An Overview of the Modeling Used in Great Lakes CEAP and Enoughness Projects

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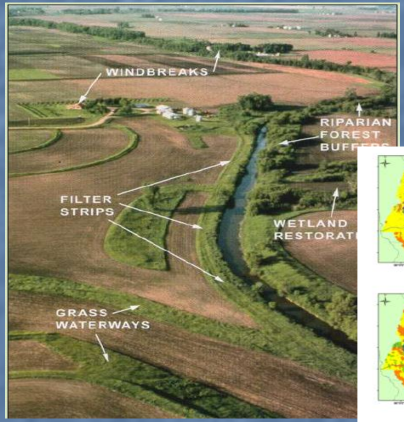
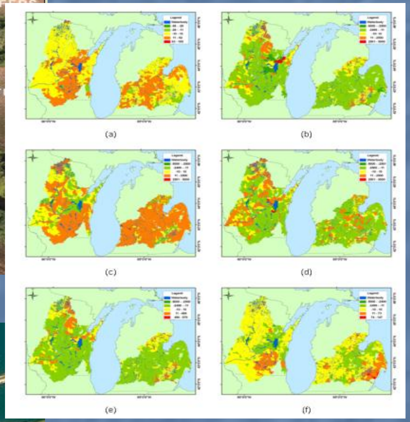
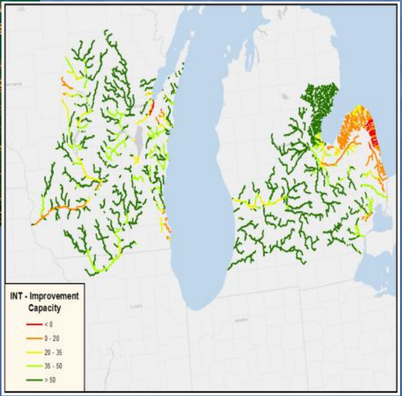
May 3, 2012





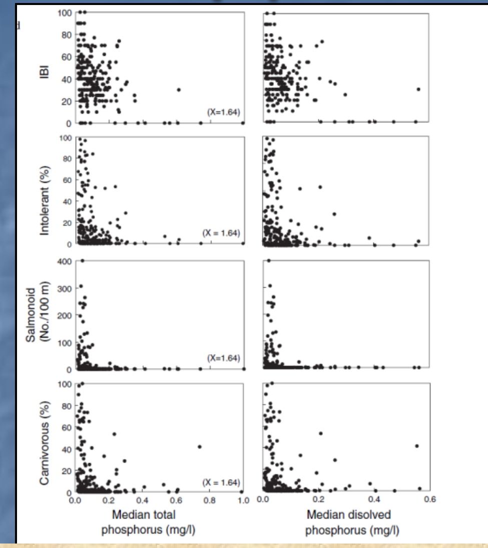


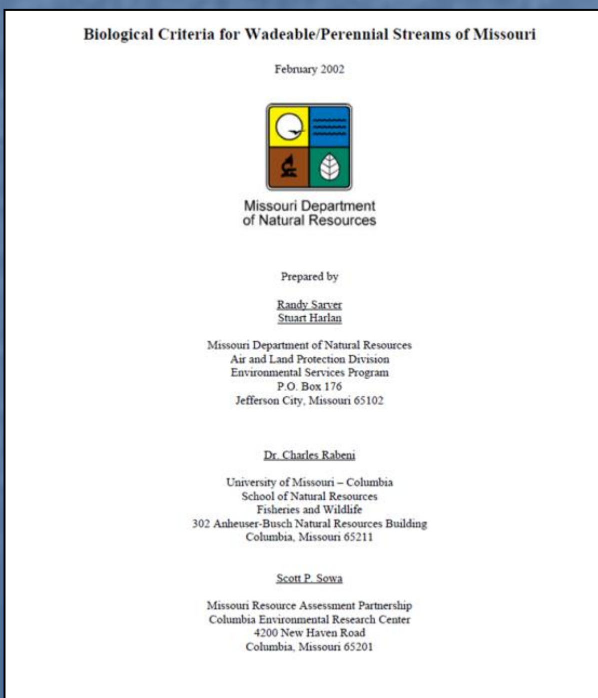
Elements of Presentation

- Foundations of our work
- Overview of USDA NRCS CEAP
- Overview of Great Lakes CEAP Project and related elements of TNC Watershed Strategy
  - Focal elements and important caveats
  - Approach
  - Current Status
  - Future Directions

A New Twist on a Seasoned Approach

- Clean Water Act
  - Water Quality Criteria
    - TMDL
  - Biological criteria




Biological Criteria for Wadeable/Perennial Streams of Missouri

February 2002

Missouri Department of Natural Resources

Prepared by

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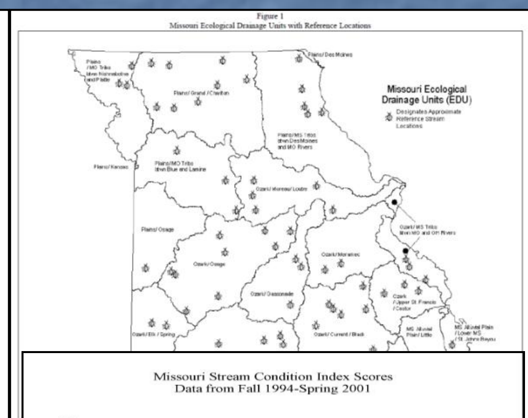
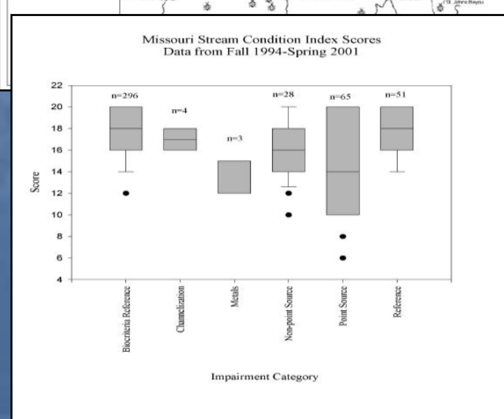
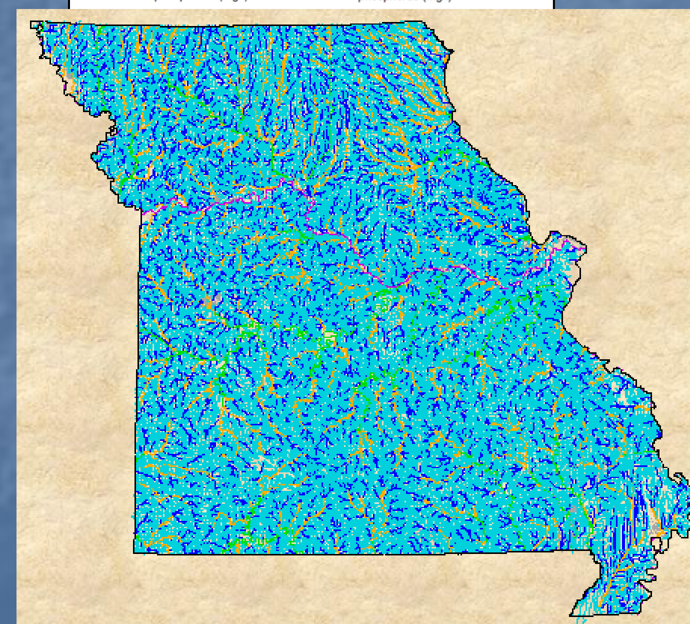




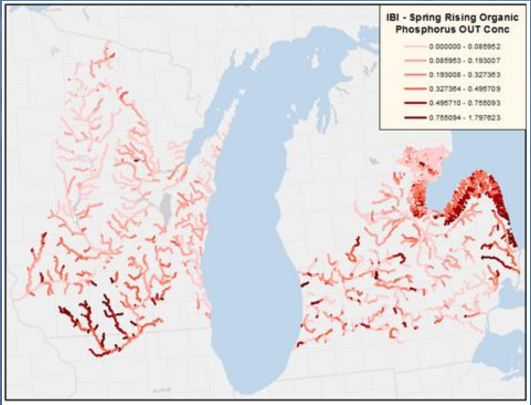


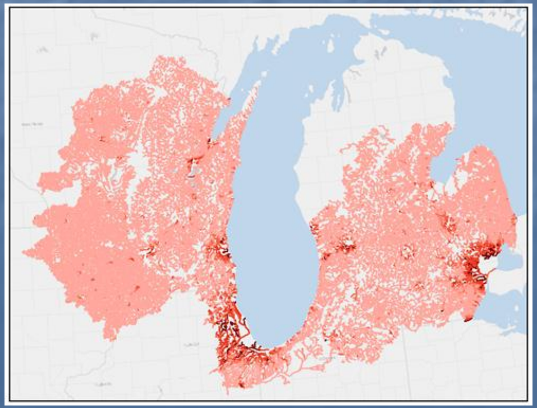
Had only sampled 0.03% of stream miles

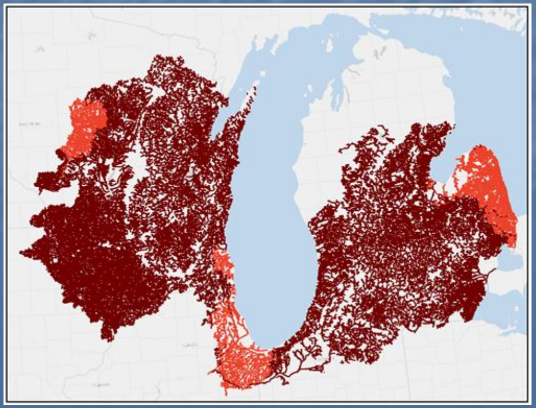
Field-Based vs. GIS-Based Models

- Field Based
  - Requires <u>user</u> to collect data on predictor variables at site of interest

- GIS-Based
  - Requires <u>modeler</u> to have spatially <u>comprehensive data</u> on all predictor variables across region of interest

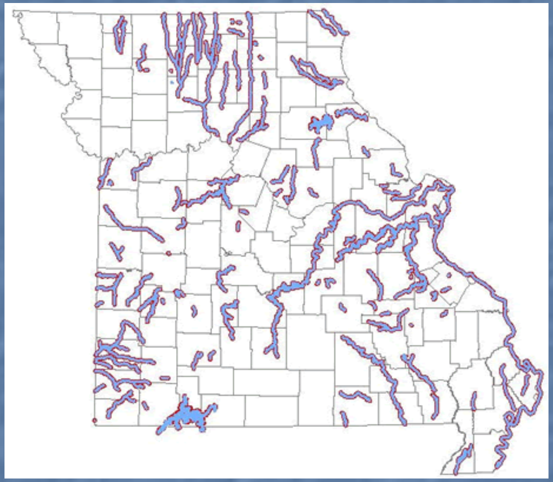


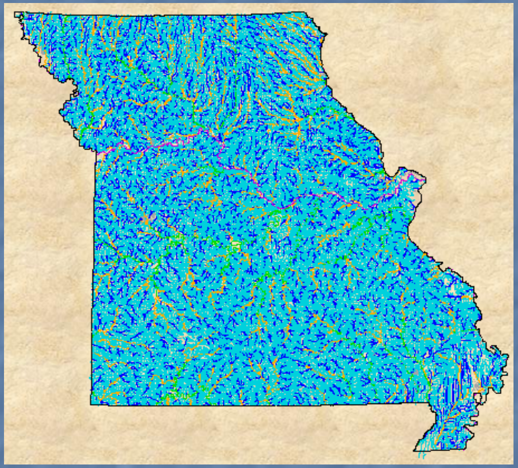




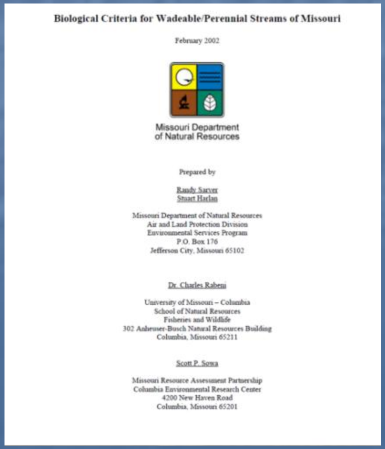
Old Way Has Many Problems

- Can't assess all waters from field samples





- Doesn't assess likely causes or if criteria (goals) are realistic
  - How Much?
    - Costs
    - Types and placement of practices



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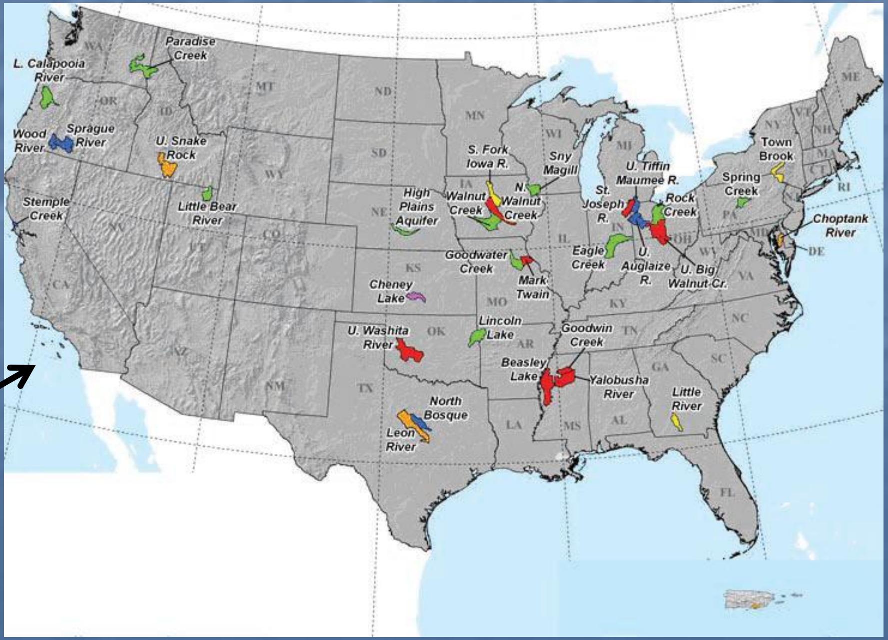
A New Way of Defining the Problem and Realistic Solutions

- GIS-Based to provide spatially-comprehensive coverage
- SWAT-Based to forecast alternative future scenarios

- Core Questions:
  - What are the relations between BMPs, water quality, flow, and fish communities?
  - What are the current water quality, flow, and biological conditions?
    - Is there are problem?
    - Is Ag non-point source pollution the likely primary cause?
  - If so, how much improvement in conditions will we see under different BMP scenarios (levels of investment)?
  - What are realistic ecological goals? (Demand)
  - How much of an investment will it take to achieve them? (Demand)
  - Which suite of BMPs should we use and where should they be placed on the landscape to maximize the return on our investments? (Supply Chain Efficiencies)

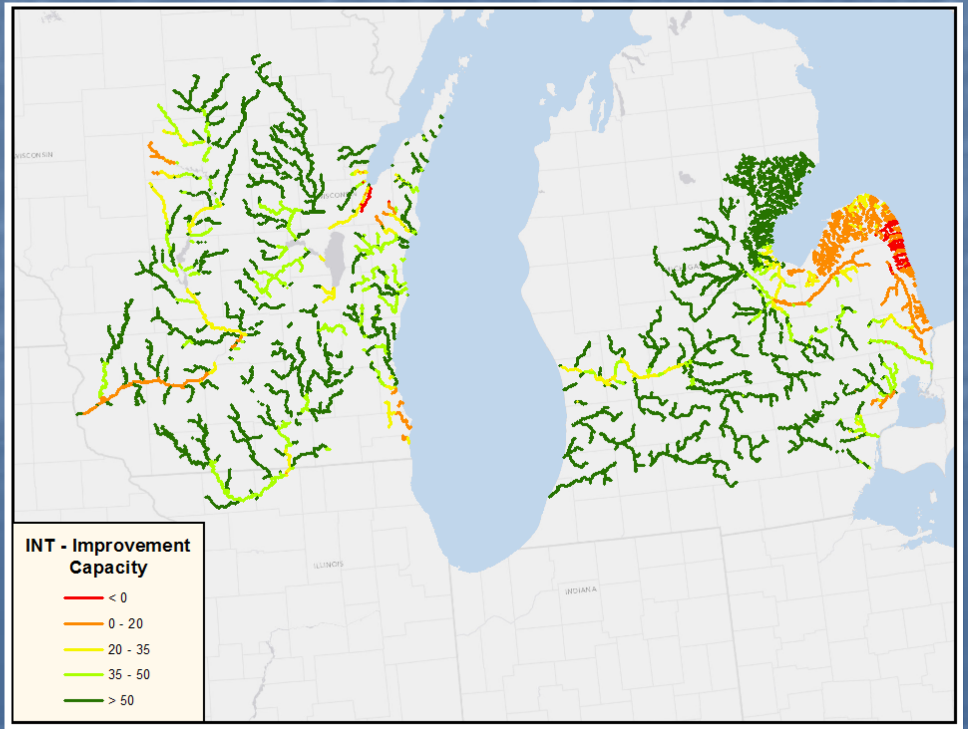
USDA NRCS
Conservation Effects Assessment Project

- Result of Government Performance and Results Act of 1993 and Sig increased $ in 2002 Farm Bill
- **Goal**: improve efficacy of conservation practices and programs by providing the science and education needed to enrich conservation planning, implementation, management decisions, and policy
- Components
  - Assessment: Cropland
  - Research:
    - Wetland
    - Rangeland
    - Wildlife
  - Hybrid
    - Watershed



