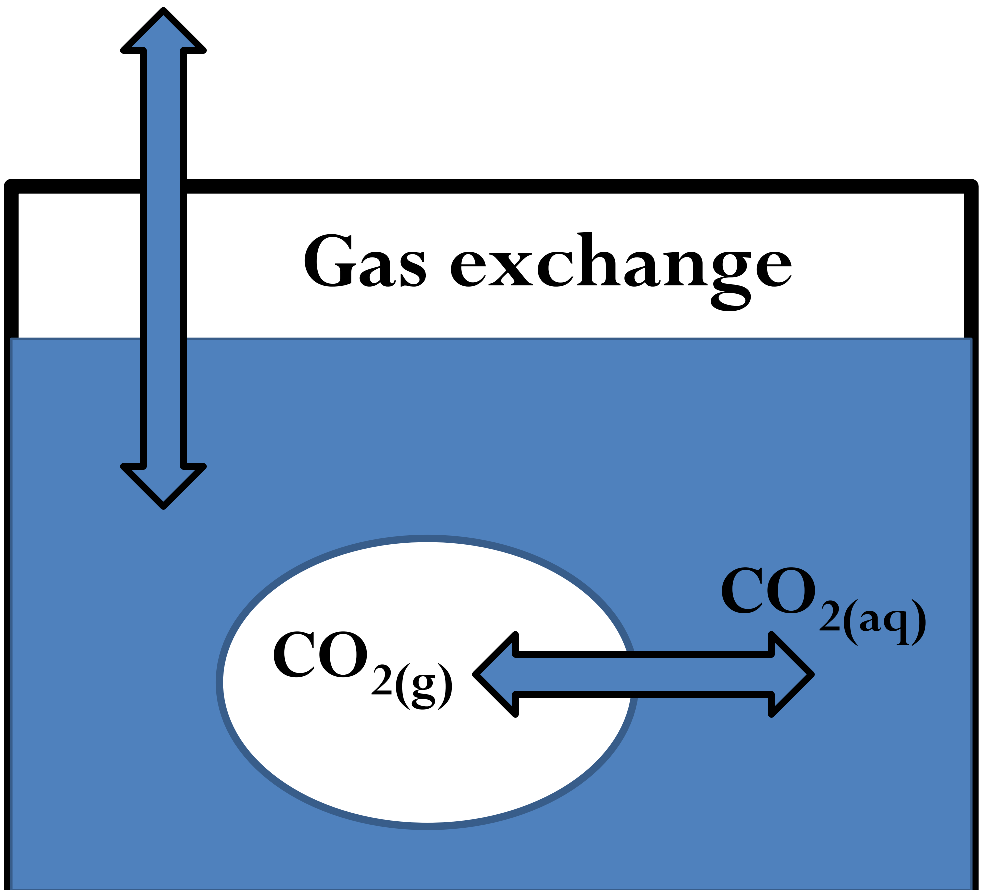


How long does it take for the carbonated water to achieve equilibrium with atmospheric conditions?

Step 1: Field-Measure Gas Transfer

$$\Delta CO_{2(aq)}/time = -K_{LCO2,\mathbf{a}}*(CO_{2(aq)sat\ atm} - CO_{2(aq)raw})$$

a = surface to volume ratio



Step 1: Field-Measure Gas Transfer

- **Studied two sites that use surface aerators for decarbonation. These sites are configured as Continuous stirred Reactors (CSR) (Pump Water into Air)**

- **Studied two sites that use a Maelstrom Oxidizer for decarbonation. Plug Flow Reactor (Pump Air into Water)**

$$\Delta CO_{2(aq)} / \text{time} = -K_{LCO2,a} * (CO_{2(aq)\text{sat atm}} - CO_{2(aq)\text{water}})$$

