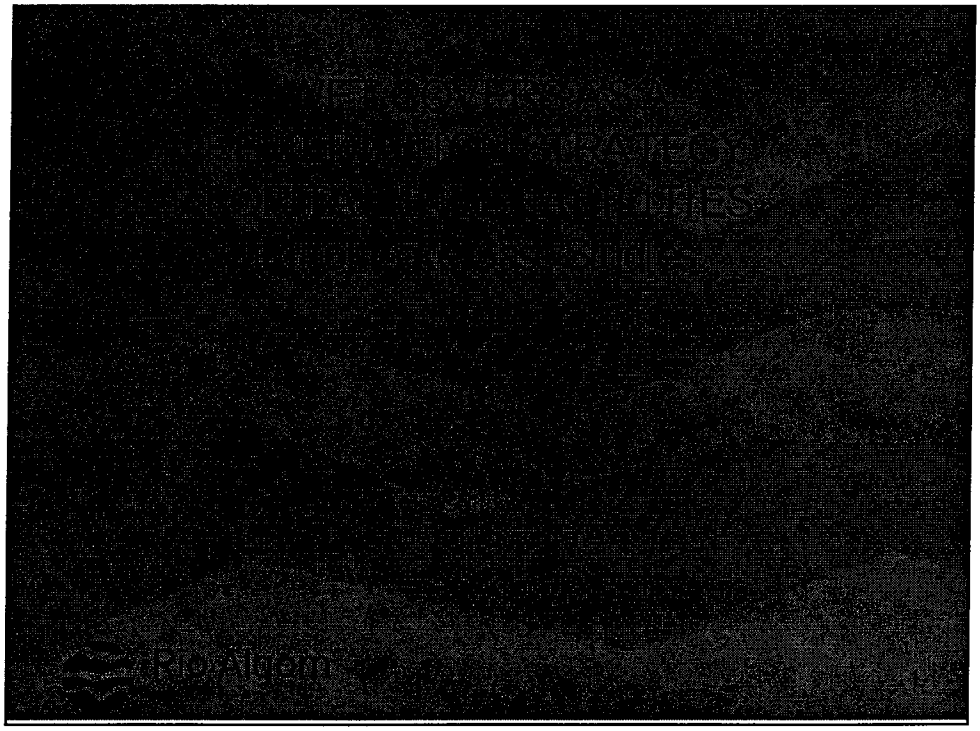
B.6. Wet Covers as a Remediation Strategy for Tailings Facilities – Elliot Lake Case Studies

by
Ross Gallinger
Rio Algom Limited



Wet Cover Applications for Closure

Uranium Mines - Elliot Lake, Ontario

- Spanish American - use of a former lake to provide water cover
- Panel - water cover using two basins
- Quirke - design required to resolve topography resulting in multiple cells to create water cover
- Stanleigh - design for closure with water cover

Wet Cover Considerations

Geochemistry
- mineralogy/geology
- static/kinetic testing
- mineral leaching characteristics

Hydrology
- climate
- watershed analysis

Rio Algom 3

Wet Cover Considerations (Con't)

Hydrogeology
- seepage quantification

Design Criteria
- seismic criteria
- hydraulic design (wet and dry years)
- water cover depth
- wave action - resuspension

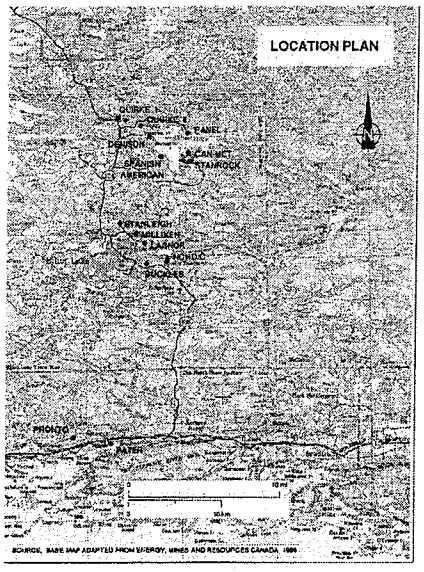
Rio Algom 4

Uranium Properties - Elliot Lake, Ont..

- Quirke
- Panel
- Spanish American
- Stanleigh

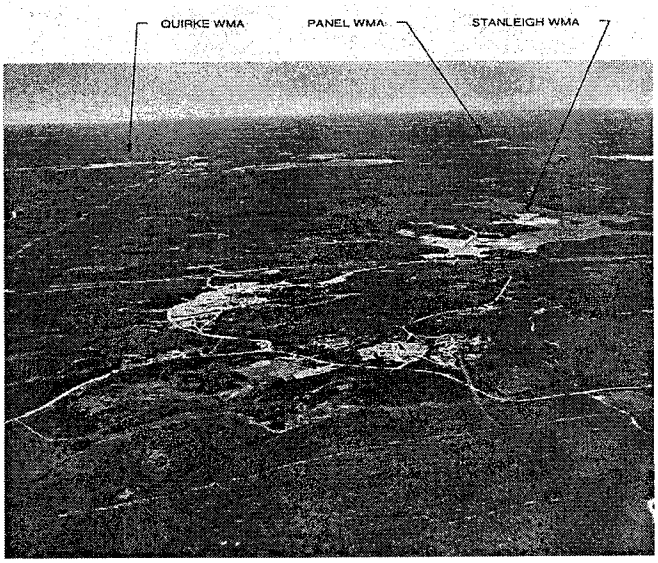
Rio Algom

5



Rio Algom

6



Rio Algom

7

Hydrology

Climate

- annual average precipitation 872 mm - 636 mm as rainfall, 267 mm from snowfall
- mean annual temperature is 3.5°C - range from -8.5°C to 24.8°C

