

B.4. Segregation of ARD Tailings at the Duthie Mine

by

*Clint Logue, Iain Bruce
BGC Engineering Inc.*

and

*Max Holtby
Silver Standard Resources Inc.*

Segregation of ARD Tailings at the Duthie Mine

An Observational Approach to ARD Mitigation

by

**Clint Logue, Dr. Iain Bruce
BGC Engineering Inc.**

and

**Max Holtby
Silver Standard Resources Inc.**

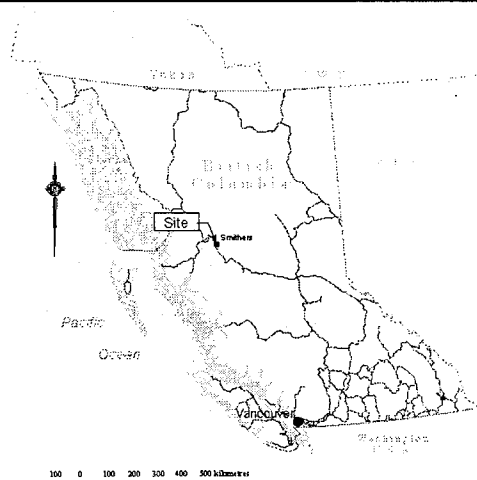
Presentation Outline

- **Site Location**
- **Site History**
- **Site Description**
- **Description of ARD Problem**
- **Proposed Mitigation**
- **Numerical Modeling**
- **Site Remediation to Date**
Photographs From Site Clean-Up



