PREDICTING MINE INFLOW FOR WATER TREATMENT

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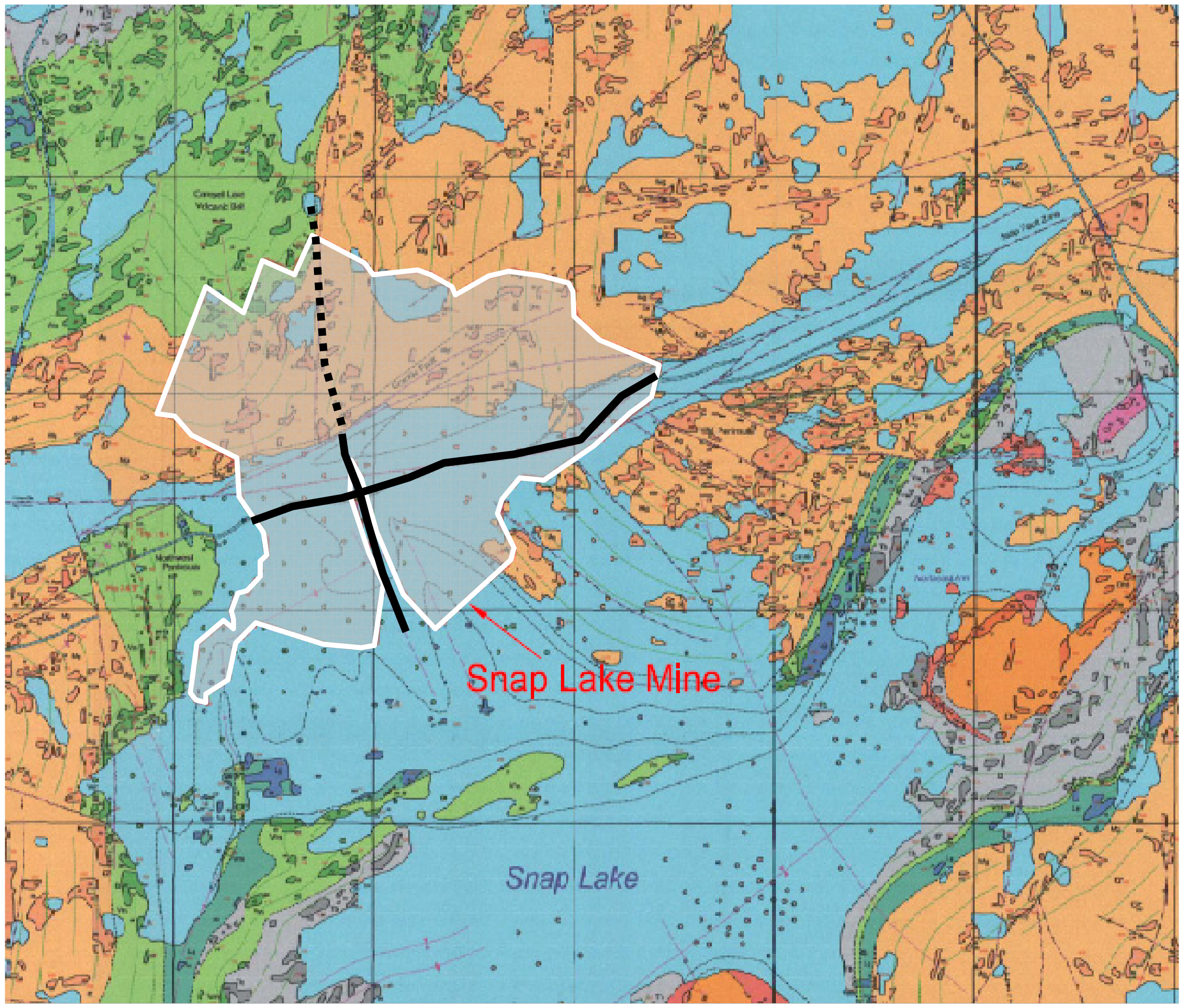
MINE INFLOW PREDICTIONS...

- are required for mine planning and design
- are required for mine discharge permitting
- are required for treatment design

