Hydrology and Hydrogeology Assessments of Boat Harbour, Nova Scotia

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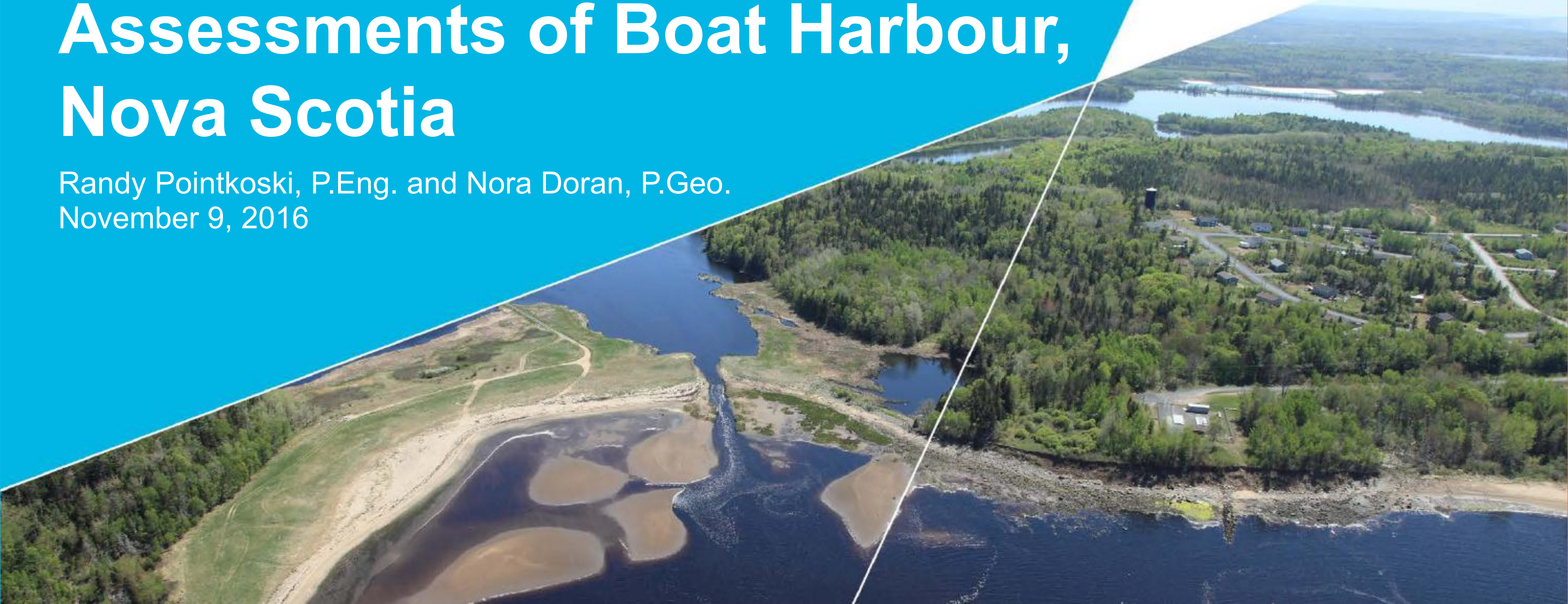

Overview

– Introduction

– Hydrology of Boat Harbour
  - Model Approach
  - Model Predictions
    - Remediation Project

– Hydrogeology of Boat Harbour
  - Conceptual Model
  - Model Approach
  - Model Predictions
    - Remediation Project
    - Interaction with Pictou Landing Water Supply Wells

– Implications and Applications for Remediation

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Introduction

– Nova Scotia Lands Inc. retained AECOM for 2 separate contracts to assist in the planning process for the remediation project:
  - Hydrology Assessment (July 2015)
  - Hydrogeology Assessment (September 2015)

NSLands
nova scotia lands

– AECOM team involved local staff from Halifax and Sydney offices with subject matter experts from London and Guelph
  - AECOM's field work was supported by a local staff member from Pictou Landing

– AECOM completed plain language reports and provided presentations on these projects to the local Pictou Landing First Nation Community

Introduction (continued)

– AECOM's hydrology group led by Christopher Moon, P.Eng., developed a hydrologic model (PCSWMM) to understand surface water function under varying climatic conditions, with objectives to:
  - Determine catchment characteristics;
  - Develop hydrologic / hydraulic models; and
  - Review water management opportunities and constraints for the remediation project.

Chris Moon, AECOM

– AECOM's hydrogeology group led by modeller Miln Harvey, P.Eng. Ph.D, developed a groundwater model (MODFLOW-NWT) to understand:
  - Groundwater discharge to the harbour;
  - Groundwater flows around the Boat Harbour Treatment Facility; and
  - Potential interaction with the Pictou Landing First Nation water supply wells.

Miln Harvey, AECOM

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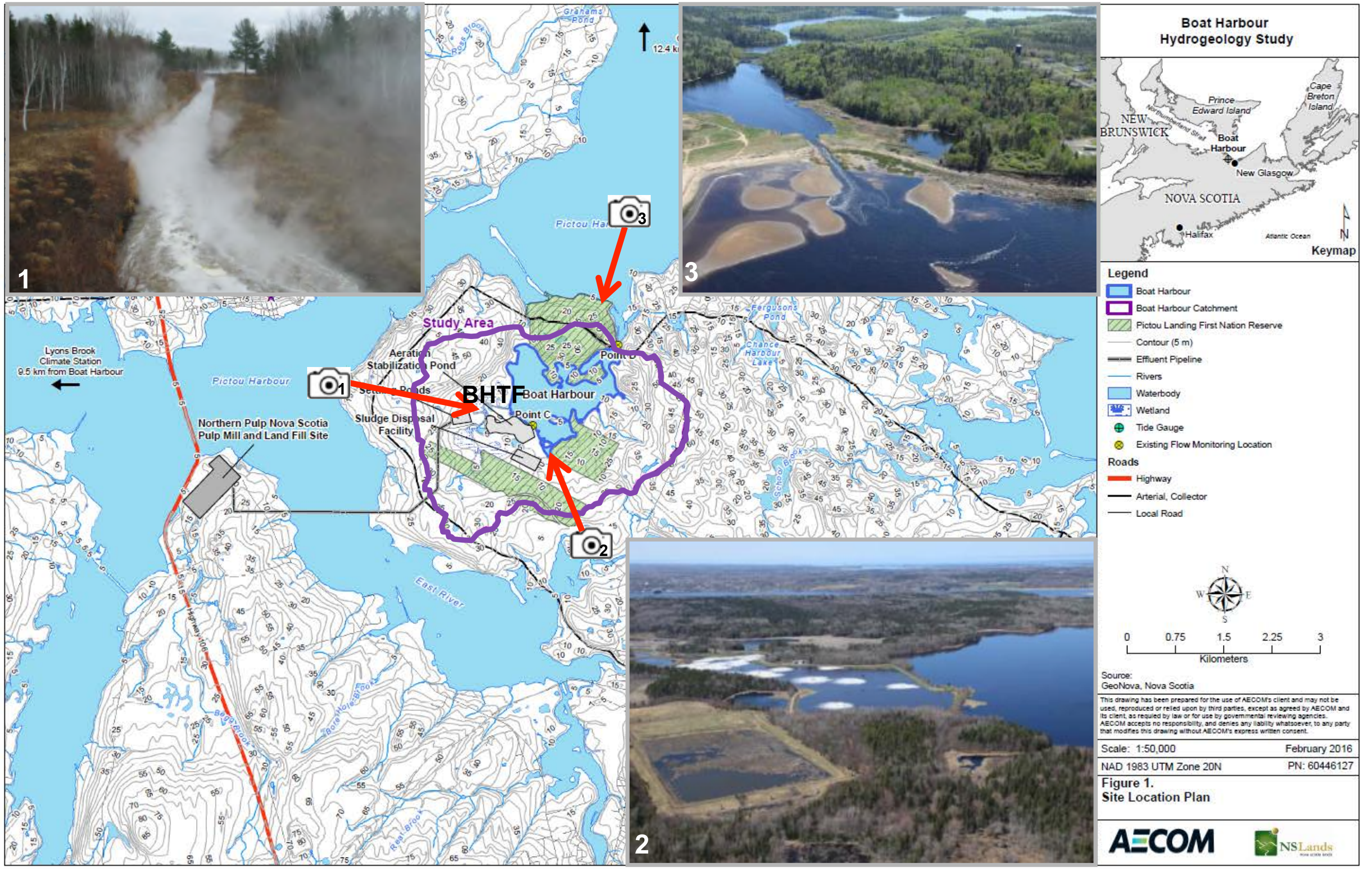
Boat Harbour Treatment Facility (BHTF)