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

Duthie Mine - Site Location



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

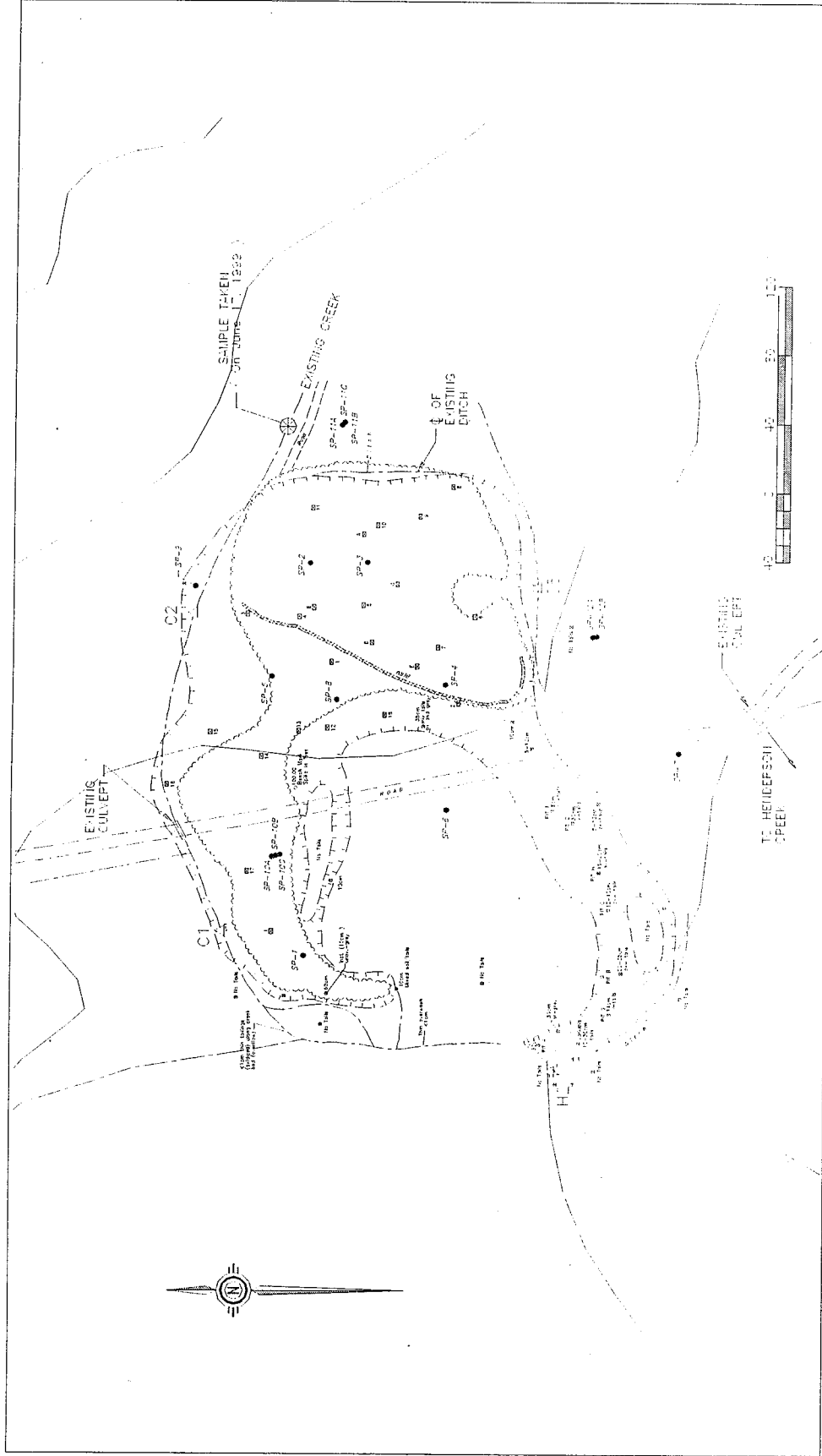
Duthie Mine - Mining History

- Mineralization discovered in 1908
- Property changed hands 6 times Since 1922
- Mining operations by numerous parties
- Property acquired by Silver Standard Resources Inc. in 1978
- In total approximately 26,000 m³ Tailings
~ 4,000 m³ Since 1978

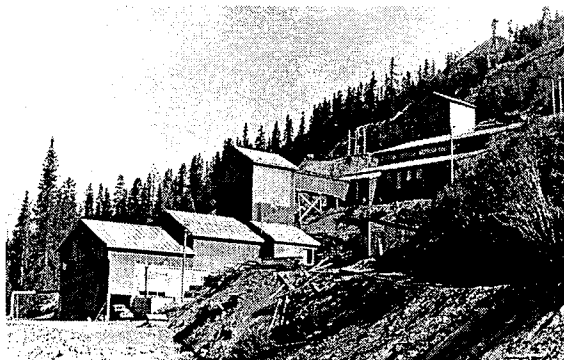


BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

Duthie Mine - Site Layout



Duthie Mine - Project History



1952 - Mill Operated by Sil-Van
Consolidated Mining and Milling Company
Ltd.



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

Duthie Mine - Project History



1994 - Aerial Shot of Tailings Facility



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

Duthie Mine - Project History

- **1982 - Permit Application prompts Water Quality Monitoring by Government Agencies**
- **1987 - Partial Remediation of "Spilled" Tailings by B.C. Ministry of Energy and Mines**
- **Deemed as a Source of Heavy Metal Contamination**
- **Silver Standard Resources Inc. Requested to Define Extent of Contamination and Ascertain Methods of Mitigation**



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

Duthie Mine - Project History

- **1993 - Silver Standard Began Site Investigation**
- **GeoViro Engineering Ltd. Retained to Establish Water Quality Monitoring Program**
- **BGC Engineering Inc. Retained to Provide Geotechnical Input for Mitigation Investigations Undertaken by Silver Standard**



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

Duthie Mine - Stratigraphy

- **Sand and Gravel Tailings (0 m to the South, ~ 3 m to the North)**
- **Underlain by Glacio-Fluvial Sands and Gravels (0 m to the South, ~ 5 m to the North)**
- **Underlain by Glacial Till (High Plastic, Clayey Silt with Trace Sand)**
- **Glacial Till is quite variable - Sand and Gravel seams identified.**



