Linking watershed-scale stressor gradients to nearshore habitat types for setting restoration targets

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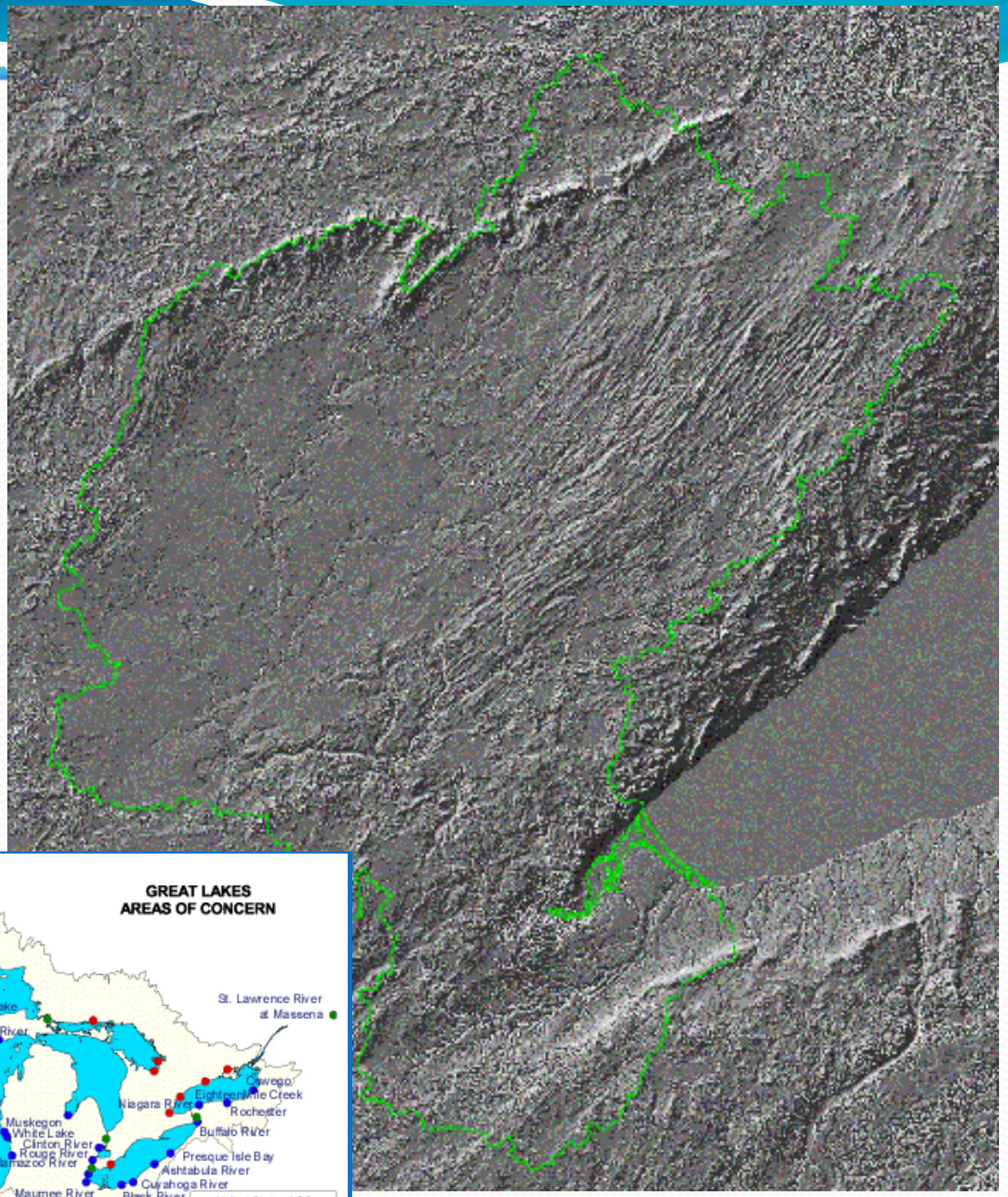
St. Louis River watershed

- Duluth-Superior harbor/industrial area
- ~100,000 urban population
- Extends north to the Mesabi Iron Range
- Rural areas predominately forest, wetland, light residential
- Area of Concern



Motivating questions

Are we there yet?

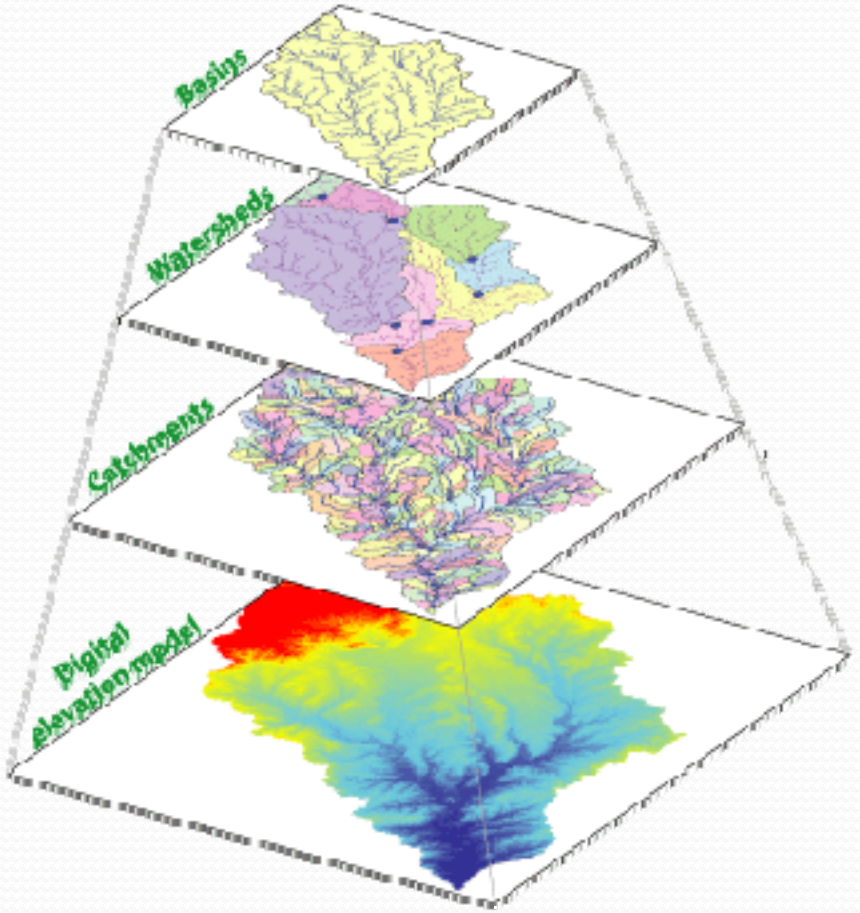
- What do healthy habitats look like?
  - Water chemistry, vegetation, fish, invertebrates…
- How do we measure progress toward restoration goals?
- What conditions in the watershed are affecting the AOC?
  - Are there 'hot spots' contributing to impairment
  - Are there refugia or reference conditions?
- What is the role of watershed remediation in resolving AOC issues?

Objectives

- Quantify the stressor gradient for watersheds contributing to the St. Louis River Estuary
- Link stressors to nearshore aquatic habitats within the AOC
- Identify and sample 'reference' habitats to inform development of restoration targets

