



US Army Corps  
of Engineers®

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# Ohio River Basin

## Long Term Water Resource Plan

U.S. Army Corps of Engineers and the Ohio River Valley  
Water Sanitation Commission  
8-18-2022

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## Executive Summary

Water resources are vital to life. With future challenges related to climate change, population growth and other stressors, a long-term plan is needed to ensure that abundant, clean water is available to meet domestic, economic, and environmental needs. Population projections for the year 2050 predict the world will have to feed and provide energy for an additional 2-2.5 billion people. According to the 2020 U.S. census, the population of the Ohio River Basin is estimated to be 30,580,000 people. This number is expected to continue to grow at an annual rate of 0.59%.

Building on previous studies by ORSANCO and USACE, and in coordination and collaboration with ORSANCO's Water Resources Committee, this report aims to address water shortages and other relevant water resource challenges within the Basin.

The focus areas of this report are derived from the 2020 Plan for the Ohio River Basin (USACE et al, 2019). These focus areas are located under the Abundant Clean Water goal within the plan, which aims to provide guidance and address current and future challenges to clean water. This includes the need to increase the number of water bodies that meet the standards of both the EPA's Clean Water Act and Safe Drinking Water Act. The goal calls for a need to reduce the frequency and severity of Harmful Algal Blooms (HABs) over time as well as a need for performing an inventory to address drinking and wastewater systems needs in the Basin.

The water resource issues discussed in the 2020 Plan for the Ohio River Basin are all important to the health of the Basin's waters. However, this long-term water resources plan focuses on the strategies under the objective to "establish common goals directed at identifying Basin-wide problems affecting water quantity management and recommend strategies to address these goals". With ORSANCO as the lead organization, this document lays out the implementation of these strategies to sustain healthy, abundant waters in the Basin over the next 50 years.

Below (Table 1) is a summary table of the six strategies discussed in this plan with their corresponding key steps to success.

Focus Area	Key Steps for Success	Page Number
Secure financial and other resources to support Strategic Actions	1. Compile and maintain database of current and future resiliency legislation.	19
	2. Continue to push for legislation (such as recent infrastructure bill) that provides resiliency funding.	
	3. Create database of organizations working in the Basin, their geographic range, and key issues.	
	4. Maintain communication between organizations by creating interactive database of funding opportunities.	
Develop and maintain data layers for inclusion in the comprehensive Ohio River Basin GIS platform	1. Develop framework for comprehensive geospatial database and data gap analysis through a Basin wide Data Management Plan.	20
	2 Fill data gaps identified through Data Management Plan.	
	3 Maintain geospatial database with USACE.	
Develop partnerships to maintain and expand the US Geological Survey (USGS) Stream Gage network and use data to improve hydrologic and hydraulic modeling.	1 Establish communication with the USGS, with a contact for information on the USGS stream gage system for the Basin.	21
	2 Conduct a prioritization of stream gages in the Basin for use in a climate change impact study.	
	3 Utilize data from prioritization to identify infrastructure needs regarding climate change.	
Utilize ORSANCO's Water Quantity Committee to improve long term planning as it relates to climate change, population growth and other stressors.	1 Maintain ORSANCO's Water Resources Committee and ensure representation from all Basin states and develop a framework for the group.	22
	2 Find commonalities with respect to water resource priorities between the Water Resource Committee workgroups.	
	3 Work to find topics to prioritize across all Water Resource Committee workgroups.	
Collaborate with water quantity-related commissions to improve strategies and goals to protect the Basin's assets.	1 Identify domestic and international water quantity commissions and compile background information and goals.	23
	2 Find conflicts between water management commissions within the Basin and form strategies on how these commissions can avoid these conflicts.	
	3 Identify entities that have authority within or around Ohio River Basin.	

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Pursue a study that builds on the "Plan for the Ohio River Basin 2020-2025" focusing on water quantity and climate change.	1 Convene groups based on Strategy 5 that have interest in climate change and impacts to water quantity.	23
	2 Update the Ohio River Basin Climate Change Pilot Study on a 5-year basis with the 2025 update focusing on implementation (moving beyond strategy).	

*Table 1 Summary table of the strategies and key steps for success discussed in this plan.*

### 1.0 Introduction

#### 1.1 Background

The Ohio River Basin covers 204,000 square miles encompassing parts of 15 states. It comprises about 5% of the total U.S. land area and is home to over 30 million people equaling 10% of the population of the United States. The Ohio River is 981 miles long and runs from the confluence of the Allegheny and the Monongahela Rivers in Pittsburgh, Pennsylvania and ends in Cairo, Illinois. The Ohio River provides drinking water to several million people (Ohio River Foundation, 2020). The Ohio River and its seven navigable tributaries comprise over 2,500 miles of waterways, upon which more than 270 million tons of coal, aggregates, chemicals, agricultural, industrial and petroleum products are transported annually.

According to the climate change models performed in the Ohio River Basin- Climate Change Pilot Study Report, a half- degree (Fahrenheit) average temperature rise per decade is expected for 2011-2040. That number increases to one whole degree Fahrenheit per decade for 2041-2099. Additionally, precipitation changes are expected to impact water flows. These changing precipitation patterns drive increased water related challenges for agriculture, river transportation, water-dependent industries, and communities that require reliable water. The waters contained in the Ohio River Basin provide a wide range of functions including reliable and safe drinking water, transportation of goods and people, ecosystem services such as flood control, recreation, and support of diverse wildlife.

#### 1.2 Purpose

This report is prepared by the U.S. Army Corps of Engineers (USACE) Louisville District in collaboration with Ohio River Valley Water Sanitation Commission (ORSANCO) and the Ohio River Basin Alliance (ORBA).

The purpose of this study is to identify long term problems while considering the impacts of changes that will likely impact water quality and quantity, notably climate change. Considering these problems, focus areas for application of long-term strategies will be identified, as well as proposed strategies to address these issues. This report will also provide information on implementation of long-term strategies including a policy and regulation summary, key risks, and key benefits.

#### 1.3 Planning Assistance to States (PAS) Study

Driven by ORSANCO, and later by the Clean Water Act and other environmental regulations, billions of dollars have been invested by states, the federal government, and communities to improve water quality and restore ecosystems in the Ohio River Basin. In addition to the government initiatives, many agricultural, business, and watershed organizations have been integral to the Basin improvement. While there has been substantial progress over the past 70 years, much work remains to address both existing and emerging challenges. Efforts are likely to continue improvements in the Basin if water resources and ecosystems are a high priority. Clear priorities for the Ohio River Basin were identified as a critical need by the U.S. Environmental Protection Agency (U.S. EPA), USACE, and ORSANCO at their inaugural 2009 Summit. The Summit is now an annual event where Basin stakeholder groups come together to discuss and plan improvements throughout the Basin.

The collaboration of key organizations through these Summits resulted in the development of the six driving goals adopted by ORBA, and the USACE study that resulted in the report titled: Ohio River Basin -

Formulating Climate Change Mitigation/Adaptation Strategies through Regional Collaboration (Drum et al, 2017).