and

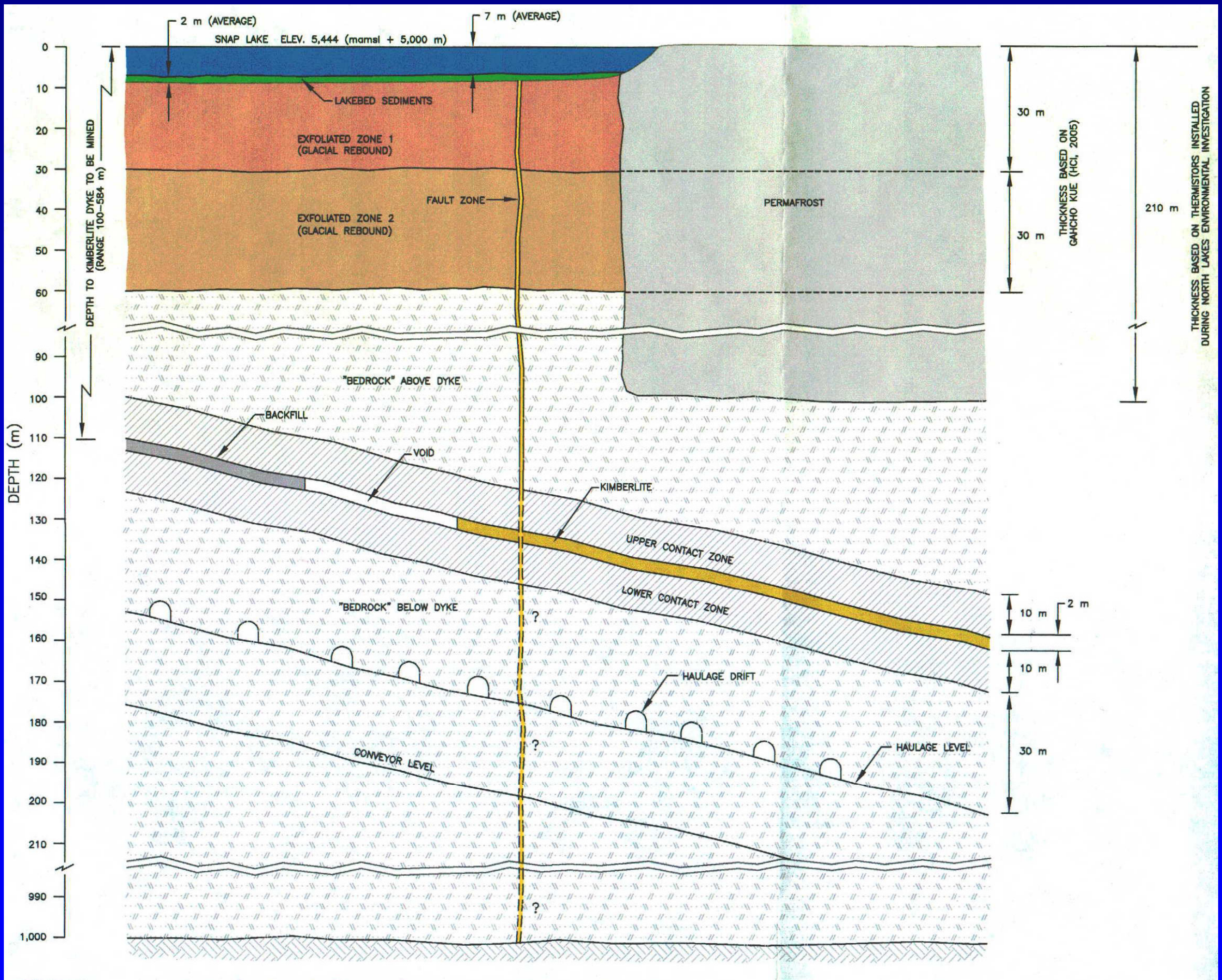
- are frequently wrong

Case: Snap Lake Diamond Mine



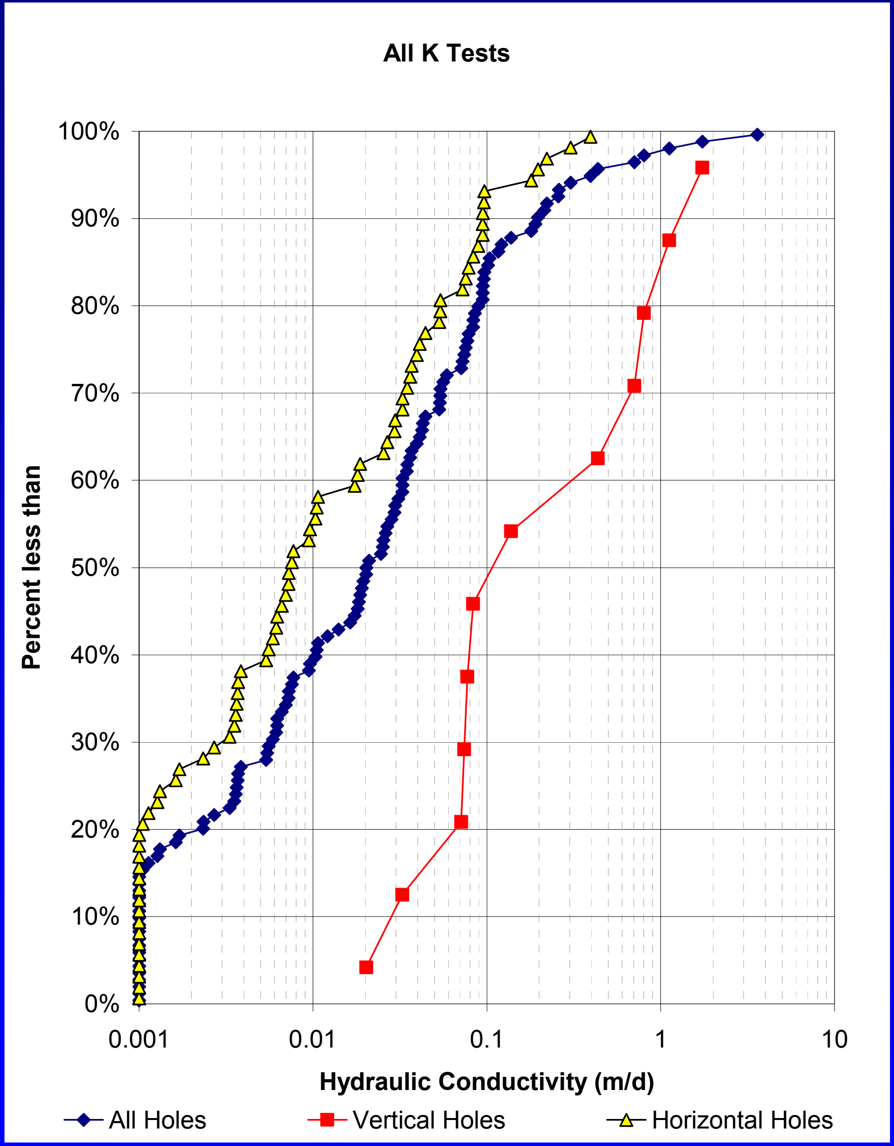
- Diamond deposit in a tabular kimberlite sill
- Underground mine partially under Snap Lake
- Detailed investigation of geohydrology conducted to support inflow evaluation
- High inflow expected along major fault zones beneath lake

