Environmental Tracers to Delineate Recharge and Flow Processes in the Gibsons Aquifer, British Columbia

Water Technologies Symposium April 12, 2013 – Fairmont Banff Springs

Presented by:
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NSERC CRSNG

UBC

Waterline Resources Inc.

Presentation Overview

- Project Team
- Town of Gibsons and Study Objectives
- Approach to Aquifer Mapping Study
- Conceptual Hydrogeological Model
- Environmental Tracers
- Numerical Groundwater Modeling
- Future Groundwater Scenarios
- Aquifer management and sustainability

Project Team

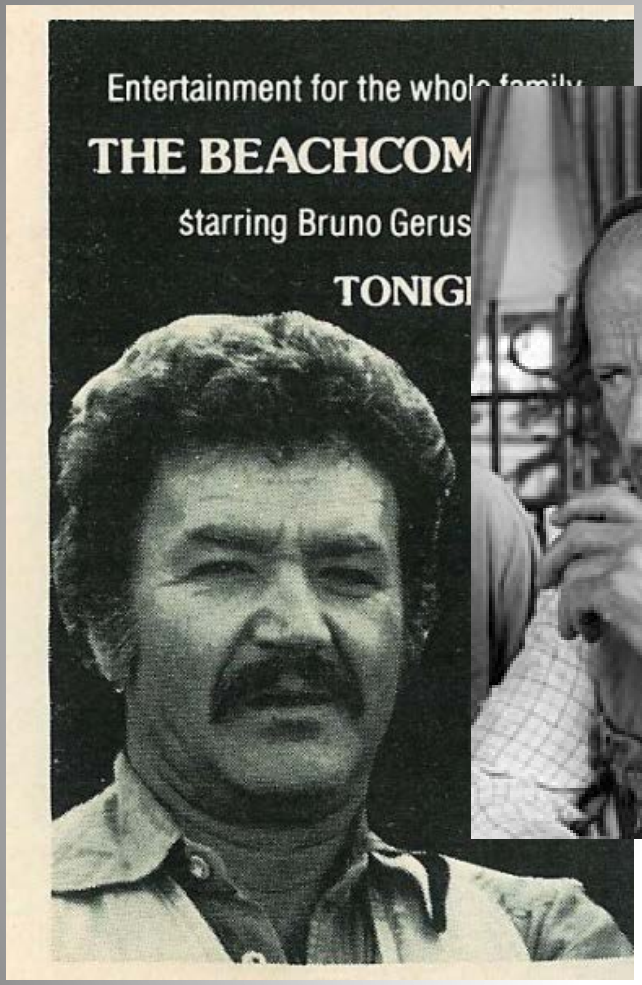
- Waterline Resource Inc.
  - ✓ Project Development and Management
- University of British Columbia
  - ✓ Environmental Tracer Study
  - ✓ Numerical Modeling
  - ✓ Supervisors: Uli Mayer and Tom Gleeson (McGill)
- Gordon GroundH2O (Gibsons)
  - ✓ Community Outreach

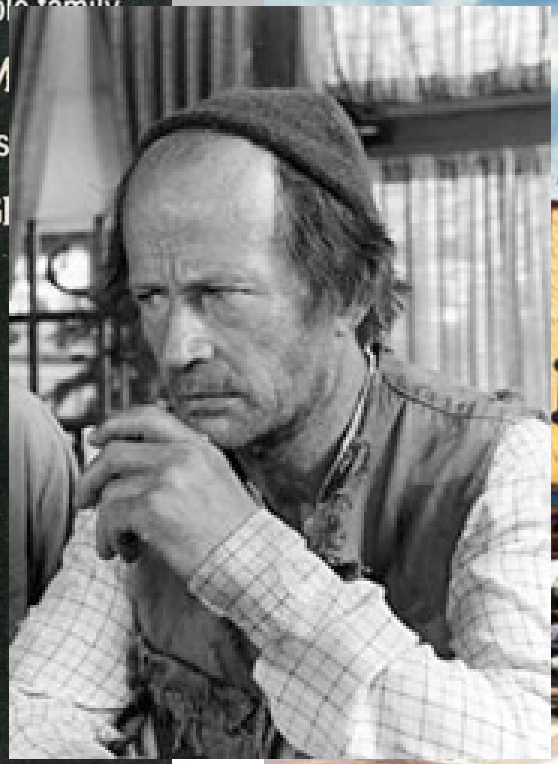
Gibsons, British Columbia

Google Earth 2012

- Located on the Sunshine Coast, BC
- Humid, Mediterranean-like climate
- 1500 mm precipitation/year
  - ✓ 70% during winter months
  - ✓ Snow at high elevation

Home of The Beachcombers!



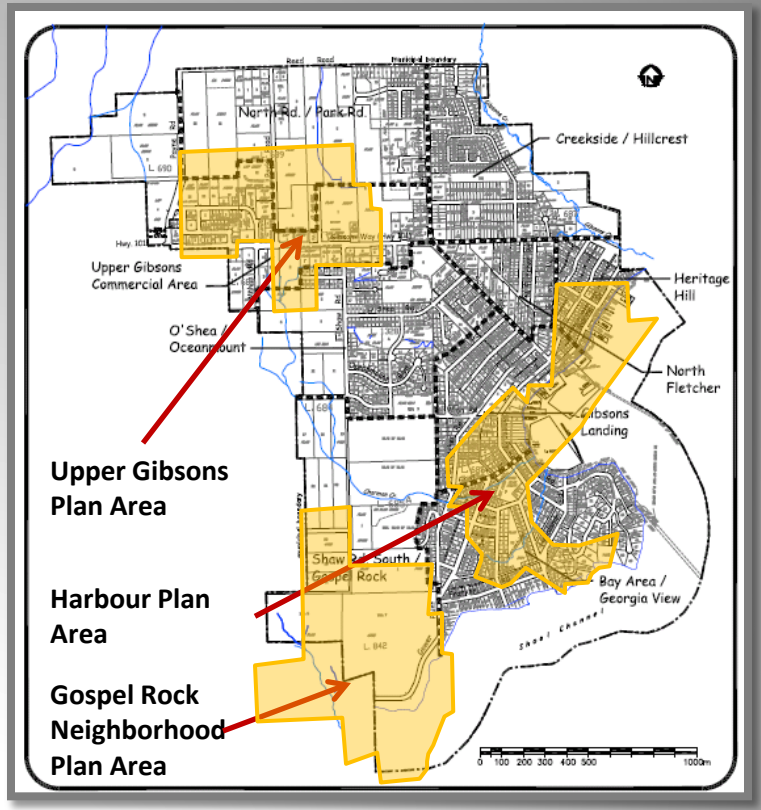


Town of Gibsons

- Voted "World's Most Livable Town" – 2009
  - ✓ International Awards for Liveable Communities.
  - ✓ Award program endorsed by the United Nations.
- Voted "World's Best Drinking Water" - 2005
  - ✓ Berkley Springs International Water Tasting Contest
- 4,300 residents
  - ✓ 2/3 rely on groundwater
  - ✓ Untreated

Plan for Growth

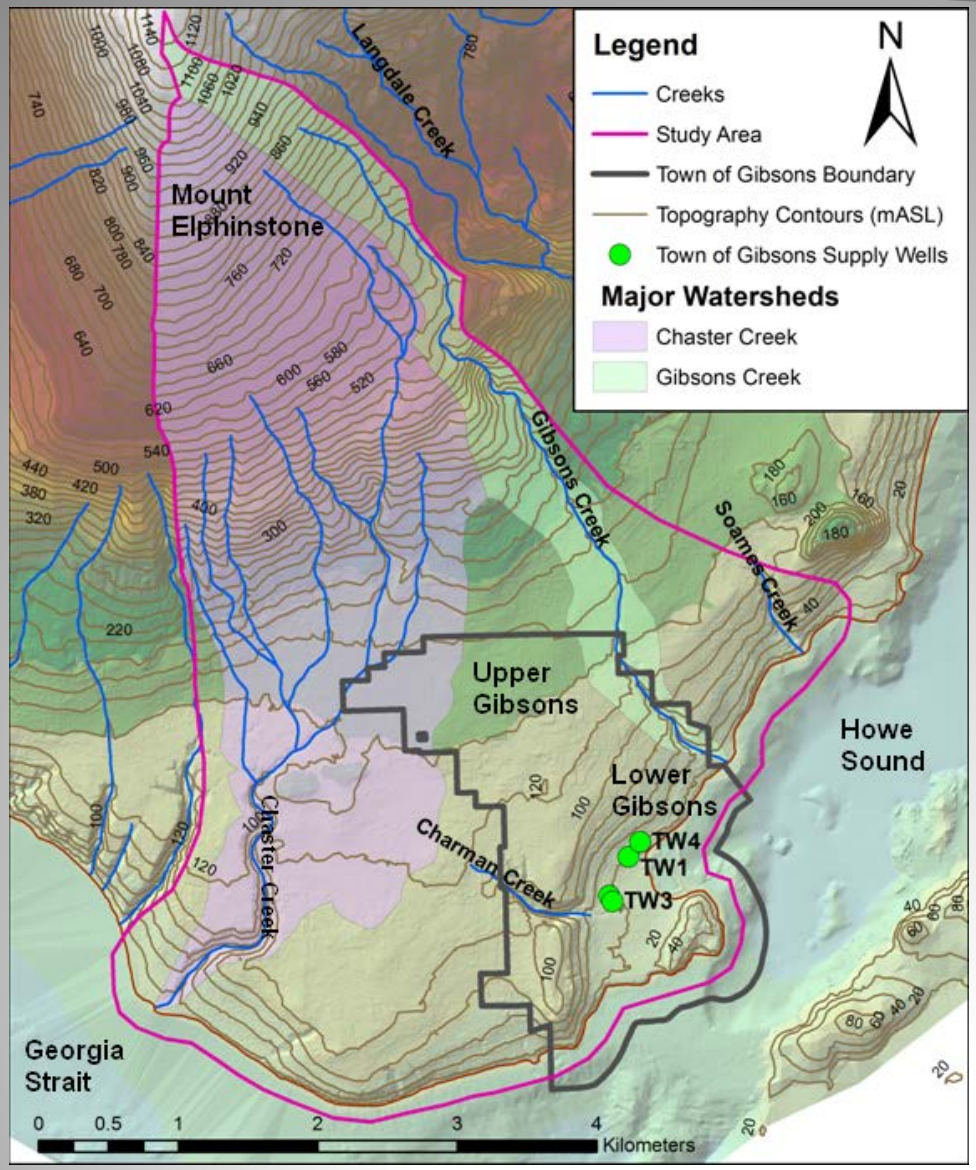
- Bedroom community to Vancouver;
- Expected population increase from 4,300 to 10,000 by 2026;
- 73% (7,300) supplied by groundwater;
- Demand up from 2,000 to 4,200 m^3/day.



Source: Town of Gibsons Official Community Plan, Neighbourhood Areas, Oct. 2003

Aquifer Mapping Study - Approach

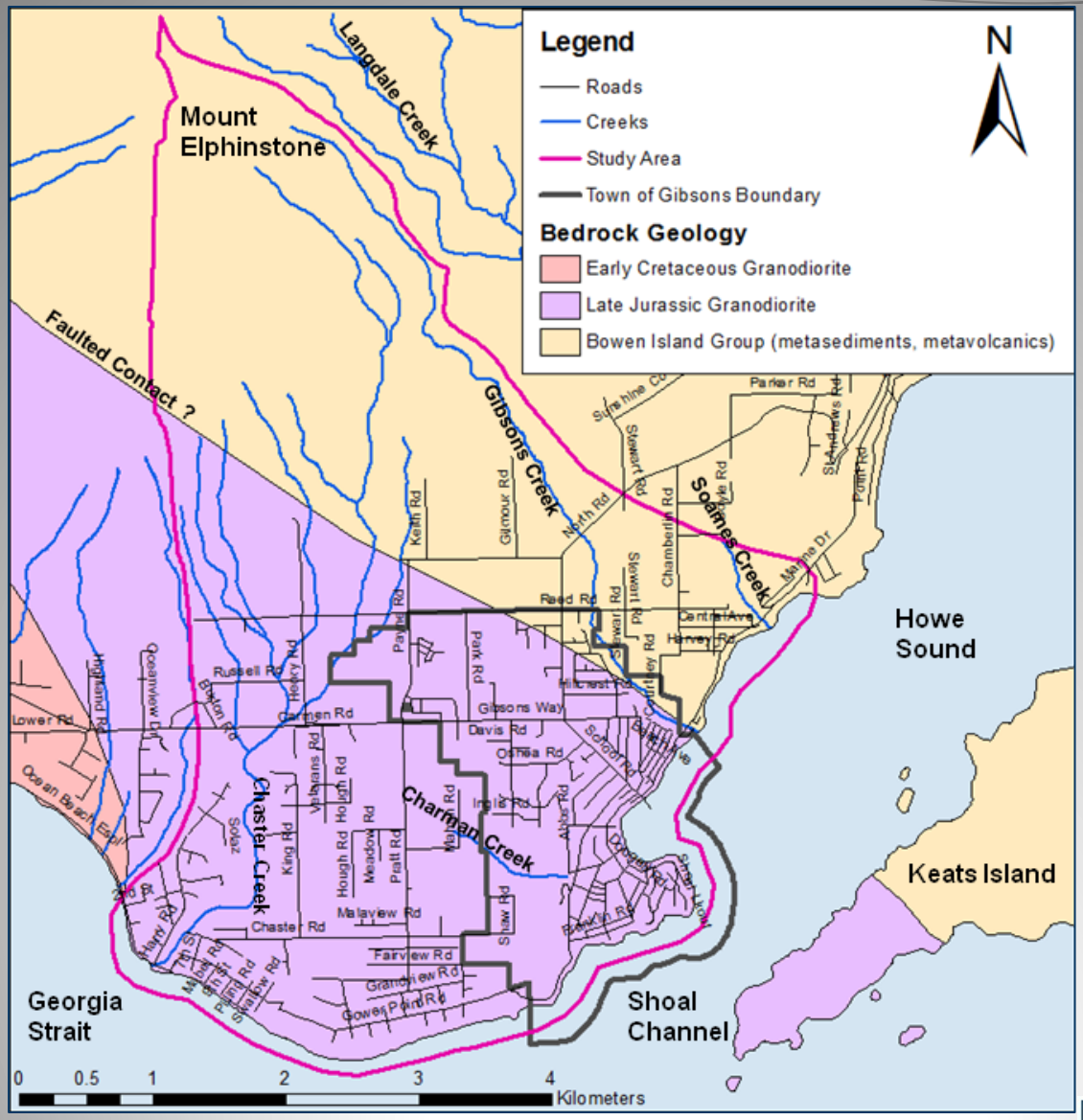
- Phase 1 (2011 – 2013)
  - ✓ Data Compilation, field work, initial conceptual model
- Phase 2 (2011-12):
  - ✓ Refine conceptual model
  - ✓ UBC Involved (NSERC)
    - ✓ Environmental Tracers
    - ✓ Numerical Modeling
  - ✓ Community Outreach
  - ✓ Report (April 2013)



