WATER AND ECONOMIC DEVELOPMENT IN INDIANA:

MODERNIZING THE STATE'S APPROACH TO A CRITICAL RESOURCE

INDIANA CHAMBER[SM]

LEADING BUSINESS | ADVANCING INDIANA

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Water Advisory Council

This report was produced by INTERA for the Indiana Chamber of Commerce. However, the process of crafting the report and the many decisions about emphasis and structure were made interactively with a diverse set of professionals who met for monthly meetings. This group (listed below) volunteered their time, participated in lengthy discussions and provided perspective on the scientific work to assure that the hydrologic analysis would produce a report that was accessible and on target. They are, in many ways, co-authors of the work.

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ED CHARBONNEAU	Indiana Senate
DOUG ECKERTY	Indiana Senate
ERIC KOCH	Indiana House
JIM MERRITT	Indiana Senate
STEVE STEMLER	Indiana House

COMMON ABBREVIATIONS

IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
IURC	Indiana Utility Regulatory Commission
IGS	Indiana Geological Survey
IDOT	Indiana Department of Transportation
IWRRC	Indiana Water Resources Research Center (at Purdue)
USGS	United States Geological Survey
USACE	United States Army Corps of Engineers
MGD	million gallons per day

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PREFACE

Why water? The Indiana Chamber of Commerce has been asked the same question over the years regarding education and a few other topics.

The answer: Water, like the students in school who go on to become company leaders and comprise the future workforce, is a jobs and economic development issue. In Indiana, we build things. It takes plentiful supplies of water to do so. In Indiana, we want to continue to grow and thrive. Water is one of the necessary elements to support that growth.

Our state has an economic advantage right now with its water availability. Droughts, however, do happen – remember 2012 – and without proper management our water strength will become a liability.

The Indiana Chamber has called for a statewide water resource plan for a number of years. The task force that formed our *Indiana Vision 2025* economic blueprint identified it as one of the key goals in the plan. The time is now to begin what will be a long, but important, process to "ensure adequate fresh water for citizens and businesses."

Thank you to Jack Wittman, Ph.D., of INTERA for his expertise and passion in preparing this in-depth report. Our appreciation goes to the advisory council members, listed on the first page, who shared their insights and dedication to this topic.

It will take a team effort going forward to achieve this much-needed statewide water resource plan. We hope this report will serve as a playbook in that critical game.

Indiana Vision 2025: www.indianachamber.com/2025

Water resource study (including county-by-county data):
www.indianachamber.com/water

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EXECUTIVE SUMMARY

Water is a valuable resource and Indiana, unlike many areas of the country, is fortunate to have abundant water resources. The state has the highest fraction (in the country) of its economy that requires abundant water supplies (Rosaen, 2014). We have built an economy that expects water when it needs it. While current high capacity users are accessing the resource, local shortages have and will continue to occur. Today, only with conservation and proper management, can the state's rivers, streams, lakes, and aquifers sustain current water needs. Future demands will increase with economic growth and industrial development, increasing the need for more formal and technical methods to meet our water supply needs.

Just as water supplies are based on natural conditions that vary from place to place, the demands for water fluctuate throughout a given year and are different between hydrologic basins. This report provides lawmakers, water consumers, and all Hoosiers with useful data that can guide the development of new laws to help manage critical resources and preserve and protect the many water assets of Indiana.

A NOTE TO THE READER:
This document is not a statewide water plan, but rather a background report that provides a basis for developing a plan. The work described here goes beyond data collection about water supplies and demands to include a survey of other states and the approaches they are using to address the emerging issues of water supply planning. Specific recommendations are offered that can help propel Indiana along a path toward a sustainable water future.

Recognizing that water and its many uses – including municipal, industrial, agricultural, and recreational – are critical to economic growth and sustainability, several states are already implementing plans that integrate the management of this resource on a statewide basis. The level of investment in these efforts reflects the specific needs of the state and the level of commitment to water management. States like Texas and Florida spend in excess of $500 million each year on water supply planning, while others like Minnesota and Oklahoma spend around $50 million each year on similar programs. Developing and maintaining a vibrant economy in Indiana means investing in the state's water infrastructure. An evaluation of the scope and magnitude of similar programs around the country and an analysis of available hydrologic data in Indiana suggests that water planning and analysis in the state will require substantial annual investments. If water is viewed as a priority, Indiana should begin drafting a comprehensive water plan. This report is a first step in that process.

Overview of Key Findings

The analysis of hydrologic data in Indiana results in the following key findings with respect to water supply, demand, and the planning process needed to effectively manage the state's water resources.

SUPPLY

North of the Wabash River, Water is Relatively Abundant

In and around the Kankakee River Basin in the northern part of the state, there are thick regional aquifers and reliable, drought-resistant streams. In general, this part of the state has relatively abundant supplies to support expected growth in irrigation and population. However, the recent increases in seasonal irrigation make collecting data on these aquifers and streams important to: 1) ensure future supply reliability; 2) manage the impacts on stream depletion; and 3) determine the sustainable uses in these basins. Since the Great Lakes Compact defines water availability and management in the Great Lakes Basin, it is not included as a factor in this analysis.

Central Indiana has Marginal Supplies

The water supply in Central Indiana is diverse. It includes diversions from the West Fork of the White River, storage in water supply reservoirs in tributary streams, and groundwater from shallow and deep aquifers. The diversification of the water portfolio reflects the fact that there is no single solution to water supply and growth in this portion of the state. Although utilities have identified the need and taken initial steps, supplies are limited and, without new sources, economic growth is at risk.

South of Indianapolis, Supplies are Only Locally Available

In Southern Indiana, local water resources are not always able to meet anticipated future public water-supply needs. Given that this portion of the state is poised for economic growth, it makes sense to provide incentives for developing more diversified supplies for these communities. This may mean targeting distant water supplies, including the large U.S. Army Corps of Engineer (USACE) reservoirs built in the 1960s, as sources that can supplement small community systems and accommodate growth.

DEMAND

Groundwater Use is Increasing

While industrial use, power generation, and mining operations continue to pump water from rivers and streams, over the last decade groundwater withdrawal has increased more rapidly than surface water diversions. The aquifers of the state are becoming increasingly important as a means of satisfying seasonal demands while controlling costs of treatment and conveyance. The water use data reported to the Indiana Department of Natural Resources (IDNR) suggests that this trend will continue if the climate becomes less stable and regional shortages develop.

Irrigation is Expanding in Northern Indiana

Irrigation of row crops continues to be the fastest growing sector of water use in the state, even in some areas that have declining populations. This reflects the significant returns on investment provided by irrigation (primarily new high-capacity wells) and the increasing value of insurance against dry periods. Because most areas that are dominated by irrigation water use also have more prolific aquifers and more reliable water supplies, the primary impacts that require analysis are the seasonal rebound of aquifers from summer pumping, impacts on municipal or industrial neighbors, irrigation well spacing, and the need for additional groundwater monitoring. Actual irrigation water use, rather than numbers of wells, fluctuates according to seasonal rainfall. While additional wells may be installed in many locations, their use increases when there is a deficit of precipitation. This seasonality and annual variability are distinct characteristics of irrigation pumping relative to other users in a basin.

Public Supply Growth Drives Demand in Central Indiana

The population in Central Indiana is growing rapidly, and estimates of future demand suggest another 50 million gallons per day (MGD) of supply will be required to meet the needs of the region by 2050. (Only one third of the water delivered in a public supply system is <u>not</u> returned through the municipal wastewater discharge, National Academy of Science, 2012). As the water utilities in the middle of the state consider new well fields to satisfy growth, conservation and demand management will become standard policy in meeting seasonal peak demand for water. Limited groundwater and relatively low flows in streams limit available options. This part of the state will need to build new surface water storage capable of satisfying future demands or develop well fields in other watersheds. The latter alternative will require that water from distant well fields be piped in to meet the demands of population growth. Before using either alternative to meet the public water supply needs of a metropolitan area, it is important to determine the magnitude of consequences to downstream water users. It is equally important to understand the long-term impacts and risks of any proposed solution before making such an important investment.

Infrastructure Investment: Strategic, Not Opportunistic

The Interstate 69 expansion in Southern Indiana, along with continued funding of the Crane Division of the Naval Surface Warfare Center (Crane NSWC), creates a long-term economic growth opportunity in this part of the state. This growth depends, in part, on the availability of safe and reliable water supplies. Along I-69, water is either abundant or absent. There are few aquifers or perennial streams present immediately south of Bloomington. Further south, however, water is available from along the White and Wabash rivers. Continued development of these investment corridors means ensuring that businesses have access to adequate supplies of water. When new infrastructure is planned, water supply should be an important consideration in the siting process.

Power and Industrial Use May Locally Increase and Continue to Dominate Other Uses Statewide

Throughout the state, the largest surface water withdrawals are not increasing but they may add capacity as opportunities open for new development. Thermoelectric power generators have become more conservative as they switch from coal- to gas-powered plants and develop more efficient designs and operational methods for new facilities. While statewide use is less than prior years, new plants continue to be built. To avoid conflict, new generating stations are often located along the largest rivers to support the cooling water needs of the system. In previous decades industrial water use has steadily declined, and the use of surface water is correspondingly falling. New developments could shift this trend even though estimates of future use account for no increase in these sectors.

PLANNING

Conflicts Can Be Avoided

During the drought of 2012, domestic well owners in some locations sought assistance from IDNR to mitigate problems with their wells (e.g., dry wells or significantly declining water levels). In some cases, high capacity aquifer withdrawals could have been designed or managed to reduce well interference and eliminate impacts. Where these conflicts occur, the uncertainties associated with water supplies have negative impacts on the commercial sector, which relies on these supplies to manufacture products. For the most part, unanticipated water shortages can be avoided through better data collection on the aquifers, using regional water supply models of the hydrologic system, and improved planning that is designed to anticipate the effects of combined withdrawals.

Watersheds are Natural Planning Areas

The water supply planning process includes coordinating, among the various users, the management of limited water resources during times of shortage. By defining regions within a state, which generally coincide with major watershed boundaries, plans can be developed that represent regional water user interests and economic conditions. These regional plans can then be integrated into a comprehensive state water plan. There is currently no coordination of water use in Indiana's major river watersheds and, while implementing a regional/state planning process will require establishing rules and procedures, the cooperation among water users that this process establishes will enhance resource utilization and improve water supply reliability throughout the state.

Development Can Produce Jobs Near Existing Resevoirs

The Brookville Reservoir was built by USACE in the early 1970s for flood control. Like many of Indiana's other reservoirs, the stored water in the Brookville Reservoir, absent other infrastructure and opportunity, is inadequate to attract new investment. Through proactive planning and the systematic renegotiation of priority of use and other issues with USACE, these reservoirs represent development opportunities. Establishing high-water-demand facilities such as bottling plants, breweries, and food processing operations in close proximity to some of Indiana's larger reservoirs offers the potential to add jobs through the use of these available and sustainable natural resources.

Instream Flows Should Be Understood

Generally, the term "instream flows" is defined as the amount of water set aside in a stream or river to ensure downstream environmental, social, and economic benefits are met. Maintaining adequate stream flows can contribute to the basic ecological integrity of the aquatic environment, support endangered species, and facilitate interstate compact compliance. Tourism and recreation also rely heavily on dependable stream flows. While there are definite benefits to maintaining stream flows in some streams and rivers, there are likewise valid concerns to consider, such as potential impacts to consumptive users due to reduced water availability, changes in the location of that availability, and related economic development implications. Regional water planning serves to prioritize instream flows among all other uses.

Conservation Plans are a Necessary Management Tool

Unless the primary source is a drought resistant supply (e.g., the Ohio River), establishing and implementing a conservation plan should be a normal part of every water utility's operations. Implementing conservation plans allows communities to reduce the cost of additional infrastructure and saves customers money. Although these plans may not be able to provide protection from a chronic shortage, they are ideal for infrequent but expected dry spells that have occurred previously and will occur in the future.

Recommendations

While the Indiana Utility Regulatory Commission (IURC), the state legislature, IDNR, and the Governor's Water Shortage Task Force (Water Shortage Task Force, 2009) have all made useful recommendations over the past several years to modernize water supply planning in Indiana, these recommendations have been somewhat general in nature. This report identifies the geographic location of major water resources and future demands within the state to provide a new level of specificity to the water planning tasks that lie ahead. The recommendations that follow, based on the findings summarized above as well as the common elements of other state plans and processes, reflect the steps which need to be implemented within the next decade to set the appropriate course for effective water resource planning in Indiana.

CREATE AWARENESS ABOUT THE NEED FOR WATER SUPPLY PLANNING

Beyond flood conditions, Indiana has never before needed to actively manage water resources. That is no longer true. Changes in water use and natural limits on availability need to be explained to the public. The only way for Indiana to grow economically and demographically is to manage the critical resource that supports industry, power generators, ecosystems, agriculture, and drinking water supplies.

Failure to properly plan for increasing demands in growing parts of the state may create significant water supply challenges. Educating farmers, local government, conservation, and business leaders on the need for responsible water planning and use is a necessary step to long-term water security in Indiana.

Begin Public Outreach

The most important aspect of the water resource planning process is interaction with the public and high-capacity water users. Water supply planning succeeds when people at the local level – irrigators, public water supply operators, power plant operators, industrial water users, gravel and aggregate processors, and coal mine operators – all understand the many uses and long-term value of our water resources. These key stakeholders are generally informed about the local water resource issues. Other states have found that it takes up to three years to understand and document how each region of the state differs in both supply and use, While the public process proceeds, initial analyses could be done to define the state planning regions and develop regional groundwater and surface water simulation tools to determine water availability. This is an investment necessary to define local needs and provide information that will guide the work. Outreach is critical to determining the most practical processes and geographies needed to manage technical data and models.

Conduct Statewide and Regional/Local Outreach

It is important to remind the public of the values that underlie the commitment of diverse stakeholders and government to responsible water resource planning. This could be initiated with a statewide symposium to focus on the importance of water to our economy and to listen to the many perspectives of forward-thinking water users. Local and regional meetings can be held to describe the water resources in each region and to record different concerns and questions that are offered by the public. These local and regional meetings should be professionally coordinated and conducted by a credible organization (e.g., a university) to ensure that information gathered is used to guide the decision-making processes embedded in planning.

CREATE CAPACITY TO COORDINATE EFFORTS

Establish Communication and Accountability Framework

To ensure long-term success, one state-level entity needs to be designated to lead planning efforts of the agencies and universities. The General Assembly should pass legislation that ensures agencies and universities work toward a common goal for water resource planning. There are many state and federal agencies in Indiana that currently play a role in water management. IDNR, IDEM, IURC, IGS, USGS, and state universities all collect data or implement programs that in some way or another protect our streams and aquifers. Collectively, the state relies on these agencies to manage a resource, but without coordination or focus. Sadly, when everyone is responsible, no one is responsible. Given the imperatives of growth, Indiana needs a dedicated team with the technical capacity to support local planning while providing rules, models and data for the broader regional planning process.

Fund Water Research

In as much as Indiana needs to develop new ways to manage this precious resource, it needs to fund research in water resources engineering and policy development. Establishing and using a water planning program to enhance water security means investing in the research needed to understand the state's particular hydrologic systems. Decisions that are being made today, such as how to decide whether to build the Mounds Reservoir upstream of Indianapolis, will impact the availability of water for generations to come. The data, methods, and tools created and developed through research should support the state to help it make the best possible decisions that both protect and promote our water resources.

CREATE A ROBUST SYSTEM FOR MONITORING WATER RESOURCES

Monitor Groundwater Availability

There is little information on total available groundwater in the state. Public and private efforts have been made to describe aquifer dimensions, water levels, well yields and recharge. However, the few clusters of monitoring wells in the aquifers of the state make it impossible to track trends, determine impacts, and provide the validation needed to avoid conflicts among users. An expanded network of groundwater monitoring wells should be installed around the state, beginning with areas of greatest concern, to collect aquifer data to optimize uses and increase short and long-term dependable yields.

Regularly Analyze Low Flow In Streams

The USGS has historically been funded by IDNR and IDEM to observe, report, calculate, and estimate low flow statistics of Indiana rivers and streams. While this information is needed to estimate surface water availability and drought yield, the funding for this work has been sporadic and unreliable. By monitoring flow trends, signals of drought will not be missed. Low-flow analysis can be extended to estimate storage properties of aquifers that discharge into gaged streams. Tracking how low-flow varies over time and within a basin would allow the state to calibrate recharge models and use engineering techniques to better manage supplies during shortage. This would leverage existing cooperative agreements for data collected between USGS and the state.

CREATE A STANDARDIZED SYSTEM FOR DATA ANALYSIS

Evaluate Aquifer Sustainability and Yield

Currently, there is no standardized technical framework for determining and describing the properties of aquifers in Indiana. IDNR, IGS, IDEM, and USGS all maintain data on water levels, flows, and hydrologic properties of aquifers. By developing water availability models for the most heavily used aquifers and river basins in the state, decisions can be made based on integrated assessments of the effects of all water uses. In addition to bringing together the hydrologic data collected by different agencies, the state can use this information to develop basin-scale estimates of aquifer recharge that will inform water use and planning. A feasibility assessment of riverbank filtration well fields along large rivers in the state could also be performed. These well fields offer the potential to increase water yield while reducing some of the negative impacts associated with other types of large well fields.

CREATE SYSTEMS TO EFFECTIVELY MANAGE WATER RESOURCE

Optimize Reservoir Management

There are two different problems associated with reservoir management in Indiana: 1) each reservoir has a different priority of use that reflects the funding and mandate when it was built, and 2) operation of the reservoirs (outside of the Army Corps reservoirs) does not consider downstream uses. This means that a reservoir originally constructed 50 years ago for flood control is operated today in a way that reflects the original mission, regardless of whether the reservoir could be an important supplement to water supplies in some part of the state. Multiple reservoirs within a basin can be operated with an integrated understanding of the needs of all water users. The development and application of hydraulic models, using software codes such as RiverWare or OASIS, enable reservoir operators to manage drought by simulating and optimizing flows within the basin. Properly applied, these models can provide the information needed to make drought plans effective and practical.

Develop Water Demand Forecasts By Drainage Basin

As water resource planning begins across the state, detailed water demand forecasts are needed to account for the regional factors that affect growth and water use. Modeling future changes in demand for the largest surface water users (energy and industrial supply) will be an important part of planning in the southern portion of Indiana. Water demand forecasts provide an opportunity to use the planning process to educate the public about the effect of conservation while providing time frames for engineering and planning studies to fill supply gaps. Understanding the degree to which future demand is affected by prices or population or other economic factors will make predictions of future use more robust during planning. Water demand forecasts ideally reflect the interests of the communities being served and are one example of "home rule."

ALLOW THREE YEARS TO PREPARE FOR IMPLEMENTATION

As the state moves forward with developing a comprehensive water plan, someone needs to lead the way. The only way to evaluate proposals for interbasin transfers, infrastructure development and maintenance, regulatory requirements, priority among different users, responsibility for impacts to neighbors, impacts to ecological flows, as well as public health and safety, is with the technical support provided by an appropriate level of oversight (i.e. state, regional and/or local) and a stable funding mechanism. Planning requires a responsible entity with appropriate levels of authority to provide the confidence needed. The work of an existing agency, organization or university could be expanded to fill this role. It is also possible that the General Assembly and/or the Governor could establish a new entity that has this responsibility. Some tasks may fall to regional or local planning teams put in place to manage their water resources. Whatever structure is created, it will be necessary that the direction of the state and the responsibility of the various parties are articulated in a statewide plan that is supported by the Governor and the General Assembly.

ECONOMIC EFFECT OF WATER AVAILABILITY

As water becomes more valuable throughout the United States, Indiana can become an even stronger economic destination. Long-term planning based on efficient use and a regional approach to managing water supplies will improve the state's economic opportunities, promote continued regional growth, and help secure Indiana's future.

A recent report evaluated the degree to which the economy of each state was dependent on water resources (Rosaen, 2014). **Indiana ranked first in the country in the percentage of the economy that depends on water.** Figure 1 compares the output in 21 economic sectors in Indiana to averages for the entire country, and finds that in several of these sectors Indiana differs quite significantly from the national average. The focus on manufacturing and the growing medical/pharmaceutical industries have naturally made water resources critical to the business investments made in the state. This recent report found that more than 23 percent of the current economy depends on the water that flows over and through the state. As a fraction of Indiana's GDP, this translates into nearly $70 billion. Water is critical to maintaining today's economy, and it will be more important in the future.

Indiana law allows individual high-capacity users to extract supplies from shared resources without constraint. There is no limit on the timing, purpose, or impact of withdrawals. In some cases, high-capacity withdrawals may be limited by the effects of development on homeowners served by shallow wells. This local approach to defining water development impacts may unnecessarily limit the use of resources and is more likely to result in conflicts between users. Local single-user management of water resources generates a patchwork of uneven supply and demand and uncertainty about future yield. Today, high-capacity water users compete for regional resources rather than a system that collects and analyzes data on the resource and then coordinates use.