Case: Snap Lake Mine



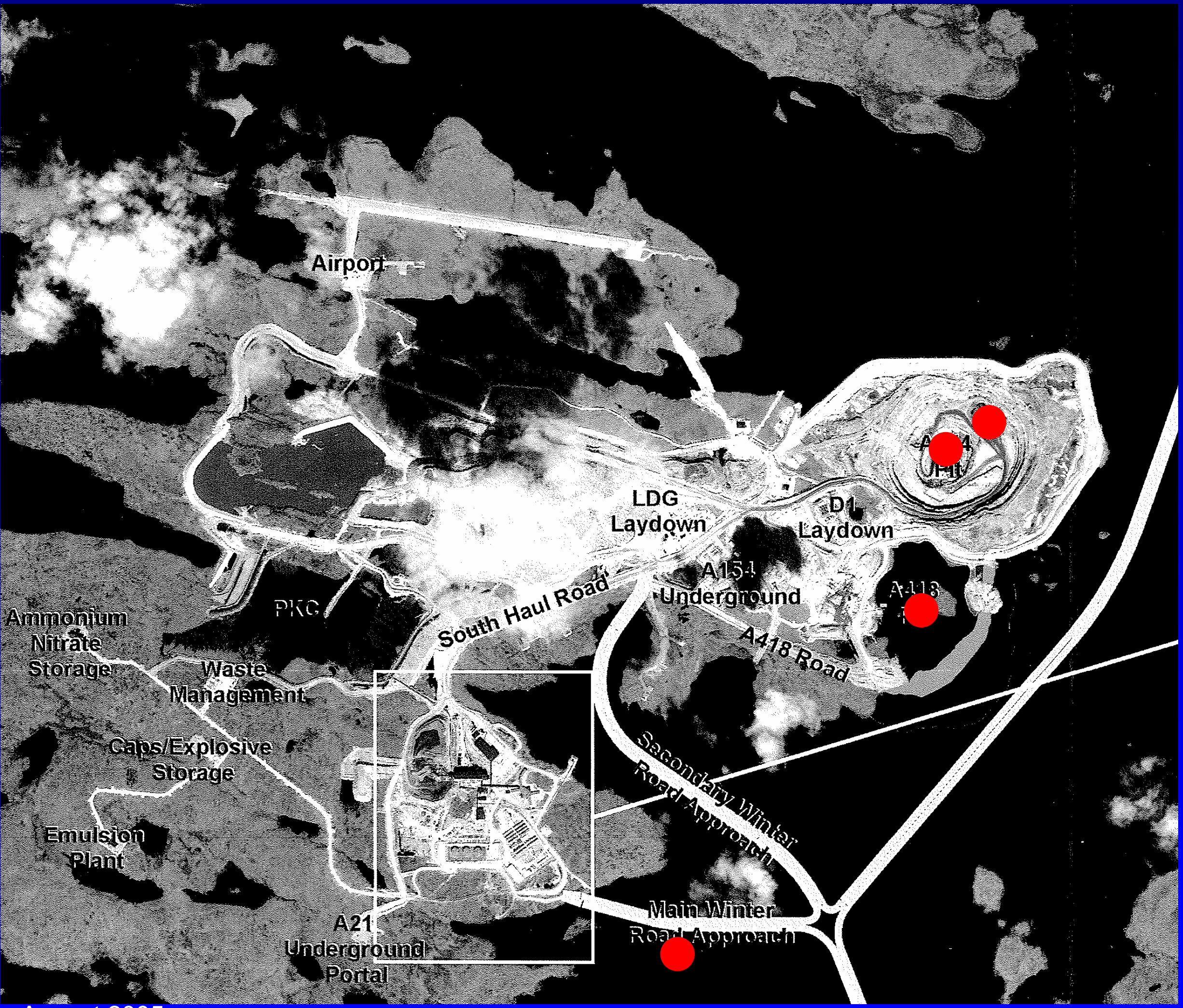
- Mine inflow analysis performed using a complex 3D fracture flow model
- Mine inflow predicted to be 59,000 cu.m/day (11,000 gpm) to 530,000 cu.m/day (100,000 gpm)
- Mine inflow with lake dewatered predicted to be 4,000 cu.m/day (700 gpm)
- Mine inflow with progressive mine backfill predicted to be similar to inflow without backfill
- Mining, dewatering, treatment and mitigation decisions too uncertain with this flow range

Case: Snap Lake Mine



- Huge range in inflow estimate results from uncertainty about hydraulic conductivity
- Re-evaluation performed with permeability data appropriately applied
- Mine inflow computed to be ~91,000 cu.m/d (~17,000 gpm)
- Mine inflow with progressive mine backfill predicted to be ~26,000 cu.m./d (~5,000 gpm)
- Mine inflow with lake dewatered predicted to be ~18,000 cu.m/day (~3,000 gpm)
- Mining, dewatering, treatment and mitigation decisions can be made with this flow range

