Acid Mine Drainage Treatment at Herbert Stream, Stockton
• Location and background

• Flow rate and chemistry

• Use of passive treatment flow chart

• Field trials to identify best solution
Datalogger

Water level every 15 min
Converted to flow rate
Herbert Stream Flow Rate

Average Flow 5.3 L/s

>6 L/s 10.2%
>7 L/s 3.8%
>8 L/s 2.2%
>9 L/s 1.1%
>10 L/s 0.4%
Herbert Stream Chemistry

pH 2.8 to 3.2
Aluminium is the dominant contaminant, followed by iron
Dissolved oxygen concentration ~9 mg/L
64% of total iron in oxidised state (Fe$^{3+}$)
Incised streambed with riparian strip of native trees and shrubs
Passive Treatment Options Flow Chart

AMD

Fe high (> 10 mg/L)

Fe 3+ < 10%
DO < 2

Fe 3+ > 10%

Steep topography

Not steep topography

Large flat area
Long narrow land area

Reducing System:
ALD

Reducing System:
VFW
Anaerobic Wetlands

Oxidising System:
Diversion Well
Steep OLC
Limestone Sand Dosing

Oxidising System:
OLC with access for dozer to break up oxides

Fe low (< 10 mg/L)

Large flat area
Long narrow land area

Reducing System:
VFW (with very long residence time)
Anaerobic Wetlands (with very long residence time)

Oxidising System:
Slag Leaching Bed

(see next slide)
Fe low (< 10 mg/L)

Al high (> 25 mg/L)
- Long narrow land area
- Limited land area - steep
- Large flat area

**Oxidising System:**
- Limestone Leaching Bed
- Slag Leaching Bed (both with settling pond)

Al low (< 25 mg/L)

DO > 2
- Large flat area

**Oxidising System:**
- Diversion Well + Settling Pond

DO < 2
- Long narrow land area
- Large flat area

**Reducing System:**
- ALD

**Reducing System:**
- VFW + Settling Pond
- Anaerobic Wetlands (both with very long residence times)

**Reducing System:**
- Anaerobic Wetlands

**Oxidising System:**
- OLC or OLD
- Limestone Sand Dosing
Limestone Leaching Bed (LLB)

Horizontal flow with vertical flushing capability to remove accumulated precipitates
Limestone treatment media, 76% between 15 and 25mm diam
Reducing and Alkalinity Producing System (RAPS) 
Vertical Flow Wetland (VFW)

Perforated Pipe  
(normal flow and flushing)

Inlet

Outlet normal flow

Vertical flow system
Limestone treatment media at base (12cm thick)
Mushroom compost over limestone (30cm thick)
Water depth over compost (8cm)
Open Limestone Channel (OLC)

Water flow during operation

Inlet
Results

- Residence times in each system mostly between 10 and 35 hours
  - Average flow rates
    - OLC 5 L/hr
    - LLB 12 L/hr
    - RAPS 13 L/hr
- LLB, RAPS raised pH to neutral
- OLC raised pH to neutral at long residence times
Reducing conditions achieved by RAPS unit
- DO lowered
- Percentage of iron in oxidised ferric form lowered

Oxidising conditions in LLB, OLC
Aluminium consistently lowered by LLB and RAPS

OLC initially lowered aluminium (res time 20 hrs) but later was less effective (res time 150 hrs!)

Iron lowered by all systems
LLB most effective
OLC, LLB effective at manganese removal

RAPS initially effective at manganese removal

net export at end of trial

LLB, RAPS effective at zinc removal (no data from OLC)
All three systems equally effective at aluminium, iron removal

LLB best at manganese removal

LLB, RAPS equally effective at zinc removal (no data for OLC)

Therefore, for aluminium and iron removal any of these systems may be sufficient for treatment
Effectiveness of Flushing Systems

**LLB**
- Flushing effective at removing:
  - 11% of the aluminium
  - 31% of the iron
  - 8% of the manganese

**RAPS**
- Flushing removed:
  - <10% of all metals
- Majority of aluminium, iron, zinc retained in compost
- Manganese retained in limestone
No significant armouring of limestone with oxides and oxyhydroxides
No significant armouring of limestone with oxides and oxyhydroxides
Black precipitate in upper layer likely from monosulphides
Herbert Stream Remediation Trials
Limestone Leaching Bed
9 Aug 06
Armouring with ferric hydroxide
Herbert Stream Remediation Trials
Open Limestone Channel
9 Aug 06
Although no significant armouring of limestone in LLB, this system removed the greatest mass of contaminants.
Monosulphides in RAPS
Pathway to Pyrite

\[ 2\text{CH}_2\text{O} + \text{SO}_4^{2-} \rightarrow \text{H}_2\text{S} + 2\text{HCO}_3^- \]
Organic Carbon \hspace{1cm} Sulphate \hspace{1cm} Hydrogen Sulphide \hspace{1cm} Bicarbonate

\[ \text{Fe}^{2+} + \text{H}_2\text{S} + 2\text{HCO}_3^- \rightarrow \text{FeS} + 2\text{H}_2\text{O} + 2\text{CO}_2 \]
Ferrous Iron \hspace{1cm} Hydrogen Sulphide \hspace{1cm} Bicarbonate \hspace{1cm} Mackinawite Water Carbon Dioxide

\[ 3\text{FeS} + \text{S}^{2-} \rightarrow \text{Fe}_3\text{S}_4 \]
Mackinawite Sulphide Greigite

\[ \text{Fe}_3\text{S}_4 + \text{S}^{2-} \rightarrow 3\text{FeS}_2 \]
Greigite Sulphide Pyrite
Summary of Trials

• LLB, RAPS, OLC each capable of treating AMD to acceptable levels

   Effectiveness of OLC may be compromised if limestone becomes armoured with oxides and hydroxides

   OLC not feasible to construct at site (would require ~5km of open limestone channel)

• LLB simpler than RAPS, therefore full-scale LLB proposed for the site

   Although aluminium > iron, aluminium does not armour limestone and precipitates can be flushed from a leaching bed
Full Scale LLB Conceptual Design

Design
• 50 metres long, 25 metres wide, 2 metres deep
• 1000 m³ limestone (~40-70mm dia)
• Horizontal flow with vertical flushing capability
  perforated vertical pipes to induce horizontal flow
  network of perforated pipes at base for vertical flush
• Two settling ponds in series
• Holding pond capable of holding full volume flushed water

Operating Parameters
• 20 hour residence in system
• 20 hour residence in each settling pond
• 25 year life expectancy
• 100 m³ sludge accumulation per year (assumes 5% solids)