Alkaline Flush: An Emerging Technology for In Situ Treatment of Mine Impacted Alluvial Aquifers

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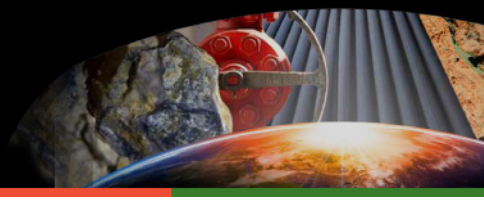
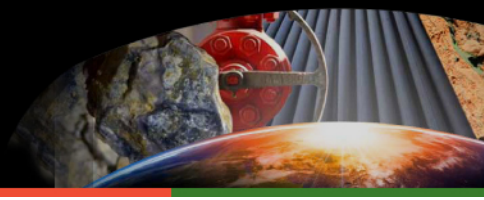
Discussion Points



- Nature of Impact
- Alkaline Flush (ALF) Technology
- Laboratory Testing and Results
- Summary

Nature of Impact



- Acid Rock Drainage (ARD)
  - Produced when sulfide-bearing materials (mainly pyrite) are exposed to oxygen and water as a result of mining activities and/or natural processes
  - Characterized by low pH and increased metals concentration
  - Source of impact across eastern and western US

- Historical releases of ARD drainage into waterways can result in impacted alluvial aquifer sediments and groundwater

Nature of Impact

Photo by G. Miller via www.pebblescience.org

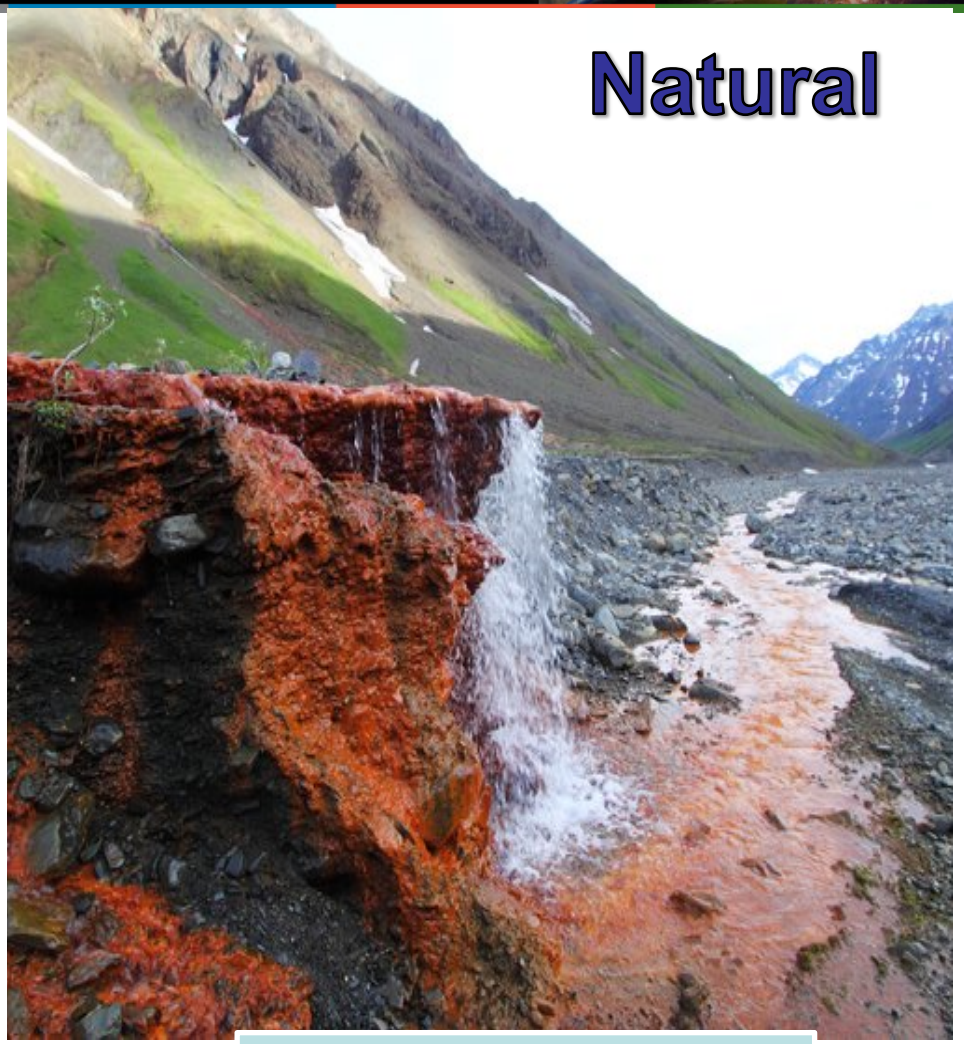
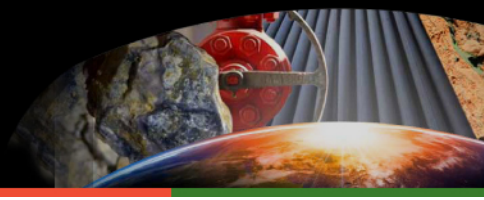


Photo by Andrew Mattox, Ground Truth Trekking

Alkaline Flush (ALF) – An Emerging Technology

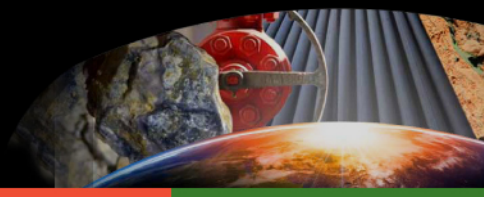
What is ALF?



