

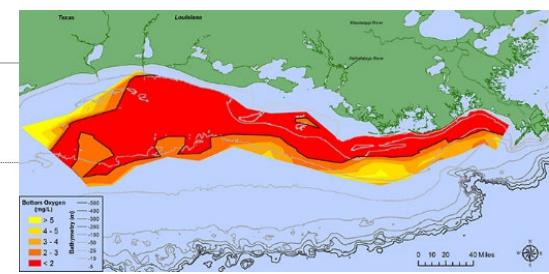
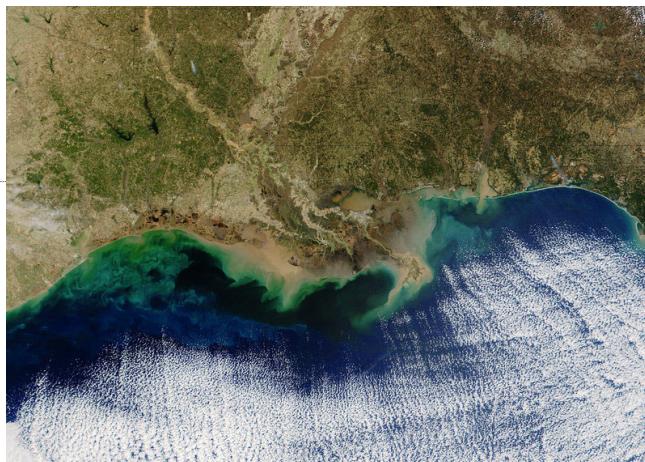


