Downeast Drainage

Examining and Communicating Pollution Problems Along the Coast of Maine

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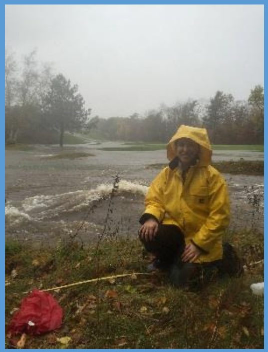
Photo of clam harvesting in a coastal mudflat taken by Bridie McGreavy, University of Maine

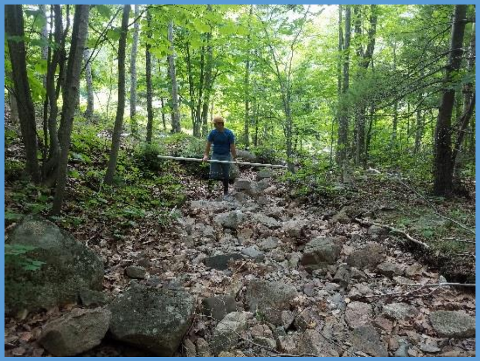
Component	Management Question
Source	What conditions generate pollution sources that cause bacteria pollution problems?
Delivery	How do patterns of pollutant delivery affect the timing and magnitude of bacteria pollution events?
Residence Time	How long do bacteria pollution events last after a watershed delivery event?

NEST Biophysical Research Team

Gulf of Maine Scale: A runoff-based coastal bacteria pollution *vulnerability analysis*

- High bacterial counts often correlate with rainfall events
- Rivers deliver terrestrial contaminants to the coast
- Using geospatial data and hydraulic models, we can:
  - Identify watershed metrics that correlate with high contamination frequency
  - Estimate residence time and concentration of runoff within harvesting zones





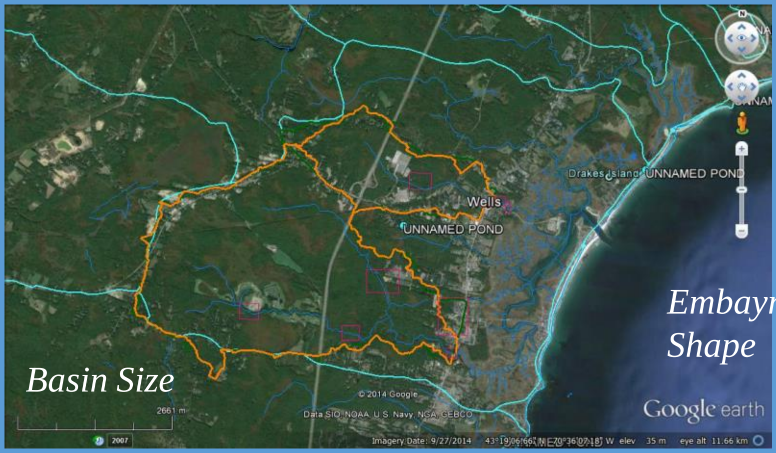

Gulf of Maine Scale

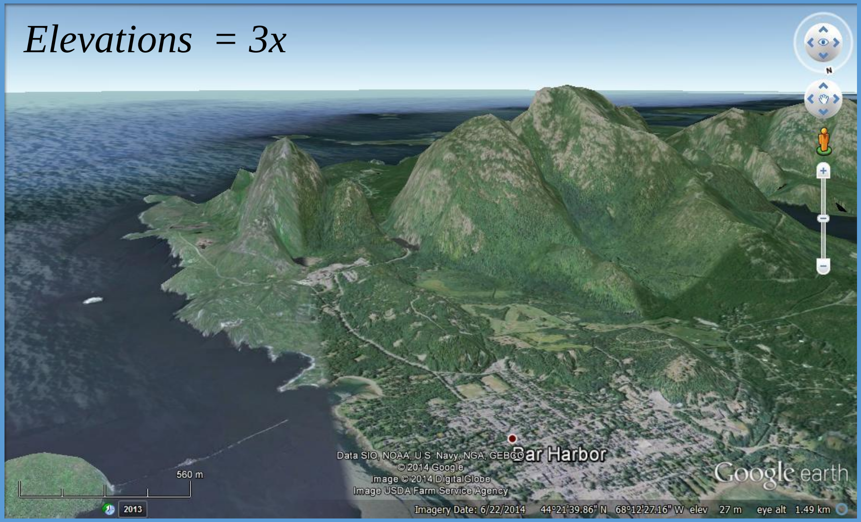
Landscape Pollution Response Units:

Sources
- Basin Size
- Soil Drainage
- Human Population
- Land cover

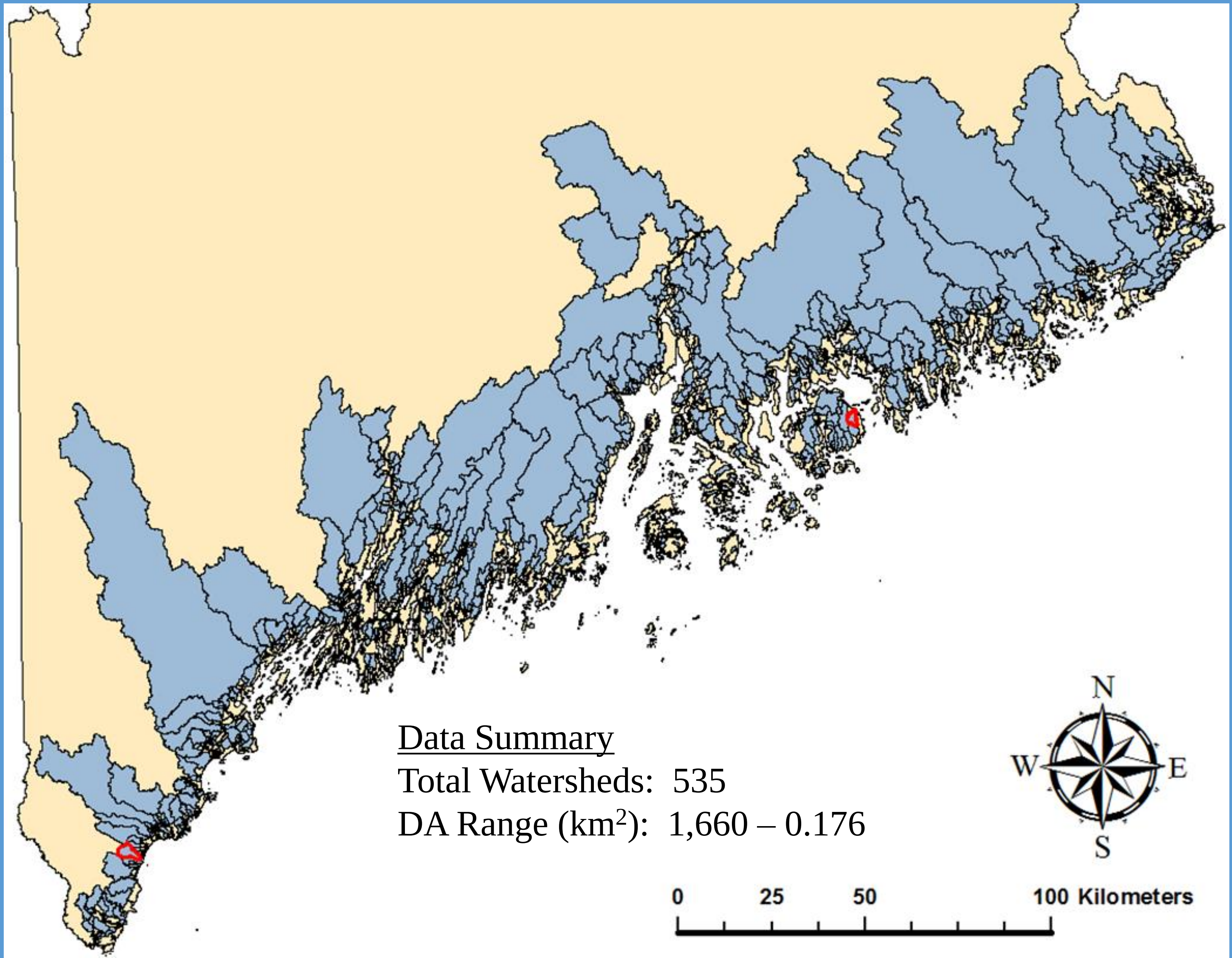
Delivery
- Basin Size
- Relief
- Drainage Density

Residence Time
- Tidal Embayment Hydraulics



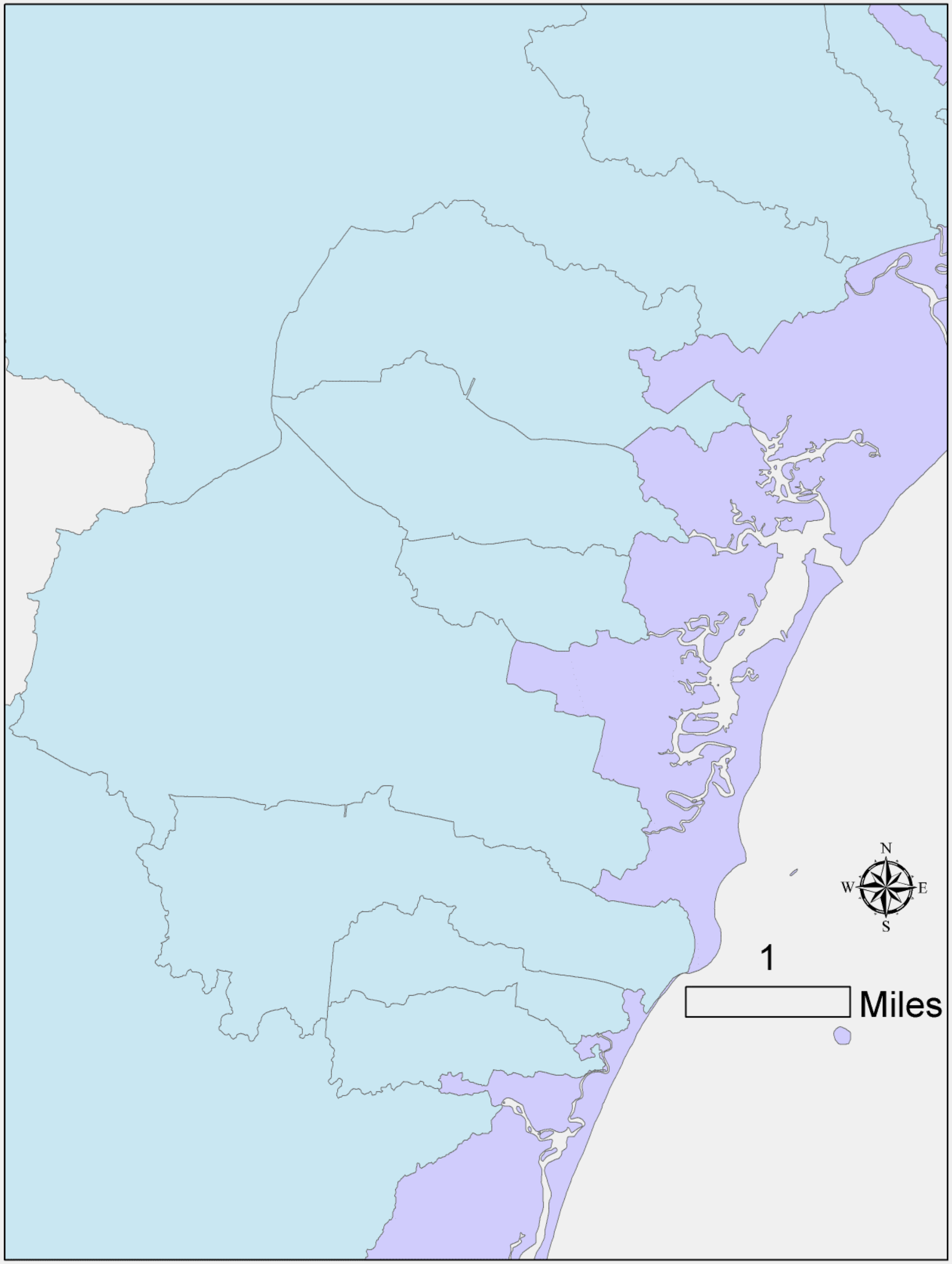


First Step: Identify and delineate small coastal watersheds



Data Gap:

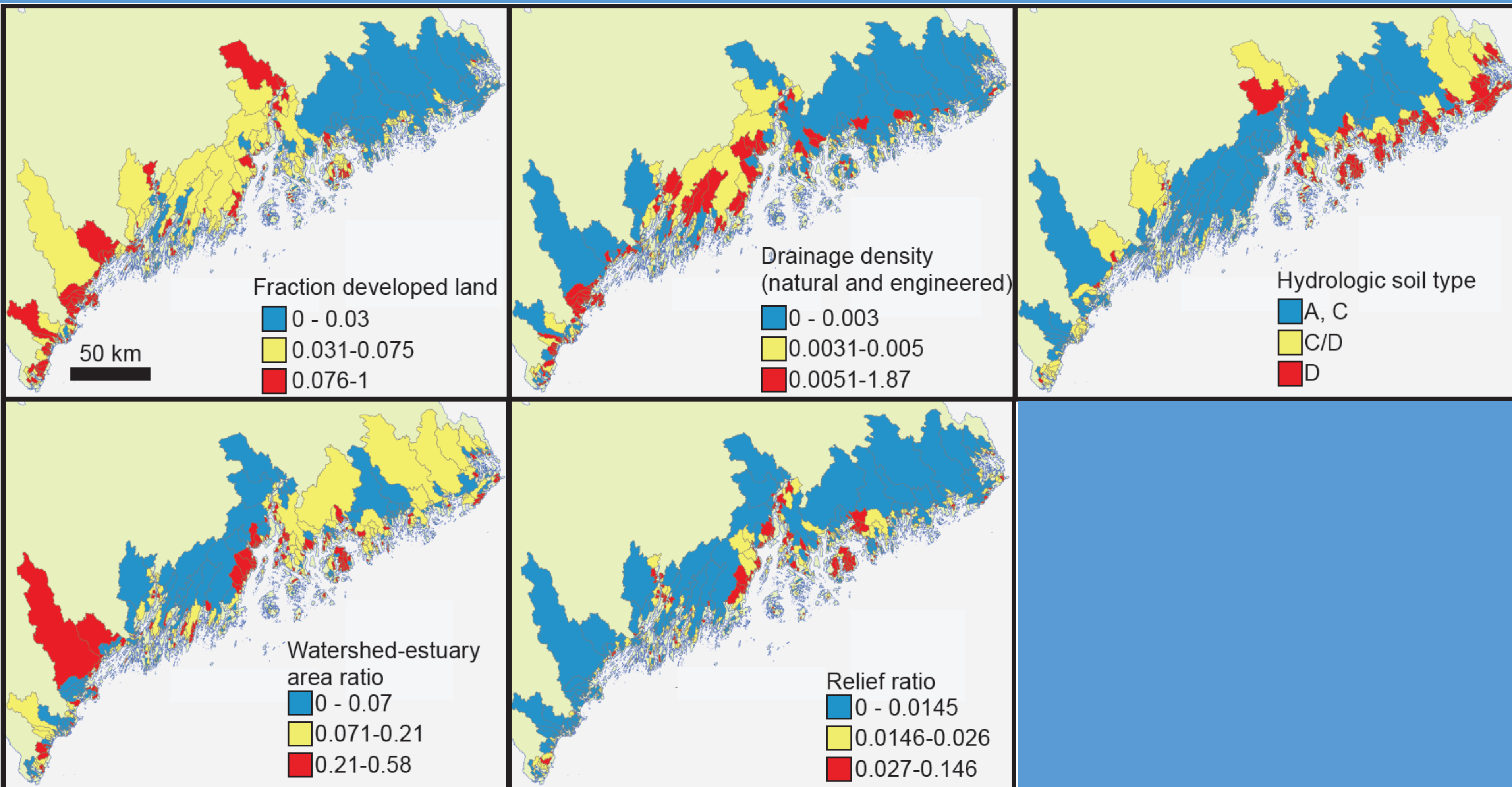
New delineations of “Intertidal Watersheds” were necessary.



Watershed Metrics

Source of runoff, TSS & bacteria
Delivery by overland surface flow
Residence time of runoff in estuaries

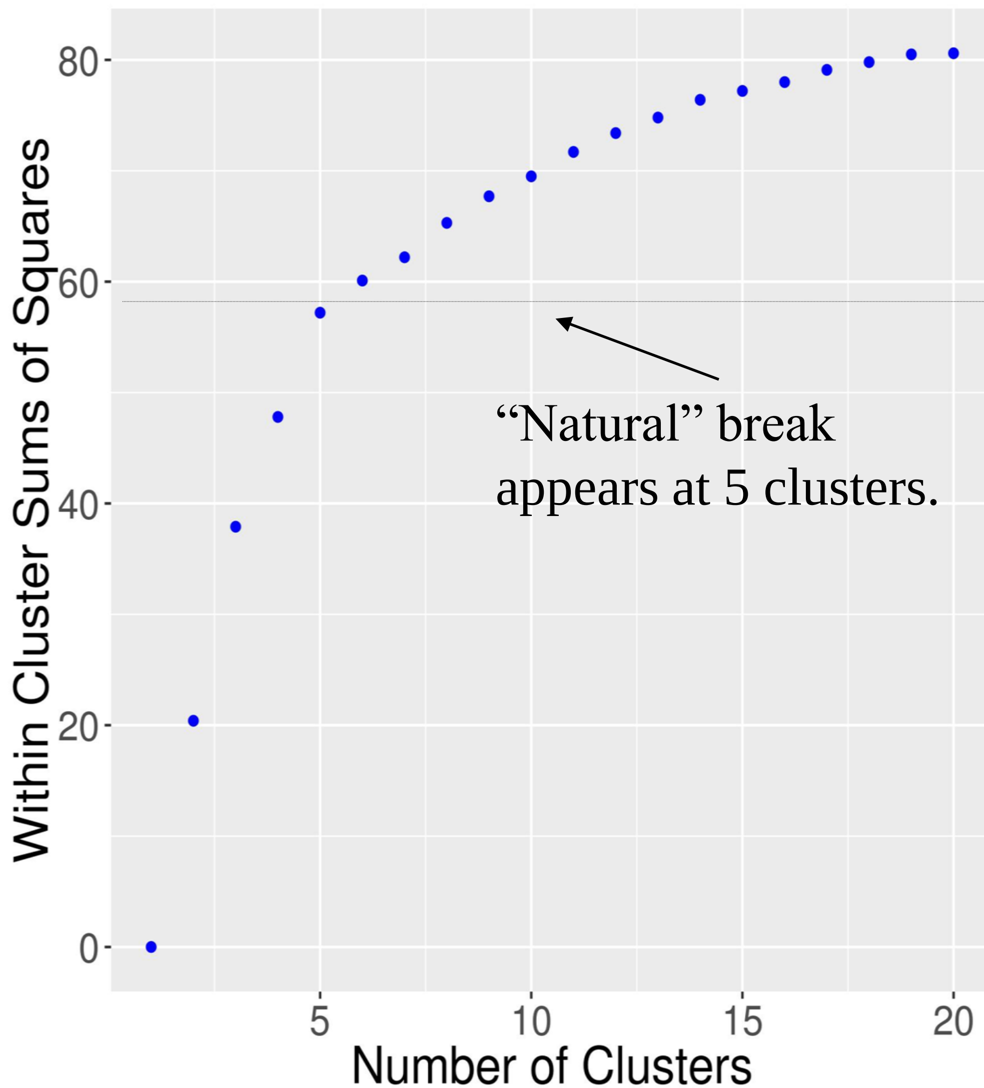
Example Proxies to Account for Watershed Processes



