Poster W1

A Quantitative Consideration of Sociodemographic Factors in Water Quality Research Prioritization

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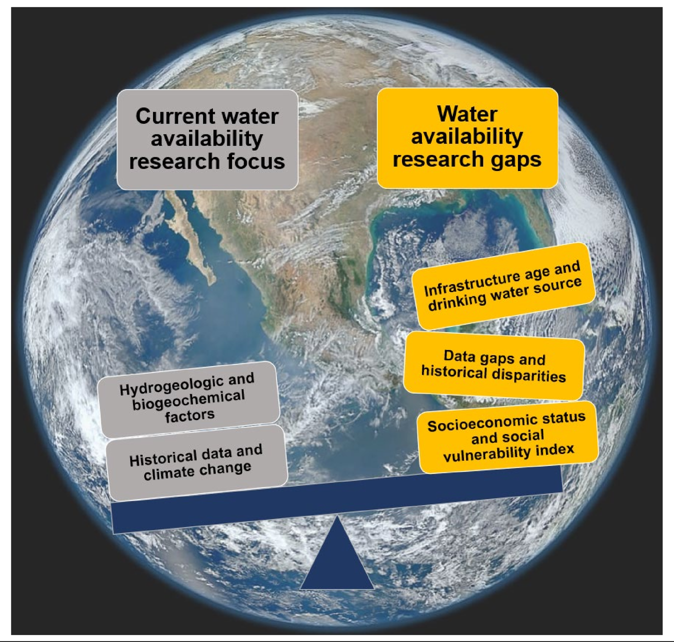
Abstract

Water availability depends on water quantity and quality. Geogenic contaminants, including non-metals, metals, and metalloids from geologic sources, are among the most prevalent contaminants limiting water availability in the U.S. and globally. Typical geologic materials have geogenic concentrations such that dissolution of very small fractions can cause concentrations exceeding drinking water, ecological, and other water use thresholds. Geogenic contaminants often occur in groundwater due to subsurface water-rock interactions, but their distribution and concentration can also be affected by human activities such as mining, energy production, irrigation, and pumping practice.

Many hydrogeologic and biogeochemical factors contribute to causing geogenic contamination that limits water availability. However, sociodemographic features, including drinking water source and missing water quality information, are often overlooked when evaluating, determining, and ranking the merit and benefit of research. Sociodemographic features, data gaps resulting from historical data collection disparities, social vulnerability indices, socioeconomic status, and infrastructure condition/age are examples of environmental justice (EJ) factors. To avoid perpetuating knowledge gaps while setting research priorities, EJ factors can be considered when developing ranking schemes to prioritize water availability research activities.

The U.S. Geological Survey (USGS) is working to quantitatively incorporate and prioritize EJ factors in ranking regional-scale, geogenic-related water availability research priorities. USGS ranking schemes incorporate typical physical and geochemical factors such as existing data, climate variables, and water use. Missing and sociodemographic information will also be incorporated to begin addressing EJ inequities. EJ factors include, for example, sparse information about water quality in lower income and minority areas, and unknowns about water quality in areas of substantial cultural or subsistence hunting, fishing, or gathering. By considering both EJ and hydrogeological/biogeochemical factors, decision makers will have a more diverse, interdisciplinary toolbox to increase equity and reduce bias in prioritizing future water availability studies.



Approach

1) *Develop conceptual framework* for prioritization ranking
2) *Select variables* to represent the conceptual framework in ranking calculations
3) *Calculate individual percentile rank* for each variable in each of the 163 level-4 hydrologic unit (HUC04) watersheds
4) *Calculate HUC04 watershed percentile ranks* by summing variable ranks
5) *Assign National Ranks:* 1 to 163, using all summed percentile ranks
6) *Assign Regional Ranks:* 1 to number of HUC04 watersheds in region, Region by Region, using HUC04 watersheds within each Region

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Variables selected for ranking regional-scale, geogenic-related water availability research priorities

Our ranking calculations included 5 variables representing human alterations, 4 variables representing historic disparities, and 3 variables representing system response or stress. From the many variables that are mapped across the United States, we selected these 12 variables to represent the 3 major categories in our conceptual framework. Each variable was then apportioned to the HUC04 watersheds.

