BRITANNIA MINE REMEDIATION PROJECT
Water Management

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Scope of Presentation

- Overview of the Britannia Mine Remediation Project
  - Background
  - Summary of environmental problems at Britannia
  - Province's remediation concept
- Water Management – the Key to Remediation
  - Surface water
  - Mine water
  - Groundwater
- Lessons Learned/Next Steps
- Questions

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Where and What is Britannia?

- Located on Sea-to-Sky Hwy
- Copper Mine from 1904 to 1974
- Was the ‘Largest copper mine in British Empire’
- Ore produced: 48 million tonnes

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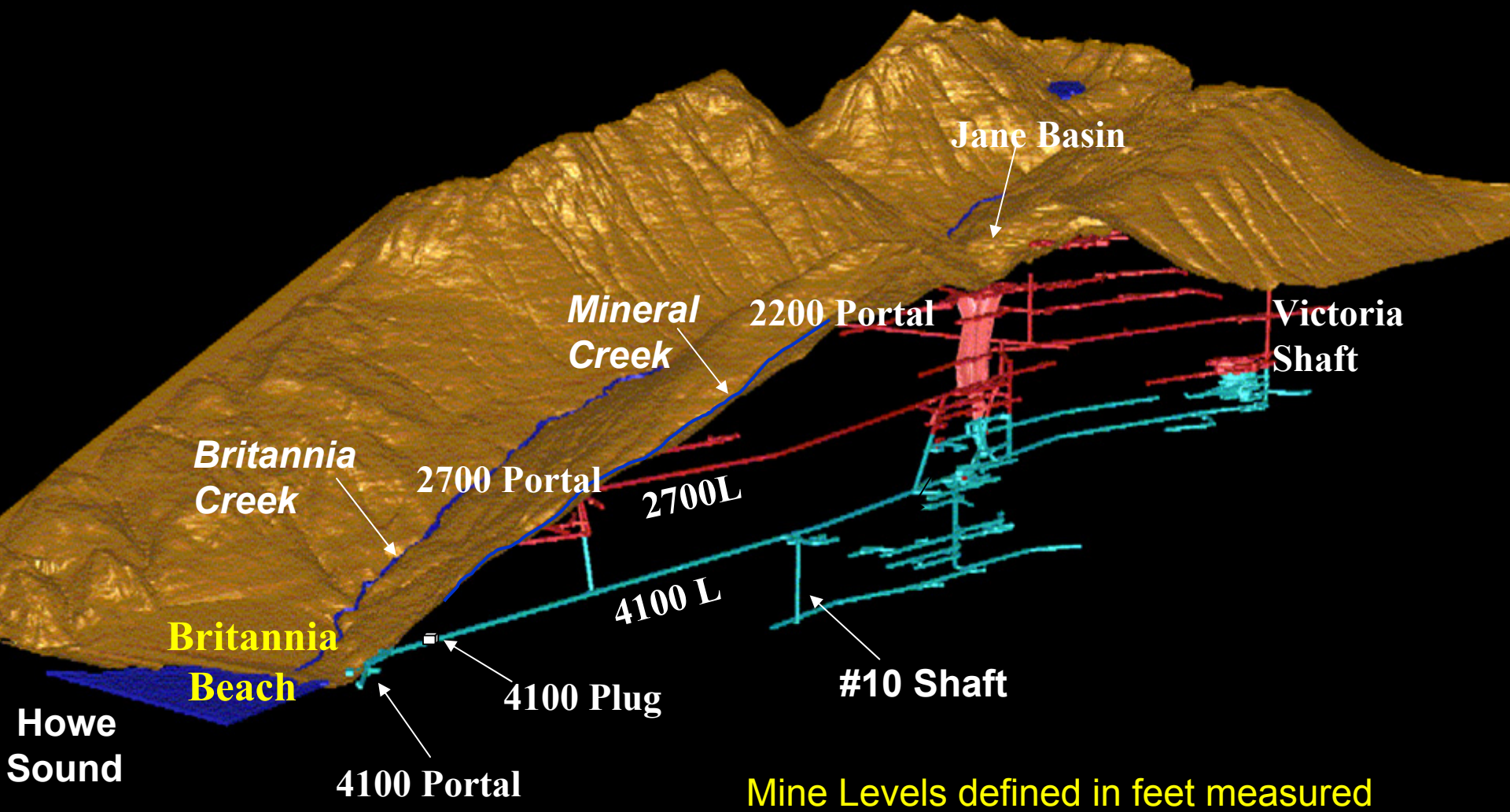
Britannia Creek
Britannia Beach
Jane Basin
Howe Sound
Victoria Camp
Furry Creek
Porteau Cove
N
W
E
S
Image © 2005 DigitalGlobe
Google
Pointer 49°35'29.80" N 123°10'45.56" W elev 3601 ft
Streaming 100%
Eye alt 29673 ft

3D Cutaway of Britannia Mine



Mine Levels defined in feet measured downwards from highest elevation in mine

What's the Problem?

- Naturally occurring metal sulphide orebody
  - Many underground openings
  - Massive disturbance of rock from historical mining
  - Most of the workings not permanently flooded
  - Almost unrestricted flow of surface drainage into workings
  - Mining voids convey water to 4100 Level
- "The largest point source of metal pollution in North America discharging to a marine environment"

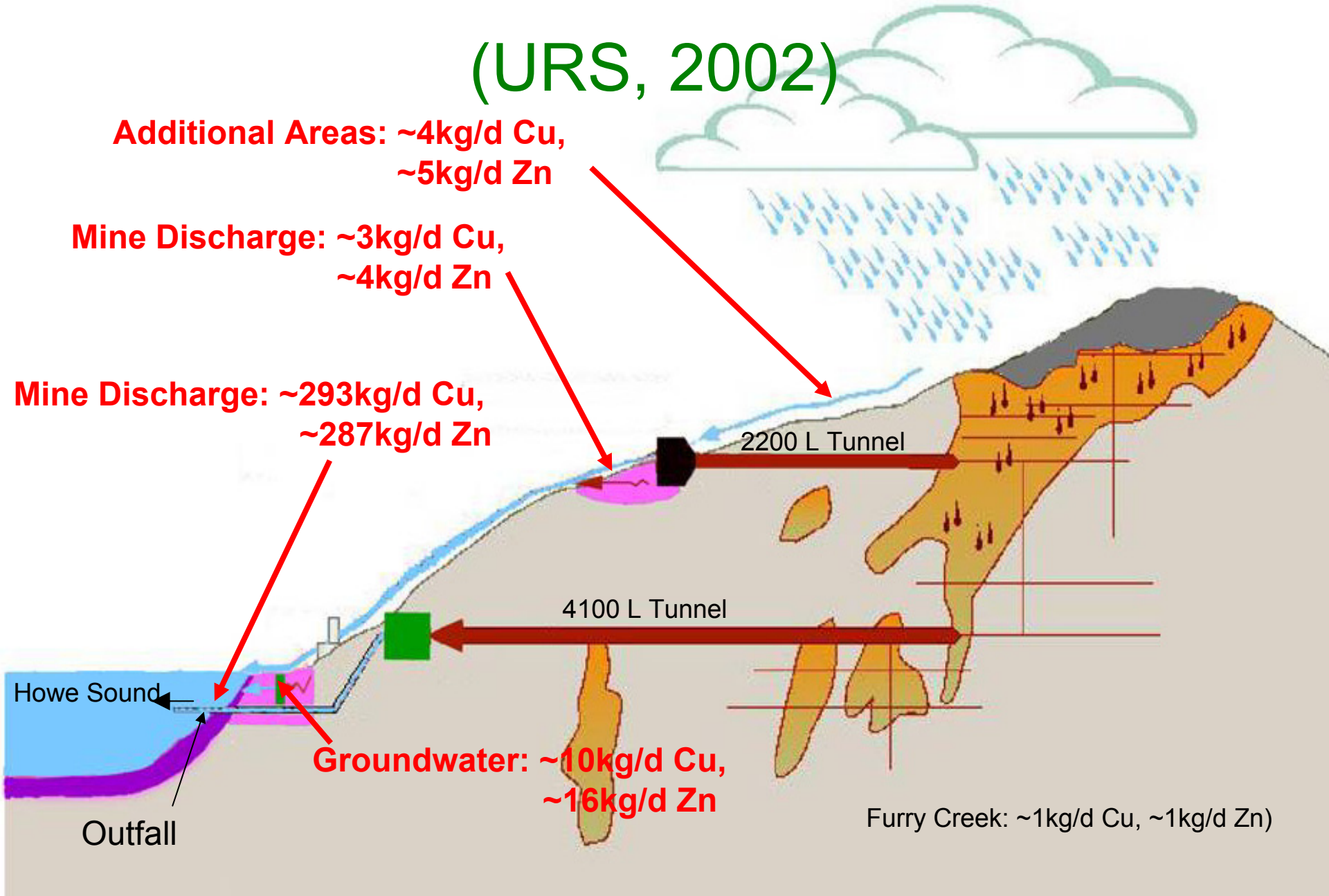
What's the Problem?

Issues:

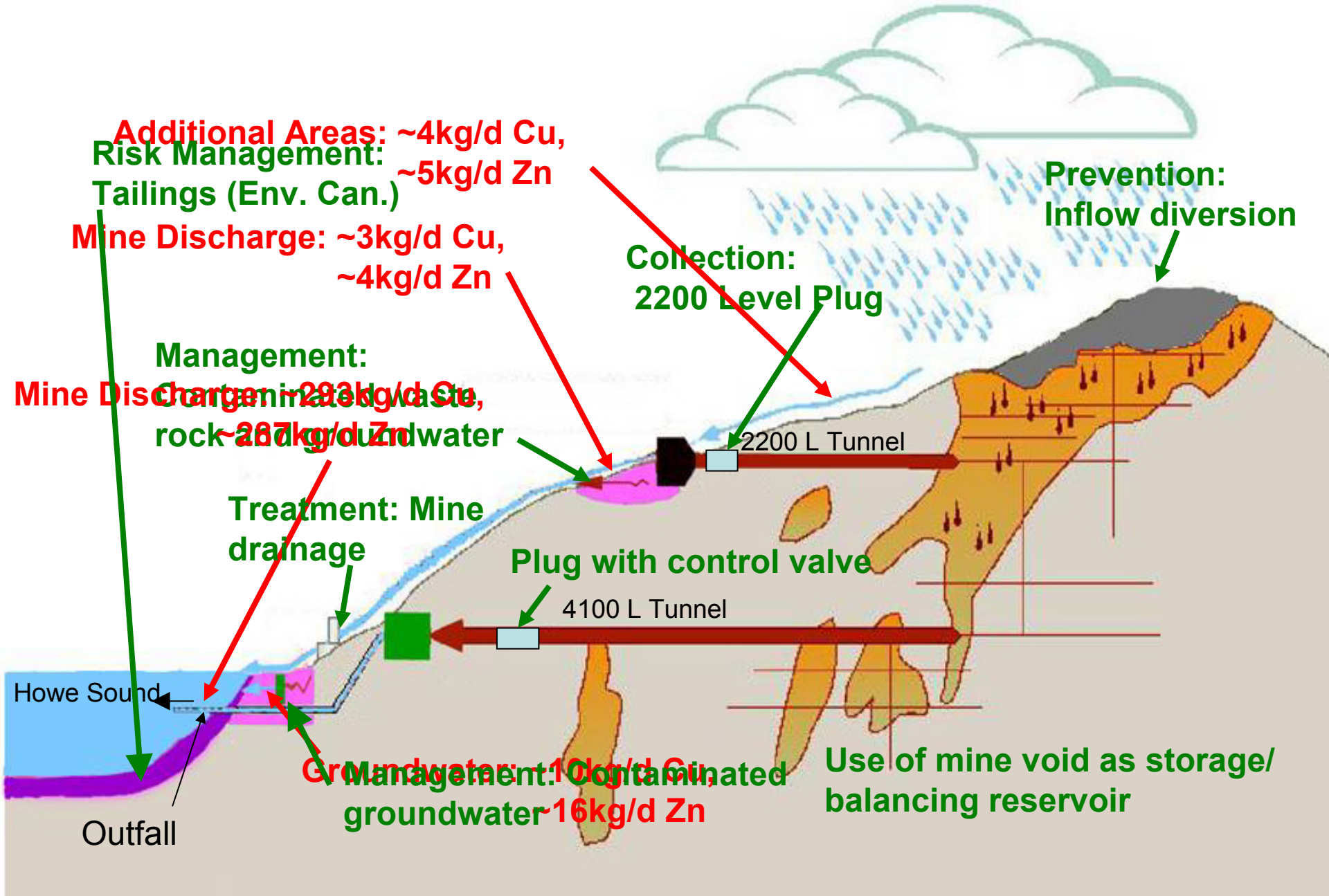
- ~5million m^3/year ARD from mine workings
  - copper, zinc, cadmium, pH~3.5
- Metal-contaminated groundwater discharging to Howe Sound:
  - Alluvial Fan of Britannia Creek
  - Waste dump leaching
- Metal-contaminated surface water (run-off)
- Impact of aquatic life in Howe Sound and local waterways:
  - Squamish River salmon run