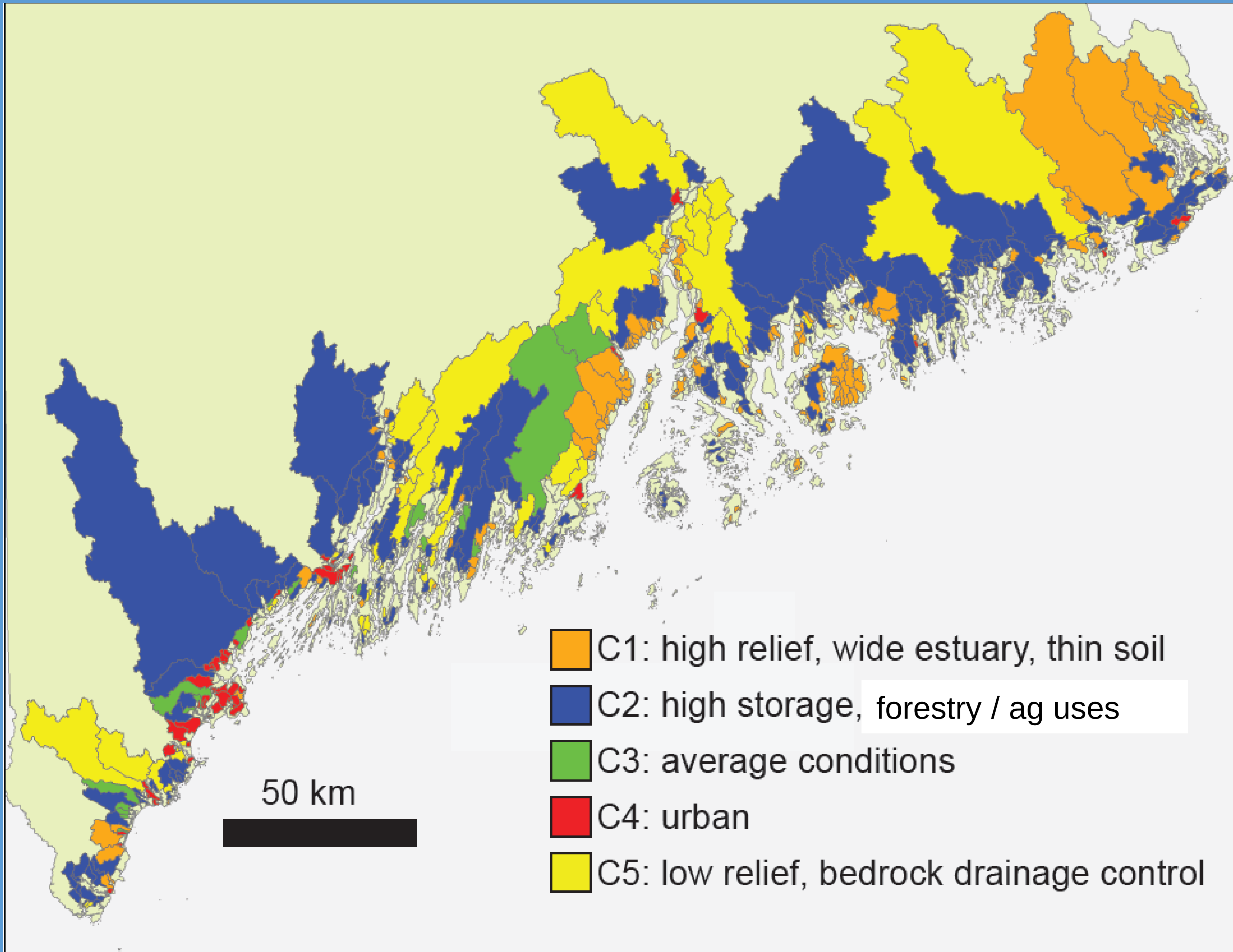
Watershed Process Metrics (*Proxies*):

Source of runoff, TSS & bacteria
Delivery by overland flow
Residence time of runoff in estuaries

Drainage Density
% Developed
% Worked
% Rural
% Storage
Soil Runoff
Population Density
Relief Ratio
Fraction Igneous Bedrock
Tectonic Fault Density
Geolocic Contact Density
Fault Orientation
Mean Bedrock Orientation
Estuary Circularity
Estuary/Watershed Ratio

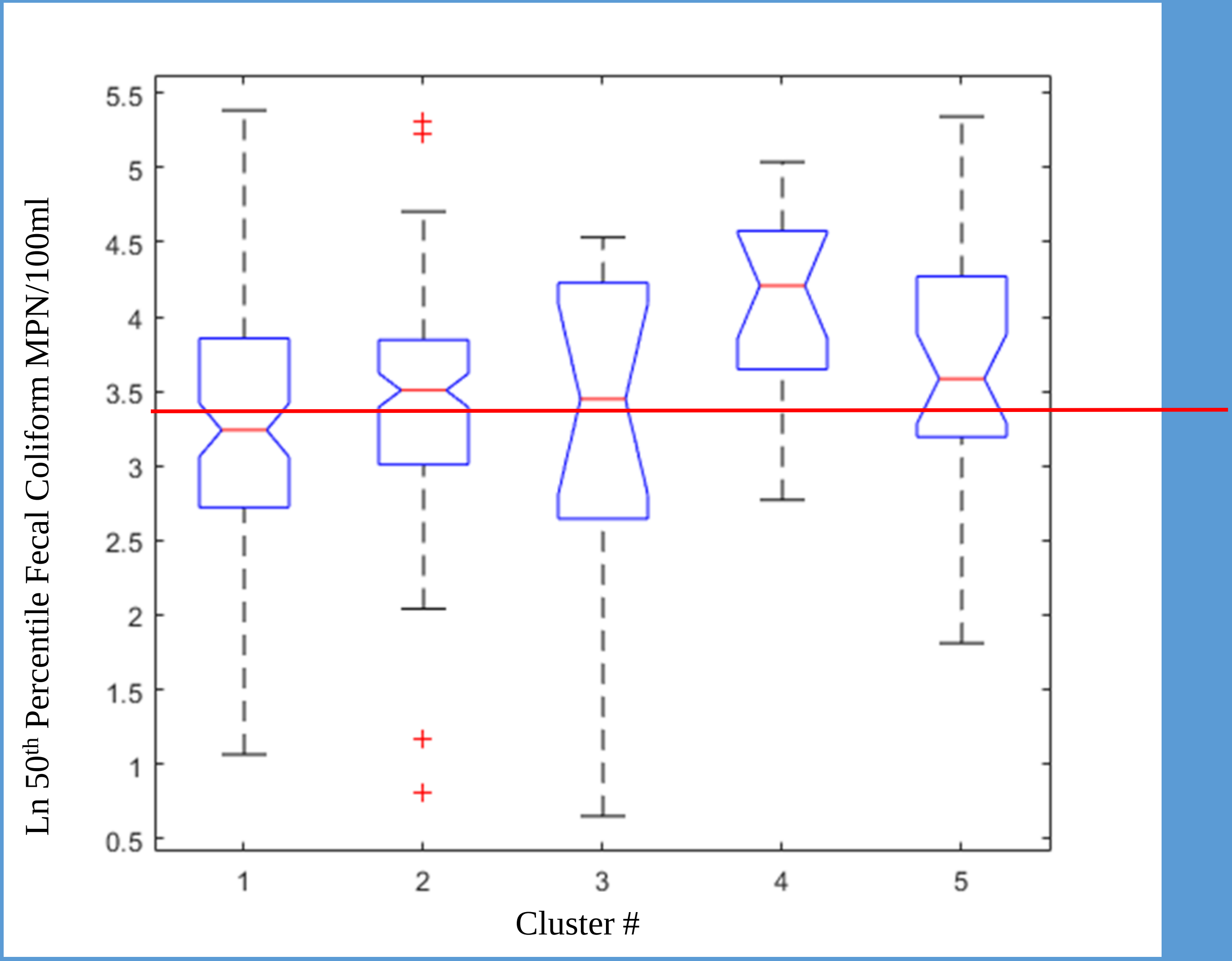


Coastal Watershed Clusters



Watershed Cluster vs. Bacteria Sample Data

- Visible correlation between the urban cluster (C4) and high mean bacteria counts
- Largest variability among least distinct watersheds (C3)



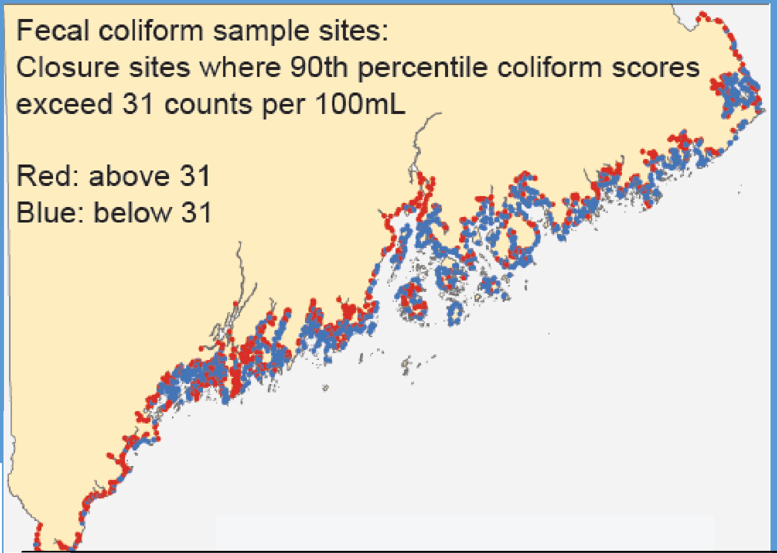
Safety threshold: 31 ct mL^{-1}

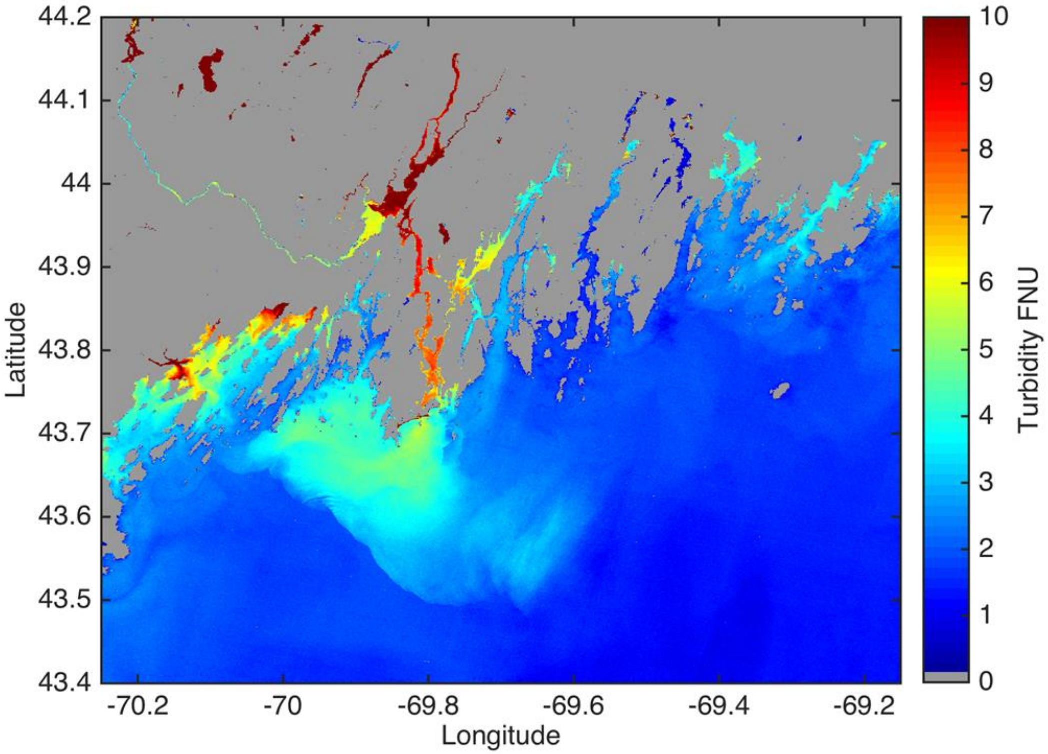
Statistically similar worst cases conditions (90th Percentile MPN)

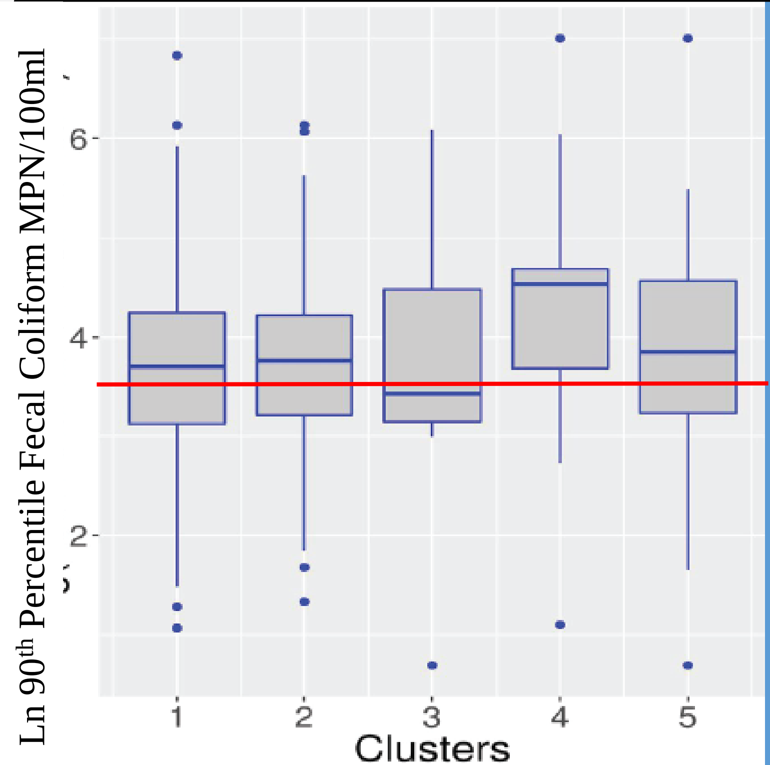
Culprits!