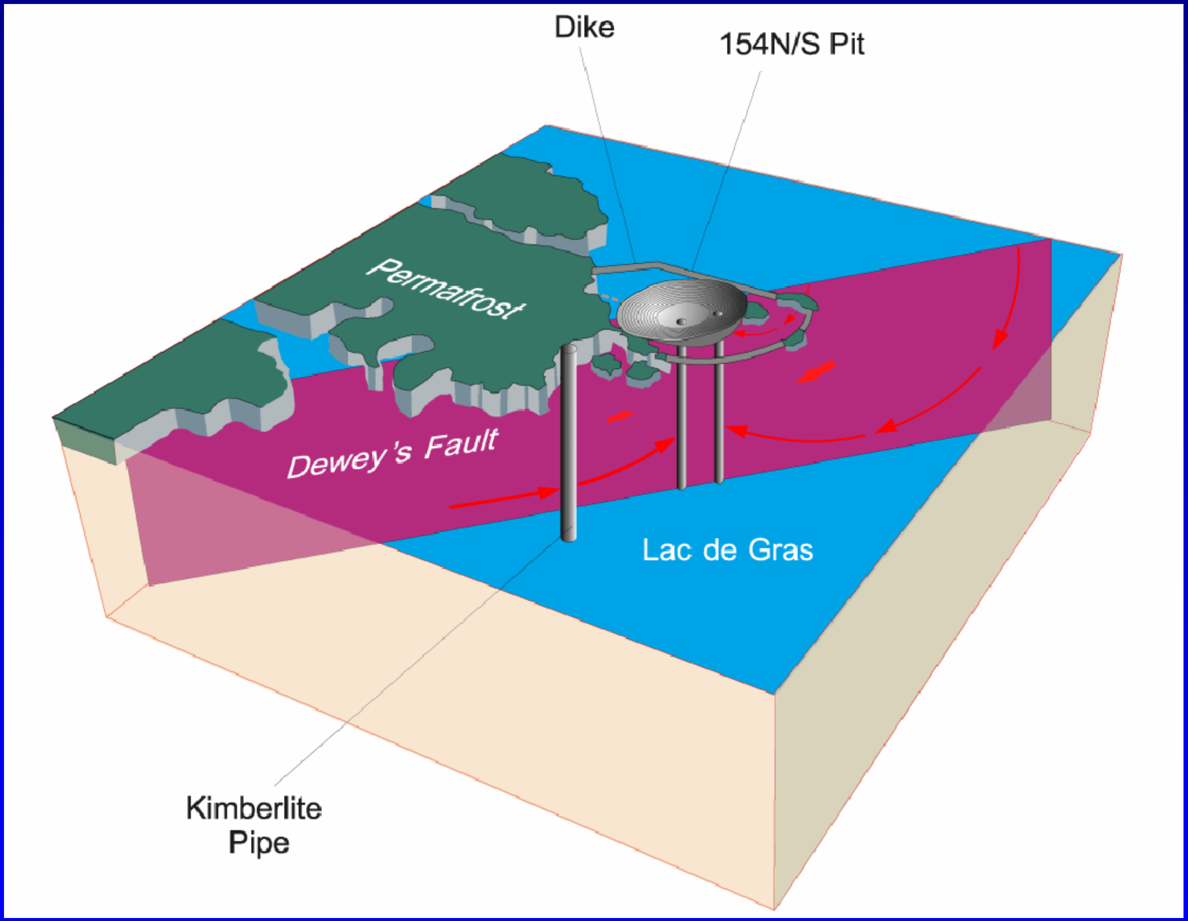
Case: Diavik Diamond Mine



August 2005

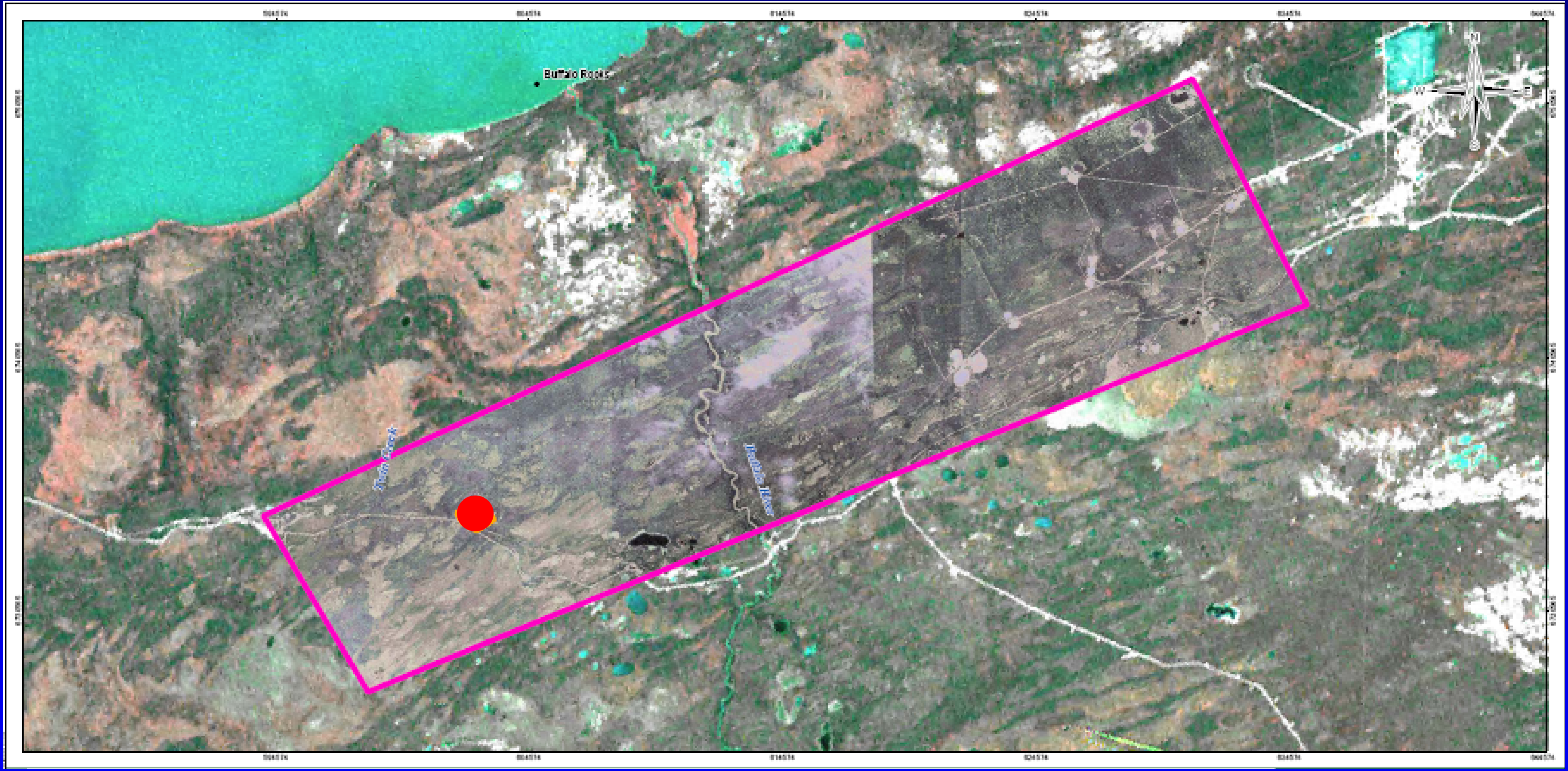
- Diamond deposit includes four kimberlite pipes
- Mine design comprised surface mining followed by underground development
- Lake bermed off and drained to surface mine perimeter to allow surface mining
- Groundwater investigation conducted to determine inflow
- Extensive drilling and permeability testing
- Computer simulation of groundwater system to determine inflow
- Mine water inflow predicted to be ~1,000 m3/d (200 gpm)
- Water requires treatment to remove phosphorus to protect receiving water in Lac de Gras

