Chloride In Northeast Illinois: Connecting Land Use to Contamination in Groundwater

NWPA February 2021

Cecilia Cullen and Devin Mannix
Illinois State Water Survey

Image credit:
Allan Scott Walker

About Us

Cecilia Cullen earned a masters of science in Geology at the University of Illinois in 2019 and now works at the Illinois State Water Survey. In the last year she's been part of a team developing the model discussed in this presentation.

Quarantine skill gained: can now make REALLY good French Onion Soup

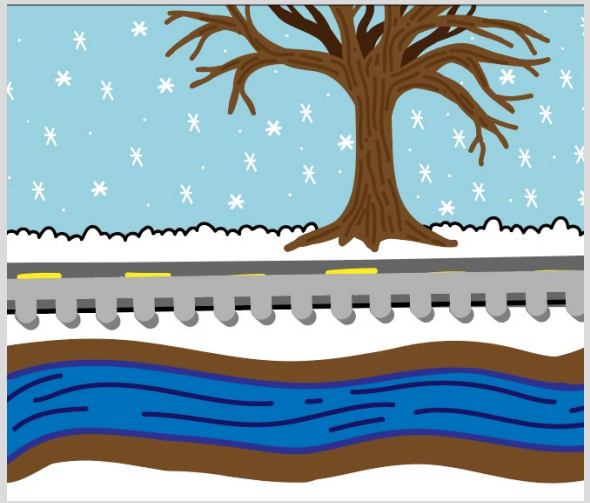
Devin Mannix earned a master of arts in Geology at Southern Illinois University Carbondale in 2013 and has since worked at the Illinois State Water Survey. He has most recently worked to understand how uncertainty influences model development and receptivity by stakeholders in the region.

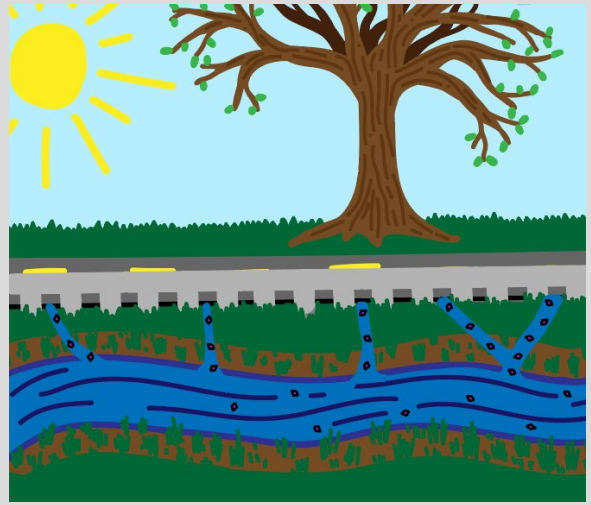
Quarantine skill gained: Learned how to build a computer

Part I. Motivation

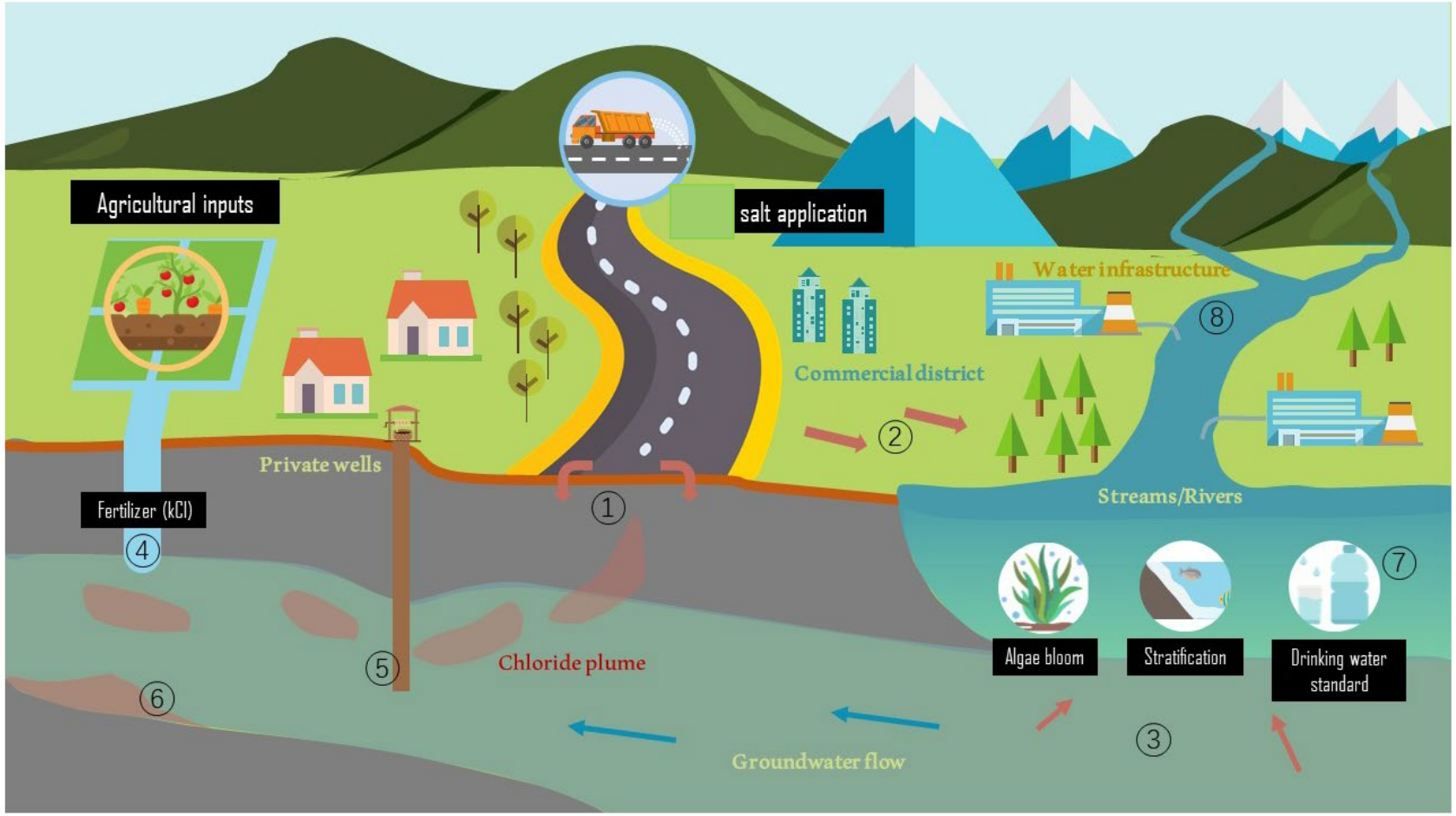
The Risk of Chloride

- The EPA secondary standard for chloride in drinking water is 250 mg/L, where water first tastes salty, 230 mg/L for chronic exposure, and 860 mg/L for acute exposure
- Chloride contamination can harm freshwater species and increase corrosive potential of water
- Chloride can originate from many human activities, but the most impactful is winter deicers





Sources of Chloride in the Landscape



1. Salt enters the aquifer through infiltration
2. Salt enters through snow melt runoff or discharge
3. Groundwater adds to river chloride
4. Chloride through agricultural inputs
5. Chloride concentrations impact private wells
6. Chloride builds up in aquifers
7. Chloride affects river water quality
8. High chloride concentrations in rivers increases costs of water treatment

Pu Xia, 2021

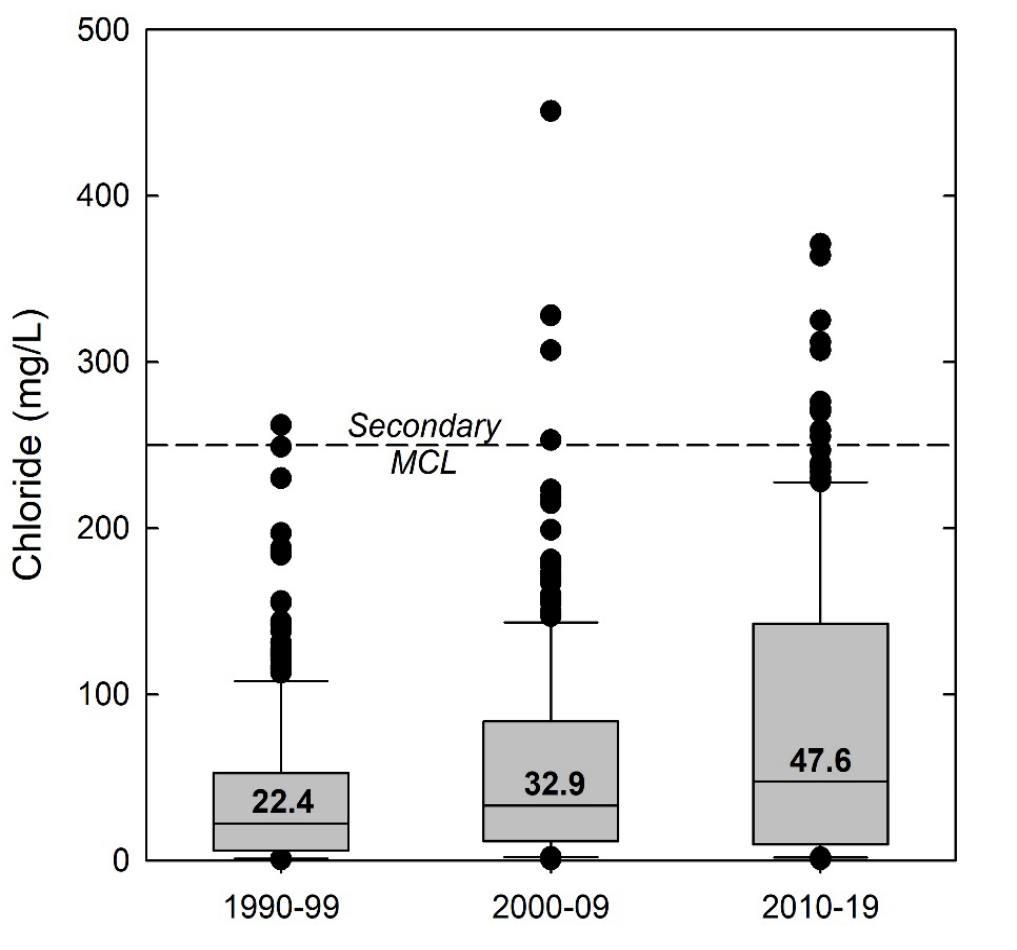
‘Road Salt’ is not the sole chloride contributor

In this presentation we refer to winter deicers as salt applied on all paved surfaces

Every winter in Illinois, many paved surfaces are deiced, not just roads.

While some of these sources will be smaller inputs than others, all winter deicers have the potential to reach groundwater

Calibrating Chloride: Concentrations through time



Observations for Will County:

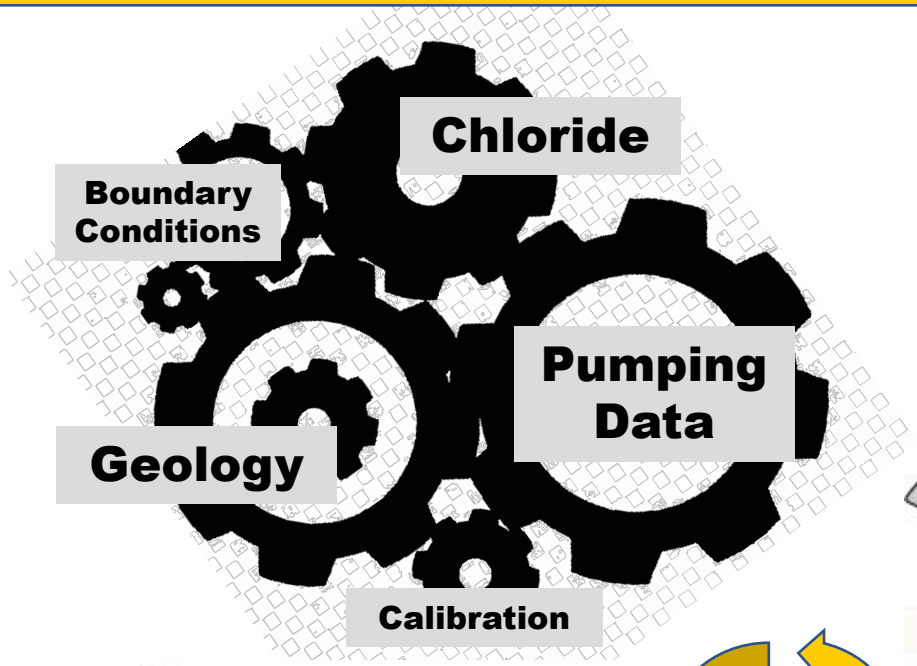
- The mean value of chloride concentrations in the region are steadily increasing over the past three decades
- Chloride sticks around once in the shallow aquifer
- Outlier measurements greatly vary, but the 90th percentile is close to surpassing the secondary standard of chloride

Figure credit: Walt Kelly, 2020 this data is from a IWWS IEPA database of community data

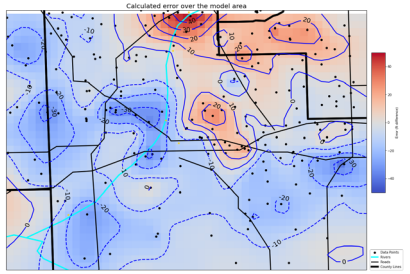
Will County Chloride Trends in Focus

1. Will County has mixed and changing land use over time, transitioning from domestic use and natural areas to increasing commercial and industrial land use
2. With deep groundwater demands in the region no longer sustainable, many groundwater users also concerned with rising treatment costs in shallow aquifers
3. ISWS has been working with the Southwest Water Planning Group (SWPG) to understand critical sources and uncertainty with chloride trends