- Effluent from kraft pulp mill directed to settling ponds via 3 km pipeline
- Settling basins remove total suspended solids
- Aeration Stabilization Basin (ASB) remove biodegradable fines and total dissolved solids
- Treated effluent from ASB is discharged at Point C and flows through harbour to an aeration cell controlled by a weir structure, Point D

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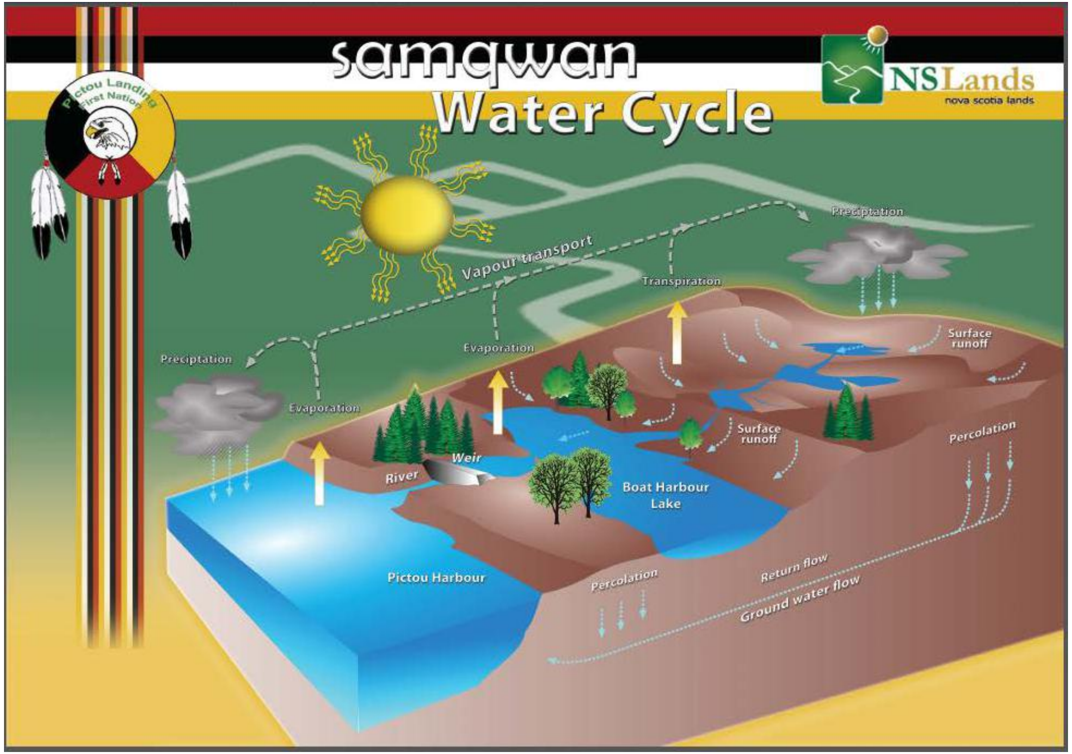
The Water Cycle and Water Balance



– The Water Budget: quantifying movement of water in a basin

Inflows = Outflows +/- ΔStorage

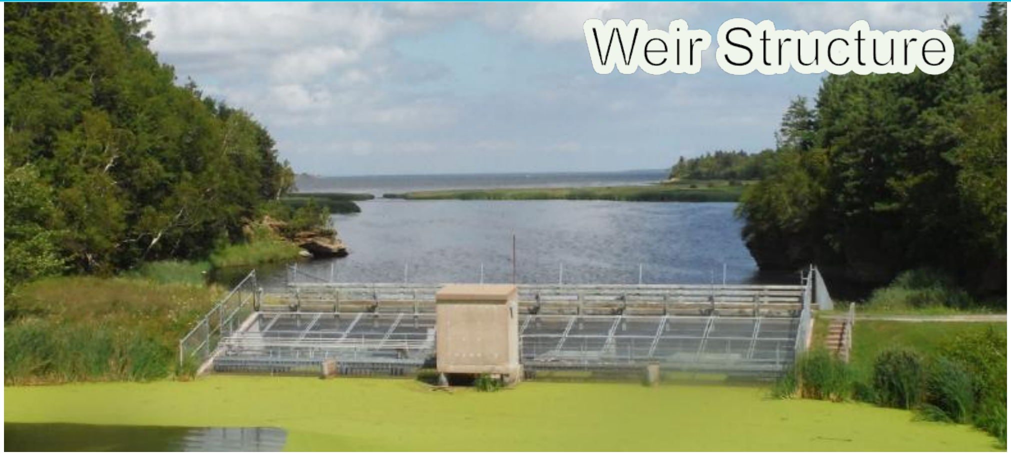
$$P = RO + R + ET + \Delta Ss + \Delta Gs$$

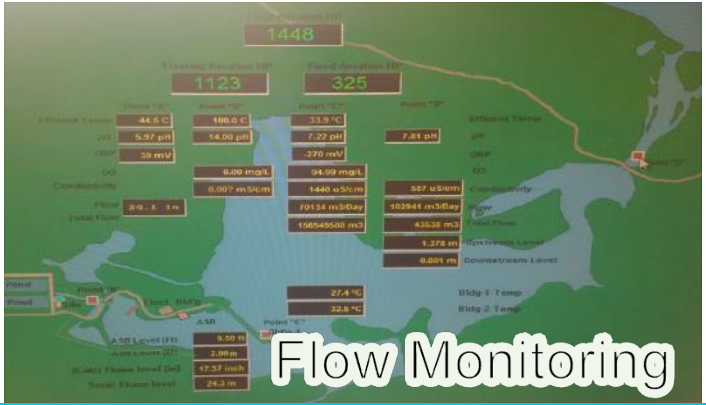
Where:

P = precipitation;
RO = runoff;
R = groundwater recharge
ET = evapotranspiration
ΔSs = change in soil moisture storage
ΔGs = change in groundwater storage

Units = mm/year

Hydrology Assessment – Field Work





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Modelling Approach

Continuous vs Event Based

Continuous	Event Based
• Daily time step • Long-term Modelling • Calibration • Misses actual peak flow • Understanding of 'average' conditions	• 15 minute time step • Single Data Event • Captures maximum instantaneous peak • Understanding of worst case conditions

Existing Conditions → Continuous Model – 4 years → Calibration using flow monitoring data → Estimate groundwater input

Base Conditions → Continuous Model – 21 years of historic climate data → Long-term assessment of snowmelt vs rainfall → Event based modelling using 2 to 100 year design storms → Determine the maximum peak flows

