Task 11
Environmental Overview
Review of Environmental Resources and Climate Variability

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1. INTRODUCTION

This technical memorandum supplements the Access Ohio 2040 (AO40) long-range transportation plan by providing an overview of the following three components:

- Review of Environmental Resources
- Review of Climate Variability
- Environmental Analysis

By engaging in the National Environmental Policy Act (NEPA) process, states benefit from the early identification, documentation, and communication of potential environmental consequences resulting from a federally funded project. As stewards of Ohio's transportation infrastructure, ODOT is tasked with sustaining and modernizing an aging transportation system in a cost-effective manner, while balancing the needs of its stakeholders and natural resources. Considering environmental elements in the transportation planning process should allow for more informed decision-making and improved outcomes by ODOT and its stakeholders.

2. REVIEW OF ENVIRONMENTAL RESOURCES

This section provides an overview of the major aquatic, terrestrial, endangered species, and geographic resources that are located within Ohio. This section includes mapping to indicate the location of these resources in relationship to the transportation network and other important administrative boundaries throughout the state. By overlaying future projects with location information of known existing resources, avoidance and minimization planning may be initiated or alternatives evaluated very early on in project planning.

2.1 Administrative Boundaries and Transportation Resources

2.1.1 Major Transportation Systems

Ohio is bounded by Pennsylvania to the east, the Ohio River to the south, Indiana to the west, and Lake Erie and Michigan to the north. There is roughly 312 miles of coastline provided by Lake Erie and along the Ohio River. Along Ohio's portion of Lake Erie there are eight Principal Ports. Along the Ohio River there are Three Ohio Port Authorities.

Ohio has the nation's 10th largest highway network totaling 1,600 miles, including the east/westbound interstates IR-70 and IR-90 and the north/southbound interstates IR-71 and IR-75.

Ohio is served by two U.S. Class 1 railroads, CSX and Norfolk Southern, in addition to 16 regional and short line railroads, and 15 terminal carriers. The Canadian National Railway (Class 1) also serves the state but on a more limited basis. **Figure 1** depicts Ohio's major ports, highways, airports, and rail lines.

2.1.2 Counties, Population Areas and ODOT Districts

While Ohio's population has grown over the past ten years, it has done so at the third lowest rate in the nation (1.59% annually between 2000 and 2012) according to the U.S. Census. From a jurisdictional standpoint, Ohio is governed by 88 counties which are further disaggregated into more

than 1,000 townships of varying size. In many cases, municipal governments have been established to support localities within the townships. Incorporated municipalities are referred to as either cities (population more than 5,000) or villages (population less than 5,000). Major cities include Cincinnati, Cleveland, and Columbus (the capitol); other large cities include Youngstown, Dayton, Toledo, Canton, and Akron. These cities are supported by the state's largest airports. **Figure 2** depicts Ohio's counties and major population centers.

The Ohio Department of Transportation (ODOT) coordinates transportation within Ohio as well as externally with other states and the federal government. It is currently organized into 12 districts as shown in **Figure 3**.

2.2 Aquatic Resources

2.2.1 Watersheds and Major Streams

According to the Ohio Environmental Protection Agency, Ohio is a water-rich state with thousands of miles of streams and rivers, a 451-mile border on the Ohio River, more than 5,000 lakes, ponds, and reservoirs (>1 acre), and 236 miles of Lake Erie shoreline. Ohio has 10 scenic rivers comprising more than 629 river miles, the fourth largest total of any state in the nation.

The primary rivers within the state are the Cuyahoga River, Great Miami River, Maumee River, Muskingum River, and Scioto River. Rivers in the northern third of the state drain into the Atlantic Ocean via Lake Erie and the St. Lawrence River, while rivers in the southern two-thirds of the state drain into the Gulf of Mexico via the Ohio and Mississippi rivers.

Approximately 28,900 miles of the over 58,000 miles of stream channels digitally mapped in Ohio are headwater streams. However, the digital maps do not include the smallest of headwater channels. Estimates place the extent of primary headwaters between 146,000 and 250,000 miles.

Figure 4 shows the major streams and watersheds in Ohio.

2.2.2 High Quality and Low Quality Waters

The Ohio Environmental Protection Agency - Division of Surface Water (DSW) is responsible for maintaining water quality in the state. DSW ensures compliance with the Federal Clean Water Act (CWA) and works to maintain and increase the number of water bodies that can be safely used for swimming, fishing, or other uses.

The goal of Ohio's surface water program -- restoration and maintenance of Ohio's water resources -- reflects the national water quality objective in the CWA to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (often referred to as the "fishable/swimmable goal"). Among the regulations being used to achieve this goal are:

- The National Pollutant Discharge Elimination System (NPDES), which issues permits to municipal and industrial wastewater and stormwater dischargers;
- Permits-to-Install (PTI), which are issued for the construction of wastewater facilities, sewers, and wastewater sludge treatment;
- Indirect Discharge Permits, which are issued for the discharge of industrial wastewater into public sewer systems; and
- Section 401 Water Quality Certifications, which are issued for the discharge of dredge and fill material to waters of the state.

Ohio's elective, incentive-based "Balanced Growth" program is also serving to protect and restore watersheds throughout the state through implementation of Best Local Land Use Practices. The goal of this program is to "link land-use planning to the health of watersheds and major water bodies" (Source: http://balancedgrowth.ohio.gov/).

Figure 1: Major Transportation Assets

Source: *Access Ohio 2040 SharePoint Site (ODOT, 2012)*

Figure 2: Major Population Areas
Source: Census TIGER® 2000

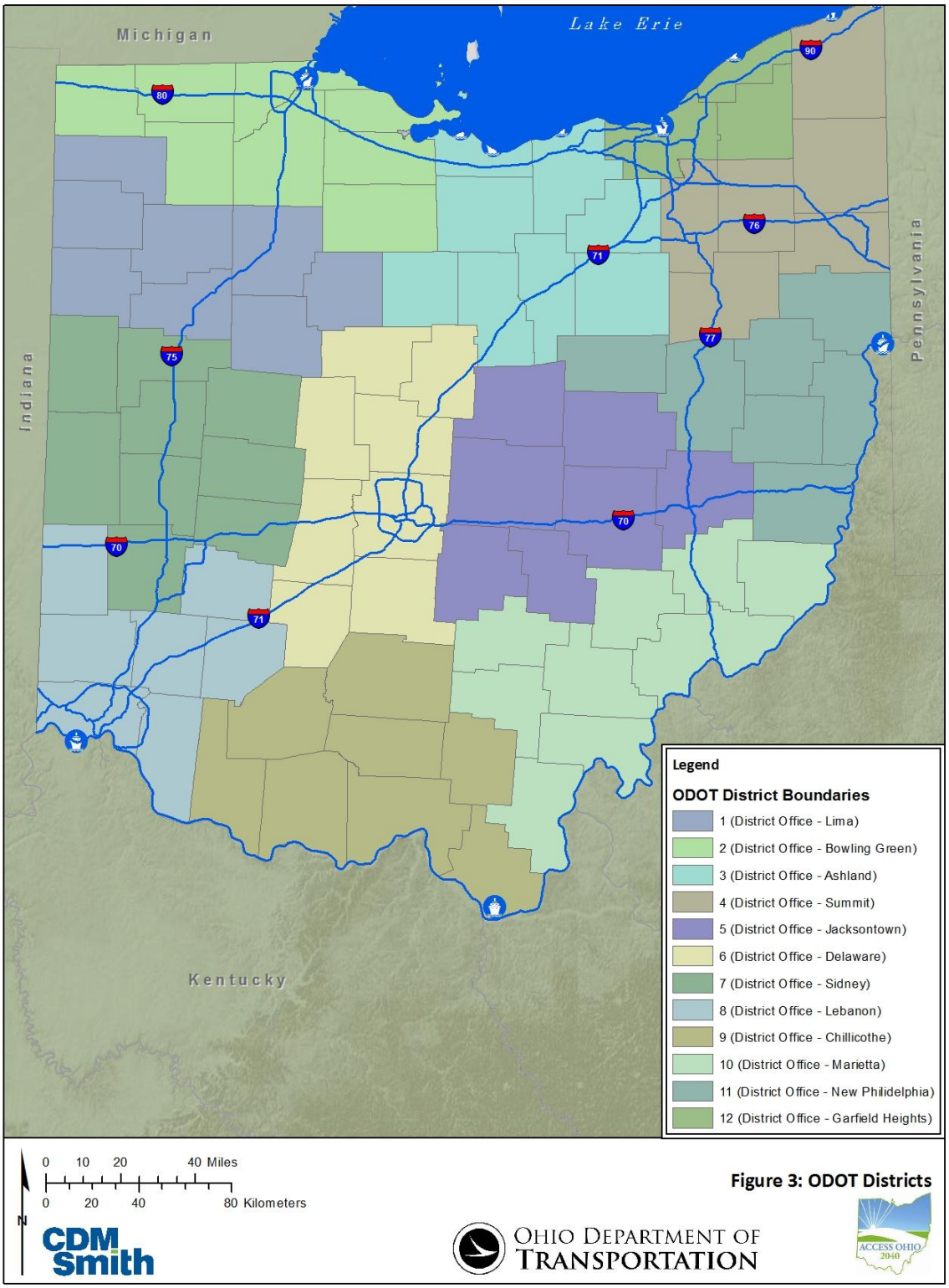


Figure 3: Ohio Department of Transportation (ODOT) Districts

Source: Socio-Economic Data Library, Access Ohio 2040 SharePoint Site (ODOT, 2012) and Census TIGER® 2000

Figure 4: Ohio Watersheds and Major Streams

Source: National Watershed Boundary Dataset (USDA-NRCS, 2012)

Antidegradation rules are required for compliance with the Clean Water Act (CWA) and are used to protect the existing use and quality of the water body, allowing water quality to worsen (within reason) only when necessary to support social and economic development. Along with water quality criteria and beneficial use designations, the antidegradation rule provides the overall structure of the Water Quality Standards Program. Ohio has two antidegradation rules that establish procedures and requirements to ensure that the concepts outlined by the federal regulations are met: Ohio Administrative Code (OAC) 3745-1-05, which outlines the overall requirements for appropriate activities on water bodies within the state; and OAC 3745-1-54, which outlines additional provisions to be implemented when evaluating project impacts relating to wetlands.

To facilitate implementation of the antidegradation rules, numerous categories of both high, medium, and low quality waters have been established. These designations are assigned to individual water bodies based on narrative and numerical criteria that reflect their potential to support aquatic life. As their name suggests, surface waters classified as Superior High Quality Waters are among the highest quality. They possess exceptional ecological values as assessed based on the presence of threatened or endangered species and the high level of biological integrity. These waters provide a habitat for federally threatened and endangered species and state threatened and endangered species; harbor stable populations of declining fish species or coincide with an essential migration path for these species; and display a level of biological integrity equivalent to the Exceptional Warmwater Habitat (EWH). Water bodies identified as Limited Resources Waters reflect the lowest degree of biological integrity. The two ends of the spectrum of water quality in Ohio, Superior High Quality Waters and Limited Resource Waters, are shown in **Figure 5**.

