A runoff-based vulnerability analysis to examine and communicate the dynamics of bacteria pollution events in the Gulf of Maine

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Maine Sustainability & Water Conference, May 30, 2017

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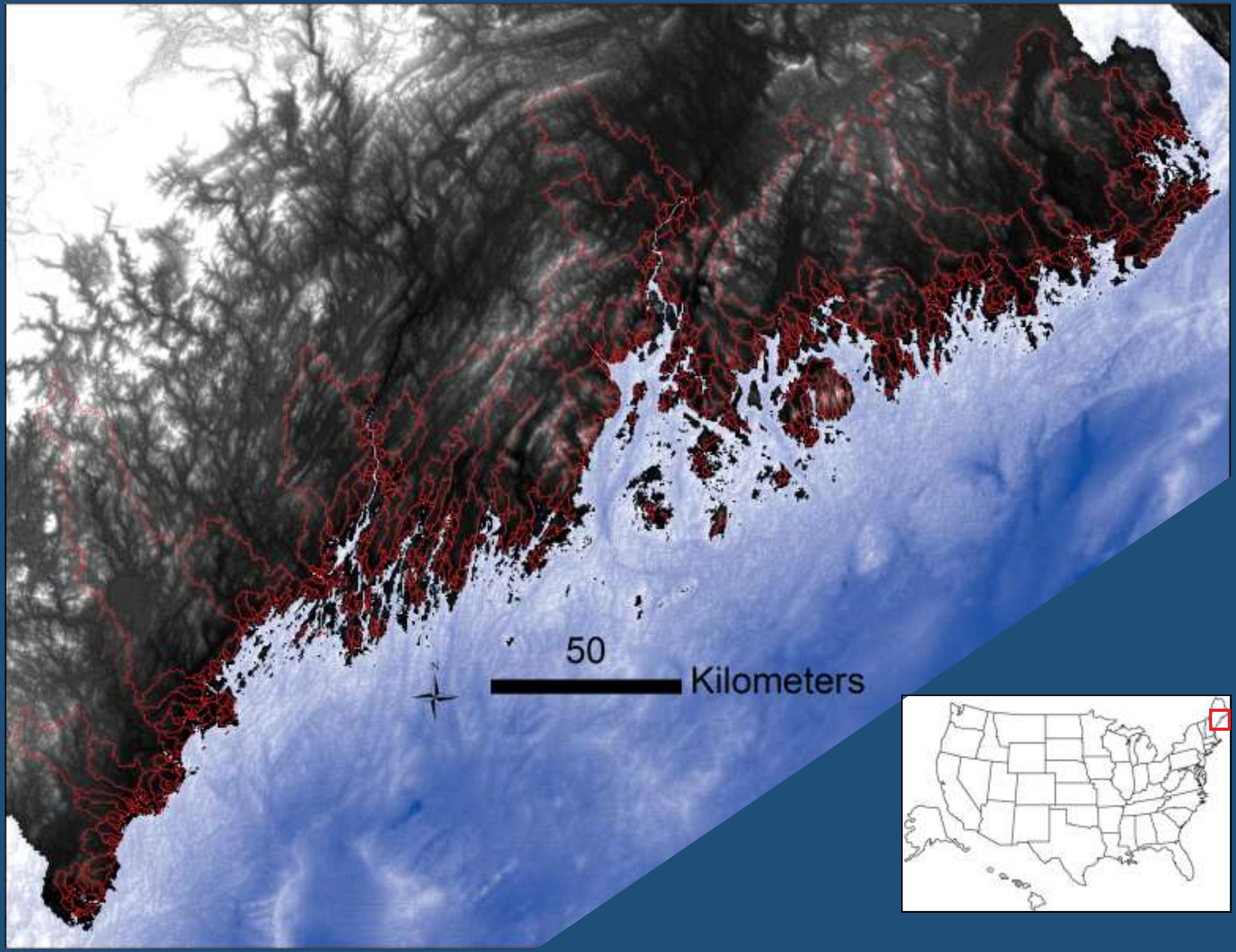
Maine Agricultural & Forest Experiment Station

https://umaine.edu/mitchellcenter/safe-beaches-and-shellfish-beds/

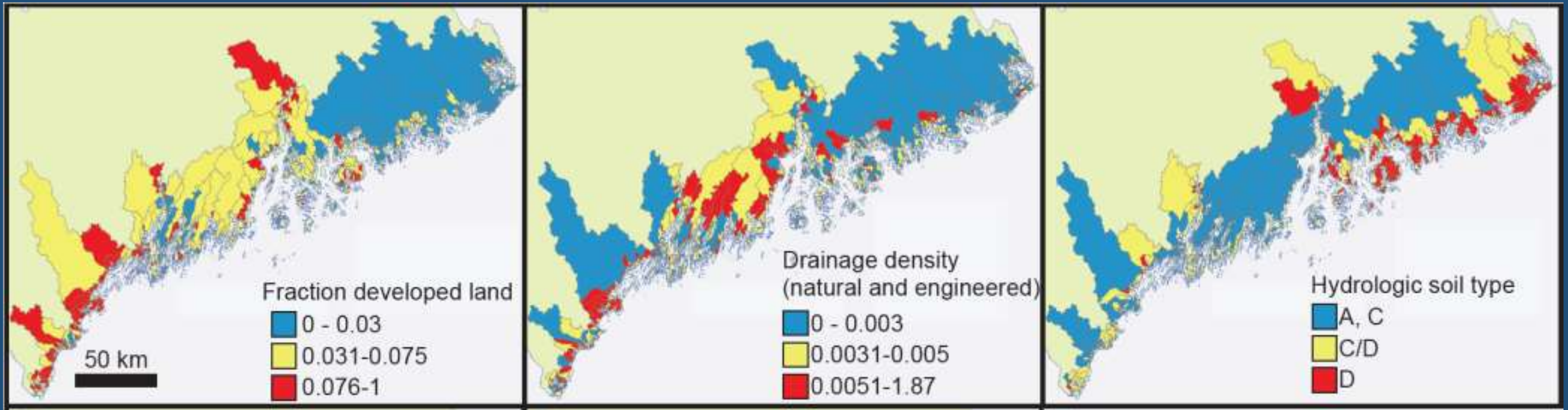
Motivations and Questions

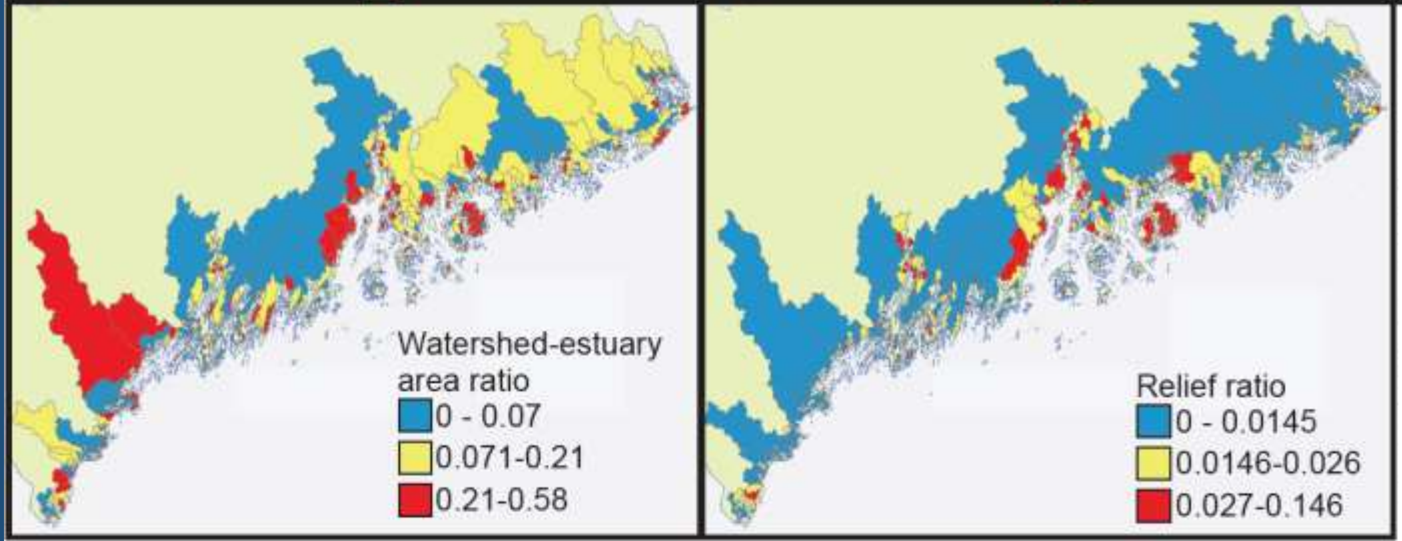
- Coastal contamination by fecal coliforms account for many unpredicted clamflat closures during peak harvest season
- Current closure regulations are based on a “one size fits all” rule: 2” rainfall in 24 hours triggers closure, often for 2 weeks.
- Not every clamflat is the same, nor watersheds, nor rainstorms.
- Can we improve the capacity to tailor closure rules for local conditions?
- Can we do this efficiently over the entire Maine coast?



