Developing Synoptic Human Stressor Indicators for Assessing the Ecological Integrity of Freshwater Ecosystems

3nd Regional Oversight Committee Meetings

St. Joseph, MO

January 24th, 2007

Project Funded by US Environmental Protection Agency
Region 7 Wetland Program Development Grant

Project Period
September 2005 thru September 2008

http://www.cerc.usgs.gov/morap/projects.asp?project_id=44

Overview

- Background and project goal
- Review of last meeting
- EPA Region 7 HSI development and progress
- Working meeting and discussions

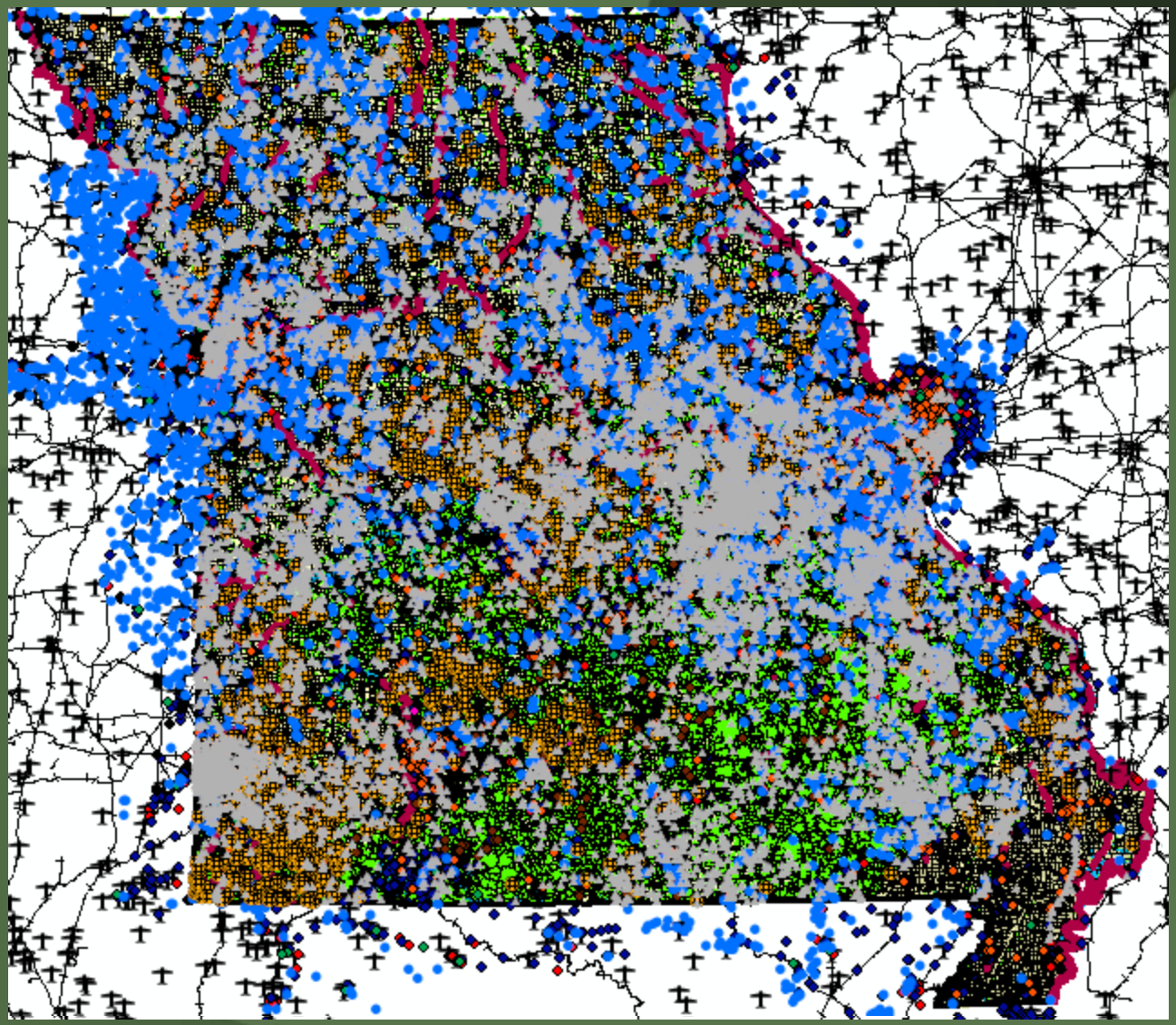
Background/Problem

Review – What we are trying to accomplish

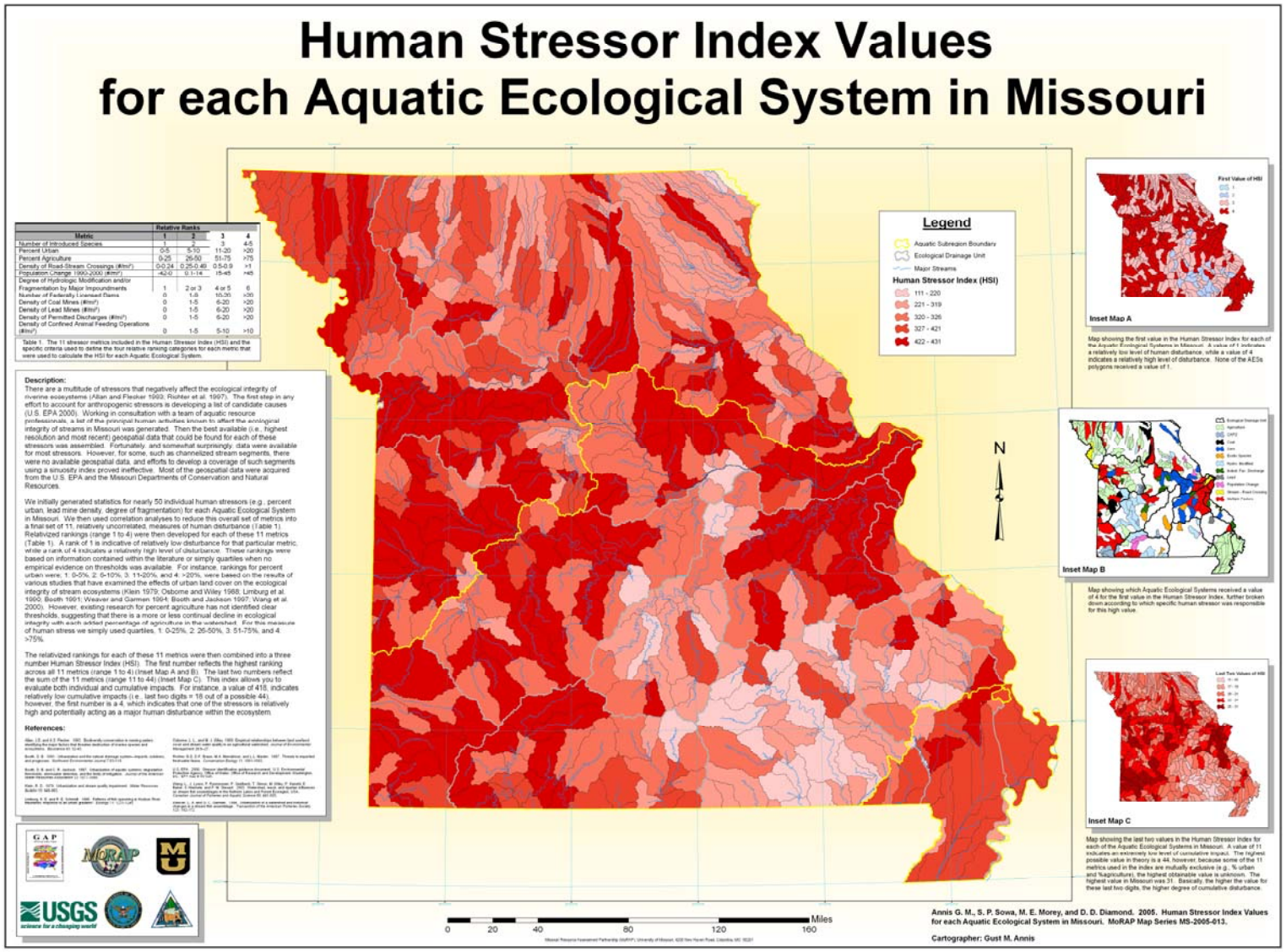
Goal:
Develop reach scale GIS-based Synoptic Human Stressor Indices (HSI) for assessing ecological integrity of freshwater ecosystems

Human Stressors (Missouri Example)

- Land Use
- Municipalities
- Railroads
- 303d Streams
- Airports
- Toxic Release
- Superfund
- Point Sources
- In-stream gravel mines
- Landfills
- Industrial Facility Discharges
- Hazardous Waste Generators
- Drinking Water Supplies
- Dams
- CAFOs
- Mines
- Roads



What do we have now?



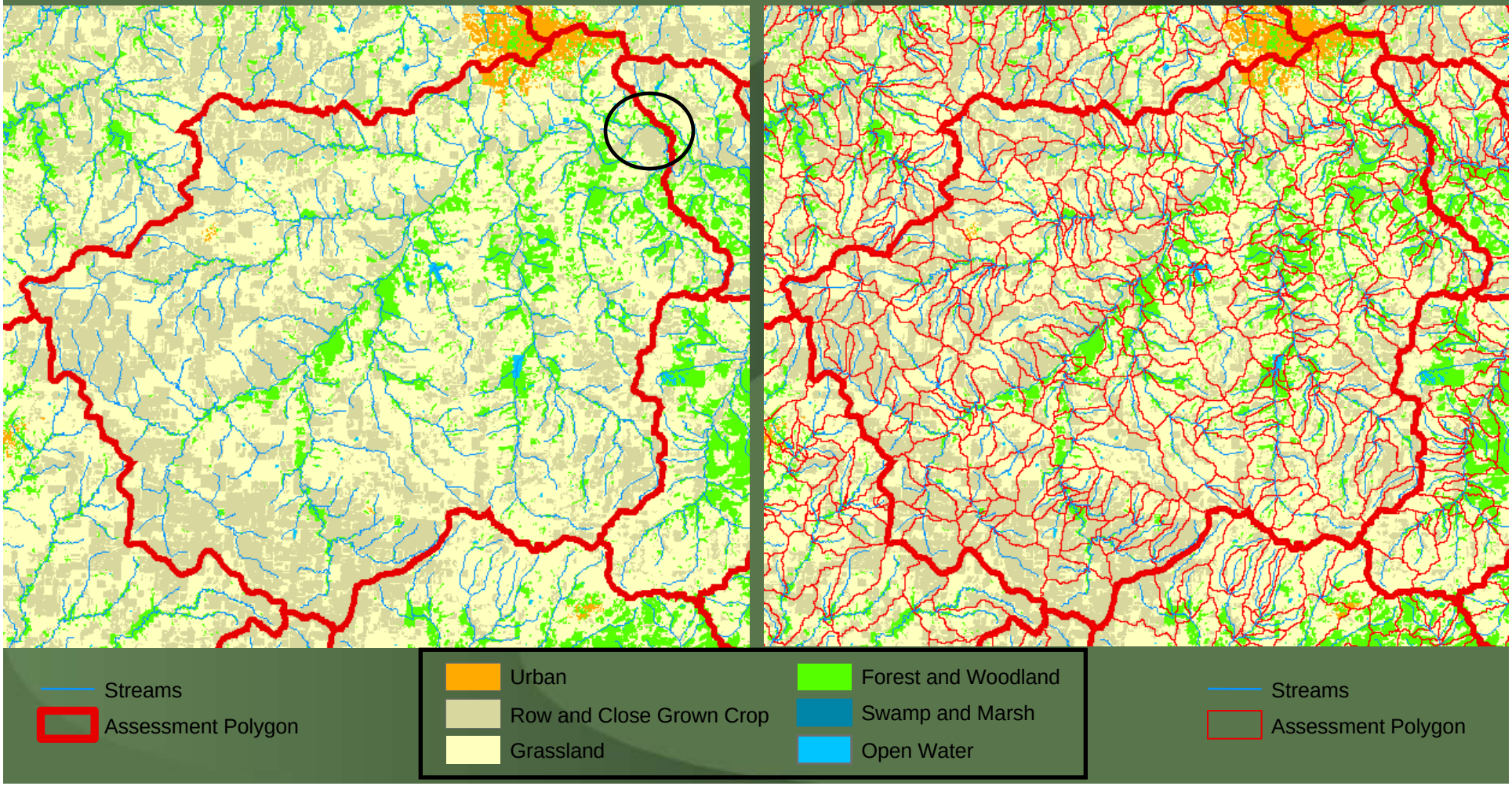
Problems with HSI

- Only accurately quantifies conditions at outlet
- Treats all stressors equally
  - Weighting (ex., 3xUrban vs. 1xAg)
- Does not account for magnitude of individual stressors or temporal and spatial considerations
  - Unsure if this can be accounted for
- Does not account for principal ecological effects
  - Develop separate stressor indices (Physical habitat, water quality, flow regime, energy/nutrient dynamics, biotic interactions)
- Data availability and quality