Lancashire: Continuous Stirred Reactor Surface Aerator

Surface Aerator configured as CSR at Lancashire Treatment Plant

Surface Aerator configured as CSR at Renton Treatment Plant

Plug Flow Coarse-bubble Aerator at Trent Site

Plug Flow Coarse-bubble Aerator at Sykesville

Step 1: Field-Measure Gas Transfer

$$\Delta CO_{2(aq)}/\text{time} = -K_{LCO2,a} * (CO_{2(aq)\text{sat atm}} - CO_{2(aq)\text{raw}})$$

- **Time = Measured using dye and stopwatch**
- **$CO_{2(aq)\text{water}}$ = Measured $CO_{2(aq)}$ using two methods:**
    1. **Calculated from pH, temp, and alkalinity**
    2. **Collected Total Inorganic Carbon (TIC) sample for lab analysis**
- **$CO_{2(aq)\text{Sat Atm}}$ = Geochemist Workbench to equilibrate water to atmospheric conditions**

Measured the retention time at both Plug Flow Reactor sites using dye tracer and stopwatch

Step #1: Field-Measure Gas Transfer

	Reactor Type	HP	Retn Time (min)	Flow (gpm)	Raw pH	End pH	Raw $CO_{2(aq)}$ (mg/L)	End $CO_{2(aq)}$ (mg/L)	Kla (sec-1)
Lancashire	CSR	30	X	4100	6.1	6.4	129	64	5.20E-4
Renton	CSR	25	X	1600	6.1	6.5	448	143	8.23E-4
Trent	Plug	20	0.5	1108	5.9	6.5	254	62	4.72E-2
Sykesville	Plug	39	2	918	6.4	7.4	46	11	1.21E-2

Step #2: Predict Decarbonation at St. Michael

- Pumped Flow ranges 2,000 to 10,000 gpm
- pH = 5.75
- Fe = 120-140 mg/L
- Alkalinity = 48 mg/L as CaCO3

3 Sources of Acidity:

1. Fe ppt
2. CO_2
3. Calcite ppt

Step #2: Predict Decarbonation at St. Michael

- **St. Michael uses slaked lime to achieve treatment pH 8.7**
- **3 sources responsible for lime consumption during pH increase:**

1. **Fe ppt**
2. **CO_2 Species**
3. **Calcite formation (difficult to predict lime consumption)**
   - Dissolved-precipitate

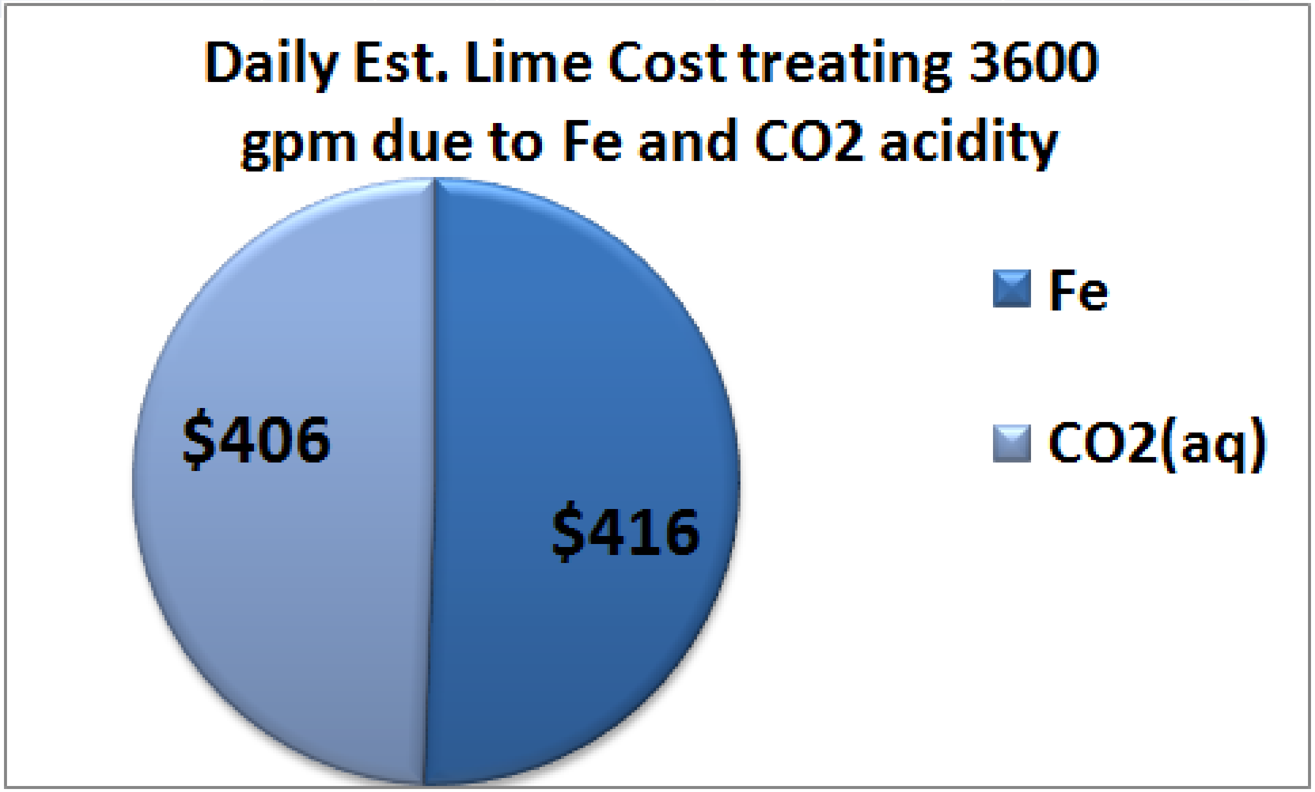
     $Ca^{2+} + HCO_3^- = CaCO_{3(s)} + H^+$