Case: Diavik Diamond Mine



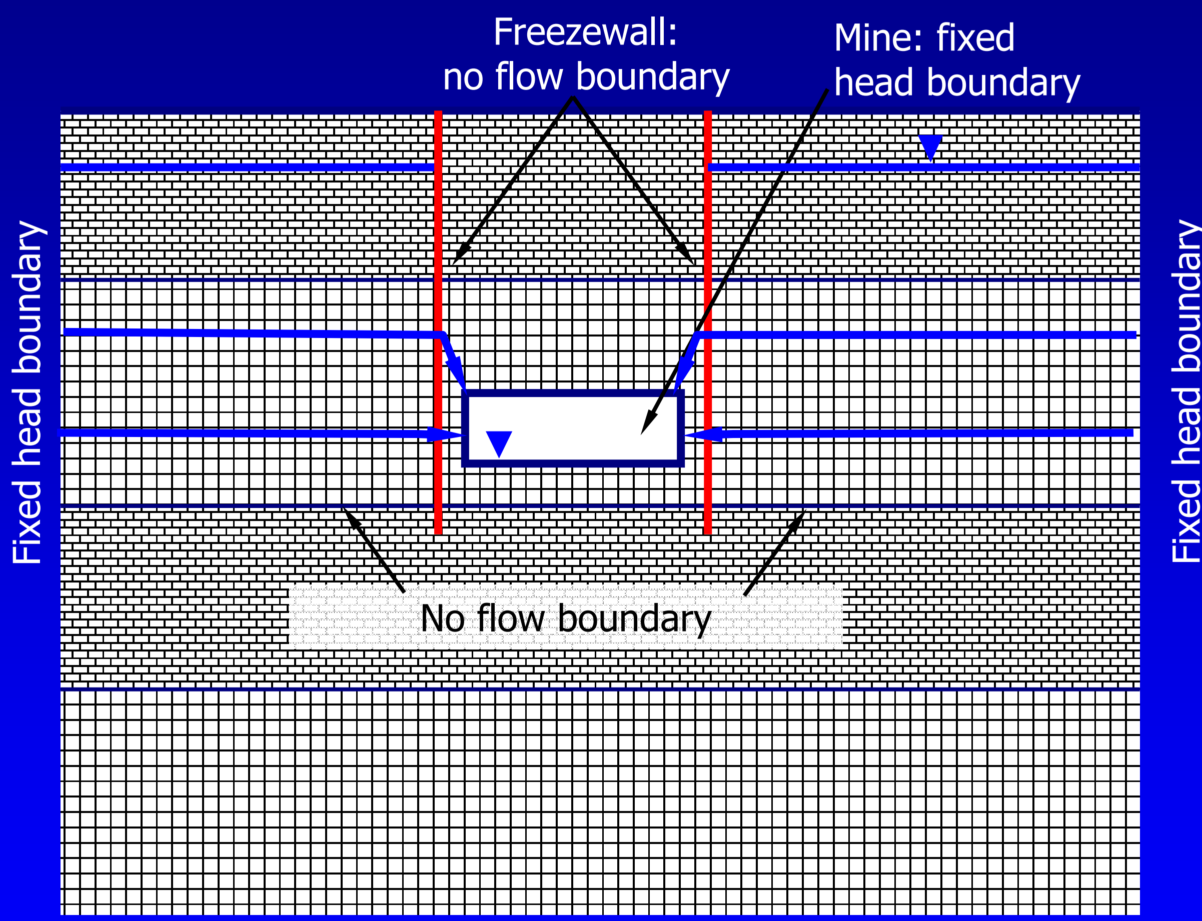
- Actual inflow 20,000 cu.m/d (4,000 gpm) due to encountering unidentified Dewey's Fault zone
- Inflow much higher and dewatering much more expensive than expected
- Discharge to Lac de Gras much higher than originally expected
- High inflow caused high dissolution of ammonium nitrate from blasting agents
- Large mass of ammonium and nitrate discharged to Lac de Gras
- Treatment impractical; discharge standards not met

Case: Pine Point Pilot Project



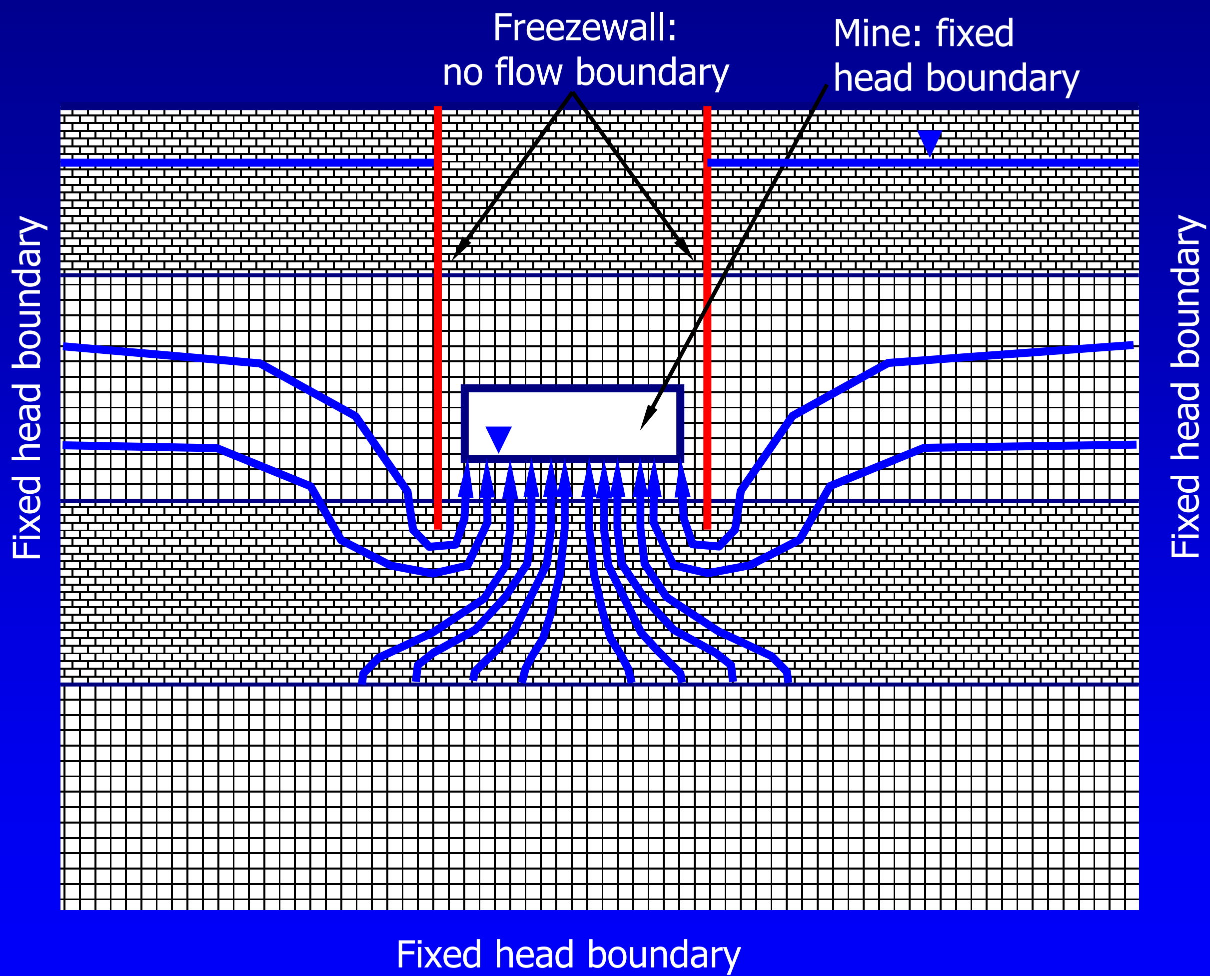
- Mine in Pine Point district
- Formerly wettest mine in world: flows >1,000,000 cu.m./d (>200,000 gpm)
- New freeze-wall mine design proposed
- Predicted inflow ~1,320 m3/d (250 gpm)