Step 1: find watershed and estuary characteristics that coincide with contamination frequency

Source of fecal coliform | **Delivery by rivers, overland flow** | **Residence time in estuaries**





Data from:

- Maine office of GIS
- USGS National Hydrography dataset
- NRCS SSURGO Database

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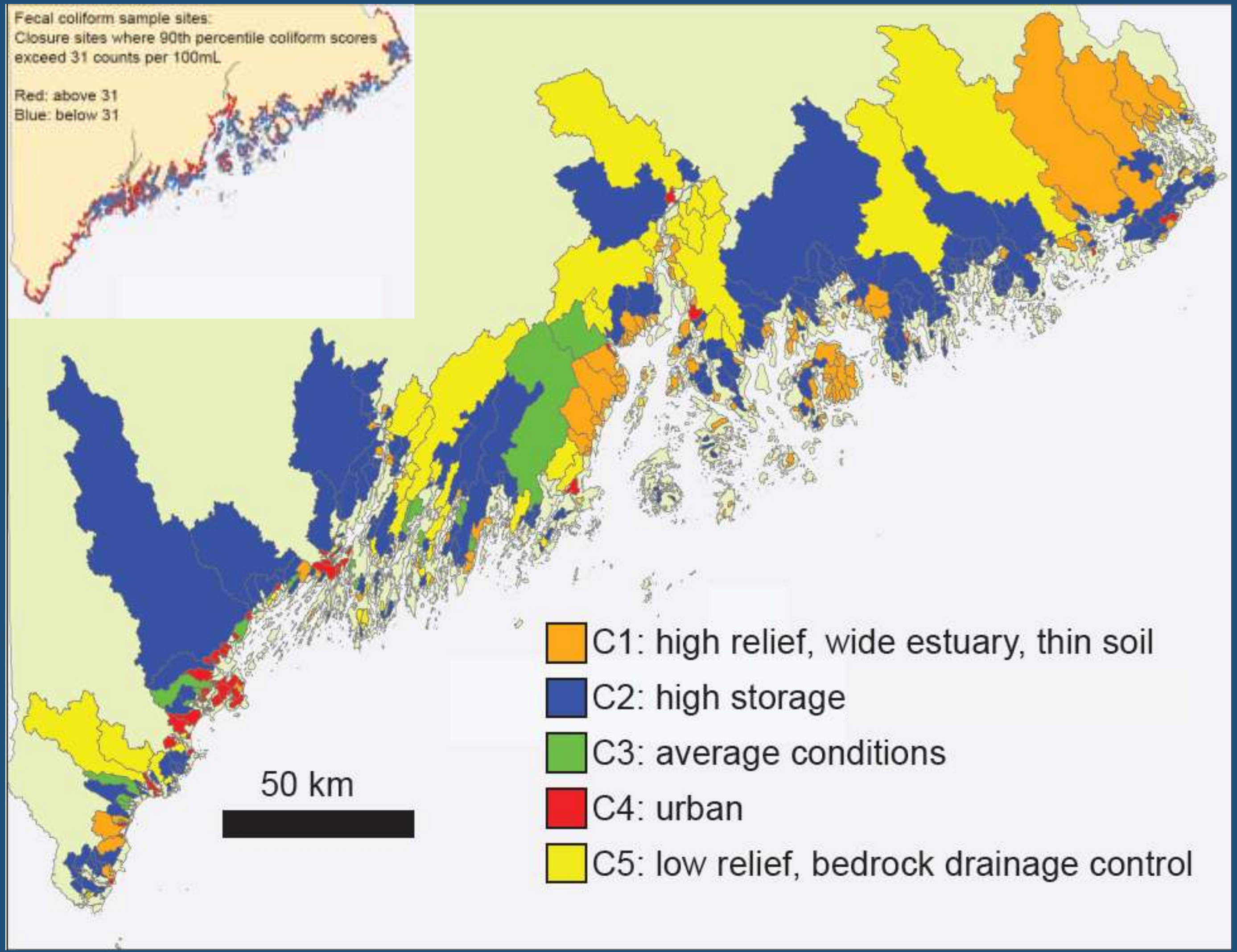
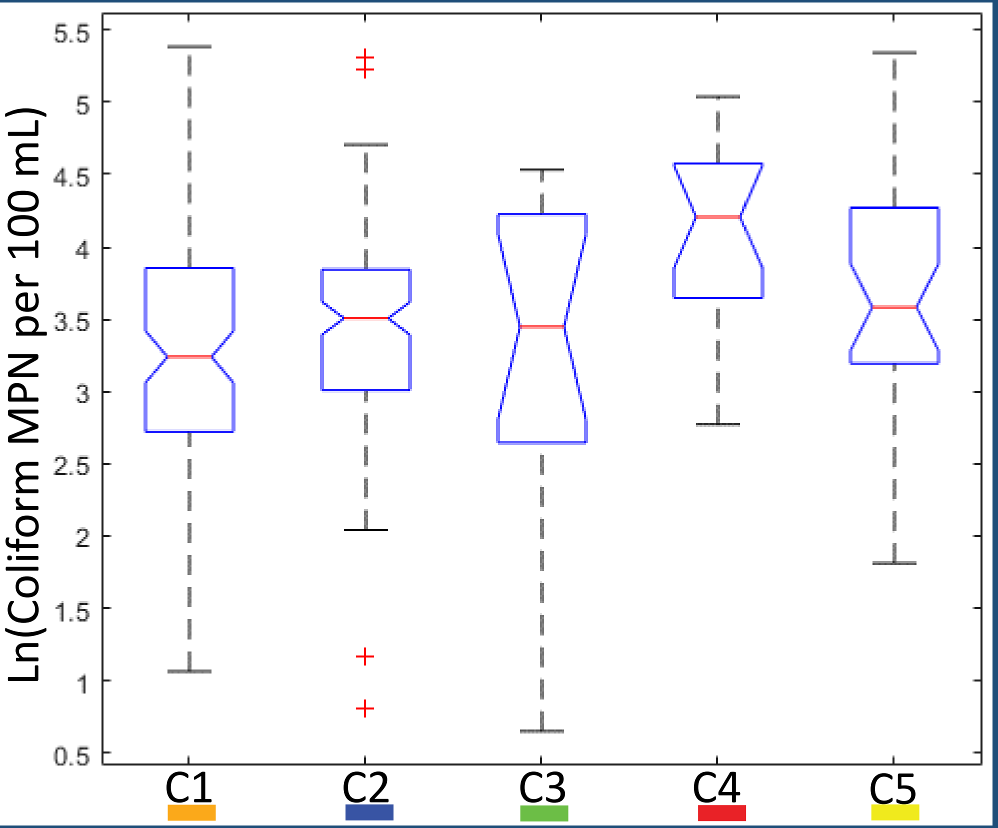