- The introduction of an alkaline solution into an impacted alluvial aquifer to adjust water/sediment pH and chemistry
  - Increase in pH causes heavy metals to precipitate into more stable forms
  - Secondary minerals that serve as sorption sites for heavy metals are formed

- Why Evaluate ALF:
  - Represents potential *in situ* remedial action
  - Potential to accelerate rate of natural attenuation
  - Could mitigate long-term water treatment requirements

Science behind ALF



- Introduce alkaline solution into impacted sediments
- Form secondary minerals, creating sorption sites

$$Fe^{3+} + 2\ H_2O \rightarrow FeOOH + 3\ H^+$$

$$Al^{3+} + 2\ H_2O \rightarrow AlOOH + 3\ H^+$$

- pH increase aids in metal sorption on secondary minerals
- Surface acidity is neutralized, causing heavy metals to bind to sediment

$$Pb^{2+} + \equiv FeOH \rightarrow \equiv FeOPb^+ + H^+$$

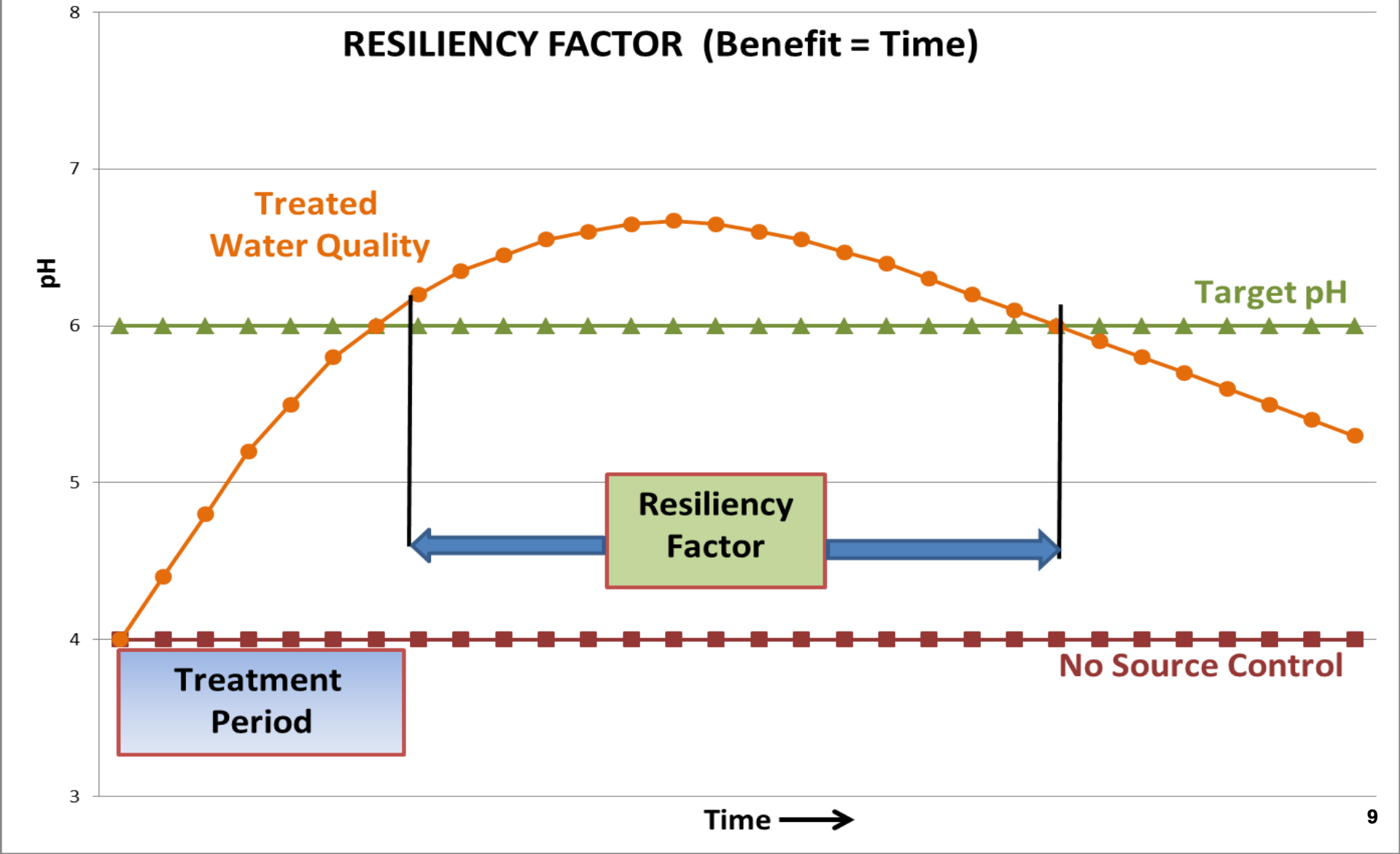
Key ALF Terms

- **Source control**: Identify and minimize source(s) of impact

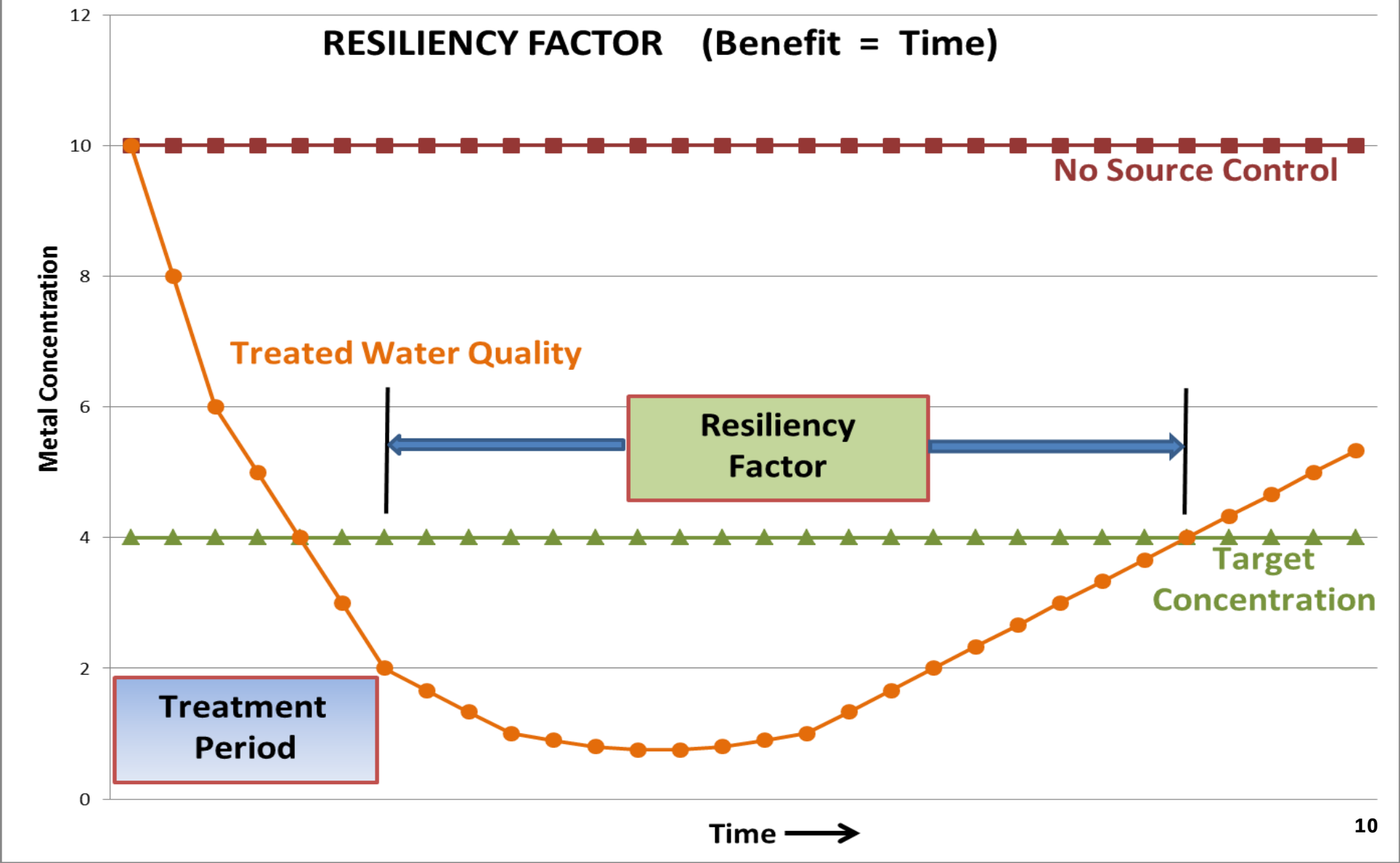
- **Resiliency factor:** Capacity of the remediated system to resist return to the conditions prevailing before implementing ALF
  - Provides time for source control to be implemented

- **Enhanced attenuation:** Accelerated remediation achieved compared to natural attenuation