Section 303 of the CWA establishes the water quality standards and Total Maximum Daily Load (TMDL) programs. TMDL represents the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety and account for seasonal variation in water quality to ensure that the waterbody can be safely used for its designated purpose. States determine the uses and corresponding water quality standards for each waterbody within their jurisdiction- for example, drinking water supply, contact recreation (swimming), and aquatic life support (fishing).

The TMDL Tracking System created under Section 303(d) of the Clean Water Act contains information on waters that are not supporting their designated uses. Based on TMDL standards, waterbodies located within Ohio that are identified as impaired are shown in **Figure 6**. TMDL also provides a good regulatory driver for the integration of green infrastructure practices.

2.2.3 Scenic Rivers

Scenic rivers in Ohio (**Figure 7**) were established by state and federal law. Ohio established the Scenic Rivers Act in 1968 (the first in the nation of its kind) to protect high quality rivers for future generations. This legislation classifies rivers as wild, scenic, or recreational, and requires for each designated river the appointment of a Citizens' Advisory Council to voice the concerns of preservation and give river protection advice. The Scenic River Act uses three broad approaches for scenic river protection. First, the Ohio Department of Natural Resources (ODNR) has the authority to approve or disapprove all publicly funded projects on designated scenic rivers outside municipal corporation limits. Second, ODNR staff advises landowners about streamside protection techniques and restoration. Finally, ODNR works cooperatively with the Ohio Environmental Protection Agency and local governments to conduct effective watershed protection through stream quality monitoring, biological surveys and nonpoint source pollution reduction strategies.

Also created in 1968, the National Wild and Scenic Rivers System supplements river protection with the recognition of appropriate uses and development. As designated by Congress or the Secretary of the Interior, river classifications under this legislation similarly include wild (free of impoundments and generally inaccessible over land), scenic (watersheds still primitive but accessible by roads), or recreational (some development or impoundments). Each river is administered by either a federal or state agency with the goal of protecting and enhancing the values that determined its designation.

Figure 5: Superior High Quality Waters and Limited Resource Waters
Source: Division of Surface Water Geographic Information Systems (OEPA, 2010)

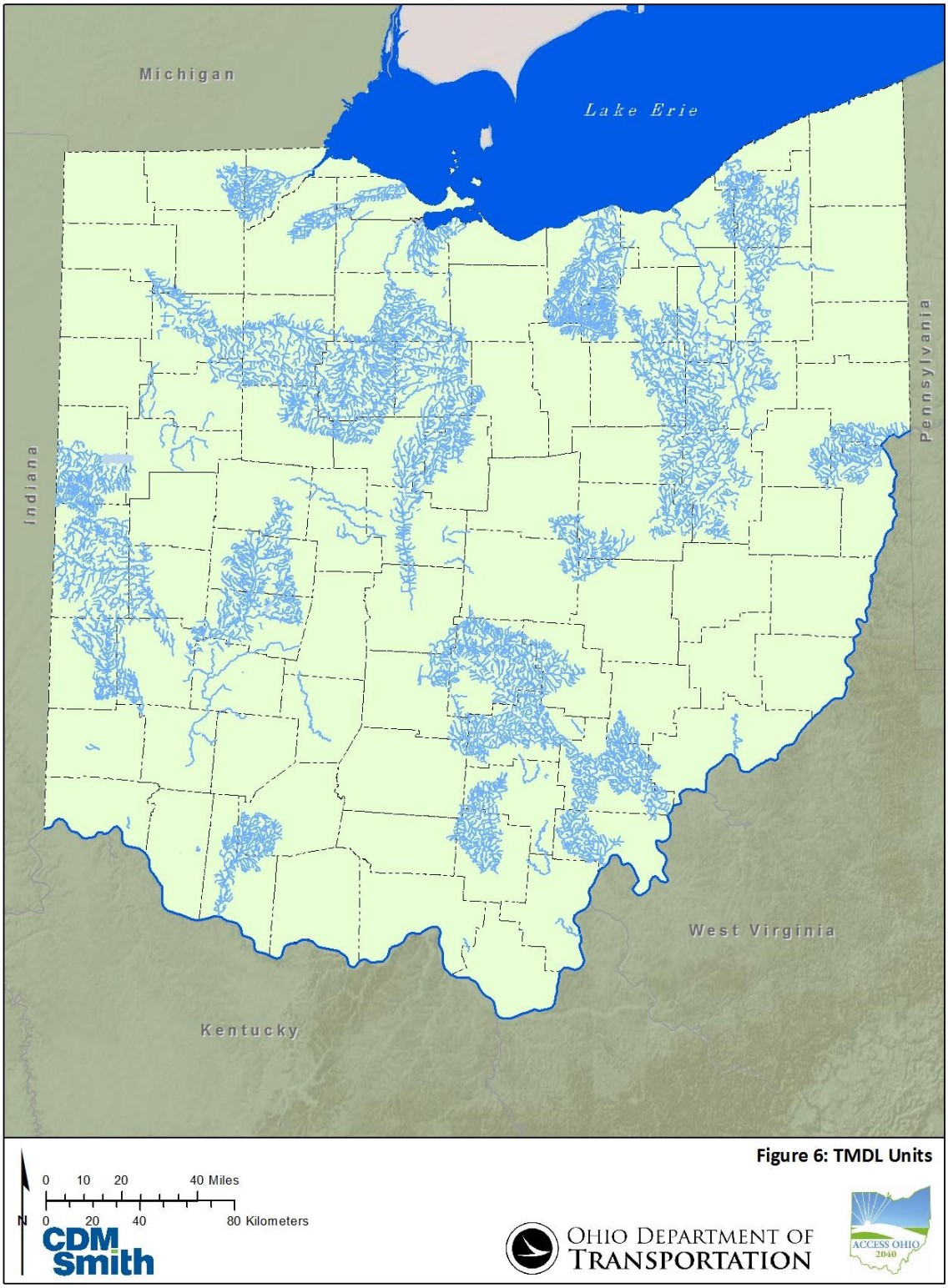


Figure 6: Total Maximum Daily Load (TMDL) Units
Source: USGS National Assessment of Oil and Gas Project

Figure 7: National and State Scenic Rivers

Figure 7: National and State Scenic Rivers
Source: ODNR Division of Watercraft

2.3 Endangered Species

2.3.1 Federal Endangered Species

The U.S. Fish and Wildlife Service (USFWS) is responsible for administering the 1973 Endangered Species Act (ESA). [1] Principal USFWS responsibilities include:

- **Candidate Conservation**: assessing declining species that may need protection under the ESA;
- **Listing**: identifying candidate species as endangered and designating the critical habitat;
- **Recovery**: protecting, conserving and restoring listed species;
- **Consulting (Section 7 of ESA)**: consulting with federal agencies to help them fulfill their obligations to conserve threatened and endangered species and to avoid jeopardizing their continued existence;
- **Permitting**: issuing permits to "take" listed species under certain conditions;
- **Habitat Conservation Plans (Section 10 of ESA):** assisting applicants throughout the HCP process, allowing development to proceed consistent with conserving listed species;
- **Grants:** providing grants to states under Section 6 of the ESA.

Federally-designated endangered species found in Ohio are identified at http://www.fws.gov/midwest/ohio/endangered_index.html and shown in **Figure 8**.

2.3.2 Ohio Endangered Species

The Ohio Department of Natural Resources' Division of Wildlife has legal authority over Ohio's fish and wildlife. This division seeks to find a balance between the protection and beneficial uses of natural resources. A status assessment of Ohio's fish and wildlife species is conducted every five years, including the categorization of species as endangered, threatened, species of concern, special interest, extirpated, or extinct. Based on this categorization, **Table 1** summarizes the distribution of Ohio's endangered species.

Table 1: Number of Species in Major Taxa Classified as Endangered, Threatened, Species of Concern, Special Interest, Extirpated, or Extinct in Ohio, October 2012

Taxon	Endangered	Threatened	Concern	Special Interest	Extirpated	Extinct
Mammals	4	2	20	1	10	0
Birds	14	5	14	33	5	2
Reptiles	4	4	11	0	0	0
Amphibians	5	1	2	0	0	0
Fish	20	13	9	0	8	2
Mollusks	24	4	8	0	11	6
Crayfishes	0	2	3	0	0	0
Isopods	2	1	0	0	0	0
Psuedoscorpions	1	0	0	0	0	0
Dragonflies	13	3	1	0	0	0
Damselflies	3	3	0	0	0	0
Caddisflies	3	6	3	0	0	0
Mayflies	2	0	1	0	0	0
Midges	1	3	1	0	0	0
Crickets	0	0	1	0	0	0
Butterflies	8	1	2	1	1	0
Moths	14	4	22	11	0	0
Beetles	2	2	6	0	0	1
Total	**120**	**54**	**104**	**46**	**35**	**11**

[1] 7 U.S.C. § 136, 16 U.S.C. § 1531 et seq.

Figure 8: Federally-Designated Endangered, Threatened, Candidate Species, and Species of Concern in Ohio

Source: Federally Endangered, Threatened, Candidate Species, and Species of Concern in Ohio (Fish and Wildlife Service, October 16, 2012)

2.4 Terrestrial Resources

2.4.1 Ecoregions/Physiographic Provinces

Ecoregions denote areas with similar ecosystems and types, qualities, and quantities of environmental resources. They are used to provide a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components. The division of North America into ecoregions varies depending on the level of analysis: Level I establishes 15 ecological regions; Level II establishes 52 regions; Level III establishes 99 regions; and Level IV further subdivides the Level III ecoregions. These ecoregions were defined by the USEPA based on an analysis of the biotic and abiotic phenomena that affect or reflect differences in ecosystem quality and integrity, including geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology. Six Level III USEPA ecoregions exist within Ohio as shown in **Figure 9** and identified below; further subdivisions of these regions used for Level IV analysis are shown in **Figure 10**.

Eastern Corn Belt Plains: Covering much of the western part of the state, the Eastern Corn Belt Plains is primarily a rolling till plain with local end moraines. Glacial deposits of Wisconsinan age are extensive; they are not as dissected nor as leached as the pre-Wisconsinan till. Originally, natural tree cover was substantial, beech forests were common, and elm-ash swamp forests dominated the wetter soils. Today, stream chemistry and turbidity have been affected by extensive corn, soybean, and livestock production in the region.

Erie Lake Plains: Covering the western counties along Lake Erie, the Erie Lake Plain is a broad, fertile, nearly flat plain punctuated by relict sand dunes, beach ridges, and end moraines. Originally, soil drainage was poor, swamp and beech forests were dominant, and oak savanna was mainly restricted to sandy, well-drained dunes and beach ridges. Today, most of the area has been cleared and artificially drained to accommodate high yielding farms producing corn, soybeans, livestock, and vegetables, in addition to extensive urban and industrial areas. Stream habitat and quality have been degraded by channelization, ditching, and agricultural activities.

Western Allegheny Plateau: Covering the southeastern portion of the state, the Western Allegheny Plateau is a rugged, hilly, and wooded terrain that has not been muted by glaciations. Extensive mixed mesophytic forests and mixed oak forests originally grew in this area. Today, most of its rounded hills remain forested; dairy, livestock, and general farms as well as residential developments are concentrated in the valleys. The horizontally-bedded, sedimentary rock that underlies the region is mined for bituminous coal, though not to the extent that it has been in the past.