Human alterations
1) Irrigation water use
2) Number of EPA regulated sites
3) Density of non-aggregate mine sites
4) % population using groundwater for drinking water
5) Projected magnitude of change of precipitation due to climate change

Historic disparities
6) Sociodemographic measure based on income, race
7) Density of Native American population
8) Population using domestic wells for drinking water
9) Number of existing trace element samples

System response or stress
10) Magnitude of change in groundwater storage
11) Groundwater with arsenic concentrations > 5 µg/L
12) % of area with shallow brackish groundwater (<500')

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Key Points

There is substantial geographic and sociodemographic variability in where high concentrations of geogenic contaminants are present in drinking water, for both public supply and domestic well supply.

- Groundwater supplies drinking water to about 1/3 of the Nation's population. About 43 million people get drinking water solely from self-supplied domestic wells. About 100 million get drinking water via groundwater public water supplies (PWS).
- Arsenic, one example among many geogenic constituents, is estimated at high concentration in groundwater serving more than 2 million domestic well users[7]; drought is predicted to increase arsenic contamination in domestic wells[8].
- Environmental justice concerns are important considerations for studies designed to understand contaminant hazards and potential human health risk.[3-6] As an example, there may be disparities in concentrations of geogenic contaminants in PWS across sociodemographic strata; e.g., relatively high uranium concentrations in semi-Urban, Hispanic communities[3].
- For PWSs that use groundwater sources, concentrations of geogenic contaminants are often higher for smaller systems than for larger systems, and small systems can lack financial and technical resources to implement better monitoring or treatment strategies. Economic and knowledge barriers about contaminants and treatment are even higher for private well owners.
- The relative lack of existing trace element data is one of several measures of water quality research needs.
- Our study design aims to better account for disparities in environmental risk from geogenic contaminants in underserved populations by explicitly identifying and incorporating variables related to environmental justice and socioeconomic status. With this approach we can better target research to populations in vulnerable climate and hydrogeochemical settings while helping to reduce potential disparities in sampling and analysis strategies.

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Percentile ranks of the individual variables were summed and the sums were used to rank HUC4 watersheds both nationally and regionally for prioritizing areas for water quality research related to geogenic contaminants.