The 2020 PAS study entailed an extensive outreach effort to organizations throughout the Ohio River Basin to guide a strategic plan for the Basin. Through a series of virtual meetings, as well as in-person break-out groups at the 2019 Summit and focus groups in Pittsburgh, Cincinnati and Nashville, consensus was reached on six guiding goals and the strategies to reach these goals. The goals included are the following:

- **Abundant Clean Water:** Ensure the quality and quantity of water in the Ohio River Basin is adequate to support its dependent economic, social, and environmental functions.
- **Healthy and Productive Ecosystems:** Conserve, enhance, and restore ecosystems within the Ohio River Basin to support natural habitats and the fish and wildlife resources that depend upon them.
- **Knowledge and Education to Inform Decisions:** Ensure that research and education adequately inform Ohio River Basin-wide economic, social, and environmental decisions; enhance the profile of education organizations in the Basin that synergize efforts to garner effective public involvement in the stewardship and management of the Basin's resources.
- **Nation's Most Valuable River Transportation and Commerce Corridor:** Provide for safe, efficient, and dependable commercial navigation within the Ohio River Basin to ensure a competitive advantage for our goods in global and regional markets; sustain a water use system to efficiently and effectively support agricultural, industrial, and energy productivity.
- **Reliable Flood Risk Management:** Provide reliable flood risk management through well-managed and maintained infrastructure, including appropriate floodplain connections for water conveyance and ecosystem benefits, and management of surface and storm water runoff to better protect life, property, and economies.
- **World-class Nature-based Recreation Opportunities:** Enrich the quality of life for people and recreation-based economies by maintaining and enhancing riverine, lake, and wetland-associated recreation within the Basin.

Information from the outreach effort as well as background research from related studies was compiled into the strategic document and circulated for comment from the public and stakeholder groups before report finalization.



### 2.0 Challenges and Long-Term Effects

#### 2.1 Existing Conditions

It has been recognized that the demand for water has increased both nationally and globally. The section below describes the current conditions of water usage for the Ohio River Basin, which contains 546 counties fully or partially within the watershed from 14 states (ORSANCO, 2012). Watershed boundaries are shown below in Figure 1.

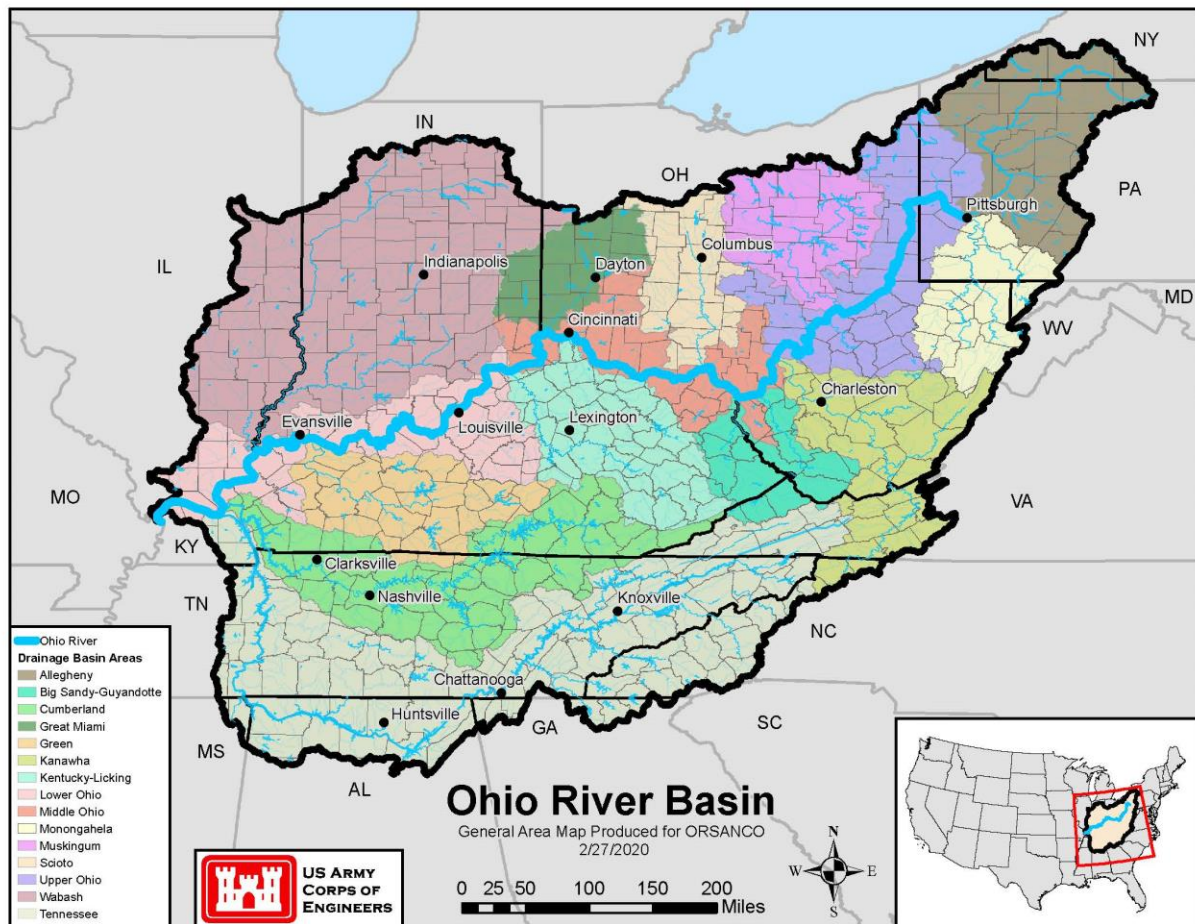


Figure 1 Ohio River Basin watershed area containing parts of 14 states

##### 2.1.1 Demands

The current data provided by the United States Geological Survey (USGS) represents the amount of water withdrawn from a source but does not indicate the amount that is consumptively used. Water use is defined simply as water that is withdrawn from a source. Consumptive-use is defined as water that is withdrawn and subsequently rendered no longer immediately available for other withdrawals. Examples include water that is evaporated, transpired, consumed by humans or livestock, or assimilated into crops or products (ORSANCO, 2012).

According to the report “Characterizing the Water-use in the Ohio River Basin” (ORSANCO, 2012), the total freshwater use in 2005 within the Basin is estimated at 43,817 Mgal/day which is approximately 12.5% of the nation’s total freshwater use. Figure 2 below shows daily withdrawal by county for the Basin.