Hydrology

- sites located in Serpent River Watershed which drains into Lake Huron
- Upper Serpent River sub-basin is 15,466 ha with a mean annual flow of 2.92 m^3/sec
- drought events modeled for 1000 yrs water cover design requirements

Rio Algom

8

Geochemistry

- Tailings are net acid generating, with sulphide content averaging 5%
- lysimeter and column testing of water cover for 12 years
- radiological releases with ARD and gypsum dissolution

Rio Algom

9

Hydrogeology

- groundwater movement restricted to pervious overburden and to zones of sheared or fractured rock associated with geological structures
- groundwater is easily predicted and is concluded to be effectively impermeable

Rio Algom

10

Design Criteria

Aspect	Criteria
Perimeter Dam Stability	Static FOS 1.5 Dynamic Stability for 1,000 yr seismic event(0.053g)
Hydraulic Design	Adequate to prevent loss of water cover Spillways capable to handle PMF
Effluent Discharges	Meet PWQOs Permitted Radium 226 loadings
Dose Limits	Environment - As low as reasonable achievable (ALARA)

Rio Algom

Goals and Objectives for Closure Design

- Protection of public health
- protection of the environment
- long-term security of the containment area

Rio Algom

Alternatives Analysis

Options evaluated but rejected from alternatives analysis:

- Vegetation establishment with long-term treatment
  - high operating cost, long-term sludge management required
- Quirke Lake Disposal
  - high capital cost, potential water treatment cost, potential for impact
- Underground Disposal
  - only accommodate <35%; would require other alternatives to secure the tailings
- Pyrite Reduced Cover and Radionuclide Reduced Cover
  - high capital cost; unproven technology; potentially higher radiation exposure than soil cover or water cover

Rio Algom

13

Quirke and Panel - Short List of Options Flooded Tailings vs. Soil Cover

Criteria	Comparison
• water quality	• soil cover - longer term interim water treatment required
• outside disturbances	• soil cover - disturb large area for soil materials
• construction aspects	• construction - high cost, worker exposure
• intrusion	• soil cover - potential use in future
• stability/robustness	

Rio Algom

14

Criteria	*Flooded Tailings*	*Soil Cover*	*Quirke Lake Disposal*	*Underground Disposal*
Water Treatment Short Term Long Term (>20 years) Water Quality Effects	 Yes No Minimal	 Yes No Minimal	 Yes Yes Major	 Yes No Minimal
Seepage Losses	Low	Low	Essentially Eliminated	Lower
Stability of Tailings	Modest Maintenance Required	Modest Maintenance Required	No Maintenance Required	Modest Maintenance Required
Resource Recovery Mine Tailings	 Available Available	 Available Available	 Available Major Comstraint	 Major Constraint Minor Constraint
Construction Requirements	Moderate	Major	Very Major	Very Major
Relevant Experience	Adequate	Adequate	Very Limited	Very Limited
Future Burdens	Minor	Minor	Unknown	Minor
Potential radiation Exposure Public Worker	 Acceptable Acceptable	 Acceptable Acceptable	 Acceptable Acceptable	 Acceptable Acceptable
Safety Concerns Construction Phase Long Term	 Low Risk Low Risk	 Higher Risk Low Risk	 High Risk Low Risk	 High Risk Low Risk
Intrusion Considerations	Low Risk	Higher Risk	No Risk	Low Risk
Regulations/Policy Constraints	No	No	Yes	No
Cost (millions) Capital Costs at Panel Capital Costs at Quirke Long-Term Costs	 $15 (2) $30 (2) $100,000/y	 $28 (4) $59 -$100,000/y	 $238 (3) incl. Quirke Unknown	 $125-$223 (1) $125-$223 (1) $100,000/y
Responsibilities Short Term Long Term	 Rio Algom MNR	 Rio Algom MNR	 Rio Algom MNR	 Rio Algom MNR
Aquatic Environment Terrestrial Environment	Minimal Effect Minimal Effect	Minimal Effect Minor Improvement	Degraded Improved	Minimal Effect Minor Improvement
Future Land Use	Some Restrictions	Some Restrictions	Some Restrictions	Some Restrictions
Monitoring Performance	Verifiable	Verifiable	Verifiable	Verifiable

Rio Algom

15

Quirke - History and Characteristics

- Operated from 1956 to 1961, then 1968 to 1990
- milling rate of 6300 tpd
- 41 million tonnes of tailings
- tailings pond is 192 ha
- watershed area is 275 ha

