

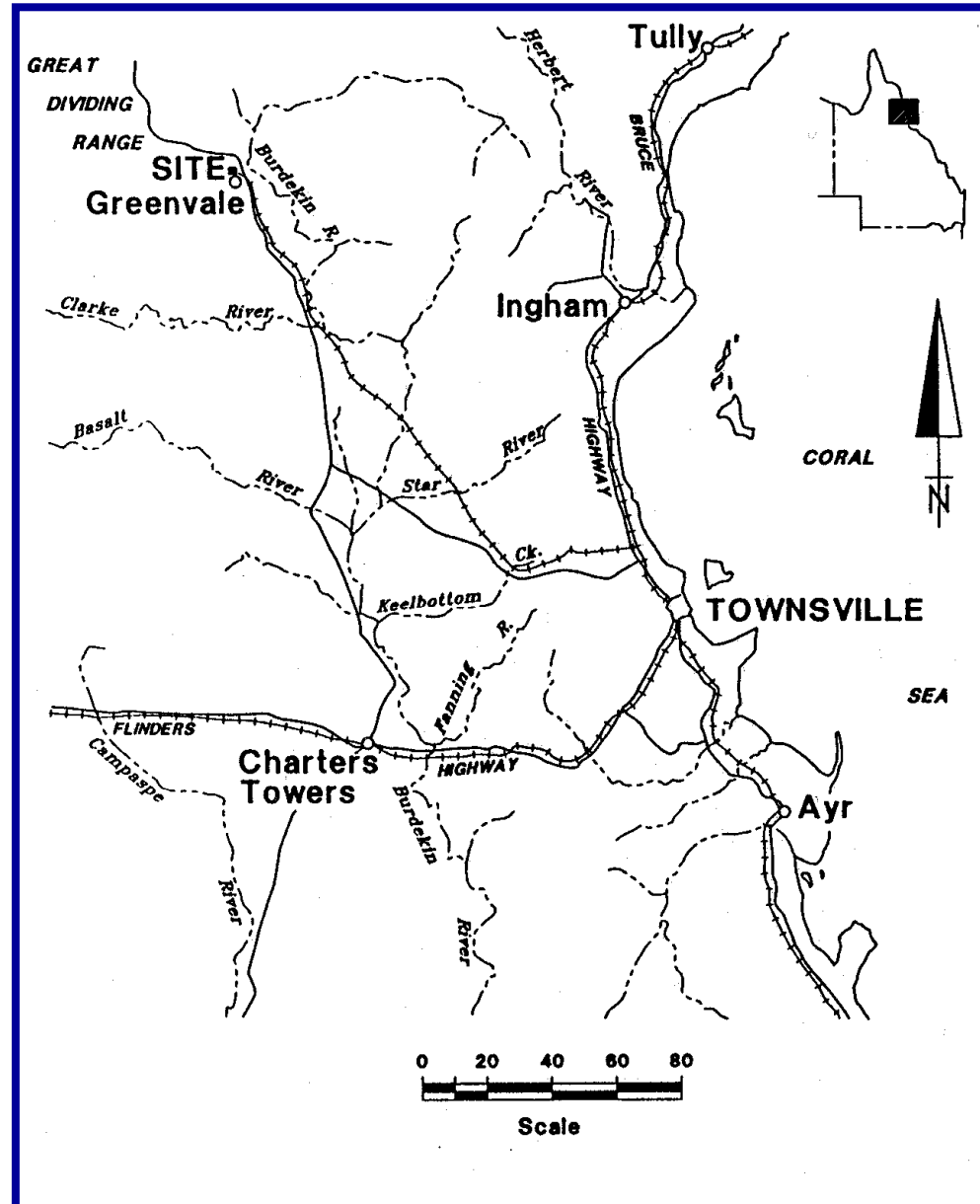
The Greenvale Nickel Mine

An Example of Innovative Mine Closure



Greenvale Nickel Mine - Background

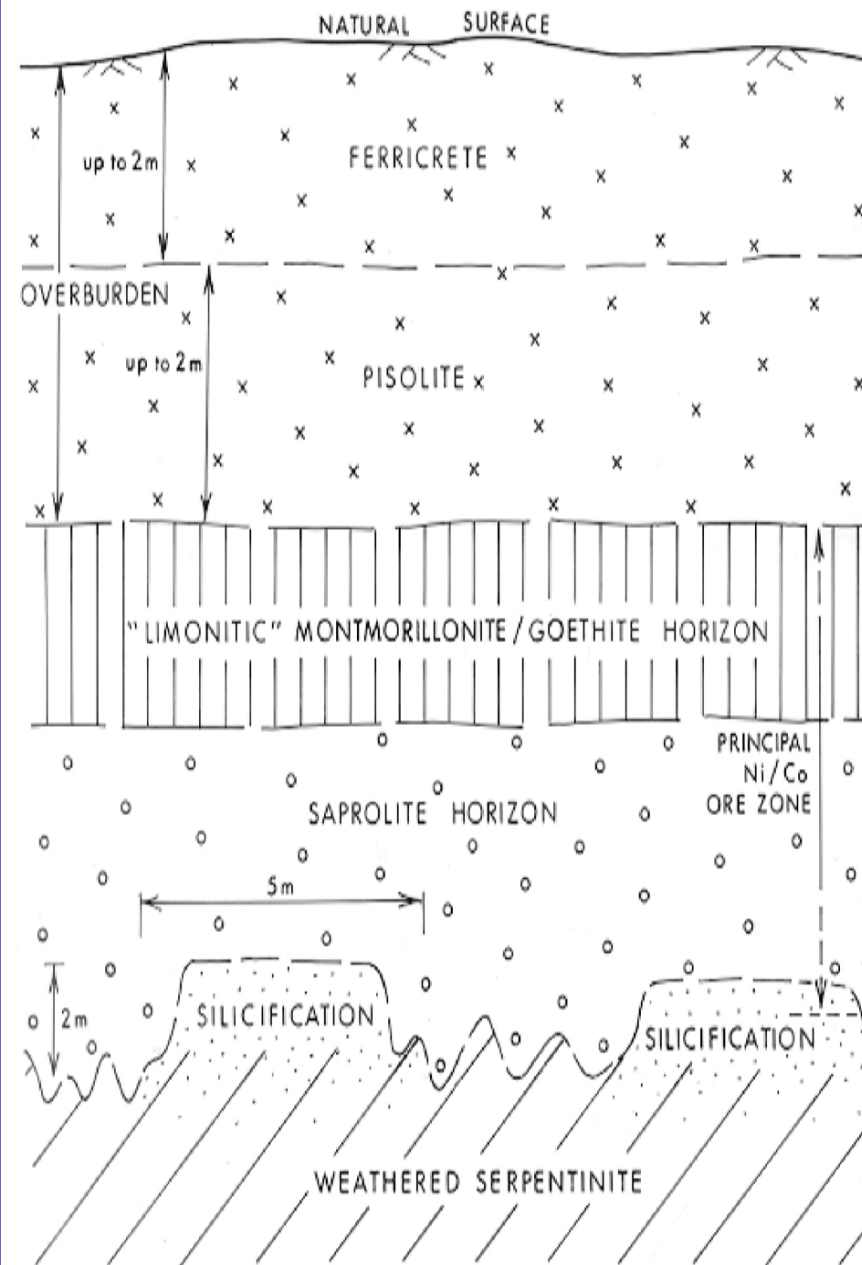
- Mined from 1970 to 1993 for nickel and cobalt
- Reserves of 40 million dry tonnes
- “Dry Tropics” - Annual rainfall 800mm, evaporation 2000mm