Interior Plateau: Located along the Ohio River in the vicinity of Cincinnati, the Interior Plateau has rolling to deeply dissected, rugged terrain with areas of karst topography. The original beech and oak-hickory forests were located on the well-drained upper slopes. The soils developed from the underlying sandstone, siltstone, shale, and limestone. Land use/land cover in the region alternates between crop and livestock farms and forests.

Erie Drift Plain: Curving through the northeastern portion of the state, the Erie Drift Plain is a low lime drift and lacustrine deposit blanket with rolling to level terrain. Lakes, wetlands, and swampy streams occur where stream networks are deranged or where the land is flat and clayey. Soils in this region are often lower in carbonate and less fertile than those of other glaciated ecoregions. Urban development, industrial activity, and agriculture are widespread; scattered woodland also occurs. Lake Erie's influence substantially increases the growing season, winter cloudiness, and snowfall of the northernmost areas.

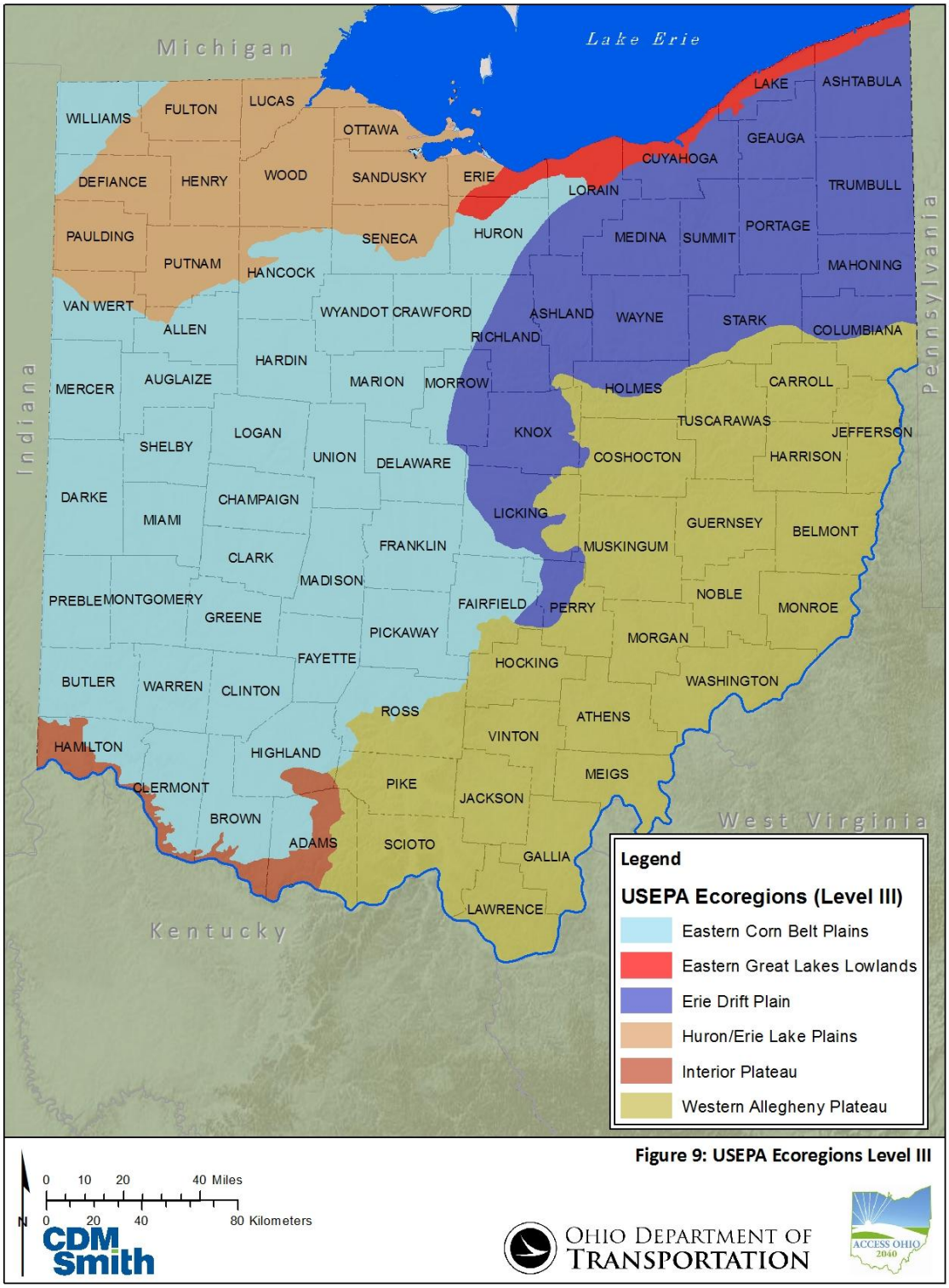


Figure 9: Level III Ecoregions in Ohio based on Environmental Protection Agency (EPA) Designation
Source: Level III and IV Ecoregions of the Continental United States (U.S. EPA, 2011)

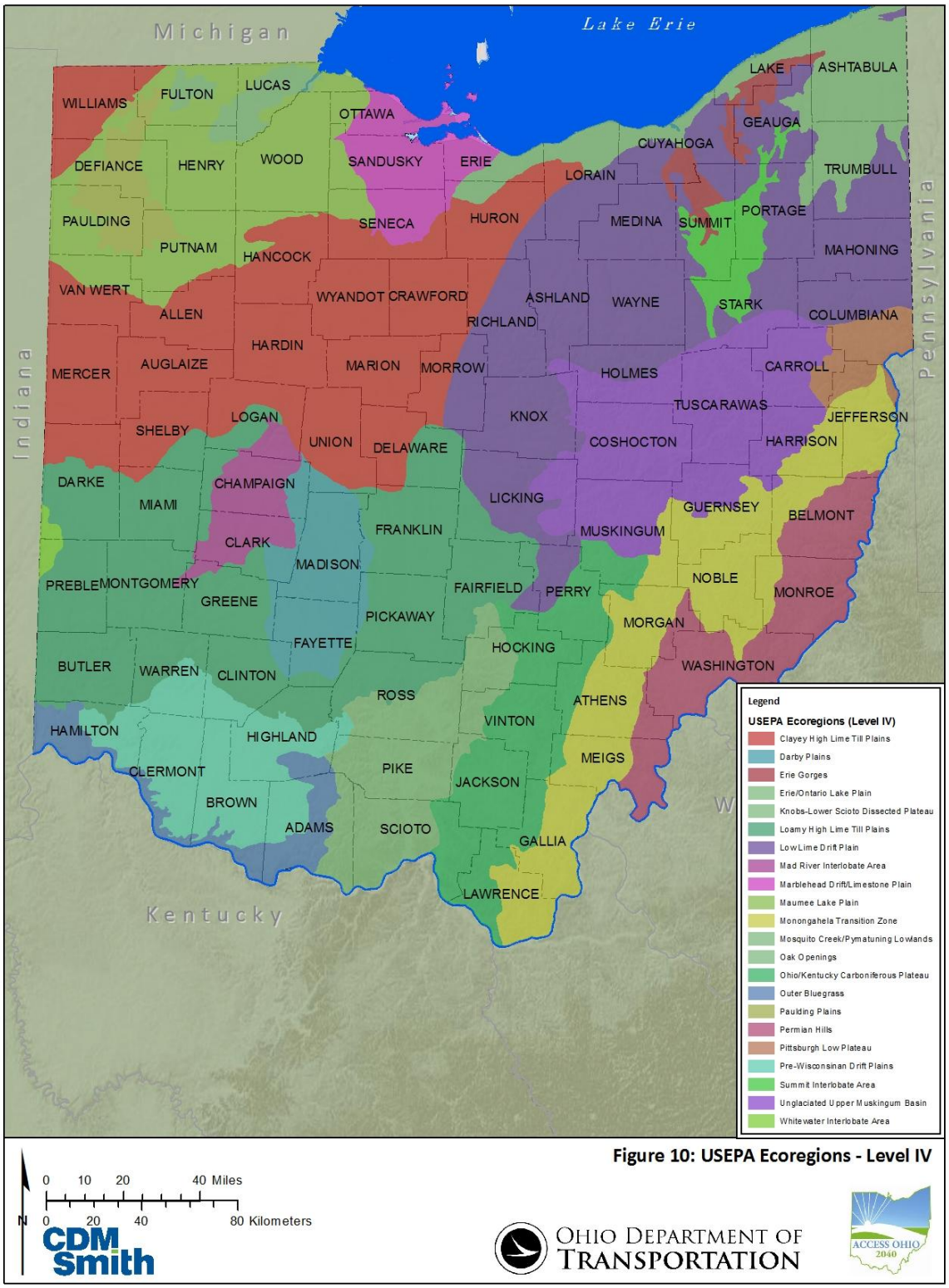


Figure 10: Level IV Ecoregions in Ohio based on Environmental Protection Agency (EPA) Designation
Source: Level III and IV Ecoregions of the Continental United States (U.S. EPA, 2011)

Eastern Great Lakes Lowlands: Along the eastern edge of Lake Erie, this narrow, nearly level, coastal strip of lacustrine deposits is punctuated by beach ridges and swales. Its lake-modified climate differentiates it from other nearby ecoregions, resulting in an annual growing season that is often several weeks longer than inland areas. Urban-industrial sites, ports, fruit and vegetable farms, and nurseries have developed on the plain.

2.4.2 Unique Natural Resources

Ohio is home to many unique resources (**Figure 11**) that are capable of supporting wildlife with highly specialized habitat requirements, or that represent significant man-made features. While not intended to be an exhaustive list of unique resources, a few of note are identified below.

Lake Erie Islands: Ohio has jurisdiction over 13 Lake Erie islands that range in size from the 2,824-acre Kelley's Island to the 1.2-acre Starve Island. Although these islands are distinct from the neighboring mainland with respect to climate, topography, surface geology and soils, they have similar vegetation. Shoreline characteristics vary but generally consist of beaches of sand, gravel or small stones, loose rocks, limestone shelves, and sheer cliffs—all with varying amounts of vegetative cover.

Oak Savannas: Located in the northwestern portion of the state, this region (also known as Oak Openings) consists of roughly 132 square miles of sandy soil, resulting in an area that is dry and dominated by drought-resistant prairie plants (such as little bluestem grass and lupine) and widely-spaced oak trees that are surrounded by poor drainage areas which support wetlands. Ohio's Oak Openings region, identified by the Nature Conservancy as "One of America's Last Great Places", is home to more endangered native plant species than any other region in Ohio.

Ohio's Caves/Hocking Hills Region: Most of Ohio's approximately 300 known caves occur within a 40-mile-wide tract of land aligned north-south through the middle of the state, spanning from Adams County to the Lake Erie Islands**.** The majority of caves found in Ohio are carbonate or non-carbonate depending on the bedrock in which they develop: carbonate caves are found in the dolomite and limestone of western Ohio, while non-carbonate caves are found in the sandstones and conglomerates of eastern Ohio. Despite the relatively small size of most caves in Ohio, many animals depend on them for some part of their life including salamanders, bats, and insects. In fact, four cave-dwelling organisms that are found in Ohio have not been discovered anywhere else in the world.

