# ACCURATE WATER TABLE CHARACTERIZATION

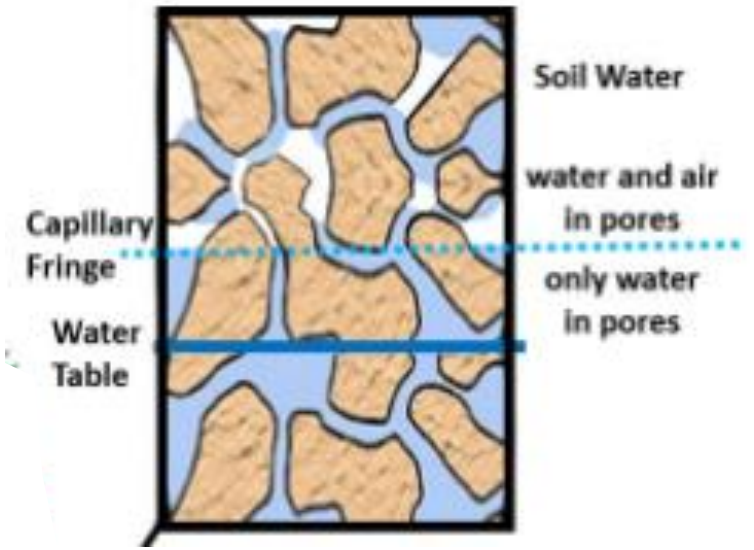
ALANNA FELSKE, GIT – GROUNDWATER RESOURCES INFORMATION TECHNOLOGIES LTD. (GRIT LTD)

LOUISE VERSTEEG, P.BIOL – SOLSTICE CANADA

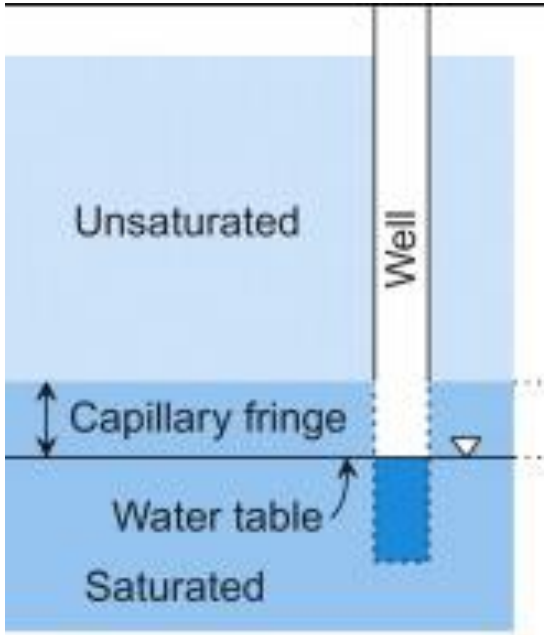
ENVIROTECH CONFERENCE JUNE 3, 2021

# WATER TABLE VS. CAPILLARY FRINGE

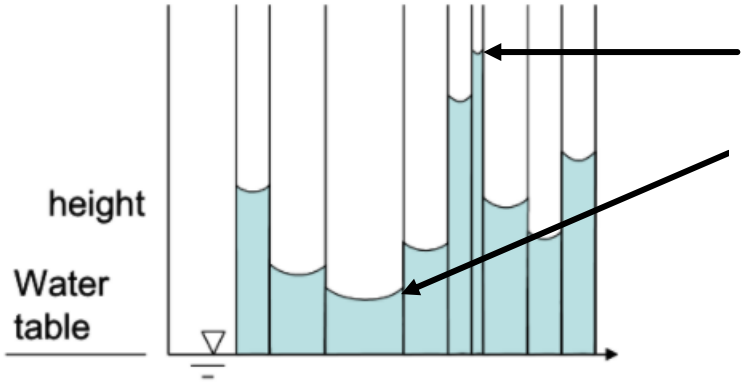
- Water table
  - Fully saturated – where pressure head is equal to zero (subsurface pressure = atmospheric pressure)
- Capillary fringe
  - Height is governed by pore size
  - Larger in fine grained material
  - Fully saturated – water held under negative pressure (suction)




https://books.gw-project.org/groundwater-in-our-water-cycle/part/the-earths-plumbing-system/




https://www.sciencedirect.com/topics/earth-and-planetary-sciences/capillary-fringe




Largest rise in smallest pores

Smallest rise in largest pores

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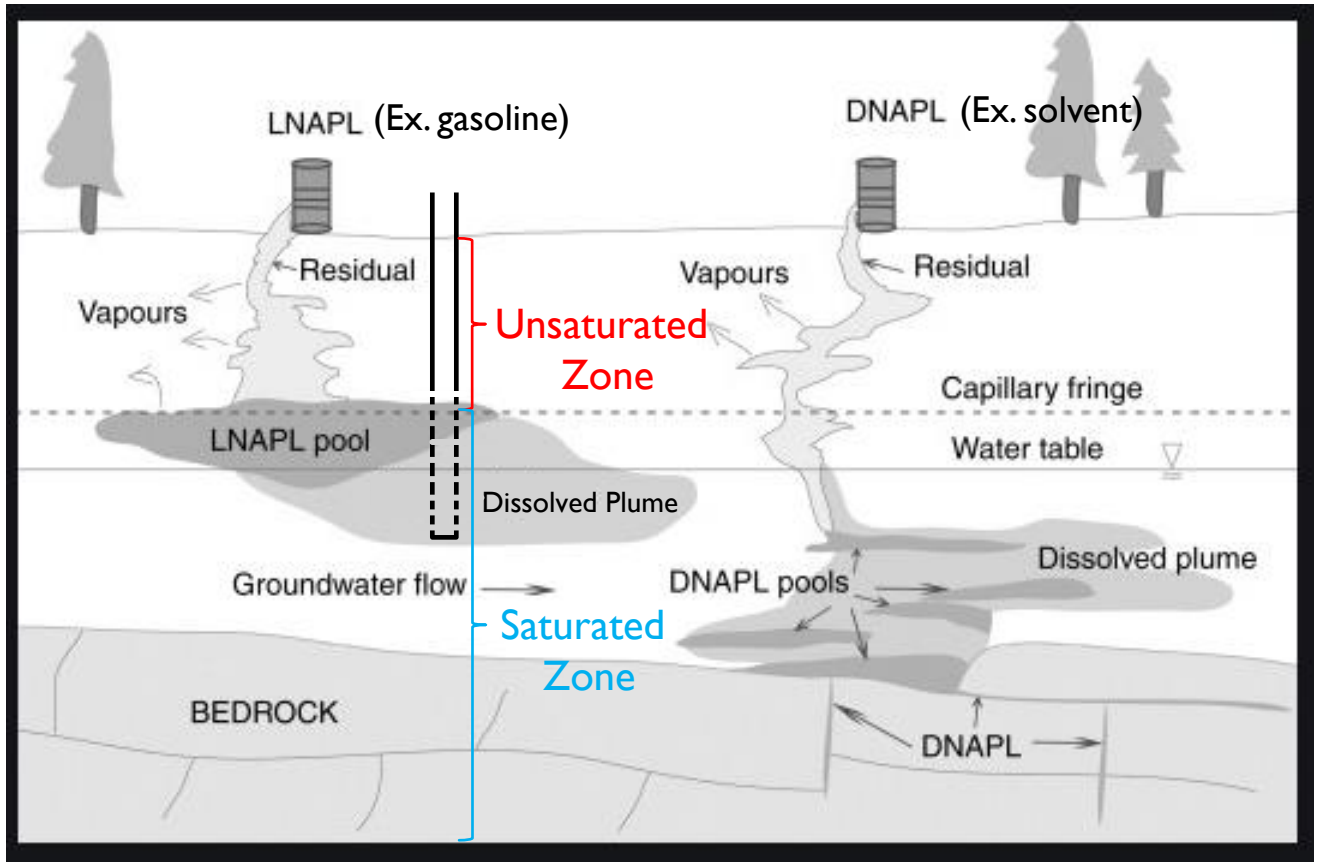
# WHY DO WE CARE?