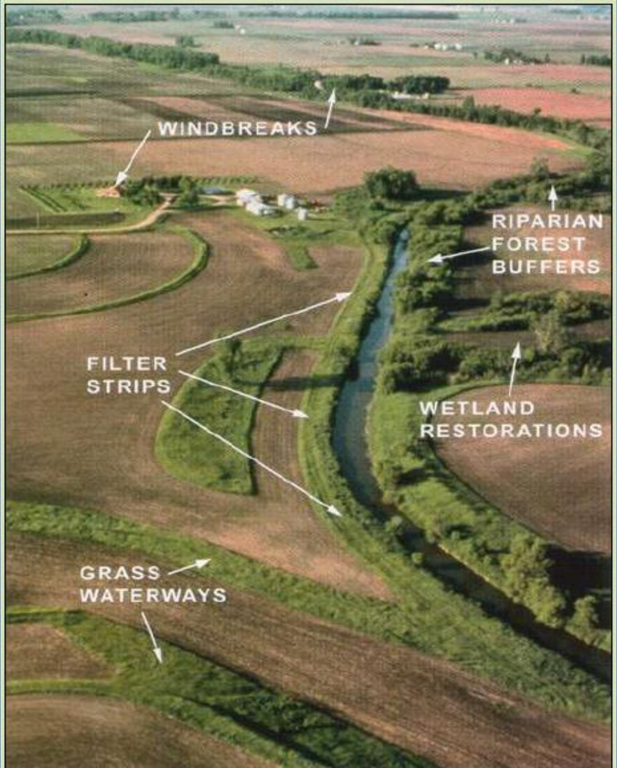
Great Lakes CEAP Project

- GOAL: provide decision makers with information and models on the relations between biological endpoints, water quality/flow, and conservation practices to help establish realistic desired conditions and guide strategic conservation



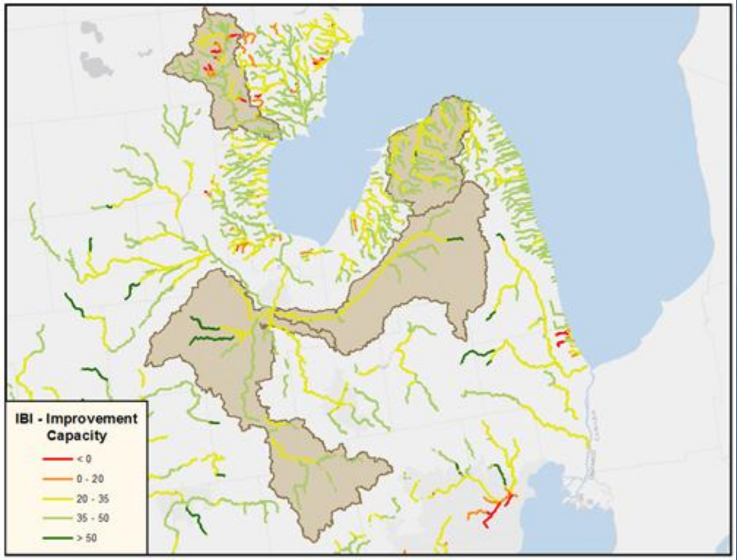
Strategic Conservation

- Getting the right conservation practices to the right places, in the right amount, at the right time, as efficiently as possible to address the right problem and achieve realistic desired conditions



Realistic Expectations

- Goals that incorporate relevant ecological, logistical, legal, social, and economic realities that; a) determine what is valued by society, b) constrain what is achievable, or c) determine what is acceptable to society
- What are realistic goals for;
  - Rifle?
  - Shiawassee?
  - Cass?
  - Pigeon/Pinnebog?



Elements of Realism That Must Be Considered

- What is Valued?: Social and Legal Realities
  - Social: People value clean water for health and recreation: Biota are the canaries in the coal mine
  - Legal: Clean Water Act mandates that designated waters of the US are fishable and swimmable OR have Biological Integrity
- What is Achievable?: Ecological, Logistical, and Economic Realities
  - Ecological: water quality and flow are not the only factors affecting riverine biota; inherent natural variation in ecological conditions among sites
  - Logistical: Agriculture is not the only disturbance source in most watersheds, so AG BMPs have limited capacity to improve conditions; supply chain constraints for implementing BMPs at various levels
  - Economic: Limited public funding available
- What is Acceptable?: Economic realities
  - Economic: People use return on investment to guide many decision: Direct and indirect costs (farmer income, price of food) to achieve different levels of water quality or biological integrity

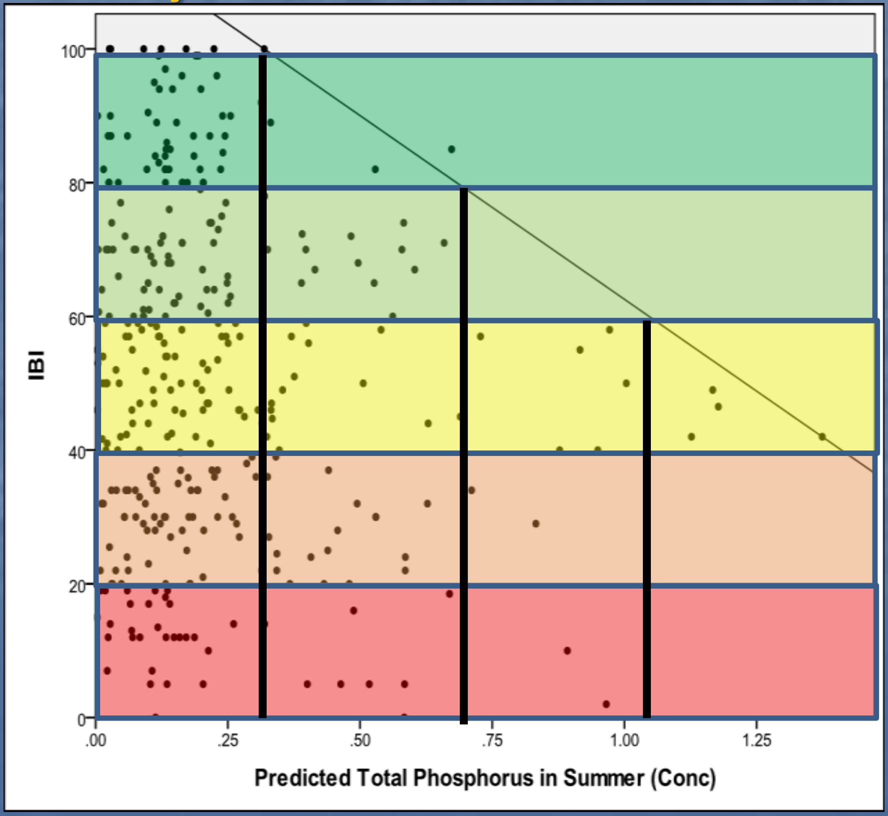
Important Caveats and Cautions

- Out of necessity we are focusing on specific:
  - Source of Disturbance; AG non-point source
    - We do account for other sources(e.g., urban, cattle, dams)
  - Ecosystem: Rivers
  - Biological endpoints: Fish
  - Elements of habitat quality: Sediments, Nutrients, and Flow
  - Conservation practices: 12 AG BMPs

- Our realistic desired conditions and strategies might be insufficient for addressing other issues;
  - E.g., Nearshore ecosystem, algae

Linking Data to Values

- Do people value total phosphorous concentrations?
- No, they value human health, quality of life, recreation: Biotic Integrity of System
- Index of Biotic Integrity
  - %Intolerant Individuals
- "Canary"
- Currency relevant to TNC



Biological Integrity

- "…the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region." (Karr 1991)
- We use an IBI developed for WI and MI (Lyons)

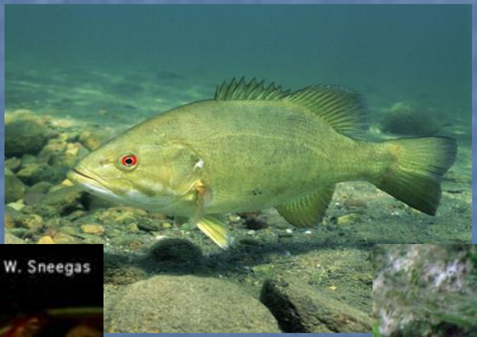


12 IBI Metrics

IBI Metrics
Species Richness and Composition
Total number of native species
Number of darter species
Number of sucker species
Number of sunfish species
Number of intolerant species
Percent of tolerant individuals
Trophic and Reproductive Function
Percent omnivores
Percent insectivores
Percent top carnivores
Percent lithophilous spawners
Fish Abundance and Condition
Number of individuals in sample
Percent with deformities, eroded fins, lesions, or tumors

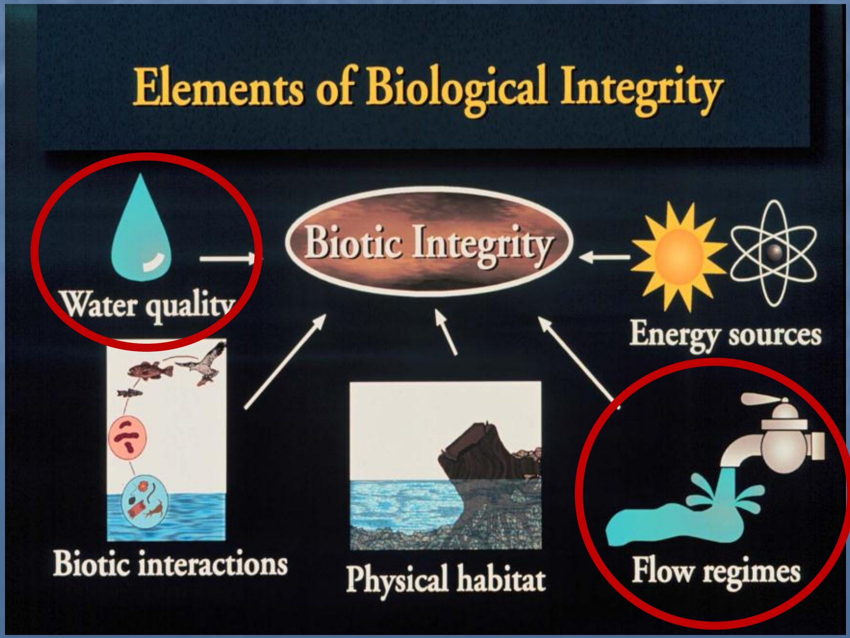
Intolerant Species

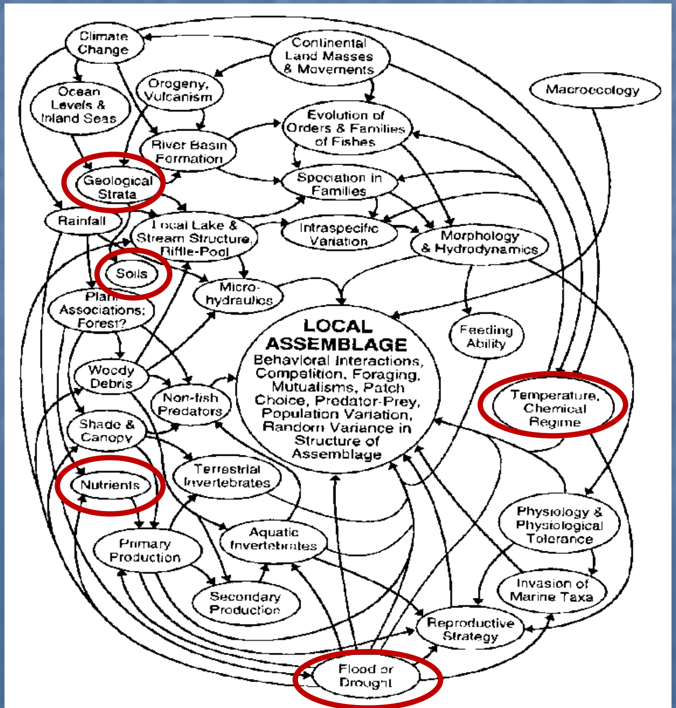
- Species unable to withstand environmental degradation (Sediment, Temperature, DO)
- 42 Intolerant fish species in MI and WI
  - E.g., Brook trout, rosyface shiner, smallmouth bass, rainbow darter



Constrain What is Achievable

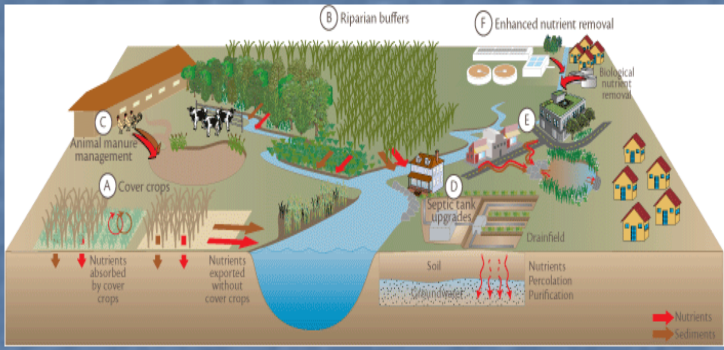
- Water quality and flow are not the only factors that influence biological integrity of streams
- We are addressing only a subset of factors: Be Honest/Transparent
- We are trying to determine at what point are water quality and flow no longer limiting the riverine fish community





Constrain What is Achievable

- Ability of selected practices to improve water quality and flow conditions
  - Nutrient Management/ Waste Utilization
  - Conservation Crop Rotation
  - Filter Strip
  - Conservation Cover
  - Residue and Tillage Management
  - No-Till/Strip Till/Direct Seed
  - Mulch Till, Residue Management
  - Residue Management, No-Till/Strip Till
  - Cover Crop
  - Pasture and Hay Planting
  - Wetland Creation/Restoration
  - Wetland - Floodplain restoration

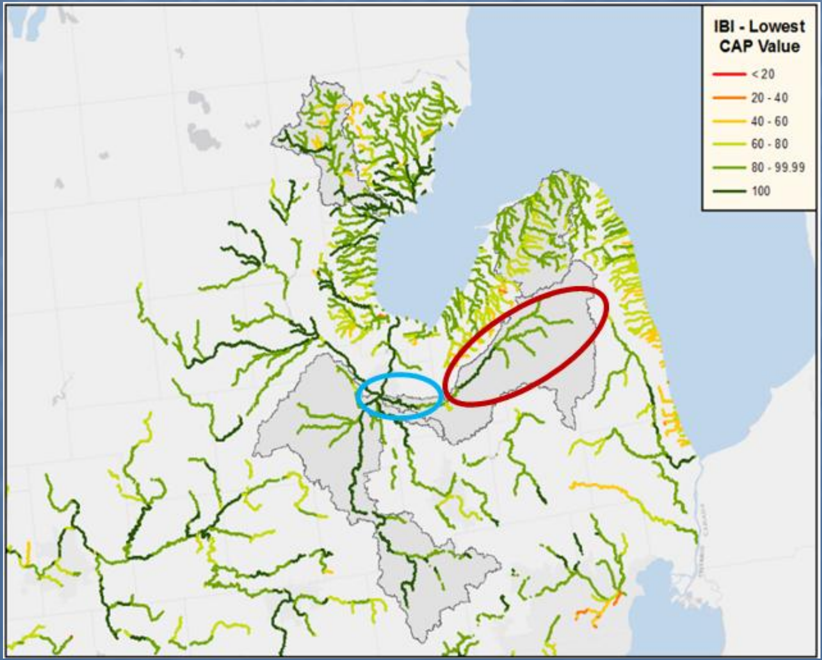


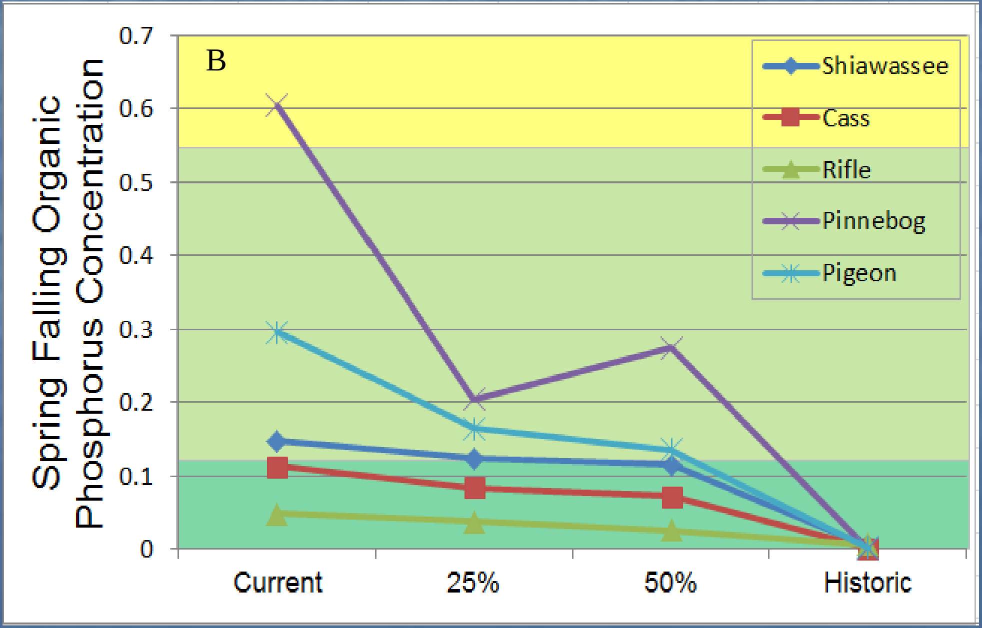
What is Acceptable?

