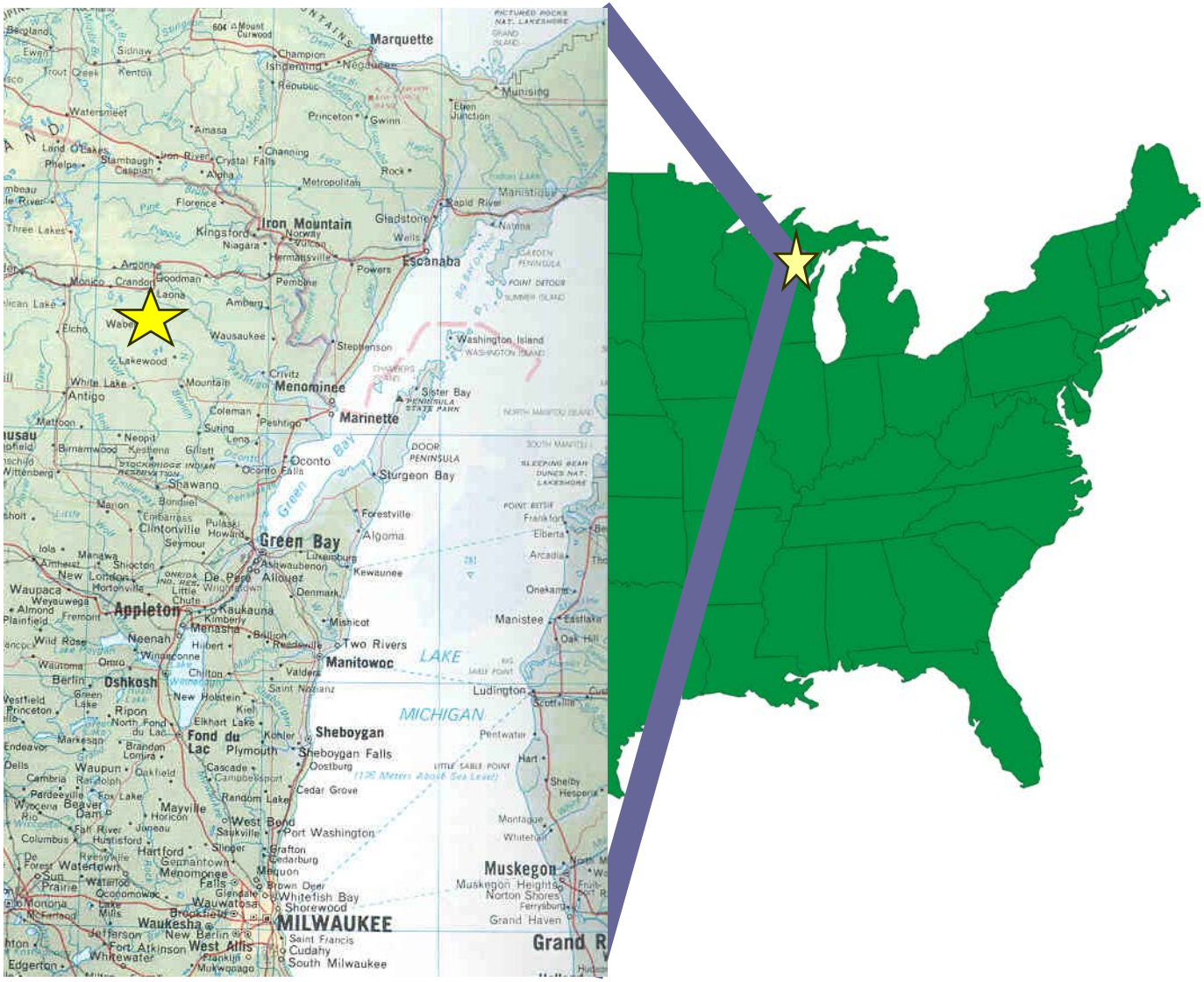
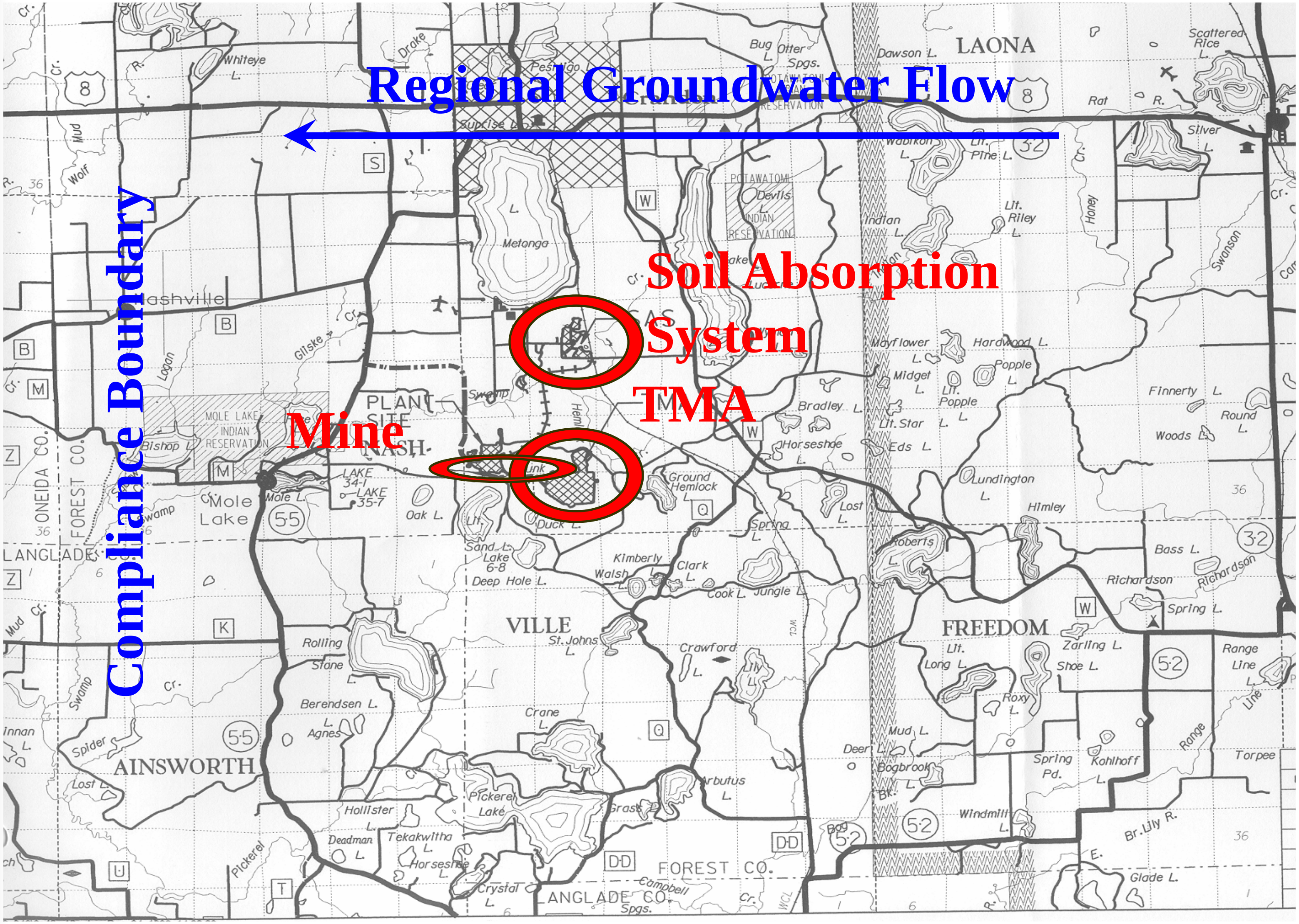
Predicting Water Quality from the Reflooded Mine at the Crandon Project