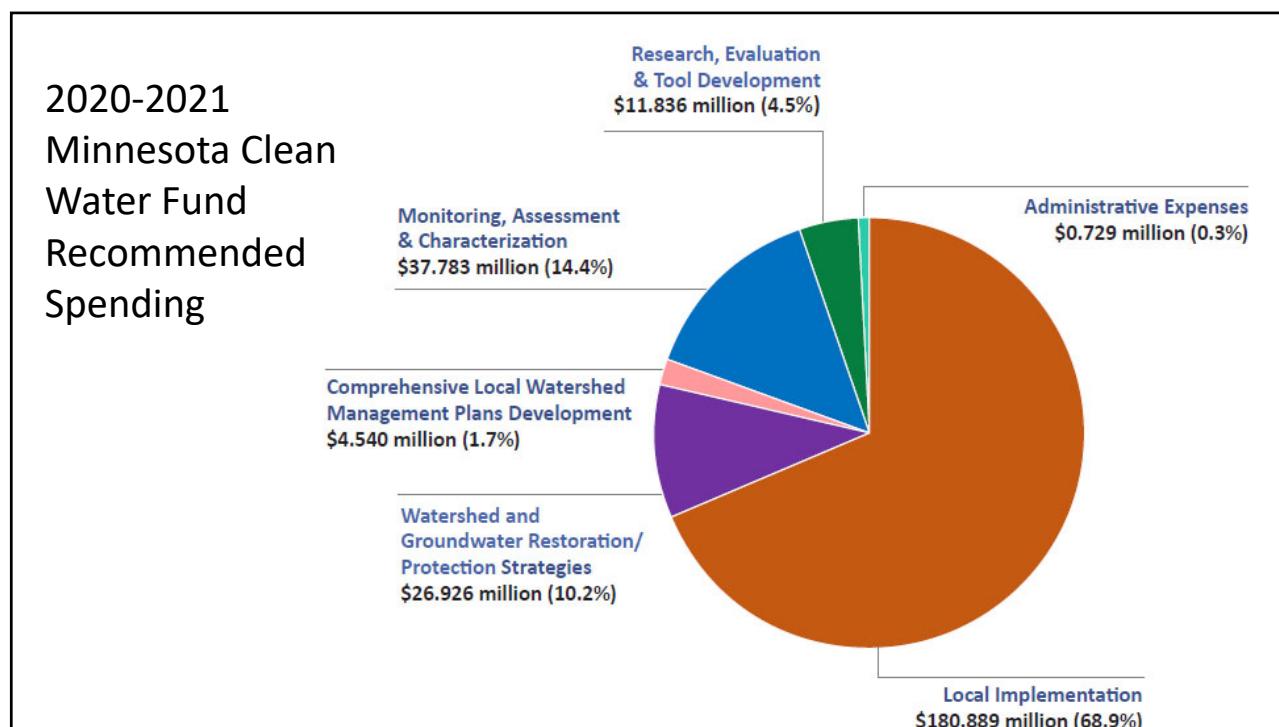




Gulf of Mexico 'dead zone' is the largest ever measured

June outlook foretold New Jersey-sized area of low oxygen





Homeowner Melissa Hanson, left, worked with conservationist Meghan Darley about making improvements to help protect Spring Lake. Photo by Leila Navidi • Star T

Minnesota's big water ambitions yield benefits, no simple answers

By Josephine Marcotty Star Tribune | MAY 24, 2018 — 5:10PM

A TEXT SIZE

Behind uneventful Minnesota summer weather lurks signs of climate change

Lake Superior algae bloom, hazy skies might become the norm, scientists say.

MUDAC 2019 PROBLEM 1



WHAT IS A WATERSHED?

The Making of a River

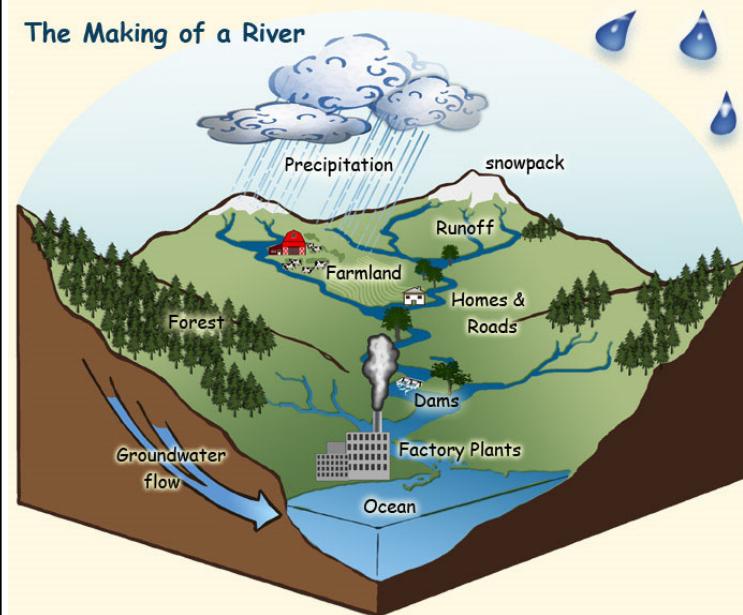


Image Credit: A. Vicente, U.S. Forest Service.





