Capturing the Annual State of Indiana Water Resources

Stephen J. Kines[a], Laura C. Bowling[b,c], Keith A. Cherkauer[a,c]

[a] Agricultural and Biological Engineering, Purdue University, West Lafayette, IN. 47907

[b] Agronomy, Purdue University, West Lafayette, IN. 47907

[c] Purdue Climate Change Research Center, Purdue University, West Lafayette, IN. 47907

Key Points:

- A methodology is presented for generating a consistent assessment of the annual water resources for the state of Indiana.
- Metrics quantifying water state are used to put the most recently completed water year into context with the previous 29 years.
- Analysis results are made publicly available via the State of Indiana Water Resources Website (https://iwrrc.org/indiana-water/).

1. Abstract

Quantifying annual fluctuations in the volume of water resources available for public and private use is essential for planning. Although data is available to quantify the state of water resources across the United States, many Federal and State level agencies develop their own systems for serving the data to the public. Additionally, the time period for analysis is inconsistent between systems, and even between sites on the same system. We have developed a single centralized web site for disseminating information on water quantity in Indiana that provides an annual snapshot of water resources at the start of each water year. Analysis presented here was conducted using USGS water data for the last 30 water years up to and including the 2017 water year. The current state of Indiana water resources was assigned based on a ranking of how the current groundwater and surface water metrics compare to previous water years. The statistical significance and magnitude of 30 years trends are also calculated. The 2017 water year had above average mean water levels for both surface and groundwater. Over the past 30 years, there has been an overall increase in surface water levels with no overall trend in groundwater levels. The rankings and long-term trends can also be displayed geospatially to represent the location and status of water resources within Indiana using interactive webmaps. These webmaps and other water resource summaries are shared with the public through the State of Indiana Water Resources Website (https://iwrrc.org/indiana-water/).

2. Introduction

Water resources are here defined as sources of water that are of sufficient quantity to meet human needs, when and where they are needed. Water, regardless of its form, can be viewed as a unitary resource as excess surface water can refill groundwater and groundwater is often extracted, used, and then returned as surface water in streams (Rogers, 1992). Because of this, surface and groundwater should be evaluated concurrently when looking at overall water resources. These resources reflect both water supply – the useable sources of surface and groundwater, as well as demand, where and when is water being extracted for what purpose. Long-term water scarcity results when these two are out of balance, such that the human demand for water represents the majority of renewable supply. Sustainable water resources management therefore reflects a management approach that ensures that these resources will be available to meet the human and ecosystem needs of the future (WCED, 1987; Sandoval-Solis and McKinney, 2014). Loucks (1997) concluded that sustainable water resource systems can be classified as those that contribute fully to the objectives of society as they are currently, as well as in the future, while still maintaining the ecosystems supported by these resources. Sustainable use of water resources therefore requires the balanced allocation of renewable natural resources to people, farms and ecosystems. Balanced allocation in turn requires that we understand the nature of the available resources, including the mean, seasonal variability and extreme conditions.

The problem is, that although many federal (e.g., United States Geological Survey [USGS], National Oceanic and Atmospheric Administration, United States Corps of Engineers) and Indiana state agencies (e.g., Indiana Department of Natural Resources, Indiana Department of Environmental Management) have their own publicly-available databases of water quantity, there is no one portal to obtain an overall summary of water availability for the entire state of Indiana. Each agency has its own website and methods of displaying this information, their own data formats, and their own methods for computing summary statistics. The State of Indiana Waters Website was therefore created in order to provide the general public with an up-to-date quantitative look at water resources in Indiana (https://www.agry.purdue.edu/indiana-water). This site provides a framework for analysis of historical observations using uniform periods and summary statistics to assess the current state of Indiana water resources, to quantify how those resources have changed over time and to make results available via an easily accessible web portal designed to inform the public of the state of Indiana's water resources. This paper presents the analysis methodology along with a static view of the 2017 water year, while results on the web site are dynamic and are updated annually to reflect the most current state of water resources.

