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# Integrated Surface Water and Groundwater Modelling for Oil Sands Reclamation

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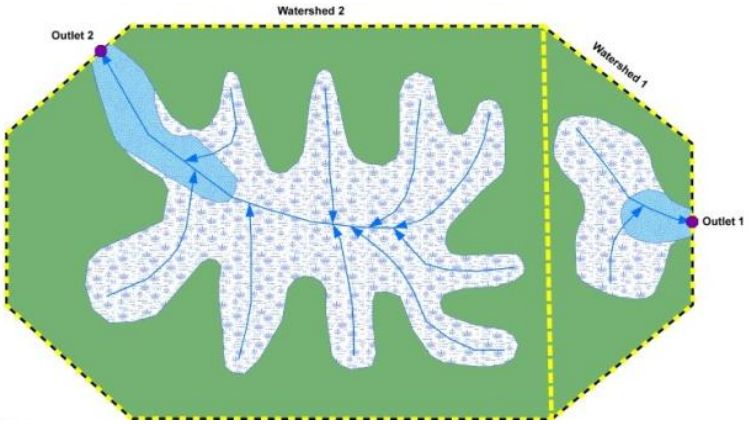


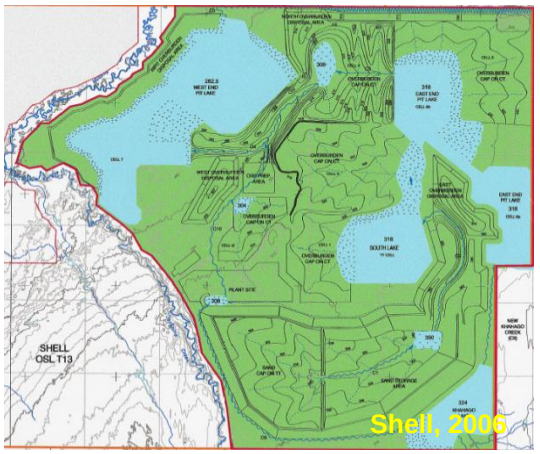


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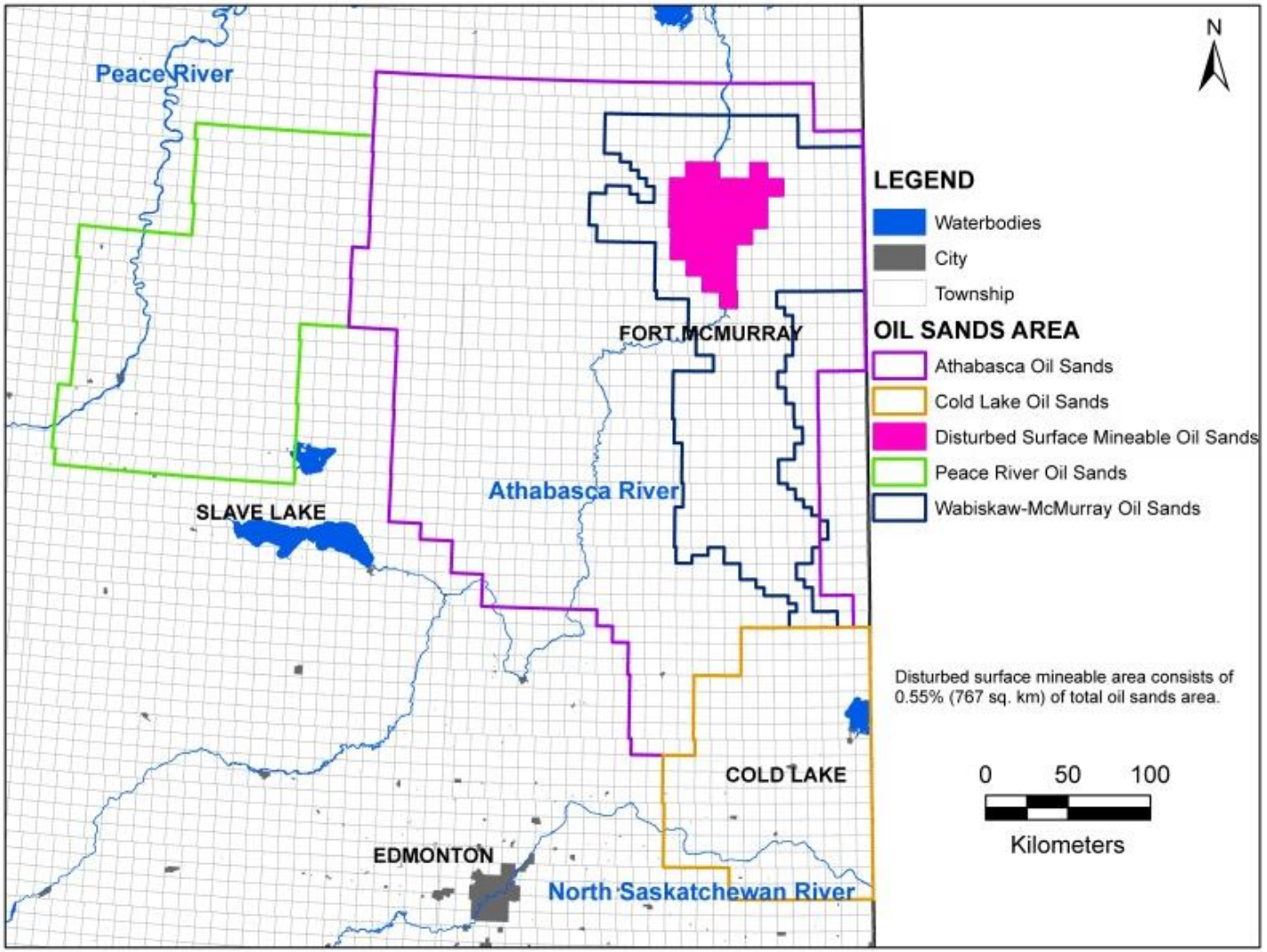
# Alberta Oil Sands