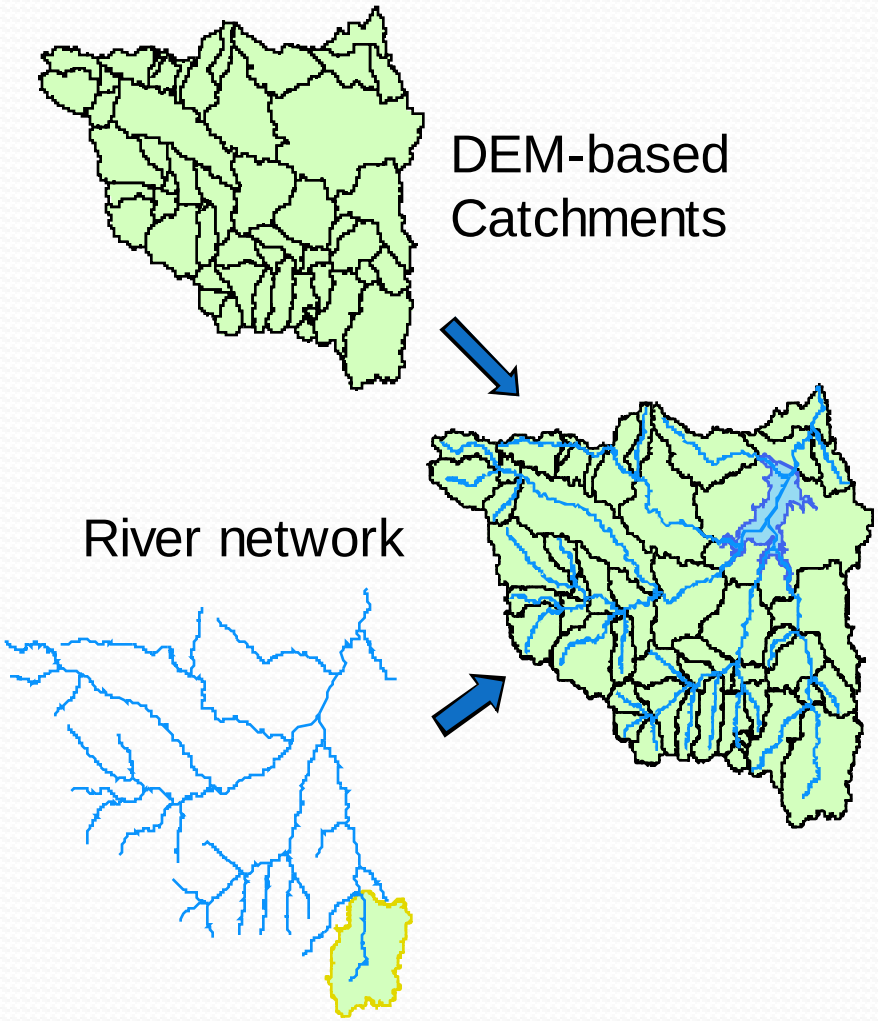
Scalable Watershed Delineations

- ArcHydro data model
  - Based on digital elevation models "pre-processed" to more efficiently delineate watersheds
  - Uses National Hydrologic Dataset (NHD) linework to enforce drainage (AGREE algorithms)
  - Fill sinks
    - flow direction
    - flow accumulation,

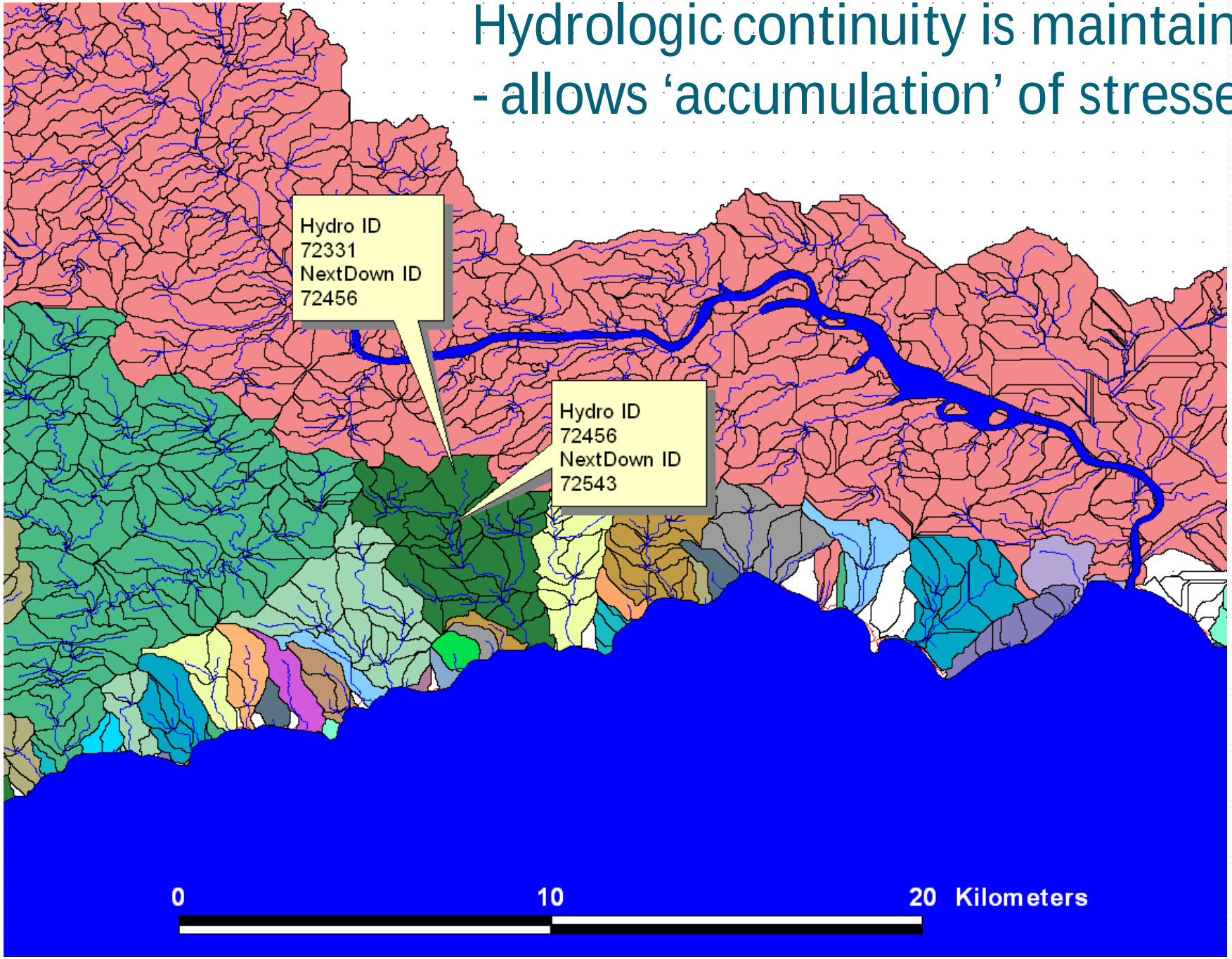


Defining catchments

- Fine-scale catchments are delineated for each stream confluence and at river mouths
- Catchments for river systems can be dissolved into single entities
  - Scaleable framework for sampling & analysis



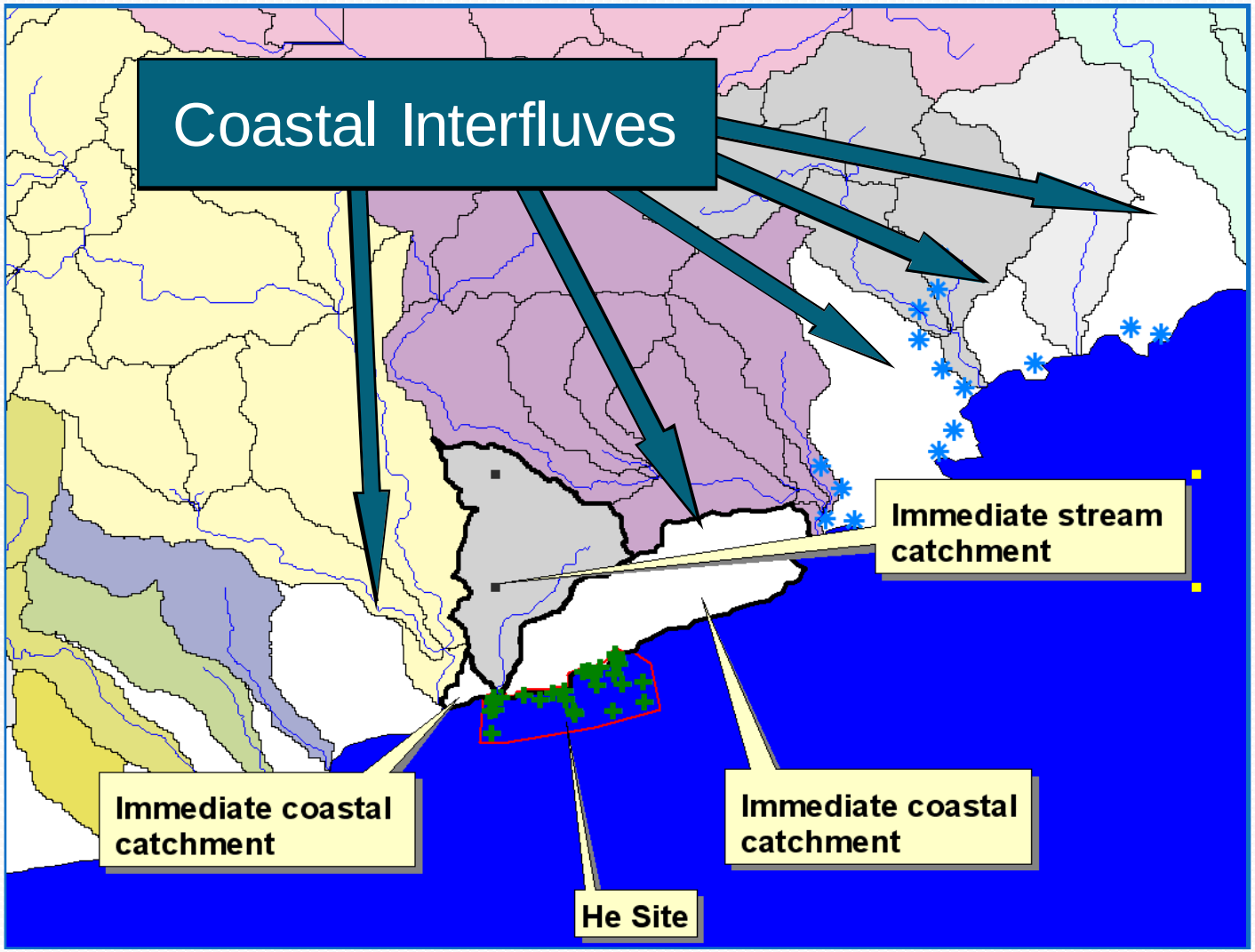
Hydrologic continuity is maintained - allows 'accumulation' of stresses