3. Methodology

3.1. Data Preprocessing:

Data for this project was acquired from the United States Geological Survey [USGS] online database (U.S Geological Survey, 2018). Groundwater and surface water daily data for the previous 30 water years up to and including the most recent water year was used. Water years are defined by the USGS to begin on October 1 and end on September 30 (USGS, 2016). For this paper this was the 1987 water year through the 2017 water year. This cutoff was chosen to balance the selection of sites with a record length sufficiently long for trend testing, while minimizing the loss of stations without a sufficient record length. Limiting the length of record allowed for the creation of a uniform geospatial comparison across the state. More information regarding the time period and data types used can be found in Table 1.

Data quality was evaluated based on several constraints. Records that did not have complete dates (day, month, year) were removed. Any no-data values such as ice-affected stream discharge values were excluded from analysis. Also, any years in which the monitoring sites did not have at least 300 daily data values were excluded. Additionally, only sites with at least 24 years of acceptable data were used for analysis. For the trend analysis, there were 33 groundwater sites and 108 surface water sites with adequate data for long-term trend analysis. For the current state analysis, which also requires adequate data for the most recent water year (2017), there were 31 groundwater sites and 106 surface water sites used. The number of sites displayed on the website used will be updated annually as the number of stations meeting the analysis criteria changes.

There were several additional steps required to prepare a consistent statewide groundwater dataset for analysis due to greater variation in how data is made available. All groundwater measurements were converted to depth below the land surface. Several sites provide the water level as a height above a specified datum. For Indiana, the USGS used two datums: NAVD88 and NGVD29. The elevation and datum were both provided within the metadata for each USGS site. Conversion to depth below the surface was completed by subtracting the reported elevation of the surface from the height of the water table when both were measured from a consistent datum. Values were reported as negative depth so that the direction of trends has the same meaning as for surface water (positive trend in the metric means and increase in water availability). Because each site used the same datum for the entire period of record and the there was no cross-site analysis being performed, this was deemed an acceptable method to normalize the data, resulting in a consistent datum independent measurement of depth below the land surface.

Groundwater data also contained several different types of daily values. These included mean, maximum, minimum, and value at midnight. Each site had a different combination of these data types. Analysis was based on mean daily water level, but how the mean was determined depended on what data was available. If the mean level was reported by the USGS, it was used directly. If it was not, then the average of the daily maximum and minimum water level was used as an approximation of the mean water level for that day. If neither of these variables was available for the day, then the midnight reading was used as the mean daily water level. For sites with minimum and maximum daily measurements, there was found to be minimal variation in daily groundwater levels with the average daily range being 0.15 ft. Therefore, all of the above water level calculations were deemed to be appropriate approximations of the mean daily value.

3.2. Current State Analysis:

The metrics chosen to represent the current state of Indiana groundwater were annual mean, annual (one-day) maximum, annual (one-day) minimum, and annual range (annual one-day maximum minus one-day minimum), as well as the value on September 30th (the last day of the water year). Annual extreme values of the one-day maximum and one-day minimum water level were chosen to represent the periods of high and low water levels, respectively. Range was chosen to represent the rate and degree of recharge of the groundwater over the course of the year, and the September 30th value was chosen to be the 'current state' of groundwater resources in Indiana as it is the last recording for the water year, and the change between one water year and the next represents the direction of the annual water balance.

Surface water metrics were similar to those for groundwater, with the exception that range was not included, and the 7-day minimum flow was chosen in place of the 1-day minimum water level to better represent longer duration dry periods.

To determine the current state of Indiana waters, the current water year metrics were ranked against the previous 29 water years for each of the metrics using the Hazen formula for assigning non-exceedance probability (Hazen, 1914). This is a simple yet widely accepted method of assigning empirical probability that can be applied to a variety of data and distributions (Cunnane, 1978; Harter, 1984). This makes it an appropriate choice for hydrologic studies. The Hazen formula is given by:

$$H = \frac{i - 0.5}{n} \times 100\%$$

Where, *i* is the ranking of the annual value (1 is smallest, n is largest), and *n* is the number of years of acceptable data for the site. Values closer to 100% indicate wetter than average conditions (high probability that observed values are less than this value), probabilities closer to 0% indicate drier than average conditions, and probabilities around 50% indicate median conditions. We consider this 50^{th} percentile value to be baseline or "normal" conditions for the 30 year climatology. The non-exceedance probabilities of the range of groundwater levels actually indicates the degree of variability in annual conditions, where a probability close to 100% indicates above average variability in a given year.