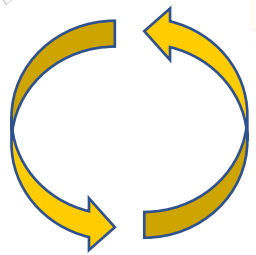
Participatory modeling as a means to increase model accuracy and legibility

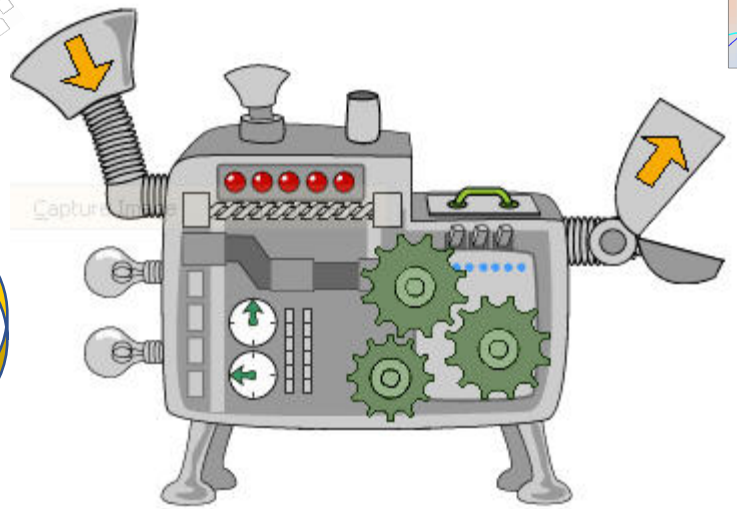


Results



Engagement with SWPG members





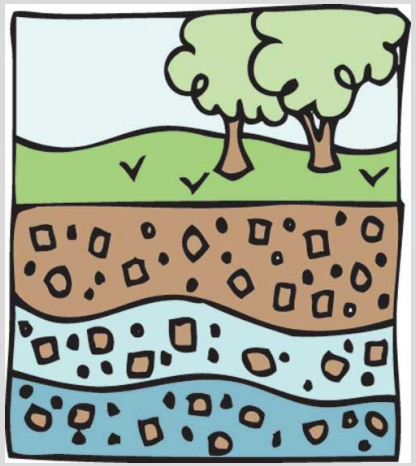
Iterative Modeling

Motivations

1. Understand what causes the rise in chloride concentrations over our thirty years of collected data
2. Given the current application of de-icers and projected future application, evaluate future chloride concentrations over the next three decades
3. Evaluate areas in Will County susceptible to chloride contamination

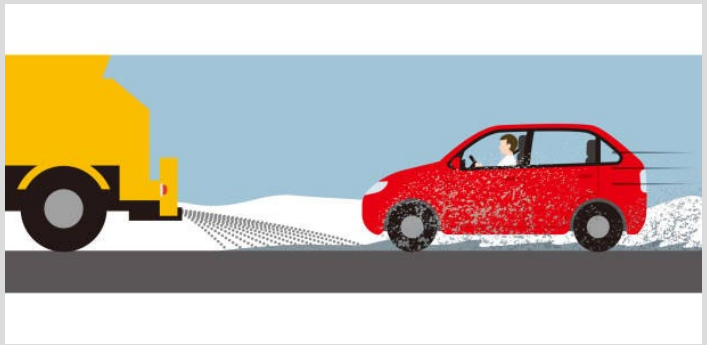
Our model has two components

FLOW
Understanding of how water levels within the shallow dolomite system change in the shallow model through time with community growth



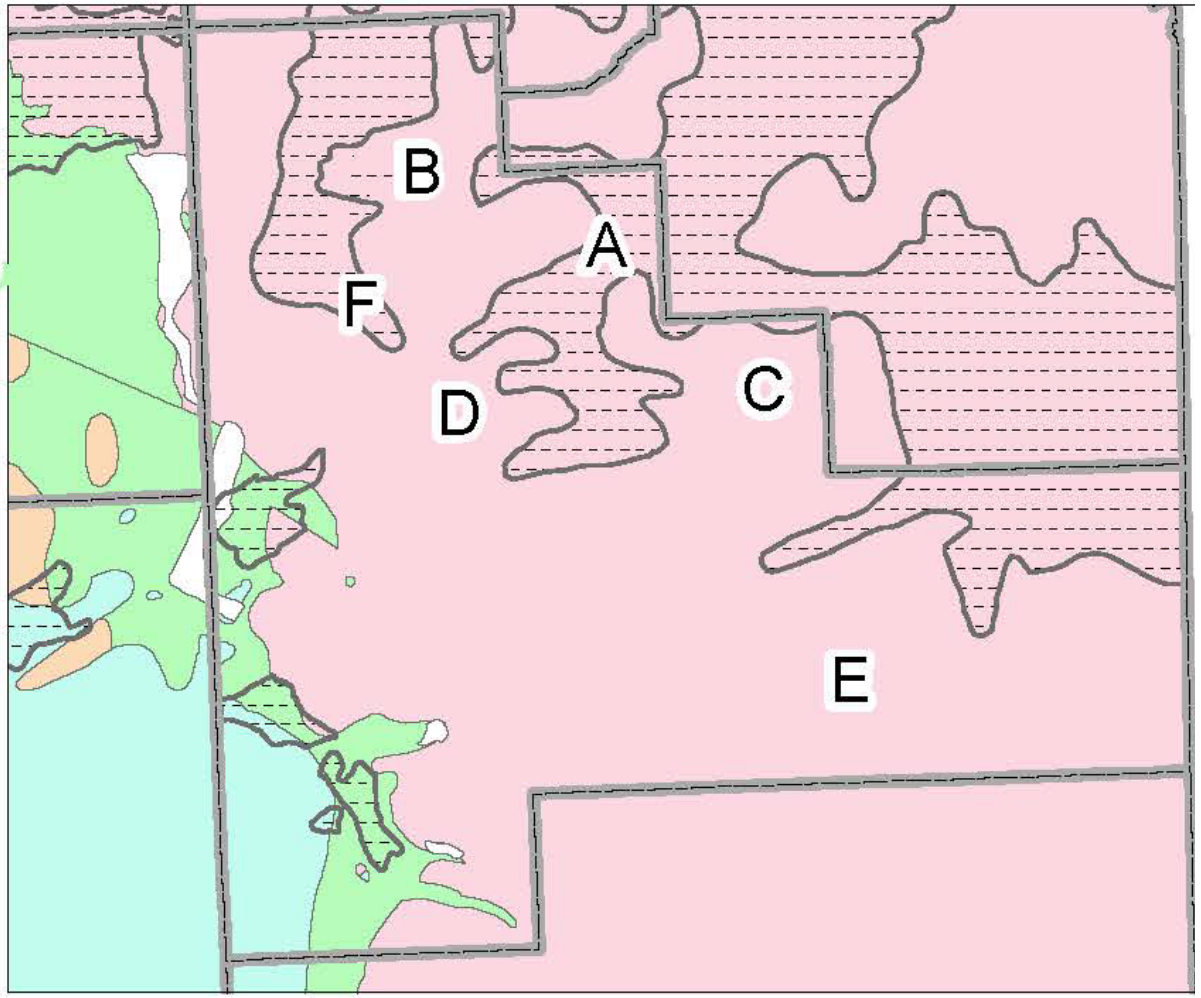
A model capable of simulating water levels and chloride transport

TRANSPORT
Measuring chloride build-up as a result of deicer application through time



Part II. Model Insights

Sample Wells and Geology



N

Legend

County lines

Major sand and gravel aquifers

Geologic Units

Galena-Platteville Carbonates

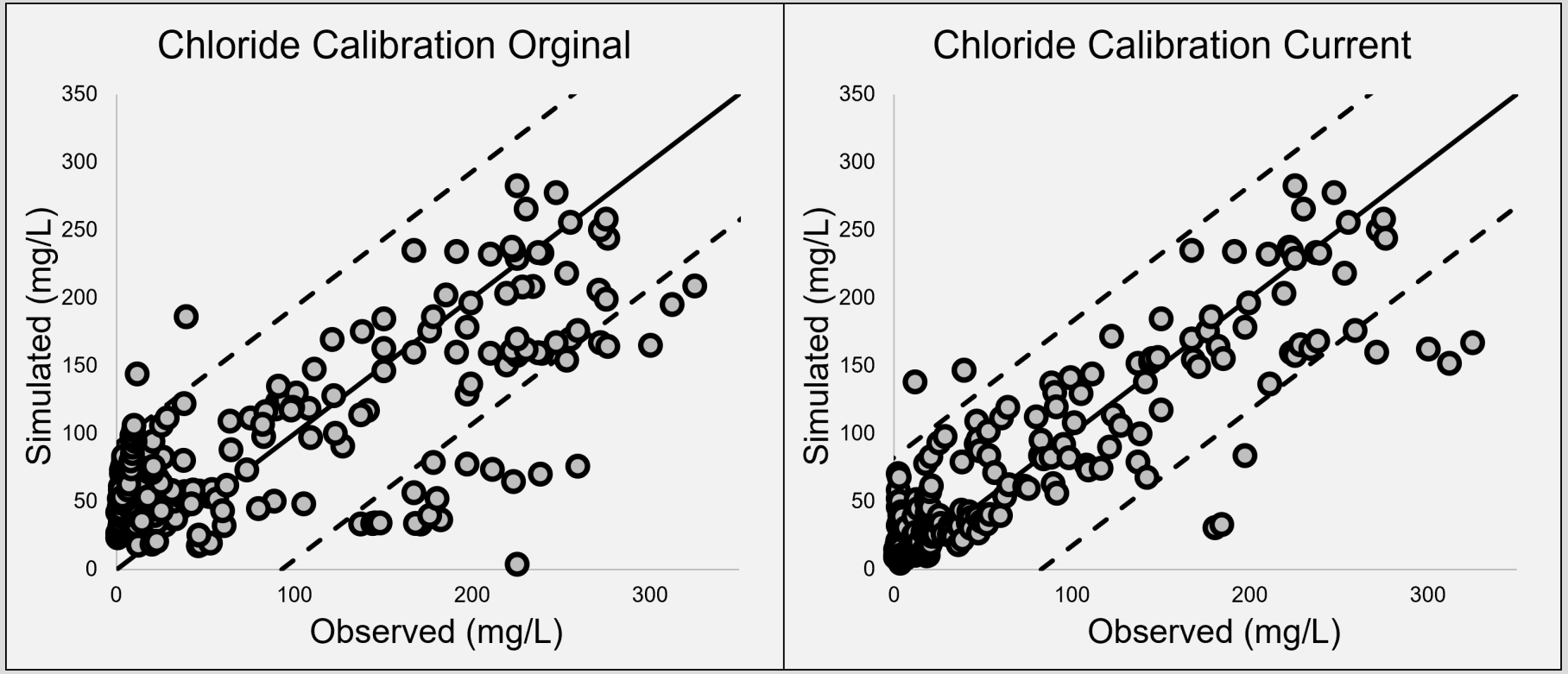
Maquoketa Shale Group

Pennsylvanian-Upper Devonian

Silurian-Devonian Dolomite

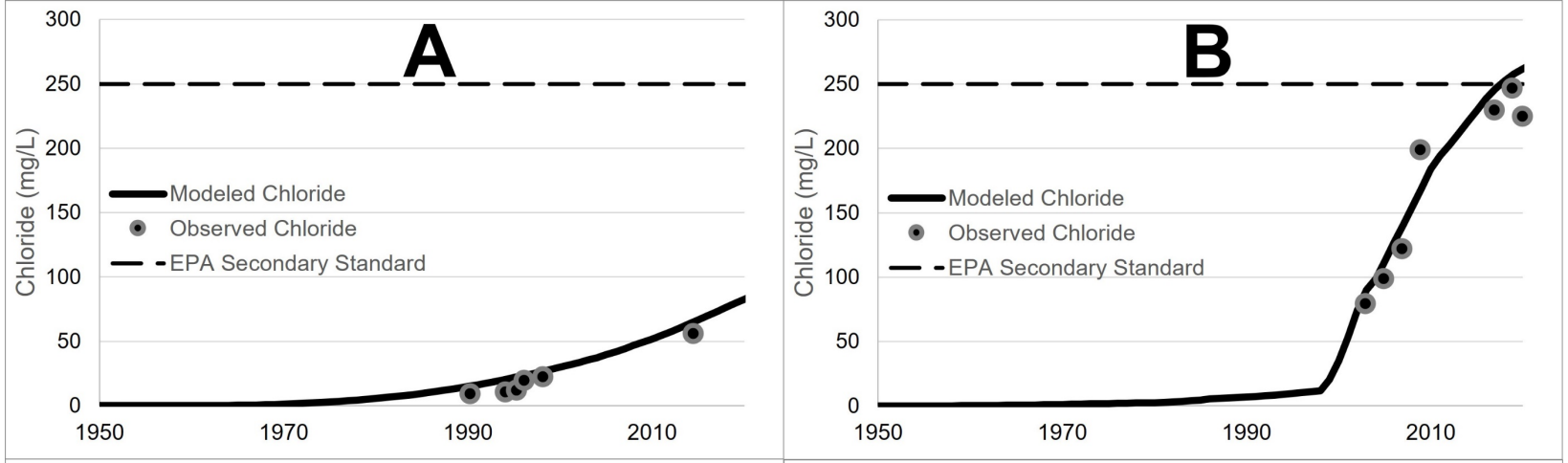
Geology is highly variable in Will County