Diana Sollner, Daryl Hockley, John Chapman and Ken Black

LOCATION

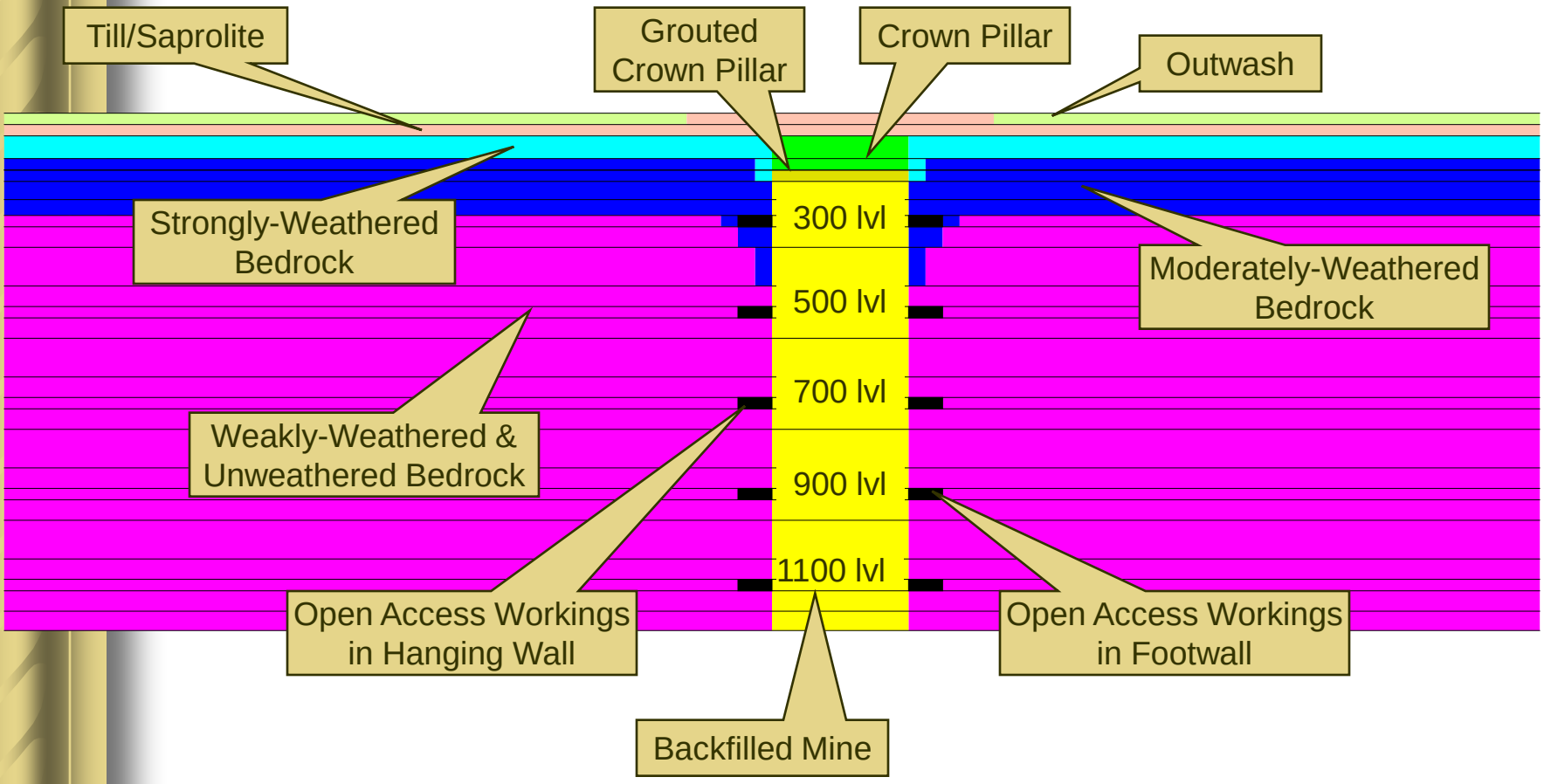

Marquette
Escanaba
Iron Mountain
Menominee
Marinette
Sturgeon Bay
Green Bay
Appleton
Oshkosh
Manitowoc
Sheboygan
Fond du Lac
MILWAUKEE
Waukesha
West Allis
Muskegon
Grand Haven
MICHIGAN
LAKE

LOCATION



Regional Groundwater Flow
Compliance Boundary
Soil Absorption System
TMA
Mine
LAONA
FREEDOM
AINSWORTH
VILLE
PLANT SITE
NASH
Metonga
Mole Lake
FOREST CO.
LANGLADE CO.
ONEIDA CO.

GROUNDWATER MODEL



SOURCE TERM COMPONENTS

- **Pyritic Paste Backfill**
- **Wall Rock in Access Workings**
- **Crown Pillar**
- **Combustion By-Products and Blasting Residues**

