Is salinity stratification impairing the performance and volume of stormwater management ponds?

STEP Webinar Series – November 3, 2022

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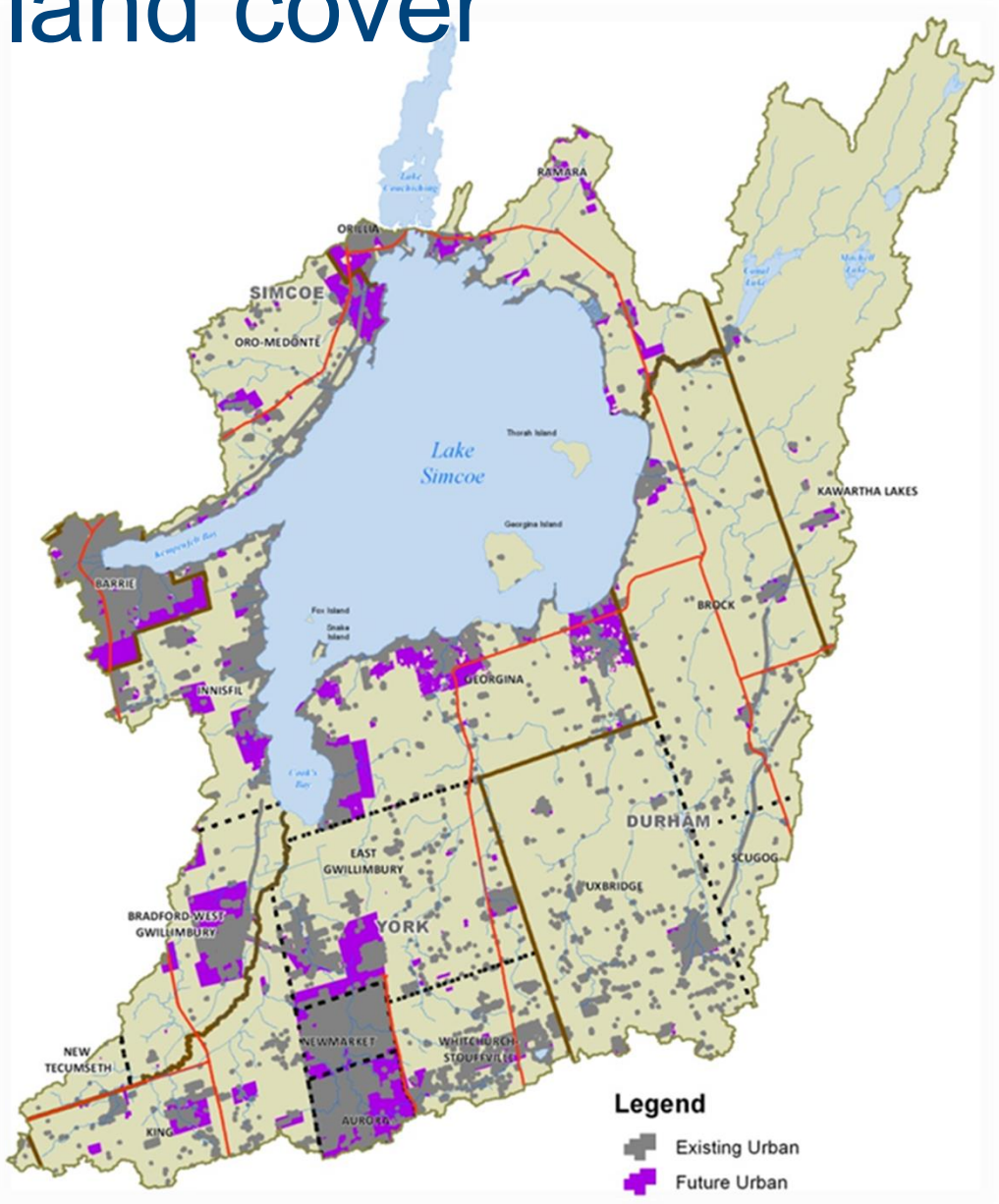
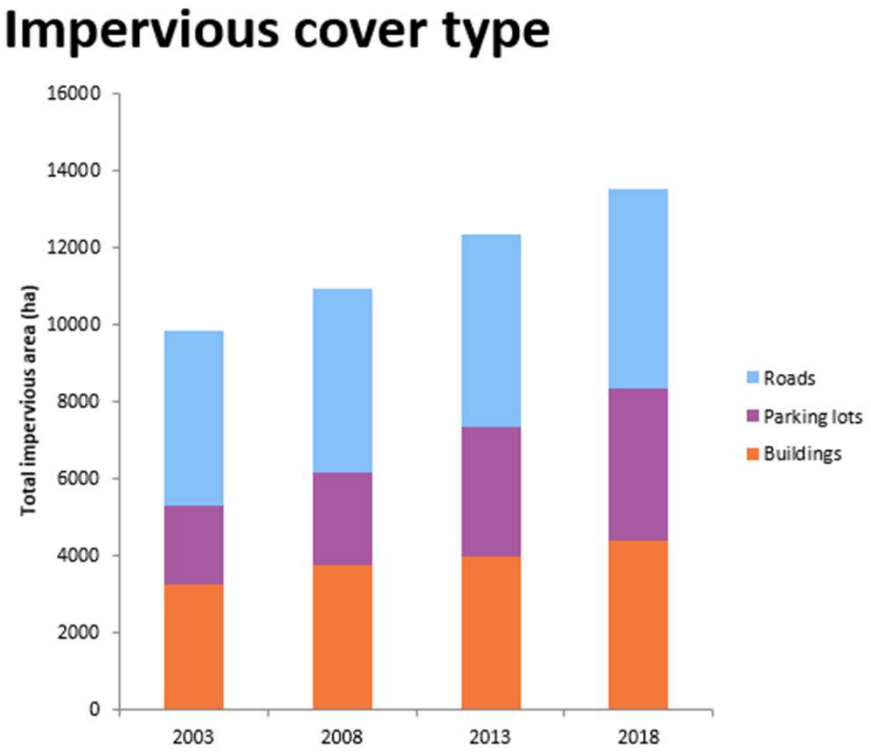
Urban land cover

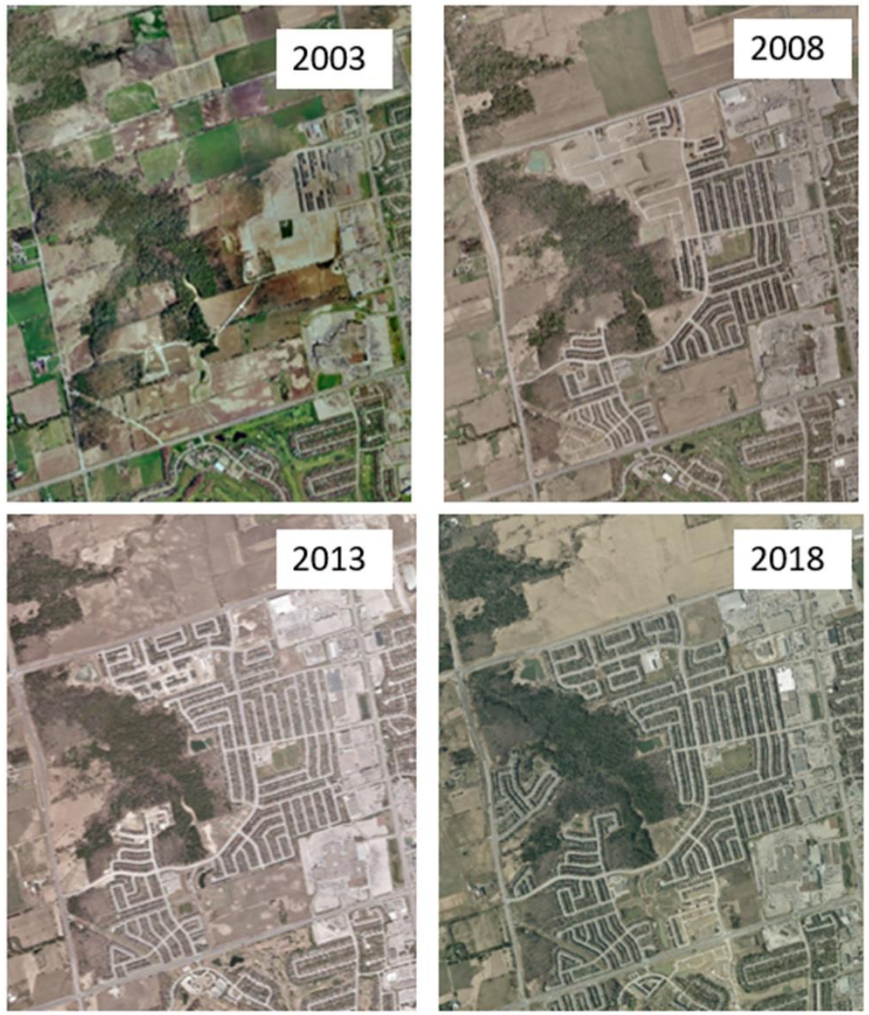
- Close to Toronto (~ 6 million)
- Watershed: 450,000
  - + 50,000 seasonal
  - + 50% by 2041
- Rapid growth coincides with enhanced public transit (rail)
- 2020: pandemic “invasion”