The existing patchwork of local water delivery systems does not provide economies of scale for supply, regulatory compliance, funding, support systems, or treatment. Some individual high-capacity users do not have the reliable supplies or systems necessary for economic growth. Furthermore, water rates will continue to increase as additional infrastructure and regulatory compliance is required. If no change occurs, the state will be unprepared for future growth and unable to serve increasing demands in an affordable and reliable manner. This locally-focused approach to managing supply and demand does not provide effective response during droughts or other water shortages. Where the region's water systems are not interconnected, it is impossible to move water when local demands outpace local supplies. The inability to move water between users means that during emergencies, a high-capacity user may not have an alternative source of water.

Infrastructure development is only one component of economic development. The other part is coordinating development of infrastructure to magnify the impact of roads and other investments with available water supplies. New interstate highways, airports and public transportation naturally affect the geography of growth and development. Federal facilities and other business growth can lead to additional business opportunities and commerce. The southwestern part of the state has had recent investments in improvements to I-69 and decades of federal support at Crane Naval Surface Warfare Center (NSWC). Regional development should be guided by the cost and reliability of a secure supply of water. Brookville Reservoir and other available storage could be the centerpiece of a strategic plan to attract new businesses to the state.

Figure 1. Comparison of Indiana's economy to the national economy by sector. This graph shows the strength of the state's manufacturing and durable goods sectors.

BACKGROUND

In the summer of 2011, as directed by legislation enacted by the Indiana General Assembly, the state's Water Resources Study Committee met and made the following seven recommendations:

1. Create an inventory of the state's water resources.
2. Identify the areas that will need water in the next 15 years.
3. Review the gaps between where water exists and where it is needed and determine how best to meet any shortcomings – even in the event of drought.
4. Develop industry infrastructure investment priorities.
5. List alternatives for reforming and restructuring water usage and regulation, with special attention to a regional approach.
6. Draft necessary legislation, rules, and best practices to maximize the value of the state's water resources.
7. Prepare a comprehensive plan of water and wastewater needs to put Indiana in the most advantageous position and promote aggressive economic development.

Three particularly critical and immediate needs were identified by the legislature: 1) determine how much water Indiana has; 2) estimate how much water the state will need in the future and where it will be needed; and 3) identify what it will take to satisfy the needs of expected growth for all users.

Based on these recommendations and testimony from a number of interested parties, the 2012 General Assembly passed a bill (SB 132) that required the Indiana Utility Regulatory Commission (IURC) to inventory all drinking water utilities in the state to determine how they were managing their supplies and their systems. The first year's report, delivered by the IURC in the fall of 2013, was based on the responses received from the utilities and included the following eight recommendations:

1. Indiana needs to develop rules or laws to establish procedures for additional significant withdrawals from aquifers, surface waters, or inter-basin transfers.

2. The state should begin integrated water management with a common vision shared by all stakeholders.

3. Water utilities should promote efficiency, sound management, and best practices so as to capture economies of scale.

4. Water utilities should be required to develop drought plans.

5. Managerial, financial, and technical requirements for forming water utilities should be improved.

6. There is a need to evaluate the adequacy of existing resource monitoring – including water levels in aquifers and reservoirs and flows in streams.

7. The state needs to make better use of existing underutilized reservoirs in Southern Indiana and consider the use of quarries and other methods to improve reliability.

8. The state should hold a water symposium to bring all water users, regulators, and consultants together to discuss water policy.

Following this initial IURC report, the Indiana Chamber of Commerce and its Foundation reiterated its position that water supply was particularly critical to the future economy of the state. As part of its *Indiana Vision 2025* economic development plan, the Chamber commissioned this report to describe the nature of the hydrological and institutional problems related to long-term water availability in the state and present a series of recommendations that will best solve those problems.

Purpose and Vision

The purpose of this report is to provide a technical basis for a modern water supply policy for the state of Indiana. More than any other state in the nation, Indiana's manufacturing economy relies on a sustainable and adequate supply of water (Rosaen, 2014). **In its study released in 2014, the University of Michigan-commissioned group found that more of Indiana's economy depends on abundant water supplies than any other state in the nation.** Pharmaceuticals, medical device manufacturers, steel fabrication, and manufacturing, together with power generation and irrigation, support a diverse state economy. While finding an adequate supply of water is a challenge in many arid states, in Indiana regional supplies can be abundant while local resources vary. The state is at the

THE GEOGRAPHY OF INDIANA'S WATER RESOURCES:

Though the scientific tools and techniques in use today were not available decades ago, there were nevertheless many attempts to understand and describe Indiana's available water resources. The droughts of the 1940s in particular stimulated scientists and hydrologists to develop ways to prepare for shortages in the future.

One of the most successful of these efforts was a bulletin prepared in 1951, by the Indiana Flood Control and Water Resources Commission (Perrey et al, 1951). One paragraph from that bulletin, presented below, provides a succinct and accurate picture of the hydrologic conditions in the state that existed at that time and still exist today. The description serves as an ideal illustration of the fact that water resources are assets of the state that are fixed in place by the geologic history of the land.

> *Being located in the more humid part of the midwest, Indiana is not faced with a problem of insufficient total quantity of water being available, but one of having the right amount available in the right place at the right time. Of the water that falls on Indiana as rain or snow, only about 30 per cent is available for use by man. The remainder is evaporated back into the atmosphere. Only a portion of the 30 per cent can be put to practical use, because unequal distribution throughout the year produces excessive quantities during some periods and deficient amounts during others. Nature attempts in a limited way to equalize the availability of water by storing great quantities in the ground during the periods of plenty and releasing them gradually throughout the year. However, the natural underground reservoirs are not uniformly distributed throughout the state, with the result that some areas are not as plentifully supplied as others. Increases in population, expansion of industry, and intensification of agriculture are continually placing a greater and greater demand on available water supplies. In the areas of inadequate natural storage, continued growth and development are being hampered and even stopped.*

headwaters of many streams that drain into continental rivers – so Indiana does not depend on the effects of upstream water use on availability. With exception to the Ohio River, Hoosiers are not "downstream" of other states. Unfortunately, there is no active strategy to manage the state's water supply to ensure the regional resources continue to be abundant.

Integrated water management has not been done in the Midwest. An effective policy based on integrated water management requires a deeper understanding of the resource than most agencies have developed. The planning process requires tools that help hydrologists and decision-makers consider alternative ways to use, conserve, and manage the resource. The planning process connects conservationists and water users with one another while supporting their forecasting needs. Regional collaboration and cooperation are the founding principles of such an open process.

This report provides the foundation for a water supply policy that will allow Indiana to meet its current needs, plan for future innovation and development, and protect the environment that sustains Indiana's position in the nation.

Goals

The primary goal of this report is to set the stage for water supply planning in Indiana that will assure sustainable supplies for as many users as possible. To reach this goal requires a great deal of information, including:

- How the hydrologic systems operate throughout the state
- How the use of water at one time and in one place affects other users in the area as well as future users of the same resource
- How the state's aquifers are storing the water recharged years or decades earlier
- How to meet the needs of agricultural users so that their seasonal water use is replenished by recharge and is not in conflict with others
- How to ensure that drinking water systems have safe and affordable sources of supply that are resilient to drought
- How to deliver adequate water to meet the needs of manufacturing and other industrial users
- How to provide access to water for power generators who create the electricity that drives Indiana's economy
- How to ensure that the aquatic ecosystem, an important end user of the water supply system, is adequately protected

At the same time, this report describes relevant experiences in other states to assist Indiana in developing more effective water governance. Moreover, it advocates for the naming of a responsible group to do the work and for dedicated funding to manage the resource. Ultimately, this report serves as one of the first steps in a process that will determine the best technical approach for Indiana to use in managing its water resources.

INTRODUCTION

The eastern United States enjoys a relatively humid climate. Water is plentiful and has usually been considered a public asset that can be used by power generators, public drinking water suppliers, irrigators, manufacturers, and all other users to maintain a healthy and vibrant economy. Over time, the responsibility of managing water resources has fallen on individual states, and generally the regulatory focus has been on protecting and maintaining the quality of the water.

The benefits of water have always been a *usufructuary* right, a civil law term defined in the box at the left. Historically, it was thought that the combined withdrawals of all users could not alter the hydrologic system; the basic "substance" of the water flowing downstream or stored in aquifers would not be affected. There was often too much and then too little water, but generally use of the resource did not appear to affect availability.

USUFRUCT: *The right of enjoying a thing, the property of which is vested in another, and to draw from the same all the profit, utility and advantage which it may produce,* ***provided it be without altering the substance of the thing.*** *(from The Free Dictionary; emphasis added).*

Irrigators have always added water to their fields to supplement precipitation. Water utilities have delivered what the customer consumes. Power generators have used whatever their demands require, and industrial withdrawals have changed only in response to production. However, the drought that hit Indiana in 2012, the worst in decades, made it clear how many sectors of the economy depend on water availability, and in some areas availability is limited by use. In other words, in exercising usufructuary rights, Indiana water users may in fact be "altering the substance of the thing." With increases in water use and local limitations of the resource, the many unconstrained demands and the uncoordinated timing of withdrawals have caused local conflict.

Today, the Division of Water in the Indiana Department of Natural Resources (IDNR) inventories the water resources of Indiana; the Indianapolis office of the U. S. Geological Survey (USGS) monitors these same resources while the Department of Environmental Management (IDEM) protects the state's rivers and aquifers from pollution. Other agencies map, evaluate, and track some part of the hydrologic system. Each of these agencies may informally work with the others, but each has a very distinct mission and responsibility. This situation, when combined with the uncertainty in supplies, creates a risk to future business. The degree to which electrical power generators, industry, agriculture, and municipalities depend on the water supply suggests that longer-term thinking is needed to fulfill responsibilities to future generations.

The drought of 2012 helped focus attention on the problem of water supply for all users around the state. In July 2012 the National Drought Monitor mapped most of Indiana as in a "severe drought." That summer brought attention to the limits of surface and groundwater resources in Central Indiana, where the newly purchased metropolitan water utility was struggling to satisfy demands. At the same time, the drought demonstrated the value of irrigation wells in the northern tier of the state, where aquifers were being used to make up for the lack of rain during the growing season. In the southern part of the state, small water sources were rapidly diminished as water levels and stream flows declined.

Motivated by this dry spell and the attendant public concern, the Indiana legislature took up the challenge by passing Senate Bill 132, requiring all water utilities in the state to describe their systems and plans for meeting future needs. While new information was developed by the first annual report in 2013, the bill did not include other water users that are pumping from the same supplies as the municipal utilities. A more comprehensive assessment would be required to evaluate all of the water usage in any part of the state.

While the 2012 drought brought much-needed attention to the water resources of the state, even more attention was focused on the fact that there was no single agency that could identify appropriate solutions to the shortage. It became clear that the agencies involved in water regulation or protection each have a different mission, and those differences prevent any one of the existing institutions from addressing the larger problems faced by the many disparate users.

The demand for water is expected to increase as the economy and population grow. As Figure 2 shows, Indiana's current population, just over 6.5 million, is projected to approach 7.5 million by 2050. The increase will not be uniform throughout the state. Most of the new residents will live and work in Central Indiana, particularly in the counties that surround Indianapolis, with some growth stretching out along the major interstates toward Chicago and Cincinnati.

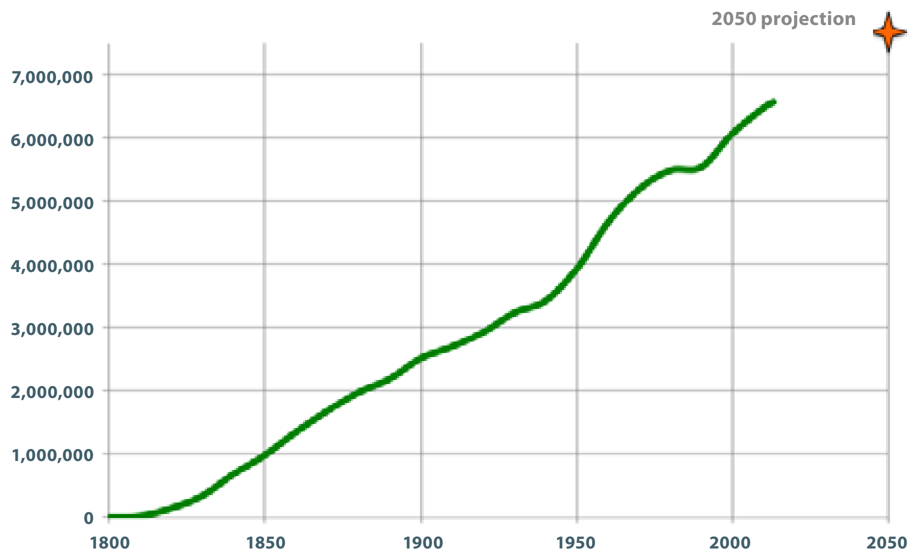


Figure 2. Indiana population from 1800 to 2013. The 2050 projection is an estimate of the Indiana Business Research Center (IBRC 2012) at Indiana University's Kelly School of Business.

Indiana Water Facts

While rainfall varies somewhat from north to south, across the state the annual average stream flow in Indiana streams is 12–14 inches per year. Of that total, Indiana now uses a little more than one-half inch per year for irrigation, power generation, municipal supply, and industry. On average, there is enough water to satisfy the needs of the population, but one problem with water supply is that demand is highest when the resource is least abundant. Another problem is that water supplies are developed as clusters of wells; water is not used evenly across the landscape. Water is needed where there are people, power plants, businesses, and crops. Thus, its use is concentrated in time and space; however, there is adequate water if the resource is properly managed.

The dry conditions in July, August, and September of 2012, which were accompanied by extremely warm temperatures, made it clear that many of Indiana's local water supplies are vulnerable to drought. The preceding decade had been one with 3½ feet of rainfall above the long-term average and, as a result, energy, agriculture, and municipal suppliers had been expanding their water use. While the social and economic impacts of the drought were unanticipated and surprising, the same drought during a decade of average rainfall would have been much more disruptive.

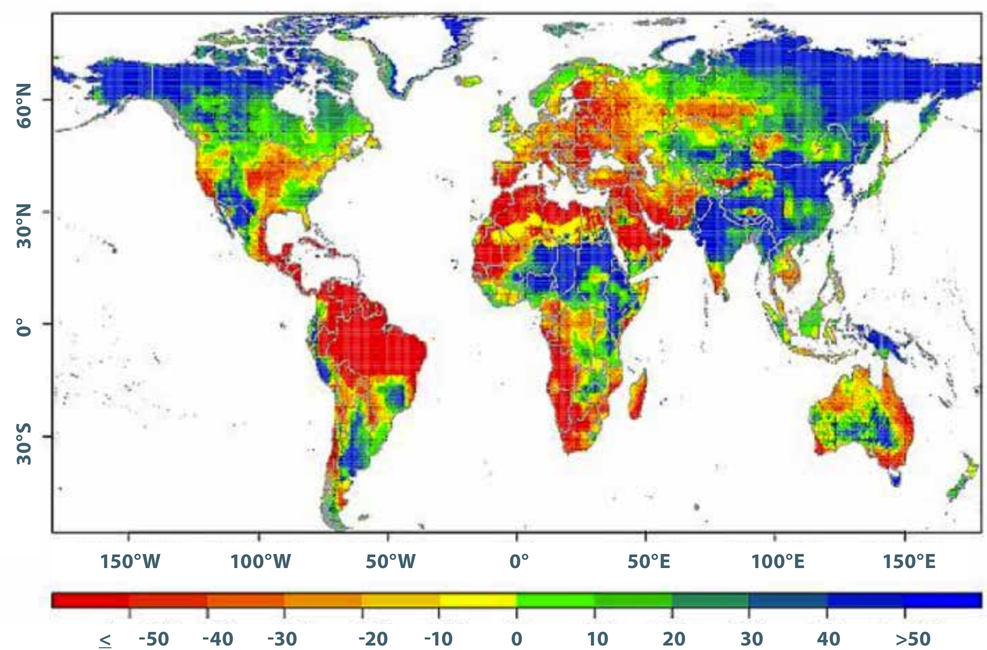
Past Water Shortages

Prior to 2012, Indiana experienced serious, disruptive droughts in 1934–1936, 1940–1941, 1952–1954, 1964, 1988, and 2007. Before the 1950s, the economy of the state was more dependent upon agriculture and less on manufacturing. Water users had to manage with limited resources and few alternatives. In nearly every decade since, there has been one year when the rains stopped, and local problems with water supply were confronted around the state.

The droughts of the 1940s and 1950s (along with some support from Indiana's federal delegation) prompted the U.S. Army Corps of Engineers (USACE) to design and build Monroe Reservoir, just south of Bloomington, which helped Indiana University grow into a national institution. In general, the southern part of the state has had fewer options for water supply than the communities north of Indianapolis. There are fewer productive aquifers, groundwater supplies are limited, and yet there remain many opportunities for sustainable economic growth. More than the rest of the state, the reliability of the water supply has always been the key to economic development south of Indianapolis.

When these historic droughts occurred, the city of Indianapolis managed the problems of water supply security by building reservoirs to supplement the low flows in the streams during the summer. Additionally, some of the reservoirs were provided with separate intakes that supplemented other surface water sources. The city's well fields provided additional security when flows decreased and reservoir levels fell. All of these improvements were constructed to reduce the risk of water shortages as development occurred throughout the state. Historically, it was possible to solve water supply problems with local solutions. Unfortunately, the local approach used in the past to solve water supply problems may not be capable of addressing the demands that will be faced in the future.

Figure 3. Some climate models predict reduced flows in Midwestern streams (Arnell, 2013)



The Future of Water

Today, the state of Indiana has three million more people than it did during the drought of 1941. As shown in Figure 2, another million people will be arriving before 2050. Clearly, the state is more vulnerable to water shortages than it was 70 years ago. There are more water diversions from streams for power, mining, irrigation, and municipal use. There are more wells pumping from aquifers. There is more investment depending on the reliability of that supply than there ever was in the past. In short, the risks are much higher as the state works to maintain its economic position and compete with its neighbors in the Midwest for jobs and investment. Indiana wants to provide a business-friendly setting to attract companies that are part of the biotech, medical, and energy sectors. More than ever before, companies are asking if water is available before committing to a new location.

Climate forecasting models suggest the possibility that precipitation and stream flow may fall in the Midwest before the end of the century. The global map in Figure 3 shows one scenario which predicts a 4°C rise in temperature. These same models indicate that droughts will be more common in the southwestern United States and Central America (Arnell, 2013).

Current climate model predictions indicate that climatic changes in the Midwest may include higher temperatures in summer and winter with measurably less annual rainfall, but more intensive rainfall events when they do occur. The most recent data indicates that average temperatures in the Midwest have risen in recent decades. This increase in temperature has extended the growing season by approximately one week due to earlier dates for the last spring frost; a longer growing season could increase the amount of irrigation used on row crops. These same models, as well as the most recent updates, also predict heat waves that are more frequent, severe, and sustained. Higher summer temperatures would generate greater rates of evaporation from reservoirs and greater water supply needs for irrigation and potable water from those same shrinking resources. Warmer temperatures could cause other related problems for water supplies. For example, higher temperatures could reduce recreation on reservoirs and increase the threat of northward migration of warm-weather invasive species. Despite the fact that future warming and precipitation patterns will affect water availability and demand, the uncertainty in the forecasts make it impractical to include in this analysis. Consequently, climate change scenarios have not been included in this report.

Regional Water Constraints in the U.S.

Each region of the country has particular economic growth and water supply dilemmas that Indiana can leverage. The southwestern United States struggles with continuous drought and limited ability to expand water supplies. Water rights have locked the water market into a difficult position, especially given the fact that there is a growing population that needs to work. It could be some time, perhaps another decade or more, before this area finds solutions to the problems of rights and is able to address other basic needs.

The Southeast is entangled in court cases that can be expected to continue. These cases all relate to disagreements among the states about the amount of water that needs to be in the basins at state lines. The interstate stream-flow compacts make this area more vulnerable to shortage. The region has adequate rainfall, but individual states are struggling with the complexity of dealing with their neighboring states while they alter their own water policy.

Coastal areas, including California, Texas, and Florida have an opportunity to use desalinated water to solve their local and regional water shortages, but that solution requires an investment in energy production and energy policy that further complicates an already difficult situation. In the past, the costs of this approach to producing water have been prohibitive. Technologies continue to improve while the economic risks of inaction drive innovation and investment. Again, it will be at least another decade before the problems are worked out and technology can be applied to the problem in a practical way.

INDIANA'S WATER GOVERNANCE

The state of Indiana employs many professionals in institutions whose defined missions and particular responsibilities advance the understanding of the hydrologic systems at work in the state. These technically trained hydrologists, water scientists, and engineers gather and analyze information about Indiana's water resources and publish or otherwise disseminate that information to concerned stakeholders. Funding for these agencies and institutions is in most cases provided by the state. In addition to state and local entities, a number of federally funded national agencies also provide information relevant to the management of Indiana's water resources. Table 1 provides a representative selection of these entities, giving the budget of each in terms of the number of full-time employees (FTEs) dedicated to the management and understanding of Indiana's water supply. The Office of the State Climatologist at Purdue does not have a large staff but it is associated with forecasting Indiana's climate and managing climate data. The National Weather Service, a part of the National Oceanic and Atmospheric Administration (NOAA), is the federal agency responsible for forecasting and data collection in the state. Brief descriptions of a number of these agencies follow.