Topo and Study Area Boundary

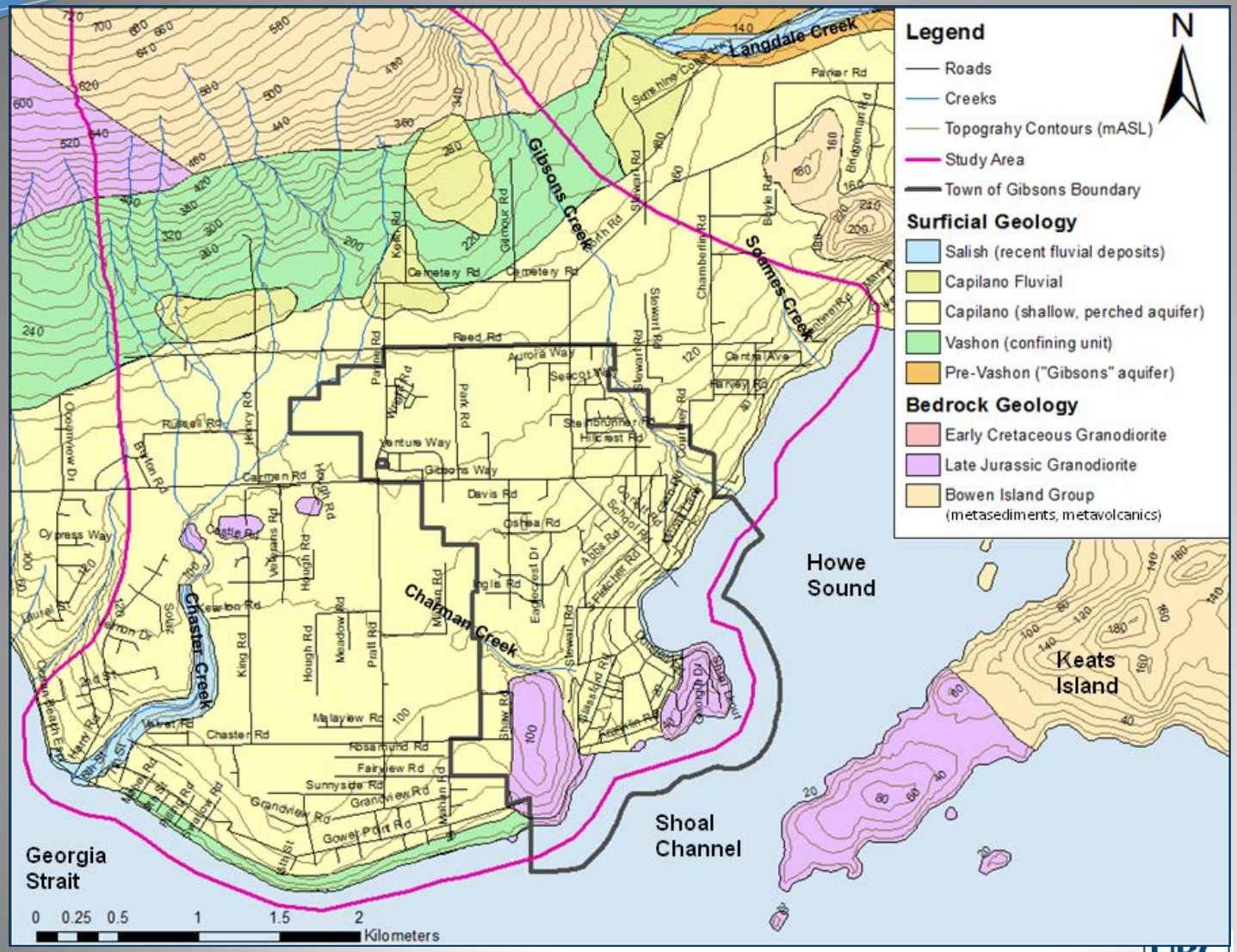
Source: Elevation data from Sunshine Coast Regional District, 2012

Bedrock Geology

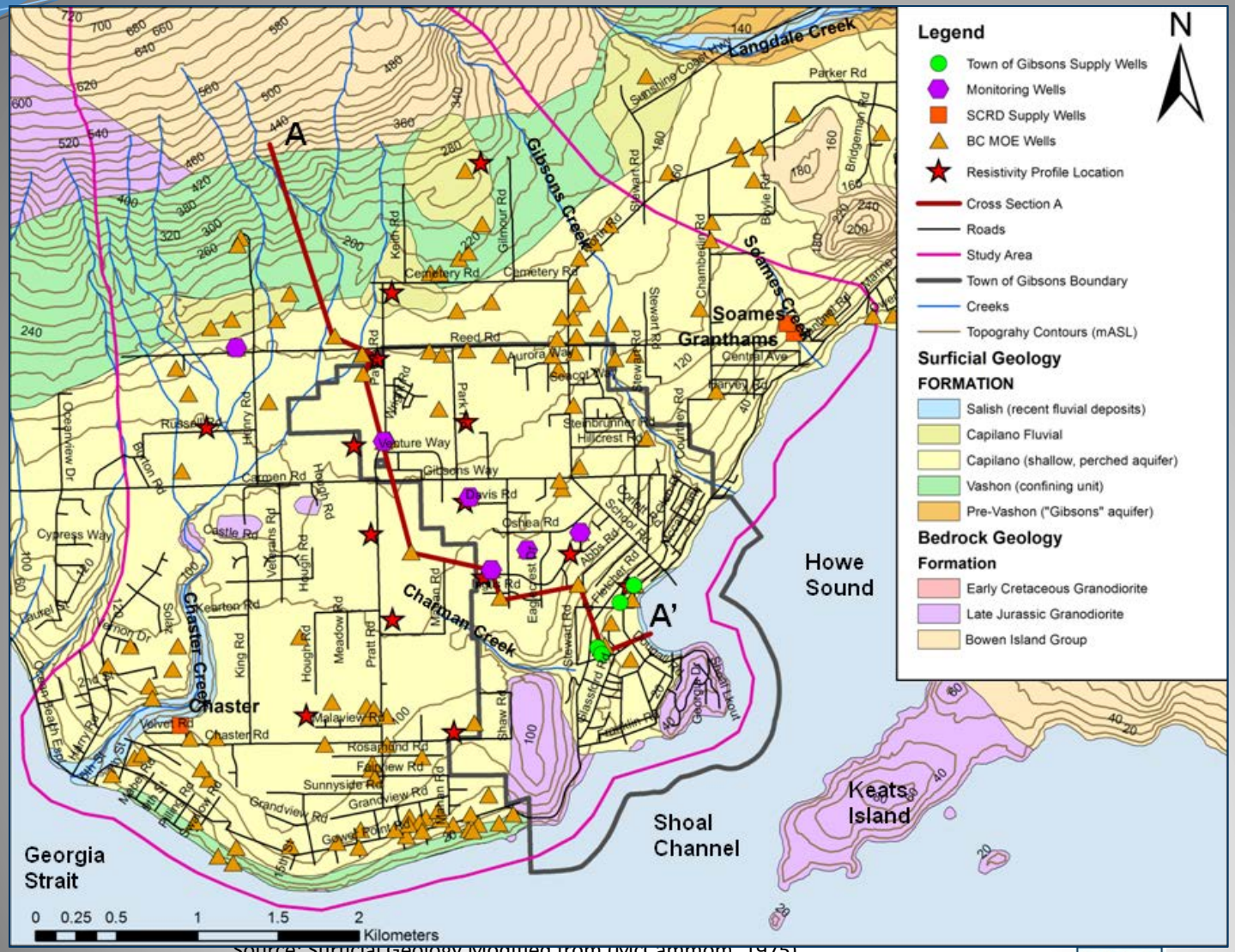


Source: Bedrock Geology: (Journey and Monger, 1997)

Surficial Geology



Source: Surficial Geology Modified from (McCammom, 1975)

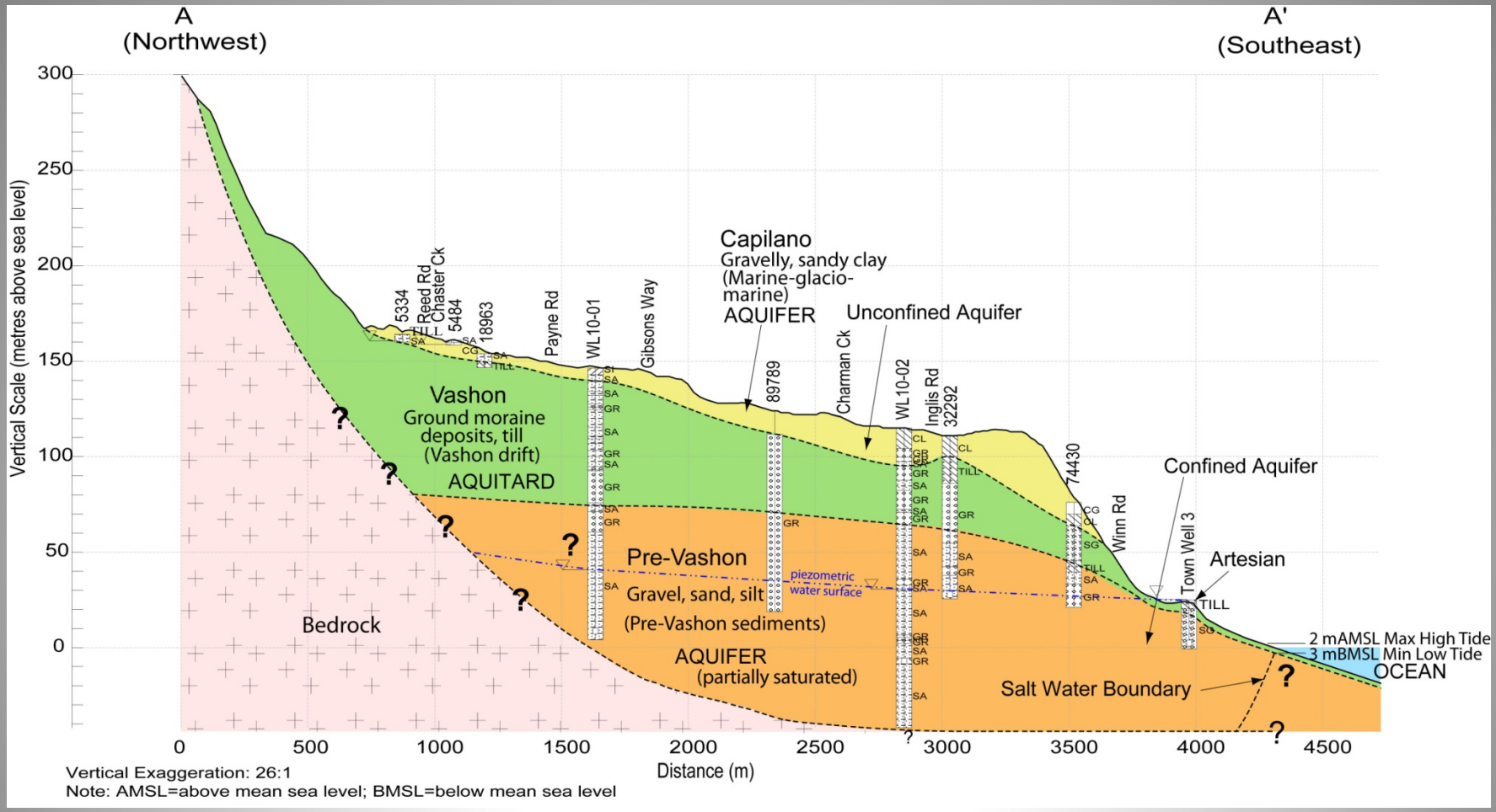


Source: Surficial Geology Modified from (McCammon, 1975)

