

Vegetation Research for Closure and Reclamation of the BHP Billiton Diamonds Inc. EKATI Diamond Mine

BHP Billiton Diamonds Inc

Northern Latitudes Mining Reclamation Workshop
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Vegetation Research for Closure and Reclamation of the EKATI Diamond Mine

PRESENTATION OUTLINE

- Mine Setting
- Mine Components
- Reclamation Goal
- Soil and Plant Materials
- Revegetation Research
 - Progressive Reclamation
 - Research Studies
 - On-going Studies

Mine Setting



Location

- Low Arctic Tundra
- Approximately 300 km NE of Yellowknife

Landscape

- Flat to moderately rolling
- Boulder fields
- Eskers
- Numerous kames and lakes
- Till blankets
- Poorly developed soil
- Active Layer
 - Organic rich soil: 30 to 40 cm
 - Coarse-textured soils: > 2m

Vegetation

- Uplands: Ericaceous shrubs and lichens
- Riparian: Willow, emergent wetland and tussock tundra



Climate

- Continental Climate
 - Cold long winters (-10° to -30° C)
 - Short relatively warm summers (10° to 20° C)
- Precipitation: approx 300 mm, half as rain
- Short growing season: 10 to 12 weeks

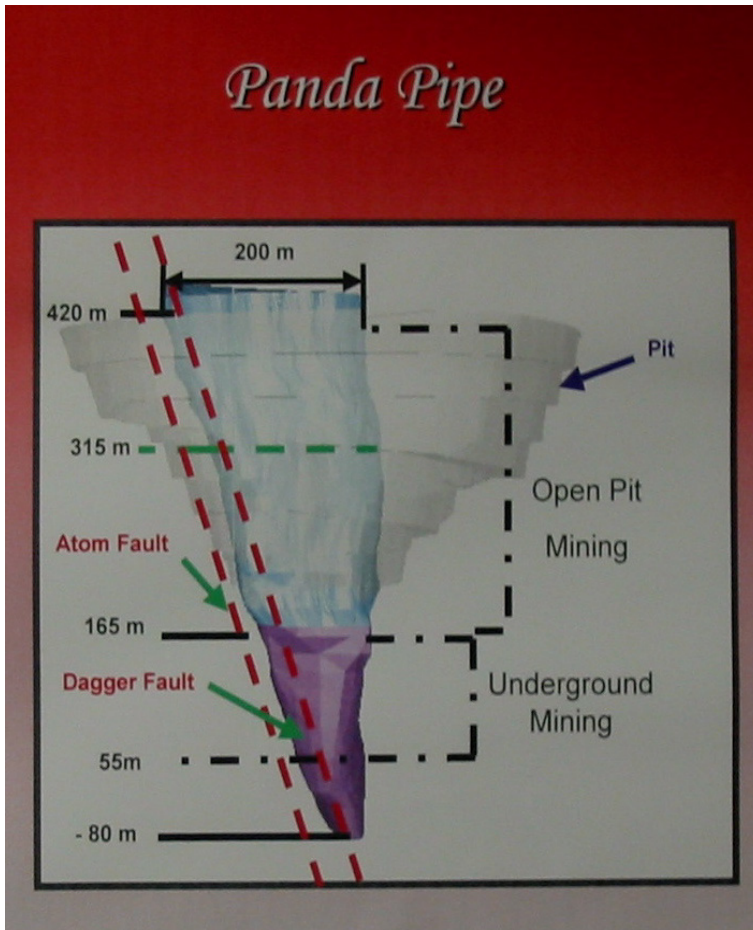
Mine Component Groups



1. Open Pits
2. Underground Mines
3. Waste Rock Storage Areas
4. Processed Kimberlite Containment Area
5. Dams/Dykes/Channels
6. Buildings & Infrastructure
 - Camp pads
 - Laydown areas
 - Airport esker
 - Roads

Reclamation Goal

To return the EKATI Mine site to viable, and wherever practicable, self sustaining ecosystems that are compatible with a healthy environment, human activities, and the surrounding environment.



Topdressing Materials

- Topsoil (TS)
 - Lake Sediment (LS)
 - Glacial Till (GT)
- Primary source: pit development.