Indiana Department of Natural Resources (IDNR) – Water Use and Water Resources

The Department of Natural Resources has historically been Indiana's lead agency on water resources. *Indiana's Water Resource*, published in 1980 (Clark, 1980), is the modern reference for a comprehensive survey of water in the state. In the late 1980s and early 1990s, the IDNR published a series of basin studies that considered availability of water resources in a number of basins (this work was halted before all basins had been evaluated).

Today, geologists, engineers, and scientists at the IDNR are working on a variety of programs. The groundwater section has developed and distributes county-scale aquifer maps for use by the public. They collect and manage drilling logs from homeowner wells and water use information from high-capacity withdrawal facilities. They work alongside the USGS to

State Agency	Water-Related Mission	FTEs Supported
Department of Natural Resources	Water resources / conflict resolution	12
Department of Environmental Management	Water quality / pollution prevention	45
State Department of Agriculture	Nutrient management / irrigation	5
Utility Regulatory Commission	Water utilities / fiscal management	2
State Geological Survey	Mapping aquifers / defining resources	10
Office of the State Climatologist	Precipitation recording / drought	1
State Universities	Research	7
Federal Agency	**Water-Related Mission**	**FTEs Supported**
U.S. Geological Survey	Data collection / analysis	20
Army Corps of Engineers	Reservoir operations / dam safety	45
National Weather Service	Predict rainfall and track drought	1
U.S. Department of Agriculture	Soil survey / nutrient management	5
Local Government	**Water-Related Mission**	**FTEs Supported**
Water Utilities	Water treatment and supply	
Waste Water Utilities	Waste water treatment and disposal	
County Storm Water Utilities	Managing excess water / protect quality	
County Surveyor's Office	Planning and mapping of development	
County Drainage Boards	Oversight of drainage alteration / flooding	

Table 1. Roles and responsibilities of federal, state, and local governments in Indiana

monitor groundwater levels, but the focus is on measuring localized impacts of high-capacity withdrawals. Another group of engineers evaluates permit applications for construction in floodways; the goal is to limit the cumulative effects of bridges and other development on flood levels.

Indiana Geological Survey (IGS) – Geologic Resources

The Indiana Geological Survey is not a regulatory agency, but rather a team of research level investigators (associated with Indiana University) working to determine the dimensions and conditions of the state's mineral resources. The state geologist is responsible for providing geologic information and counsel to support the hydrocarbon, mineral, and energy development activities around the state. While the IGS has a long history of investigating and mapping water resources, most of this work has been done to understand how the physical character of the landscape itself determines the availability of water.

Indiana Department of Environmental Management (IDEM) – Water Quality Protection

IDEM is an agency of regulators responsible for determining compliance with the rules protecting public and environmental health. Many hydrologists employed by IDEM are working to improve water quality in rivers and streams (under the authority of the federal Clean Water Act). IDEM is also responsible for supporting and managing the source water protection provisions of the Safe Drinking Water Act.

Indiana Utility Regulatory Commission (IURC) – Water Utilities and Planning

In 2011 the Indiana Utility Regulatory Commission was charged by the state legislature with developing an assessment of the water resources of the state and with collecting data to determine the risk of water shortage for regulated and unregulated drinking water systems across the state. While its interest was in developing an inventory of the public water supply systems, the IDNR high-capacity water use database allowed it to include all competing users. The Commission's 2013 report was an important milestone that helped define the problems and issues that are related to utility planning. That report focuses on the infrastructure that is needed to develop a source of supply, convey it to the treatment plant, treat it with the appropriate technology, and deliver it to the end user.

Universities – Education and Research

Indiana's public and private universities are critical to solving the larger problem of water supply through their research and teaching missions. A partial list of these institutions is provided in the box at the left. The universities are staffed with nationally and internationally recognized water experts, although much of the research is unrelated to the state. Notable among the efforts that benefit Indiana is Purdue, which is the state's land grant school and home of the state climatologist and the Indiana Water Resources Research Center (IWRRC). The Center is supported by a small federal grant funded through the U.S. Water Resources Research Act. The state provides the Center an additional $90,000 each year to be used as seed money to leverage other funds to support water resource research around the state. Indiana University also has programs and expertise in aquatic and environmental sciences as well as a College of Geological Sciences. IUPUI in Indianapolis has been a leader in water research through the Center for Earth and Environmental Sciences (CEES). Other universities have programs that focus on some particular technology or science that is critical to understanding the management and protection of streams, lakes, watersheds, and aquifers.

UNIVERSITIES WITH WATER PROGRAMS:

- **Purdue –** *Agricultural engineering, geology, civil engineering, watershed, modeling, soil science, meteorology, Indiana Water Resources Research Center (IWRRC)*
- **Indiana University –** *Geology, geography, environmental science, water law, lake management*
- **Indiana University–Purdue University Indianapolis (IUPUI) –** *Geology and earth sciences, engineering, the Center for Earth and Environmental Science (CEES)*
- **Indiana State University (ISU) –** *Geoscience, GIScience*
- **Notre Dame –** *Civil and environmental engineering, earth science*
- **Ball State –** *Geological science*

U.S. Geological Survey – Water Resources Data Collection and Analysis

The U.S. Geological Survey has an Indianapolis office that is responsible for implementing the federal land and water resource survey responsibilities in Indiana. The primary function of USGS is to collect high-quality data on stream flows at fixed locations in each of the major drainage basins that flow through the state. The USGS has become the technology leader in data collection and storage and now works cooperatively with local governments, industrial users, and the state to monitor stream flows and groundwater levels.

U.S. Army Corps of Engineers – Flood Control and Drainage

USACE has a long and important history in the state of Indiana. The first major drainage project in the state began before the Civil War in the middle of the 19th century. The Kankakee River basin was modified to drain the Great Marsh in Northern Indiana so that the land could be cultivated. This project, which took more than 50 years to complete, opened the transportation route between Chicago and Indianapolis for rail and eventually automobile traffic. This connection was critical to commerce between the industrial manufacturing activities along the south shore of Lake Michigan and the transportation hubs in Indianapolis, Louisville, and Cincinnati. The modifications of the Kankakee helped lower water levels for farming, but at the same time this work drained one of the largest wetlands in the country and caused new flooding problems downstream in Illinois.

The USACE again became active in the state after the droughts in the late 1950s and early 1960s. The U.S. government worked with the state of Indiana to build new flood control and water supply reservoirs in the southern half of the state to supplement the small streams that were the source of drinking water to local communities.

U.S. Department of Agriculture – National Drought Monitor

The Department of Agriculture has developed research institutes to aggregate information about water supply and, in particular, to assess the depth and duration of drought across the country. This effort is critical in determining the intensity and scale of drought and its impact on agriculture and other sectors of the economy.

The relationship among these agencies and jurisdictions is complex. Funding moves from the state to the federal government for data collection, while the different agencies in the state divide responsibilities of water resource mapping, analysis and reporting. Figure 4 illustrates the dominant features of these relationships, including transfers of funds, information, money, research activity, and responsibility. As the green arrows show, most of the funding is substantial, ranging in the millions of dollars. The exceptions, shown with the single $, are the funding from the USGS to universities and the funding from the drinking water utilities to the USGS to provide water resource data.

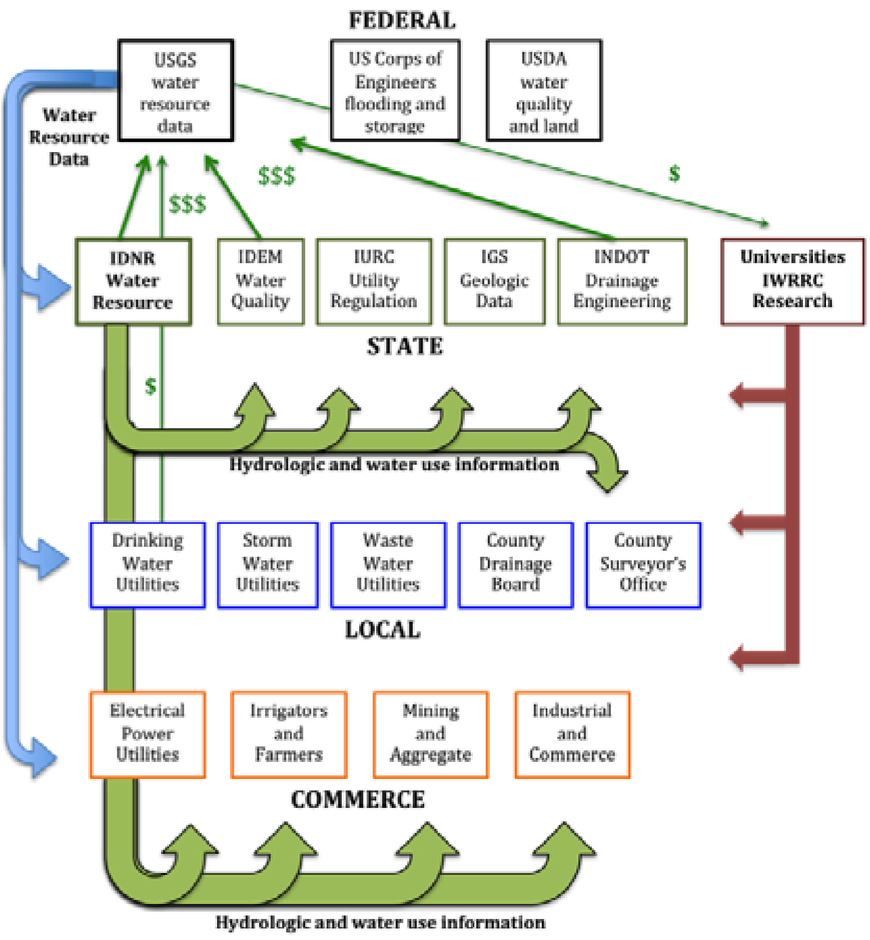


Figure 4. Illustration of the relationship among the water management jurisdictions and agencies in Indiana. Funding moves through several state agencies to USGS for data collection. Additional funds (some federal) are used to generate other data sets for the Indiana Geological Survey as it identifies the hydraulic properties of the state's geologic resources. This information is used to generate reports and maps developed by IDNR, other agencies, and the private sector. Universities, coordinated by the IWRRC at Purdue, work to gain insight into the chemical and physical systems that control the resource.

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AVAILABILITY OF WATER IN INDIANA

The amount of water available for use in any basin varies with location and time of year. Stream flows and water levels commonly fall to their annual low at the end of the growing season. Consequently, the availability of water depends both on the time of year and any water use (withdrawals) or discharges that have occurred further up the watershed. Other factors come into play, including storage in surface water reservoirs, storage in aquifers, and the administrative purposes of engineered reservoirs (determining rules for releasing water). Because the water cycle naturally oscillates through time and is constrained by the particular geography of any area, there is no common metric to determine long-term water availability at a single location.

Many attempts have been made to create a metric that would quantify the availability of water within a basin. The idea of a "safe yield" for a basin captures the combination of low flow that might be expected based on the record of flows and the effects of up-stream storage that could supplement stream flows. Low-flow values based on measurements of a given stream can be used statistically to determine the likelihood of water being available at any location along that stream when it is needed most, during the driest part of a dry year.

The amount of water that can be depended on to be available in any location is the least that can be extracted for the period of interest. This amount is limited to the stream flow during the dry period and the amount that can be removed from storage either in the aquifers or reservoirs in the vicinity, including waste water discharge. The diagram presented in Figure 5 illustrates how all of these components of the water budget are hydrologically connected.

In this model of the hydrologic cycle, the water available for use is either a mix of runoff and groundwater discharge flowing in the stream during the wet seasons or it can be removed from storage. Withdrawals from a reservoir are made with the knowledge that it will refill during periods when less water is diverted. During dry periods there may be no runoff but, if conditions are right, there will be flow into the stream from the surrounding local and regional aquifers. This is known as “base flow” in the stream. During droughts, flow in the stream is made up of discharge from the deeper, regional aquifer; discharges to the stream from waste water systems are not included in calculating this flow. This low flow is the lower limit of surface water availability.

Indiana does not experience the arid conditions found further west, but the aquifers and streams have limits on what can be withdrawn during dry seasons. That limit is much lower along the headwaters of tributaries where streams are ephemeral and aquifers are unproductive. Currently, the sustainable withdrawal rates in the more productive aquifers exceed the uses that can be foreseen. However, some parts of the state may already be reaching the hydraulic limits of surface and groundwater availability.

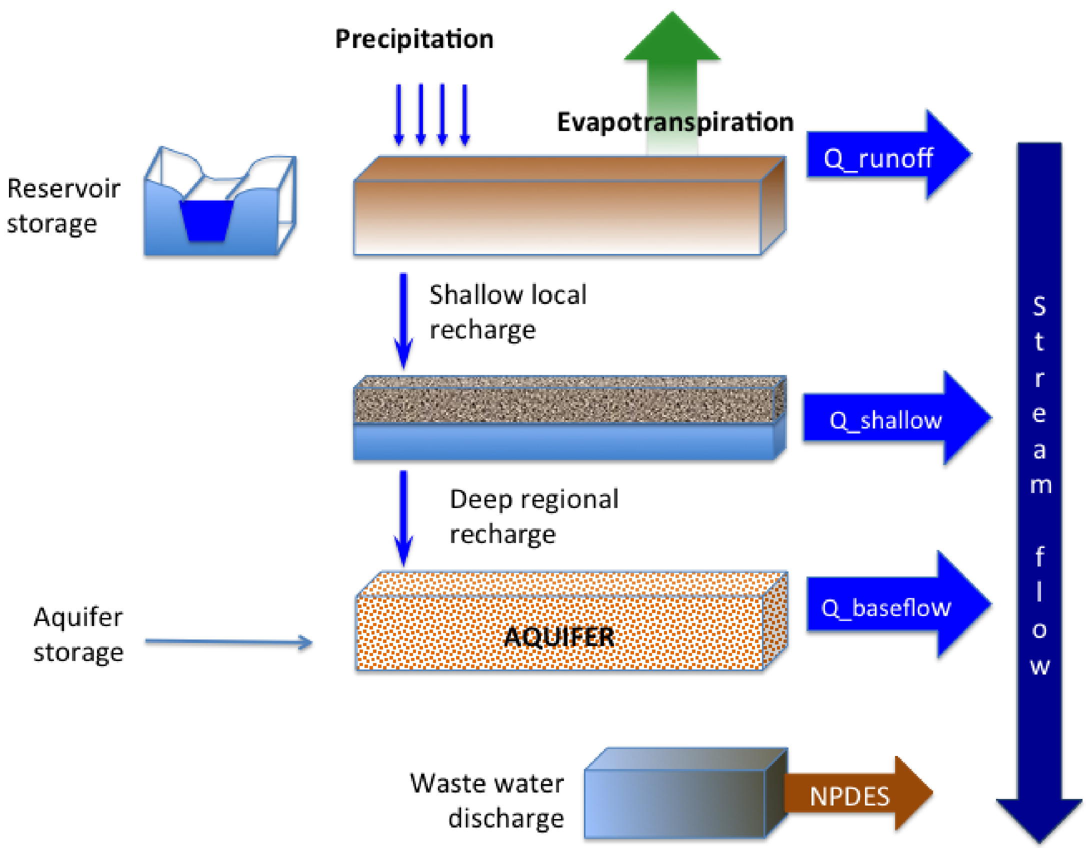


Figure 5. Conceptual diagram of various components of stream flow

Measuring Water Availability

Gages at fixed locations generate a record of stream flow that can be evaluated according to the interests of the user. Some of the most important elements of a stream record are measures of low flow, indicators of overland flow relative to seepage from groundwater, and an aggregator of data recorded at a gage – the flow duration curve. These records indicate stream-flow response to precipitation events as well as seasonal variations in the water budget. The data can be used to define surface water availability across the state. While no limits have been established, instream flow needs – the requirements for a healthy aquatic ecosystem – are a standard baseline for water availability in rivers.

LOW FLOW

For purposes of this report, the problem of water supply planning has been defined as a problem of shortage, so it is important to anticipate the limits of stream flow to satisfy expected demand. Low-flow statistical parameters are used for planning because they integrate the history of data at the site using statistical analysis of probability of any flow. The standard regulatory threshold for streams used to permit discharges from NPDES facilities is the 7Q10, or the low flow that can be expected over a seven-day period, once every 10 years. On small streams in the southern part of the state, this is often a near-zero value. These small headwater streams no longer carry water during the decadal drought period. In contrast, the 7Q10 on streams in the northern part of the state is often not much different than the average annual low flow in the stream. This low-flow resilience reflects the fact that, during the dry season, these streams are fed by extensive aquifers that have large storage volumes, so they are buffered during drought. In the middle of the state, because regional aquifers are less extensive than further north, the 7Q10 is low relative to the annual average low flow.

For the analysis of surface water availability used for this report, the 7Q2 threshold was used. This is the average flow that can be expected to occur every other year for a seven-day period. The 7Q2 is a standard statistic for planning purposes because it represents an expected low flow for the stream. Note that IDNR basin studies used the drought low flow as an estimate for water supply planning purposes. Figure 6 locates the sites where stream flows were gaged throughout the state. The shading delineates the northern, central, and southern areas based on the recorded stream flows.

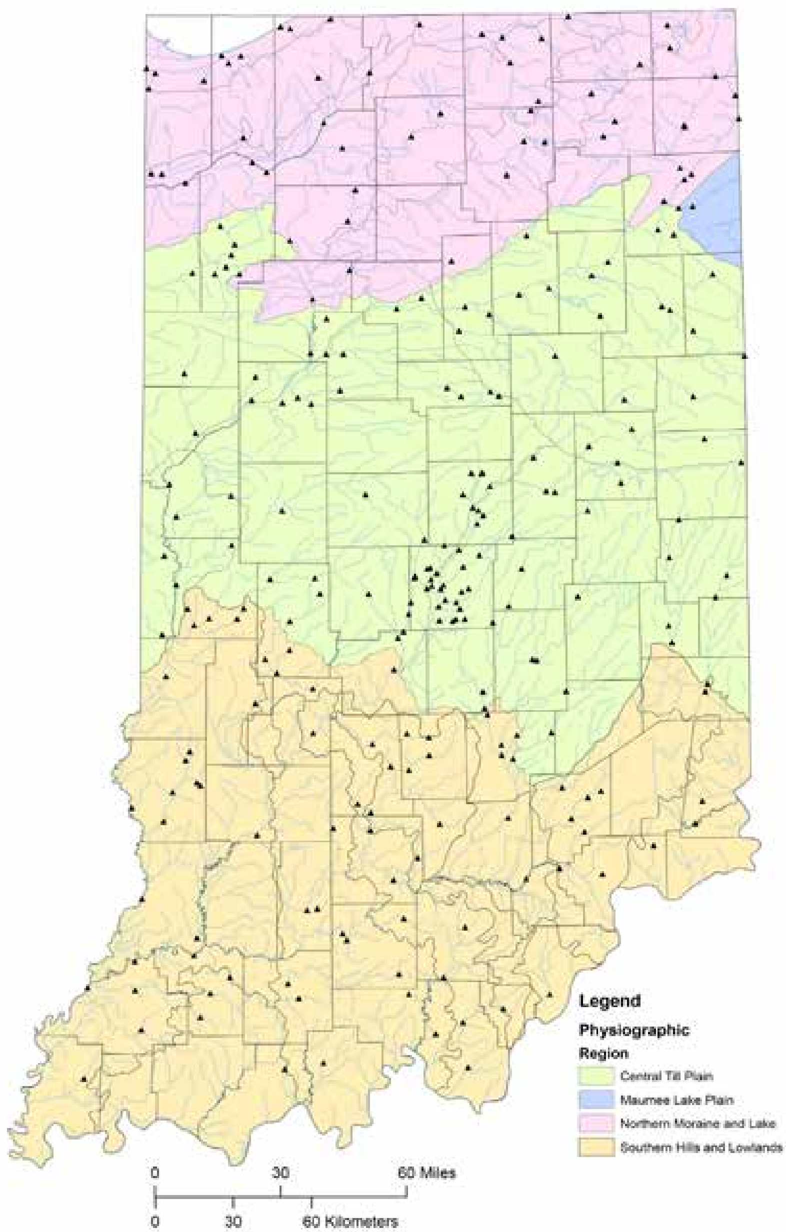


Figure 6. Low flows (7Q10) at selected gage sites throughout the state of Indiana. As expected, low flows in the northern part of the state are greater than those in the central area, which, in turn, has higher low flows than streams in the southern part of the state (Gray 2000).