Impervious surfaces: 3.4 → 4.7% (2003-2018)

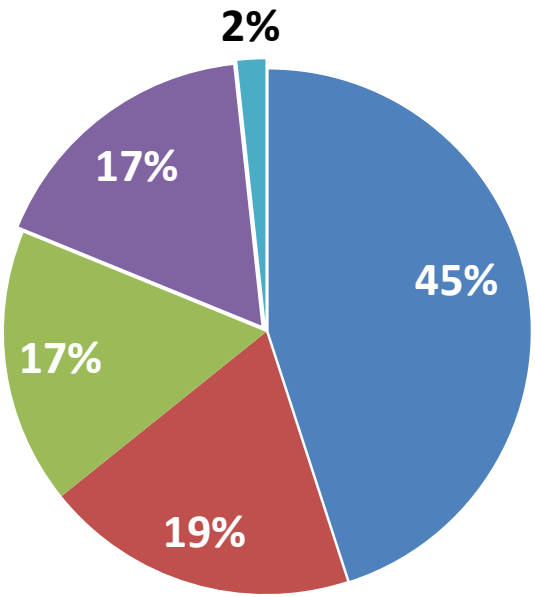
Move toward higher density urbanization

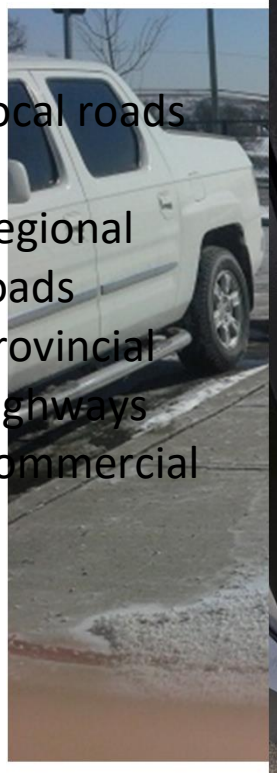




Winter salt

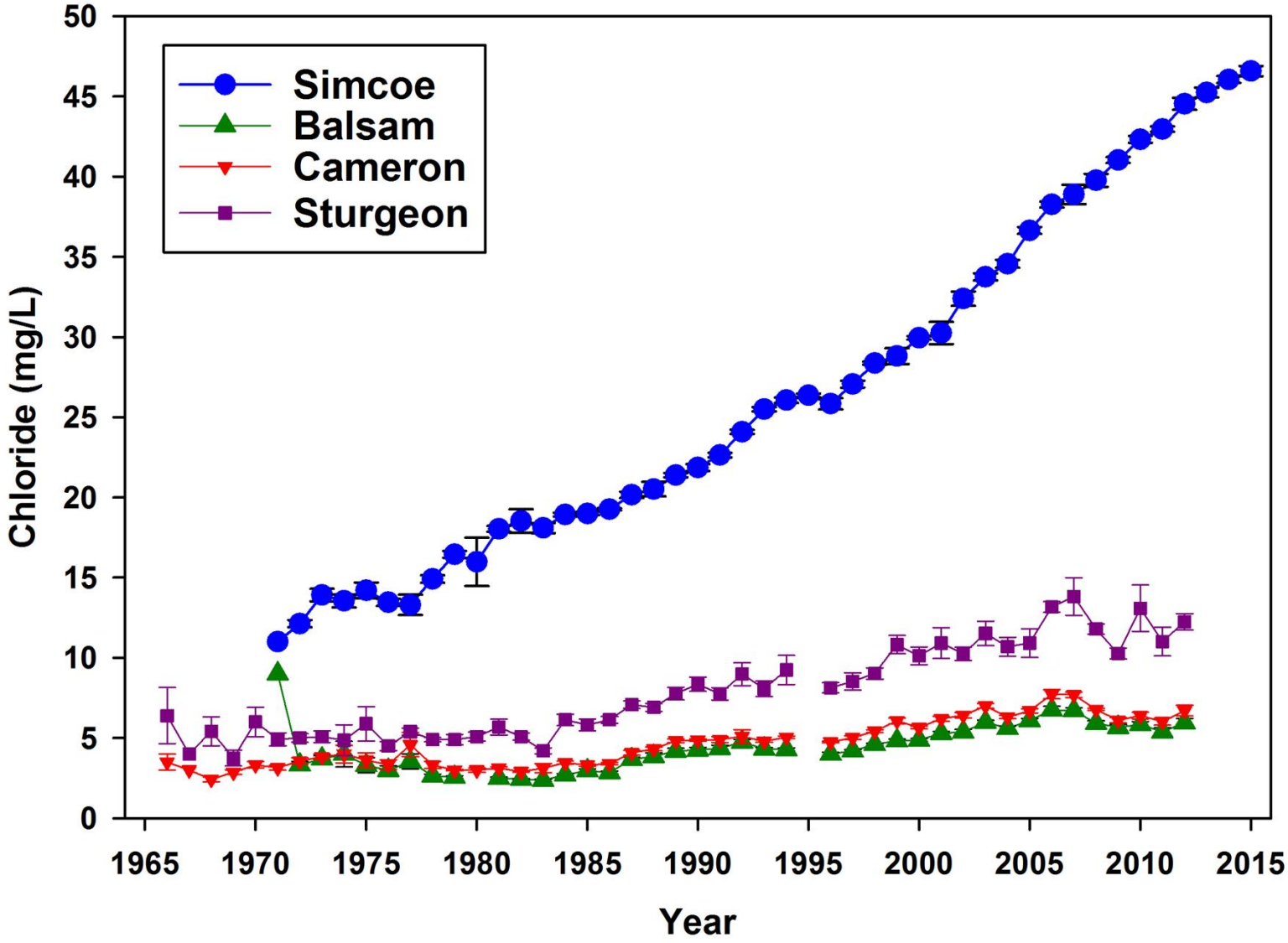
- Salt is overused (100,000 tonnes, 2012)
- “Better safe than sorry”
    - Fear of lawsuits





LSRCA; Twitter: @SaltShaming

Chloride trends



Chloride guidelines: Chronic: 120 mg/L; Acute: 640 mg/L

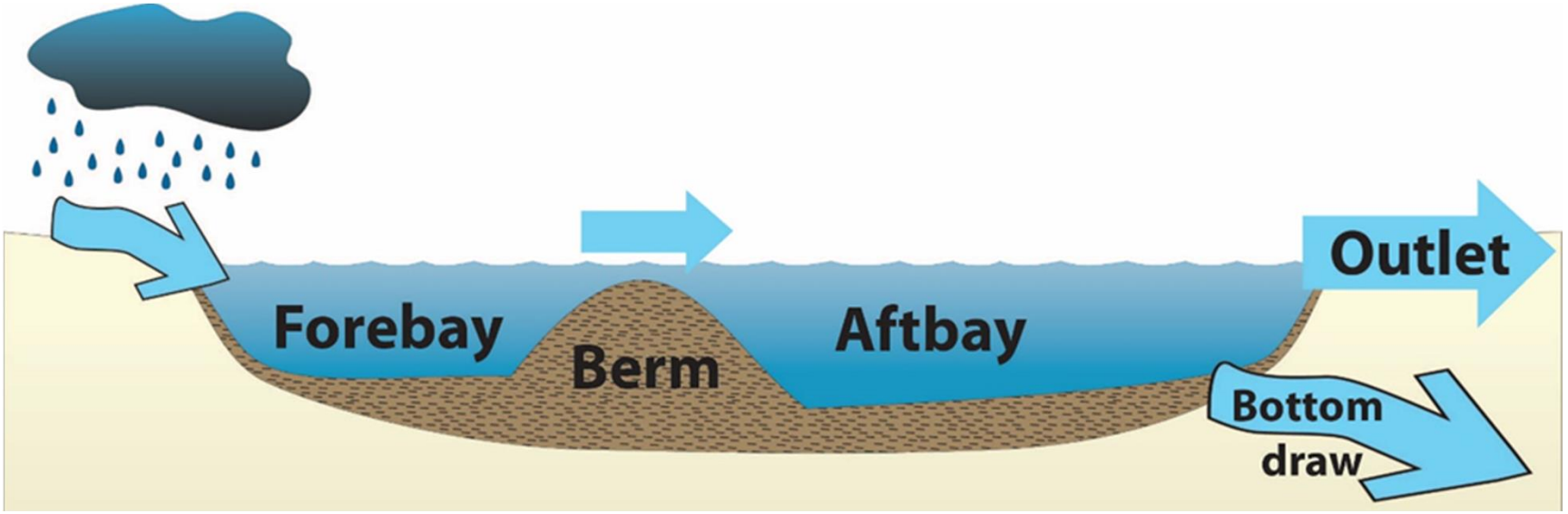
Data: LSRCA, Dugan et al. 2017 PNAS 114: 4453-4458