Howe Sound Metal Loading Estimates

(URS, 2002)



Remedial Concepts



Water Management

- Management of mine water, groundwater & surface water:
  - Key to the Province's remediation plan for the site
- Three main components:
  - Reduce volume of clean water becoming contaminated:
    - In the mine
    - In surface water courses
  - Capture and treat contaminated groundwater to prevent its discharge to the shallow marine environment
  - Manage mine water storage to allow efficient treatment (and generate micro-hydro power)

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Surface Water Diversions

- 80% of mine water enters through the open pits in Jane Basin (SRK study)
- Three catchment areas had the potential for partial diversion of surface flows:
  - Likely that the diversions would be most effective at ‘shaving’ the peak inflows during freshet and summer/fall rainstorm events
  - Up to 15% of the mine inflow had the potential to be captured and diverted as clean water
  - Cost benefits
- Three diversions constructed
  - Upper Jane Creek
  - East Bluff
  - Victoria

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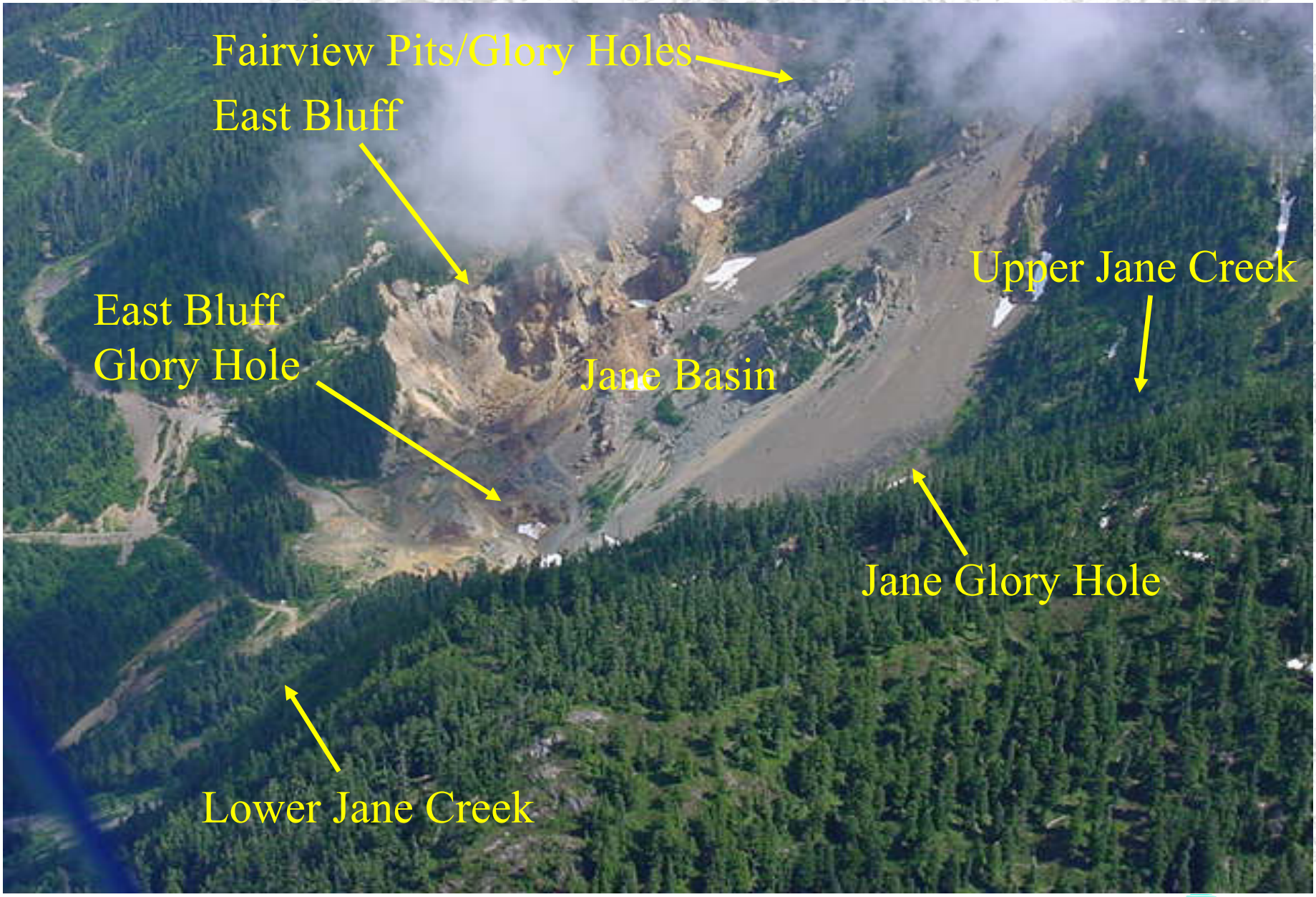

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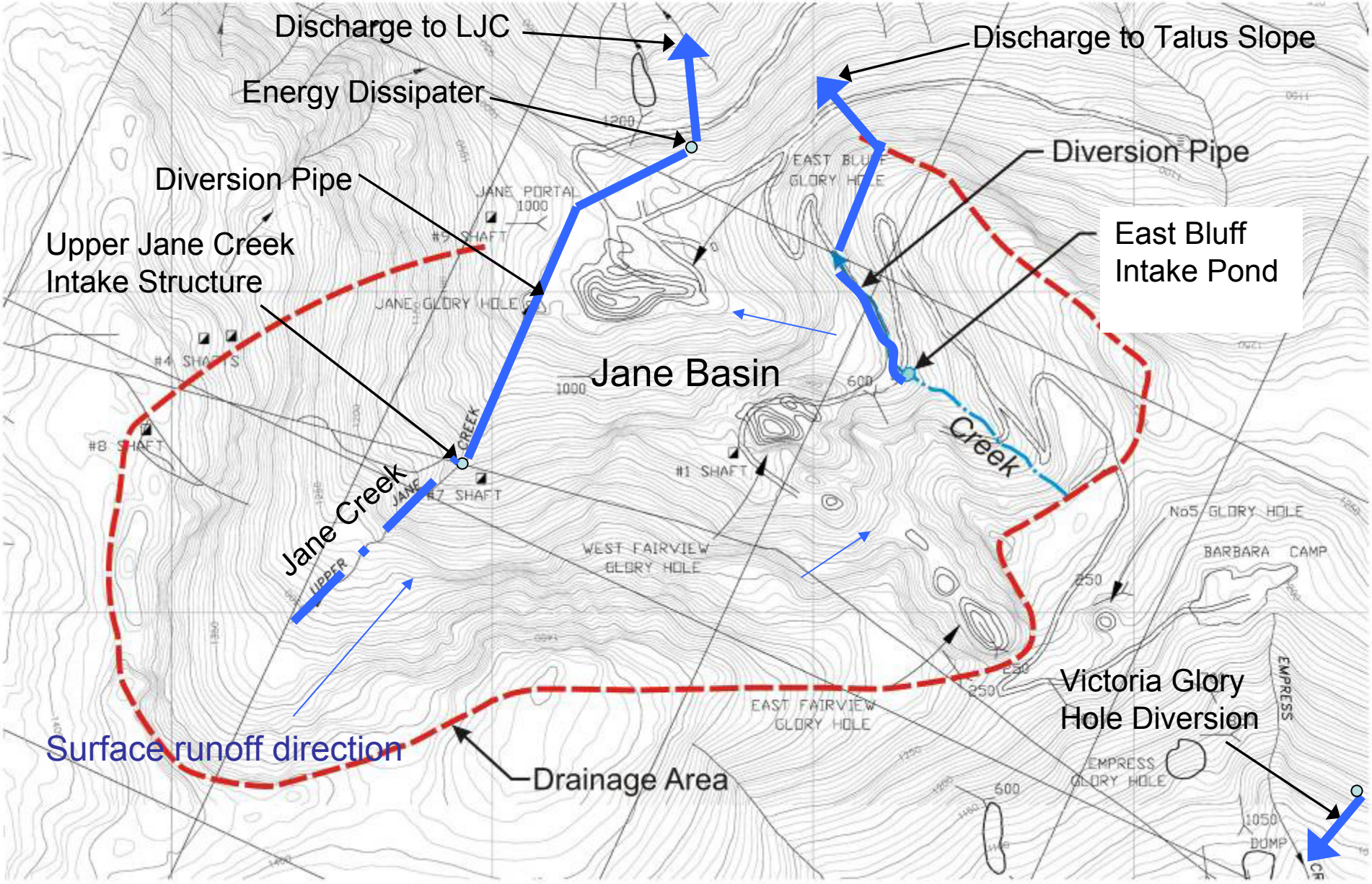
Surface Water Diversions