TS, LS and GT:

- Limited supply
- Apply as topdressing to selected areas

Processed Kimberlite

- Deposited in the LLCF
- Revegetate selected areas

Plant Materials



- Native Grass Cultivars
 - Available seed
 - Primary plant cover
 - Surface stabilization

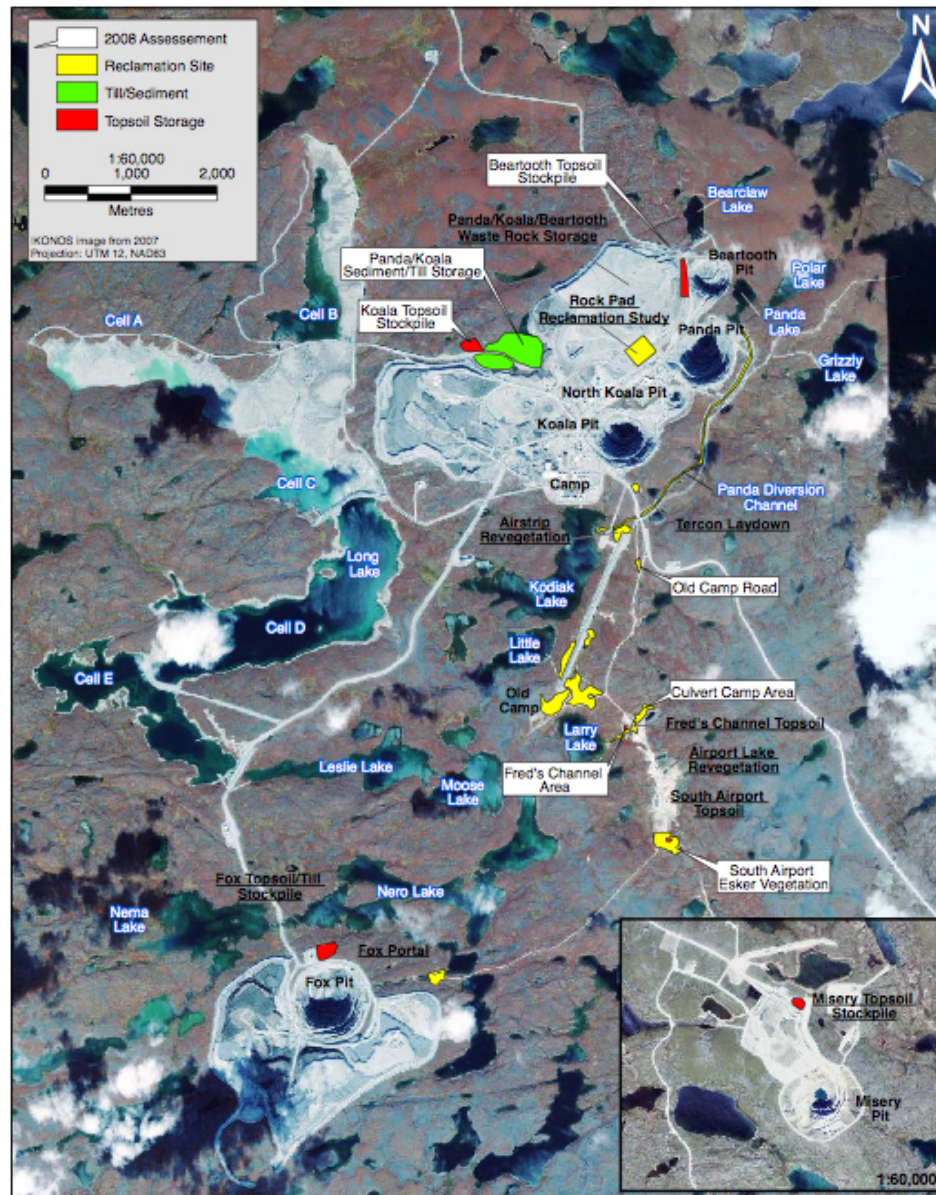
- Local herbs, shrubs and grasses
 - Natural colonization
 - Apply seed, seedling plugs, cuttings, sprigs, sod transplants