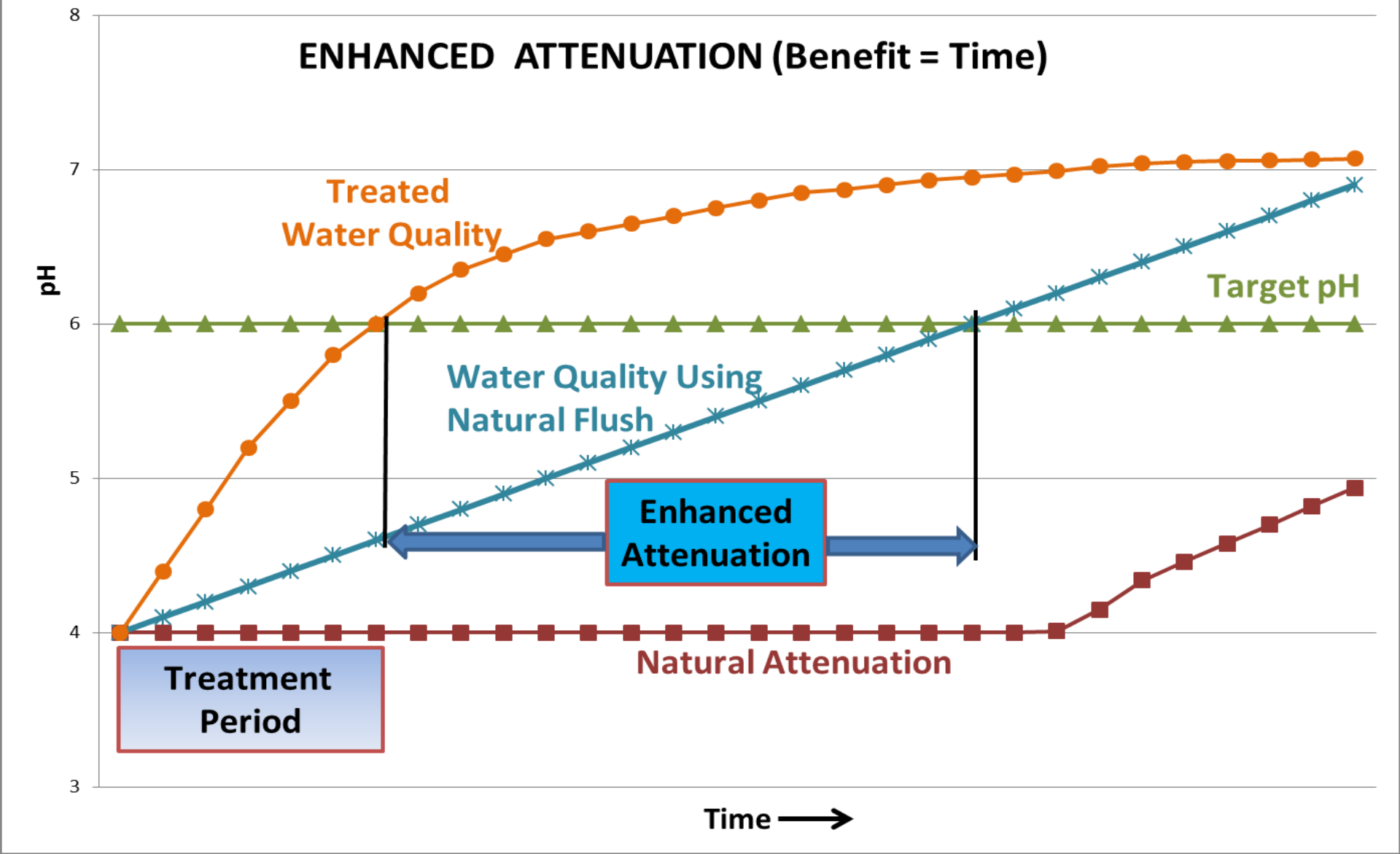
ALF Without Source Control – pH



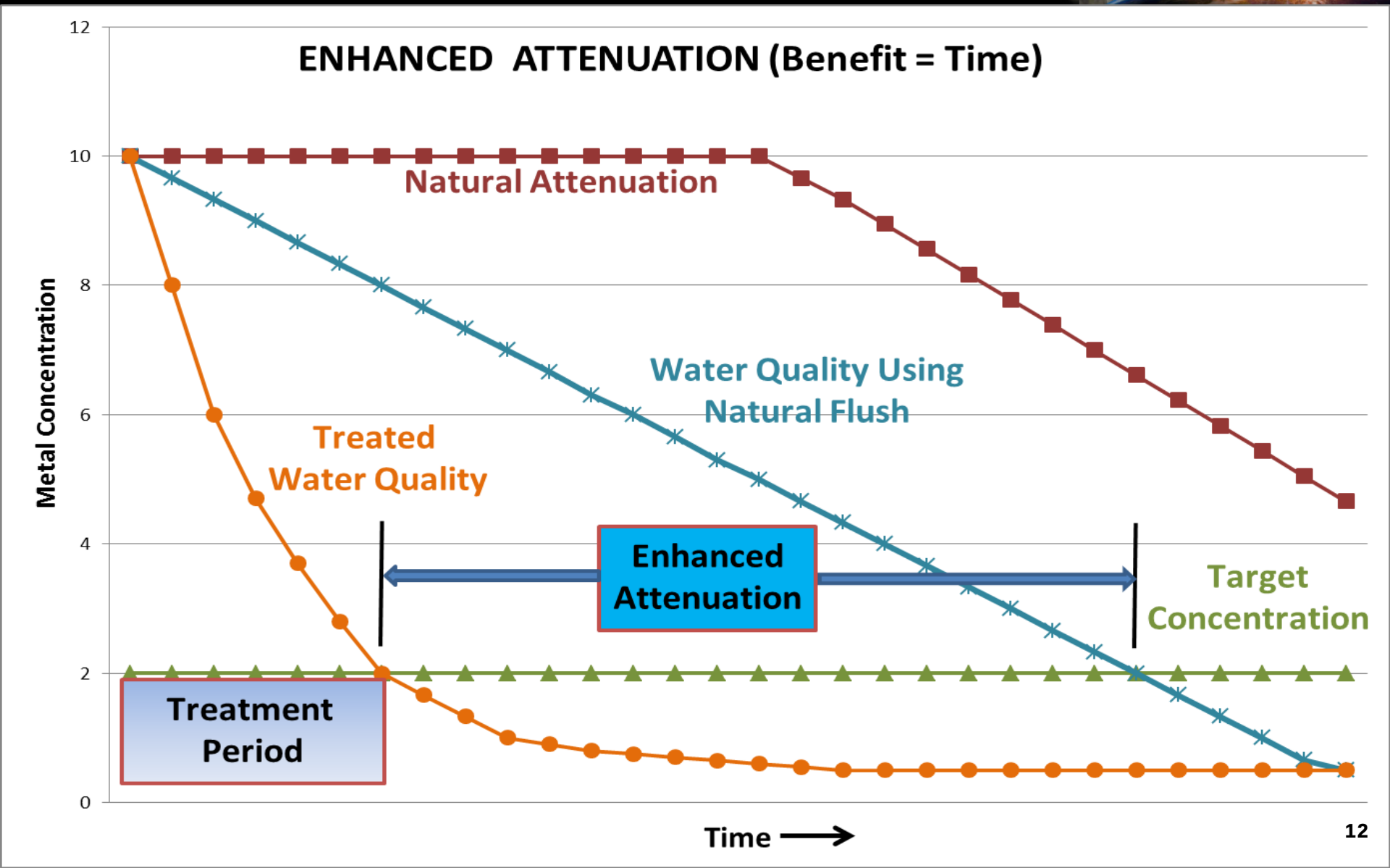
ALF Without Source Control – Metals



ALF With Source Control – pH



ALF With Source Control – Metals