3.3. Long-term Trend Analysis:

Annual trends were calculated for many of the same metrics used for the current state analysis. The metrics used were annual mean, 1-day maximum, 1-day minimum (groundwater), 7-day minimum (surface water) and range (groundwater). These trends were evaluated using the non-parametric Mann-Kendall test (Kendall, 1975; Mann, 1945). This test is rank based and works well with hydrologic data, which often has a skewed distribution with prevalent outliers. This test has been widely used in many streamflow studies both in Indiana and worldwide (Kumar et al., 2009; Linns and Slack, 1999; Dixon et al., 2006; Birsan et al., 2005). This makes it an ideal test for trend analysis for both Indiana surface and groundwater. For this study a 90% significance level was chosen as the cutoff when determining if a trend was significant or not.

Because the Mann-Kendall test only provides the statistical significance of the trend being examined, the Thiel-Sen slope approximation method was used to estimate the magnitude and direction of the trends (Sen, 1968; Thiel, 1950). The resulting units used to display trend magnitude were [in/yr] for groundwater. For surface water, the daily flowrate was integrated over time yielding a volume of discharge, and then normalized based on the drainage area of the watershed at the gauging location. The resulting rate of change is then a depth per unit time with the same units as the groundwater trend [in/yr]. English units were used for improved communication with the public through the web interface.

4. Results

4.1. Current State:

The results displayed here are a static snapshot for the water resources as of the conclusion of the 2017 water year. The water year 2017 was selected for presentation because the year ended with more variation in water resource rankings than more recent years. An assessment of water resources for the most recently concluded water year, using the methods described here, can be found on the State of Indiana Water Resources Website (https://iwrrc.org/indiana-water/).

4.1.1. Groundwater

The median Hazen rankings for the 31 groundwater sites were calculated for each of the metrics and can be seen in Table 2. Groundwater results were separated into two groups based on whether the aquifer being monitored was within the zone of glacial deposits or was a bedrock aquifer. Due to the limited number of sites for each type of bedrock aquifer, all types of bedrock aquifers were treated as a single entity.

Mean water table depths for all observing wells in Indiana were on average wetter than normal (59.3%), with 19 out of 31 sites ranked wetter than normal. The majority of sites are above normal for both glacial and bedrock aquifers. The annual mean probabilities were plotted spatially and can be seen in Figure 1. Sites across the state were wetter than normal with the exception of the northeast and southwest corners of the state where non-exceedance probabilities were lower. The end of the 2017 water year (September 30th) was slightly below normal with 18 out of 30 sites having non-exceedance probabilities less than 50%. One site has no data reported after mid-August, so is not included in the end of year rankings. There were no apparent spatial patterns for the end of year state.

Annual maximum groundwater levels were near normal, while the minimum water levels were higher than normal with 74% of the sites having non-exceedance probabilities greater than 50% (higher percentages indicate wetter conditions). The drier sites with were generally located in the northeast corner of the state. The range in groundwater level in 2017 was less than normal, but this is almost entirely due to the bedrock aquifers with an average probability of 36.4%, while the glacial aquifers reflected median values (probability 49.2%). This was also seen as a spatial pattern, as sites below the 40^{th} parallel are predominantly located in bedrock aquifers and displayed probabilities below normal for annual range. There were no other discernable differences between glacial and bedrock aquifers in the state for any of the other calculated metrics.

4.1.2. Surface Water

Mean non-exceedance probabilities for the 108 surface water sites were calculated for each of the metrics and can be seen in Table 2. The 2017 mean annual flow was above normal with 86% of the sites having non-exceedance probabilities greater than or equal to 50% and an average probability of 72.3%. The majority of the state had non-exceedance probabilities for mean annual flow that were well above normal with the exception of sites below 39° N, where sixteen of the twenty sites had below normal conditions (Figure 2). The end of year surface water levels were lower than normal based on the September 30th values with 71% of sites having non-exceedance probabilities that are lower than 50%, for an average ranking of 42.0%. There was no apparent spatial pattern for end of year rankings for surface water.

