

# Where and how is streamflow altered in the United States?

<https://hovergirl.wordpress.com/photos/banner-archive/>

## INTRODUCTION

The United States Geological Survey (USGS) national streamgauge network provides essential streamflow records to local, state, and national agencies. These gages track the effect of floods, droughts, climate, and land use changes, allowing stakeholders and decision makers to estimate risk and plan for the future.

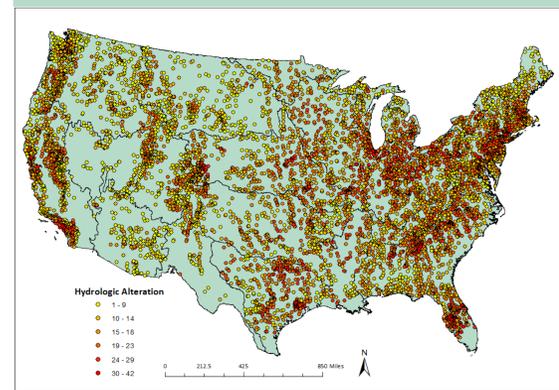
We also rely on streamflow information for drinking water management, hydroelectric power production, and protection of wildlife habitat. Therefore, it is important that these gages report accurate and reliable flow data.



<http://www.fondriest.com/news/stream-gauge.htm>

A combination of climatic, landscape, and anthropogenic characteristics including precipitation, air temperature, land use, and catchment aspect and elevation influence streamflow regimes. The management of stream and river systems not only rely on our ability to characterize streamflow, but also understand the relationship between the factors that affect streamflow. The USGS came up with the hydrologic disturbance index, which is based on seven variables:

### Level of Hydrologic Alteration of Streamgages



- 1) Major dam density, 2) Water withdrawals, 3) Change in dam storage 1950-2009, 4) Percent of stream kilometers coded as "Canal," "Ditch," or "Pipeline" 5) Density of National Pollutant Discharge Elimination System, 6) Road density, and 7) Level of fragmentation by development.
- The map to the left depicts the level of hydrologic alteration in streamgauge watersheds. The hydrologic disturbance index only takes into

account anthropogenic influences, and not climatic characteristics. With heightened impacts of climate change, it would be useful to know where streamflow might be impacted by climate and anthropogenic factors. Another gap to address with hydrologic alteration is that while this system may indicate gages that may not be reliable to predict streamflow, it does not take into account the differences in hydrologic alteration over space. For example, what is causing hydrologic alteration in the western U.S. is different than what is controlling streamflow in the East. Through spatial analyses and regressions, this study aims to address:

- 1) Where do areas of high precipitation and temperature overlap with areas high hydrologic alteration?
- 2) Does hydrologic alteration have spatial components that are lost when aggregated into an index?

## DATASET

The streamgauge network used in this project is from the dataset, GAGES-II, an acronym for Geospatial Attributes of Gages for Evaluating Streamflow, and it is available online at the USGS website. There is geospatial data for 9,322 USGS stream gages. In the dataset, there are over 200 attributes associated with the gages, which are related to climate, geology, and hydrologic alterations within the gages' watersheds. The major variable of focus in this study is hydrologic alteration, which has Low values that represent low anthropogenic hydrologic modification in the watershed and high values that are high anthropogenic hydrologic modification.

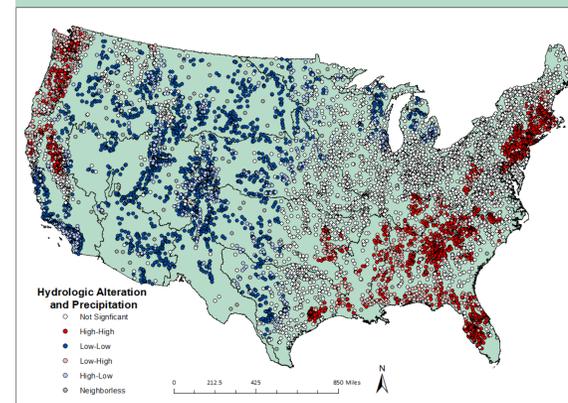
Below the streamgauge network is a layer of 21 major watersheds that piece together the U.S. This shapefile was also acquired online at the USGS website.