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

Duthie Mine - Groundwater

- **Piezometers Indicate that Groundwater is Highly Variable**
- **Water Table Responds Quickly to Precipitation Events**
- **Top 0.5 m Tails Oxidized - Rest Stay Saturated**



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

Duthie Mine - ARD Problem

- **Mining Operations** undertaken with no regard to closure
- **26,000 m³** of tailings sporadically placed over an estimated area of **40,000 m²**
- **Water Flushing Through Tailings - Sources:**
 - Direct Precipitation**
 - Seepage through Glacio-Fluvial Sands and Gravels**



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

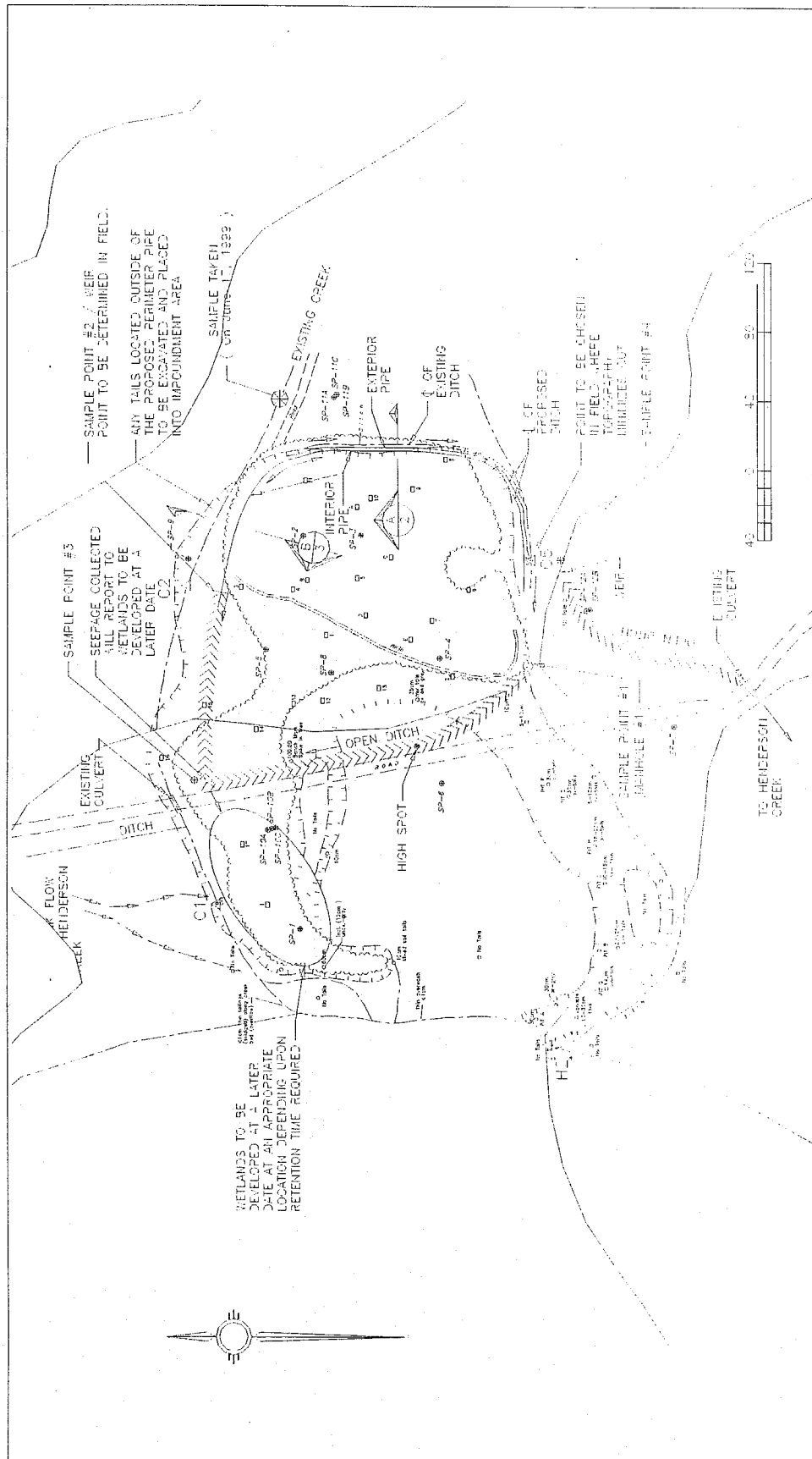
Duthie Mine - Proposed Mitigation

- **Diversion Ditch** to prevent Seepage from Glacio-Fluvial Sands and Gravels
