

# **Projecting Long-Term Chloride Concentrations in Lake Simcoe - Where Are We Likely to Be by 2100?**

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# Road salt use continues to drive up Lake Simcoe Cl levels

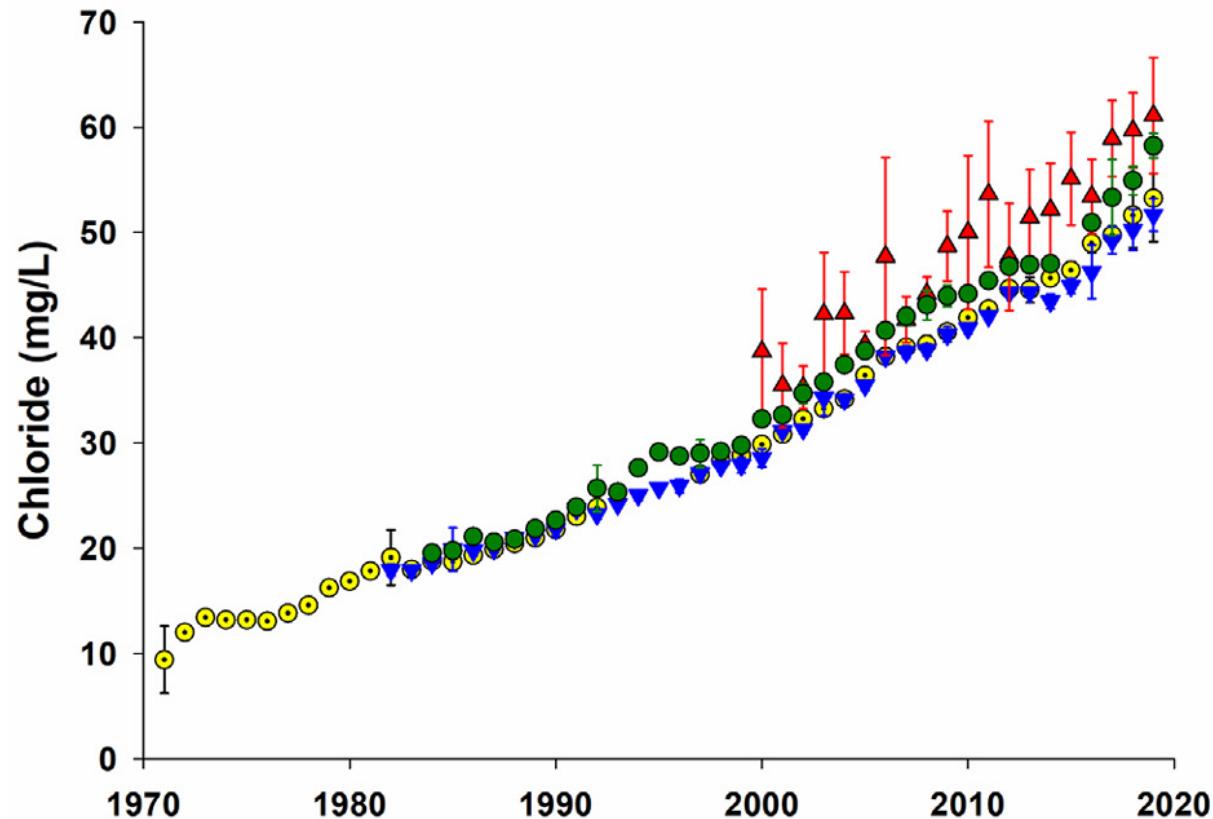
**Project goal: Use a simple mass balance model and a simple watershed model to assess future conditions of Lake Simcoe with respect to Cl concentration.**

CCME has suggested a chronic guideline of 120 mg/l.

Hintz et al. (2022) show 120 mg/l may not be sufficiently protective, so we also examine 80 mg/l.



Barrie Today



Sorichetti et al., 2022 JGLR

When will Lake Simcoe surpass 120 mg/l?