- Return on Investment
  - Costs to achieve different conditions
    - Total cost
    - Cost per unit benefit

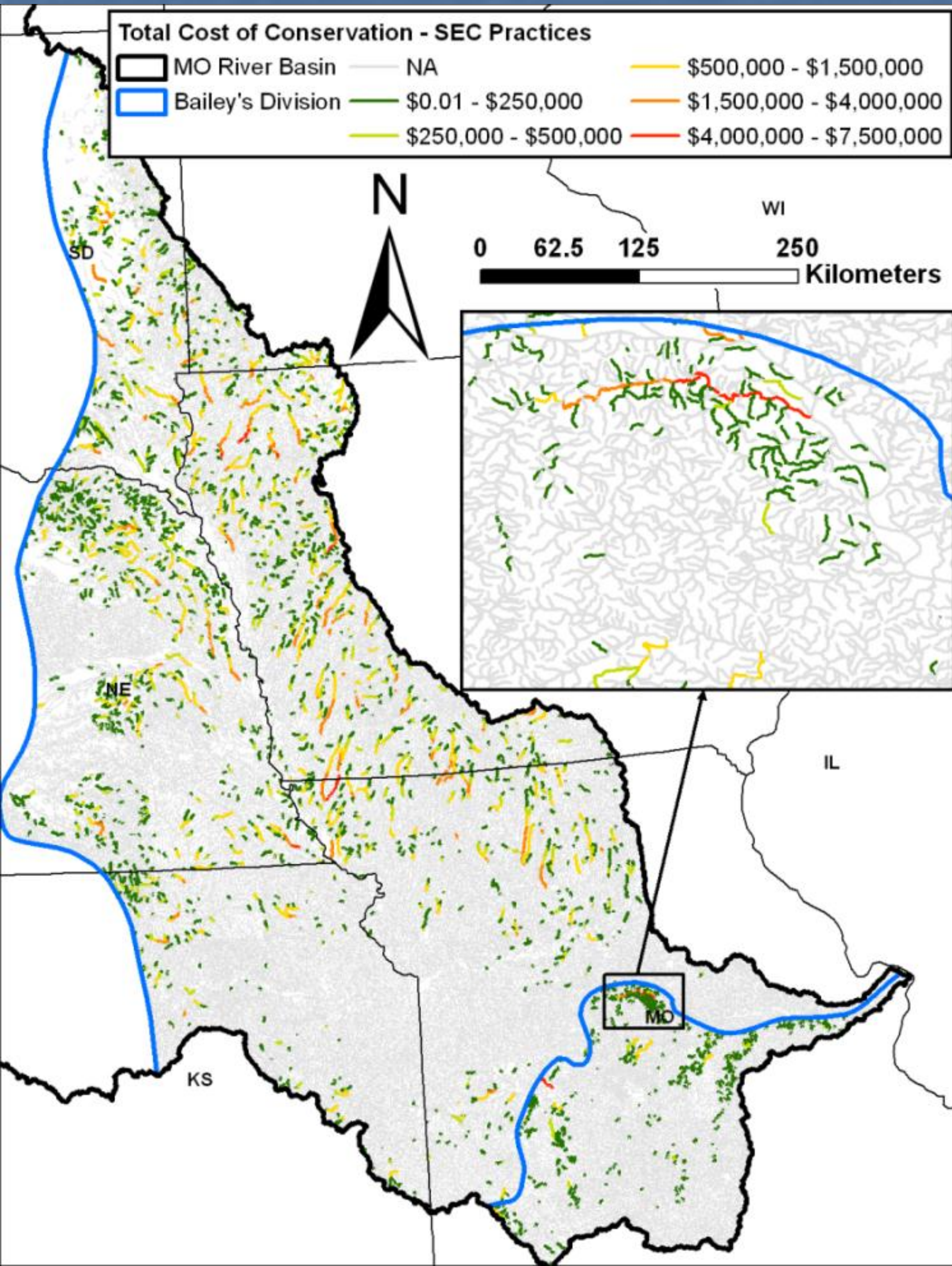
Statewide Conservation Practice Typical Installation Cost Information

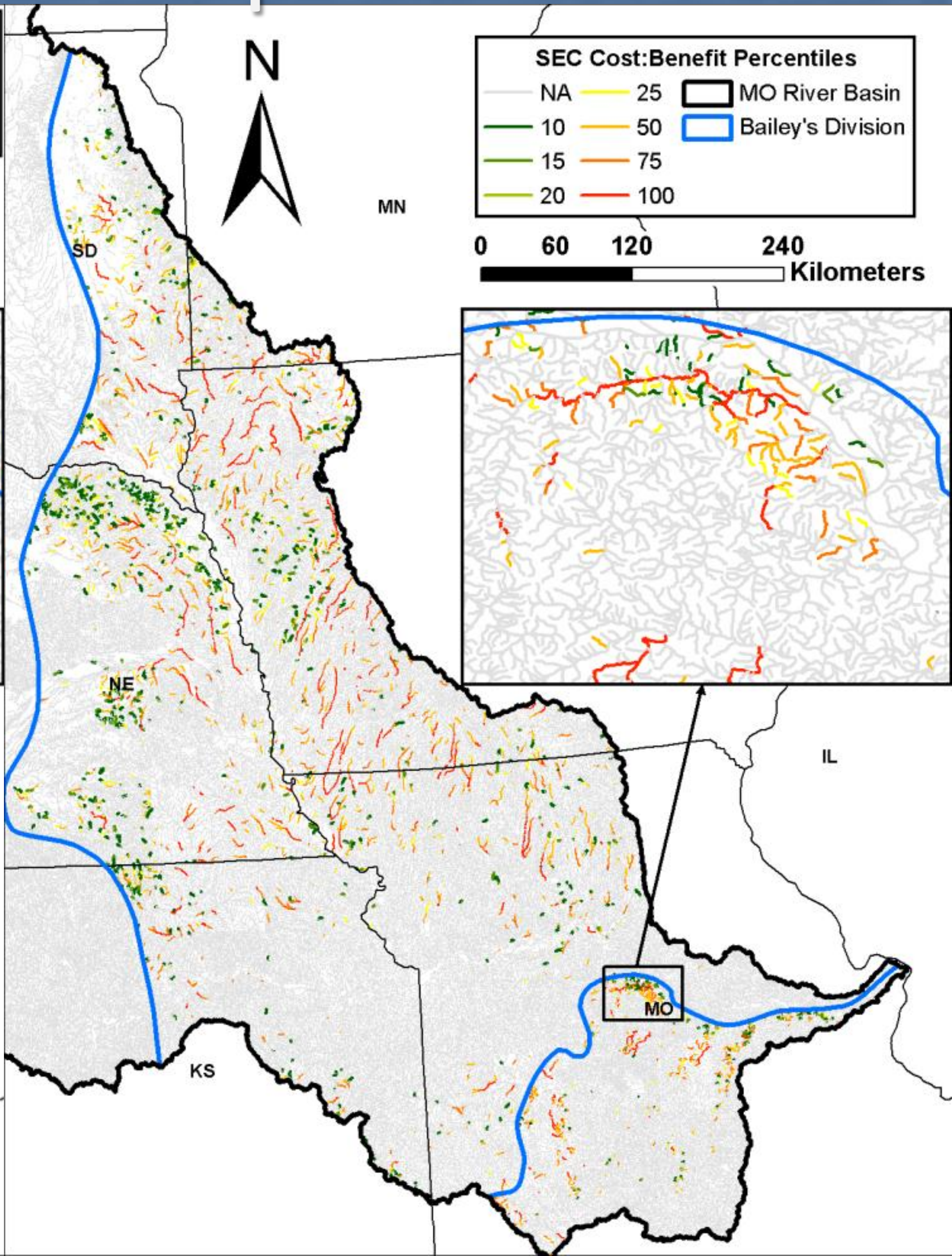
Practice Name and Unit	Code	Description (from Practice Standard)	Typical Installation Scenario	Unit	Installation Cost per Unit	Design Life (years)	National NRCS O&M Factor	Annual Maintenance Cost per Unit (installation x O&M factor)	Average Annual Cost per Unit (amortized installation @ design life, 3.9% interest rate + annual O&M)
Conservation Cover (Ac.)	327	Establishing and maintaining permanent vegetative cover to protect soil and water resources.	One acre of warm season grasses and Michigan native specified pollinator wildflower mix.	Ac.	$456.22	10	3%	$13.69	$69.65
Conservation Cover (Ac.)	327	Establishing and maintaining permanent vegetative cover to protect soil and water resources.	Vegetative plugs installed in wetland soils to facilitate establishment of native communities of plants. Used with wetland restoration and/or upland areas to do a rapid re-establish of native plant community. Installed on 18" centers without seeding. 4,444 plugs per 10,000 sq ft. purchased	sq. ft.	$0.75	10	3%	$0.02	$0.11
Conservation Cover (Ac.)	327	Establishing and maintaining permanent vegetative cover to protect soil and water resources.	Vegetative plugs installed in wetland soils to facilitate establishment of native communities of plants. Used with wetland restoration and/or upland areas to do a rapid re-establish of native plant community. Installed on 18" centers with seeding. 4,444 plugs per 10,000 sq ft. purchased in flats of 32. Seeding with 100 seeds per sq ft.	sq.ft. ft.	$0.78	10	3%	$0.02	$0.12
Conservation Cover (Ac.)	327	Establishing and maintaining permanent vegetative cover to protect soil and water resources.	Used with wetland restoration to re-establish of native plant community. Seeding mix to be specific to wetland site conditions as per biologist decision.	Ac.	$1,348.83	10	3%	$40.46	$205.94
Conservation Crop Rotation (Ac.)	328	Growing crops in a recurring sequence on the same field.	Cropland with 2-4 crops in rotation, analysis of crops, and acreages to determine rotation. Includes recordkeeping of fields and crops. Typical field is 20 ac	Ac.	$10.00	1	0%	$0.00	$10.39
Conservation Crop Rotation (Ac.)	328	Growing crops in a recurring sequence on the same field.	Cropland with 6-8 crops in rotation, analysis of crops, and acreages to determine rotation. Includes recordkeeping of fields and crops. Typical field is 10 ac vegetable farm.	Ac.	$20.00	1	0%	$0.00	$20.78
Contour Buffer Strips (Ac.)	332	Narrow strips of permanent, herbaceous vegetative cover established across the slope and alternated down the slope with parallel, wider cropped strips.	Tillage site prep so can be organic or non-organic, seed, fert and 2 post plant trips to establish vegetative stand in buffer strips.	Ac.	$250.00	10	3%	$7.50	$38.17





Total Costs and Cost per Benefit



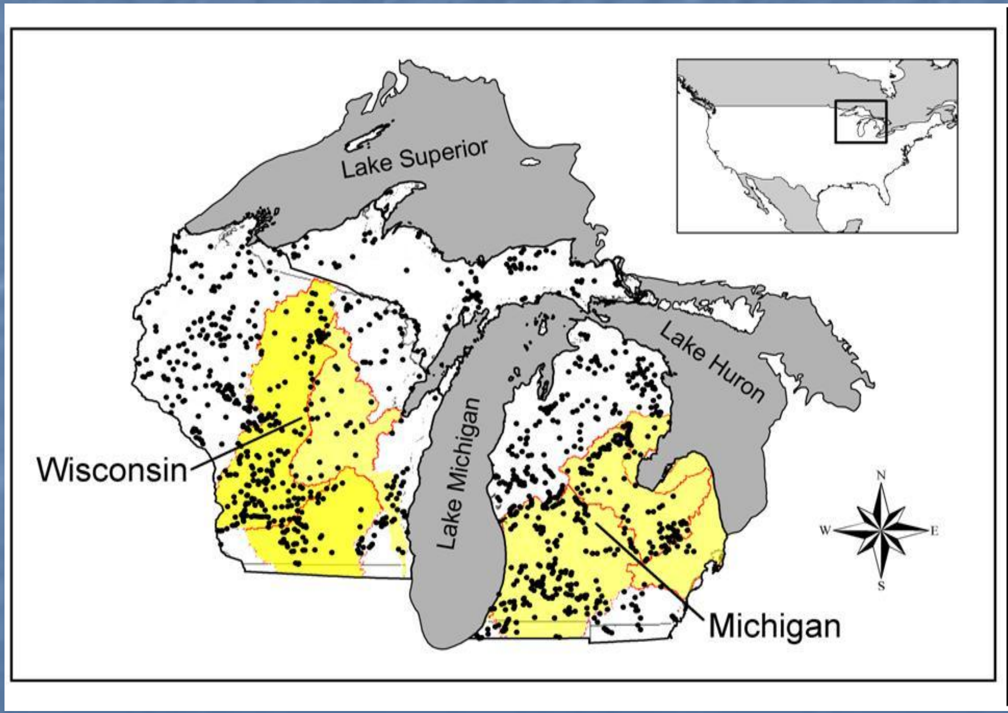


Key Questions We Are Trying to Address

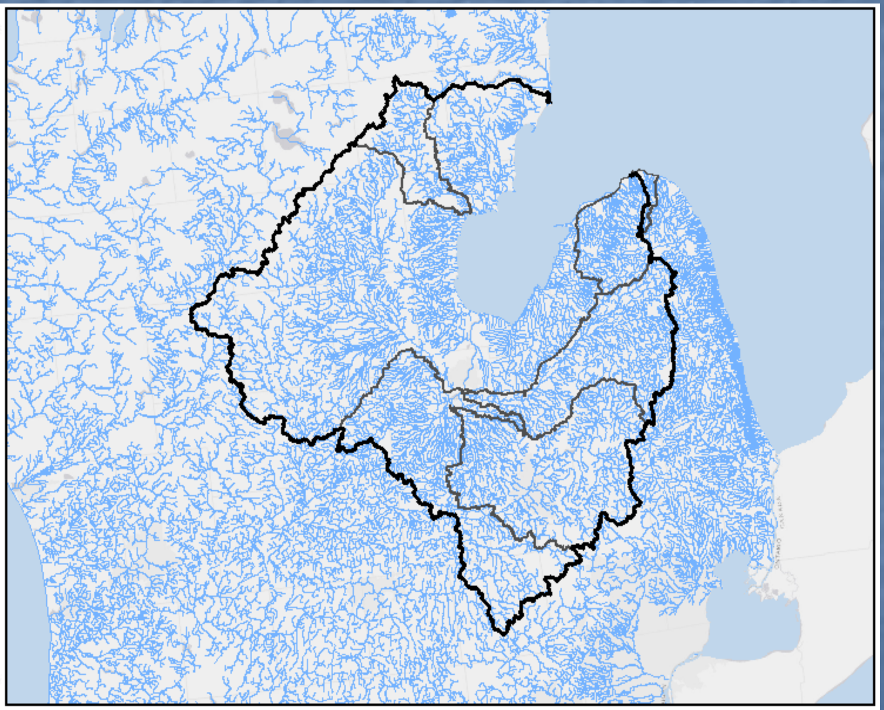
- Phase 1:
  - What is the relationship between measures of biological integrity and water quality and flow variables?
  - At what point do variables become limiting?
    - Target variables (Ag related water quality and flow)
    - Non target variables (Natural, Urban, etc.)
  - Which streams are limited by Ag related WQ and flow?
- Phase 2:
  - How much of an investment will it take to remove water quality and flow as limiting factors?
  - What are realistic, biologically-based, water quality and flow goals given:
    - direct and indirect costs of restoration?
    - return on investment?
    - limited public funding or other “funding mechanisms”?
    - logistical constraints of existing AG BMP supply chains?

Where are We Working?

Phase 1



Phase 2



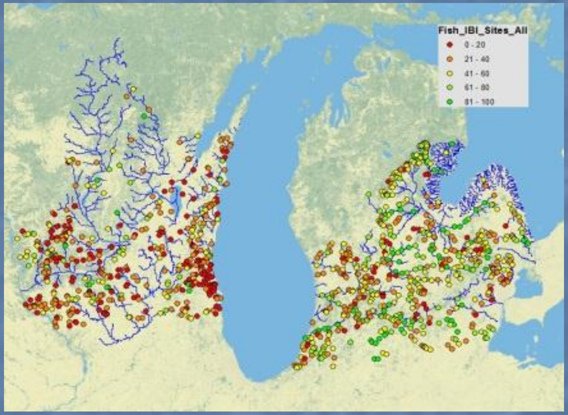
Great Lakes CEAP Phase 1: Major Tasks

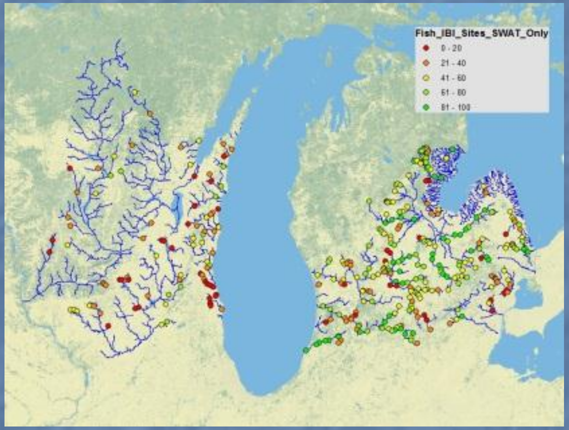
- Model Water Quality and Flow across study area via SWAT
  - Historic (for context) and current land use/cover conditions

- Identify relations and thresholds/ceilings between:
  - Response variables:
    - Fish community Index of Biotic Integrity
    - % of Community Comprised of Intolerant
  - Predictor Variables:
    - Natural Watershed Variables (e.g., groundwater contribution)
    - Non-target disturbances (e.g., %urban)
    - Target predictor variables
      - Water quality and flow variables from <u>SWAT</u>

Response Variables and Sources

- Response variables (N = 1022 or N = 345)
  - Fish Index of Biotic Integrity (IBI)
    - » N = 1022 N = 345



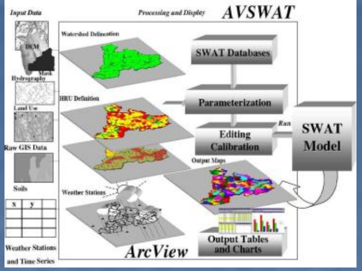


  - Relative Abundance of Functional Guilds
    - » Ominvore, Insectivore, Piscivore, Lithophilus, Intolerant