Case: Pine Point Pilot Project



- Proponent performed analysis of mine inflow using previously determined parameters
- Assumed the underlying formation was impermeable
- Predicted inflow ~1,320 m3/d (250 gpm)

Case: Pine Point Pilot Project



- Boundary conditions for analysis inappropriate
- Prior (1983) analysis shows two orders of magnitude higher flow than estimated by proponent
- Reanalysis by regulatory representatives indicated inflow would be ~30,000 m^3/d (6,000 gpm)
- Required treatment and discharge changes at permit time

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Correct prediction of mine inflows matters

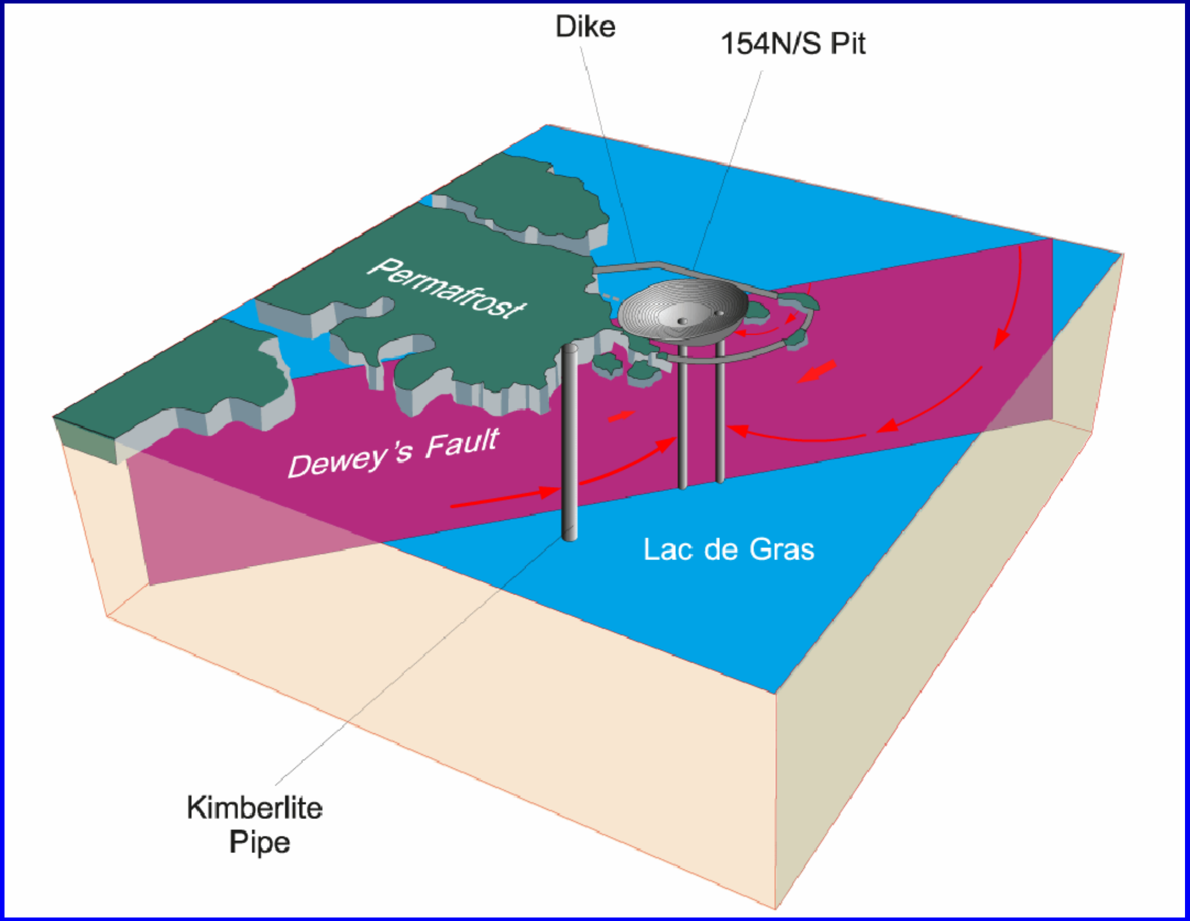
- Water treatment costs and mine feasibility are strongly dependent on the quantity of water that must be handled and often treated
- An inaccurate inflow estimate can have a strongly negative effect on mine economics, particularly when the inflow is much higher than the estimate.
- An incorrect inflow estimate may lead to inappropriate or unachievable mining choices with respect to dewatering, mitigation, and/or treatment

Why inflow is difficult to predict:

- uncertainty in the conceptual model for flow to the mine
- uncertainty in the location and handling of boundary conditions for the flow regime
- uncertainty in the measurement and application of hydraulic parameters

Conceptual Model

- Fundamental to all analyses
- Reflects all feasible flow systems
- Depends on hydrogeology
- Requires comprehensive testing
- If wrong, flow estimate will be wrong