Rio Algom

16

Quirke WMA Design

- 14 m difference in elevation between west and east ends
- basin divided into five cells with construction of 4 internal dykes to allow flooding
- dykes are 3 to 4.5 m high, constructed of waste rock, glacial till seepage barrier and erosion protection
- tailings re-graded in Cell 14 to allow a minimum 0.6m water cover
- limestone cover @ 180 to 240 t/ha to control acidity prior to flooding

Rio Algom

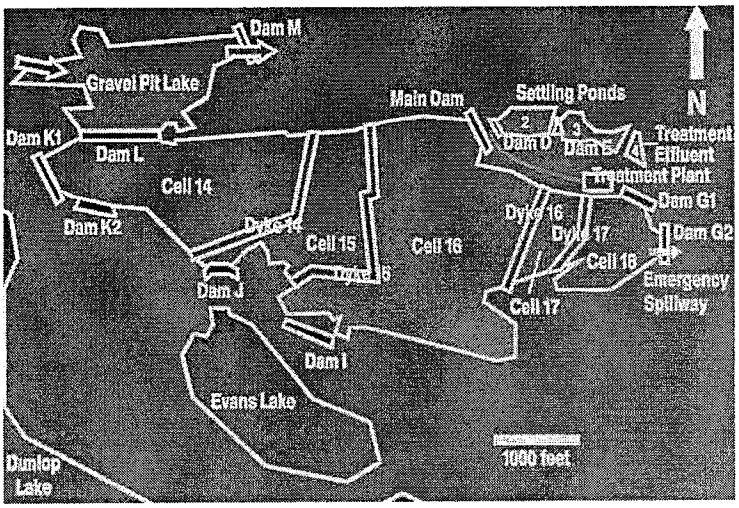
17

Quirke WMA Design (Con't)

- Dykes have spillways to pass peak flows
- flooding initiated in 1994
- eight dams along perimeter of facility are low permeability structures, designed to accommodate tailings and reduce seepage
- Gravel Pit Lake supplies water to cell 14, thus flowing cell to cell, discharging from cell 18
- some organics introduced along shoreline to enhance wetland vegetation colonization