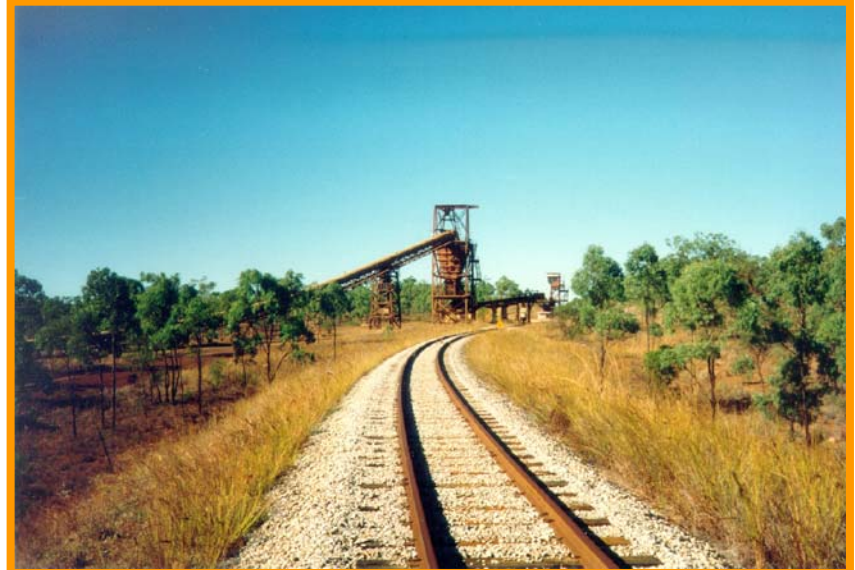
Greenvale Nickel Mine - Background

- Exposed ore drilled and blasted
- Draglines and excavators load broken ore to crusher and stockpile area
- Removal of overburden by conventional tractor/scrapper

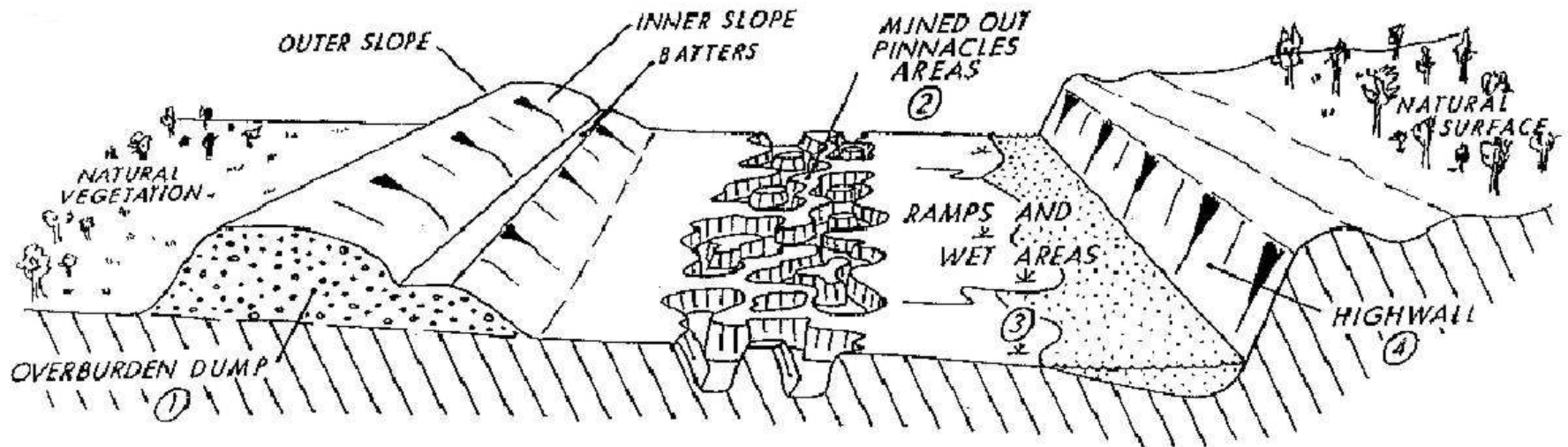


Greenvale Nickel Mine - Background

- Rejects to stockpile
- Bucket wheel stacker reclaimers loaded ore to rail cars
- Ore railed to Yabulu processing plant



Post Mining Landforms



Disturbed Footprint of Approx 553ha



15 Different Open Pit Areas



Pinnacles Within Mined Area



Highways





Nine Major Overburden Dumps - Outer Batters



Overburden Dumps - Erosion Features



Internally Draining



Significant Mine Infrastructure

- Crusher
- Switchyard
- Mine Office
- Ore Loaders
- Railway Line
- The Greenvale Township



Mine Rehabilitation - Authority Goals

- Comply with the Greenvale Agreement Act (1970)
- “There shall be no abnormal batters”
- “There shall be a minimum of interference with the natural drainage system except and unless it is found beneficial to use any mined area for the storage of water”
- “There shall not arise any pollution of any drainage system which is dangerous or injurious to health”
- “The companies shall take competent advice as to what steps are possible to promote regeneration of vegetation and shall progressively promote such regeneration to the satisfaction of the Minister”

Mine Rehabilitation - Land Owner Goals

- Preserve all water holes created by mining
- Plant pasture grasses and stylos in preference to native trees
- Leave unwanted buildings intact
- No requirement for highwall fencing or bunding