# CONTAMINANT MIGRATION AND DETECTION




https://www.sciencedirect.com/topics/earth-and-planetary-sciences/dense-non-aqueous-phase-liquid

- Light non-aqueous phase liquids (LNAPL's) sit on top of the saturated zone
  - Effected by height of capillary fringe
  - Monitoring wells must be screened across the water table to detect free product
  - Consider seasonal water table fluctuations
- Dense non-aqueous phase liquids (DNAPL's) sit on top of low permeability layers
  - Monitoring wells screened below the water table with short screen lengths

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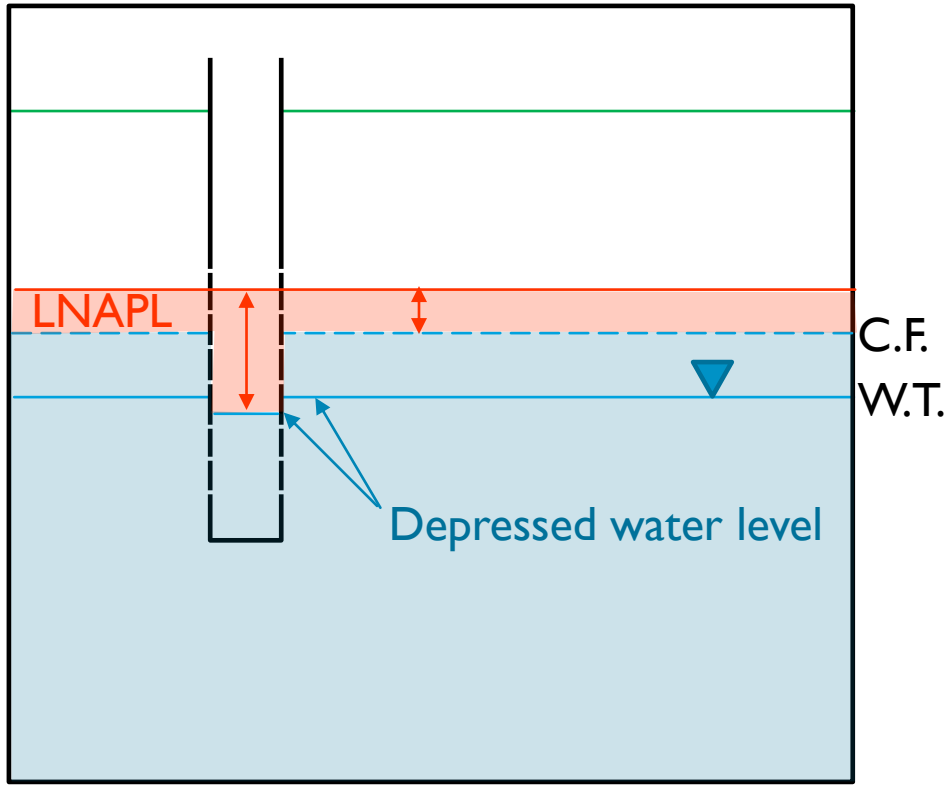
# CONTAMINANT MIGRATION AND DETECTION




- Light non-aqueous phase liquids (LNAPL's) sit on top of the saturated zone
  - Thicker free product in monitoring well due to lack of capillary forces
  - Water level measurement in monitoring well slightly lower than the actual water table due to weight of free product

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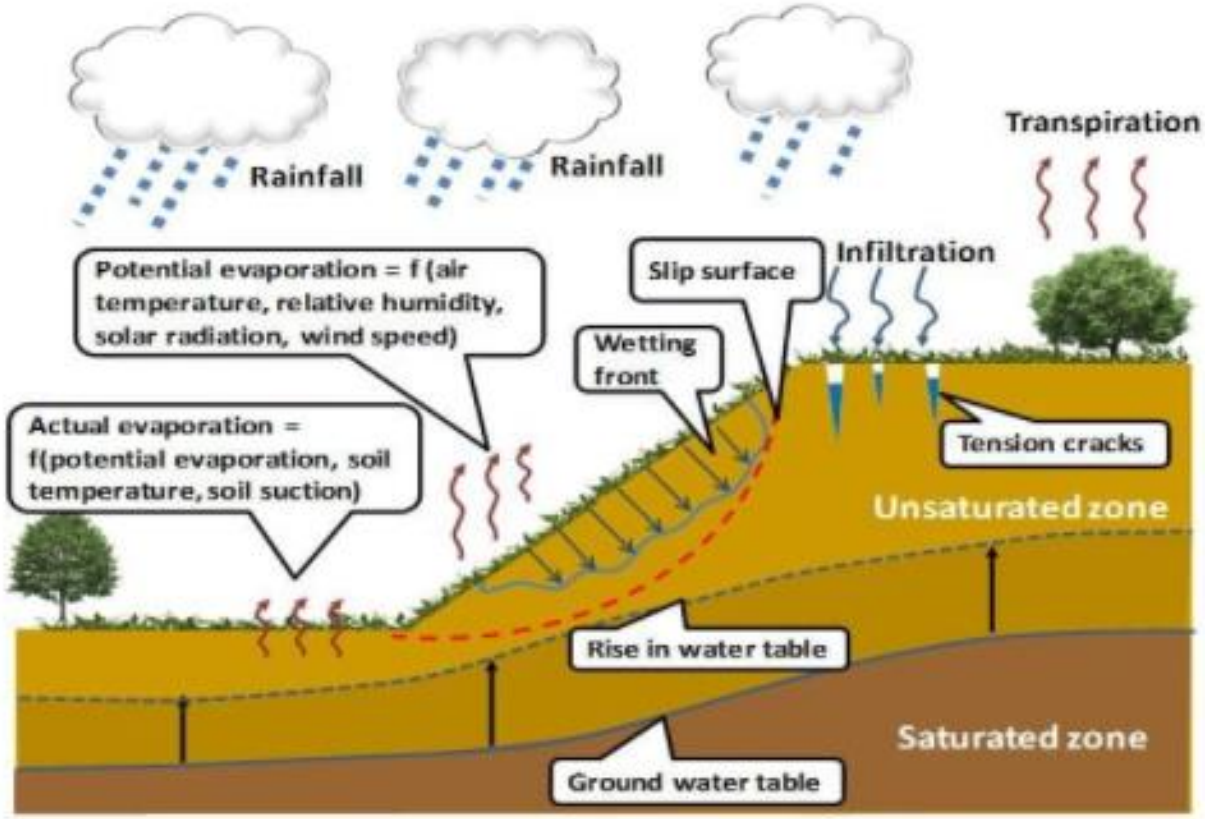
# SLOPE STABILITY