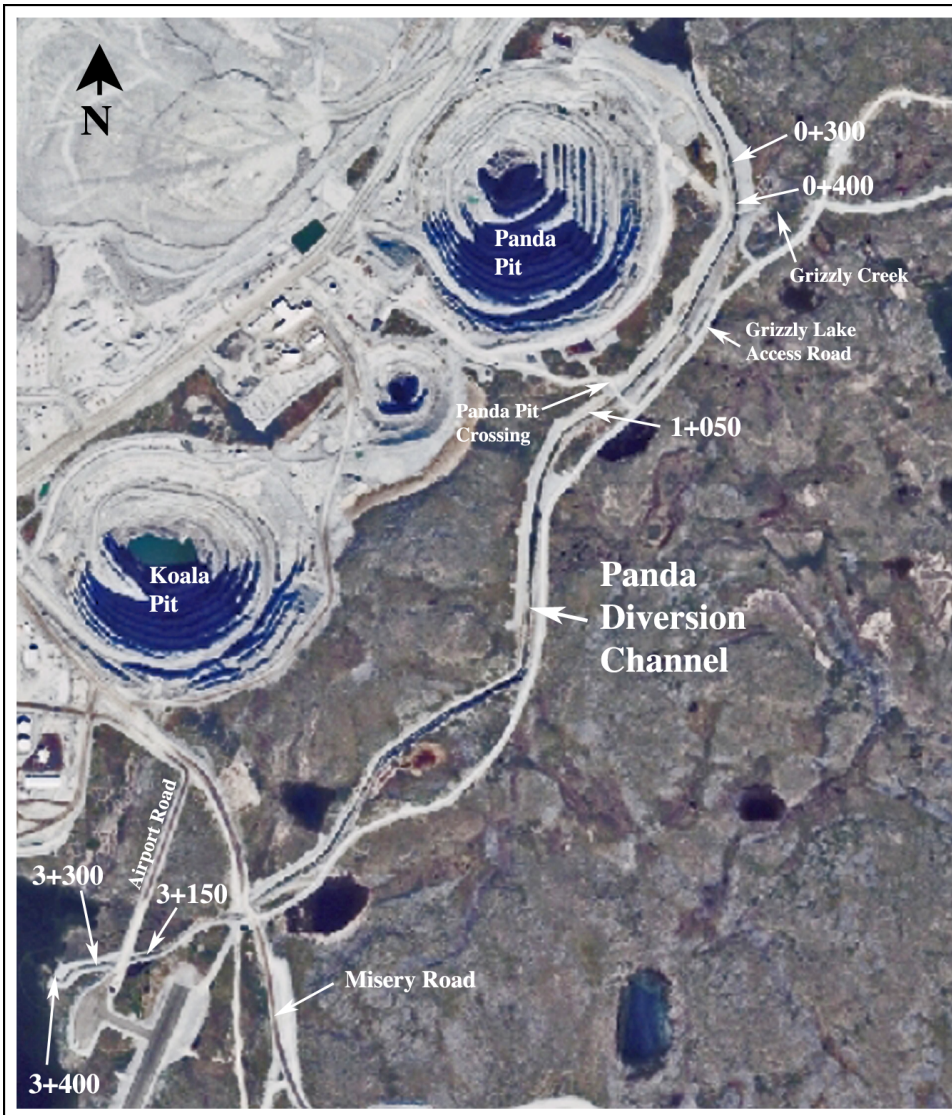


Topdressings/Substrates

Physical and Chemical Characteristics

Parameter	Topsoil	Glacial Till	Lake Sediment	Processed Kimberlite
Gravel (%)	8 - 30	28 - 33	10 - 26	0
Sand (%)	37 - 55	42 - 64	26 - 54	83
Silt (%)	12 - 36	3 - 24	16 - 50	10
Clay (%)	7 - 14	1 - 5	3 - 13	7
Erosion Risk	Low to Moderate	Low to Moderate	Low to Moderate	Moderate to High
pH	4.5 – 6.0	4.5 – 8.0	4.1 – 8.1	7.8
E.C. (dS/m)	< 0.5	< 0.8	< 0.7	4.5 Decreasing with depth
Organic C (%)	1.0 – 3.7	0.10 – 0.46	0.14 – 0.27	0.5
C.E.C. (me/100g)	3 - 12	1 – 10	4 – 7	36
Available Nutrients	Low	Low	Low	Low
Trace Metals	N/A	N/A	N/A	Ni, Cr, Mg





Panda Diversion Channel

Selective application of plant material targeting areas with soil fines (1998-2001)