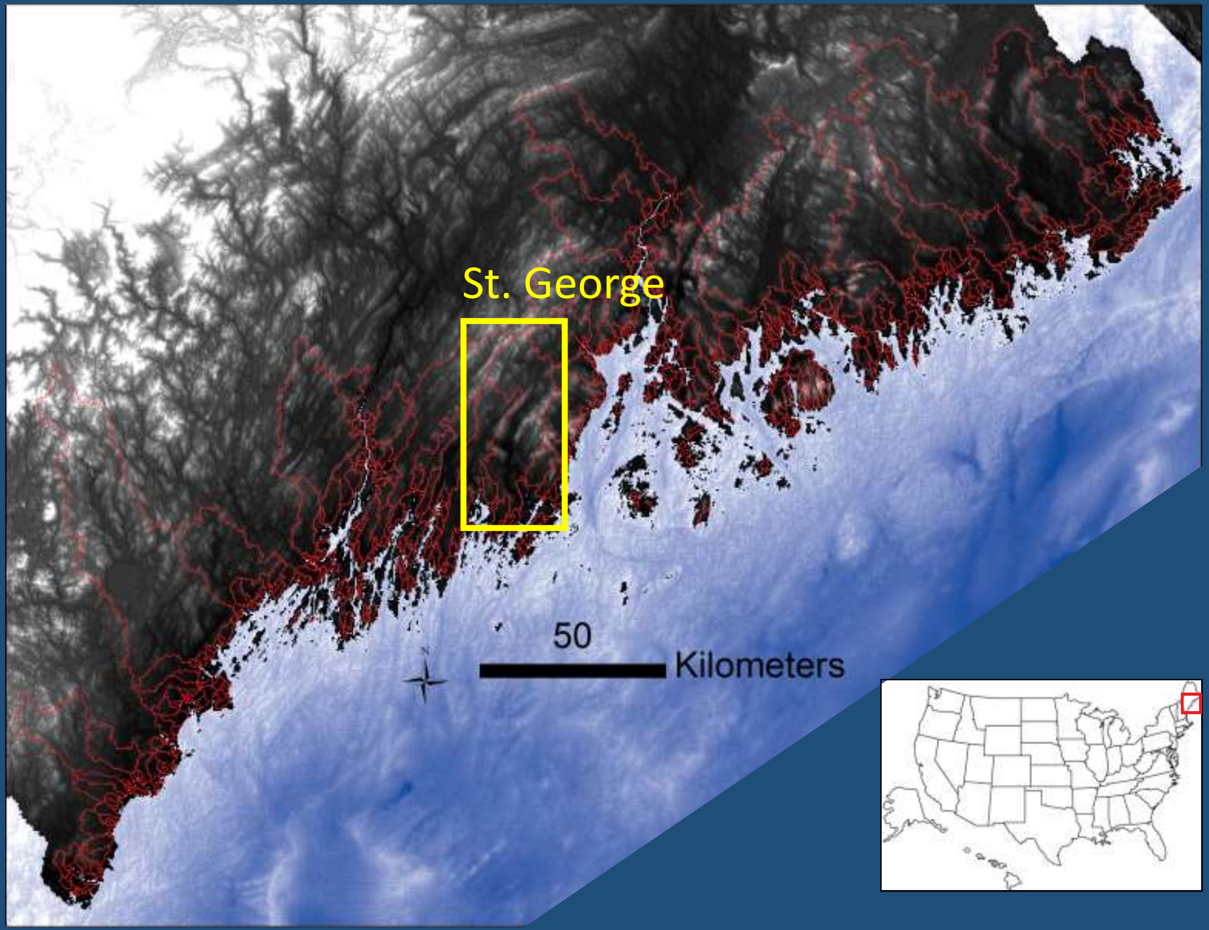
- Estuaries with urban watersheds have statistically significant higher risk
- Keep in mind: coliform sampling is biased toward contamination events

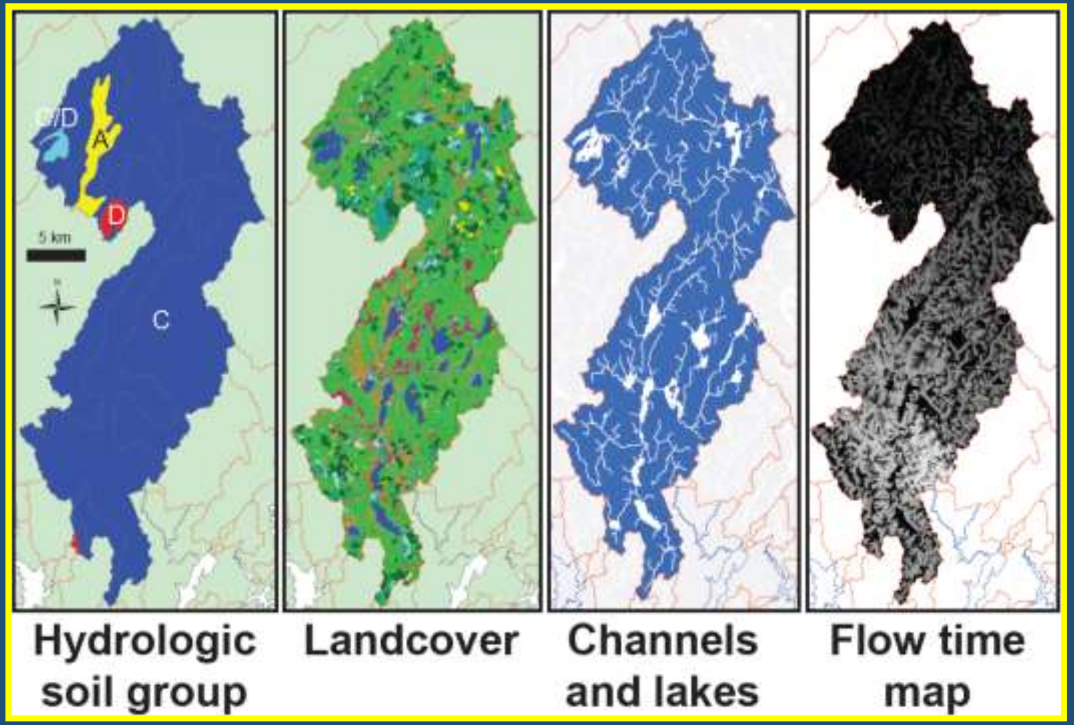
Step 2: estimate the timing and magnitude of major runoff events driving clamflat contamination

Sub-questions:

- How much runoff is brought to the estuary?
- How long does it take to get there?
- How long does it take to flush the runoff?