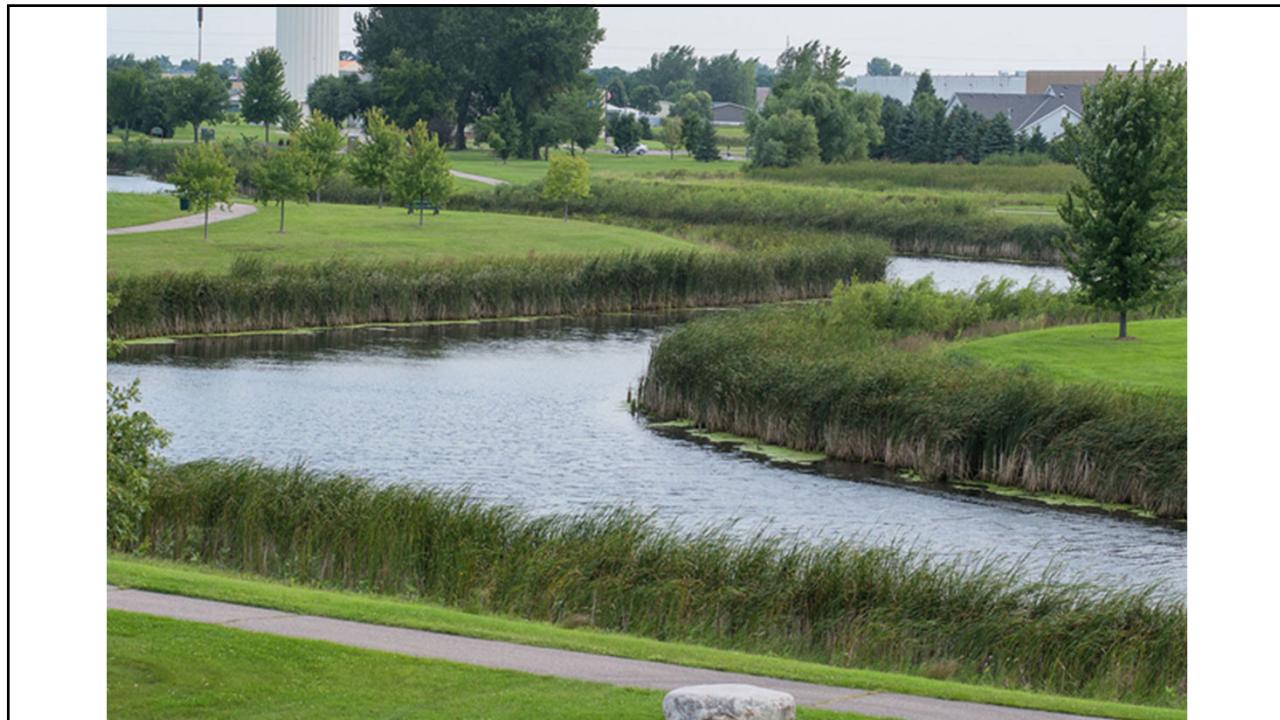




Photo courtesy of Barr Engineering

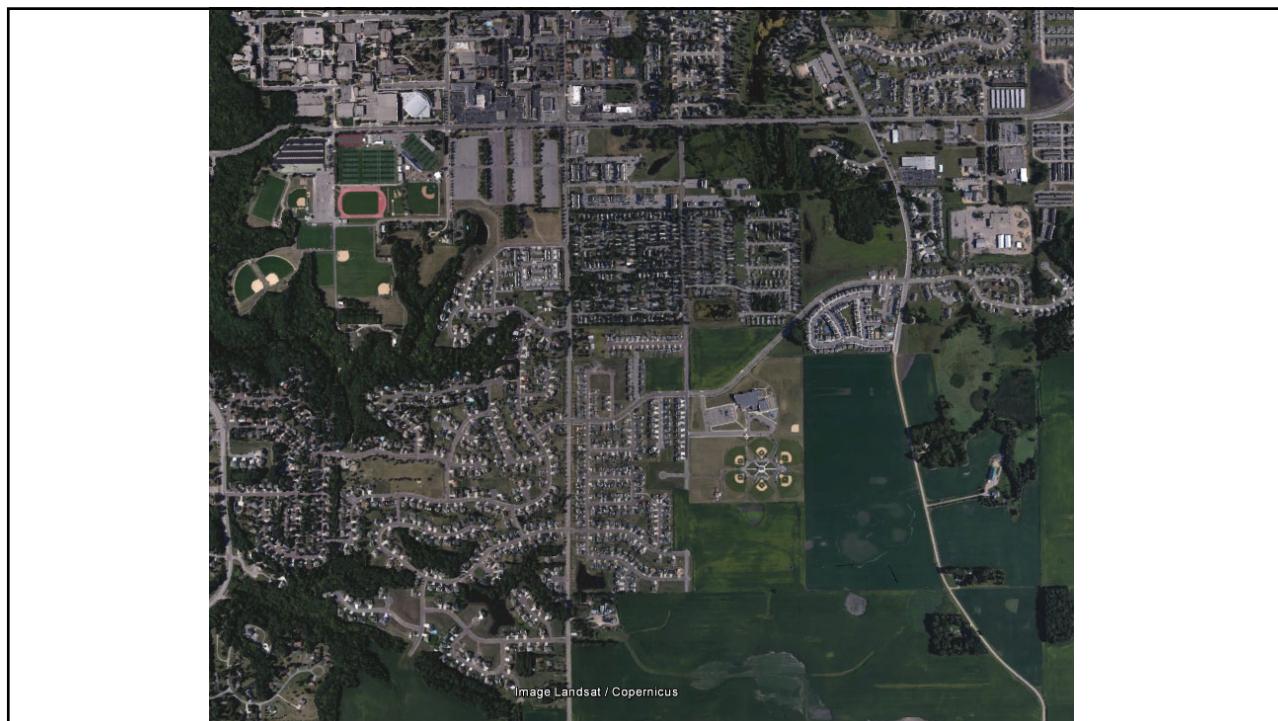


Image Landsat / Copernicus

For 50 Watersheds:

15 Watershed Variables
2 Water Quality Variables

Locational Coordinates
for the Water Quality
Monitoring Stations

Watershed Monitoring Site Location	WATERSHED VARIABLES										WATER QUALITY VARIABLES				LOCATION		
	Forest/Grass and Hay	Wetlands/Orchard	Altered Stream/Trailed land/Onshore bedrock/Sand	Sites	Icty	Organic matter/land slope/ lakes	lake interception	Total Suspended Solids/Water	Sec.	Long.	Sec.	Long.	Sec.	Long.			
Big Fork River at Bemidji, MN	42.3%	3.1%	45.1%	0.2%	19.8%	0.0%	0.3%	32.5%	47.80	20.5%	27.7%	3.8%	5.7%	40.7%	15	0.04	46.19893/-93.8072
Big Fork River at Big Falls, MN	0.7%	2.4%	96.9%	0.0%	18.4%	0.0%	0.0%	2.4%	33.70	10.7%	20.0%	3.0%	4.0%	34.8%	14	0.04	46.19893/-93.8072
Birch River at Dassel, MN	0.8%	3.8%	5.8%	89.3%	71.6%	10.0%	0.0%	31.8%	40.00	28.2%	3.4%	1.2%	2.7%	43.2%	84	0.14	46.15234/-96.7595
Buffalo River at Georgetown, CR208	9.5%	9.3%	7.0%	85.3%	57.3%	8.3%	0.0%	49.7%	37.30	22.0%	5.7%	2.2%	3.0%	9.6%	75	0.04	47.04978/-96.7537
Cedar River at Austin, MN	9.5%	10.5%	10.5%	74.5%	49.8%	10.5%	0.0%	31.9%	40.00	22.5%	4.5%	1.2%	2.7%	43.2%	177	0.04	46.19893/-93.8072
Cedar River at Austin, MN, MND	1.4%	6.3%	2.0%	79.7%	75.5%	36.5%	1.7%	33.3%	42.20	24.6%	6.0%	1.7%	0.8%	61.4%	64	0.14	46.19893/-93.8072
Cottonwood River at Red Lake Falls, MN	4.5%	13.2%	1.1%	82.2%	52.0%	12.0%	0.0%	32.0%	39.80	17.2%	13.0%	1.8%	2.4%	31.3%	43	0.71	47.04908/-96.7245
Cottonwood River at Red Lake Falls, MN	22.0%	20.0%	15.8%	33.4%	65.4%	8.6%	0.0%	32.2%	39.80	17.2%	13.0%	1.8%	2.4%	31.3%	43	0.71	47.04908/-96.7245
Cottonwood River at New Ulm, MN	1.2%	3.8%	3.9%	84.9%	50.8%	31.7%	10.1%	34.6%	37.00	27.2%	4.9%	2.0%	0.7%	1.7%	181	0.14	46.19893/-93.8072
Cottonwood River at Pipestone, MN	1.1%	3.2%	3.2%	87.5%	52.4%	12.0%	0.0%	32.0%	39.80	17.2%	13.0%	1.8%	2.4%	31.3%	201	0.04	46.19893/-93.8072
Kettle River at Sodalis, MN	38.4%	11.0%	40.0%	1.8%	26.2%	0.0%	3.7%	31.9%	34.60	12.3%	20.1%	2.2%	1.8%	28.2%	72	0.14	46.19893/-93.8072
Le Sueur River at Segun, CR4401	1.4%	3.7%	3.6%	83.5%	62.7%	44.0%	0.3%	25.5%	31.40	21.3%	7.7%	2.0%	2.1%	9.6%	533	0.14	46.15105/-94.0416
Le Sueur River at Segun, MN	1.4%	3.7%	3.6%	83.5%	62.7%	44.0%	0.3%	25.5%	31.40	21.3%	7.7%	2.0%	2.1%	9.6%	533	0.14	46.15105/-94.0416
Little Rock River at Little Rock, MN	22.0%	27.6%	9.5%	35.5%	53.6%	1.9%	0.0%	0.0%	15.90	21.0%	12.2%	12.2%	2.6%	7.3%	7.3	0.64	46.19893/-93.8072