Mine Rehabilitation - QNI Goals

- To be a good “corporate citizen”
- To ensure that rehabilitation works will have a direct benefit to the site - “best bang for your buck”
- To develop a detailed scope of work
- To obtain approval/acceptance of this scope of work from the authorities
- Define a budget price for the works (before construction commenced) that can be managed
- To establish rehabilitation goals, with key measures, as the basis for site relinquishment

Rehabilitation Approach - Key Elements

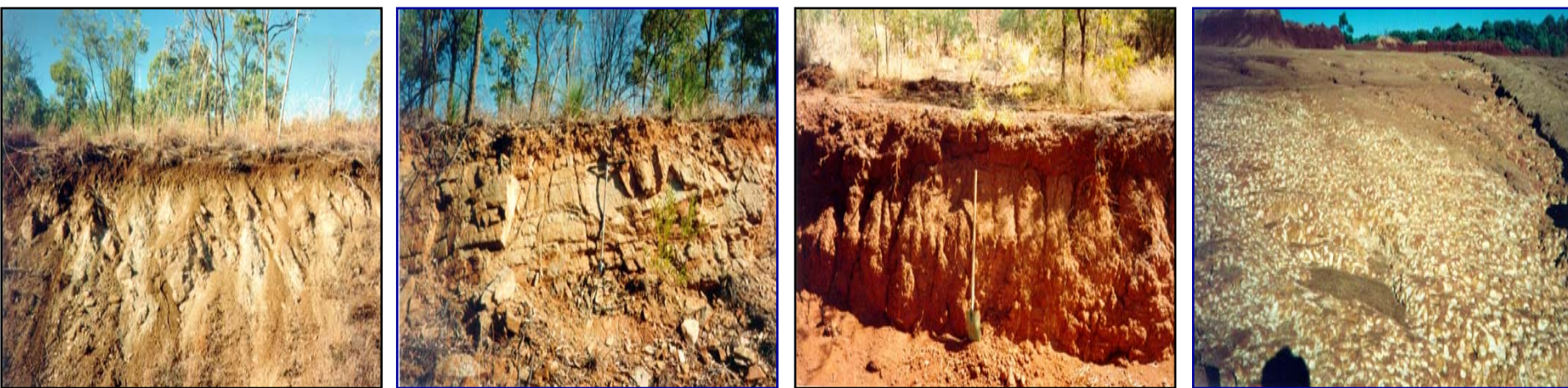
- Define **pre mine** land use
- Target **post mine** land use
- **Research** rehabilitation techniques
- **Consultation** with stakeholders and authorities
- Develop appropriate rehabilitation **techniques**
- Manage and monitor the **implementation** of the works
- **Monitor** the performance of the works
- **Demonstrate** that site performance meets rehabilitation targets as the basis for relinquishment of the site

Define Pre-Mine Land Use



Pre-Mining Land Use

- Land suitability assessment - based on grazing potential and utilising historic aerial photography and previously published studies



- Five Classes

- ▶ Slope of land
- ▶ Rockiness of land
- ▶ Effective soil depth
- ▶ Surface crust strength
- ▶ Erosion potential
- ▶ Nutrient deficiency

Land Suitability

- **Class 1:** *Highly productive land* - requiring only simple management practices
- **Class 2:** *Suitable with minor limitations* - requiring more than simple management practices
- **Class 3:** *Suitable with moderate limitations* - lower production
- **Class 4:** *Marginal land* - unsuitable due to severe limitations
- **Class 5:** *Unsuitable* - extreme limitations preclude use

Land Suitability Assessment

- Majority of site characterised by steep slopes, shallow soils, rock outcrops and dense Lancewood, which was considered to be unsuitable for grazing
- Major drainage lines dominated by red earths, native trees and grasses. Limitations on beef grazing use due to soil erodibility, surface condition, rockiness and rock outcrops
- Mid slopes and footslopes on structured red earths, suitable for grazing
- Variable colluvial/alluvial fans adjacent to major drainage lines suitable for grazing