On average maximum water levels were normal for the 2017 water year, though there was spatial variation present in the results. The majority of sites to the north of the Wabash River, which crosses the state from east to west and south from 41^{st} parallel to the 40^{th}, experienced below normal maximum flows, despite the higher than normal mean flows. The majority of sites south of the 39^{th} parallel also experienced above normal maximum flows despite below normal mean flows. Minimum flows were above average with 89% of the sites having Hazen probabilities greater than 50% and an average Hazen ranking of 42.0%. There were no discernable spatial patterns for annual minimum.

4.2. Trends:

4.2.1. Groundwater

The Mann-Kendall statistical test was utilized to determine the presence of long-term groundwater trends, and the breakdown of the number of sites displaying each trend along with directionality for each metric is presented in Table 3. For mean annual depth to groundwater, there was no apparent statewide trend. Fifty-eight percent of wells were found to have increasing trends with 15% of the wells having statistically significant trends (p-value < 0.10). Twenty-one percent of all wells were found to have statistically significant decreasing trends. There was minimal difference between glacial and bedrock wells. Thirteen out of the nineteen glacial aquifer wells were found to have increasing trends, with only three of these statistically significant. Five of the glacial aquifer wells were found to have statistically significant decreasing trends. The overall average trend magnitude for the sites was also negligible for annual mean at -2.17×10^{-4} in/yr. Trends for the maximum or minimum metrics were more mixed, with slightly more sites experiencing increasing than decreasing trends. The annual range has been increasing at 64% of the sites, but only 15% of the sites experienced a statistically significant increase. Three percent of all sites have a statically significant decreasing trend.

These trends were also evaluated spatially, and the plot of the annual mean depth to groundwater trends can be seen in Figure 2. All seven sites experiencing statistically significant decreasing trends in mean depth to groundwater are north of the 40th parallel, and all five sites with statistically significant increasing trends are to the south of the same line. Annual maximum, minimum, and range did not experience any noticeable spatial patterns in trends. Additionally, there were no geospatial differences between glacial and bedrock aquifers in the state.

4.2.2. Surface Water

Trends and their corresponding directionality were also calculated for surface water data (Table 3). For mean annual flow, 89% of the sites (98 out of 108) were found to have increasing trends with 22% of all sites experiencing statistically significant increasing trends. There were no sites with significantly significant decreasing trends. The average change in magnitude for annual mean streamflow was 8.79×10^{-7} in/yr. For annual maximum flow, 74% of sites were found to have increasing trends, but only four sites experienced statistically significant increases. Most sites also experienced increases in minimum flow (68% of sites), and 24% of all sites experiencing statistically significant increases.

The calculated trends for annual mean flow rate for each of the surface water sites were plotted spatially in Figure 2. The majority of sites were found to have increasing trends in annual mean flow with the exception of the northeast corner of the state where trends were primarily decreasing, though no sites with decreasing trends were statistically significant. Sites with statistically significant increases were mostly clustered in the center of the state, around Indianapolis and its suburbs. There were no discernable spatial patterns related to the annual maximum flow metric. For the 7-day minimum flow, there were two clusters of sites that had statistically significant increasing trends, one around Indianapolis and another around Chicago/Gary in the northwest corner of the state.

5. Discussion

Overall, the groundwater and surface water levels in Indiana in 2017 were higher than normal as compared to the 29 water years prior, indicating that water resources in the state were above average in 2017. Maximum groundwater and surface water levels were normal for the 2017 water year indicating there were little to no extensive periods of extreme wetness. Additionally, minimum levels were well above average indicating there were no significant droughts in the 2017 water year. Water levels at the end of the 2017 water year were slightly below normal when compared to the end of previous water years for both groundwater and surface water. Below normal water conditions at the end of the water year suggest that annual recharge is delayed, and conditions require additional observation over the winter.

There were similar spatial patterns for both groundwater and surface water resources. The southern part of the state (south of the 39th parallel) showed surface and groundwater water resources slightly below normal. This area is not strongly influenced by urban or agricultural land uses, so the pattern of below average water resources in that area for 2017 is likely due to spatial climate variability. There was also a cluster of surface water sites around Indianapolis that experienced mean annual flow rankings well above average for the 2017 water year. These high rankings may best be explained by the increasing trend found in the same area during trend analysis.