PUGAP_CODE	IBI	PCINTONB	PCOMNINB	PCINSENB	PCLITHNB	PCPISVNB	PISINSRATIO
black596	35.00	3.29	30.21	43.75	34.89	0.00	0.00
clint100	57.00	11.59	33.33	43.32	53.30	0.97	0.02
clint103	34.50	1.22	22.43	76.76	29.83	0.00	0.00
clint108	53.00	22.27	19.09	51.59	50.00	0.23	0.00
clint116	35.00	1.40	0.00	20.98	12.59	0.00	0.00
clint206	32.00	1.38	13.17	3.82	69.69	0.33	0.09
clint224	12.00	0.00	29.58	2.82	45.07	0.70	0.25
clint237	49.00	2.39	18.97	49.91	20.63	0.00	0.00
clint244	19.00	0.00	26.46	4.79	44.55	1.20	0.25
clint249	47.00	26.69	1.40	42.98	35.39	0.28	0.01
clint254	87.00	17.42	0.00	84.85	7.58	13.64	0.16
clint29	57.00	64.86	8.78	8.78	18.92	0.00	0.00
clint299	58.33	18.19	10.08	18.93	33.82	0.00	0.00
clint306	47.00	3.28	24.59	11.48	28.96	0.55	0.05
clint308	42.33	20.08	15.53	22.63	52.46	0.06	0.00
clint355	35.00	0.00	2.25	1.13	23.10	0.85	0.75
clint362	59.00	31.92	14.81	35.48	29.07	0.75	0.02
clint365	49.00	2.51	58.19	13.38	60.37	2.17	0.16
clint393	34.00	8.17	26.14	13.40	56.21	0.33	0.02
clint441	37.00	1.90	18.25	6.46	25.10	0.38	0.06

fsmetric

Ready Count: 9 130%



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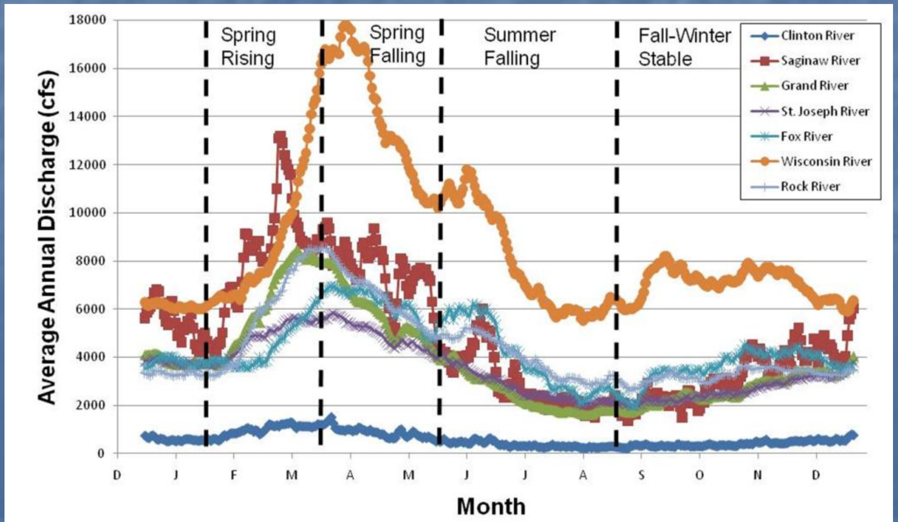
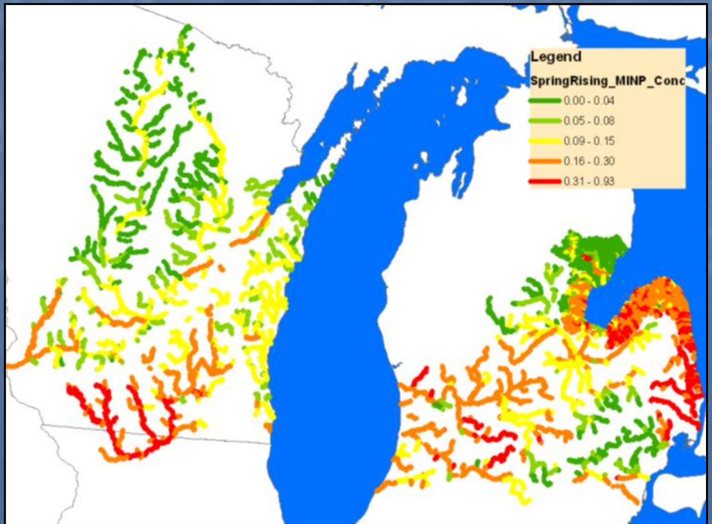
Target Predictor Variables

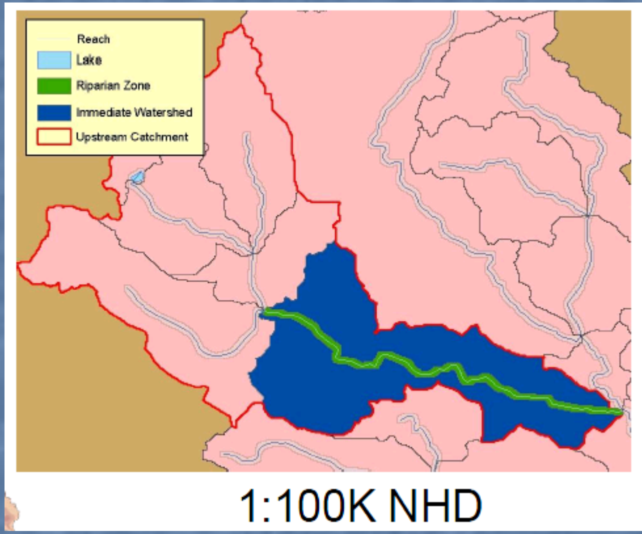
- Modeled (SWAT) Variables (N = 345)
  - Sediments, Nutrients, and Flow
    - » Current, Historic, % change, gross difference
    - » Annual and Seasonal Min, Max, and Means
    - » Runoff, Concentrations and Loads





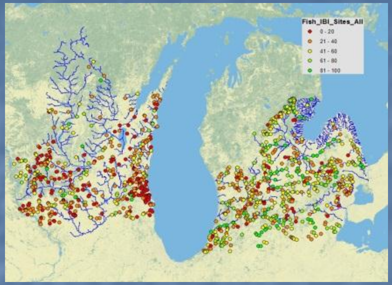
Other Predictor Variables

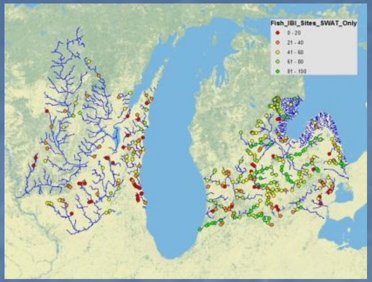
- Predictor Variables (N = 1022)
  - Stream size, Drainage Area, Gradient
  - Physiography and Land Cover
  - Non-Target Threats (e.g., %urban)
- Spatial Units
  - Watershed, overall riparian, local catchment, local riparian
- Sources
  - NFHAP Assessment
  - Great Lakes Aquatic GAP



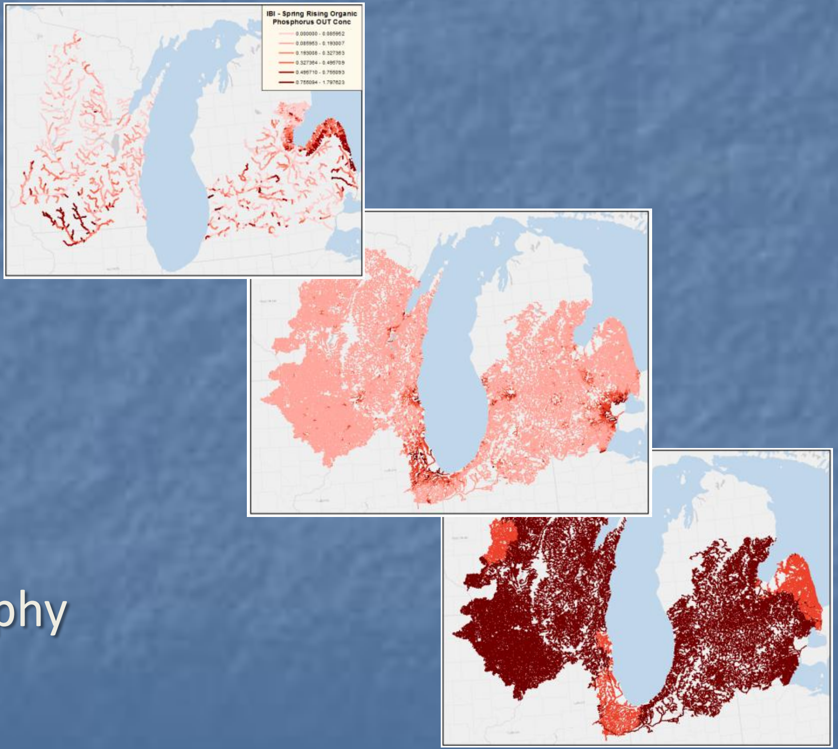
Identify Thresholds and Relations

- Response Variables
  - IBI and Percent Intolerant Fish





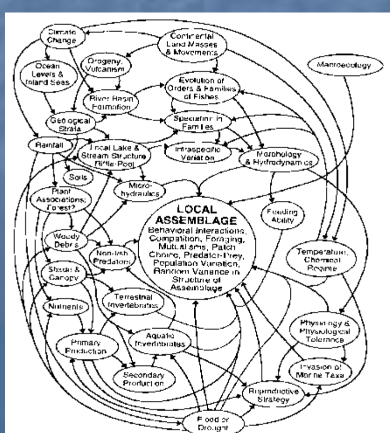
- Predictor Variables
  - Target: (N of 345)
    - SWAT Water Quality and Flow
  - Non-Target: (N of 1022)
    - Watershed Disturbances
  - Natural: (N of 1022)
    - Watershed hydrology/physiography

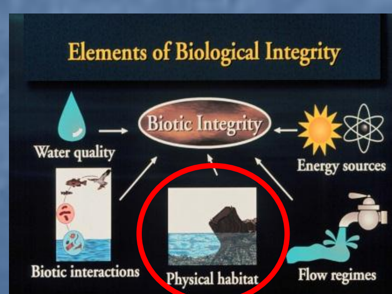


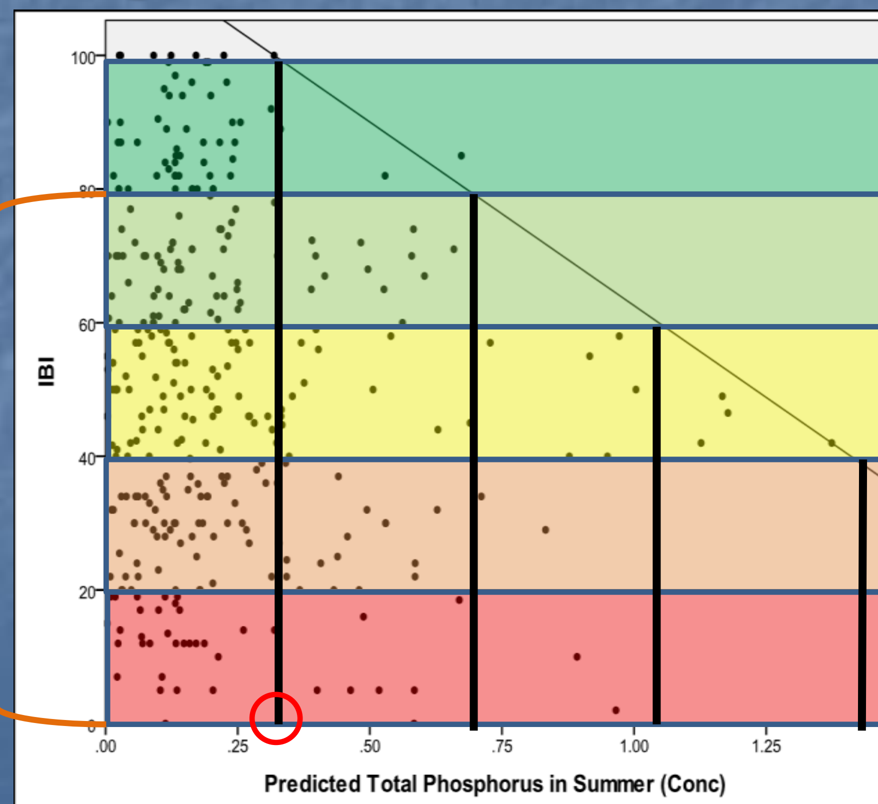
Identify Thresholds and Relations

Deciphering Wedge Plots

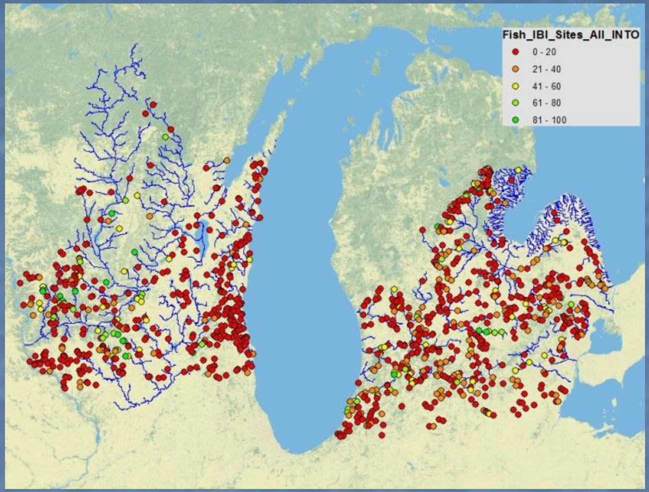
- At what point are water quality and flow variables no longer limiting?
- Other factors often limiting
  - Local physical habitat
    - Sediment, woody debris
  - Contaminants
  - Barriers, Invasive species