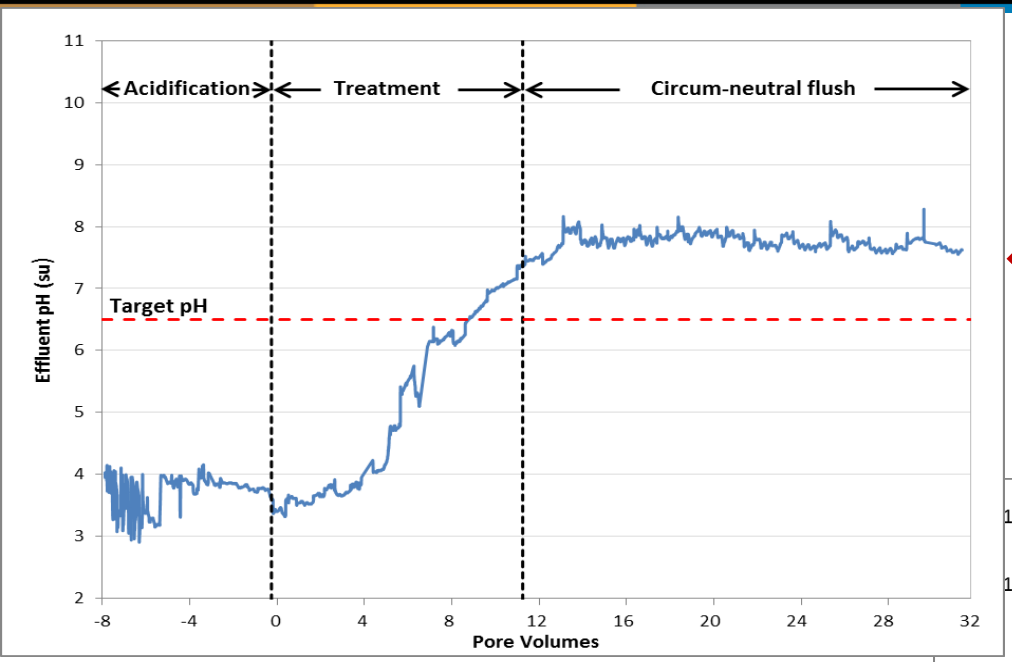
Laboratory Testing and Results

Experimental Design

- Objectives:
  - Determine the appropriate alkali for implementing ALF
  - Estimate long-term sediment acidity to guide pilot test design