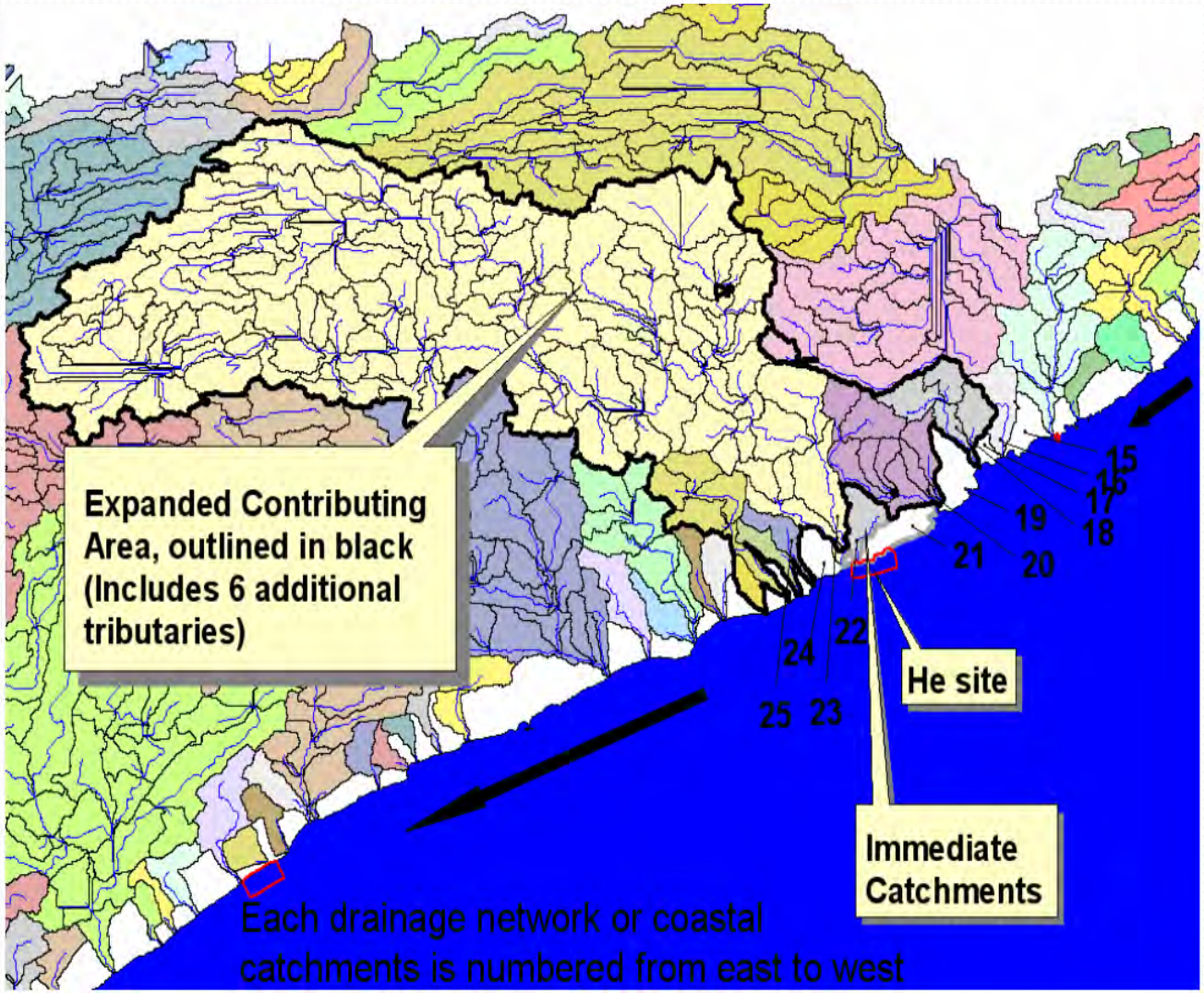
Extending Watersheds to the Coast

Coastal Interfluves

- Areas between river mouths but outside watersheds
- Small in area, but major part of coastline



