West Coast Coal and Gold Mine Drainage Workshop

CRL Energy Ltd | UNIVERSITY OF CANTERBURY Te Whare Wānanga o Waitaha CHRISTCHURCH NEW ZEALAND | UNIVERSITY of OTAGO Te Whare Wānanga o Otāgo | Manaaki Whenua Landcare Research

Introduction

A framework to assist with planning of future mine developments on the West Coast and in Southland is being developed as part of a collaborative research programme between CRL Energy, University of Canterbury, University of Otago and Landcare Research. This programme is focussed on preventing or minimising impacts to aquatic environments and combines information from several research areas including:

- Rock geochemistry and aquatic chemistry
- biological surveys
- aquatic toxicity experiments
- management, remediation and rehabilitation studies

The purpose of the workshop is to introduce the programme and present results from the first two years of research to potential end-users and other stakeholders. An additional aim of the workshop is to obtain feedback from end-users to ensure development of a relevant and applicable framework.

In detail, the research programme is split into 4 projects referred to as Objectives 1 to 4.

- **Objective 1** examines the geochemistry of rocks in mined areas and the chemistry of mine drainages.

- **Objective 2** identifies the biological affects and eco-toxicity of Mine Draiange.

- **Objective 3** examines the range and effectiveness of waste management and remediation options.

- **Objective 4** collects information from objectives 1, 2 and 3 and integrates these data with National and Regional resource management systems.

Results and interpretation from each of the four objectives will be presented today.

Programme

8:30 – 8:45	*Assemble – coffee*
8:45 – 9:00	Introduction and Research Programme Overview A. Clemens (CRL Energy)
9:00 – 9:30	Framework overview and potential application **Objective 4** J. Cavanagh (Landcare Research)
9:30 – 10:15	Coal and Gold Mine Drainage Geochemistry **Objective 1** J. Pope (CRL Energy) D. Craw (Otago University)
10:15 – 10:40	*Morning Tea*
10:40 – 11:25	Impacts on the aquatic environment **Objective 2** J. Harding (University of Canterbury) K. O'Halloran (Landcare Research) J. Cavanagh (Landcare Research)
11:25 - 12:00	Acid Rock Drainage Rehabilitation **Objective 3** J. Pope for D. Trumm (CRL Energy) R. Buxton (Landcare Research)

12:00 – 12:10	Integration of Objectives 1, 2 & 3 into a framework **Objective 4** J. Cavanagh (Landcare Research)
12:10 – 12:20	Questions or comments to the research team **Objectives 1-4**
12:15 – 12:35	Solid Energy Acid Rock Drainage Research P. Lindsay (Solid Energy)
12:35 – 2:00	*Cut Lunch Provided - Transport to Stockton Mine Site*
2:00 – 4:30	Field Trip to Stockton Mine including: **Objectives 1-3**

- Site Induction and Safety Briefing
  P. Rossiter

- Herbert Stream Trial Rehabilitation sites
  J. Pope and J. Harding

- Visit Stockton Capping Sites
  R. Buxton and P. Weber

4:30 – 5:30	Return to Westport

Workshop Notes

Objective 4: Development and application of a decision-making framework

By Jo Cavanagh and Tony Clemens

We are developing a framework to assist with the planning of future mine developments on the West Coast and Southland. This will focus on the prevention or minimisation of detrimental impacts on aquatic environments. The framework draws together the different strands of research being undertaken in this research programme including:

- geochemistry of rocks and streams in mined areas
- biological information from aquatic systems downstream of mines
- aquatic toxicity of mine drainage
- remediation and rehabilitation

A major aim of producing the framework is to present the research in a way that may be applied by end-users – industry, local councils, central government agencies (e.g. DoC), community, iwi. The involvement of these end-users is an essential aspect of the research programme.

The framework comprises a flow chart outlining a series of decision points, and supporting information. Supporting information includes the data (e.g. rock geochemistry, mine type) required and it's interpretation, to enable prediction of the likely impact of a given proposed mining operation on aquatic systems; and selection of management or remediation options should an 'unacceptable' level of impact be predicted. This information may also be used to manage existing mining operations, or select appropriate remediation options for historic mining operations.