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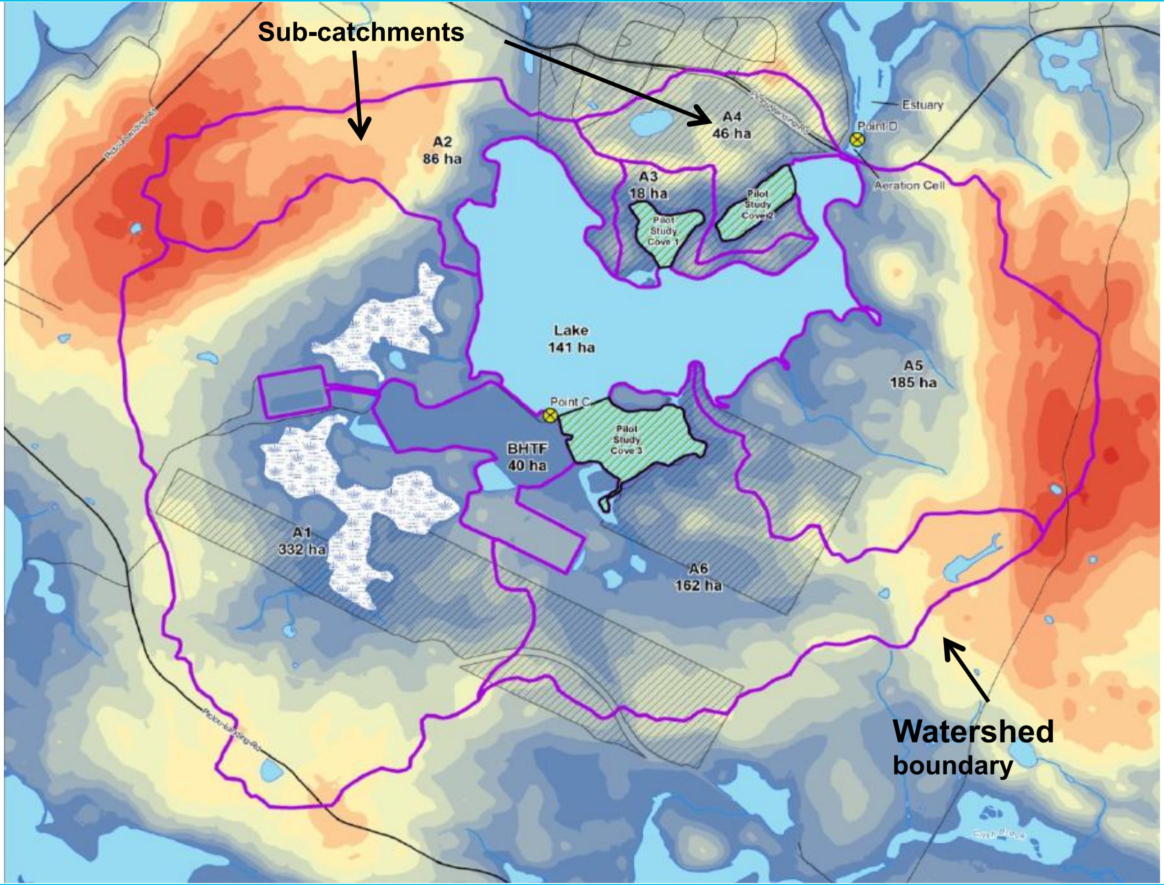
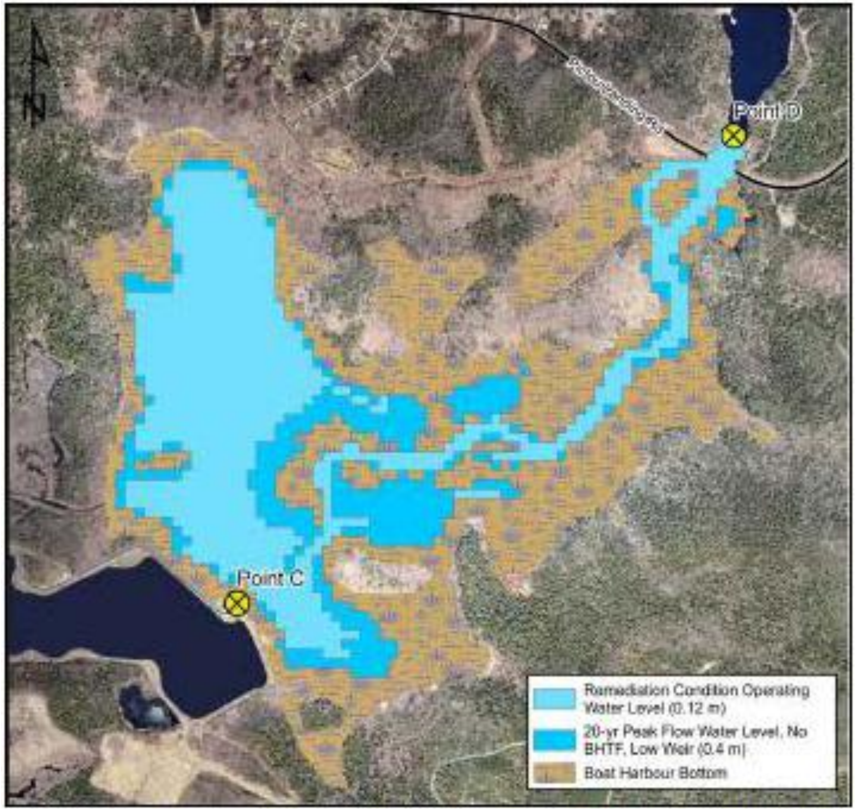
Model Development and Calibration



- Model development using data sources:
  - Bathymetry
  - Topography (LiDAR)
  - Landuse / soils
  - Climate / tide data
  - Flow monitoring
- Catchment divided into sub-catchments to allow modelling of peak flows at pilot coves
- Corrections made during calibration for:
  - Snowmelt timing
  - Groundwater base flow
  - Dampening of rainfall peaks

Results



Estimated water edge during 20 yr Design Storm (0.40 m elevation)

Drawdown Modelling

- Initial Drawdown from 1.30 m to 0.12 m water elevation
- Water Volume = 253 ML

Design Storm During Remediation

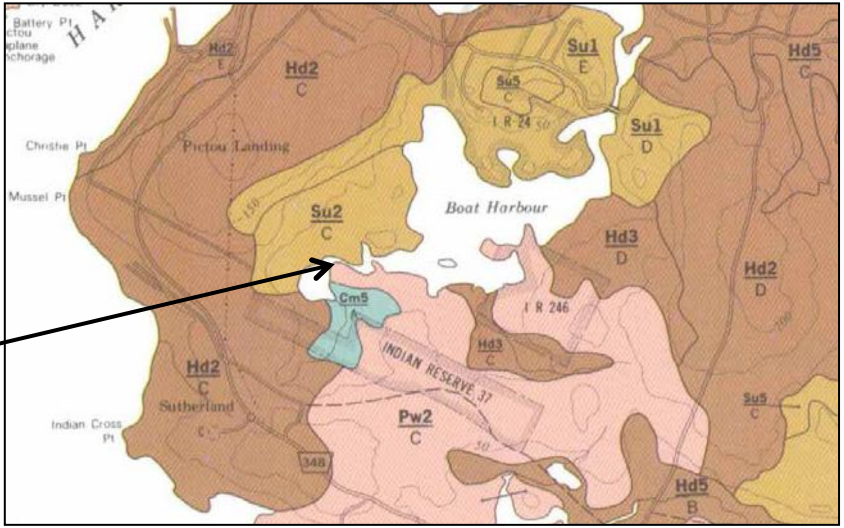
- 20-year instantaneous peak flow = 22.7 m^3/s
- Total runoff volume = 305 ML (occurs over 30 hours)
- Peak water level = 0.40 m elevation

The Water Balance – Transition to Hydrogeology Work

– From the Hydrology Study we know:
  - Precipitation = 1,060.3 mm (42")/yr
  - Evapotranspiration = 427.1 mm/yr
  - Runoff = 190.0 mm/yr
  - Recharge = **443.2 mm/yr** ⟶ **Area = 10,120,700 m^2** ⟶ **GW Discharge, Q = 0.14 m^3/s**

– In Hydrogeology Study: recharge was distributed using the soils map of Nova Scotia

- – Each soil type is given a value of recharge
- – The area of each type determines net recharge



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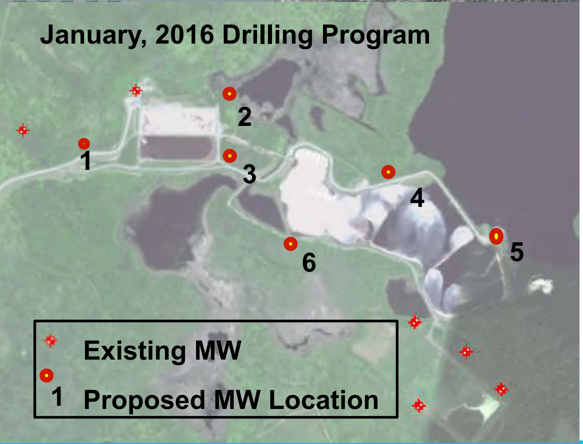
Background Review & Field Investigations – October, 2015 and January, 2016