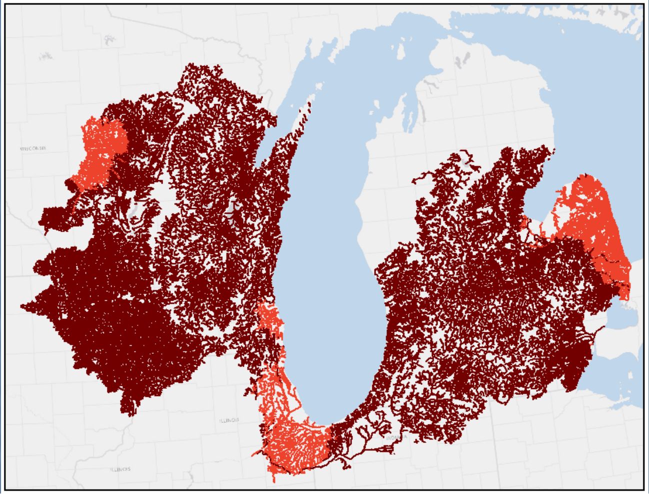


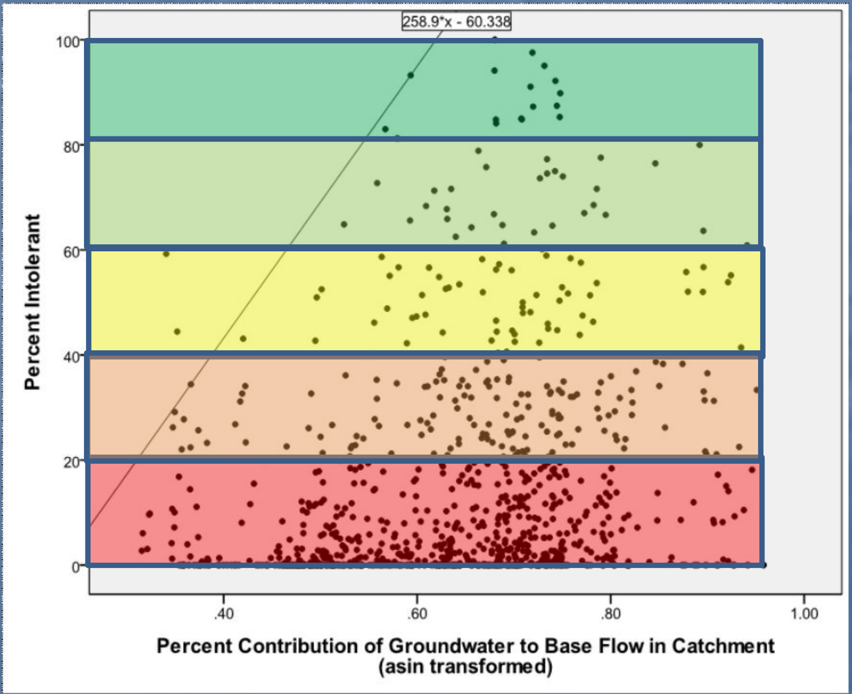


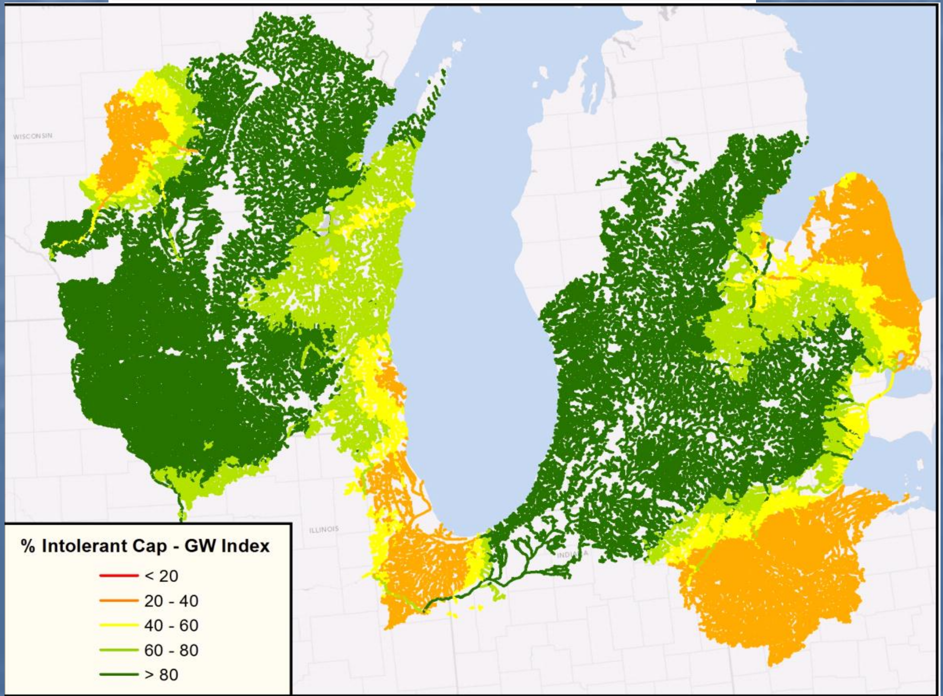


Natural Limit: % Intolerant and Percent Groundwater

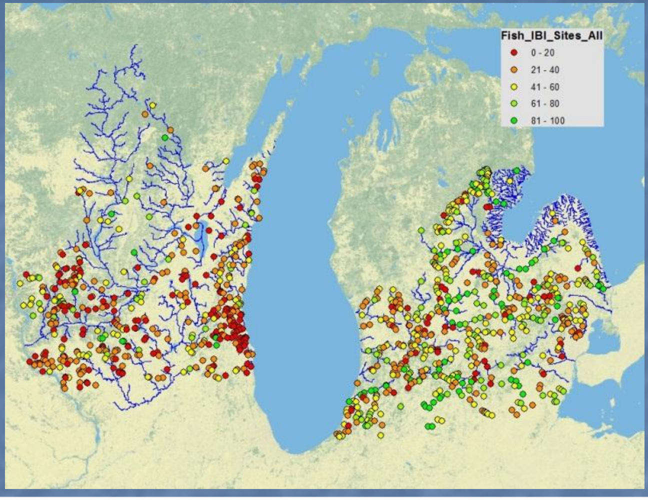


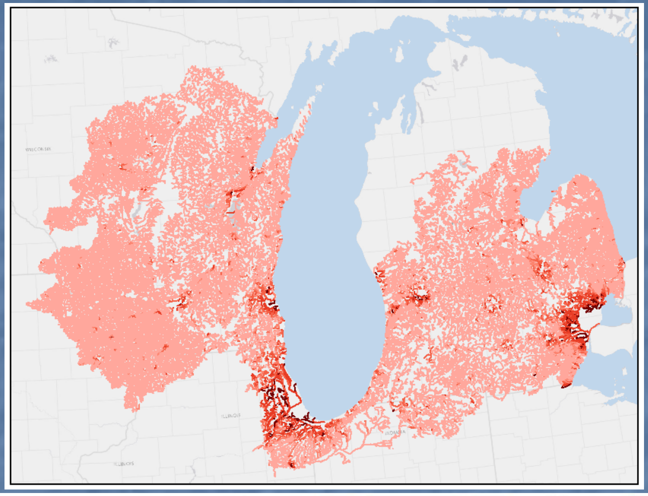


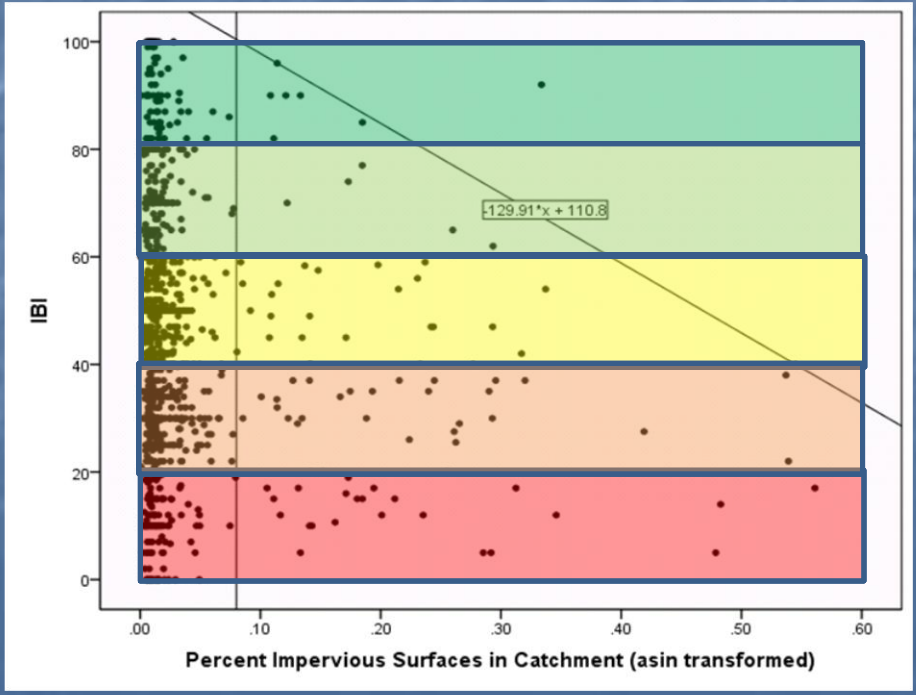


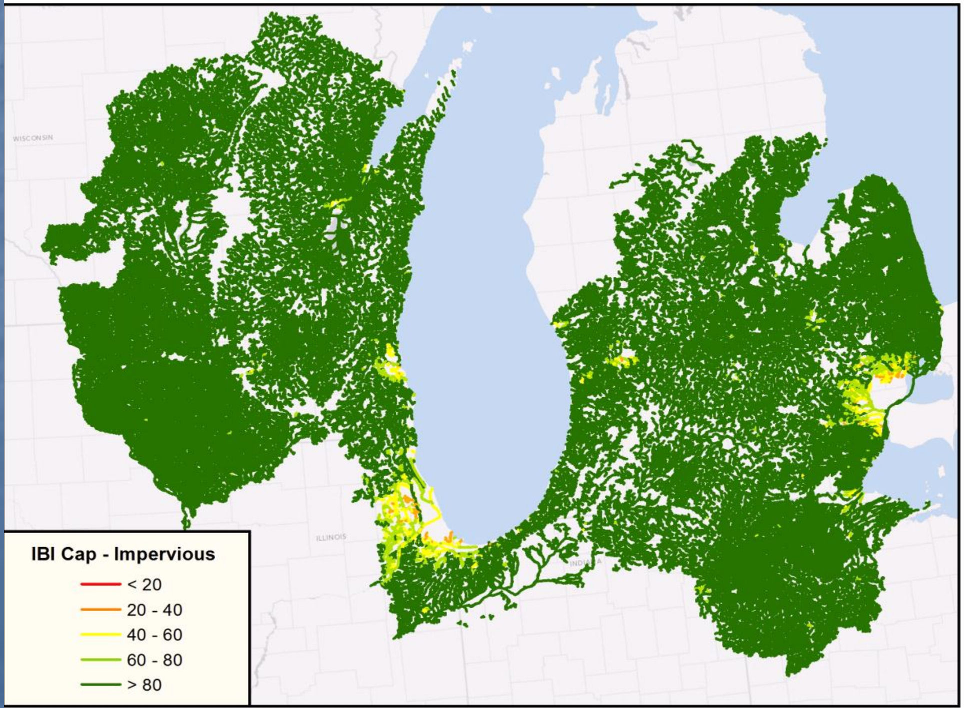


Non-Target Disturbance Limit: IBI and Percent Impervious

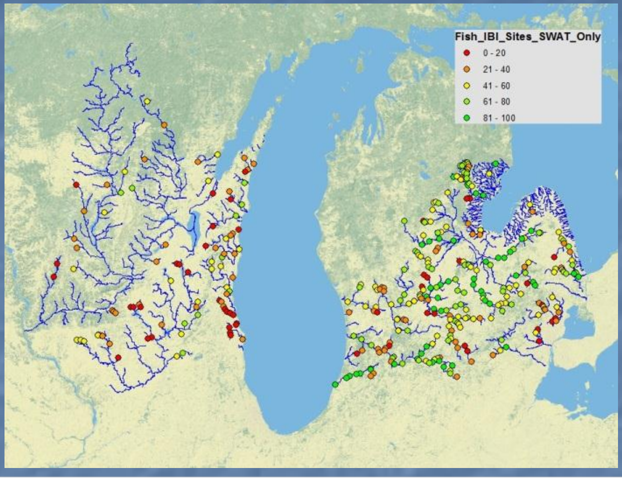


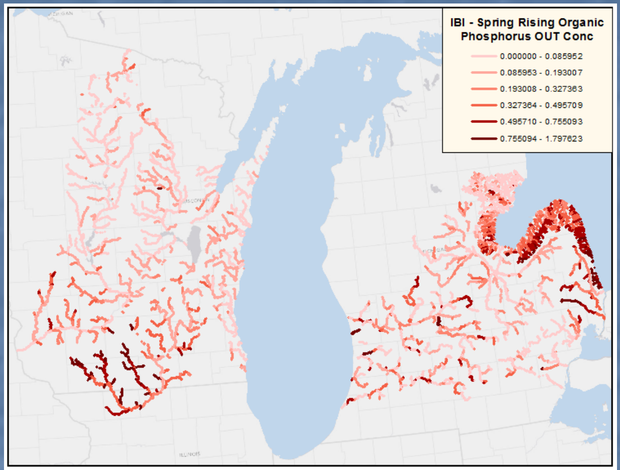


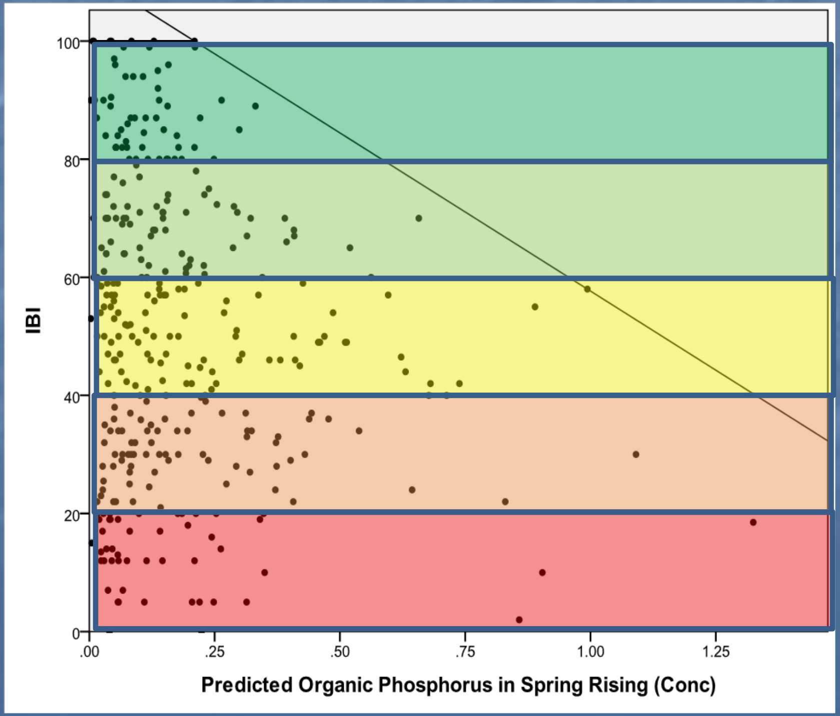


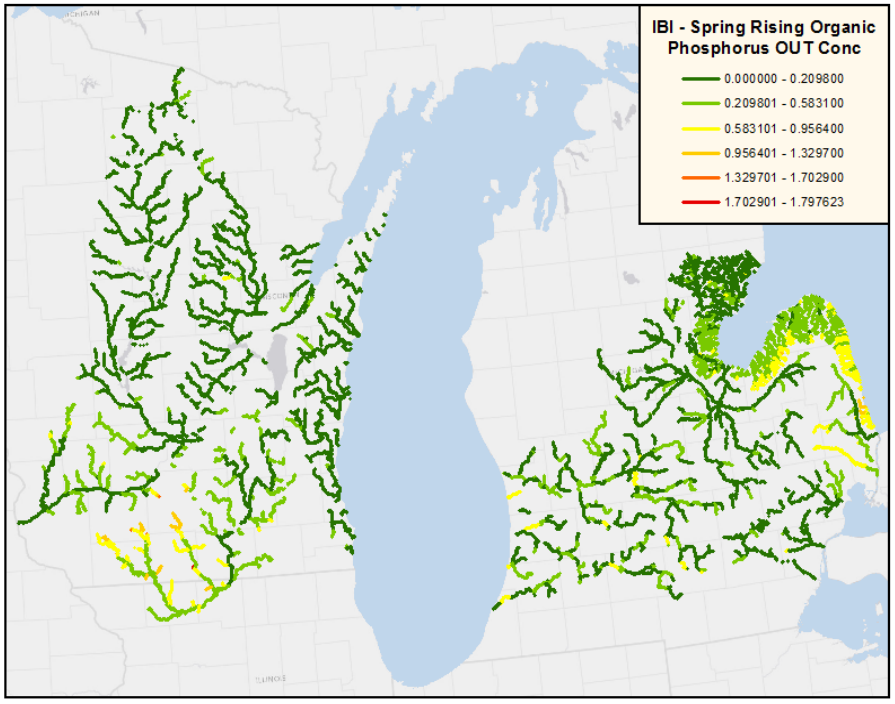


Target Disturbance Limit: IBI and Spring Rising Organic P Concentration

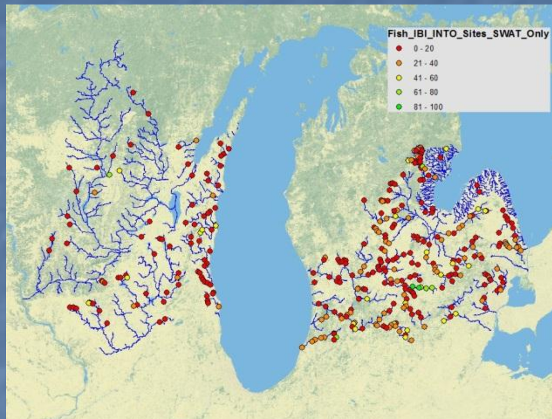


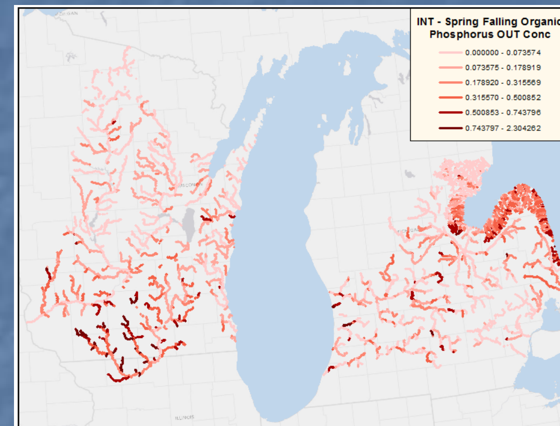


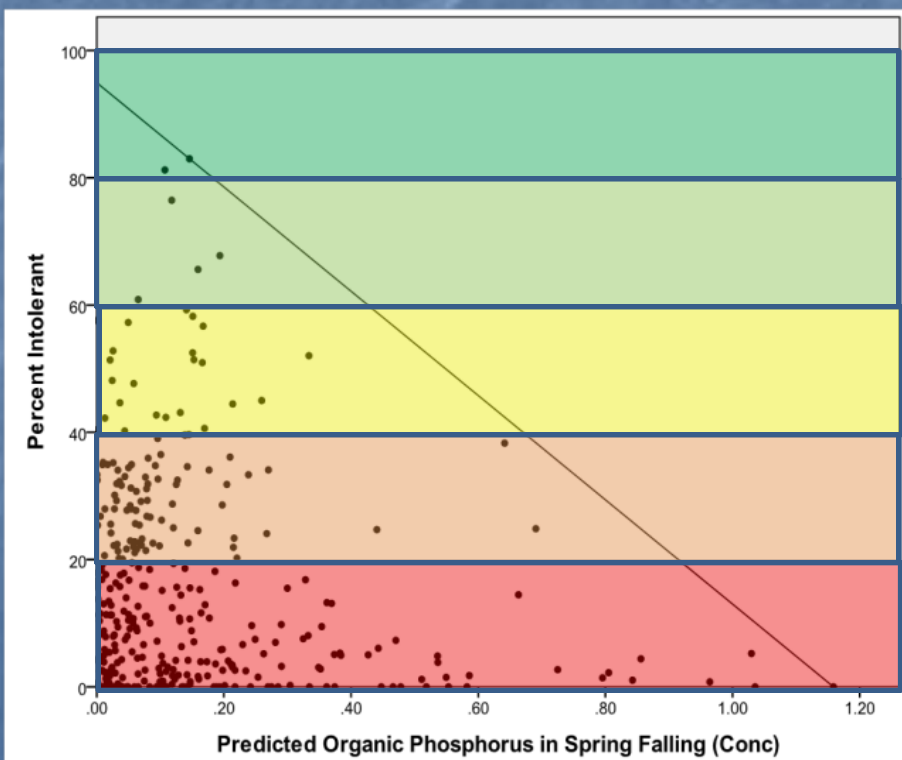


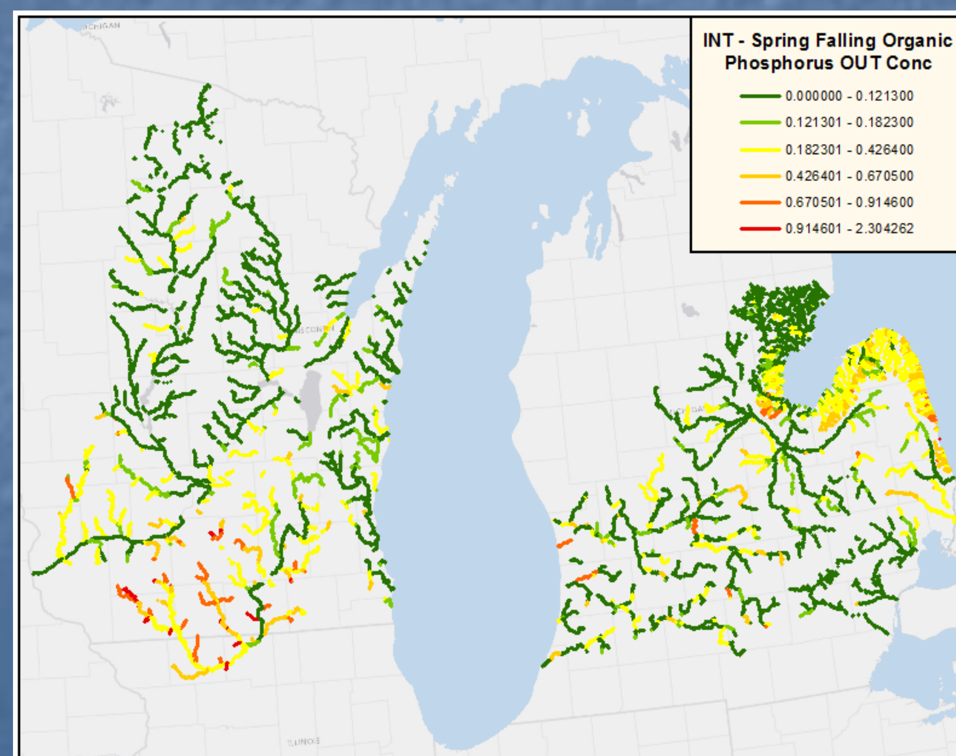


Target Disturbance Limit: %Intolerant and Spring Falling Organic P Concentration









Integrated Mapping of Ecological Limits

1	New_UnqID	IBI_pre_001	CAPIBI_SURQmm	CAPIBI_Spr1_ORGP_OUTConc	CAPIBI_LogSum_SEDCONCmg/kg	CAPIBI_Sum_TOTALP_OUTConc	IBICap_AWT_QG3P	IBICap_LogPONDWA
2	040301-040400_1_doorp600_13063073_20551	51.628571	100	100	100	100	100	100
3	040301-040400_1_doorp600_13063835_20552	51.628571	100	100	100	100	100	100
4	040301-040400_10_pendk390_6801354_20659	51.628571	100	100	95.08013793	100	100	100
5	040301-040400_10_pendk390_6801358_20661	51.628571	100	100	95.08013793	100	100	100
6	040301-040400_10_pendk390_6801368_20660	51.628571	100	100	95.08013793	100	100	100
7	040301-040400_10_pendk391_6801354_20662	51.628571	100	100	95.08013793	100	100	100
8	040301-040400_10_pendk391_6801358_20663	51.628571	100	100	95.08013793	100	100	100