(AER, 2014)

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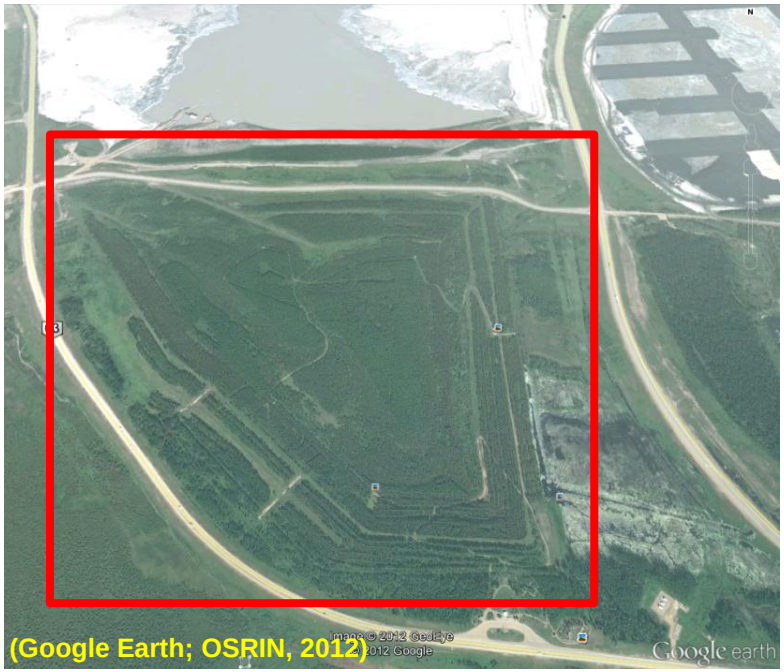
# Surface Mining

- Approximately 750 sq. km area disturbed (AER, 2014)
- Disturbances: forest clearing, muskeg and soil displacement, modifications to wildlife habitat, soil and water contamination, etc.
- Results into in-pit (mine pits) and out of pit features (tailings ponds, overburden dumps, landfills and coke cells)

# Objective of Reclamation

1(e) “equivalent land capability” means that the ability of the land to support various land uses after conservation and reclamation is similar to the ability that existed prior to an activity being conducted on the land, but that the individual land uses will not necessarily be identical (EPEA 115/1993)

(Google Earth; OSRIN, 2012)



(Google Earth; OSRIN, 2012)

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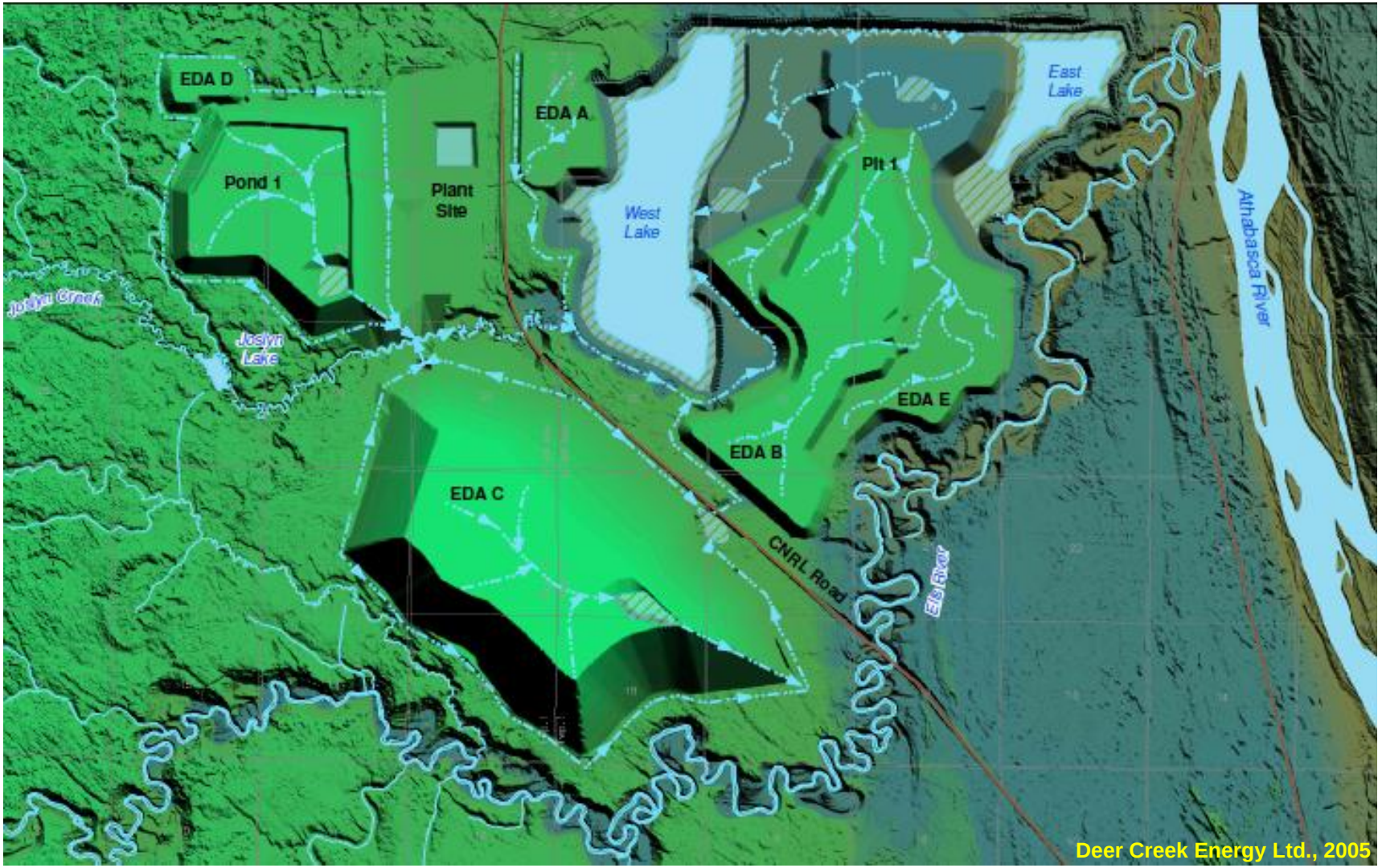
# Closure Landscape