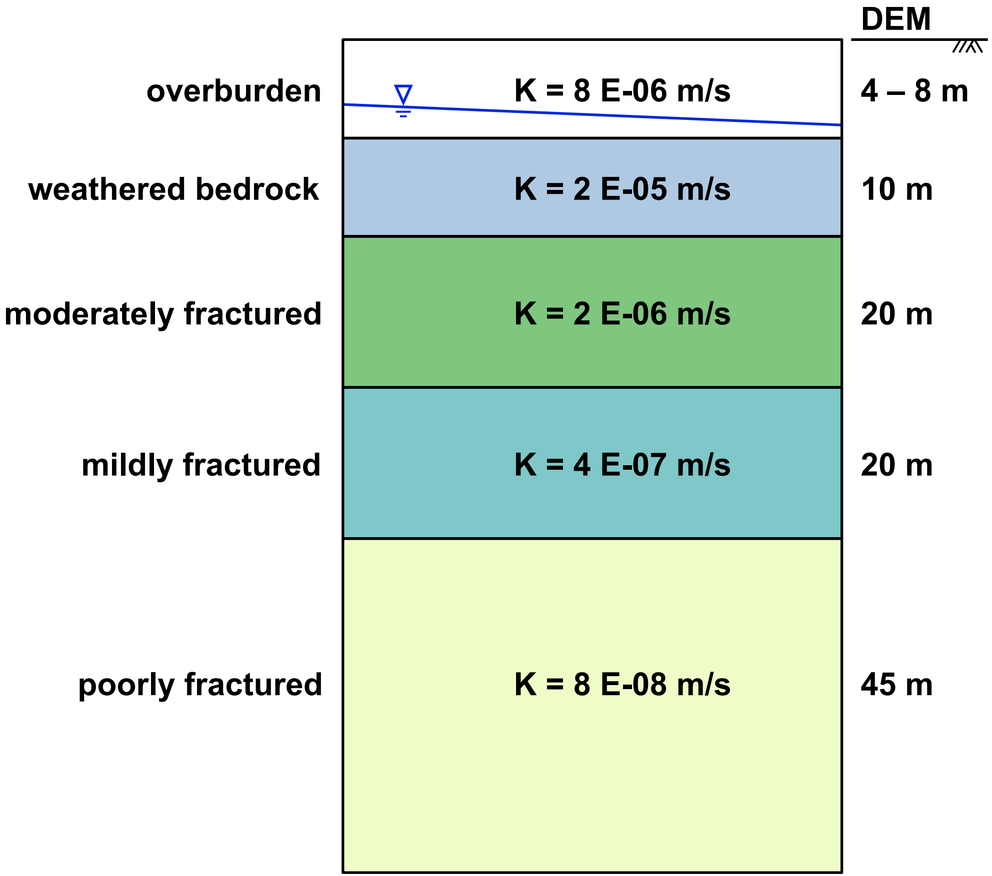
- Background review
  - 21 of 112 reports reviewed relevant to hydrogeologic setting:
    - Thorburn water supply – regional investigation
    - Pictou Landing First Nation – water supply study
    - Boat Harbour Treatment Facility – sludge disposal facility monitoring
    - Boat Harbour – hydrology, sediment characteristics
- Static water levels measured in 31 MWs in the Old / New Wellfields
- Stream flow measured at spring on NW of Boat Harbour
- Data gap around BHTF created need for a drilling, hydraulic testing and survey program in January, 2016:
  - 6 well nests (shallow, deep) around the BHTF
  - Land survey of well location, elevation and pond elevations
  - Slug testing, water levels

Site Hydrogeology

Bedrock outcrop at estuary outlet at Compliance Point D

- Thin glacial till underlain by Pictou Group sandstone and shale bedrock
- Till / bedrock interface and bedrock surface
  - Area of abundance of fracturing
  - Majority of groundwater occurs in this area
- Groundwater flow:
  - Primarily via bedrock fractures
  - Horizontal to sub-horizontal fracturing
- Fracture density and hydraulic conductivity decrease with depth

Site Hydrogeology - continued



– Conceptual hydrogeological model:

- **Ground surface** – using the Digital Elevation Model (DEM) that was developed for the hydrologic model
- **Overburden** from the well logs
- **Weathered bedrock layer**
  - Highly fractured
  - 10 m constant thickness
- **Moderately fractured**
  - 20 m constant thickness
- **Mildly fractured**
  - 20 m constant thickness
- **Poorly fractured**
  - 45 m constant thickness

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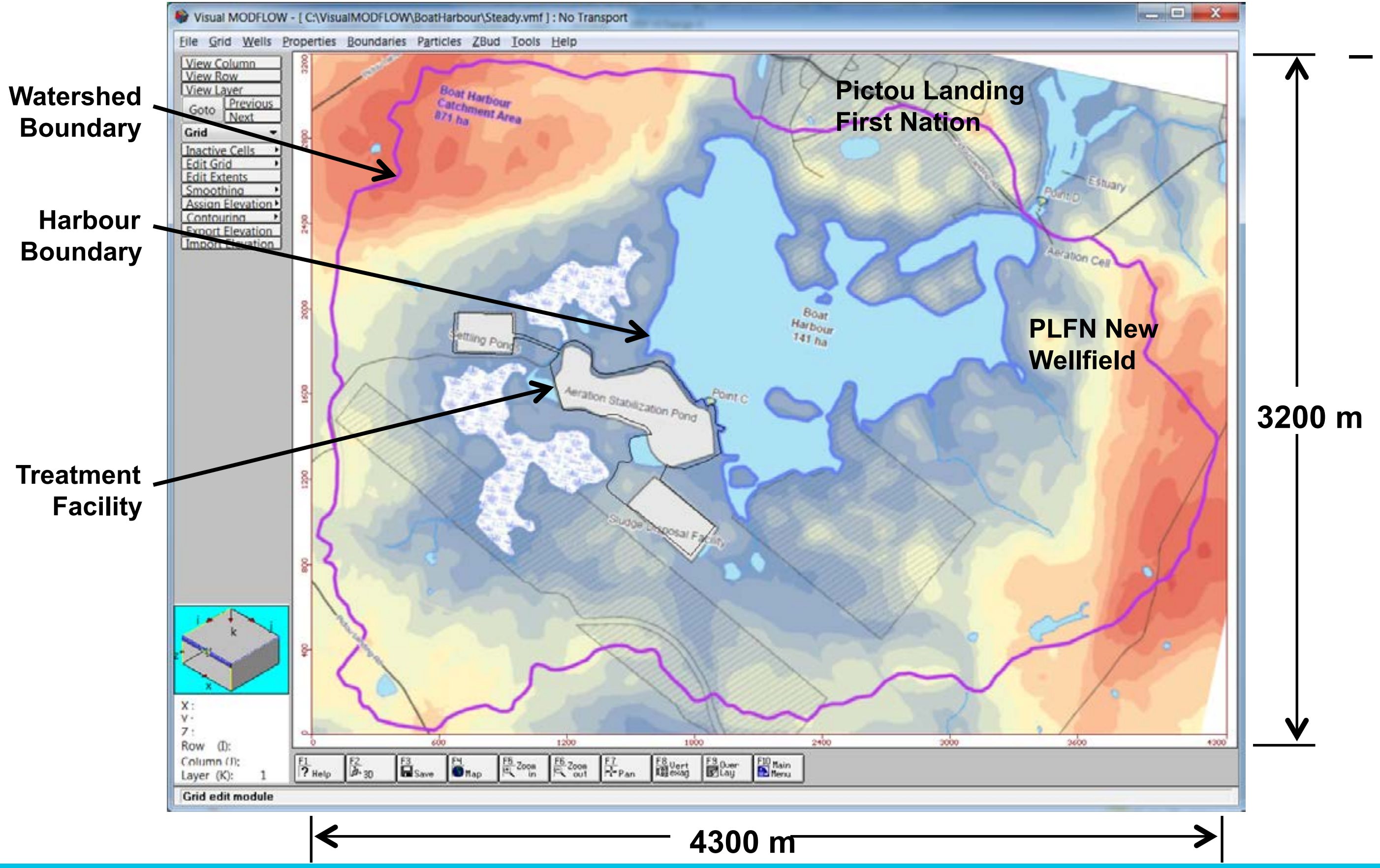
MODFLOW Model Domain