The framework does not establish explicit 'acceptable' water quality criteria because these are likely to be different at different sites and because there are social, economic and cultural factors that may also influence decision-making. Instead the framework provides a robust scientific basis for this decision to be made by end-users during consultation on a proposed mining operation.

It is intended that the framework will provide consistency and transparency in decision-making in establishing water quality targets for proposed mining operations. Specifically it is viewed that the information provided in the framework will assist the resource consenting process such as during consultation (pre-application, pre-hearing), development of AEEs, and setting resource consent conditions. The framework may also be useful in developing future regional plans for water quality.

Objective 1: Coal and Gold Mine Drainage Geochemistry

By James Pope and Dave Craw

Data relating to mine drainage chemistry, stream chemistry and rock geochemistry for the West Coast and Southland have been digitised and compiled into a GIS database. Analysis of the dataset indicated that many streams with poor water quality had been identified in previous studies, but few thorough analyses of Mine Drainage chemistry had been made. So relationships between rock geochemistry, mining and water quality were poorly understood.

A sampling programme of Mine Drainages where downstream water quality problems had been identified was conducted in 2005. In some areas samples were also collected downstream and upstream of mining to improve understanding of attenuation processes and baseline stream chemistry, respectively. These additional datasets have been correlated with rock geochemical data, field observations and mine history/activity to identify factors that influence water quality downstream of mining.

On the West Coast, water quality problems relating to gold mining and coal mining are fundamentally different and interpretation of the dataset has been split to reflect these differences. Water quality problems that can occur in association with coal mining relate to pH reduction and elevated concentration of dissolved Iron (Fe), Aluminium (Al) and trace elements. In contrast, possible water quality issues from hard rock gold mining relate to elevated concentrations Arsenic (As) and sometimes Antimony (Sb).

Analysis of Coal Mine Drainage chemistry and rock geochemistry indicates that there are several risk factors that influence water quality downstream of mines including:

- regional geology
- mine type
- hydrogeology
- local geology

Similarly there are several factors that influence water quality downstream of gold mines, including:

- ore rock mineralogy
- ore processing method
- hydrogeology
- presence of As adsorption substrate (FeIII oxide/hydroxide minerals)

Objective 2: Impacts on the aquatic environment

By Kathryn O'Halloran and Jon Harding.

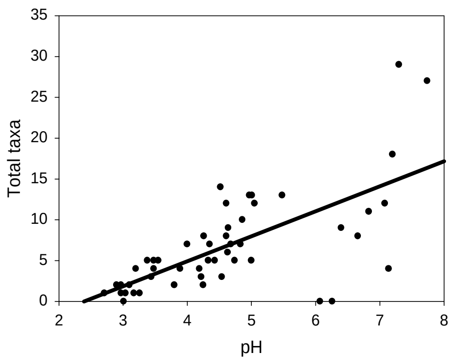
This objective aims to identify mine drainage impacts on the ecology of receiving freshwater ecosystems, and provide guidance on water quality conditions which might support aquatic life.

Numerous streams on the West Coast are already impacted by mine drainage from current and historic mining activities.

This objective will improve our understanding of the toxicity mechanisms underlying mine drainage impacts, and determine what processes are vital to the recovery of a system once impact management strategies are put into action (objective 3).

Mine drainage toxicity is a complicated by the complex relationship that exists between dissolved and precipitated metals (e.g. Fe, Al, Ni, As) and pH.

Field data has been collected at over 60 sites in order to determine levels of environmental impact on stream communities associated with different levels of mine drainage. Taxonomic richness was consistently low below pH 4.



Ninety six hour toxicity tests using different mine drainage waters are being conducted on representative species in an effort to tease out the key factors driving toxicity under different conditions.

Survey and toxicity information will be used to classify levels of impact that can occur under various conditions. This classification will enable industry and regulators to work together to select acceptable levels of impacts for a given ecosystem and will provide a defined end point for mining industry and regulators to agree upon prior to commencing mining activities.

Objective 3: Acid Rock Drainage Rehabilitation

By Dave Trumm

The aim of Objective 3 is to provide a methodology to prevent or minimise impacts to water quality from mining activities. Acceptable levels of water quality impact are determined by stakeholders using the data from Objectives 1 and 2.