- Saturated soils due to increase in water table height, precipitation or snow melt can result in slope failure
  - Account for seasonal and annual fluctuations in water table in calculations
- Capillary fringe height related to increased sheer strength in the this zone depending on soil type




https://blogs.ntu.edu.sg/usmsul/slope-stability/

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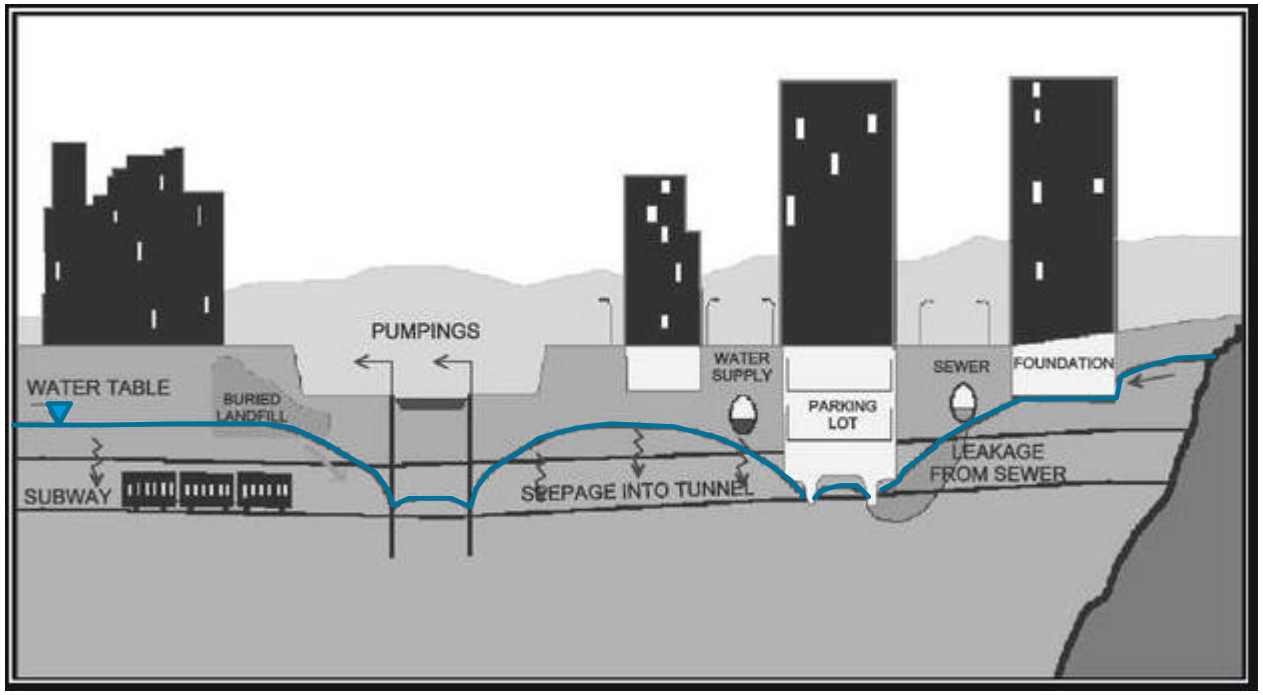
# NEED FOR GROUNDWATER CONTROL FOR SUBSURFACE STRUCTURES

- Underpasses, residential basements, commercial buildings, parkades, sewers etc.
  - Must know the location of the water table and how it fluctuates through time when planning development
  - Sump pumps in most downtown Calgary buildings




Vázquez-Suñé, E., Sánchez-Vila, X. & Carrera, J. Introductory review of specific factors influencing urban groundwater, an emerging branch of hydrogeology, with reference to Barcelona, Spain. *Hydrogeol J* **13,** 522–533 (2005). https://doi.org/10.1007/s10040-004-0360-2

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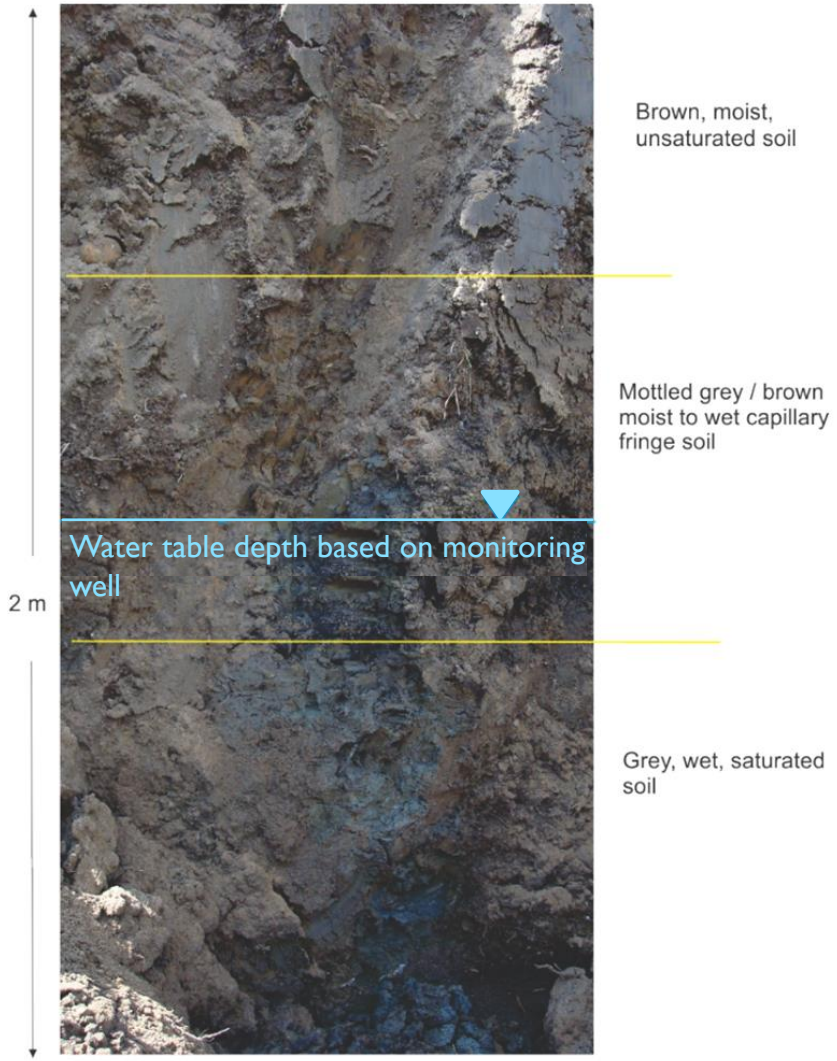
# SEPTIC FIELD EVALUATION

- Treatment of septic field effluents requires oxygen to nitrify ammonia to nitrates

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$$

- Soil below the water table has substantially less oxygen
- Sufficient thickness of unsaturated soil to avoid groundwater/surface water contamination issues