- Stochastic events (*spills and breaks*)
- Large river flows

All watershed types are susceptible to contamination at some point in time







Source: UMaine Coastal Satelite Oceanography Team

Reference Watershed Scale

How do specific coastal watershed features contribute to problematic pollution loadings?

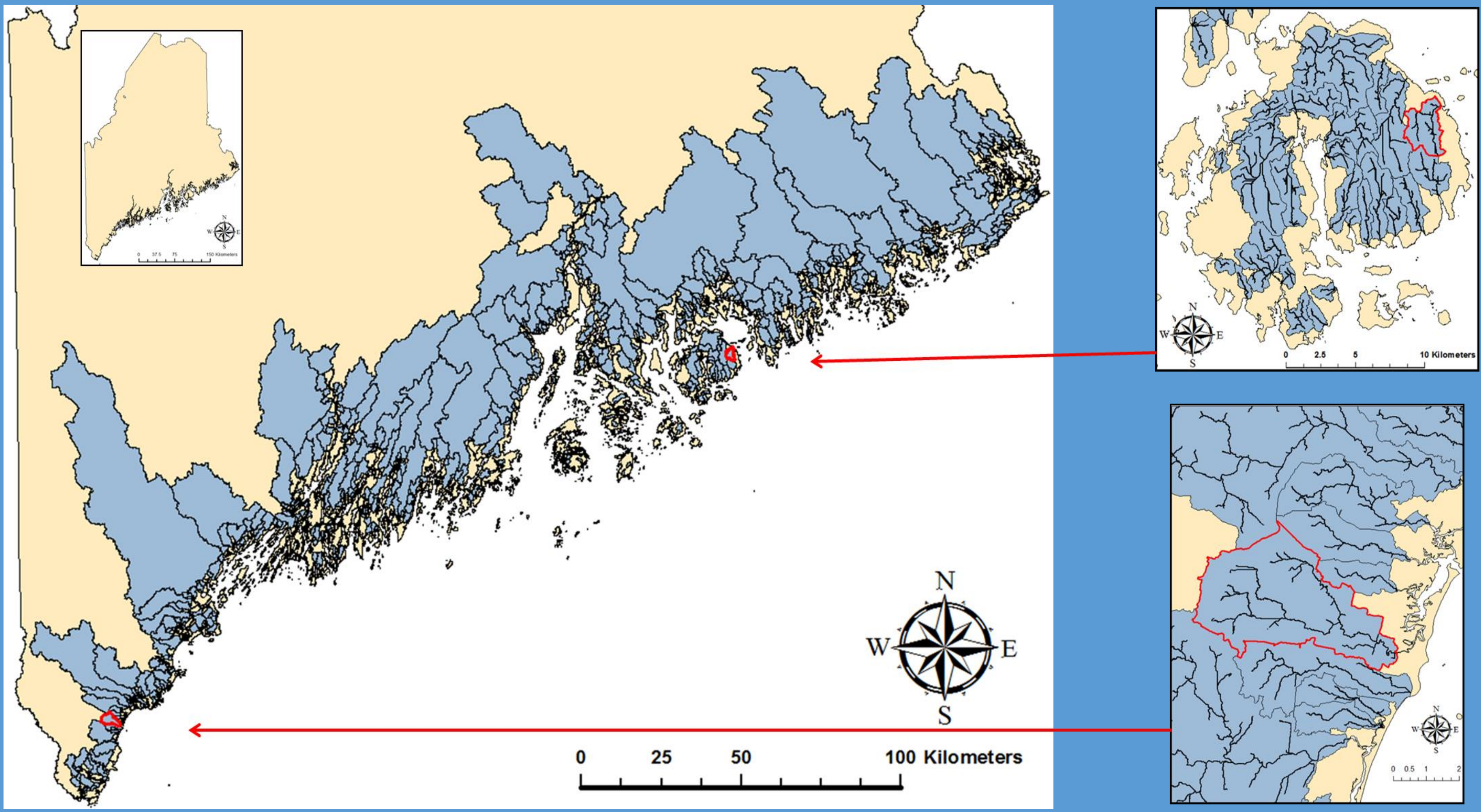
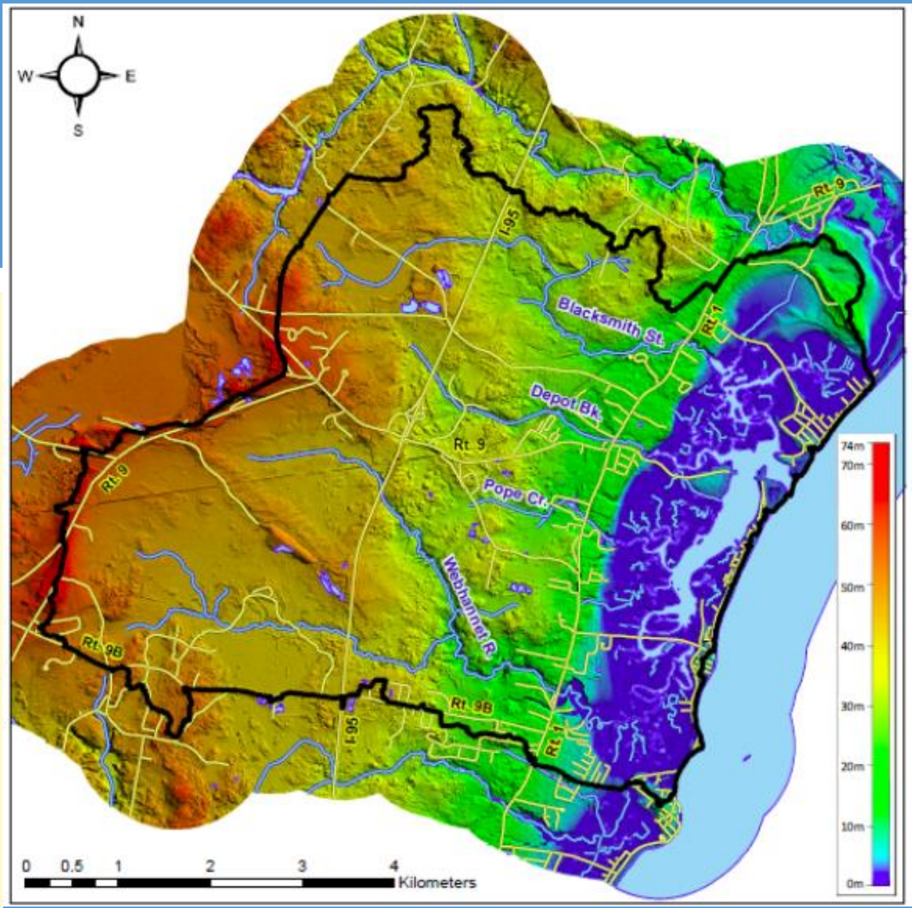
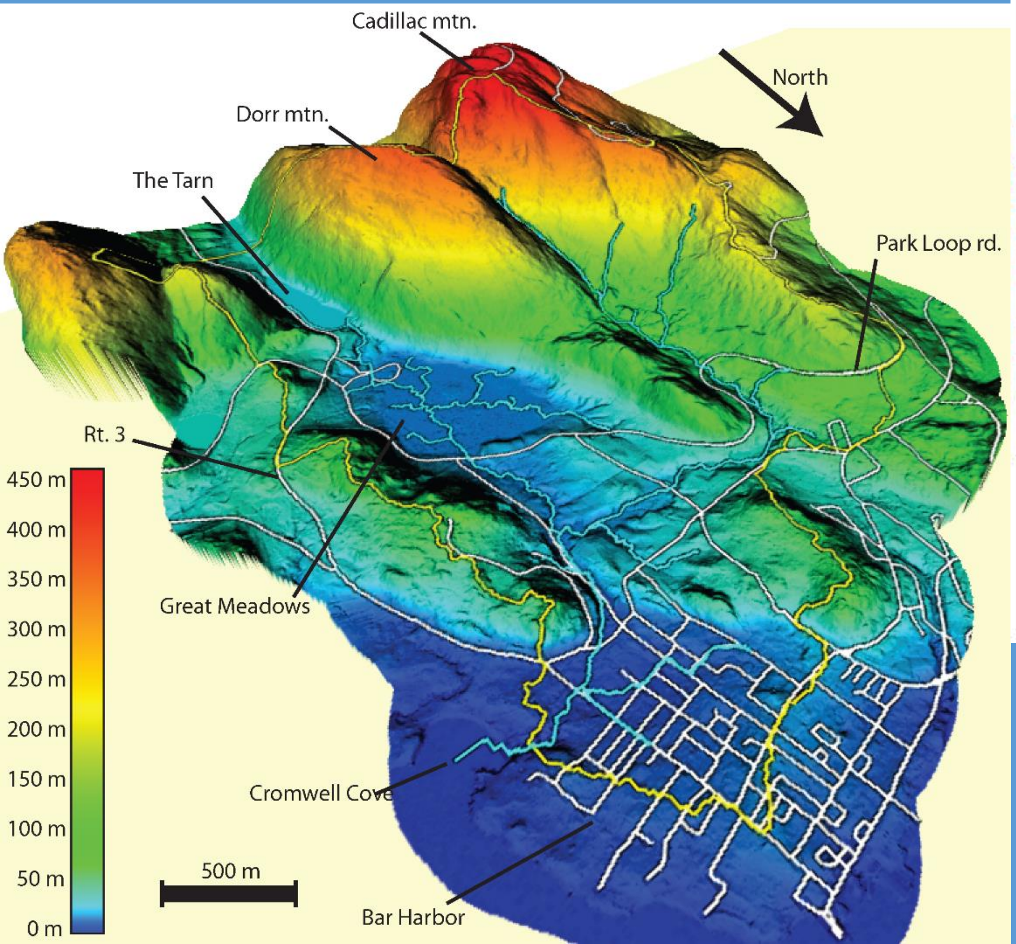


Image of coastal Gulf of Maine watersheds, with insets of Wells Harbor and Cromwell Brook watersheds. Created by Abigail Bradford, Univ. of Maine

Reference Watershed Scale: How do specific watershed attributes contribute to problematic pollution loadings?