   - Recarbonation

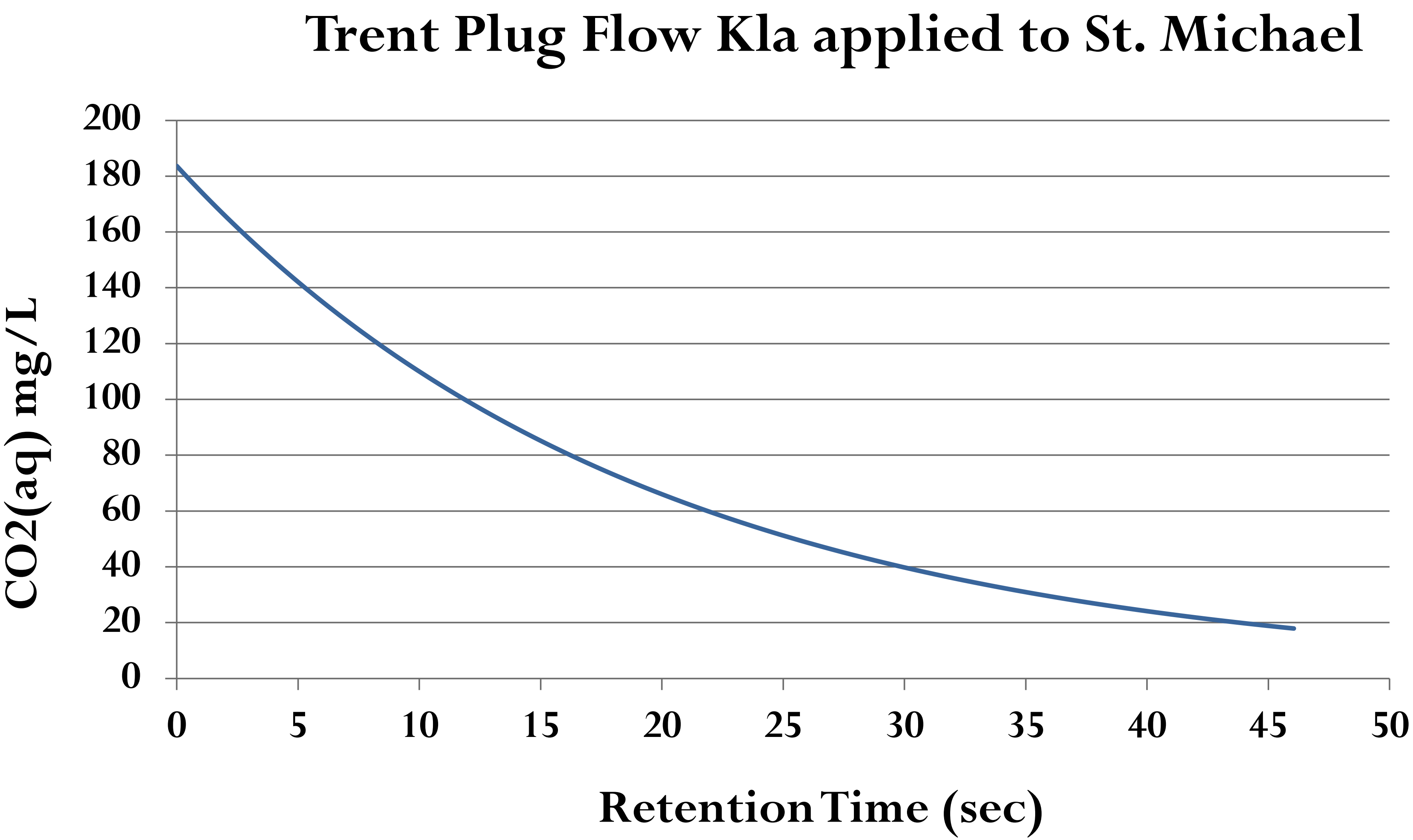
     $Ca(OH)_{2(s)} + CO_{2(aq)} = CaCO_{3(s)} + H_2O$