9	040301-040400_10_pendk399_6801368_20664	51.628571	100	100	95.08013793	100	100	100
10	040301-040400_10_pendk399_6802086_20665	51.628571	100	100	95.08013793	100	100	100
11	040301-040400_10_pendk438_6802086_20666	51.628571	100	100	95.08013793	100	100	100
12	040301-040400_10_pendk471_6801388_20667	51.628571	100	100	95.08013793	100	100	100
13	040301-040400_10_pendk471_6802086_20668	51.628571	100	100	95.08013793	100	100	100
14	040301-040400_100_shman1201_12175494_15979	51.628571	74.6796077	100	100	100	100	100
15	040301-040400_100_shman1218_12175494_15982	51.628571	74.6796077	100	100	100	100	100
16	040301-040400_100_shman1218_12175510_15981	51.628571	74.6796077	100	100	100	100	100
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21	040301-040400_100_shman1224_12175522_15986	51.628571	74.6796077	100	100	100	100	100
22	040301-040400_100_shman1224_12175536_15985	51.628571	74.6796077	100	100	100	100	100
23	040301-040400_100_shman1242_12175536_15988	51.628571	74.6796077	100	100	100	100	100
24	040301-040400_100_shman1259_12175536_15989	51.628571	74.6796077	100	100	100	100	100
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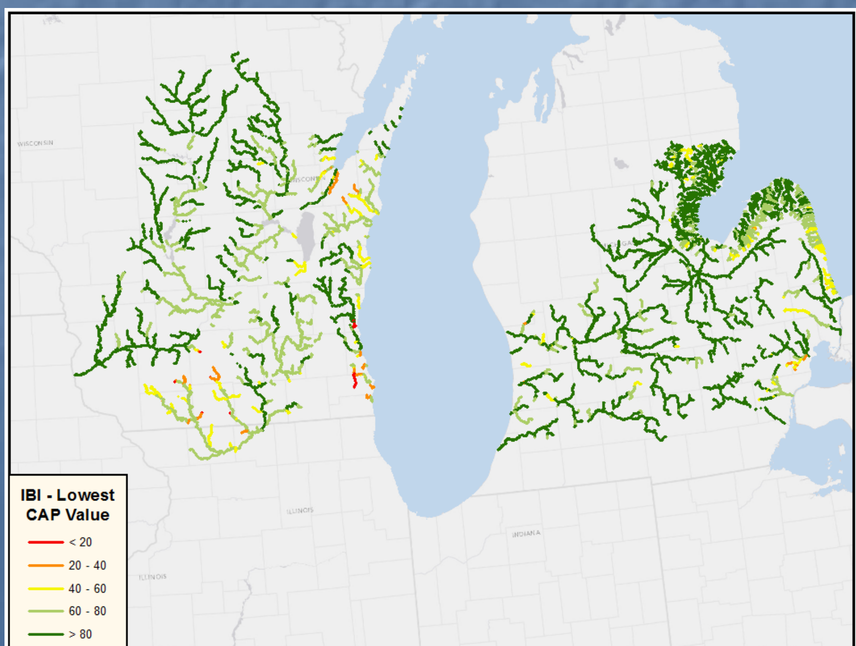
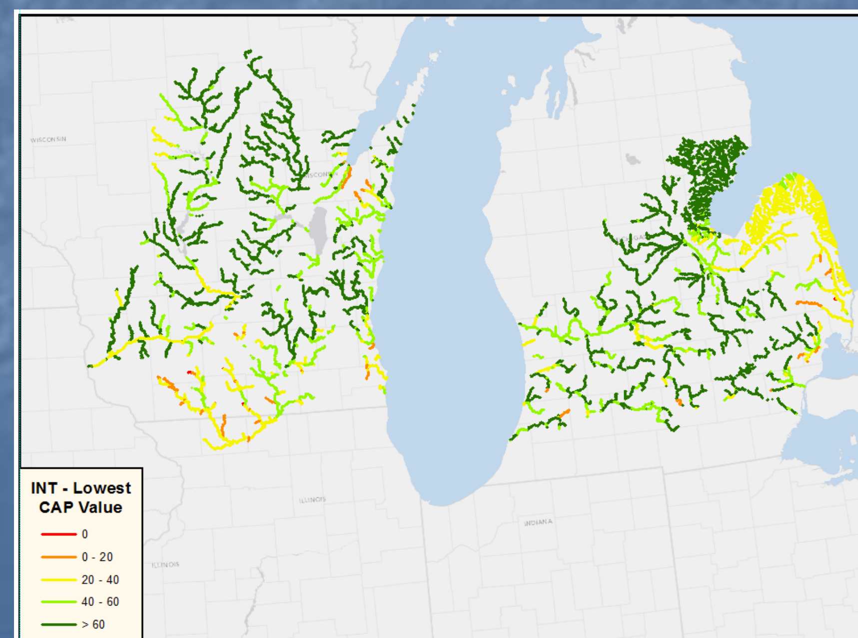
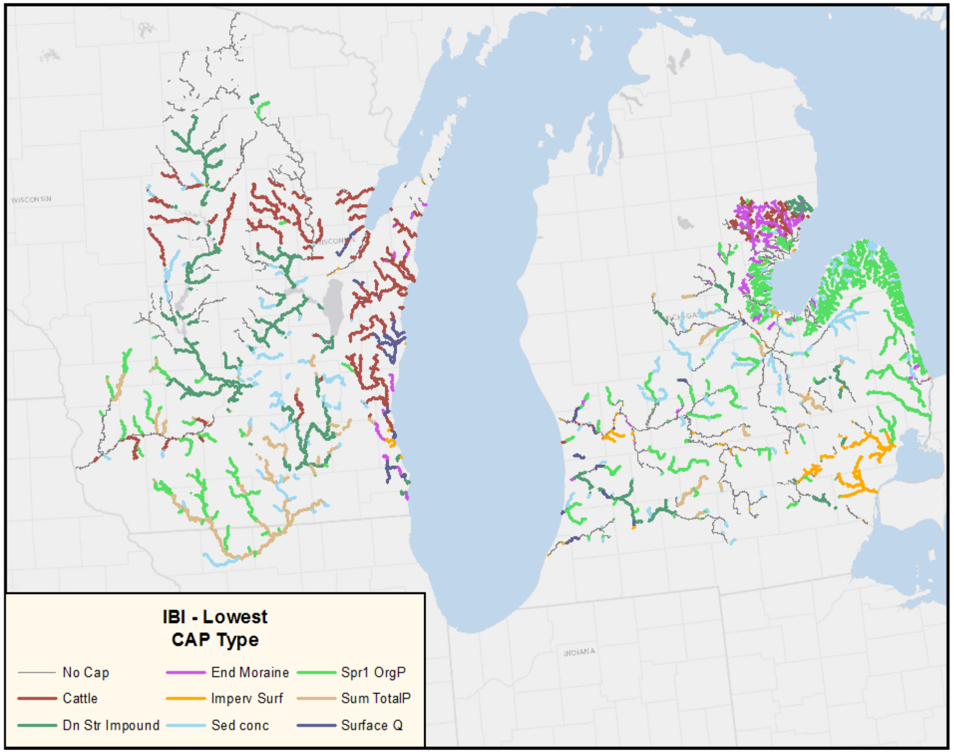
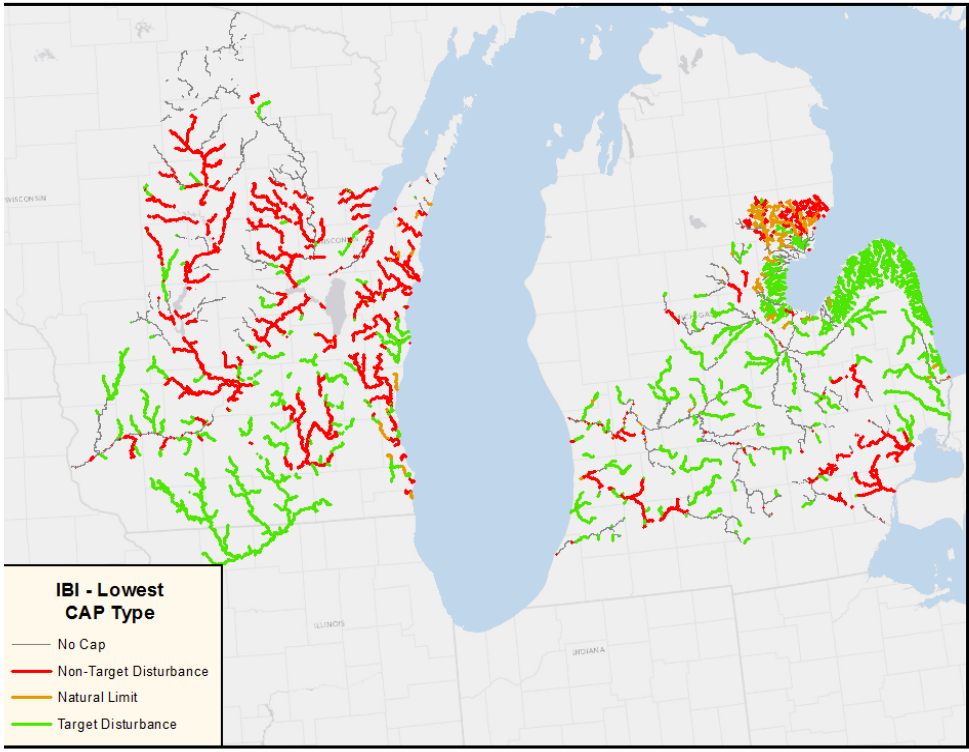




Deciphering Integrated Data
IBI

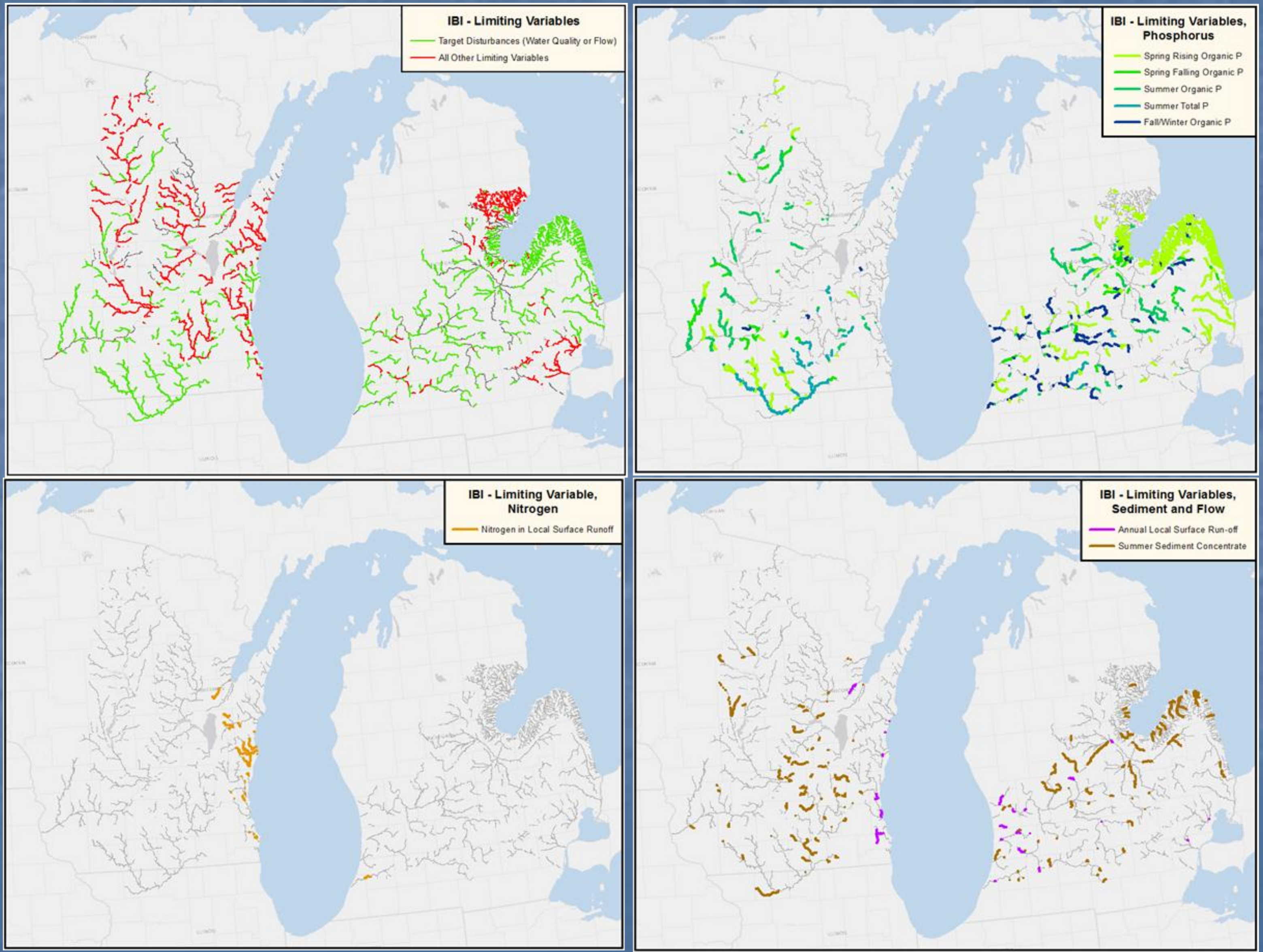
- Which variables are limiting IBI?
- Where are target variables limiting?





Deciphering Integrated Data

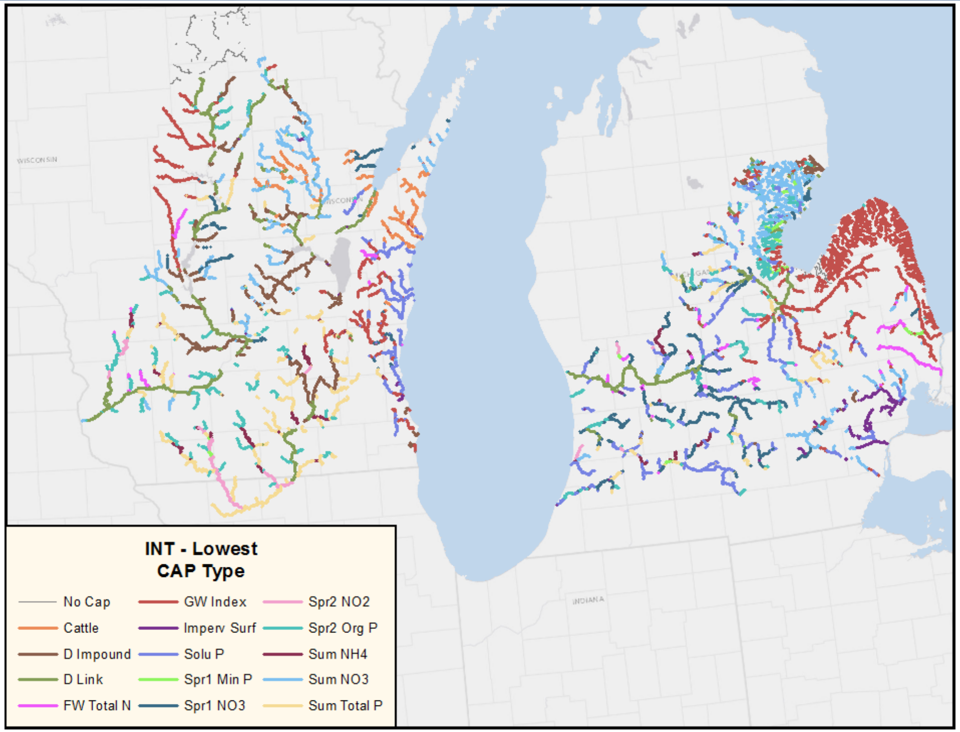
- IBI

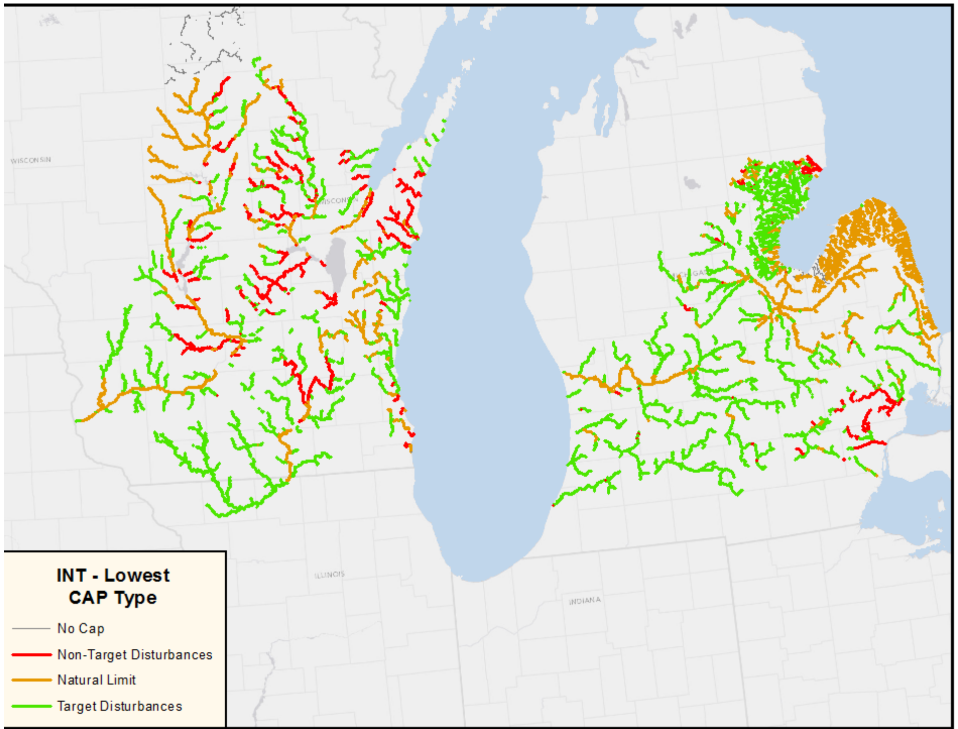


Deciphering Integrated Data

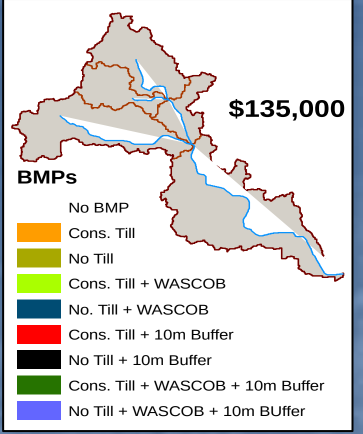
Percent Intolerant

- Which variables are limiting %Intolerant?
- Where are target variables limiting?