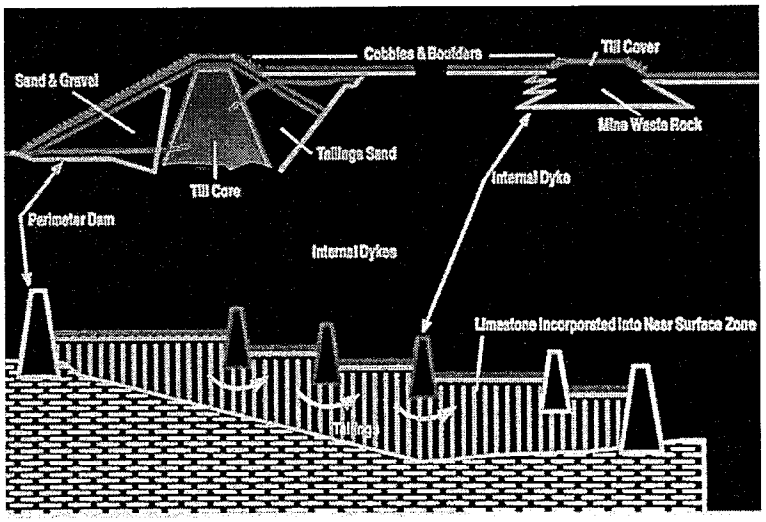
Rio Algom

18



Rio Algom

19

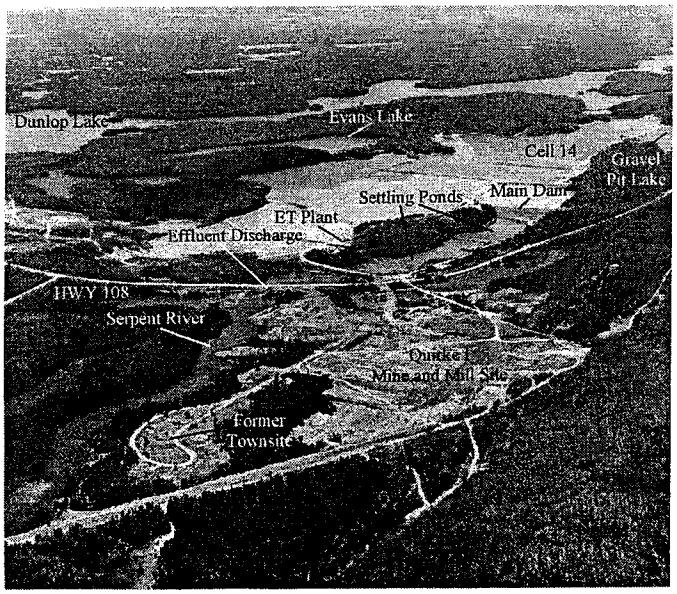


Rio Algom

20

Rio Algom

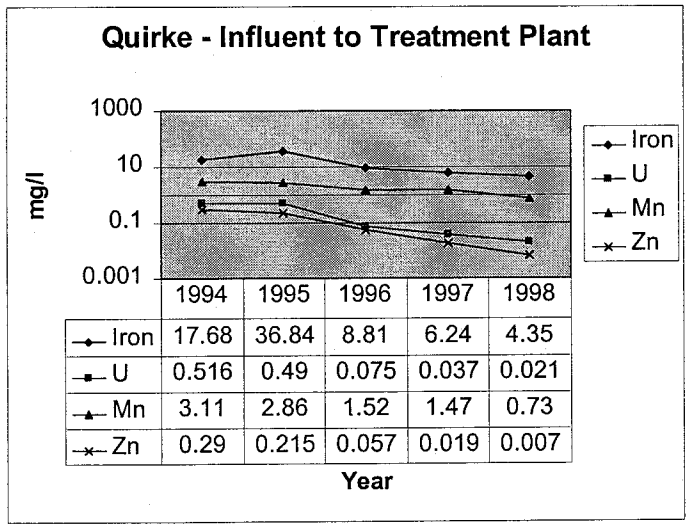
21



Rio Algom

22

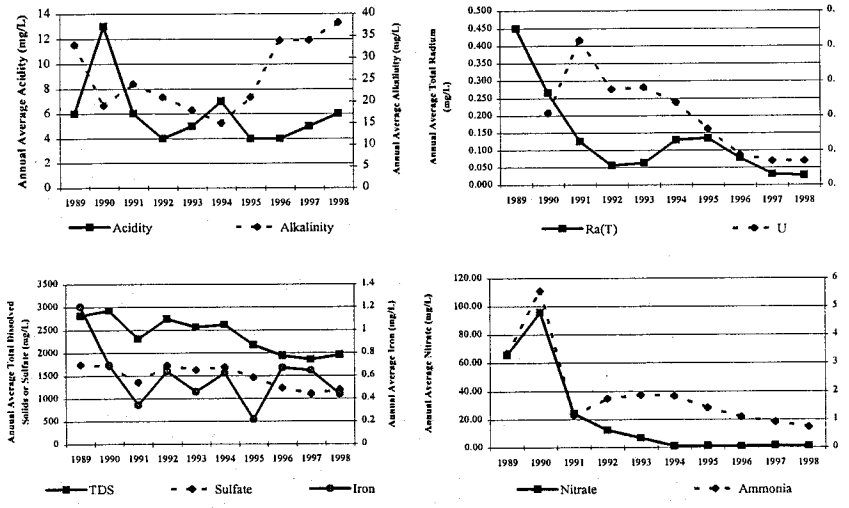
Quirke Water Quality



	1994	1995	1996	1997	1998
Iron	17.68	36.84	8.81	6.24	4.35
U	0.516	0.49	0.075	0.037	0.021
Mn	3.11	2.86	1.52	1.47	0.73
Zn	0.29	0.215	0.057	0.019	0.007

Rio Algom

Quirke WMA Discharge



Rio Algom

Panel - History and Characteristics

- Operated from 1958 to 1961, then 1979 to 1990
- 14 million tonnes of tailings
- WMA consists of two basins - North Basin(84 ha) and South Basin (39 ha)
- watershed area is 280 ha

Rio Algom

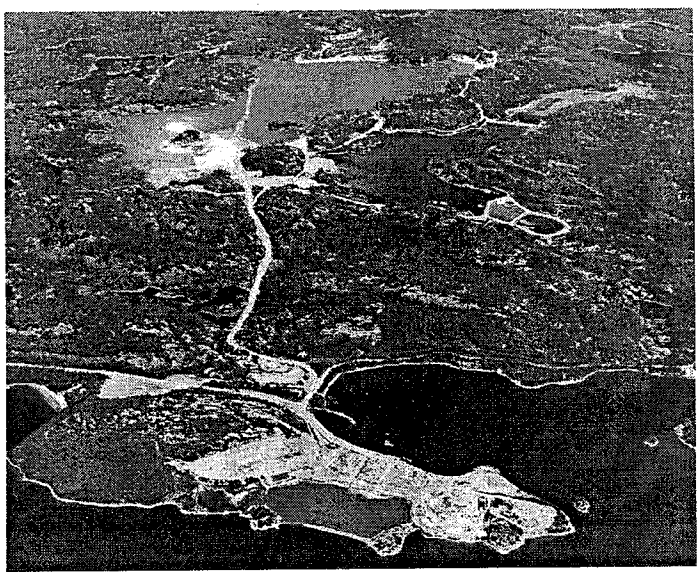
25

Panel - Design

- To enable flooding of the North Basin, Dams H, D, B and E were constructed
- excess water from the North Basin flows into the South Basin
- a minimum water cover of 0.6m is maintained
- lime is added to the basins to neutralize acidity