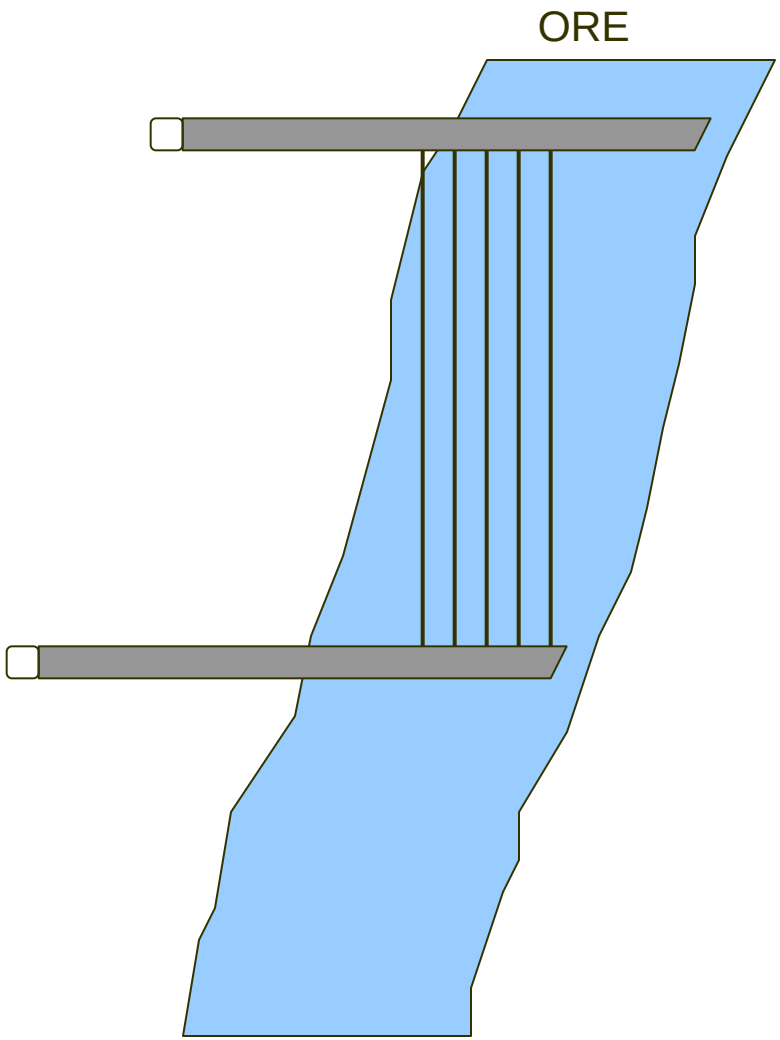
APPROACH

- **Best Engineering Judgment (BEJ)**
- **Upper Bound (UB)**

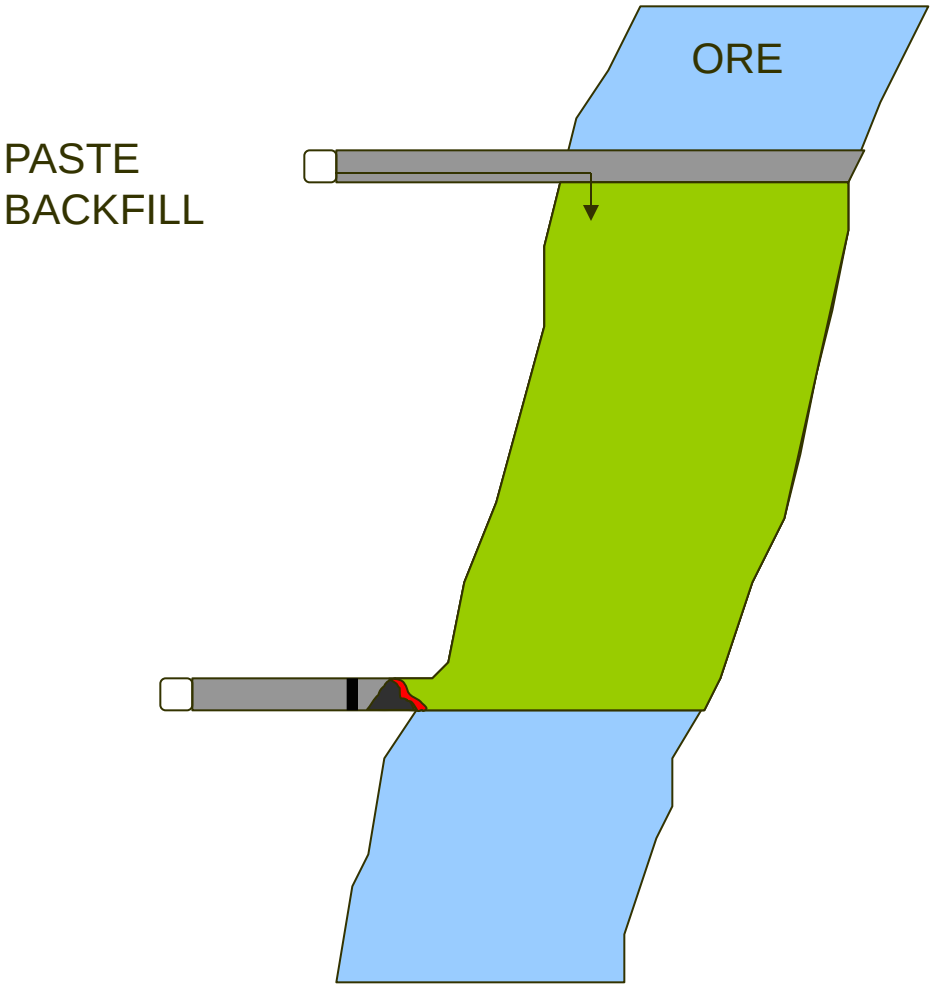