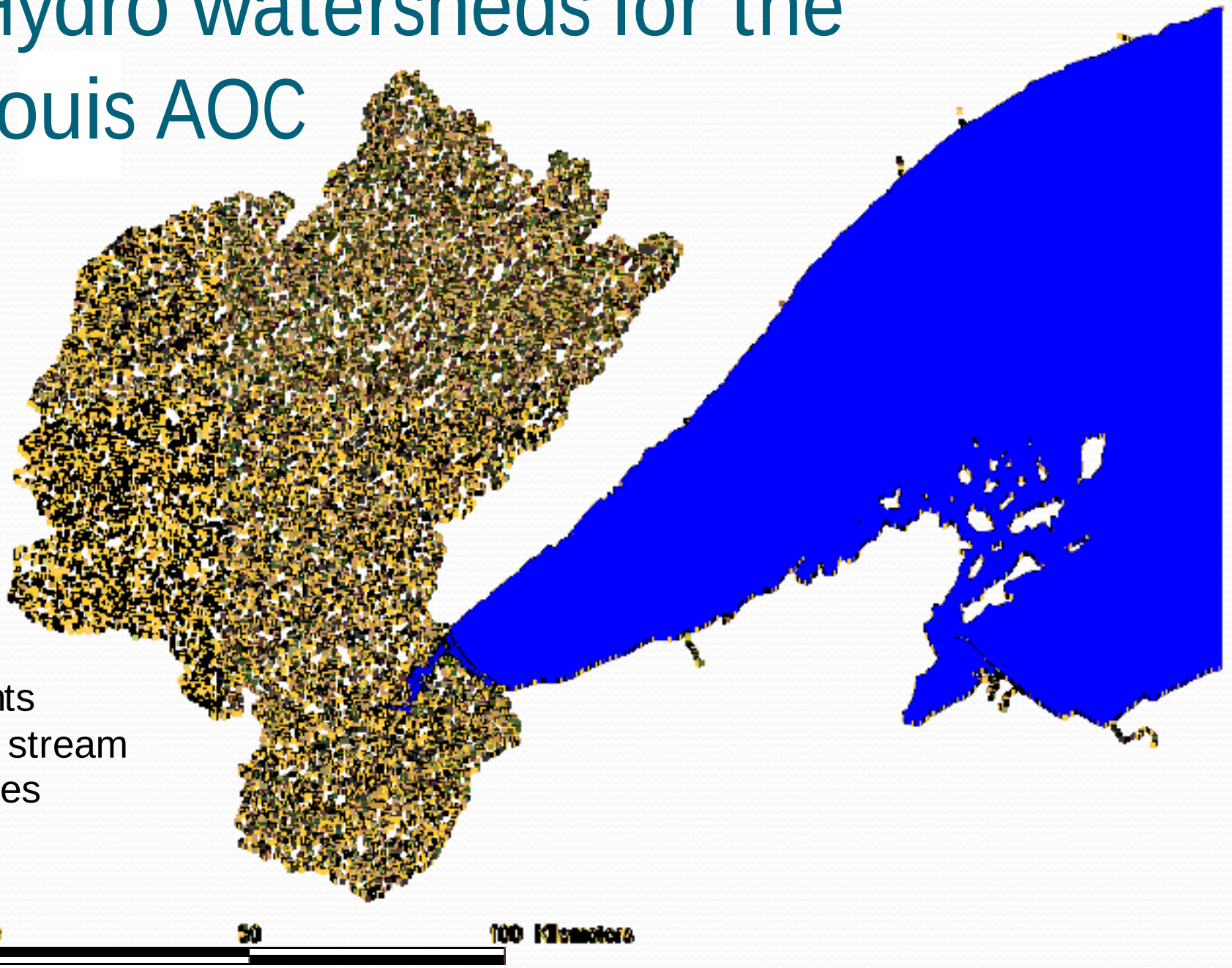
Ordering watersheds



Stream and interfluve sheds can be ordered and numbered along the coast

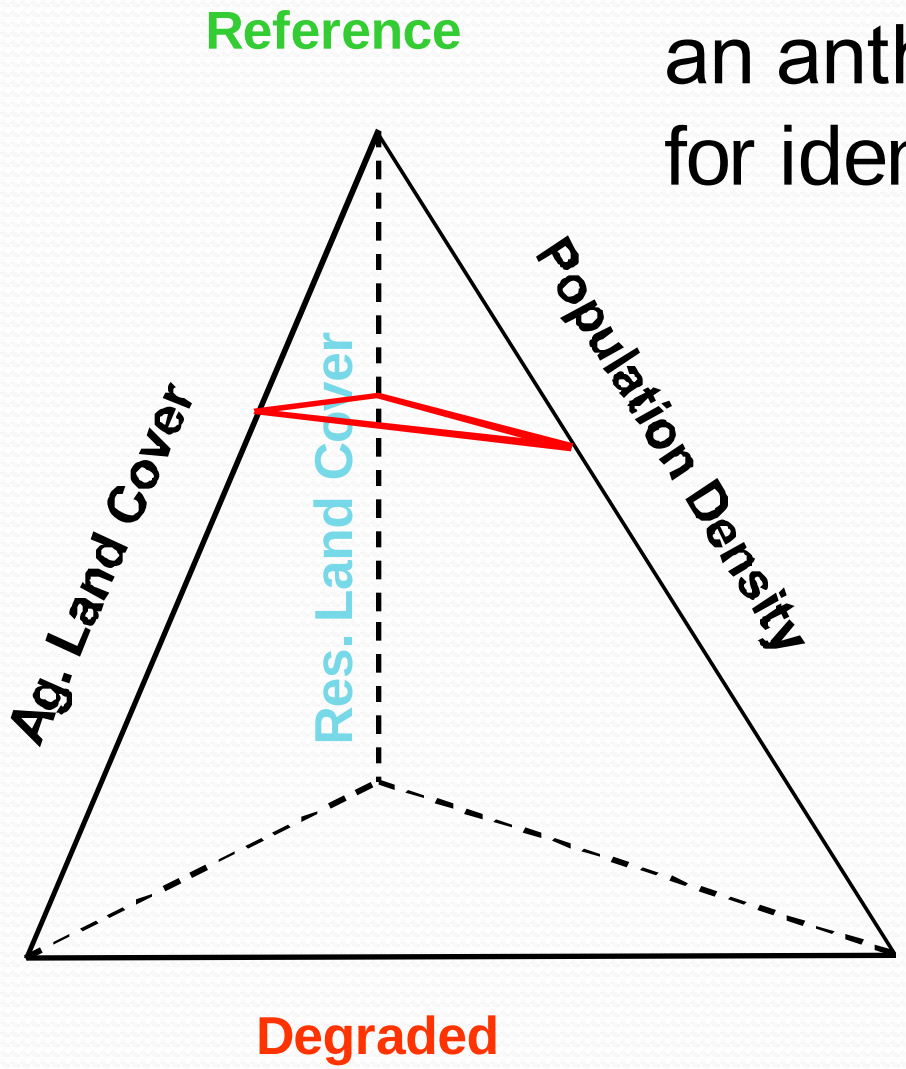
This provides a framework for scaling stressor summaries up and down the coast

ArcHydro watersheds for the St. Louis AOC



3,444 catchments based on stream confluences

Axes of Evil:
an anthropogenic stress model for identifying reference conditions



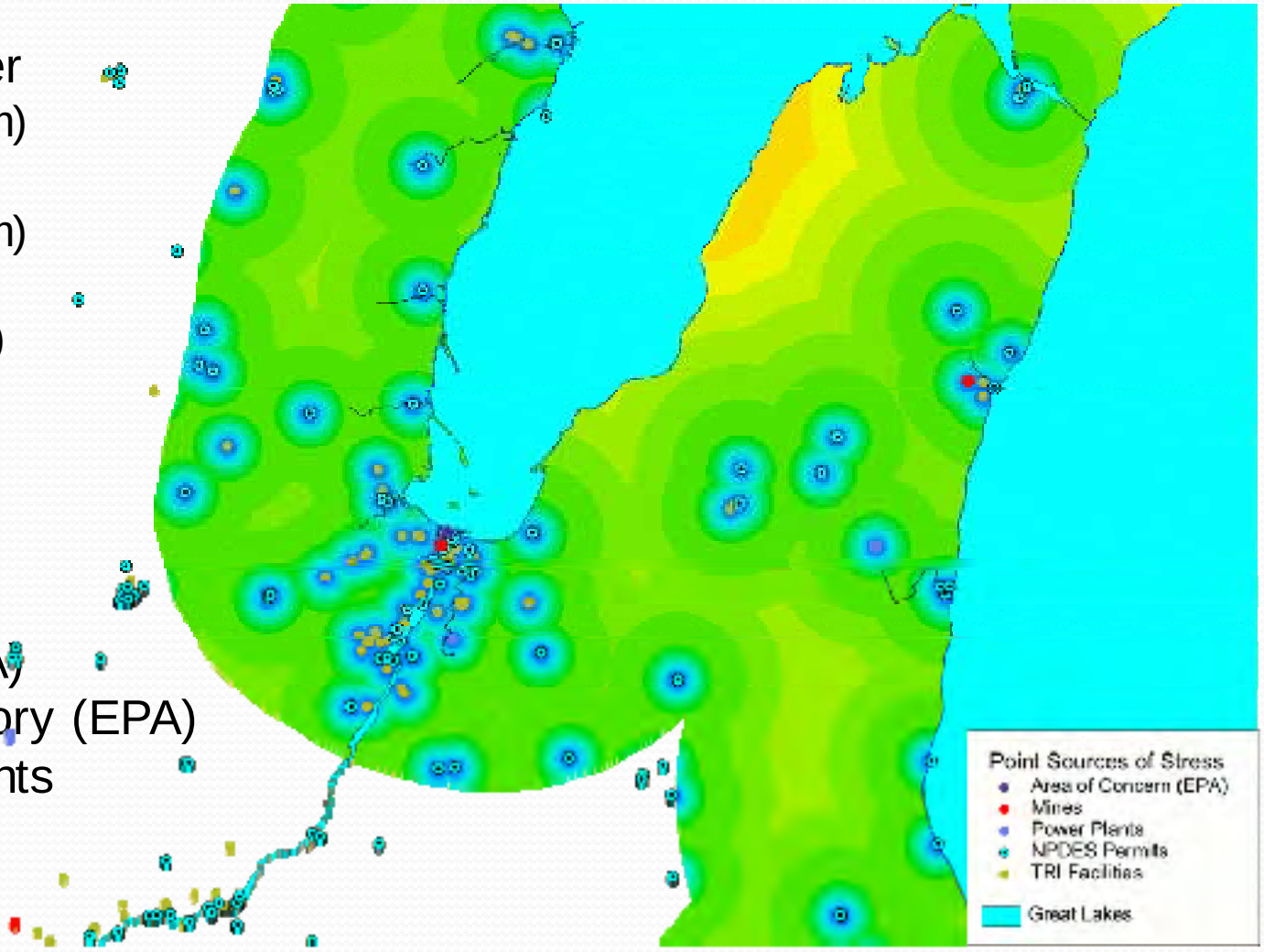
Objective:

Identify habitats with minimum anthropogenic pressure values across multiple stress axes

Host et al. IJRS 2006

Quantifying Anthropogenic Stress: Data Sources

- Publicly available spatial data (raster/polygon/line)
  - Agricultural land cover
    - (USGS-NLCD – 30 m)
  - Residential land use
    - (USGS-NLCD – 30 m)
  - Population density
    - (2000 Census Block)
  - Road density
    - (TIGER)
- Point source data
  - NPDES permits (EPA)
  - Toxic Release Inventory (EPA)
  - Mines and power plants



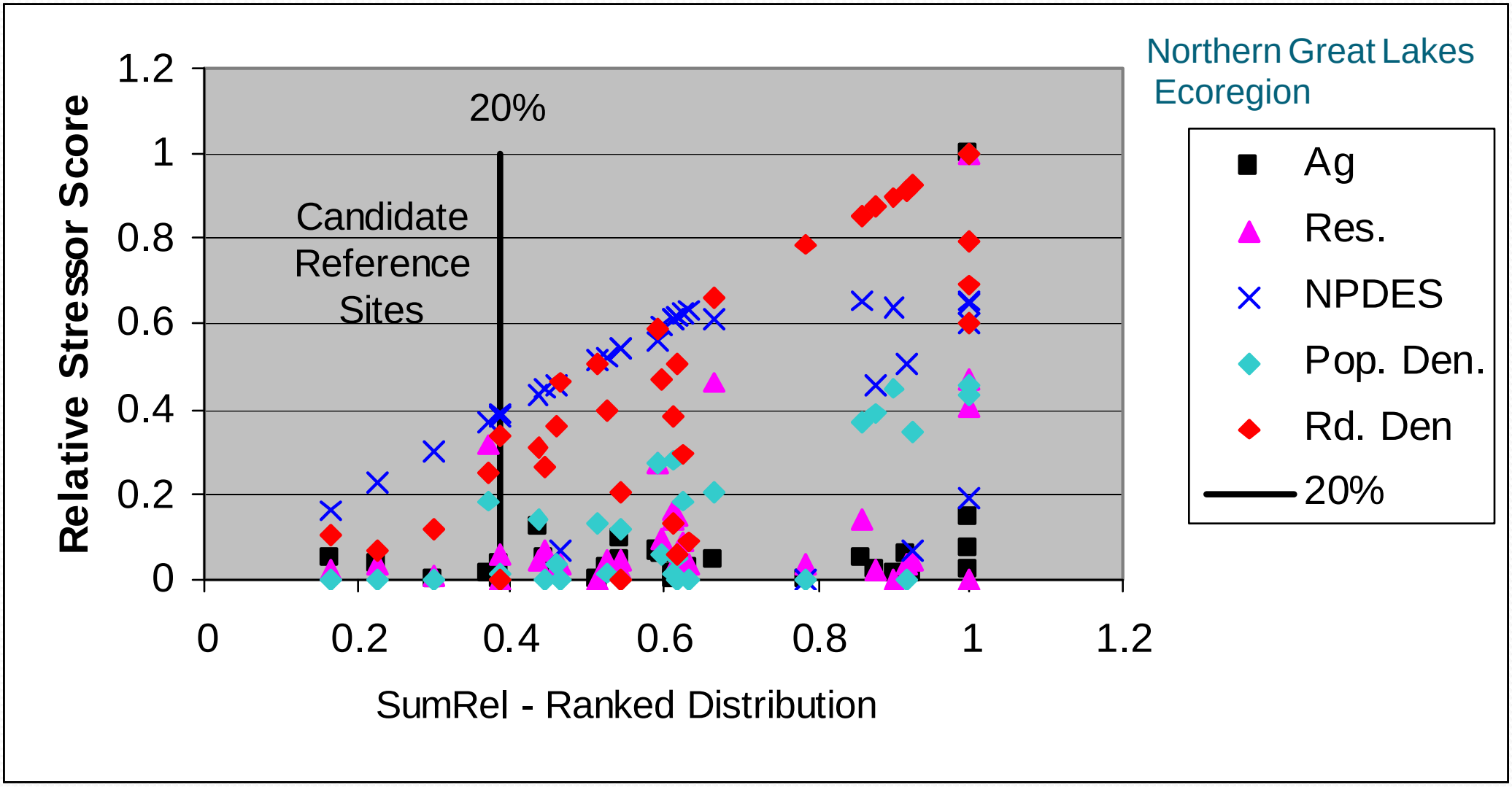
Integrating across stressors: MaxRel & SumRel
- create a single metric based on multiple stressors