Wells Harbor Estuary (Webhannet River)





Cromwell Brook Watershed, MDI

Watershed Measurements

- Stream Flow
- Channel Dimensions
- Water Quality Sampling

Method	2.4%	-	
# Stations	3.6%	-	
Overall	**4.6%**	**12.9%**	

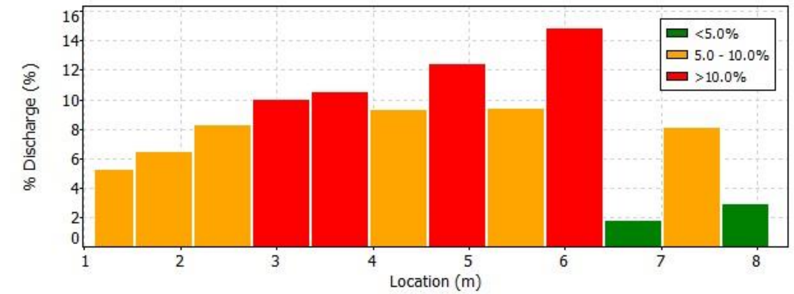
Summary

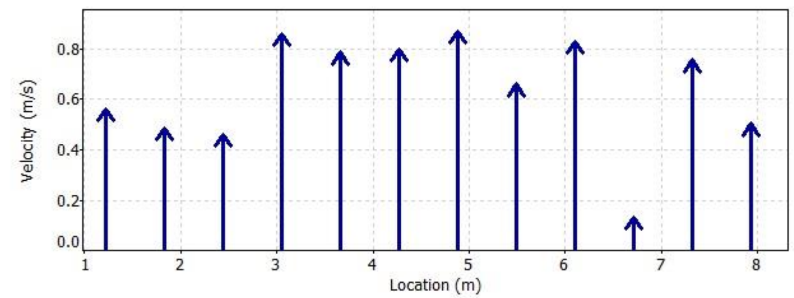
Averaging Int.	40	# Stations	14
Start Edge	LEW	Total Width	7.346
Mean SNR	35.8 dB	Total Area	1.599
Mean Temp	10.73 °C	Mean Depth	0.218
Disch. Equation	Mid-Section	Mean Velocity	0.6477
		Total Discharge	**1.0356**

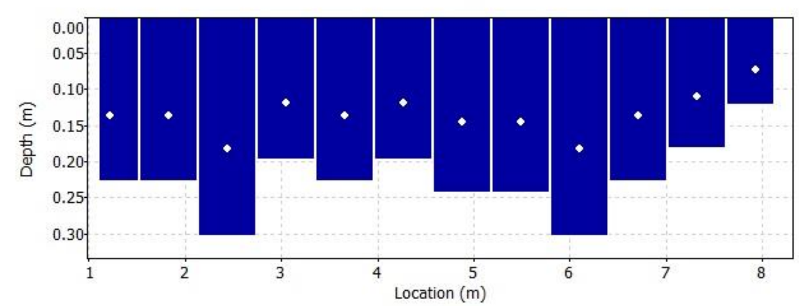
Measurement Results

St	Clock	Loc	Method	Depth	%Dep	MeasD	Vel	CorrFact	MeanV	Area	Flow	%Q
0	15:17	0.98	None	0.000	0.0	0.0	0.0000	1.00	0.0000	0.000	0.0000	0.0
1	15:19	1.22	0.6	0.229	0.6	0.091	0.5639	1.00	0.5639	0.098	0.0550	5.3
2	15:20	1.83	0.6	0.229	0.6	0.091	0.4864	1.00	0.4864	0.139	0.0678	6.5
3	15:21	2.44	0.6	0.305	0.6	0.122	0.4634	1.00	0.4634	0.186	0.0861	8.3
4	15:22	3.05	0.6	0.198	0.6	0.079	0.8618	1.00	0.8618	0.121	0.1041	10.0
5	15:29	3.66	0.6	0.229	0.6	0.091	0.7877	1.00	0.7877	0.139	0.1098	10.6
6	15:32	4.27	0.6	0.198	0.6	0.079	0.8007	1.00	0.8007	0.121	0.0967	9.3
7	15:33	4.88	0.6	0.244	0.6	0.098	0.8706	1.00	0.8706	0.149	0.1294	12.5
8	15:35	5.49	0.6	0.244	0.6	0.098	0.6606	1.00	0.6606	0.149	0.0982	9.5
9	15:37	6.10	0.6	0.305	0.6	0.122	0.8308	1.00	0.8308	0.186	0.1544	14.9
10	*15:38*	*6.71*	*0.6*	*0.229*	*0.6*	*0.091*	*0.1357*	*1.00*	*0.1357*	*0.139*	*0.0189*	*1.8*
11	15:40	7.32	0.6	0.183	0.6	0.073	0.7562	1.00	0.7562	0.111	0.0843	8.1
12	15:42	7.92	0.6	0.122	0.6	0.049	0.5056	1.00	0.5056	0.061	0.0310	3.0
13	15:42	8.32	None	0.000	0.0	0.0	0.0000	1.00	0.0000	0.000	0.0000	0.0

Rows in italics indicate a QC warning. See the Quality Control page of this report for more information.







Watershed Modeling Platform – MIKESHE (DHI)

Coupled Groundwater – Surface Water Modeling

50 m grid ; Continuous Precipitation Time Series

Evapotranspiration:
$Evap = ET_{ref} * \Delta t$
$E_{at} = f(LAI)*f(\Theta)*RDF*ET_{ref}$

Rainfall and Snowfall

Canopy Interception:
$Inter. = C_{int} * LAI$

Channel Flow:

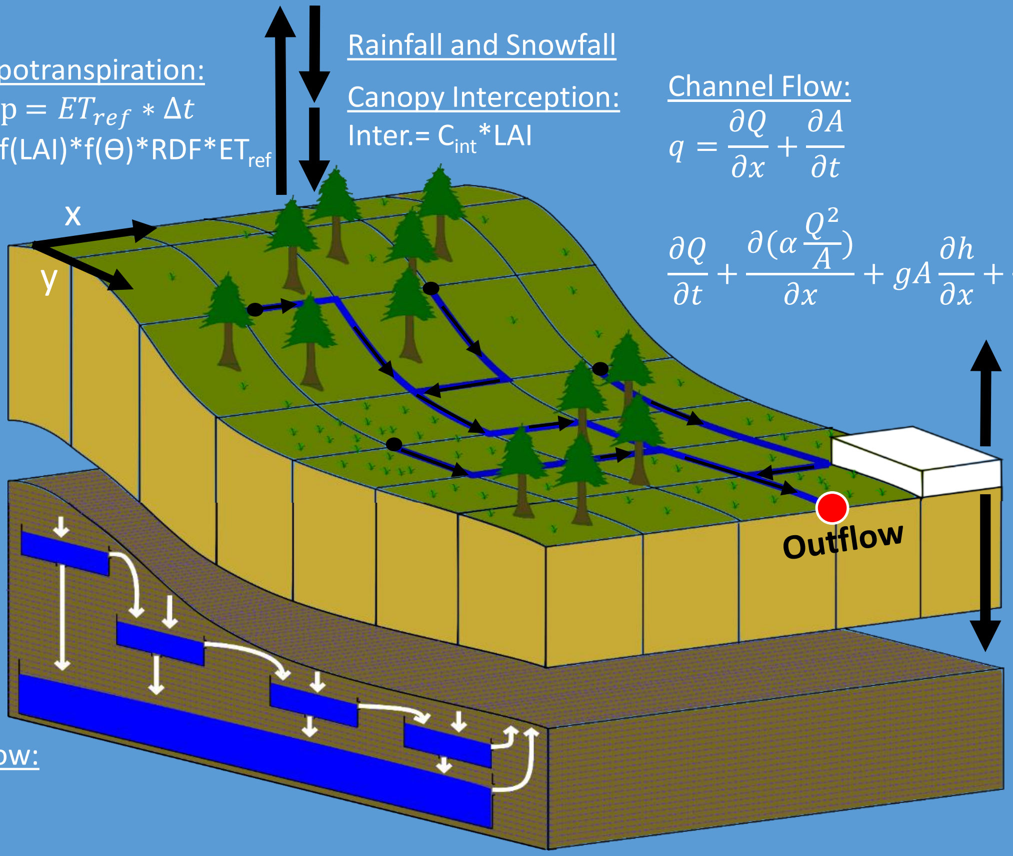
$$q = \frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t}$$

$$\frac{\partial Q}{\partial t} + \frac{\partial(\alpha \frac{Q^2}{A})}{\partial x} + gA\frac{\partial h}{\partial x} + \frac{gQ|Q|}{C^2 AR} = 0$$

Overland Flow:

$$uh = K_x(-\frac{\partial z}{\partial x})^{\frac{1}{2}} h^{\frac{5}{3}}$$

$$vh = K_y(-\frac{\partial z}{\partial y})^{1/2} h^{5/3}$$



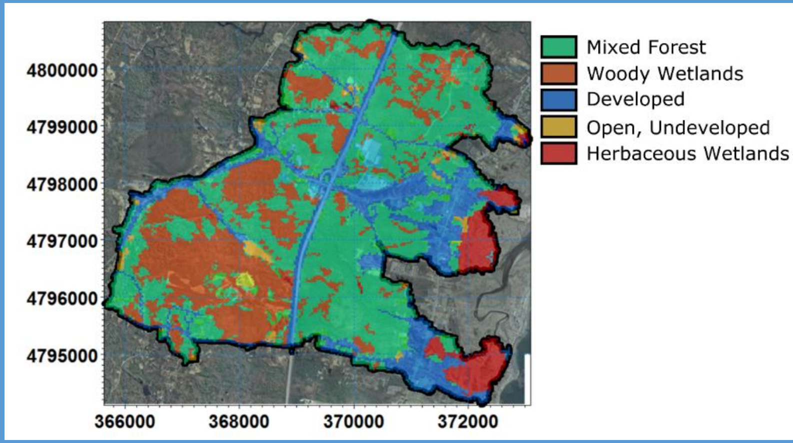
Snow Melt:
Temp. Melt= $C_T(T_{air} - T_0)$
Radiation Melt= $-C_{Rad}R_{SW}$
Energy Melt= $C_E P(T_{air} - T_0)$