  Waste characterization program and mine plan

- **Sensitivity Analyses**

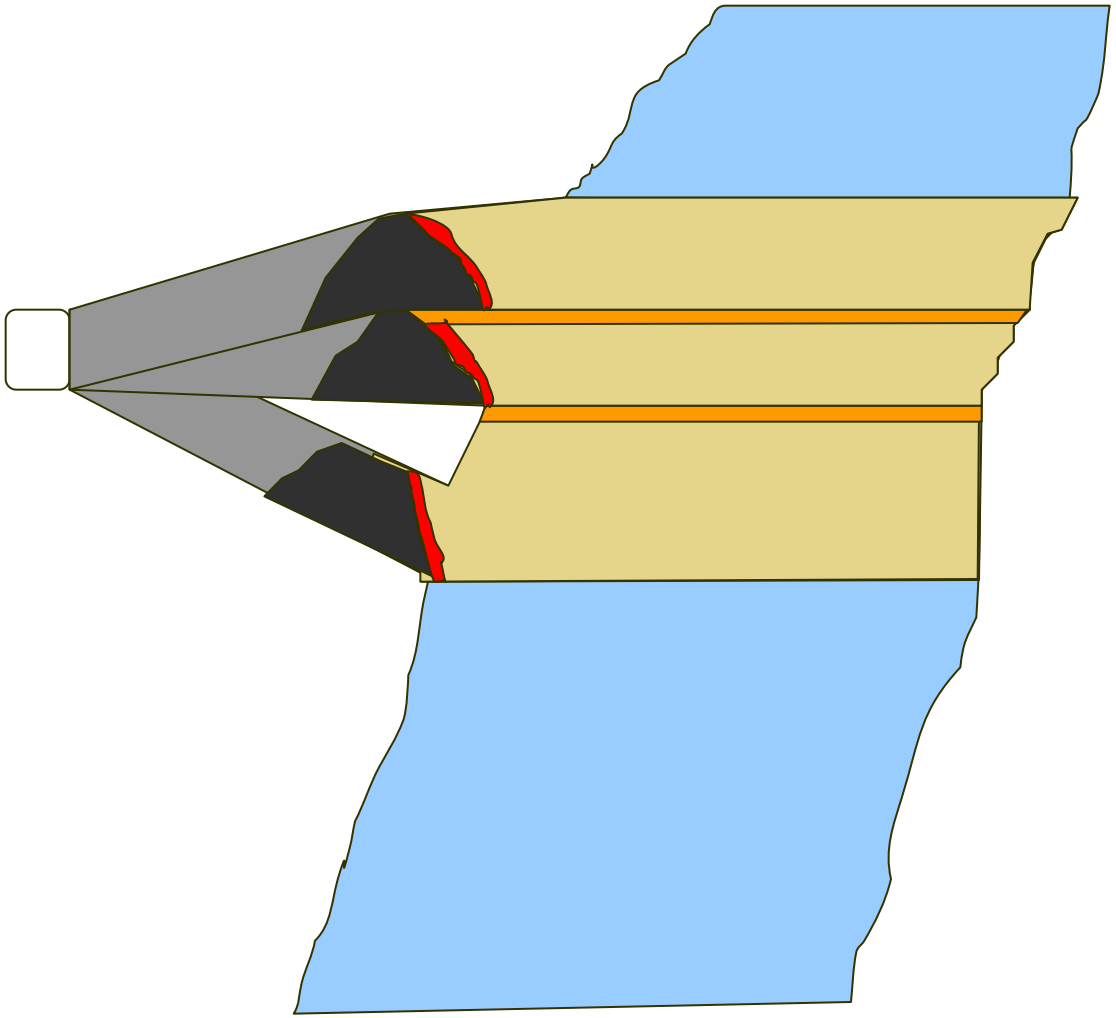
PYRITIC PASTE BACKFILL – BLASTHOLE STOPES