- Willow cuttings & grass sprigs along shoreline
- Native grass cultivars, forbs & legumes seeded along channel side slopes
- Rock features were placed to simulate and facilitate development of natural stream habitat



PDC 0+300 – Fireweed and Licorice Root



PDC 0+400 – Arctic Pendant Grass



PDC 1+050 Willows, Native Grasses



PDC 3+150 Willows, Native Grasses



PDC 3+300 Native grasses



PDC 3+400. Pendant Grass, Kodiak Lake outlet

Panda Diversion Channel Results - 2006

- Diamond-leaf willow cutting survival: 4% to 92%; Mean survival - 64%
Grazing by Arctic hare reduced survival in early plantings
- Arctic Pendant Grass: Successful establishment in soil fines
- Fireweed, Licorice root, locoweed, elegant milkvetch well established and producing seed
- Native grass cultivars established and colonizing adjacent areas with soil fines
- Natural colonization: 41 vascular and 6 non-vascular species
Increase of 9 vascular species between 2002 - 2006

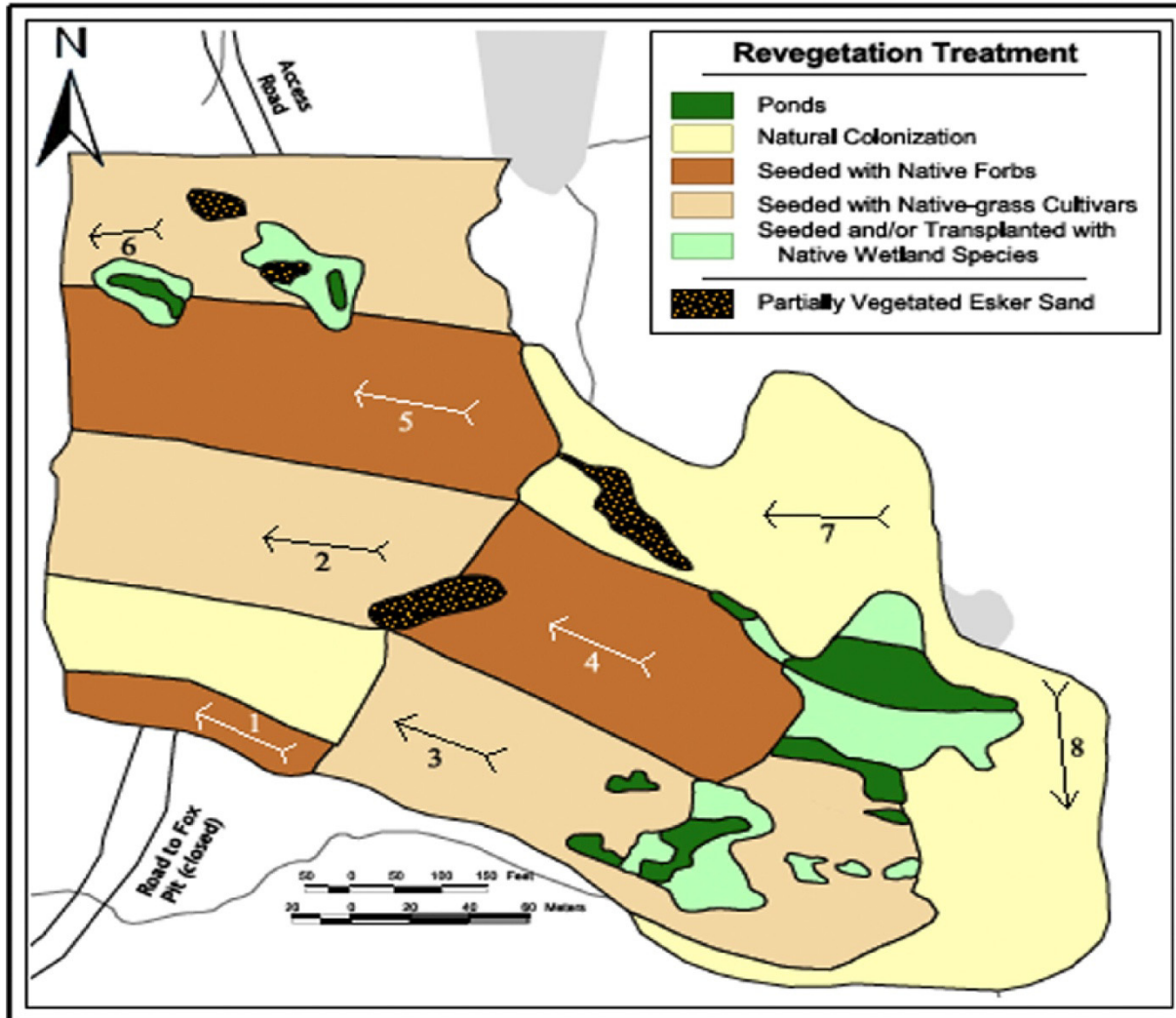


Airport Esker

- Site Reclamation: began in 1999
 - Recontoured 7.4 ha
 - Glacial till substrate
 - Created several depressions
 - Large boulders pulled back and randomly scattered on area to create roughness and blend in with adjacent landscape

- Revegetation Treatments - 2002