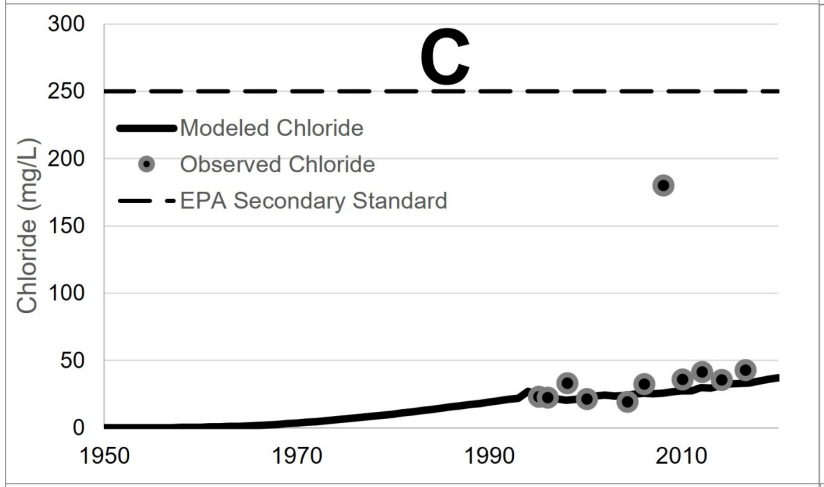
Model calibration to over 250 observations across Will County

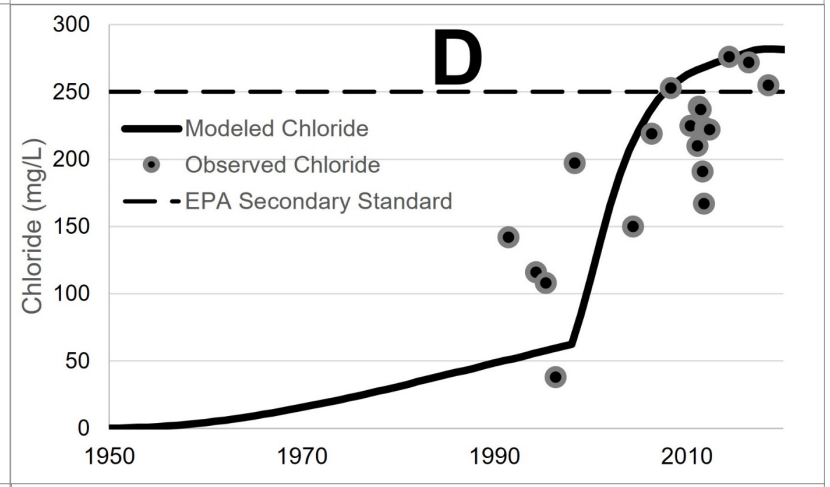


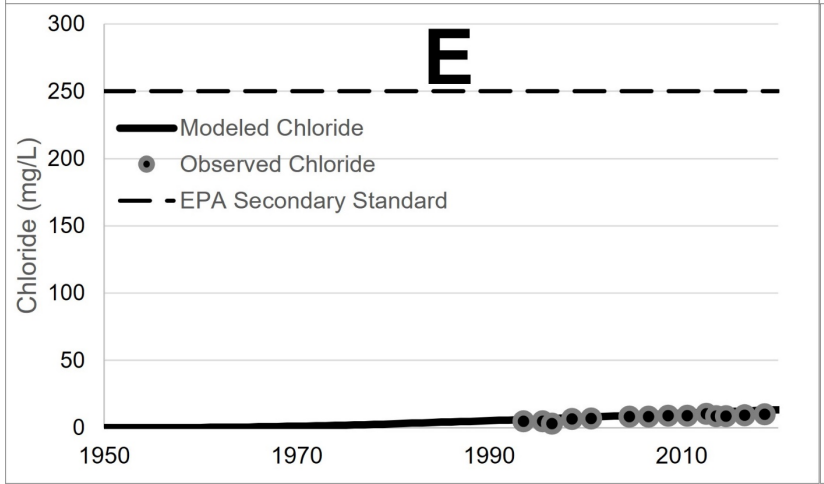
We were under-simulating chloride measurements in select places

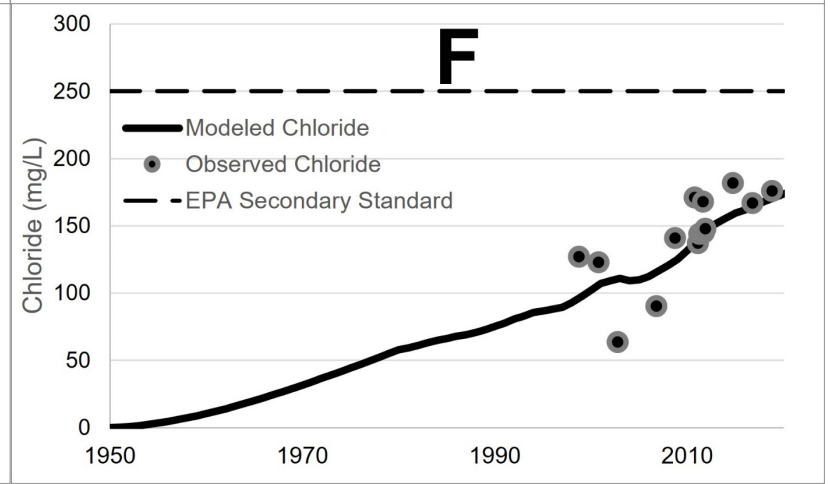
We need localized improvement

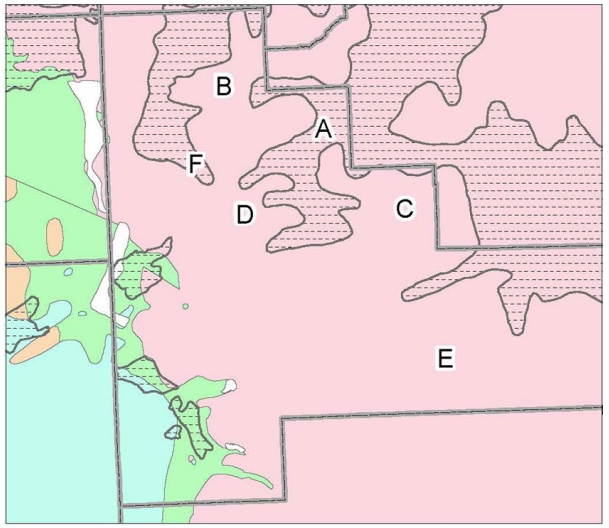












Our model results simulate chloride concentrations in wells with different depths and lithologies across Will County

What we did to improve the model

Consider Land Use

- Increase chloride concentration on lands associated with commercial/industrial purposes
- Decrease chloride applications on public roads and interstates

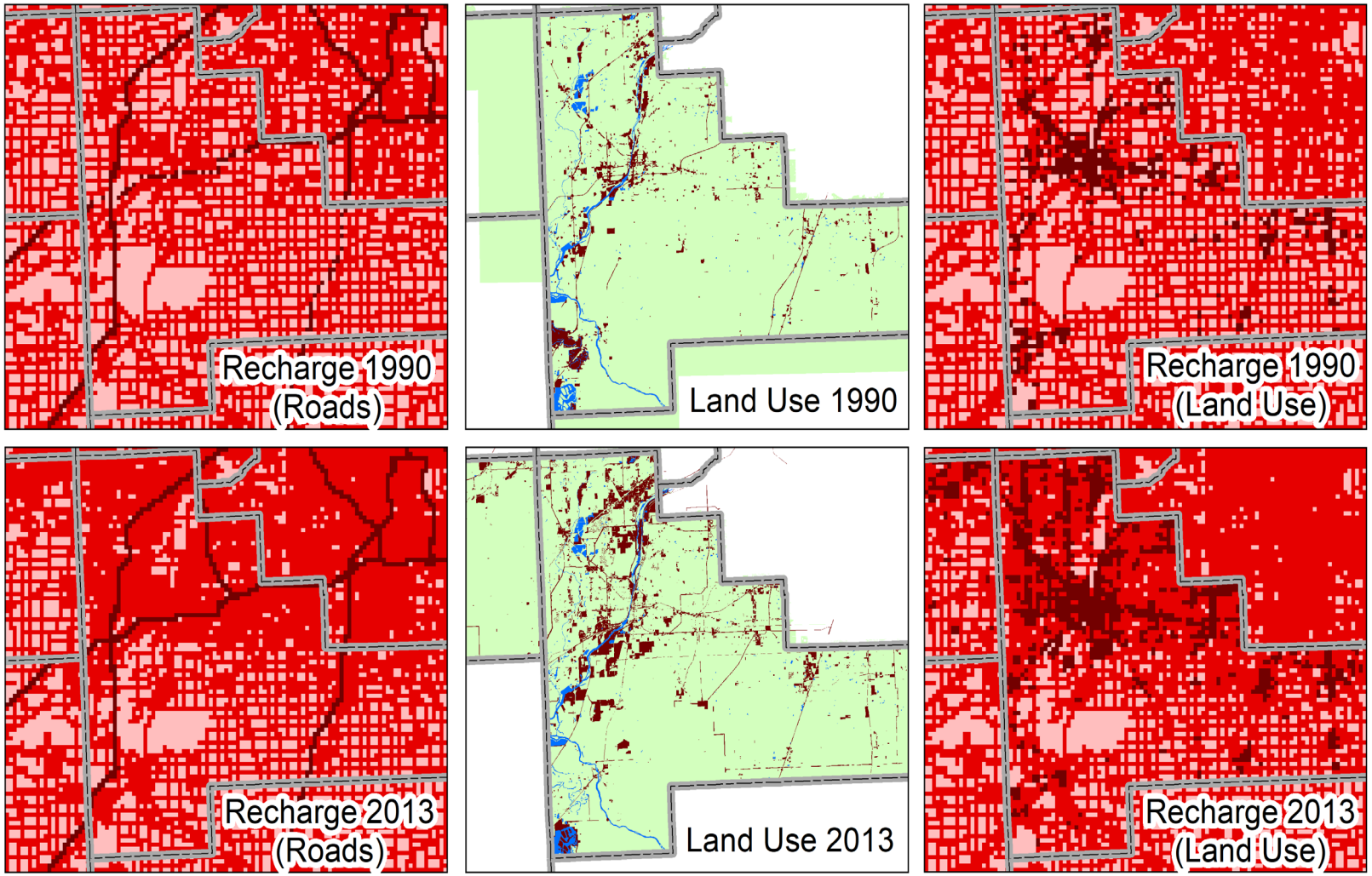
Refine Geology

- Use well logs to make sure our model was including enough gravel, sand, or clay for each well

Insert Point Sources

- At select areas, chloride concentrations jumped in the last 20 years
- To simulate this sudden rise, we created pathways in our model to speed chloride's emergence in the aquifer