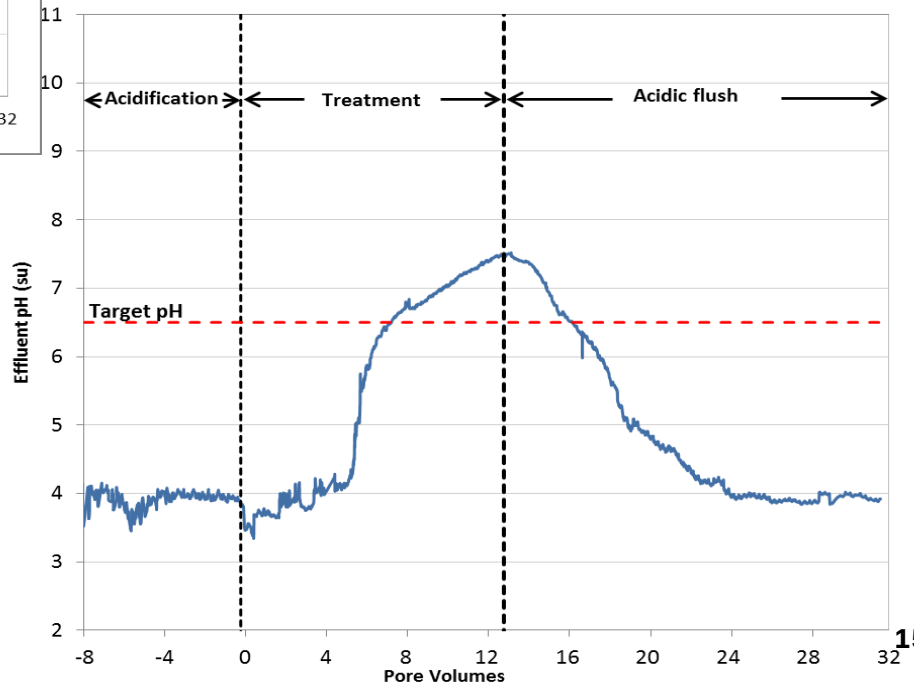
- Setup and design:
  - Columns
  - Impacted sediments and groundwater
  - Alkali(s): $Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$ (Sesqui™), NaOH, $NaHCO_3$ and $Ca(OH)_2$
  - Scenarios tested:
    - Natural flush
    - ALF (with and without source control)
  - Three stages:
    - Acid equilibration
    - Treatment
    - Acidic or circum-neutral flush