- **Cover** to prevent Direct Precipitation
 - Tailings will stay Saturated - Cover to be Designed at a Later Date**



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

Duthie Mine - Proposed Mitigation



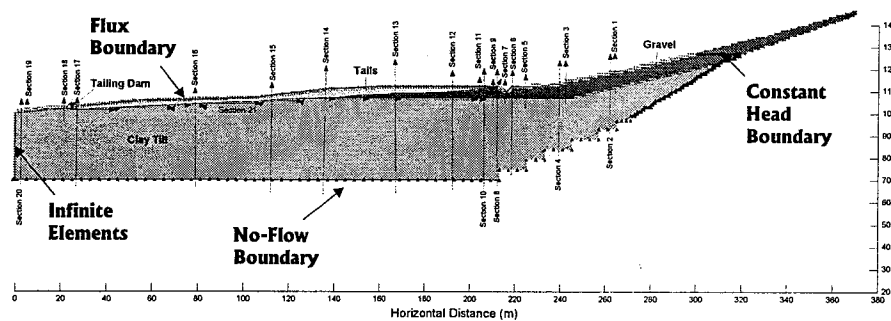
Duthie Mine - Numerical Modeling

- **Steady-State Finite Element Model - Tool to indicate effectiveness of Mitigation**
- **Hydraulic Conductivities based on index tests (grain size, etc)**
 - Tails - $K = 1 \times 10^{-5} \text{ m/s}$
 - Glacio-Fluvial - $K = 1 \times 10^{-3} \text{ m/s}$
 - Glacial Till - $K = 1 \times 10^{-8} \text{ m/s}$
- **Boundary Conditions based on Precipitation Data Average Wet Conditions**



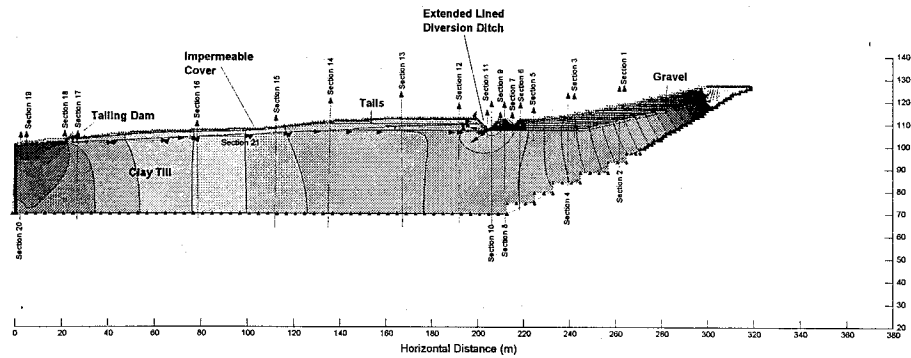
BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

Duthie Mine - Seepage Model Stratigraphy and Boundary Cond.