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Surface Water Diversions

Upper Jane Creek Diversion

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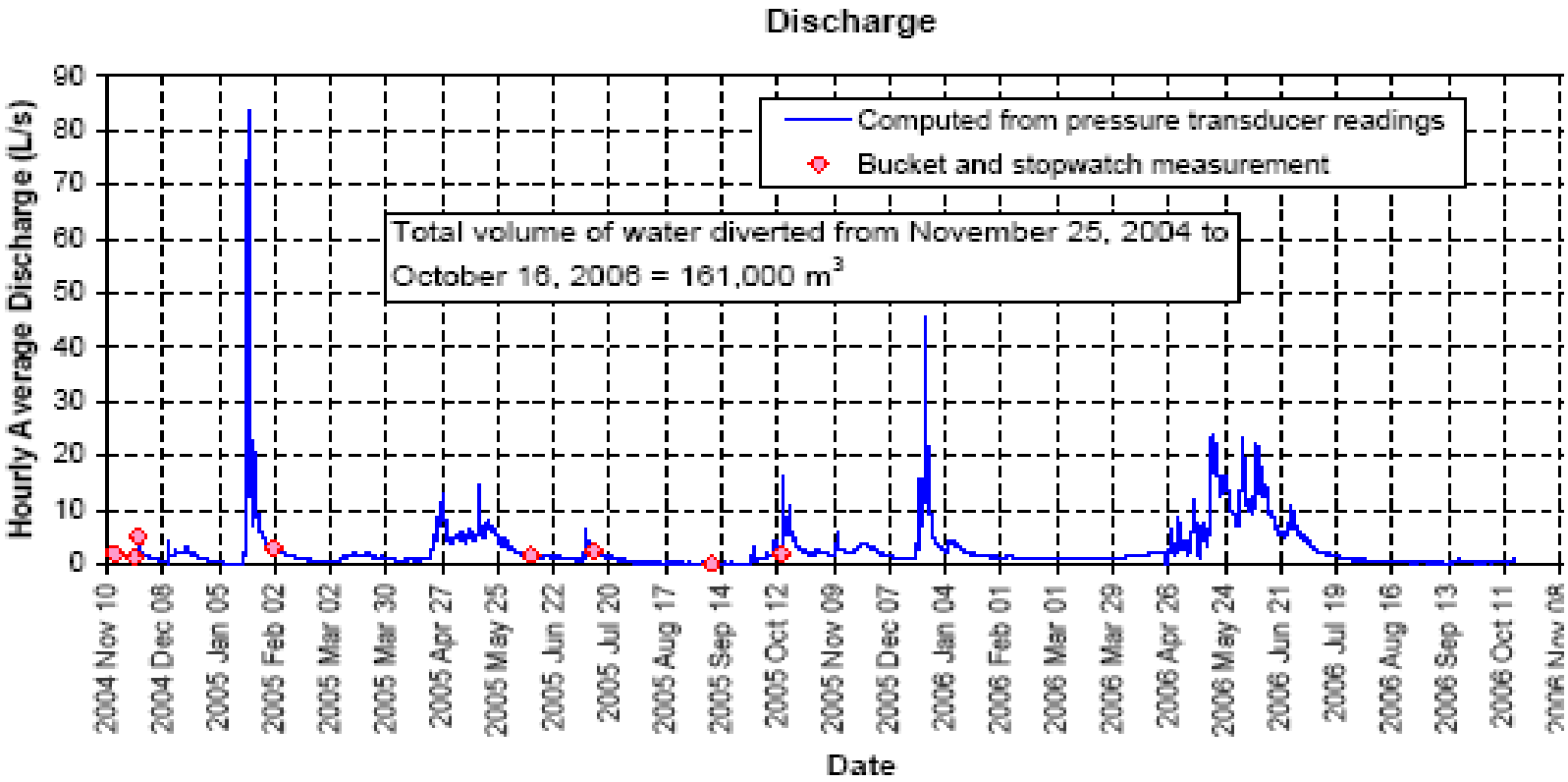
East Bluff Diversion Performance



- Water treatment cost savings ~$35,000/annum
- Payback in treatment costs ~6 years

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Water Treatment Plant

- Treat mine water and groundwater
- Design capacity - 1,050m^3/hr
  Hydraulic capacity - 1,400m^3/hr
- Province opted for a Design-Build-Finance-Operate (DBFO) contract in a Public Private Partnership:
  - Single entity responsible to design, build, operate and finance plant
  - Province pays periodic operating fee when discharge within permit limits
  - Contract includes 20 year operation

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Water Treatment Plant

- Selected contractor (EPCOR)
  - HDS technology
  - Committed to reviewing alternates for future
- Construction commenced March 3, 2005
  - First water treated (24hr operation) October 20, 2005,
  - Tests up to 1,400m^3/hr (~400L/s) indicate successful treatment

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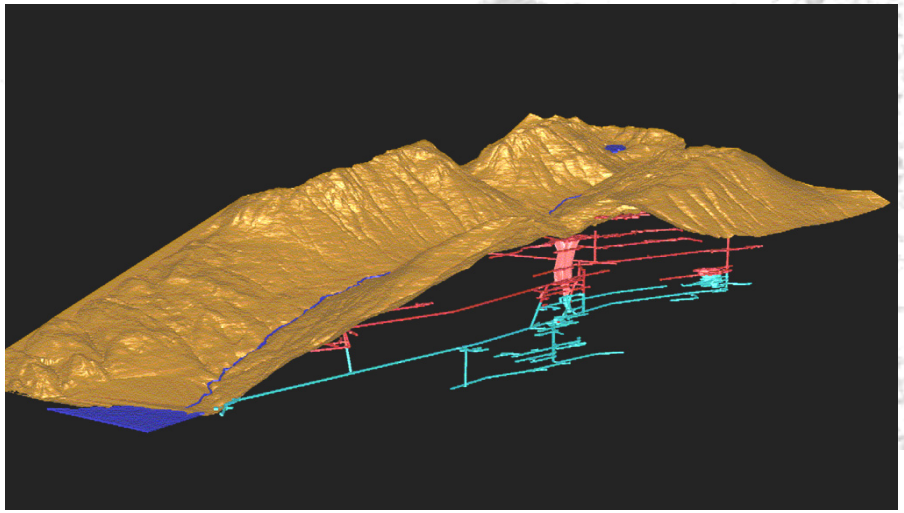
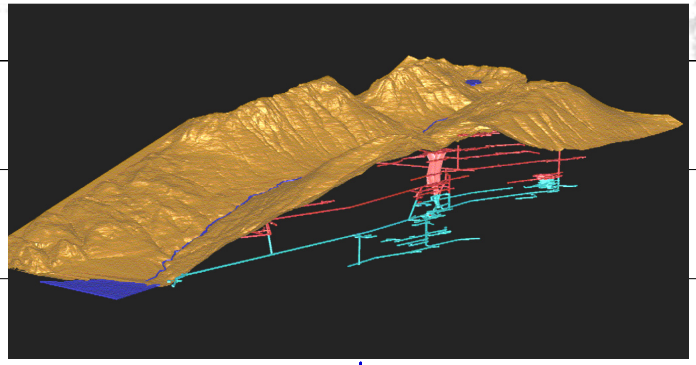
Mine Reservoir Management

- WTP capacity based on estimated mine inflows and reservoir modelling
- Mine inflows estimated for 25 year period using:
  - Records of historical mine outflows
  - Simulations and correlations linked to historical meteorological data ('UBC watershed model' applied by SRK)



Estimate Of Mine Inflows Over 25 Years



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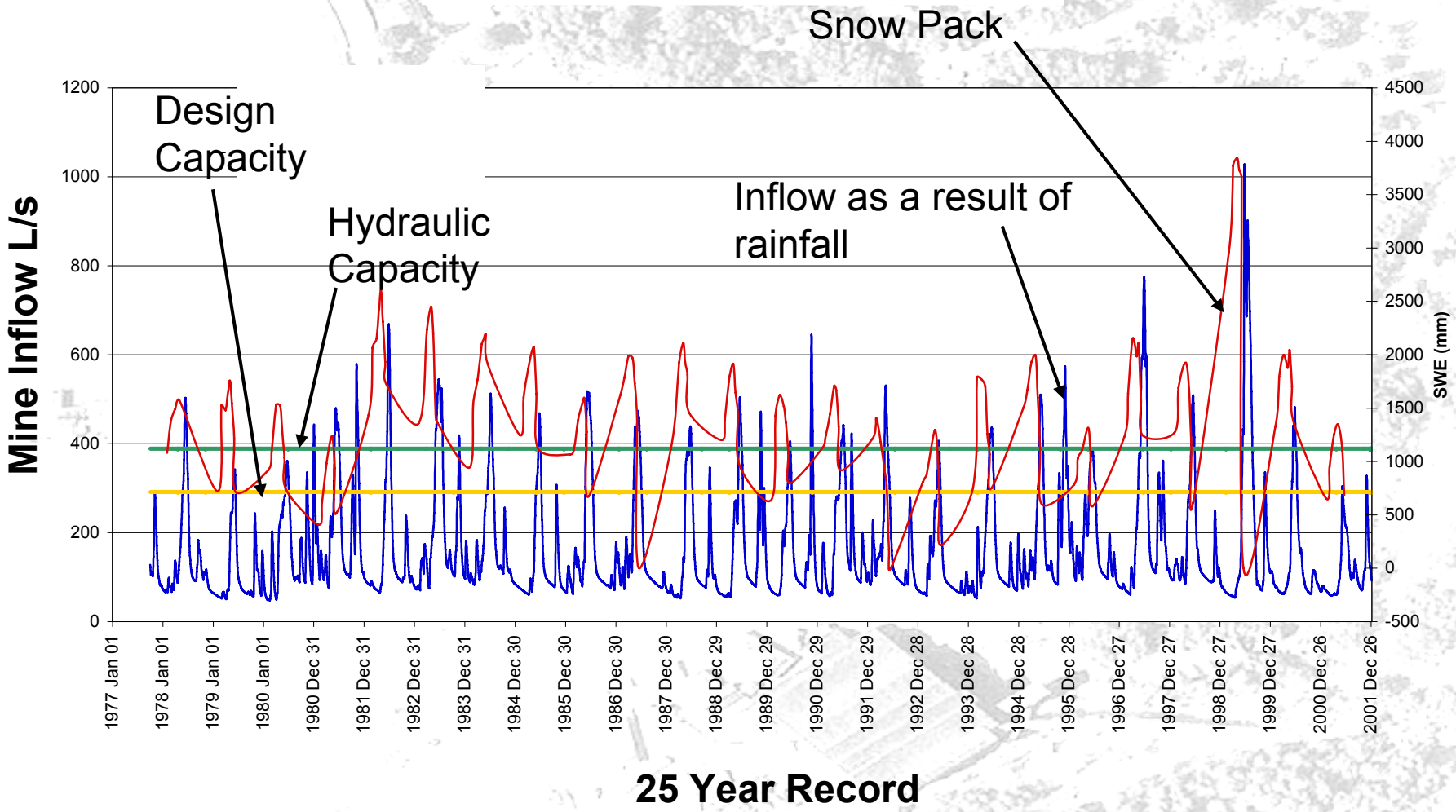

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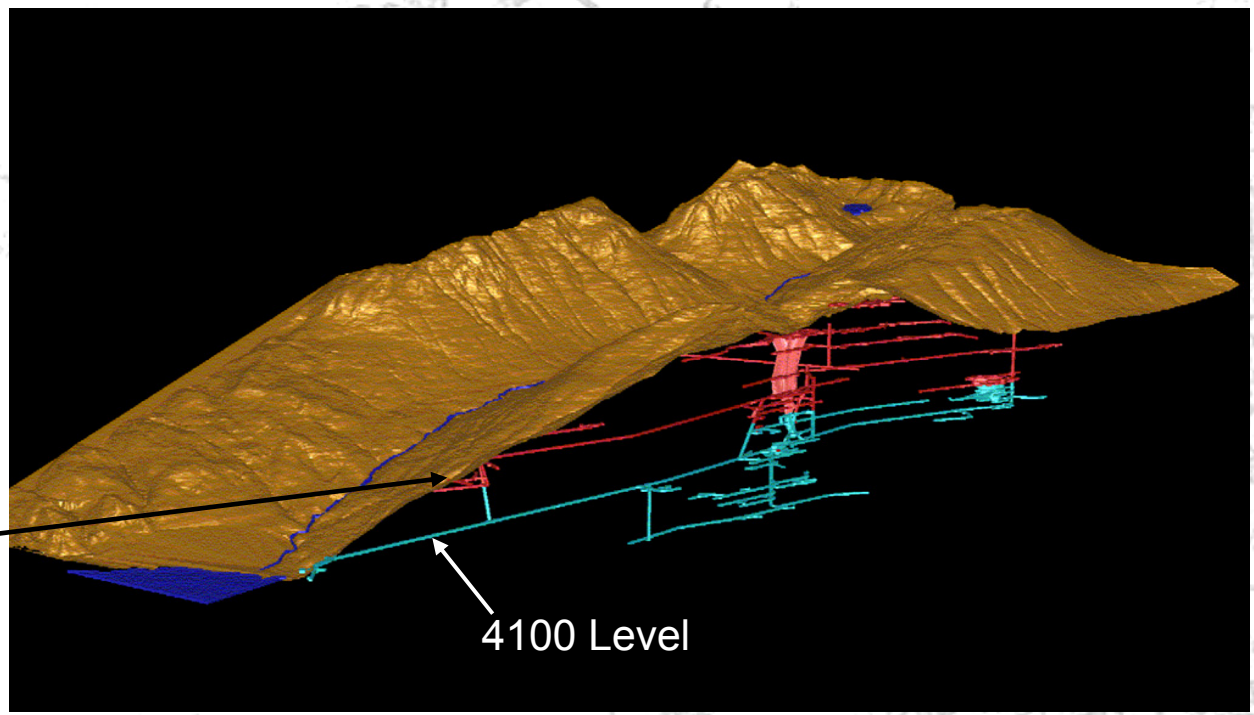
Mine Reservoir Management