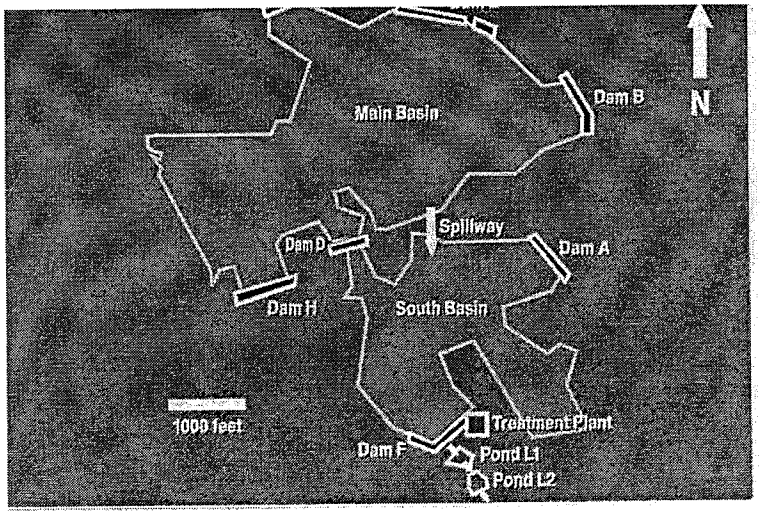
Rio Algom

26



Rio Algom

27



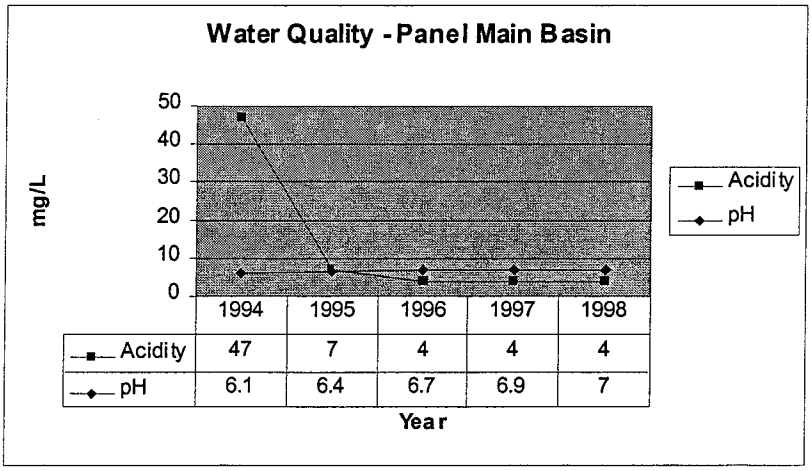
Rio Algom

28

Rio Algom

29

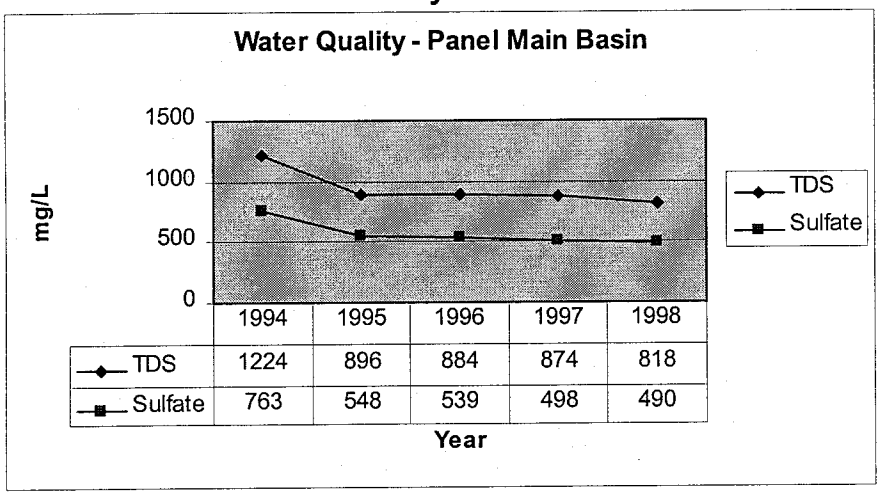
Panel Water Quality



Rio Algom

30

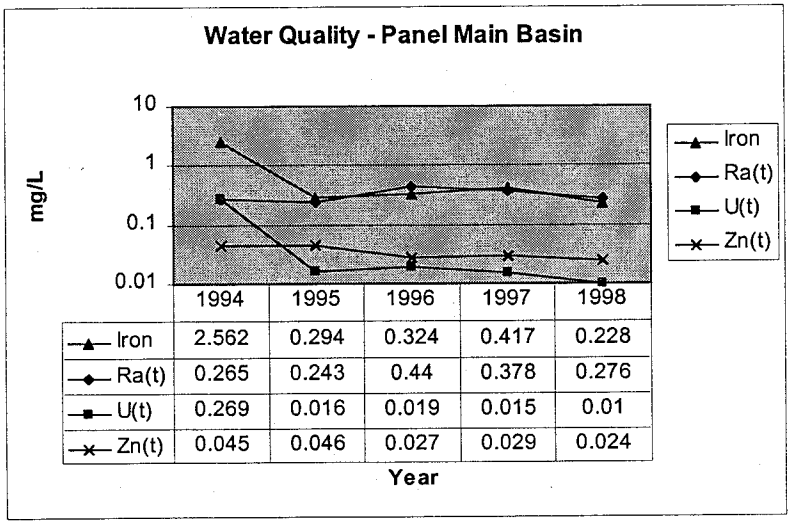
Panel Water Quality



	1994	1995	1996	1997	1998
TDS	1224	896	884	874	818
Sulfate	763	548	539	498	490

Rio Algom

Panel Water Quality

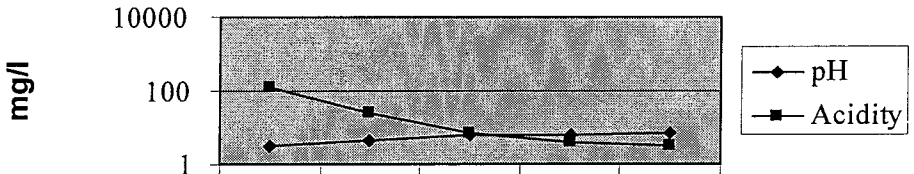


	1994	1995	1996	1997	1998
Iron	2.562	0.294	0.324	0.417	0.228
Ra(t)	0.265	0.243	0.44	0.378	0.276
U(t)	0.269	0.016	0.019	0.015	0.01
Zn(t)	0.045	0.046	0.027	0.029	0.024

Rio Algom

Panel Water Quality

Water Quality - Panel South Basin



	1994	1995	1996	1997	1998
pH	3.3	4.6	6	6.5	6.8
Acidity	133	24	7	4	3