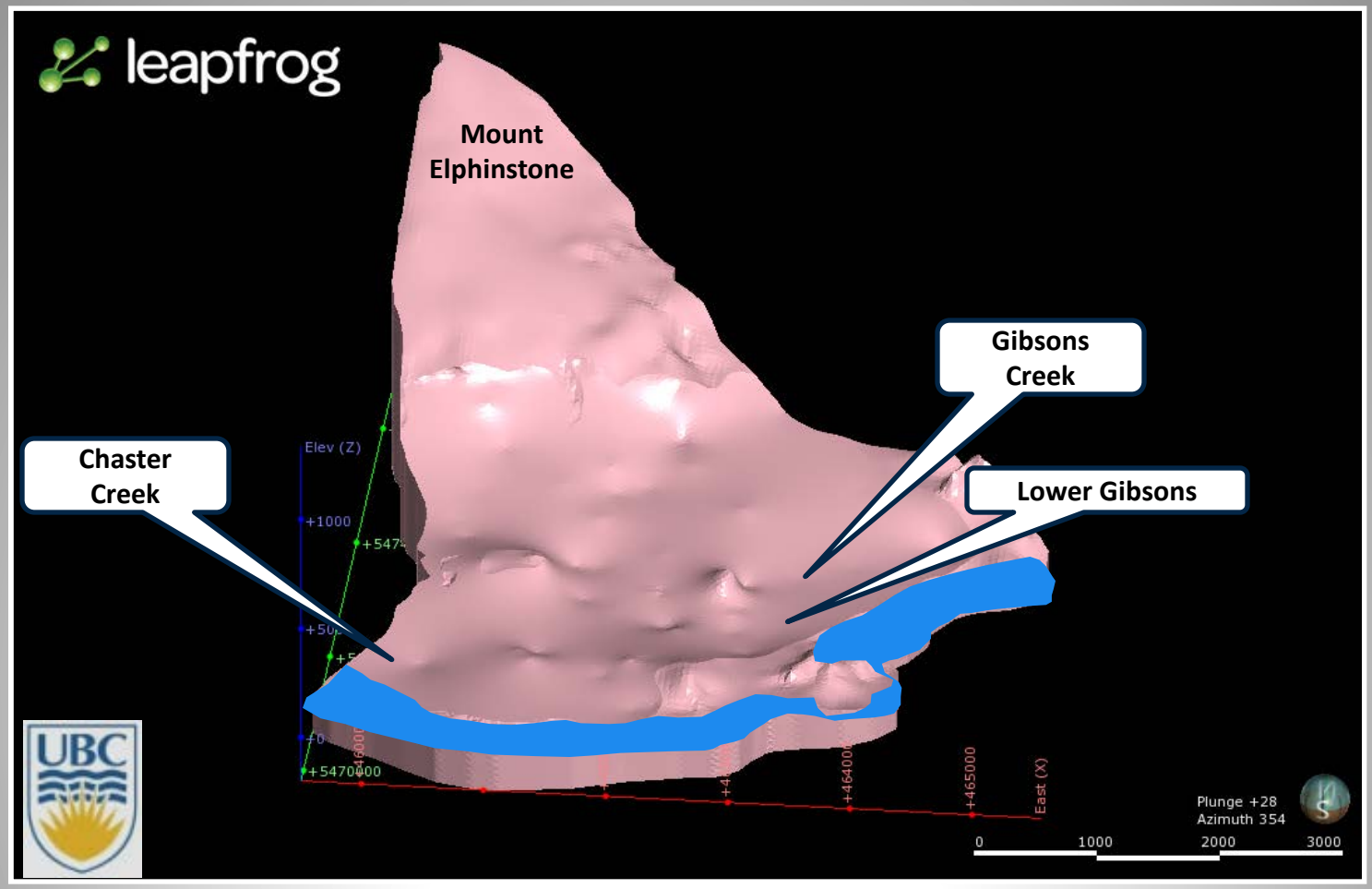
Geo-model Input

- 101 wells in BC MOE database
- 15 monitoring wells
- 15 Geophysical Soundings

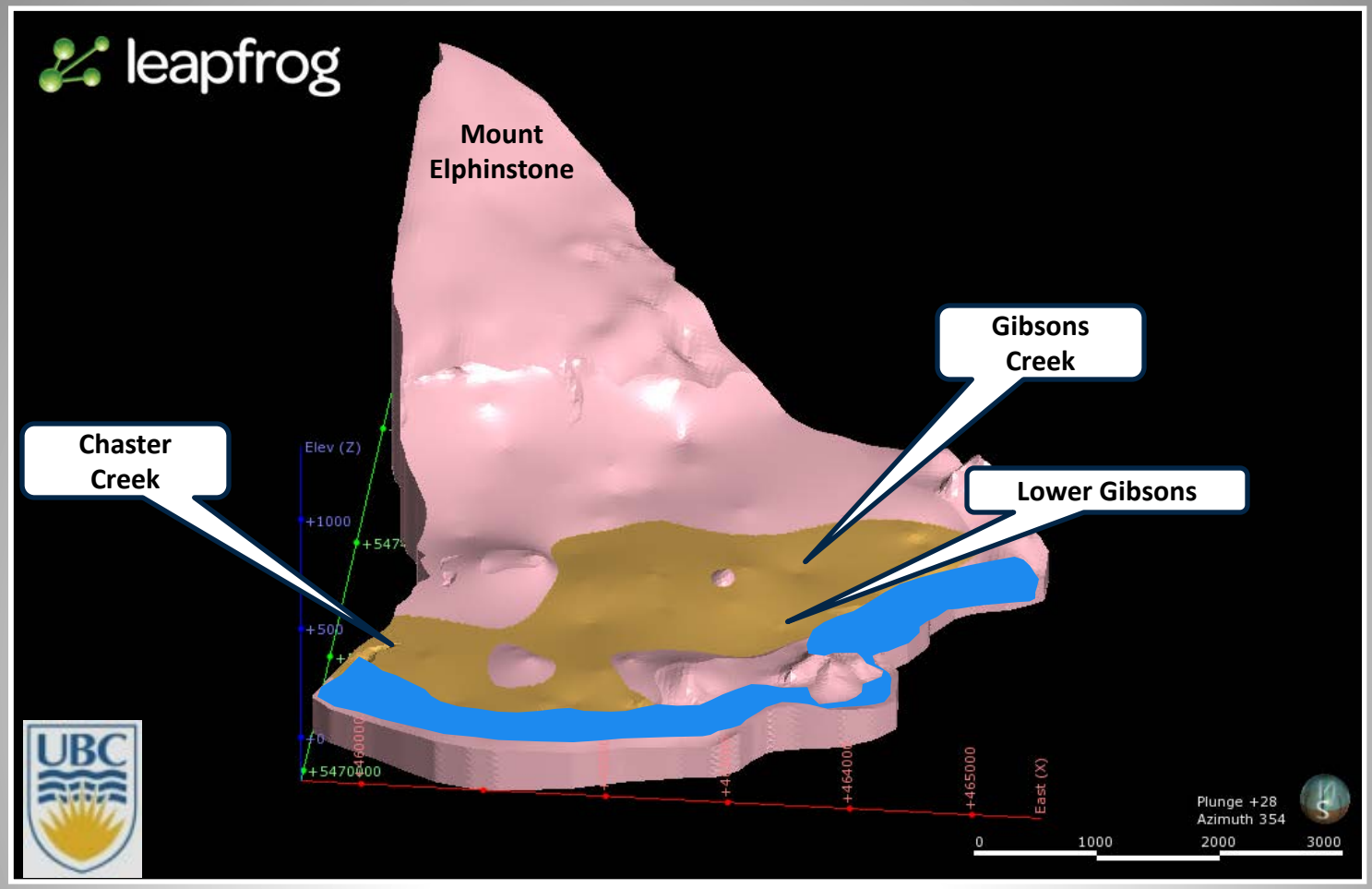
Cross Section A-A’ (NW-SE)



3D Conceptual Model: Bedrock Layer



3D Conceptual Model: Pre-Vashon (Aquifer)



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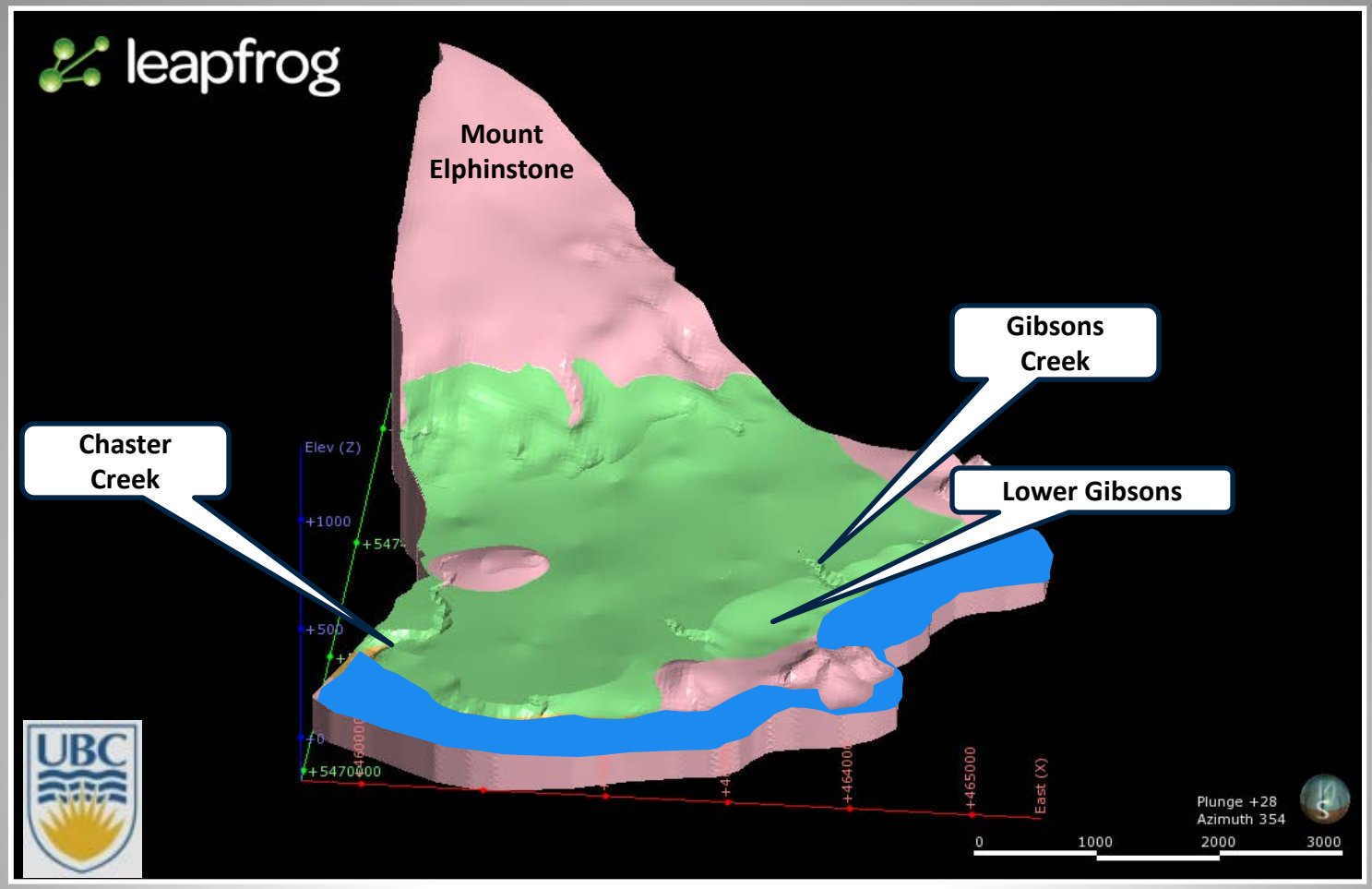
3D Conceptual Model: Vashon Till/Basal Capilano