Many of Ohio's most popular caves are located in the Hocking Hills region. Hocking Hills is a deeply dissected area of the Allegheny Plateau in Ohio, primarily in Hocking County, that features cliffs, gorges, rock shelters, and waterfalls. The relatively extreme topography in this area is due to the Blackhand Sandstone, a particular formation that is thick, hard and weather-resistant, and so forms high cliffs and narrow, deep gorges.

Figure 11: Ohio's Unique Natural Resources

Sources: NFS Land Unit Inventory (USDA Forest Service) and Bruce A Skubon

Wayne National Forest: The Wayne National Forest covers over a quarter million acres of Appalachian foothills in southeastern Ohio. It is divided into three units that are located across twelve counties and is managed out of two Ranger District offices in Nelsonville and Ironton. Most of the land within the boundaries of the forest is privately held. The national forest exists as a patchwork across the land, normally occupying lands less suitable for agricultural or commercial development. It features over 300 miles of trails for hiking, all-terrain vehicle riding, mountain biking, and horseback riding. As the only national forest in Ohio, it provides a mix of open land and forest that supports a wide variety of wildlife habitats.

National Park Service (NPS) Units: The NPS manages 7 facilities in Ohio (**Figure 12**) with the largest being the Cuyahoga Valley National Park located outside of Cleveland. Collectively, these parks hosted approximately 2.6 million visitors in 2012. In addition to the parks, the NPS manages 23 national natural landmarks and 72 national historic landmarks located in Ohio.

2.4.3 Land Use

The National Land Cover Database (NLCD-2006) is a land cover classification scheme that has been applied consistently across the country by the Multi-Resolution Land Characterization (MRLC) consortium. The creation of this consortium has resulted in a comprehensive land cover mapping of the United States based on Landsat satellite imagery. The primary NLCD2006 land cover classifications are:

- Water
- Perennial Ice/Snow
- Low Intensity Residential
- High Intensity Residential
- Commercial/Industrial/Transportation
- Developed High Intensity
- Bare Rock/Sand/Clay
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Shrub/Scrub
- Grasslands/Herbaceous
- Pasture/Hay
- Row Crops
- Woody Wetlands
- Emergent Herbaceous Wetlands

As shown in **Figure 13**, the major NLCD categories in Ohio are high intensity development in urban centers, cultivated crops along the western part of the state, and forested areas to the east.

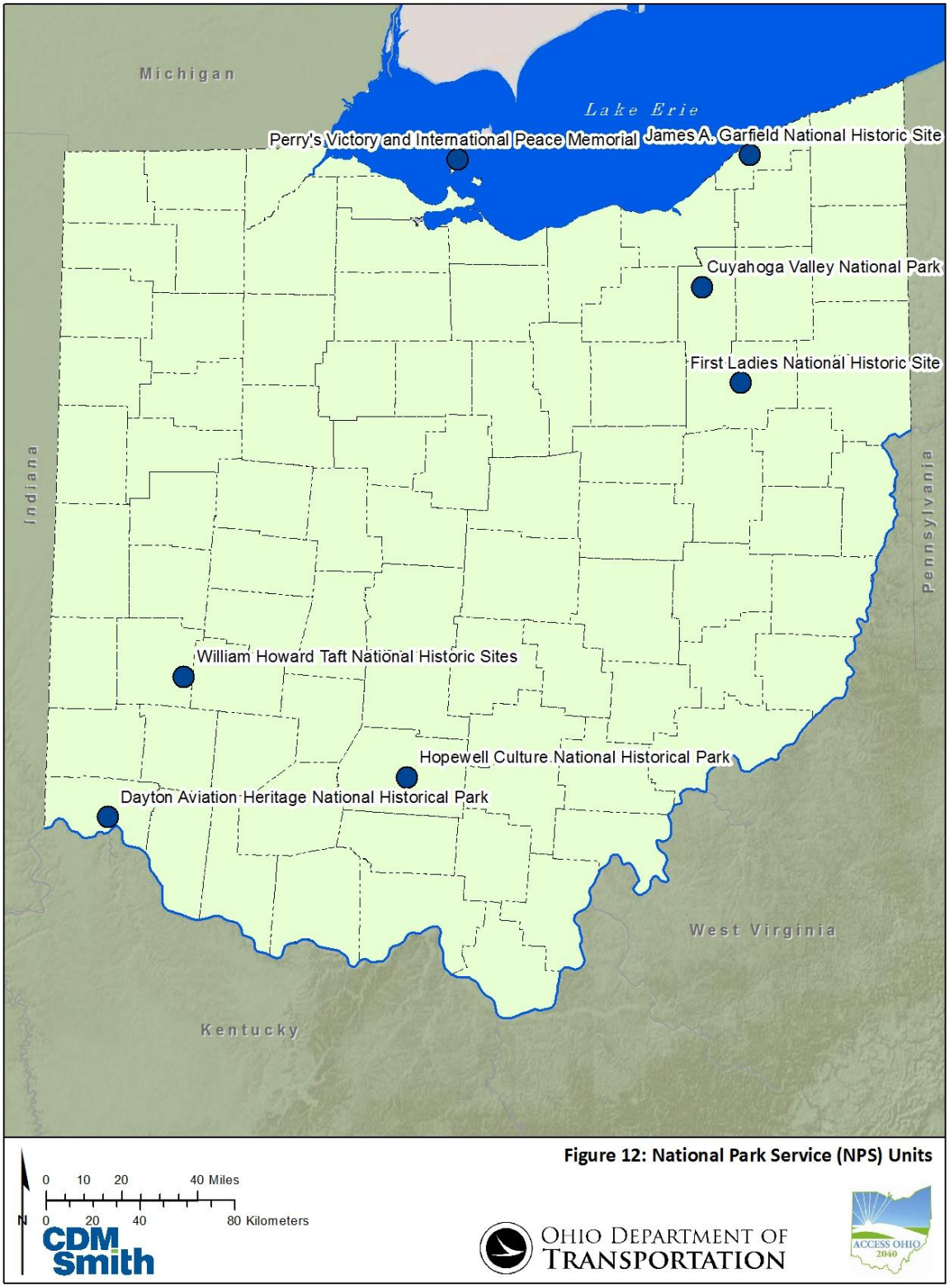


Figure 12: National Park Service (NPS) Units in Ohio
Source: National Park Service

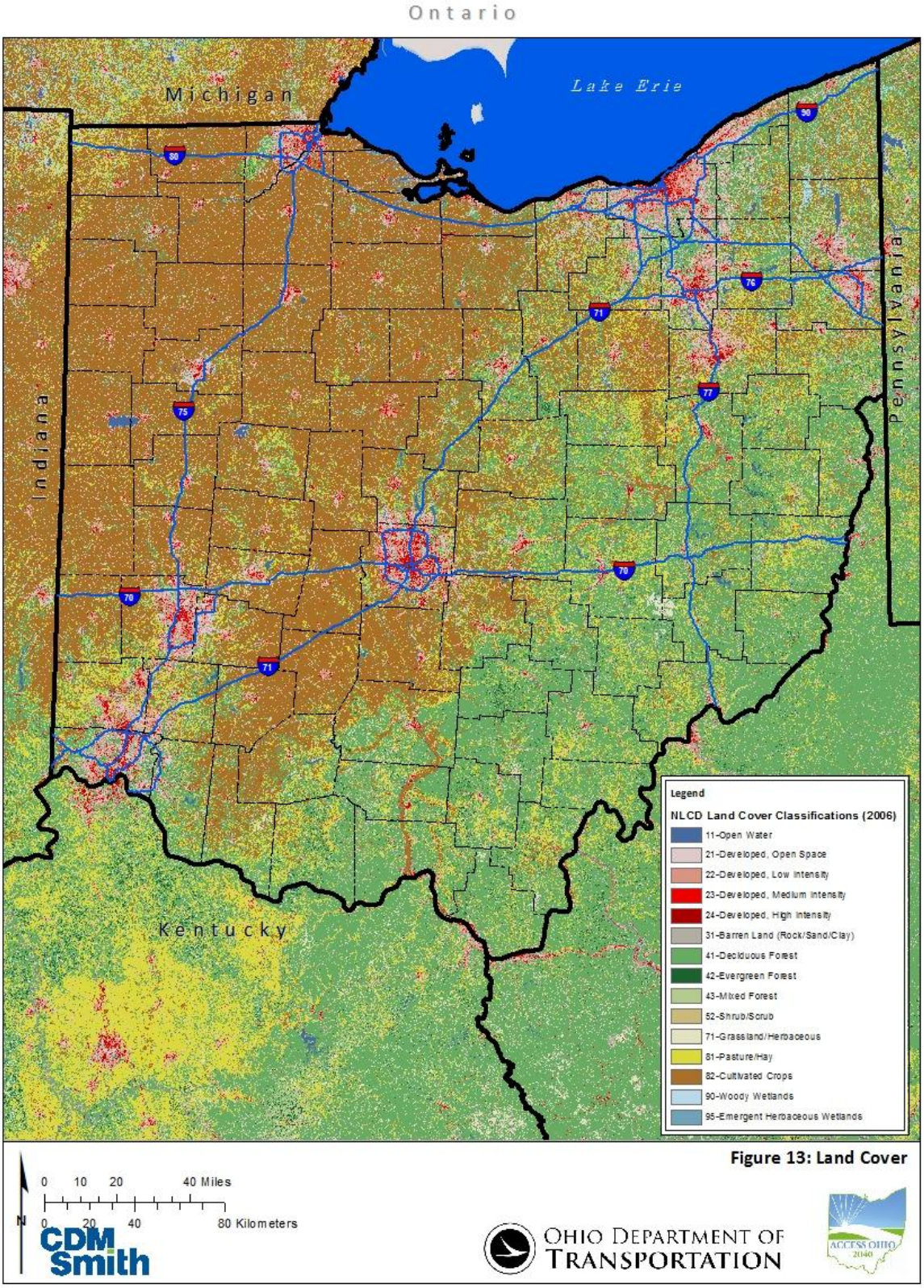


Figure 13: National Land Cover Database (NLCD) Classifications in Ohio
Source: National Land Cover Database (U.S. Geological Survey, 2006)

2.5 Geological Resources

2.5.1 Karst Outcroppings

Karst terrain is created from the dissolution of soluble rocks, principally limestone and dolomite. It is characterized by distinctive landforms (e.g., springs, caves, sinkholes) and a unique hydrogeology that supports highly productive aquifers. These aquifers are vulnerable to contamination from nearby agricultural activities. Karst terrain poses challenges for developers and engineers seeking to build in these areas.

Karst formations in Ohio are located within the Midwest Paleozoic Carbonate Aquifers, with the greatest development occurring in the Devonian-Silurian aquifer system. The limestone outcrops in some areas, and in others is overlain by deep unconsolidated Quaternary deposits. **Figure 14** shows areas of known or probable karst terrain from the Ohio Department of Natural Resources (ODNR) Division of Geological Survey (DGS) (Map EG-1).

2.5.2 Major Oil and Gas Wells

Based on the data maintained by the DGS (**Figure 15**) it is estimated that more than 267,000 oil-and-gas wells have been drilled in Ohio since 1860.