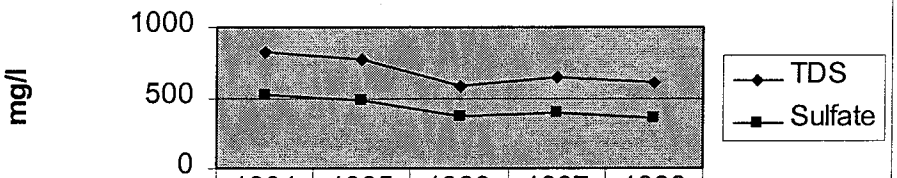
Year

Rio Algom

33

Panel Water Quality

Water Quality - Panel South Basin



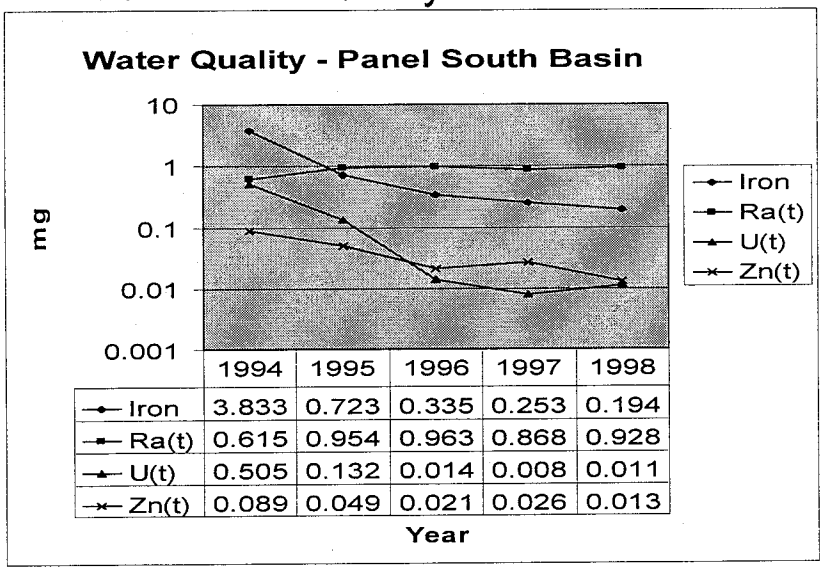
	1994	1995	1996	1997	1998
TDS	828	768	585	642	613
Sulfate	518	475	361	389	355

Year

Rio Algom

34

Panel Water Quality



	1994	1995	1996	1997	1998
Iron	3.833	0.723	0.335	0.253	0.194
Ra(t)	0.615	0.954	0.963	0.868	0.928
U(t)	0.505	0.132	0.014	0.008	0.011
Zn(t)	0.089	0.049	0.021	0.026	0.013

Spanish American - History and Characteristics

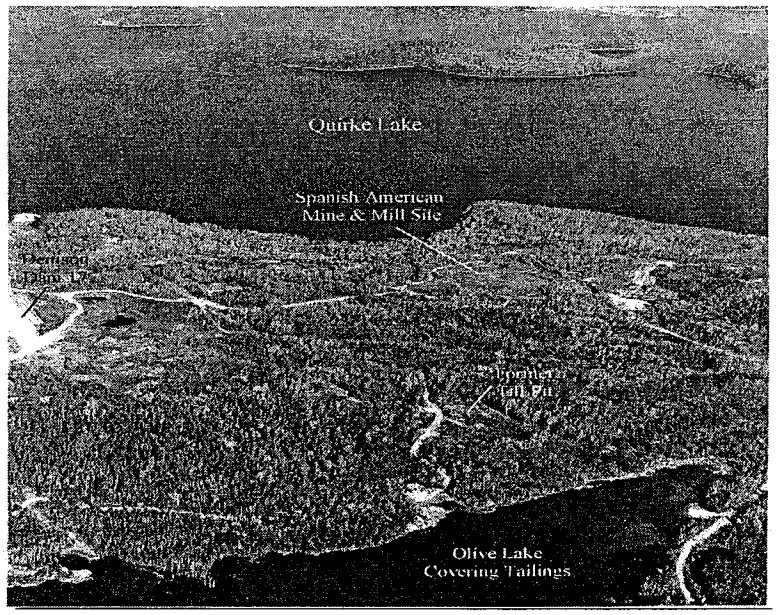
- Operated less than one year in the late 1950's
- <0.5 million tonnes of tailings disposed in Olive Lake
- watershed area is 37 ha
- drainage through a series of beaver ponds to TMA-1 of Denison Tailings Management Area