Test pit profile from Calling Lake

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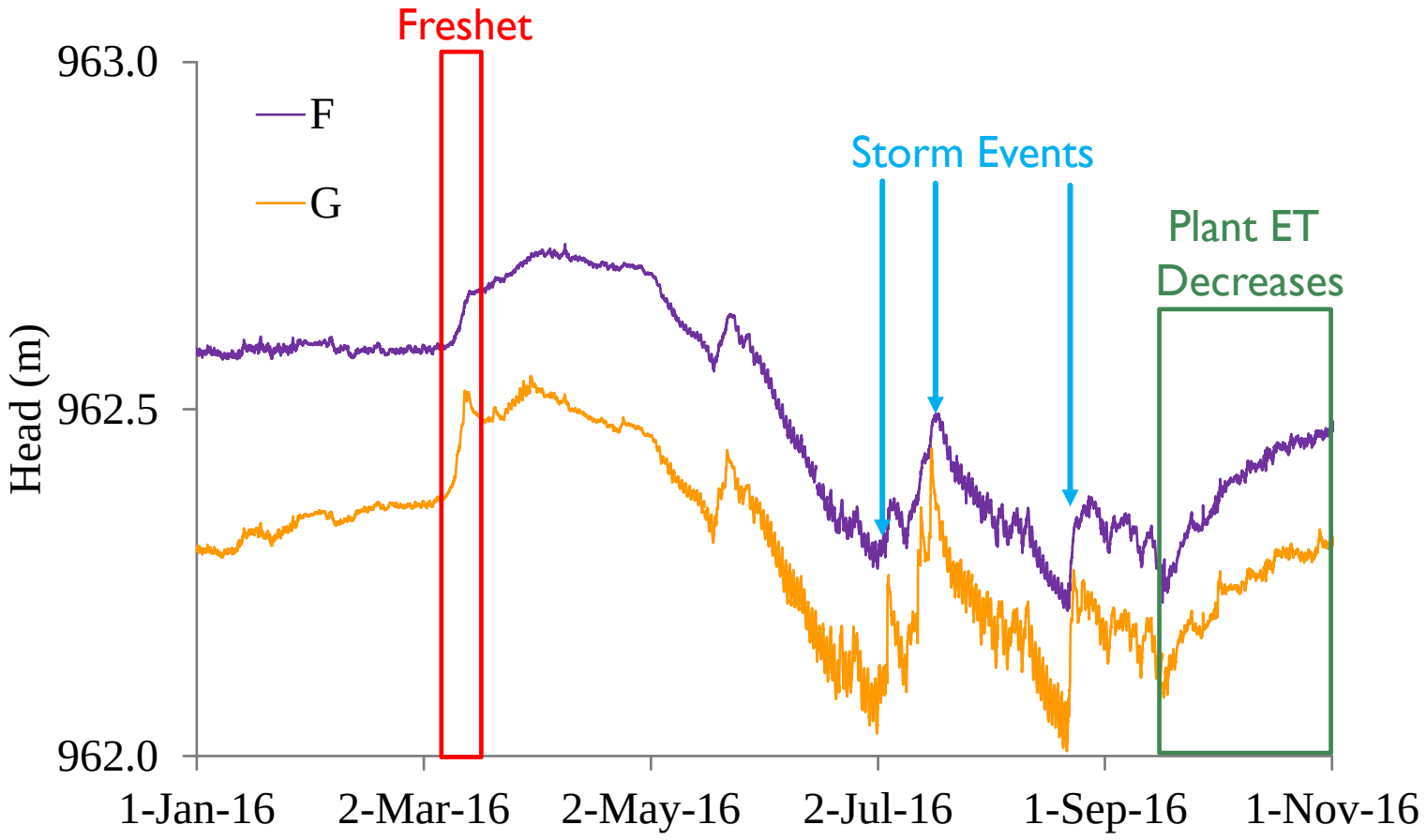
# ACCOUNT FOR SEASONAL WATER TABLE VARIATIONS




- Groundwater levels fluctuate seasonally
  - Spring freshet (snowmelt)
  - Spring/Summer storm events
  - Plant evapotranspiration (ET) decreases in fall as plants go dormant or reduce water uptake
- Wet years vs dry years
  - Number of chinooks (volume of snow accumulation)

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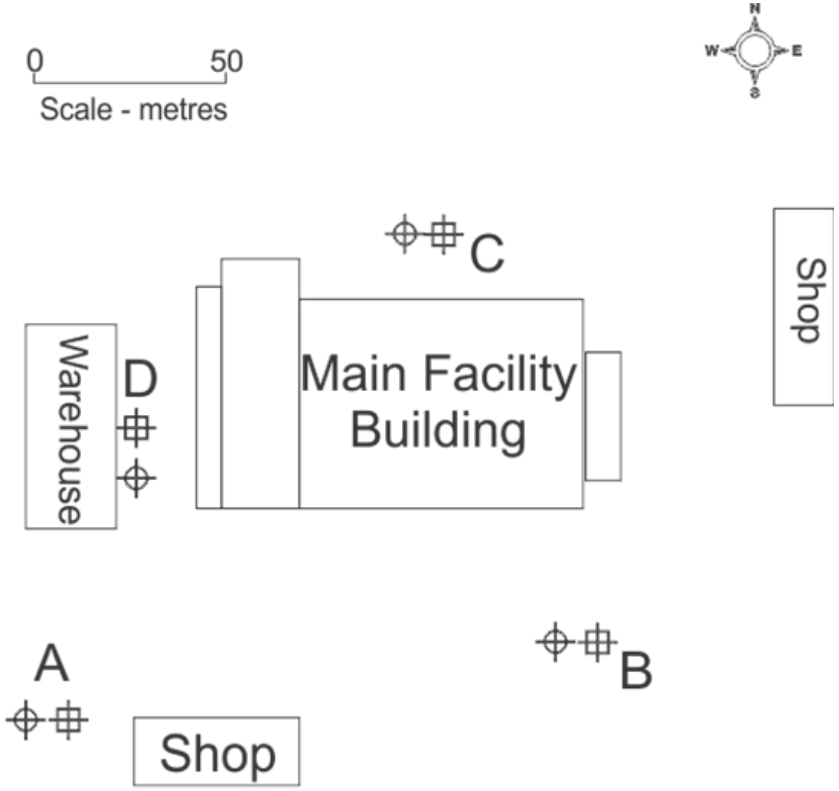
# EFFECT OF LARGE SCREENED INTERVAL ON WATER LEVEL MEASUREMENTS - EXAMPLE




**2020 Water Level Measurements**

| Location | Deep Geotech Well | | Shallow Groundwater Well | |
|---|---|---|---|---|
| | Well Depth (m) | Depth to Water (m) | Well Depth (m) | Depth to Water (m) |
| A | 8.8 | 4.15 | 2 | 0.81 |
| B | 8.7 | 0.55 | 1.5 | 0.40 |
| C | 7.6 | 0.53 | 2 | 0.53 |
| D | 8.8 | 2.38 | 2.2 | 0.77 |

- Highly variable water level measurements in deep wells with long screened interval
- Consistent water level measurements with shallow wells screened across the water table

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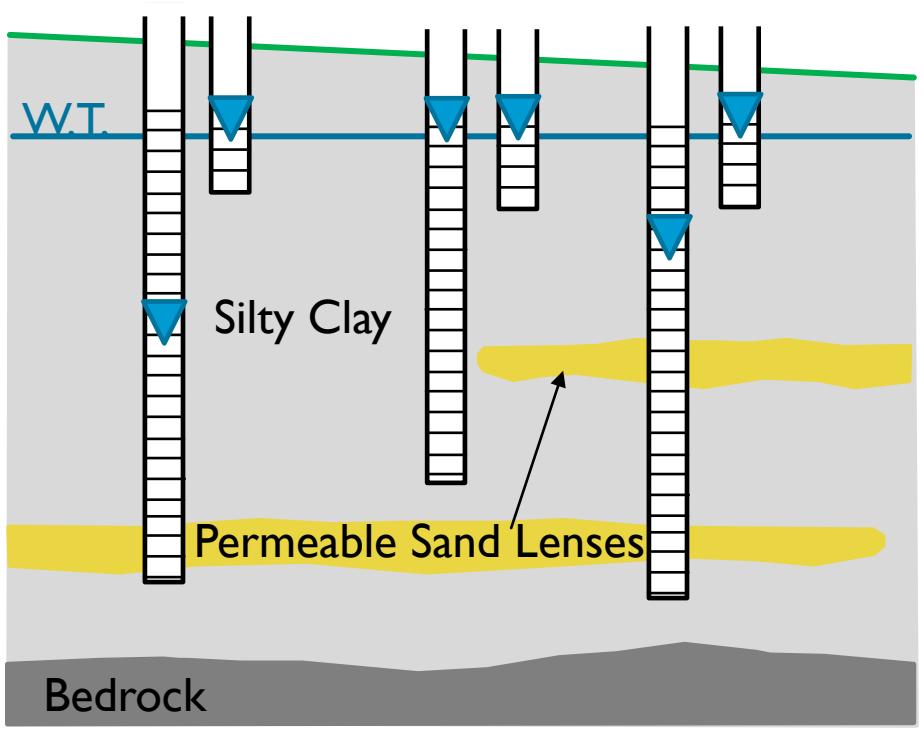


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- Deeper wells are screened over multiple permeable zones
- Should use short screens and careful examination of soil while drilling to ensure accurate water table measurements