Step #2: Predict Decarbonation at St. Michael

	pH	Alk	CO2(aq)	CO2 Acidity @ pH 8.7	Fe Acidity
Raw	5.8	60	194	251	121



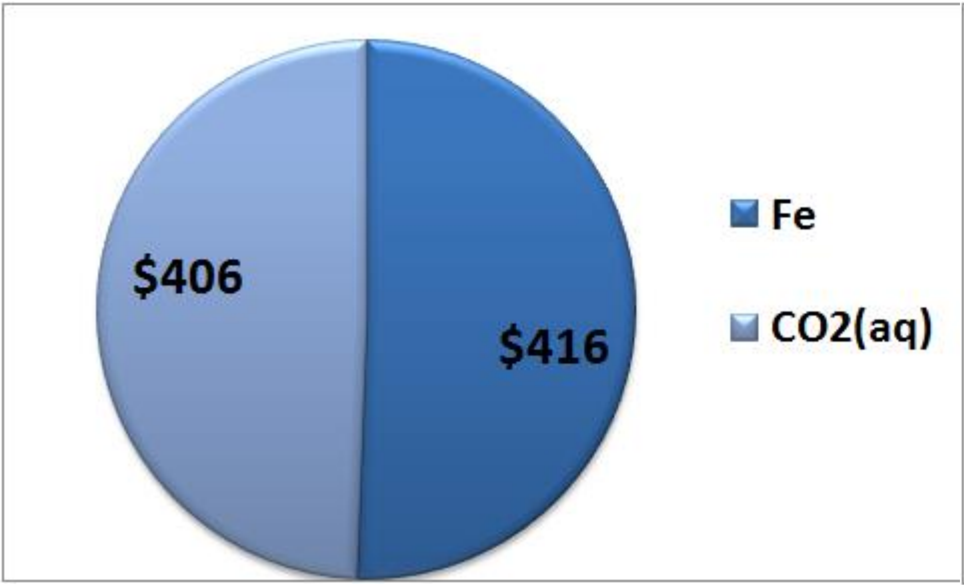
- Estimate purposefully didn't include cost associated with calcite ppt. Very conservative estimate (on purpose)