Spanish American - Design

- Construction of a permanent berm and spillway to control water levels
- relocation of tailings underwater
- lime addition to neutralize acidity
- water cover of a minimum 1.5m
- North and South Berms 1.5m high and 9 m long, constructed of rock and till, with erosion protection

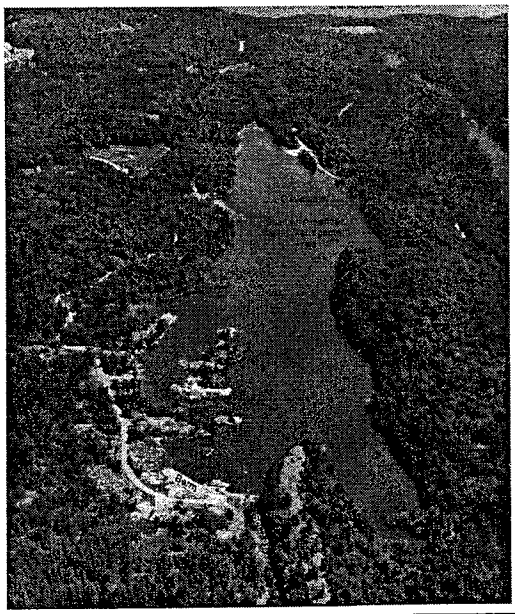
Rio Algom

37



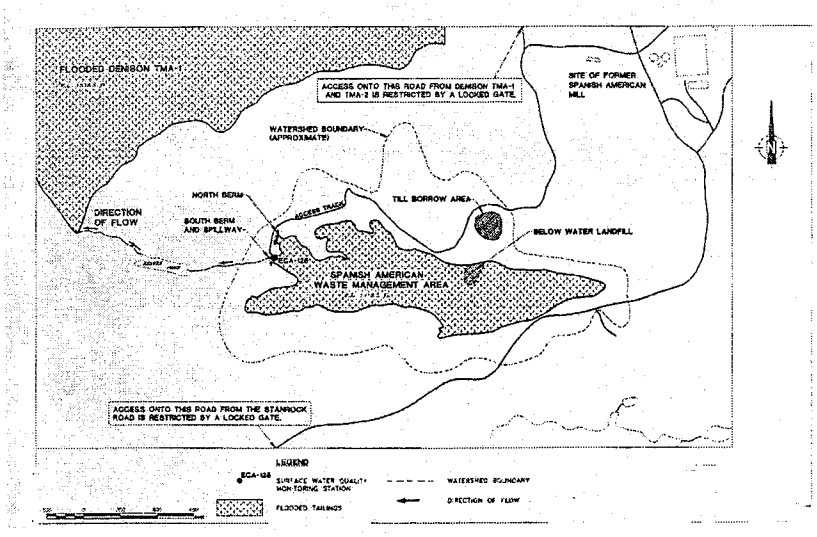
Rio Algom

38



Rio Algom

39



Rio Algom

40

Stanleigh - History and Characteristics

- Operated in the 1950's, then 1983 to 1996
- milling rate of 4550 tpd

Rio Algom

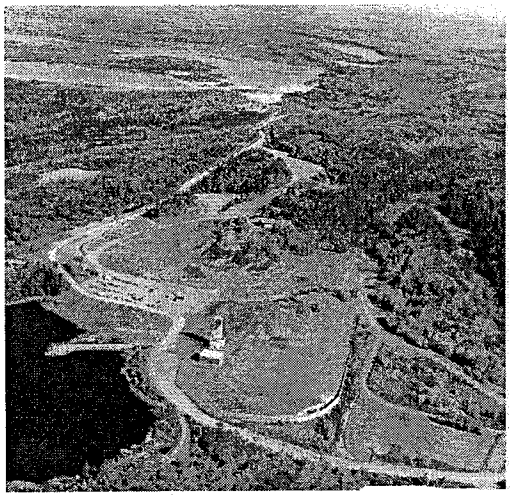
41

Stanleigh - Design

- Relocate tailings - move 50,000 tonnes of tailings below flooded elevation of 1200 ft.
- Lower main dyke
- Dam construction includes:
  - construct Dam A1
  - raise Dam A
  - Replace Dam B
  - Construct Dam C
  - spillway to pass PMF
- 1.5 m water cover