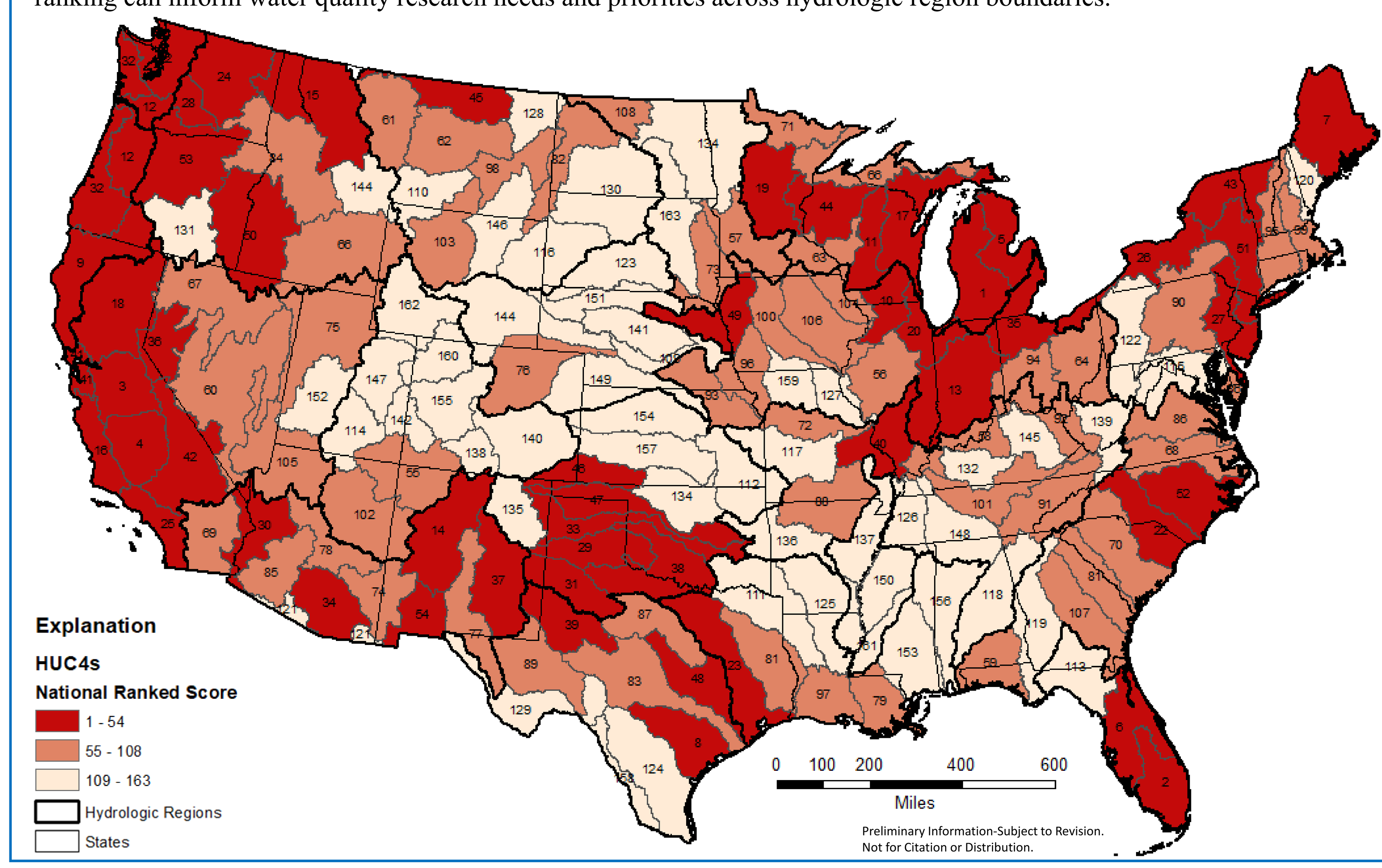
Example of National and Regionalized Ranking: Larger sum of percentile rank (table columns "VarX %tile rank" with the 163 HUC04 basins scaled to percentile ranks ranging 0 to 1) yields higher Ranked Score.

- **National Ranked Score**: 1 to 163, based on the sum of percentile ranks of all HUC04 watersheds.
- **Regional Ranked Score**: 1 to number of HUC04 watersheds in Region, based on the sum of percentile ranks of HUC04 watersheds within the hydrologic region.

Hydrologic Region	HUC04 Basin ID	HUC4 Basin name	Var1 %tile rank	Var2 %tile rank	Var3 %tile rank	Var4 %tile rank	Var5 %tile rank	Var6 %tile rank	Var7 %tile rank	Var8 %tile rank	Var9 %tile rank	Var10 %tile rank	Var11 %tile rank	Var12 %tile rank	Sum of %tile Variable Ranks	National Ranked Score	Regional Ranked Score	Van Metre Ranked Score[1]
Mississippi Embayment	802	Lower Mississippi-St. Francis	0.99	0.45	0.52	0.78	0.18	0.66	0.21	0.44	0.23	0.30	0.15	0.35	5.268	137	1	1
	803	Lower Mississippi-Yazoo	0.94	0.43	0.50	0.97	0.21	0.91	0.10	0.43	0.33	0.07	0.05	0.01	4.946	150	2	2
	805	Boeuf-Tensas-Big Black	0.72	0.36	0.37	0.76	0.71	0.91	0.08	0.28	0.20	0.02	0.24	0.01	4.635	161	3	
Pacific Northwest	1708	Willamette	0.73	0.92	0.63	0.24	0.80	0.34	0.79	0.80	0.43	0.96	0.36	0.01	7.011	12	2	1
	1710	Oregon-Washington Coastal	0.63	0.40	0.94	0.29	0.86	0.55	0.69	0.63	0.65	0.77	0.20	0.01	6.618	32	4	
	1711	Puget Sound	0.27	0.91	0.82	0.35	0.98	0.37	0.94	0.73	0.03	0.98	0.43	0.01	6.805	22	3	2
	1801	Klamath-Northern California Coastal	0.84	0.47	0.96	0.57	0.62	0.72	0.88	0.56	0.57	0.56	0.47	0.01	7.232	9	1	