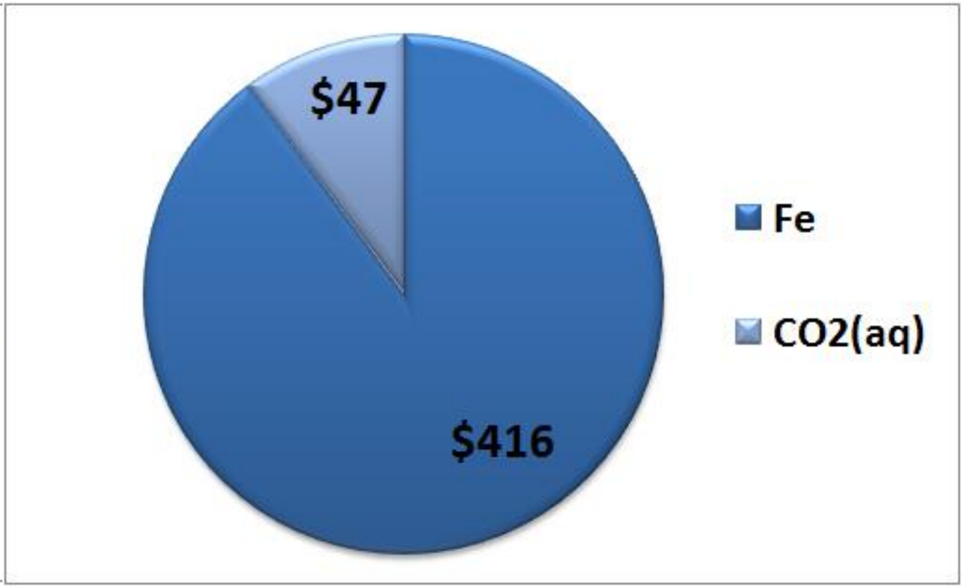


- **A 2,730 gallon tank is required for a 3,600 gpm flow to provide 45.5 sec of RT**