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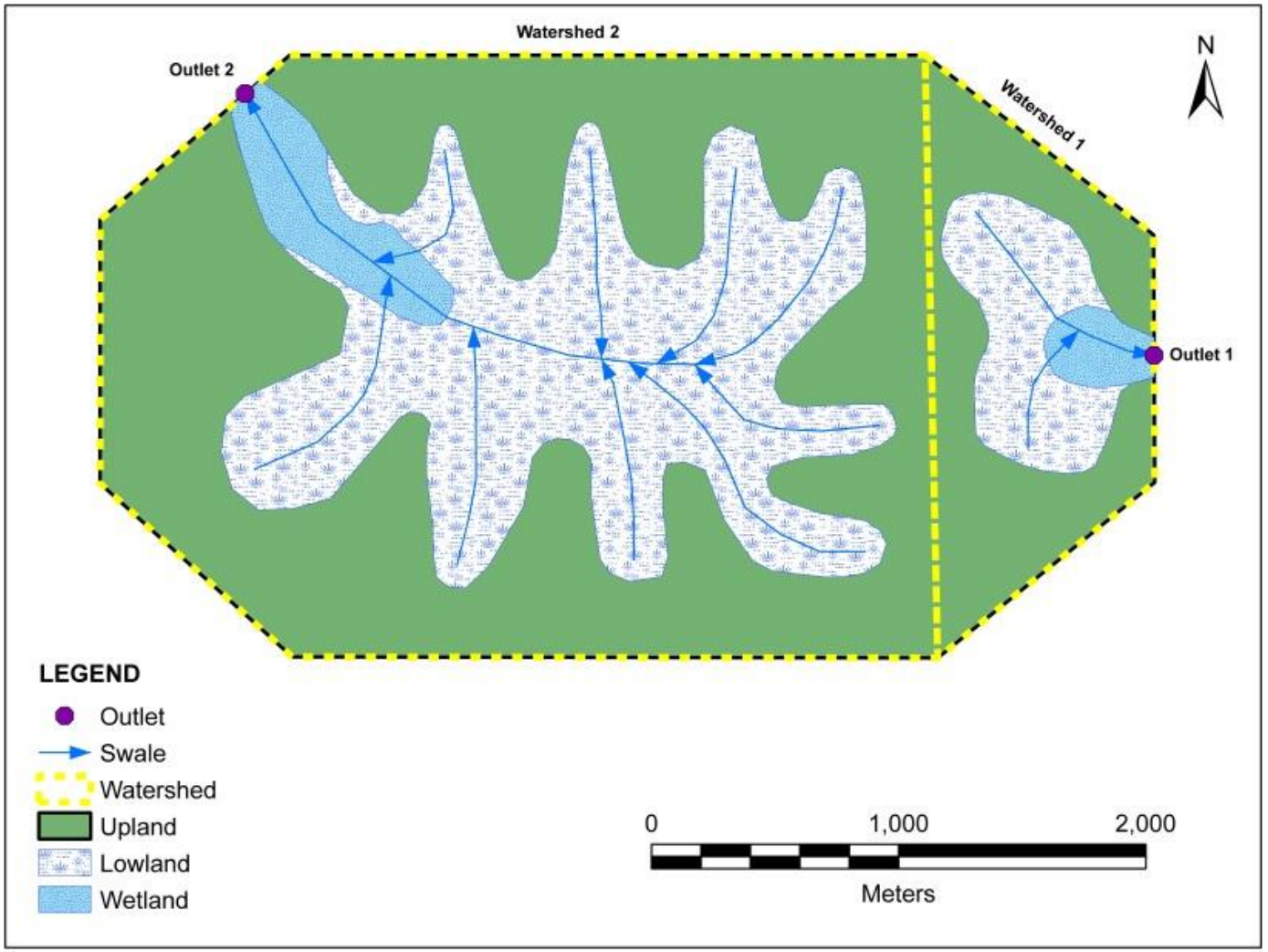
# Reclamation Design

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# Reclamation Design

- Geotechnical criteria: hummock slopes, erosion control, groundwater seepage;
- Dam safety criteria: hummock height, erosion control;
- Hydrotechnical design criteria: extreme precipitation events;
- Material balance: capping material, cover soil;
- Environmental performance: water quality, successful re-vegetation.

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# Environmental Performance: Evaluation Criteria

- Favourable water balance to maximize outflow under wet, average and dry climate cycles;
- A shallow subsurface flow system to limit the depth of flushing to improve water quality reporting to end pit lakes;
- Favourable depth to groundwater table in the uplands that limits potential for upward migration of salinity during dry climate cycles.

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# Environmental Performance: Key Considerations

- Boreal forests are water deficit regions – evapotranspiration (ET) exceeds precipitation;
- Water quality is governed by groundwater discharge;
- Water movement is governed by overland flow;
- Coupling occurs through ET due to water deficit conditions;
- Ground freezing and thawing could play a significant role in water balance and quality.

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# Integrated Models

- Overland and subsurface flow and transport including unsaturated zone;
- Appropriate representation of unsaturated zone – coupling in water deficit areas is through ET;
- Accurate calculation of ET;
- Ground freezing and thawing processes.