Problem:
Only Quantifies Conditions at Outlet

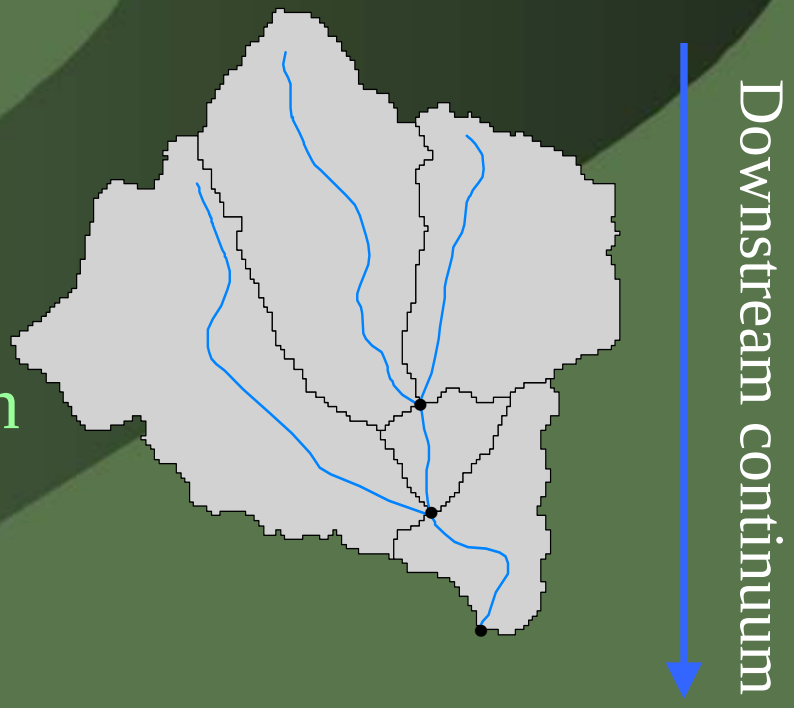
Problem: Only accurately quantifies conditions at outlet

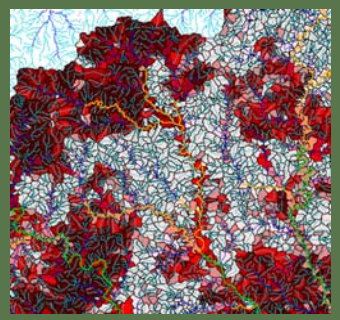
Solution: Utilize higher resolution assessment unit (segment shed)



Stream segments linked to segment sheds

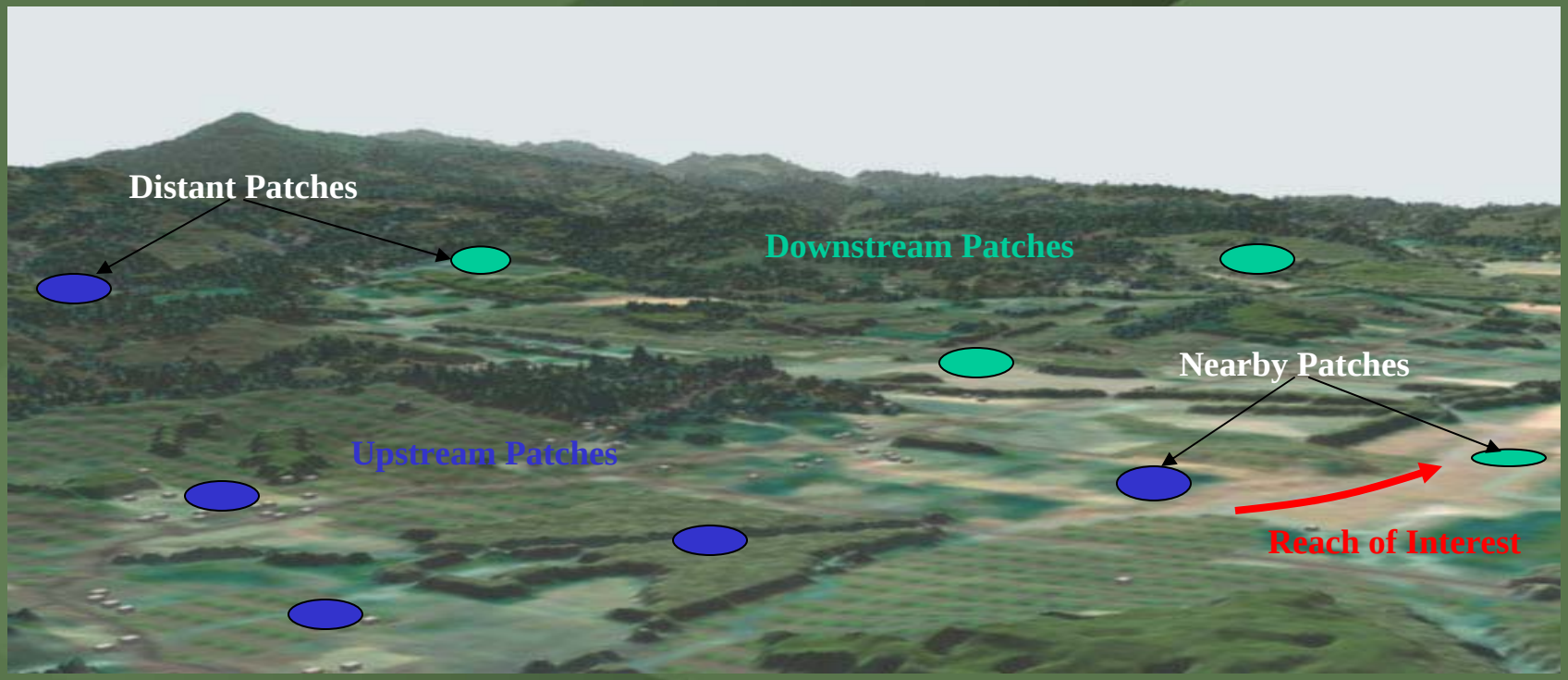
- 1 to 1 relationship
- Almost any properties of the watershed can be linked to the stream network for accumulation downstream
  - Soils, land cover/use, population, point data
  - Can be converted to a proportion of the drainage area or stream miles





Problem:

Failure to Account for Magnitude or Temporal and Spatial Distribution of Individual Stressors



To overcome some of these shortcomings we need to:

Goal: Develop reach scale GIS-based Synoptic Human Stressor Indices (HSI) for assessing ecological integrity of freshwater ecosystems

Objectives

1. Increase coordination
2. Increase knowledge
3. Develop centralized repository
4. Quantify human stressors at reach-scale (1:100K NHD)
5. Develop human stressor indices
6. Calculate HSIs for each stream reach
7. Field validate accuracy of HSIs

Ideal Scenario

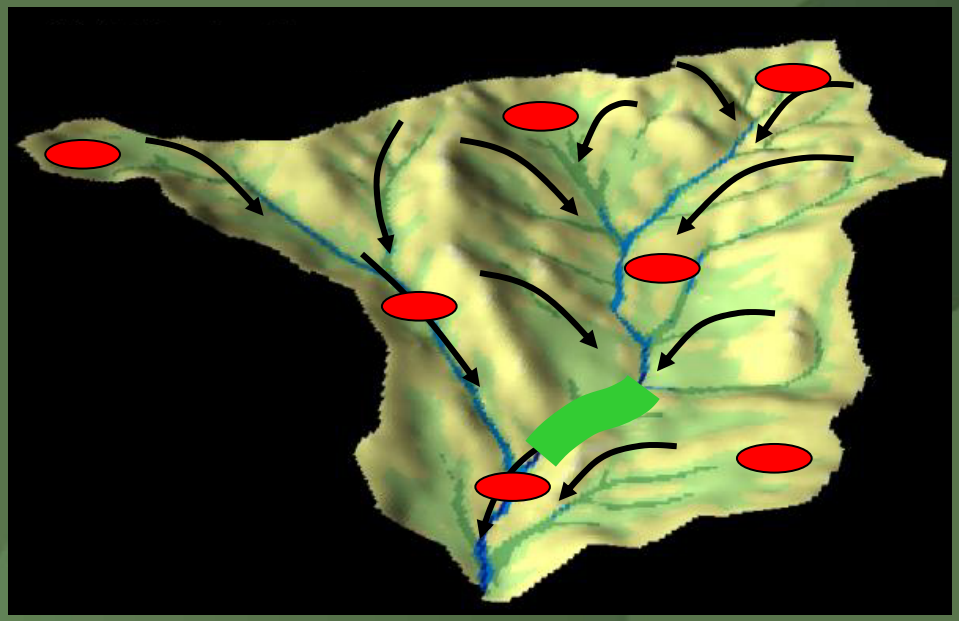
- Account for timing, magnitude, frequency, and location of each human disturbance
  - Timing and frequency
    - Available data lacks this context
  - Magnitude
    - Within a given stressor data often lacks given context
    - Differences among stressors can possibly be accounted for
  - Location
    - Can quantify for different geographic units (overall watershed, RSD, upstream buffer, local buffer, etc.)
    - Distance issues are a more difficult technological challenge
- Quantify mechanistic relations between individual and multiple human disturbances and ecosystem responses (flow, sediment, temperature, etc.)
  - Lack standardized data for response variables
  - Difficult to account for natural variation
  - Must rely on associative relations with surrogate measures (IBI)

Weighting the Stressors

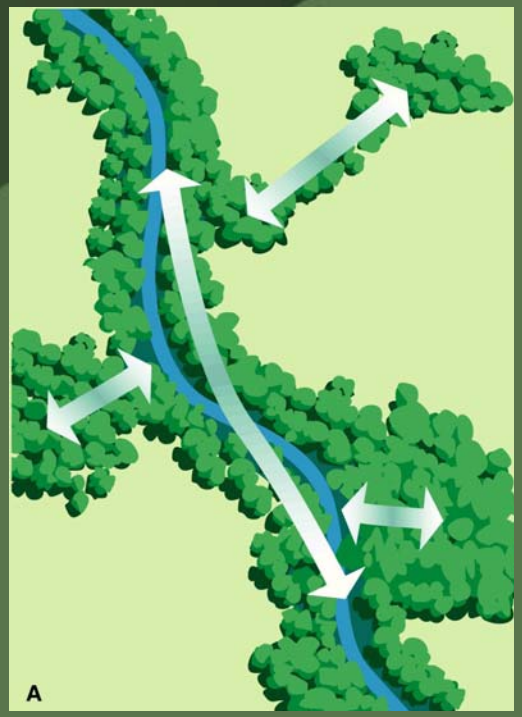
- For example, 3 times urban vs. 1 times agriculture
- A “big” mine has more impact than a “small” mine
- Discharge X is worse than discharge Y

Spatial Considerations

- Distance to stressor
- Is stressor upstream, downstream or local



Ecological Integrity of Riverine Ecosystems is Dependent Upon Integrity of the Entire Watershed



Accounting for Connectivity

Account for Principal Ecological Effects Separately

(Physical habitat, Water quality, Flow regime, Energy/Nutrient dynamics, Biotic interactions)

- For example, stressor X impacts water quality, but has little effect on flow regime
- Stressor Y impacts physical habitat, but has little effect on water quality
- Can we account for these kinds of impacts separately?