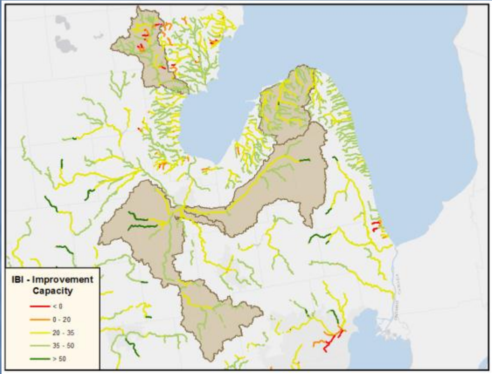


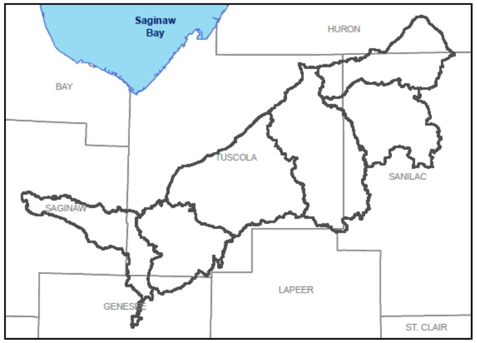


Great Lakes CEAP
Phase 2 Tasks

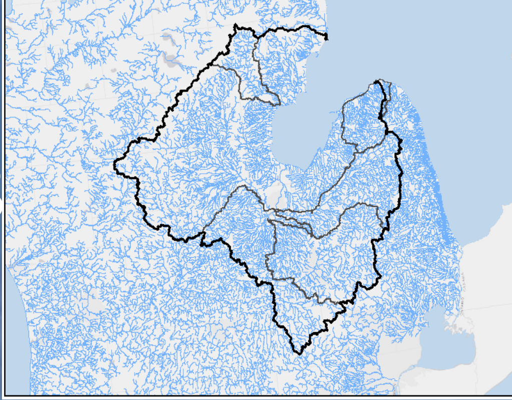


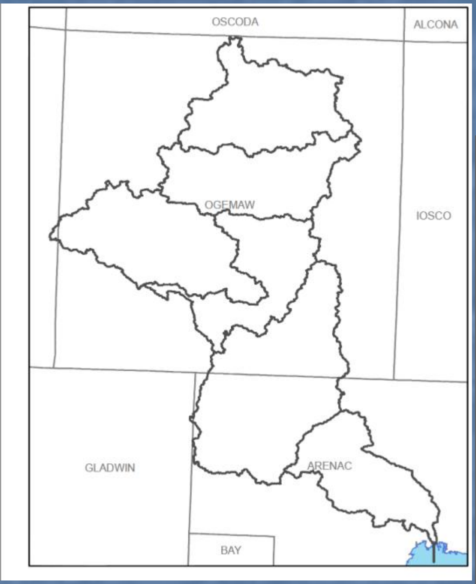
- Within 4 Subwatersheds of Saginaw Bay
  - Use SWAT to model changes in flow and water quality (and fish communities) under different scenarios
    - Current, Medium (25%), High (50%), Historic
  - Assess costs and benefits for each scenario
  - Select priority subwatershed(s)
    - Level 1 Supply chain efficiencies
  - Work with key partners to develop:
    - Realistic subbasin goals ("Demand")
    - Subbasin priorities
      - Level 2 Supply chain efficiencies

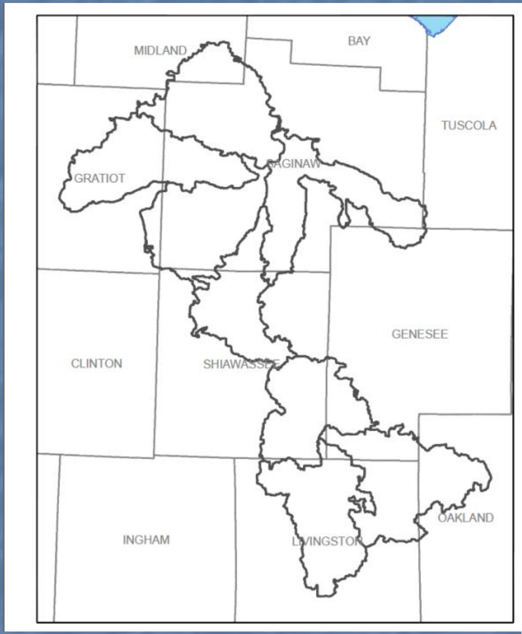


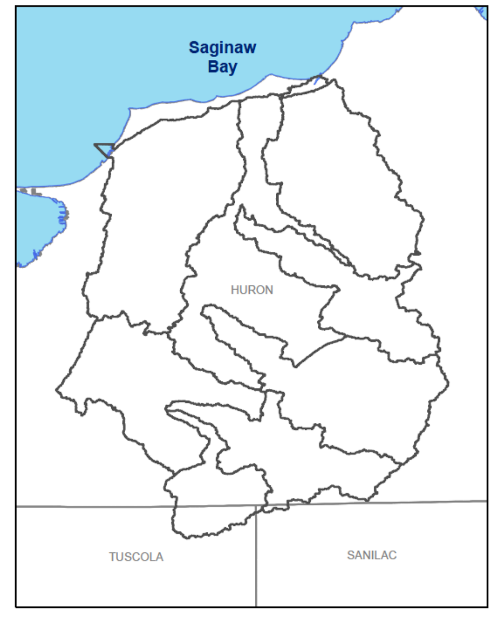


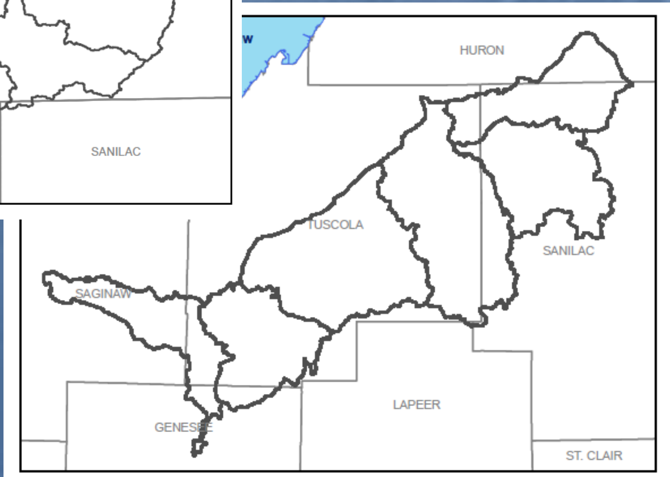
Spatial Grain of SWAT BMP Scenarios



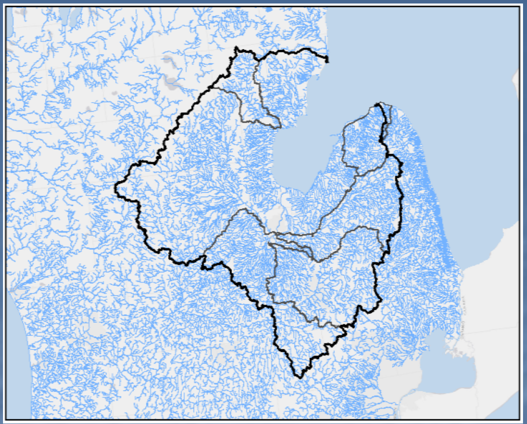


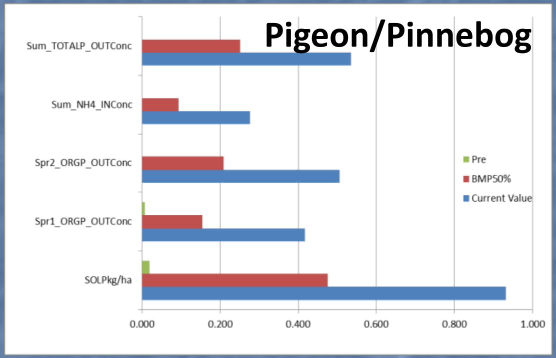


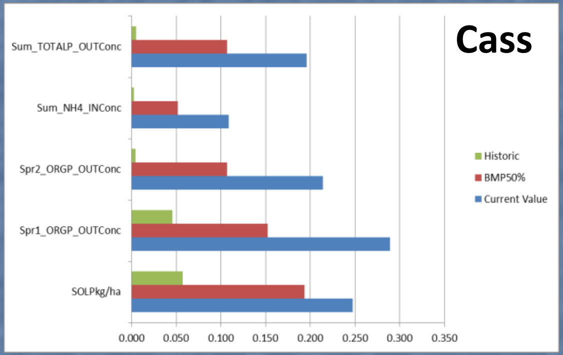


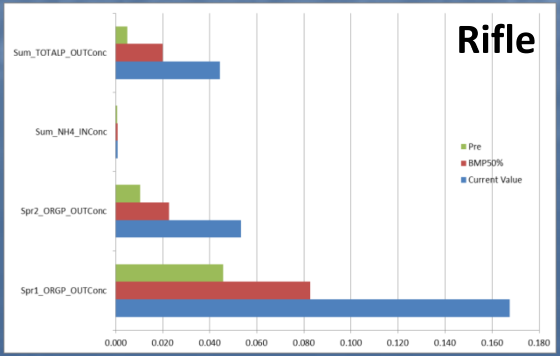


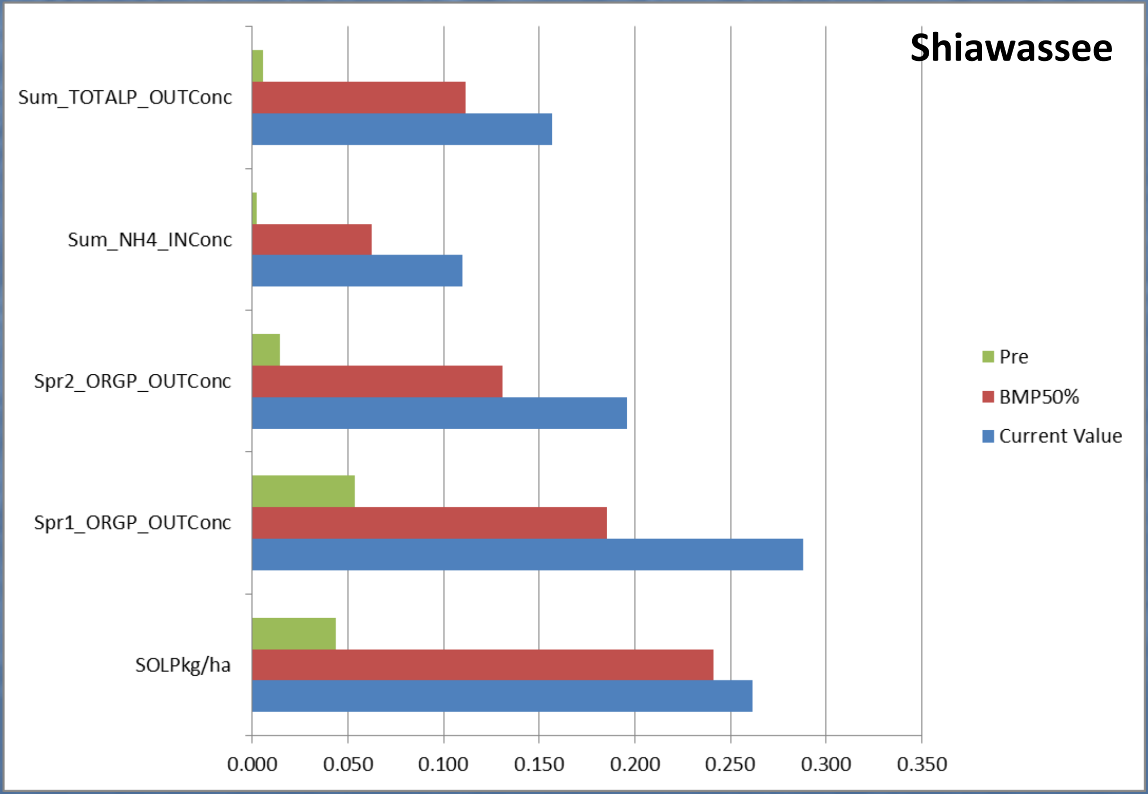
Predicted Water Quality Under Different Scenarios



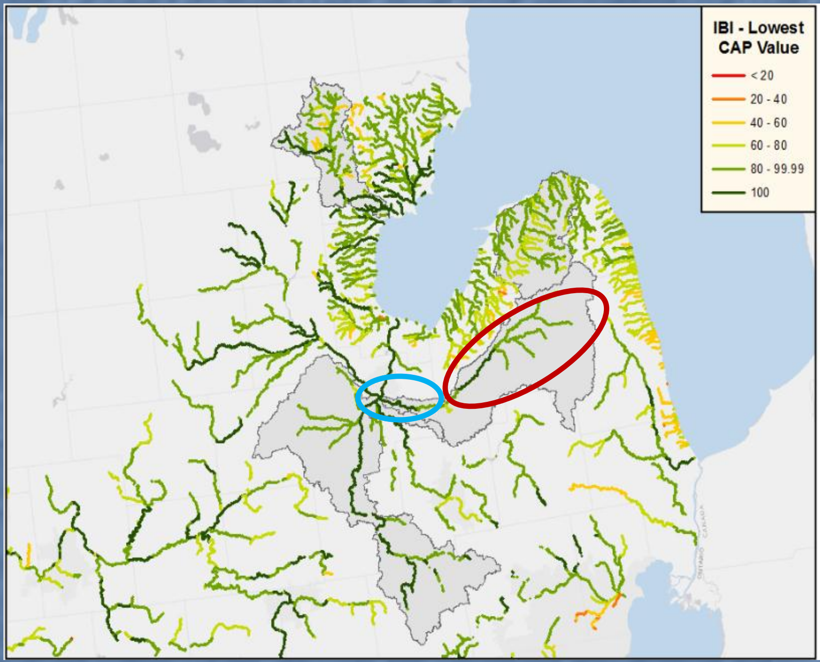


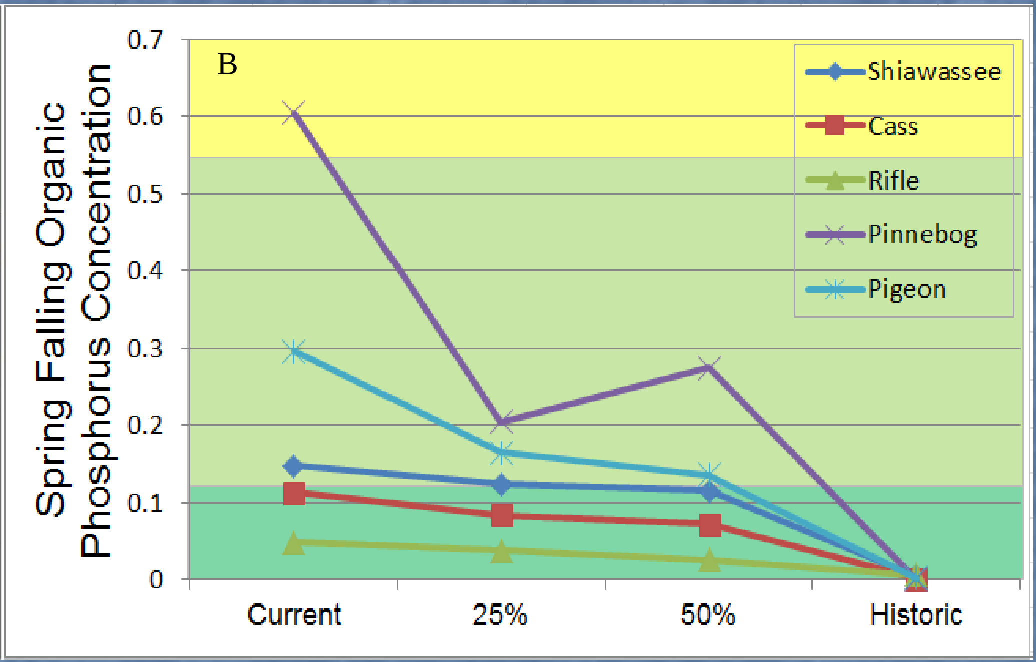






Predicted Water Quality and IBI Under Different Scenarios

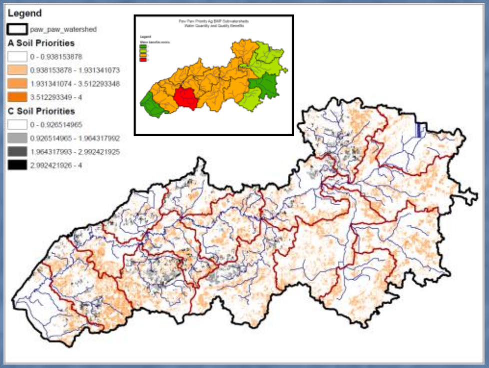




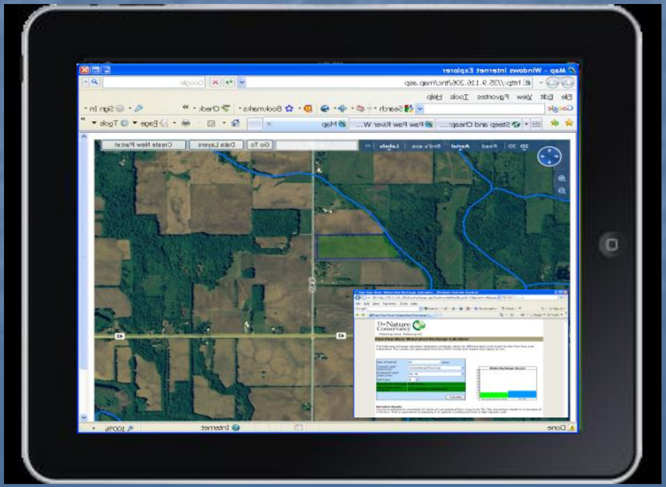
- Shiawassee: Swan, Beaver, N&S Bad River
- Cass: N and S Branch