A relatively new drilling technology in Ohio is horizontal hydraulic fracturing (commonly known as fracking). According to ODNR, hydraulic fracturing has been used for more than 50 years in Ohio to stimulate oil and gas well production. Since 1990, more than 15,000 Ohio wells have used hydraulic fracturing. In 2011, more than 73 billion cubic feet of natural gas was produced in Ohio. The Ohio Department of Natural Resources reports that 882 sites in the state of Ohio have been awarded permits for hydraulic fracturing.

Hydraulic fracturing uses sand, water, and chemicals injected at high pressures to release the trapped gas inside. This technique makes it possible to reach natural gas reserves that underlie much of the eastern part of Ohio including the Marcellus and Utica-Point Pleasant deposits. Together, the Marcellus and Utica Shale regions extend across New York, Pennsylvania, Maryland, West Virginia, Ohio and portions of Kentucky and Tennessee. The deposits sit between 7,000 and 12,000 feet below ground. **Figure 16** shows the approximate location of Marcellus shale deposits in Ohio.

Most drilling is now occurring in the Marcellus Shale region of Pennsylvania, with growing interest in West Virginia and New York. Because the Marcellus Shale is much thinner on its western edge, Ohio is experiencing far less Marcellus Shale drilling than other states. However, Ohio will likely see a significant increase in future drilling, as much of the state sits over the Utica Shale formation, which experts predict holds large natural gas reserves and potentially oil.

The Ohio Department of Natural Resources (ODNR) and the Ohio Environmental Protection Agency (EPA) are responsible for regulating oil/gas drilling and production. Relative to hydraulic fracturing, ODNR regulates the disposal of brine and other drilling fluids from oil and gas drilling/production. They also regulate disposal of waste fluids from underground injection wells and transport hauling. Overall, the ODNR regulatory authority over oil/gas drilling and production can be summarized as:

- Issues permits for drilling oil/gas wells in Ohio.
- Sets requirements for proper location, design and construction for wells.
- Requires controls and procedures to prevent discharges and releases.
- Requires that wells no longer used for production are properly plugged.
- Requires registration for water facilities with a capacity over 100,000 gallons.

- Sets design requirements for on-site pits/lagoons used to store cuttings and brine.
- Requires proper closure of on-site pits/lagoons after drilling is completed.
- Sets standards for managing drill cuttings and sediments left on-site.
- Regulates the disposal of brine and operation of underground injection wells
- Reviews specifications and issues permits for Class II wells.
- Sets design/construction requirements for underground injection wells.

Ohio EPA has wide ranging authority over hydraulic fracturing activities. For example, their water quality certification requirements help reduce impacts to waterbodies from the construction of a drill site. Ohio EPA also regulates sources of air emissions, and may require air permits for some of the equipment at the drill site. Any solid waste sent off-site for disposal must be properly managed, as authorized by Ohio EPA's Division of Materials and Waste and Management (DMWM).

Hydraulic fracturing presents some important transportation issues. For example, because Ohio has a significant number of underground injection wells, many drilling companies have been transporting brine into Ohio for deep-well disposal. While ODNR has the exclusive authority for brine disposal in Ohio, they have limited authority over roadway issues. Transportation issues include accommodating heavy vehicles and higher traffic volumes resulting from fracking activities, especially during installation when activity is the highest. In addition, drilling vehicles can produce damaging effects on the infrastructure. Transportation planning is needed to support the needs and mitigate the impacts of hydraulic fracturing on Ohio's transportation system.

Hydraulic Fracturing Vehicles on Public Roadways

2.5.3 Earthquakes

Ohio is on the periphery of the New Madrid Seismic Zone, an area encompassing Missouri and adjacent states that was the site of the largest recorded earthquake sequence in the continental United States. According to ODNR, at least 200 earthquakes have been felt in Ohio since 1776 as shown in **Figure 17**. Zero deaths and a few minor injuries were recorded for these events, and very few resulted in significant damage. Based on historical observations, three areas in Ohio are particularly susceptible to seismic activity:

- Shelby County and surrounding counties in western Ohio have experienced more than 40 felt earthquakes since 1875;
- Northeastern Ohio has experienced more than 100 earthquakes since 1836, many of them beneath Lake Erie offshore from Lake County, and in association with an injection well in Ashtabula;
- Southeastern Ohio has been the site of at least 12 felt earthquakes since 1776.

As part of the mission of the Ohio Seismic Network, the DGS operates the Ohio Earthquake Information Center (OEIC) to serve as the primary source for the dissemination of earthquake information in the state.

2.5.4 Sole Source Aquifers

Sole Source Aquifers (SSA) supply at least 50 percent of the drinking water consumed in the area overlying the aquifer; thus, these areas have severely limited options for alternate sources of drinking water. Areas designated as having a SSA are protected under Section 1424(e) of the Safe Drinking Water Act of 1974,[2] which requires the EPA to review all proposed projects receiving federal funding within the designated area to ensure that they do not endanger the water source. In fact:

> *"...no commitment for federal financial assistance (through a grant, contract, loan guarantee, or otherwise) may be entered into for any project which the Administrator determines may contaminate such aquifer..."*

There are four SSAs in Ohio as shown in **Figure 18**:

- **Greater Miami SSA** – located throughout the Miami River watershed in southwestern Ohio;
- **Allen County SSA** – located in western Allen County near the Auglaize river;
- **Catawba Island SSA** – located throughout the entirety of the Lake Erie island of Catawba;
- **Pleasant City SSA** –located in Guernsey County off of I-77.

2.5.5 Abandoned Underground Mines

The Abandoned Underground Mine Inventory is a proactive method for identifying and prioritizing risk assessment sites such as mines that exist beneath the roadway. The DGS maintains detailed abandonment maps for over 4,000 underground mines. In addition to the mines shown on these maps, the DGS estimates that there are approximately 2,000 mines in Ohio for which no detailed maps are available. The location and extent of the known mines are shown in **Figure 19**.

[2] Public Law 93-523, 42 U.S.C. 300 et seq.

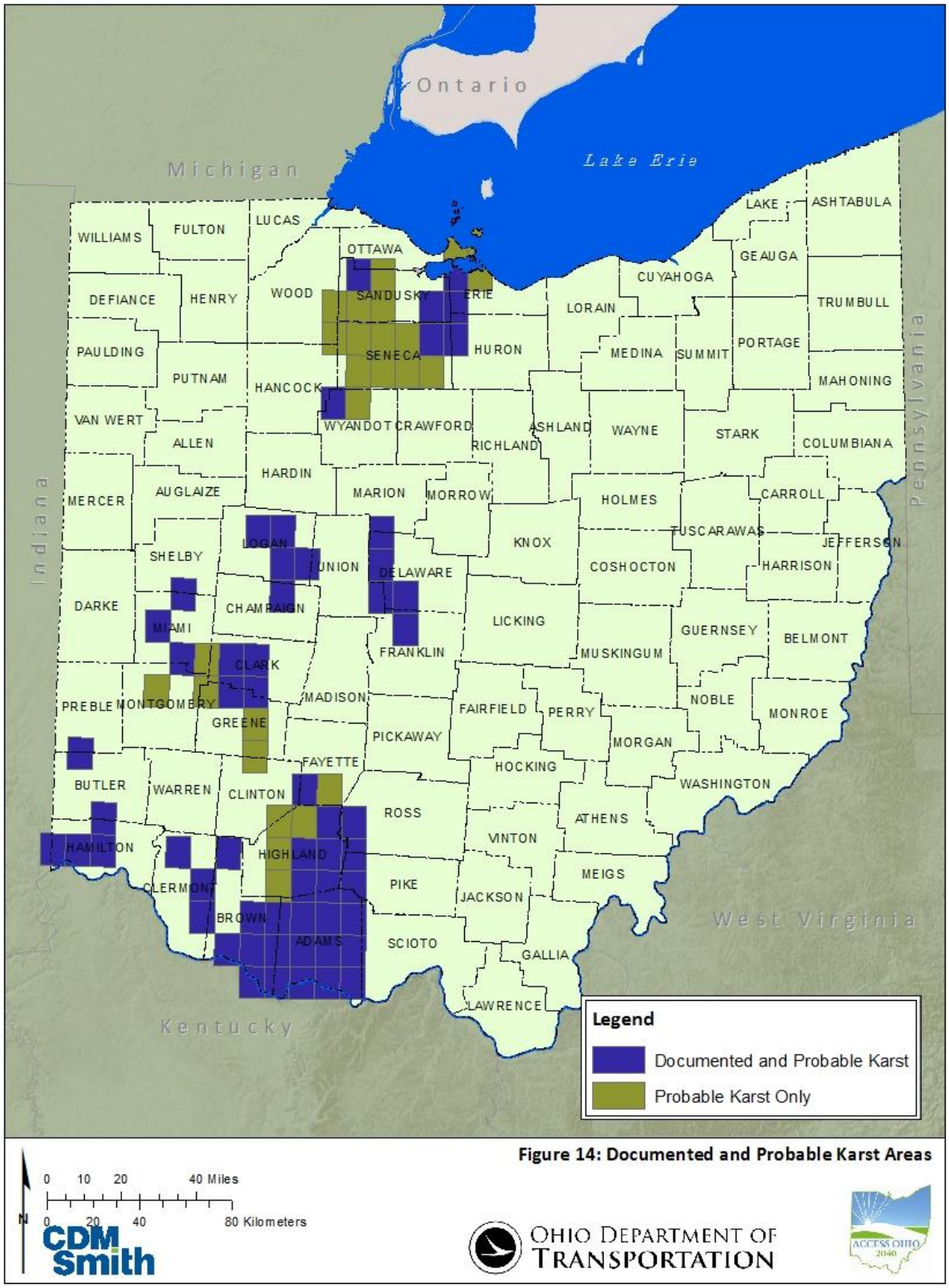


Figure 14: Known and Probable Karst Regions in Ohio

Source: Known and Probable Karst in Ohio - EG-1 (ODNR Division of Geological Survey, 2007)