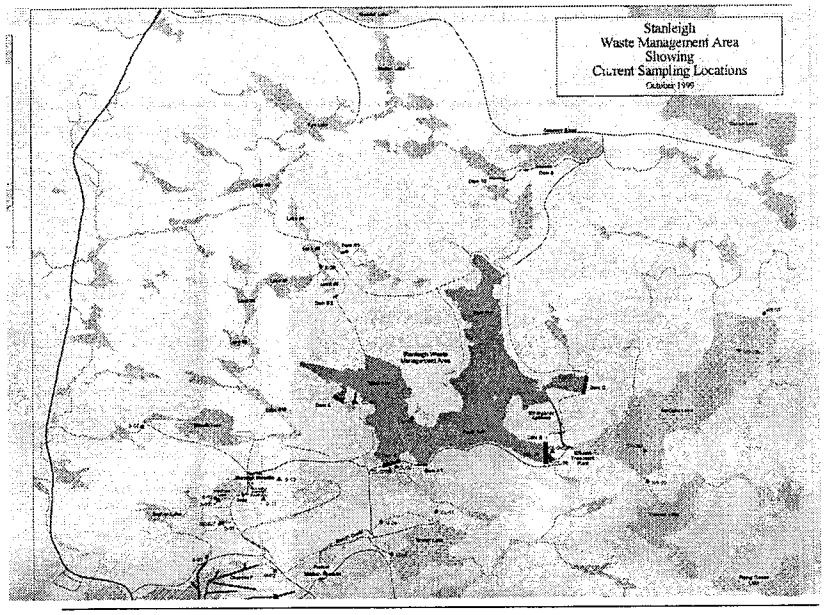
Rio Algom

42



Rio Algom

43



Rio Algom

44

Rio Algom

45

Monitoring

Monitoring phases include a transition phase shortly after the closure design has been achieved, and long term monitoring. Monitoring includes:

- Inspections - identify maintenance requirements, confirm dam stability, confirm hydraulic performance
- Routine Monitoring - flow monitoring, water quality, meteorological data
- Special Surveys - confirm environmental conditions - fish, sediment, benthic invertebrate surveys

Rio Algom

46

PERFORMANCE ASSESSMENT CRITERIA

Medium	*Performance Objective*	*Verification Technique*
Engineered Structures	1. Hydraulic performance 2. Stability 3. Care and maintenance	1. Piezometer readings, inspect drains 2. Routine inspection program 3. Record of maintenance
Tailings Basin Hydrology	Confirm water cover is sustainable	Meteorological data, flow monitoring, water levels
Tailings Basin Water Quality	1. Ensure acid production has been curtailed 2. Achieve Long term Ra-226 mass loading criteria 3. Confirm acceptable seepage rates	1. Pore water and pond water monitoring 2.. Discharge quality 3. To be confirmed by mass balance assessments using pore water data, groundwater monitoring and surface water quality data
Environmental Quality 1. Radionuclide Uptake 2. Surface Water Quality 3. Air Quality	1. Objective is for levels in vegetation, sediments and fish to expected levels or declining trends 2. Meet Provincial Water Quality Objectives 3. Attain near background level of dust, radon	1. Special surveys 2. Trend analysis 3. Track etch cup, suspended particulate and dustfall data
Surface Gamma	Meet criteria	Post decommissioning gamma surveys
Radiological Exposure	1. Pubic Dose - meet criteria 2. Worker Dose -meet criteria	1. Radiological pathways calculations 2. Worker monitoring

Rio Algom

47

MONITORING PROGRAM AND MONITORING FREQUENCIES

Type of Monitoring	*Transition Phase (5 Years)*	*Long Term*
INSPECTIONS		
• Visual inspection of all engineered structures	- monthly	- seasonal
• Piezometer water levels	- semi-annual	- annual
• Water level measurements	- monthly	- seasonal
• Detailed review – Professional Engineer	- annual	- annual
ROUTINE MONITORING INDICATORS		
• Meteorological data – Quirke WMA	- continuous (as appropriate)	- not required
• Effluent discharges	- weekly	- semi-annual
• Internal basis pond water	- monthly / quarterly	- not required
• Tailings pore water	- semi-annual	- not required
• External groundwater	- semi-annual	- not required
• Receiving water quality - upstream and downstream	- monthly / quarterly	- semi-annual
• Flow monitoring	- weekly or at time of sampling	- not required
SPECIAL SURVEYS		
• Air quality – radon, dust and suspended particulate	- survey in 1996 to confirm low levels	- not required
• Water quality	- annual survey to confirm trends and impacts	- not required
• Sediments	- survey in 1997 and 2000 at key receiving water quality stations	- not required
• Fisheries	- survey in 1997 to confirm trends and low radionuclide levels	- not required
• Benthos	- survey in year 2000 at key receiving water quality stations	- not required
• Vegetation	- survey of aquatic vegetation in 1997	- not required

Rio Algom

48

Public Consultation - Post-Closure

Decommissioning Review and Advisory Committee (DRAC 1998)

- community based public advisory panel
- reviews decommissioning program, license applications, monitoring data and programs
- 10 representatives from the Community of Elliot Lake, Township of North Shore, Serpent River First Nation
- 2 year term, produce annual report, distributed to local, provincial, federal, ENGO's and NGO's - DRAC is supportive of monitoring efforts to date and is confident in future collaborations with Rio Algom

Conclusions

- Radiation exposures to local residents will be minimal and well within standards
- dams and dykes designed, constructed, operated and inspected to assure continued performance
- monitoring data demonstrates encouraging results for long term environmental protection
- care, maintenance and monitoring program established to ensure continued performance