Trend analysis identified an increase in mean flow rates across the state, while mean groundwater levels have remained fairly constant. There were no statewide trends detected for maximum or minimum groundwater levels or annual maximum flowrates for surface water. Surface water 7-day minimum flow rates were found to be generally increasing possibly indicating an increase in basin storage as a result of increases in precipitation (Douglas et al., 2000). Annual range in groundwater depths was also found to be generally increasing. Spatially, groundwater sites in the southern part of the state were found to have statistically significant increasing trends for annual mean water level. All sites with statistically significant decreases for the same metric are located in the northern half of the state, where there is a greater concentration of significant water withdrawal facilities. Statistically significant increases in annual mean surface water levels were found to cluster in the center of the state around Indianapolis. One explanation for this increase is the effect that population density has on streamflow. Greater population density may result in an increase in streamflow due to the changes associated with land use and increased impervious areas (Slater and Villarini, 2017). The 7-day minimum metric displayed a similar spatial trend pattern as clusters with trends increasing with confidence around both Indianapolis and Chicago. Slater and Villarini (2017) found increasing trends in streamflow as a result of population density in several Midwestern cities including Indianapolis and Chicago.

6. Conclusions

Current state rankings were calculated, and long-term trends were identified for 31 groundwater monitoring sites and 108 surface water streamflow monitoring sites for the last 30 water years up to and including the 2017 water year for the state of Indiana. Hazen non-exceedance probabilities were utilized to created normalized rankings across sites to represent the current state of water resources relative to a consistent 30 year historical period. Trend detection was performed over the 30 year period using the Mann-Kendall statistical test in conjunction with the Thiel-Sen slope estimator to quantify trend magnitude. Overall, the 2017 water year had above average normal water levels for both surface and groundwater. Annual minimum water level was also above average for the 2017 water year indicating there were no periods of sustained drought. The 2017 water year ended with water levels that were below average for both groundwater and surface water. Over the past 30 years, there has been an overall increase in annual mean and annual minimum surface water levels. Over the same time period, there have been no detectible trends in any groundwater level metrics.

In addition to the analysis presented in this paper, a webpage is available through the Indiana Water Resources Research Center (IWRRC; https://iwrrc.org/) that includes interactive ArcGIS based webmaps to show the full results of the study and is updated annually to display results based on the most recent water year with available data (https://iwrrc.org/indiana-water/). Webmaps are available for each of the four categories of groundwater current state, surface water current state, groundwater long-term trends, and surface water long-term trends. Layers depicting each of the calculated metrics and their corresponding magnitudes are displayed within the maps.

6.1. Acknowledgements

This research is/was funded as 2017IN406B under the provisions of section 104 of the Water Resources Research Act of 1984 annual base grants (104b) program through the

United States Geological Survey and distributed through the Indiana Water Resources Research Center, www.iwrrc.org.

7. References

Birsan, M.-V., Molnar, P., Burlando, P., Pfaundler, M. 2005. Streamflow trends in Switzerland. Journal of Hydrology 314, 312-329.

Cunnane, C. 1978. Unbiased plotting positions - A review. Journal of Hydrology 37, 205-222.

Dixon, H., Lawler, D.M., Shamseldin, A.Y., 2006. Streamflow trends in western Britain. Geophysical Research Letters 33, L19406. doi:10.1029/2006GL027325.

Douglas, E.M., Vogel, R.M., Kroll, C.N., 2000. Trends in floods and low flows in the United States: impact of spatial correlation. Journal of Hydrology 240, 90-105.

Harter, H.L., 1984. Another look at plotting positions. Communications in Statistics - Theory and Methods, 13:13, 1613-1633.

Hazen, A., 1914. Storage to be provided in impounding reservoirs for municipal water supply. Trans. Amer. Soc. Civ. Eng. Pap., 1308 (77), 1547–1550.

Kendall, M.G., 1975. Rank Correlation Methods. Griffin, London.

Kumar, S., Merwade, V., Kam, J., Thurner, K., 2009. Streamflow trends in Indiana: Effects of long term persistence, precipitation, and subsurface drains. Journal of Hydrology 374, 171-183.