Long Prairie River at Pipestone, MN	22.0%	1.5%	3.2%	87.5%	52.4%	12.0%	0.0%	32.0%	39.80	17.2%	13.0%	1.8%	2.4%	31.3%	201	0.04	46.19893/-93.8072
Mahnomen River at Grand Rapids, MN	51.5%	5.3%	4.8%	48.8%	43.2%	12.0%	0.0%	32.0%	39.80	17.2%	13.0%	1.8%	2.4%	31.3%	201	0.04	46.19893/-93.8072
Mahnomen River or South Superior, WI	56.6%	10.8%	27.1%	0.9%	2.5%	0.0%	0.0%	48.1%	24.60	22.6%	13.0%	3.8%	0.7%	9.7%	254	0.04	46.02333/-92.9820
Mahnomen River or South Superior, WI	56.6%	10.8%	27.1%	0.9%	2.5%	0.0%	0.0%	48.1%	24.60	22.6%	13.0%	3.8%	0.7%	9.7%	254	0.04	46.02333/-92.9820
Other Tail River at Breckenridge, CR440	28.0%	17.8%	6.7%	72.9%	39.7%	1.5%	0.0%	56.5%	27.00	15.4%	10.3%	3.4%	34.2%	100.0%	36	0.25	46.27440/-96.5790
Pine River at Pipestone, CR4401	53.3%	5.8%	3.2%	87.5%	52.4%	12.0%	0.0%	32.0%	39.80	17.2%	13.0%	1.8%	2.4%	31.3%	201	0.04	46.19893/-93.8072
Pine River De Terre River at Akeley, MN	5.6%	11.0%	6.0%	42.9%	80.4%	7.8%	0.0%	35.6%	37.30	26.4%	4.9%	2.9%	7.4%	100.0%	49	0.14	46.20307/-96.5225
Pine River De Terre River at Pipestone, CR4401	56.6%	10.4%	2.8%	87.5%	52.4%	12.0%	0.0%	32.0%	39.80	17.2%	13.0%	1.8%	2.4%	31.3%	201	0.04	46.19893/-93.8072
Rapid River at Clements, MN	2.0%	1.8%	94.5%	1.0%	74.5%	0.2%	0.4%	29.9%	35.70	12.4%	54.6%	0.3%	0.0%	0.0%	17	0.14	46.15237/-94.4311
Rapid River at Pipestone, MN	2.0%	1.8%	94.5%	1.0%	74.5%	0.2%	0.4%	29.9%	35.70	12.4%	54.6%	0.3%	0.0%	0.0%	17	0.14	46.15237/-94.4311
Rock River at Lanes, CR4405	0.8%	34.4%	1.0%	79.4%	59.0%	9.2%	5.8%	27.7%	49.70	23.7%	3.5%	2.8%	6.1%	0.0%	169	0.14	46.15143/-96.2011
Rock River at Lanes, CR4405	20.9%	20.9%	20.9%	44.4%	44.4%	2.2%	31.3%	35.30	22.5%	2.2%	1.6%	1.4%	28.8%	204	0.14	46.15143/-96.2011	
Ram River at Andra, E Main St	21.0%	19.0%	16.5%	37.4%	52.1%	3.2%	1.5%	34.6%	34.60	9.6%	17.6%	1.6%	14.7%	28.8%	9.37	0.14	46.19893/-93.3013
Ram River at Andra, E Main St	6.4%	27.0%	9.3%	89.6%	71.1%	10.8%	4.6%	14.5%	31.80	19.7%	4.6%	1.4%	2.7%	11.1%	131	0.14	46.15143/-96.2011
Seau River at Seau Rapids, CR4401	8.4%	27.0%	9.3%	89.6%	71.1%	10.8%	0.0%	45.5%	31.80	19.7%	4.6%	1.4%	2.7%	11.1%	131	0.14	46.15143/-96.2011
Shall Rock River at Gustavia, CR4401	1.6%	3.1%	3.9%	70.5%	60.2%	28.5%	8.7%	2.7%	3.5%	70.0%	0.0%	0.0%	0.0%	24	1.1	46.15143/-93.2084	
Shall Rock River at Gustavia, CR4401	5.6%	3.1%	3.9%	70.5%	60.2%	28.5%	8.7%	2.7%	3.5%	70.0%	0.0%	0.0%	0.0%	24	1.1	46.15143/-93.2084	