Water quality targets are typically set by resource consent for a discharge point from a mine site, however it is up to mine operators to decide *how* to meet these targets. Objective 3 provides:

- Options for mine operators to meet targets
- Methods to select options
- Confidence that mine operators have ability to meet targets

Impacts from mining that we are investigating in this work include acid mine drainage (AMD) from coal mines and neutral mine drainage (NMD) containing elevated arsenic concentrations from gold mines. These impacts can either be addressed at the source through management of overburden stockpiles at opencast mines, or through water treatment downstream of the source. Various strategies for overburden management include: pre-mining stratagraphic analysis and planning, segregation and isolation of potentially acid forming rocks, covers and cementation, blending with neutralising material, and revegetation. Strategies for water treatment include active water treatment systems and passive AMD treatment systems.

To select among the spectrum of treatment options, critical parameters need to be identified and measured at the site and flow charts or selection keys can be used to choose potential solutions. We recommend that field trials be constructed to test the feasibility of potential solutions before full-scale implementation.

Field Trip Notes

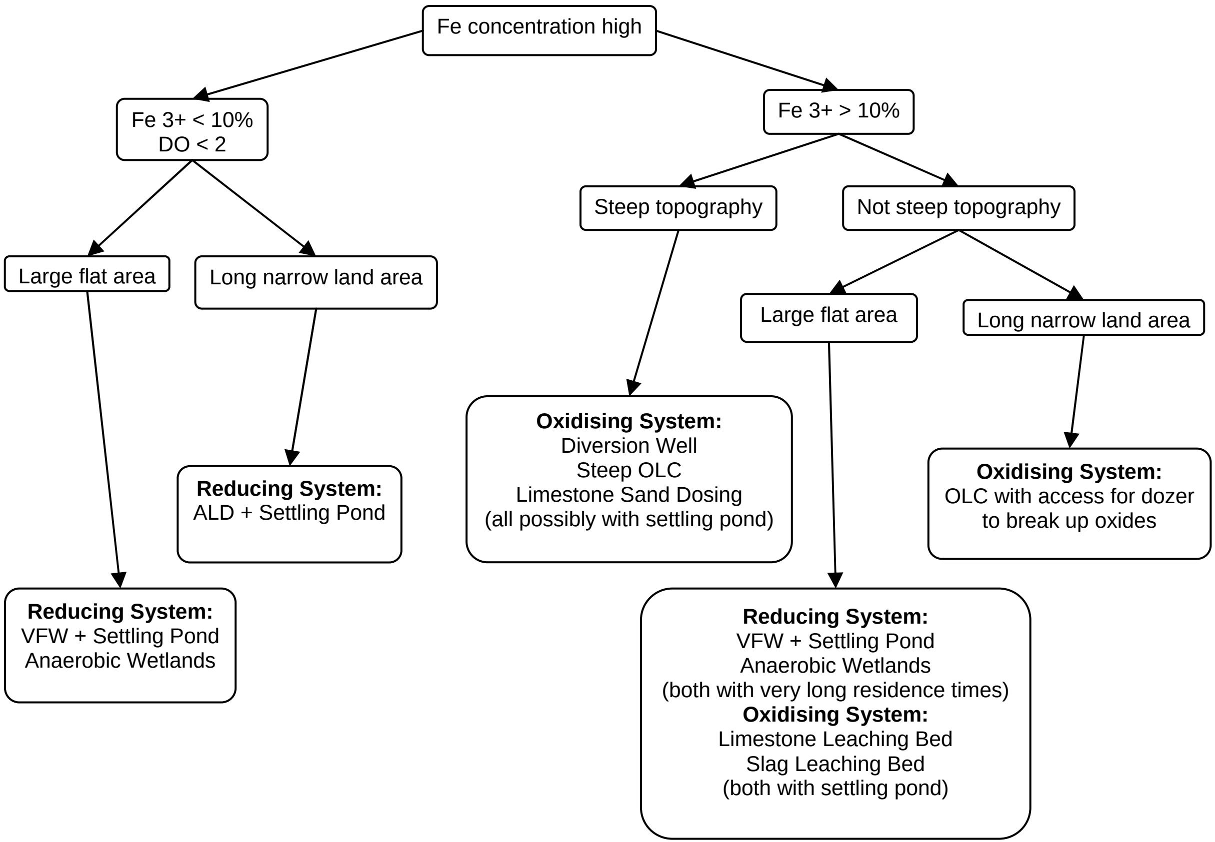
Herbert Stream

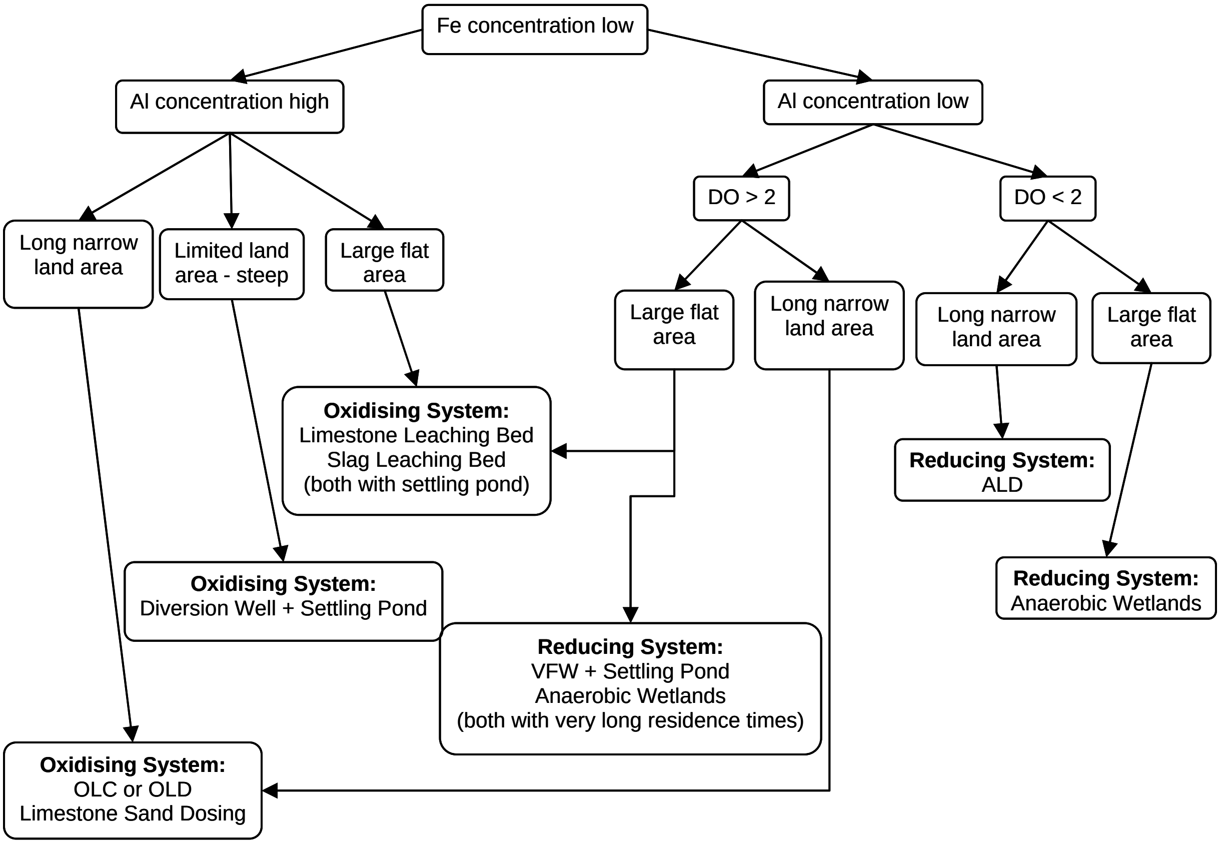
Choose potential AMD passive treatment systems which can be used to reduce the level of contaminants to acceptable levels in the Herbert Stream. The steps in this exercise involve using the parameters determined for the site (Table 1) in conjunction with flow charts and selection keys to choose potential systems which can be trialled at the site.