Lettenmaier, D.P., Wood, E.F., Wallis, J.R., 1994. Hydro-climatological trends in the continental United States, 1948–88. Journal of Climate 7 (4), 586–607.

Lins, H.F., Slack, J.R., 1999. Streamflow trends in the United States. Geophysical Research Letters 26 (2), 227–230.

Loucks, D.P., 1997. Quantifying trends in system sustainability. Hydrological Science Journal 42(4), 513-530.

Mann, H.B., 1945. Non-parametric tests against trend. Econometrica 13, 245–259.

Rogers, P., 1992. Comprehensive water resources management: A concept paper. The World Bank, Policy Research Working Paper Series.

Sandoval, S., McKinney, D.C., 2014. Integrated water management for environmental flows in the Rio Grande. Journal of Water Resources Planning and Management 140(3), 355-364.

Sen, P.K., 1968. Estimates of the regression coefficients based on Kendall's tau. Journal of the American Statistical Association 63, 1379–1389.

Sinha, T., and K.A. Cherkauer, 2008. Time series analysis of soil freeze and thaw process in Indiana. Journal of Hydrometeorology 9, 935-950.

Slater, L.J., Villarini, G., 2017. Evaluating the drivers of seasonal streamflow in the U.S. Midwest. Water 9, 695.

Thiel, H., 1950. A rank-invariant method of linear and polynomial analysis, part 3. Nederlandse Akademie van Wettenschappen, Proceedings 53, 1397–1412.

U.S. Geological Survey, 2016. Explanations for the National Water Conditions, accessed January 22, 2019, at URL http://water.usgs.gov/nwc/explain_data.html.

U.S. Geological Survey, 2018, National Water Information System data available on the World Wide Web (USGS Water Data for the Nation), accessed April 9, 2018, at URL https://waterdata.usgs.gov/in/nwis/nwis.

WCED (World Commission on Environment and Development), 1987. Report of the world commission on environment and development: Our common future. Oxford University Press, Oxford, UK.

8. Figures and Tables

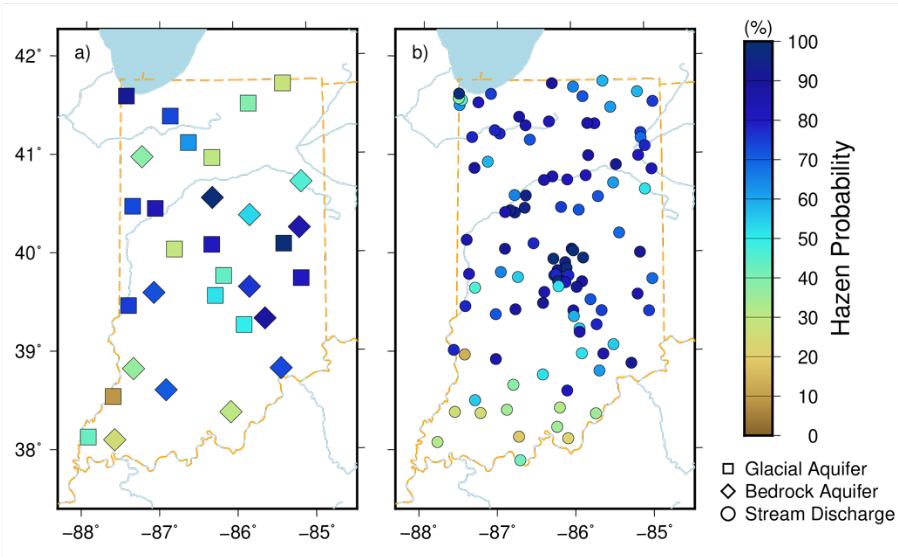

Figure 1. Hazen Non-Exceedance Probability of Annual Mean Levels for Water Year 2017 (a) Groundwater and (b) Surface Water resources. Groundwater site aquifers are classified as glacial (squares) and bedrock (diamonds).