Major Tasks

1. Establish regional oversight committee ✓
2. Establish comprehensive list of human stressors and potential data sources ✓
3. Compile geospatial data ~ ✓
4. Identify data gaps and limitations ~ ✓

Major Tasks Continued

5. Quantify stressors for each stream reach ~
6. Conduct literature review on human stressor related research ~
7. Conduct literature review on GIS-based stressor assessment methods ~
8. Develop GIS-based HSIs

Major Tasks Continued

9. Perform QA/QC on accuracy of input data and resulting HSI values

10. Field validate HSI using fish and macroinvertebrate community data

What we need help with:

- ✓ Identifying principal "Threats"
- ✓ Identifying data sources for these threats and any data limitations
- ✓ Determining the principal ecological effects for the various stressors
- Methodology
  - Relative vs. empirical
  - Weighting stressors
  - Accounting for spatial and temporal considerations
- Identifying key literature

Review of Last Meeting

- Data set discussion
  - Lacking data sets
  - Data sets to create or modify
- Web survey discussion
  - Weighting and ranking methods

Review of Last Meeting

Data Suggestions

Key Points

- Many suggestions were received on how to fill in data gaps
- Many data sets overlap – be sure not to double count
- Channelized streams are important
  - Try to create from a variety of sources: NHD, NWI, straightness index
- Should try to modify some of the agricultural use (and land use) by slope and/or soils
- CAFOs vs. other animal impacts; can we get at more than CAFOs?

Review of Last Meeting

Web Survey Discussion

	A	B	C	D	E
1	Threats	Physical Habitat			Key
2		Mean	Mode		0 = No Impact
3	Channelization	3.0	3		1 = Low Impact
4	Instream Sand And Gravel Mines	2.9	3		2 = Moderate Impact
5	Major Reservoirs	2.8	3		3 = High Impact
6	Navigation (Channel and Bank Maintenance)				
7	Row Crop Agriculture				
8	Impervious Surface				
9	Headwater Impoundments (Impoundments on Second-Order and Smaller Streams)				
10	Introduced Plants				
11	Water Withdrawals				
12	Roads (Paved And Gravel)				
13	Flow Diversions (No Return Flow)				
14	Dispersal Barriers / Low Head Dams				
15	Artificial Drainage (Agricultural Field Drainage)				
16	Military Sites (With Regard to Land Disturbance)				
17	Flow Diversions (With Return Flow)				
18	Road-Stream Crossing (Culverts And Low-Water)				
19	Upland Mining				
20	Ranging Livestock				
21	Storm Water Systems				
22	Bridges				
23	CAFO				
24	Golf Course				
25	Point Source Discharges (NPDES: Municipal, Agricultural, And Industrial)				

	A	B	C	D	E
1	Threats	Water Quality			Key
2		Mean	Mode		0 = No Impact
3	Waste Water Treatment Facility	2.8	3		1 = Low Impact
4	Point Source Discharges (NPDES: Municipal, Agricultural, And Industrial)				2 = Moderate Impact
5	CAFO				
6	Row Crop Agriculture				
7	Toxic Releases				
8	Storm Water Systems				
9	Artificial Drainage (Agricultural Field Drainage)				
10	Road Salt Applications				
11	Major Reservoirs				
12	Upland Mining				
13	Impervious Surface				
14	Golf Course				
15	Military Sites (With Regard to Chemical Contamination)				
16	Flow Diversions (With Return Flow)				
17	Rail Yards (Fuel And Coal Dust)				
18	Headwater Impoundments (Impoundments on Second-Order and Smaller Streams)				
19	Septic Tanks / Lagoons				
20	Instream Sand And Gravel Mines				
21	Roads (Paved And Gravel)				
22	Oil And Gas Wells				
23	Salt Scars (From Old Abandoned Oil And Gas Wells)				
24	Airports (National and International)				
25	Landfills				

	A	B	C	D	E
1	Threats	Flow Regime			Key
2		Mean	Mode		0 = No Impact
3	Major Reservoirs	2.8	3		1 = Low Impact
4	Flow Diversions (No Return Flow)				
5	Impervious Surface				
6	Channelization				
7	Storm Water Systems				
8	Water Withdrawals				
9	Headwater Impoundments (Impoundments on Second-Order and Smaller Streams)				
10	Artificial Drainage (Agricultural Field Drainage)				
11	Navigation (Channel and Bank Maintenance)				
12	Flow Diversions (With Return Flow)				
13	Row Crop Agriculture				
14	Roads (Paved And Gravel)				
15	Waste Water Treatment Facility				
16	Dispersal Barriers / Low Head Dams				
17	Point Source Discharges (NPDES: Municipal, Agricultural, And Industrial)				
18	Instream Sand And Gravel Mines				
19	Airports (National and International)				
20	Road-Stream Crossing (Culverts And Low-Water)				
21	Upland Mining				
22	Military Sites (With Regard to Land Disturbance)				
23	Bridges				
24	Golf Course				

	A	B	C	D	E
1	Threats	Energy / Nutrient			Key
2		Mean	Mode		0 = No Impact
3	CAFO	2.6	3		1 = Low Impact
4	Waste Water Treatment Facility				
5	Point Source Discharges (NPDES: Municipal, Agricultural, And Industrial)				
6	Row Crop Agriculture				
7	Major Reservoirs				
8	Artificial Drainage (Agricultural Field Drainage)				
9	Storm Water Systems				
10	Headwater Impoundments (Impoundments on Second-Order and Smaller Streams)				
11	Septic Tanks / Lagoons				
12	Golf Course				
13	Introduced Plants				
14	Channelization				
15	Flow Diversions (With Return Flow)				
16	Impervious Surface				
17	Ranging Livestock				
18	Introduced Aquatic Animals				
19	Navigation (Channel and Bank Maintenance)				
20	Pasture And Range Land				
21	Flow Diversions (No Return Flow)				
22	Upland Mining				
23	Dispersal Barriers / Low Head Dams				
24	Roads (Paved And Gravel)				
25	Water Withdrawals				
26	Instream Sand And Gravel Mines				
27	Landfills				

	A	B	C	D	E
1	Threats	Biotic Interactions			Key
2		Mean	Mode		0 = No Impact
3	Introduced Aquatic Animals	2.9	3		1 = Low Impact
4	Major Reservoirs	2.8	3		2 = Moderate Impact
5	Introduced Plants	2.6	3		3 = High Impact
6	Headwater Impoundments (Impoundments on Second-Order and Smaller Streams)	2.4	3		
7	Channelization	2.3	3		
8	Dispersal Barriers / Low Head Dams	2.3	3		
9	Waste Water Treatment Facility	2.2	2,3		
10	Point Source Discharges (NPDES: Municipal, Agricultural, And Industrial)	2.1	3		
11	Row Crop Agriculture	2.0	1,3		
12	Instream Sand And Gravel Mines	2.0	2,3		
13	CAFO	1.9	1		
14	Navigation (Channel and Bank Maintenance)	1.8	1		
15	Toxic Releases	1.8	3		
16	Water Withdrawals	1.8	2		
17	Artificial Drainage (Agricultural Field Drainage)	1.8	1		
18	Road-Stream Crossing (Culverts And Low-Water)	1.8	2		
19	Impervious Surface	1.7	2		
20	Roads (Paved And Gravel)	1.7	2		
21	Flow Diversions (With Return Flow)	1.7	1,2		
22	Storm Water Systems	1.6	2		
23	Flow Diversions (No Return Flow)	1.6	2		
24	Golf Course	1.5	1		
25	Upland Mining	1.4			
26	Ranging Livestock	1.4	1		

Principal Ecological Effects

Point source pollution					
Level of Influence	Physical Habitat	Water Quality	Flow Regime	Energy/Nutrient	Biotic Interactions
Low	X		X		
Medium					
High		X		X	X

Web Survey Discussion

Key Points

- Results will reflect participants areas of expertise
- Should look at standard error in responses
- Will likely create individual HSI's for each principal ecological effect and create a combined HSI
- By weighting stressors we may lose information about those weighted least
- Possibly use just top 5 rated stressors
- Any ranking method may be fine; the raw data are most important
- Three potential weighting methods: Use mode; Use actual rankings; Use "top 5" and multiply by some factor

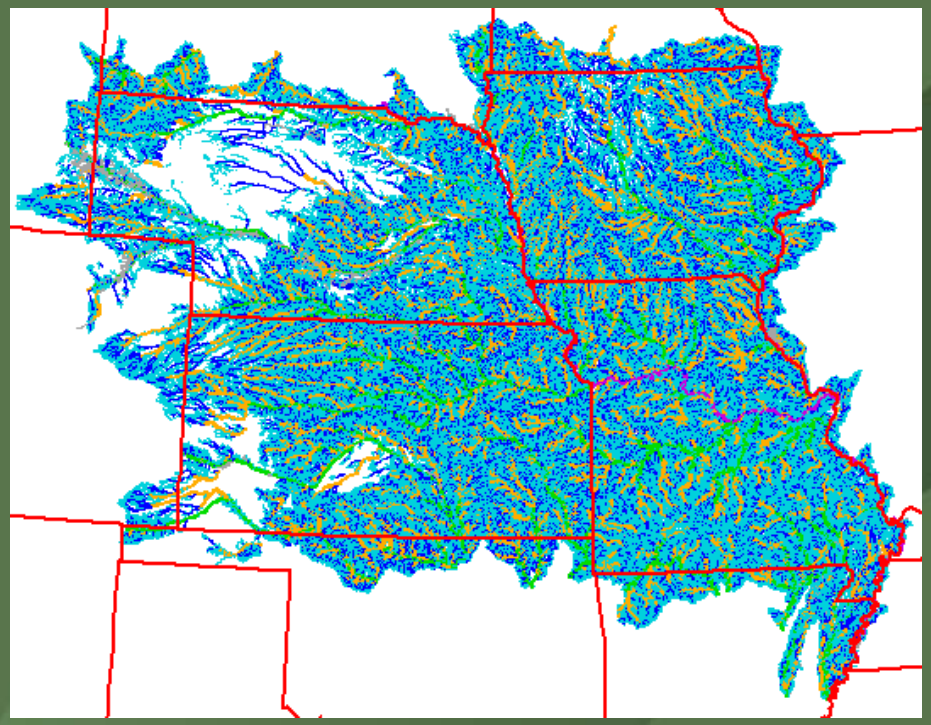
Progress to Date

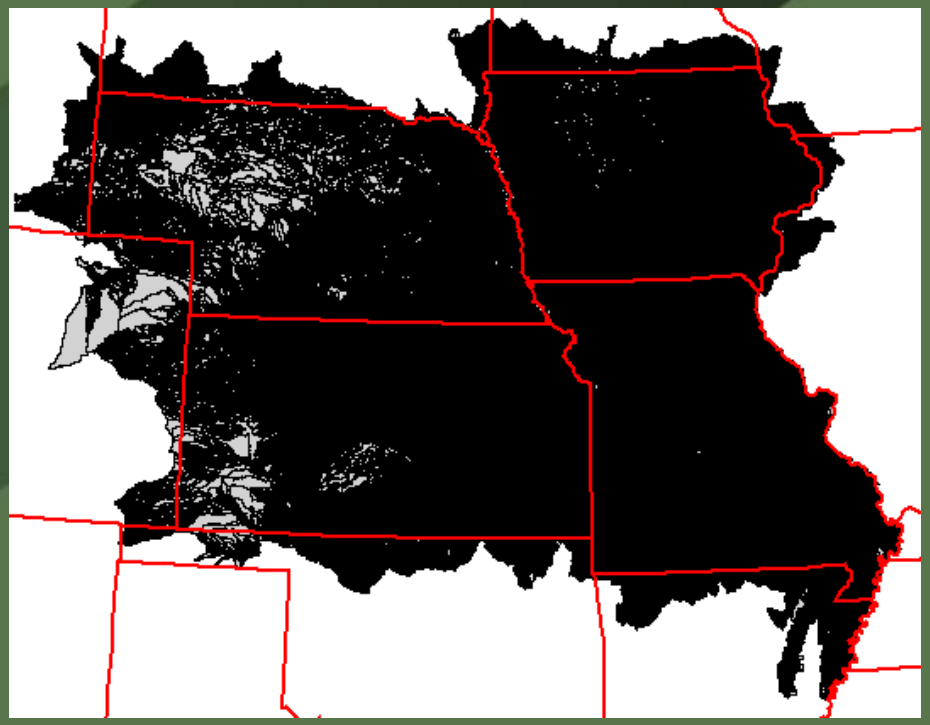
- Cleaned and prepared our stream networks
- Generated the segment shed polygons
- Gathered data (stressors)
- Developed our own tool for distance weighting

Progress to Date (cont.)