- Goal: to **minimize** number and duration of **by-pass events**, with paramount importance placed on **preventing overtopping** of the mine reservoir (uncontrolled discharge)



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Mine Reservoir Management

Tests in 2002 & 2004 by SRK confirmed/indicated:

- Approximately 430,000m^3 of 'dynamic' storage available between 4100 Level and 3250 Level
- Some restrictions to flow that change with time and discharge rate:
  - Possibly the result of silting-up/release of sediments, and/or debris accumulation and release
- The mine is a dynamic system that is subject to change over time:
  - Internal flow regime may change from the time to time
  - Contingencies considered and engineering concepts developed for problems that may develop
- Water chemistry changes with storage
  - Effect reduces with reservoir operation

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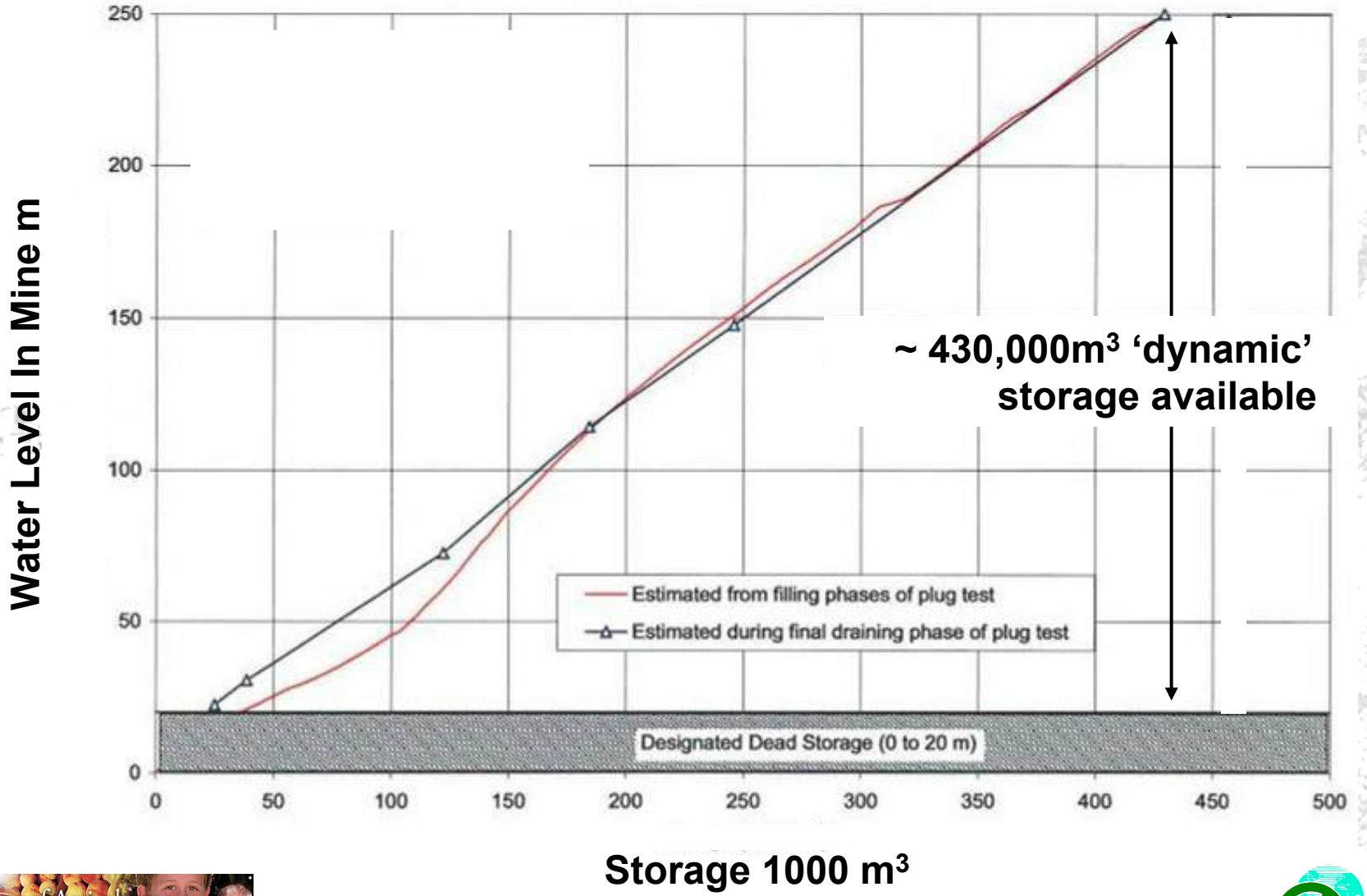
Mine Reservoir Management



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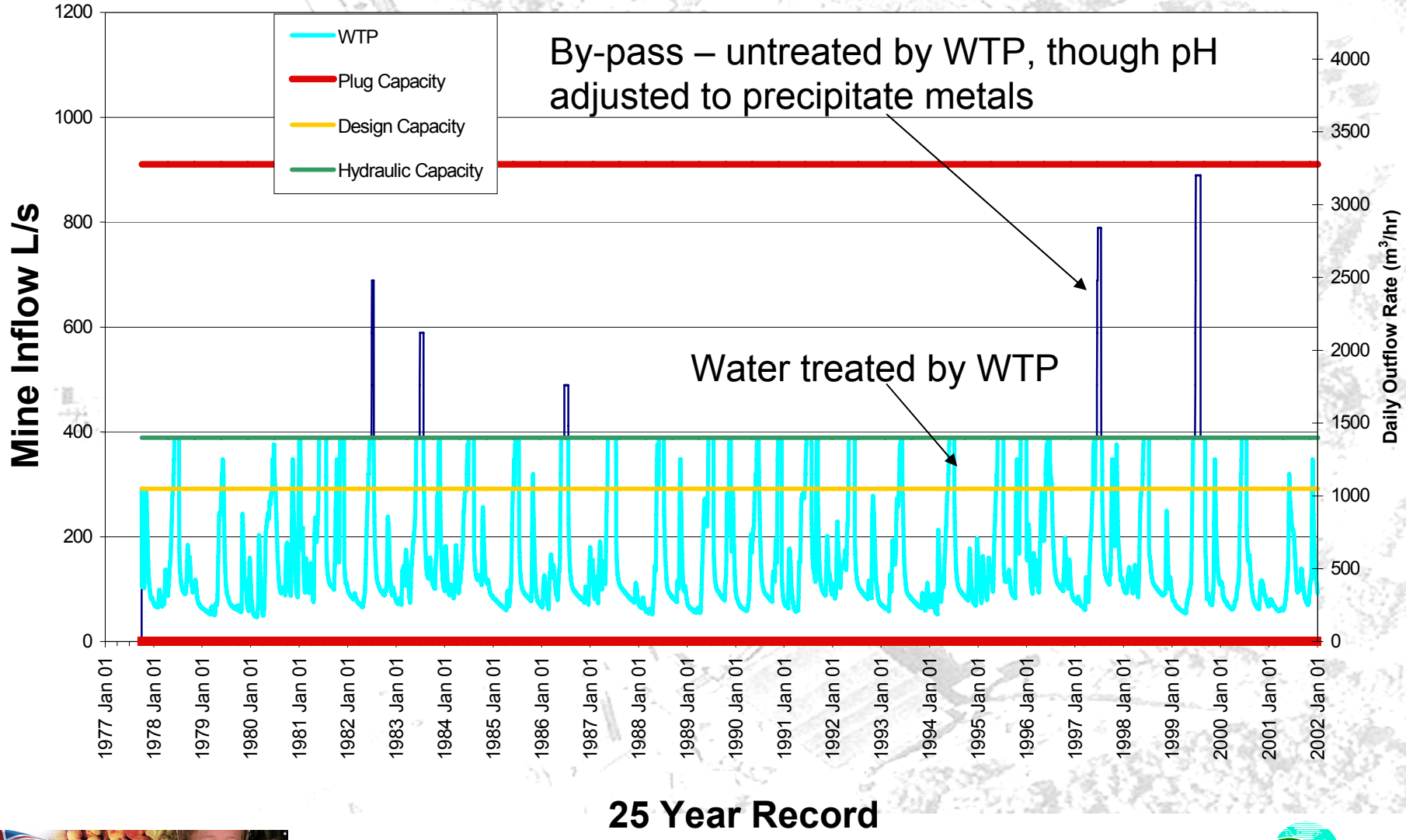
Mine Reservoir Management

- Reservoir Operation Simulation
  - Proposed reservoir operating plan
    - Design Capacity - 1050 m^3/hr
    - Hydraulic Capacity - 1400 m^3/hr
    - Maximum possible flow through Plug – 3276 m^3/hr
    - Up to 1400 m3/hr released through plug when available from 0-150m head in mine
    - Release rate increased quickly up to 3276 m^3/hr from >150m head in mine
  - Percentage of outflow by-passed/untreated by WTP – 96.9%

Mine Reservoir Simulation



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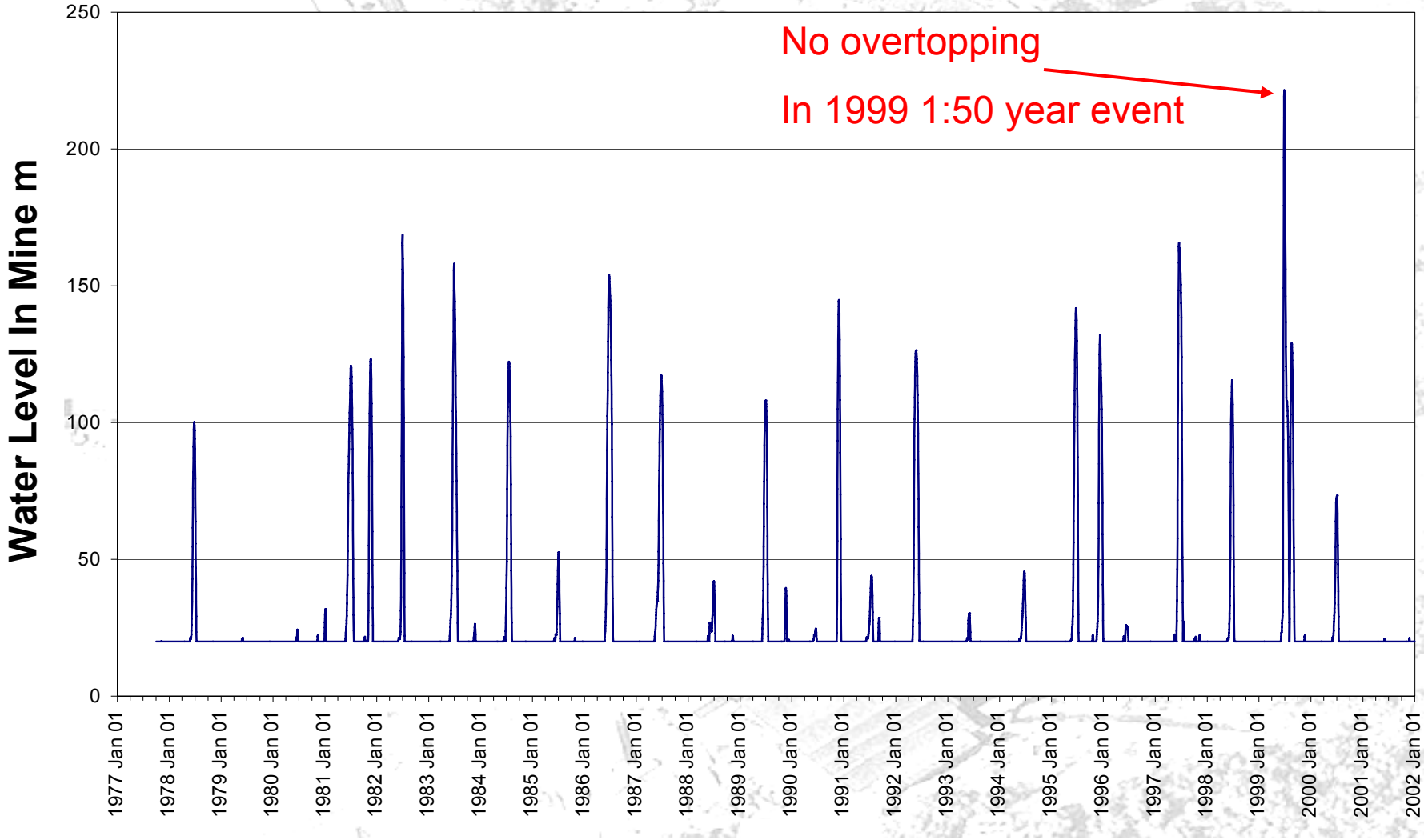
Mine Reservoir Simulation