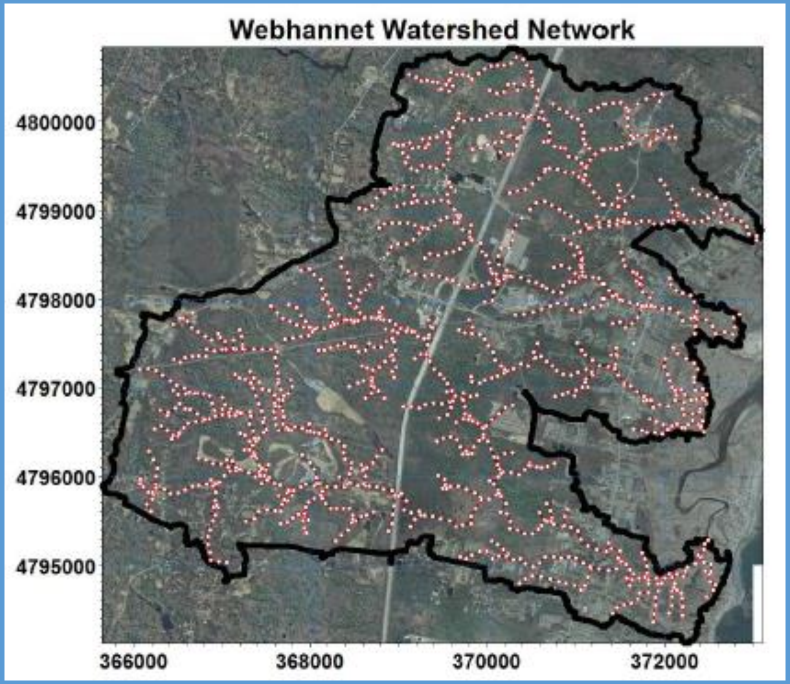
Two-Layer Water Balance:
$Infil. = min(P_b, I_p, ASSV)$
$ASSV = (S - \theta)(z - h)$
$I_p = r(x,y) * \Delta t$

Groundwater Flow:
$S = k * Q$

Figure created by Brett Gerard, U Maine Sch. of Earth and Climate Sciences

Model Parameterization

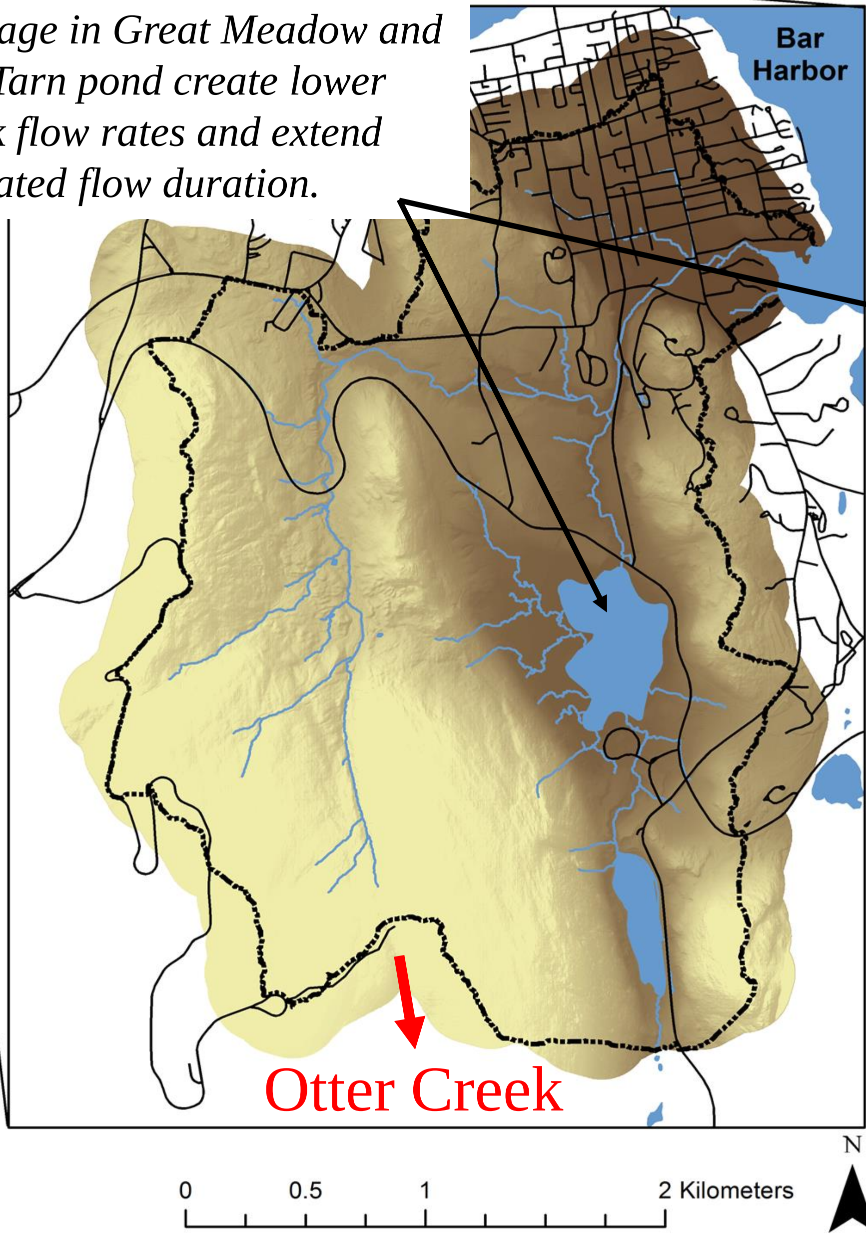




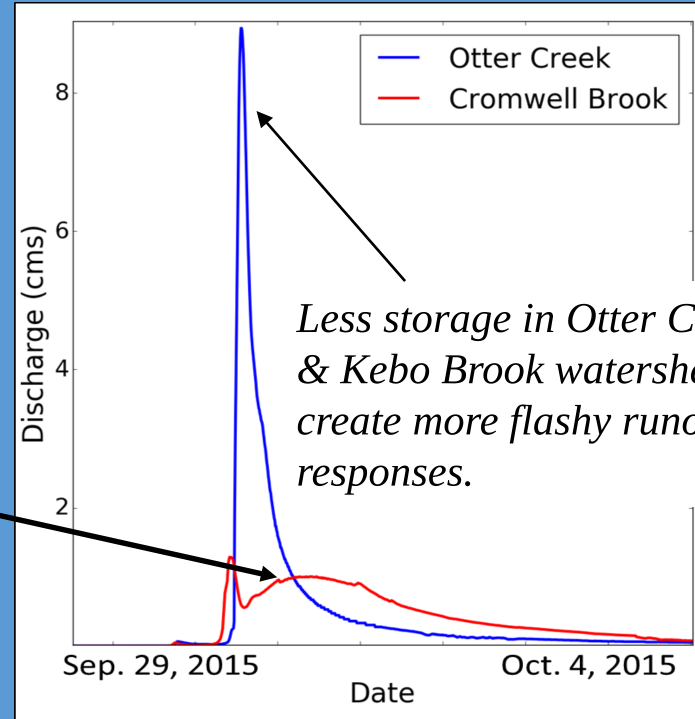
<u>Variable</u>	<u>Source</u>
1. Land Cover	MEGIS
2. Elevation	LiDAR
3. Climate	WUunderground
4. Leaf Area	MODIS
5. Root Depth	Literature
6. Soils	USDS SURGGO
7. GW	Basin Derived

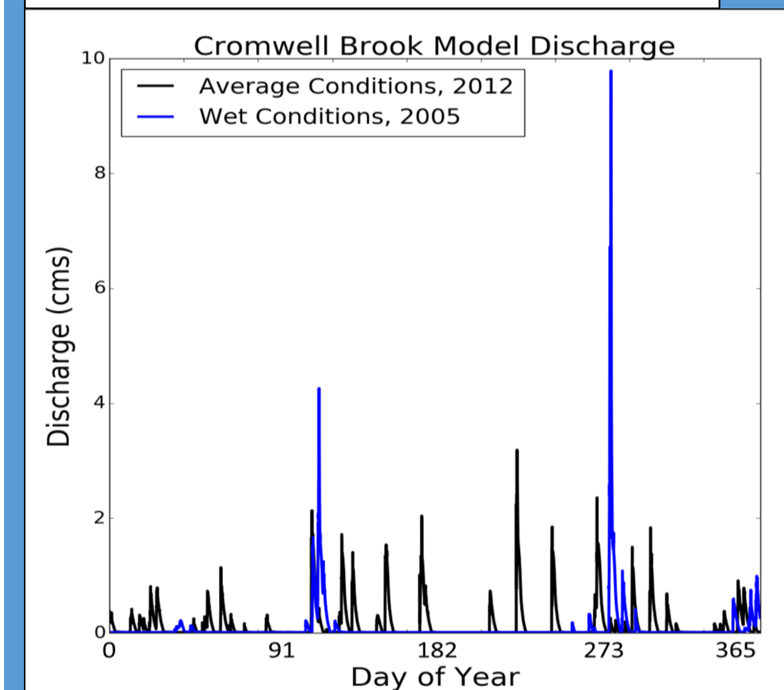
Cromwell Brook

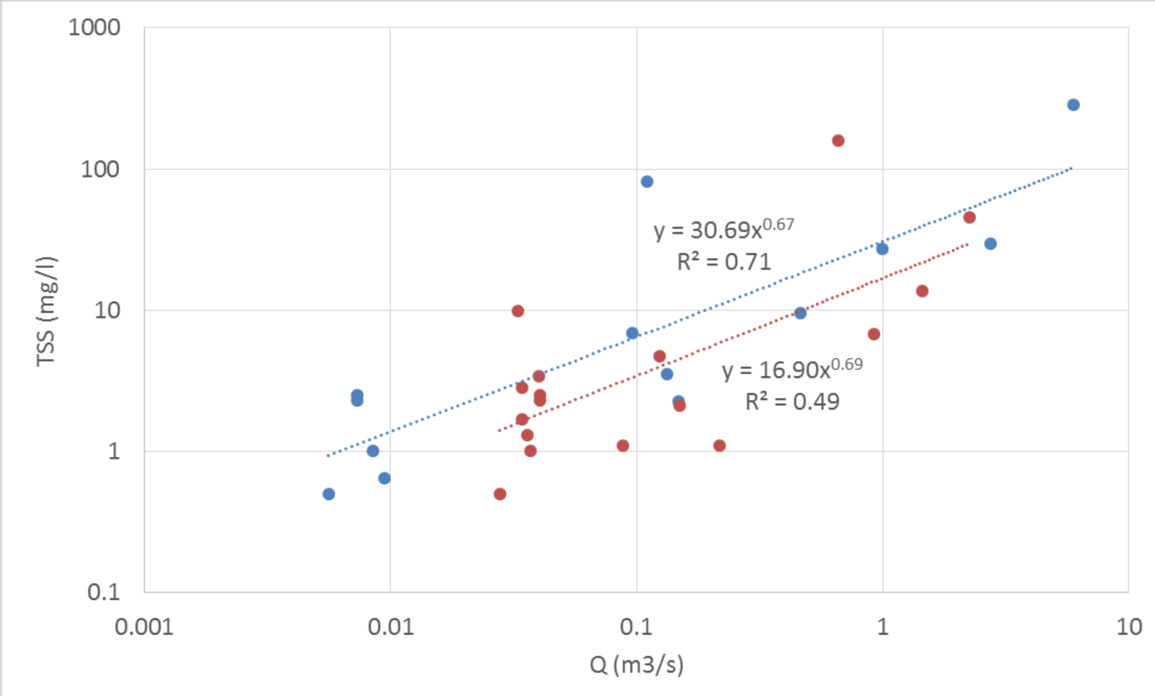
Storage in Great Meadow and the Tarn pond create lower peak flow rates and extend elevated flow duration.