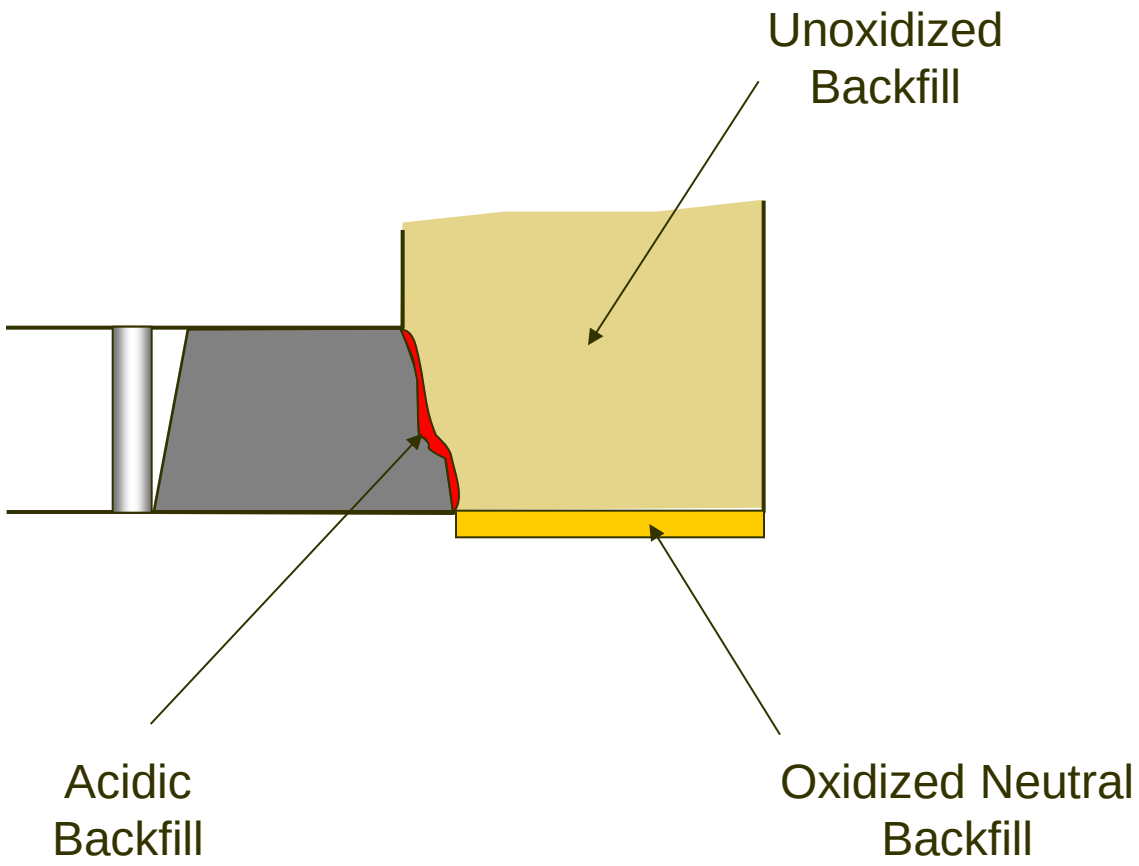
PYRITIC PASTE BACKFILL – BLASTHOLE STOPES



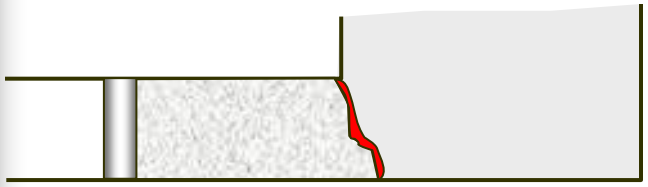
PYRITIC PASTE BACKFILL – CUT AND FILL STOPES