Predicted Daily Lime Costs using Trent K_{la}

No Decarbonation | **Decarbonation**



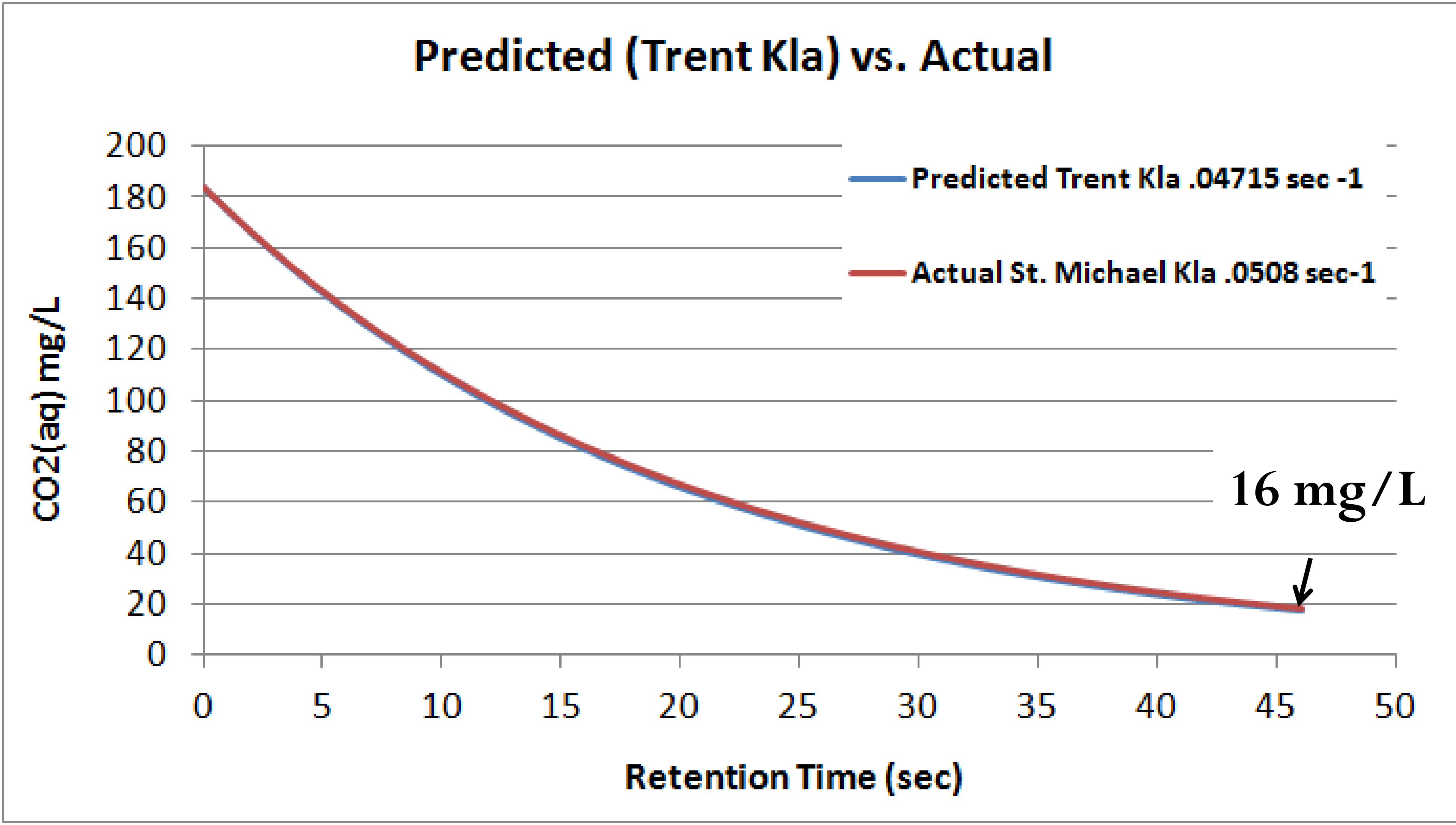


- Estimate a 43% reduction in Lime consumption; Not considering effect of calcite ppt.
- Power requirement of 68 HP, so net predicted daily savings = $297 treating at 3,600 gpm (not considering any reduction in calcite ppt)

Step #3: Compare Predicted vs. Actual Savings

- 2 Installed in Aug. 2014, each sized for max flow of 2,500 gpm. Two 60 HI blowers with VFD
- At 3,600 gpm, $CO_{2(aq)}$ decreased from 183 to 19 mg/L in 46 secs of RT

Step #3: Compare Predicted vs. Actual Savings



Step #3: Compare Predicted vs. Actual Savings

	Daily Lime pH 8.7 (tons/day)	Annual Electrical Cost for blower	Annual Lime Cost	Annual Net Savings
Predicted No Decarbonation (Assume No calcite ppt)	**5.8**	**NA**	**299,866**	
Actual No Decarbonation	**10.1**	**NA**	**$516,110**	
Predicted using Trent KLa	**3.3**	**$51,231**	**$168,852**	**$117,621**
Actual	**3.8**	**$44,785**	**$194,180**	**$277,146**

Unexpected side effect of effective Decarbonation: Sedimentation issues

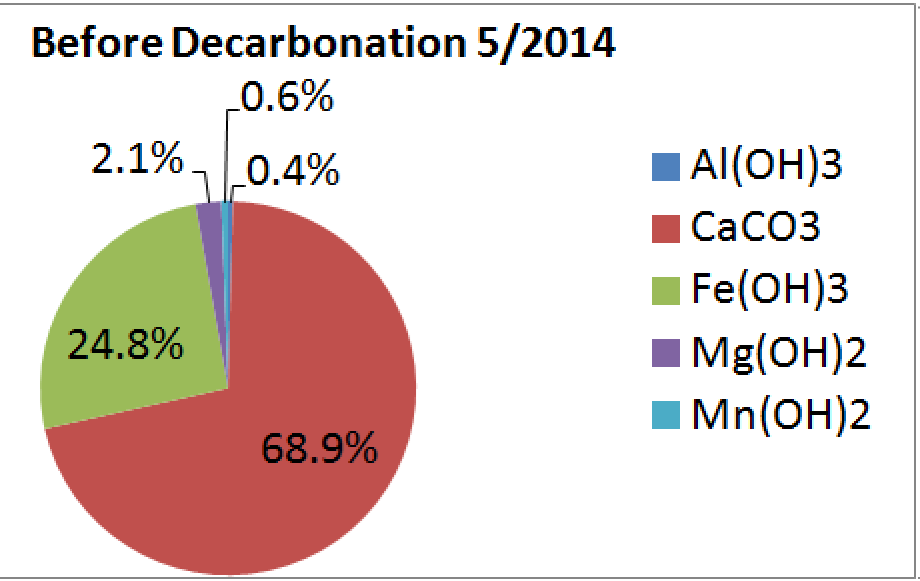
St. Michael: Unexpected side effect of effective Decarbonation