- Started processing and quantifying data sets
- Literature review under way

Base Data Layers Created





385,000 primary channel stream segments
and corresponding segment shed polygons

Gathering Stressor Data

- Acquiring, assembling, editing, patching, and modifying
- Many data issues exist
  - Often inconsistent from state to state
  - Metadata often absent or incomplete

Ever-present Challenges: Consistent Data and Metadata

- State to state data variability
- Data without a spatial component
- Little or no Metadata
  - Data set dates
  - Source information
  - Field and attribute definitions
  - Data set contact information
- We need a regional effort to overcome some of these challenges!

Example Data Issue and Solution

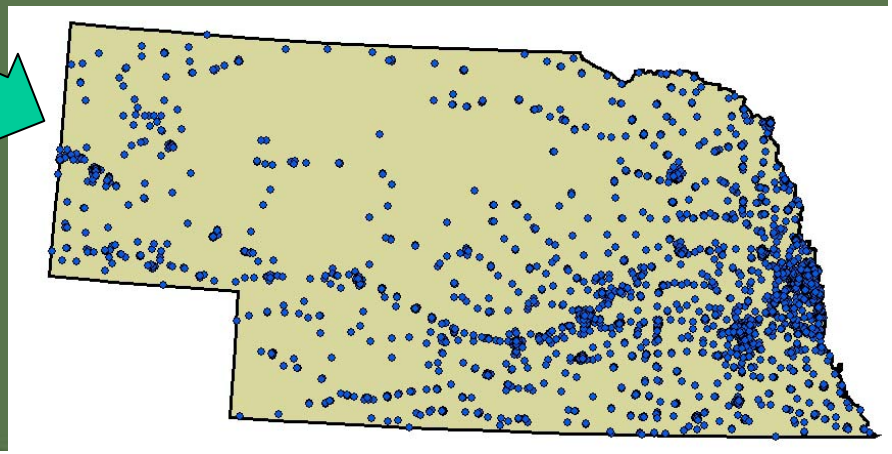
Geocoding

- Nebraska did not have a GIS layer of Leaking Underground Storage Tanks (LUST)
- The only spatial information available was a street address
- Geocoding from text file with street address to create points

SPILLFAC.CSV

	C	D	E	F	G	H	I	J	K	L
1	OWNCO----------	OWNSTRE	OWNCITY	OS	OZIP	TY	DIDATE----	SPLOC----------	SPCITY----------	MATERIAL----
2	TESTING THIS	02 PGM	LINCOLN	NE	68123			AT PLANT SITE	SEWARD	BARSOL D-2(
3	TESTING	123 TEST	OMAHA	NE	68132			123 TEST ST	OMAHA	
4	TESTING AGAIN	123 TEST	OMAHA	NE	68054			123 TEST ST	OMAHA	
5	TESTING		BELLEVU	NE	68123			124 TEST ST	BELLEVUE	
6	MADONNA	2200 S 52	LINCOLN	NE	68506	14	10/12/1989	2200 S 52ND ST	LINCOLN	HEATING OIL
7	FARMERS MUTUAL INSURANCE	1220 LINC	LINCOLN	NE	68508	14	3/24/1993	1220 LINCOLN MALL	LINCOLN	HEATING OIL
8	BELLEVUE SCHOOL DIST #2	2009 FRA	BELLEVU	NE	68005	14	8/26/1991	2107 E AVERY RD	BELLEVUE	HEATING OIL
9	BELLEVUE PUBLIC SCHOOLS	2009 FRA	BELLEVU	NE	68005	14	7/24/1990	2202 WASHINGTON ST	BELLEVUE	HEATING OIL
10	GRAND ISLAND PUB. SCHOOLS	615 N ELN	GRAND IS	NE	68801	14	8/7/1992	602 W STOLLEY PARK RD	GRAND ISLAND	DIESEL/HEA
11	OMAHA PUBLIC SCHOOLS	4041 N 72	OMAHA	NE	68134	14	11/27/1989	3520 MAPLEWOOD BLVD	OMAHA	#2 FUEL OIL
12	OMAHA PUBLIC SCHOOLS	3902 DAV	OMAHA	NE	68131	14	7/21/1989	2758 ELLISON AVE	OMAHA	DIESEL
13	OMAHA PUBLIC SCHOOL	4041 N 72	OMAHA	NE	68134	14	6/27/1990	3109 PEDERSON DR	OMAHA	
14	HAGERBAUMER BROTHERS INC	RR 1 BOX	ARLINGTC	NE	68025	14	10/4/1990	RR 1 BOX 152	ARLINGTON	GAS
15	LINCOLN PUBLIC SCHOOLS	5901 'O' S	LINCOLN	NE	68510	14	9/23/1992	7700 LEIGHTON AVE	LINCOLN	HEATING OIL
16	NORFOLK PUBLIC SCHOOLS	512 PHILI	NORFOLK	NE	68701	14	7/28/1989	1703 PHILIP AVE	NORFOLK	HEATING OIL
17	HOOVER GROUP INC	700-710 S	BEATRICE	NE	68310	14	5/18/1989	700-710 S 7TH ST	BEATRICE	HEATING OIL
18	IBP, INC.	BOX 515	DAKOTA (	NE	68731	7	12/14/1987	HWY 275	WEST POINT	FUEL OIL
19	SCHUYLER CENTRAL HIGH SCH	401 ADAM	SCHUYLE	NE		14	12/13/1988	401 ADAMS STT	SCHUYLER	#2 FUEL OIL
20	CEDAR HOLLOW DIST 3	RR 2 BOX	GRAND IS	NE	68803	14	5/30/1991	RR 2 BOX 73A	GRAND ISLAND	HEATING OIL
21	ST PAULS LUTHERN CHURCH	1515 S HA	GRAND IS	NE	68801	14	12/12/1988	1515 S HARRISON	GRAND ISLAND	DIESEL
22	MUNICIPAL LIGHT AND WATER	4TH AND I	NORTH PL	NE	69101	7	3/30/1993	4TH AND PACIFIC NW CRNR	NORTH PLATTE	DIESEL
23	COLUMBUS CITY SCHOOLS	2200 26TH	COLUMBU	NE	68601	14		1610 9TH ST	COLUMBUS	HEATING OIL
24	COLUMBUS CITY SCHOOLS	2200 26TH	COLUMBU	NE	68601	14		2316 9TH ST	COLUMBUS	HEATIN OIL
25	COLUMBUS CITY SCHOOLS	2200 26TH	COLUMBU	NE	68601	14	12/5/1989	4100 ADAMY ST	COLUMBUS	OIL
26	NE MILITARY DEPARTMENT	1300 MILIT	LINCOLN	NE	68508	14	6/14/1989	6929 MERCY RD	OMAHA	
27	CITY OF LOUP CITY	134 S 8TH	LOUP CIT	NE	68853	14	4/10/1991	626 N" ST"	LOUP CITY	
28	CHERRY CO COURTHOUSE	365 N MAI	VALENTIN	NE	69201	14	8/8/1990	365 N MAIN ST	VALENTINE	

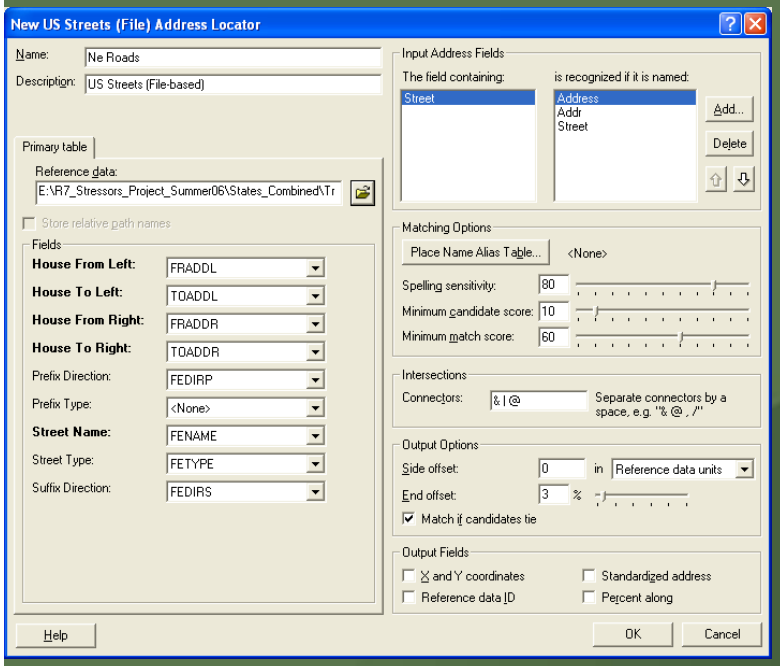
SPILLFAC

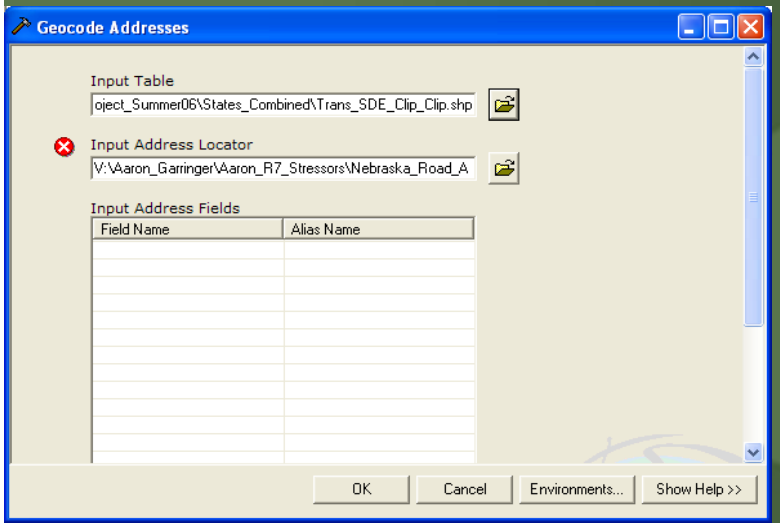


Resulting GIS layer contains all attribute data attached to points

Example Data Issue and Solution

Geocoding

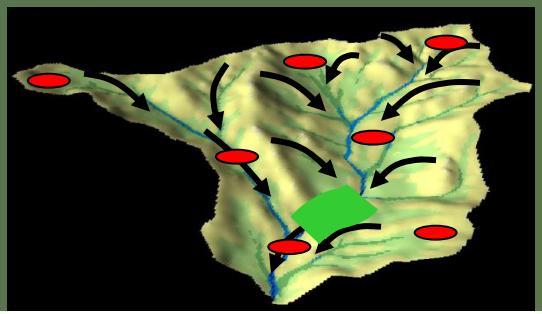




- Inputs:
  - Roads with address information
  - LUST sites with address
- TIGER files were used to create an address locator
- Settings were adjusted to account for spelling sensitivity between the two files
- Computer placed points along roads according to address location