Landscape metrics used to model runoff production, routing, and travel time





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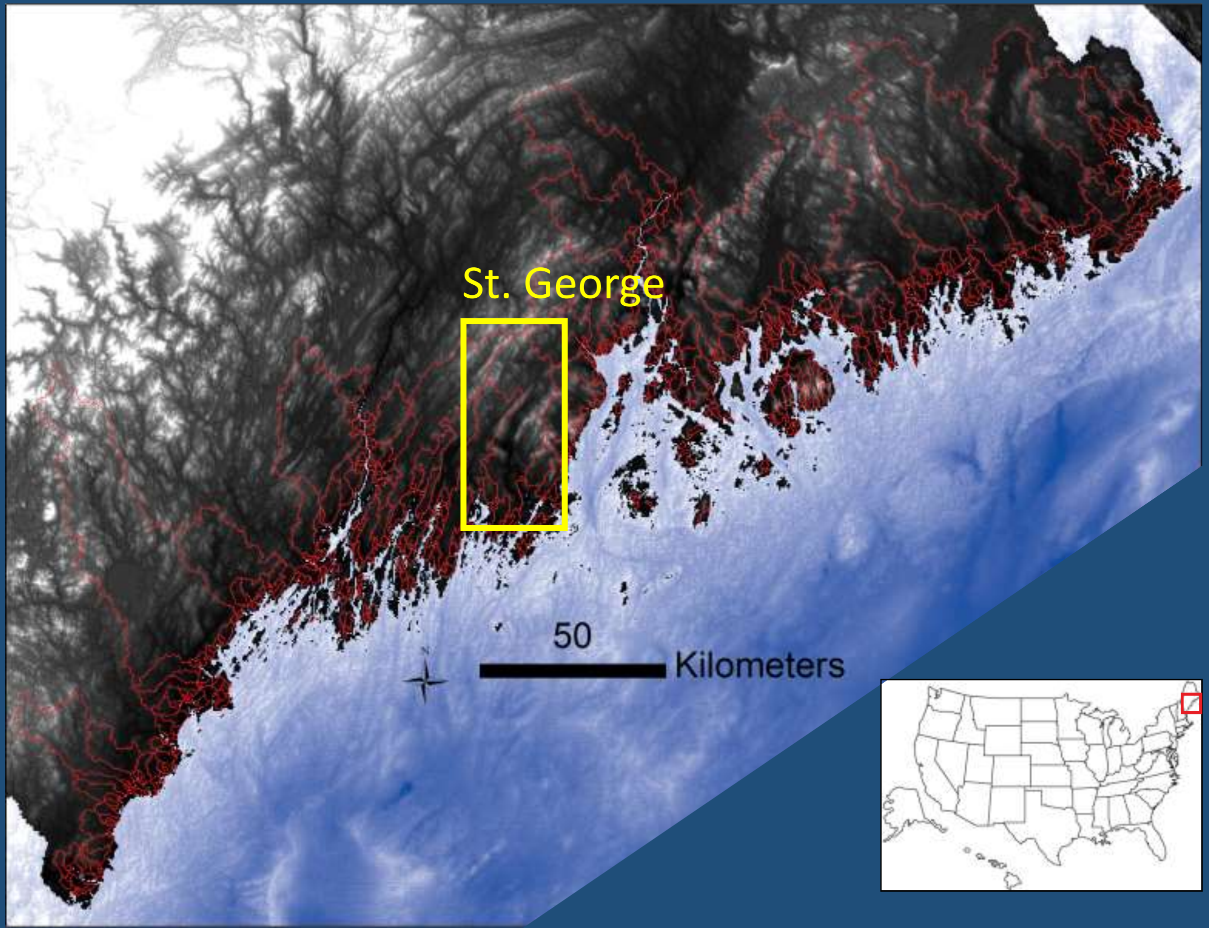
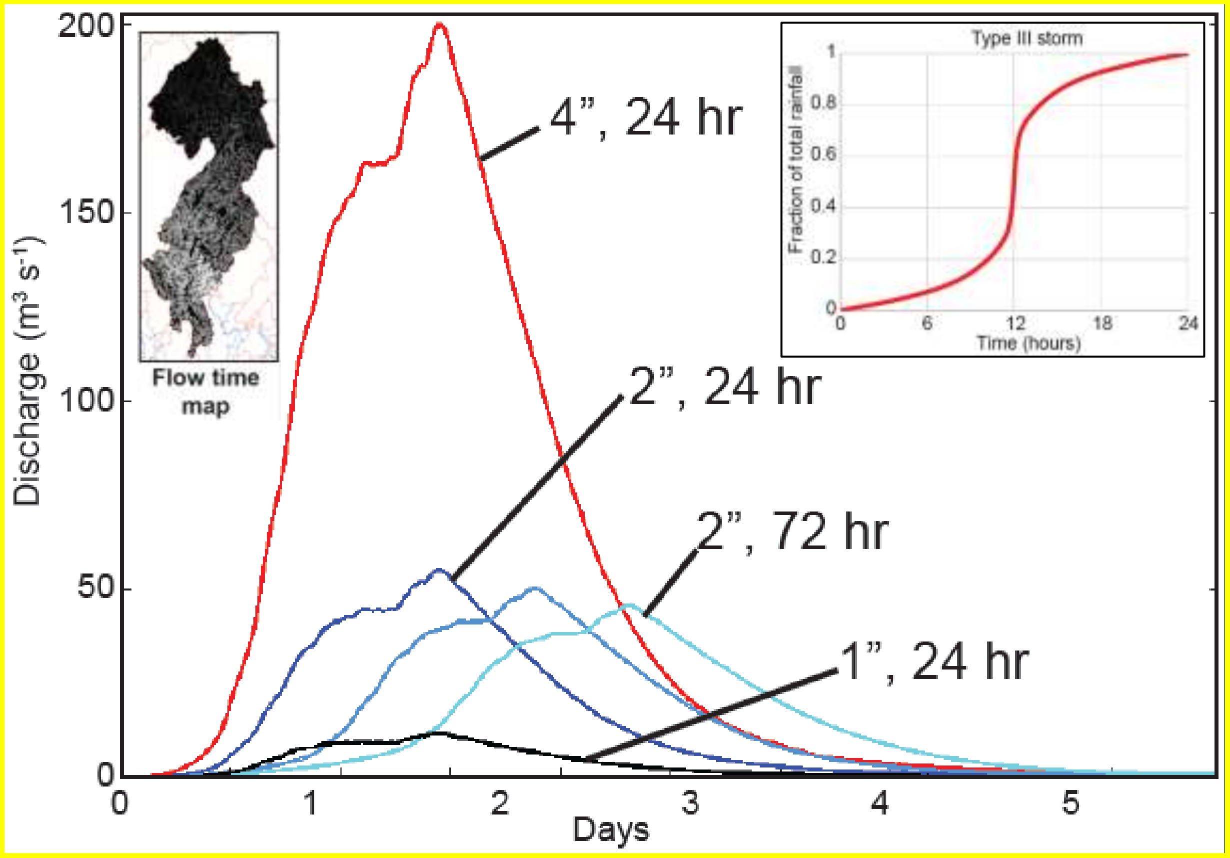
Runoff production and flow time maps are then used to estimate runoff volume delivered to estuaries





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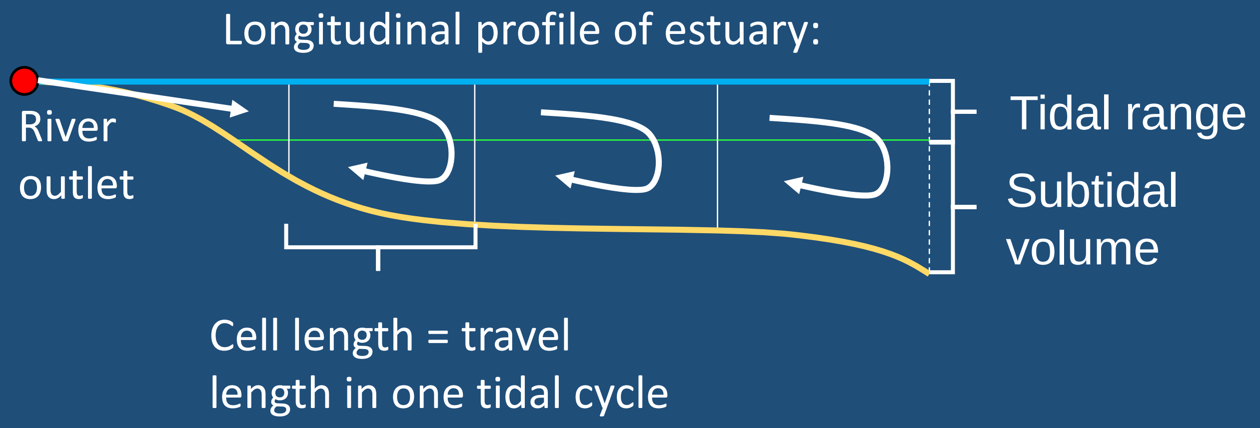

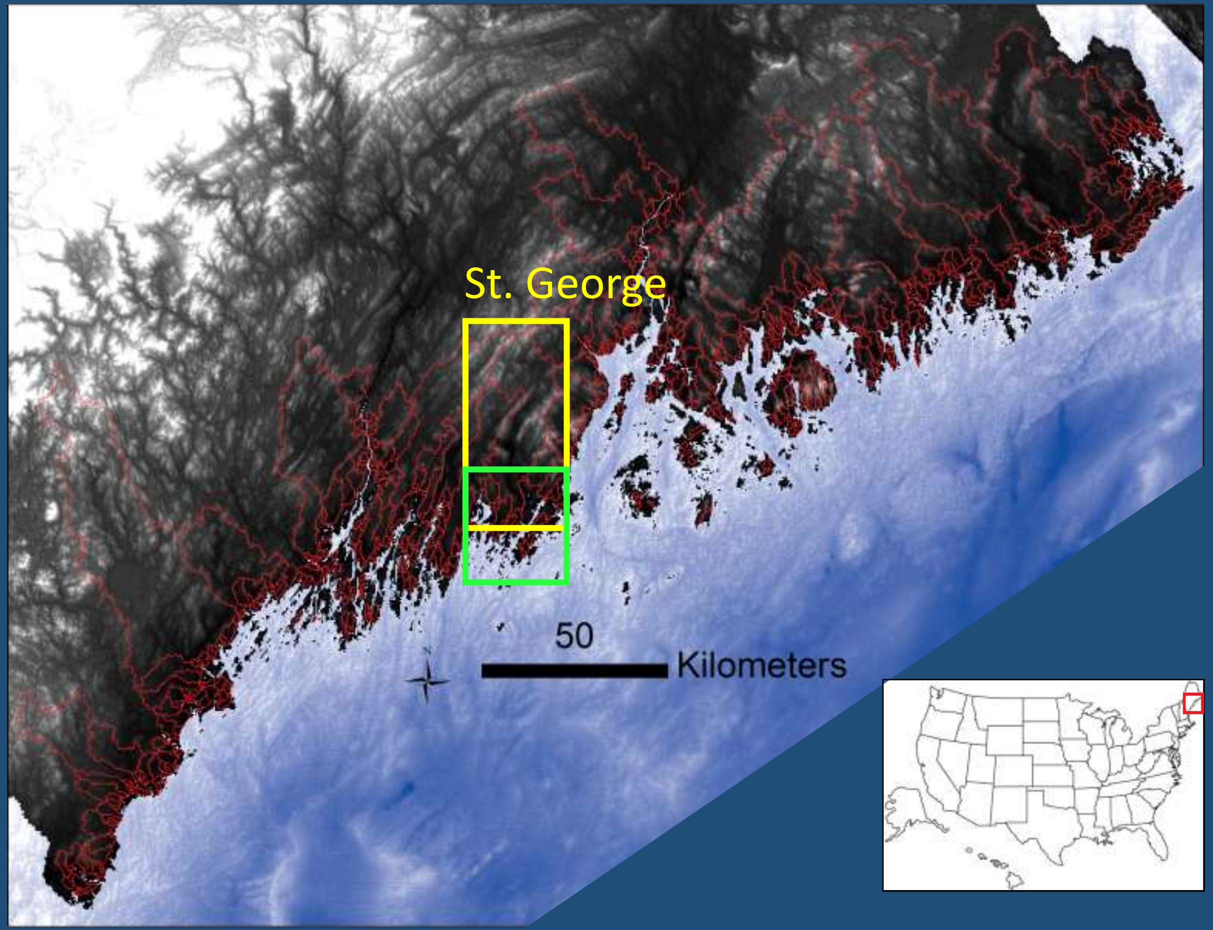

Estimate the capacity of an estuary to flush contaminated water by tidal power (Ketchum, 1951)