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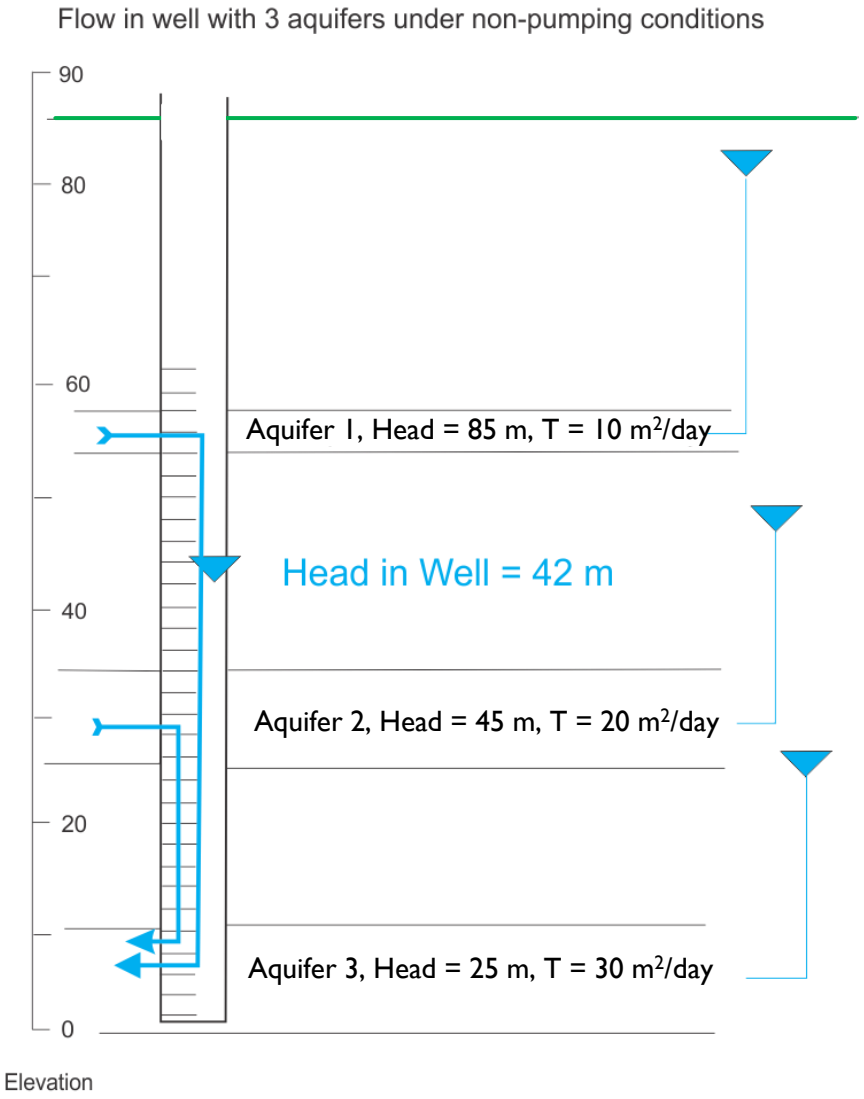
# EFFECT OF LARGE SCREENED INTERVAL ON WATER LEVEL MEASUREMENTS




$$\text{Head in Well} = \frac{(T1 \times H1) + (T2 \times H2) + (T3 \times H3) + \ldots.}{T1 + T2 + T3 + \ldots..}$$

- Resulting water level in the monitoring well is a weighted average of the head in the three aquifers over which the well is completed across
- Can induce groundwater flow between aquifers

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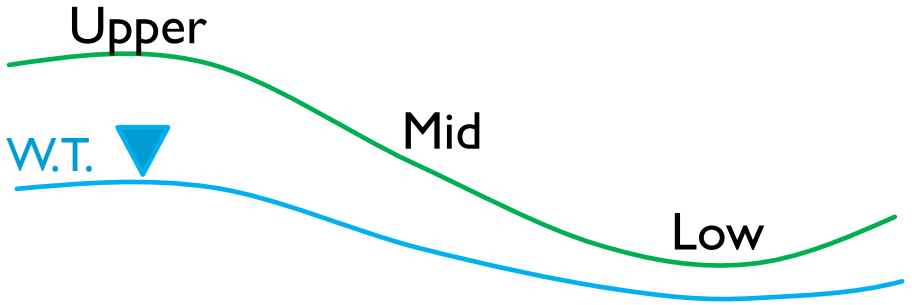
# METHODS OF DETERMINING THE WATER TABLE

# USING SURFACE CONDITIONS

- Topographic position of the site
  - Water table is a subdued replica of the topography

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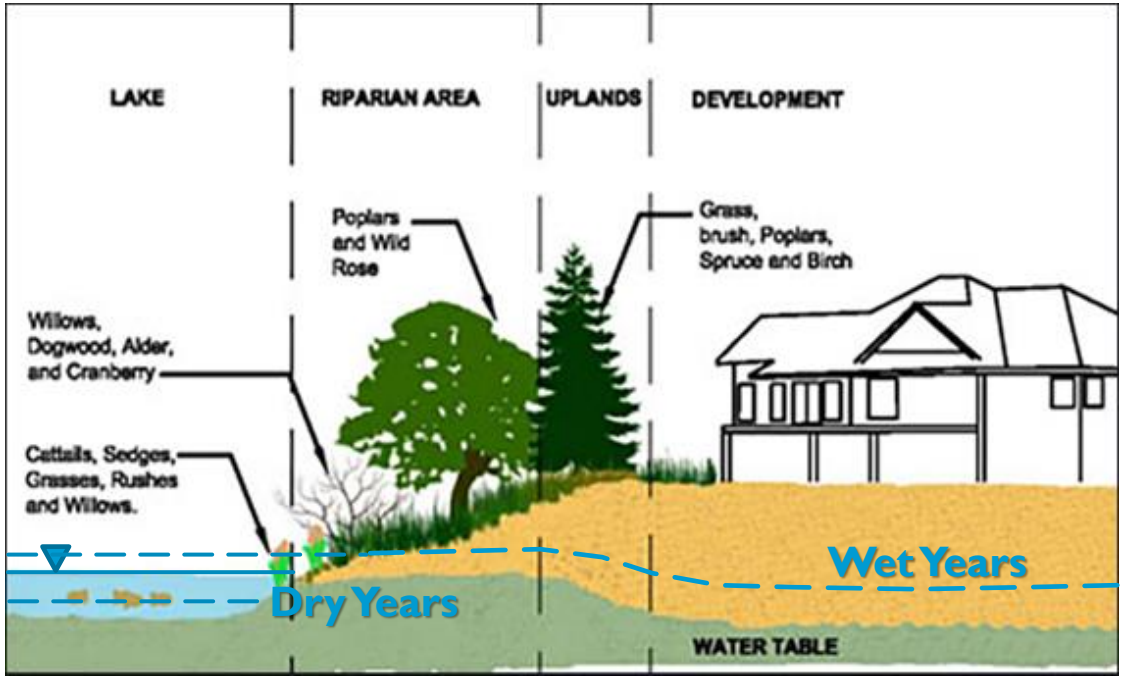
# USING SURFACE CONDITIONS

- Topographic position of the site
  - Water table is a subdued replica of the topography
- Relation to nearby surface water bodies (rivers, lakes, wetlands etc.)