Distance Weighting

- Spent time finding a feasible “tool”
- Explored several promising methods but . . .
  - Functional Linkage of Water basins and Streams (FLoWS) v1 tool did not work for us
  - Wrote an AML program, but won’t process an extremely large file
  - Various user-written GIS tools all had shortcomings
- VBA in Microsoft Access



Distance Weighting

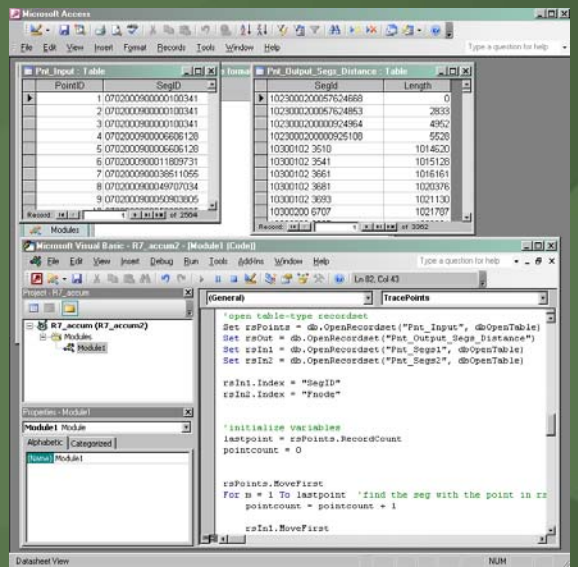
- Wanted average distance to all upstream stressors (i.e. mines)
- Additionally, wanted the minimum and maximum distances
- Must run on a very large file

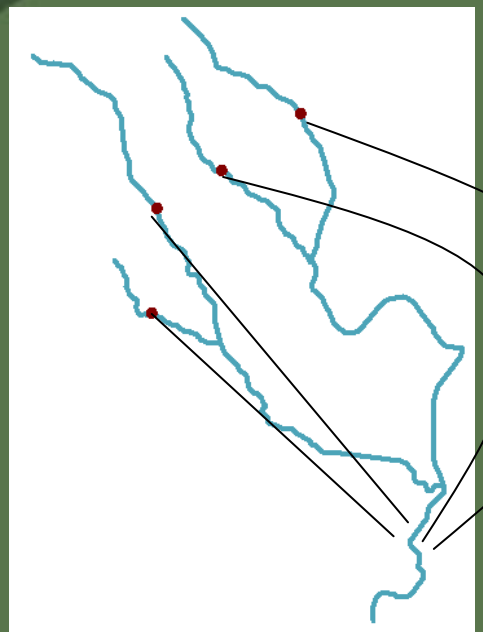
Solution

- Mike Morey used Visual Basic for Applications (VBA) for MS Access to write a sub-procedure that will calculate the distance from each stream segment to every “stressor” upstream

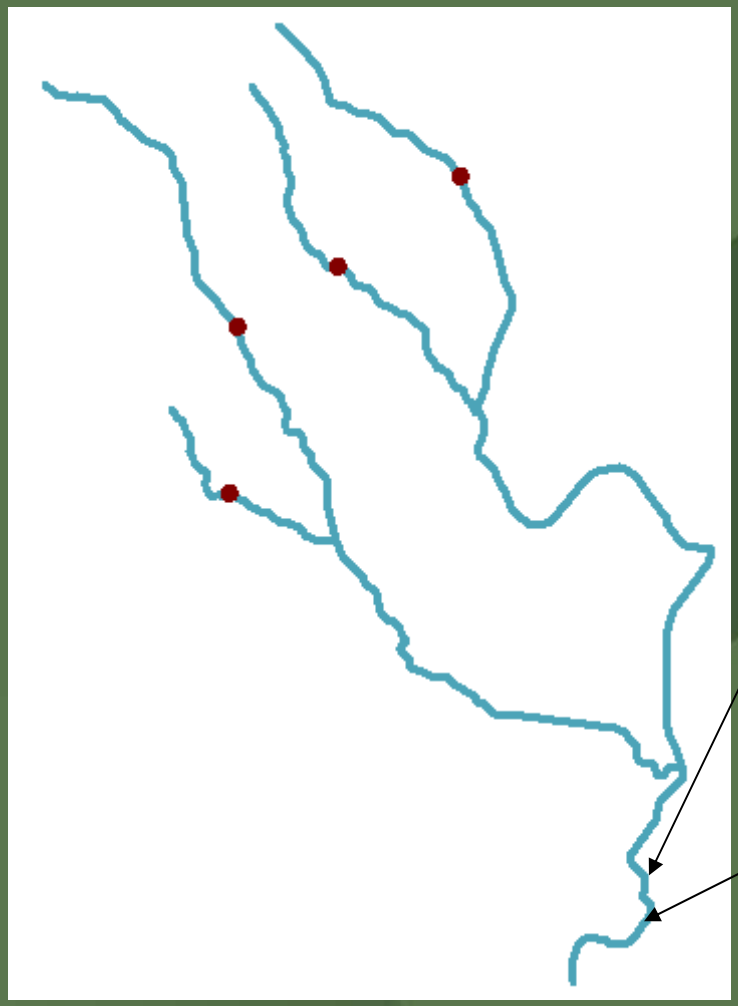
Distance Weighting (VBA)

- Required a dbf with:
  - Steam segment identifier
  - A tag if a segment contained a “stressor” locally
  - Length of stream segment
  - From node #
  - To node #





Distance Weighting (VBA)



SegId	Length
1023000200000825408	4074
1023000200000825408	5531
1023000200000825408	5885
1023000200000825408	6252
1023000200000924964	4585
1023000200000924964	4952
1023000200000925108	5161
1023000200000925108	5528
1023000200053024825	0
1023000200053224670	0
1023000200057624668	0
1023000200057624853	2466
1023000200057624853	2833
1023000200057724824	0
1023000200057725052	1376
1023000200057725052	2833
1023000200057725118	3526
1023000200057725118	4983

SegId	Ave_Length
1023000200000825408	5436
1023000200000924964	4768
1023000200000925108	5344
1023000200053024825	0
1023000200053224670	0
1023000200057624668	0
1023000200057624853	2650
1023000200057724824	0
1023000200057725052	2104
1023000200057725118	4254

Distance and Average Distance Upstream to each Stressor

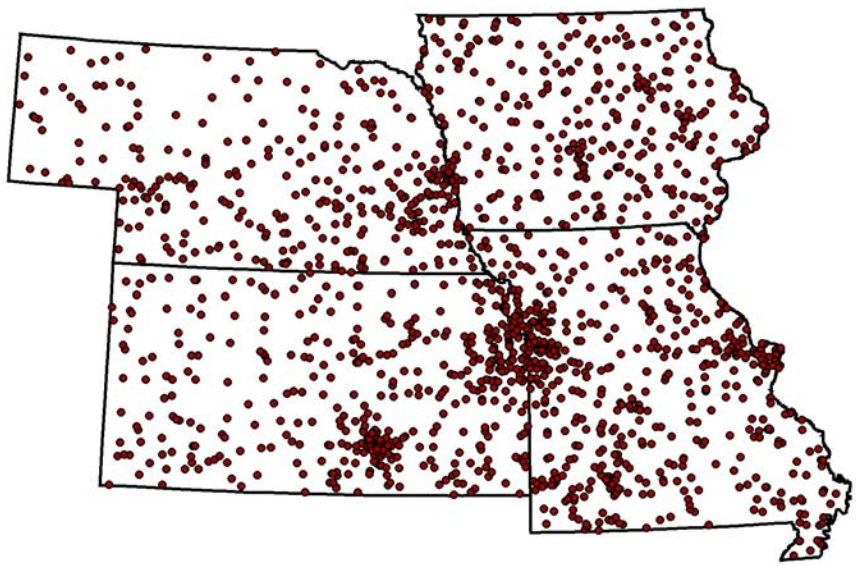
Distance Weighting (VBA)

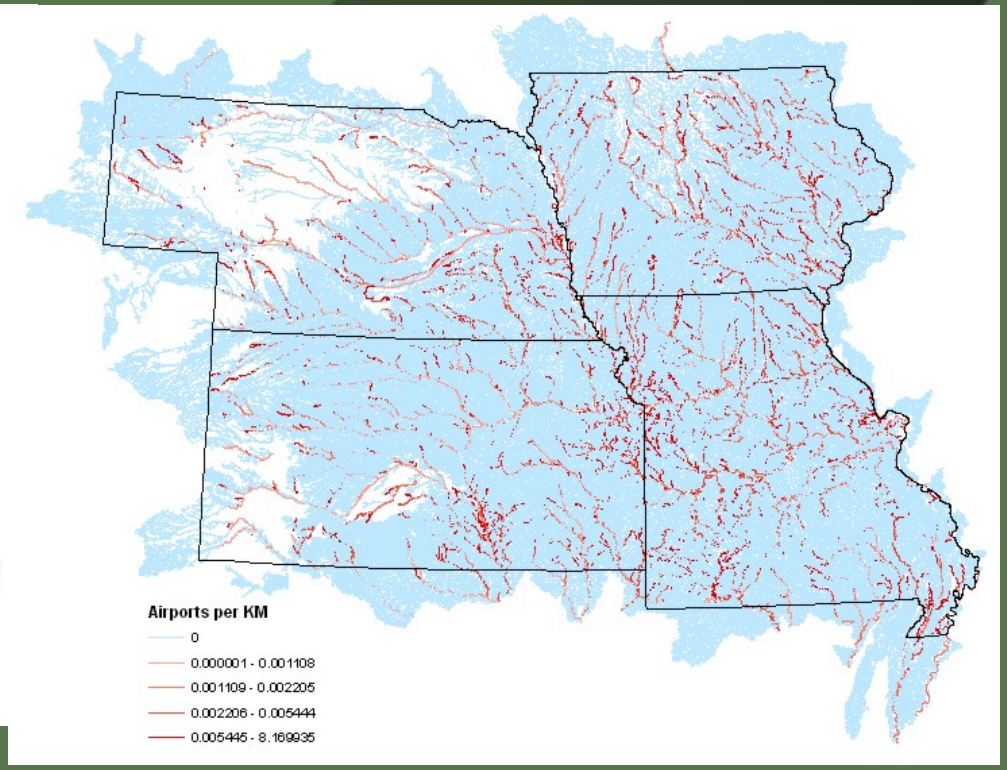
- This method works well for localized or point type stressors
- Probably does not make sense for all stressors (i.e. road-stream crossings)
- Does not work for continuous surface type stressors like land use
  - Can this be done?

Processing and Quantifying Stressors

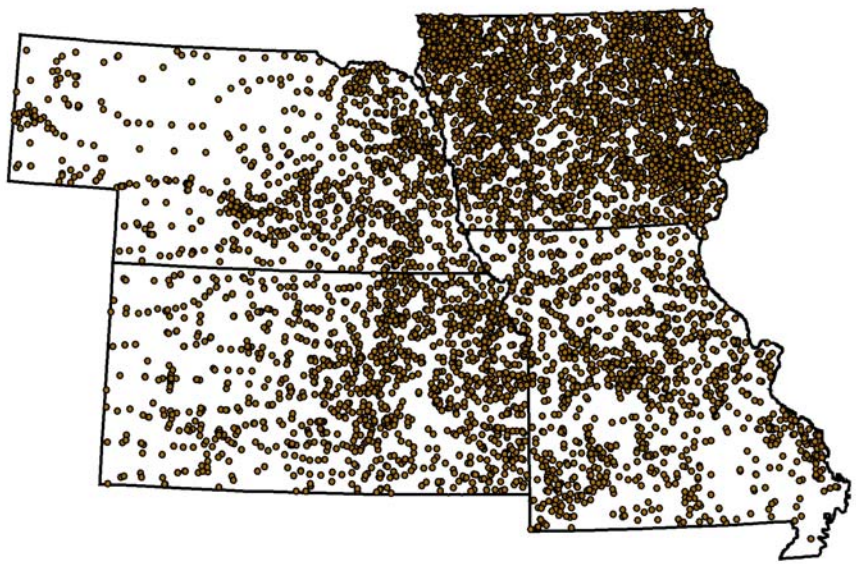
- We have run ~13 stressor data sets
  - Local
  - Watershed above <u>every</u> stream segment
- 4 data sets have been run through the distance weighting process
- Some examples . . .