LSRCA

# Mass Balance Model

$$C_s(t + 1) = C_s(t) + \frac{1}{V_s} \left[ \underbrace{\sum_{u \in U(s)} Q_u C_u(t)}_{\text{Inflow from upstream segments}} + \underbrace{\beta_s(t) (W_s(t) + B_{in,s}(t))}_{\text{Watershed load}} + \underbrace{E_{net,s}(t)}_{\text{Exchange with neighboring segments}} - \underbrace{Q_s C_s(t)}_{\text{Outflow to downstream segments or outlet}} \right]$$

Inflow from upstream segments

Watershed load

Exchange with neighboring segments

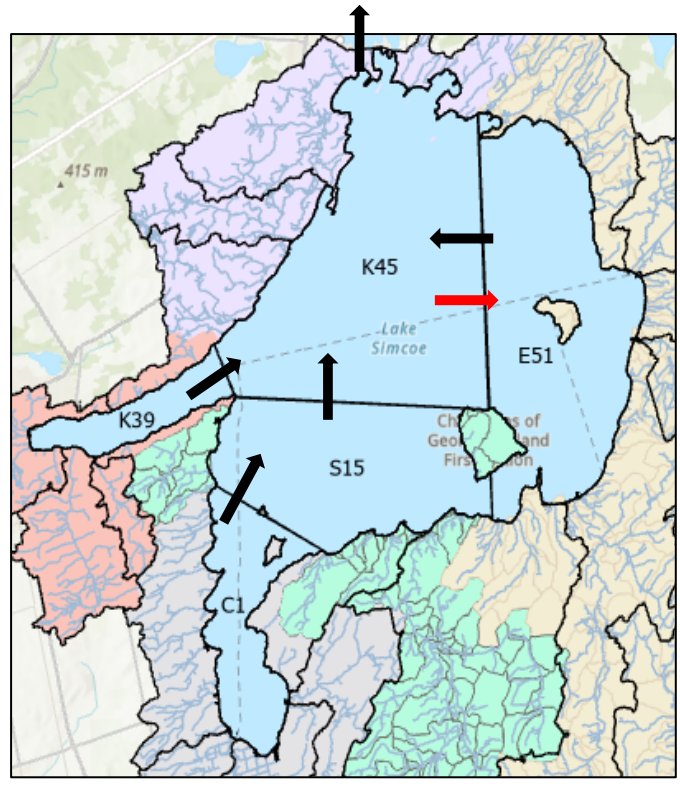
Outflow to downstream segments or outlet

Annual timescale model built on principles of **conservation of mass**, not on statistical trends.

Lake is divided into 5 compartments. This equation describes the concentration of Cl<sup>-</sup> in each.