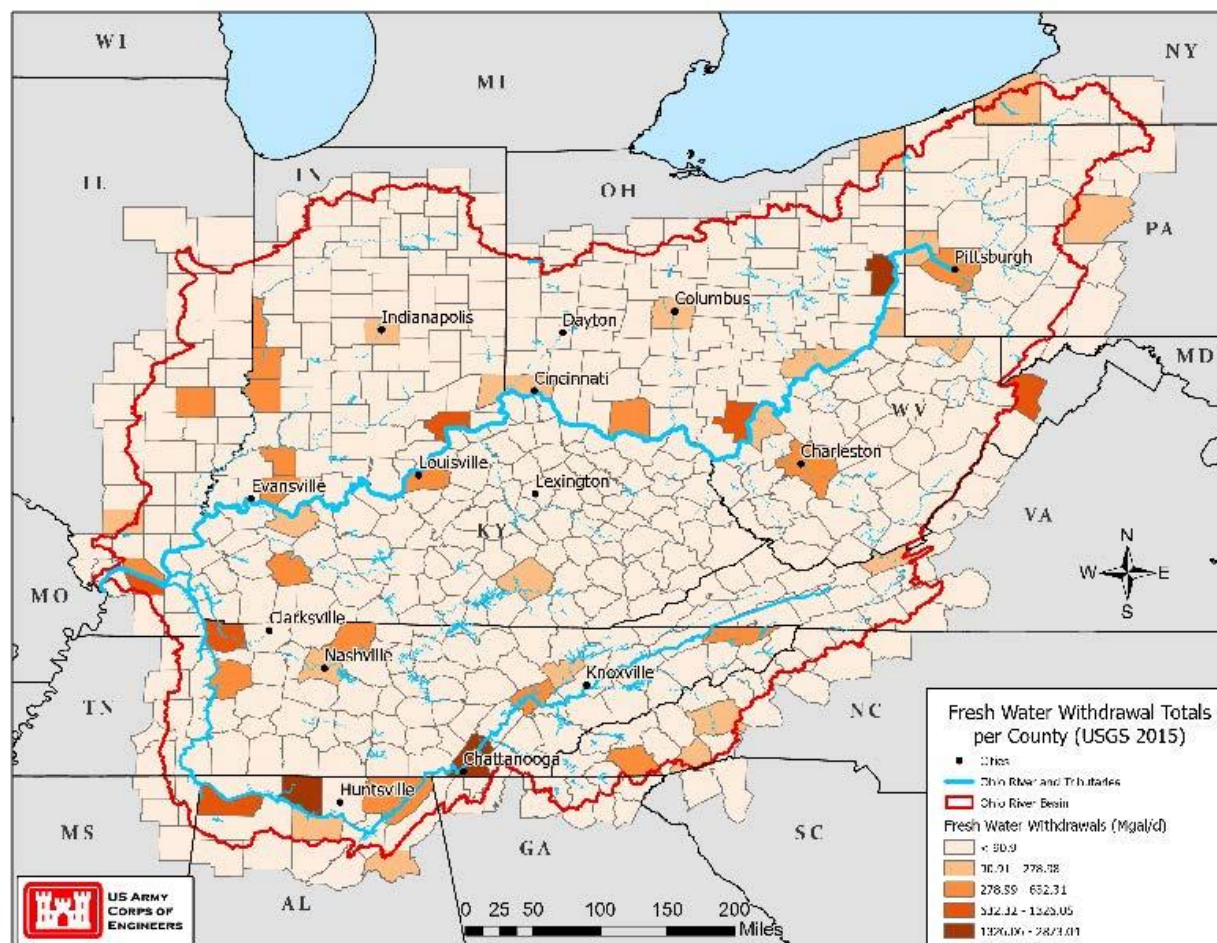


Figure 2 Daily water withdrawal by county

Of the total amount 4.9% was from ground water sources and 95.1% was from surface water sources. This report states that water withdrawals can be categorized into distinct uses such as thermoelectric, public water supply, industrial, etc. By far thermoelectric withdrawal comprises most water use at 79% of total withdrawals while uses such as irrigation, livestock, mining, and domestic water supply only comprise 1% of use. See Figure 3 below for the breakdown of water use in the Basin by category.

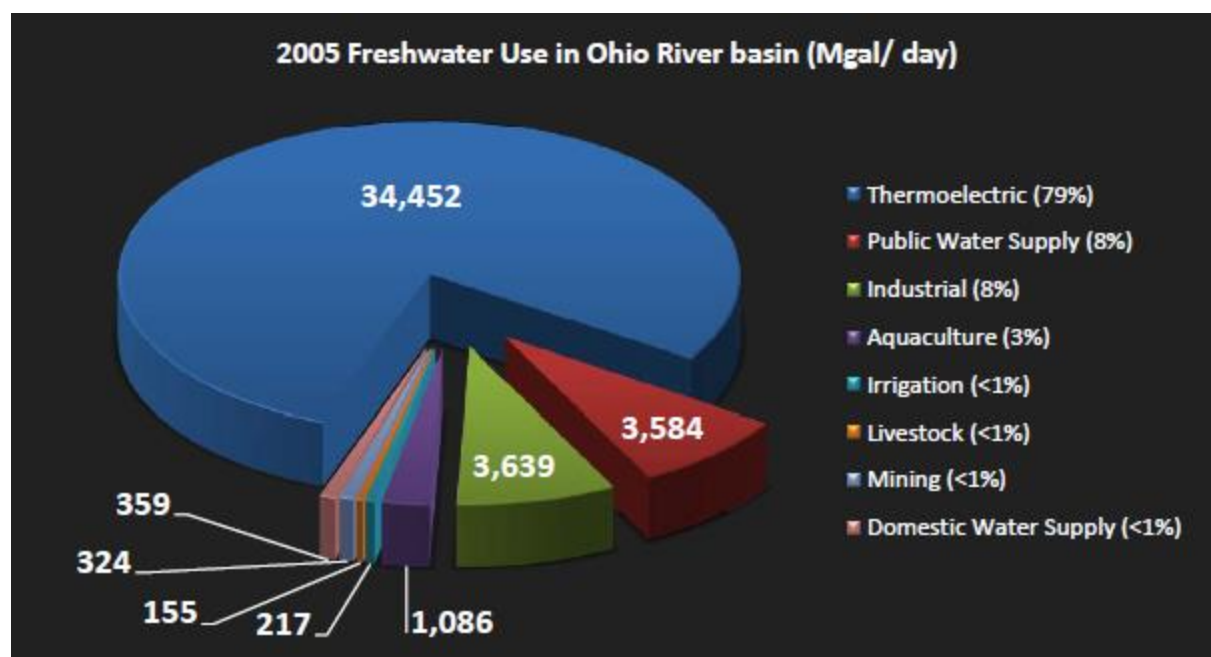


Figure 3 Water usage within the Basin by category. (ORSANCO, 2012)

The high usage of water for thermoelectric purposes (for cooling purposes in fossil fuel and nuclear energy production) reflects the regional economic importance of energy production. The Basin produces approximately 19.8% of the nation's thermoelectric energy supply. The second highest use, public water supply, goes to domestic, commercial, industrial, public services and system losses. The average per-capita water use for the population served by the Basin is 154 gallons per day.