Flushing time: number of tidal cycles required to effectively flush storm runoff (Arons & Stommel, 1951)

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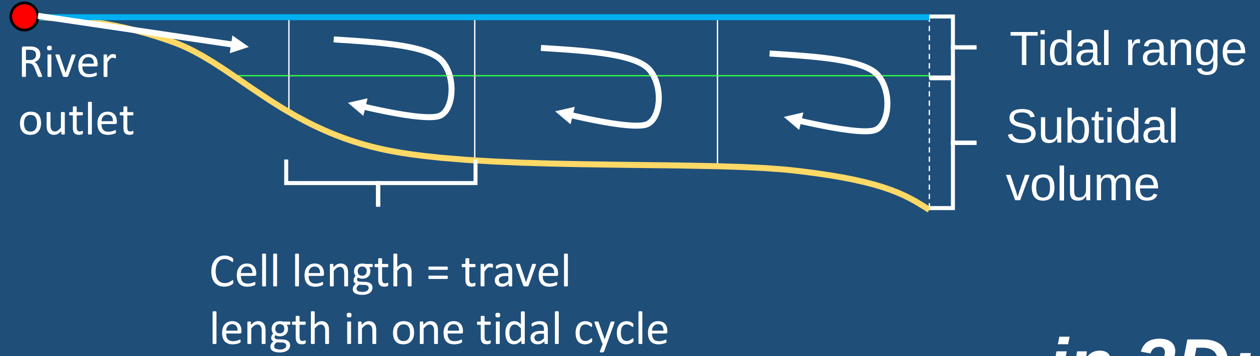
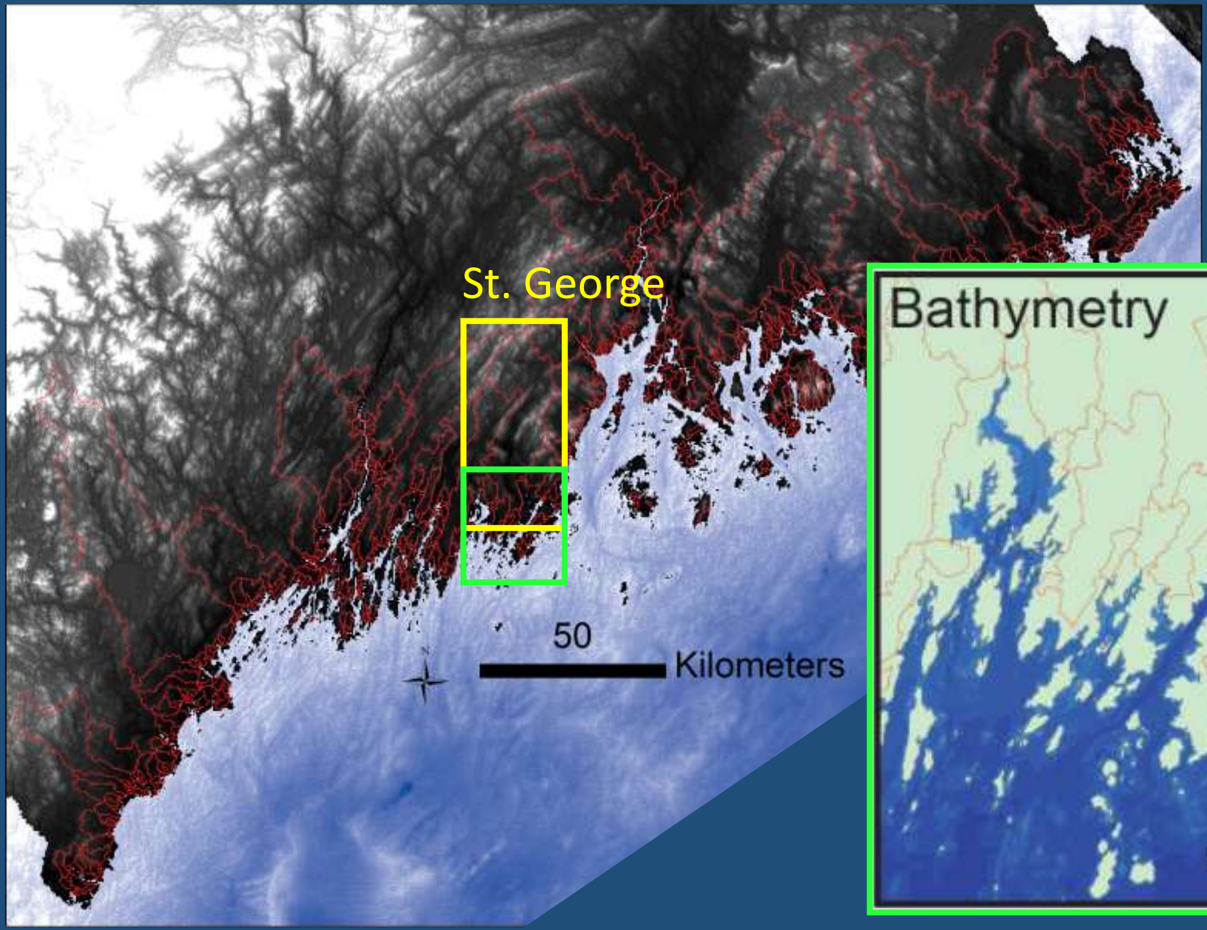
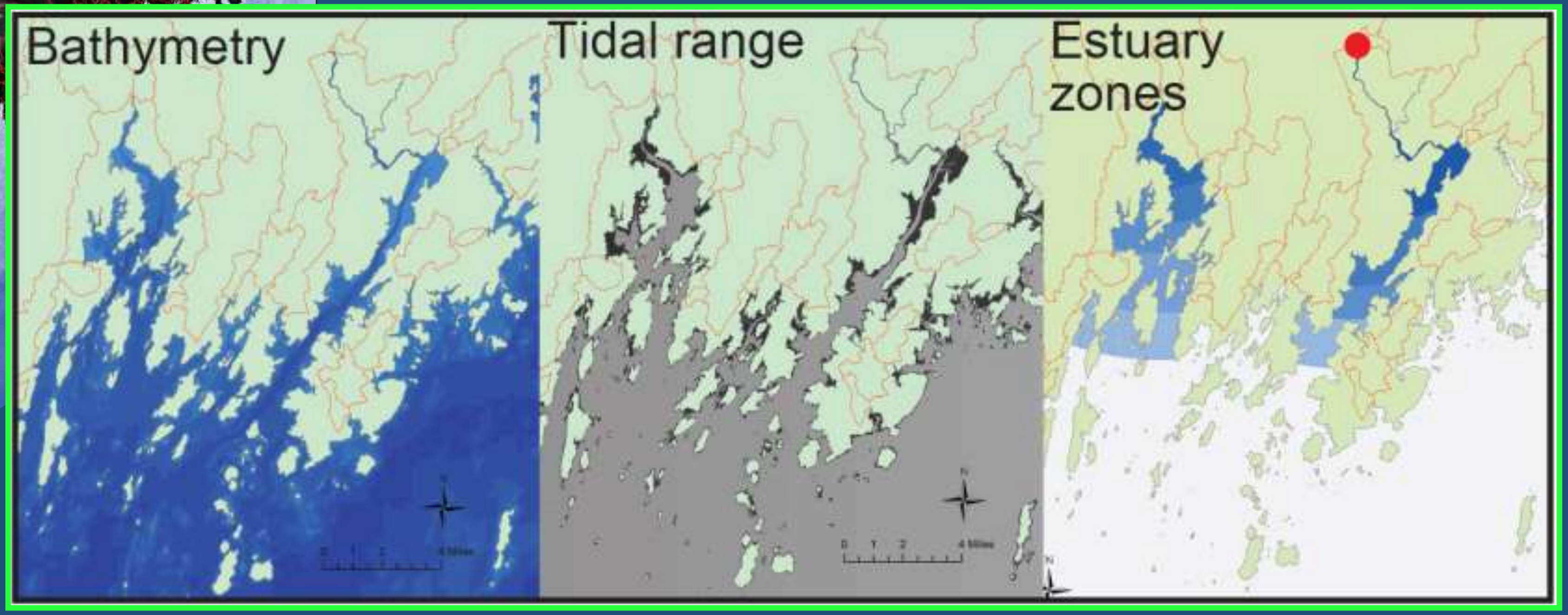
Longitudinal profile of estuary:





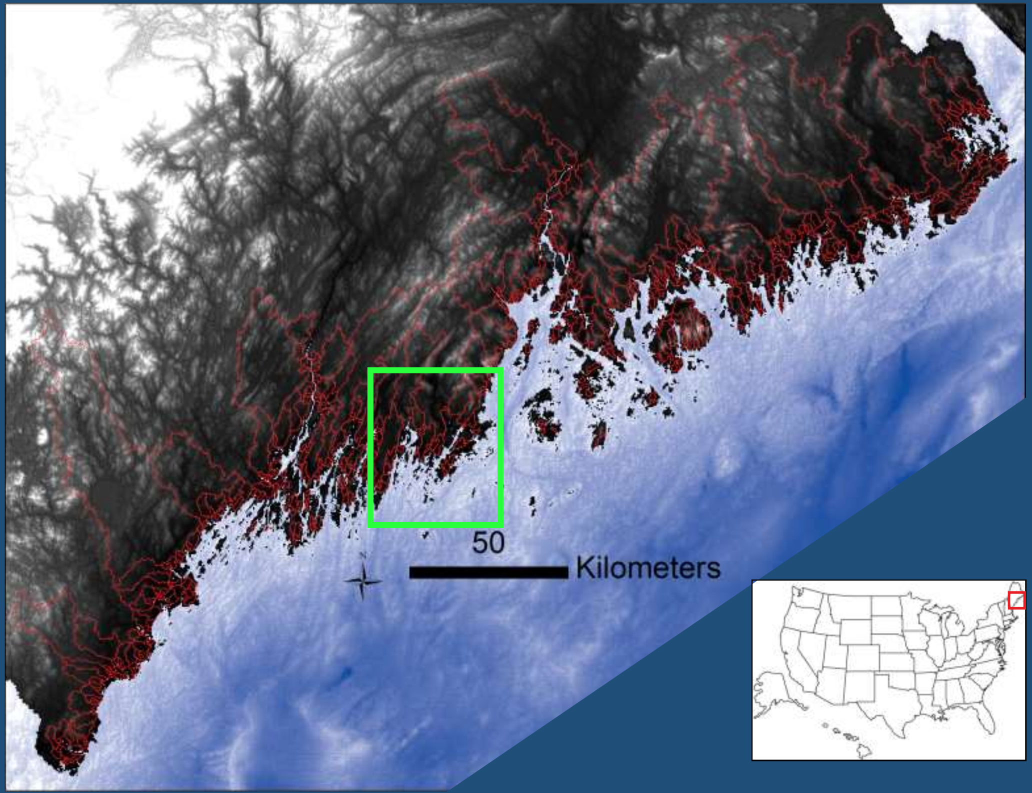
in 3D:

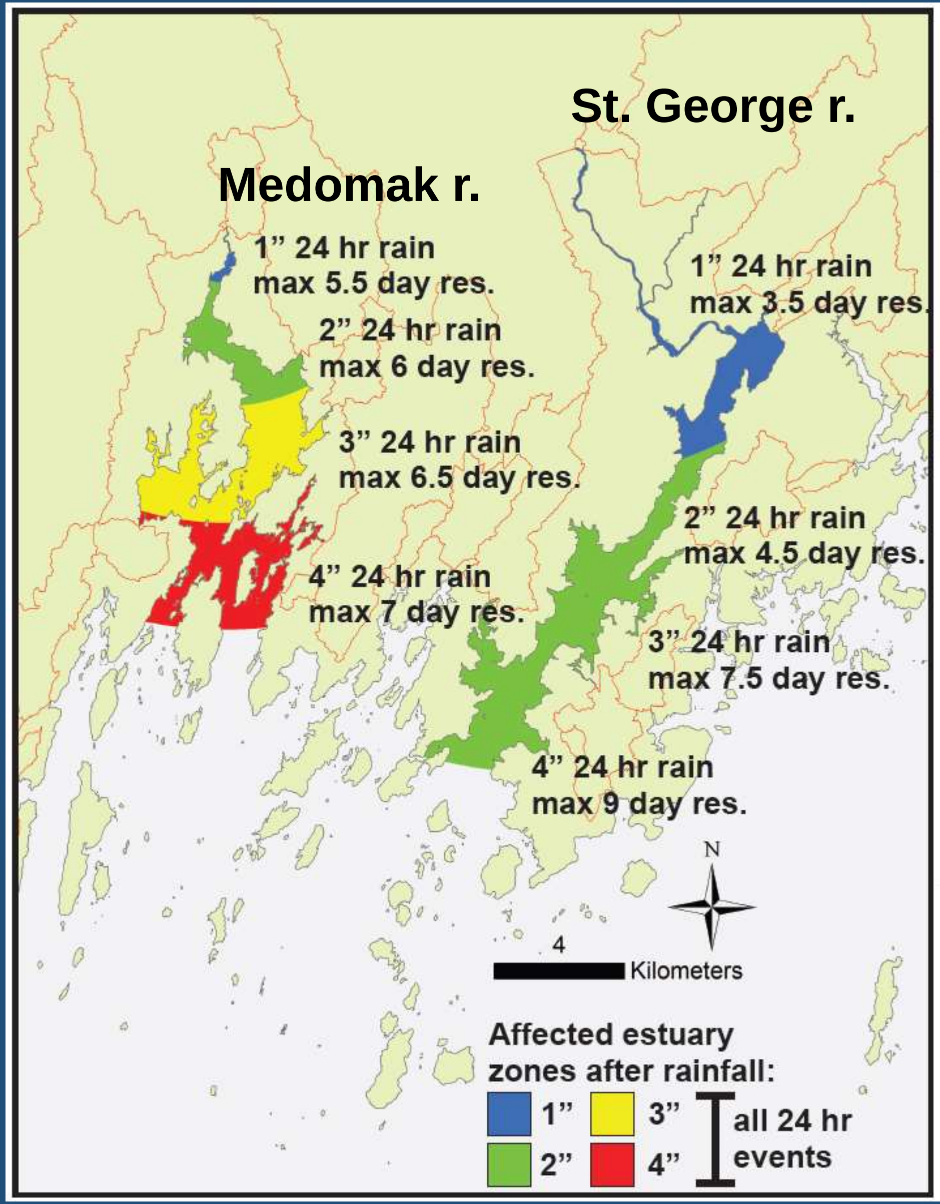


Can we improve the capacity to tailor local closure rules?

Initial results

- Larger rivers = more runoff = longer flushing time
- Larger estuaries = greater flushing capacity
- Shallow estuaries = faster flushing for small rainfall events