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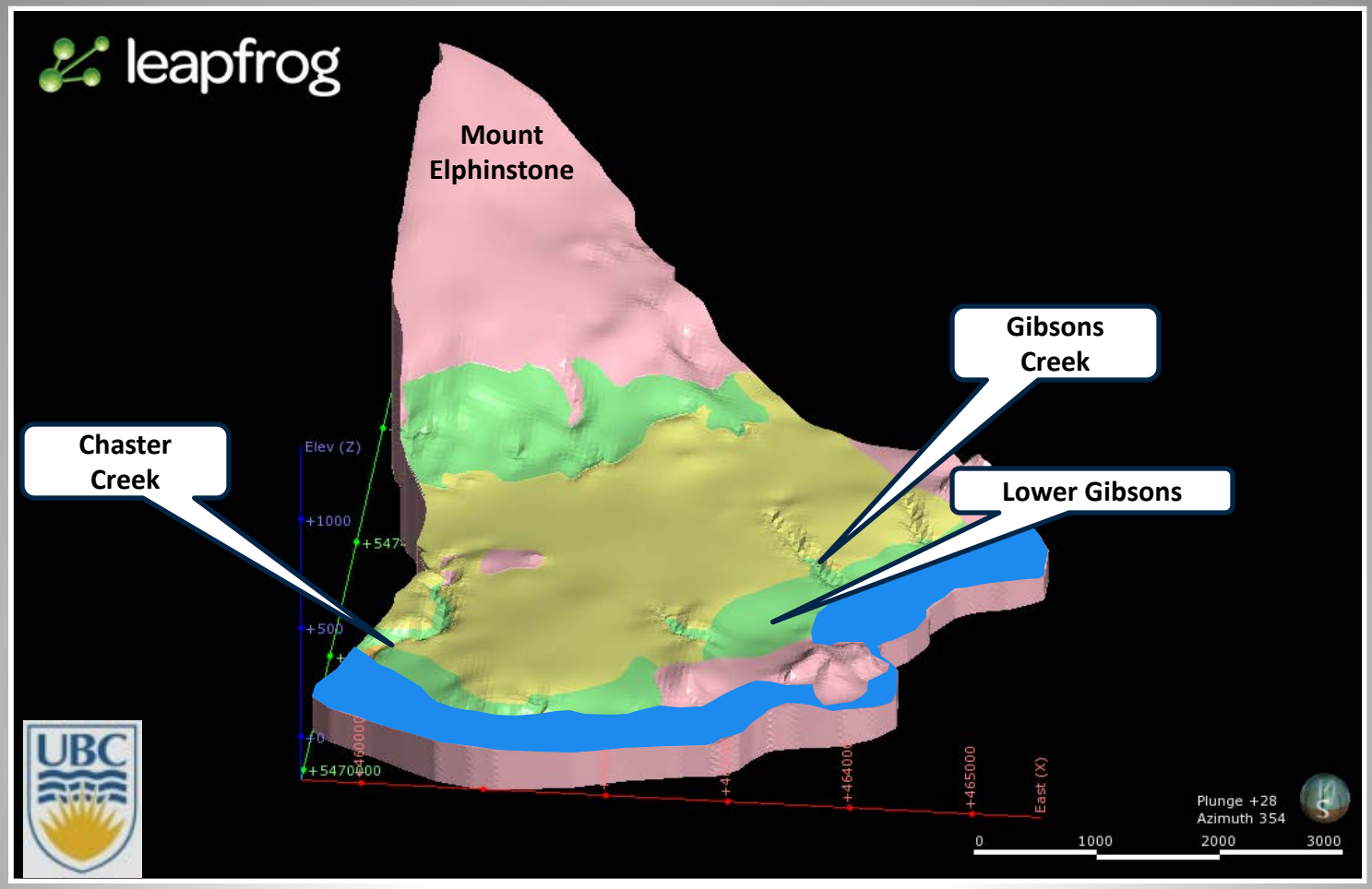
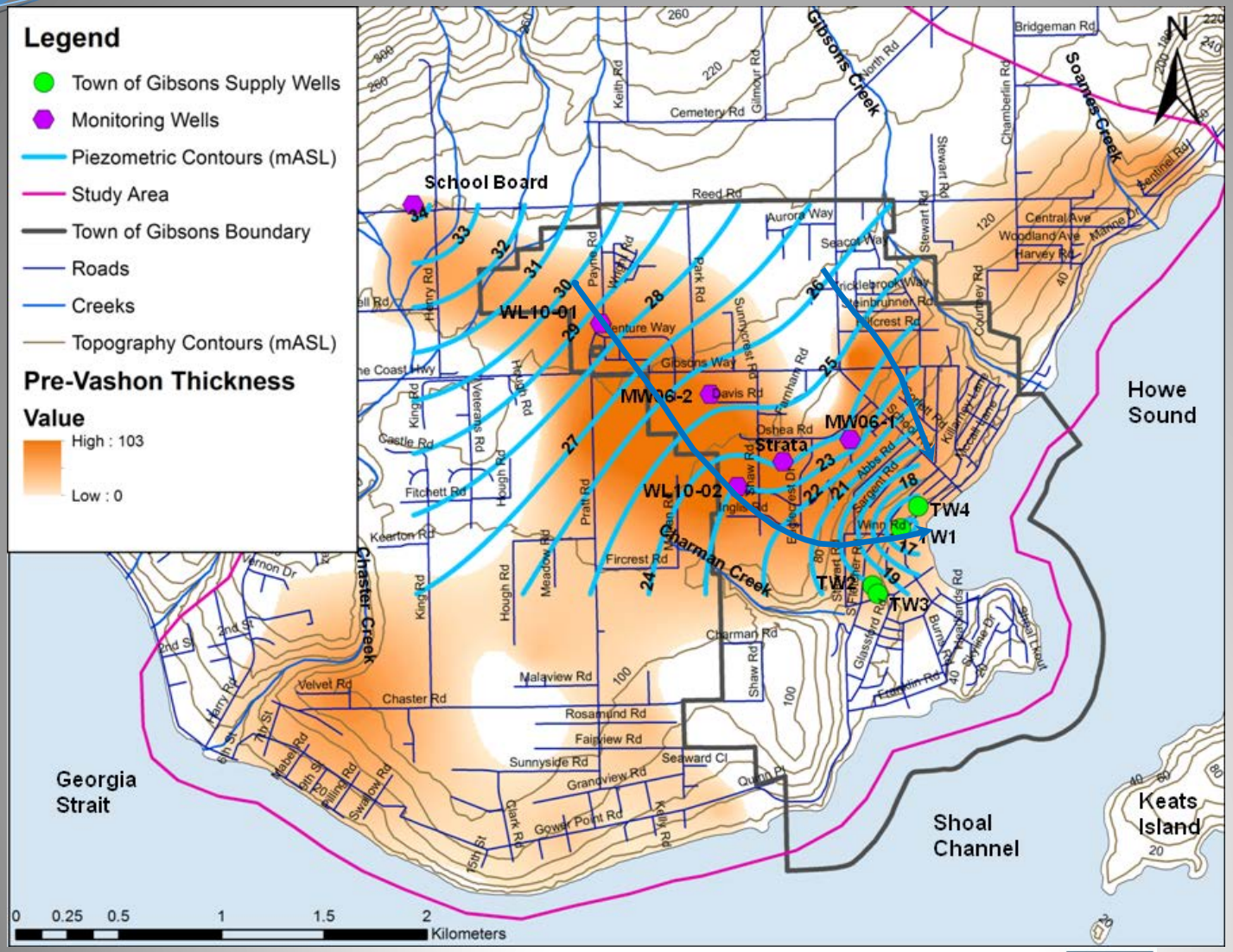
3D Conceptual Model: Capilano Layer

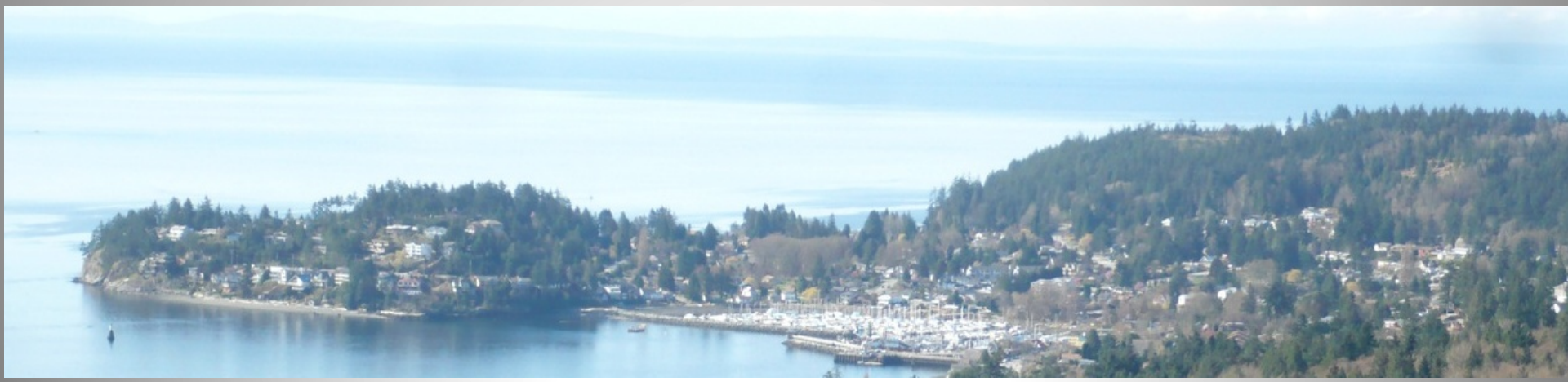


Aquifer Extent



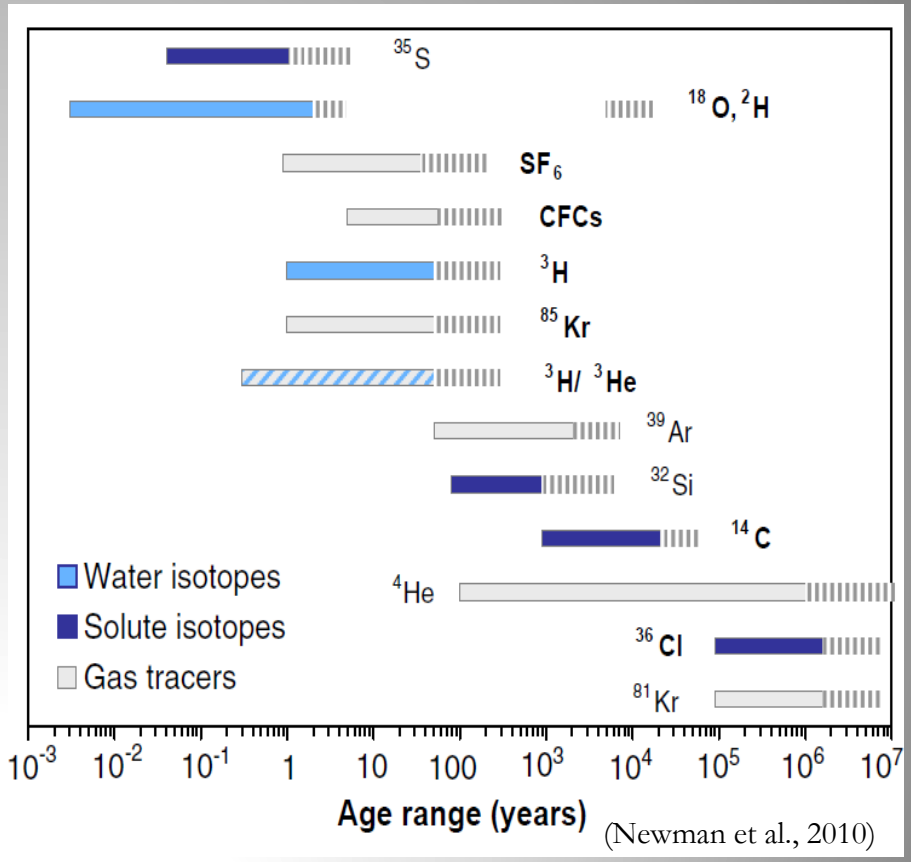
UBC Research

- Use environmental tracers to delineate recharge locations and processes into the Gibsons aquifer
- Integrate tracer results into a numerical groundwater flow model to calculate recharge rates
- Model future groundwater scenarios to predict and guide sustainable groundwater use for future growth



Environmental Tracers

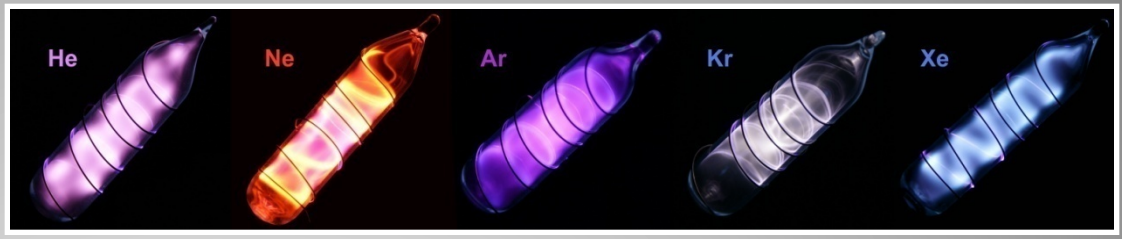
- Groundwater samples analyzed for:
  - ✓ Chlorofluorocarbons (CFCs)
  - ✓ Sulfur-hexafluoride (SF_6)
  - ✓ Tritium (^3H)
  - ✓ **Noble Gases (He, Ne, Ar, Kr, Xe)**
  - ✓ Stable Isotopes (^{18}O, ^2H)
- Limitations with CFCs/SF_6 method
  - ✓ Discuss noble gas, tritium results



(Newman et al., 2010)

Atmospheric Noble Gases

- Naturally occurring;
- Dissolve into groundwater at time of recharge;

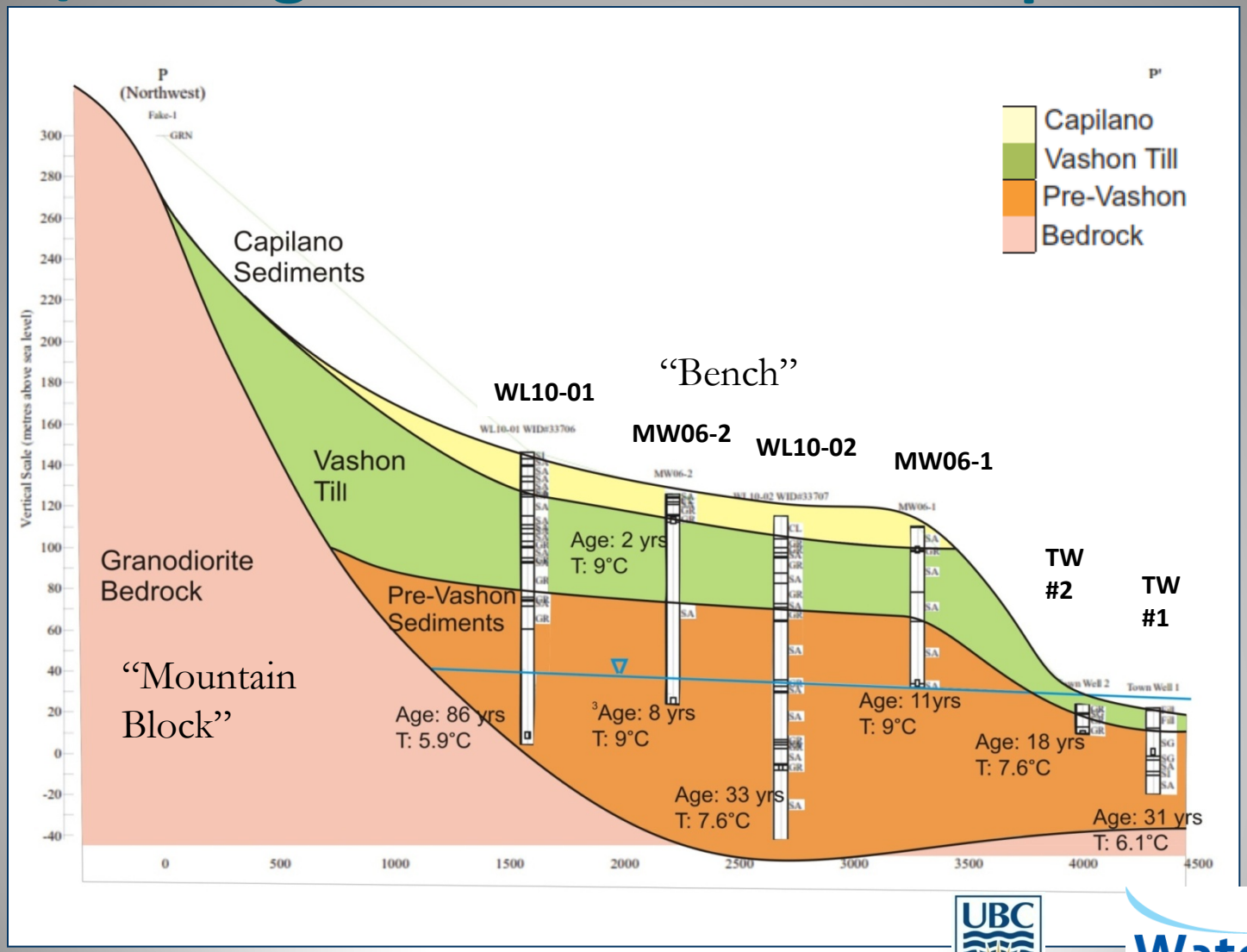


- Concentrations based on Henry's Law;
  - ✓ Function of temperature, elevation (pressure) and salinity at time of recharge
- Take measured gas concentrations to solve for unknown recharge parameter – temperature
  - ✓ Assume: Salinity = 0 mg/L, Elevation (ground elevation at each well).