Considering Land Use



County Line

Land Use

- Commercial/Industrial
- Residential/Agricultural
- Water

Recharge Zones

- Background
- Medium
- High

Considering Land Use

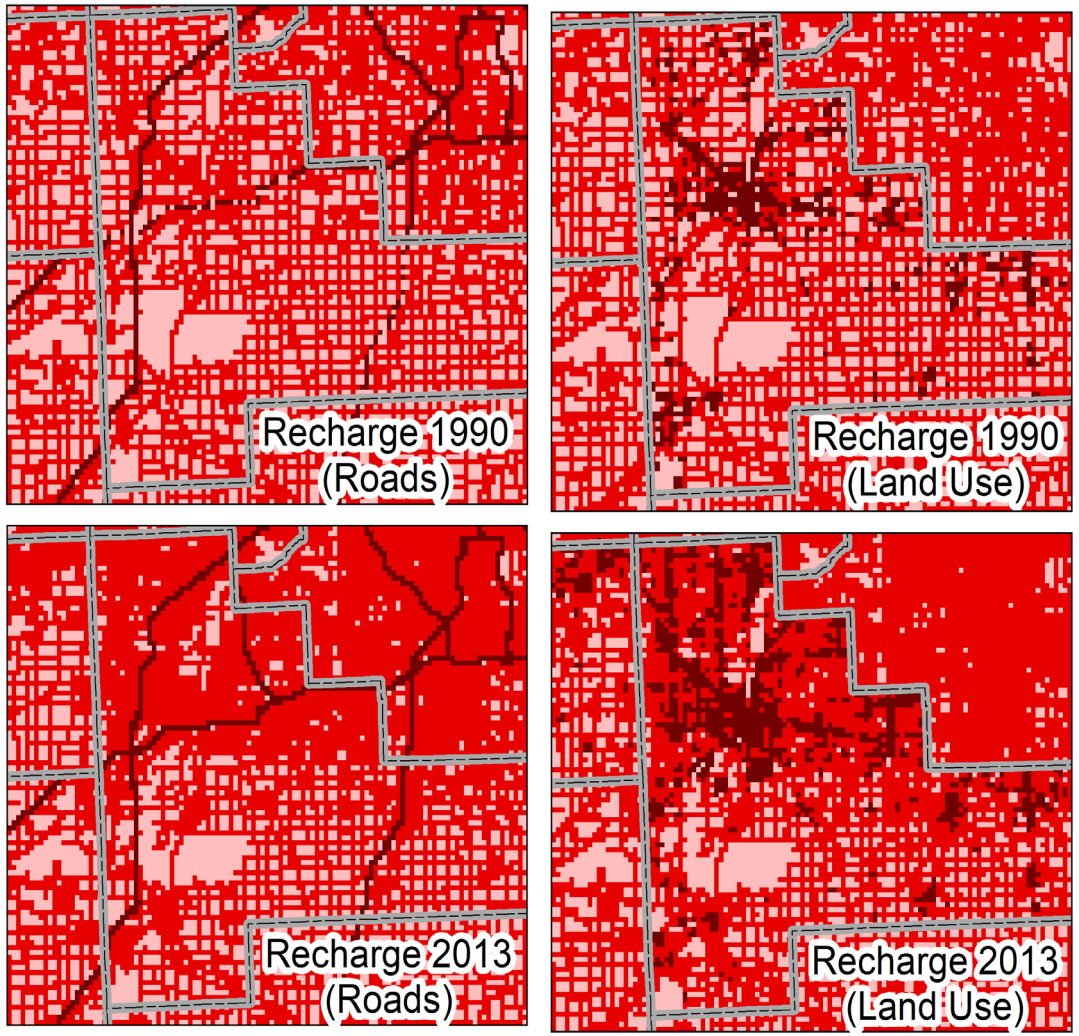


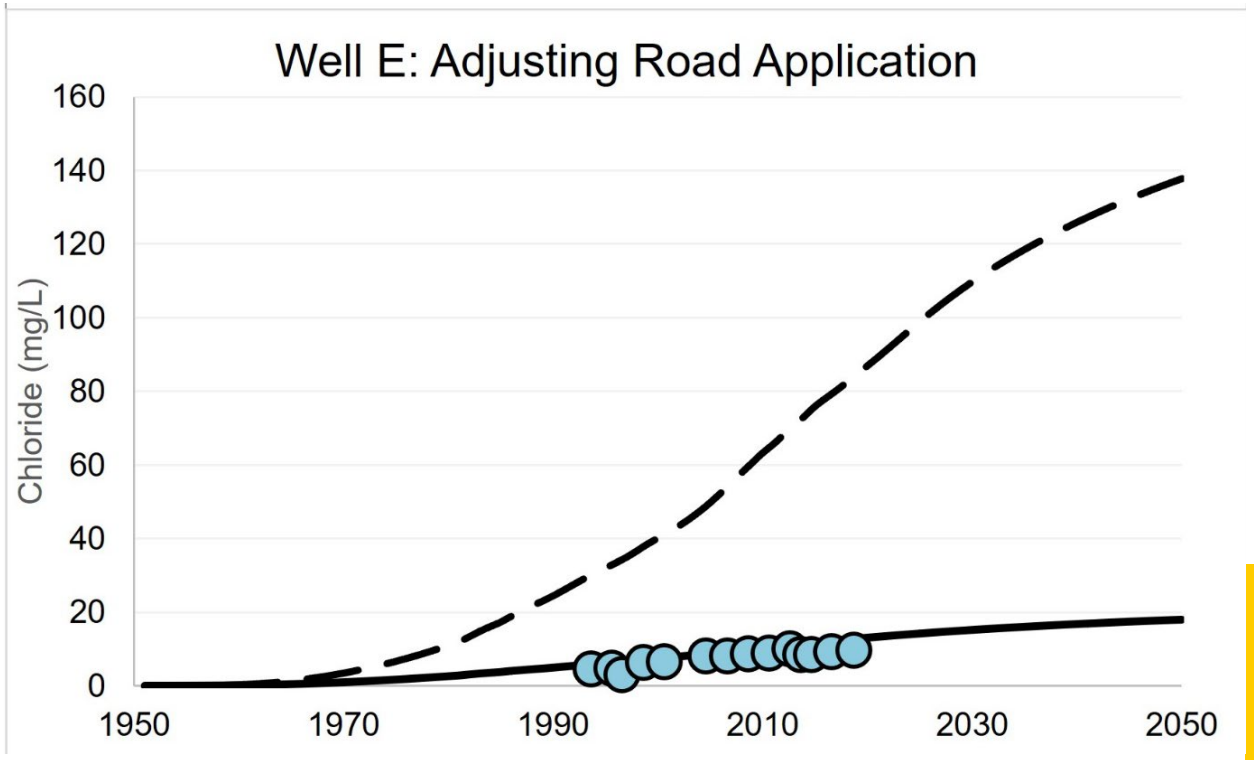
Table 1. Model inputs for surficial chloride injections

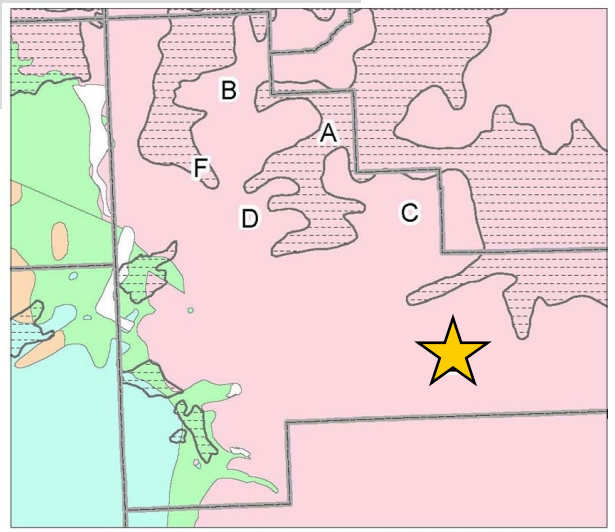
Land use corresponding with model cell	Road Networks Only Cl^- application mg/L	Land Use Hypothesis Cl^- application mg/L
Background	10	2.5
Roads	250	25
Interstates	500	25
Commercialized Areas	-	330
Point Source Areas	-	1500

Recharge Zones

- Background
- Medium
- High

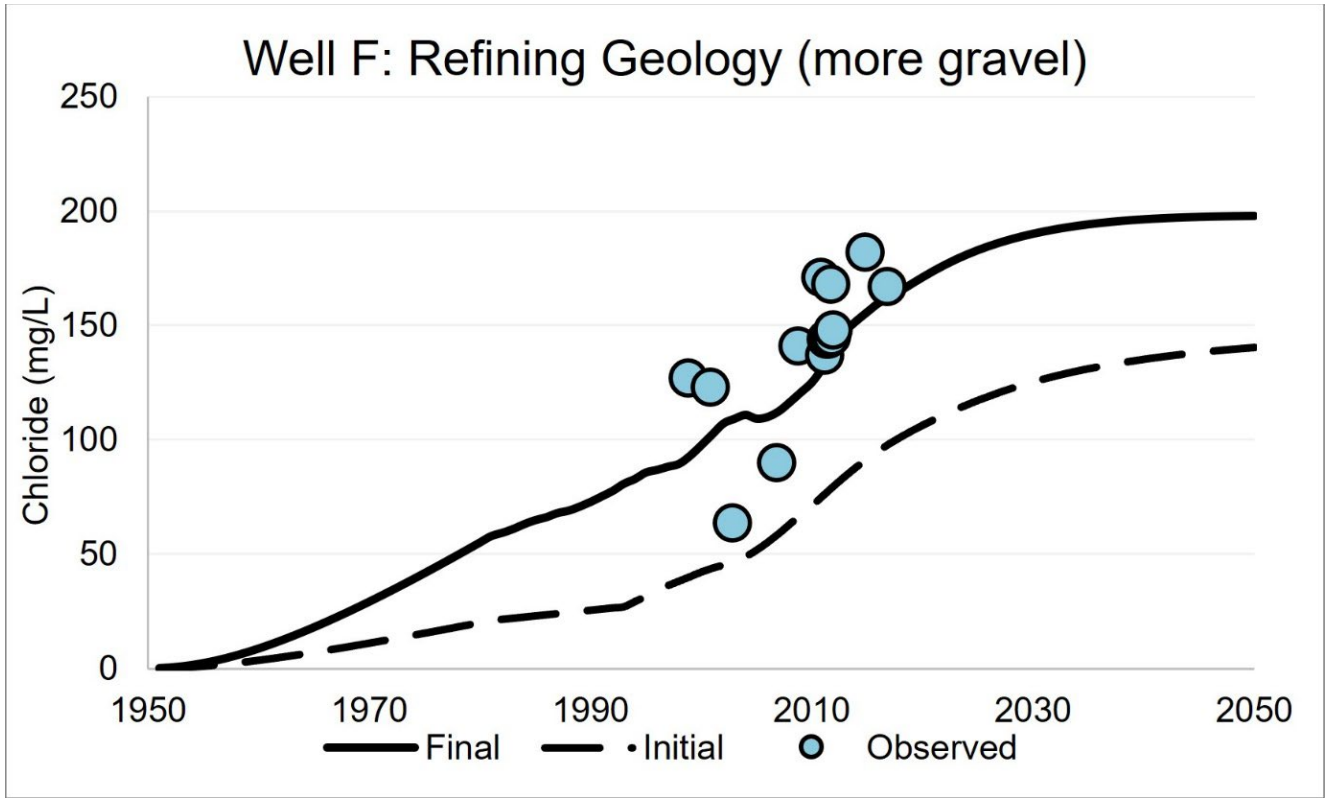
Considering Land Use

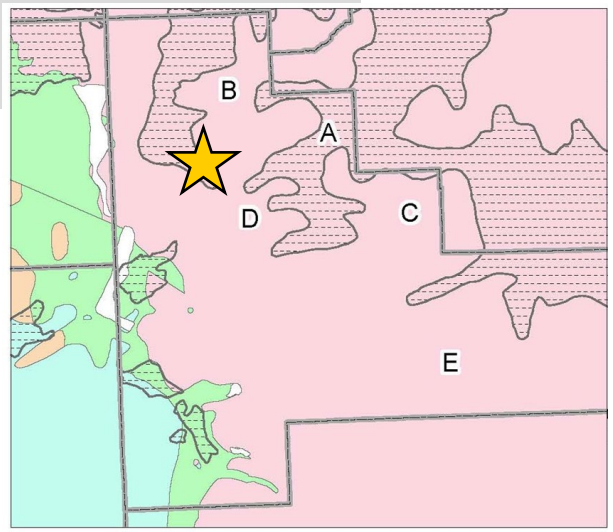




Well calibration improved when chloride application on roads was lowered

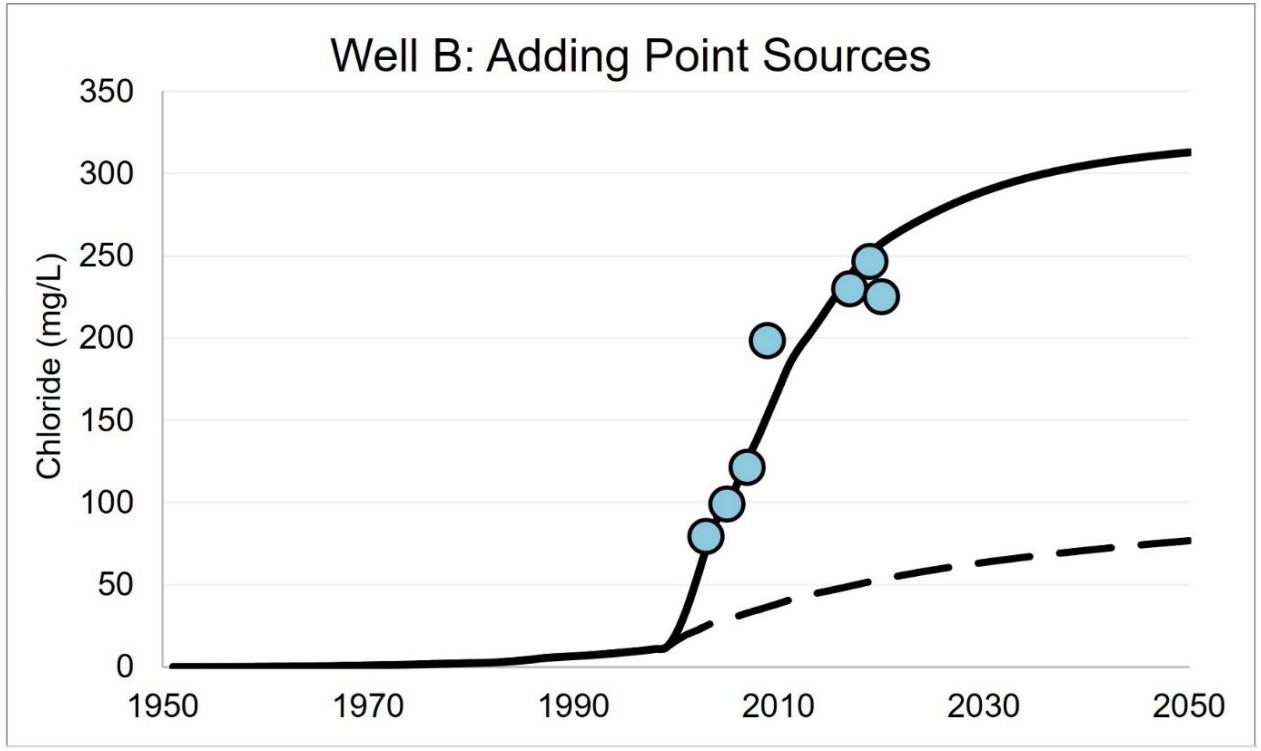
Refining Geology

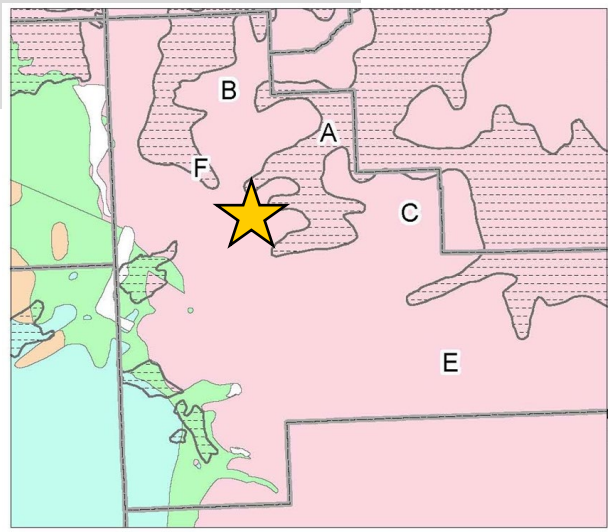




Well F calibration improved when we adjusted the model geology based on the well log