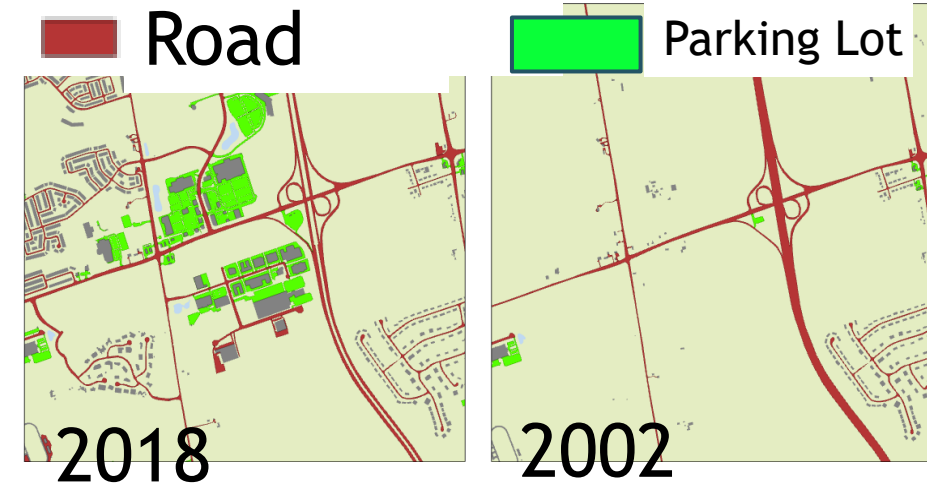
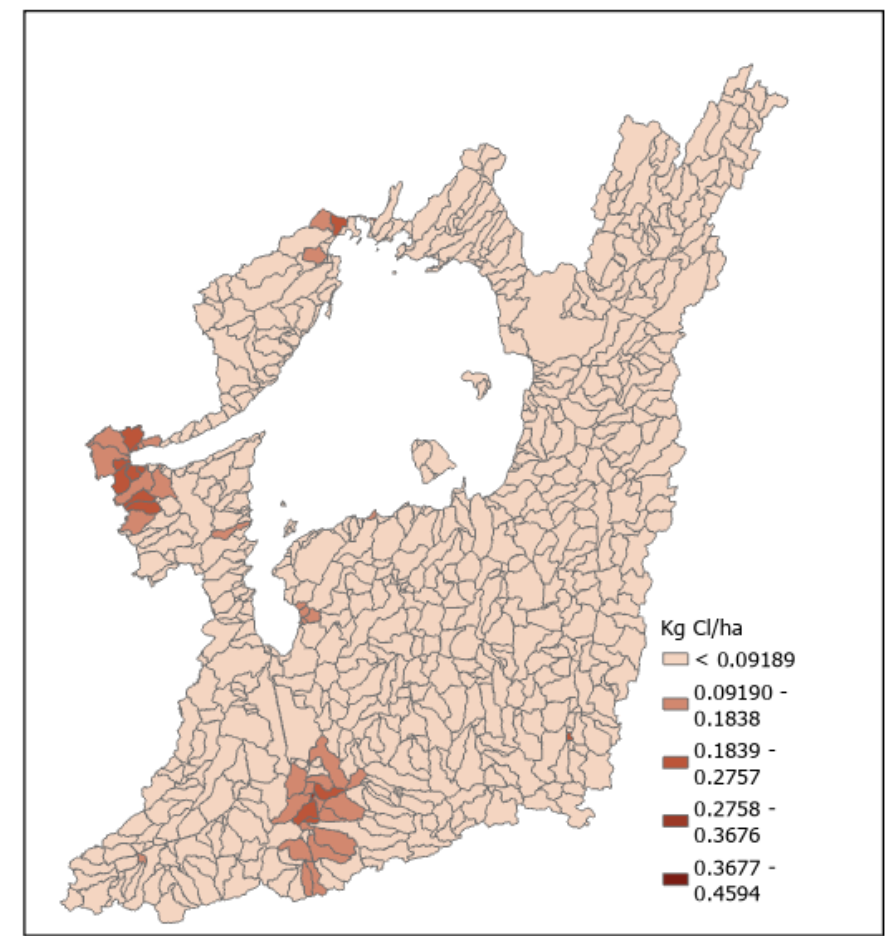
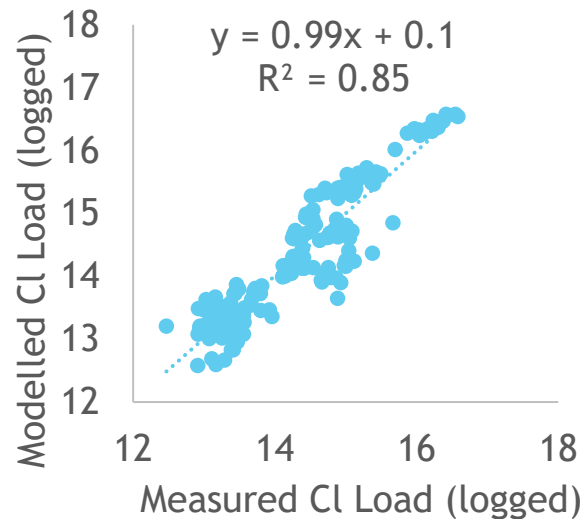
‘Bypass’ from upstream segments

- $C_s(t+1)$ : Chloride concentration in segment s at time t+1
- $C_s$ : Chloride concentration in segment s at time t
- $V_s$ : Segment s volume
- $Q_s$ : Segment s outflow
- $Q_u$ : Upstream segment u outflow
- $W_s$ : Terrestrial Cl load to segment s
- $B_{in,s}$ : Bypass mass arriving from immediate upstream
- $\beta_s \in [0,1]$ : Local mixing (retention) fraction of  $(W_s(t) + B_{in,s}(t))$
- $E_{net,s}$ : Lateral exchange (positive = net gain)