FLOW-DURATION CURVE

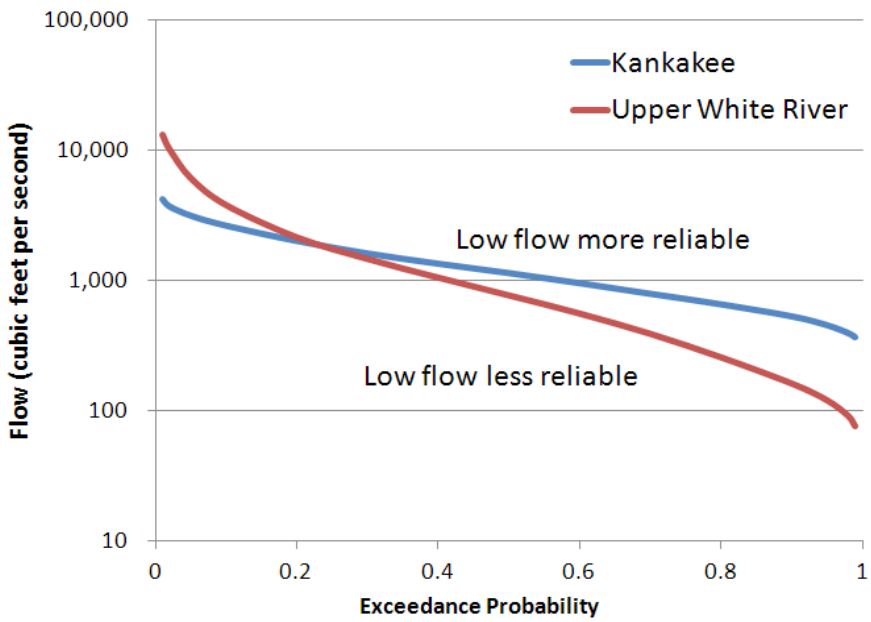
The flow-duration curve assembles the data from a stream gage and reports it in a way that allows the user to see how the flow at any time fits into the cumulative record of flows at that site. The flow-duration curve reflects the "flashiness" of the stream (how quickly stream flow will increase in response to rainfall) as well as the minimum flow that has been measured at the location. A standard way to "read" the flow-duration curve is to determine what percent of the time flows can be expected above or below some identified value.

To illustrate how the flow-duration curve can describe the watershed, in Figure 7 the flow-duration curve of the Upper White River is plotted along with the flow-duration curve of the Kankakee River. Steeper flow-duration curves indicate that higher percentages of flow are generated by overland flow during storm events, so such streams are prone to flooding. They drain basins that have limited surface or groundwater storage, and consequently, during dry periods flows are much lower. It is clear from the two curves that the Upper White River is more vulnerable to drought than the Kankakee River.

HYDROGRAPH SEPARATION

The relationship between rainfall and stream flow can be evaluated using hydrograph separation techniques. Over the course of a year, the rivers and streams that drain any basin are composed of a mix of different waters: a) runoff during and after storm events; b) shallow groundwater discharge that drains the soils some time after storms or wet seasons; and c) deeper regional groundwater discharge. The approach to differentiating these waters is to graphically or statistically "separate" the hydrograph on any stream into these three components. During drought periods, when there has been no rain for some time, the assumption is that most of the water in the stream is discharging from the adjacent aquifers. This groundwater discharge has moved slowly from the recharge areas toward the stream through the soil and rock, down-gradient of where it exits into the surface water system. These components of the hydrograph are

Figure 7. Upper White and Kankakee Flow Duration Curves for Water Years 1948-2011 (USGS, 2013).



also indicated by the different chemistry of the surface water in response to runoff and groundwater discharge.

This hydrographic background information is important in interpreting the map of the major streams in the state (see Figure 8) and the "every-other-year" low flow – technically the 7Q2 threshold. The 7Q2 is not a drought flow but a planning flow. Every other year there will be a week with these flows in the state's streams. If a power plant needs to divert 100 million gallons per day (MGD) into the thermoelectric system for cooling and for turning the turbines, it is vital that the facility be sited on a stream where that withdrawal will be available year in and year out.

Surface Water Availability

Most areas of Indiana have an abundance of what are called perennial streams, i.e., streams that flow in defined channels throughout the year, though there may be low or no flows in times of drought. Figure 9 shows the locations of these perennial streams. The availability of surface water in a given stream varies through the year, with that variability depending on the properties of the watershed and the connection of the stream to aquifers that discharge to the stream.

Two decades ago, USGS collaborated with IDNR to track low-flow statistics in streams throughout the state. This effort, published in 1996, is currently being revisited to see if there have been any changes in stream-flow characteristics, given the changes in use and the most recent precipitation regimen. That report (Fowler and Wilson, 1996) showed that, moving from north to south in a given watershed, the low flows in streams generally decreased. This is a reflection of

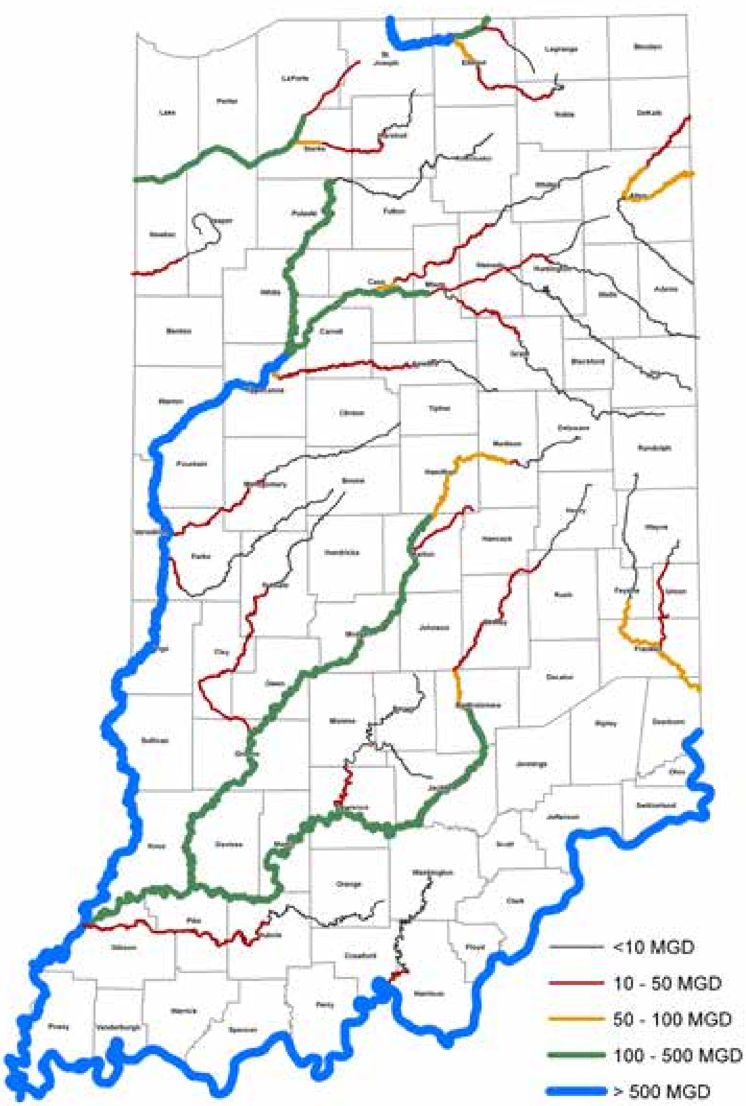


Figure 8. 7Q2 stream flow on major streams in Indiana (USGS, 2013).

the fact that the low flows in streams are made up almost entirely of groundwater discharging from the alluvial aquifers along the stream. In other words, surface water in streams during low flow times of year is groundwater. In the middle of the state, where the Wabash River and the headwaters of the White River drain the landscape, the low flows increased from 0.02 to just over 0.13 cubic feet per second (cfs) per square mile from the smaller tributaries to the downstream rivers. This translates to a depth per unit area in the basins that discharge into these streams of between ¼ inch and 1¾ inches of water. This same quantity of water is also discharging as base flow annually to the streams in the state or being added to aquifer storage.

Figure 9. Perennial streams in Indiana (USGS, 2008).

Figure 10 presents a hydrograph of flows for the Kankakee and the West Fork of the White River over a five-year period, as recorded by USGS. A comparison of these flows indicates that the West Fork of the White River drains a basin with clayey soils – there is naturally more run-off during storm events and less recharge into aquifers. In addition, in the White River Basin, the relatively narrow alluvial aquifer stores less water so low flows are lower during dry periods. As noted, surface water availability in a river or stream is determined by the low flow in that waterway. In the case of the White River Basin, that low flow is supplemented by local reservoirs designed to augment flows during high-demand periods.

If the effects of the reservoirs in the watershed are ignored, the record of stream flow maintained by USGS can be used to determine the availability of surface water. The stream-gaging network is used by IDNR and IDEM to track changes in flows during both floods and droughts. The state's $2.5 million annual budget for this data collection system supports more than 200 stream-gaging stations scattered across the state that are funded cooperatively by the state (28%), cities and counties (20%), USACE (12%), some utilities (6%), and contributions from USGS (34%). This system of gages allows state hydrologists to track the dynamic character of the flows in streams and rivers and use that knowledge to determine when to release water from reservoirs and how to anticipate future flows.

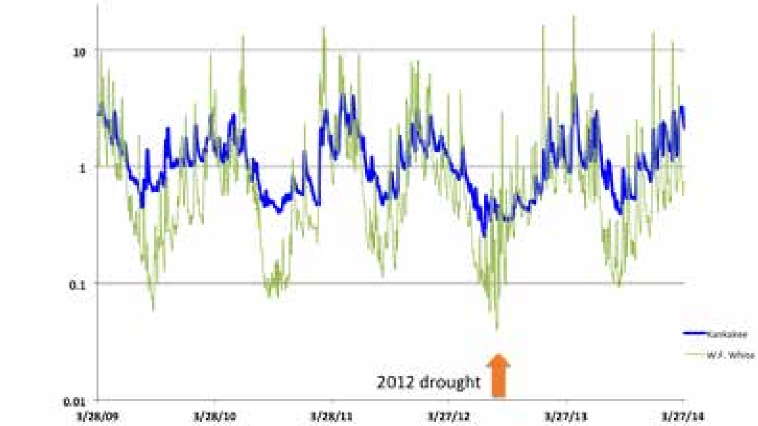


Figure 10. Comparison of normalized stream flow for two hydrologically contrasting streams – the Kankakee River (USGS 2014b) and the West Fork of the White River (USGS 2014a). Lower flood flows and higher drought flows are indications that the Kankakee River is receiving more groundwater discharge from the adjacent sand and gravel aquifer.

Reservoirs

A watershed is defined as an area of land that drains all surface water and rainfall to a common outlet. A larger watershed may contain many smaller watersheds. In Indiana, the largest watershed is the Wabash River watershed, shown in Figure 11, which has a total drainage area of 32,910 square miles at the point where the Wabash drains into the Ohio River. The headwaters of the Wabash River, the second largest tributary to the Ohio River, are located in western Ohio, approximately 15 miles east of the Indiana-Ohio state line. The river extends generally in a westerly direction through Indiana, and then flows in a southerly direction forming the boundary between Illinois and Indiana for a total length of 503 miles.

Figure 11. The Wabash River, highlighted in pink, within the watershed (in yellow) which drains into the Ohio River (Image from Wikipedia entry for Wabash River).

FLOOD CONTROL IN THE WABASH RIVER BASIN

After major flooding occurred in 1937, USACE prepared a report that discussed and/or recommended flood-control measures that could be implemented in the Wabash River basin. These included 70 levee or channel improvement projects and nine large reservoir projects. As of December 2011, after several revisions, updates, and additional studies, a total of three of the original nine reservoirs have been constructed at or near the originally proposed sites: C.M. Hardin, Monroe, and Cagles Mill. Four other large multipurpose reservoir projects have been constructed at other locations in the basin: Roush, Salamonie, Mississinewa, and Patoka. Of the 70 originally proposed levee/channel projects, 36 were ultimately implemented under various types of construction authorizations; 13 were authorized for construction by Congress but never funded; and one is currently scheduled for construction under a recently executed cost-sharing agreement. One additional levee at Mt. Carmel was added to the original project list and has been constructed.

Figure 12. Map of major water supply reservoirs (Basch 2014).

One of the truly unique features of the Wabash River is that not a single dam has been built anywhere along its entire 503-mile length. In early 1937, after the Great Ohio and Mississippi River Valley Flood left a million people homeless from Pittsburgh, Pennsylvania, to Cairo, Illinois, USACE developed a plan designed to prevent future potentially devastating events. The details of that report, titled *Flood Control Plan Wabash River and Tributaries Basin Study*, are presented in the box at the left. It is important to note that the efforts were primarily to provide controls to mitigate flooding. Relatively little attention was given to providing storage in the Wabash River Basin, which will have consequences for Indiana in the not-so-distant future.

Three of the reservoirs, Roush, Salamonie, and Mississinewa, help to control flows in the upper Wabash River watershed, while the Cecil M. Harden, Cagles Mill, Monroe, and Patoka reservoirs serve the middle portion of the watershed. Both Cagles Mill and Monroe Lakes reduce flood flows along the White River, as well as along the Wabash River. For the floods that occurred in June 2008, it is estimated that these seven lakes reduced flood damages downstream of the lakes by $14,448,000 based on 2008 dollars.

The main purpose of USACE reservoir projects is flood control, and each resulting lake is a unit in the general comprehensive plan for flood control and allied purposes in the Wabash River and Ohio River basins. During the fall and winter months, when excessive rainfall is likely, the lakes are kept at a relatively low level, referred to as "winter pool." Should heavy rains occur, surface water runoff is stored in the lake until the swollen streams and rivers below the dam have receded and can handle the release of the stored water without damage to lives or property. In addition, the lakes also operate for recreational and fish and wildlife activities and to provide a constant supply of water for downstream low-flow augmentation. All seven lakes exist as a cooperative management effort between USACE and IDNR.

Indiana has stored surface water in reservoirs for the last 100 years. The value of these basins is to buffer the seasonal variation in stream flow that is especially difficult to manage in the south and central part of the state. Reservoirs in these areas are useful for flood impact mitigation (holding back flood water during wet seasons) as well as during extended dry periods (releasing water to satisfy demands downstream). While there are many small ponds throughout the state, from a water management perspective, only those reservoirs that can be used to supplement stream flow for high-capacity users are critical to the state and the water budget of the basin. A map of the state-owned reservoirs illustrates the varying storage of those reservoirs that have been built at a scale that is important to basin water budgeting (Figure 12).

The southern part of the state is host to several USACE reservoirs, and all but one of them is used as a regional source of supply. Patoka and Monroe reservoirs are important sources in the counties that surround them, but Brookville reservoir is hardly used at all. This area of the state is otherwise lacking in demographic growth and there are no crops that require irrigation grown in the vicinity, but the reservoir remains an important supply that could be used to satisfy future demands in the region.

MOUNDS RESERVOIR: A STORAGE PROPOSAL FOR CENTRAL INDIANA

The Anderson Corporation for Economic Development has recently been promoting the concept of a new dam and reservoir that would store water upstream of Indianapolis on a main stem of the West Fork White River. The developers hope that the new reservoir would increase land values in the Madison County and Anderson metropolitan area while providing a solution to the persistent problems of water supply for the Indianapolis metropolitan area. Page 39 notes some of the potential challenges.

Map of the proposed Mounds Lake near Anderson.

Water Supply Benefit: The initial estimates are that this reservoir could be operated to generate 40 MGD during moderate to severe drought. The storage volume in the reservoir would be large enough to buffer all but the most extended and severe droughts. Cost estimates for the land acquisition, dam construction, and infrastructure project have been around $400 million. The economic development corporation is planning to market the water to Central Indiana utilities for some price that would offset the price of the reservoir. Early estimates of the first designs indicated that severe drought yields could be higher than 40 MGD, which would be used to supplement flow into the White River intake. This reservoir could add significant storage in the basin and potentially increase flows in the river enough to alleviate some concerns about growth and peak demands for the metropolitan region.

Groundwater Availability

All groundwater used to supply Indiana's needs is pumped either from shallow unconsolidated material that was deposited by glaciers or from fractures and openings in the deeper carbonate bedrock. The distribution of the sand and gravel aquifer systems reflects the history of Pleistocene glacial deposits throughout the Midwest. The deeper bedrock aquifer is productive and important where the carbonate rock has been weathered so that fractures and solution features have made the rock more permeable.

For hundreds of thousands of homeowners in the state, private wells are used to supply their domestic needs. Because a home only needs about 10 gallons per minute (gpm), some tight rock and clayey zones are able to supply enough

Rendering of Mounds Lake Dam.

Potential Challenges: There are several challenges associated with an investment in a new reservoir in this basin. Water quality in reservoirs has been a treatment issue for the city water utility for many years. Eagle Creek Reservoir has had high MIB (a chemical produced by algae) and geosmin counts that have historically caused taste and odor and treatment difficulty. These biological systems have not yet been fully understood and are only now becoming less expensive to treat. In addition, the development seems to rely on some particular interpretation of ownership and rights to the stored water. It is unclear that there is any precedent for storing and selling water to a downstream user when Indiana is a riparian water rights state. Do all users (or at least some users) have a right to the water that was previously flowing in the river without the dam? Priority of use and ownership of the resource, as well as water quality and treatment, all present challenges that can be met if the state has a planning mechanism and public process that can help administratively strengthen these regional relationships.

water for a small well. Higher-capacity wells used as a source for drinking water utilities, power plants, industrial users, or irrigation can only be located where there are transmissive aquifers with adequate recharge. While private wells may locally be affected by shortages, the larger concern of the state is the ability to supply water from regional aquifers to the high-capacity wells used by commercial enterprises and cities.

One of the most commonly used methods to describe groundwater availability in Indiana is the potential yield of wells. The most widely known source for data about well yields is the 1980 report by IDNR, *Indiana's Water Resource* (Clark, 1980), mentioned earlier. For this document, well yields were mapped across the entire state; the results are shown in Figure 13, grouping them into seven categories ranging from 10 gpm to more than 1,000 gpm. In low-production areas, where wells produce less than 50 gpm, there are regions where dry holes are so common that many well drillers estimate they drill three wells for every two that produce enough to be useful.

Groundwater has always been an important source of water in rural areas of the state, but it was not until the dry years in the early part of the 20th century that the first wells were drilled for the public drinking water supply in Indianapolis. At that time, flows in the West Fork of the White River had gotten so low that there were problems diverting enough water for treatment. Some of the wells were drilled into the deeper sand and gravel near the confluence of Fall Creek and the White River near the office of the city's water works. Other wells were drilled deeper into the fractured bedrock formation along Fall Creek. These wells were all pumped into the surface water plant to simply supplement the flow from the river and to help control seasonal temperature variations in the treatment system. Since that time, groundwater has been critical to the city in meeting the higher demands that are experienced in the summer months.

Withdrawal from groundwater storage is similar to pumping from a reservoir and can result in the same type of problems relating to supply and demand. A well-known example is the Ogallala Aquifer (see box below). Water levels in the Ogallala have continued to decline for the last several decades. Agriculture in the High Plains is removing water stored in the aquifer faster than it can be replaced by infiltrating recharge. The current imbalance is unsustainable. Without a more direct method of injecting recharge into the aquifer to refill storage, at current rates of use much of the aquifer will be unusable in 100 years (Parsons et al, 2014). Groundwater levels continue to fall as attempts are made to reduce the rate of pumping. Because water law is controlled by the state and no single authority exists to manage the aquifer, there is no simple way to prevent permanent declines (and further reductions in storage). This suggests that aquifer management requires more than information about water levels that can indicate changes in storage and data about withdrawals to determine how groundwater is being used. In the semi-arid High Plains, water rights are owned by the farmers but long-term management requires an inter-state authority that can prioritize and regulate use.

Generalized Groundwater Availability

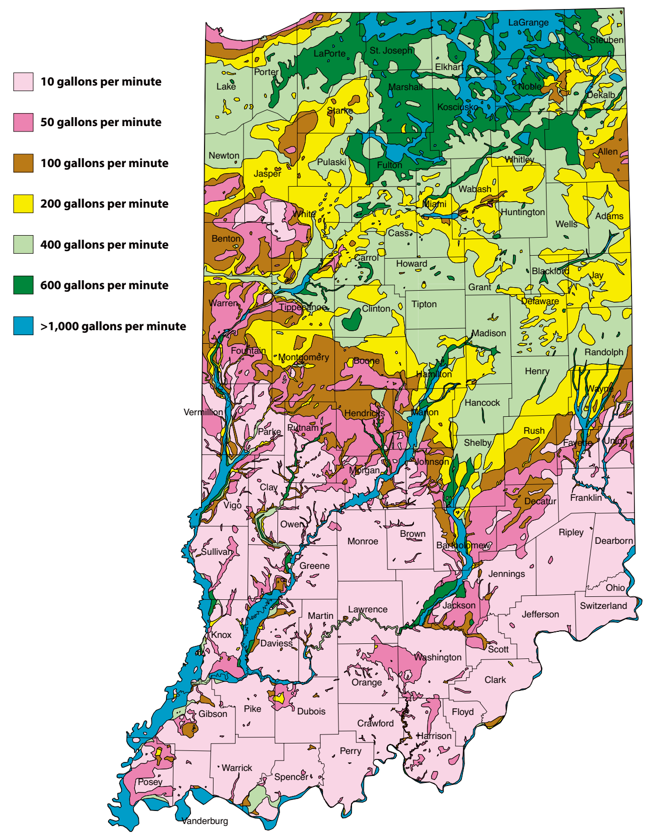


Figure 13. Potential yield of wells throughout Indiana (Clark, 1980).

THE OGALLALA AQUIFER

The Ogallala Aquifer is one of the world's largest aquifers, underlying an area of approximately 174,000 square miles in portions of eight states: South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas. The aquifer is part of the High Plains Aquifer System. Approximately 27 percent of irrigated land in the United States is served by its water supply, which provides about 30 percent of the groundwater used for irrigation in the country.