Industry makes up 8% of water usage in the basin and utilizes water for purposes such as cooling, transport of produce, processing, and sanitation of facilities. This water also goes toward the production of chemicals, refined petroleum, metals, food, and paper. Manufacturing makes up the largest income producer in the state (Britannica).

The five other categories make up a much smaller percentage of water use in the Basin but also reflect economic conditions in the region. For example, agriculture was considered Kentucky's most prolific economic sector until the mid-1900s when other sectors began taking over as major contributors to the state's gross product. Still, over half of the state's lands are used for agriculture and approximately one-fifth of Kentucky's workforce is employed by the agricultural industry (Britannica).

Figure 4 (below) shows the Basin's water usage as compared to nation usage. These figures reflect the economic and manufacturing history of the region that capitalizes on the rich water resources provided by the region's natural resources (ORSANCO, 2012).

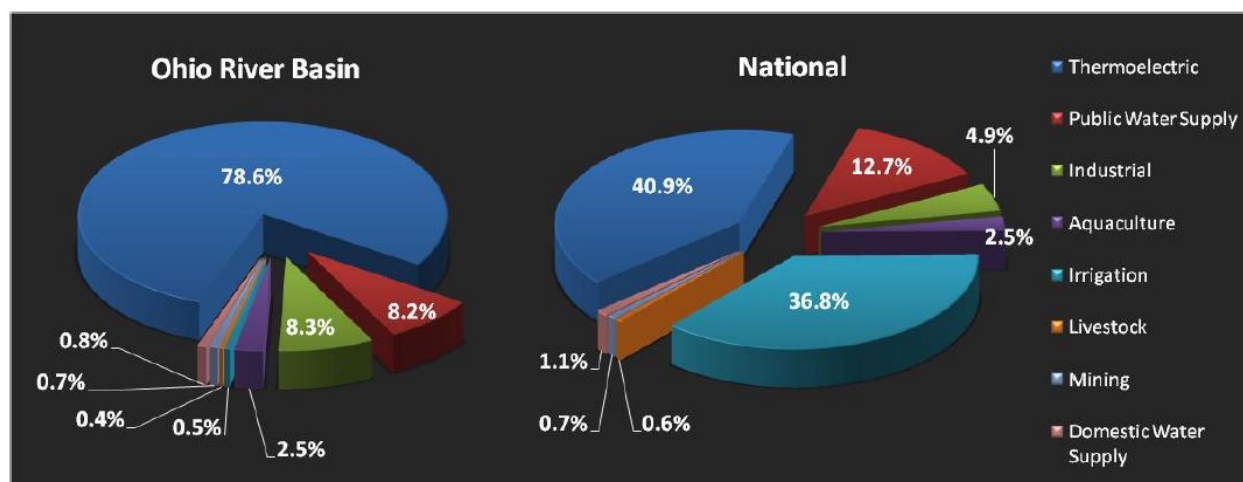


Figure 4 Water usage in the Basin compared to the Nation. (ORSANCO, 2012)

## 2.1.2 Domestic Supply

As discussed in the Section above, the domestic water supply contributes less than 1% to the total water usage for the Basin. Still, the Ohio River alone provides drinking water to more than five million residents. While the Basin has been deemed “water rich” due to its many sources of water, it is important to ensure that clean water continues to be available to those who depend on it in the face of current and future threats, especially when considering the impacts of climate change. Daily domestic water use is shown by county below in Figure 5.



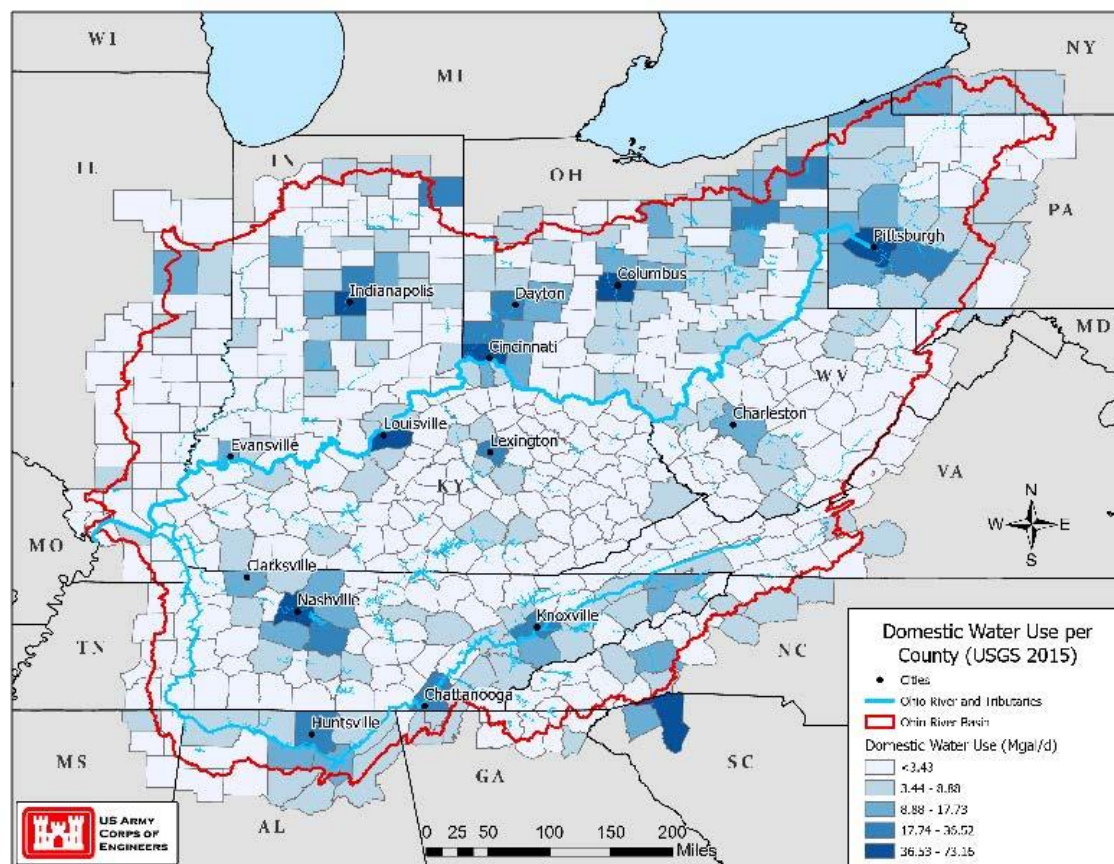


Figure 5 Daily domestic water usage for the Basin

## 2.2 Problems and Challenges

### 2.2.1 Fracking

Fracking or hydraulic fracturing is a “well developed process that involves injecting water under high pressure into a bedrock formation via the well. This is intended to increase the size and extent of existing bedrock fractures” (ORSANCO, 2015). This process paired with horizontal and/or vertical drilling is required to extract natural resources such as natural gas, oil, geothermal energy, and water, that is trapped thousands of feet below the earth’s surface.