Adding Point Sources





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Background	10	2.5
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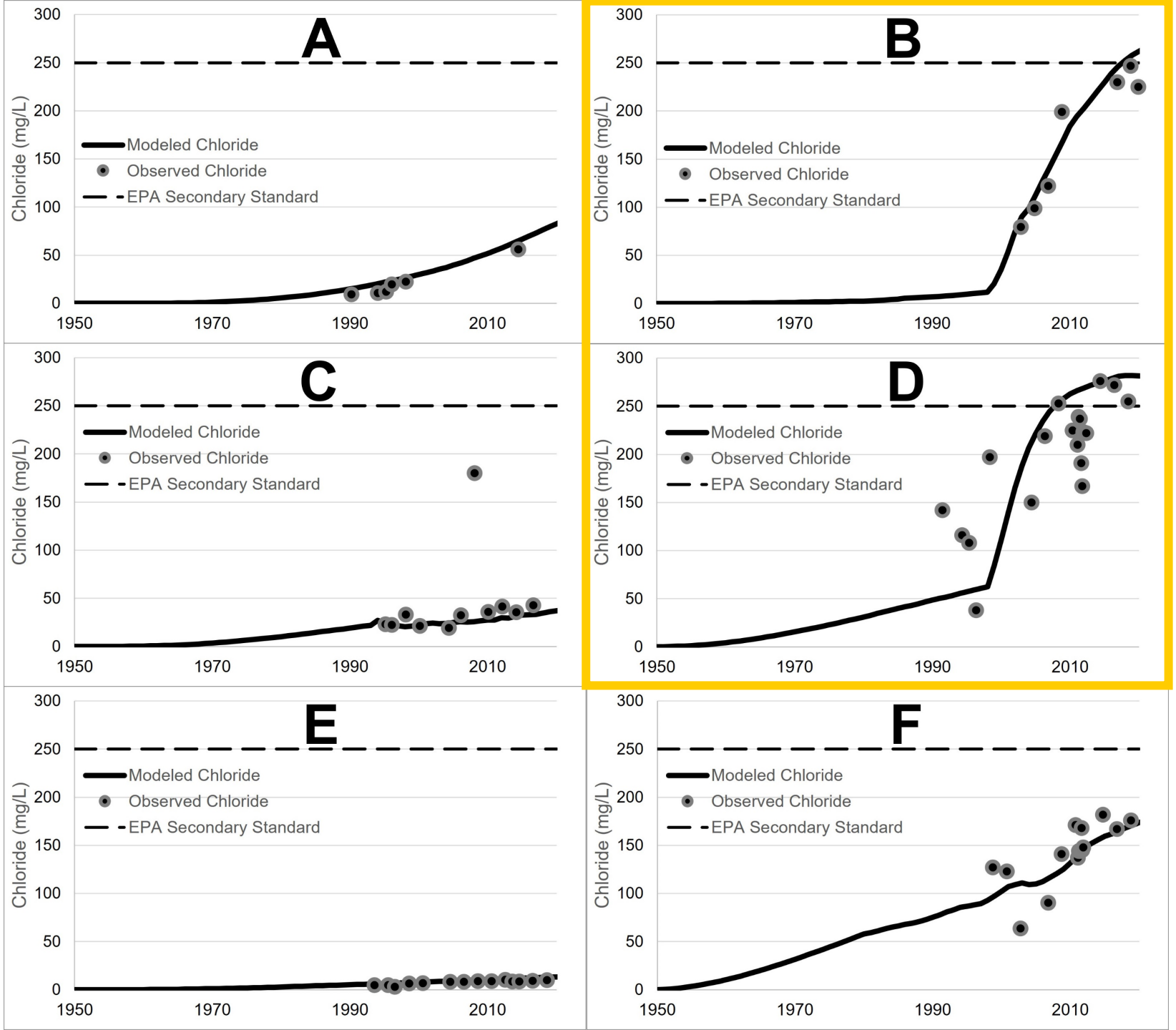
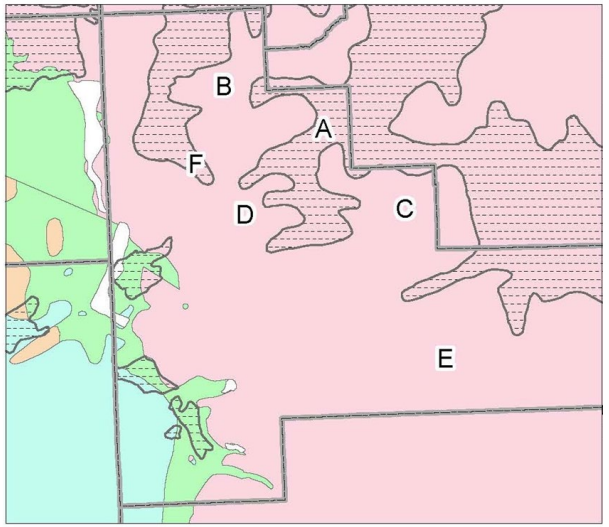
This well required extra chloride

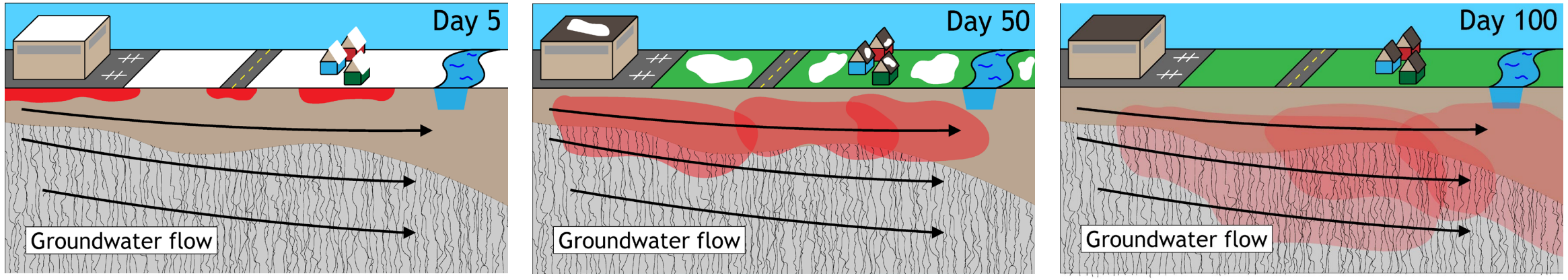




Wells B and D have the highest observed chloride concentrations needed point source recharge to calibrate

Part III. Point Sources in Reality

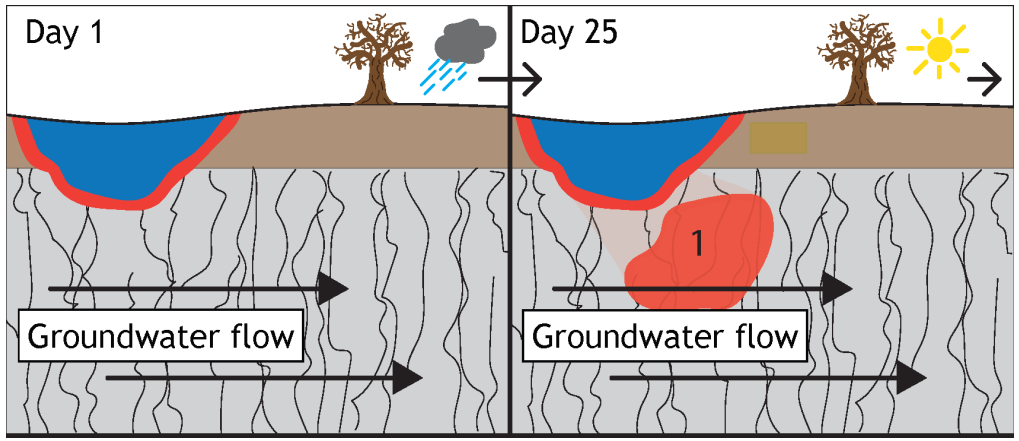
Usual chloride transport to aquifer

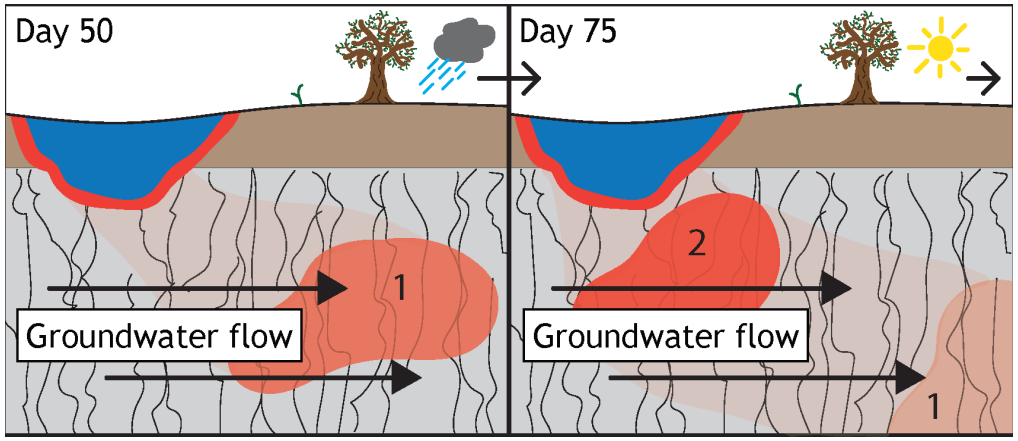


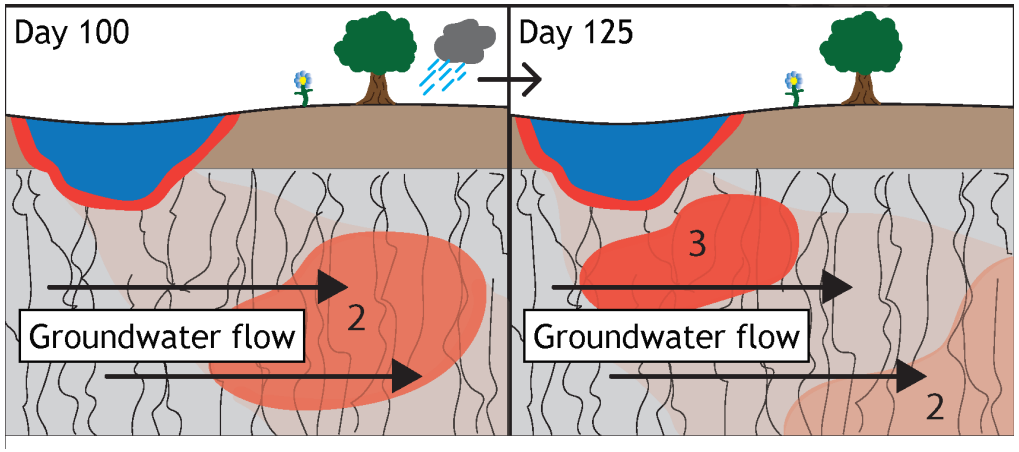
Salt is applied in winter then chloride migrates to the aquifer over seasons or years

Anthony Groenewold, 2021

Point source recharge concept



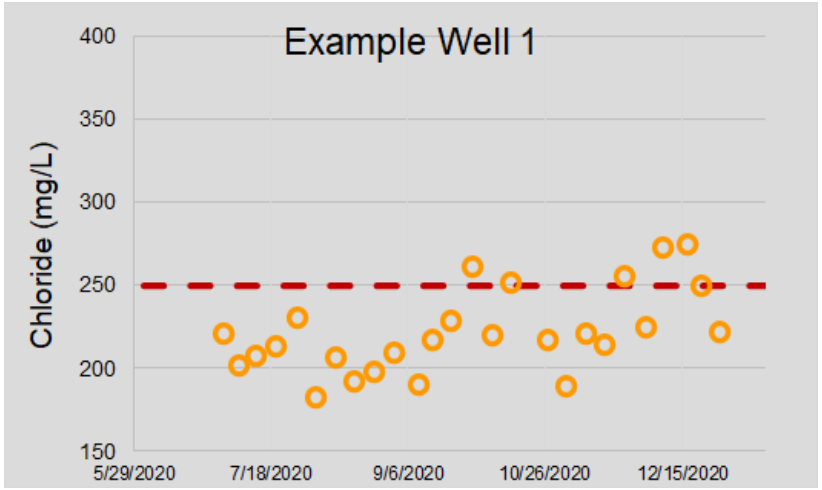


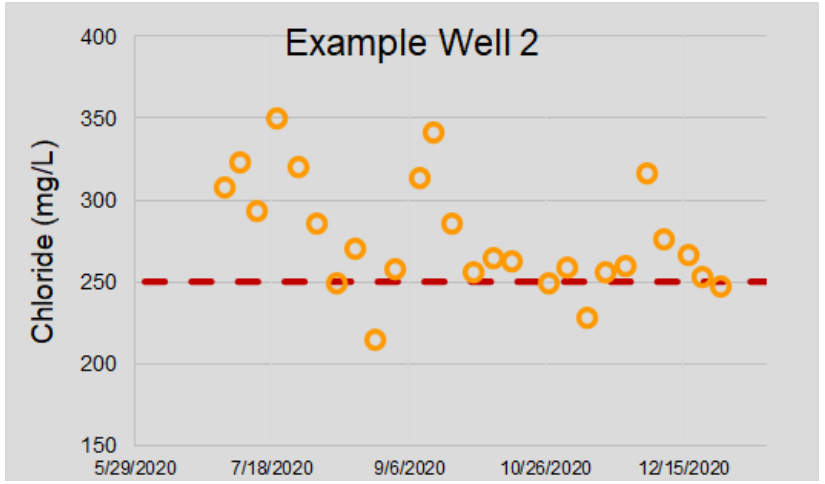


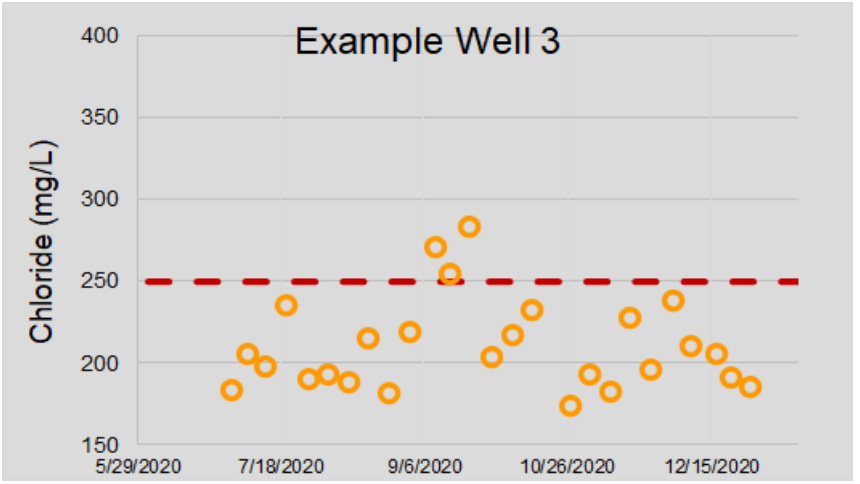
Point sources may hold higher concentrations and emit chloride year round

Anthony Groenewold, 2021

Do we see this variability on a smaller timescale?