INDIANA AQUIFERS

The "potential well yield" approach to defining groundwater availability discussed in the previous section is ideal for purposes of drilling, but it is less useful when discussing how much groundwater can be extracted from the aquifer system. The total amount of groundwater that can be pumped from any aquifer over any time period is determined by three factors: 1) the amount of water in storage; 2) the rate that water is removed (in total); and 3) the rate that water is recharging the system at the land surface and along rivers, streams, and lakes. In effect, knowing how much water can be pumped from the aquifers is more like determining reservoir yield than estimating the potential yield from a single well. The unconsolidated sand and gravel deposits that overlie bedrock in much of the state are generally thicker and more transmissive in the northern part of the state than they are to the south. These unconsolidated aquifers also include reworked materials along the streams – alluvial aquifers – that are the most productive locations for wells in the middle of the state [see Figure 14(a)].

The productive part of the bedrock aquifer is that portion of the Silurian Devonian carbonate sequence that is fractured and weathered along the western flank of a regional syncline known as the Kankakee Arch. The USGS

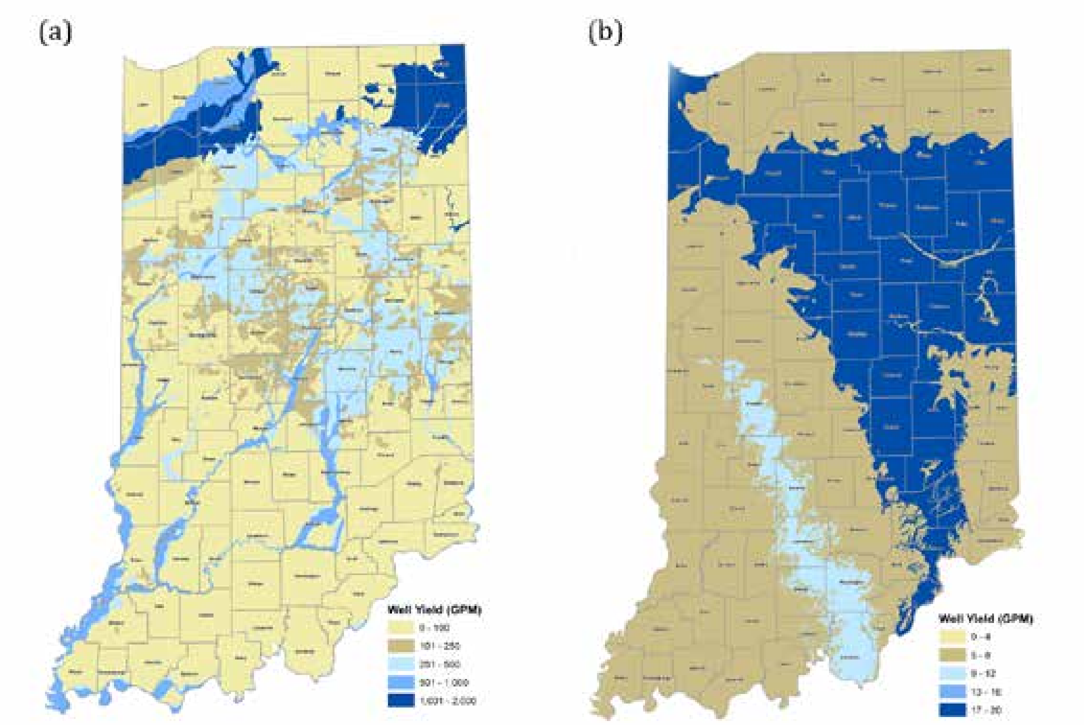


Figure 14. Typical well yields in the (a) unconsolidated aquifers and (b) bedrock aquifers based on IDNR GIS Data (USGS and IGS, 2008).

conducted a multi-year investigation of the Cambrian-Ordovician bedrock aquifer in Indiana as a part of its Regional Aquifer System Analysis (RASA) program in the 1990s. It evaluated the properties of the aquifer and determined, to some degree, how well it was hydraulically connected to the overlying sand and gravel and how it was affected by long-term, high-capacity withdrawals [see Figure 14(b)].

Another metric of groundwater availability is the storage in the aquifer being used as a source of supply. To determine this volume, an estimate was made across the state of the saturated thickness of the unconsolidated section that is described as aquifer material (e.g., sand, sand and gravel, gravel, etc.) The total thickness was estimated using the drilling logs from wells that penetrated at least half of the unconsolidated section in the state water well log database. This volume was mapped (Bayless, 2014) to better determine the dimensions of aquifer storage throughout the state (see Figure 15). Storage volumes were then converted to an equivalent depth to better visualize the volume in each county (see Figure 16).

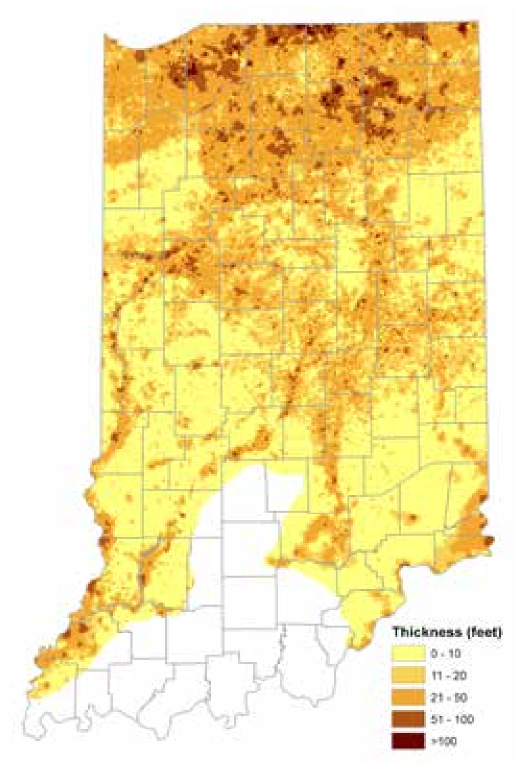


Figure 15. Estimated saturated sand and gravel thickness (Bayless, 2014).

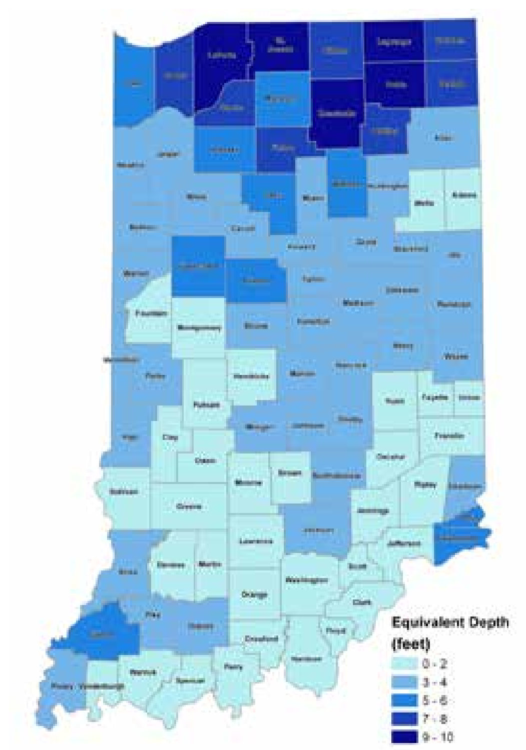


Figure 16. Equivalent depth of groundwater stored in the sand and gravel in Indiana. The depths listed are the groundwater reservoir depth for each county (Bayless, 2014).

GAPS IN THE UNDERSTANDING OF GROUNDWATER

Indiana has very little information about water levels in the aquifers that are used by thousands of high-capacity water users. The map illustrates the locations of the wells that currently track water levels in the sand and gravel and bedrock aquifers. While industrial and power can locally be large users of shallow groundwater, historically this shallow aquifer has been used to satisfy growth in irrigation and public water withdrawal. If Indiana is going to continue to rely on groundwater for its future supply, planners need enough information (e.g., storage, recharge, discharge, etc.) to manage the aquifers as extensive refilling reservoirs. Sixty new monitoring wells would need to be added to return to previous levels of coverage. If only 20 were added each year, it would take at least five years before we would be able to compare the response of the regional aquifers used by any group of users. The effects of increasing demands on the alluvial aquifers along the rivers need to be integrated for municipal water supply planning.

Location of existing USGS and IDNR groundwater monitoring wells (Basch, 2014).

Summary of Water Availability

Indiana has always had a great deal of water, although it may not always have been available at the right time or in the right place. In other words, not all of the state has always had equal access to the abundant supplies. Water in the Great Lakes, for example, can be developed but only within the Great Lakes Basin. This water is effectively unavailable for any use outside of that regulated watershed. Figure 17 provides a summary of alternative water supplies throughout the state, indicating the locations and limitations of each, as well as issues associated with their implementation.

In the northern tier of the state, water is stored in thick extensive aquifers limited only by the local hydraulics of the system and the spacing between wells in the vicinity. Regional sand and gravel aquifers, along with a productive carbonate bedrock system, provide groundwater to the many water users in the Kankakee Basin in the northwest and St. Joseph River Basin in the northeast. As the downstream flows in Northern Indiana increase, the aquifers narrow and storage shrinks. This area is where irrigation is growing fastest. Best practices are needed to assure that aquifers are not overused and withdrawals are sustainable.

In the center of the state, the water supply reservoirs that surround Indianapolis are the most sensible approach to supplement locally limited supplies. However, based on studies and analyses, it appears that the water supplies in and around Central Indiana are modest relative to the importance of this area to the state.

While there are thick aquifers in the north, the southern part of the state has several large underused reservoirs that could supply the needs of future growth. The success of Patoka Lake, 35 miles north of the Indiana/Kentucky border, as a source for multiple water districts demonstrates that these reservoirs can support communities that have limited local supplies. The supplies in these reservoirs, developed with federal support, have never been systematically considered as economic development tools. Instead, the communities in the vicinity are allowed to use the water for a fee (once $44/million gallons (MG), now $33/MG). Thus, managing the many small systems in the southern part of the state will most likely require a regional infrastructure.

Figure 17. Matrix of alternative water supplies, their limitations, geography and issues.

Source	Limitations	Distribution	Issues
flowing stream	low flows drainage density other users	see map on Page 34	habitat water quality dischargers
reservoir	land impacts inflow purpose jurisdiction	large in the south few on Wabash many near Indy	altered flows higher low flow lower high flow
local aquifer	vulnerable to drought limited capacity local cooperation	most in north important in central along streams in south	short-term limited local
regional aquifer	seasonal use requires regional plan interference	most in north bedrock along Arch important in central	climate change models needed monitoring needed cumulative effects
river bank filtration (RBF)	near big river 50 ft sat thickness regulatory limits low maintenance	along major rivers history along Ohio River new technology	high yields water quality improvement low hardness

WATER USE

The IDNR's Division of Water maintains a database of all water withdrawals organized by the purpose of use. Since 1985, any system with the capacity to withdraw more than 100,000 gallons per day is required to report monthly withdrawals at the end of each calendar year. This data, collected and assembled by purpose of use (irrigation, rural, mining, public supply, industrial, energy generation, and miscellaneous) provides the state with a unique window into the growth and change in water use throughout the state for the past 30 years. Currently, the records maintained by IDNR include over 3,800 facilities with over 6,700 groundwater wells and almost 1,400 surface water intakes (see Figure 18). The findings described in this report are based upon the information in that database and reflect the support of the staff at the IDNR Division of Water.

It is clear from the locations of the facilities that there is more water withdrawal and use in the north than in the south. This can partially be explained by surface and groundwater availability (more in the north, less to the south), but the use is driven by economic factors as well. The geography of water use is based on demographics and development, which historically follow major rivers and aquifers. One exception to this is mine water use. This is primarily located in the southwestern counties, where coal and other minerals are being mined [see red triangle symbols in Figure 18(a)].

Trends in Water Use

Water use in Indiana is reported to IDNR through the high-capacity water withdrawal database. The total amount of water withdrawn varies between counties and the distribution among users varies throughout the state (see Figure 19). The water use trends for each sector are described and the record of statewide use for each of the sectors is illustrated in the graphs on Figure 20 that follow.

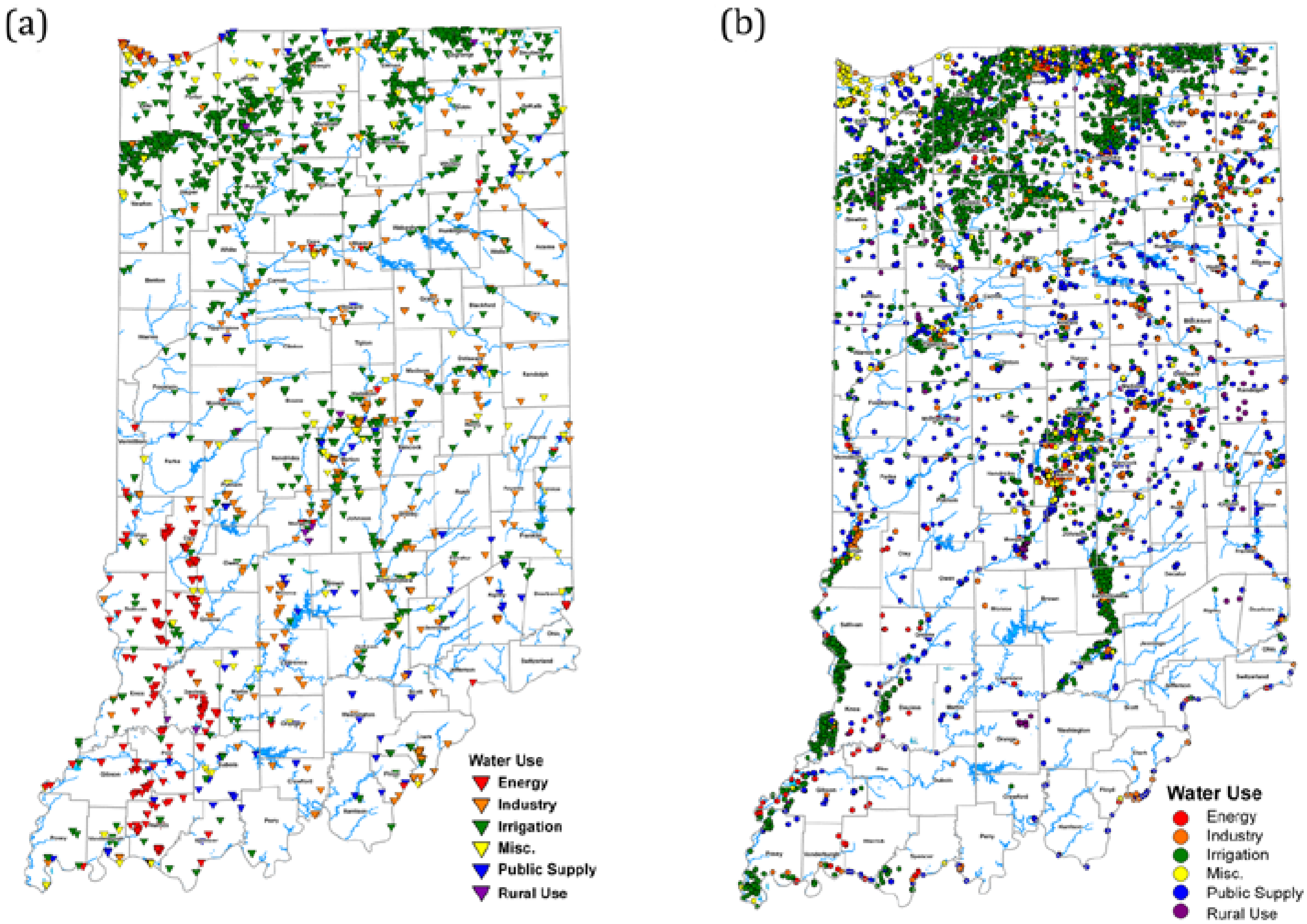
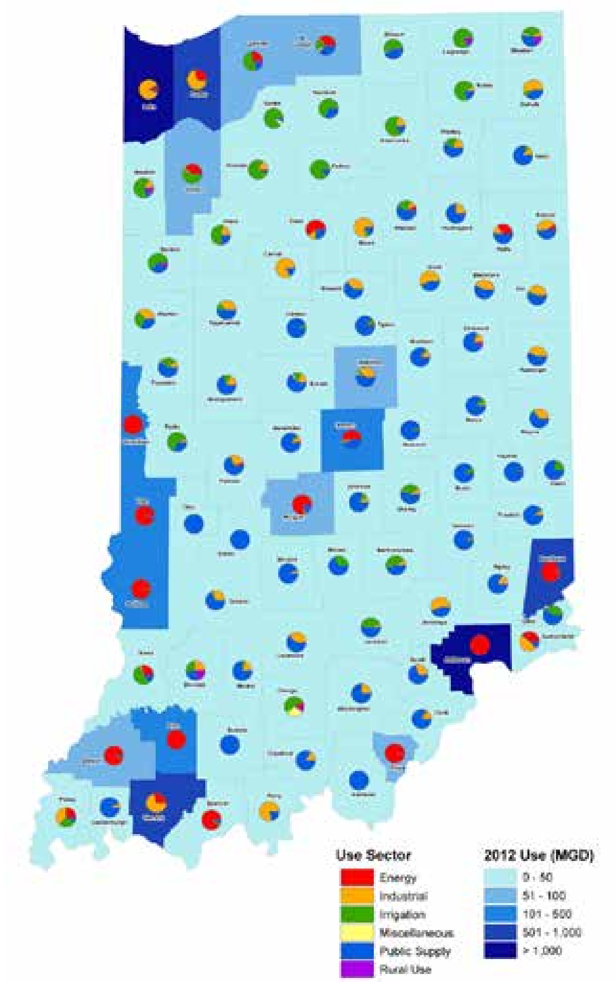


Figure 18. Locations of (a) surface water intakes and (b) wells from IDNR database (IDNR, 2013).



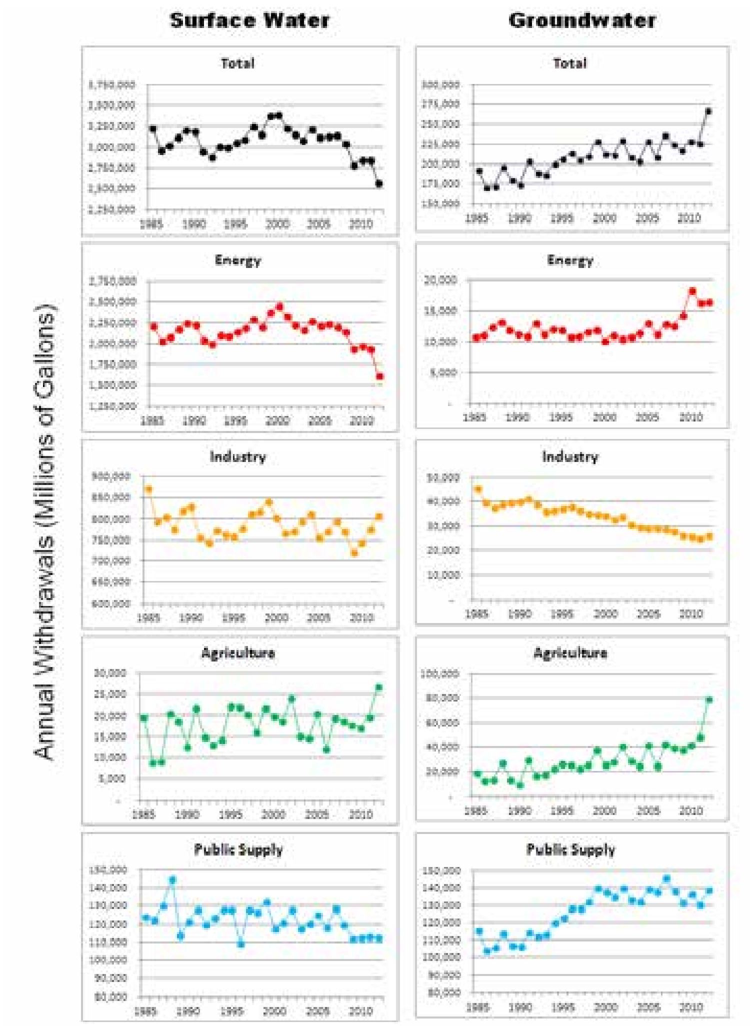


Figure 19. Indiana reported water use in 2012 by county and sector (IDNR, 2013).

Figure 20. Water use from IDNR high-capacity water facilities database 1985–2013 (IDNR, 2013).

ENERGY PRODUCTION

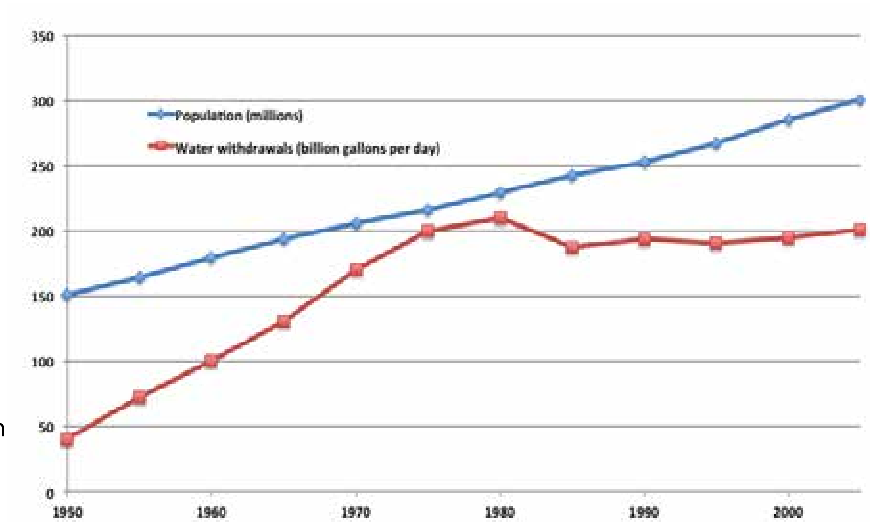


Figure 21. Trends in population and thermoelectric power 1950–2005 (USGS, 2008).