Var1, Irrigation water use; Var2, number of EPA regulated sites; Var3, Density of non-aggregate mines; and so on from Variables as numbered in the center panel.

Map of National Ranked Score of 163 HUC04 watersheds for research prioritization based on variables relevant to groundwater quality, geogenic contaminants, and sociodemographic factors (see variable descriptions and maps, left, and table above). Darker colors indicate the highest ranked HUC04 watersheds across the continental United States. National-scale ranking can inform water quality research needs and priorities across hydrologic region boundaries.



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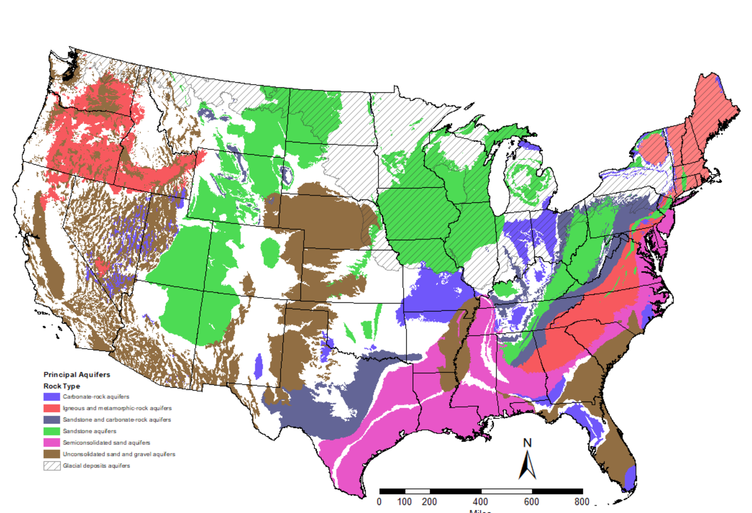
Hydrologic Regions and Principal Aquifers

Geogenic contaminants more commonly limit groundwater drinking water availability than surface water availability. Freshwater resources were considered at multiple scales using the structure of Hydrologic Regions[1], level-4 hydrologic units (HUC04) watersheds[1], and Principal Aquifers (PA)[2] grouped by lithology.