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4150 Level Portal
Penstock
By-Pass Line


Micro-hydro Plant

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Discharge Permit

- Permit discharge limits (dissolved, mg/L) :
  - copper ≤ 0.1
  - iron ≤ 0.1
  - zinc ≤ 0.2
  - aluminium ≤ 1
  - manganese ≤ 0.4
  - cadmium ≤ 0.01
  - total suspended solids ≤ 30
- No overtopping predicted for 25 year history and 1:200 mine inflow event
- Permit acknowledges controlled by-passes as ‘emergency conditions’
  - Predicted ~3% of outflow will be by-passed
  - Untreated but pH adjusted to precipitate metals mixed with fully-treated water: blended water discharged to deep outfall/diffuser

WTP Discharge Quality

Parameter (mg/L)	Permit Limit	Plant (July 2006)
➢ dissolved copper	≤ 0.1	< 0.005
➢ dissolved iron	≤ 0.1	< 0.005
➢ dissolved zinc	≤ 0.2	0.008
➢ dissolved aluminium	≤ 1	0.61
➢ dissolved manganese	≤ 0.4	0.265
➢ dissolved cadmium	≤ 0.01	< 0.002
➢ total suspended solids	≤ 30	< 4
➢ pH range	6.5 to 9.5	8.6
➢ 96HRLC50 fish bioassay	100% (non-acutely toxic)	100%
➢ Authorized discharge	25,200m^3/day	24,200m^3/day

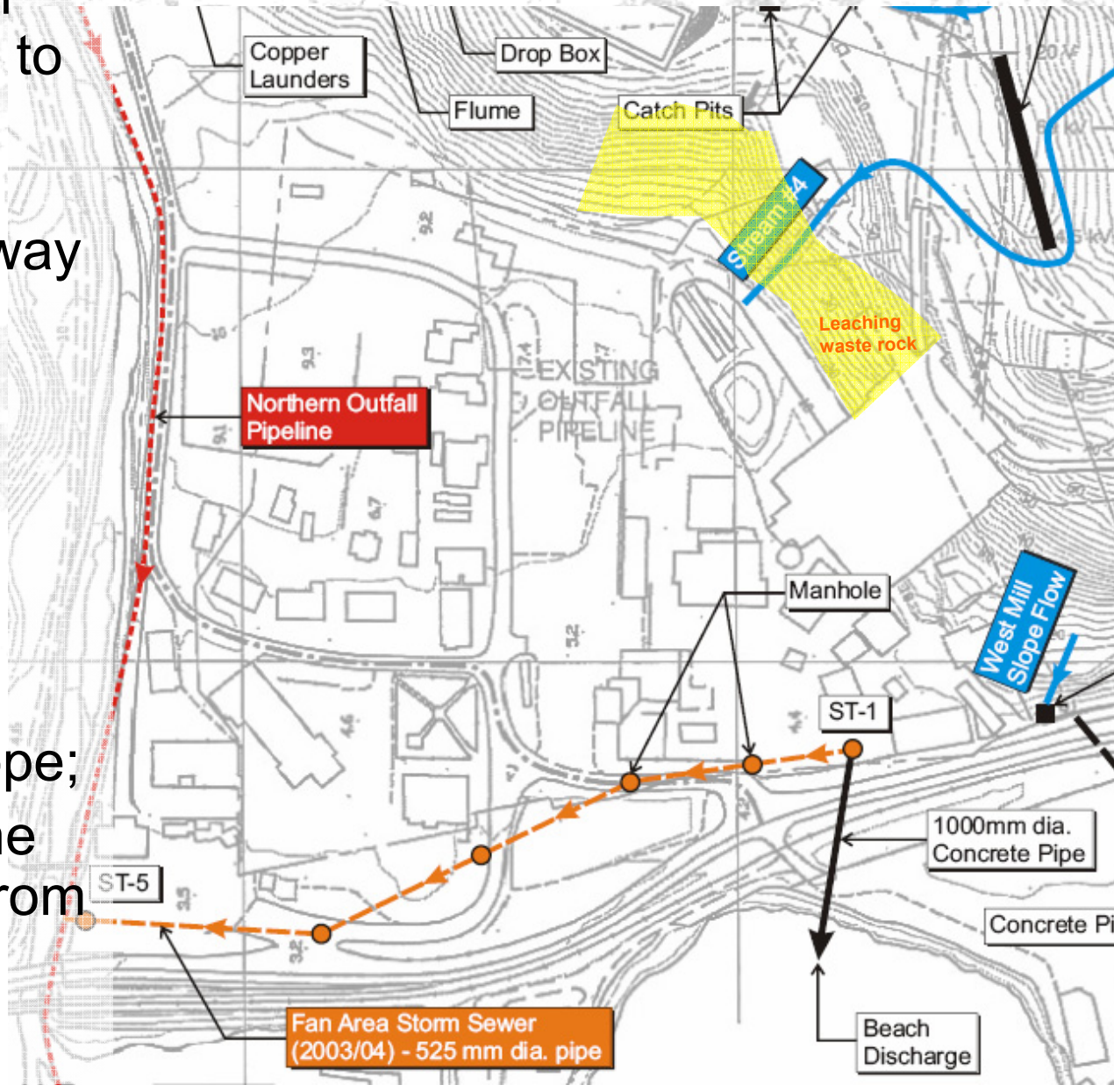
New Deep Outfall

- Old outfall extends to only 26 metres depth
  - Is located on unstable sub-sea terrain
  - Susceptible to blockages
- Requires 50 m depth and diffuser to meet receiving environment criteria
- Geotechnically stable location required to reduce risk of future failures:
  - Cost of replacement
  - Environmental effects
- Site selected south of Britannia Beach


Diffuser
New Outfall Under Construction

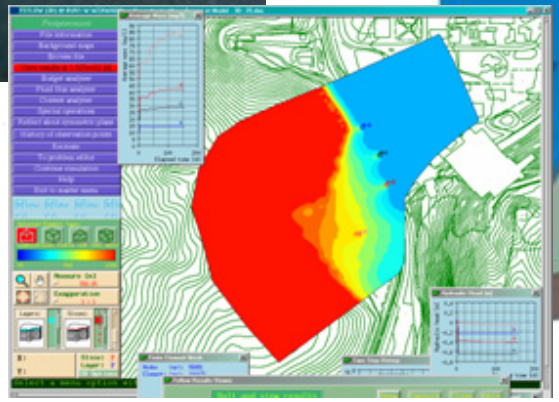
Fan Area Surface Water Management

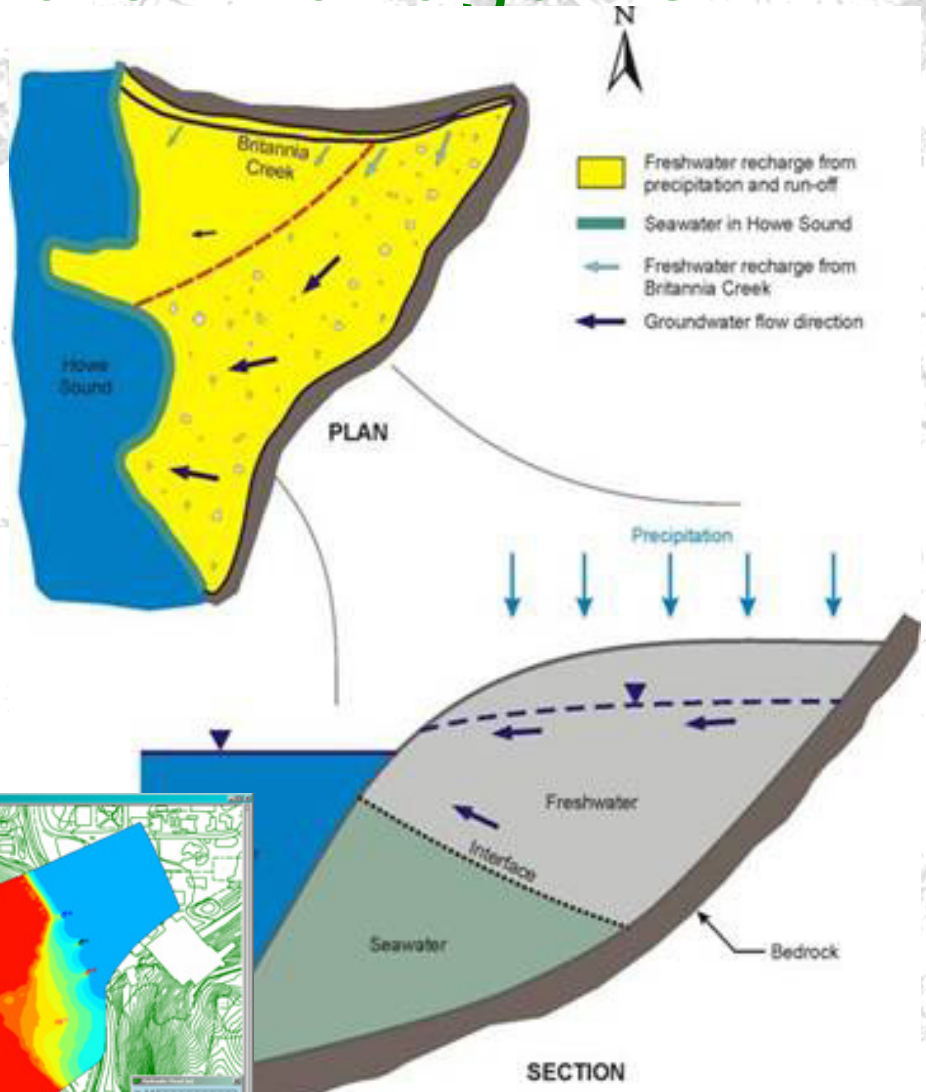
- Storm water system upgraded in 2003/4 to divert most run-off away from beach;
- Assessment underway to identify further improvements;
- Proposed actions include:
  - Diversion of streams from leachable mine waste on Mill slope;
  - Collection of mine water seepage from West Mill slope.