PYRITIC PASTE BACKFILL COMPONENTS



ACIDIC BACKFILL

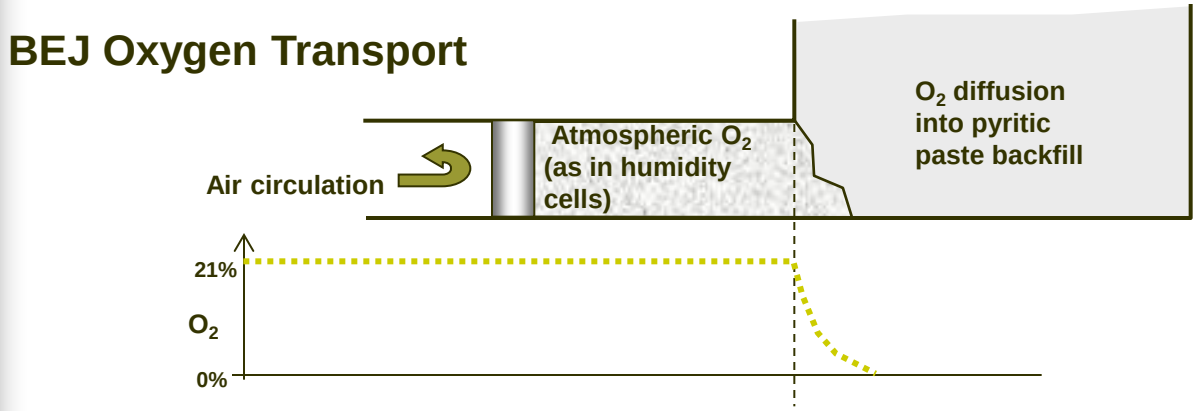


Estimate O_2 flux into
backfilled stopes

Convert O_2 flux into
volume of acidic tailings

Estimate water quality
in acidic backfill

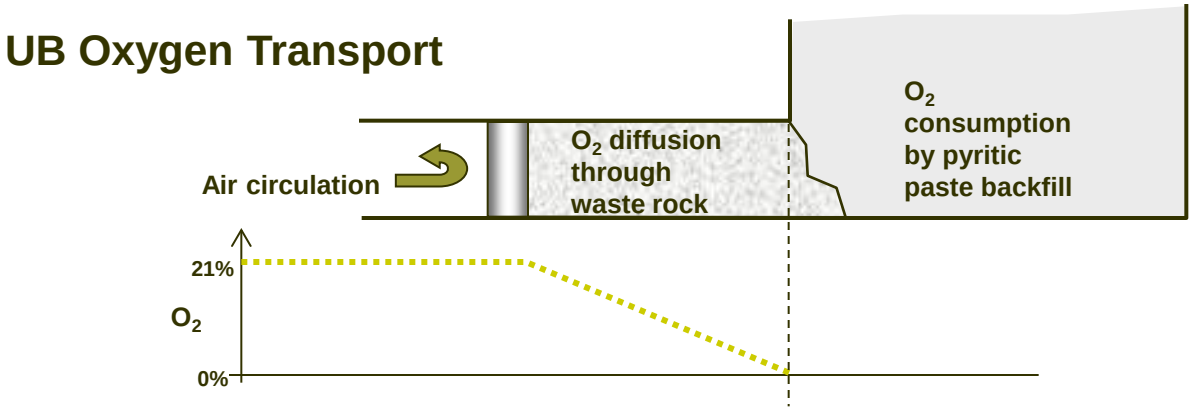
ACIDIC BACKFILL



Assumption: Rate limiting step is diffusion into backfill

O_2 flux from results of column tests with pyritic paste backfill cubes

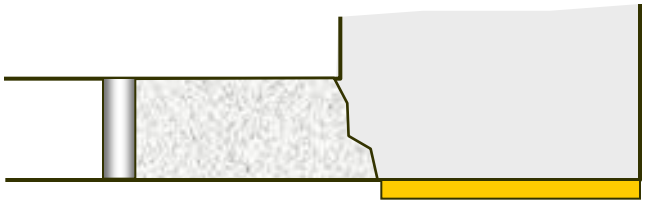
ACIDIC BACKFILL



Assumption: Rate limiting step is diffusion through waste rock

Fick's Law → O_2 Flux = D dC/dx = D C_o / L

OXIDIZED NEUTRAL BACKFILL



Humidity cell test on (cemented) pyritic paste backfill

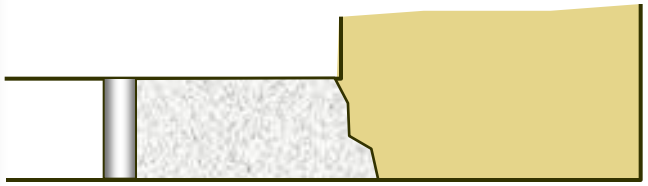
Remains neutral after 65 weeks

Rates of solute release from short term tests

BEJ → first five weeks

UB→ all twenty weeks

UNOXIDIZED BACKFILL



Saturated column test on (cemented) pyritic paste backfill

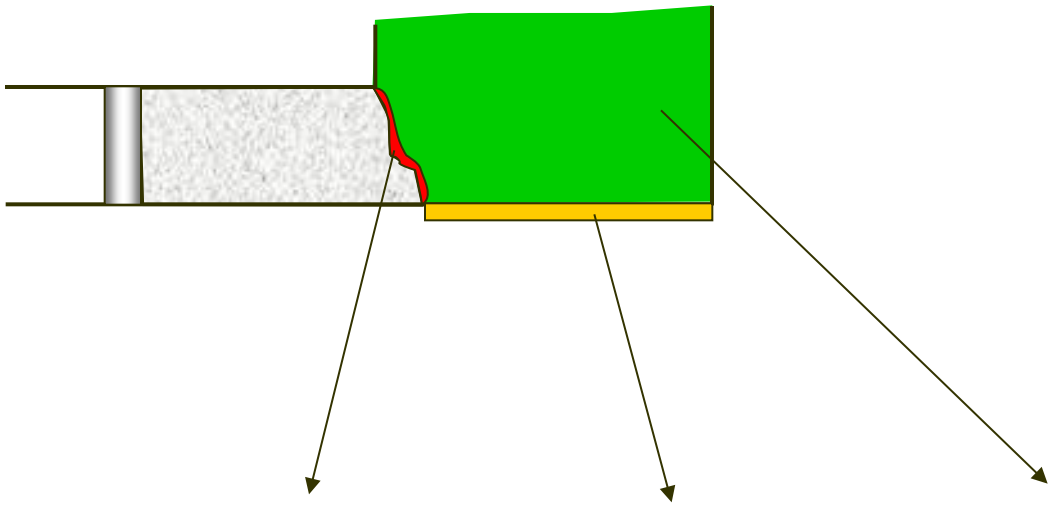
Initial estimates of solute concentrations