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# HYPOTHETICAL CASE STUDY

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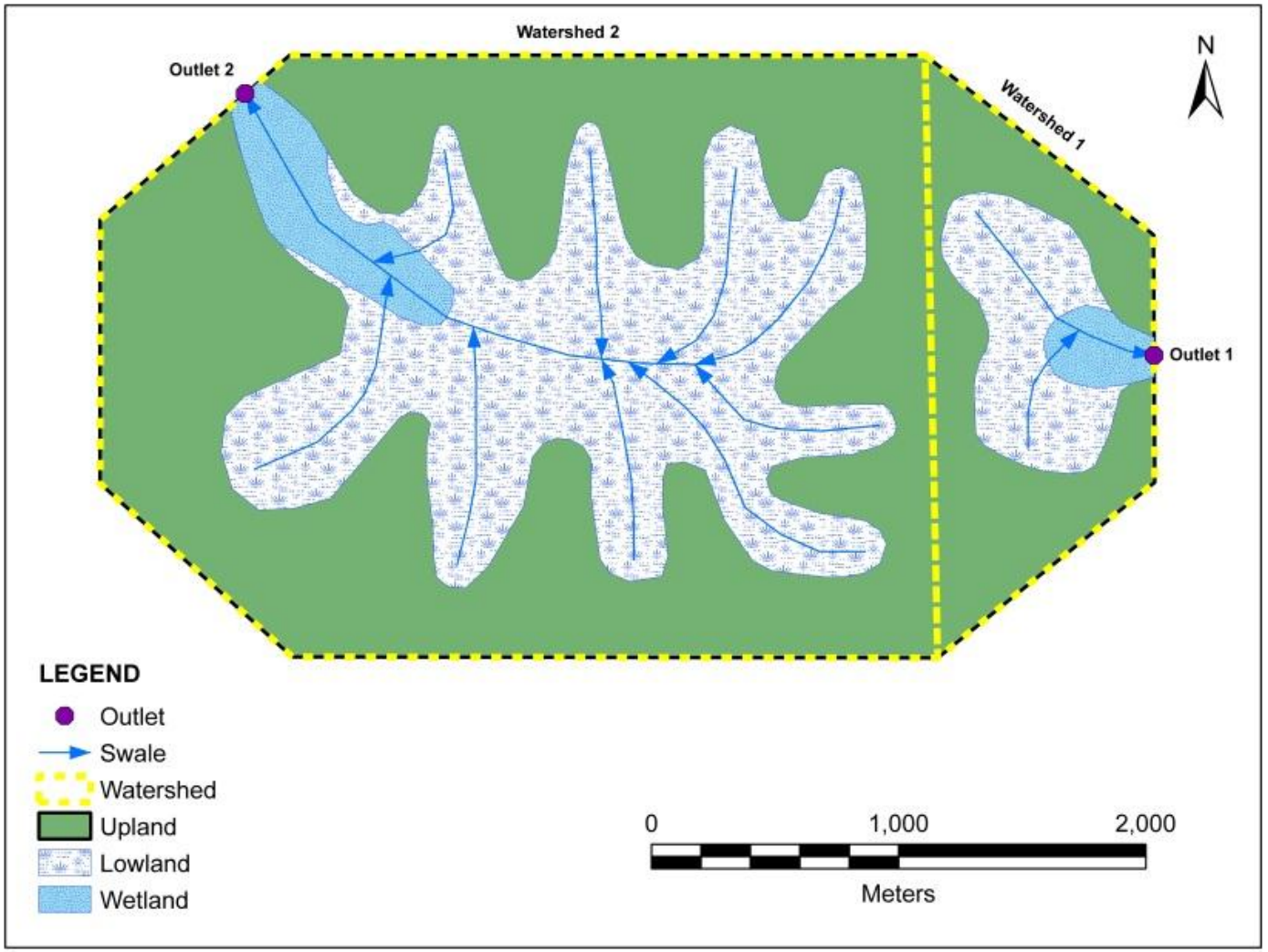
# Landscape Conceptualization

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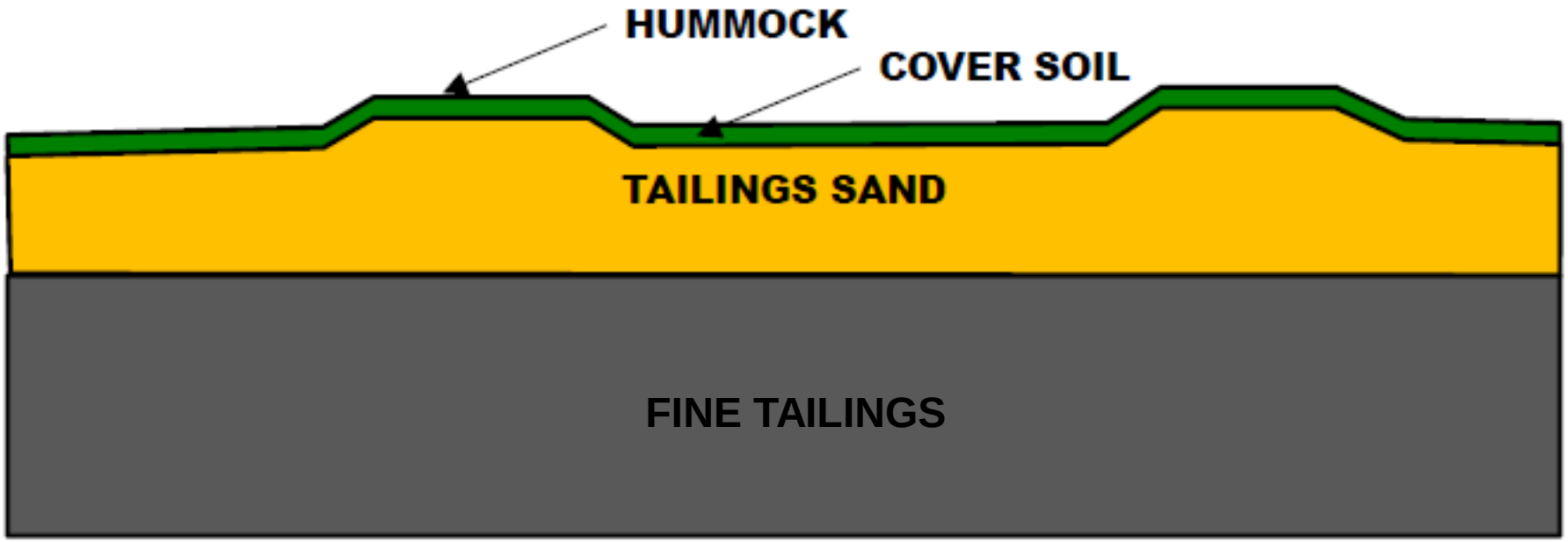
# Model Layering