Consistent with national water-use data, the largest water user in Indiana is energy production (Figure 21, USGS, 2008). Technology and energy policy are changing as new fuels enter the market and policies are developed to stimulate non-hydrocarbon energy sources. Nevertheless, power plants continue to use large volumes of water in once-through cooling systems. The high-water needs have meant that power plants often rely on intakes from larger rivers as the source of cooling water. These cooling systems only consume a small fraction of the intake water, so more than 95 percent of the diverted water is returned as warmed effluent discharge. While the fraction of groundwater use is growing, in Indiana about 95 percent of all cooling water is diverted from streams and surface supplies. Energy production is a centralized water user; that is, there are a few facilities, each of which requires large amounts of water. The power generation use class is unlike the others in that it has fewer facilities, each of which uses (and returns) a large part of the annual total withdrawal (Reilly, 2008).

INDUSTRY

Figure 22 shows total water withdrawals for industrial use across the country in 2000. Indiana is one of four states (along with Louisiana, Texas, and Washington state) with the highest per-day withdrawals. However, unlike other sectors of the economy, self-supplied industrial water use has been shrinking as a percent of total water use, both across the country and in Indiana. As one of the most heavily industrialized states in the nation, Indiana has seen a decrease of 30 percent in industrial high-capacity water use over the period from 1985 to 2005 (see Figure 20). The change is explained by a number of factors, among them globalization of manufacturing, the normal regulation of industrial wastewater discharge, and the general shift to more efficient operations to focus on competitiveness.

Figure 22. Industrial water use throughout the United States in 2000 (USGS, 2005).

This trend in lower industrial water use reflects one of the important changes to the economy of the state that has occurred over the period of record. However, water is an important asset and the industrial history of the state is being used by economic development directors to attract new fabrication, manufacturing, and commercial enterprises. Industrial water use is an important component of what Indiana has to offer to manufacturers and industries.

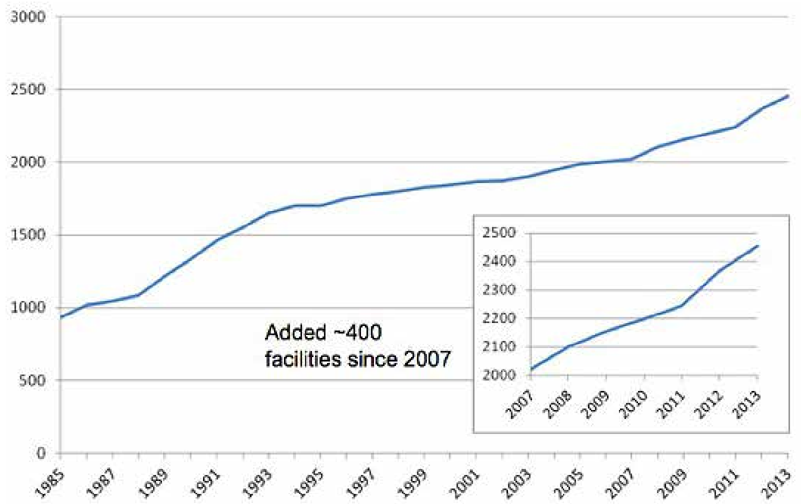
AGRICULTURE

Agriculture remains one of the most important elements of the state's economy. The agricultural component of the state's gross domestic product (GDP) has monotonically increased over the past decade. Recent consolidations and mergers in the agricultural sector indicate that increases in water use will follow as the business of growing food and fuel demands increased management and higher profit margins. Over the last decade, the price of corn and soybeans has made it critical that, even in historically moist areas, farms add irrigation systems to ensure yields. Consequently irrigation water use has been the fastest growing category of high-capacity withdrawal facilities, more than doubling since the first year of the program (see Figure 23).

Agriculture has become an important water user where prime farmland is located near abundant water resources. In the Kankakee Basin, many irrigation systems are established with diversions from ditches and streams. This northwestern part of the state has the most active agricultural water management systems operated by farmers. This explains why the northern part of the state has experienced consistent growth in irrigation and why the flood plains of the largest river valleys have been the growth areas throughout the state. Like other sectors, most of the increase is coming from groundwater withdrawal.

Unlike other water use, irrigation is entirely seasonal. Almost all water use in this sector occurs between the middle of May and the middle of September, when most water users experience their peak demand. Average annual withdrawal rates are growing in many rural areas, and monthly withdrawals are correspondingly higher in many counties. Another notable difference

Figure 23. The number of registered irrigation facilities in the state from 1985 to 2013 (IDNR, 2013).



between this use and others is that agricultural water use is increasing in areas regardless of population change. Some of the counties with the highest growth rates in irrigation have either flat or declining populations. Unlike other uses, irrigation pumping depends entirely on weather. This means that the difference between a wet and a dry year is substantial. From a planning perspective, irrigation-pumping rates remain low until there is a dry period and then it magnifies seasonal withdrawals. Irrigation can remain steady over long periods while capacity during drought and shortage expands.

PUBLIC SUPPLY

Nationally, drinking water utilities withdraw about 10 percent of the total used. Naturally, this percentage varies dramatically between counties in any state. In many parts of Indiana, the dominant water user is the community drinking water system. In many rural counties in Central Indiana, the local water systems are responsible for more than 75 percent of all water use. Over the past decade, more municipal systems are adding new wells to satisfy growth in community needs.

Indiana has over 830 drinking water utilities that together supply nearly 720 MGD to the public. The top 12 water utilities in the state supply more than 1.1 million drinking water customers (each home or billing location is one customer) for domestic use. For a variety of reasons, public supply withdrawals are becoming more seasonal with higher peaks relative to the average day. Much of this can be explained by the increase in lawn irrigation.

Indiana has many very small water systems that have one or two wells that may be connected to a small treatment plant to supply a few customers. Depending on circumstances, the difficulty and cost of developing the source, treating and safely delivering the water to the end-user while at the same time satisfying regulatory requirements is more than some systems can manage (IURC, 2013). It is in this context that regionalization of utilities is proposed – a more robust approach to satisfying local needs – often requiring changes in operations but providing a more secure drought-proof supply.

Summary of Water Use

Water use in Indiana continues to increase for irrigation and public supply, while staying relatively constant for power and shrinking for industrial supply. Simultaneously, more water users are now drilling wells than diverting water from streams. This reflects the relative simplicity of using local supplies when compared to intakes along streams or reservoirs. Central Indiana has been shifting to groundwater to satisfy the needs of demographic growth and the northern part of the state is using more groundwater to supply more irrigation wells. These two trends will determine how long current resources can satisfy local demand. Fortunately, some of the most rapid growth in irrigation water use is in areas of the state with the most abundant supplies. Industrial water use and cooling water demands for power generation are not likely to grow in the next few decades. Both of these users have historically diverted surface water to satisfy their needs.

ESTIMATING FUTURE DEMAND

In the 1980 report, *Indiana Water Resources* (Clark, 1980), IDNR made a number of predictions about water usage in 2000, 20 years in the future. These predictions turned out to be marginally incorrect but, on balance, reasonable (see Figure 24). This work assumed that there would be continuing growth of self-supplied industrial water uses and that other water uses would grow in the context of conservation programs. It further estimated that water use in 2000 would include a much lower intake from the power sector and a much higher intake from other sectors. While these estimates were off somewhat, the estimate for public supply was within a percentage point of the recorded water use. The analysis presented in 1980 generally charted the path for state policy in the 1980s (Governor's Water Resource Study Commission, 1980).

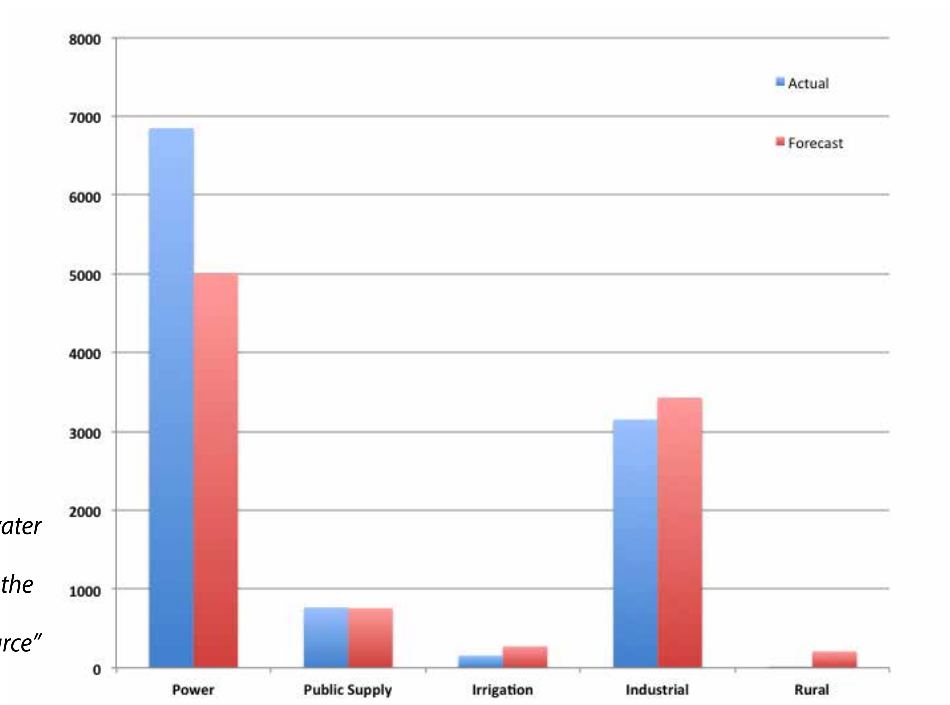


Figure 24. Predicted and actual water use (MGD) in the year 2000. Predictions from the 1980 IDNR publication "Indiana's Water Resource" (Clark 1980).

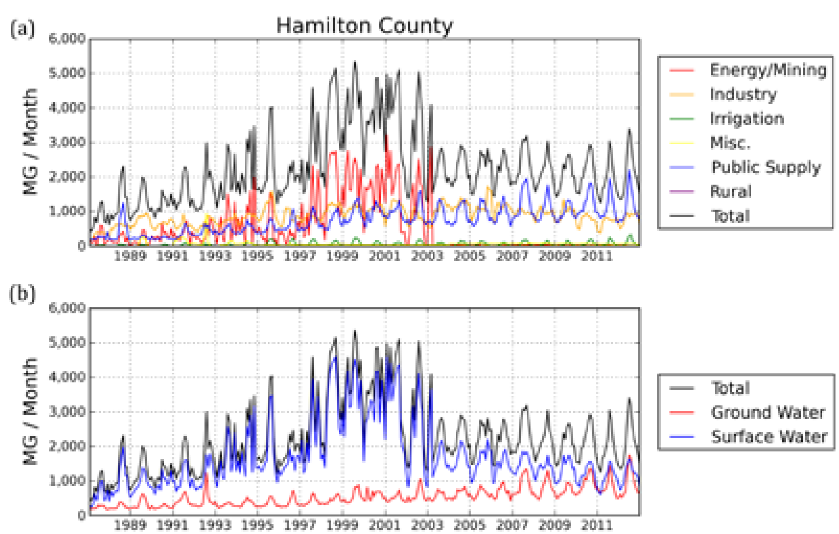
As it turned out, in many sectors across the country, water usage peaked in 1980. Since then water use has decreased in the industrial sector because of the reduction in manufacturing while other sectors not expected to increase at that time added more each year than had been estimated. These estimates, made 35 years ago, were necessarily based on many broad assumptions that had limitations. By definition, estimates are not capable of anticipating actual changes in the economy, the climate, or the culture that will alter water use in the future. However, in 1980 the state did not have a comprehensive database of reported water withdrawals to better record trends and to account for future growth and consequent changes in demands.

In contrast, in preparing the present report, the information available about water usage in Indiana is considerably more comprehensive, and the analytical and predictive tools used to evaluate that data are more numerous and accurate. The first step in the forecasting approach was to identify the sectors of reported water use that were changing predictably and to use a regression analysis to extrapolate those parts of the total water use for each county. This growth was added to the average of the water use for the non-trending uses. Statewide, there is a statistically significant trend in public supply (in most counties) and irrigation (in some counties), but this is less common in power or industrial use. For reasons that were explained in the previous section, these components of the water use in the state are subject to variation that is not clearly correlated to any of the variables that were assumed to be drivers of water use.

Implementing the Approach

To illustrate how this approach was implemented, consider the water use data for one county, Hamilton County, a 403-square-mile area located just north of Indianapolis, with a population of slightly under 300,000. Water usage for the county for the period from 1988 to 2012 was collected and graphed for five sectors (energy/mining, industry, irrigation, public supply, and rural), as well as a sixth factor to account for other uses. The source of the water, whether surface water or groundwater, was also graphed; the results are presented in Figure 25.

Figure 25. Hamilton County water use, 1987–2013. Illustrating (a) the "noise" caused by power plant use before 2003 and (b) the subsequent trends in use (IDNR, 2013).



As the figure shows, water use in the industrial and energy sectors had substantial variability between 1987 and 2003 and made up a very large fraction of the total water use in the county, so there was no statistically simple way to use these data to predict future use. The lack of predictability was especially clear after 2003, when a power plant was shut down and total water use was reduced to the other major water users – public supply and peak irrigation use, both of which were increasing steadily. If the regression analysis is done on the "predictable" elements of the water use, there is a very clear regression that can be used to estimate future withdrawals. The regression in this case shows that these sectors will grow at a steady rate into the future and the contribution of the others will be limited to some average of their contribution that has been seen in the last decade (since the power plant was taken offline). By 2050, the expectation is that Hamilton County will require an additional 55 MGD to satisfy the needs of the growing population in the area.

The limited extrapolation technique applied in Hamilton County was effective in spite of the element of unpredictability resulting from the loss of a major water user in the county. Applying it across the state, therefore, produced a reliable and conservative estimate of where water use will be expanding throughout Indiana.

Anticipated Increases

Analysis of the water use data indicates that, in addition to Hamilton County, several other counties could have additional water demands by 2050 that may exceed 30 MGD. Figure 26 shows anticipated increases by county. The largest increases are seen along the northern tier of counties where new irrigation wells could become an important component in aquifer management. In Central Indiana many counties will have higher demands, with Hamilton, the fastest growing county in the state, leading the way. The increases in irrigation, it should be noted, would only occur during dry years. Irrigation during normal precipitation years will reduce so the use will be less important regionally.

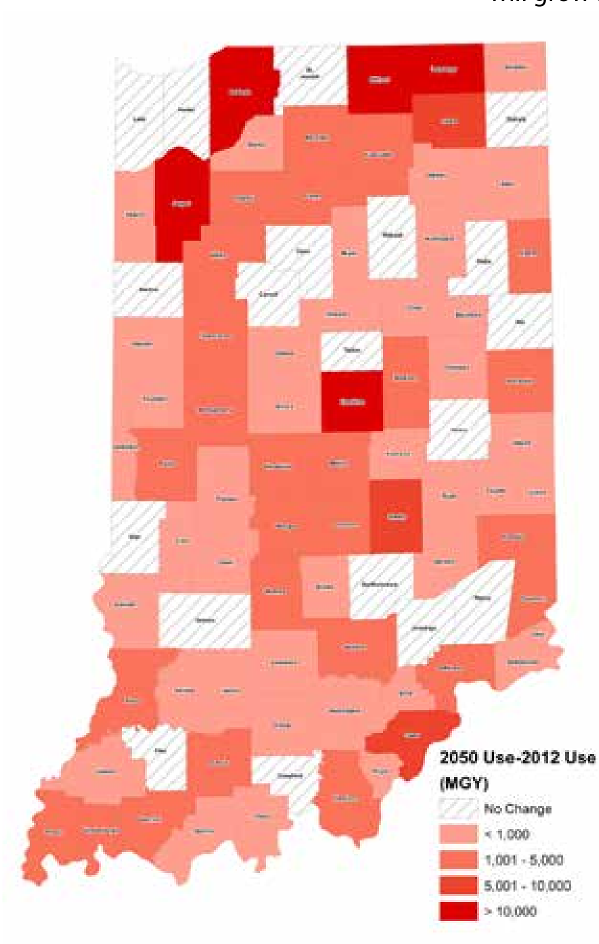


Figure 26. Estimated water use increase by county between 2012 and 2050. Note: 20,000 MG/yr ~ 50 MGD

Table 2 lists the 25 counties in the state with the largest expected increase in water use between 2012 and 2050. The results reflect some of the embedded methodologies that were used to expedite the work, as well as the nature of statewide water use trends. About half of the water that is forecasted for use in 2050 is irrigation. Of the 347 MGD that these 25 counties will use, if trends remain the same, 170 MGD will irrigate crops. Another important characteristic of the change in water use in these counties is dependence on groundwater. Aquifers are being used for new irrigation and are also the primary source for new municipal growth. More than 60 percent of the water that will be delivered in 2050 will be pumped from aquifers during four months of the year. Such heavy reliance on aquifers needs to be managed so as not to conflict with other users depending on the same groundwater sources.

County	2012 Water Use (MGY)	2012 Surface Water	2012 Ground Water	2012 Energy Production	2012 Industrial	2012 Irrigation	2012 Public Supply	Predicted Growth 2050-2012 (MGY)
LaGrange	10,359	18.1%	81.9%	0.0%	0.5%	82.4%	3.7%	23,082
LaPorte	20,246	59.9%	40.1%	28.2%	0.1%	50.4%	16.7%	22,424
Hamilton	25,695	55.3%	44.7%	0.3%	37.7%	4.7%	54.4%	19,245
Jasper	18,669	78.4%	21.6%	39.3%	4.8%	53.8%	2.0%	16,480
Elkhart	13,340	12.5%	87.5%	1.3%	1.9%	51.1%	43.1%	13,951
Noble	5,000	7.6%	92.4%	0.0%	7.3%	72.2%	19.6%	10,324
Clark	9,792	16.7%	83.3%	0.0%	16.1%	1.5%	82.5%	8,311
Shelby	4,107	12.8%	87.2%	0.9%	10.0%	34.2%	53.3%	6,453
Pulaski	5,021	29.3%	70.7%	0.0%	16.5%	77.4%	3.2%	6,370
Kosciusko	10,210	7.1%	92.9%	1.6%	17.5%	65.7%	15.1%	6,113
Marshall	3,545	9.5%	90.5%	0.0%	2.0%	66.6%	31.4%	4,970
Madison	6,369	10.9%	89.1%	0.0%	12.6%	3.1%	84.3%	4,179
Morgan	28,747	81.7%	18.3%	77.9%	3.2%	1.4%	13.3%	4,159
Tippecanoe	12,715	2.5%	97.5%	0.0%	37.7%	11.4%	50.3%	3,611
White	2,502	100.0%	0.0%	0.0%	20.7%	56.2%	21.4%	3,523
Knox	9,368	10.8%	89.2%	28.2%	3.6%	52.7%	15.5%	3,150
Dubois	3,613	100.0%	0.0%	0.2%	0.0%	2.0%	97.8%	2,810
Johnson	5,870	9.5%	90.5%	0.0%	9.2%	9.2%	81.2%	2,804
Posey	8,396	65.2%	34.8%	25.1%	37.8%	27.9%	8.6%	2,716
Monroe	6,602	100.0%	0.0%	0.0%	5.8%	0.4%	93.8%	2,699
Fulton	4,655	4.5%	95.5%	0.0%	0.1%	88.3%	11.6%	2,511
Jefferson	450,673	99.5%	0.5%	99.5%	0.0%	0.0%	0.5%	2,193
Parke	1,125	2.6%	97.4%	0.0%	5.2%	64.0%	30.8%	2,176
Starke	4,262	21.0%	79.0%	0.0%	0.0%	86.4%	5.6%	1,873
Dearborn	199,999	97.5%	2.5%	97.4%	1.6%	0.0%	0.9%	1,866

Table 2. The 25 counties in Indiana with the highest predicted water use increase by 2050.

SUSTAINABILITY

One of the essential tasks in preparing a regional water supply plan is to understand the impacts of any natural or physical constraints on estimated future water sources. While low stream flows are defined statistically, groundwater supplies are constrained ultimately by recharge. Thus, it is important to know whether expected groundwater resources are sustainable; i.e., whether the land surface will be adequate to recharge what is expected to be pumped out of the aquifers in the future.

In 2009, the state of Wisconsin commissioned a sustainability analysis for aquifers in the southeastern region of the state. A fairly detailed modeling study was performed to assess the sustainability of future increases in groundwater use near new residential developments (Bradbury and Wayne, 2009). The study reported the percentage of annual recharge captured by wells and the effect that this withdrawal would have on base flows during drought periods. This analysis, appropriate for a regional planning project, illustrated the value of comparing elements of the water budget to highlight potential problem areas. The results of the study showed that use of 50 percent of the total recharge reduced the flexibility of options and indicated a potential future shortage. Recharge estimates varied from over seven inches per year to under two inches per year in the different "demonstration areas."