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

Duthie Mine - Seepage Model Mitigation Implemented - Results



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

Duthie Mine - Modeling Results

- Modeling demonstrated that seepage through the tailings facility can be reduced by 95% by implementing Cover and Diversion Ditch



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

Duthie Mine - Limitations of Modeling

- **FEM is only a predictive tool**
- **Ability to model exceeds site-specific information**
- **Need for Water Balance for Model Calibration**



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

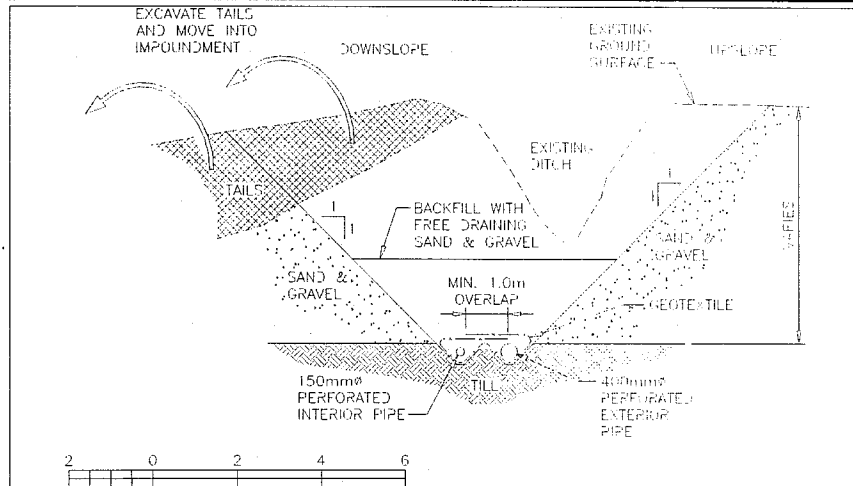
Duthie Mine - Mitigation

- **Phased-Construction**
 - Allow Water Balance for Model Calibration**
 - Better Identify Source of Contamination**
- **Clean up Tails and Construct Diversion Ditch**
- **Separate Flows for Measurement and Treatment**

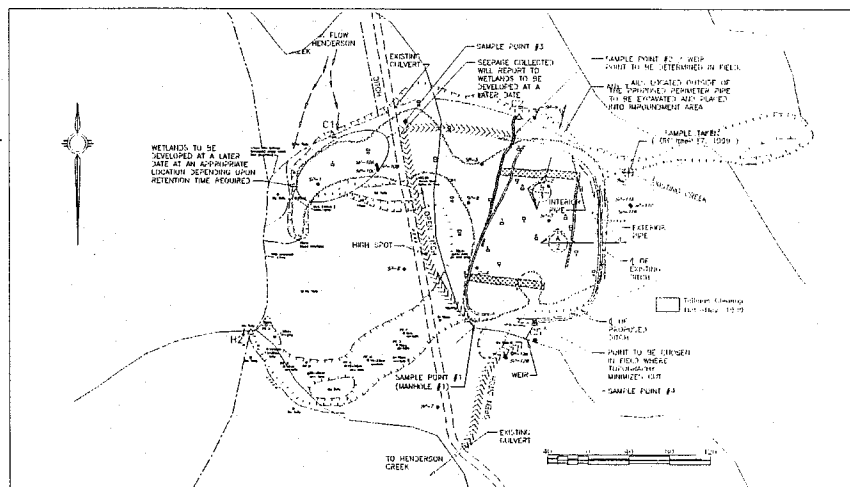


BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES
COMPANY

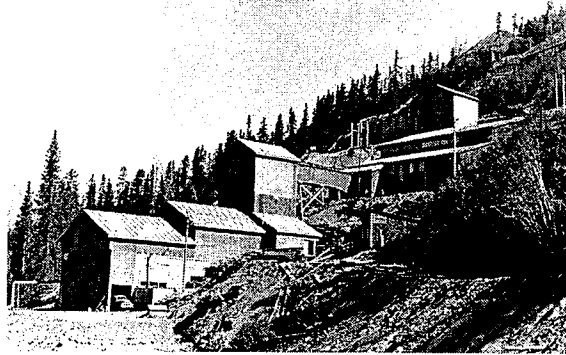
Duthie Mine - Diversion Ditch



Duthie Mine - Clean-Up to Date



Duthie Mine - Photographs



1952 - Mill Operated by Sil-Van Consolidated
Mining and Milling Company Ltd.