Since the first horizontal well was drilled in 2004, the fracking industry has flourished. As of 2015, there were over 6,000 drilled horizontal wells throughout the Ohio River Basin including 3,443 in Pennsylvania, 1,545 in Ohio, and 1,527 in West Virginia. It is estimated that there is more undiscovered natural gas in the Appalachian Basin than any other onshore Basin in the country. Kentucky’s geology, with its large areas of shale rock, is prime for natural gas extraction and could potentially host about 104,000 horizontal wells to extract gas from the Marcellus and Utica Shale alone.

The fracking industry has been criticized due to the potential negative environmental effects of the process. Fracking requires copious amounts of water and can leak chemicals into both surface and ground water sources. Water volumes required in this process vary and USGS estimates that anywhere from 1.5 to 15 million gallons of water can be used per well depending on the type of rock formation,

the operator, whether the well is vertical or horizontal, etc. For reference, 5 million gallons of water is approximately the amount that 50,000 people would use daily.

The process also includes the addition of chemicals to water that are meant to make the water more effective at opening the fissures (i.e., more viscous, change in pH). This water is usually high in total dissolved solids (TDS) and can leak into groundwater. This water or “flowback” is often reused or sold to other companies for reuse or can be legally disposed of. Disposal regulations are managed by the states and methods of disposal can vary and include sending it to public wastewater treatment facilities or centralized water treatment, injection wells, and road spreading (a practice that is not legal in most fracking states).

Another negative impact of fracking is a potential for an increase in earthquakes along the faults that are being fractured. Observational studies have shown that hydraulic fracturing does increase the instances of earthquakes along the fault lines that are being injected into. The fluid that is injected into faults increases the pressure within the fault, counteracting the frictional forces and increasing the likelihood of an earthquake (USGS website).

### *2.2.2 Interbasin Transfers- Interbasin Transfers Report*

Interbasin transfers (IBTs) are defined as water that is transferred or diverted from one basin to another. Most commonly these IBTs are surface water but ground water is also lost from transfer at times. The biggest concern with IBTs is the downstream impacts of decreased water flows from upstream areas. Most populations live downstream of a watershed; therefore, most people can be impacted by IBTs.

Since watersheds cross political boundaries there is a need for interstate water commissions to manage transfers. ORSANCO is the designated authority for the majority of the Ohio River Basin, although there is currently no policy for IBTs enforced by this organization. Other authorities do require permits for IBTs including the Tennessee Valley Authority. Additionally, states have differing policies and roles when it comes to IBTs ranging from no specific policies (relying on interstate commissions) to registration or permitting systems with thresholds for amounts withdrawn from water bodies.

There are four specific categories of IBTs that currently exist in the Basin:

1. Aquaculture
2. Canals
3. Public water supply
4. Oil and gas extraction.

There could be others that exist currently, but these are not documented. Because there may be other transfers that are not documented it is likely that the estimated amount of water lost due to IBTs is underestimated.

There are 37 IBTs identified along the 3,782 peripheral miles of the Basin and an estimated net loss of 229 Mgal/day. Of the identified IBTs, there are nine that transfer water into the Basin, while the number of IBTs that transfer water out are three times as many. This is most likely due to the fewer restrictions of water transfer out of the Basin than in. An example of this would be with the Great Lakes and the Susquehanna River Basin Commission (SRBC) which require approval and permitting with restrictions for water transferred out of their Basins, while there are no restrictions for water coming in. The lax

restrictions in the Ohio River Basin for water leaving the watershed contribute to the overall net loss of water.

Of the known categories of IBTs, canal transfers contribute to about 90% of water transferred out of the basin. Even disregarding canal transfers, the Basin still loses about 22.6 Mgal/day for anthropogenic uses. The restrictions on water leaving adjacent basins and the lack of restrictions for water leaving the Ohio River Basin make it a source for surrounding uses such as industry, mining, livestock, thermoelectric, etc. Until the Basin establishes restrictions on water transfers out, it will continue to experience a net loss of water.

### 2.3 Climate Change/Forecasting

Climate change resulting from anthropogenic factors is one of the major stressors of water resources. Regional water supply uses and environmental conditions can differ, making the impacts of climate change different depending on location. In warm, dry regions such as the Southwest U.S., the demand for water is predicted to go up while the water supply is predicted to go down. In these regions where there is not enough water, increased events such as droughts and wildfires will threaten human health and agriculture as well as wildlife and native vegetation (EPA, 2017).

In other regions such as the Northeast that typically get more precipitation than Western areas, water runoff from increased frequency and intensity of events are projected to increase, causing issues with flooding and water quality. Over the past 50 years, most of the US has seen increased rainfall. The Northeast, Midwest and upper Great Plains have seen the greatest increases. Warmer winter temperatures have also changed the precipitation to more rain than snow in regions where seasonal snowfall is common. Subsequently, sea level rise may increase erosion and threaten coastlines, infiltrate freshwater supplies, and further strain aging infrastructure. (EPA, 2017).

In the Ohio River Basin and as identified by the Institute for Water Resources- Response to Climate Changes Program Ohio River Basin Pilot Study, the current climate for the Basin is influenced by several factors. Latitude, elevation differences, large bodies of water, prevailing winds, the jet stream, topography, and land cover all play a role in the Basin's climate. Since 1952, there has been a slight increase in both temperature and precipitation in the Basin, primarily in late summer and fall months (NOAA data).

According to Cisneros et al (2014), river flow discharges and mean annual air temperatures will stay relatively the same until 2040, at which time it is forecasted that precipitation may increase or decrease depending on geographical location in the Basin. The Northeastern and Southern parts of the Basin are forecasted to have increased levels of precipitation and flow, while the western and southwestern portions of the Basin will have decreased precipitation and lower discharges. The entire Basin will experience a half degree per decade rise in temperatures between the present and 2040 which will then increase to a whole degree per decade for the period 2041-2099.

Forecasted changes in precipitation are expected to worsen existing issues in the Basin such as decreasing water quality, habitat, and species loss. Both unpredictability and increased intensity of weather events are concerns for water management agencies as temperatures rise (USACE and ORBA, 2017). Existing infrastructure including dams, navigation locks and dams, power plants, transportation modes and communication systems, wastewater treatment and public water supplies will benefit from

changes in operations, policies and regulation that recognize the threat of climate change and work to become more adaptable and sustainable. Below is a list of identified key risks associated with climate change at the global scale (Cisneros et al, 2014):

- Freshwater related risks of climate change increase significantly with increasing greenhouse gases (GHG) concentrations.
- Climate change is projected to reduce renewable surface water and groundwater resource significantly in most dry subtropical regions.
- So far there are no widespread observations of changes in flood magnitude and frequency due to anthropogenic climate change, but projections imply variations in frequency of floods.
- Climate change is likely to increase the frequency of both meteorological and agricultural droughts in presently dry regions.
- Climate change negatively impacts freshwater ecosystems by changing streamflow and water quality.
- Climate change is projected to reduce raw water quality, which poses risks to drinking water.