## METHODS

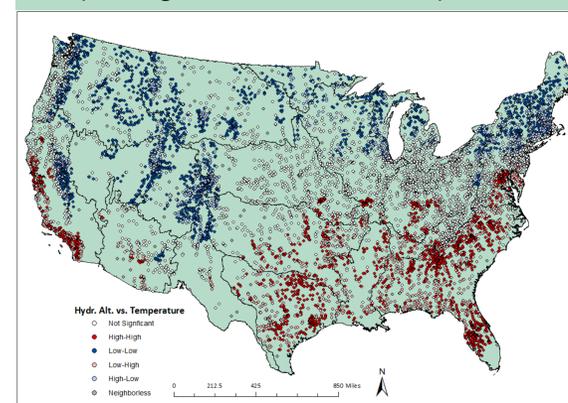
Through exploratory spatial data analysis in GeoDa, a geospatial analysis program, and ArcMap, I assessed the distribution and basic statistics of the variables included in this analysis. To begin the spatial analysis, I created a distance based weight matrix with a threshold distance of 50 km, which assigns a set of neighbors to each observation to analyze the similarities between locations and values. Next, I looked at the clustering of hydrologic alteration with temperature and precipitation. I used Bivariate Local Moran's I, which is a tool that regresses one variable (y) on the values of another variable (x). The output of the Bivariate analysis gives a significance map, cluster map, also known as a Local Indicator of Spatial Analysis (LISA) map, and Moran's I scatter plot. The LISA maps display significant spatial clusters or outliers for each gage location. The Moran's I value explains how spatially autocorrelated the two variables are. When there is a positive spatial autocorrelation, there are more spatial clusters for high-high or low-low values than high-low or low-high values. When it is positive, there are clusters of high values correlated with neighboring values or low values correlated with low neighboring values. When data are spatially autocorrelated, it is possible to predict the value at one location based on the value sampled from a nearby location. Therefore, I also used spatial regression to assess the relationship between temperature and precipitation on the hydrologic disturbance index. I tested this relationship using an OLS regression and then used spatial autoregressive models (SAR) to account for the spatial autocorrelation. The SAR model includes the spatial context of each observation and considers the spatial error and missing variables.

## RESULTS

### Hydrologic Alteration and Precipitation



### Hydrologic Alteration and Temperature



The LISA maps on the left show the results of clustering hydrologic alteration with the climatic factors of temperature and precipitation. Because there is a positive spatial autocorrelation between the two variables, there is significant clustering of gages with high values of hydrologic alteration and high values of precipitation along the east coast and the northwest coast. One implication of this relationship is the combined effect of the two variables, which could lead to higher flows and flooding during storm events. Hydrologic alteration and temperature also have a positive spatial correlation. Higher air temperature could exacerbate the effects of thermal pollution into waterways, which can occur because of urban runoff or hot water discharges from powerplants. The results of the regression analysis are summarized on the top right. Temperature has a positive correlation with hydrologic alteration while precipitation has a negative correlation. It makes sense that there is a low R<sup>2</sup> value because hydrologic alteration is determined solely from anthropogenic influences. However, what is interesting is the improvement in the spatial regression model, which shows an increase in the R<sup>2</sup> value and statistical significance for both precipitation and temperature.

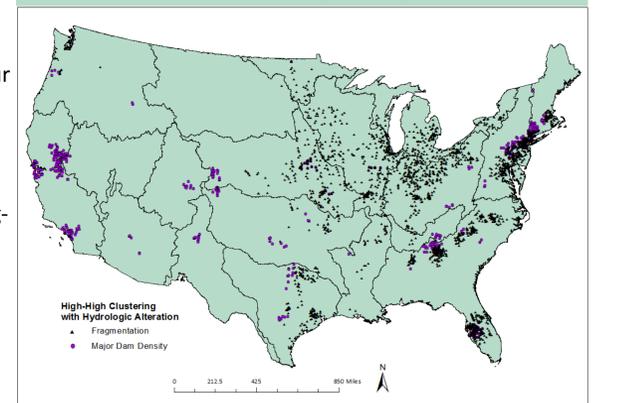
The map on the right shows high-high clustering of both hydrologic alteration with fragmentation and hydrologic alteration with major dam density. While fragmentation and major dam density are only two of the variables that were used to predict hydrologic alteration, there is clear differences in where they cluster in relation to hydrologic alteration. The level of fragmentation due to development clusters in the Mid Atlantic, Upper Mississippi, Ohio, and the Great Lakes regions. On the other hand, high-high clusters for major dam density fall more in the western half of the U.S.

### Prediction of Hydrologic Alteration (n=9,058)

Variable	OLS Regression	Spatial Error Model
Constant	11.12898*	11.94476*
Ave Annual Precip	-0.001665	-0.0177004*
Ave Annual Temp	0.40956*	0.4274434*
Adjusted R <sup>2</sup>	0.089485	0.410101

\*significant at p<0.0001

### Spatial differences in Hydrologic Alteration



## CONCLUSIONS & LIMITATIONS

The positive spatial autocorrelation between hydrologic alteration and precipitation and temperature highlights the possibility that the effects hydrologic alteration have on streamflow could be magnified when temperature and precipitation are added to the picture. Therefore future analyses of streamflow should take into account the combination of anthropogenic and climatic variables when looking at stream gages in these high-high clustered areas. Because there are pretty stark differences in what type of hydrologic alteration occurs spatially, there should be an index of hydrologic alteration based on region instead of the entire USGS streamgauge network. This way, scientists and stakeholders can better understand how streamflow is impaired. A limitation of this study stems from the distance-based weights. Observations that are more connected than others may give more weight in the model. It would have been useful to show the effect of different distance based weights on the cluster analysis.

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**Class** UEP 294- Advanced GIS  
**Professor** Sumeeta Srinivasan  
**Projection** NAD 1983 Albers  
**Data source** [http://water.usgs.gov/GIS/dsdl/gagesII\\_9322\\_point\\_shapefile.zip](http://water.usgs.gov/GIS/dsdl/gagesII_9322_point_shapefile.zip)