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

Duthie Mine - Photographs

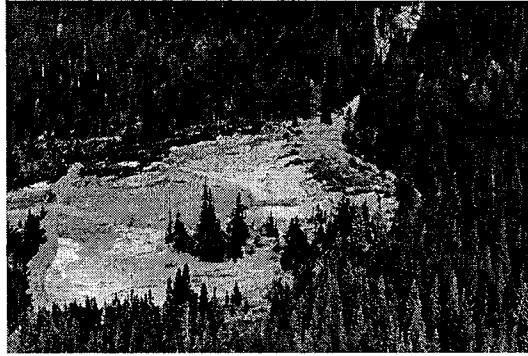


1994 - Aerial Shot of Mill



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

Duthie Mine - Photographs

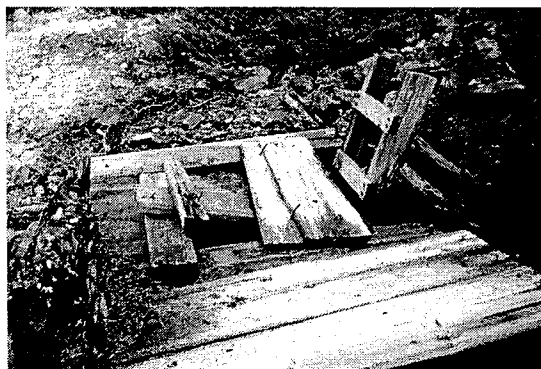


1994 - Aerial Shot of Tailings Facility



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

Duthie Mine - Photographs

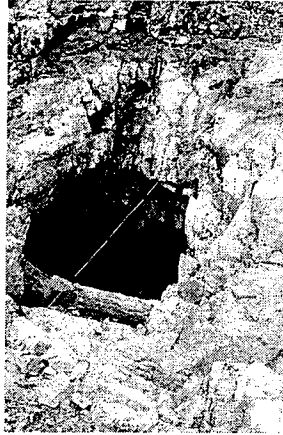


Typical Old Workings Prior to Clean-Up



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

Duthie Mine - Photographs

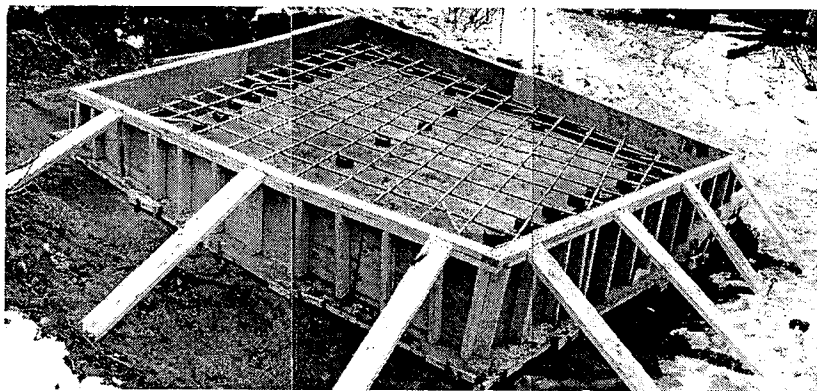


Typical Old Workings After Clean-Up



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

Duthie Mine - Photographs

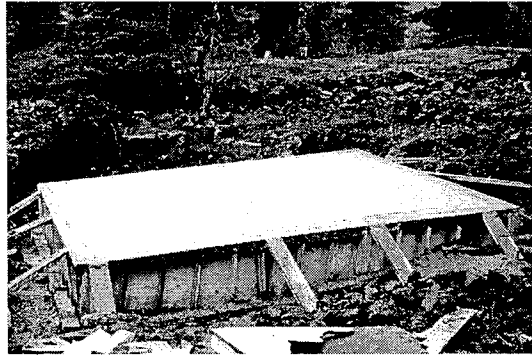


Completed Form Ready for Pour



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

Duthie Mine - Photographs



Form After Pour



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

Duthie Mine - Photographs

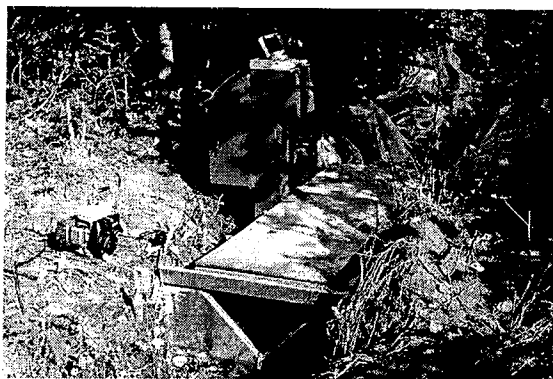