Spill Rock Creek at Pipestone, Bridge Ave	37.4%	21.5%	27.0%	8.1%	39.5%	0.9%	2.6%	47.3%	41.20	11.5%	16.0%	1.9%	1.2%	100.0%	4.8	0.14	46.19893/-93.8072
Spill Rock Creek at Pipestone, Bridge Ave	38.0%	21.4%	27.0%	8.1%	39.5%	0.9%	2.6%	47.3%	41.20	11.5%	16.0%	1.9%	1.2%	100.0%	4.8	0.14	46.19893/-93.8072
Spill Rock Creek at Pipestone, Bridge Ave	0.8%	12.4%	6.4%	80.5%	47.5%	6.2%	27.9%	33.9%	54.80	29.2%	3.2%	1.8%	0.1%	45.4%	115	1.2	46.19893/-93.8072
Spill Rock Creek at Pipestone, Bridge Ave	38.6%	4.4%	3.1%	80.5%	47.5%	6.2%	27.9%	33.9%	54.80	29.2%	3.2%	1.8%	0.1%	45.4%	115	1.2	46.19893/-93.8072
Sucker River at Pipestone, CR4401	66.8%	2.4%	28.2%	0.1%	2.2%	0.0%	0.0%	41.6%	44.50	10.7%	18.4%	3.9%	0.3%	0.0%	23	0.09	46.15201/-91.8802
Sucker River at Pipestone, CR4401	66.8%	2.4%	28.2%	0.1%	2.2%	0.0%	0.0%	41.6%	44.50	10.7%	18.4%	3.9%	0.3%	0.0%	23	0.09	46.15201/-91.8802
Thief River at Thief River Falls, MN	7.0%	7.5%	48.1%	33.1%	96.25%	9.6%	0.0%	41.8%	31.20	16.4%	24.6%	0.3%	4.6%	63.3%	25	0.28	46.16367/-96.1701
Thief River at Thief River Falls, MN	7.0%	7.5%	48.1%	33.1%	96.25%	9.6%	0.0%	41.8%	31.20	16.4%	24.6%	0.3%	4.6%	63.3%	25	0.28	46.16367/-96.1701
Vernon River at Crane Lake, MN	55.8%	2.3%	26.2%	0.1%	4.6%	0.0%	0.0%	32.6%	34.60	11.5%	14.8%	4.9%	13.2%	72.3%	3.8	0.05	46.20461/-92.9650
Vernon River at Crane Lake, MN	55.8%	2.3%	26.2%	0.1%	4.6%	0.0%	0.0%	32.6%	34.60	11.5%	14.8%	4.9%	13.2%	72.3%	3.8	0.05	46.20461/-92.9650
Wheat Fork Des Moines River at Jackson, CR4401	1.1%	1.4%	1.4%	88.6%	88.6%	1.1%	0.0%	35.3%	39.30	23.0%	4.8%	2.0%	2.0%	77.9%	81	1.5	46.15137/-94.9843
Wheat Fork Des Moines River at Becker, CR4401	15.7%	27.2%	0.7%	88.6%	20.5%	1.1%	49.5%	39.5%	59.30	21.2%	2.2%	7.9%	0.0%	77.9%	189	1.5	46.15137/-94.9843
Wheat Fork Des Moines River at Becker, CR4401	23.3%	3.2%	3.2%	88.6%	20.5%	1.1%	49.5%	39.5%	59.30	21.2%	2.2%	7.9%	0.0%	77.9%	189	1.5	46.15137/-94.9843
Yellow Bear River at Oboz, CR4401	1.0%	34.7%	4.9%	88.6%	49.7%	4.8%	0.9%	34.9%	34.80	26.9%	3.2%	2.6%	1.2%	8.8%	97	1.6	46.20522/-96.3533
Yellow Bear River at Oboz, CR4401	0.9%	34.7%	4.9%	88.6%	49.7%	4.8%	0.9%	34.9%	34.80	26.9%	3.2%	2.6%	1.2%	8.8%	97	1.6	46.20522/-96.3533
Zumbro River at Kellogg, US61	9.7%	23.2%	3.5%	54.0%	42.5%	8.6%	21.3%	22.9%	54.80	22.5%	3.2%	5.5%	0.2%	59.6%	155	1.2	44.31217/-92.0030