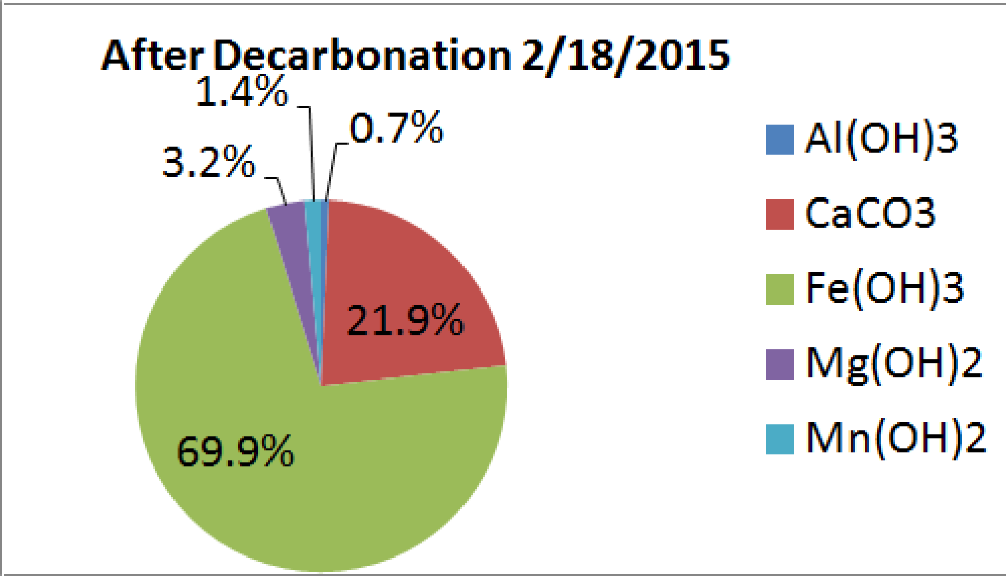
	Effluent Total Fe (mg/L)	Polymer	Sludge % Solids (w/w)	Sludge pumping Frequency	Sludge Recycle Ratio (recycled solids/produced solids)
No Decarbonation	< 1.6	No	32.9%	Weekly	251:1
Decarbonation	2- 3*	Yes	9.1%	Daily	60: 1
*Until a polymer, sludge recirculation rate, and sludge pumping program was instituted to solve the settling issue					

- Hypothesized the settling issue was a result of drastic reduction in calcite ppt (sludge glue)

Pre and Post Decarb Sludge Analysis

Method	Method	Units	Pre Decarb	Post Decarb
CO_2 (as $CaCO_3$)	ASTM C 471M	% CaCO3 Dry	67.7%	23.9%
TIC (as $CaCO_3$)	ASTM D 1756	% CaCO3 Dry	63.8%	17.6%
Neutralization Potential, Dry	PA DEP	% CaCO3 Dry	73.1%	30.1%





Conclusions

- Its important to determine the amount of CO_2 species in any mine water (not just "AMD") if pH adjustment occurs via chemical dose
- Important to evaluate whether the payback exists for decarbonation

- Its important to evaluate the type of decarbonation unit for a site (not all decarbonation units created equal)