– The outer limit of the flow system is the watershed boundary

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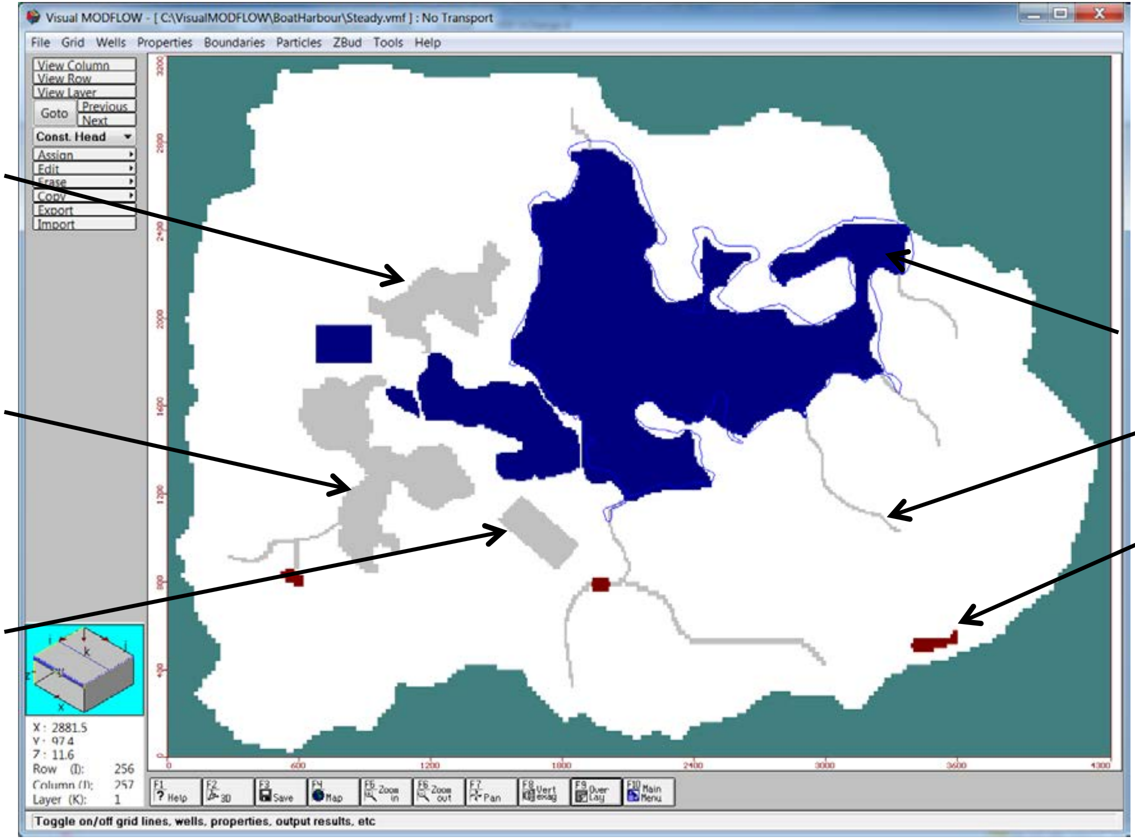
Model Boundaries



- Rivers, drains and constant head boundaries assigned (location based on mapping)
  - Each feature type has properties depend on function of water contribution in the water balance

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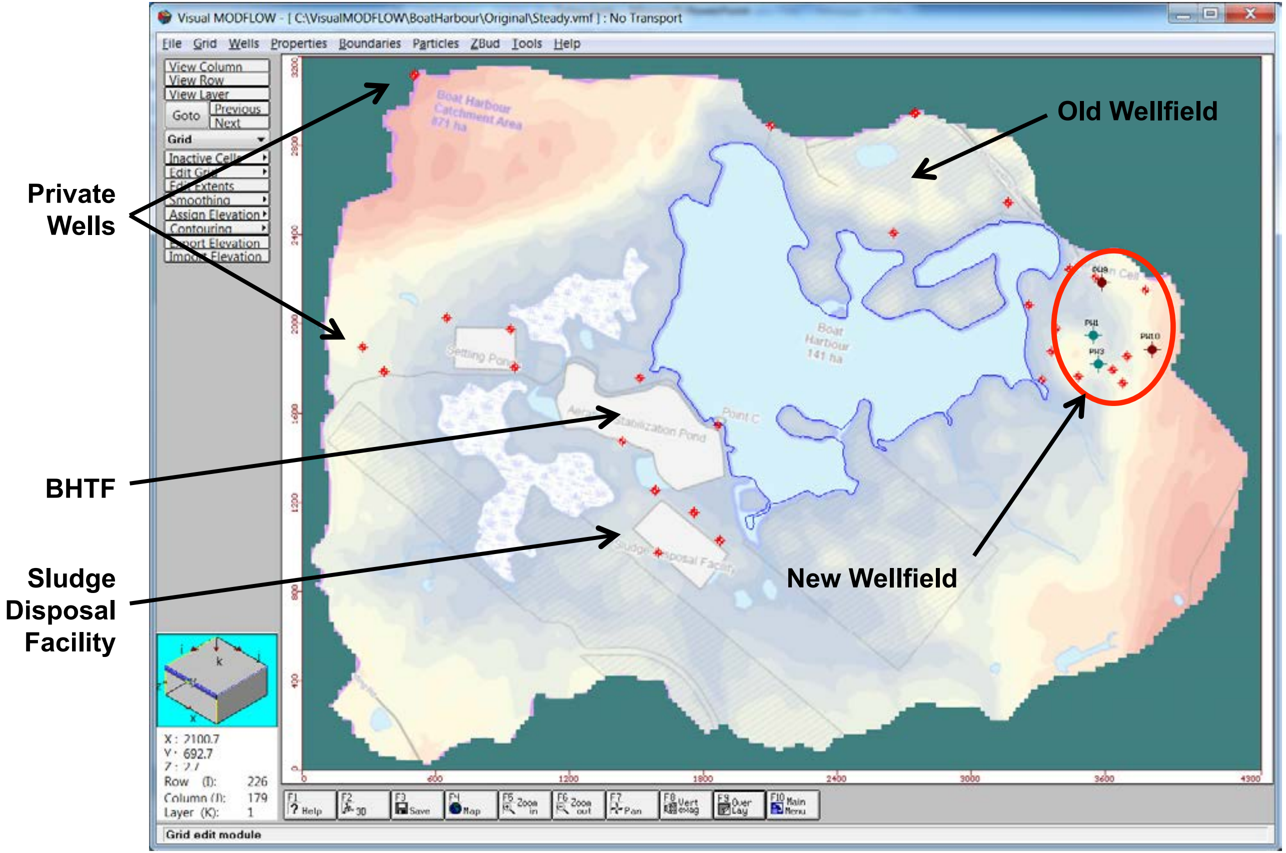
Pumping Wells and Monitoring Wells



– Head observation wells (MWs) used for model calibration

– Pumping Wells (PW1, PW3, PW9 and PW10)

– Visited the New Wellfield and spoke with the operator, confirmed
  - PW9 and 10 active
  - PW1 and 3 inactive
  - PW8 never used