Less storage in Otter Creek & Kebo Brook watersheds create more flashy runoff responses.







Water Quality Load Estimation

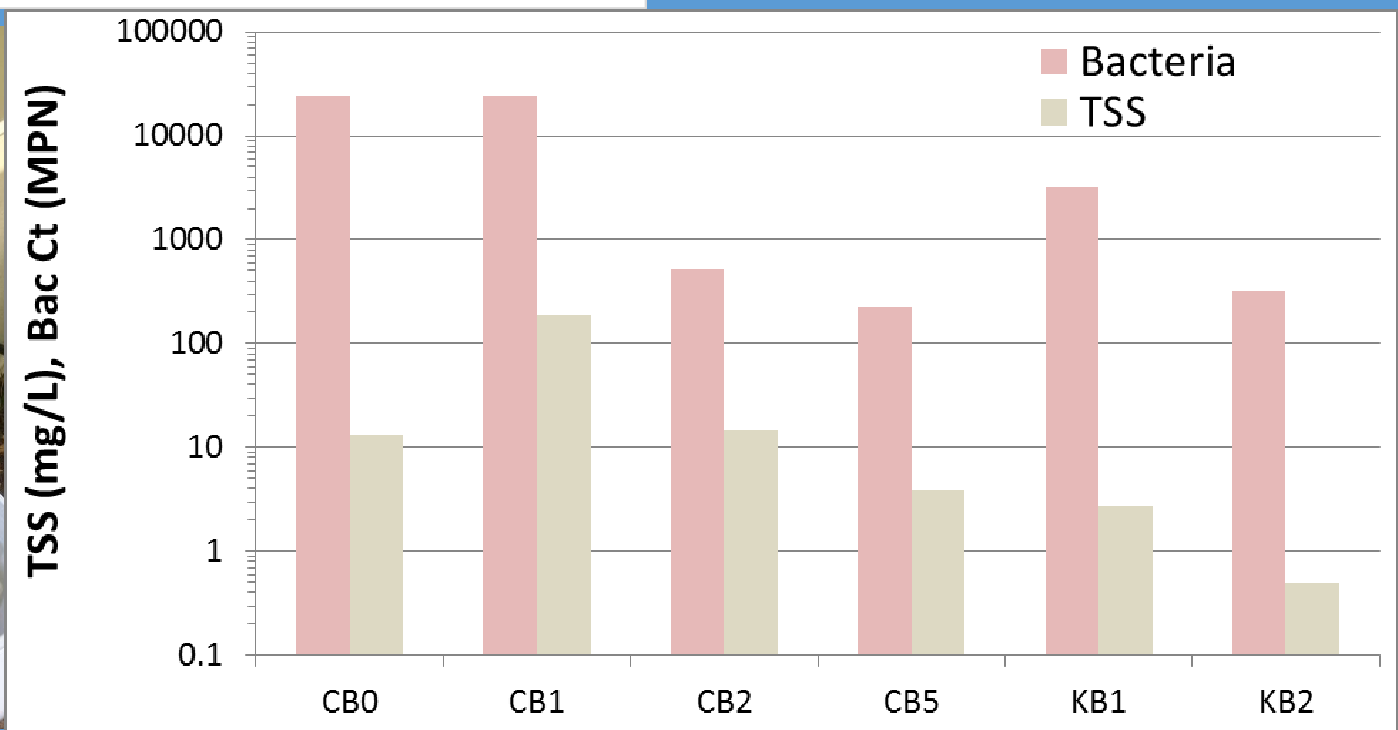
L (M/t) = Q (L³/t) x C (M/L³)

L = load

C = concentration

Q = water flow rate

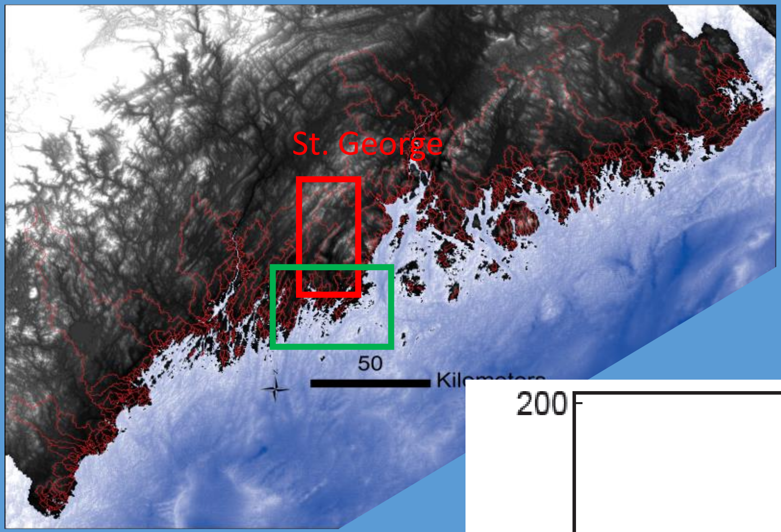
TSS – Total Suspended Solids



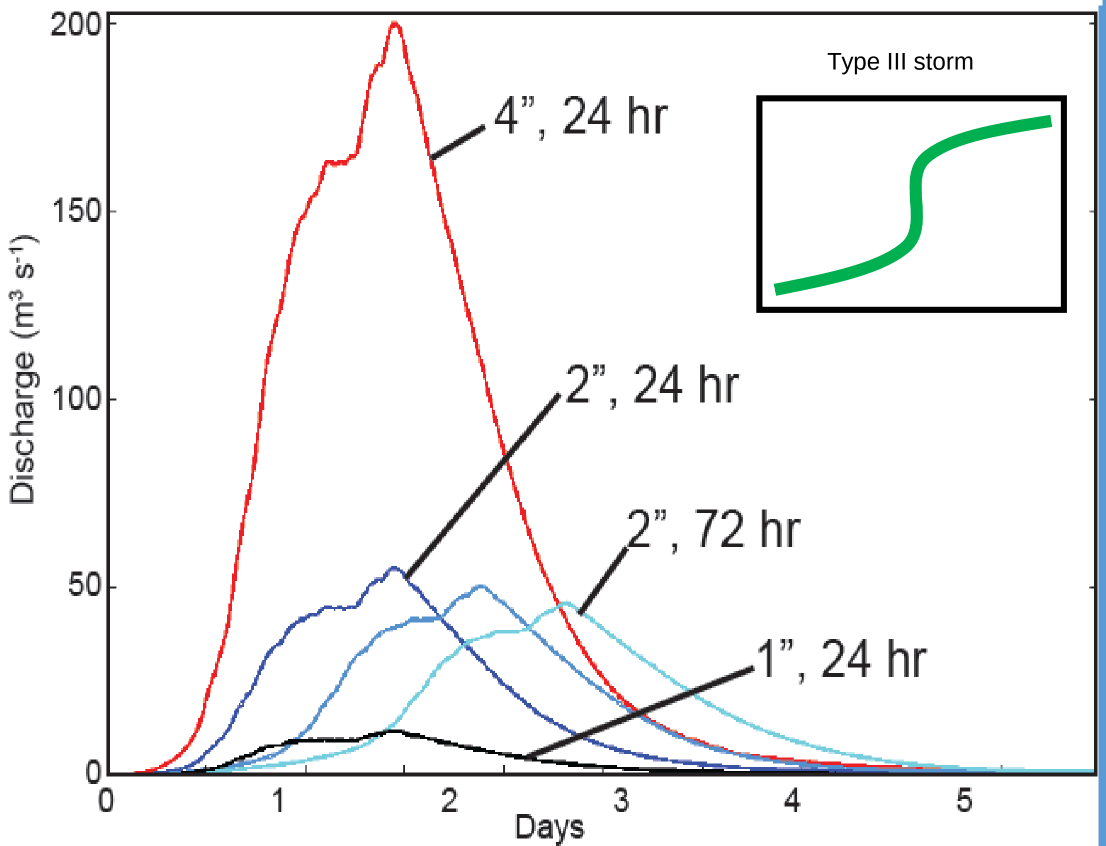
Timing and Magnitude of Watershed Surface Runoff

Spatial data and USDA Type III storm to estimate Runoff Production and Routing

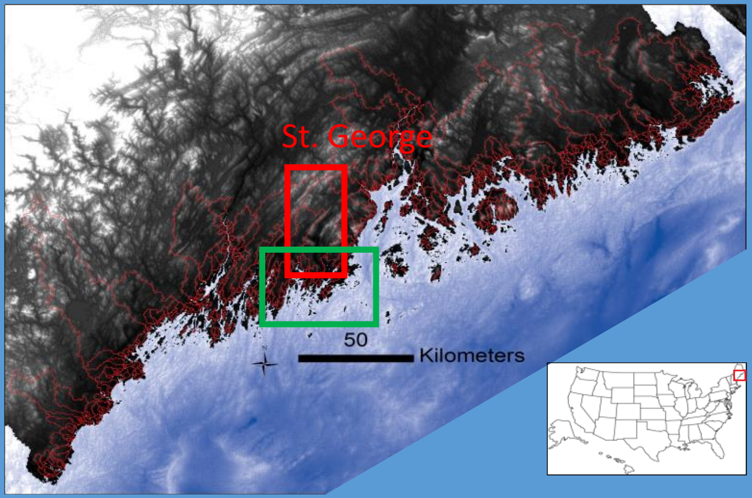
- Volume – hydrologic soil group, land cover, USDA Type III storm
- Travel time – Manning's equation for surface flow velocity $V = (1/n)\,(h^{2/3})\,(S^{1/2})$