https://www.strathcona.ca/agriculture-environment/environment-and-conservation/environmental-initiatives/lake/

https://www.ecofriendlysask.ca/2014/05/protecting-and-constructing-urban.html

http://www.wetlands-initiative.org/growing-wetlands-for-clean-water

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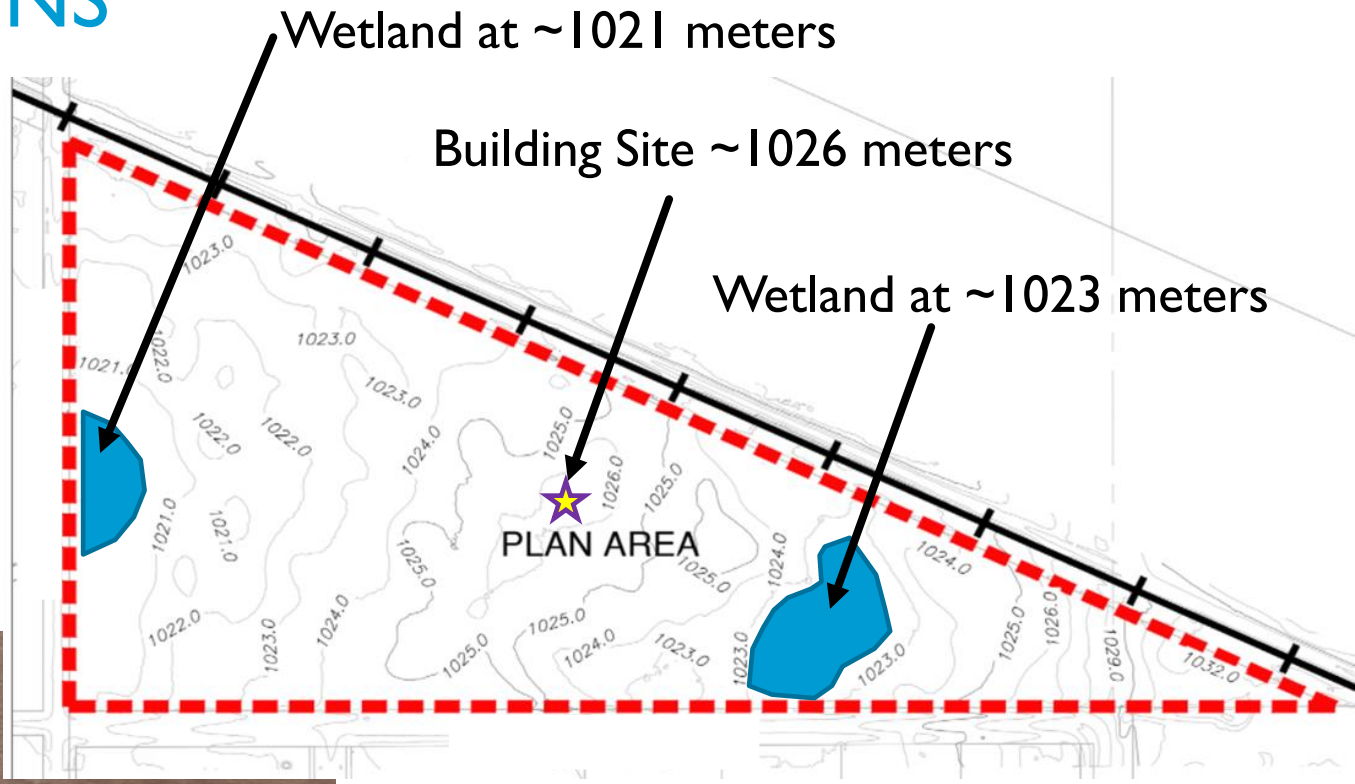
# USING SURFACE CONDITIONS

- Topographic position of the site
  - Water table is a subdued replica of the topography
- Relation to nearby surface water bodies (rivers, lakes, wetlands etc.)
- Surface contour maps
- Aerial photos

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# USING VEGETATION AS INDICATORS

- Presence of water adapted vegetation



- Sedges, tall manna grass, slough grass

(temporary to seasonal marsh wetlands – water table below the surface)



- Cattails and rushes

(semi-permanent to permanent marsh wetlands – water table at or above surface)

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# USING VEGETATION AS INDICATORS

- Presence of water adapted vegetation




- Treed Swamps
  - Balsam poplar, white spruce, black spruce, birch, willow, dogwood, horsetail, stinging nettle, raspberry

(water table at or generally just below the surface; presence of organic soils)

- Shrubby swamps
  - Willow spp, dogwood, stinging nettle, mint, sedges

(water table at or generally just below the surface; presence of organic soils)



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# SOIL INSPECTION (DRILLING & TEST PITS)

- Soil color (mottling, gleying)
- Change in soil stiffness (plastic)
- Precipitates, anhydrite/evaporites


https://www.soils.org/about-soils/basics/

http://nesoil.com/images/redox.htm

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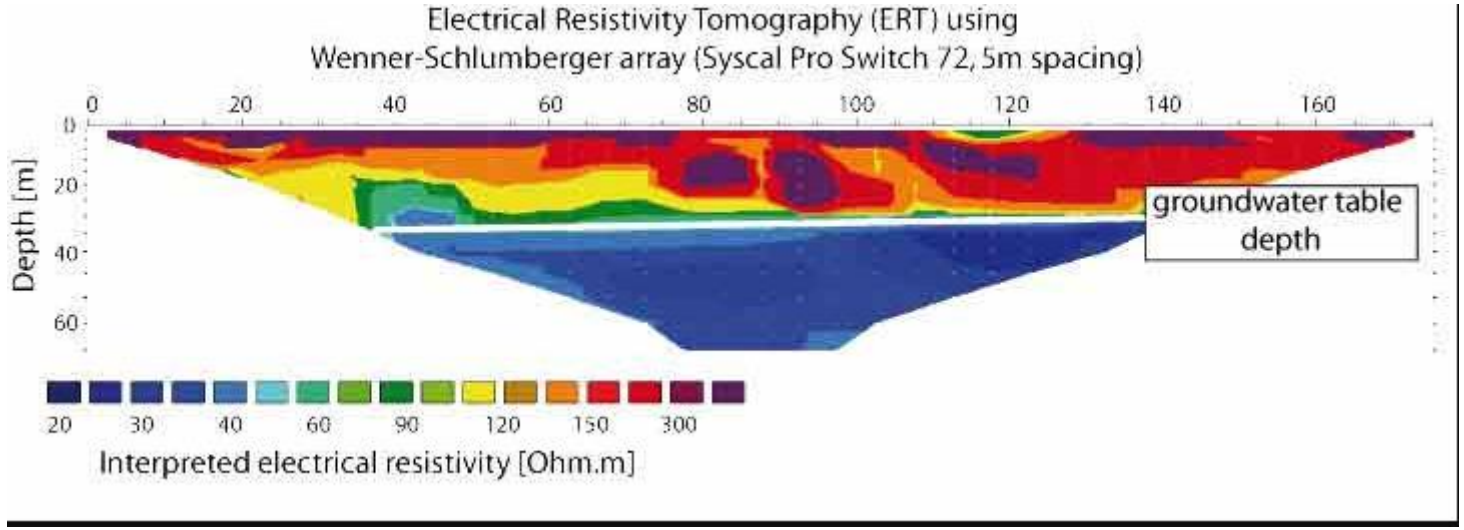
# GEOPHYSICAL METHODS FOR DETECTING THE WATER TABLE




Koch et al. 2009. *Joint interpretation of hydrological and geophysical data: electrical resistivity tomography results from a process hydrological research sit in the Black Forest Mountains, Germany.* Hydrological Processes, 23(10). 1501-1513

- Electrical Resistivity Tomography (ERI) can be used to locate the water table over large areas
  - If water table varies laterally
  - LNAPL contaminant investigations
  - Best for coarse grained soils (waste rock, gravel, some sands)