Stormwater management ponds

- Stormwater management ponds (or detention ponds / basins):
  - Contain surface run-off, flood prevention, passive water quality treatment

- Originally: stop flooding (dry ponds) but…
  - solid particles settle out (designs changed to enhance this); 80% retention
  - Solid particles contain phosphorus → nutrient reduction strategy (~40-50 %)
  - shift to permanently wet ponds

- Increased complexity from simple “basin” → two basins, berm, wetland features, bottom draws to “protect coldwater fish habitat”



But ponds have problems...

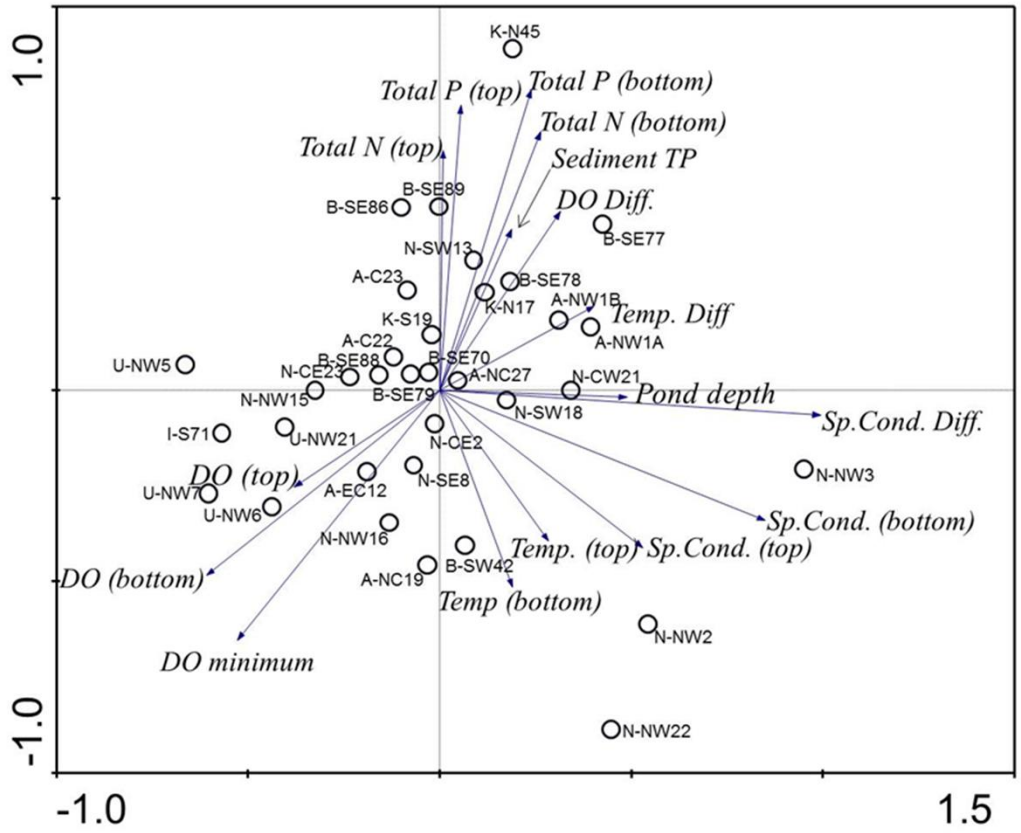
- built shallow to prevent stratification (it happens anyway)
- often not much of a temperature difference (top vs bottom)
- some ponds go anoxic (are bottom draws protecting anything?)
- anoxia --> sediment P release
- Salt compounds these problems!

Salt run-off: 85,000 mg Cl^-/L →

(Seawater: 19,500 mg Cl^-/L)
(Guidelines: 120 / 640 mg Cl^-/L)

Stormwater management ponds

- Surveyed 92 ponds in 2010
- 34 ponds sampled for chemistry
- Sp. Cond & salt = 59.3 % of variation
- Nutrients = 13.9% (axis 2)
- 11 pond subset for on-going study
- 3 ponds for continuous monitoring:
  - Residential
  - Small commercial
  - Large commercial