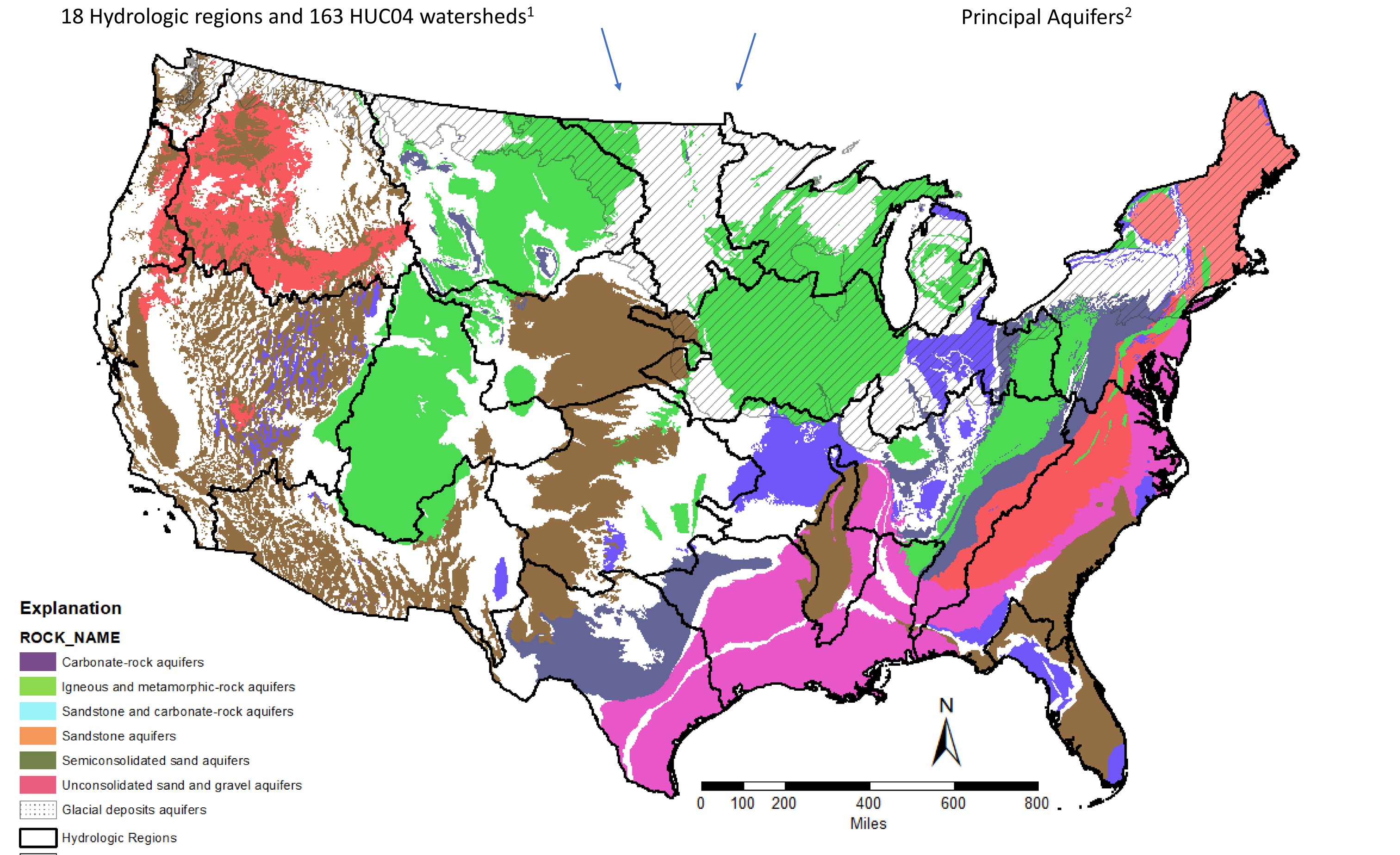
Aquifer lithology influences geogenic contaminant distributions. HUC04 watershed basins can be used to break up the PAs into rankable units and provide consistency between USGS ranking efforts[1].

These PAs represent more than 90% of groundwater-sourced drinking water supply in the United States.