Fan Area Groundwater Management

- Modelling (Feflow)





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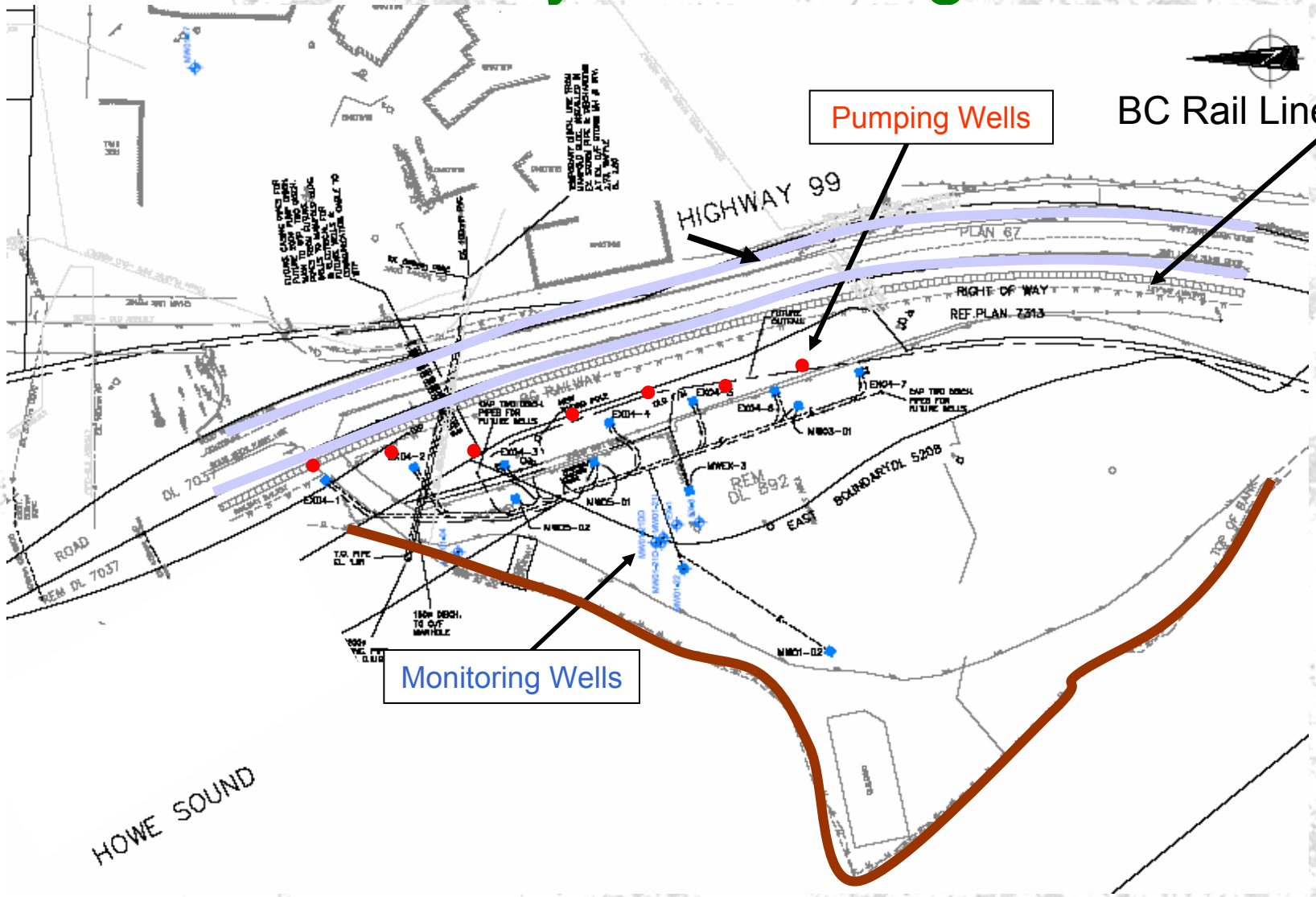
Fan Area Groundwater Remedial Options

Operational Constraints:

- Saline water corrosive to treatment plant components/may affect process
- Capacity and Operational requirements of treatment plant:
  - Limit pumping rate (100m3/hr)
  - Limit chlorides concentration (1000ppm)
- Physical constraints on system installation:
  - Hwy99
  - BCRail

GMS System Design



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Groundwater Management Status

- System constructed by EPCOR between March and May, 2005
- Pumping trials commenced in May, 2005
- System operational and currently in optimization phase:
  - Correlation of chlorides to conductivity
  - Maximise (fresh) groundwater capture efficiency within design constraints and minimise salt water pumping
  - Identify control and/or installation improvements

Groundwater pump installation

Wellhead installation

Groundwater pumphouse

Groundwater Management System

Transfer Pumps

Flow monitoring equipment

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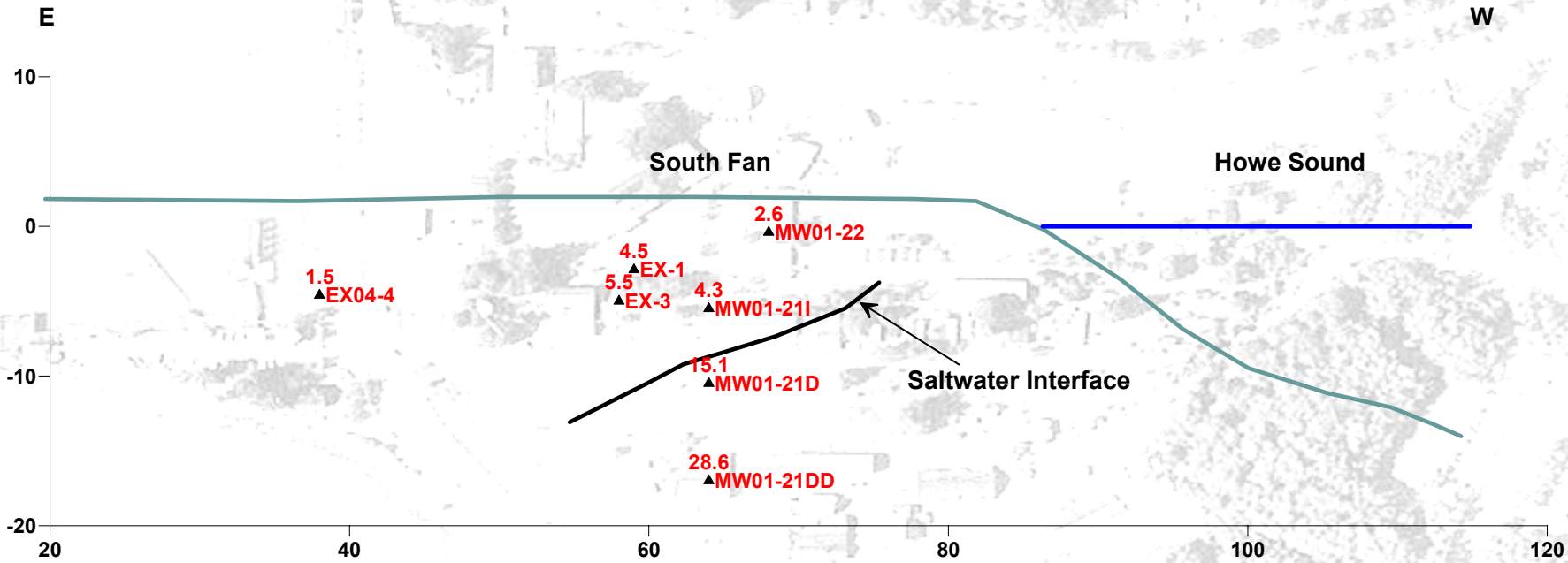
Phase 1 – Operation Data

Electrical Conductivity (mS/cm) Before of Pumping



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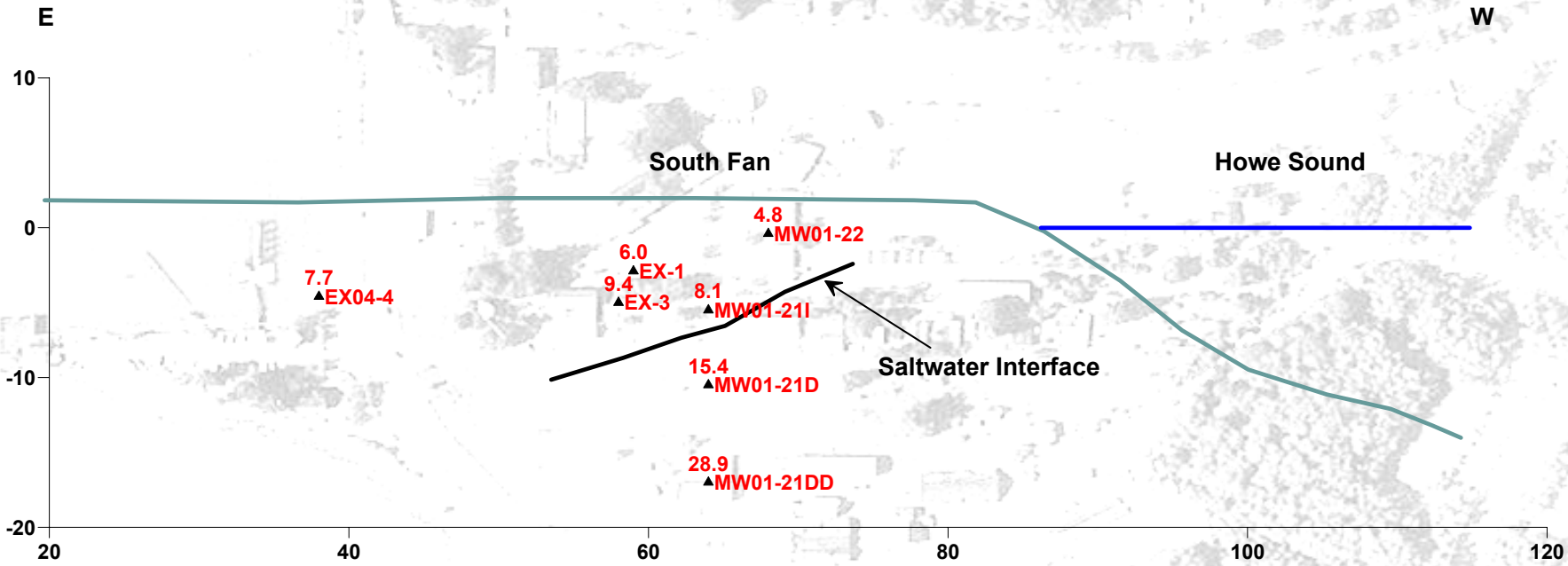
Phase 1 – Operation Data