For the sustainability analysis for Indiana, a similar approach was adopted, with somewhat different conditions. The analysis that was completed across the state used IDNR digital aquifer maps, classified each according to whether they were exposed at the surface or buried, and then distributed recharge according to the algorithm illustrated in the diagram in Figure 27.

This analysis generated a set of recharge distributions that were then "clipped" to county boundaries to obtain the weighted average recharge into each county across the state (see Figure 28). These recharge estimates were checked against stream flow data to confirm that the estimates were not out of line with the flows in these streams. While more detailed methods could be used to model recharge at a county level, this approach satisfied the needs of a "back of the envelope" estimate that fit the purpose of the analysis. Recharge into the system is actually variable and is not uniform in any county, but these values provide the bounding values to compare to other elements of the water budget, particularly groundwater withdrawal.

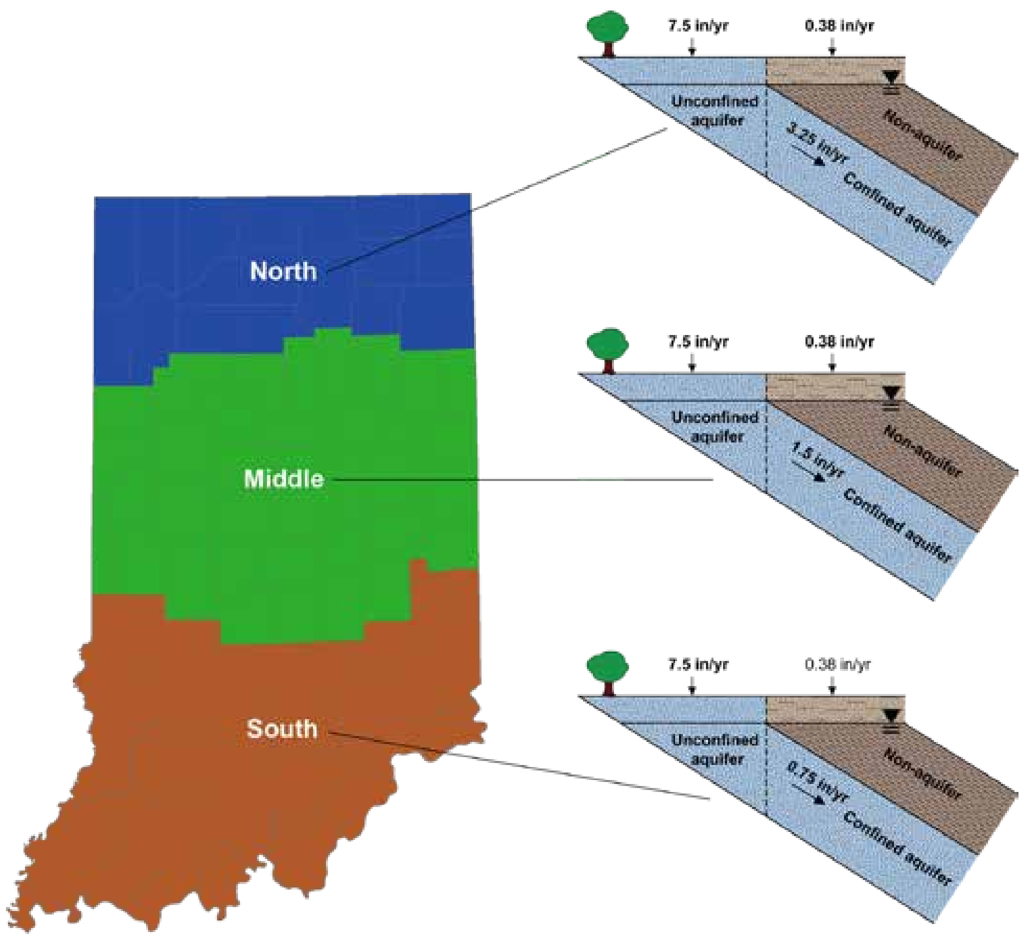


Figure 27. Diagram illustrating statewide recharge estimation approach. The approach differentiates between mapped surficial aquifers and buried aquifers (IDNR). The least recharge is assumed for areas mapped as non-aquifer areas.

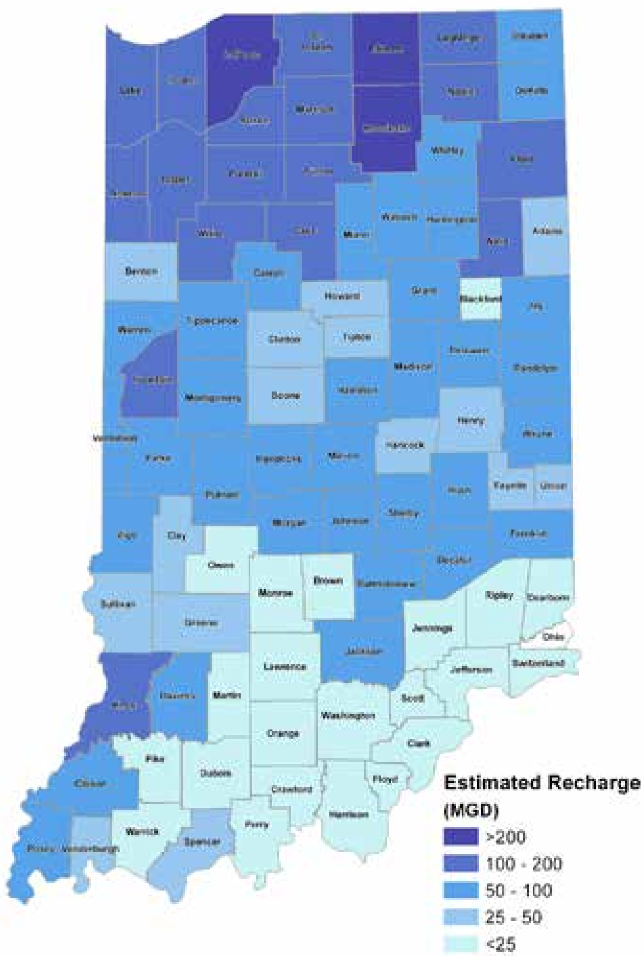


Figure 28. Estimated aquifer recharge based on average conditions and base flow in streams (Bayless, 2014).

Sustainability of Groundwater

This analysis estimates future groundwater use to 2050 in each of the counties that were predicted to see an increase in total withdrawals. In this statewide assessment, the future groundwater demands (as a fraction of total demands) were estimated and compared to reported 2012 groundwater use as a baseline for gauging increase in use. This approach is conservative because 2012 was a high-use year so the increase was attenuated by the dry conditions in the reference year. The results of that change in groundwater withdrawal are illustrated in Figures 29(a) and 29(b).

In each county where water use was expected to increase, growth in groundwater demand between 2012 and 2050 was estimated and then mapped by the ratio of additional pumping to the total estimated recharge in each county. This provides an indication of potential hydrologic constraint on future groundwater use [Figures 29(c) and 29(d)]. Where withdrawals approach the estimated recharge, it is likely that water level declines will occur when pumping rates are higher than average. The analysis indicates that there is a cluster of high withdrawal/recharge ratios in the industrial counties along Lake Michigan, near the large rivers in Southern Indiana and another extending from Tippecanoe County east and south to metropolitan Central Indiana. The expected growth could push both Hamilton County and Marion County into the highest (>1) category of potentially unsustainable withdrawal.

Our findings are consistent with what has been described in recent groundwater planning and development in the West Fork White River Basin. The ratio is very high in some of the growing counties in Central Indiana. The fact that these ratios approach one is supported by recent water supply exploration and utility planning analyses for the middle of the state (Malcolm Pirnie, 2005). This work, commissioned nearly a decade ago to provide information about system expansion to the municipal utilities, reached some important conclusions:

1. Surface water supplies in the basin will be fully allocated by 2020
2. Groundwater resources are not being monitored or managed so conflict is difficult to avoid

Based on an earlier water supply analysis conducted for the same utility (Black and Veatch, 2003), groundwater supplies in this part of the state are at least locally limited. Drillers' logs from Hamilton County show that the river and streams are often separated from the 50- to 70-foot-thick sand and gravel deposits by an intervening clay layer. This clay creates a hydraulic barrier in the saturated zone that reduces the amount of induced recharge that can occur as wells lower groundwater levels along the stream. This limit on induced recharge is one of the reasons that the county cannot simply drill more wells to satisfy future demands. The approach to managing water resources will determine the degree to which communities and other local and regional water users will need to develop new plans and sources to accommodate the expected growth.

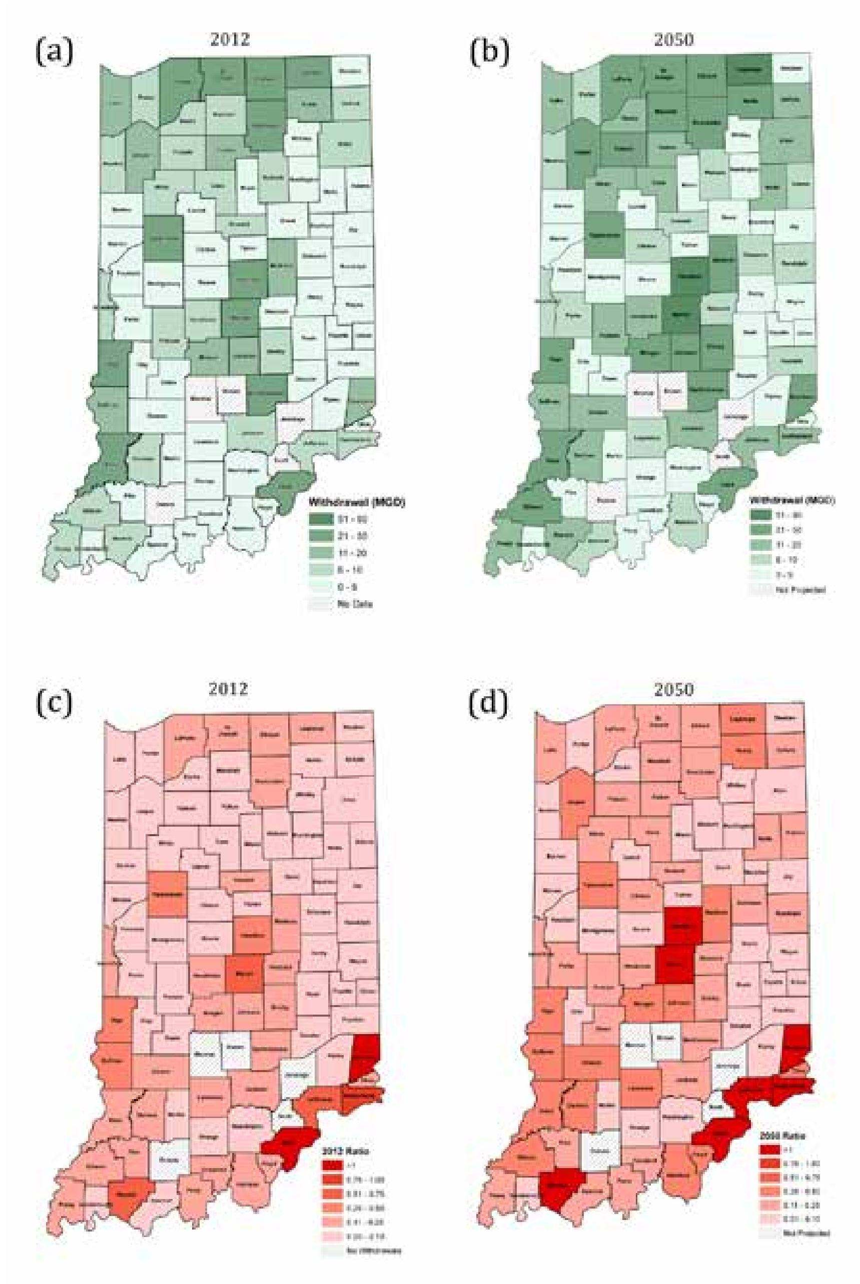


Figure 29. Groundwater pumping in (a) 2012 and (b) 2050 and the ratio of pumping to recharge in each county in (c) 2012 and (d) 2050.

Groundwater Demands and Supplies in 2012 and 2050

In addition to assessing how future groundwater extraction compares to estimated recharge rates, it is useful to consider how the projected pumping compares to the aquifer storage in each county. Figure 30 presents this information graphically: the estimated future increases in water use are mapped onto both the surface water availability map and the groundwater availability (storage) map. The purpose is to illustrate the areas where future demands may not be easily satisfied with either stream flows or groundwater. The large red dots indicate the increase of future water use scaled to show high water-use counties (Jefferson along the Ohio River, and Hamilton, in the middle of the state) relative to the lower-growth counties (Rush, Fayette, and Jay counties along the eastern side of the state). The counties shown in tan have less water in groundwater storage than the counties shown in blue. This means that the counties to the north have substantial groundwater in storage that could be used to satisfy temporary increases in demand, and the counties along the large rivers (shown in blue in this figure) are also not vulnerable to shortage.

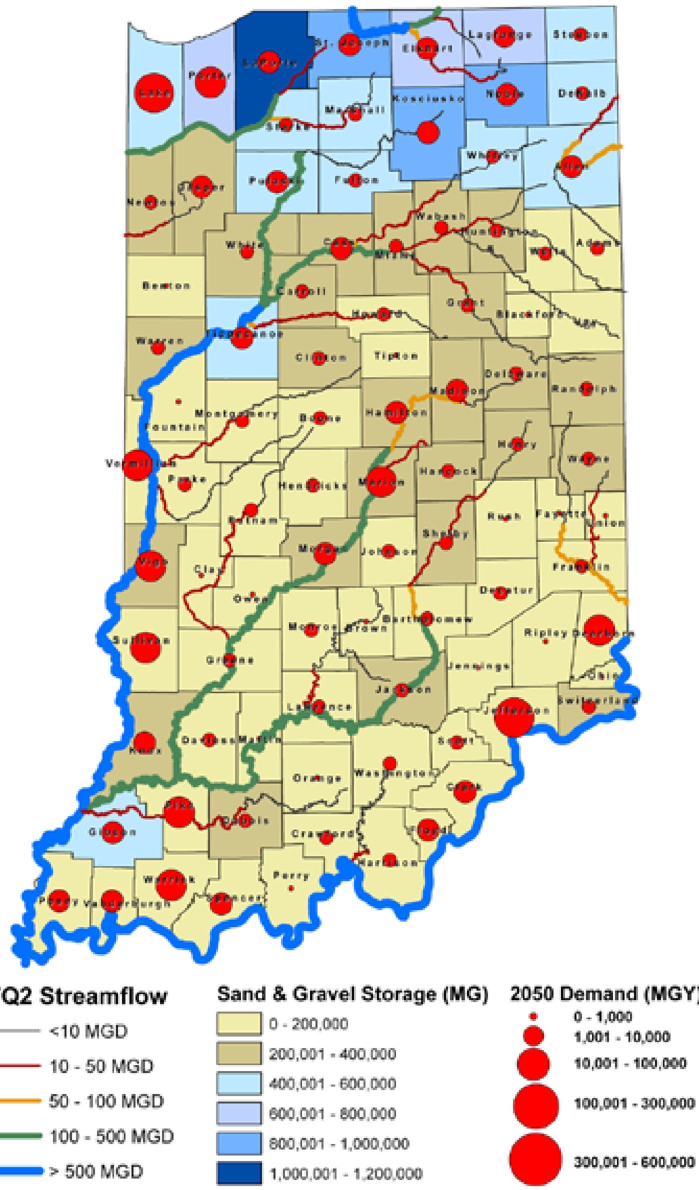


Figure 30. Groundwater storage in shallow aquifers compared to 2050 forecast use.

The figure indicates that, consistent with what others have been saying and reporting for the past 10 years, Central Indiana needs a new source of supply to satisfy anticipated growth. Marion County and, southwest of it, Morgan County, both of which rely on surface water withdrawals to meet their power and industrial demands, are high-water users relative to aquifer storage. Hamilton and Madison counties, however, rely heavily on groundwater for growth, so these counties that had historically used groundwater to satisfy new demands, will not be able to develop new, sustainable groundwater given their anticipated growth in future demands.

Counties in the northern part of the state are using supplies that have, at least recently, not been noticeably affected by use. IDNR monitoring wells in a few locations suggest that the trend in water levels at the end of the growing season has been downward. Recovery continues to occur but more of the water that is pumped is being removed from storage than ever before. These increases in use suggest that Northern Indiana needs to monitor groundwater levels if the aquifers are the default supply for irrigation.

Essentially, the counties in the figure with large red dots indicate high future use. If counties are lighter (green/tan) colored, this indicates a gap so they may not be able to provide for long-term shortages with additional aquifer development. These counties are at risk because they do not have large groundwater reserves or large rivers.

This combined data set illustrates how many counties could have problems meeting their water needs in the future. This graphic corroborates the earlier sustainability analysis and strengthens confidence in the conclusions reached in this report about the geography and scale of potential problems. Planning is needed to connect available supplies to the areas in the state that will be required to provide water for growth.

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REVIEW OF STATE WATER SUPPLY PLANNING

In the middle of the last century, water supply planning was the exclusive domain of the federal government. Large water supply and storage projects required federal attention and the U.S. Army Corps of Engineers was the lead agency responsible for designing reservoirs, estimating the required demands of different users, and balancing these uses against the limits of storage and funding.

As federal funding has become more scarce, the responsibility for water planning has shifted somewhat in recent decades, with a number of states preparing water plans. In 2006, the American Society of Civil Engineers (ASCE, 2006) established a task committee to produce a summary of state water-resource planning efforts from 1986 to 2005. This work evaluates the plans produced by the various states and summarizes the key elements the plans shared:

- Resource assessment
- Conflict identification and management
- Issue identification
- Involving the right stakeholders
- Developing coordinated and collaborative planning partnerships
- Developing long-term financing
- Identifying implementation strategies
- Developing monitoring and assessment programs
- Educating the public and decision-makers
- Providing feedback to support updates to the plan

In addition, the report provided a profile of each state's efforts in regard to water resource planning, including the goals established, the agencies involved, and the extent of inter-regional involvement. The study pointed out regional trends and noted a number of state programs that have been implemented to solve problems similar to those found in Indiana. In the west, where the recent drought has left many agencies and water systems stunned by the effects of long-term drought, headlines are now suggesting that "states are running out of water" (USA Today, 2014). The western landscape has always been arid; typically, western states have used formal water rights adjudication to prioritize withdrawals and federal projects to move water across the landscape. Desalination, conservation, and higher water prices are all methods being used to avoid economic difficulty. However, this is the first time when reductions in water availability could affect regional economies. In the past decade, states in the eastern U.S. have begun engaging in the process of water supply planning in spite of limited experience and technical resources. The work is being done in most states because they have each independently determined the need to actively manage water resources to maintain a healthy economy. States in the humid part of the country, including Georgia, Minnesota, and Virginia, have all developed programs that incorporate water supply planning elements so they could meet the challenges of shortage.

Water is generally more available in the Midwest than in the drier states of the west and northeast, but as states that use the riparian doctrine as the basis for water use, planning is the most efficient approach to management. After the summer drought in 2005, the state of Illinois developed a two-phase approach to regional water supply planning. In 2006, the governor signed Executive Order 2006-01 that established funding to develop two plans in two very different parts of the state. One plan was developed for the metropolitan Chicago area by the Chicago Metropolitan Agency for Planning (CMAP), while another was completed in Central Illinois in the counties that use the Mahomet Aquifer. The Mahomet Aquifer planning effort included rural communities, small towns, and many industrial and agricultural water users. The Chicago planning effort was focused almost exclusively on the largest water users that were developing groundwater supplies in the suburban areas west of the city (CMAP, 2009). Several million dollars were used to organize and develop a water supply plan for the two pilot planning regions. Because Illinois had many fiscal problems that were exacerbated by the economic collapse in 2008, funding eventually was lost, but not before a basic plan had been completed in each area. Since the 2012 drought, the state has worked to implement these plans in the existing regions and add new regions, supported by the state water survey and planning agencies. (For more information, see http://www.cmap.illinois.gov/documents/10180/14452/NE+IL+Regional+Water+Supply+Demand+Plan.pdf/26911cec-866e-4253-8d99-ef39c5653757)

In Georgia, droughts in the early 2000s were coupled with more than a decade of regional growth near Atlanta to create a regional water supply shortage and reawaken an old dispute. Known as the tri-state water dispute, the argument arose between the states of Georgia, Alabama, and Florida over water rights in two major basins. Georgia's Lake Lanier reservoir was constructed by USACE in 1957 and was under the administration of the Corps. When USACE recommended assigning more water from the reservoir for use in Atlanta's municipal supply, downstream users in Florida and Alabama complained and filed suits. The arguments over where the water should be going have not yet been resolved, but the state of Georgia has published its first state water supply plan (Mullen, 2011). This plan defines the planning regions, describes the regional-state planning responsibilities, provides a schedule for meetings to begin the process, and notes legislative funding in the range of $10 million a year could help to avoid further legal difficulties. (For more information, see http://www.georgiawaterplanning.org).