18 Hydrologic regions and 163 HUC04 watersheds[1]



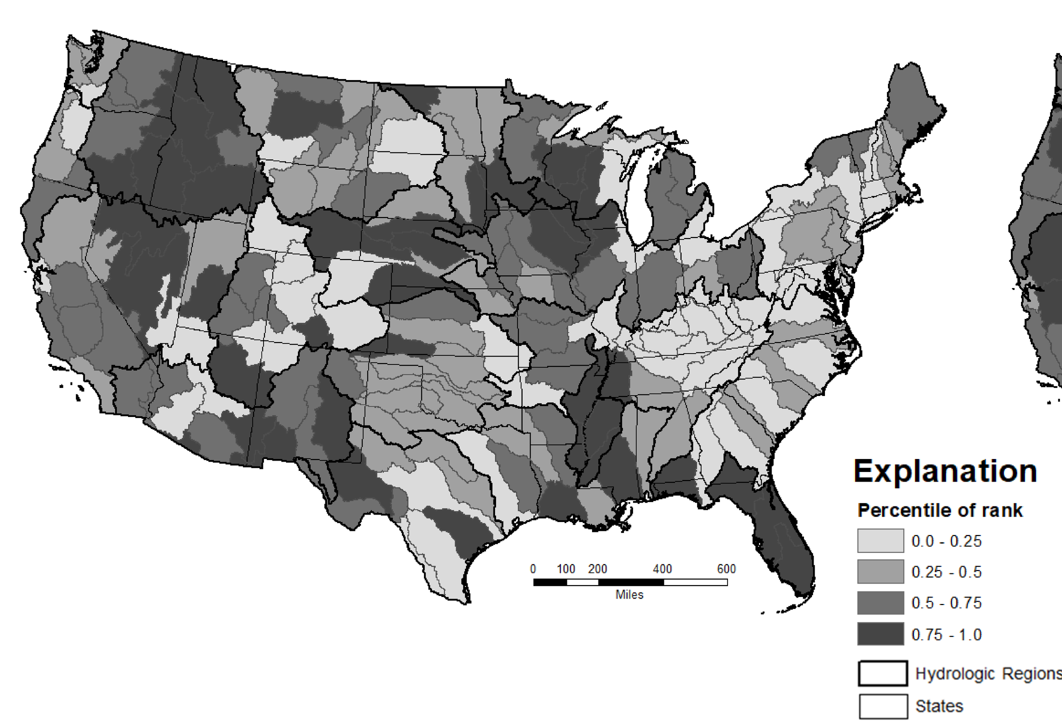
Principal Aquifers[2]



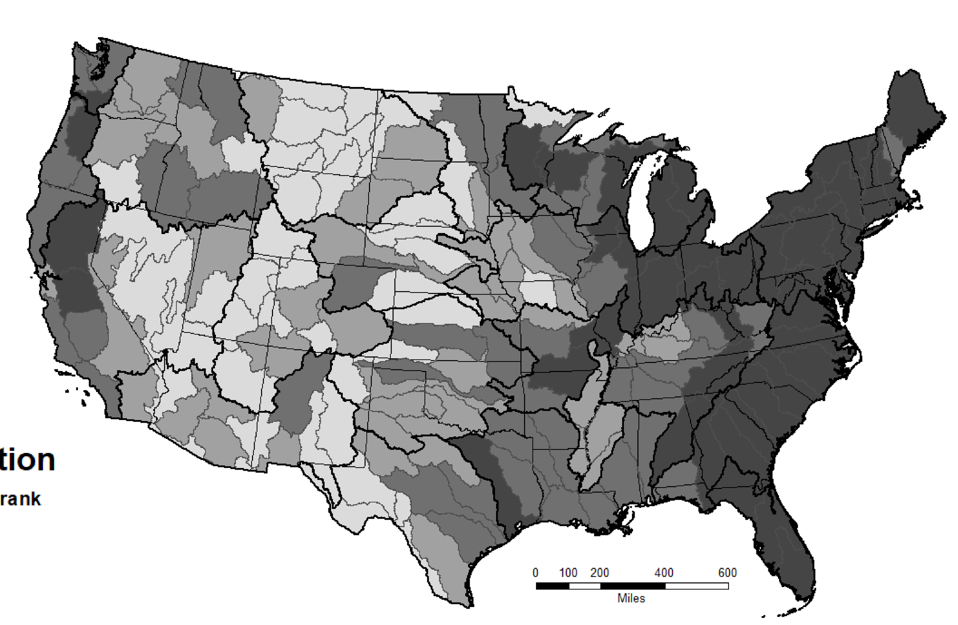
Examples of national variable rankings for 4 individual variables.

These variable numbers are consistent throughout the poster. These examples illustrate how different variables yield different rankings within HUC04 watersheds in different regions of the country, how rankings can vary within a hydrologic region, and by extension, how individual variables influence the overall national, regional, and HUC04 watershed rankings.