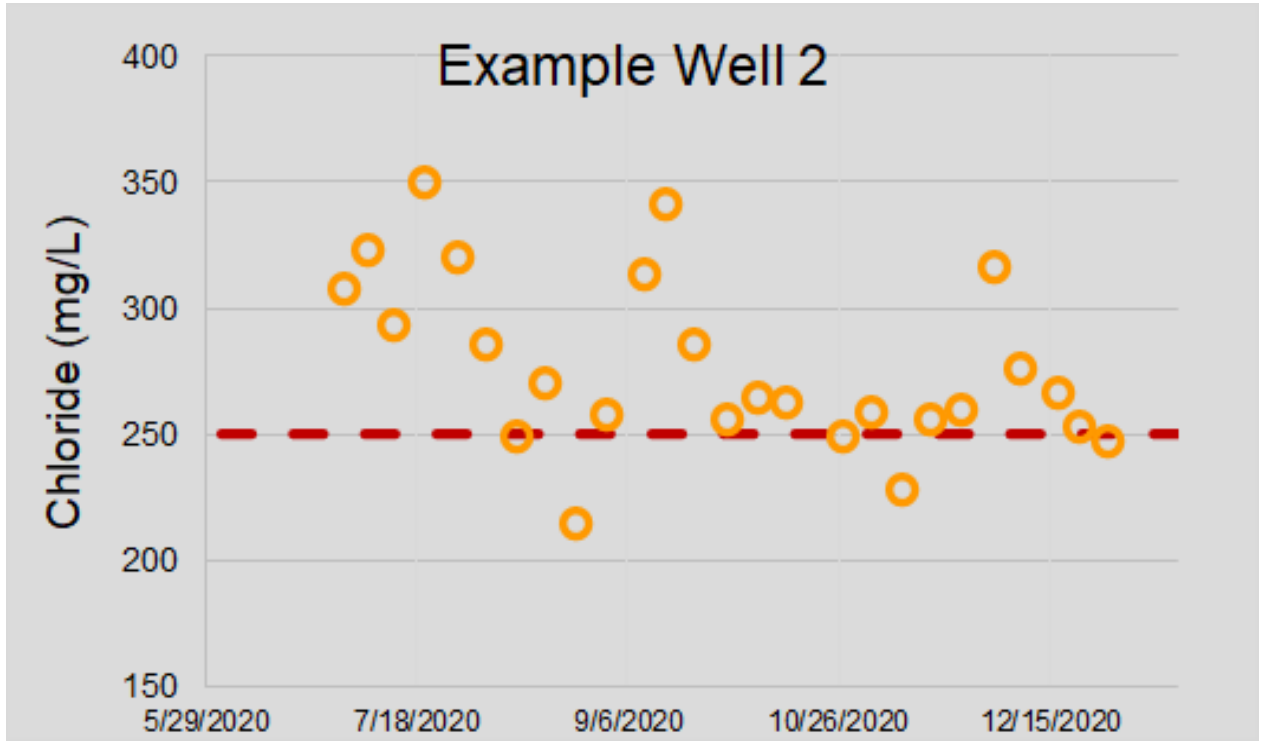


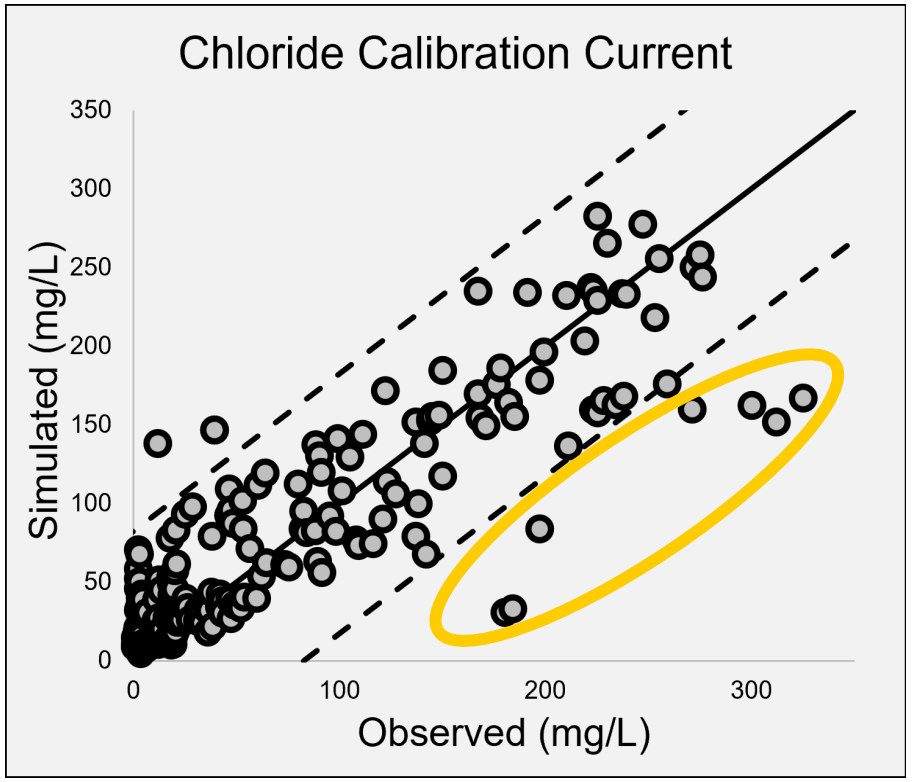


Yes, a Will County community that takes weekly chloride data can see great variation in two weeks (over 50 mg/L)

Stakeholder calibration is key in identifying these features

With such variability, how well can a model with annual stress periods calibrate?





A well calibrated model would capture the average of these points, but mute the variability

These point source recharge areas could be

leaky retention ponds
quarries
infiltration ponds
leaky culverts or pipes with wastewater

More impervious surface – higher chloride concentrations in stormwater drainage

Source: https://gisapp.willcountyillinois.com

Other sources – leaky infrastructure

Leaky infrastructure can also play a role, in this context primarily in the form of leakage from stormwater runoff and wastewater infrastructure.

While it might be a minor component of overall flow, it can be locally important especially where impervious surfaces minimize natural recharge – water that would be infiltrating instead routed through drainages that entrain chloride along the way

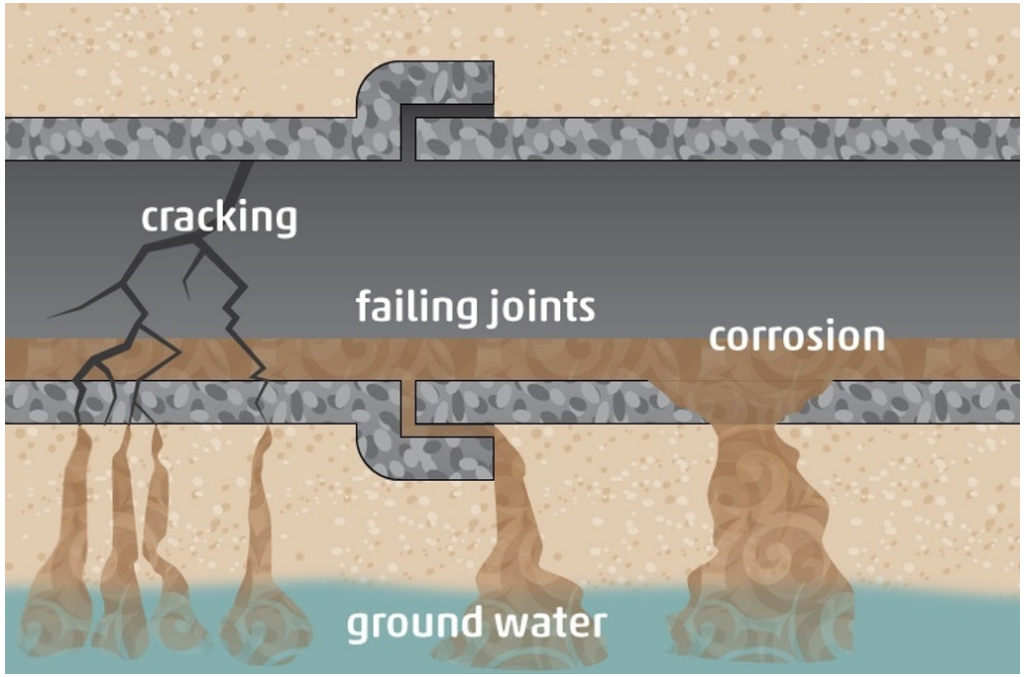
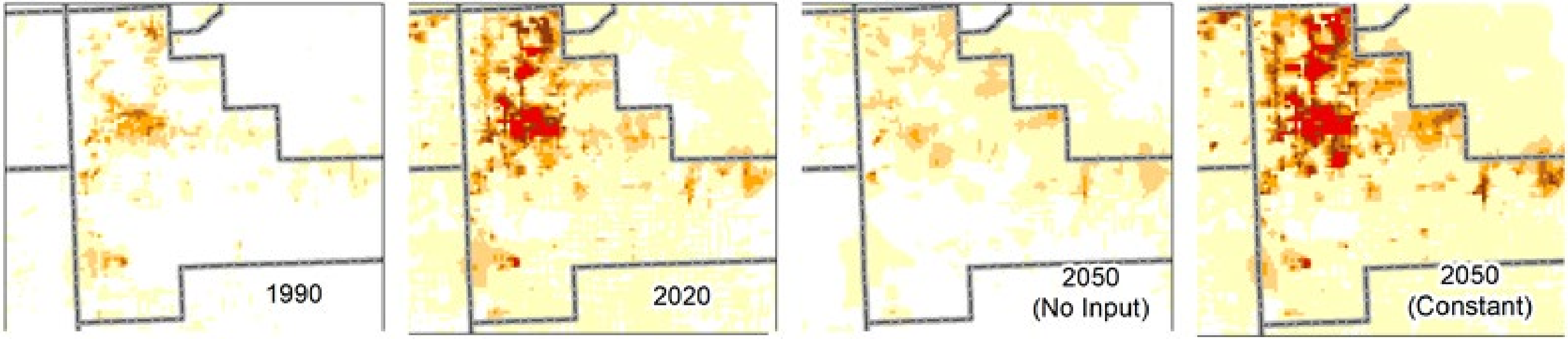


Image source: https://www.mswmag.com/online_exclusives/2019/04/sewer-exfiltration-the-leaking-enemy_sc_00125

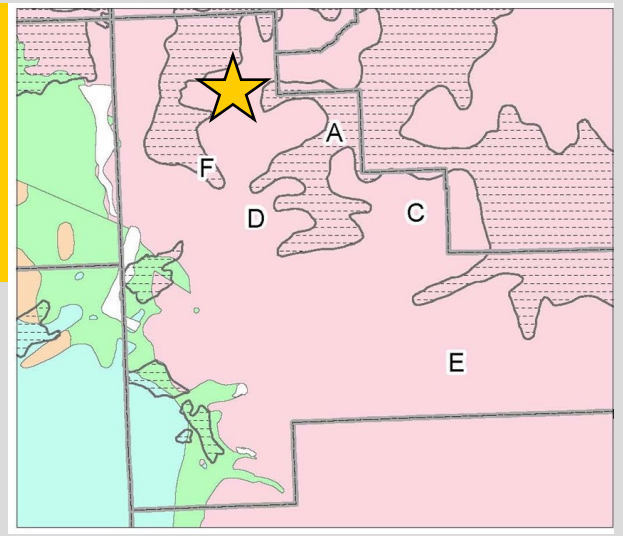
Part IV. Projecting Future Chloride Scenarios