MUDAC 2019 PROBLEM 2

1. The following table lists the locations and characteristics of 50 water monitoring sites. The sites are located in 10 different watersheds. The first column lists the site location and the second column lists the watershed variables for each site. The third column lists the water quality variables for each site. The fourth column lists the location (latitude and longitude) for each site.

WATERSHED MONITORING SITE LOCATION	WATERSHED VARIABLES	WATER QUALITY VARIABLES	LOCATION
Big Fork River at Bemidji, MN	42.3%	3.1% 45.1% 0.2% 19.8% 0.0% 0.3% 32.5% 47.80 20.5%	47.80000/-93.80000
Big Fork River at Big Falls, MN	0.7%	2.4% 48.4% 50.8% 31.7% 10.1% 0.0% 32.0% 39.30 27.0%	46.19893/-93.8072
Brule River at Brule, MN	0.6%	3.6% 5.8% 89.3% 71.6% 10.0% 0.0% 31.8% 40.00 28.2%	46.15234/-96.7595
Buffalo River at Georgetown, CR4401	9.5%	9.3% 7.0% 85.3% 57.3% 8.3% 0.0% 49.7% 37.30 22.0%	47.04978/-96.7537
Cedar River at Austin, MN	1.4%	6.3% 2.0% 79.7% 75.5% 36.5% 0.0% 32.0% 39.80 24.6%	46.19893/-93.8072
Cottonwood River at Red Lake Falls, MN	22.0%	20.0% 15.8% 33.4% 65.4% 8.6% 0.0% 32.2% 39.80 17.2%	47.04908/-96.7245
Cottonwood River at New Ulm, MN	1.2%	3.8% 3.4% 84.9% 50.8% 31.7% 10.1% 0.0% 32.0% 39.30 27.0%	46.19893/-93.8072
Cottonwood River at Pipestone, MN	1.2%	3.2% 3.2% 87.5% 52.4% 12.0% 0.0% 32.0% 39.80 17.2%	46.19893/-93.8072
Kettle River at Segun, MN	38.4%	11.0% 40.0% 1.8% 26.2% 0.0% 3.7% 31.9% 34.60 12.3%	46.15105/-94.0416
Le Sueur River at Segun, MN	1.4%	3.7% 3.4% 83.5% 62.7% 44.0% 0.3% 32.5% 31.3%	46.15105/-94.0416
Le Sueur River at Segun, MN	1.4%	3.7% 3.4% 83.5% 62.7% 44.0% 0.3% 32.5% 31.3%	46.15105/-94.0416
Little Fork River at Little Fork, MN	34.0%	14.0% 42.5% 0.4% 22.5% 0.0% 3.0% 32.0% 41.80 23.0%	46.19893/-93.8072
Long Prairie River at Pipestone, MN	22.0%	27.6% 9.5% 35.5% 53.6% 1.9% 0.0% 0.0% 15.90 21.0%	46.19893/-93.8072
Mahnomen River at Grand Rapids, MN	51.5%	5.3% 3.2% 87.5% 52.4% 12.0% 0.0% 32.0% 39.80 17.2%	46.02333/-92.9820
Mahnomen River at South Superior, WI	56.6%	10.8% 27.1% 0.9% 2.5% 0.0% 0.0% 48.1% 24.60 22.6%	46.02333/-92.9820
Other Tail River at Breckenridge, CR4401	28.0%	17.8% 6.7% 33.4% 50.5	

Confidence that climate change has *already* impacted common Minnesota weather/climate hazards