Table 1: Site characteristics at Herbert Stream

Parameter	Herbert Stream Characteristic	Comment
pH	3.2	
Dissolved Oxygen (mg/L)	9	
Flow Rate Range (L/s)	2.3 - 27	
Flow Rate Average (L/s)	5.3 (90% of time < 6)	
Iron - dissolved (mg/L)	3.7	low
Aluminium – dissolved (mg/L)	8.5	
Manganese – dissolved (mg/L)	0.7	
Dissolved Iron as Fe^{3+} (%)	88	
Available Land Area	Large low flat area available, steep cliffs and native forest along creek	

Flow Chart to use to Choose Among the Passive Systems (for low pH AMD). By Dave Trumm (CRL Energy)




Fe concentration low
Al concentration high
Al concentration low
Long narrow land area
Limited land area - steep
Large flat area
DO > 2
DO < 2
Large flat area
Long narrow land area
Long narrow land area
Large flat area
Oxidising System:
Limestone Leaching Bed
Slag Leaching Bed
(both with settling pond)
Reducing System:
ALD
Oxidising System:
Diversion Well + Settling Pond
Reducing System:
Anaerobic Wetlands
Reducing System:
VFW + Settling Pond
Anaerobic Wetlands
(both with very long residence times)
Oxidising System:
OLC or OLD
Limestone Sand Dosing

<u>Key to use to Choose Among the Passive Systems (for low pH AMD). By Dave Trumm (CRL Energy)</u>

1. Fe concentration high--2
   Fe concentration low---6
2. Fe^{3+}% low to high (10-100%) (see note 1 below)---3
   Fe^{3+}% low (<10%), DO <2 (see note 2 below)---5
3. Steep topography---Oxidising
   - Diversion Wells (possibly with settling pond)
   - Steep OLC (possibly with settling pond)
   - Dosing AMD with limestone sand (possibly with settling pond)

   Not Steep topography--4
4. Long narrow land available--Oxidising
   - Gentle OLC with access for doser to breakup rocks periodically (possibly with settling pond)

   Large flat area available--Oxidising or Reducing
   - Oxidising
     - Limestone leach bed with very coarse rocks and good flushing system+settling pond
     - Slag leach bed with very coarse slag and good flushing system+settling pond
   - Reducing
     - VFW with very long residence time in organic layer+settling pond
     - Anaerobic Wetlands with very long residence time (must design for accumulation of sludge)
     - Organic Bioreactor?
5. Long narrow land area available---Reducing
   - ALD+settling pond

   Large flat area available---Reducing
   - VFW+settling pond

- Anerobic wetlands

6. Al concentration high (see note 3 below)--7

   Al concentration low (see note 4 below)--8

7. Limited land area available, steep topography---Oxidising
   - Diversion wells+settling pond

   Long narrow land area available, steep or not steep topography-----------------------Oxidising
   - Open limestone channels
   - Dosing AMD with limestone sand

   Large flat area available---Oxidising
   - Limestone leach beds+settling pond
   - Slag leach beds+settling pond

8. DO <2--9

   DO >2--10

9. Long narrow land area available--Reducing
   - ALD

   Large flat area available---Reducing
   - Anerobic wetlands

10. Long narrow land area available--Oxidising
    - Open limestone channels / Open limestone drains
    - Dosing AMD with limestone sand

    Large flat area available---Oxidising or Reducing
    - Oxidising Strategy
      - Limestone leach beds
    - Reducing Strategy
      - VFW (but need long residence time at high DO)
      - Anerobic wetlands (but need long residence time at high DO)

Note 1:

- Treatment considerations:
- AMD highly oxidised
- $Fe(OH)_3$ readily precipitates if pH raised
- Oxidising strategy appropriate but must prevent armouring of limestone and must capture hydroxide precipitates. Primary concern is to remove Fe. If Fe remains prevalent throughout the remainder of the passive treatment system, performance will deline over time from armouring in conjunction with general hydraulic conductivity reductions from iron sludge deposition.
- If use reducing treatment strategy need to strip DO, reduce Fe^{3+} to Fe^{2+} prior to contact with limestone
- Add flume/holding pond prior to system

Note 2:

- Treatment considerations:
- AMD not highly oxidised
- Fe^{2+} will readily oxidise to Fe^{3+} upon addition of DO

Note 3:

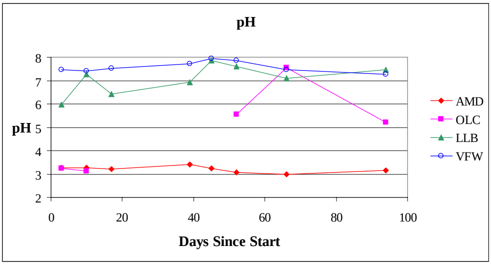
- Treatment considerations:
- Acidity in AMD mostly from pH and Al concentration
- $Al(OH)_3$ readily forms at a pH of about 6, however aluminium hydroxides geneally do not armour limestone to the same extent as iron hydroxides
- Oxidising strategy appropriate but must incorporate settling pond for storage of hydroxides

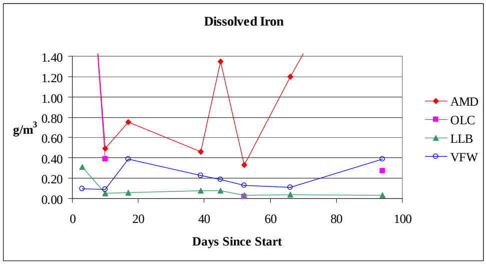
Note 4:

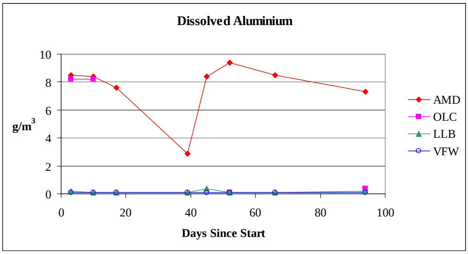
- Treatment considerations:
- Acidity in AMD mostly from pH
- Precipitation from metal hydroxides a minor concern

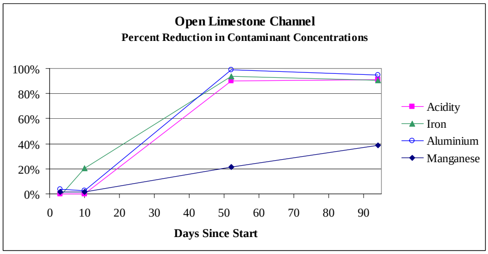
ALD = Anoxic Limestone Drain, OLC = Open Limestone Channel, OLD = Open Limestone Drain, VFW = Vertical Flow Wetland