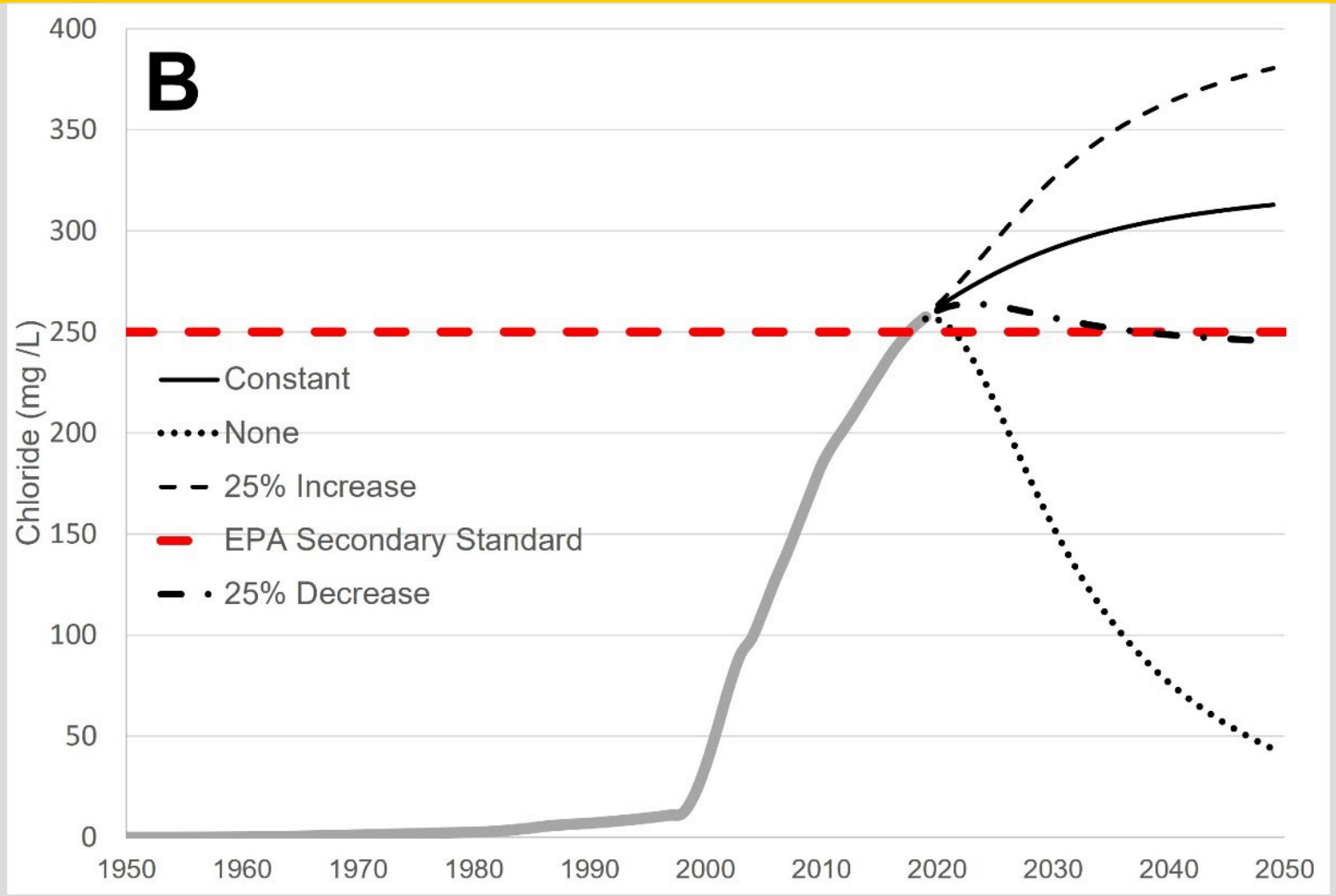
Simulated future chloride concentrations in Will County



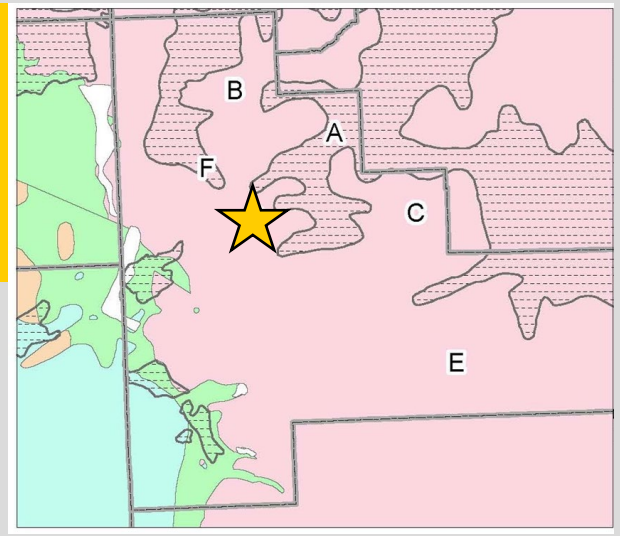
We do not have information on future land use, but we made scenarios with different salt application at 2020 locations.