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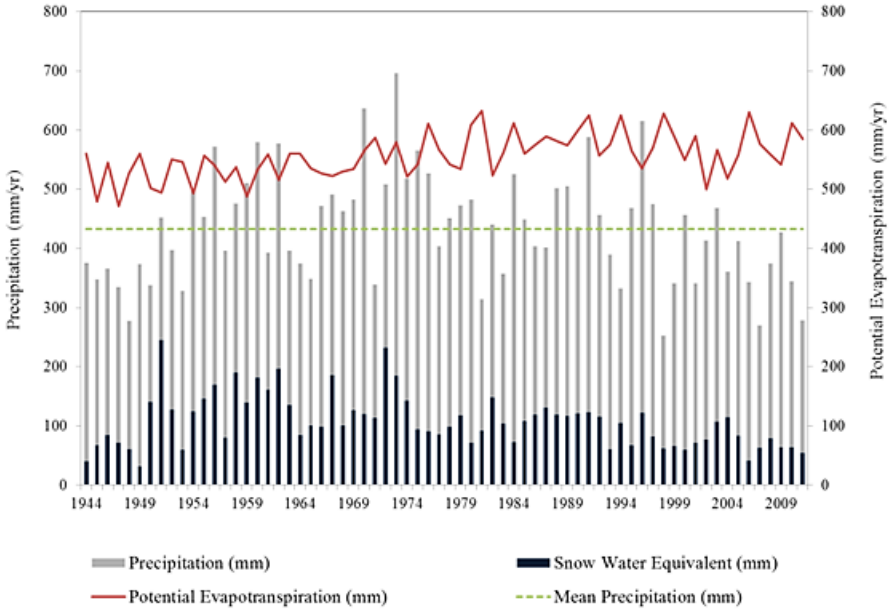
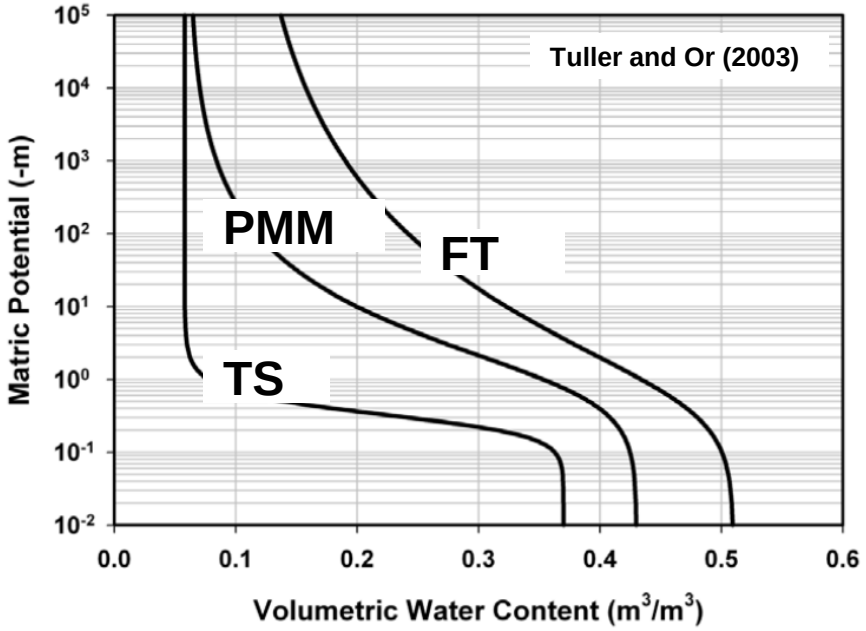
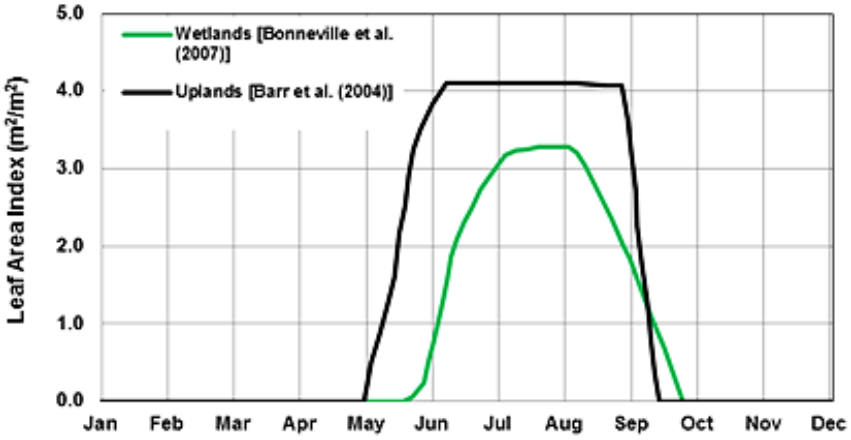
# Model Parameterization




PMM – Cover Soil
TS – Tailings Sand
FT – Fine Tailings

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# Environmental Performance Evaluation Criteria

- Favourable water balance to maximize outflow under wet, average and dry climate cycles;
- A shallow subsurface flow system to limit the depth of flushing to improve water quality reporting to end pit lakes;
- Favorable depth to groundwater table in the uplands that limits potential for upward migration of salinity during dry climate cycles.