Tritium/Helium Dating

- Tritium (^3H) in atmosphere from thermonuclear testing in the 1950's and 60's
- ^3H decays to tritogenic helium (^3He)
  - ✓ ^3He determined in noble gas analysis
  - ✓ $t_{1/2}$ = 12.3 years
- $^3H/^3He$ ratio = apparent groundwater age

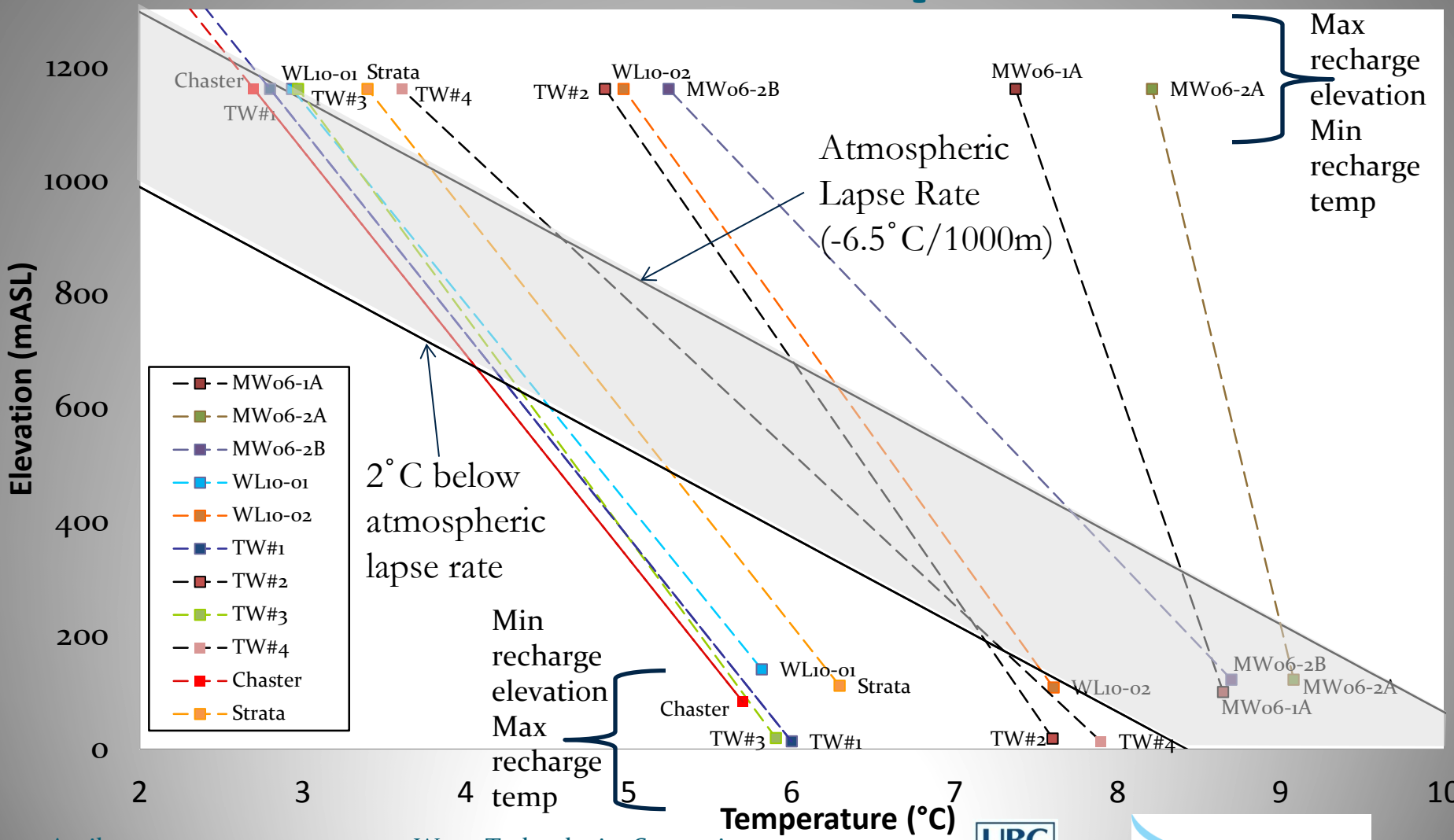
$^3H/^3He$ Ages and Noble Gas Temperatures



Mountain Block Recharge (MBR)

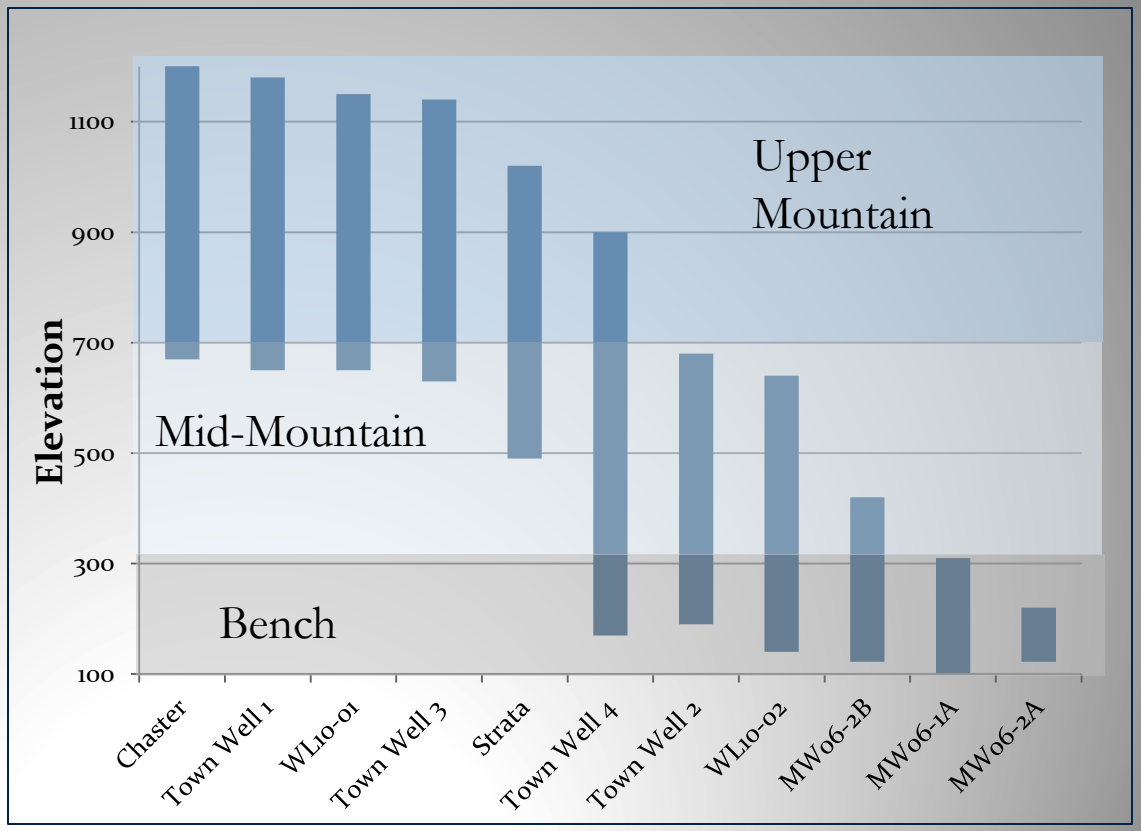
- Tracer results suggest significant amount of MBR
  - ✓ How much?
  - ✓ How do we assess recharge along the mountain where there is no physical information?
    - No wells, drill holes, bedrock permeability info, water table depth, etc…
- Approach
  - ✓ Noble gas temperatures to estimate recharge elevation
  - ✓ Recharge elevation as a calibration target in numerical model

Elevation vs. Temperature

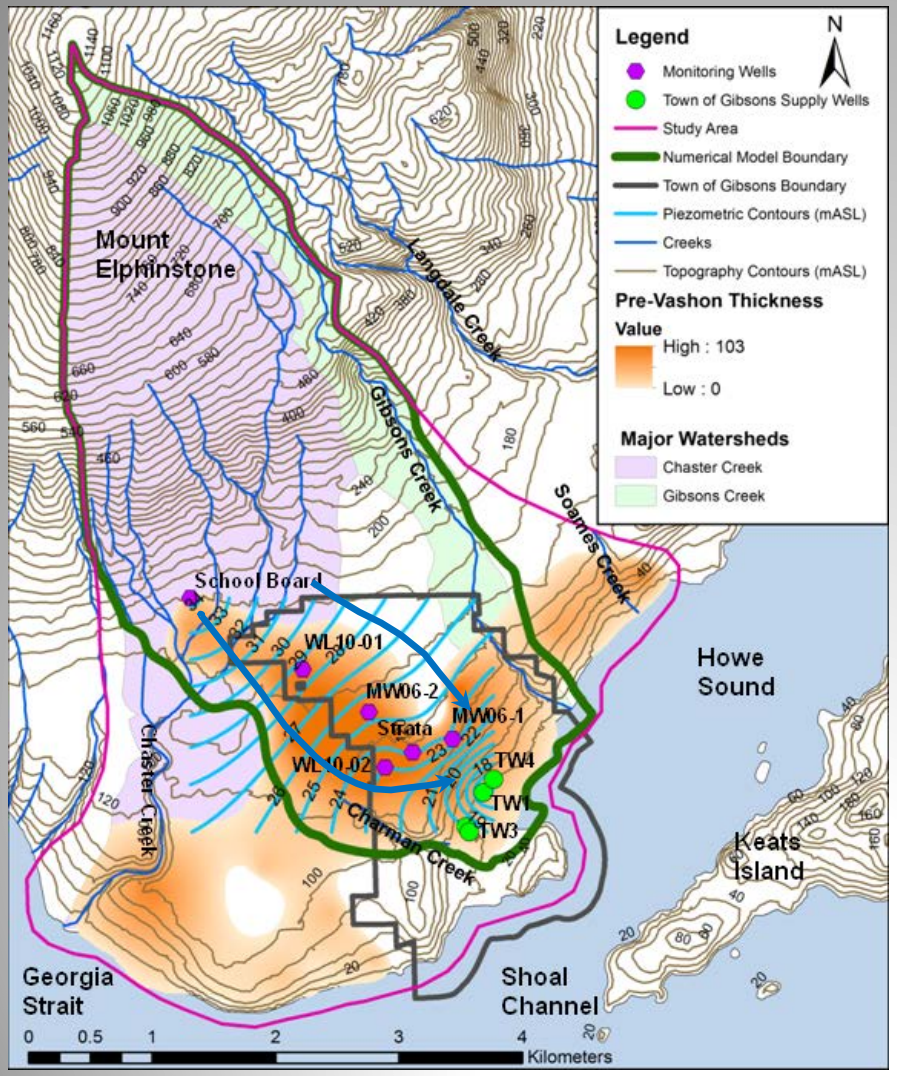


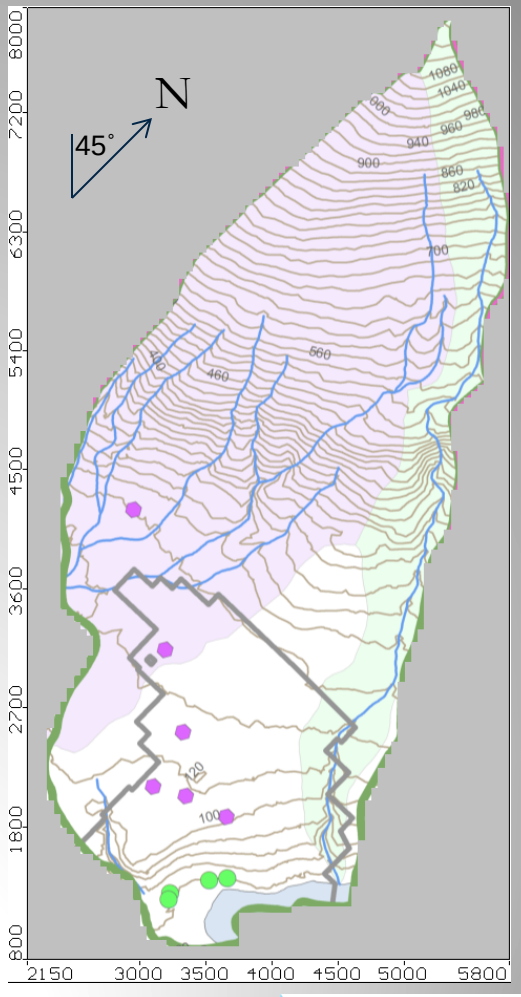
Recharge Elevation Calibration Targets

- Recharge ranges used in model calibration process
- Also calibrated to observed water levels