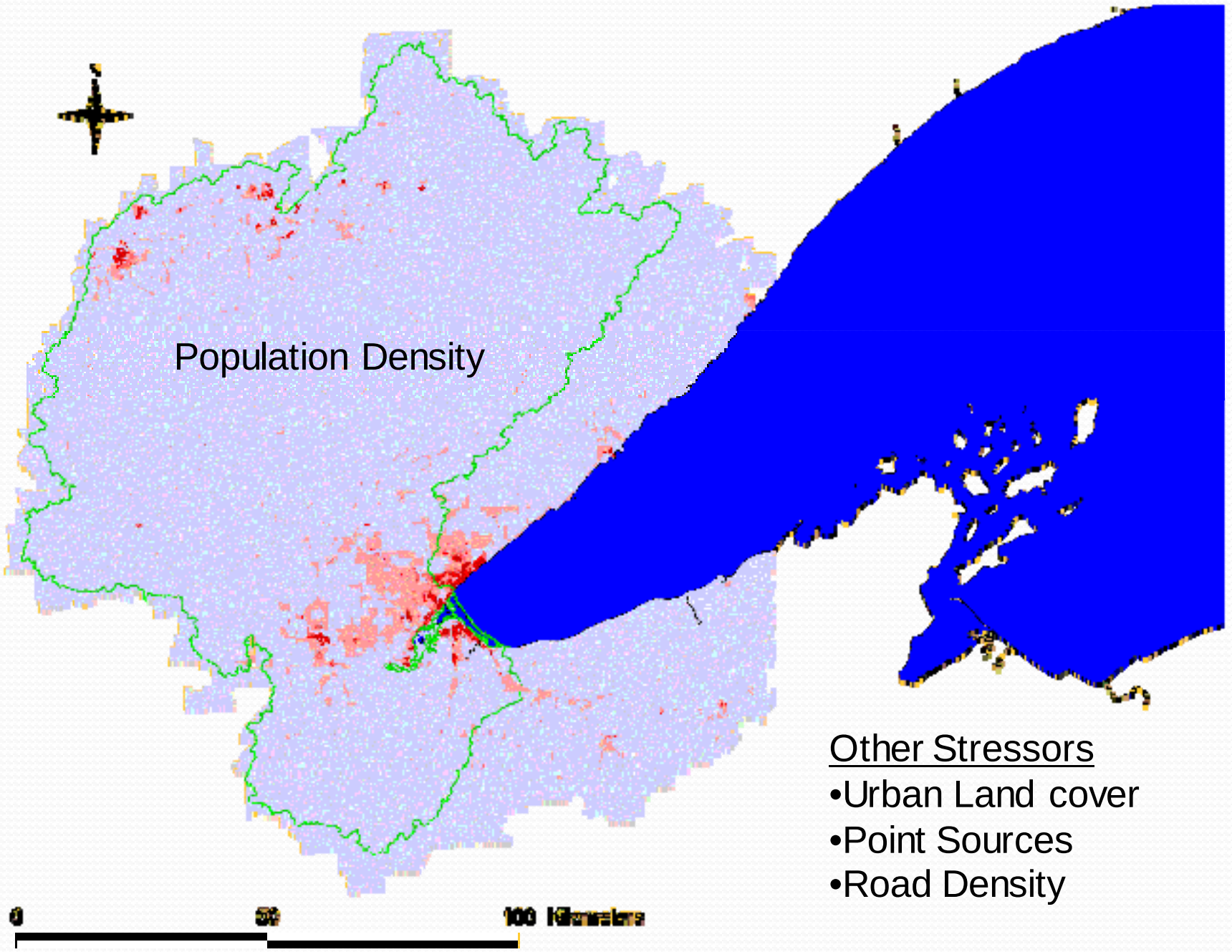
- MaxRel = Max{Agriculture, Residential, Population, Roads, NPDES}
- SumRel = Sum{Agriculture, Residential, Population, Roads, NPDES}

	Watershed Summary	Scaled (Relative) Value	
Ag	125	0.352	MaxRel = 0.352
Res	96	0.254	
Pop	.306	0.156	
Roads	1.6	0.187	
NPDES	5159	0.089	
		1.036	SumRel = 1.036

Identifying ‘reference’ habitats

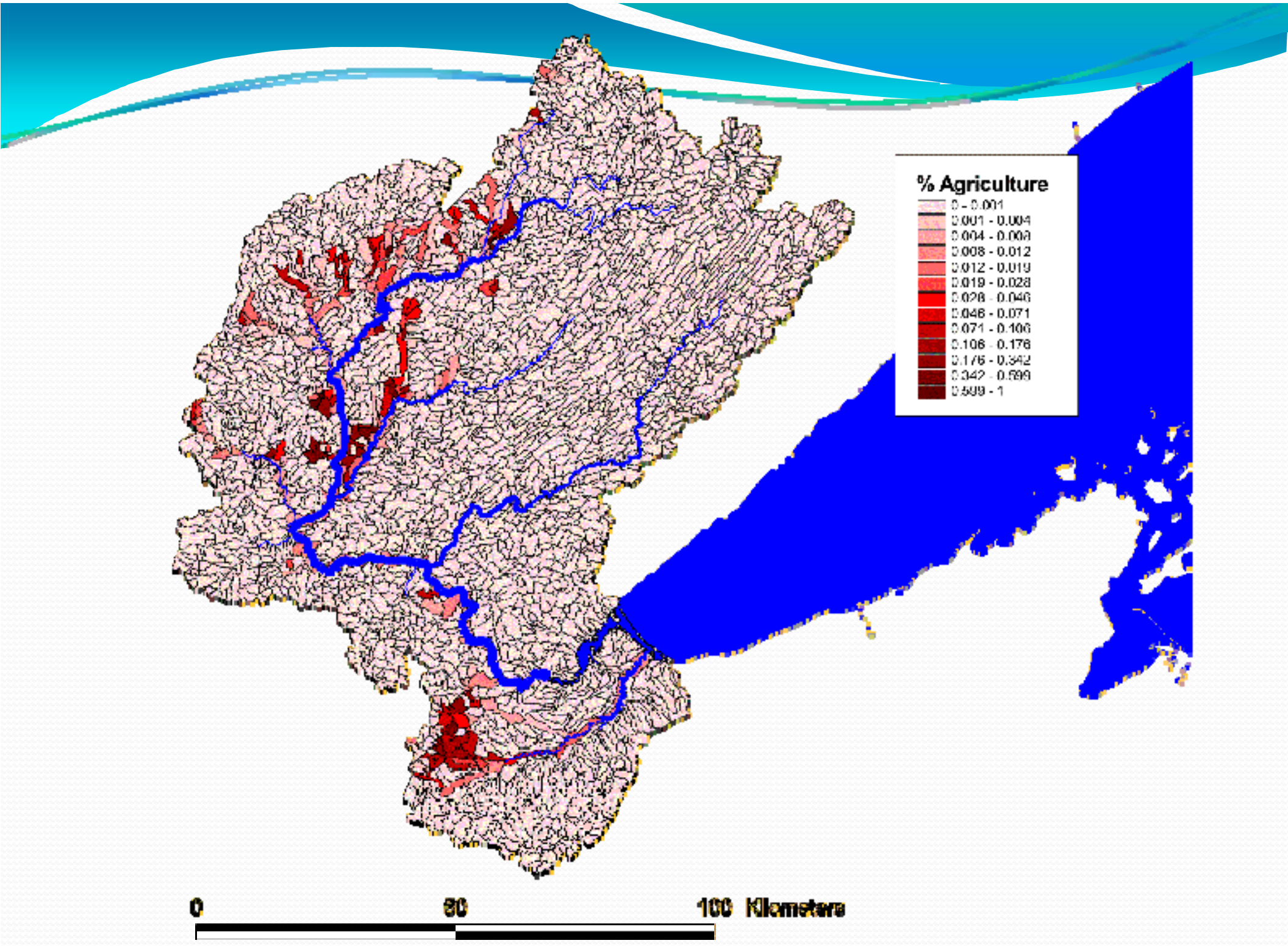
Sort habitats by score, select lowest as reference sites