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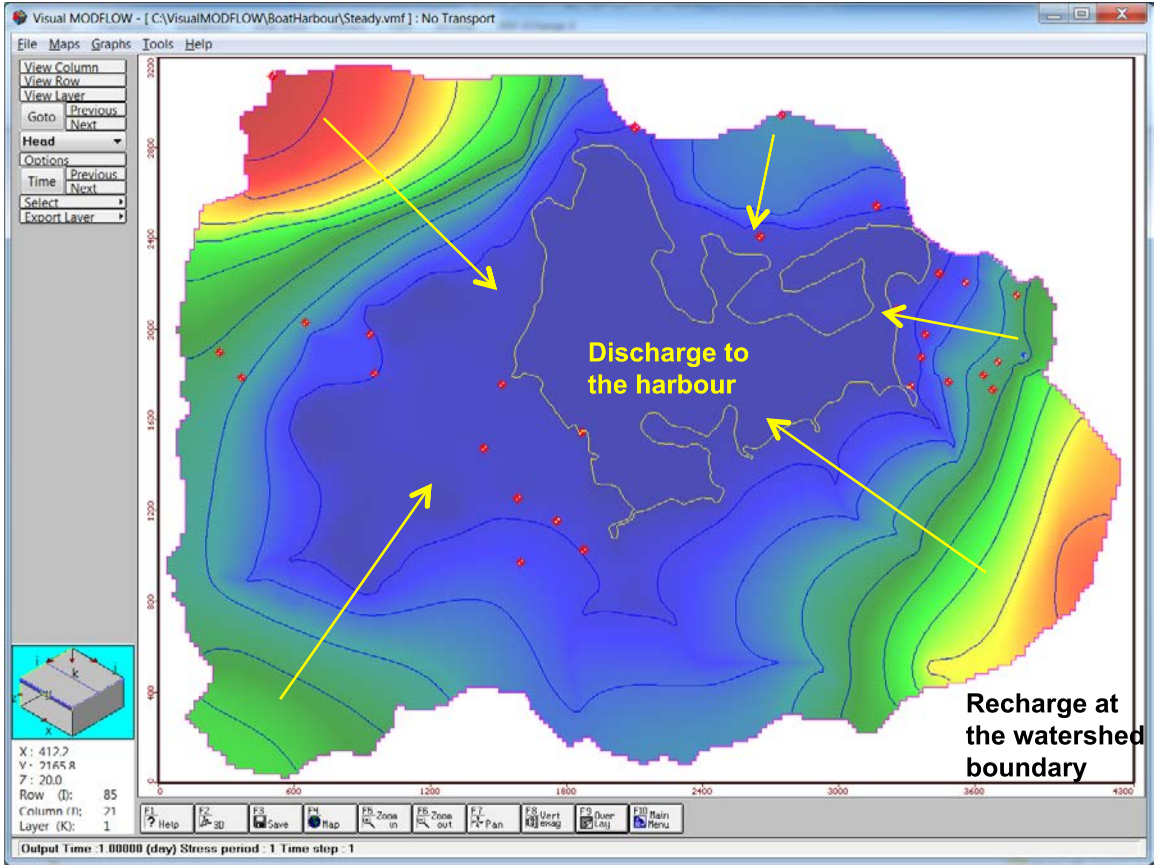
Model Simulation



- Simulated water table elevation
- All recharge must discharge to internal boundaries, or to the harbour water body.

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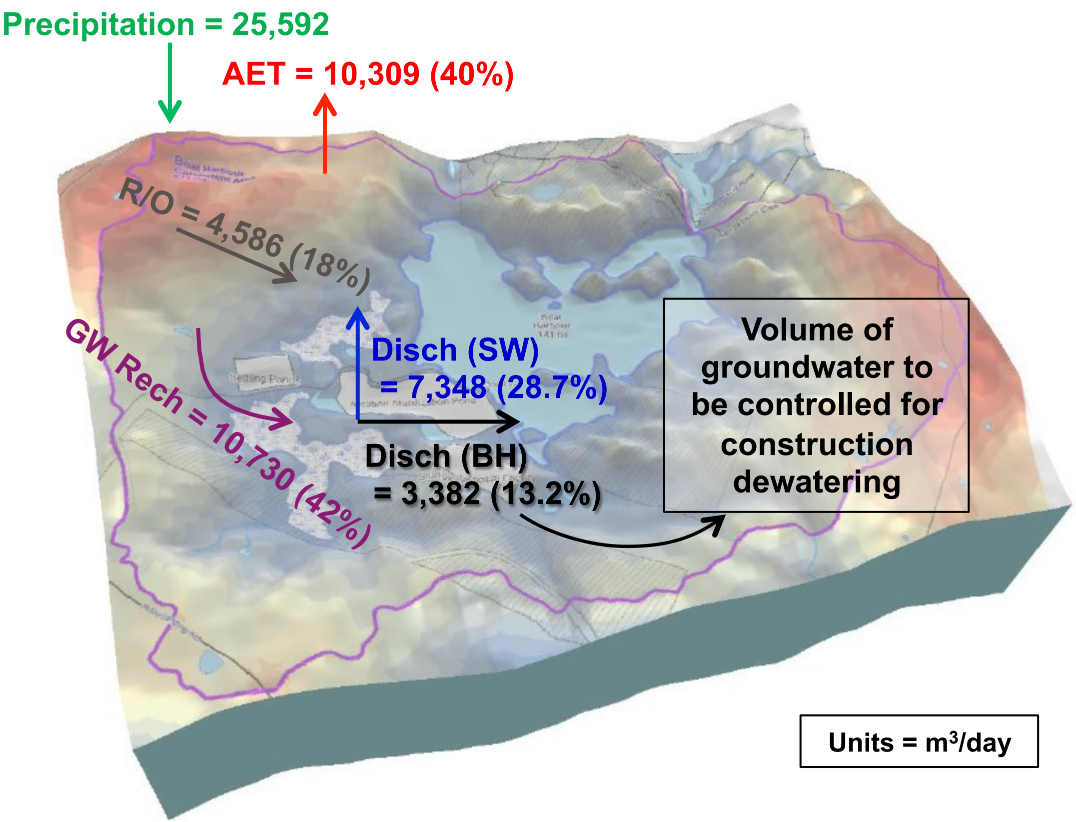
Water Budget Summary



– Watershed hydrologic cycle components

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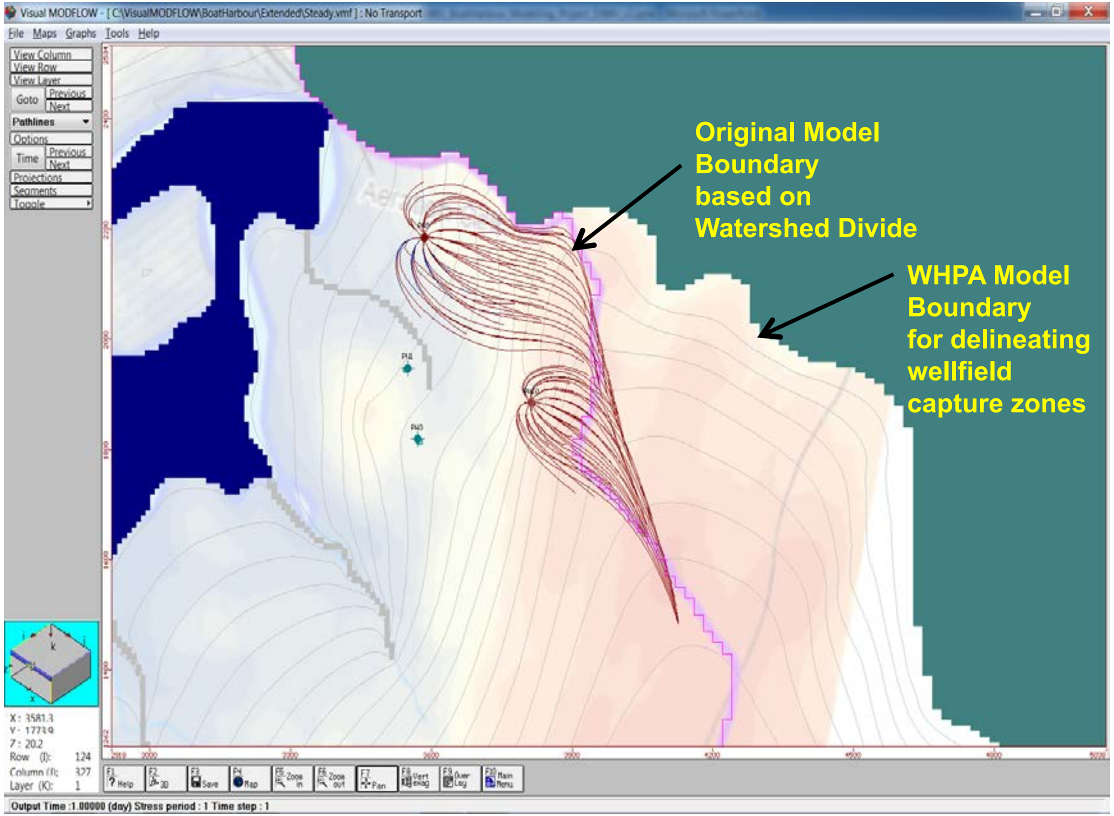
Wellhead Protection Area (WHPA) Delineation (PLFN New Wellfield)



- Capture zones for active wells PW9 and PW10 modelled based on 2014/2015 usage rates
- The capture zones extend across the watershed boundary
- Required extension of WHPA model boundary
- Predicted drawdown associated with remediation construction dewatering of:
  - 0.88 m at PW9, and;
  - 0.39 m at PW10