The Institute for Water Resources study (2017) identified the components of the current water resource infrastructure in the Basin that are most at risk from the impacts of changes in temperature, weather patterns and severity of weather events. Additionally, the study aimed to formulate mitigation and adaptation strategies that could potentially reduce the effects of climate change.

This study identified several objectives for the pilot study, one having already been completed: to convene a climate change working group within the Ohio River Basin Alliance. ORBA now incorporates climate change as an overarching concern across all working groups and provides one of the best organizational structures to disseminate climate change information to pertinent entities, supporting further research and promotion of adaptation strategies within the Basin. An adaptive approach to water management can address uncertainty due to climate change.

In 2007, the Bureau of Reclamation and USACE worked with the USGS and the National Oceanic and Atmospheric Administration (NOAA) to form an interagency working group focused on addressing climate change issues in relation to water resources called the Climate Change and Water Working Group (CCAWWG). The document “Addressing Climate Change” was meant to guide research and technology efforts to address data and tool gaps relevant to the water management user community and discusses ways to incorporate technical climate change information into long term water resource planning. The CCAWWG workgroup has identified gap categories that should be incorporated into long term water resource plans to adequately plan for the impacts of climate change. Those categories are:

- Summarizing relevant literature
- Obtaining climate change information
- Making decisions about how to use that climate change information
- Assessing natural systems response
- Assessing socioeconomic and institutional response
- Assessing system risks and evaluating alternatives
- Assessing and characterizing uncertainties identified as most critical
- Communicating results and uncertainties to decision makers



### 3.0 Planning Process

#### 3.1 Stakeholder Involvement

The Plan for the Ohio River Basin planning process included extensive stakeholder and public outreach efforts. These events were a combination of virtual and in-person meetings held from the summer of 2019 to winter 2020 and engaged stakeholders throughout the Basin from various agencies. These meetings aimed to get input on the challenges and opportunities from different geographic and professional perspectives. The outreach process is described in more detail in the Plan for the Ohio River Basin (2020).

Since the outreach effort was so expansive for the previous study and this study is more focused on specific water resource issues, the outreach effort for this study was limited to the Water Resources Committee, led by ORSANCO. This group comprises multi-agency water resource managers and were asked to review and give feedback on the early drafts of the document in order to ensure that the Long-Term Plan was comprehensive and accurate.

#### 3.2 Overarching Goal and Objective

The Abundant Clean Water goal targeted water quality and quantity and the assurance of clean water for all those living in the Basin over the long term. ORSANCO is the driving agency when it comes to both water quality and quantity on a Basin wide scale, so the report focuses specifically on the strategies listed under Objective 4 in the study:

*By 2025, The Ohio River Valley Water Sanitation Commission (ORSANCO) will convene water quantity managers Basin-wide... to establish common goals directed at identifying Basin-wide problems affecting water quantity management and recommend strategies to address these goals.*

While the Plan for the Ohio River Basin is for 2020-2025, the long-term plan looks much farther into the future and plans for strategies that will enable the Ohio River Basin (ORB) to plan for the impacts of long-term challenges and issues.

#### 3.3 Key Risks and Uncertainties

Identifying and understanding the risks and uncertainties associated with water resources is key to successful implementation of recommendations from this plan. By identifying these risks, efforts to mitigate the impacts can be made and overall effects can be decreased. Below (Table 2) is the risk table with key risks, impacts and possible mitigation measures. This table can serve as a starting point and can be utilized by ORSANCO and other agencies to mitigate risks wherever possible. It can be referenced and updated frequently to stay abreast of risks as they evolve.

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*Table 2 Water resource risk table.*

Principal Risk	Type	Risk	Direct Impact	Following Impacts	Risk Management Options
Not enough water, water goes elsewhere	Natural and human	Reservoirs are depleted due to hydrological changes caused by climate change, which causes rain and snow fall to decline in region, and evaporation to rise, leading to drought conditions with more frequency and intensity	Increased irrigation would become necessary; alternative freshwater solutions take too long, cost too much	Property in region decreases in value; people are forced to migrate elsewhere, without the financial means to do so; regional economy is disrupted while being relocated; morbidity and mortality rises; social and political unrest as migrants struggle with relocation	Sustainability and resiliency actions implemented through legislative change and partnerships to reach resiliency goals
Too much water	Natural and human	Increasing frequency and intensity of high flow events caused by climate change	Increased areas become uninhabitable due to repeated flooding, flooding causes property damage across the Basin and life loss	Property in region decreases in value; people are forced to migrate elsewhere, without the financial means to do so; regional economy is disrupted while being relocated; morbidity and mortality rises; social and political unrest as migrants struggle with relocation	Sustainability and resiliency actions implemented through legislative change and partnerships to reach resiliency goals
Change in water use demands	Human	Change in demand for water takes water away from vital uses	Not enough water for drinking, energy production and other common uses	Water diverted to uses such as irrigation or livestock (due to drought) take water away from domestic uses, social, economic, health impacts	Regulations to reduce risk of water being diverted away from vital uses
Diversions (in or out of Basin)	Human	Too much water directed in or out of Basin	Downstream impacts to flow and water quality	Social and health impacts to downstream communities, property damage and cost to treating water	Increased monitoring and regulations for interbasin transfers

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Principal Risk	Type	Risk	Direct Impact	Following Impacts	Risk Management Options
Changing regulated and unregulated (e.g., salt) contaminant loads	Human	Increased contaminants from agriculture, industry, and other uses	Health impacts, ecosystem impacts	Increased cost to treat water and maintain infrastructure	Extend regulation to include contaminants not currently covered, increase restrictions on contaminants already regulated
Changing impervious surface in watershed	Human	Land uses changes result in decrease in tree canopy and increase in impervious surface	Increased flooding, property damage and loss of life. Decreased habitat, water contamination from increased runoff	Social and health impacts to urban and downstream communities, increased costs for water treatment and infrastructure	Improved land use regulation and mitigation for development
Changing water temperature	Natural and human	Increased incidence of algal blooms and decreased suitable habitat for aquatic life	Water quality issues from algal blooms and increased minerals in water, decrease in aquatic populations due to less dissolved oxygen	Increased costs of water treatment, health impacts, decreased recreational use and economic impacts, increase in invasive species, decrease in native species	Increased monitoring and regulations to build resiliency and protect riparian zone
Changing flood plain and wetland conditions	Human	Less floodplain and wetland area due to human development	Less habitat for migratory birds and other wetland species, Increased flooding events, erosion of stream banks and water quality impacts	Decrease in land values due to flooding, social and health impacts, decrease in native species	Improved land use regulation and mitigation for development

Principal Risk	Type	Risk	Direct Impact	Following Impacts	Risk Management Options
Invasive species (e.g. zebra mussels on water intake pipes)	Natural and human	Increase in invasive species and decrease in native species	Damage to infrastructure and impacts to native ecosystems that will decrease suitable habitat for native species	Increased costs to control invasive species and fix damage to infrastructure	Invasive species prevention programs such as educational campaigns and continuation of invasive control best practices
Industrial operations push back against efforts to ensure water security	Human	Efforts to improve water resources are stopped	Funds and time spent on water resource projects are wasted	Problems in the Basin persist despite successful execution of plan recommendations	Effective communication with industries that could be impacted

### 3.4 Key Benefits

The broad benefits from water resource management are numerous but also depend on the measures being taken. Direct impacts would be water security and equity for the Basin, with available clean water to all of its 30 million residents. Benefits to ecosystems and native species would also be seen with the availability of clean water and resiliency toward the effects of climate change. Forecasting predicts that noticeable impacts from greenhouse gas emissions won't be significant until the 2050s, therefore benefits from climate change preparedness, adaptation and risk management will be most impactful closer to the end of the 21<sup>st</sup> century (Cisneros et al, 2015).