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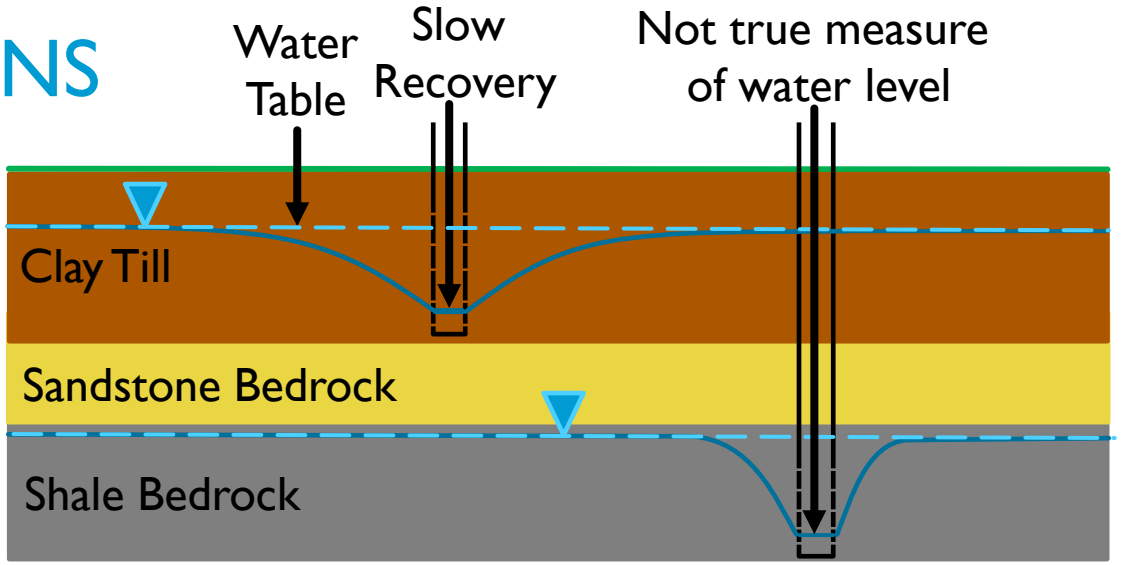
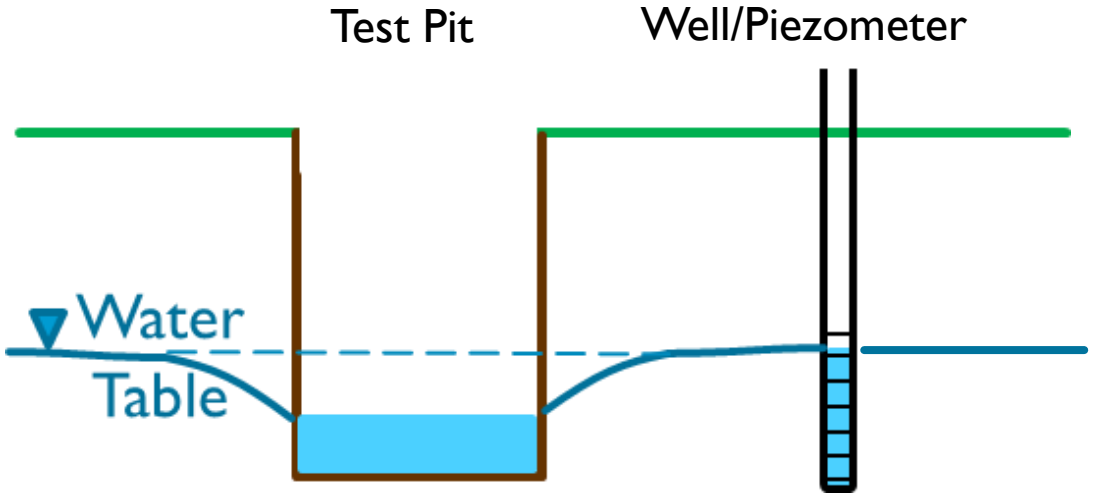
# RECOVERY TIME CONSIDERATIONS

- Low permeability soils or bedrock
  - Recovery time of weeks, months, even years
  - Hydraulic conductivity tests




- Larger excavations take longer to fill with water
  - Septic field test pits
  - Installing small diameter piezometer

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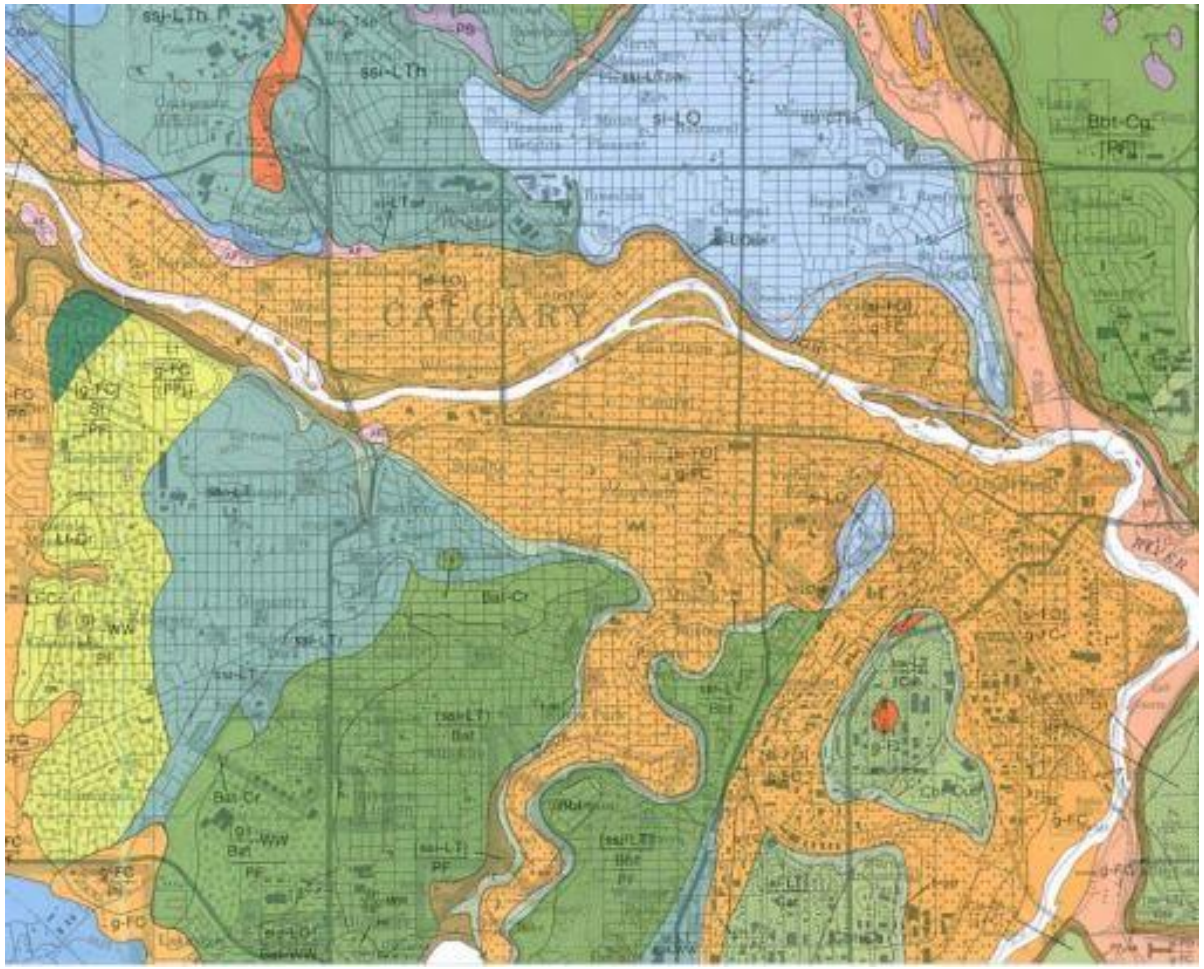
# EXAMPLE OF RELATIONSHIP BETWEEN GEOLOGY, THE WATER TABLE AND RIVER LEVELS