Target Land Suitability - Pre Mining



Target Post Mining Land Use

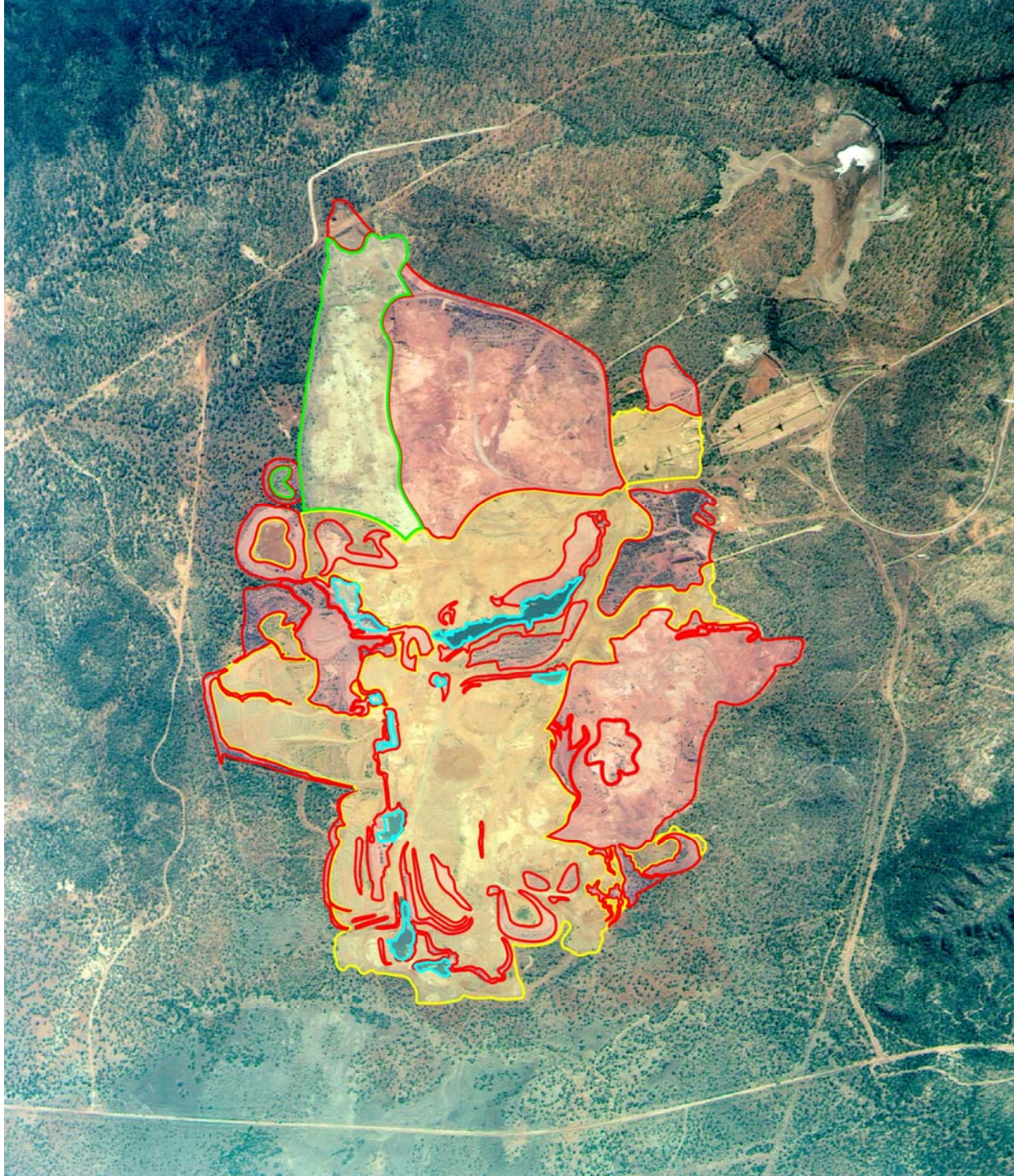
Aim to provide at least the same quantity (and quality) of grazing land that was available prior to mining

To recognise that significant areas of the site were not suitable for grazing prior to mining

To provide stable landforms

To recognise the benefits of stock watering points in assessing available land use