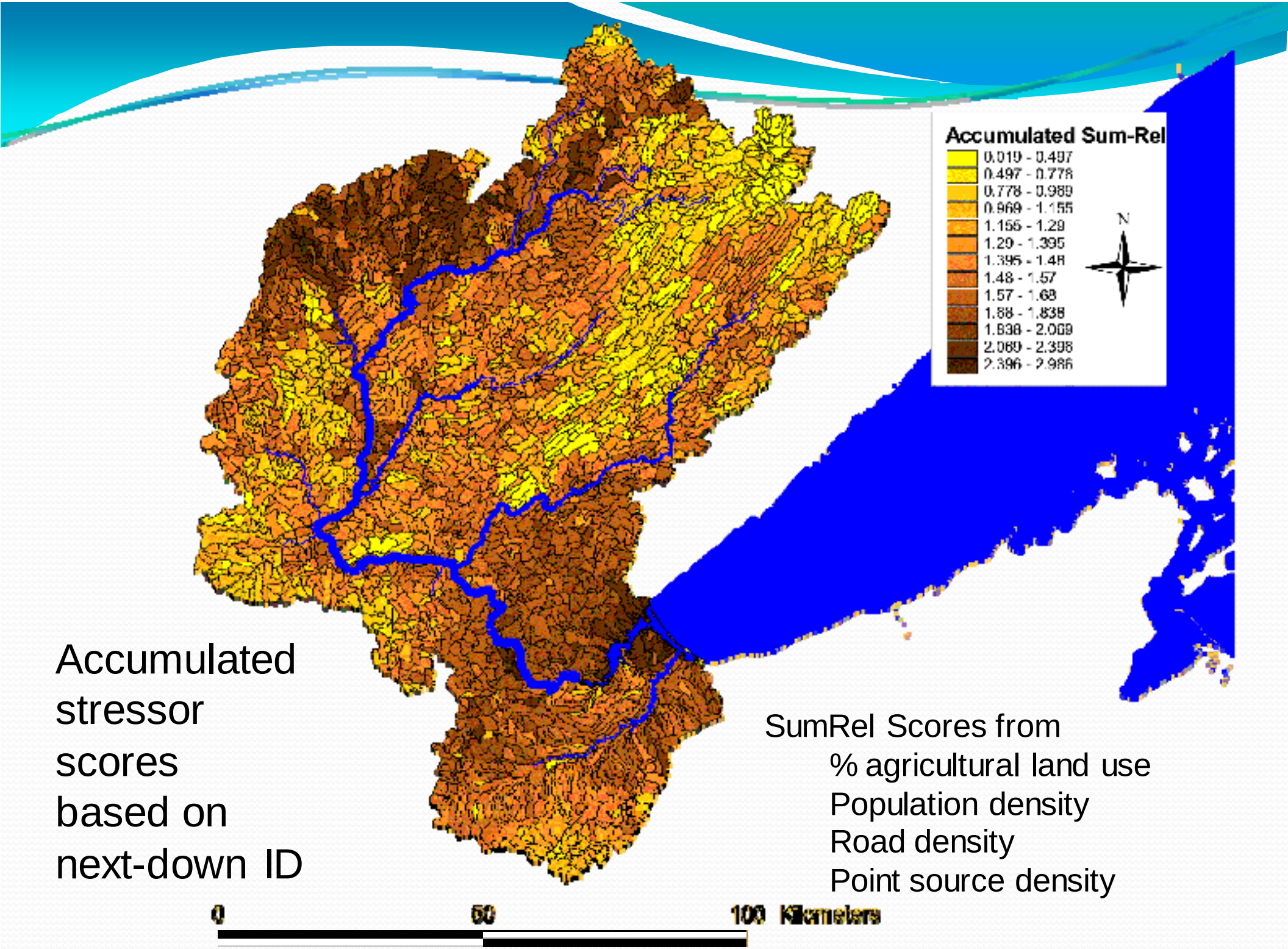




Other Stressors

- Urban Land cover
- Point Sources
- Road Density


% Agriculture
0 - 0.001
0.001 - 0.004
0.004 - 0.008
0.008 - 0.012
0.012 - 0.019
0.019 - 0.028
0.028 - 0.046
0.046 - 0.071
0.071 - 0.106
0.106 - 0.176
0.176 - 0.342
0.342 - 0.599
0.599 - 1
0
50
100 Kilometers