- Orange indicates the extent of surficial gravels
  - Expect a good correlation between the Bow River water levels and groundwater levels in the adjacent gravel

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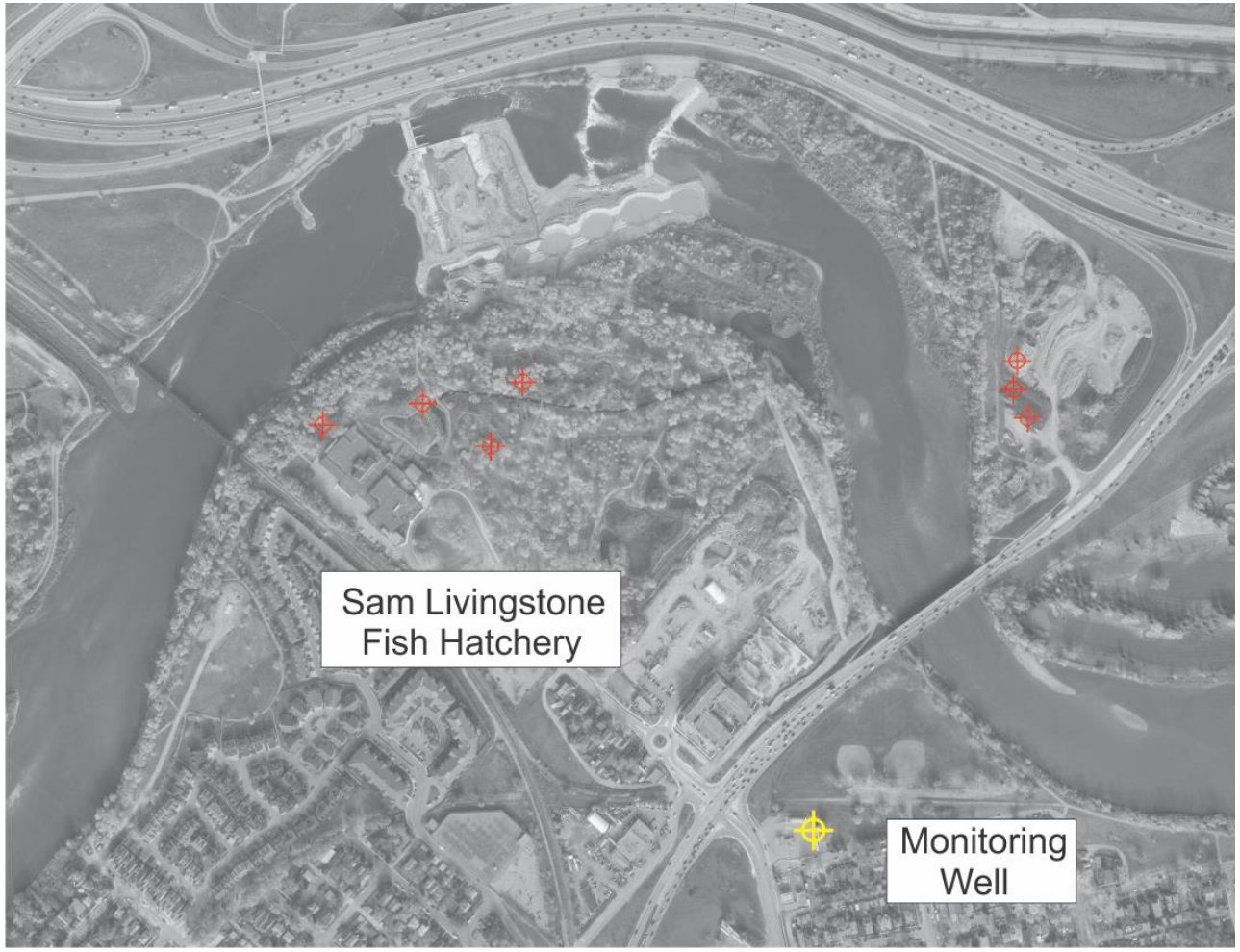
# MONITORING WELL LOCATIONS




- Air photo of Calgary area downstream of downtown
- Hatchery supply wells (in red) depend on Bow River water levels

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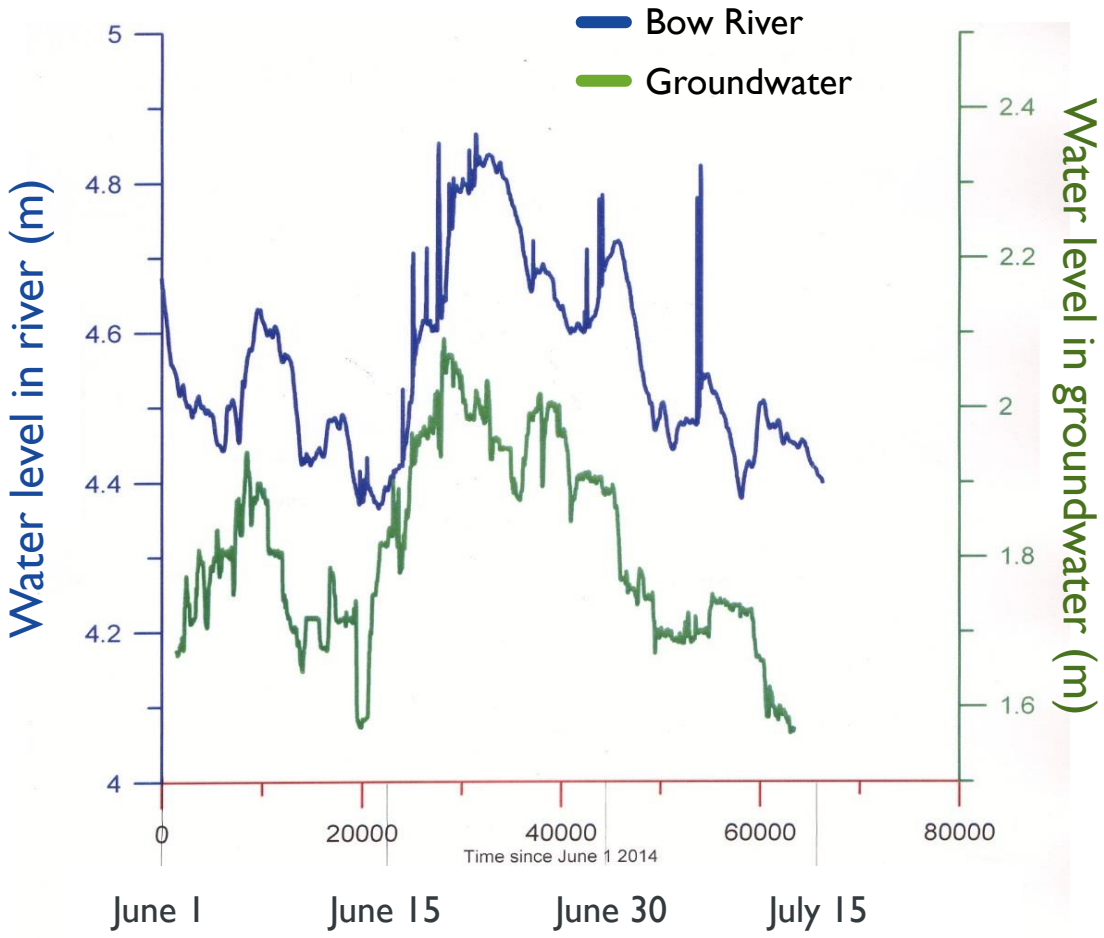
# WATER LEVELS IN BOW RIVER AND MONITORING WELL (SUMMER 2014)




- Monitoring well located 280 m away from Bow River
- Groundwater level rise in well is about 75% of river level rise
- Time lag is one day or less

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