Target Land Suitability - Post Mining



Research of Rehabilitation Techniques

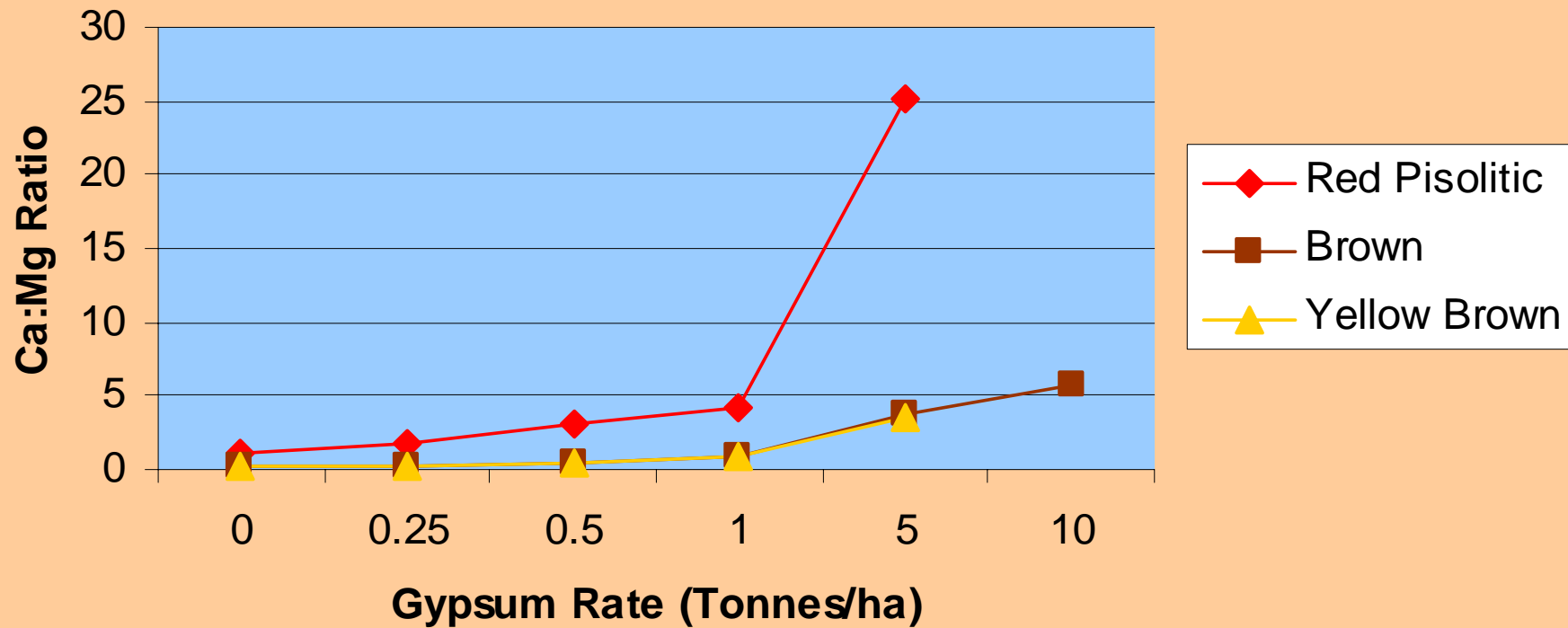
- Poor soil conditions were a major limitation on revegetation potential and lease relinquishment
- **Investigation of soils:** using the overburden as a vegetation growing medium
- **Physical properties:** “crusting” problems - no infiltration of water, increased run off, lack of soil moisture to support vegetation.
- **Chemical properties:** lack of nutrients

Soil Crusting

- Related to both the low organic matter content and low calcium which result in a severe Ca:Mg imbalance
- $\text{Ca:Mg} < 2$ indicates potential structural problems
- Ca:Mg up to 5 is desirable for vegetation growth
- Trials to assess dosing rates of gypsum to ameliorate soils - up to 10 tonnes/ha

Laboratory Test Results

Gypsum Application Rate



Soil Nutrients

- Various overburden substrate types
- Analysed for nutrients and trace elements
- Extreme deficiencies in nitrogen, phosphorous, sulfur and calcium
- Fertiliser selected to build up sufficient nutrients to establish a vigorous grass cover

Soil Amelioration

- 2.5 tonnes of gypsum per hectare
- 500kg/ha of fertiliser per hectare
- Blanket application rates to overcome variations in overburden characteristics across the site - also reduces the complexity of the operation