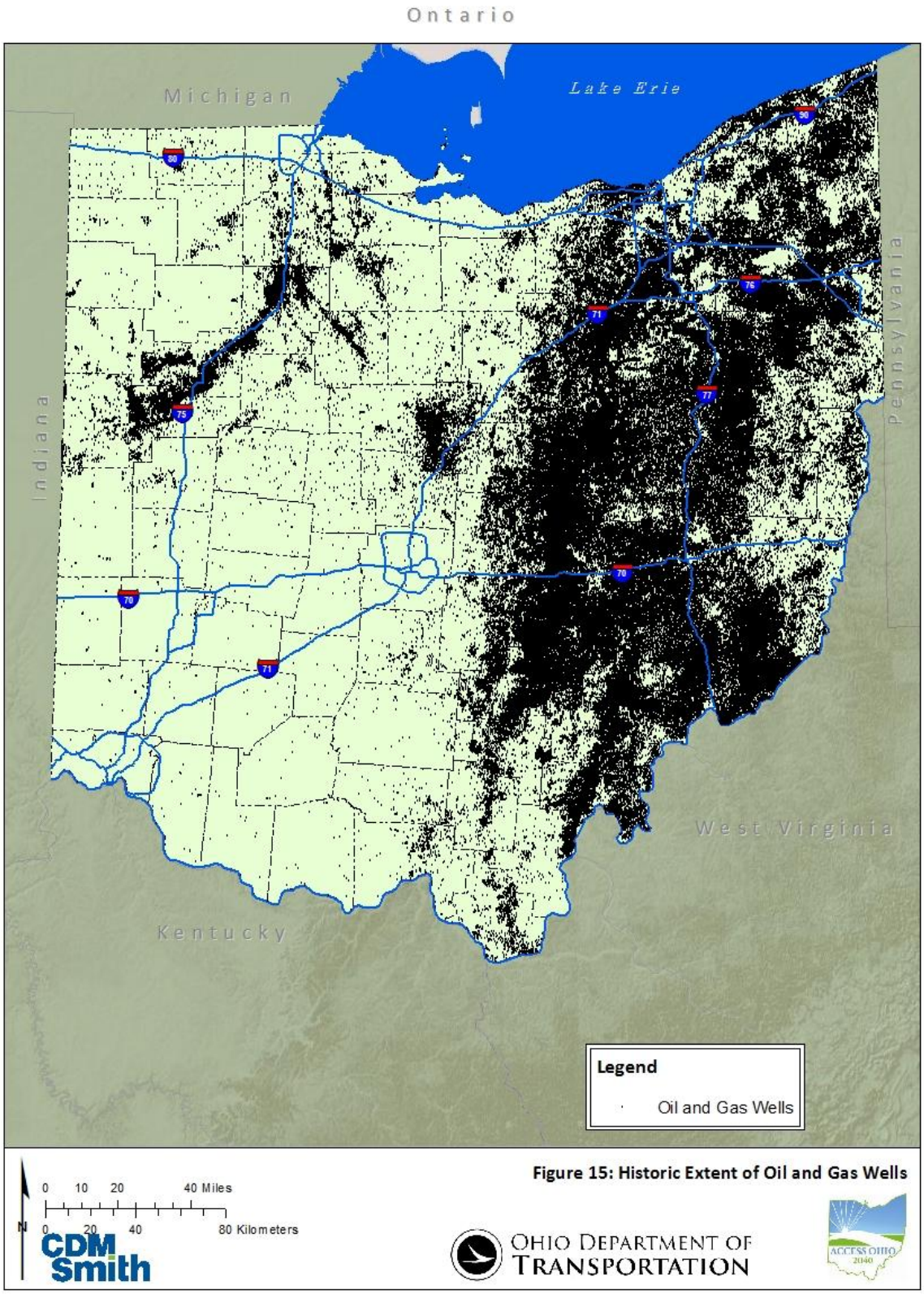


Figure 15: Oil and Gas Wells Drilled in Ohio Since 1860

Source: Oil and Gas Well Spot GIS Database – PG-4 (ODNR Division of Geological Survey, 2011)

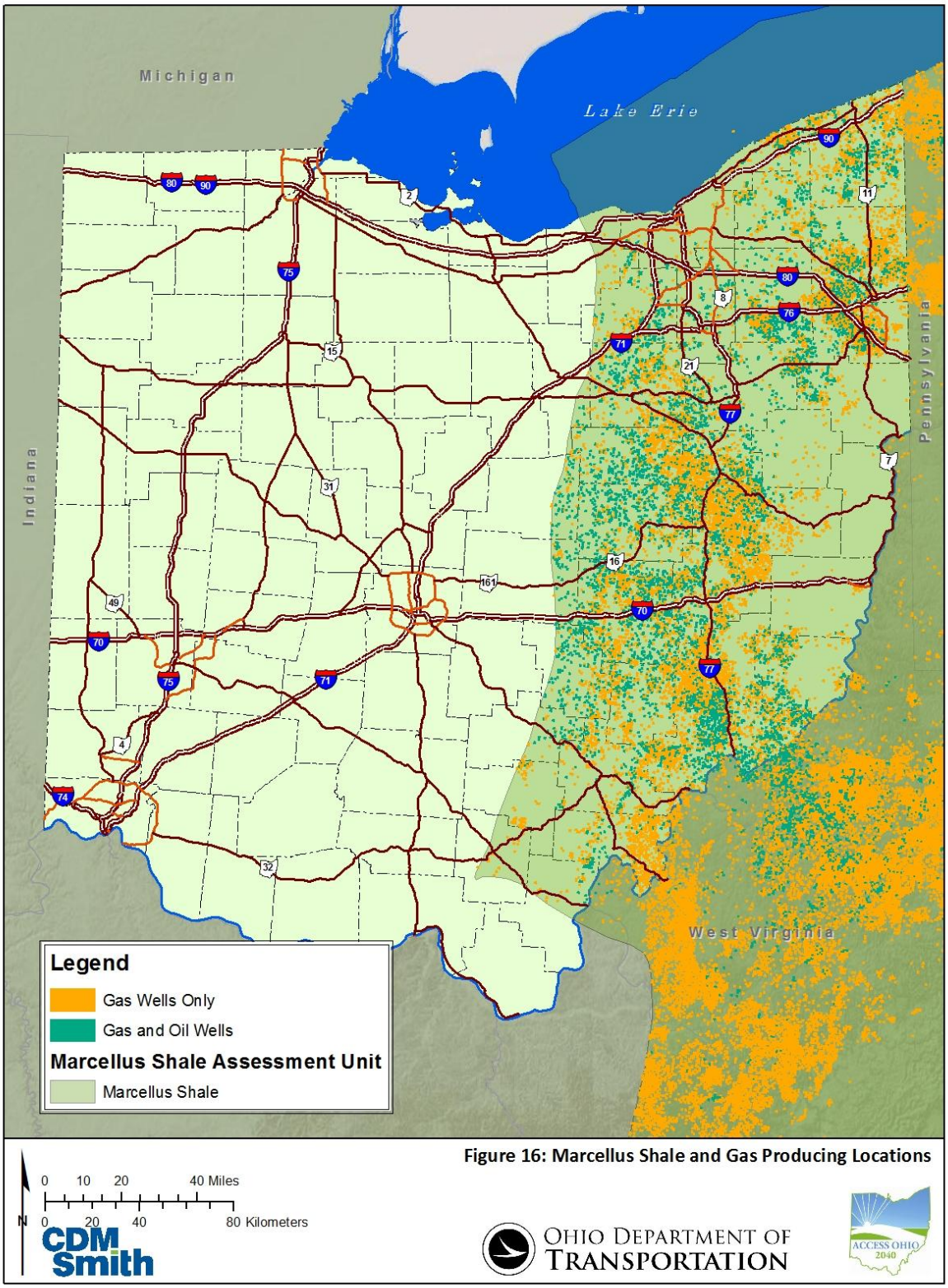


Figure 16: Estimated Locations of Marcellus Shale Deposits in Ohio
Source: USGS – National Assessment of Oil and Gas Projects

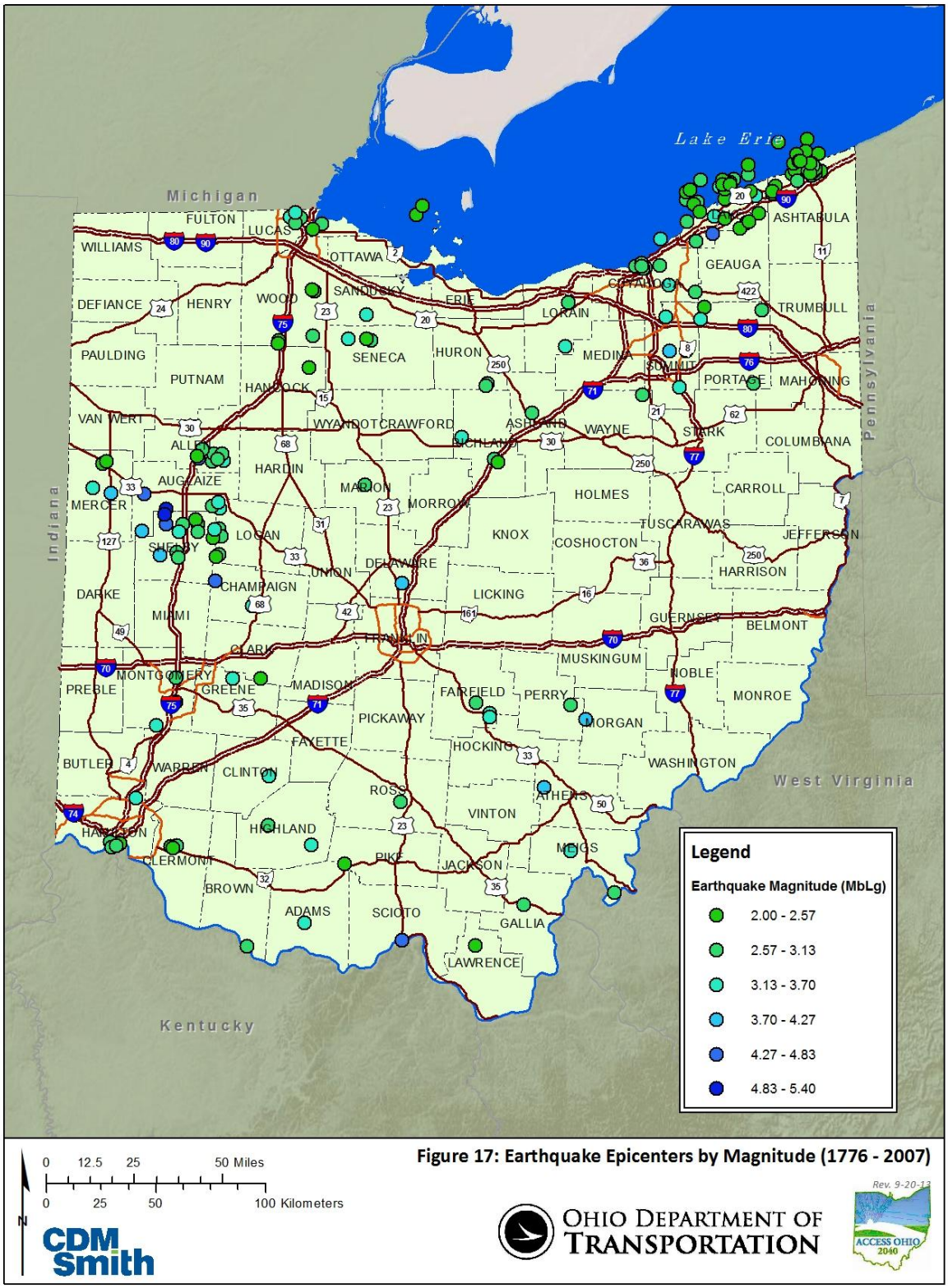


Figure 17: Earthquake Epicenters by Magnitude that Occurred Between 1776 and 2007
Source: Earthquake Epicenters in Ohio, EG-2 (ODNR Division of Geological Survey, 2007)

Figure 18: Location of Sole Source Aquifers (SSA) in Ohio
Source: The SSA Protection Program (U. S. EPA Office of Water)