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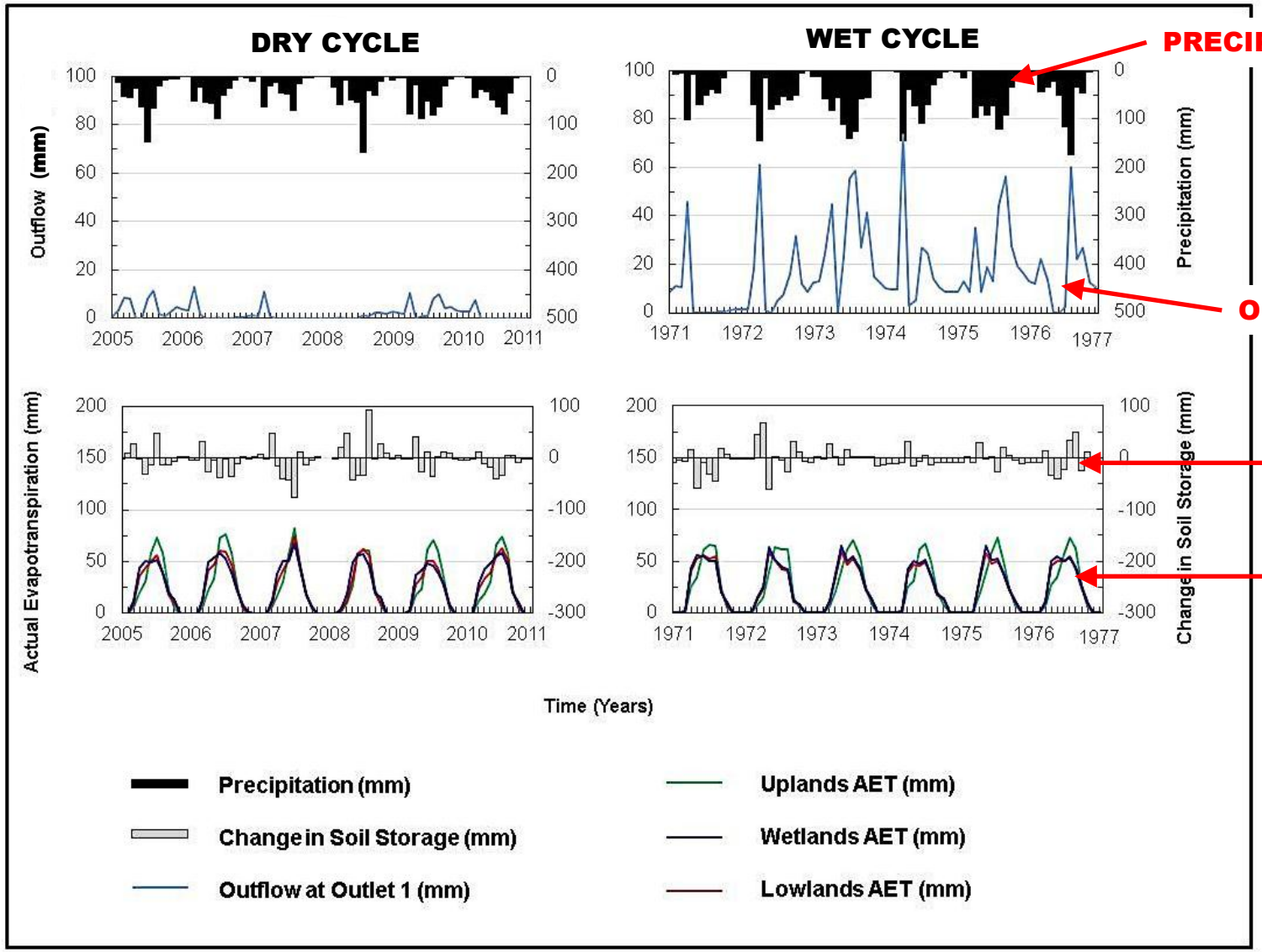
# Results: Water Balance