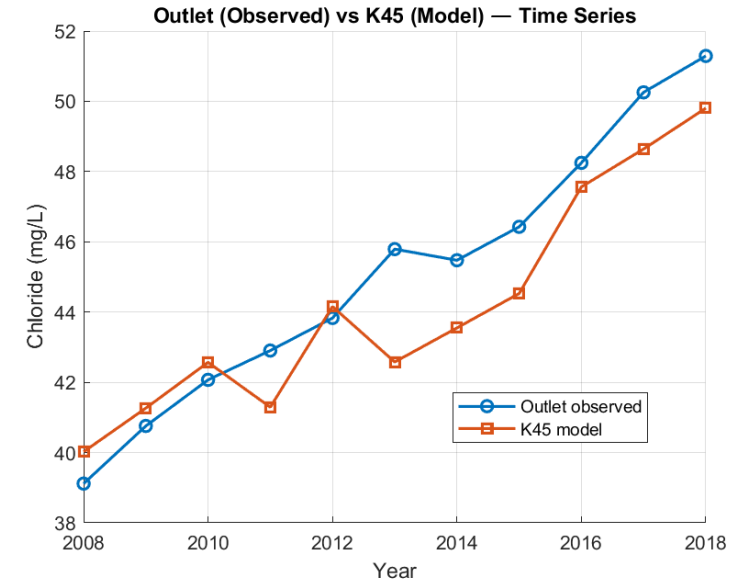
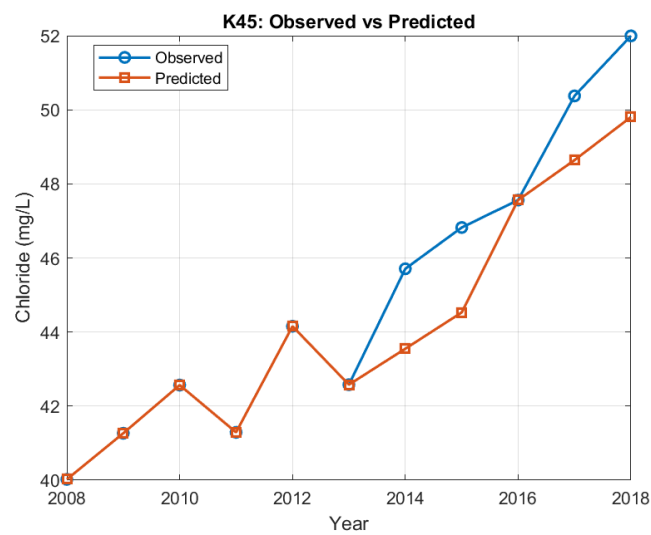
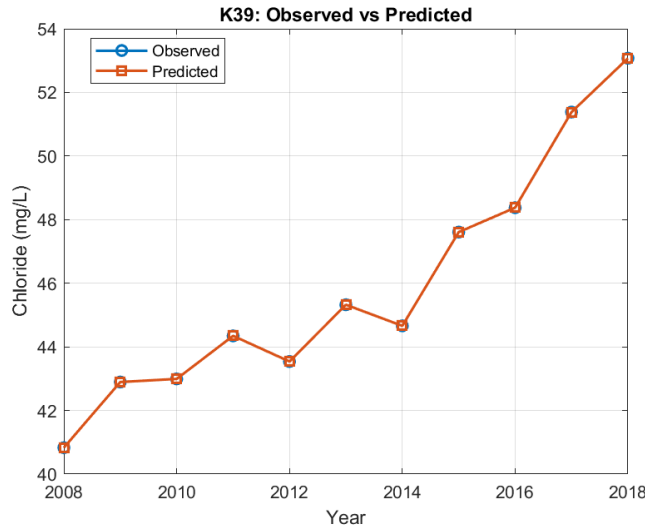
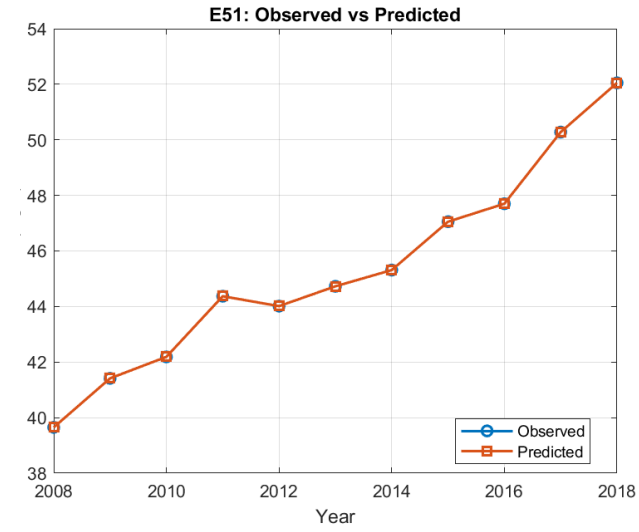
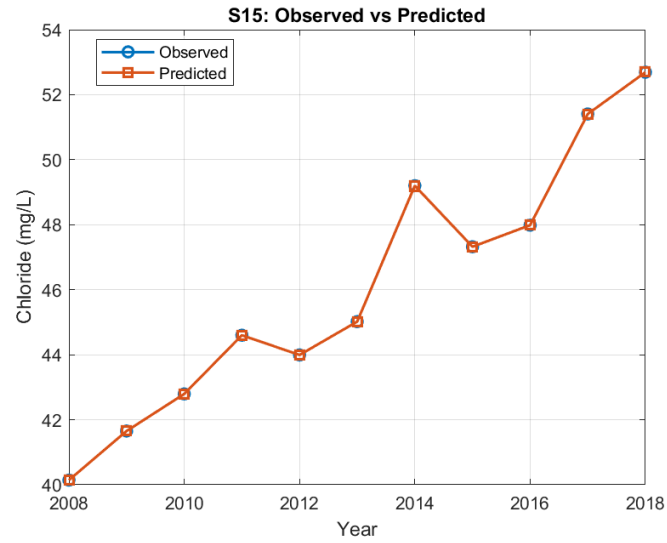
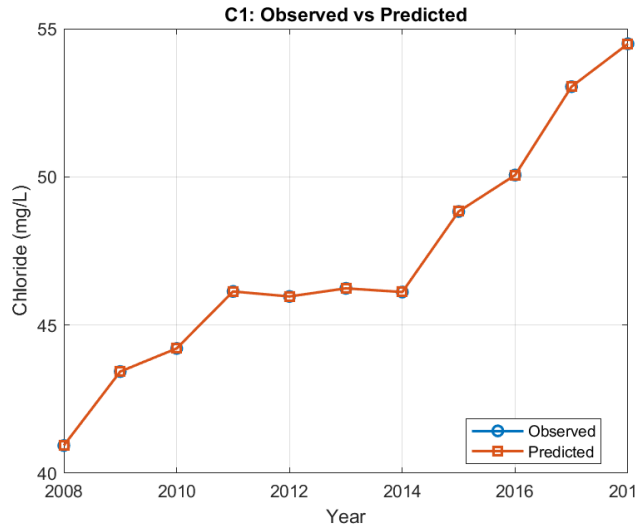