Other benefits include economic and recreation benefits. With the availability of clean water, there will be more opportunities for outdoor water recreation which can attract businesses and increase land values. Additionally, abundant water will enable the production of hydropower and provide resources for other industries.

## 4.0 Long Term Strategies

### 4.1 Focus Area 1

*Secure financial and other necessary resources through an Ohio River Basin Restoration Initiative and other appropriate funding mechanisms to support all Strategic Actions under this Objective.*

#### 4.1.1 Implementation Strategies

The implementation of this focus area has a strong influence over the success of other strategies since funding is key for maintaining organizational structure and pursuing projects. There are two main steps to pursue funding that will ensure that pools of money to support projects are readily available and consistent.

**Legislative Change** is key to ensuring that funds will be directed towards water resources. During discussions on the recent infrastructure bill, water resource advocates have stressed the importance of providing resiliency funding. Organizations such as ORBA have pushed for this legislation. Continued support and advocacy are needed to ensure the legislation contains the funding package for water resources.

One approach to legislative change is to focus on driving issues, such as shale gas extraction, as a path to garner attention to broader issues. Political interest will follow the issues that the public is most concerned about.

**Diverse partners** are also key to pursuing and successfully obtaining funding. Basin-wide funding support has been pursued by ORSANCO by reaching out to foundations, non-profits, local, state, and federal agencies with interest in water resources. The creation of a database of foundations and their topical areas would be a useful tool to assess applicable agencies and ensure comprehensive funding support across the Basin. This database could also be used as a tool for communication, where organizations can add their key issues and utilize the database to reach out to other organizations for collaboration.

The USACE has several programs that could provide support for water resource studies in the basin. The Planning Assistance to States program provides planning support for a wide variety of water resource issues at a 50/50 cost share. Additionally, through USACE, the state-based Silver Jackets program can provide funding for flood risk management issues at 100% federal cost.

### 4.1.2 Key Steps for Success

#### Focus Area 1- Key Steps for Success

- 1. Compile and maintain database of current and future resiliency legislation.**
- 2. Continue to push for legislation (such as recent infrastructure bill) that provides resiliency funding.**
- 3. Create database of organizations working in the Basin, their geographic range, and key issues.**
- 4. Maintain communication between organizations by creating interactive database of funding opportunities.**

### 4.2 Focus Area 2

*Develop and maintain data layers for inclusion in the comprehensive Ohio River Basin GIS platform to support water quantity related initiatives such as mapping flood risk areas, drought mitigation planning areas, water supply deficit/surplus areas and related initiatives.*

#### 4.2.1 Implementation Strategies

Many state, federal, local, non-profit, private, and academic organizations collect and maintain data on a regular basis. Unfortunately, not all this data is available to others that may have need or use for it.

This creates data gaps for organizations that may result in impaired decisions or inefficient duplication of efforts.

Making databases searchable and shareable improves planning and management efforts. Better still for decision making is creating comprehensive databases that are well organized, maintained, and publicized. With the technology we have today, this feat is more accessible than ever (Nevada Division of Water Planning). Many challenges are still present to create such a database. At the time of this report, USACE is working with ORSANCO and USGS to develop a Data Management Plan that will create the framework for compiling existing information, performing a gap analysis, and fill needed gaps in data for the entire Basin. As part of this data management plan, a comprehensive database will be created for important Basin-wide geospatial data.

### 4.2.2 Key Steps for Success

#### **Focus Area 2- Steps for Success**

**1. Develop framework for comprehensive geospatial database and data gap analysis through a Basin wide Data Management Plan.**

**2 Fill data gaps identified through Data Management Plan.**

**3 Maintain geospatial database with USACE.**

### 4.3 Focus Area 3

*Develop partnerships to leverage available funding streams to maintain and expand USGS Stream Gage network to be able to accurately measure flow in Ohio River Basin streams. Utilize this data to improve hydrologic and hydraulic models so as to test existing infrastructure resiliency as it pertains to expected climate changes.*

#### 4.3.1 Implementation Strategies

Development of the USGS stream gage network began in the early 1800s under the second Director of the USGS, John Wesley Powell. Since that time, the network has made major technological advances and is now one of the largest stream gaging efforts in the world. Today the USGS Groundwater and Streamflow Information Program supports data collection and/or delivery of continuous information for both streamflow and water-level information at approximately 8,500 sites throughout the country. Additionally, partial data is collected at approximately 2,900 sites (USGS website).

Water levels are measured by many of these gages on an hourly basis, and more than 80,000 onsite measurements are typically taken per year. Data collected are made available online and are used by an array of users such as emergency responders, water managers, environmental and transportation agencies, universities, utilities, recreational enthusiasts, and consulting firms. Some examples of how these data are used include: planning forecasting and warning about floods and droughts, operating waterways for power production and navigation and assessing water quality and regulating pollutant discharges, among many others (USGS website).

While the system is primarily operated and maintained by the USGS, most gages are funded in partnership with about 1,800 federal, state, local and Tribal agencies. These partnerships have made

expansion of the network and improve data sharing possible. There are also smaller networks that exist to address specific needs such as the National Streamflow Network which serves several functions including flood warning, water allocation and recreation. The Federal Priority Streamgages network is a core, federal funded system that is meant to collect data used for long term federal information needs such as National Weather Service flood forecasts (USGS website).

In terms of long-term water resources, this system could be utilized to measure changes in the Ohio River Basin watershed due to climate change over time. These data would be useful in understanding the impacts these changes have on infrastructure and could guide decisions on how to make infrastructure more resilient to climate change.