 - Native forbs (licorice root, reflexed locoweed, fireweed)
 - Native grass cultivars (alpine bluegrass, tufted hairgrass, spike trisetum)
 - Rooted seedlings - 2004
 - 110 dwarf birch
 - 60 blueberry

Progressive Reclamation



Airport Esker

Revegetation Treatments 2002

Progressive Reclamation

Airport Esker - Mean Percent Plant Cover - Year 4 (2006)

Component	Seeded Treatment		
	Native Forbs	Native Grass Cultivars	Control
Graminoids	Trace	9.7	0.7
Herbs	Trace	0.2	0
Shrubs	2.2	1.5	3.4
Total Vascular Cover	2.2	11.4	4.1
Total Non-Vascular Cover	7.5	9.8	5.1
Total Live Cover	9.7	21.2	9.2

Seedling Plugs

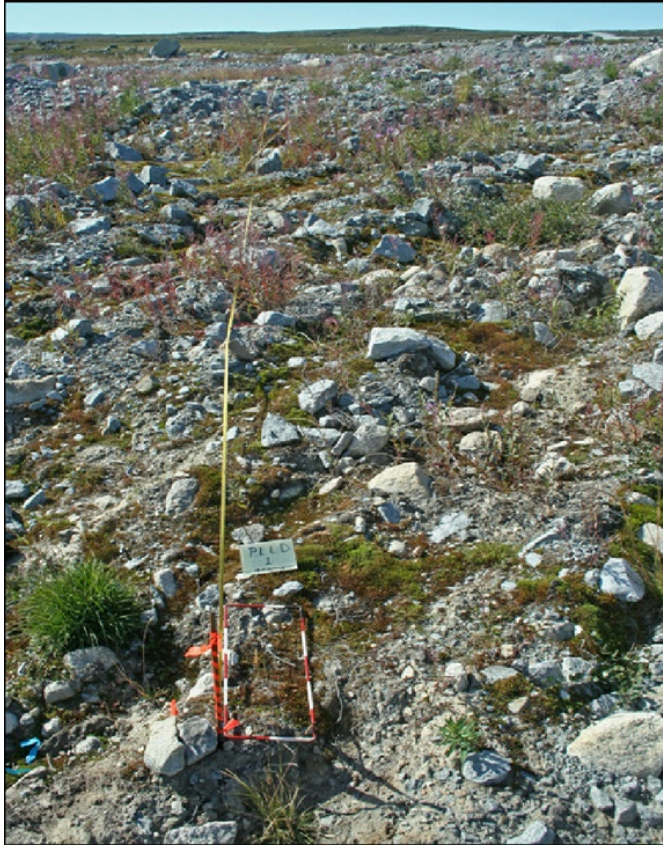
Survival constant since 2005

- Dwarf birch - 72%
- Blueberry - 94%

Transplants

- Riparian - poor, ponds mostly dry
- Upland - good

Progressive Reclamation



Paul lake Laydown Area - 2006

- Rock Pad removed in 2000
- Deep ripped
- Light seeded native grass cultivars and forbs, and fertilized in 2002



Tercon Laydown Area - 2006

- Granular pad ripped in 2002
- Seeded native grass cultivars and fertilized in 2002

Fox Portal - 1995

Objective: Assess the ability of different plant materials to establish and grow on different topdressings

Topdressings: Esker sand, lake sediment, organic topsoil (Organic Carbon - 4.3%, CEC - 16)