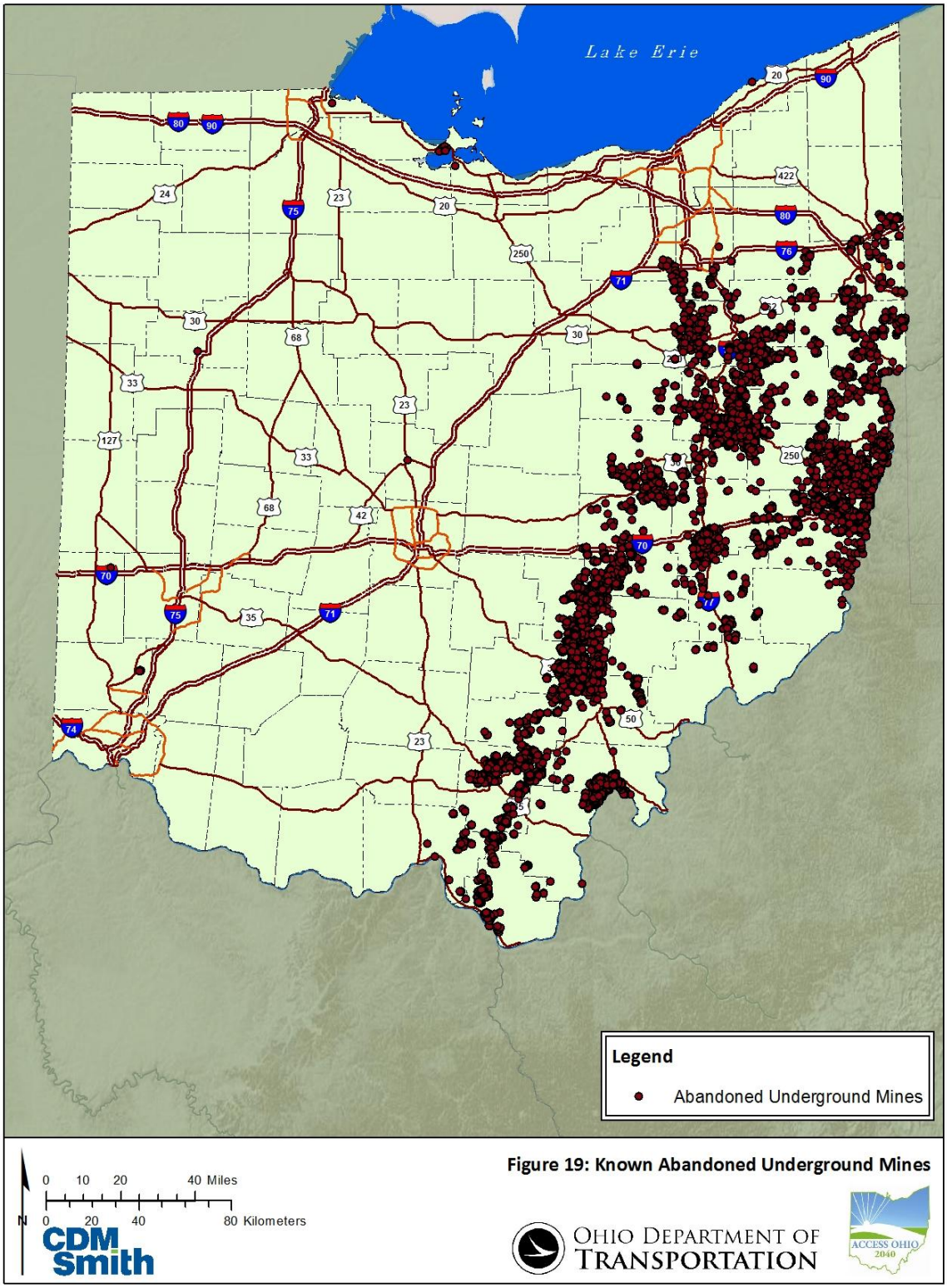


Figure 19: Known Abandoned Underground Mines

Source: Known Abandoned Underground Mines of Ohio, EG-3 (ODNR Division of Geological Survey, 2008)

3. CLIMATE VARIABILITY

This section summarizes the potential impact of climate variability on Ohio's transportation infrastructure and provides an overview of best practices that can be used to reduce transportation emissions. Further information on the potential vulnerability of Ohio infrastructure to climate variability is being assessed as part of the *Statewide Climate Variability Study*.

3.1 Climate Variability in Transportation Planning

To meet the anticipated challenge of warmer temperatures, more severe and frequent weather patterns, land subsidence, and reoccurring regional flooding and drought conditions, planning agencies have the opportunity to pursue and/or encourage mitigation strategies. By building more resilient physical infrastructure, mobility can be preserved for Ohio transportation system users. For instance, benefits of a greenhouse gas (GHG) emission reduction strategy could result in lower user costs from improved vehicle fuel efficiency and reduced dependence on foreign energy sources. While greenhouse gas (GHG) emissions - such as carbon dioxide (most widespread), methane (most potent), nitrous oxide, water vapor, and fluorinated gases - occur naturally (e.g., volcanic eruptions and forest fires), their release has been accelerated with human development. Consequently, it has been observed that such gases tend to hold reflected heat within the Earth's atmosphere, leading to more rapid environmental transformations (**Figure 20**).

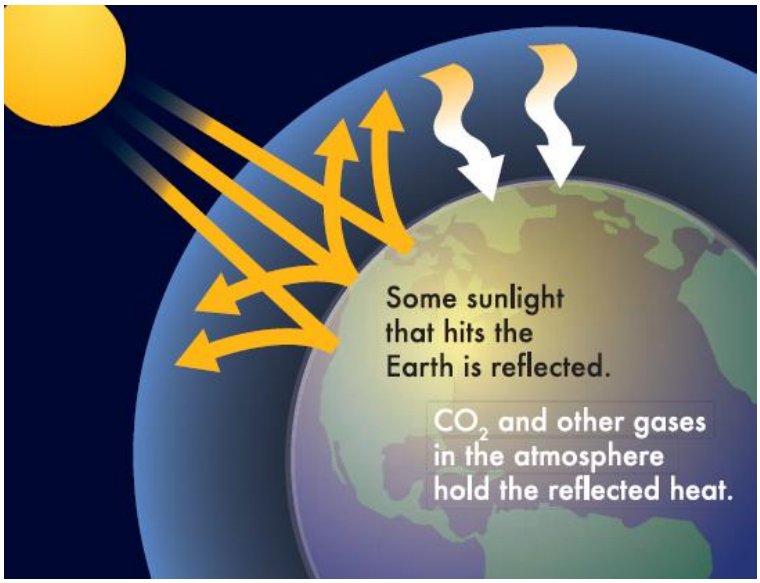


Figure 20: Illustration of the effects of the Greenhouse Effect (FHWA, 2009)

Agencies have the ability through policy and transportation improvement projects to pursue sustainable practices that lower or mitigate the consequences of transportation-related GHG emissions. As noted in the AASHTO-sponsored *Moving Cooler* report,[3] basic approaches include

[3] Cambridge Systematics, Inc. (2009). Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions. Urban Land Institute, Washington, D.C.

making vehicle and fuel technology more efficient, encouraging sustainable travel activities, and improving system operations. Successful strategies based on an evaluation of case studies at the regional planning level have included implementing Intelligent Transportation Systems (ITS), utilizing Emissions Trading Systems (ETS), encouraging alternative commuting behaviors, pricing, and land-use adjustments. While these efforts will likely not have as great of an effect as improving vehicle and fuel technology, an all-of-the-above approach may be beneficial for the state of Ohio.

3.2 Impact of Climate Variability on Transportation Infrastructure

As a result of a variable climate, various impacts including warmer temperatures (on average but with potential for localized cooling), more volatile precipitation rates, and more frequent strong storms are anticipated.[4] As a region, by 2030, the Midwest is anticipated to experience a 2.7°F increase in average temperature and an increase in precipitation by one to seven percent (**Table 2** and **Table 3**).

Table 2: Annual and Seasonal Temperature Changes for the Midwest

Season	Likelihood	Near-Term (Δ°F)	Mid-Century (Δ°F)	End-of-Century (Δ°F)
Annual	Mean	2.6 – 2.7	4.0 – 5.0	5.6 – 9.6
	Likely	1.9 – 3.3	3.0 – 6.0	4.3 – 11.7
	Very Likely	1.3 – 3.9	1.9 – 7.0	3.0 – 13.8
Winter	Mean	2.6 – 3.0	4.1 – 5.3	6.0 – 9.4
	Likely	1.6 – 4.0	2.9 – 6.6	4.6 – 11.5
	Very Likely	0.6 – 4.9	1.7 – 7.9	3.3 – 13.5
Spring	Mean	2.0 – 2.4	3.6 – 4.2	5.1 – 8.4
	Likely	1.2 – 3.3	2.2 – 5.6	3.5 – 10.6
	Very Likely	0.4 – 4.1	0.8 – 7.0	1.9 – 12.9
Summer	Mean	2.6 – 2.8	4.1 – 5.3	5.6 – 10.8
	Likely	1.9 – 3.8	2.8 – 6.8	4.2 – 14.2
	Very Likely	1.0 – 4.7	1.5 – 8.3	2.7 – 17.5
Fall	Mean	2.6 – 2.7	4.0 – 4.9	5.5 – 9.6
	Likely	2.0 – 3.4	2.9 – 5.8	4.1 – 11.6
	Very Likely	1.3 – 4.1	1.7 – 6.7	2.7 – 13.6

**Near-term* refers to 2010-2029, Mid-Century refers to 2040-2059, and End-of-Century refers to 2080-2098. All changes are relative to 1961-1979 normal temperatures.

Table 3: Seasonal Precipitation Percent Changes for the Midwest

Season	Likelihood	Near-Term (%Δ)	Mid-Century (%Δ)	End-of-Century (%Δ)
Winter	Mean	6 –7	8 – 9	10 –14
	Likely	2 – 12	1 – 15	3 – 22
	Very Likely	(3) – 16	(6) – 21	(3) – 30
Spring	Mean	3 – 4	7 – 9	10 – 14
	Likely	(1) – 8	3 – 13	2 – 25
	Very Likely	(6) – 12	(1) – 18	(9) – 36
Summer	Mean	(1)	(4) – (1)	(9) – (2)
	Likely	(7) – 6	(15) – 8	(31) – 14
	Very Likely	(14) – 13	(26) – 19	(53) – 36
Fall	Mean	1	1 – 3	2 – 3

[4] ICF International (July 2009). *Literature Review: Climate Change Vulnerability Assessment, Risk Assessment, and Adaptation Approaches.* Prepared for Mike Culp of the Federal Highway Administration – Office of Environment and Planning, Contract Number DTFH61-05-D-00018/19/20/21; TOPR Number EV0101, Washington, D.C.

Season	Likelihood	Near-Term (%Δ)	Mid-Century (%Δ)	End-of-Century (%Δ)
	Likely	(5) – 7	(6) – 11	(10) – 17
	Very Likely	(11) – 13	(14) – 18	(23) – 30

*Near-term refers to 2010-2029, Mid-Century refers to 2040-2059, and End-of-Century refers to 2080-2098. All changes are relative to 1961-1979 normal precipitation levels. Values in parenthesis indicate a potential decrease in precipitation.