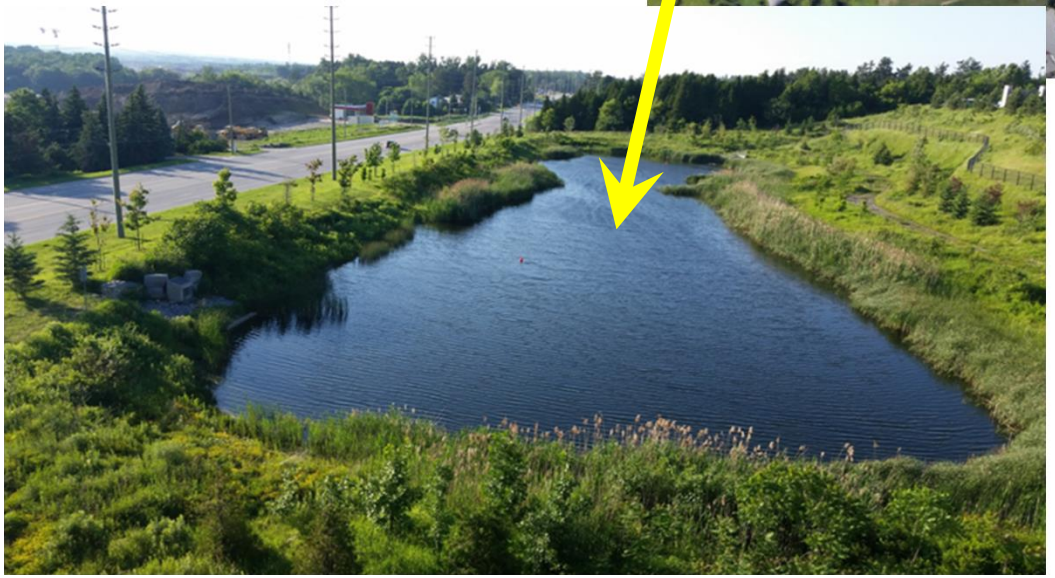


Site C Pond

- Commercial catchment
- Built 2008

- Max. depth: 2.4 m
- Vol: 8069 m^3

- Sp. Cond: 59,130 µS/cm
- TP ~42 µg/L

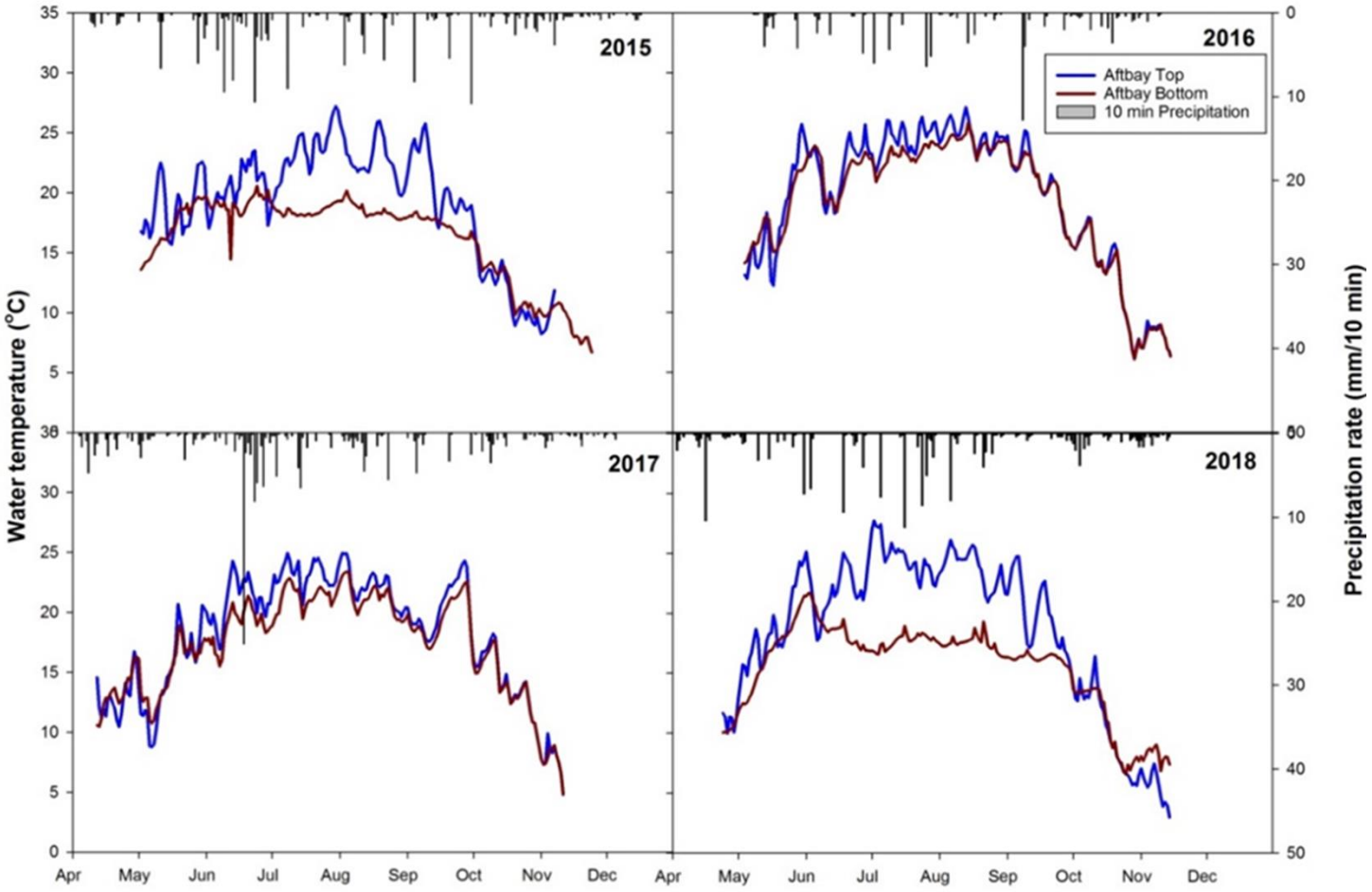


CTD, DO loggers deployed Apr – Nov 2015-2018

Top / bottom; fore- aft bays

Temperature trends

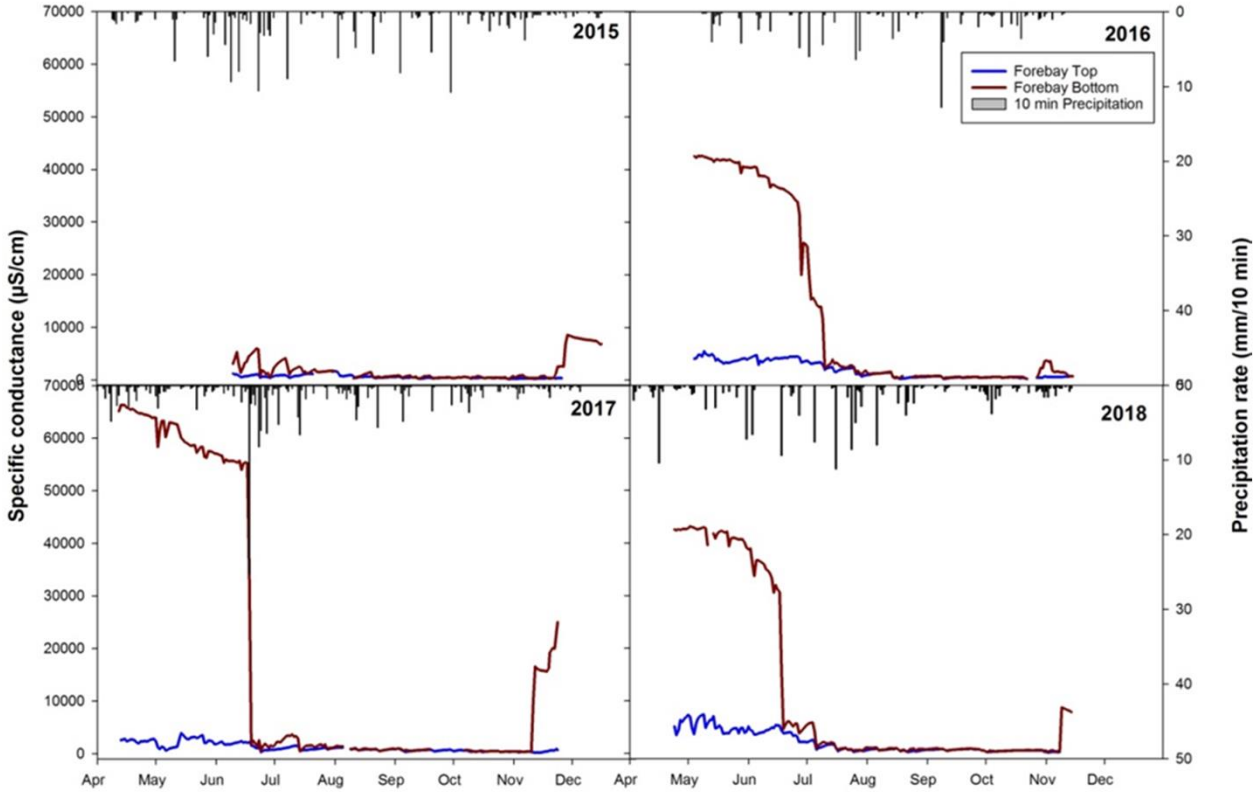
- Temperature difference between top and bottom layers seems related to mixing and air temps.
  - Bottom water can exceed 19°C threshold for coldwater habitat (2016, 2017)
  - Variations due to diurnal flux and incoming precipitation events