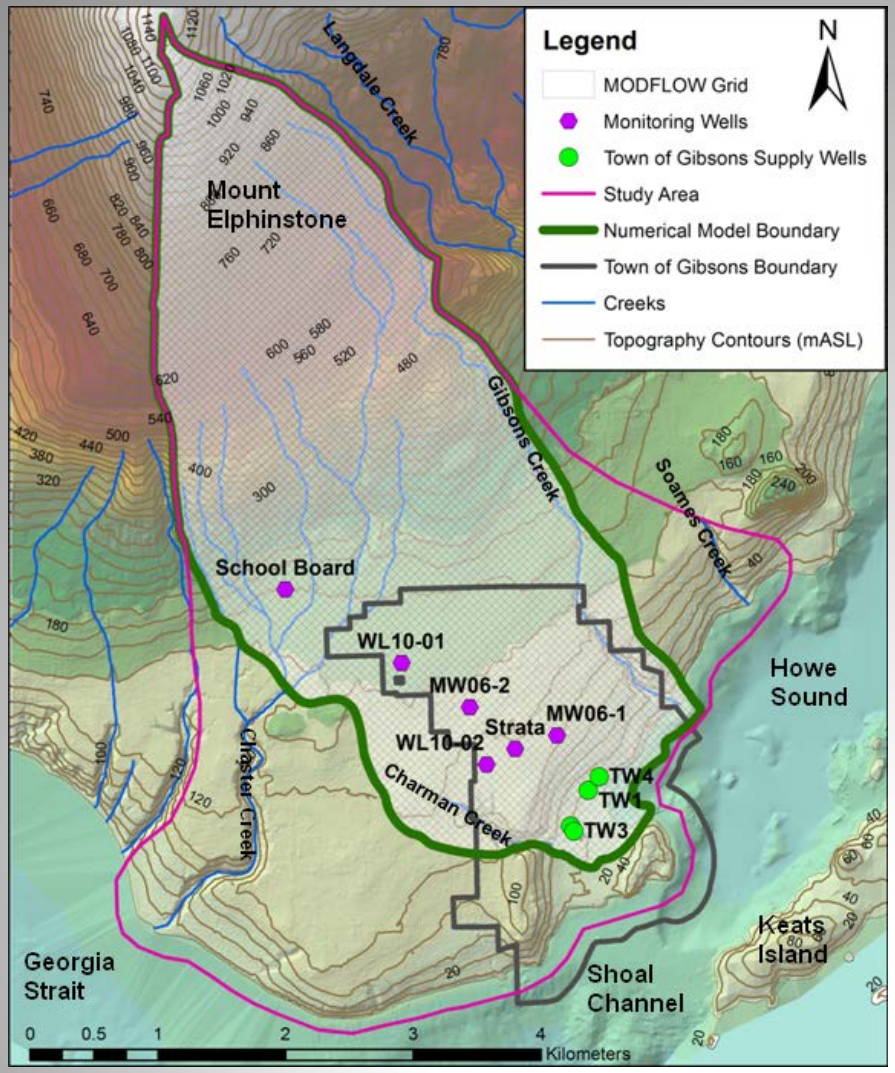


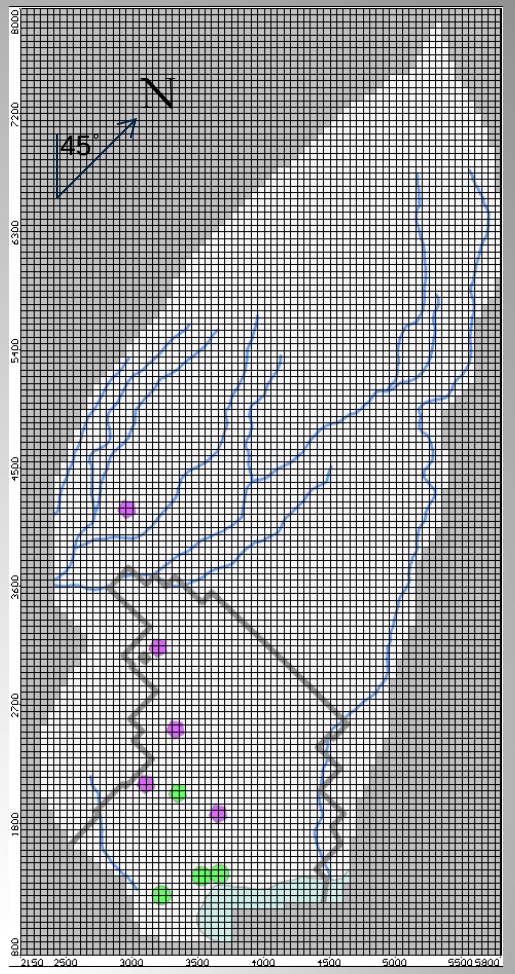
MODFLOW Model Domain



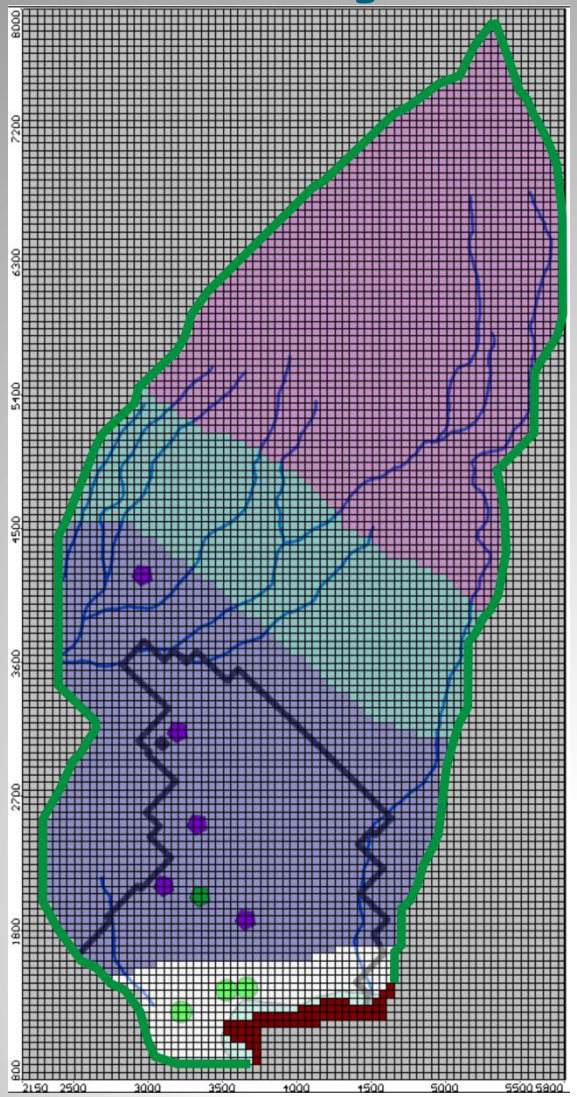


MODFLOW Model Grid





Boundary Conditions



Legend

N

45°

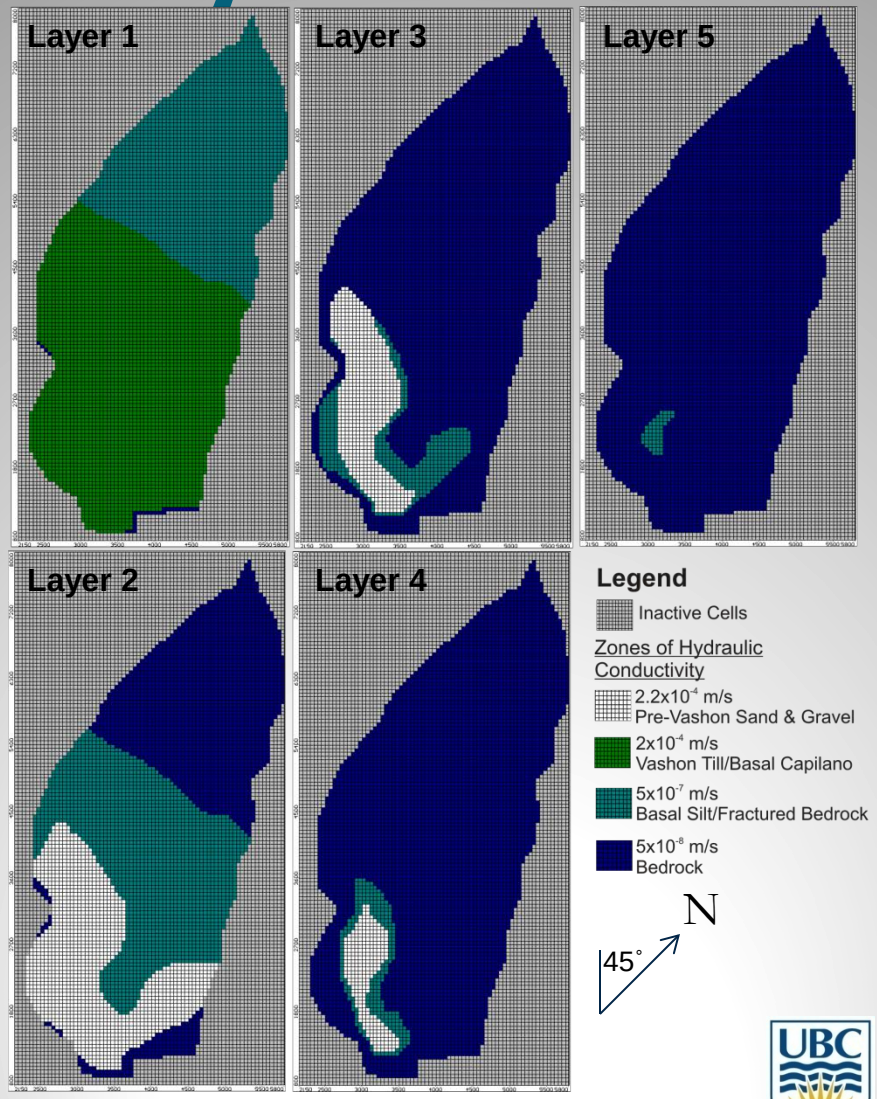
Boundary Conditions

1. No Flow
2. Constant Head
   - 0 mASL
3. Constant Flux
   - i. Recharge
     - 145 mm/year
     - 130 mm/year
     - 115 mm/year
     - 0 mm/year
   - ii. Extraction Wells
     - Town of Gibsons Supply Wells
     - Strata Condo Private Well

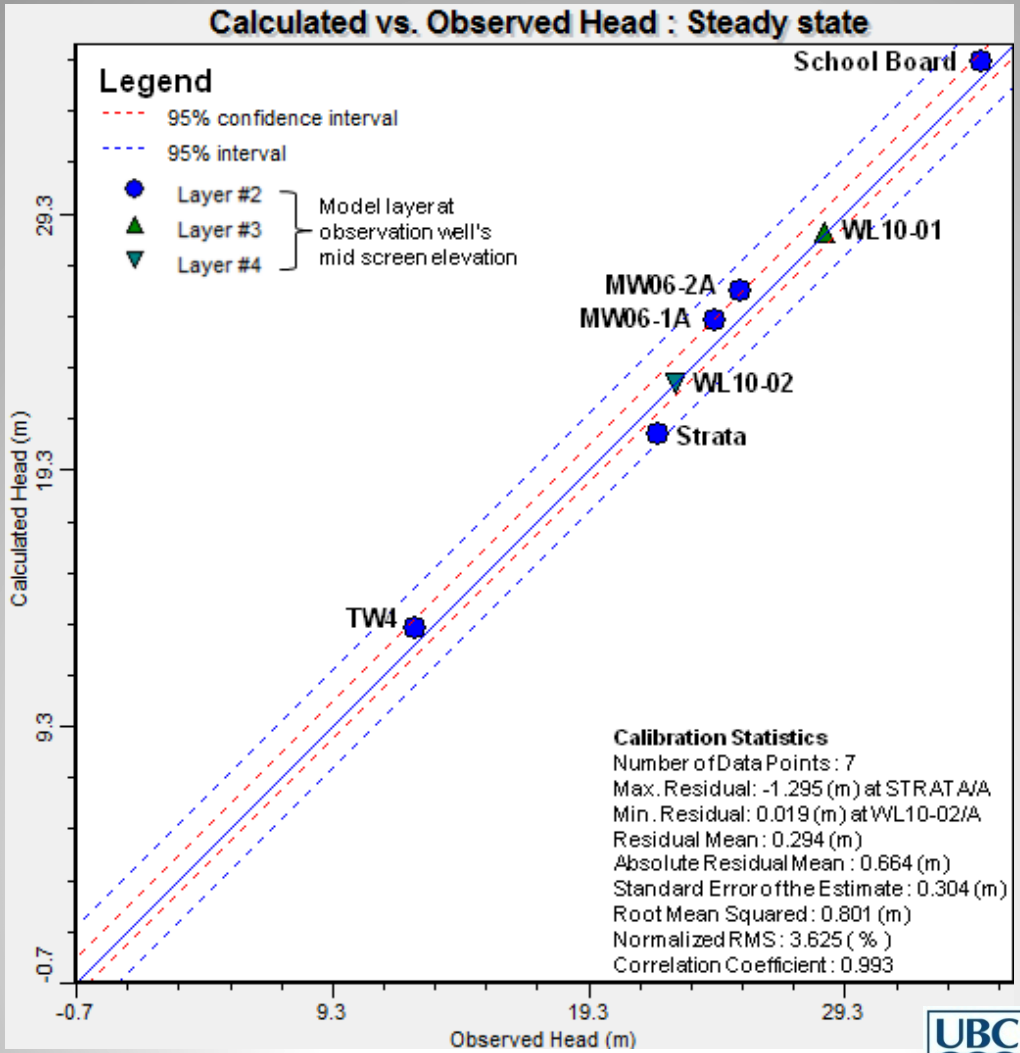
Additional Map Elements

- Monitoring (Observation) Wells
- Creeks
- Town of Gibsons Boundary
- Inactive Cells