Check equilibria with MINTEQA2

pH 11 and Eh –50 mV

Solubility controls on Ca, SO_4, Ni, Pb, Ba, Fe

AVERAGE SOLUTE CONCENTRATIONS IN BACKFILL



$$C_{overall} = \frac{C_{acidic}*Vol_{acidic} + C_{ox\text{-}neut}*Vol_{ox\text{-}neut} + C_{unox}*Vol_{unox}}{Vol_{acidic} + Vol_{ox\text{-}neut} + Vol_{unox}}$$

BEJ CONCENTRATIONS IN BACKFILL

	Volume	SO_4	As	Fe	Zn
Acidic	$6.0x10^2$	164,000	650	59,800	9300
Oxid/Neutral	$4.7x10^5$	2147	0.24	0.29	0.54
Unoxidized	$2.1x10^8$	1250	0.0053	0.008	0.042
Average	-	1252	0.0076	0.18	0.070

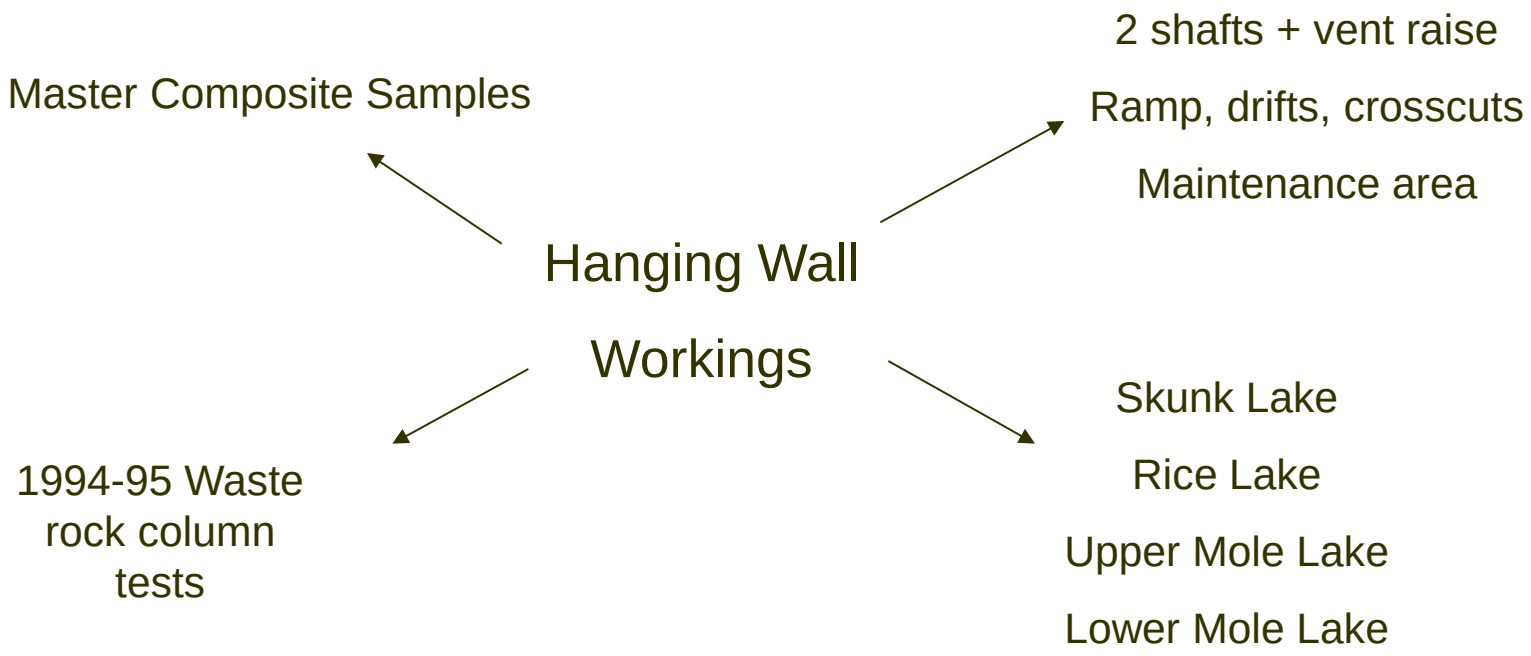
UB CONCENTRATIONS IN BACKFILL

	Volume	SO_4	As	Fe	Zn
Acidic	$1.7x10^5$	169,500	650	59,800	9300
Oxid/Neutral	$4.7x10^5$	2659	1.1	1.5	1.1
Unoxidized	$2.1x10^8$	1317	0.0053	0.037	0.042
Average	-	1451	0.52	47	7.3

SOURCE TERM COMPONENTS

- Pyritic Paste Backfill
- **Wall Rock in Access Workings**
- Crown Pillar
- Combustion By-Products and Blasting Residues

WALL ROCK


Master Composite Samples
2 shafts + vent raise
Ramp, drifts, crosscuts
Maintenance area
Hanging Wall
Workings
1994-95 Waste rock column tests
Skunk Lake
Rice Lake
Upper Mole Lake
Lower Mole Lake

WALL ROCK

Solute Release (mg)

$= \Sigma$ Specific release (mg ft^{-2} yr^{-1}) * Surface area (ft^2) * Time (yr)

Waste rock column tests

Mine plan 30x

4 - 30 years

Skunk, Rice, Upper Mole, Lower Mole

WALL ROCK

Solute release divided by workings volume to give initial concentration.