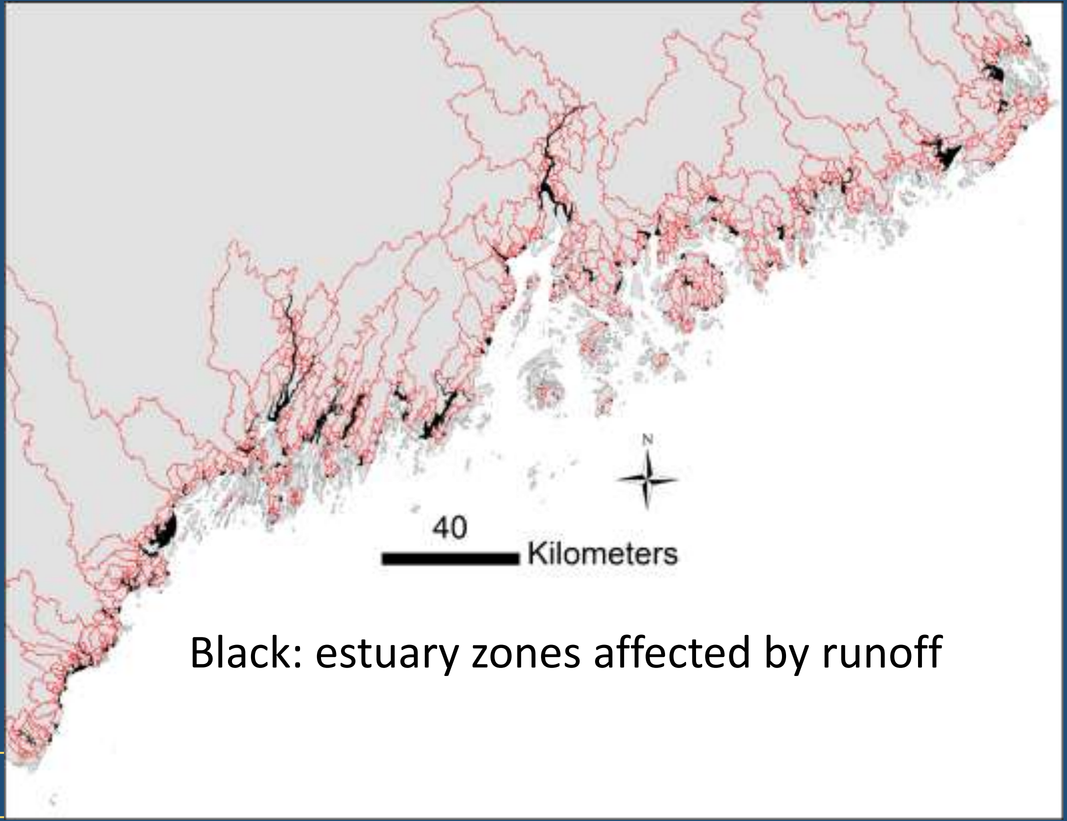




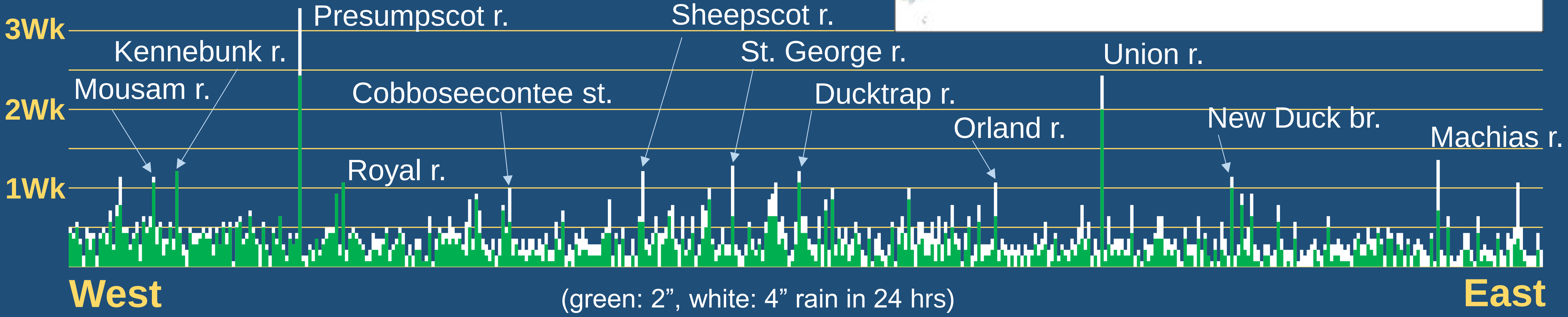
Can we improve the capacity to tailor local closure rules?

Gulf of Maine results

- Model results: for majority of locations, runoff flushes sufficiently before two weeks for a 2”, 24 hour rainstorm
- Some estuaries are highly sensitive to storm intensity
- High concern areas: urbanized watersheds draining into estuaries with poor flushing capacity
- Exploratory method, proof of concept, does not replace models studying hydrodynamics and bacterial survival!



Flushing times:



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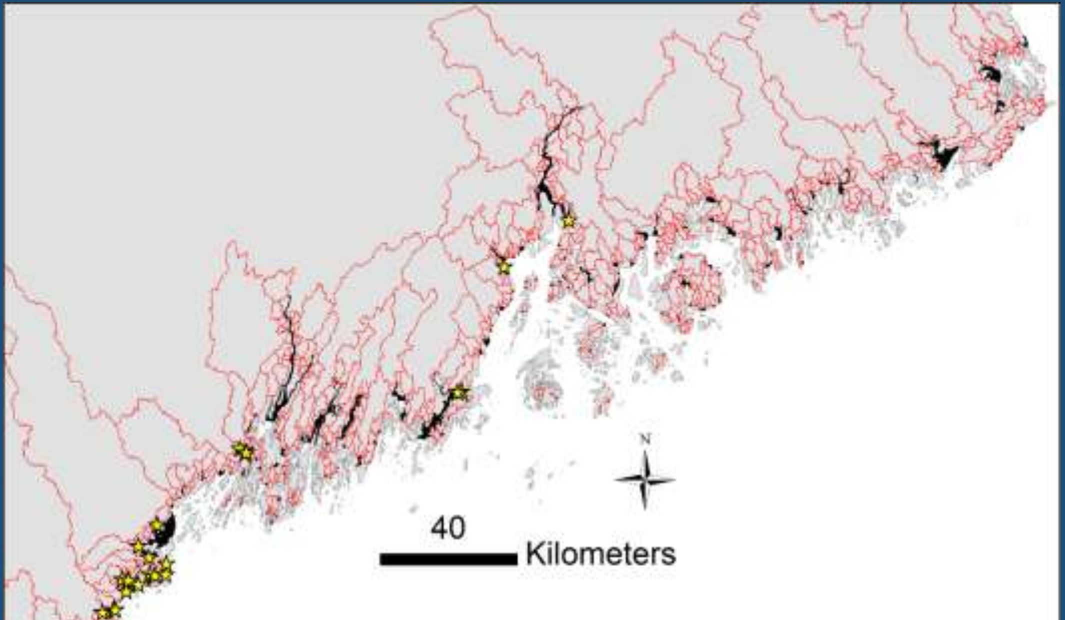

Black: estuary zones affected by runoff
Stars: urbanized watersheds with poor flushing

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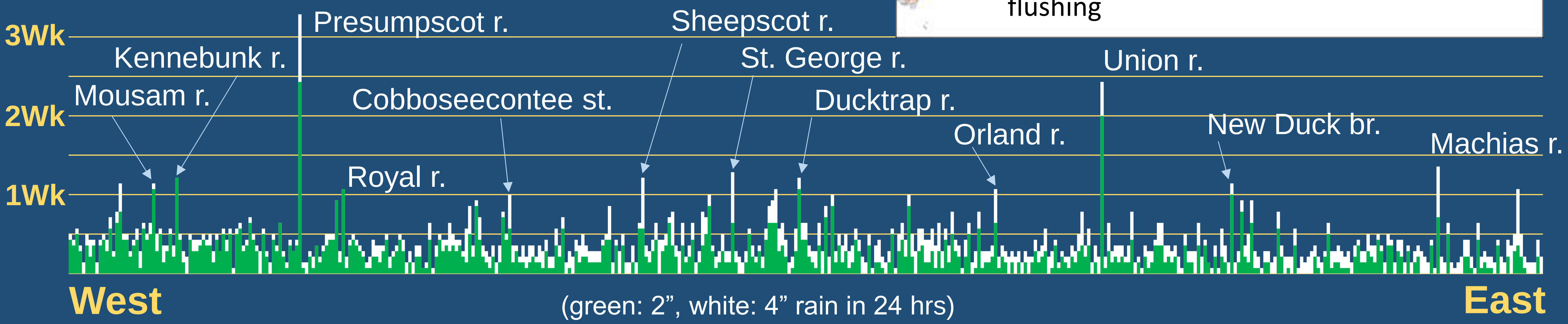

(green: 2", white: 4" rain in 24 hrs)