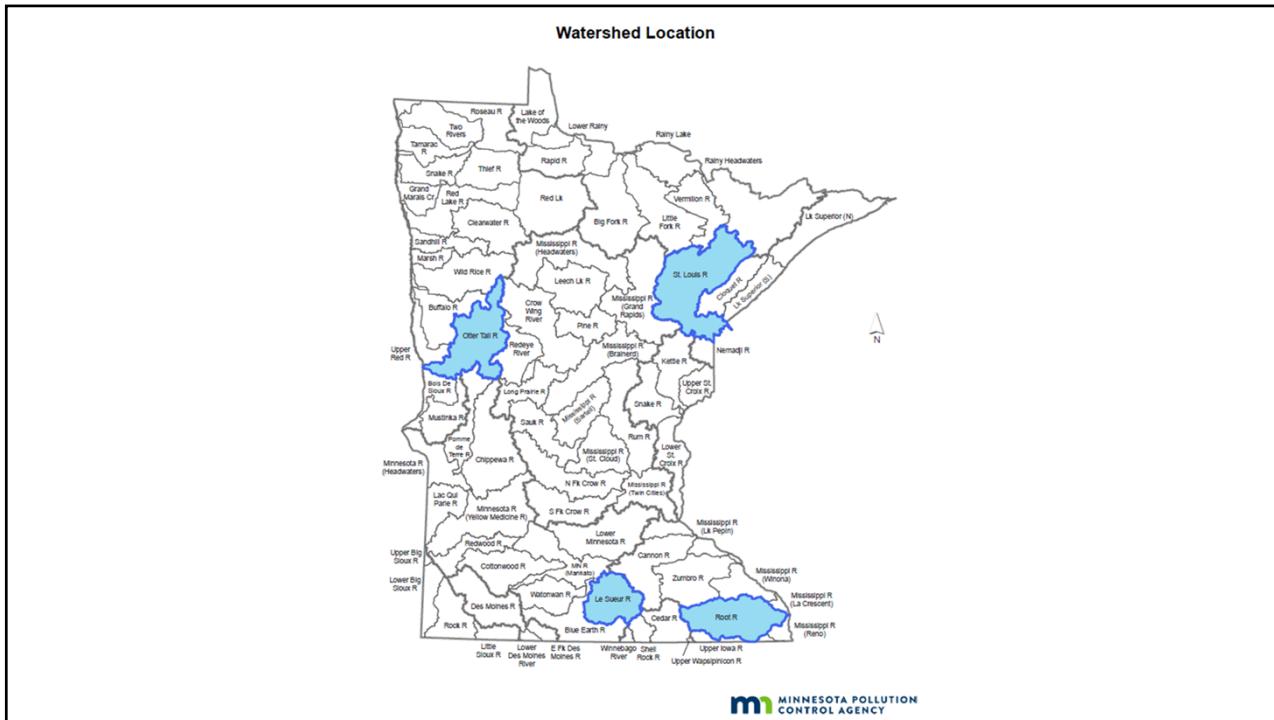
<u>Confidence</u>	<u>Hazard</u>	<u>Recent & Current Observations</u>
Highest	Extreme cold	Rapid decline in severity, frequency
	Extreme rainfall	Becoming larger and more frequent
Moderately High	Heavy snowfall	Large events more frequent
Low	Severe thunderstorms & tornadoes	Historical comparisons difficult; Few major tornadoes in MN since late 2010
Lowest	Heat waves	No recent increases or worsening
	Drought	



Confidence that climate change will impact common Minnesota weather/climate hazards beyond 2025

<u>Confidence</u>	<u>Hazard</u>	<u>Expectations beyond 2025</u>
Highest	Extreme cold	Continued rapid decline
	Extreme rainfall	Unprecedented events expected
High	Heat waves	Increases in severity, coverage, and duration expected
Moderately High	Drought	Increases in severity, coverage, and duration possible
Moderately Low	Heavy snowfall	Large events less frequent as winter warms
Moderately Low	Severe thunderstorms & tornadoes	More "super events" possible, even if frequency decreases





For 4 of the 50 Watersheds:

Multiple years of hourly precipitation at multiple locations

Water quality data for the same years

40,000-50,000 rows of precipitation data for each watershed

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