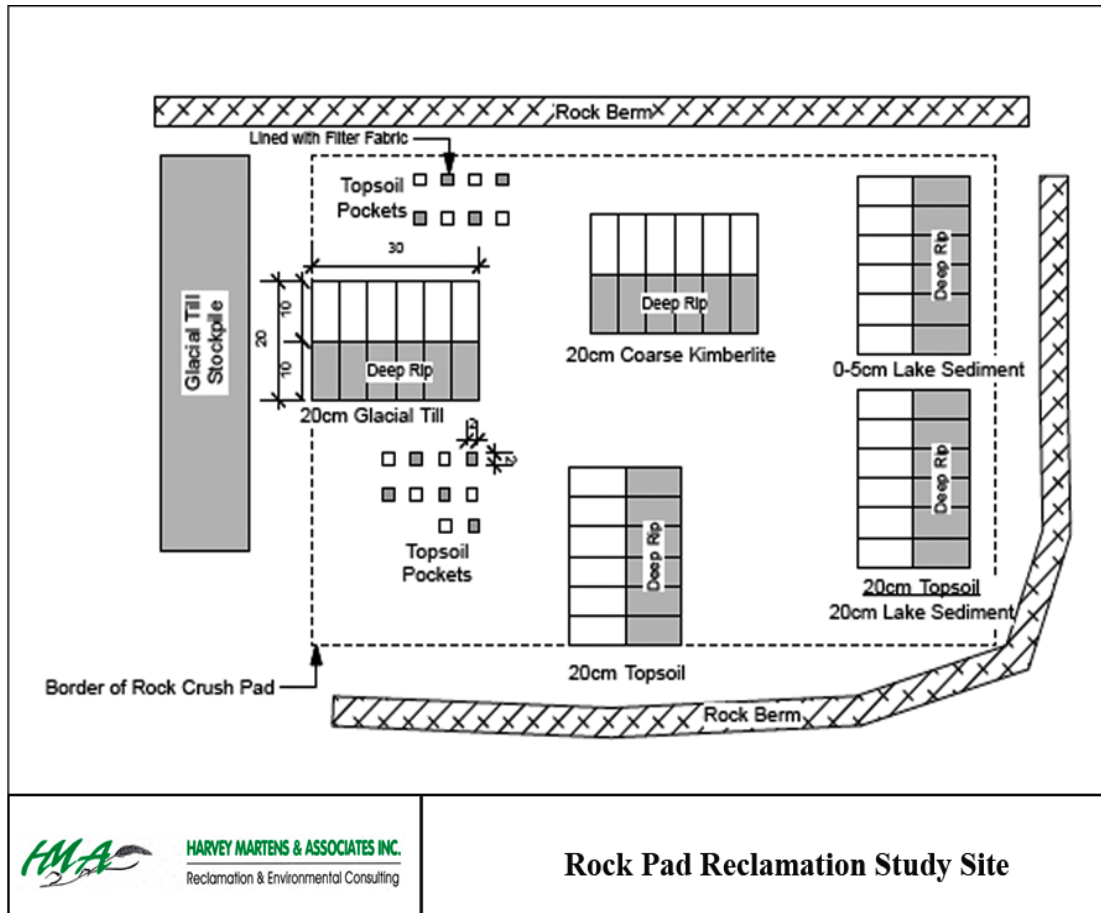
- Four replicate blocks
- Fertilizer @ 400 kg/ha (8-32-16 NPK) in 1995 and 1997
- Revegetation treatments
 - Native grass cultivars (tundra bluegrass, alpine bluegrass, Polar grass, Arctared fescue)
 - Native forb seeding (alpine milk-vetch, viscid oxytrope, wormwood)
 - Native grass/shrub mix (Lab. Tea, alpine azalea, alpine holy grass)
 - Native shrub cuttings

Findings - 2006

- Organic topsoil: supported favourable growth and colonization
- Lake sediment and esker sand: unfavourable for plant growth
 - Coarse texture
 - Low nutrient and moisture holding capacity

Rock Pad Revegetation Research - 2008

Objective: Assess the ability of different plant materials to establish and grow on different topdressings



Topdressings

- 20 cm topsoil
- 20 cm topsoil/20 cm lake sediment
- 20 cm glacial till
- 0-5 cm lake sediment
- 20 cm coarse kimberlite reject