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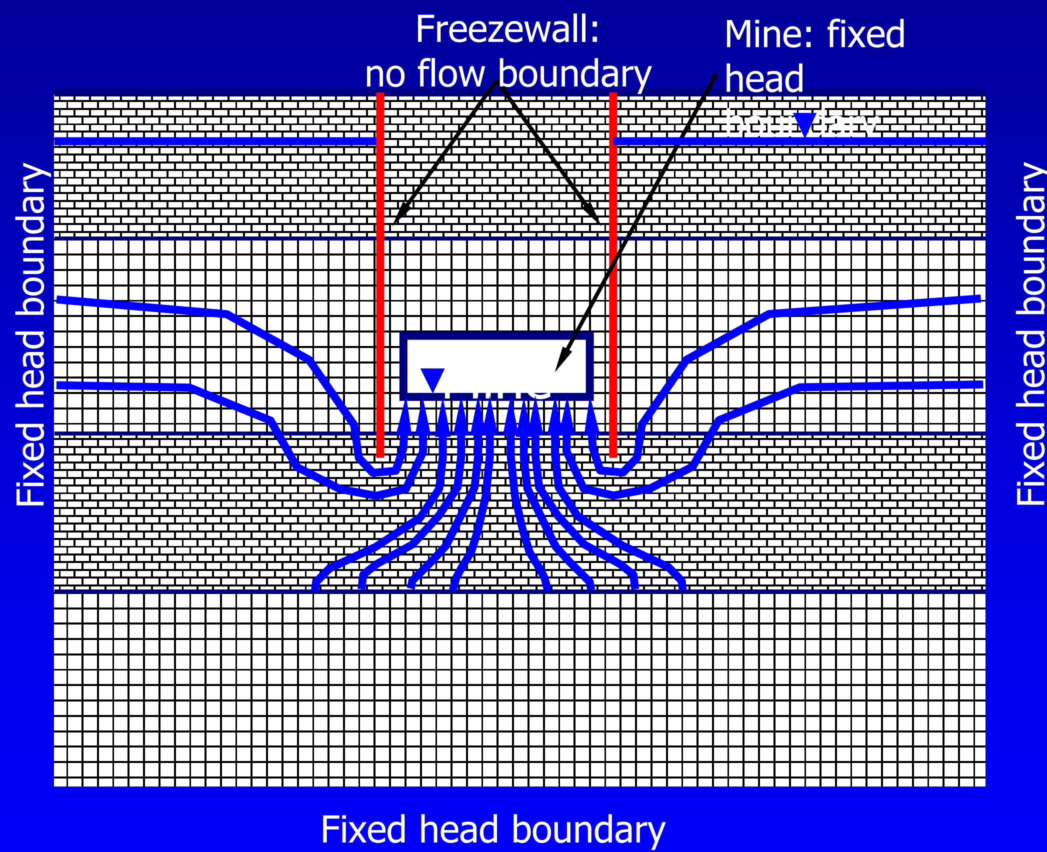
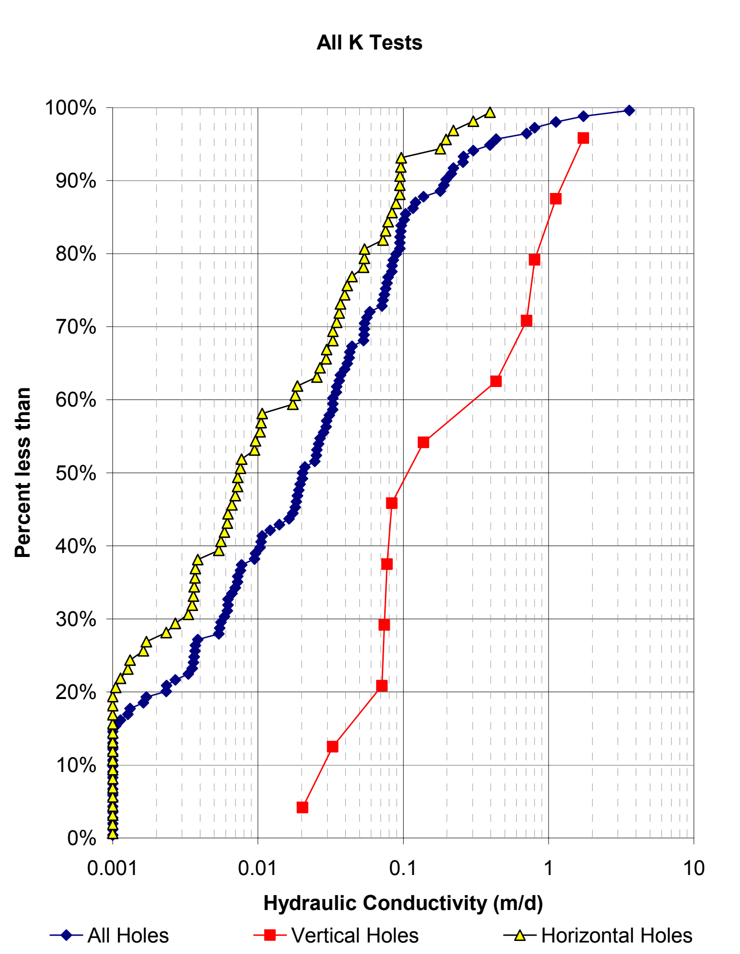
Boundary Conditions

- Control where the water is coming from
- Frequently determine inflow amount
- Usually easy to identify
- If wrong, flow estimate will be wrong



Hydraulic Parameters

- Hydraulic conductivity controls flow
- Very high variability in individual readings
- Perform mine-scale tests
- Perform tests across direction of flow