Consultation with Stakeholders / Authorities

- Ongoing consultation with authorities through legislative requirements for EMOS, Plan of Operations and Mine Closure Plans
- Discussion with authority and landowner from first rehabilitation works in 1992
- Site meetings in July and August 1994 to discuss strategy of future rehabilitation works
- Site inspections during rehabilitation works to discuss progress and extent of works
- Site inspection at completion of the works
- Site meeting to discuss proposed monitoring programme



Develop Suitable Rehabilitation Techniques

- **Reprofiling** of disturbed areas
- **Control of surface water** - target areas comprising fine, erodible soil, long slope lengths and history of erosion
- **Detention banks** - store water from small rainfall events to provide soil moisture for vegetation growth
- **Contour drains** - drains with limited fall to control erosion and divert water away from main slopes
- **Main drains** - rock lined drainage structures to collect and discharge water to drainage basins or water pits
- **Rock lining batters**



Reprofiling of Disturbed Areas



Control of Surface Water

Detention Banks

Contour Drains



Main Drains





Rock Lining of Batters



Develop Suitable Revegetation Techniques

- Gypsum spreading - 2500kg/ha
- Deep ripping
- Fertiliser application - 500kg/ha
- Pasture seed - 40kg/ha
- Harrowing
- Hand broadcast native seed - 1.5kg/ha
- Plant tubestock - slow release fertiliser, straw and watering
- Native seed to rip lines - 4.0kg/ha
- Haymulch - 500bales/ha plus 2,000L/ha emulsion

Gypsum and Fertiliser Spreading



Deep Ripping



Pasture Seed and Harrowing





Plant Tubestock





Haymulch



Implementation of Rehabilitation Works

- Specialist contractors for earthworks and revegetation
- Full time supervision by URS
- Attention to drainage details, in particular inlet and outlet works



Implementation of Rehabilitation Works

- Survey and set out for earthworks, drainage works, extent of various treatments
- Survey of works for measurement and payment
- Testing of works - Eg compaction of earthbunds, calibration of gypsum, fertiliser and seed application rates, check material deliveries





Dump 7 - Reprofile & Rock Line Outer Batters



Dump 7 - Detention Banks



Dump 7 - Revegetation Treatments



Dump 7 - Post Construction

Monitoring of the Works

- Prepare detailed monitoring procedures
- Establish criteria to be achieved
- Select representative monitoring sites in consultation with authorities
- Document monitoring results
- Implement maintenance works if and when required.


Rehabilitation Criteria

- **Land suitability** - compare land suitability to selected “control” sites
- **Landform stability** - batter stability, headwall retreat or gully growth, rill/gully
- **Vegetation** - cover of grass and trees (% groundcover), soil loss to be consistent with land suitability criteria
- **Water quality** - ANZECC stock water quality requirements
- The rehabilitation works are sustainable

Land Suitability Control Sites

- 17 land suitability stations established - 1m wide by 50m long
- 6 control sites established for use as a reference - two sites from each of Class 3, 4 and 5.
- Control sites inside the mine lease boundary but outside the project area fence (ie grazed)
- Control sites inside the project area fence (ie not grazed)
- Grazed control sites used as the baseline condition for rehabilitation success as grazing on suitable areas is the target post mining land use

Landform Stability

- 
- **Waste dump batters** - no history of instability- 3 sites selected, visual observations (cracks or bulging), measurement of slope indicators
 - **Headwall retreat** - 8 sites selected, target selected drainage lines and gullies, install gauge at head of gully, measure gully “growth” over time
 - **Rill/gully erosion** - 4 sites selected, measure average width, depth and length of rills(<300mm deep) and gullies (>300mm deep). Estimate soil loss per hectare and compare to DME threshold guideline of 40 tonnes/ha/year (4 to 23 measured)

Vegetation Monitoring

- Target vegetation cover for Class 3 and 4 of 85% of pasture cover at control sites
- Target vegetation cover for Class 4 and 5 of 85% of tree density cover at control sites
- All sites achieved or exceeded the criteria, some sites achieving a higher land suitability class
- Maintenance work identified across the site by comparing areas to monitoring sites
- Mapping of minor outbreaks of Calotrope or Parthenium - treatment during monitoring programme - no major outbreaks