Then checked solubility constraints with MINTEQA2

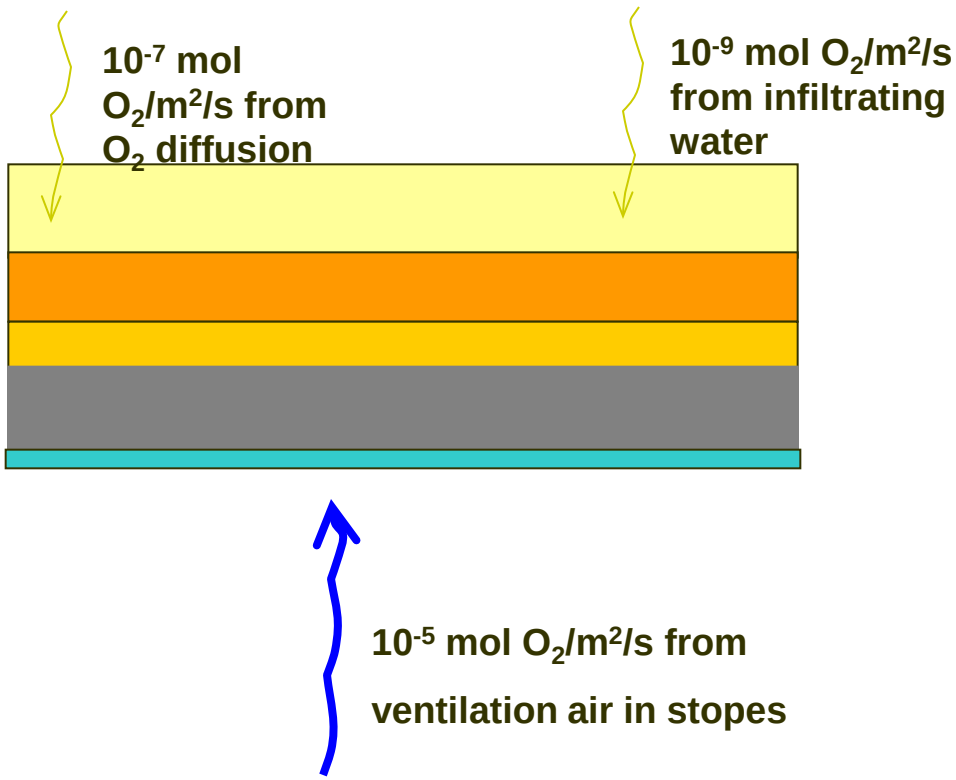
Estimated Concentrations

SO_4	16 mg/L
As	0.023 mg/L
Fe	1.1 mg/L
Zn	0.049 mg/L

SOURCE TERM COMPONENTS

- Pyritic Paste Backfill
- Wall Rock in Access Workings
- **Crown Pillar**
- Combustion By-Products and Blasting Residues

CROWN PILLAR



CROWN PILLAR

Solute Concentrations

Method same as wall rock, back of top stope only

Specific release rates calculated from humidity columns on high grade Zn ore

Estimated Concentrations

SO_4	8.2 mg/L
As	0.00036 mg/L
Fe	0.024 mg/L
Zn	1.4 mg/L

SOURCE TERM COMPONENTS

- Pyritic Paste Backfill
- Wall Rock in Access Workings
- Crown Pillar
- **Combustion By-Products and Blasting Residues**

COMBUSTION BY-PRODUCTS AND BLASTING RESIDUE

Natural Gas (heating)

Fuel Oil (equipment)

Insignificant

Blasting Residues

Mill Balance

VOLUME WEIGHTED CONCENTRATIONS - BEJ

Material	SO_4	As	Fe	Zn
Paste Backfill	1,252	0.0076	0.18	0.070
Wall Rock	16	0.023	1.1	0.049
Crown Pillar	8.2	0.00036	0.024	1.4
Average	1,145	0.0088	0.25	0.073

VOLUME WEIGHTED CONCENTRATIONS - UB

Material	SO_4	As	Fe	Zn
Paste Backfill	1,451	0.52	47	7.3
Wall Rock	21	0.026	3.8	0.065
Crown Pillar	17	0.00048	0.30	5.2
Average	1,327	0.47	43	6.7

SENSITIVITY ANALYSES

- **Number of stopes**
- **Surface area of exposed backfill (x-cut)**
- **Exposure time**
- **Pyritic paste backfill NP**
- **Wall rock surface area**
- **Early shutdown**
- **100 runs of solute/groundwater model**

SENSITIVITY ANALYSIS

- **BEJ Estimates**
  - **insensitive**
- **UB Estimates**
  - **sensitive to acidic backfill volume**

WHAT DOES IT MEAN?

- **We have a problem…**

  Acidic backfill for metals

  Rest of the backfill for sulphate

  Wall rock a possible problem

- **Solution?**

  Limit acidification of the backfill

SENSITIVITY ANALYSIS

- **Oxygen barriers**
  (90% - 99.99% effective)
- **Direct removal of acidic backfill**
- **Cleaning wall rock surfaces**
  (50% - 90% solute removal)

can achieve significant reductions

OTHER OPTIONS

Limiting SO_4 in unoxidized backfill:

- **use gypsum-free cement**
- **wash the backfill**
- **use Ba to precipitate SO_4**

No proven methods

RFLOODED MINE MANAGEMENT PLAN

- **Implementation of O_2 barriers**
- **Testing & removal of acidic backfill**
- **Wash mine workings**
- **Passive hydraulic control**
- **Monitoring**
- **Contingencies**
  - **High volume flushing**
  - **Hydraulic containment**

REFLOODED MINE MANAGEMENT PLAN

- **Continual evaluation of emerging technologies**
- **Existing plan is a work in progress**