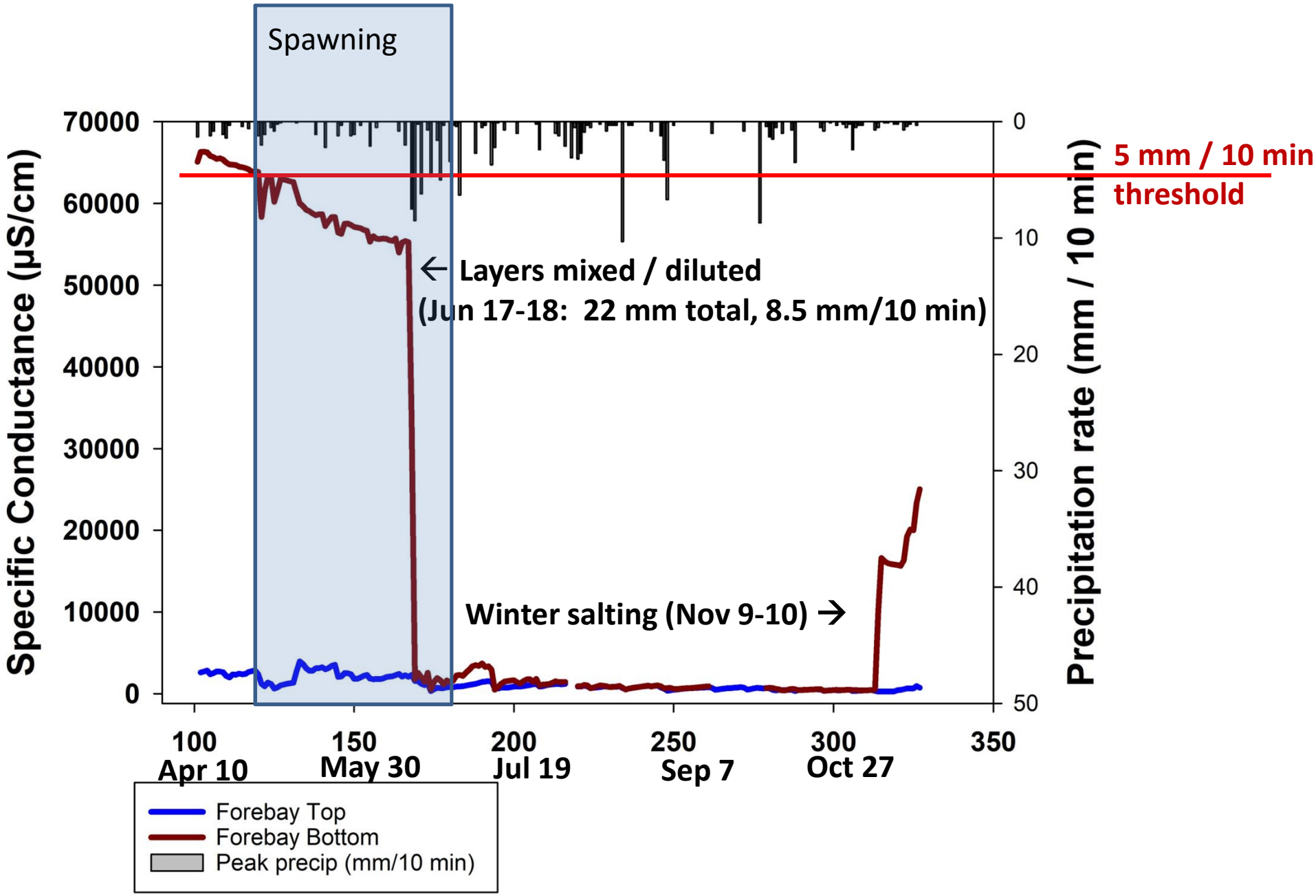
Specific conductance

- Bottom layer chloride = 40,000-65,000 mg/L
  - Guidelines: 120 / 640 mg/L; seawater = 19,500 mg/L

- Forebay typically mixes ~ June-July due to rain event with intensity exceeding 5 mm in 10 min
- Aftbay: more resistant; mixes with total volume of precipitation (often stays above guideline year-round)

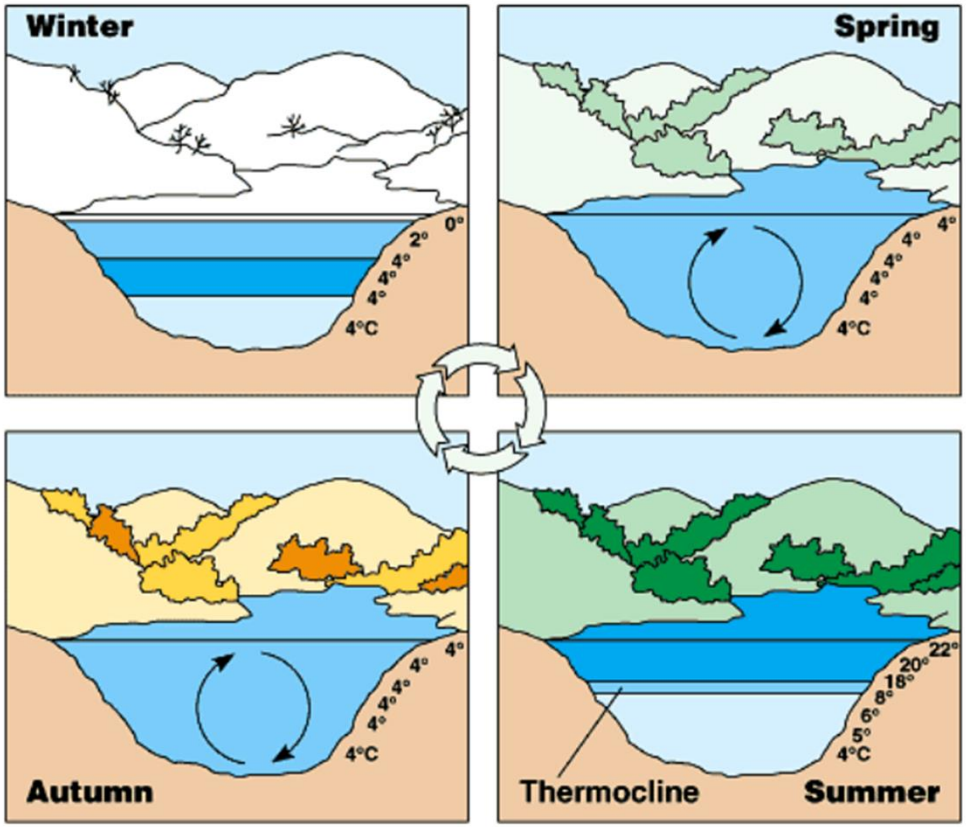


Specific conductance



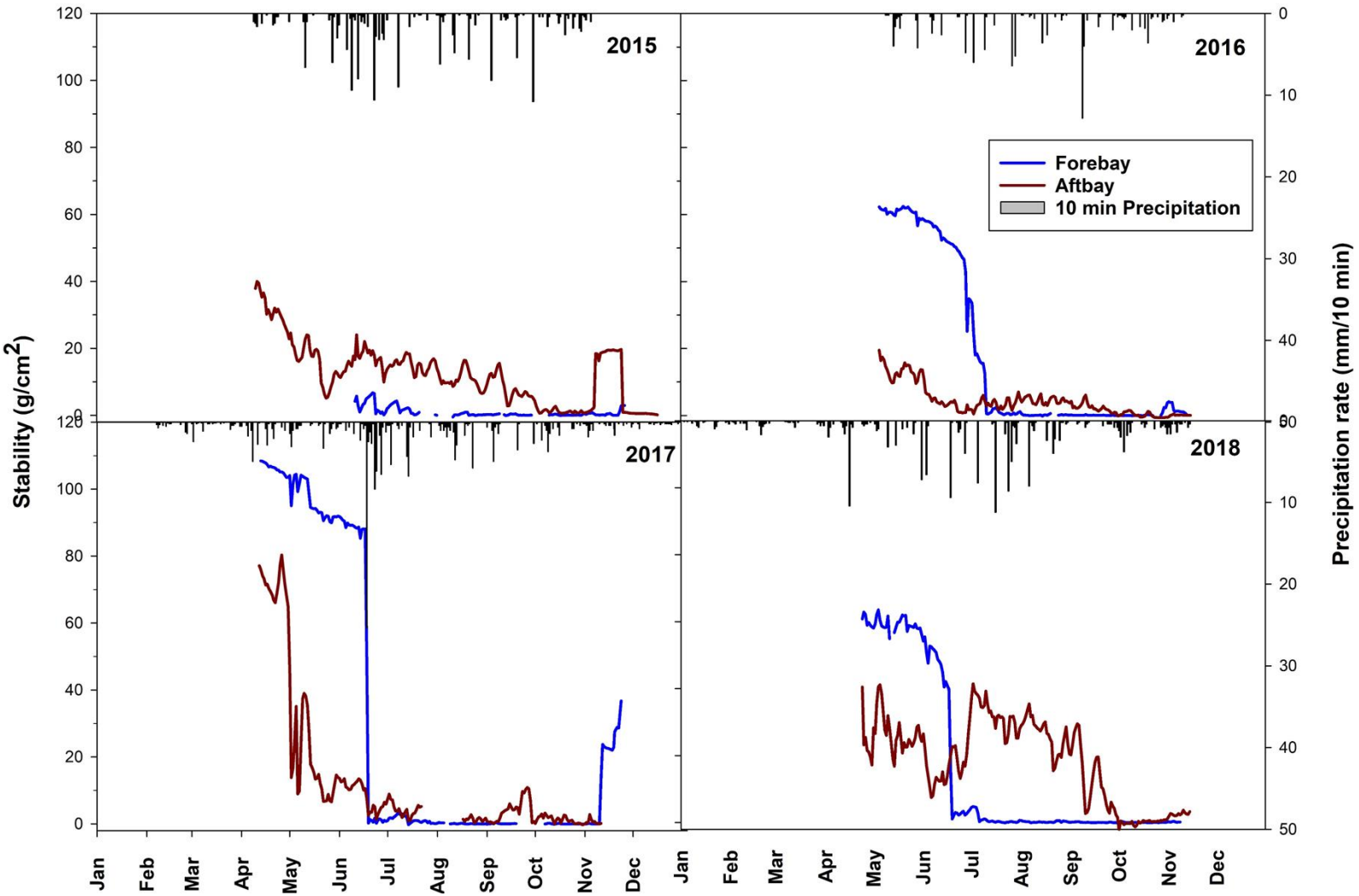
How / when do ponds mix?