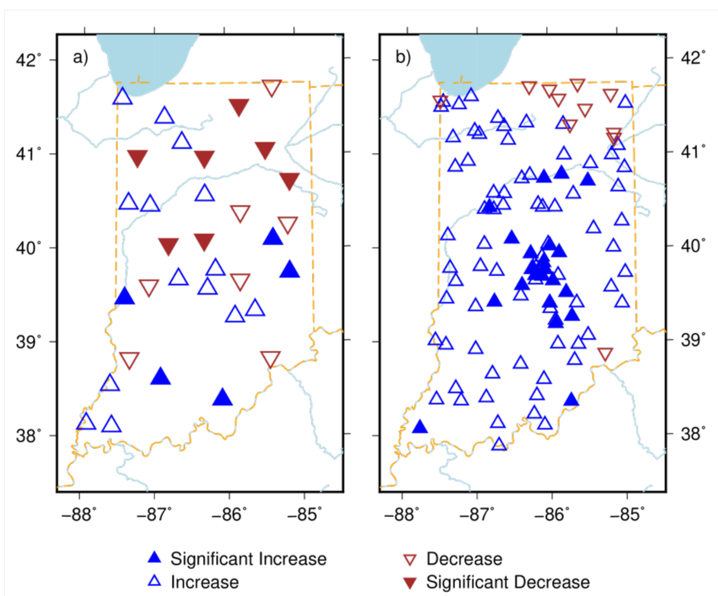

Figure 2. Trends detected in annual mean water levels in Indiana groundwater (a) and surface water (b) over last 30 water years [shading denotes statistical confidence].

Table 1. Overview of measurement types and availability of data records for the assessment of water resources in Indiana.

	Groundwater	Surface Water
Sites with Data	146	259
Record Lengths Available	1 to 60 years (Median: 3)	1 to 105 years (Median: 28)
Study Time Period	October 1, 1986 - September 30, 2017 (30 years)	
Data Type	Mean Daily Measurement	
Units of Measurement	Depth below surface (ft)	Flowrate (ft^3/sec)
Site Data	Latitude, Longitude, Site Number, Site Name	
	Elevation (ft), Aquifer Code	Drainage Area (mi^2), HUC

Table 2. Average Hazen Non-exceedance Probabilities (percentage) of water year 2017 water resource metrics. Also included are the number of observation sites that were above or below a 50% non-exceedance probability in water year 2017. Groundwater metrics are presented as a total of all sites, and filtered by type of aquifer: glacial and bedrock.

		Annual Mean	Annual Maximum	Annual Minimum	Annual Range	End of Year Water Condition
Groundwater (Total) (ft below land surface)	Rank (%)	59.3	53.4	65.0	43.8	43.3
	No. Above	19	18	23	14	12
	No. Below	12	13	8	17	18
Groundwater (Glacial) (ft below land surface)	Rank (%)	58.0	53.3	61.3	49.2	45.0
	No. Above	11	9	12	10	8
	No. Below	7	9	6	8	10
Groundwater (Bedrock) (ft below land surface)	Rank (%)	61.0	53.7	70.0	36.4	40.8
	No. Above	8	9	11	4	4
	No. Below	5	4	2	9	8
Surface Water (ft)	Rank (%)	72.3	50.9	75.1	N/A	42.0
	No. Above	93	54	96	N/A	31
	No. Below	15	54	12	N/A	77

Table 3. Summary of 30-year trends in Indiana water resources. Values presented are number of sites experiencing trends that are statistically significant increases (SI), increases that are not statistically significant (I), have no trend (NO), decreases that are not statistically significant (D), or statistically significant decreases (SD).

	Annual Mean				1-Day Maximum				1 (7)-Day Minimum				Annual Range			
	SI	I	D	SD	SI	I	D	SD	SI	I	D	SD	SI	I	D	SD
Groundwater (Total)	5	14	7	7	5	13	11	4	6	11	9	7	5	16	11	1
Groundwater (Glacial)	3	10	1	5	5	7	4	3	5	6	3	5	4	9	5	1
Groundwater (Bedrock)	2	4	6	2	0	6	7	1	1	5	6	2	1	7	6	0
Surface Water*	24	74	11	0	4	77	27	1	25	46	28	5	N/A	N/A	N/A	N/A

*Several sites had no trend in minimum surface flow due to streams regularly having zero flow for extended periods of time.