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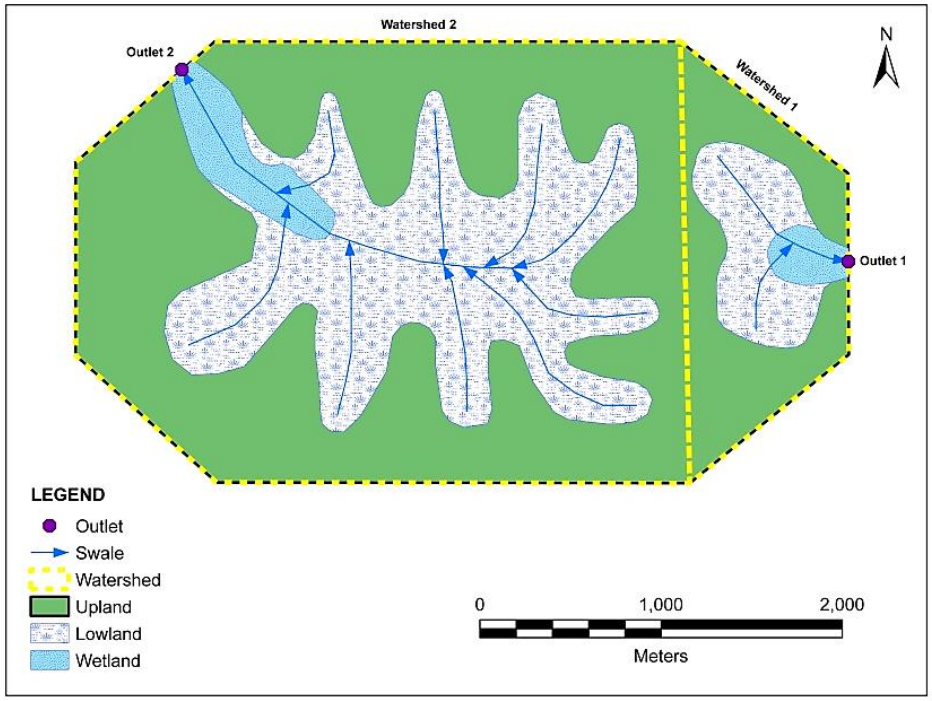
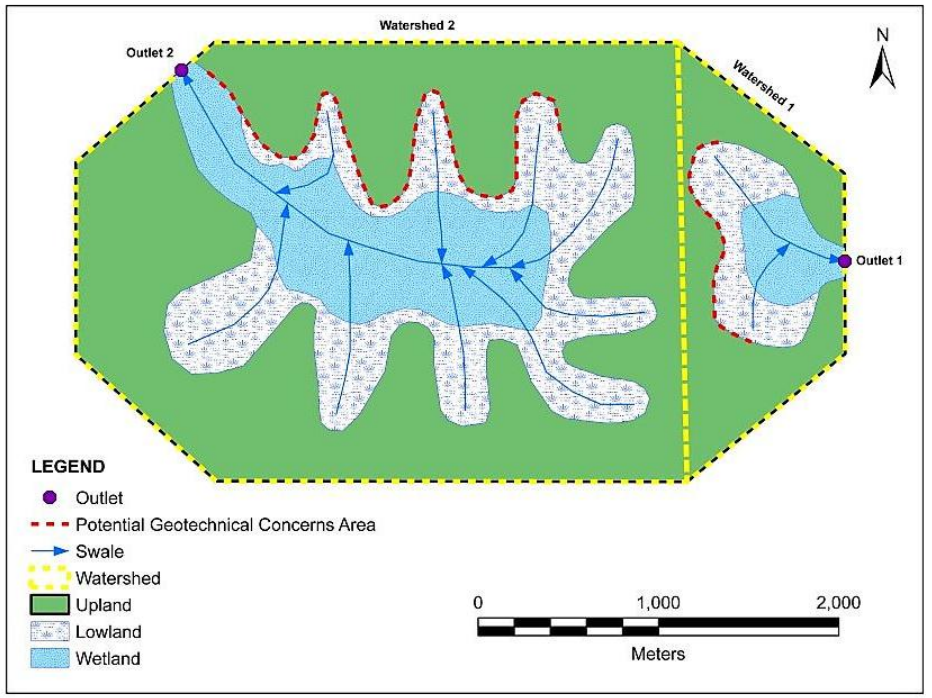
# Results: Landscape Delineation




**Initial Assumption**

**Model Results**

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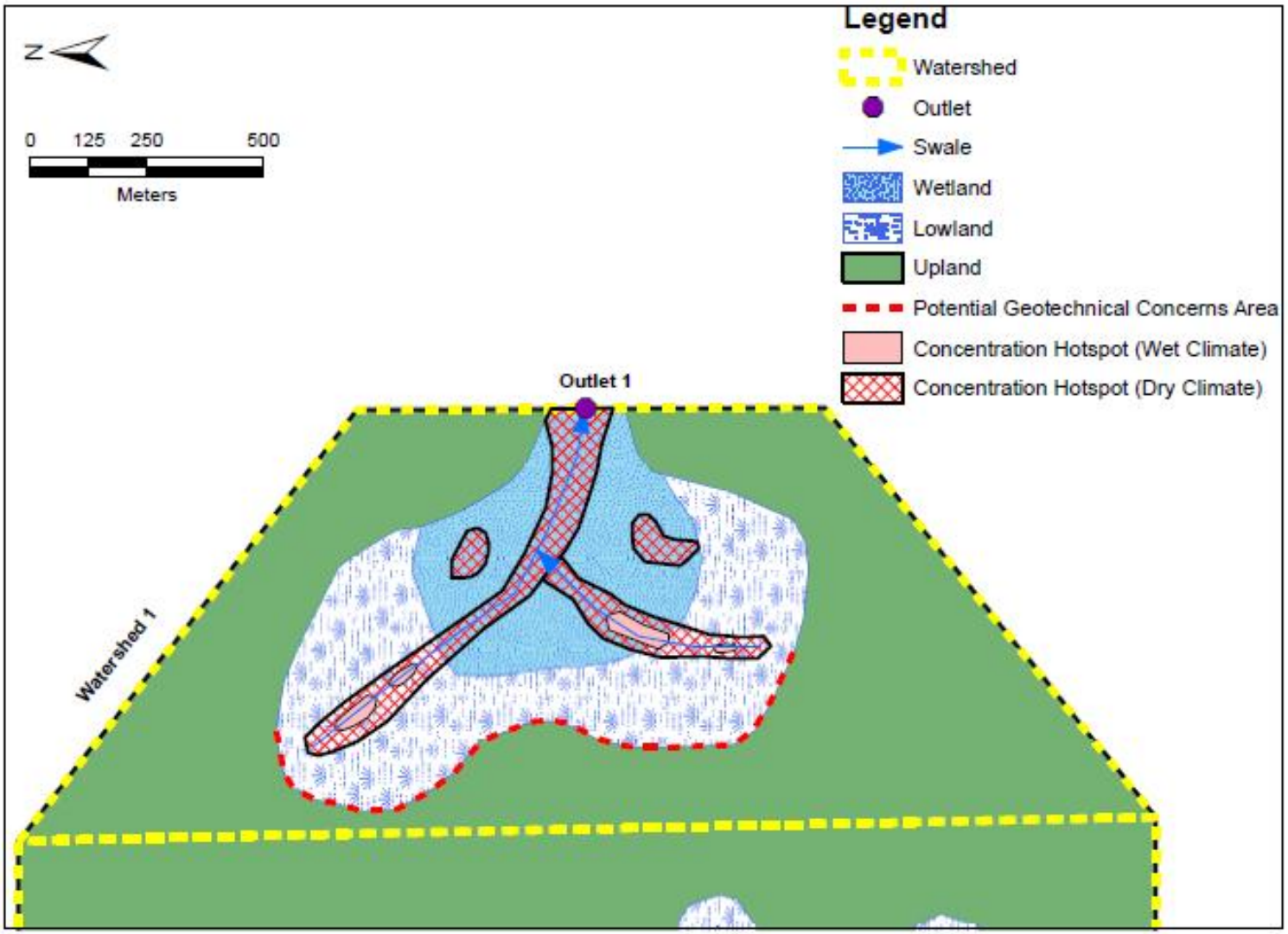
# Solute Transport Results