Surface roughening - deep ripping

Topsoil Pockets - grid pattern

- 2m x 2m x 0.5 m

Revegetation Treatments (6)

- Native grass cultivars
- Forbs: locoweed, licorice root, fireweed
- Shrubs: dwarf birch, crowberry, bilberry
- Seedling plugs
 - Spring actively growing
 - Fall and spring dormant stock
- Sod transplants

Rock Pad Revegetation Research - 2008

Plot Construction



Spreading topsoil topdressing



Topsoil plot after deepripping

Plot Construction



0-5 cm lake sediment top dressing

Rock Pad Revegetation Research - 2008

Plot Construction - Topsoil Pockets



Fabric lined pocket



Pockets filled with topsoil

Revegetation Research

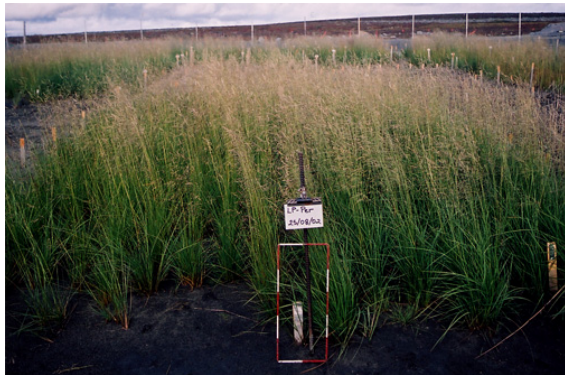
Long Lake Containment Facility



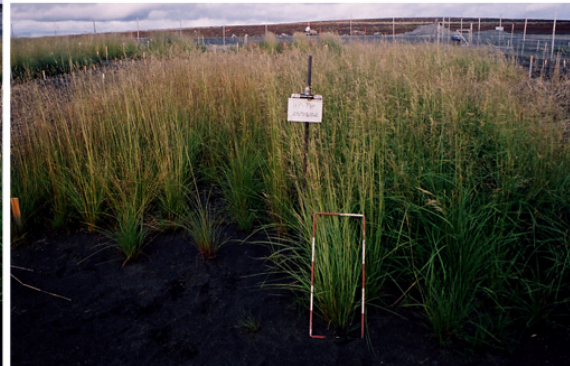
Aerial view of Cell B, 2007

Revegetation Research - LLCF 2000 - 2007

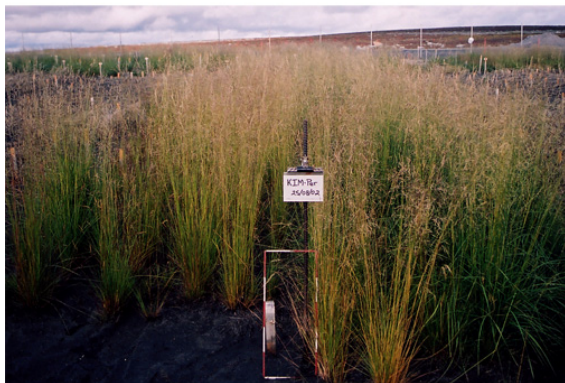
Objective: Determine whether the LLCF could be stabilized with vegetation cover instead of a rock cover as originally proposed



Low Peat Perennial



High Peat Perennial



Kimberlite Perennial



Kimberlite Annual

Year 3 (2002)

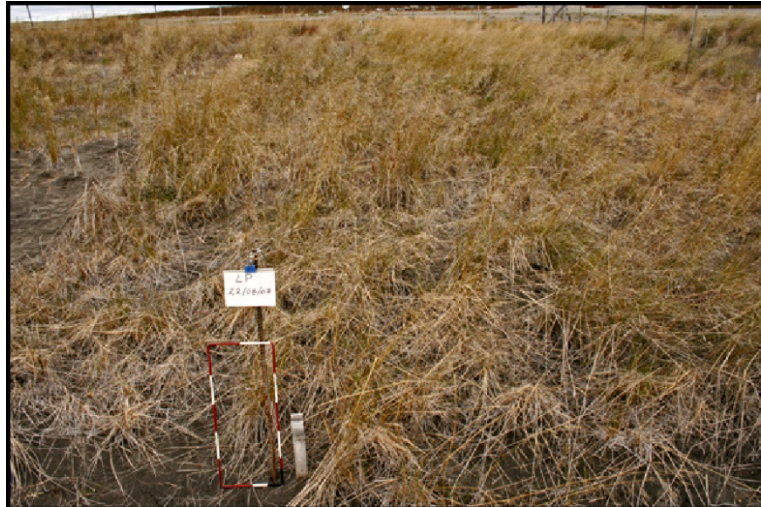
Soil Amendments

- Low Peat (4 cm depth)
- High Peat (8 cm depth)
- Processed Paper Waste (4 cm)
- Lake Sediment
- Calcium
- Sewage sludge