Source Control vs. No Source Control

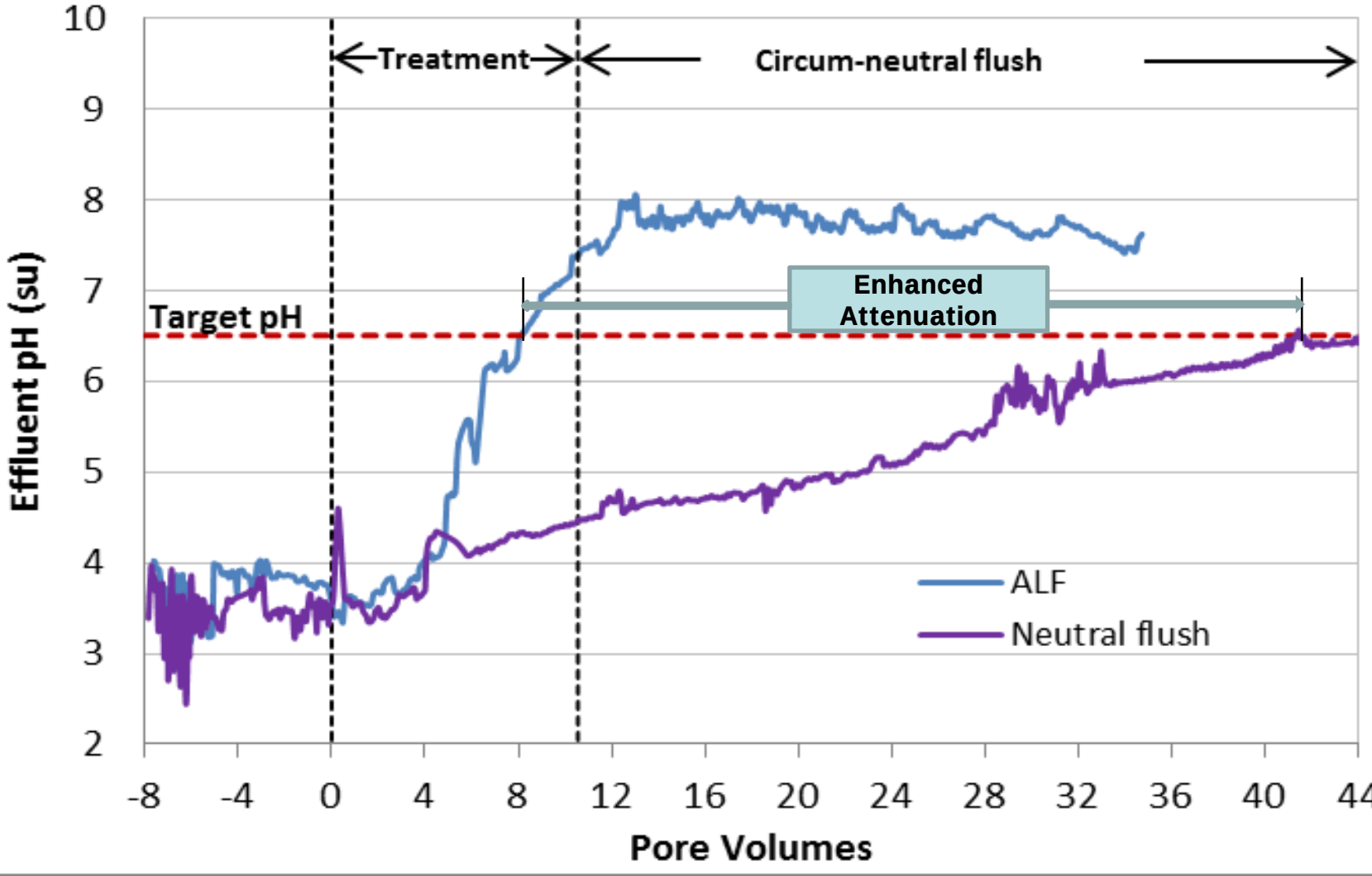


- Treated with ~ 1350 mg/L as $CaCO_3$ alkalinity
- Flushed with circum-neutral groundwater (i.e. source control) with ~ 150 mg/L as $CaCO_3$ alkalinity

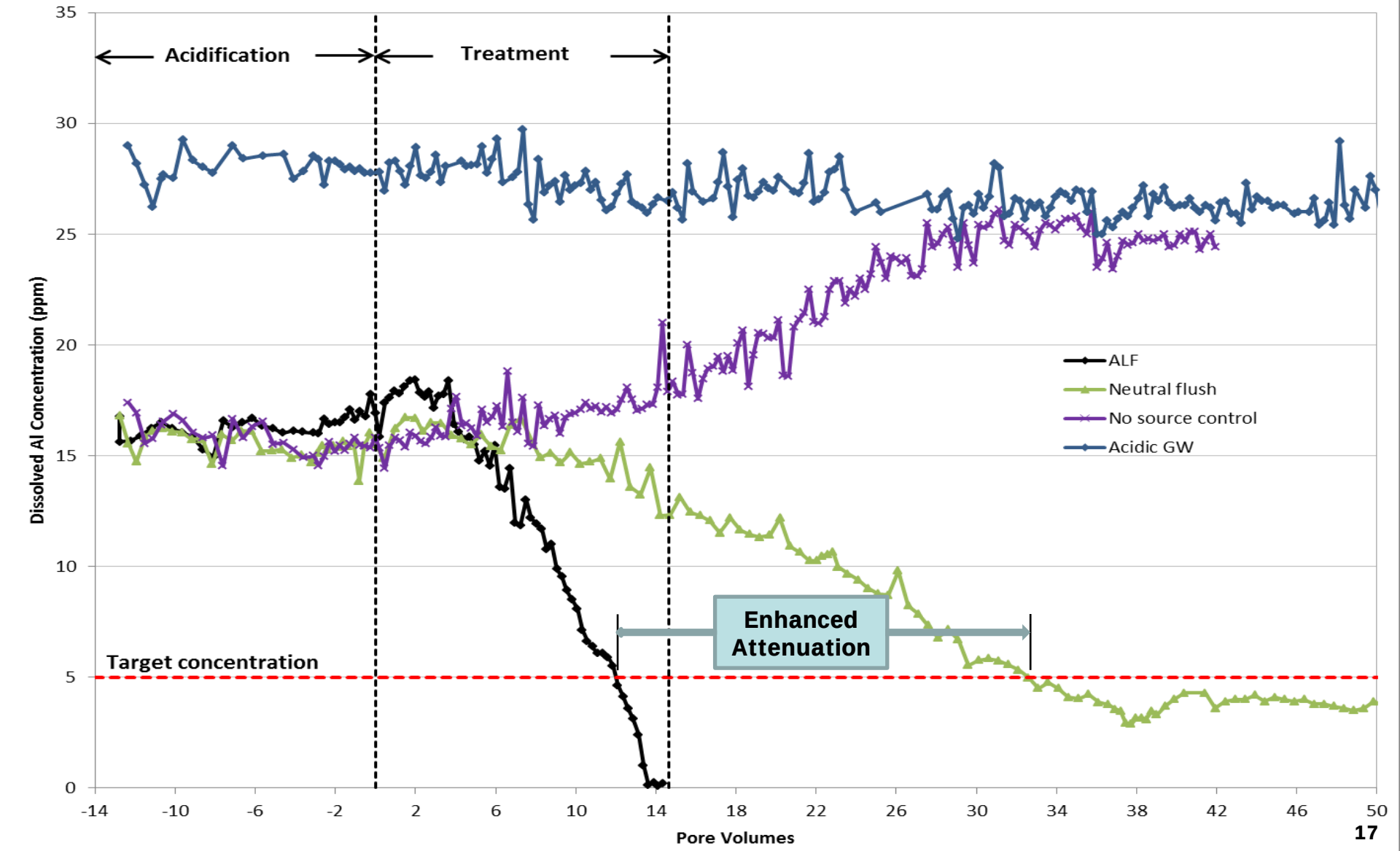
- Treated with ~ 1350 mg/L as $CaCO_3$ alkalinity
- Flushed with acidic, metals-laden groundwater (i.e. no source control) with ~ 1000 mg/L as $CaCO_3$ acidity