Finished Cap



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

Duthie Mine - Photographs



Typical Weir at Site



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

Duthie Mine - Photographs

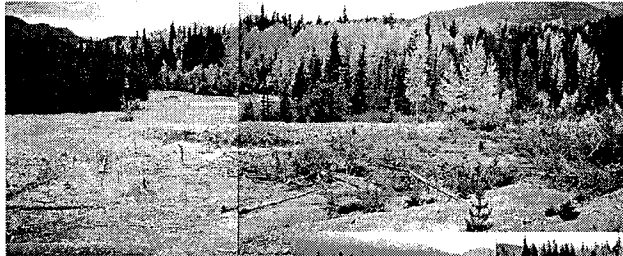


South End of Tailings Facility Before
(Above) and After (Right) Clean-Up

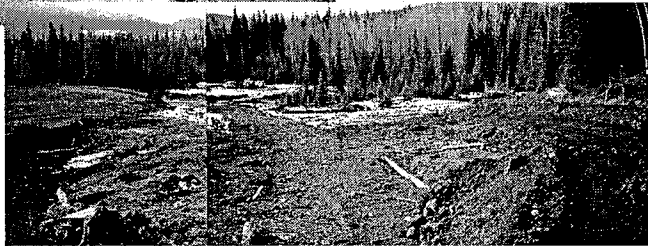


BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

Duthie Mine - Photographs



North End of Tailings
Facility Before
(Above) and After
(Right) Clean-Up



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

Duthie Mine - Photographs

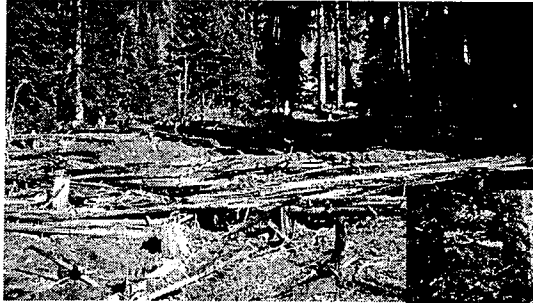


West End of Tailings
Facility Before
(Above) and After
(Right) Clean-Up

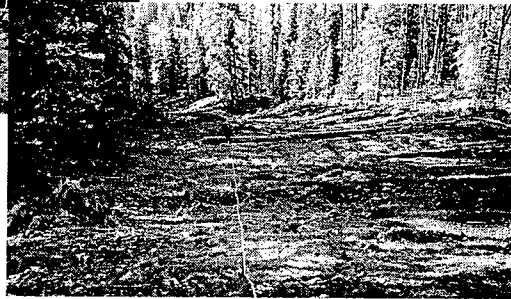


BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

Duthie Mine - Photographs



Looking North at Area Between
Tailings Facility and Mill Before
(Above) and After (Right) Clean-Up



BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