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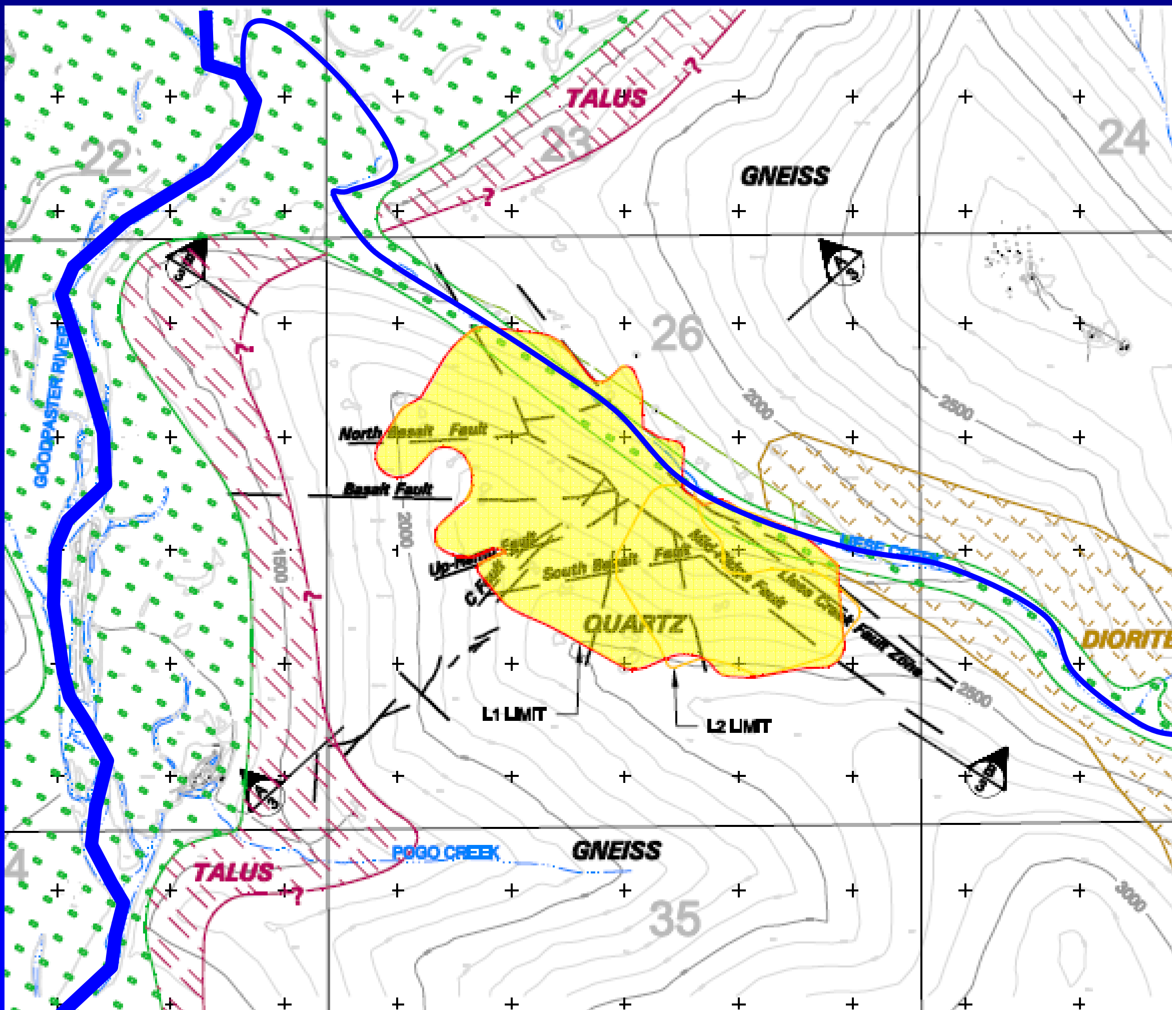
Case: Pogo Gold Mine



- Gold deposit in igneous rockmass
- Tabular orebody in two sills
- Discontinuous permafrost at surface
- Total extraction by underground mining methods
- Goodpaster River west of Mine
- Liese Creek runs alongside mine
- Pristine environment
- All discharge water must be treated to background quality
- Permitting agency believed flow would be high based on proximity to streams and history of high inflows to other Alaskan mines
- To obtain permit proponent had to prove that the inflow estimate was correct
- Driven by need to demonstrate that treatment of arsenic in inflow would not render project uneconomic

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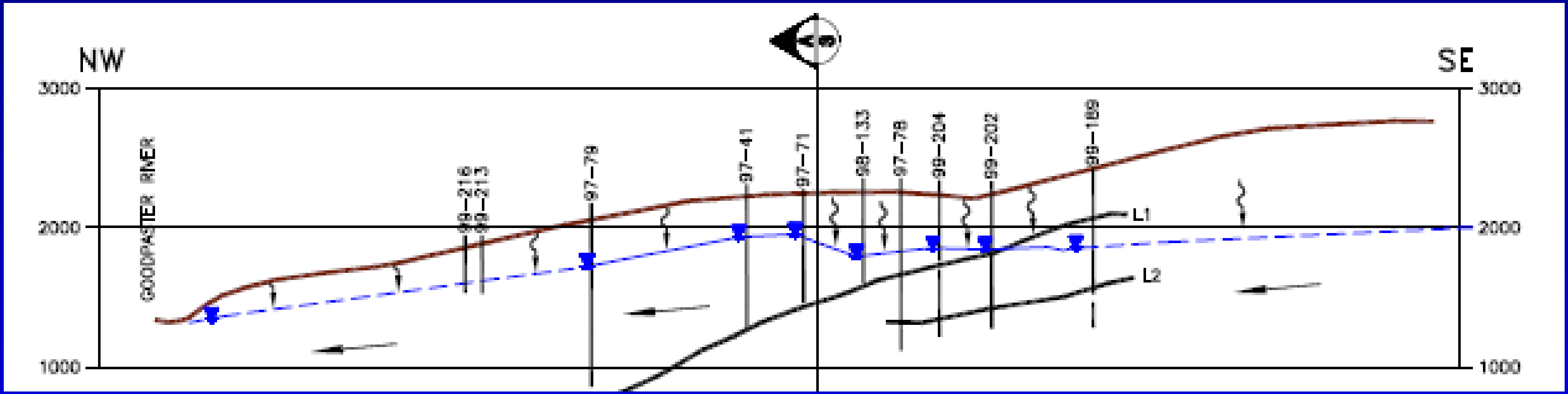
Case: Pogo Gold Mine



- Inflow prediction performed by three dimensional groundwater model
- Mine inflow is source controlled:
  - Infiltration from precipitation (through permafrost)
  - Inflow from streams
- Predicted inflow was ~300 cu.m./d (~50 gpm)
- Subsequent mining has confirmed this value

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Conclusion

- Mine water management requires accurate inflow prediction
  - Dewatering
  - Water treatment
  - Water disposal

- Accurate inflow prediction is available with
  - Comprehensive conceptual model
  - Appropriate boundary conditions
  - Accurate flow parameters