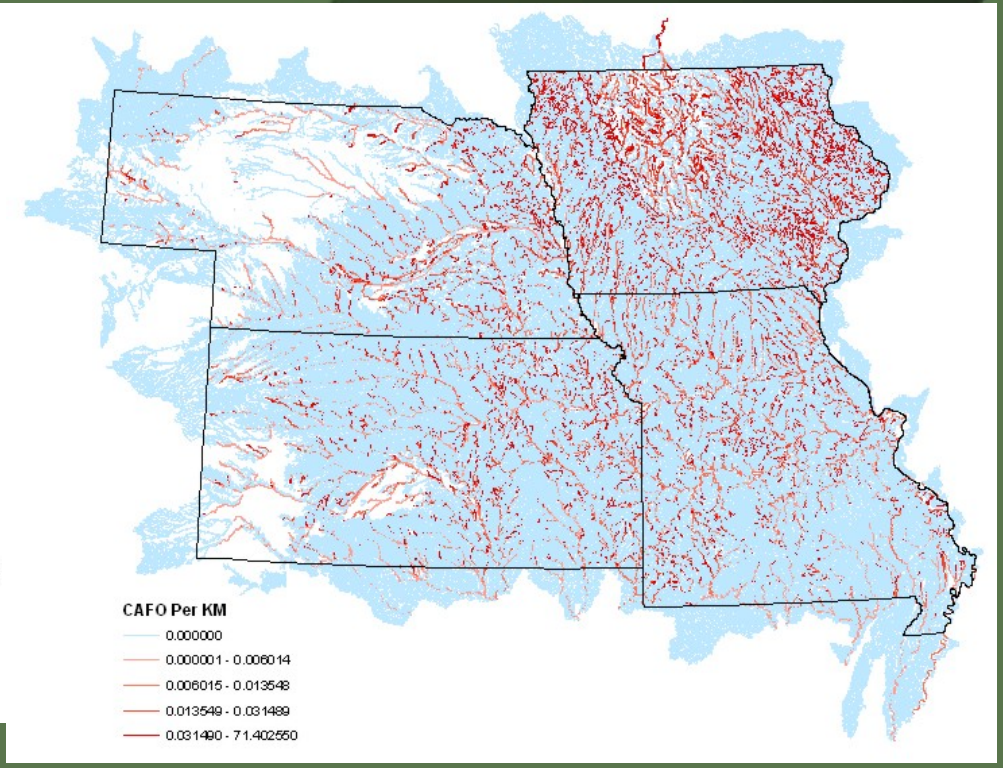
Airports



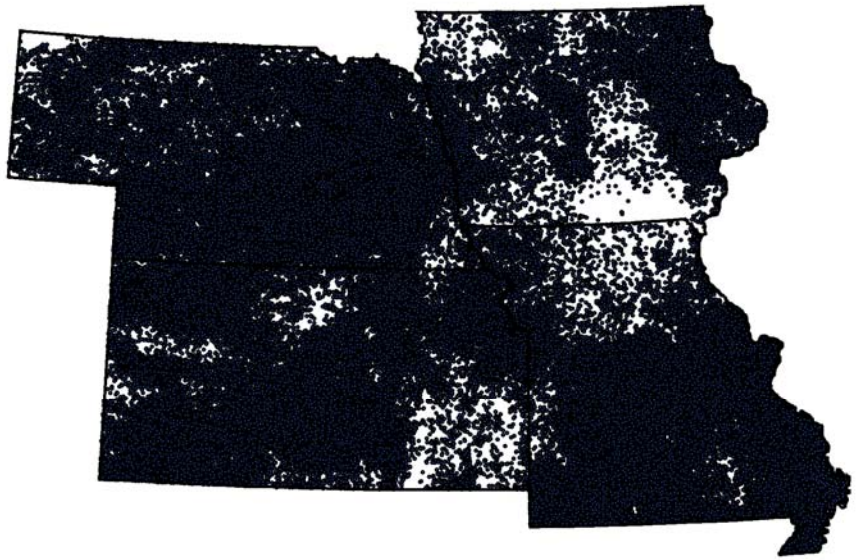

Airports per KM
0
0.000001 - 0.001108
0.001109 - 0.002205
0.002206 - 0.005444
0.005445 - 8.169935

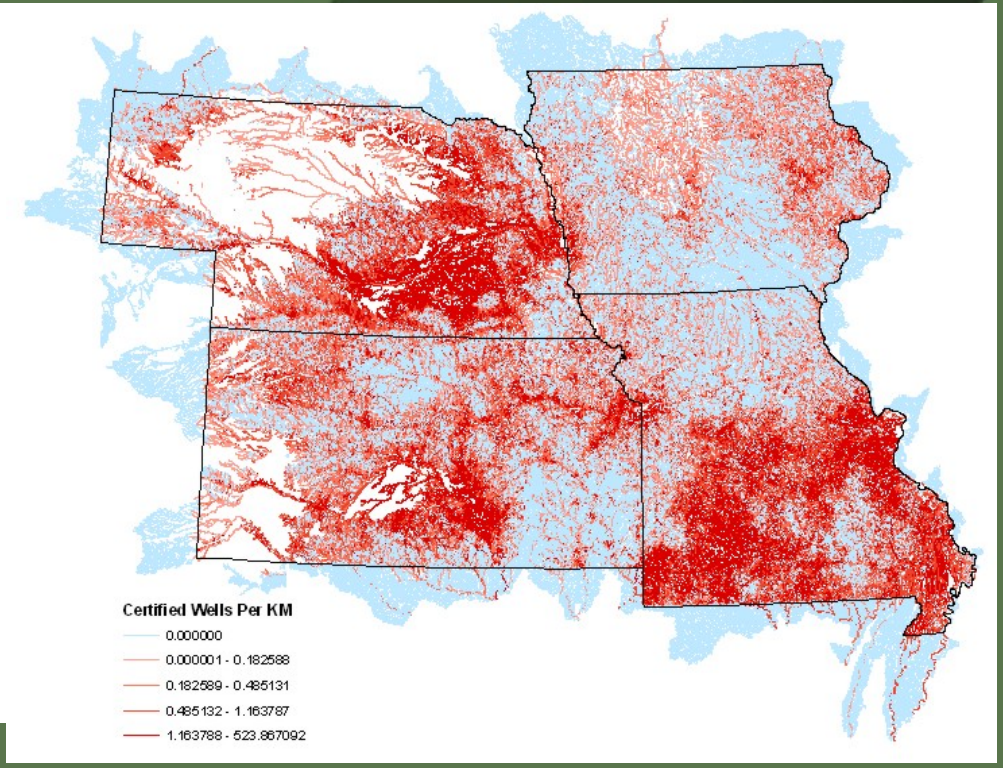
CAFO



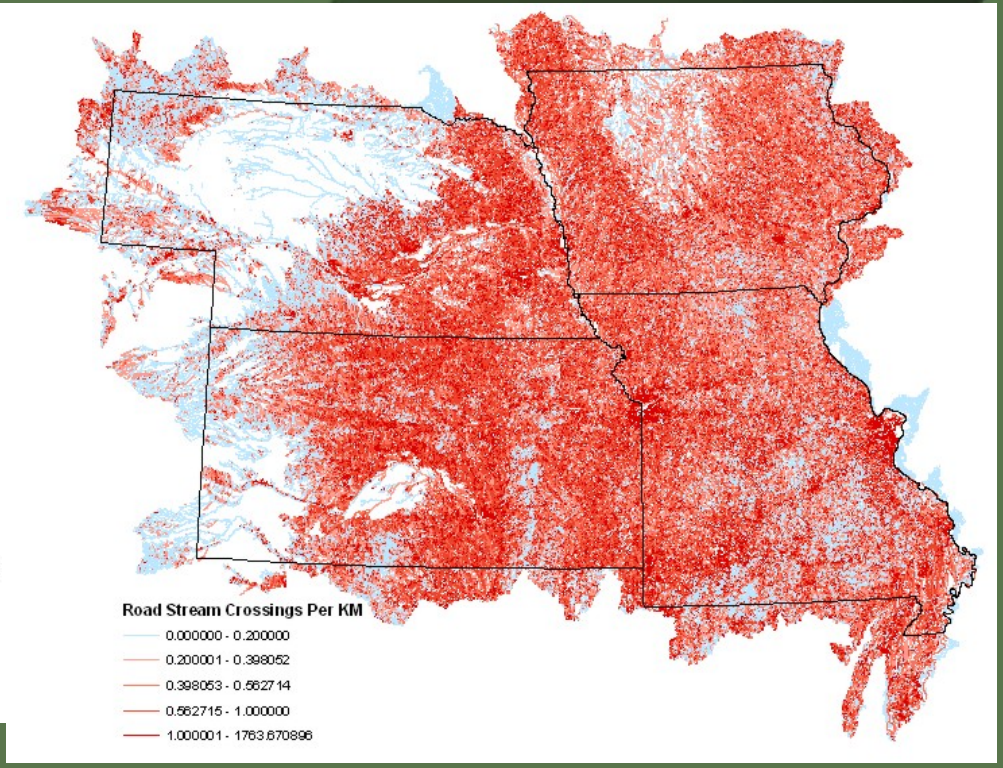

CAFO Per KM
0.000000
0.000001 - 0.006014
0.006015 - 0.013548
0.013549 - 0.031489
0.031490 - 71.402550