Electrical Conductivity (mS/cm) End of Pumping



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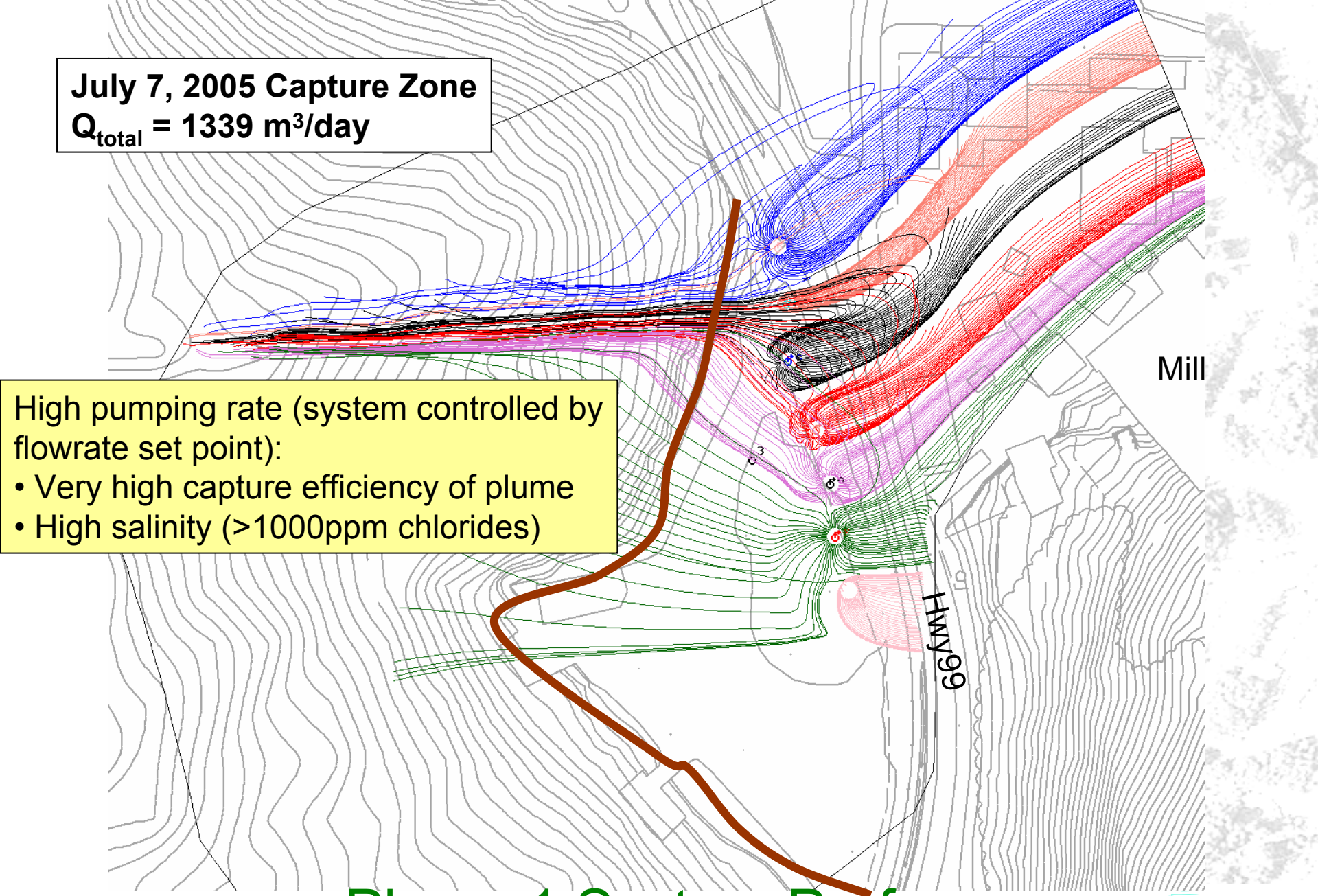

Phase 1 System Performance

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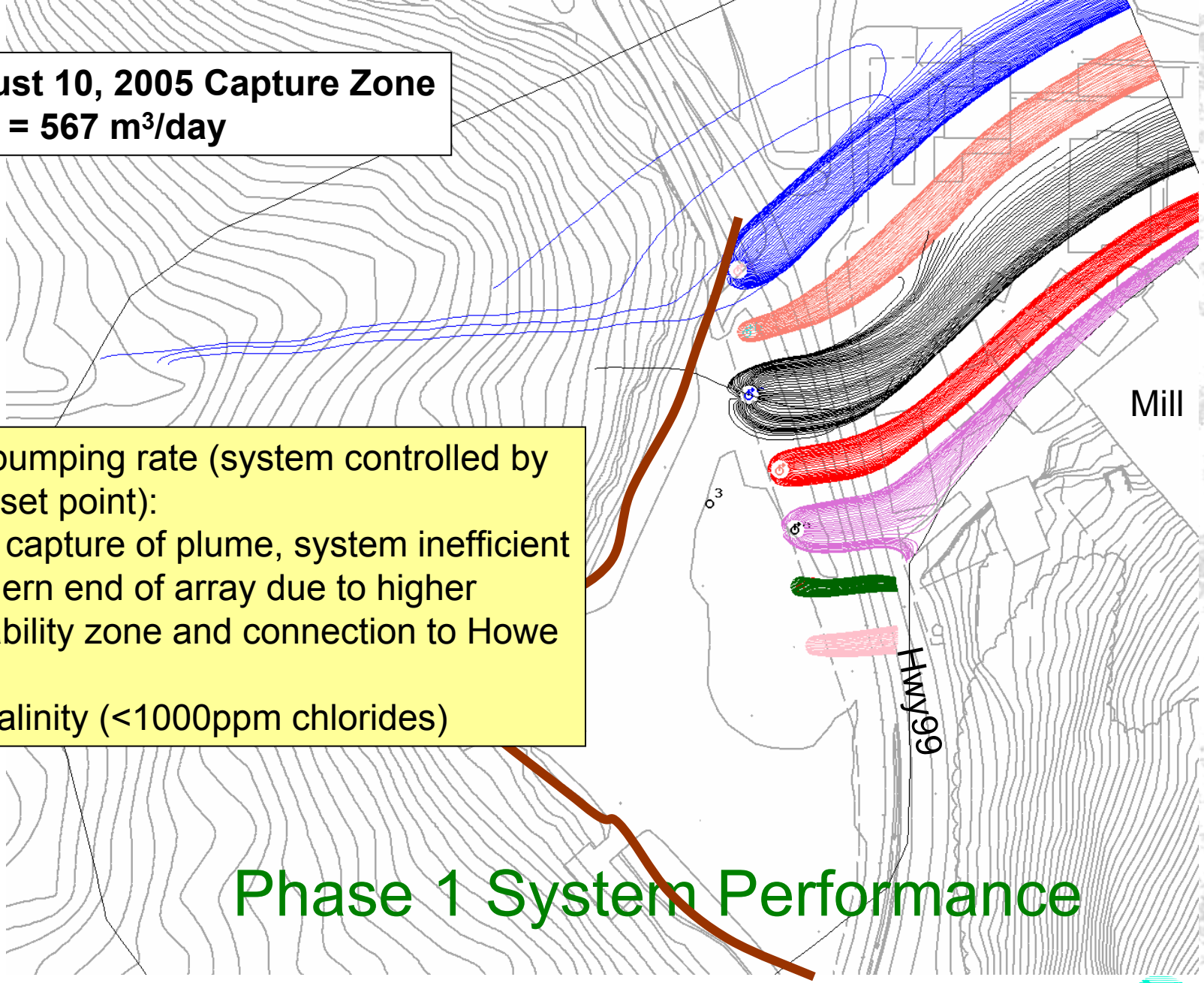
August 10, 2005 Capture Zone
Q_{total} = 567 m^3/day



Lower pumping rate (system controlled by salinity set point):

- ~50% capture of plume, system inefficient at northern end of array due to higher permeability zone and connection to Howe Sound
- Low salinity (<1000ppm chlorides)

Phase 1 System Performance

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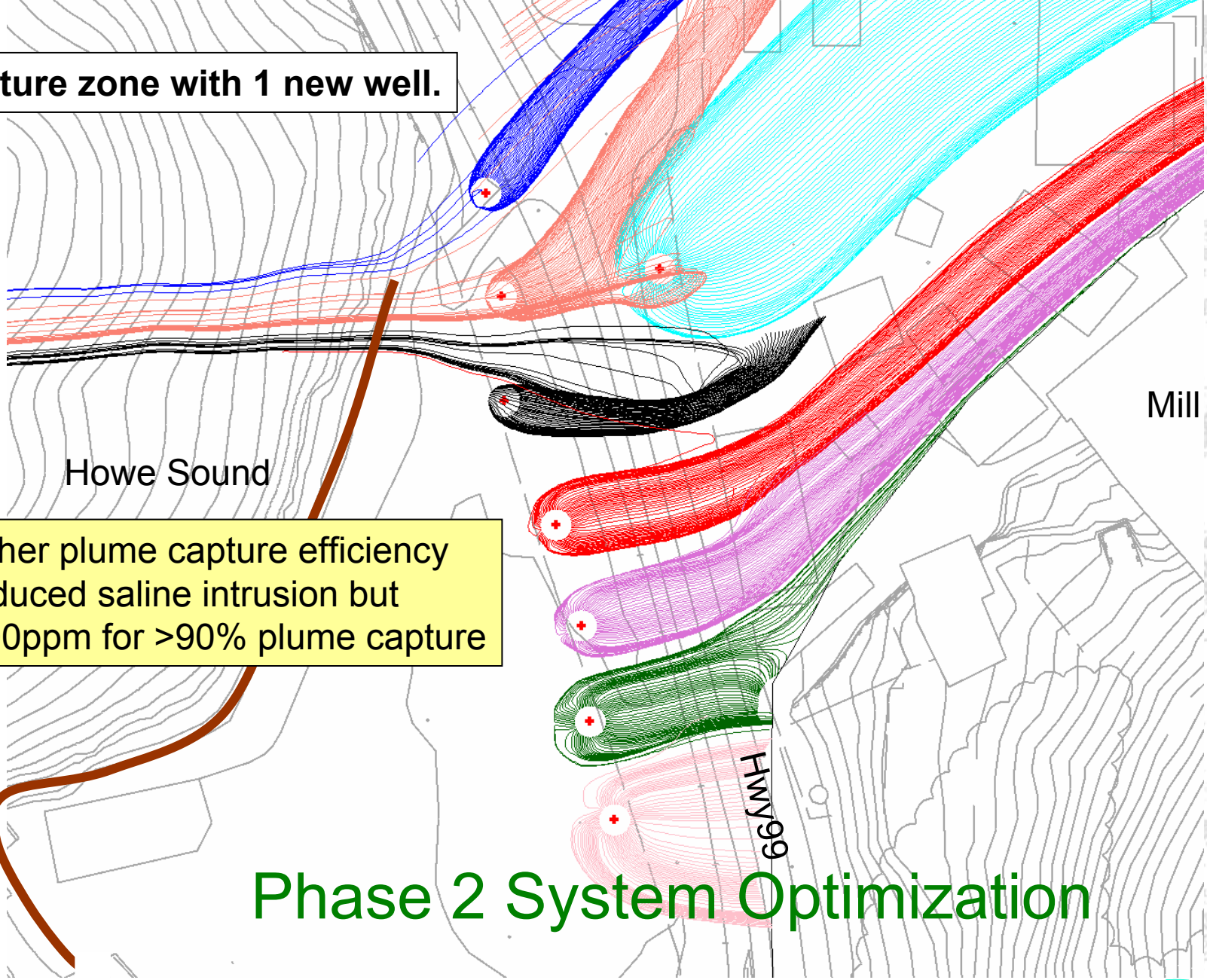
Capture zone with 1 new well.