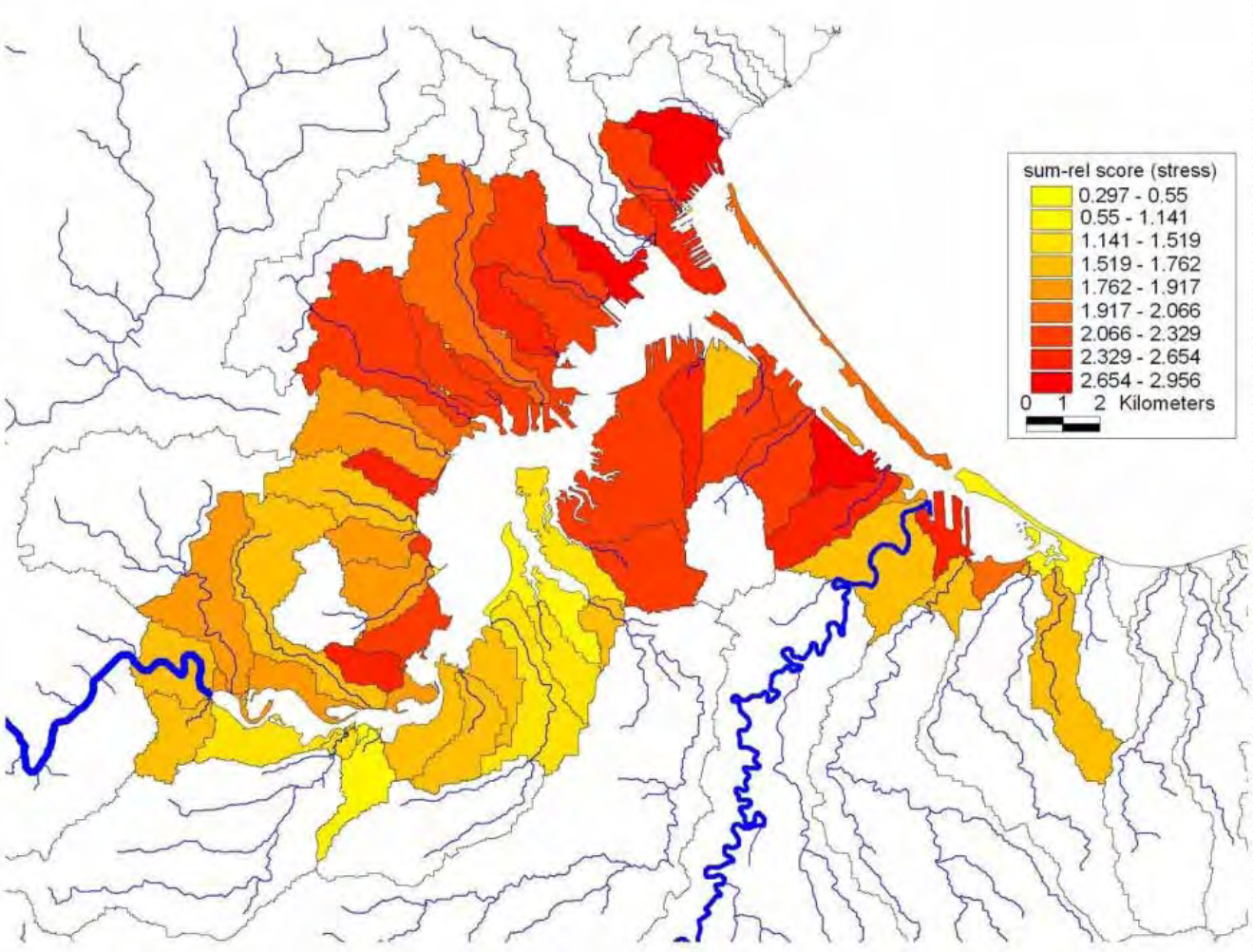


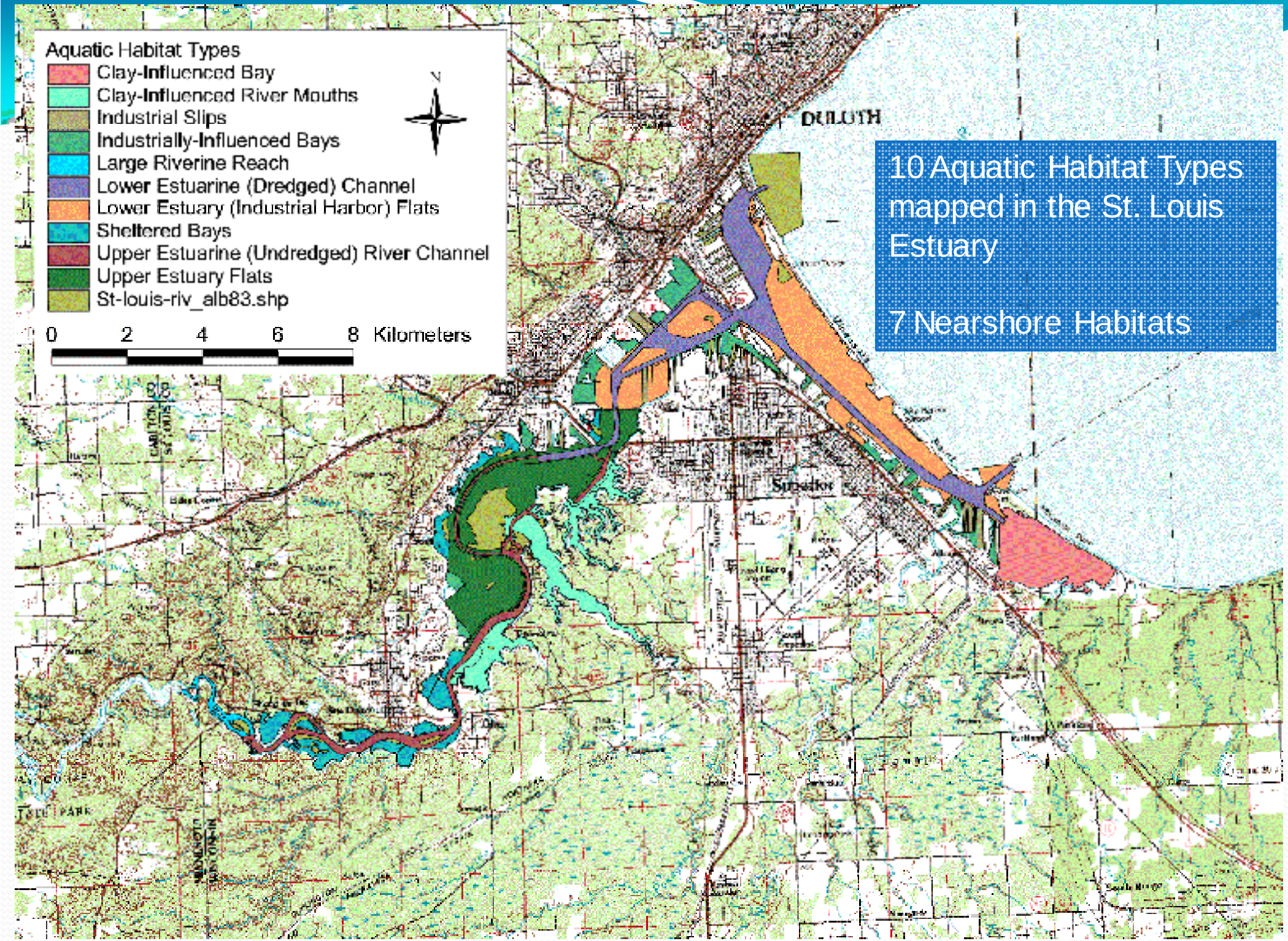
Accumulated stressor scores based on next-down ID

SumRel Scores from

- % agricultural land use
- Population density
- Road density
- Point source density

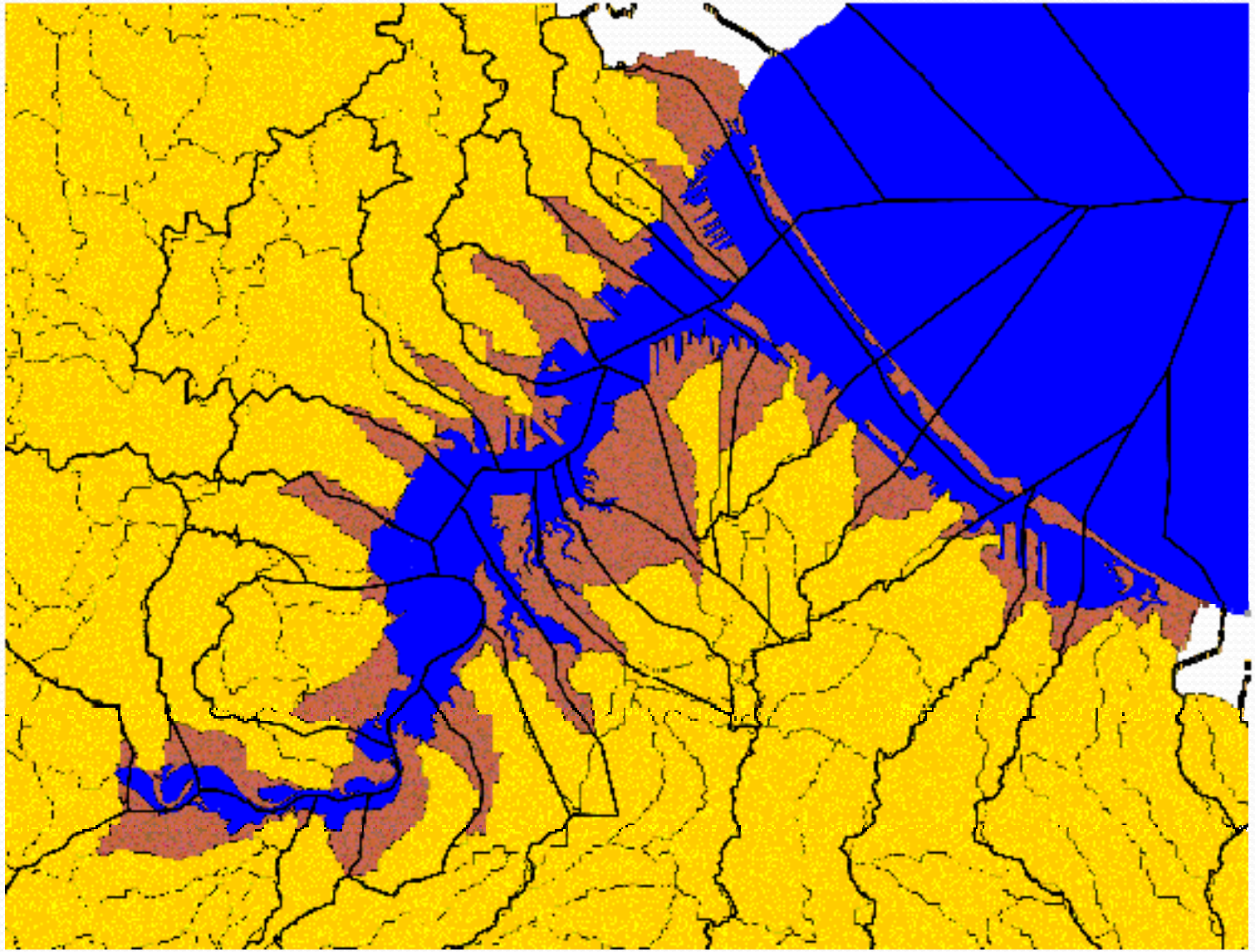
Stressors for watersheds and interfluves contacting the St. Louis estuary




Aquatic Habitat Types
Clay-Influenced Bay
Clay-Influenced River Mouths
Industrial Slips
Industrially-Influenced Bays
Large Riverine Reach
Lower Estuarine (Dredged) Channel
Lower Estuary (Industrial Harbor) Flats
Sheltered Bays
Upper Estuarine (Undredged) River Channel
Upper Estuary Flats
St-louis-riv_alb83.shp
N
0 2 4 6 8 Kilometers
DULUTH
Superior
10 Aquatic Habitat Types mapped in the St. Louis Estuary
7 Nearshore Habitats