Certified Wells

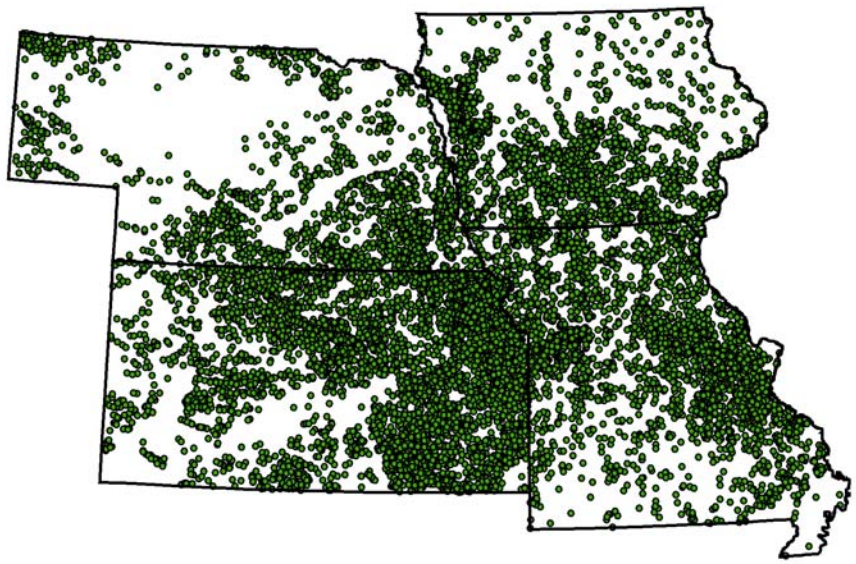


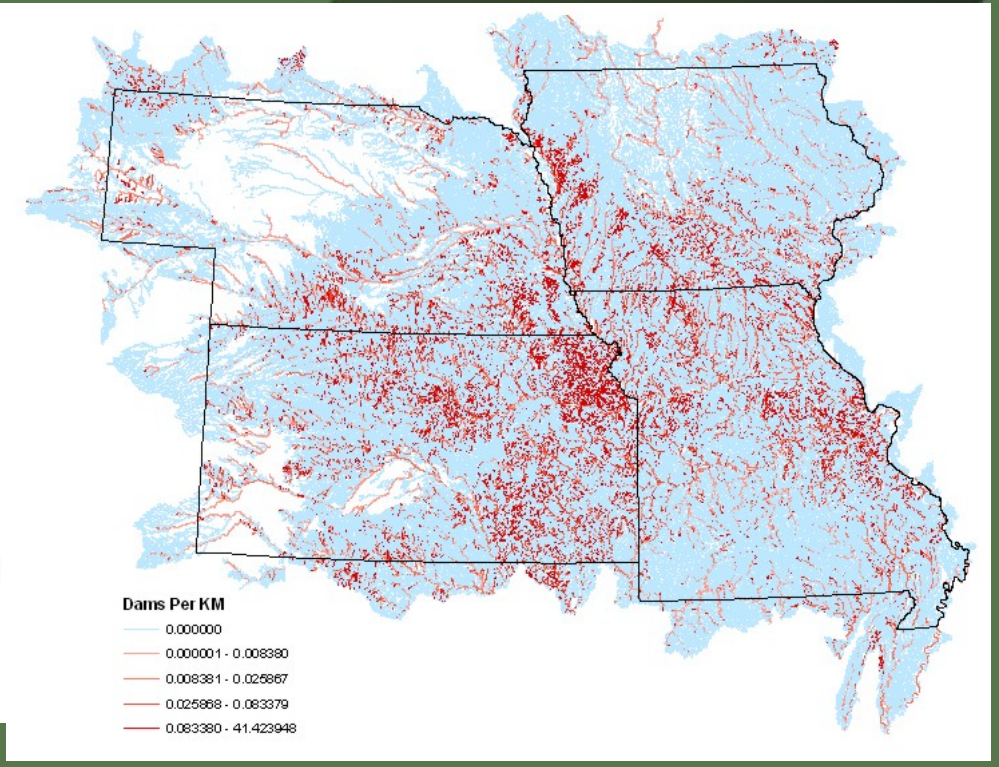


Road-Stream Crossings

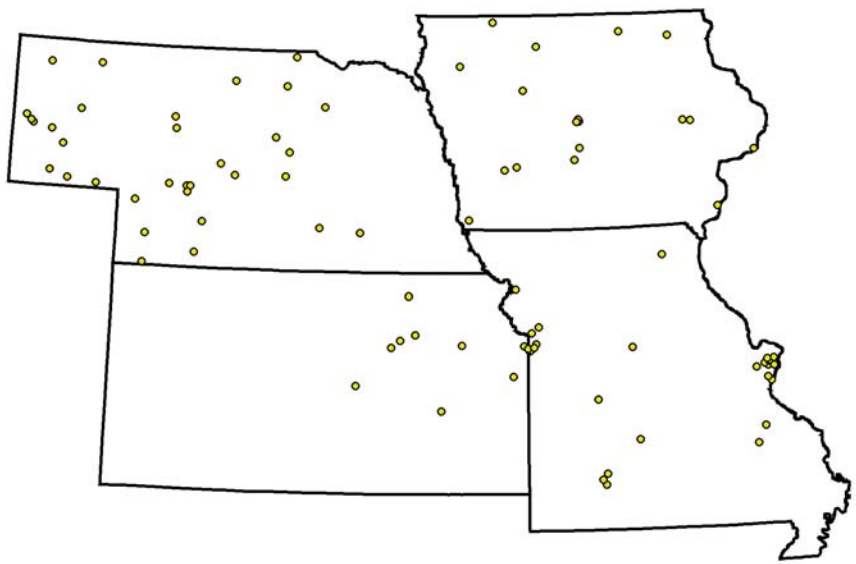


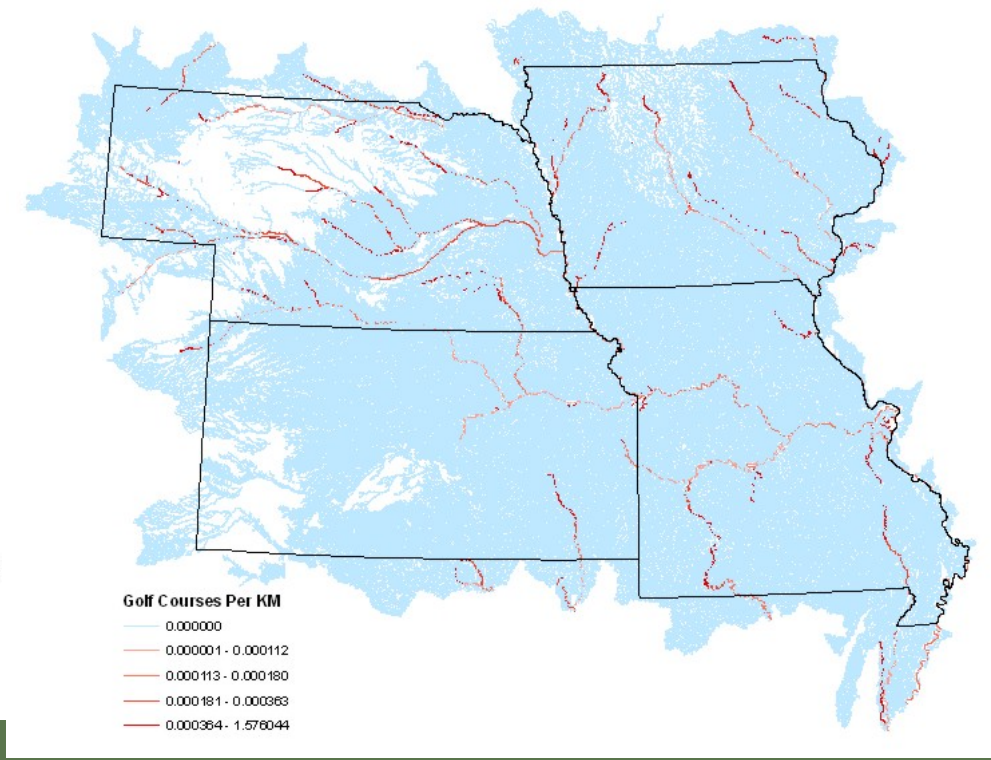
Dams



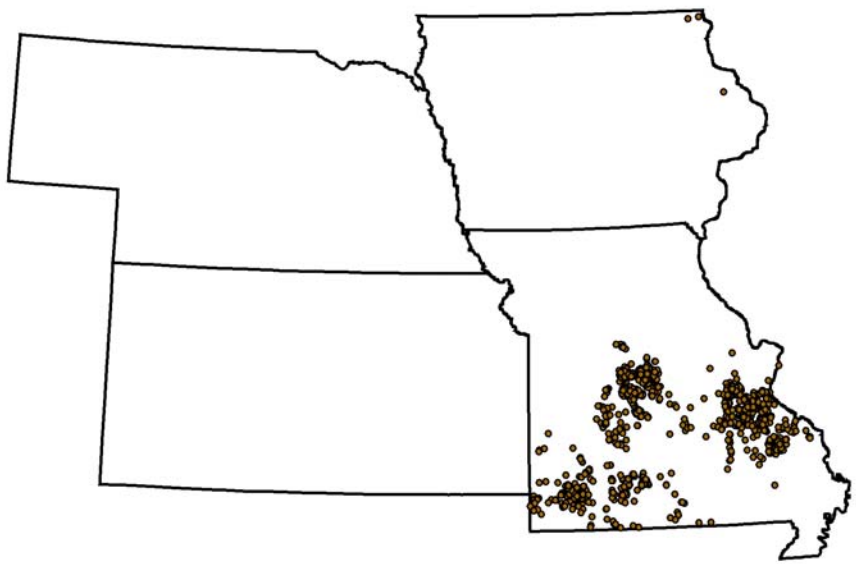

Dams Per KM
0.000000
0.000001 - 0.008380
0.008381 - 0.025867
0.025868 - 0.083379
0.083380 - 41.423948