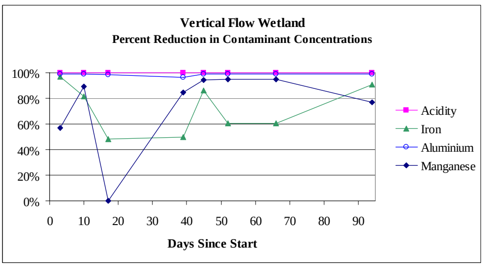
Data from Herbert Stream Trial Systems

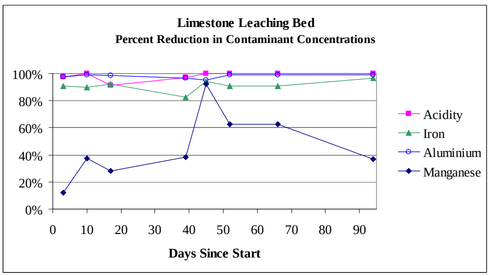












Mt Fredric Capping Site

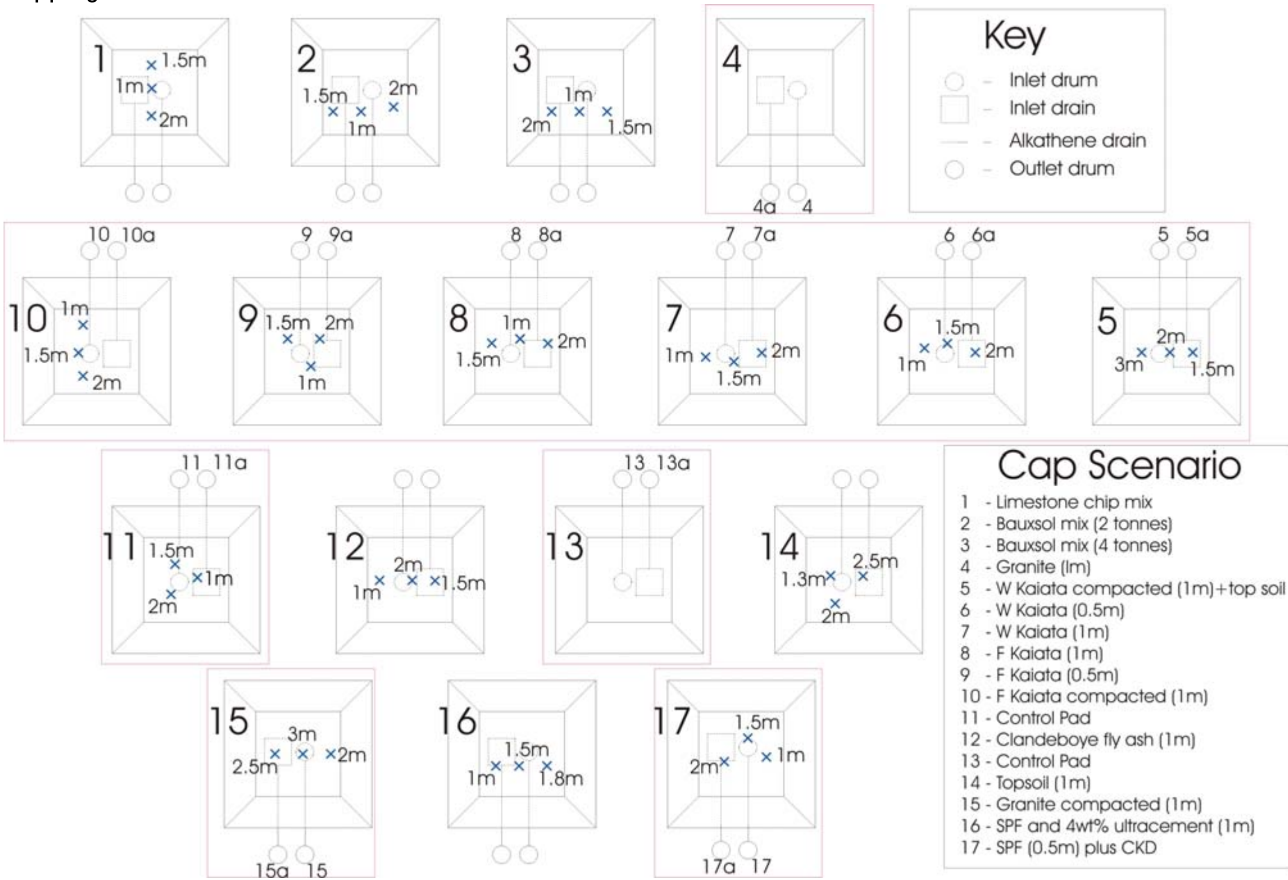
The Herbert Dam moss trials were set up in October 2003, along with two other sites at Mt Frederick and the Highwall above the Pyramids. Moss fragments, fertiliser and other material were hydroseeded onto the surface. The main points are that growth on sandstone is very slow compared with more fertile granite; steep slopes result in burial and erosion problems. Vegetative cover of up to 65% is possible in 18 months. The goal is to establish a stabilising cover that will reduce erosion and may limit infiltration into the pile.

Moss was hydroseeded on the Egypt capping trials in November 2005 primarily to see how well plants would perform on the different substrates. However, as SENZ had equipment in place to measure AMD through these piles, this presented an opportunity to see what effect, if any, a vegetation layer might have on water quality. Intact vegetation from the sandstone pavement was transported using the direct transfer method onto two of the caps to provide a fully vegetated comparison.

Pyramids 4 and 7 received direct transfer to the tops;

Pyramids 5, 7, 9, 12, 13, 15 and 17 all received hydro-seeding treatment.

Capping Trial Location Plan



Acknowledgements

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