- Used Schmidt Stability Model:
  - Lakes: amount of wind energy needed to mix water column at water temp.
  - Model based on water density from temperature
  - Replaced with salt density and inputs of precipitation



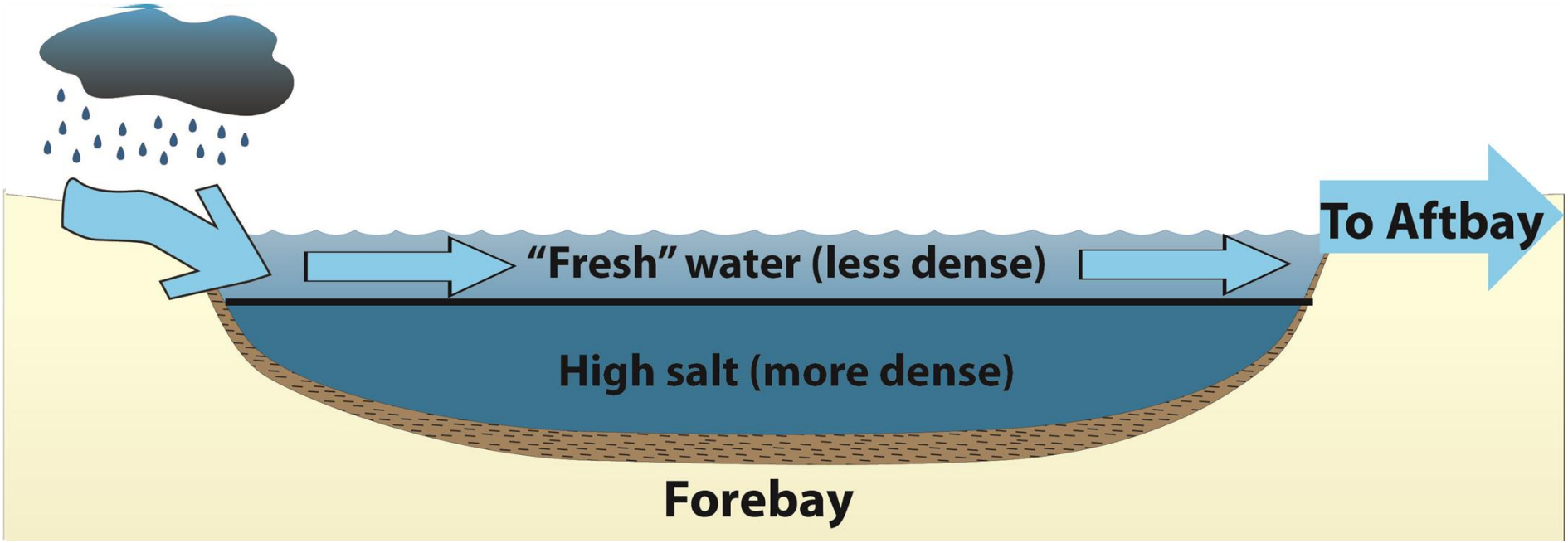
Modified stability model

- **Forebay** mixes due to rain <u>event intensity</u> exceeding 5 mm in 10 min (~June-July)
- **Aftbay:** more resistant / intensity dampened; mixes with <u>total volume</u> from inputs



Storm “skipping”

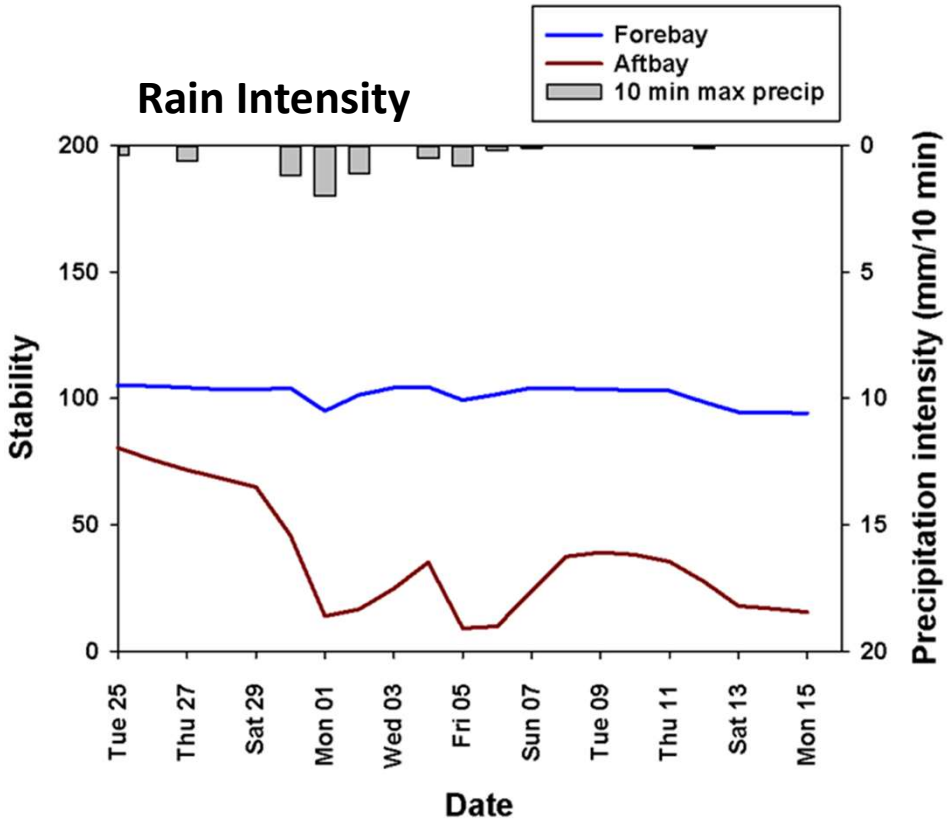
- Large density difference between top and bottom layers resist water column mixing
- Until forebay mixes (5 mm / 10 min) sub-threshold events “skip” across density boundary into aftbay (and receiving waters)
- Impairs pond functioning: reduced “design volume” / performance
  - Typically: sediment accumulation decreases volume then clean out
  - Here: salt stratification limits volume to water column above density layer
    - ~25% of forebay, ~30% of aftbay volumes

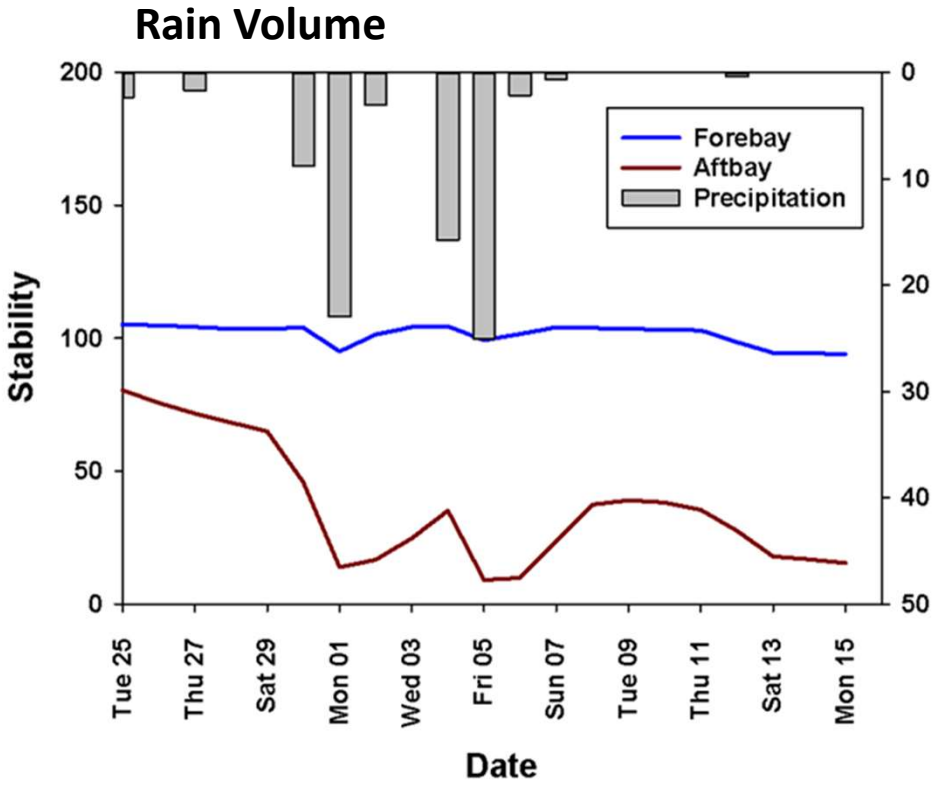


Intensity mixes forebay
Volume mixes aftbay

April 25 – May 15, 2017:

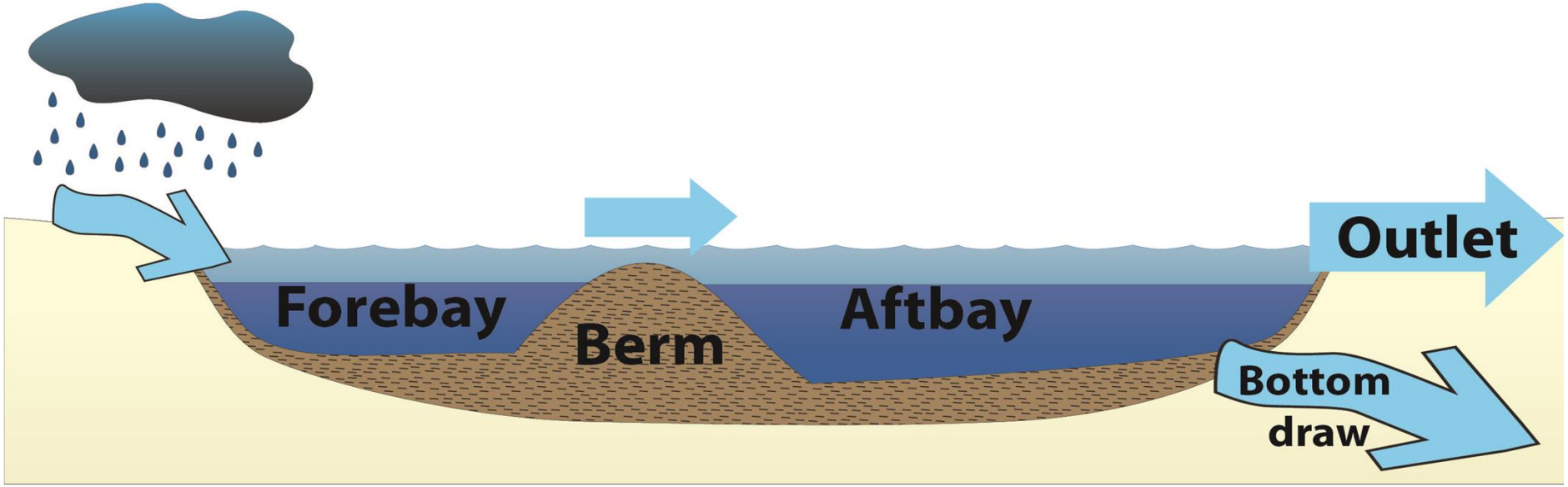
- Sub-threshold intensity events did not mix forebay
- Volume of rain (>20 mm per day) was sufficient to decrease density in aftbay



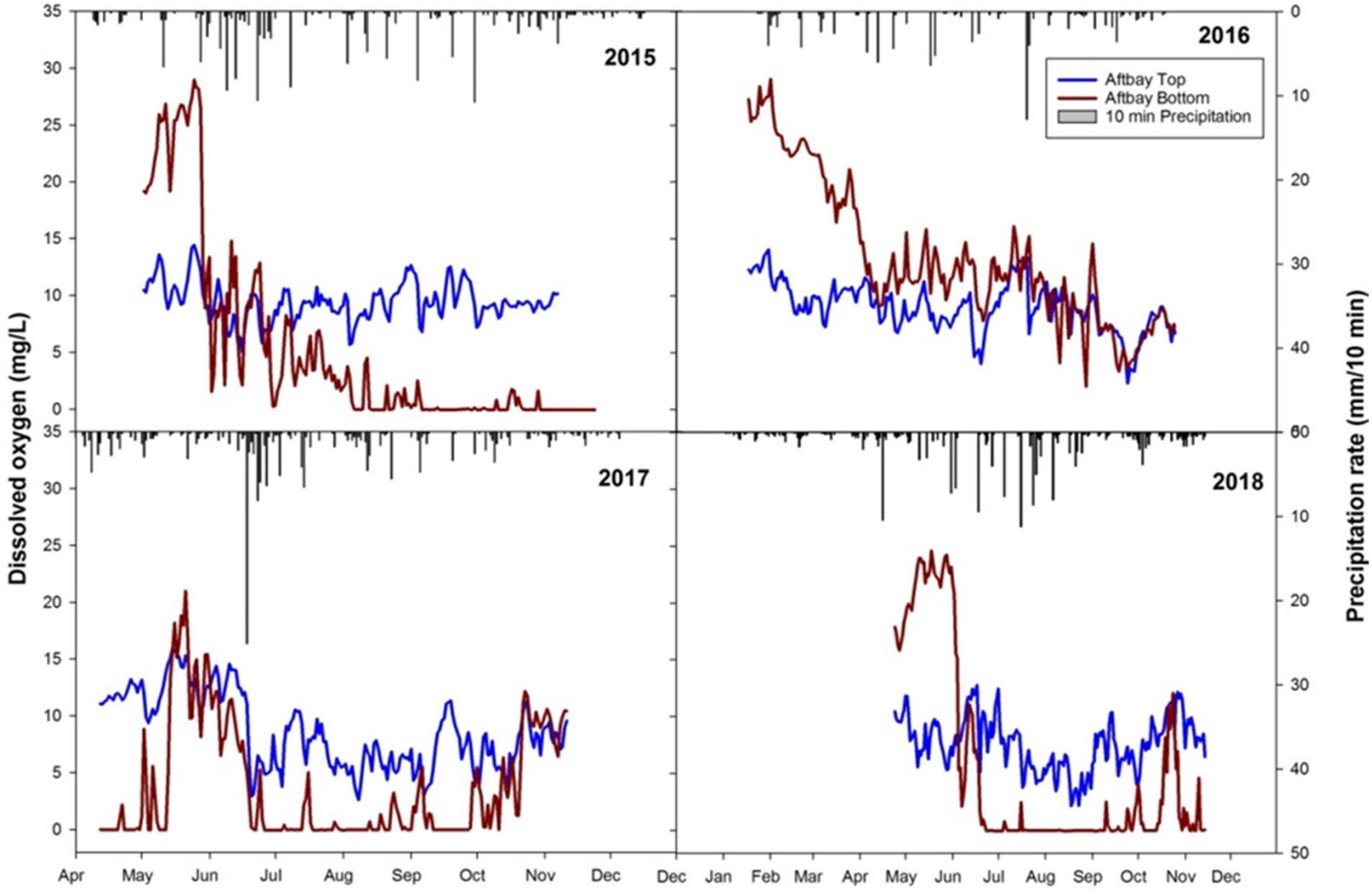


Implications of Persistent Stratification: Volume Reduction

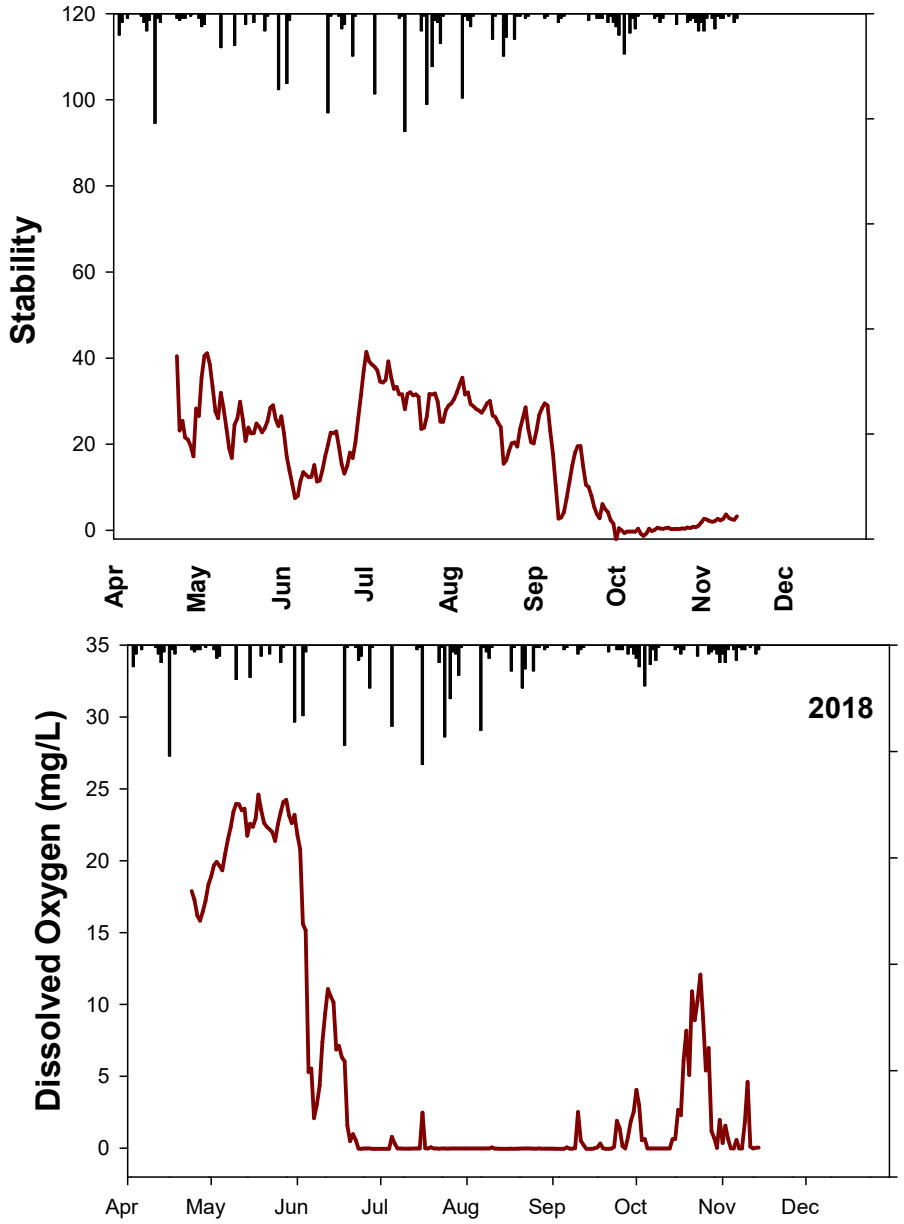
- Active volume reduction by 70-75%
- Can last for up to 8 months! November to June
- Aftbay more resistant to mixing
- Less TSS treatment (?)