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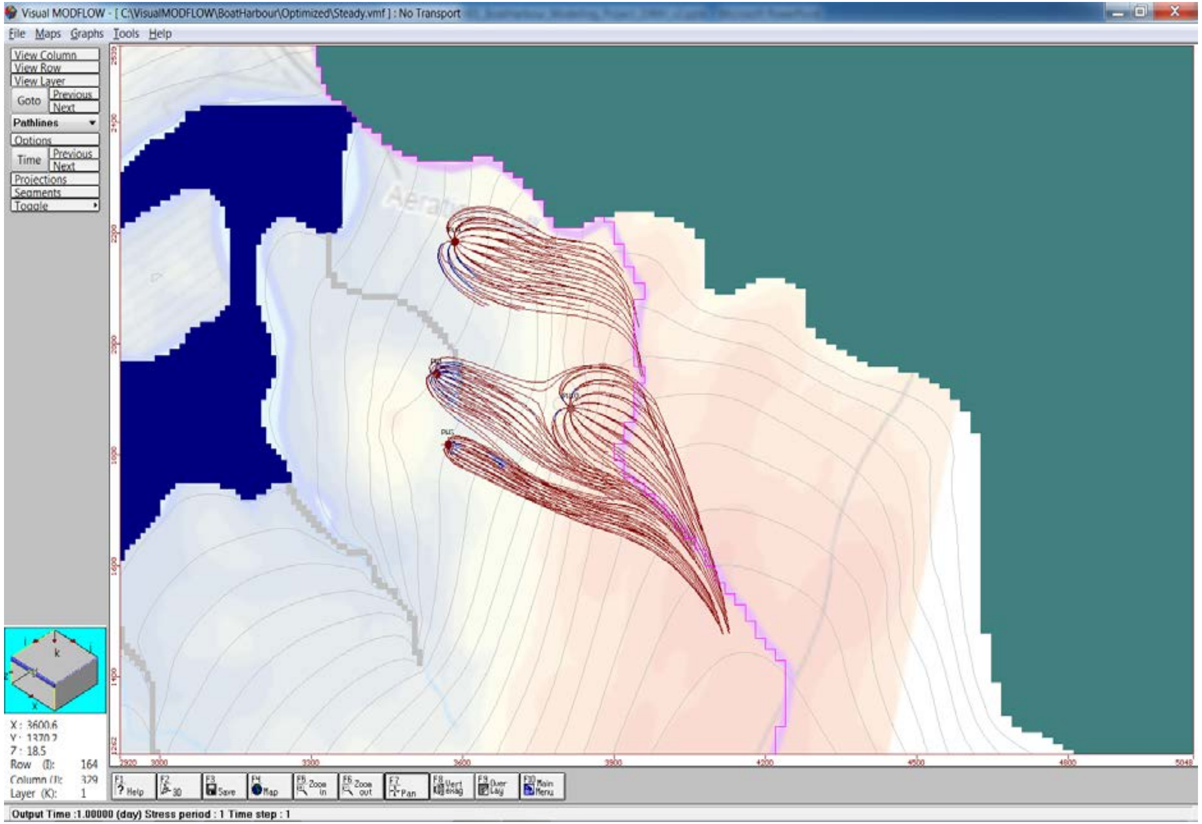
WHPA Delineation – Optimized Well Usage

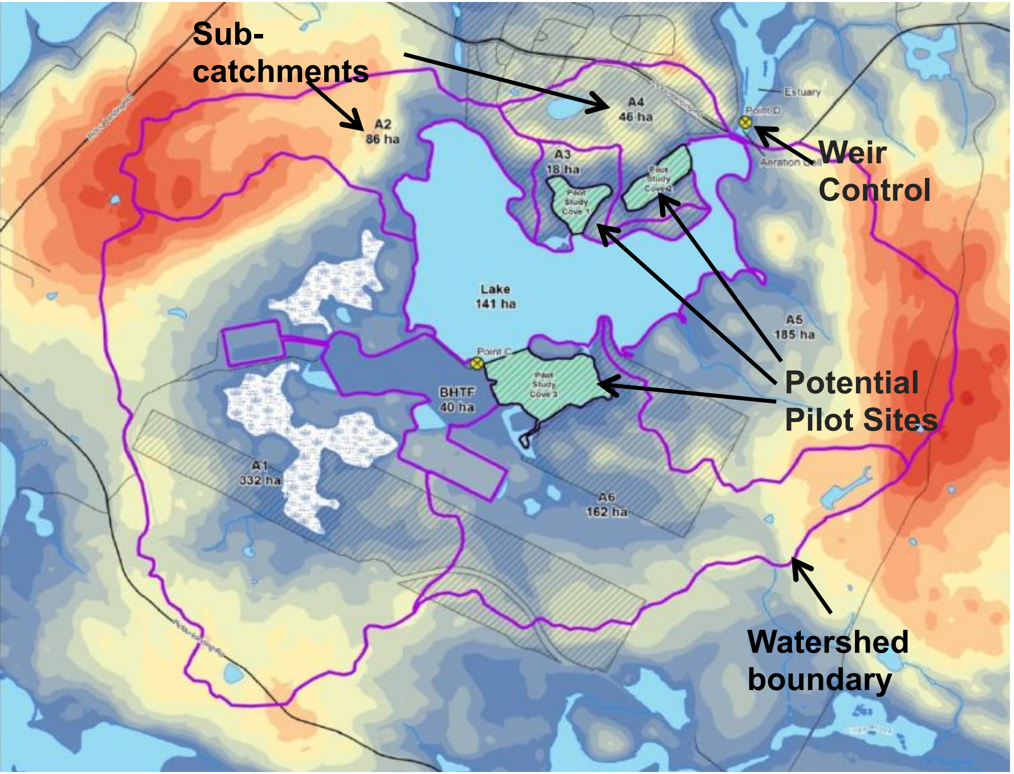


– We can minimize drawdown effects if we distribute pumping
  - Re-ran model using recommended wellfield pumping rates set out in design
  - Predicted drawdown is reduced with:
    - 0.40 m at PW1
    - 0.23 m at PW3
    - 0.57 m at PW9 (vs 0.88*) and,
    - 0.21 m at PW10 (vs 0.39*)
    - * Current-day 2 well operation

Implications and Applications for Remediation

How do we apply hydrology and hydrogeology to remediation planning?

Remediation Water Management



Phased Dewatering And Storm Water Management

- Early Stage Pilots Study Sites
- Gravity dewatering potential
- Dividing and conquering for Remediation Plan
- Storm Water Pumping and Bypass planning
- Using Bathymetry to support stage planning
- Understanding the role of Tide Gate Control during Remediation

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Pumping and Bypass

Catchment	Parameter	2-year	5-year	10-year	20-year	50-year	100-year
Boat Harbour	Peak Inflow (m^3/s)	10.77	14.93	18.09	**22.66**	26.39	30.44
	Total Runoff Volume (m^3)	149,100	206,680	248,360	305,180	349,330	395,130
	Peak Water Elevation (m)	0.28	0.33	0.36	0.40	0.42	0.45
	Daily Peak Flow from Continuous Model (m^3/s)		5.50		7.16		
Catchment A3 Pilot Study Cove 1	Peak Flow (m^3/s)	0.11	0.18	0.25	**0.35**	0.44	0.53
	Runoff Volume (m^3)	2220	3130	3800	4710	5430	6170
Catchment A4 Pilot Study Cove 2	Peak Flow (m^3/s)	0.64	0.88	1.07	**1.35**	1.58	1.83
	Runoff Volume (m^3)	7,170	9,890	11,830	14,490	16,540	18,670
Catchment A6 Pilot Study Cove 3	Peak Flow (m^3/s)	0.62	1.04	1.39	**1.93**	2.37	2.86
	Runoff Volume (m^3)	20,760	29,690	36,200	45,130	52,100	59,370