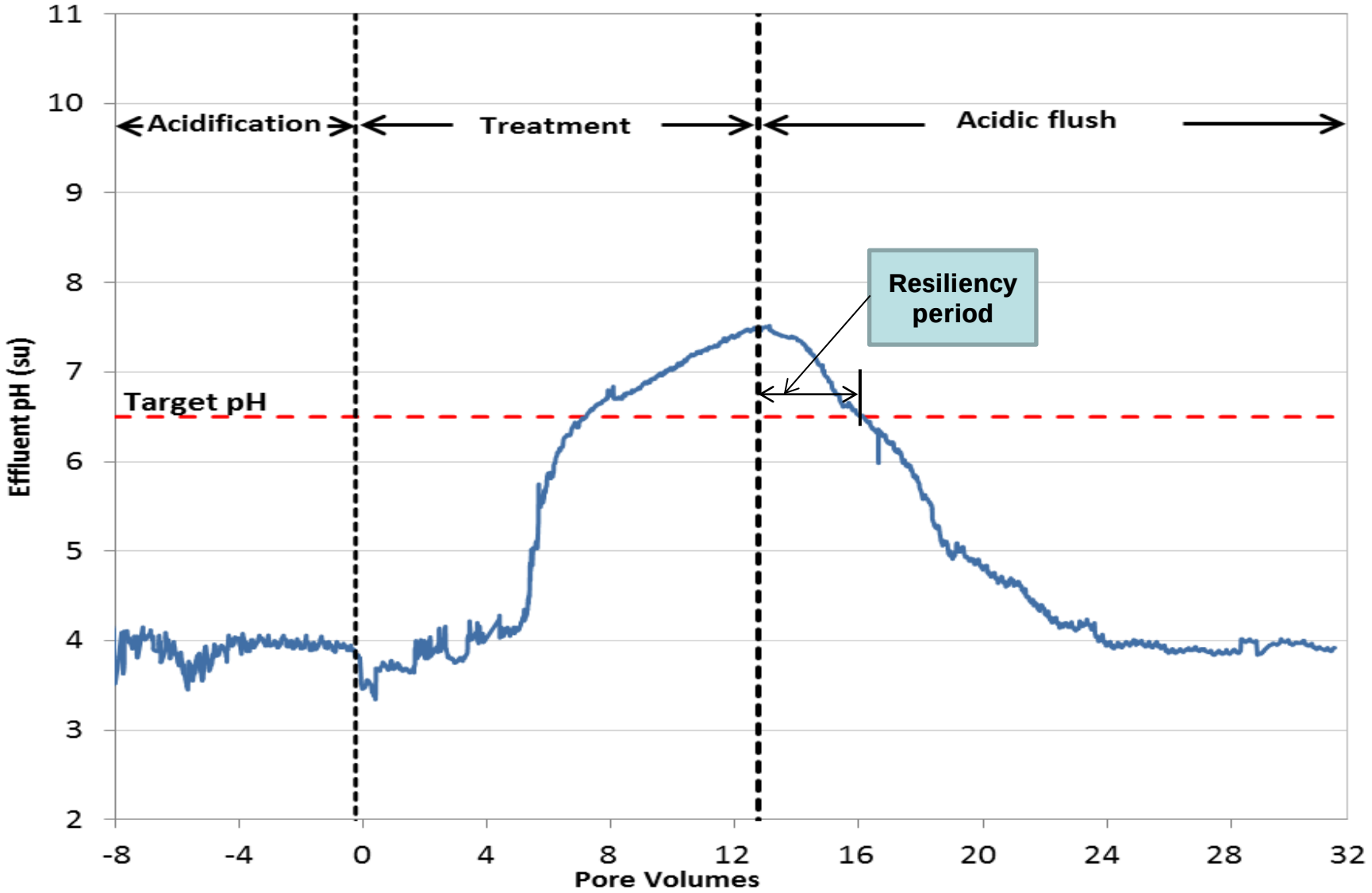
ALF Provides Enhanced Attenuation



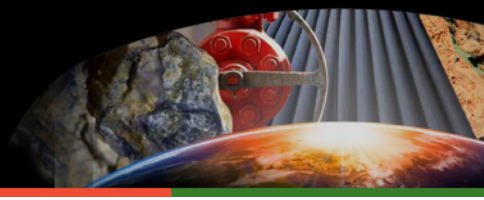
Enhanced Attenuation – Aluminum



ALF Provides Resiliency



Summary Points



- Understanding sediment acidity is critical
  - Estimation of alkalinity required for treatment and duration
- ALF is a promising emerging remediation technology, although it is not yet proven

Thank you!

Questions?