TNC Watershed Strategy
Phase 3 Tasks

- Develop field scale data and decision tools to support supply chain logistics and Level 3 supply chain efficiencies:
  - Prioritize at 10-30 m pixel to field scale
    - Reduced erosion and sediment inputs (HIT, L-THIA)
    - Reduced nutrient loss (L-THIA)
    - Reduced surface runoff and increased groundwater recharge (SWAT)

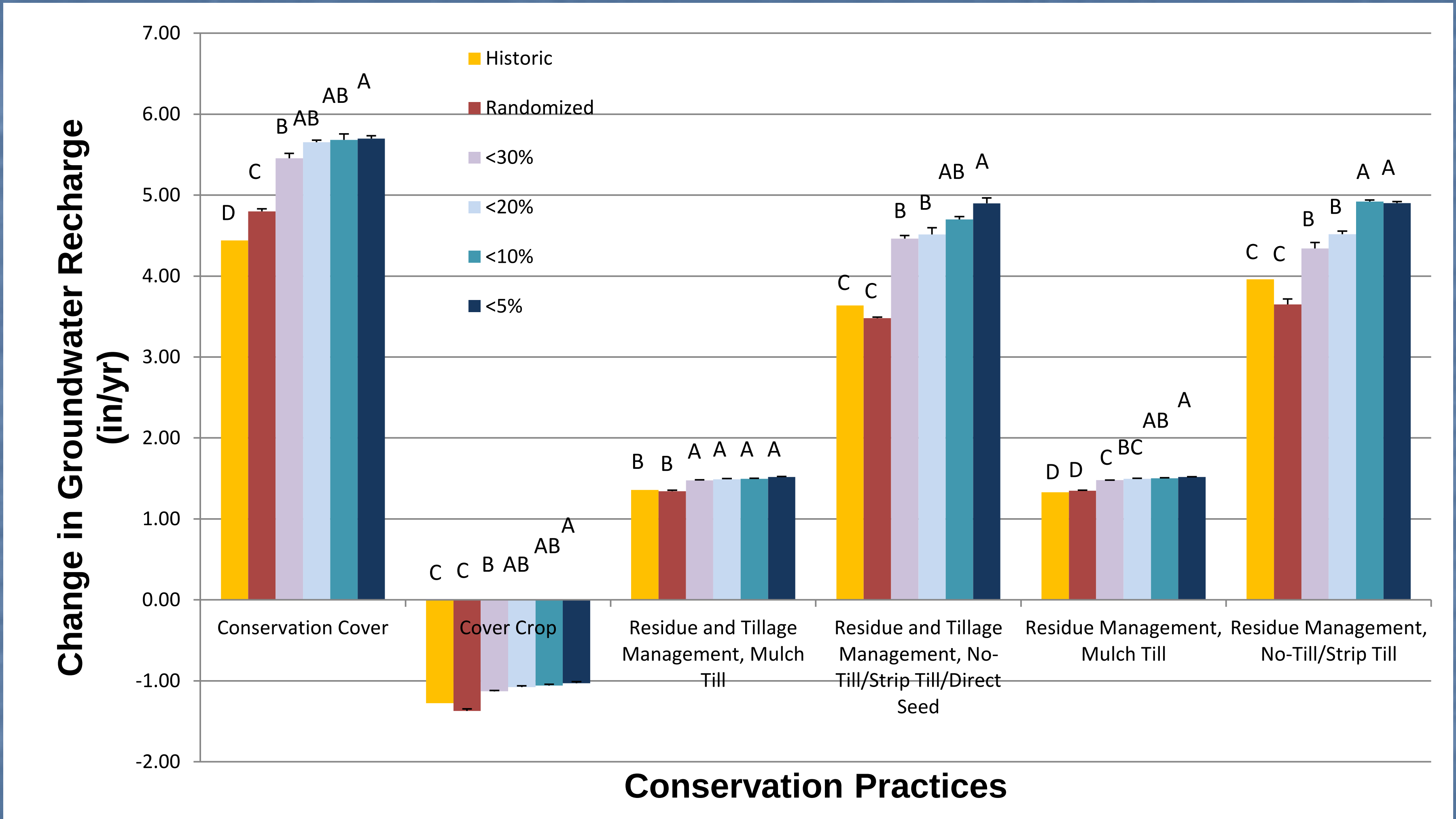


  - Facilitate strategic placement of conservation practices (cost/benefit) to more efficiently meet ecological goals



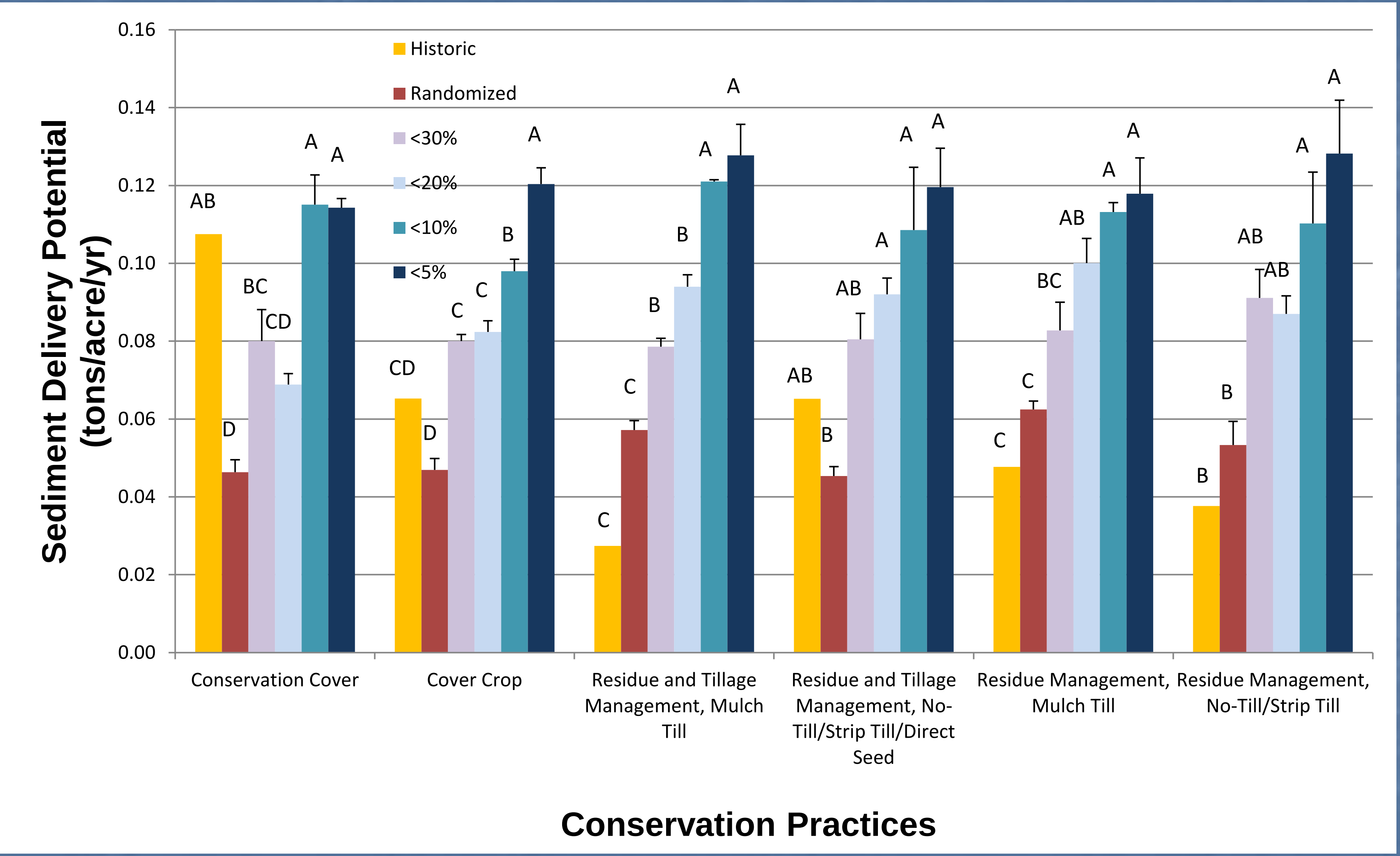
  - Support Transactions
  - Track cumulative placement of conservation practices and progress toward ecological goals
-

Level 3 Efficiencies



- 1 billion more gallons/yr in recharge for top 5%

Level 3 Efficiencies



- ~25-35% increased efficiencies for top 5%

Summary

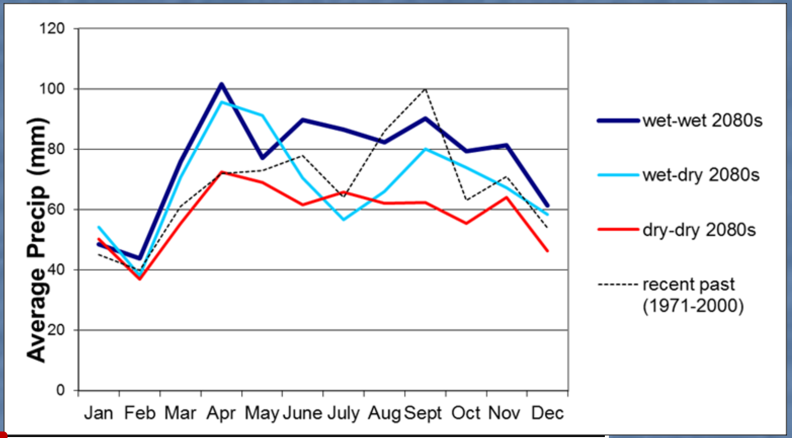
- Fish communities are influenced by WQ and flow
- AG related WQ and flow alterations appear to be limiting fish communities across about 35% of the project area
- What is the limiting factor is highly variable across space
- Can isolate where AG related disturbances associated with WQ and Flow are limiting
- Percent Intolerant fish is a more sensitive metric
- In most instances it appears that we can improve water quality to the point it is no longer limiting riverine fish communities (Does not mean fish community is healthy)
- Possibly a very different story when looking at Lakes

Improving the Approach WLEB CEAP

- Use multiple taxonomic groups as biological endpoints
- Fill other critical data gaps for predictors (more threat non-target threats)
- Further downscaling SWAT model to minimize loss of biological data
- Incorporate spatially distributed calibration into SWAT model calibration process
  - Use discrete water quality data and maybe SPARROW
- Incorporate better current land use and management data into SWAT model
- Incorporate climate change into SWAT model

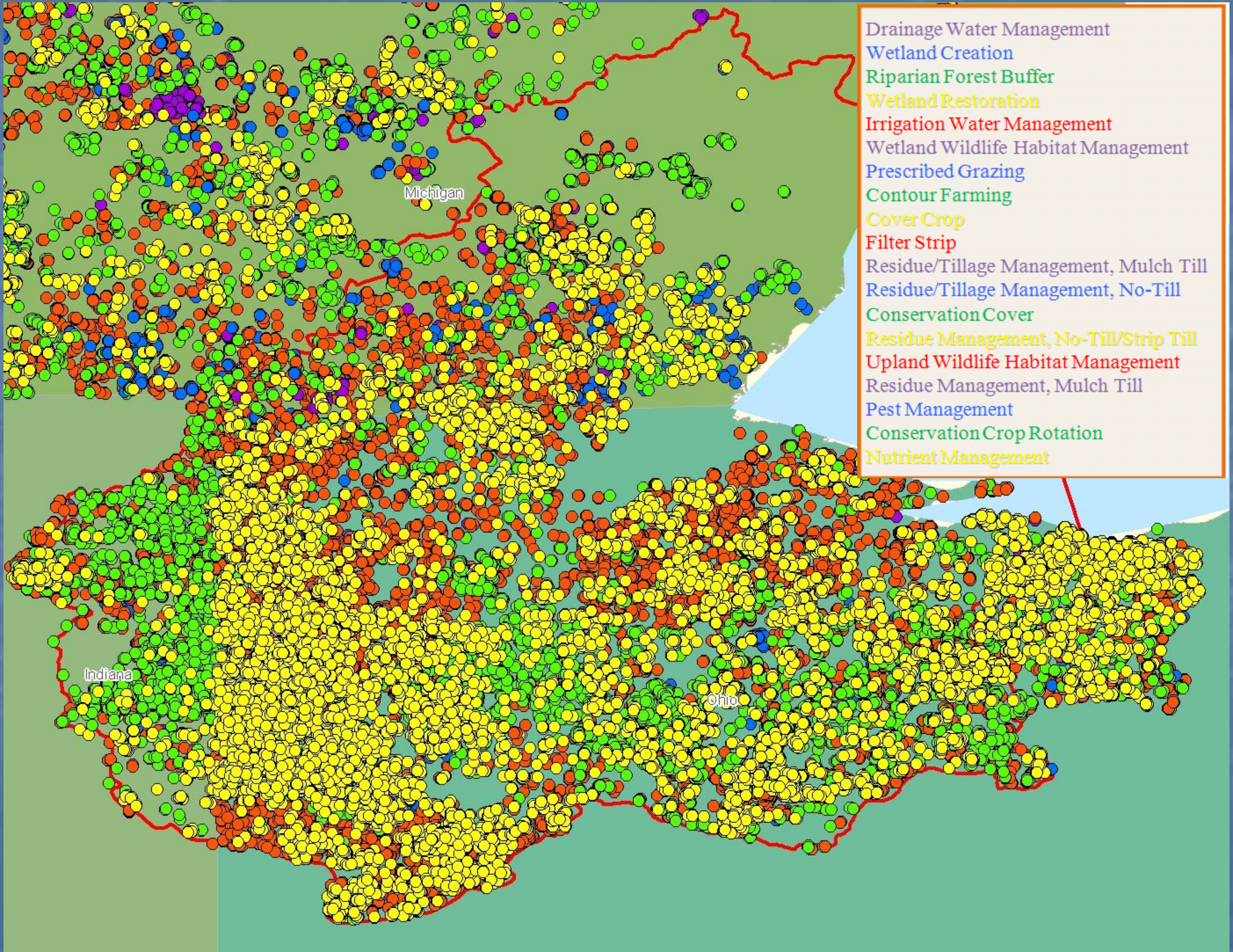
Incorporating Climate Change

- Three Scenarios focused on Precipitation
- Bad for streams, good for embayments?



Watershed	Scenario	ORGP (Load)	ORGP (Conc)	Sed (Load)	Sed (Conc)	NH4 (Load)	NH4 (Conc)
Cass	Dry-Dry No BMP	-44.2%	22.3%	-57.8%	-8.9%	-34.4%	43.5%
	Wet-Dry No BMP	-14.9%	20.6%	-31.2%	-4.5%	-4.4%	35.4%
	Wet-Wet No BMP	1.5%	8.7%	-6.8%	-0.9%	13.1%	21.1%
Shiawassee	Dry-Dry No BMP	-44.7%	13.5%	-55.4%	-10.3%	-34.1%	35.3%
	Wet-Dry No BMP	-15.7%	14.2%	-28.6%	-5.8%	-4.9%	28.9%
	Wet-Wet No BMP	1.7%	3.3%	-2.7%	-2.3%	14.9%	16.7%
Rifle	Dry-Dry No BMP	-21.0%	7.2%	-15.9%	0.5%	3.7%	40.7%
	Wet-Dry No BMP	11.2%	11.7%	27.8%	9.6%	28.8%	29.4%
	Wet-Wet No BMP	14.6%	1.6%	26.6%	8.3%	41.0%	25.0%
Pigeon/ Pinnebog	Dry-Dry No BMP	-35.5%	-1.5%	-42.6%	-6.5%	-21.9%	19.2%
	Wet-Dry No BMP	-9.5%	-2.7%	-3.8%	3.9%	6.7%	14.7%
	Wet-Wet No BMP	5.6%	-11.6%	25.5%	11.8%	21.0%	1.3%

How Much Is Enough?

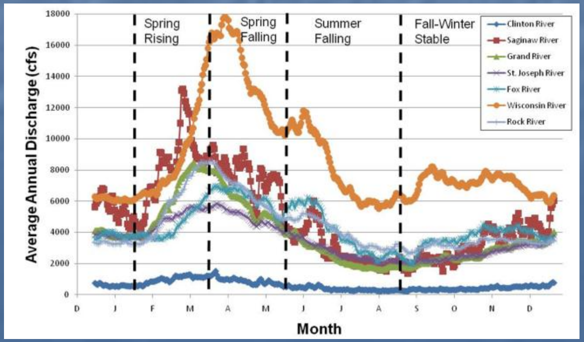


Acknowledgments

- USDA NRCS CEAP for funding
- Coauthors and collaborators
- Jana Stewart (USGS) for GL Aquatic GAP Data
- Dana Infante, Arthur Cooper, Pete Esselman, Gary Whelan and Doug Beard for NFHAP Condition Assessment Data


Time Span and Resolution

- Response variables
  - Collected between 1982 and 2007
  - Most collections made during summer base flow conditions
- Predictor Variables
  - Natural: Enduring features so temporal resolution NA
  - Non-Target Threats: Most are snapshot in time calculated on ~1-5 yr intervals
  - SWAT vars: Calculated on a daily time step using 19 years of data, but we averaged the data into annual and four seasonal periods



Spatial Units and Resolution

- Response variables
  - Stream reach
- Predictor Variables
  - Natural: Enduring features so temporal resolution NA
  - Non-Target Threats: Most are snapshot in time calculated on ~1-5 yr intervals
  - SWAT vars: calculated on a daily time step using 19 years of data, but we averaged the data into annual and four seasonal periods