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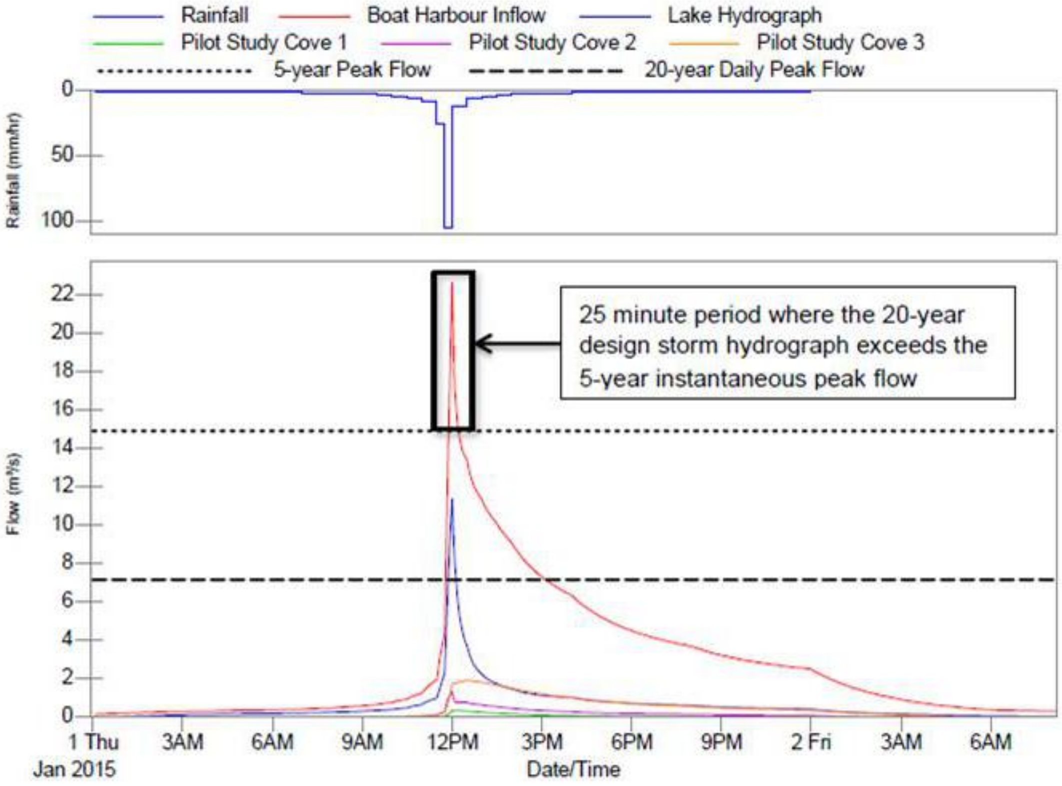
Risk Based Planning



Hydrology Study Results Inform

– Development of Performance-Based pumping criteria

– Determinations Routine Pumping Vs Intense Storm bypass rates

–

Design Storm	24 hr Rainfall Depth (mm)
2-year	55.5
5-year	67.5
10-year	75.4
20-year	85.5
50-year	92.9
100-year	100.3

– Risk Allocation strategies based on flow rates

– Assessment of risk exposure based on construction phase

– Development of Storm Event Management strategies

"Batten down the hatches!
A Nor'Easter is a coming."

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Weir / Tide Gate

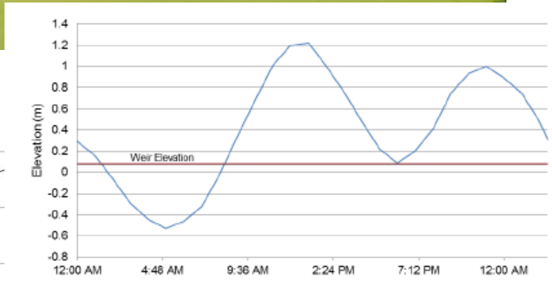
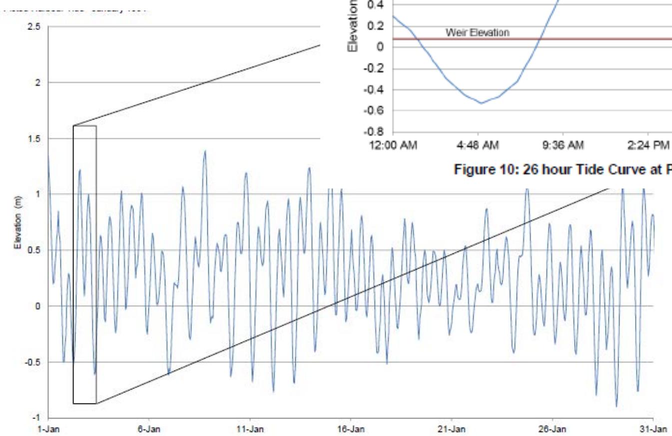


Figure 10: 26 hour Tide Curve at Pictou Harbour, NS



- Current Situation:
  - Currently 2.1 m wide rectangular weir at elevation 0.89 m
  - Tide gates to stop tidal inflow
  - Total Flow = Effluent + Precipitation Flows
  - Maintains Boat Harbour at operating level

- Potential Operation During Remediation:
  - Weir configuration to be determined
  - Tide gates to stop tidal inflow
  - Total Flow = Precipitation Flows
  - Gravity drawdown management

- Post Remediation:
  - Total Flow = Rainfall Flows + Tidal Flow
  - Potential 37.5 m wide weir at elevation 0.08 m

Groundwater and Construction Water

During Remediation all water is not "Created Equal"

- Surface water is pumped and bypassed
- Construction water and groundwater are considered potentially impacted and need to be managed accordingly
- Impacts can be:
  - Suspended solids like clays are silts causing turbidity
  - Chemical contaminants
- Hydrogeology study reports GW Discharge:

  $Q = 0.14\ m^3/s$ for entire Boat Harbour site

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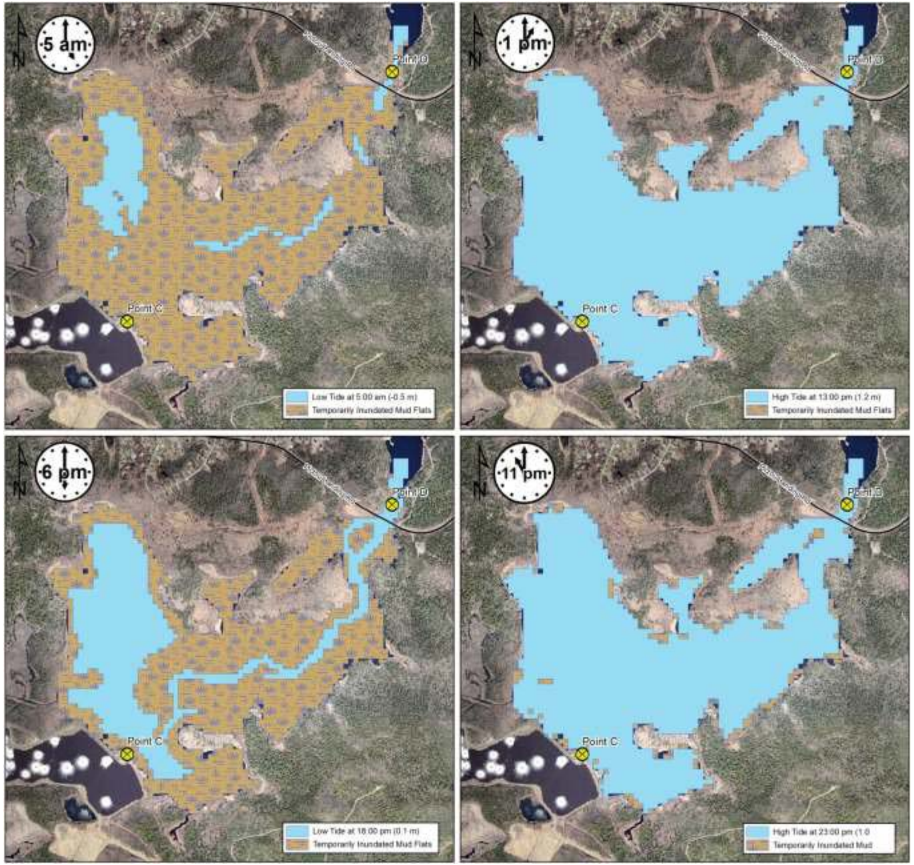
Post Remediation – Return to Tidal



– Planning the future by looking into the past

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Authors

Randy Pointkoski, Nora Doran, Christopher Moon,
Miln Harvey, (AECOM)

Donnie Burke and Randy Vallis,
(Nova Scotia Lands)

Thank You!

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