#### 4.3.2 Key Steps for Success

### Focus Area 3- Steps for Success

**1 Establish communication with the USGS, with a contact for information on the USGS stream gage system for the Basin.**

**2 Conduct a prioritization of stream gages in the Basin for use in a climate change impact study.**

**3 Utilize data from prioritization to identify infrastructure needs to address climate change issues.**

#### 4.4 Focus Area 4

*Build upon ORSANCO's water quantity initiatives developed through its Water Quantity Committee to convene Ohio River Basin Water Quantity Stakeholders to conduct discussions and long-term planning to develop strategies to address water shortages and other relevant challenges within the Basin related to climate change, population growth and other stressors.*

##### 4.4.1 Implementation Strategies

Collaboration is key to the success of water resource efforts in the Basin. Centered around ORSANCO's Water Resource Committee, an initiative is needed to identify and convene groups working for similar water resource goals. The committee strives to have representation across the Basin and from various agencies. A commitment is needed to maintain this group and to continue to identify valued representation that will strengthen the group and provide different perspectives and resources.

4.4.2 Key Steps for Success

**Focus Area 4- Steps for Success**

**1 Maintain ORSANCOs Water Resources Committee and ensure representation from all Basin states and develop a framework for the group.**

**2 Find commonalities with respect to water resource priorities between the Water Resource Committee workgroups.**

**3 Work to find topics to prioritize across all Water Resource Committee workgroups.**

4.5 Focus Area 5

*Collaborate with domestic and international water quantity-related commissions to share information, exchange strategies, incentivize conservation, and advance common goals directed at solving problems affecting water quantity and leveraging these strategies and goals as vital Ohio River Basin assets.*

4.5.1 Implementation Strategies

This strategy is intended to be a second phase to Strategy 4, by expanding the network of knowledge of water resources to groups outside of the Basin and even outside of the U.S. By reaching out beyond our borders, the water resource committee can learn best practices, make connections, and obtain data that would have been unavailable otherwise. Another facet to this strategy would be to take the known goals of these groups and work to find the conflicts that keep these groups from collaborating on shared goals.

Having a broader understanding of efforts outside the Basin will also enable the Water Resources Committee to identify other groups that have authority or influence in the Basin that may not necessarily be interested in water resource initiatives. These groups could be those that work for or against the committee's goals. Understanding these authorities would assist the committee and others with opportunities and challenges to efforts in the Basin.

4.5.2 Key Steps to Success

**Focus Area 5- Steps for Success**

**1 Identify domestic and international water quantity commissions and compile background information and goals.**

**2 Find conflicts between water management commissions within the Basin and form strategies on how these commissions can avoid these conflicts.**

**3 Identify entities that have authority within or around Ohio River Basin.**



#### 4.6 Focus Area 6

*Facilitate collaboration to pursue a focused water quantity study to follow on to the existing USACE study that specifically addresses climate change as it relates to water quantity impacts in the medium and long term (by 2040 and 2100, respectively).*

##### 4.6.1 Implementation Strategies

As discussed in Section 2.3 of this document, USACE and ORBA collaborated in 2017 to create a climate change pilot study for the Ohio River Basin. This study was funded by the Institute for Water Resources, this study presented climate change modeling to forecast future temperature, precipitation, and water flow levels for the entire Basin.

This study provided useful information for water resources but there is need to continue to perform updates on a regular basis, not only in order to keep up with changing data, but to expand upon the pilot study and move beyond strategy to implementation. In order to do this the right organizations would need to be convened and participate in the study, such as USGS, USACE, EPA and NOAA.

##### 4.6.2 Key Steps to Success

#### **Focus Area 6- Steps for Success**

- 1 Convene groups based on Strategy 5 that have interest in climate change and impacts to water quantity.**
- 2 Update the Ohio River Basin Climate Change Pilot Study on a 5-year basis with the 2025 update focusing on implementation (moving beyond strategy).**

## 5.0 Policy and Regulatory Implications

The Inventory of State Water Resource Laws and Regulations report, produced by ORSANCO in 2015 gives an overview of laws by state and discusses these laws in five categories: water management, water withdrawal, interbasin transfer, drought response, and oil and gas water use. The report contains a complete summary table of these laws in Appendix A. The report also discusses existing authorities in the Basin such as the Tennessee Valley Authority (TVA) and the U.S Coast Guard and their roles in these laws and regulations. It also lists compacts outside of the Basin and any known conflicting regulations.

This report makes apparent the gaps in regulations, especially regarding fracking and interbasin transfer. Below (Table 3) is a summary table showing the categories of regulation where no policies exist. This table could serve as a prioritization of where regulation is needed.

*Table 3 Policy gaps by state and category.*

Need for Statewide Policies by Category			
State	Interbasin Transfer Policy	Drought Response	Water withdrawals with regards to Oil and Gas Wells
Alabama	X		X
Georgia	X		X
Illinois	X	X	X
Indiana	X		
Kentucky			X
Maryland	X		
Mississippi	X	X	X
North Carolina			
New York			
Ohio			
Pennsylvania	X		
Tennessee			X
Virginia			
West Virginia	X		X

### 6.0 Conclusions and Recommendations

#### 6.1 Monitoring and Reappraisal of Water Resources

In order to measure the impacts and progress of the Long-Term Water Resource Plan, an effective monitoring plan should be established that, at minimum, contains the following:

1. Goals and objectives of plan
2. Set time frame for monitoring
3. Monitoring schedule
4. Performance measures and triggers
5. Documentation and data management

Additionally, the power of a monitoring program developed to support adaptive management lies in the establishment of feedback between continued monitoring and corresponding management. A well-conceived monitoring program is the central component of an adaptive management program as it identifies the information to assess whether the plan is having an impact as planned.

Monitoring must be closely integrated with the adaptive management components as monitoring data feeds directly into the evaluation of adaptive management needs. Objectives must be considered to determine appropriate indicators to monitor. In order to be effective, monitoring must be able to distinguish between water quality and quantity responses that result from recommended implementation (i.e., management actions) and natural variability, including the impacts of climate change. Achieving the plan objectives requires monitoring that focuses on targeted performance measures. Success is considered achieved when desired outcomes have been reached, measured by meeting or exceeding the timeframe thresholds identified.

##### 6.1.1 Performance Measures

In order to ensure the success of strategies implemented through this plan, a set of performance measures should be utilized to assess the effectiveness of chosen actions. Performance measures must be quantifiable and specific to the performance you wish to monitor. A successful measure of performance must have a method of comparison. This comparison should look at historical and current performance as compared to future or desired performance. The following measures can be compared to monitor the success of the water resource plan within a given monitoring time period.

- Water quality
- Available drinking water
- Water transferred out of basin
- Water transferred into basin

#### 6.2 Conclusion and Next Steps

The recommendations and strategies discussed in this plan are meant to serve as a guide to achieve the overarching goal of addressing the identified Basin-wide problems affecting water quantity management.

The Clean Abundant Water workgroup is a multi-agency collaborative formed and led by ORSANCO. This group was established to execute the goal to *“convene water quantity managers Basin-wide... to establish common goals directed at identifying Basin-wide problems affecting water quantity*

*management and recommend strategies to address these goals.”* The group will utilize this document for guidance as they move forward on strategies to address the water management issues discussed in this Plan.

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