# Estimating CI source areas

- ▶ Annual export coefficient model fit to 16 flow/water quality monitoring stations and land cover maps for 2002, 2008, 2013, 2018.
- ▶ Calibrated export coefficient averages:
  - ▶ Natural land: 0.001 kg/m<sup>2</sup>
  - ▶ Roads: 0.66 kg/m<sup>2</sup>
  - ▶ Parking Lots: 1.22 kg/m<sup>2</sup>



# Lake Mass Balance Model Fits

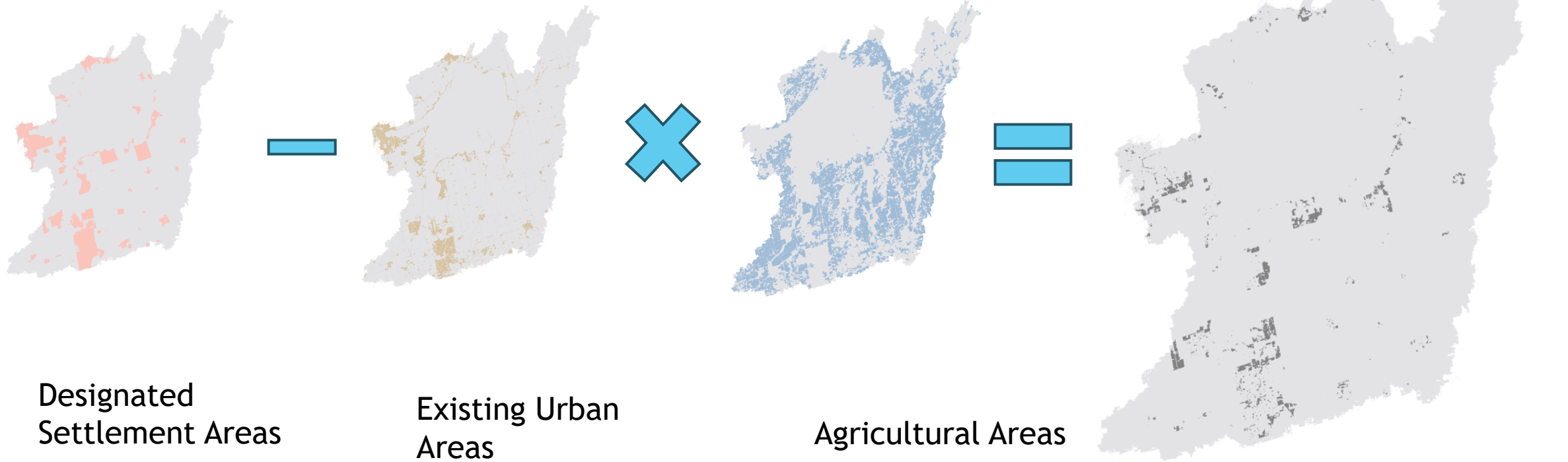


Segment	<i>NSE</i>
C1	1.00
K39	1.00
E51	1.00
K45	0.88
S15	1.00
Outlet	0.82

*NSE* (Nash-Sutcliffe Efficiency) ranges from 0 - 1 (terrible - perfect)