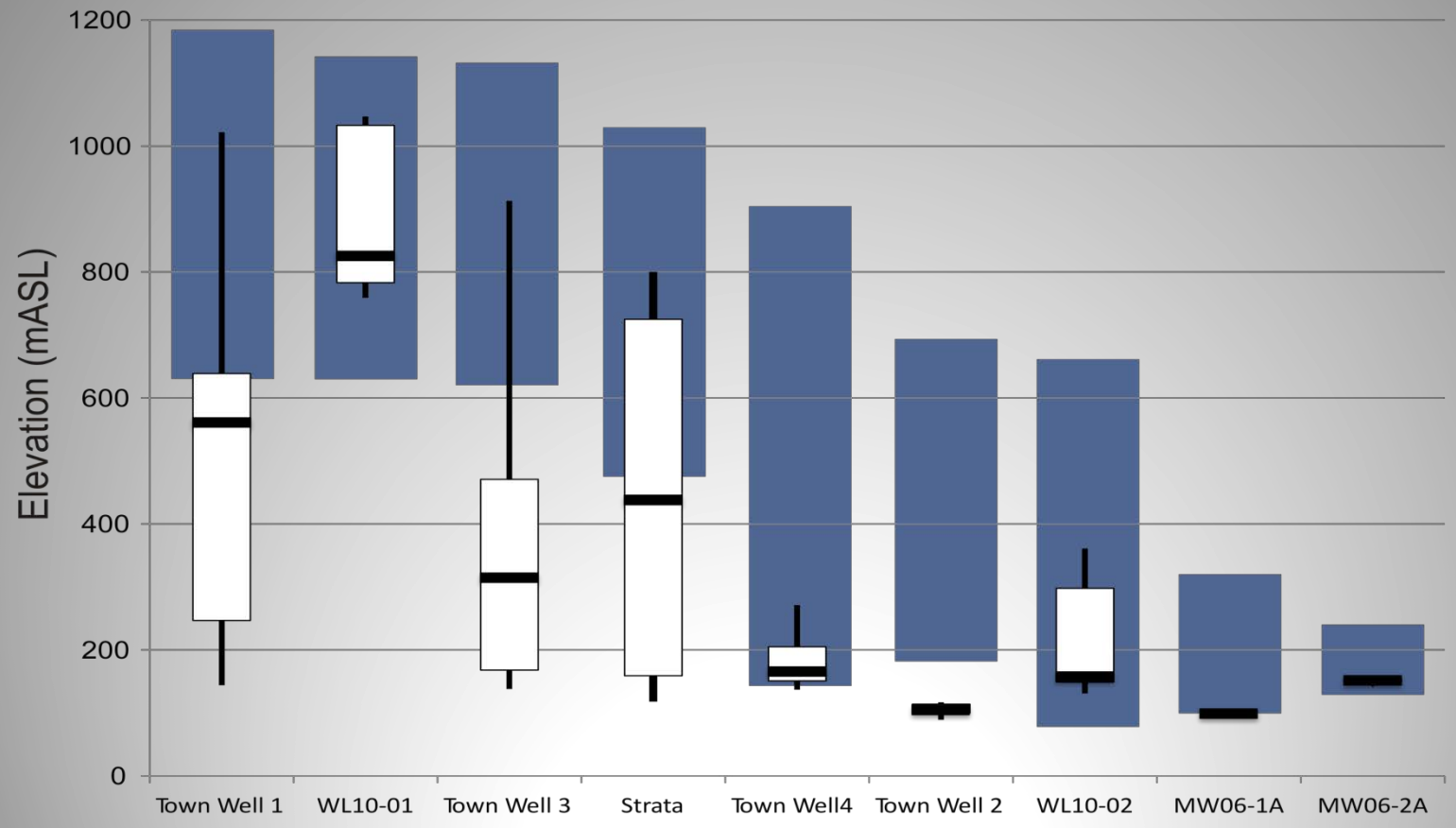
Zones of Hydraulic Conductivity



Hydraulic Head Calibration



Recharge Elevation Calibration



Modeling Results

- Groundwater in the Gibsons Aquifer consists of two recharge end members:
  - ✓ 55% MBR
    - Pre-modern, cold (>50 years, ~5C) that recharges high up on Mt. Elphinstone flows through bedrock fractures and into the aquifer
  - ✓ 45% Bench
    - Modern, warm water (<10 years, ~9C) that recharges the aquifer by leakage through the confining unit

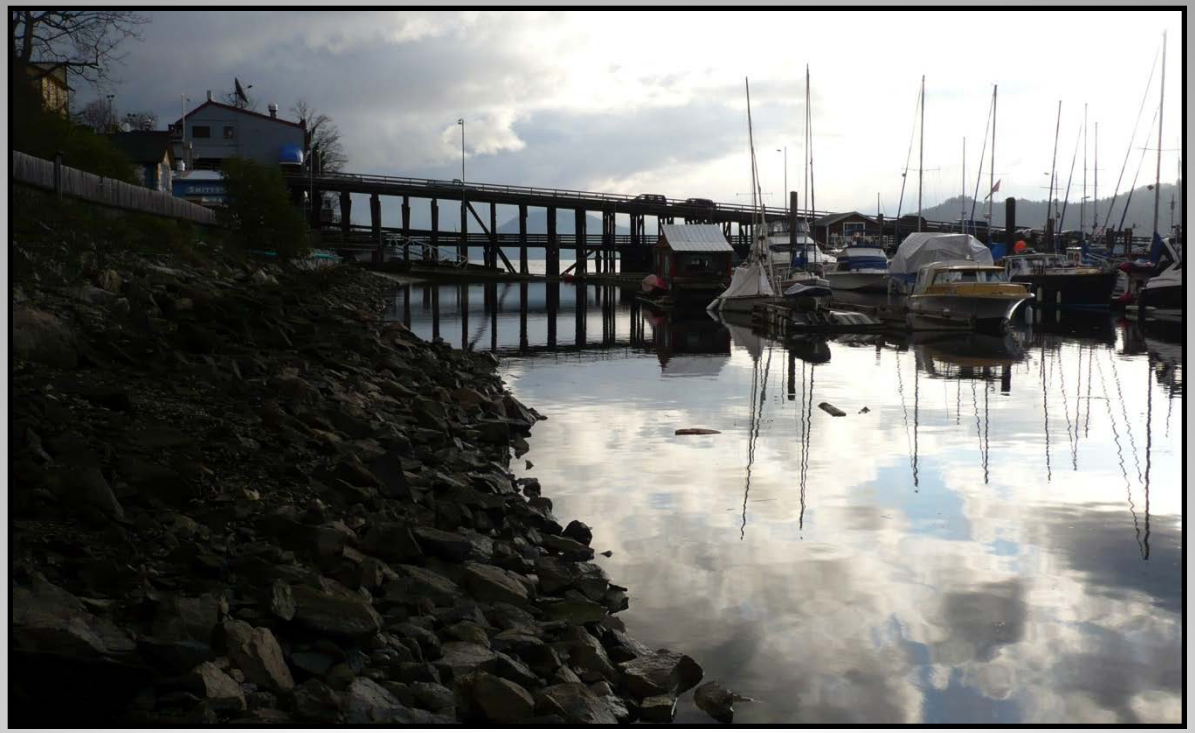
Can the Gibsons Aquifer Supply Enough Water for Future Growth – Sustainably?

- Predictive modeling shows that the Aquifer can sustainably supply up to 4,200 m^3/day, BUT
- Current wells can only supply up to 3,500 m^3/day based on calculated sustainable yield
- If any climate change or variability leads to more than 5% decrease in recharge– begin to deplete aquifer,
  - ✓ May lead to salt water intrusion

Conclusion

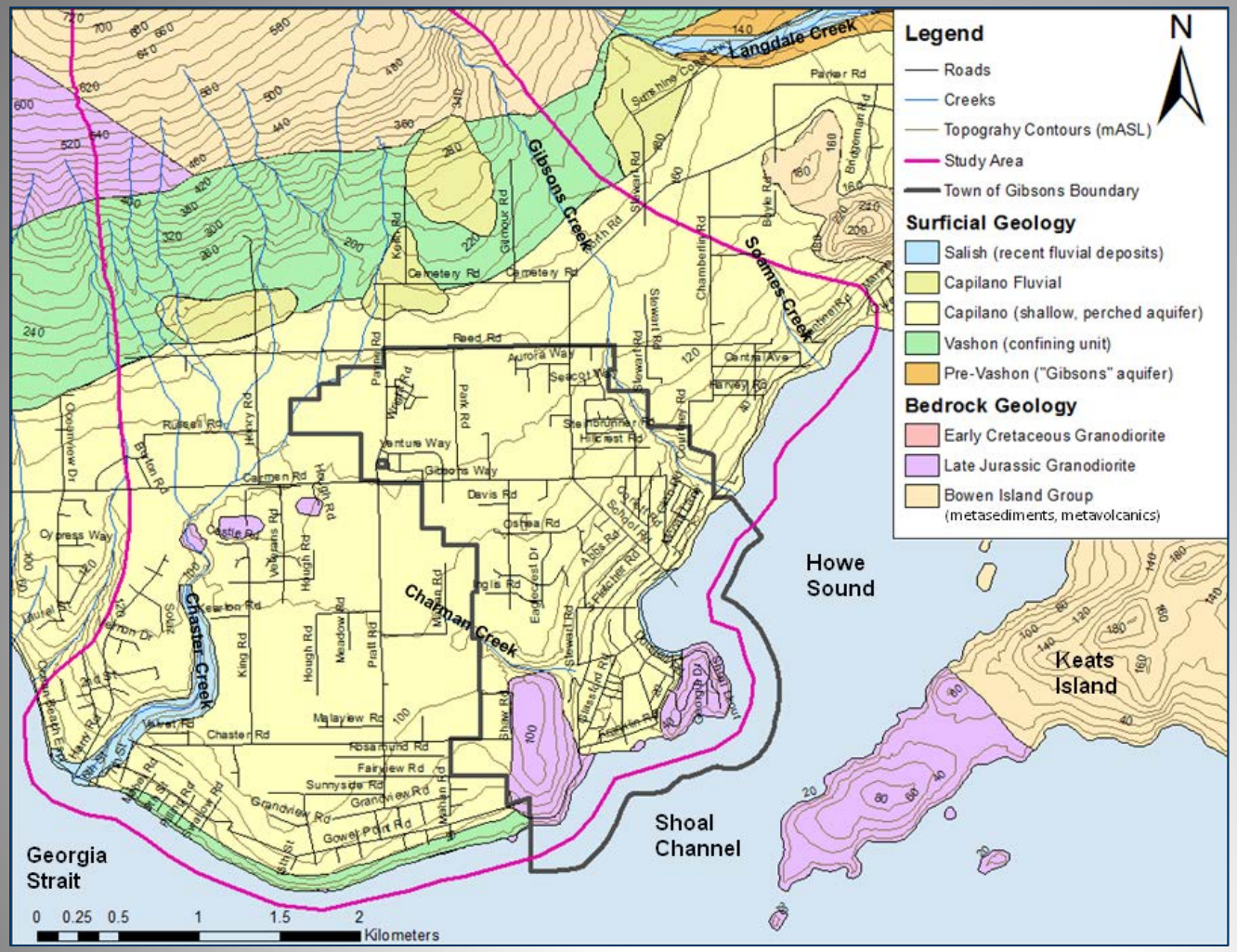
- Environmental tracer results improved our understanding groundwater recharge to the Gibsons Aquifer – MBR!
  - ✓ Also provided calibration targets in mountain where no physical data exists
- Numerical modeling suggests two end-members of recharge;
  - ✓ 55% MBR
  - ✓ 45% Bench
- Predictive modeling suggests that the Gibsons Aquifer can support growth to full built out, however the Town needs to take measures to decrease water use if climate change or variability results in decrease recharge

Thank You - Questions?