Known for its lakes and aquatic landscape, Minnesota recently initiated water supply planning. The program is funded by a referendum that mandated appropriating a small percentage of the state's sales tax and will be used to implement Minnesota's water initiative that results in an annual supplement of more than $50 million a year. As a first step, the legislature funded the University of Minnesota Water Resources Center to develop a framework that included outreach to water users, defined objectives in each region of the state, worked to integrate agricultural land uses into the implementation of the Clean Water Act, and identified tools and data gaps that must be filled to manage the resource (UMN Water Center, 2011). (For more information, see http://wrc.umn.edu/watersustainabilityframework/).

In a similar fashion, the state of Oklahoma commissioned its Water Resources Research Institute to hold meetings and facilitate local and regional meetings to identify issues and develop a framework for planning. Over three years, the meetings were held at the Institute, part of the Division of Agricultural Sciences and Natural Resources at Oklahoma State University, to educate the public, elected officials, municipal water suppliers, irrigators, and other water users around the state about water availability and to consider alternative approaches to regional planning (OCWP, 2012). Unlike in Minnesota, the technical and institutional framework already exists in Oklahoma within the Oklahoma Water Resources Board. This work was funded by a $13 million appropriation from the legislature. If it were fully implemented, the funding expected for the program, including data collection and water availability modeling, could approach $10 million a year. (For more information, see http://www.owrb.ok.gov/supply/ocwp/ocwp.php).

In Indiana, USACE has historically been responsible for some of the larger reservoir projects. The Corps used a standard engineering approach to determine the cost-benefit of each new development. The reservoirs that were built each had a primary flood control purpose that was supplemented by the benefits of recreation and water supply to balance the federal expenses of the construction and engineering. In each case the reservoirs were built after a set of agreements with the state about the priority of use for sections of the stored "pool" behind the dam. The state was a party to the memoranda of understanding that defined the management and operational responsibilities of the state and USACE. While this "top-down" approach to planning was the norm for these projects, the work being done recently in most states reverses this approach, including active stakeholders and local interests who work together to make planning decisions.

Common Themes in State Planning

Each of these programs, and the reports that have initiated them, has several common characteristics that could be instructive to Indiana:

- **Allow for variation.** Metropolitan areas dominated by municipal concerns are focused on problems that are technically and hydrologically distinct from those faced in smaller communities and rural areas. Conservation and water reuse may not be practical in rural areas with widely distributed, independently owned and operated wells. The problem of managing demand in a city is not the same as managing water use for irrigation.
- **Ensure funding is secure.** Resources for the planning process need to be secure enough to allow planners to think long term. If there are questions about the value of water supply planning, there is no possibility of success. It may not be possible to compare the water management and planning programs in Florida and Texas to those in Indiana. But in many similar-sized states with similar economies, none of the states reviewed for this report was unable to fund the new effort.
- **Seek technical objectivity.** In the eastern United States, cooperative management can solve most water conflicts. In order to cooperate, however, the parties need to trust their planning partners so all stakeholders can work together to find common ground.
- **Make sure everyone is on board.** Communication and cooperative relationships with stakeholders are critical to the planning process. In some states the planning process began as a response to: "Big city needs more water." This focus on the rural–urban divide dominated early discussions and distracted from common ground shared by the parties.
- **Choose a trusted and credible leader.** All the water user groups and agencies should have a role but planning requires a leader. The state needs one entity that has the responsibility to lead the process of producing a plan.
- **Allow regional planners to do the work.** Water supply plans require extensive public discussion, but in the end the plan needs to represent the values and priorities of each region and the state. Decades of experience across the country has shown that "bottom-up" planning is

more successful than "top-down" planning. The state needs to have a technical and administrative role but the regional planning team members should be responsible for priorities and coordination among users. In most states the regional plans are rolled up every five years into the revised state plan.

Table 3 provides a matrix of planning programs that are currently in place in seven states. For each state, the table provides the population, the dimensions of the economy, the funding used to sustain the program, and the change in GDP during the last year. Under the name of each state in column 1, the original impetus for water planning is given.

State/ *Orig. Impetus*	Population in 2013	2012 GDP	Funding Amount/ Sources	GDP growth 2011 to 2012
Texas ***Drought***	26,060,000	$1.397 T	▪ **$500 M** ▪ Conservation fees ▪ Utility water sales tax ▪ Water rights fees ▪ New development fee	4.8%
Minnesota ***Impacts***	5,380,000	$295 B	▪ **$85 M** ▪ 0.125% sales tax ▪ Clean Water Fund	3.5%
Florida ***Impacts; Storms***	19,310,000	$777 B	▪ **$1 B** ▪ Ad valorem taxes ▪ State appropriation ▪ (~3,000 employees)	2.4%
Oklahoma ***Shortage***	3,850,000	$139 B	▪ **$10 M** ▪ State appropriation ▪ (~12 FTE)	3.0%
Kentucky ***Drought***	4,395,000	$173 B	▪ **$1 M** ▪ Federal funds ▪ Water shortage plans	3.4%
Virginia ***Impacts***	8,185,000	$446 B	▪ **$2 M** ▪ State appropriations ▪ (~15 employees)	1.1%
Georgia ***Impacts***	9,992,000	$374 B	▪ **$10 M** ▪ State funding to regions	2.1%
Indiana	6,570,000	$298 B	none	3.3%

Table 3. Matrix of states with experience developing water supply plans. Demographic and economic data were obtained from the Bureau of Economic Analysis web site (BEA, 2014) and Wikipedia.

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CONCLUSIONS

The last time Indiana conducted a water supply inventory with recommendations for action was 1980. Indiana has since developed a powerful database of water use, worked with the USGS to record stream flows, and funded the work of a number of agencies, each partially responsible for water management. However, there has been no action to initiate the work. Future water requirements will need to be considered for all users if there is going to be a comprehensive plan for managing the resource. The state does not want to inhibit the growth or development of manufacturing, power generation, or agriculture. It is in the state's interest that all of these demands are met while meeting the needs of the ecosystem and supplying safe affordable drinking water to the public.

The following summarizes the findings and recommendations of the analysis and discussions described in this report:

Key Findings

SUPPLY

North of the Wabash River, Water is Relatively Abundant

In and around the Kankakee River Basin in the northern part of the state, there are thick regional aquifers and reliable, drought-resistant streams. In general, this part of the state has relatively abundant supplies to support expected growth in irrigation and population. However, the recent increases in seasonal irrigation make collecting data on these aquifers and streams important to: 1) ensure future supply reliability; 2) manage the impacts on stream depletion; and 3) determine the sustainable uses in these basins. Since the Great Lakes Compact defines water availability and management in the Great Lakes Basin, it is not included as a factor in this analysis.

Central Indiana has Marginal Supplies

The water supply in Central Indiana is diverse. It includes diversions from the West Fork of the White River, storage in water supply reservoirs in tributary streams, and groundwater from shallow and deep aquifers. The diversification of the water portfolio reflects the fact that there is no single solution to water supply and growth in this portion of the state. Supplies are limited and, without new sources, economic growth may falter.

South of Indianapolis, Supplies are Only Locally Available

In Southern Indiana, local water resources are not always able to meet anticipated future public water-supply needs. Given that this portion of the state is poised for economic growth, it makes sense to provide incentives for developing more diversified supplies for these communities. This may mean targeting distant water supplies, including the large U.S. Army Corps of Engineer (USACE) reservoirs built in the 1960s, as sources that can supplement small community systems and accommodate growth.

DEMAND

Groundwater Use is Increasing

While industrial use, power generation and mining operations continue to pump water from rivers and streams, over the last decade groundwater withdrawal has increased more rapidly than surface water diversions. The aquifers of the state are becoming increasingly important as a means of satisfying seasonal demands and controlling costs of treatment and conveyance. The water use data reported to the Indiana Department of Natural Resources (IDNR) suggests that this trend will continue if the climate becomes less stable and regional shortages develop.

Irrigation is Expanding in Northern Indiana

Irrigation of row crops continues to be the fastest growing sector of water use in the state, even in some areas that have declining populations. This reflects the significant returns on investment provided by irrigation (primarily new high-capacity wells) and the increasing value of insurance against dry periods. Because most areas that are dominated by irrigation water use also have more prolific aquifers and more reliable water supplies, the primary impacts that require analysis are the seasonal rebound of aquifers from summer pumping, impacts on municipal or industrial neighbors, irrigation well spacing, and the need for additional groundwater monitoring. Actual irrigation water use, rather than numbers of wells, fluctuates according to seasonal rainfall. While additional wells may be installed in many locations, their use increases when there is a deficit of precipitation. This seasonality and annual variability are distinct characteristics of irrigation pumping relative to other users in a basin.

Public Supply Growth Drives Demand in Central Indiana

The population in Central Indiana is growing rapidly, and estimates of future demand suggest another 50 million gallons per day (MGD) of supply will be required to meet the needs of the region by 2050. (Only one third of the water delivered in a public supply system is not returned through the municipal wastewater discharge, National Academy of

Science, 2012). As the water utilities in the middle of the state consider new well fields to satisfy growth, conservation and demand management will become standard policy in meeting seasonal peak demand for water. Limited groundwater and relatively low flows in streams limit available options. This part of the state will need to build new surface water storage capable of satisfying future demands or develop well fields in other watersheds. The latter alternative will require that water from distant well fields be piped in to meet the demands of population growth. Before using either alternative to meet the public water supply needs of a metropolitan area, it is important to determine the magnitude of consequences to downstream water users. It is equally important to understand the long-term impacts and risks of any proposed solution before making such an important investment.

Infrastructure Investment: Strategic, Not Opportunistic

The I-69 expansion in Southern Indiana, along with continued funding of the Crane Division of the Naval Surface Warfare Center (Crane NSWC), creates a long-term economic growth opportunity in this part of the state. This growth depends, in part, on the availability of safe and reliable water supplies. Along I-69, water is either abundant or absent. There are few aquifers or perennial streams present immediately south of Bloomington. Further south, however, water is available from along the White and Wabash rivers. Continued development of these investment corridors means ensuring that businesses have access to adequate supplies of water. When new infrastructure is planned, water supply should be an important consideration in the siting process.

Power and Industrial Use May Locally Increase and Continue to Dominate Other Uses Statewide

Throughout the state, the largest surface water withdrawals are not increasing but they may add capacity as opportunities open for new development. Thermoelectric power generators have become more conservative as they switch from coal- to gas-powered plants and develop more efficient designs and operational methods for new facilities. While statewide use is less than prior years, new plants continue to be built. To avoid conflict, new generating stations are often located along the largest rivers to support the cooling water needs of the system. In previous decades industrial water use has steadily declined, and the use of surface water is correspondingly falling. New developments could shift this trend even though estimates of future use account for no increase in these sectors.

PLANNING

Conflicts Can Be Avoided

During the drought of 2012, domestic well owners in some locations sought assistance from IDNR to mitigate problems with their wells (e.g., dry wells or significantly declining water levels). In some cases, high capacity aquifer withdrawals could have been designed or managed to reduce well interference and eliminate impacts. Where these conflicts occur, the uncertainties associated with water supplies have negative impacts on the commercial sector, which relies on these supplies to manufacture products. For the most part, unanticipated water shortages can be avoided through better data collection on the aquifers, using regional water supply models of the hydrologic system, and improved planning that is designed to anticipate the effects of combined withdrawals.

Watersheds are Natural Planning Areas

The water supply planning process includes coordinating, among the various users, the management of limited water resources during times of shortage. By defining regions within a state, which generally coincide with major watershed boundaries, plans can be developed that represent regional water user interests and economic conditions. These regional plans can then be integrated into a comprehensive state water plan. There is currently no coordination of water use in Indiana's major river watersheds and, while implementing a regional/state planning process will require establishing rules and procedures, the cooperation among water users that this process establishes will enhance resource utilization and improve water supply reliability throughout the state.

Development Can Produce Jobs Near Existing Resevoirs

The Brookville Reservoir was built by USACE in the 1960s for flood control. Like many of Indiana's other reservoirs, the stored water in the Brookville Reservoir, absent other infrastructure and opportunity, is inadequate to attract new investment. Through proactive planning and the systematic renegotiation of priority of use and other issues with USACE, these reservoirs represent development opportunities. Establishing high-water-demand facilities such as bottling plants, breweries, and food processing operations in close proximity to some of Indiana's larger reservoirs offers the potential to add jobs through the use of these available and sustainable natural resources.

Instream Flows Should Be Understood

Generally, the term "instream flows" is defined as the amount of water set aside in a stream or river to ensure downstream environmental, social, and economic benefits are met. Maintaining adequate stream flows can contribute to the basic ecological integrity of the aquatic environment, support endangered species, and facilitate interstate compact compliance. Tourism and recreation also rely heavily on dependable stream flows. While there are definite benefits to maintaining stream flows in some streams and rivers, there are likewise valid concerns to consider, such as potential impacts to consumptive users due to reduced water availability, changes in the location of that availability, and related economic development implications. Regional water planning serves to prioritize instream flows among all other uses.

Conservation Plans are a Necessary Management Tool

Unless the primary source is a drought resistant supply (e.g., the Ohio River), establishing and implementing a conservation plan should be a normal part of every water utility's operations. Implementing conservation plans allows communities to reduce the cost of additional infrastructure and saves customers money. Although these plans may not be able to provide protection from a chronic shortage, they are ideal for infrequent but expected dry spells that may become more common in the future.

Recommendations

While the Indiana Utility Regulatory Commission (IURC), the state legislature, IDNR, and the Governor's Water Shortage Task Force (Water Shortage Task Force, 2009) have all made useful recommendations over the past several years to modernize water supply planning in Indiana, these recommendations have been somewhat general in nature. This report identifies the geographic location of major water resources and future demands within the state to provide a new level of specificity to the water planning tasks that lie ahead. The recommendations that follow, based on the findings summarized above as well as the common elements of other state plans and processes, reflect the steps which need to be implemented within the next decade to set the appropriate course for effective water resource planning in Indiana. These recommendations indicate that other states have found that it takes several years of preparation before the regional planning process can begin. Data needs to be collected, models of reservoirs, streams and aquifers are needed so that regional planners can ask the many "what if?" questions that need to be addressed.

CREATE AWARENESS ABOUT THE NEED FOR WATER SUPPLY PLANNING

Beyond flood conditions, Indiana has never before needed to actively manage water resources. That is no longer true. Changes in water use and natural limits on availability need to be explained to the public. The only way for Indiana to grow economically and demographically is to manage the critical resource that supports industry, power generators, ecosystems, agriculture, and drinking water supplies.

Failure to properly plan for increasing demands in growing parts of the state may create significant water supply challenges. Educating farmers, local government, conservation, and business leaders on the need for responsible water planning and use is a necessary step to long-term water security in Indiana.

Begin Public Outreach

The most important aspect of the water resource planning process is interaction with the public and high-capacity water users. Water supply planning succeeds when people at the local level – irrigators, public water supply operators, power plant operators, industrial water users, gravel and aggregate processors, and coal mine operators – all understand the many uses and long-term value of our water resources. These key stakeholders are generally informed about the local water resource issues. Other states have found that it takes up to three years to understand and document how each region of the state differs in both supply and use, While the public process proceeds, initial analyses could be done to define the state planning regions and develop regional groundwater and surface water simulation tools to determine water availability. This is an investment necessary to define local needs and provide information that will guide the work. Outreach is critical to determining the most practical processes and geographies needed to manage technical data and models.

Conduct Statewide and Regional/Local Outreach

It is important to remind the public of the values that underlie the commitment of diverse stakeholders and government to responsible water resource planning. This could be initiated with a statewide symposium to focus on the importance of water to our economy and to listen to the many perspectives of forward-thinking water users. Local and regional meetings can be held to describe the water resources in each region and to record different concerns and questions that are offered by the public. These local and regional meetings should be professionally coordinated and conducted by a credible organization (e.g., a university) to ensure that information gathered is used to guide the decision-making processes embedded in planning.

CREATE CAPACITY TO COORDINATE EFFORTS

Establish Communication and Accountability Framework

To ensure long-term success, one state-level entity needs to be designated to lead planning efforts of the agencies and universities. The General Assembly should pass legislation that ensures agencies and universities work toward a common goal for water resource planning. There are many state and federal agencies in Indiana that currently play a role in water management. IDNR, IDEM, IURC, IGS, USGS, and state universities all collect data or implement programs that in some way or another protect our streams and aquifers. Collectively, the state relies on these agencies to manage a resource, but without coordination or focus. Sadly, when everyone is responsible, no one is responsible. Given the imperatives of growth, Indiana needs a dedicated team with the technical capacity to support local planning while providing rules, models and data for the broader regional planning process.

Fund Water Research

In as much as Indiana needs to develop new ways to manage this precious resource, it needs to fund research in water resources engineering and policy development. Establishing and using a water planning program to enhance water security means investing in the research needed to understand the state's particular hydrologic systems. Decisions that are being made today, such as how to decide whether to build the Mounds Reservoir upstream of Indianapolis, will impact the availability of water for generations to come. The data, methods, and tools created and developed through research should support the state to help it make the best possible decisions that both protect and promote our water resources.

CREATE A ROBUST SYSTEM FOR WATER RESOURCE MONITORING

Monitor Groundwater Availability

There is little information on total available groundwater in the state. Public and private efforts have been made to describe aquifer dimensions, water levels, well yields and recharge. However, the few clusters of monitoring wells in the aquifers of the state make it impossible to track trends, determine impacts, and provide the validation needed to avoid conflicts among users. An expanded network of groundwater monitoring wells should be installed around the state, beginning with areas of greatest concern, to collect aquifer data to optmize uses and increase short and long-term dependable yields.

Regularly Analyze Low Flow In Streams

The USGS has historically been funded by IDNR and IDEM to observe, report, calculate, and estimate low flow statistics of Indiana rivers and streams. While this information is needed to estimate surface water availability and drought yield, the funding for this work has been sporadic and unreliable. By monitoring flow trends, signals of drought will not be missed. Low-flow analysis can be extended to estimate storage properties of aquifers that discharge into gaged streams. Tracking how low-flow varies over time and within a basin would allow the state to calibrate recharge models and use engineering techniques to better manage supplies during shortage. This would leverage existing cooperative agreements for data collected between USGS and the state.

CREATE A STANDARDIZED SYSTEM FOR DATA ANALYSIS

Evaluate Aquifer Sustainability and Yield

Currently, there is no standardized technical framework for determining and describing the properties of aquifers in Indiana. IDNR, IGS, IDEM and USGS all maintain data on water levels, flows, and hydrologic properties of aquifers. By developing water availability models for the most heavily used aquifers and river basins in the state, decisions can be made based on integrated assessments of the effects of all water uses. In addition to bringing together the hydrologic data collected by different agencies, the state can use this information to develop basin-scale estimates of aquifer recharge that will inform water use and planning. A feasibility assessment of riverbank filtration well fields along large rivers in the state could also be performed. These well fields offer the potential to increase water yield while reducing some of the negative impacts associated with other types of large well fields.

CREATE SYSTEMS TO COOPERATIVELY MANAGE WATER

Optimize Reservoir Management

There are two different problems associated with reservoir management in Indiana: 1) each reservoir has a different priority of use that reflects the funding and mandate when it was built; and 2) operation of the reservoirs (outside of the Army Corps reservoirs) does not consider downstream uses. This means that a reservoir originally constructed 50 years ago for flood control is operated today in a way that reflects the original mission, regardless of whether the reservoir could be an important supplement to water supplies in some part of the state. Multiple reservoirs within a basin can be operated with an integrated understanding of the needs of all water users. The development and application of hydraulic models, using software codes such as RiverWare or OASIS, enable reservoir operators to manage drought by simulating and optimizing flows within the basin. Properly applied, these models can provide the information needed to make drought plans effective and practical.

Develop Water Demand Forecasts By Drainage Basin

As water resource planning begins across the state, detailed water demand forecasts are needed to account for the regional factors that affect growth and water use. Modeling future changes in demand for the largest surface water users (energy and industrial supply) will be an important part of planning in the southern portion of Indiana. Water demand forecasts provide an opportunity to use the planning process to educate the public about the effect of conservation while providing time frames for engineering and planning studies to fill supply gaps. Understanding the degree to which future demand is affected by prices or population or other economic factors will make predictions of future use more robust during planning. Water demand forecasts ideally reflect the interests of the communities being served and are one example of "home rule."

ALLOW THREE YEARS TO PREPARE FOR IMPLEMENTATION

As the state moves forward with developing a comprehensive water plan, someone needs to lead the way. The only way to evaluate proposals for interbasin transfers, infrastructure development and maintenance, regulatory requirements, priority among different users, responsibility for impacts to neighbors, impacts to ecological flows, as well as public health and safety, is with the technical support provided by an appropriate level of oversight (i.e. state, regional and/or local) and a stable funding mechanism. Planning requires a responsible entity with appropriate levels of authority to provide the confidence needed. The work of an existing agency, organization or university could be expanded to fill this role. It is also possible that the General Assembly and/or the Governor could establish a new entity that has this responsibility. Some tasks may fall to regional or local planning teams put in place to manage their water resources. Whatever structure is created, it will be necessary that the direction of the state and the responsibility of the various parties are articulated in a statewide plan that is supported by the Governor and the General Assembly.

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