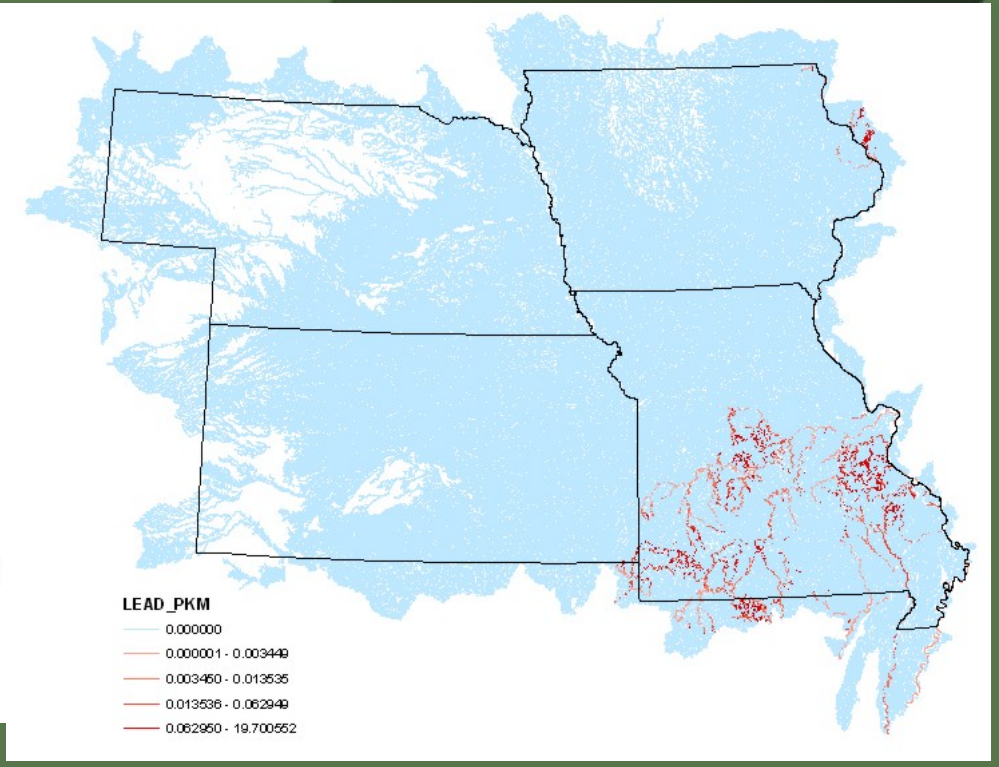
Golf Courses



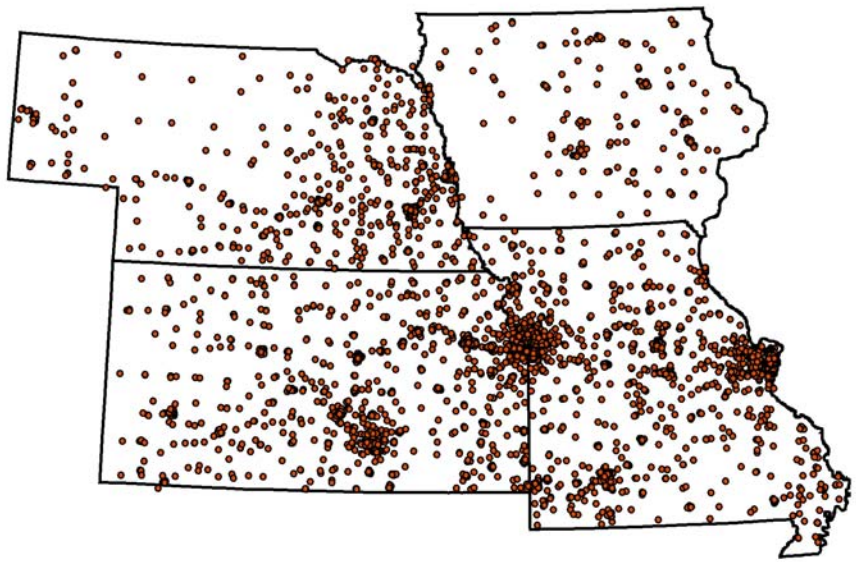


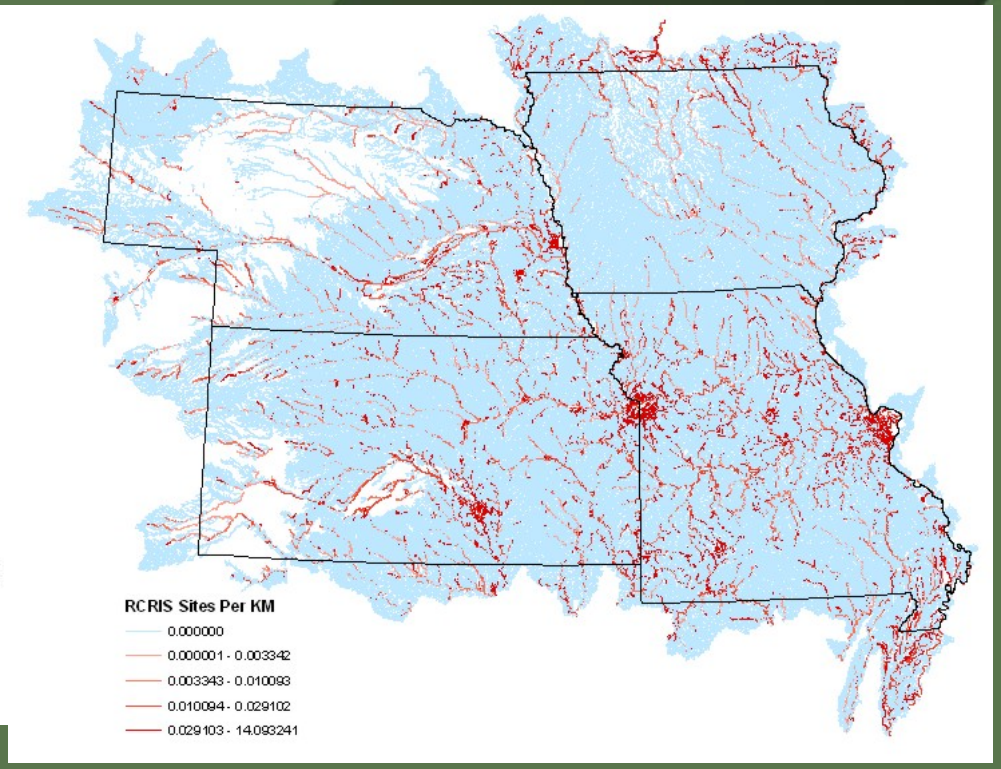
Lead Mines



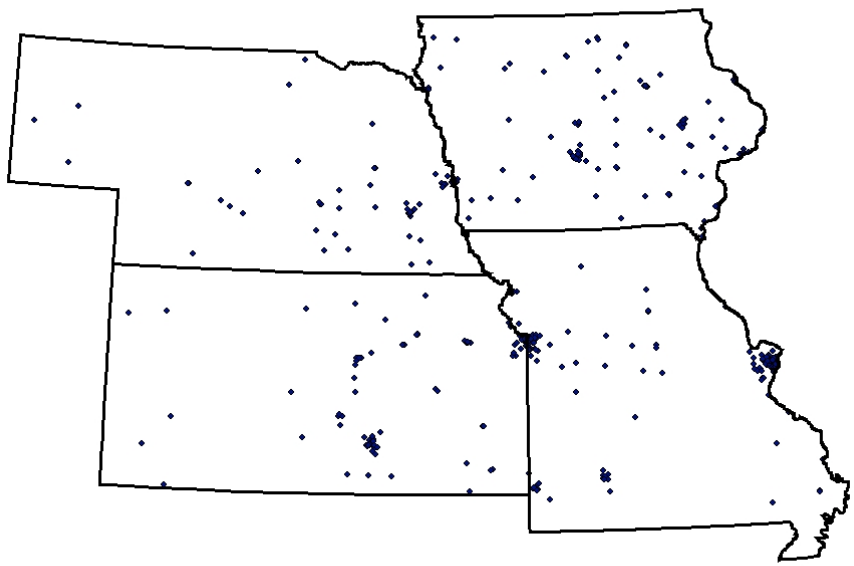

LEAD_PKM
0.000000
0.000001 - 0.003449
0.003450 - 0.013535
0.013536 - 0.062949
0.062950 - 19.700552

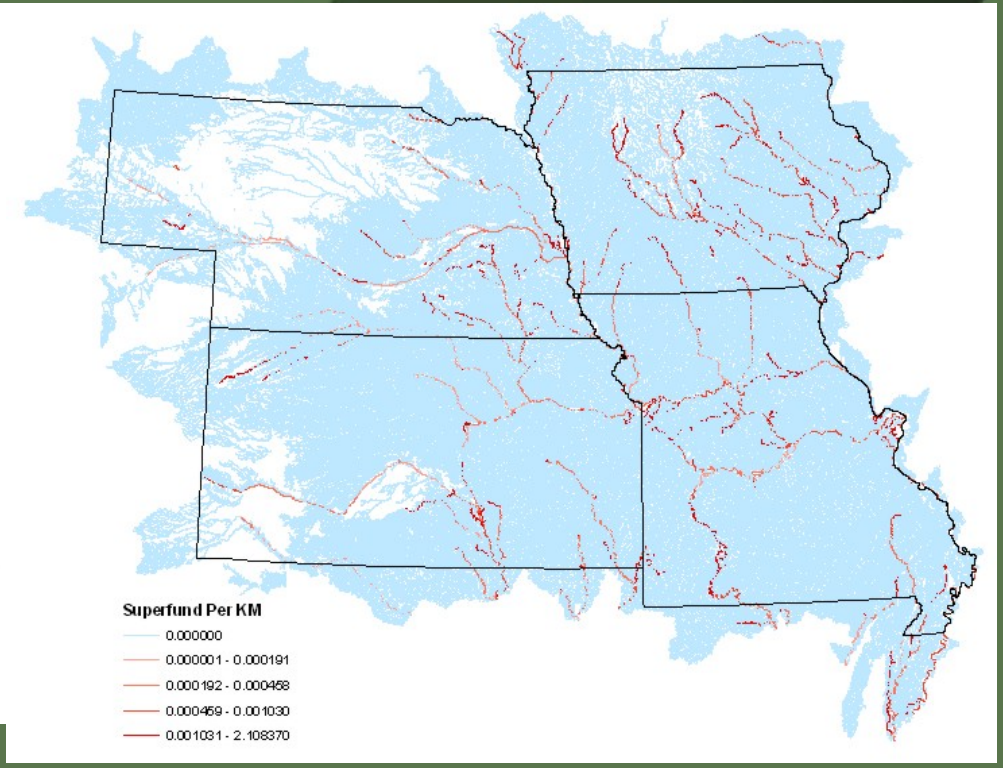
RCRIS Sites



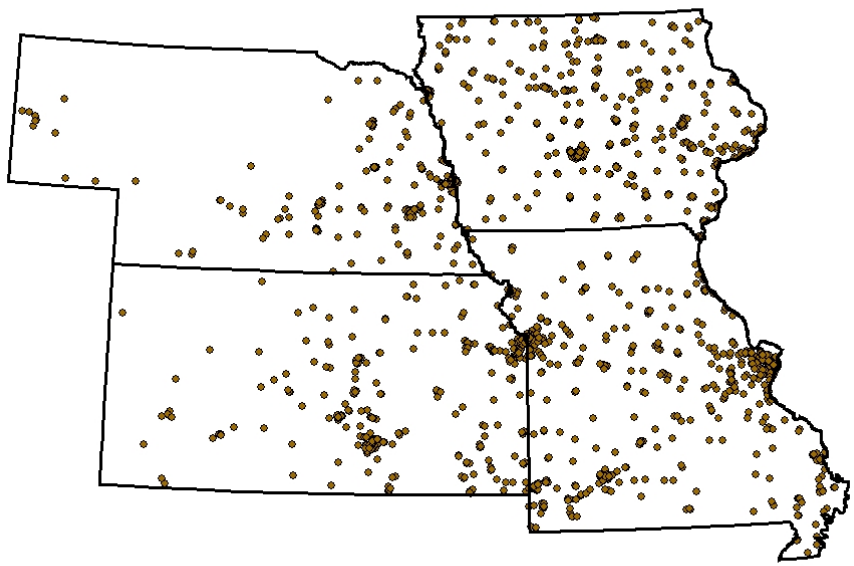

RCRIS Sites Per KM
0.000000
0.000001 - 0.003342
0.003343 - 0.010093
0.010094 - 0.029102
0.029103 - 14.093241

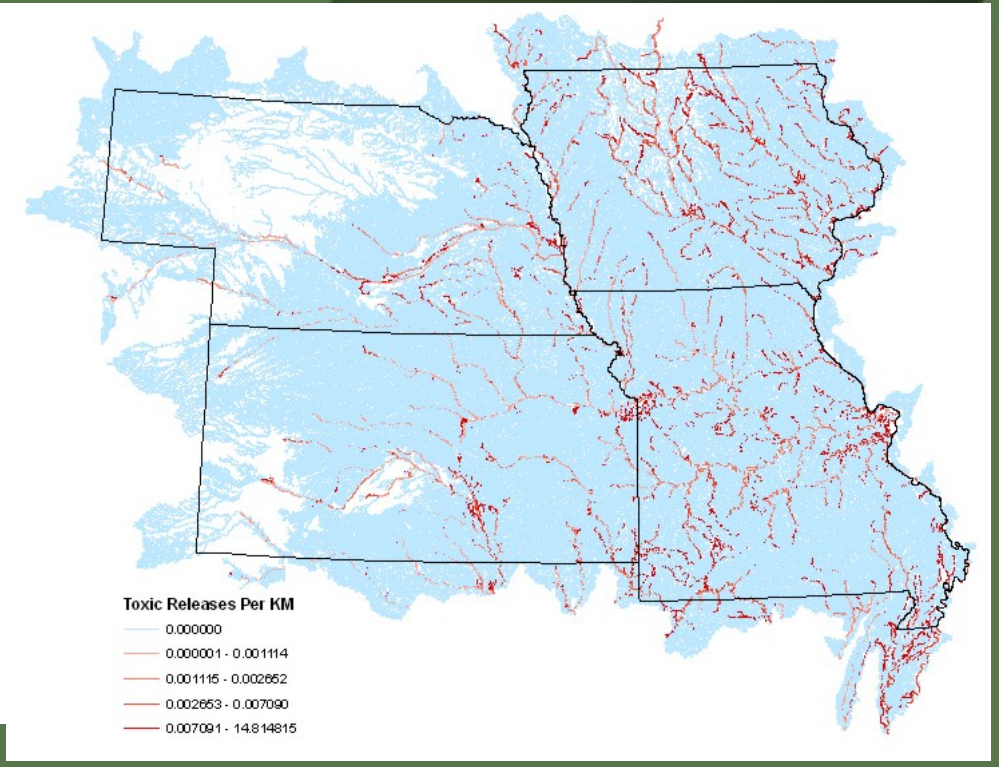
Superfund




Superfund Per KM
0.000000
0.000001 - 0.000191
0.000192 - 0.000458
0.000459 - 0.001030
0.001031 - 2.108370

Toxic Releases





Literature Review

- Kathy Doisy will give literature review update

What we want to accomplish today

- Discuss monitoring data for evaluating HSI and future applications
- Ranking and weighting discussion
  - General discussion
  - Data normalization
  - Weighting
  - Integrating distance measures as weighting factors
- Addressing data limitations and disparities across states
  - Region wide vs. state based approach or both
- Discuss some data issues
  - Metadata and using incomplete data

What Comes Next?

- Basic processes and tools assembled and in place
- Continue to run data sets
- Work on preparing data sets that will require more “set up” work
- Weighting and HSI
- Literature review