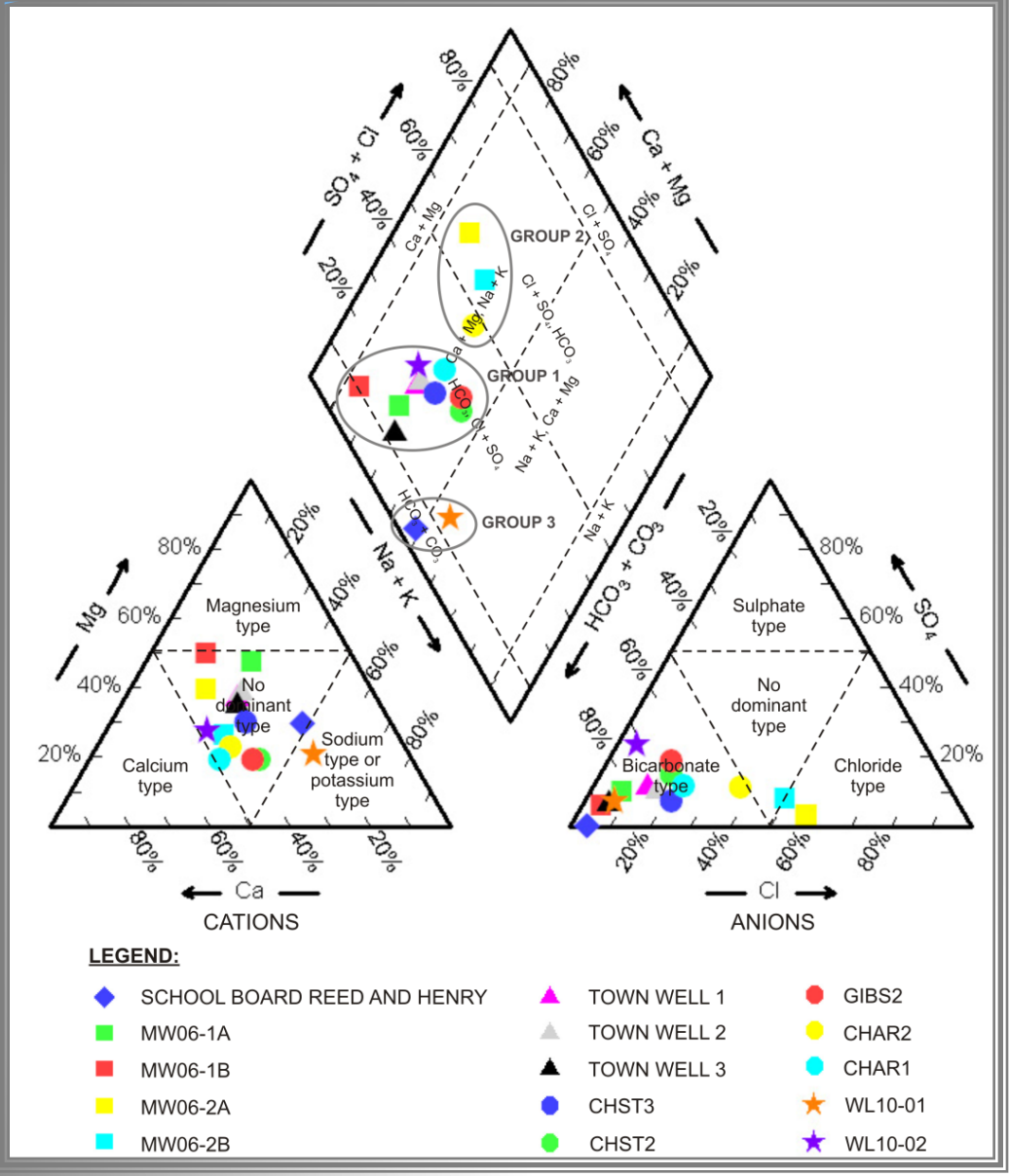
Contact:
jdoyle@waterlineresources.com

Aquifer Recharge



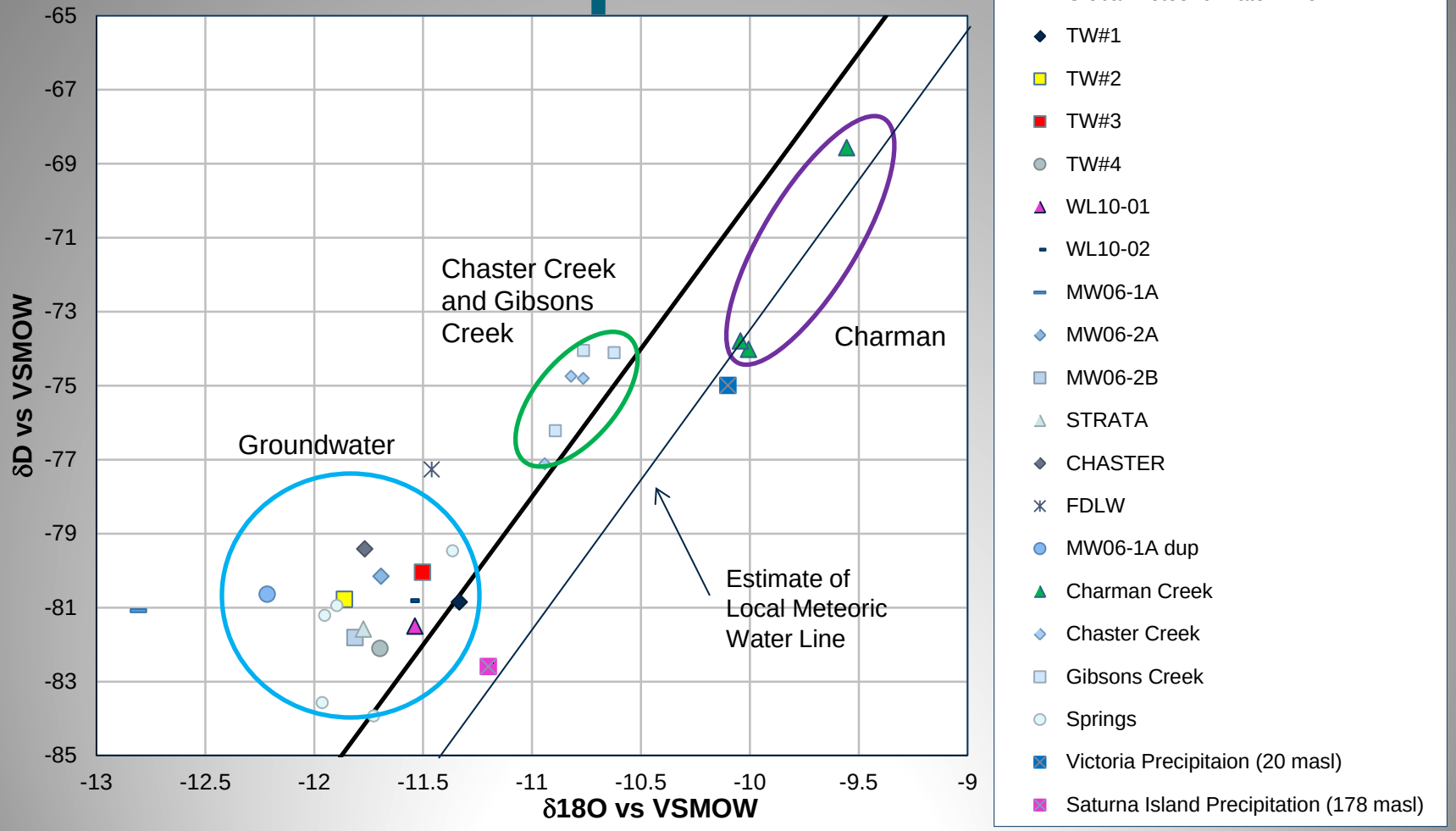
- Where ?
- Capilano Fluvial deposits?
- Recharge Windows - creeks, holes in the Vashon Till
- Fault system ?
- How much?

Water Chemistry



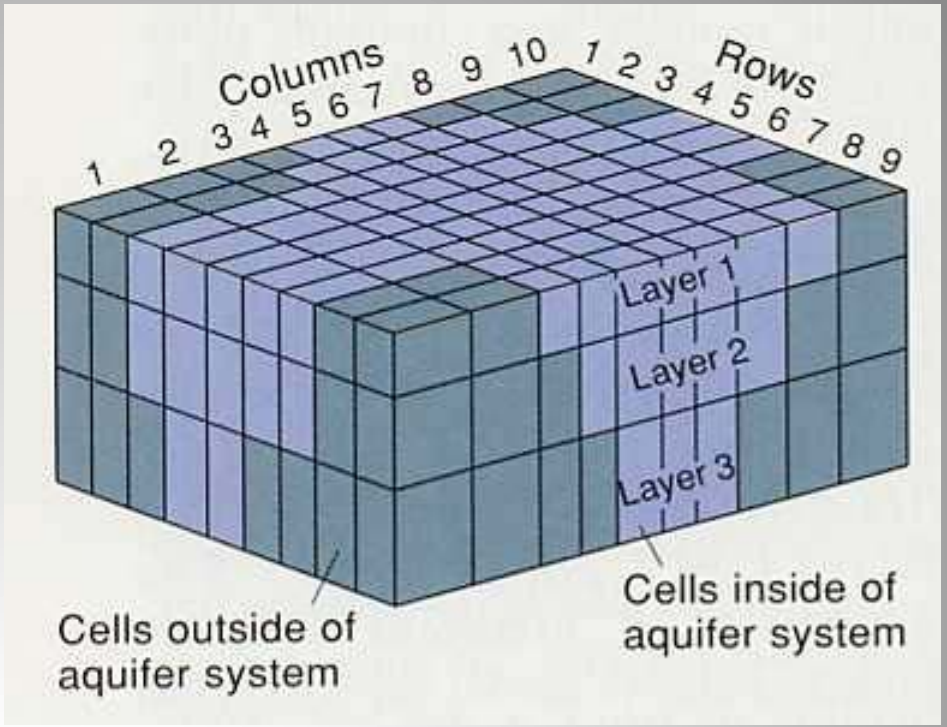
- **Group 1:** Gibsons Aquifer, Gibsons and Chaster Creek
- **Group 2:** Capilano Aquifer and Charman Creek
- **Group 3:** Upper Reaches of Gibsons Deep aquifer

Stable Isotopes



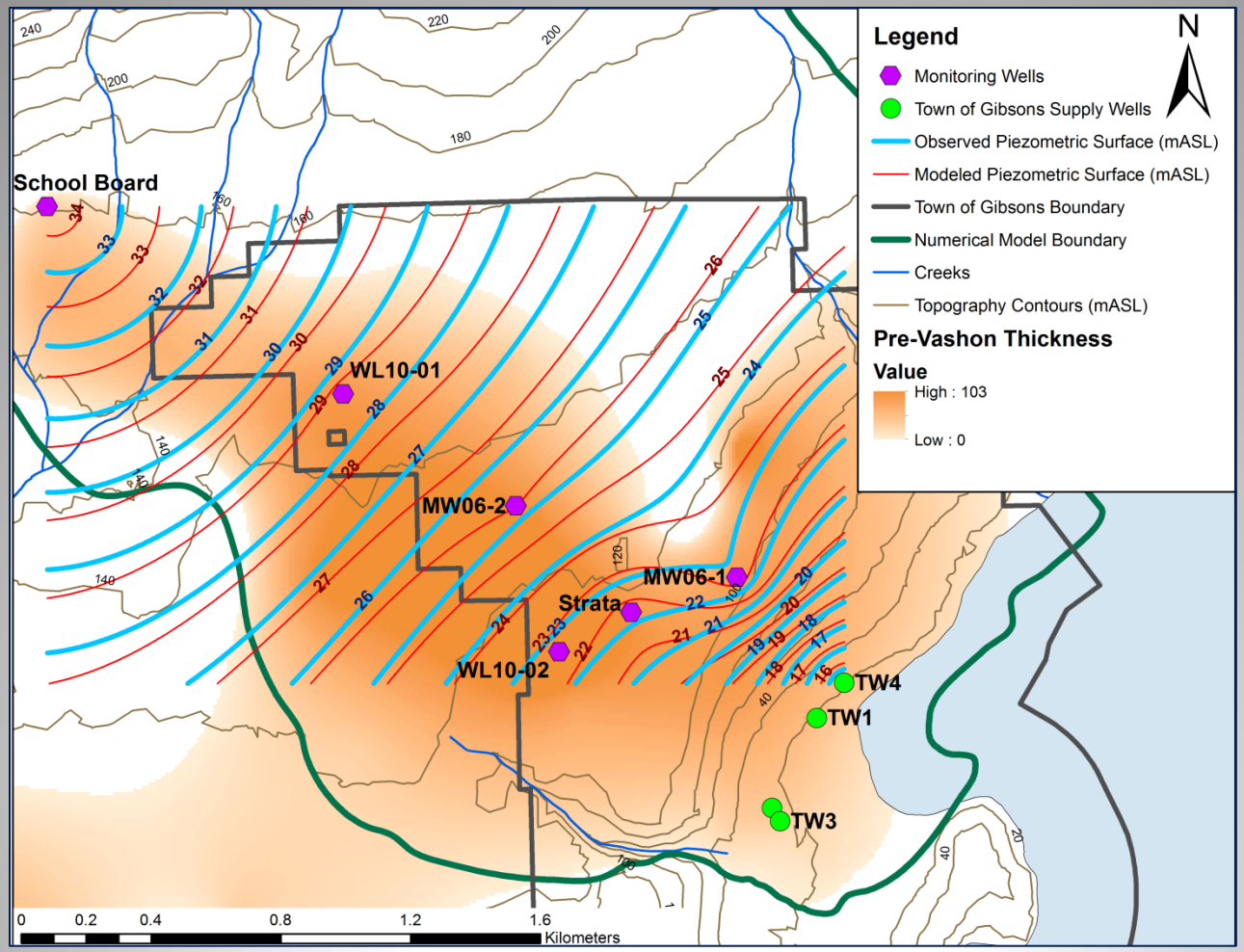
Numeric Engines

- MODFLOW – 2000
  - Visual MODFLOW 2009.1
  - Finite Difference
- Solver
  - PCG-2
- Steady State – long term averages

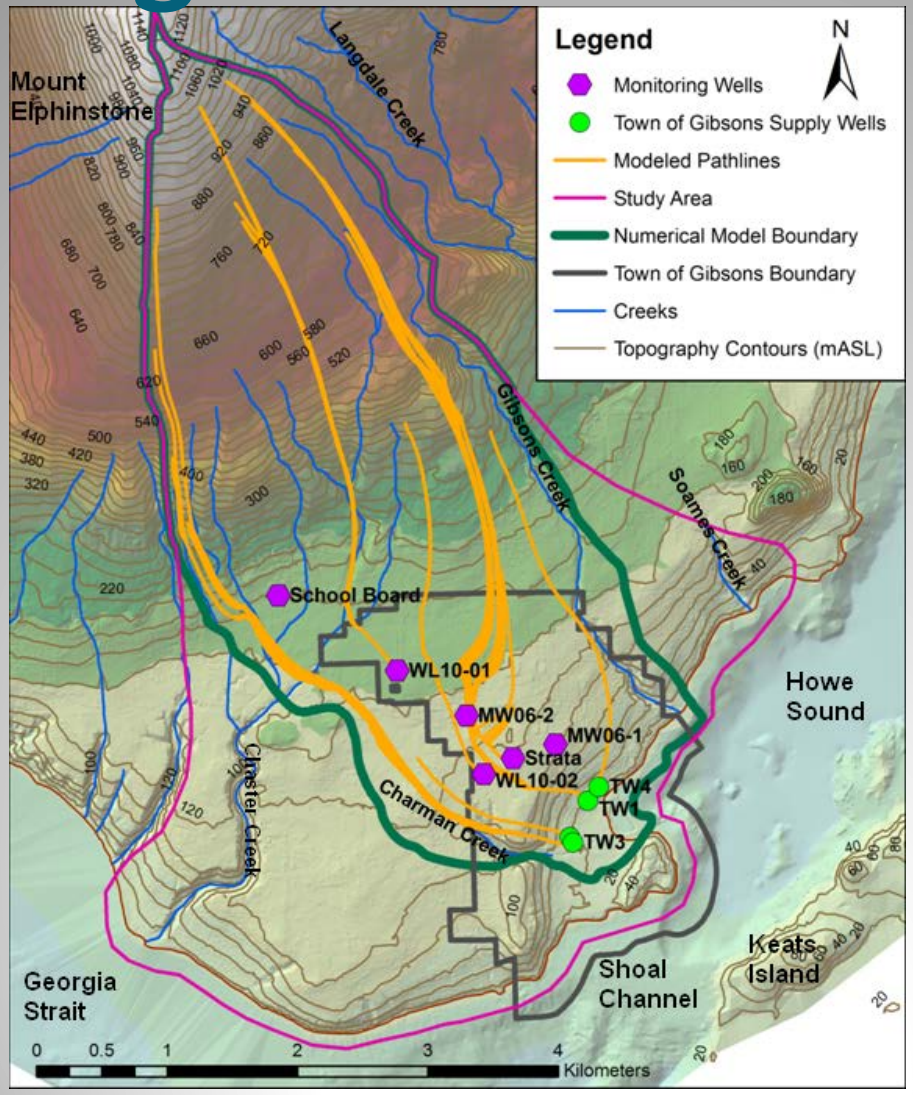


http://wi.water.usgs.gov/glpf/images/cs_st_model_modflow_grid.jpg

Hydraulic Head Calibration



Recharge Elevation Calibration



Town of Gibsons Growth and Future Groundwater Use

Full Build-Out = 4,200 m^3/day