**Model showed good fit from 2008 - 2018**

# Build-out scenario



Designated Settlement Areas

Existing Urban Areas

Agricultural Areas

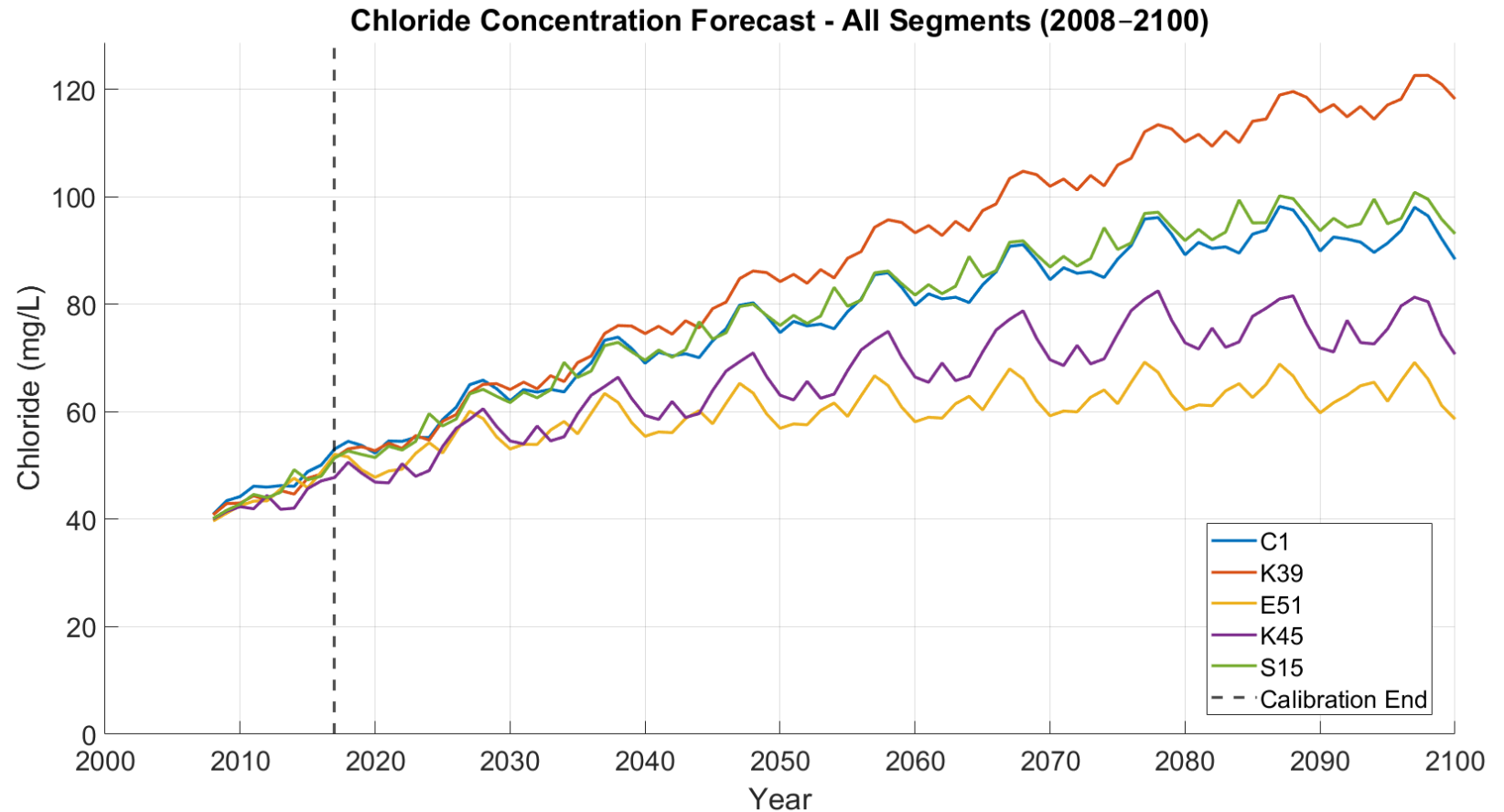
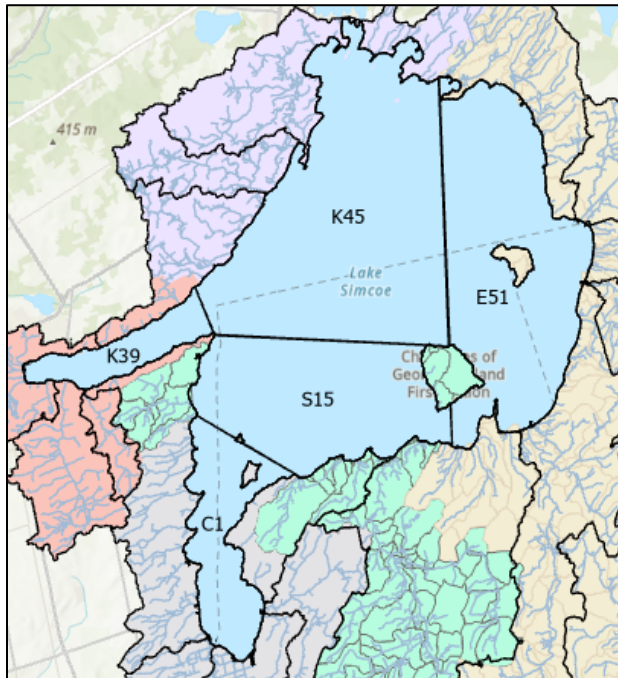
New Urban Areas