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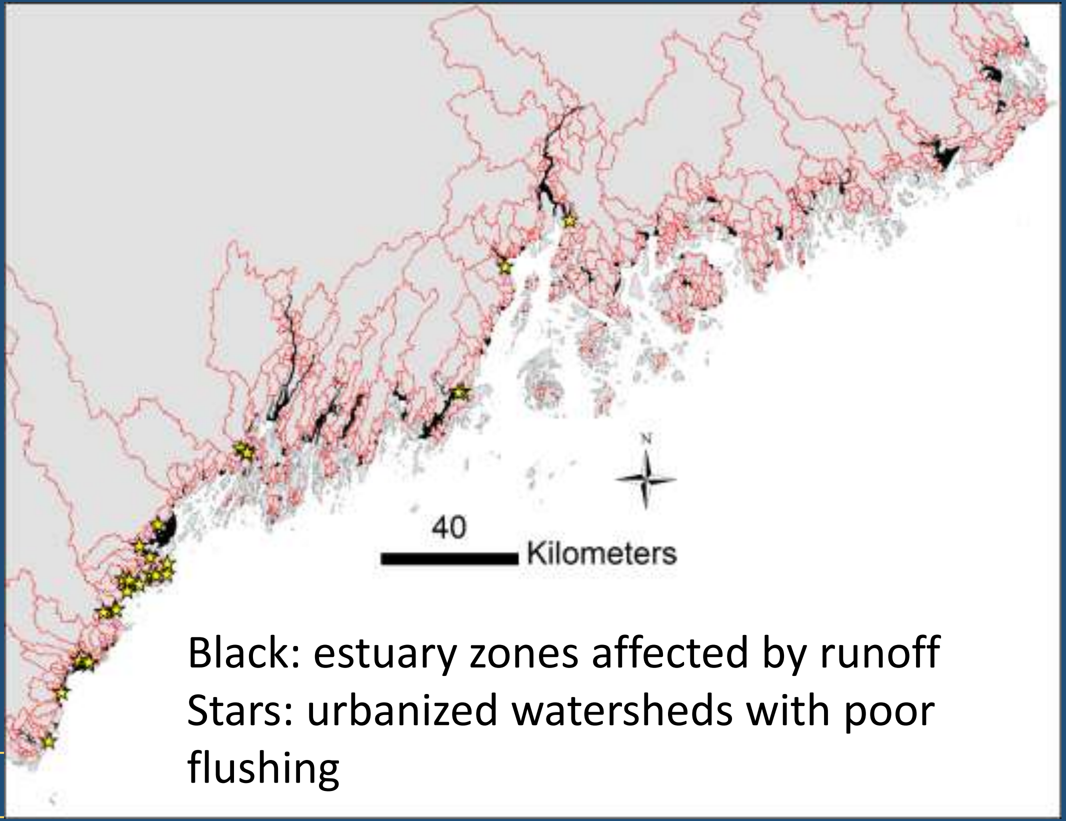
Conclusions

- Metrics for contaminant source, delivery, and residence are statistically significant for identifying closure risk
- Watershed-estuary systems with high contaminant source, rapid delivery, and poor flushing are most sensitive
- Mitigation attempts must come from source and delivery



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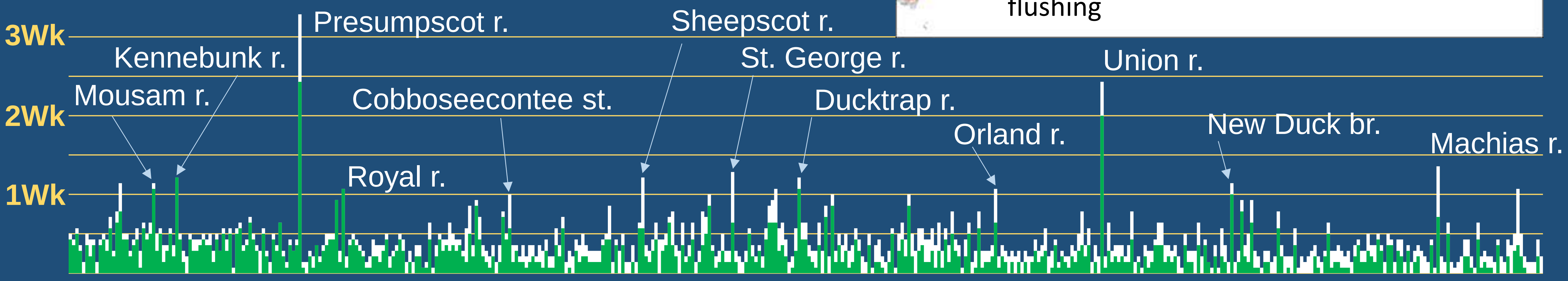


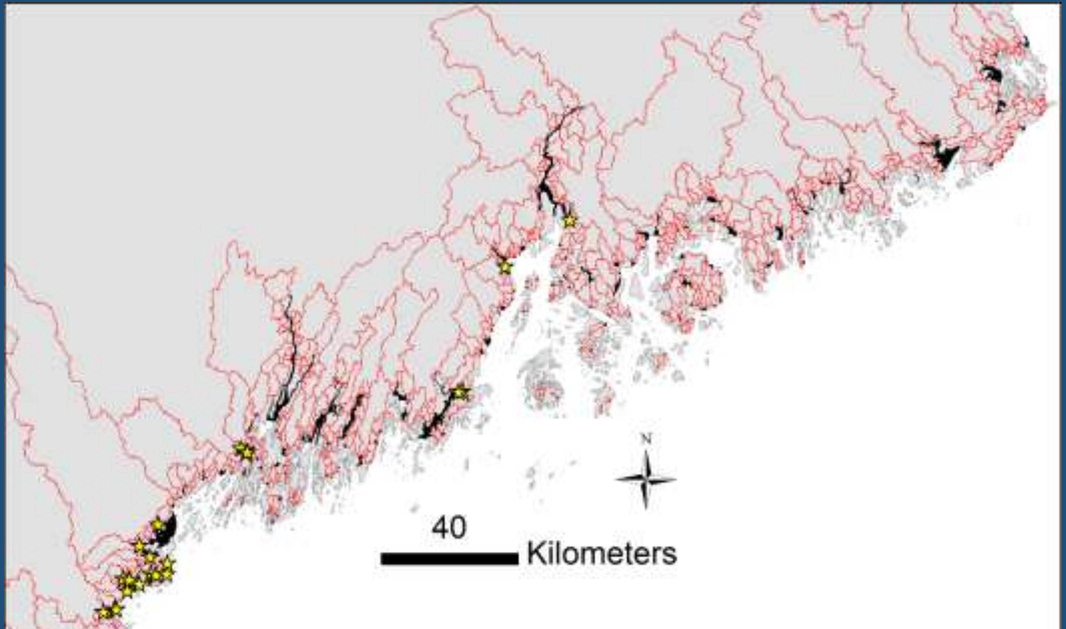
West East

(green: 2”, white: 4” rain in 24 hrs)

Can we improve the capacity to tailor local closure rules?

What needs doing

- Regular sampling at more locations, especially river outlets
- Calibrate models by salinity data, coliform scores
- Quantification of shoreline sources
- Comparison with estuary-scale circulation models



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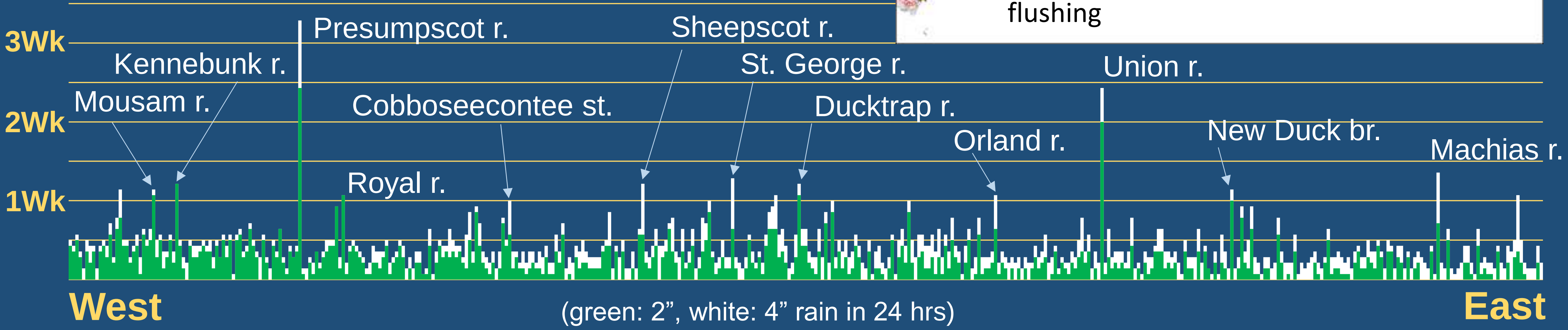

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References

- Maine office of GIS
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- USGS National Hydrography dataset
  - **https://nhd.usgs.gov/**
- NRCS SSURGO Database
  - **https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053627**
- Ketchum, Bostwick H. "The exchanges of fresh and salt waters in tidal estuaries." *Journal of marine research* 10.1 (1951): 18-38.
- Arons, Arnold B., and Henry Stommel. "A mixing-length theory of tidal flushing." *Eos, Transactions American Geophysical Union* 32.3 (1951): 419-421.