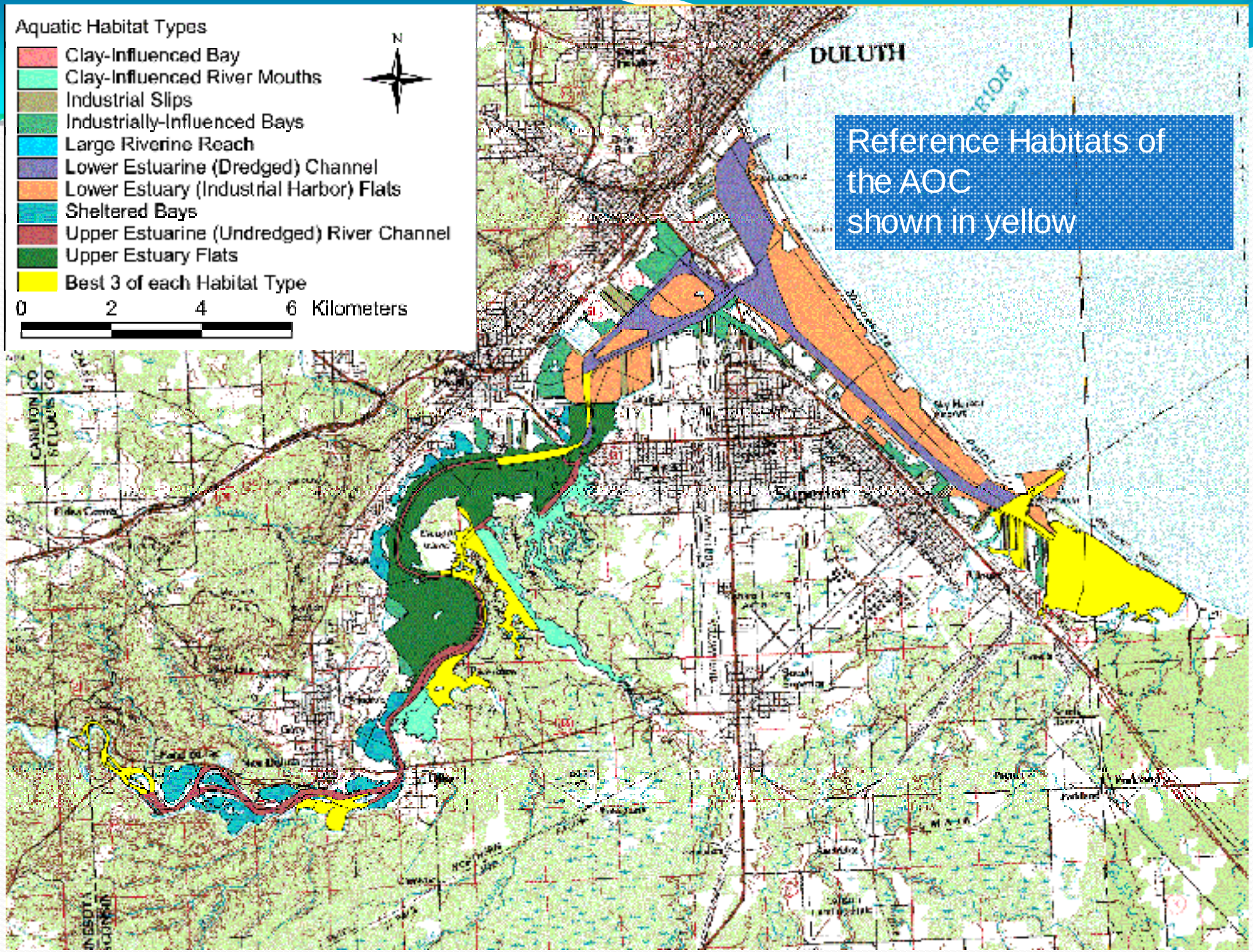
Nibbling – a GIS Tessellation routine:

‘Grows’ watersheds into the nearshore habitats



Selecting Reference Habitats

- Once watersheds are linked with nearshore habitats:
  - Calculate area-weighted stressor scores for the habitat types
  - Select those polygons with the lowest (least stress) scores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Lower Estuary (Industrial Harbor) Flats
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Upper Estuarine (Undredged) River Channel
Upper Estuary Flats
Best 3 of each Habitat Type
N
0 2 4 6 Kilometers
DULUTH
Superior
Reference Habitats of the AOC shown in yellow

Summer 2006: Field sampling of reference sites

- Conducted releve sampling of aquatic vegetation in 7 nearshore habitat types
- Sampled 3 reps of each type by canoe
- Product: full floristic species list and species abundance estimates

Nuphar rubrodisca – G. Walton

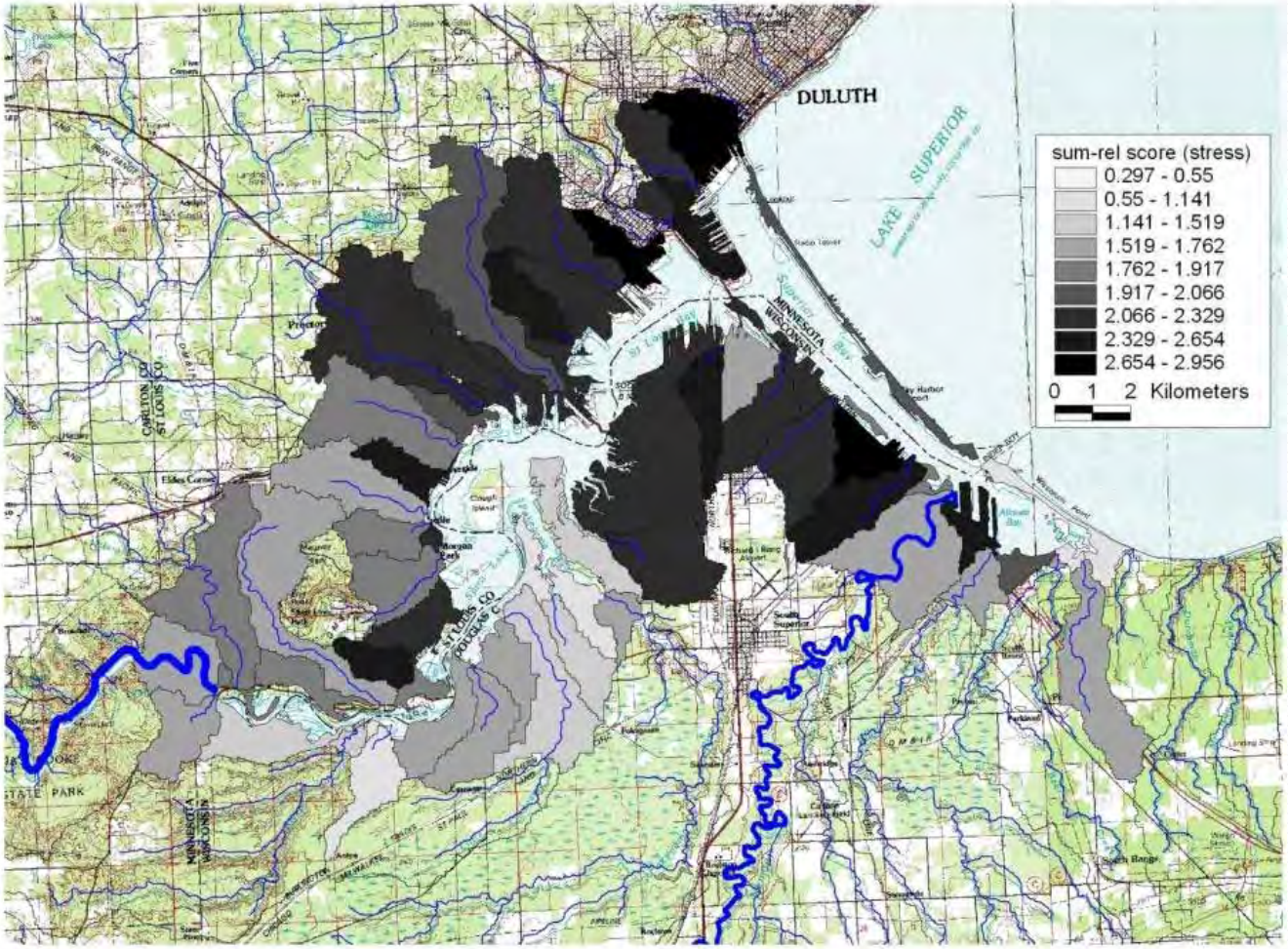
Application to developing restoration targets

- "Restore to what condition?" is a common question
- We have developed a quantitative method to identify the "best of the best" within a particular watershed/AOC , followed by a sampling program that describes characteristic biota
  - Provides stakeholders with a definition of 'reference'
  - Identifies problem areas in the contributing watershed
  - Enables restoration efforts by quantifying attainable targets for particular ecosystems within the context of the AOC

Allouez Bay – reference site for the St. Louis River AOC

Further Applications

- Once vegetation/species are known in a reference site – restoration can use as a measuring stick for success
  - e.g. 80% of species diversity has been achieved in a restoration site – therefore the vegetation portion of the project is successful.
- Can confirm or deny the presence or absence of endangered species and exotic/invasive species.
- Can serve as source for plant propagules for future restorations.
- Spatial relationships - Can use to create a green corridor or linkage to new restoration area – build upon existing sites.


DULUTH
LAKE SUPERIOR
MINNESOTA
WISCONSIN
sum-rel score (stress)
0.297 - 0.55
0.55 - 1.141
1.141 - 1.519
1.519 - 1.762
1.762 - 1.917
1.917 - 2.066
2.066 - 2.329
2.329 - 2.654
2.654 - 2.956
0 1 2 Kilometers