Revegetation Treatments

- Mid-slope Zone
 - Native grass cultivars, row seeded
 - Annual species, row seeded
 - Seedling shrub & herb plugs Year 3
- Transitional zone
 - Sod transplants
 - Cuttings
 - Direct seeding

Revegetation Research: LLCF 2000 - 2007



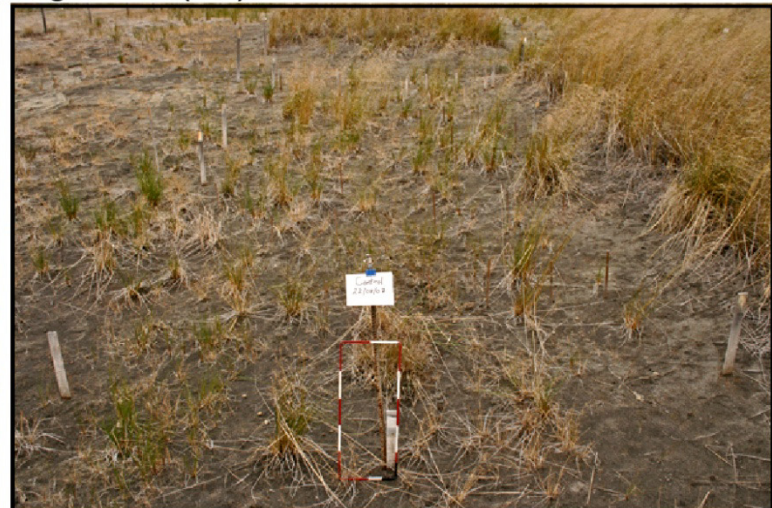
Low Peat (LP) - 2007



High Peat (HP) - 2007



Processed Kimberlite (K) - 2007



Control (C) - 2007

Revegetation Research - LLCF 2000 - 2007



Eight growing season (2007) - dwarf birch seedlings colonizing unamended processed kimberlite under the protection of grass litter.

Summary of Findings

- Native grass cultivars are capable of maintaining a grass cover in the mid-slope portion of the LLCF without the use of soil amendments - in the absence of grazing
- Maintenance fertilizer requirements not yet determined

- Sewage sludge could be used as a nutrient source
- Amendment with processed peat or lake sediment improved plant growth during the second and third growing seasons but showed no effect in subsequent years

- Soil microflora equivalent to agriculture soil in biomass, but less diverse
- Soil salt concentrations moderate at the surface and decreased with depth

- Native grass cultivars rooted to 90 cm, to the water table
- Northern alkali grass (*Puccinellia borealis*) actively colonized the mid-and lower-slope areas of Cell B

- A primary plant cover is required to provide conditions favourable to the establishment of secondary plant cover - by assisted or natural means
- Accumulation of plant litter created favourable conditions for colonization by dwarf birch

Purpose of Reference Sites

- Assist in the identification of Closure Criteria for EKATI mine components
- Help predict kind of plant community expected over specific time periods
- Monitor for change alongside reclaimed sites at EKATI
- Provide a reference against natural variation in weather or anthropogenic changes and recovery time after disturbance

Reference Sites Under Assessment

- Abandoned winter road and quarry
- Abandoned Mine Sites
 - Tundra Mine
 - Salmita Mine & Airstrip
- Other sites

Plant Propagation

- Seed collection
- Seed multiplication
- Containerized stock production and establishment, e.g., dormant planting

Vegetation Cover and Surface Stability

- Cover design for processed kimberlite containment area (PKCA)
- Grazing effects on PKCA plant cover and surface stability

Establishment of Self-Sustaining Plant Communities

- Methods to enhance plant colonization
 - Assisted
 - Natural
- Island plantings
- Maintenance fertilizer requirements
- Incorporation of findings into operational methods and procedures