- Higher plume capture efficiency
- Reduced saline intrusion but >1000ppm for >90% plume capture

Phase 2 System Optimization

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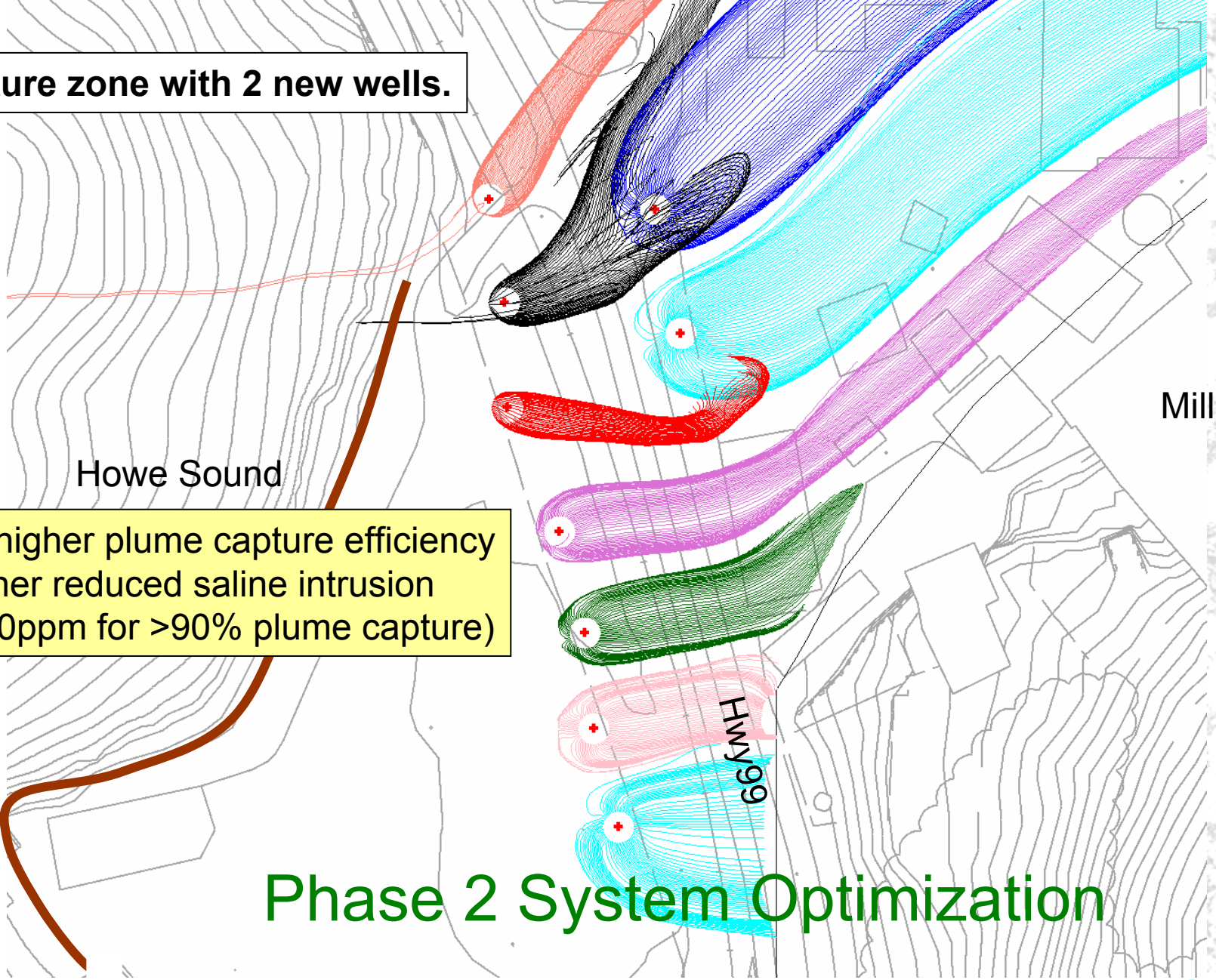
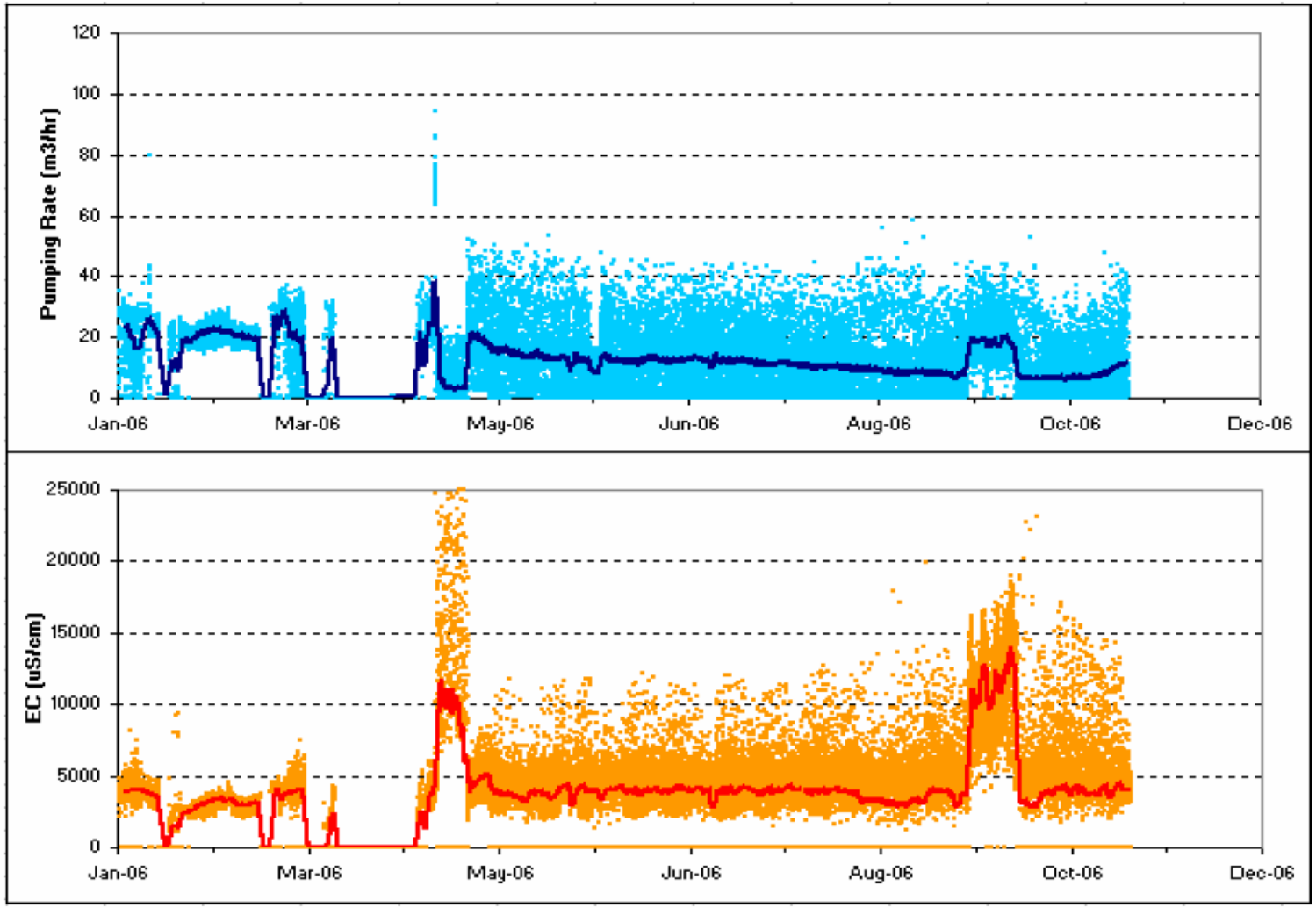
Capture zone with 2 new wells.



- Still higher plume capture efficiency
- Further reduced saline intrusion (<1000ppm for >90% plume capture)

Phase 2 System Optimization



2006 GMS Monitoring Data

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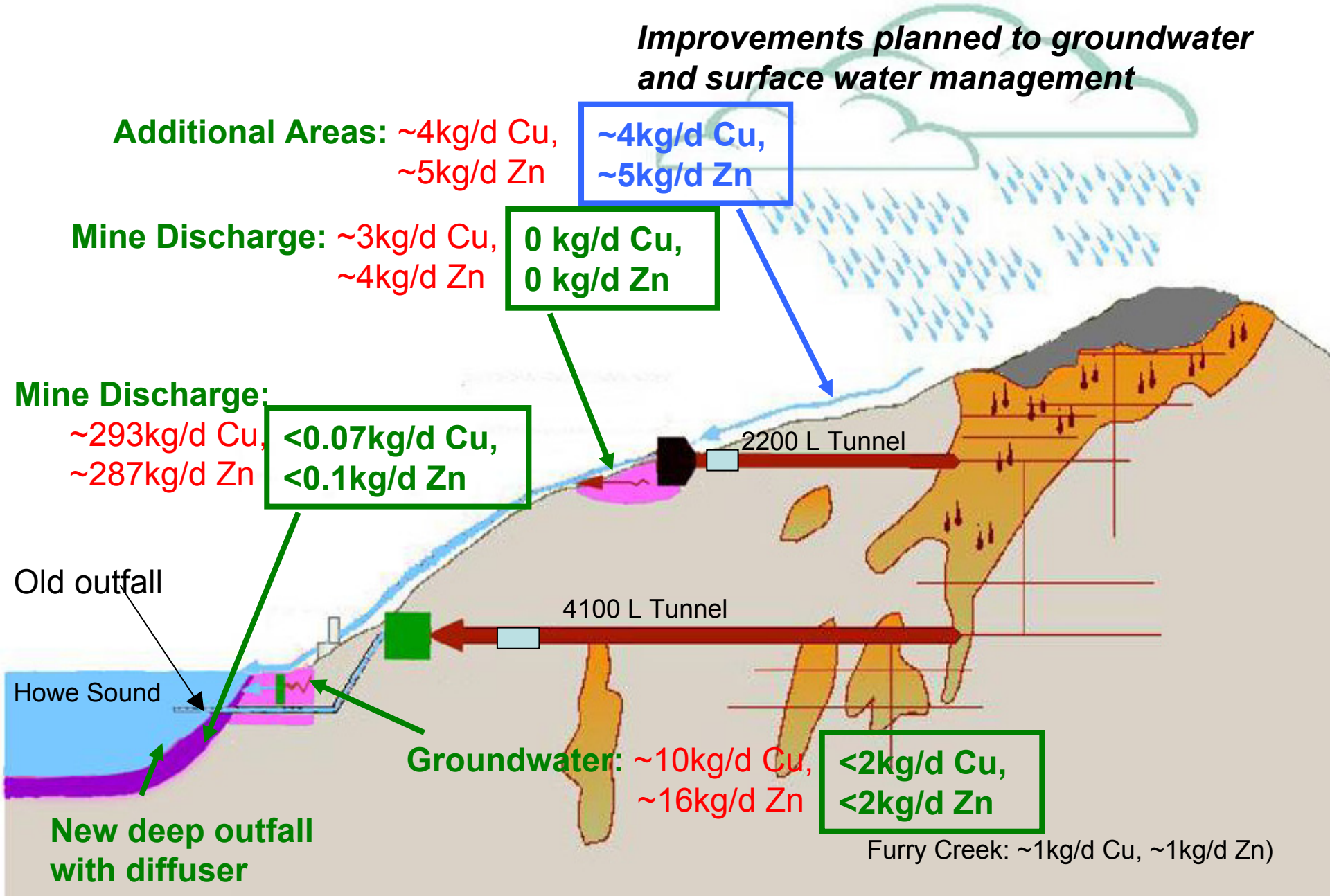
Howe Sound Metal Loading Improvements

Improvements planned to groundwater and surface water management

Additional Areas: ~4kg/d Cu, ~5kg/d Zn → **~4kg/d Cu, ~5kg/d Zn**

Mine Discharge: ~3kg/d Cu, ~4kg/d Zn → **0 kg/d Cu, 0 kg/d Zn**

Mine Discharge: ~293kg/d Cu, ~287kg/d Zn → **<0.07kg/d Cu, <0.1kg/d Zn**



Groundwater: ~10kg/d Cu, ~16kg/d Zn → **<2kg/d Cu, <2kg/d Zn**

New deep outfall with diffuser

Furry Creek: ~1kg/d Cu, ~1kg/d Zn)

Some Lessons Learned

- Cost benefit of surface water diversions must be balanced against desirability of undertaking this for long-term ‘sustainability’ or other reasons
- The availability of the mine reservoir greatly benefited the project, though efficient management is critical
- Automated groundwater management of the saline/freshwater blend linked to the WTP control systems needed a long period of optimization (>2 years)

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Ongoing Water Management Work

- Additional Areas Review/Implementation
  - Other portal seeps
  - Waste dump seeps
- Environmental Monitoring and Risk Assessment
  - Have we done enough/do we need to do more/ if so, what?
- Surface Water Drainage Review/Implementation
  - 4100 Level and Britannia Creek Fan Area
- Groundwater Management Optimization
  - Program will continue following planned system enhancements

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Information Sources

- Province's website (MAL):
  - www.britanniamine.ca
  - Contains progress reports, technical reports, regulatory correspondence, permits, background information, contact details and correspondence with Province

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