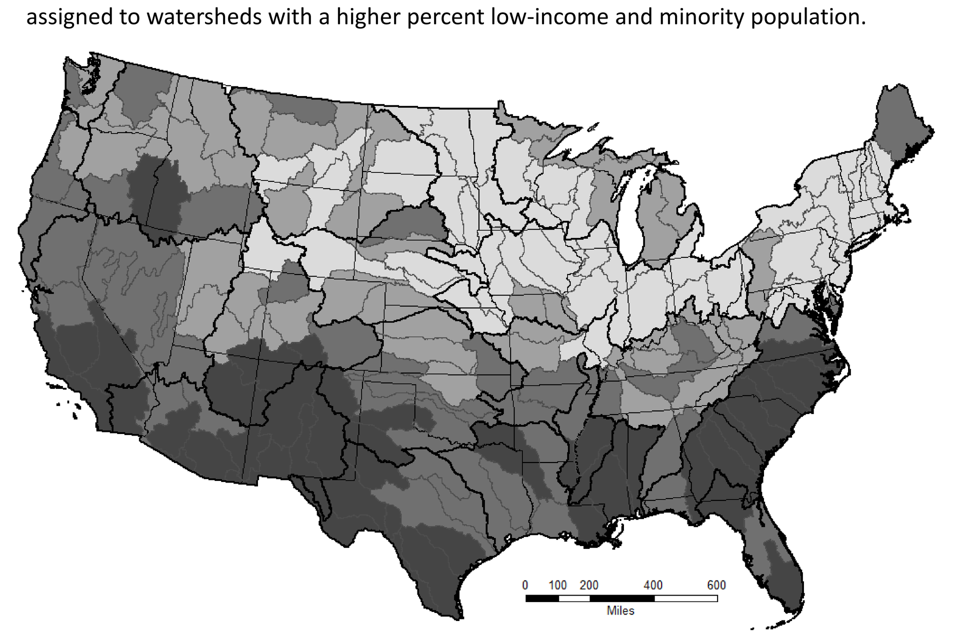
Var4) Percent of population using groundwater for drinking water. Higher rank is assigned to watersheds with a higher percent using groundwater.



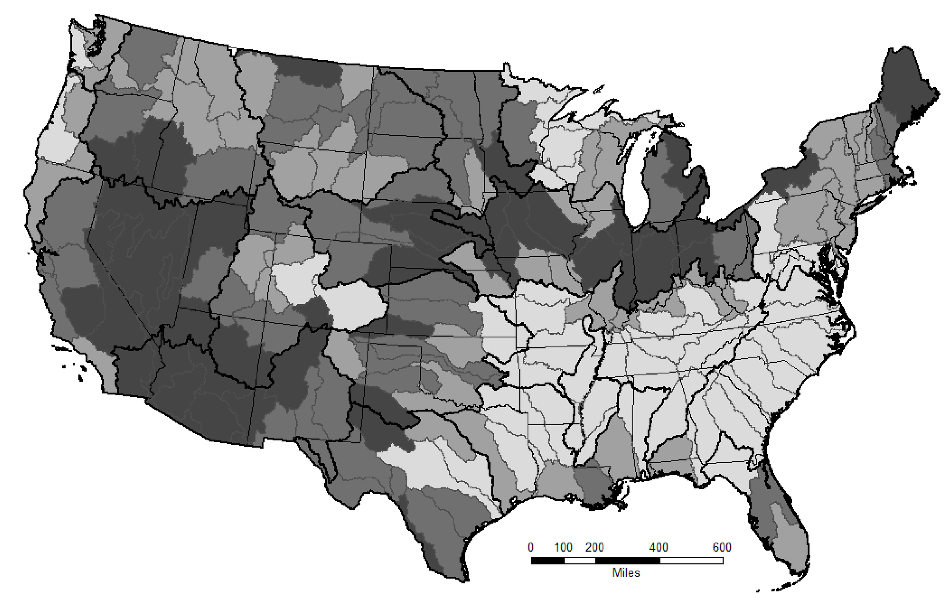
Var8) Population served by domestic wells for drinking water. Higher rank is assigned to watersheds with a larger population using domestic wells.



Var6) Sociodemographic measure based on income and race. Higher rank is assigned to watersheds with a higher percent low-income and minority population.



Var11) Groundwater with arsenic concentrations > 5 µg/L. Higher rank is assigned to larger percent of watershed area modeled as high probability of arsenic >5 µg/L.



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