- ▶ New urban areas occur within existing settlement areas but on agricultural land.
- ▶ Assumed amounts of roads and parking lots equal to averages across Newmarket and Barrie

- ▶ **15% increase of road area**
- ▶ **34% increase of parking lot area**
- ▶ Note we assumed a time horizon of 2080 for this buildout to be complete.

# Build-out scenario

- **K39 (Kempenfelt Bay)** exceeds **80 mg/L** early in the century and reaches **120 mg/L** by **2088**.
- **C1 (Cook's Bay)** and **S15 (South Simcoe)** cross **80 mg/L** later in the century.

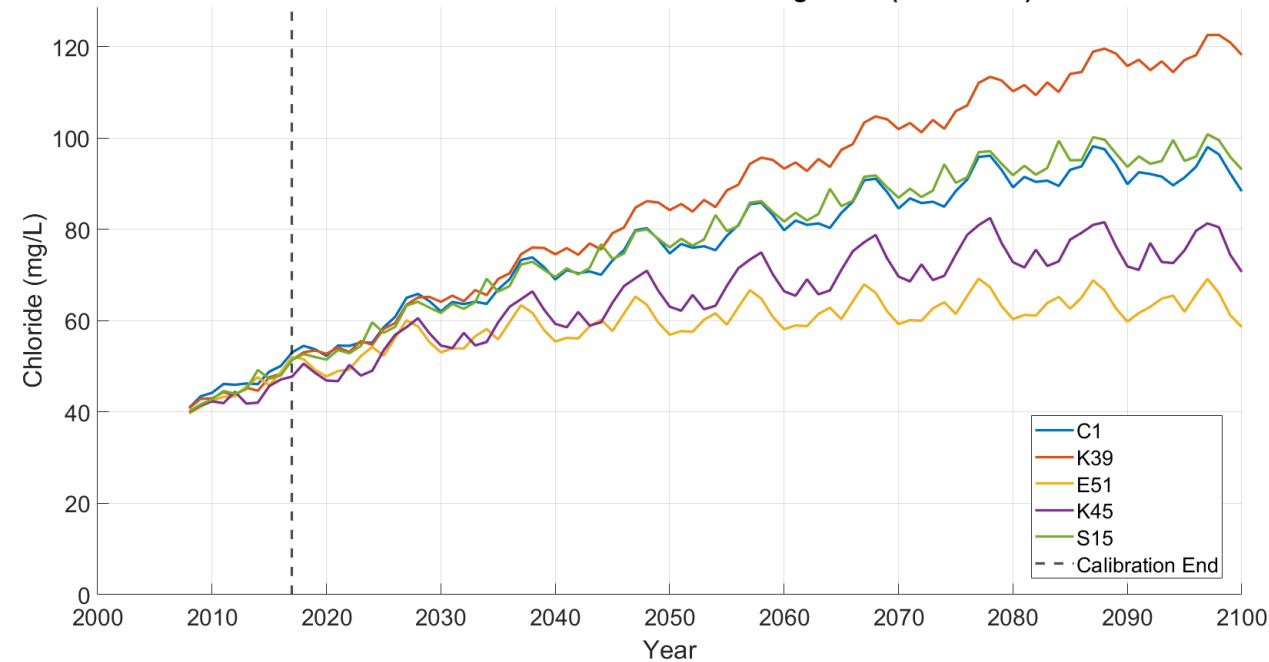


**By 2060 only the middle lake (K45 and E51) would be below 80 mg/L Cl.**

# Parking lot management scenario

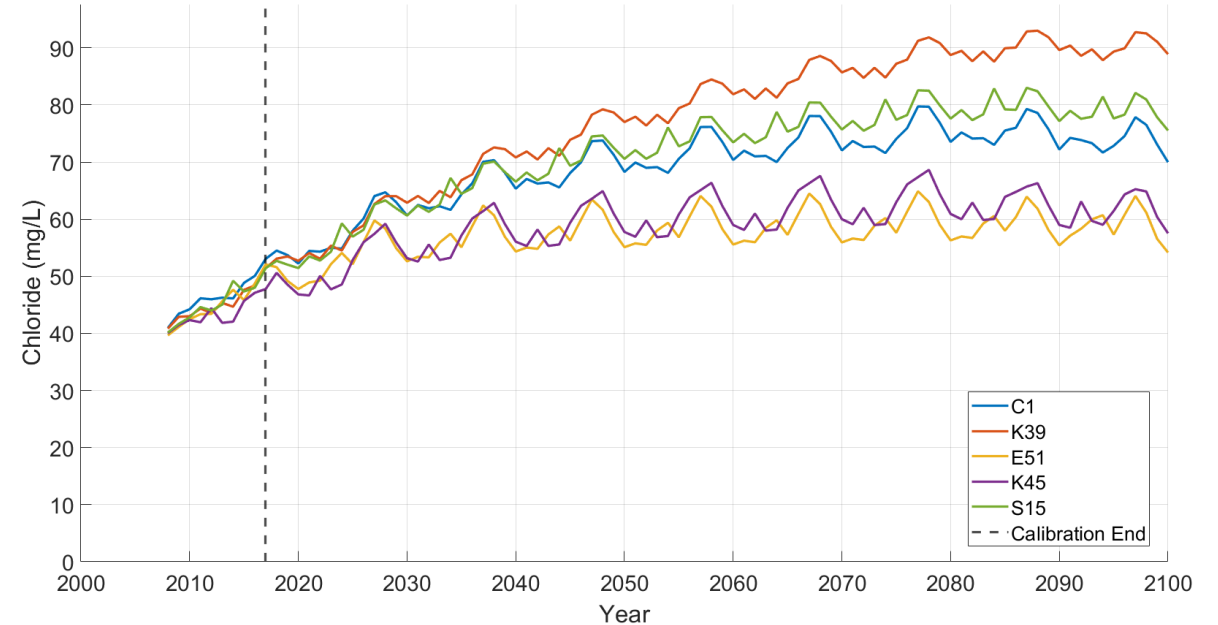
## Build-out Scenario

Chloride Concentration Forecast - All Segments (2008-2100)



## Parking lot Management Scenario

Chloride Concentration Forecast - All Segments (2008-2100)



- ▶ Our export coefficient for parking lots was about twice that for roads.
- ▶ Pilot studies have noted a reduction of nearly 50% of salt use when switching to brine instead of rock salt (Murison, 2023, Masters Thesis, Toronto Metropolitan University).
- ▶ We estimated the impact of reducing Cl export by 50% from parking lots.

- ▶ Decreasing parking lot Cl export by 50% does reduce in-Lake Cl concentrations substantially, though does not keep all segments below 80 mg/L

## Main Findings and future outlook

- **Build-Out** significantly amplifies chloride loads; **Kempenfelt Bay (K39)** can approach **110–120 mg/L**, and lake-wide averages rise to **~80–85 mg/L**. Note that this scenario was somewhat conservative, in that it was assumed that existing settlement areas do not expand, and take until 2080 to fully build out.
- **Improved Parking-Lot Management (50% cut)** substantially mitigates future increases, reducing late-century concentrations by **10–20 mg/L** compared to full build-out.
- Across all scenarios, **Kempenfelt Bay (K39)** remains the most sensitive segment, followed by **C1 (Cook's Bay)** and **S15 (South Simcoe)**, which also show strong long-term increases.
- Future work will account for climate change and further refine lake model, as well as examine more scenarios.