Monitoring Station 5

January 1995



February 1995



March 1995



Monitoring Station 14

January 1995



February 1995



March 1995



Monitoring Station 16

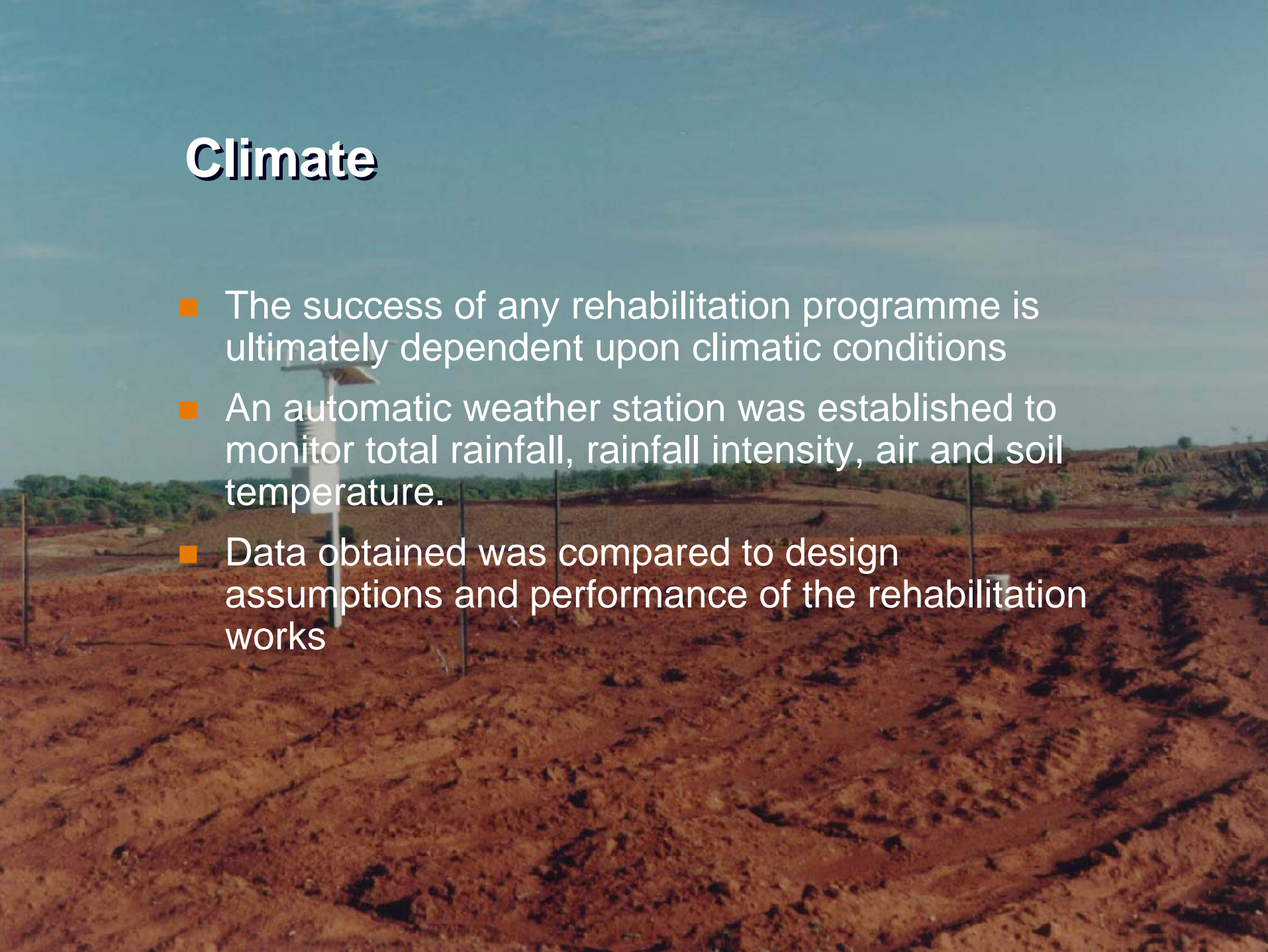


Water Quality

- Surface water sampling programme conducted since 1990
- 4 sites monitored since 1990 - ANZECC stock water quality standard achieved since 1990

Climate

- The success of any rehabilitation programme is ultimately dependent upon climatic conditions
- An automatic weather station was established to monitor total rainfall, rainfall intensity, air and soil temperature.
- Data obtained was compared to design assumptions and performance of the rehabilitation works



85 Pit - March 1993



85 Pit - April 1995



Greenvale - Successful Mine Rehabilitation

Dump 9 - March 1994



Dump 9 - March 1995