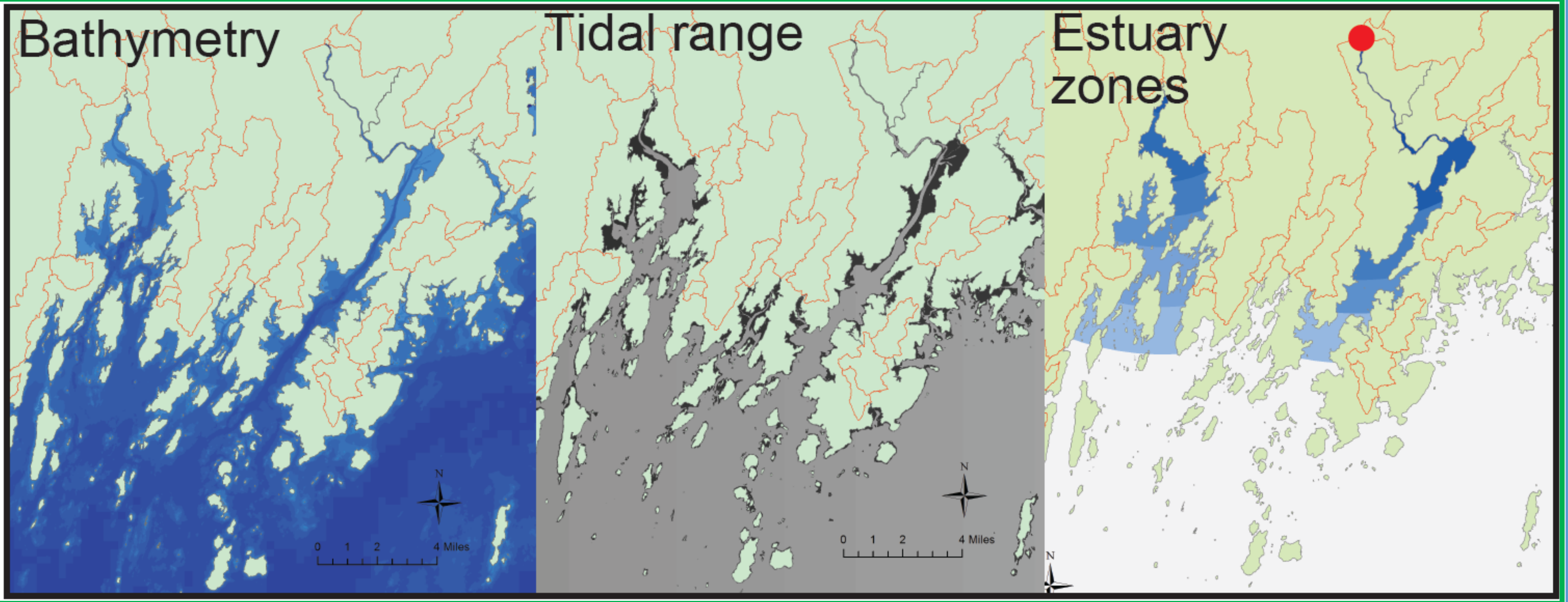
Approach:
Geomorphically Based Instantaneous Unit Hydrograph



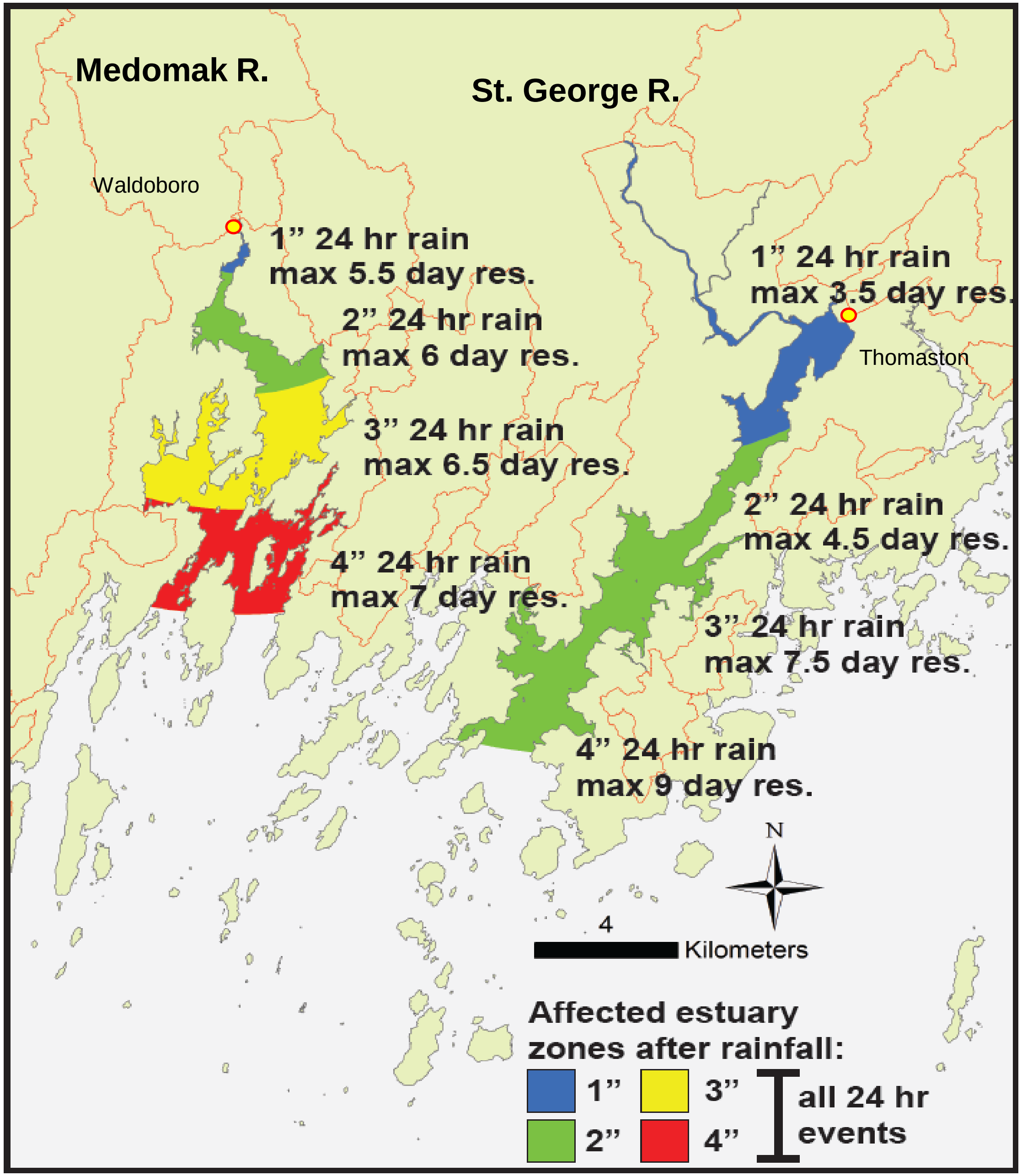
Estuary Residence Time



- Mixing capacity of estuary: tidal prism, bathymetry
- Estuary size (boundary) based on tidal flushing



Estuary - Runoff Residence Time



Result:

- Larger Rivers Estuaries – expansive & relatively long residence time
- Narrow, Shallow Estuaries – expansive but relatively short residence time

Estuary - Runoff Residence Time

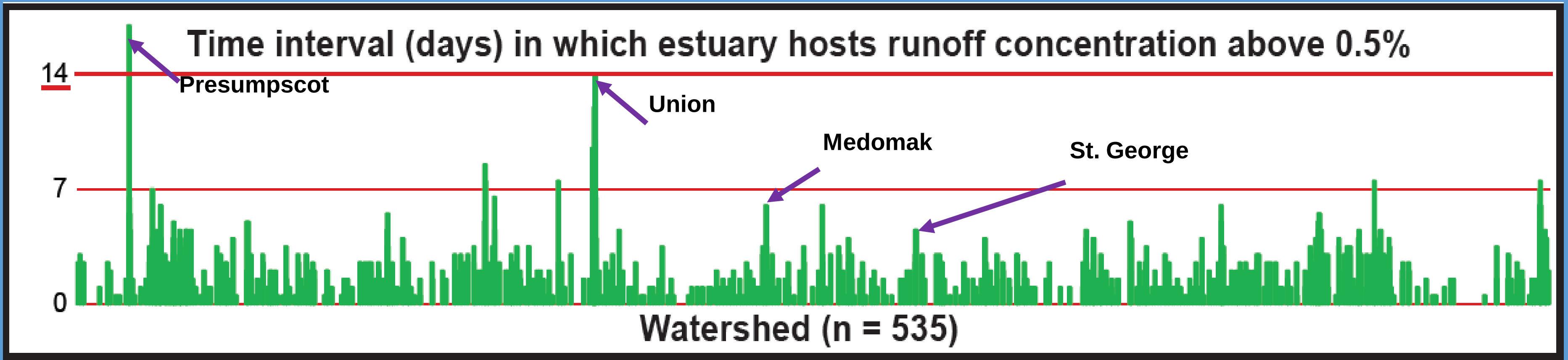
Result: Closure rules may exceed safety goals for some estuaries

- Common Rule: Automatic 2 week closure after 2 inch, 24 hour rain event

- Calculation Outcome: Freshwater volume often reaches insignificant "concentration" < 2 weeks

- Variations: Dependent on position, rainfall timing and intensity, contaminant concentration

2 inch, 24 hour precipitation event



Findings:

1. Five Watershed Types: Analysis using 15 proxy metrics for runoff and pollution sources, delivery and residence time produced 5 primary coastal watershed types.

2. Vulnerability to Bacteria Pollution: Identified watershed types coincide with statistically different bacteria pollution responses.

3. Attribute Influence: Some watershed attributes have greater influence on the frequency of bacteria pollution than others.

4. Low Correlation: No single attribute is highly correlated with bacterial pollution problems on their own.

5. Residence Time: Calculations suggest that freshwater residence time is less than two weeks in some estuaries.

6. Closure Rules: Existing data resources support varying rules relative to position in an estuary and precipitation amounts.

Recommendations

Near Term:

1. Rules for closure should vary relative to rainfall and estuary position.

2. Biases in bacteria sampling need to be examined and addressed to improve comparative evaluations of vulnerability. Locations with low frequency of bacteria contamination problems and at the outlets of nontidal watersheds need to be sampled more extensively.

3. Management attention should be focused on bacteria and runoff sources to address bacteria problems over delivery and residence time issues.

4. Several important data gaps remain to be filled to improve coastal watershed characterizations, including drainage network delineations (incl. storm and sewer networks) and detailed estuary bathymetry.

Recommendations

Long Term:

1. More attention to stochastic processes (e.g., spills and breaks) and large river hydrodynamics.

2. Better quantification of the associations between rainfall and runoff is needed in varied settings by gaging streams in representative coastal settings (clusters).

3. The relative roles of watershed features (e.g., ponds, pipes), climate change and coupled land-sea interactions in representative coastal settings need to be quantified more extensively. This work has been initiated in two of the five clusters.

4. Associations between runoff discharge, total suspended solids, turbidity and bacteria need to be better quantified, and the ability to predict bacteria contamination from turbidity should be explored.

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