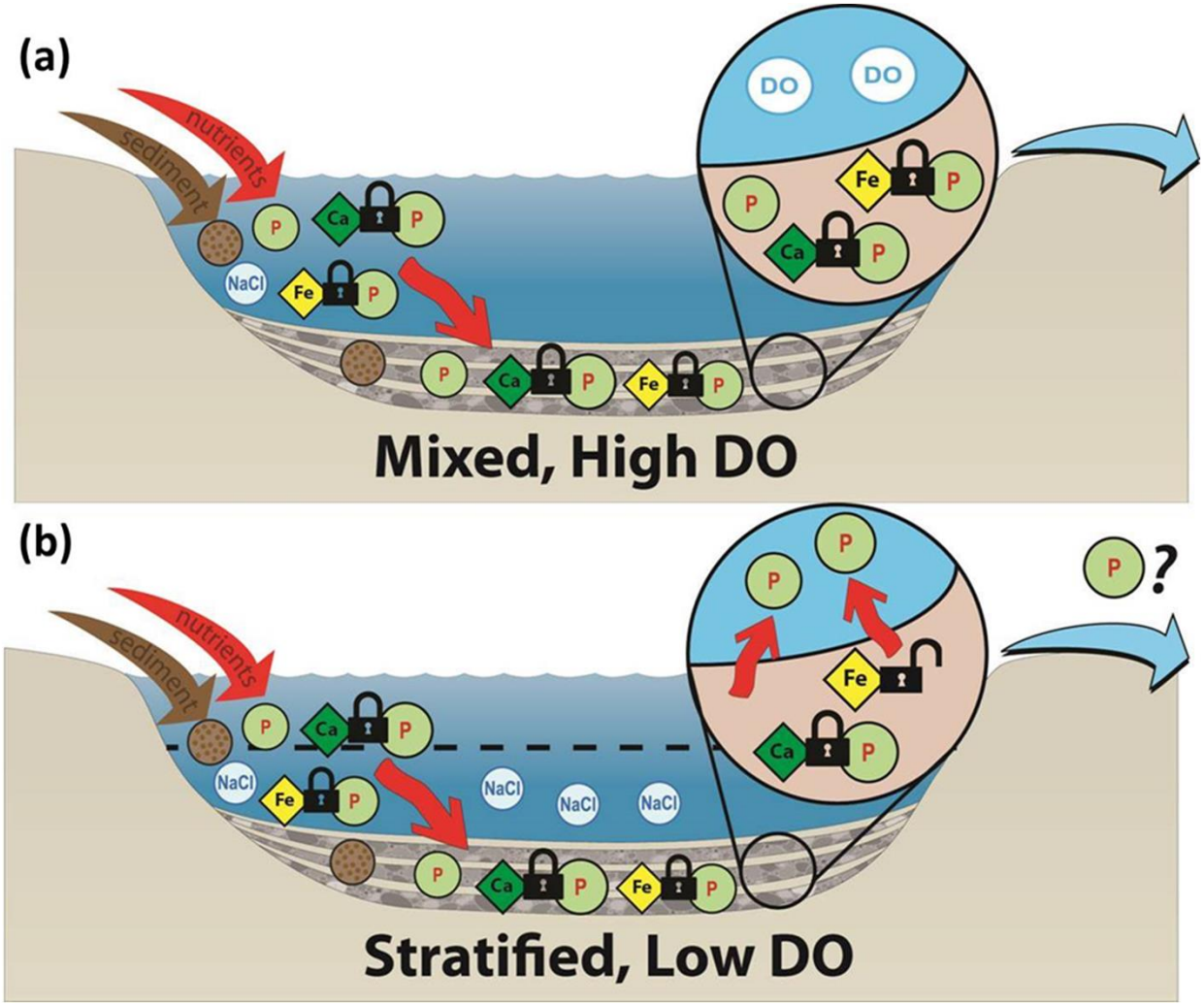
Implications of Persistent Stratification: Low Dissolved Oxygen



Site C aftbay: 2018 Stability vs bottom DO



Implications of Persistent Stratification: Low DO=Phosphorus Release



Implications of Persistent Stratification: Purple-sulphur bacteria

Implications of Persistent Stratification: Odour and Aesthetic complaints

So… What can we do?

- Aeration / mixing:
  - Bubblers or windmills to circulate water column
  - Need bottom circulation
  - Prevent anoxia and P release

  - De-stratify pond but… re-suspend particles
    - (whole reason we built the ponds in the first place!)
    - And some ponds release P under oxygenated conditions anyway

So… What can we do?

- Enhance Wind exposure
  - Ponds at low elevation and sheltered
  - Strategic tree / vegetation cutting? (phragmities)
  - Enhance wind fetch in design

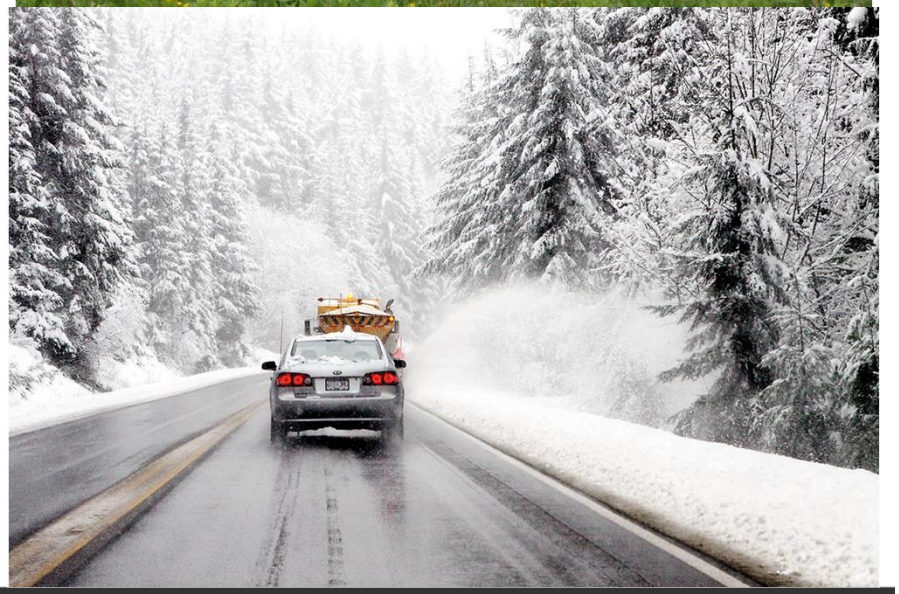
So… What can we do?

- "harvest" phosphorus
  - Harvest aquatic plants / reeds and rushes?
  - Uptake P, then remove and compost in fall?
  - Would become annual requirement moving forward

- Chemical treatment of Sediment
  - P binders: alum, Phoslock, iron
  - Expensive and likely require repeated dosing

So… What can we do?

- Time to maintain the pond / remove sediments
- Sources of salt and better salt application practices
- Consider future changes to catchment hydrology (LID retrofits)




Questions?

More details:

Technical report in the STEP resource library:

Assessing Stormwater Management Pond Performance Study

Lake Simcoe Region Conservation 2020 | *Reports*

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