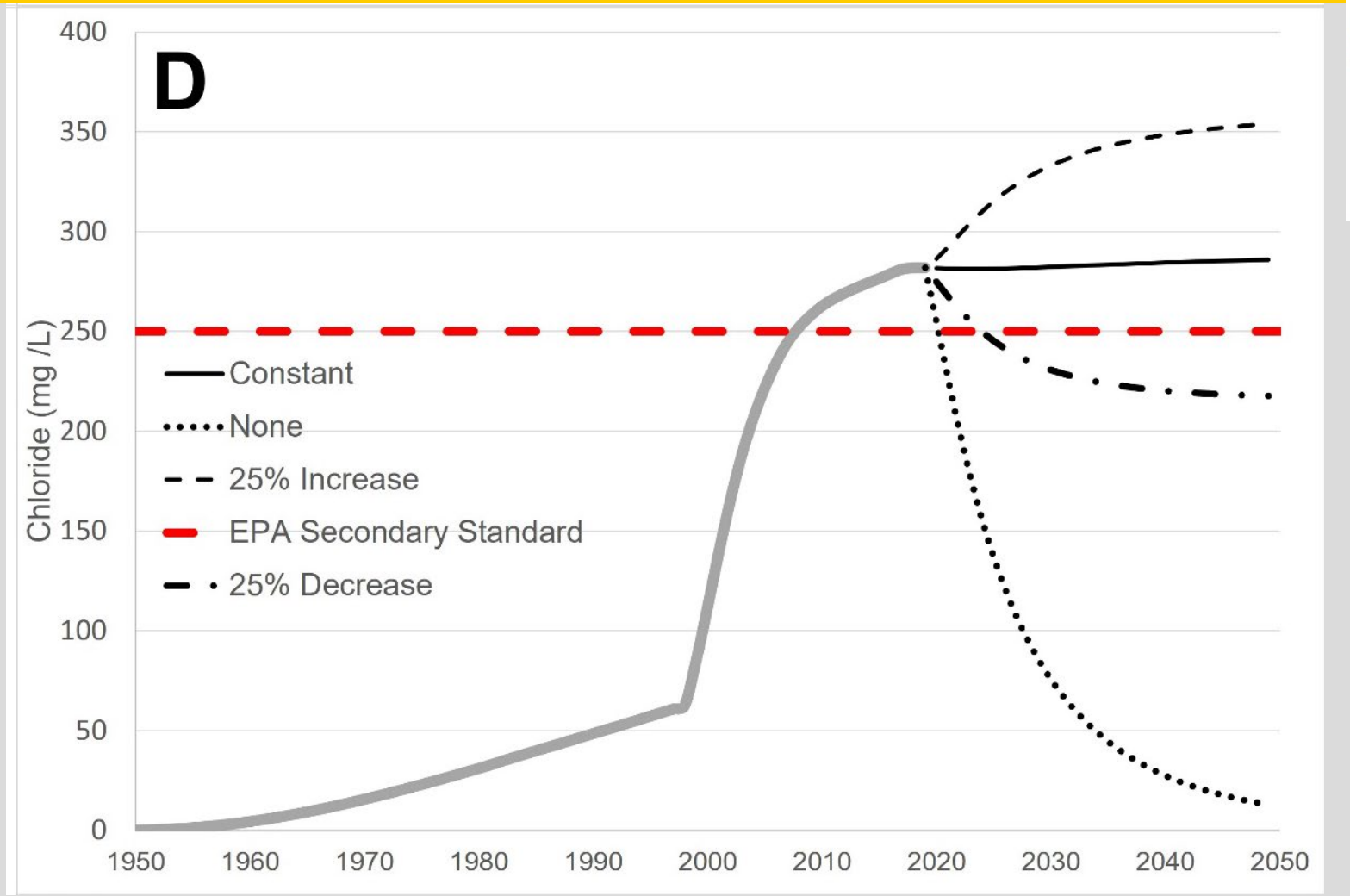
Well B: Near point source



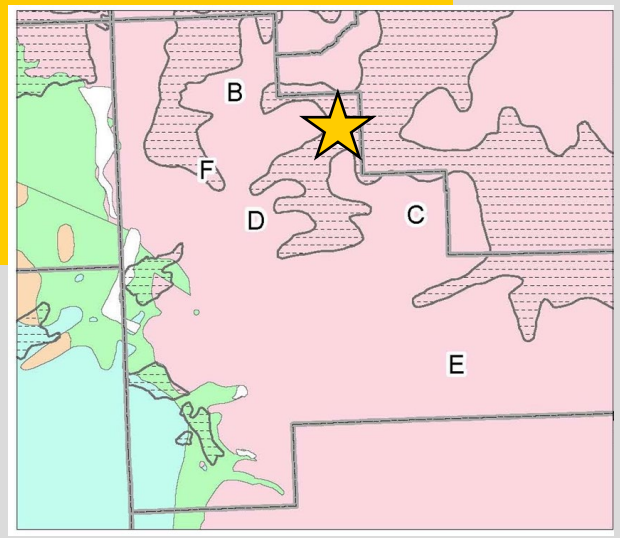


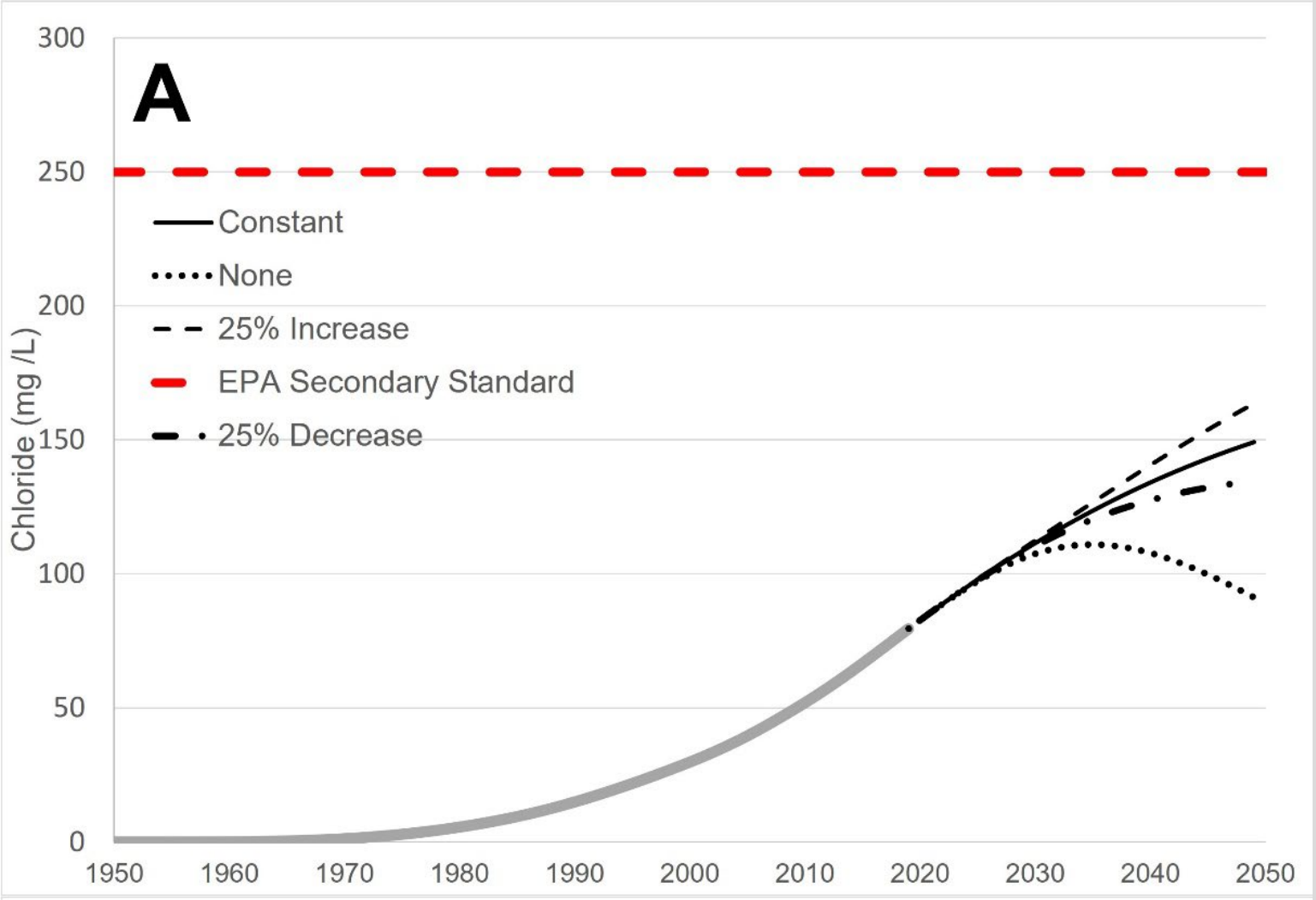
Well D: Near point source



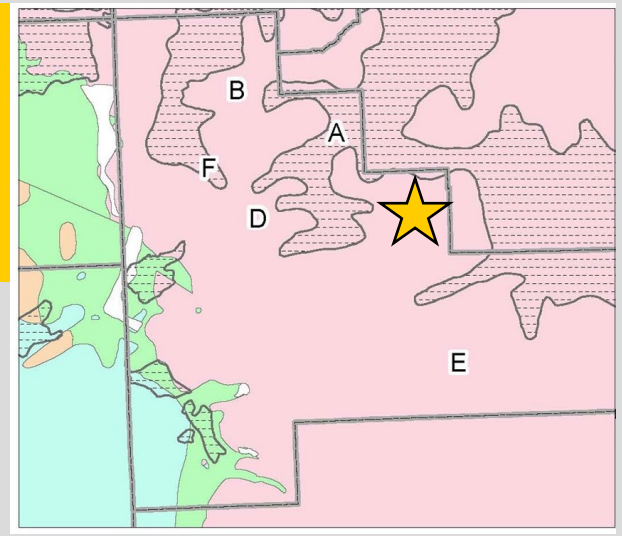


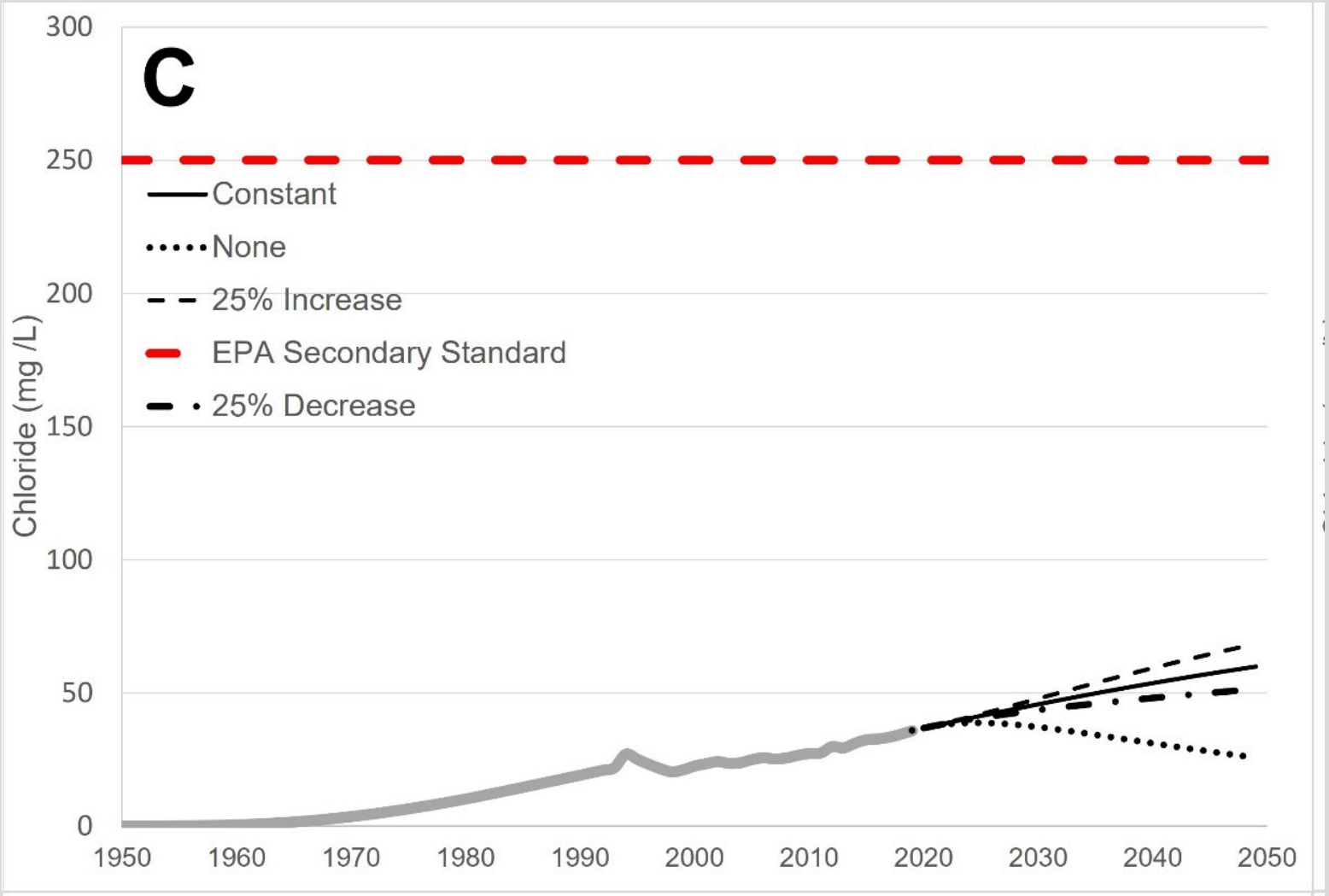
Well A: Thick gravel



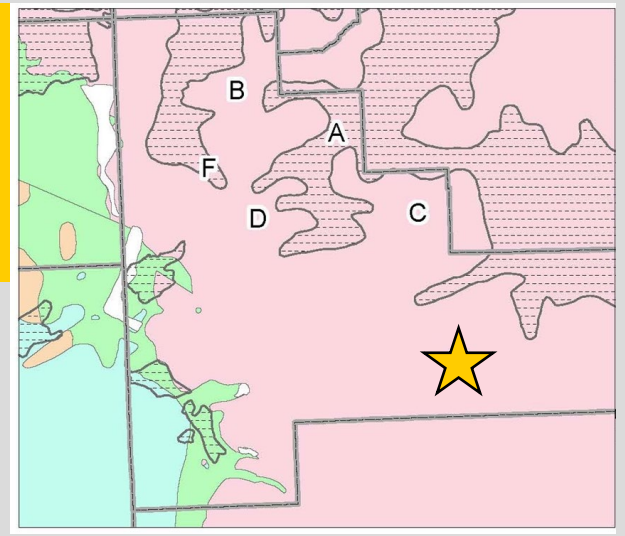


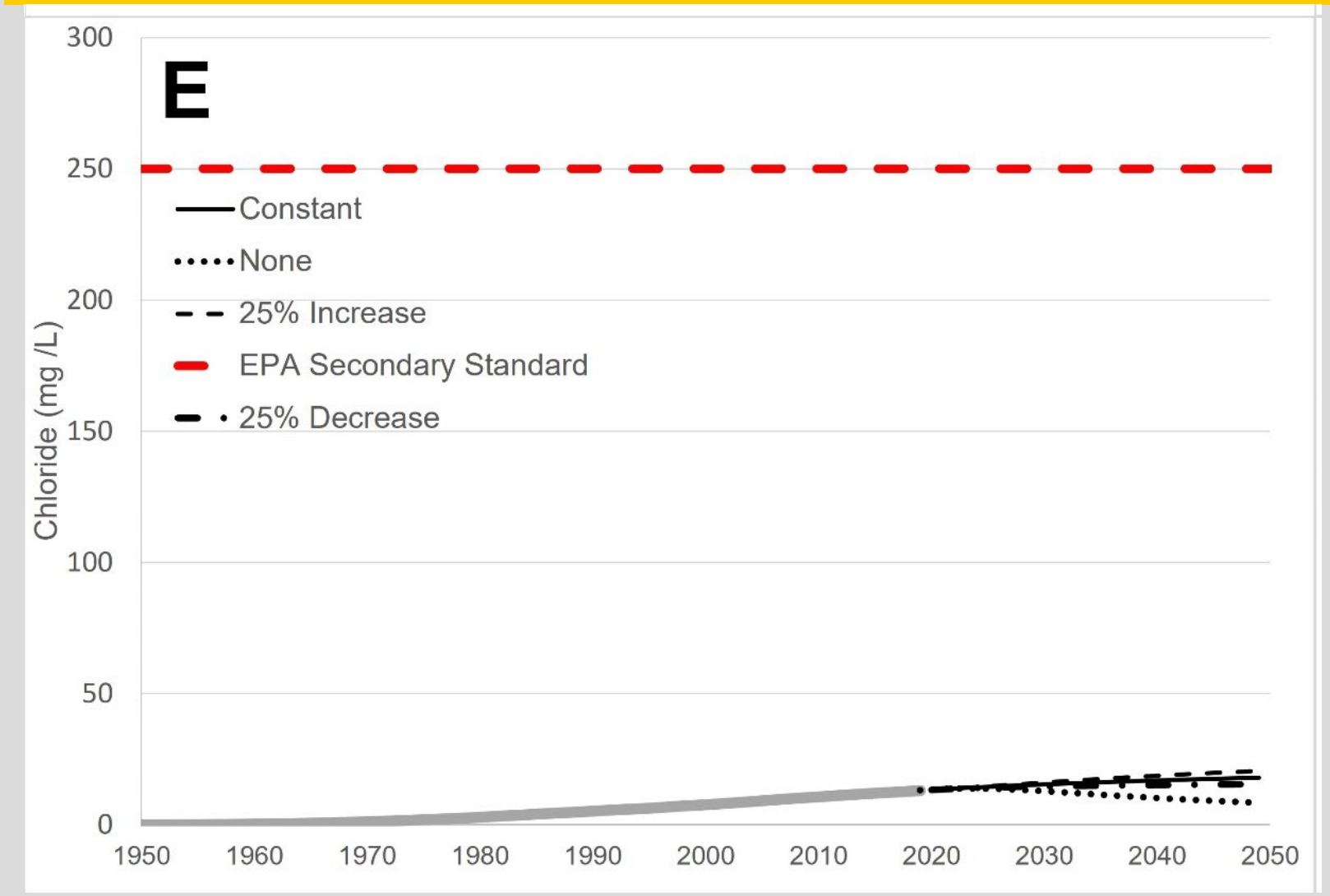
Well C: Deep with thick clay



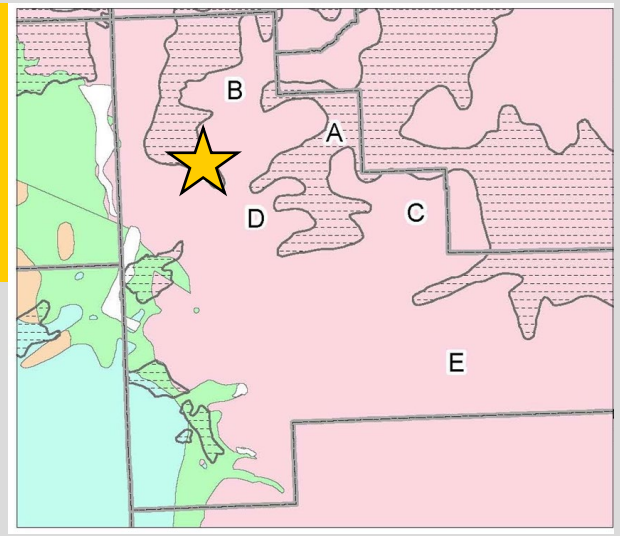


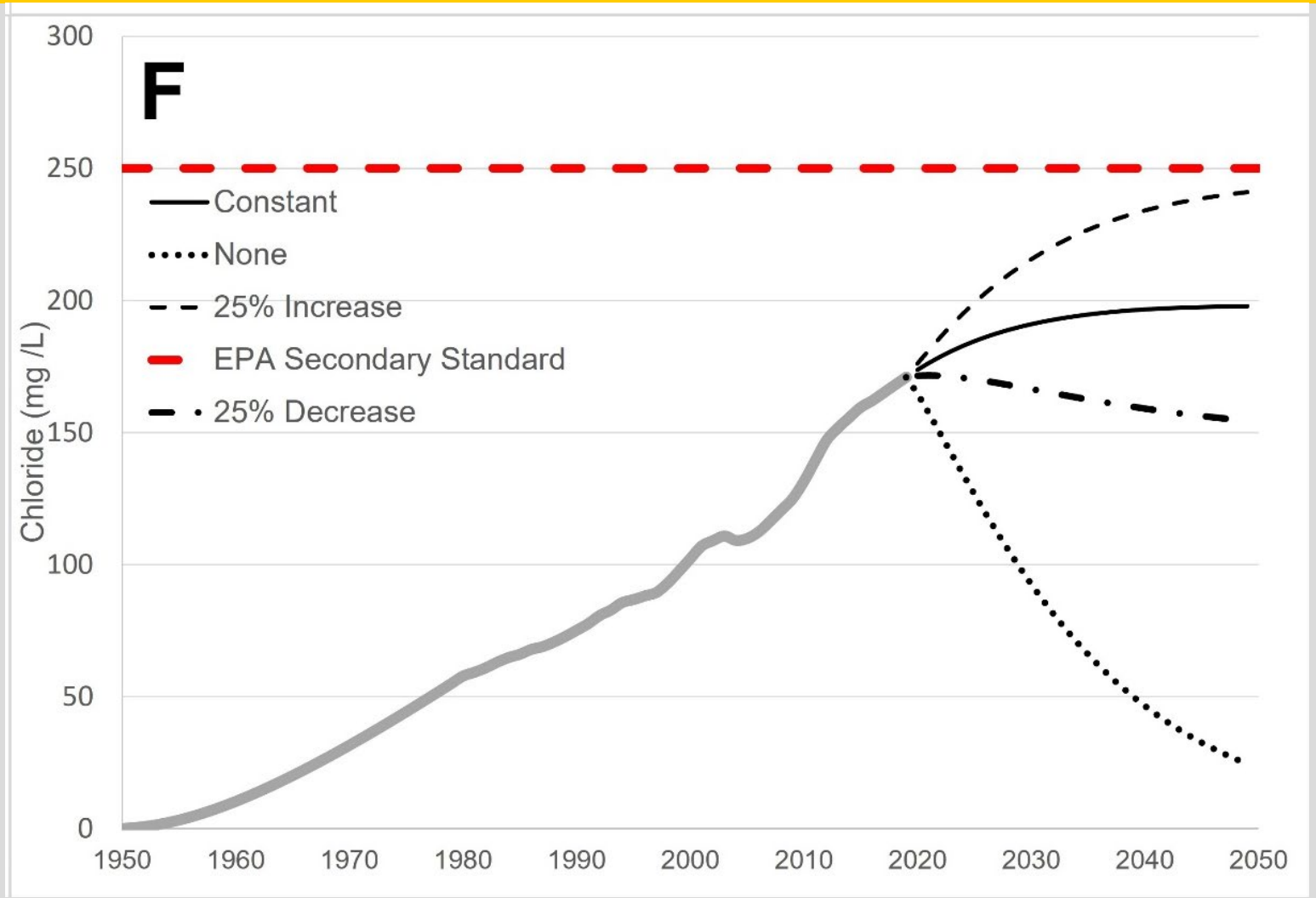
Well E: In rural Will County





Well F: Urbanized area





Part V. Conclusions

Main Conclusions from our Modeling

- Land use changes impact chloride contamination in groundwater
- Small areas of high recharge (point sources) could have a large impact on localized contamination
- To make meaningful assessment of wells at risk for chloride contamination in the future, you need an idea of future land use plans

What does this model inform about future work?

- Sample and map out landscape features that could act as conduits to the shallow aquifer
- Sample at potential point sources
- Install observation wells and sample frequently to better understand variability
- Use the model to guide areas we need more data; sampling campaign this spring

Thank you!


Image credit:
Ron Welk

Looking for talent? Two Water Survey interns, Pu Xia and Anthony Groenewold, showed great dedication on this project. Both recently earned civil engineering master degrees. Contact dbabrams@illinois.edu for reference

We want to hear what you think of all this. Any questions?

If you have any chloride data for northeast Illinois, let us know!

Please fill out our poll
https://forms.gle/6NJy7bz5Yihhv2tt6