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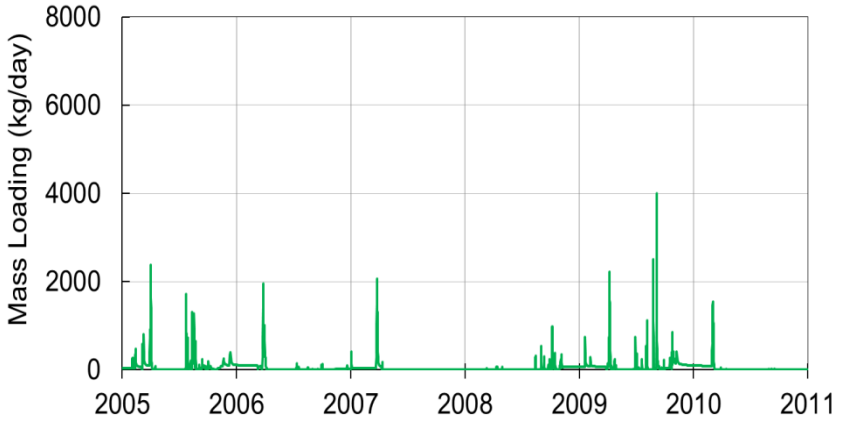
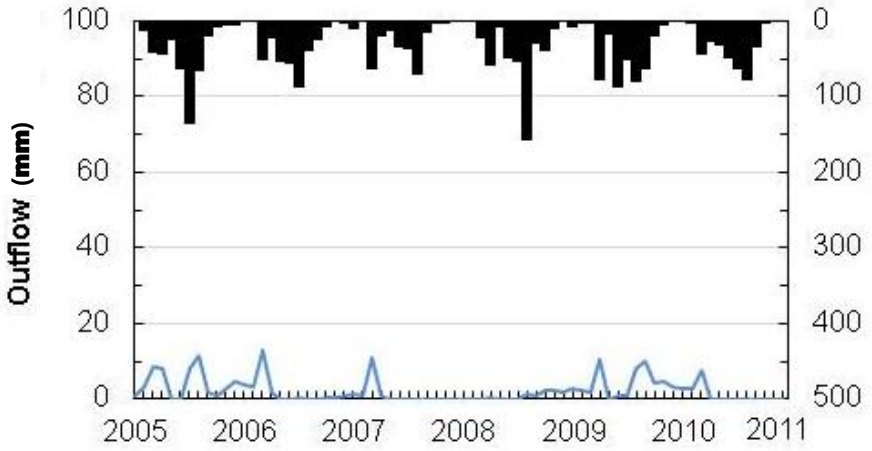
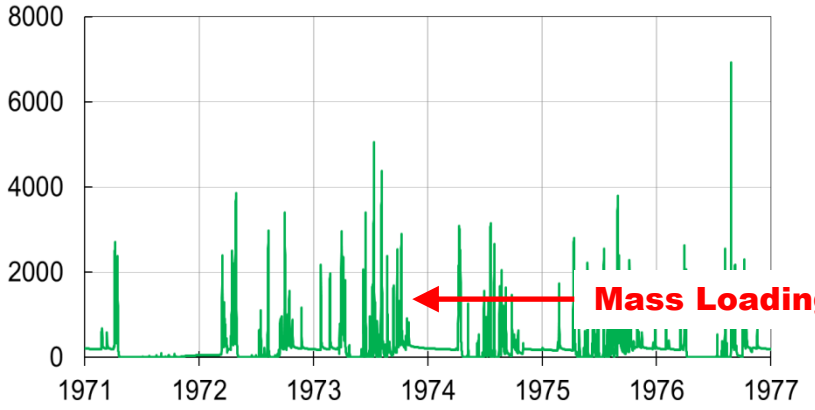
# Solute Transport Results

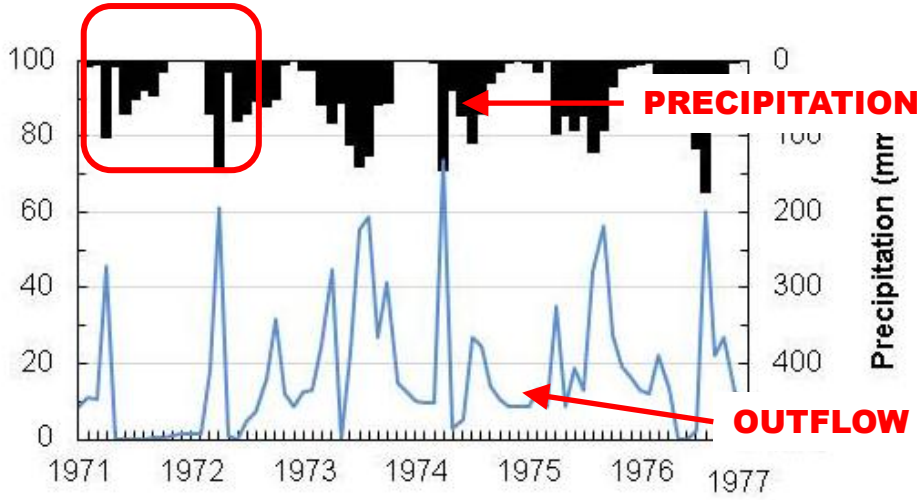
## DRY CYCLE




## WET CYCLE

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# Summary

- Water quality will be one of the most important criteria for successful closure of reclaimed oil sands leases;
- ET plays a significant role as a mode of water outflow and coupling in Boreal settings;
- Integrated models are powerful tools for landscape performance evaluation;
- Case study highlights important aspects of environmental performance evaluation of conceptual reclamation designs.

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