Transportation infrastructure is at risk due to occurrence of climatic conditions that were not originally considered in planning, design, construction, and maintenance processes (**Table 4**). Further analysis [e.g., NCHRP 20-83(05)] will be required to identify and adapt those infrastructure assets that are most vulnerable to climate variability.

Table 4: Potential Infrastructure Impacts from Climate Variability

Climate Impact	Potential Infrastructure Impact*
Increased summer temperatures, increases in very hot days and heat waves	Highway asphalt rutting, possible movement of liquid asphalt (NRC, 2008)
	Thermal expansion of bridge joints and paved surfaces (NRC, 2008)
	Limitation on construction periods during summer (NRC, 2008)
	Increased night work
	Higher maintenance/construction costs[5]
	Rail buckling[5]
Decreases in very cold days	Regional changes in snow and ice removal costs and environmental impacts from salt and chemical use (NRC, 2008)
	Fewer cold-related restrictions for maintenance workers (NRC, 2008)
Later onset of seasonal freeze and earlier onset of seasonal thaw	Improved mobility and safety associated with a reduction in winter weather (NRC, 2008)
	Regional reduction in pavement deterioration resulting from less exposure to freezing, but possibility of more freeze-thaw in some locations (NRC, 2008)
More Frequent/Severe Flooding as a Result of Increased Precipitation	Flooding of underground tunnels and low-lying infrastructure[5]
	Decreased driver/operator performance in adverse weather conditions[5]
	Reduced aircraft performance with potential air traffic disruptions[5]
	Diminished shipping access to docks and shore equipment[5]
	Restricted access to local economies[5]
Increases in intense precipitation events	Increases in weather-related delays and traffic disruptions (NRC, 2008)
	Increases in flooding of roadways; Increases in road washout, landslides and mudslides that damage roadways, increased bridge scour in the short term, compromised integrity of roads and bridges due to increased soil moisture (Department for Transport, 2004; NRC, 2008; CCSP, 2008); increased risk to ground-level infrastructure, underground tunnels and low-lying infrastructure[5]
Changes in seasonal precipitation and river flow patterns	Potential benefit if frozen precipitation shifts to rainfall (NRC, 2008)
	Increased risk of floods, landslides and damage to roads (areas where precipitation changes from snow to rain in winter and spring thaws) (NRC, 2008);
	Increased variation in wet/dry spells and decrease in available moisture may cause degradation of road foundations (CSIRO, 2007)
Increases in drought conditions	Increased risk of mudslides in areas deforested by wildfires (NRC, 2008)
Storm Surges	Increased threat to stability of bridge decks

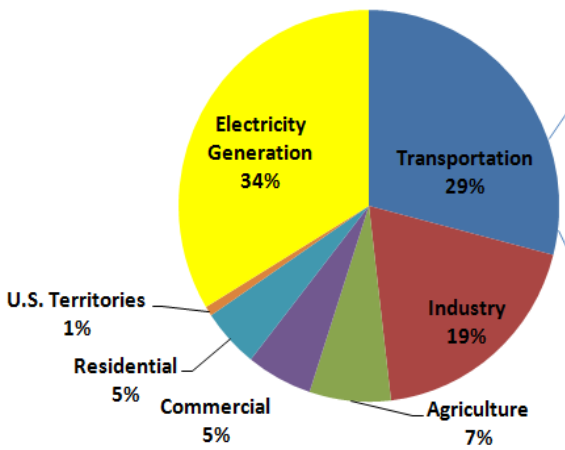
[5] U.S. Department of Transportation (n.d). Climate Adaptation Plan: Ensuring Transportation Infrastructure and system Resilience. Washington, D.C.

Climate Impact	Potential Infrastructure Impact*
	Decreased expected lifetime of highways exposed to storm surge
Increased Wind Speeds	Coastal road flooding
	Bridges at risk
Increased risk of salinity and land subsidence	Shallow, saline groundwater damages to roads and bridges (Australia) (CSIRO, 2007)
	Erosion of streams and lakes embankments

*For full reference list please see ICF International, 2009. Further information can also be found at http://climate.dot.gov/impacts-adaptations/index.html

3.3 Emissions Reduction or Mitigation Strategies

The transportation sector, which is responsible for one-third of all U.S. GHG emissions (**Figure 21**), is a prime candidate for pursuing reduction strategies. The U.S. transportation system contributed nearly 8% of all global GHG emissions[6] as of 2007, with the majority (~60%) produced by passenger cars, SUVs, pickups, and minivans.



Transportation Source	Percentage
Passenger Cars, SUVs, Pickups, and Minivans	58.9
Medium & Heavy Trucks	19.1
Aircraft	11.3
Waterborne	5.2
Rail	2.7
Pipelines	1.6
Buses	0.6
Lubricants	0.5
Motorcycles	0.1

Figure 21: Breakdown of U.S. GHG Emissions

To reduce transportation emissions, the *Moving Cooler* report[3] has identified four basic strategies:

- Vehicle Technology – improve energy efficiency of the vehicle fleet;
- Fuel Technology – encourage use of alternative fuels (e.g., compressed natural gas, biofuels, and hydrogen) with reduced carbon content;

[6] FHWA Office of Planning, Environment, and Realty (April 2009). *Highways and Climate Change Brochure.* FHWA-HEP-09-018: U.S. Department of Transportation, Washington, D.C.

- Travel Activity – reduce vehicle-miles-traveled (VMT) through policy and land-use adjustments;
- Vehicle and System Operations – improve efficiency of vehicle operations with respect to speed and smoothness of traffic flow.

Of the four basic strategies, the latter two approaches are most able to be influenced by transportation agencies.

Emissions reduction strategies have generally ranged from voluntary (public education) to mandatory (regulation) controls and have utilized tools such as economic incentives or infrastructure investments.[7] The strategies presented in **Table 5** are specifically recommended for transportation agencies at the local, state, and federal levels to reduce GHG emissions[7].

Table 5: Potential Strategies to Reduce GHG Emissions from Motor Vehicles

Approach	Strategy
Vehicle Technology	***Vehicle Technology Improvements*** ✓ Mandates on new vehicle fuel economy (CAFÉ) ✓ Research and Development on fuel economy ***Changing Vehicle Purchase/Retirement Decisions*** ✓ Disseminate fuel economy information ✓ Vehicle efficiency tax or rebates ✓ Emissions-based vehicle registration/buyback programs
Fuel Technology	***Fuel Pricing and Regulations*** ✓ Alternative fuel vehicle (AFV) mandates ✓ Research and development on fuels and AFVs ✓ Carbon taxes or differential taxes for fuels
Travel Activity	***Travel Pricing*** ✓ Road pricing ✓ VMT fees ***Provision for Alternative Modes*** ✓ Transit investment ✓ Bicycle and Pedestrian support strategies ✓ HOV lanes ✓ Park-and-Ride facilities ***Sequestration*** ✓ Planting roadside trees and plants ***Parking Management*** ✓ Parking pricing ✓ Mandatory parking cash-out ✓ Parking supply limits ***Other VMT-reduction Measures*** ✓ Telecommuting ✓ Compressed work weeks ✓ Restrictions on vehicle use ✓ Land-use and Smart growth strategies
Vehicle and System Operations	***Improving Traffic Operations*** ✓ Traffic and Freight flow improvements ✓ Congestion Relief ✓ Speed limits ✓ Driver education ✓ ITS implementation

The effectiveness of these strategies is a critical and developing area of research. While emissions are not restricted to geopolitical boundaries, regional agencies have attempted to quantify the effects of

[7] FHWA Office of Environment and Planning (June 1998). *Transportation and Global Climate Change: A Review and Analysis of the Literature.* U.S. Department of Transportation, Washington, D.C.

their policies and improvement projects. For instance, as shown in **Table 6,** several case studies have evaluated the climate-related impacts of various GHG emissions reduction strategies. [8]

Indirect strategies include improvements aimed at congestion mitigation, traffic smoothing, and speed management.[3] By limiting time spent on the road, particularly at less fuel-efficient speeds (e.g., less than 20 miles per hour or greater than 75 miles per hour)[3] a simultaneous benefit of reduced emissions can be achieved.

Travel time is representative of speed, congestion, and vehicle miles traveled (VMT). The simplest conversion is to calculate carbon emissions as a function of VMT and fuel consumption: [9]

$$Grams\ of\ Carbon = miles\ traveled\ x\ \frac{gallons}{mile}\ x\ \frac{grams\ of\ carbon}{gallon}$$

Gallons per mile estimates are readily available from the U.S. Environmental Protection Agency (EPA - http://www.epa.gov/fueleconomy/) and grams of carbon per gallon estimates are available from the U.S. Department of Energy (**Table 7**)**Error! Bookmark not defined.**.[10] Several tools and publications have been developed to help with these calculations, including those developed by the Intergovernmental Panel on Climate Change (IPCC) as shown in **Table 8**[10].

Table 6: Case Studies of GHG Reduction Strategies

Countermeasure	Scope	Climate-Related Impact(s)
Retiming Traffic Signals[8]	Collection of several U.S. and Canadian cities	↓Travel Time: 7 to 25%
		↓Delay: 13 to 94%
		↓Fuel Consumption: 2 to 9%
	Traffic Light Synchronization Program in Texas	↓Travel Time: 14%
		↓Delay: 24.6%
	11 intersections on US. 1 in St. Augustine, Florida	↓Travel Time: 10%
		↓Delay: 36%
	8 intersections on SR 26 in Gainesville, Florida	↓Delay: 94%
	Montgomery County, Maryland	↓Delay: 13%
	640 signals in Oakland County, Michigan	↓CO: 1.7 to 2.5%
		↓NO_x*: 1.9 to 3.5%
		↓HC*: 2.7 to 4.2%
Advanced Parking Management[8]	Parking facilities in St. Paul, Minnesota using 56 street signs (10 with dynamic displays)[9]	↓Travel Time: 9%
		↓Delay: 4%
	Ability to reserve parking spaces at a transit station outside San Francisco, California either pre-trip or en route with space availability displaced on roadside DMS.	↓VMT: 9.7 miles/month per person
Electronic Toll Collection (ETC) System[8]	ETC locations on the New Jersey Turnpike[11]	↓Delay: 85% (totaling 1,344,000 hours/year)
		↓Gallons of Fuel:1.2 million
		↓VOC: 0.35 tons/weekday
		↓NO_x*: 0.056 tons/weekday
	Addition of Open Road Tolling (ORT) to ETC mainline toll plazas	↓Manual Cash Customer Delay: 50%
		↓Automatic Cash Customer Delay: 55%

[8] Intelligent Transportation Systems – joint program Office (January 2009). *Investment Opportunities for Managing Transportation Performance through Technology.* Research and Innovative Technology Administration, U.S. Department of Transportation, Washington, D.C.
[9] SAIC (2007). *Advanced Parking Management Systems: A Cross-Cutting Study.* Prepared for the FHWA, Report No. FHWA-JPO-07-011, U.S. Department of Transportation, Washington, D.C.
[10] ICF International (January 2011). *The Use of Climate Information in Vulnerability Assessments.* Prepared for the Federal Highway Administration, Report No. FHWA-HEP-12-010, Washington, D.C.
[11] Wilbur Smith Associates, new Jersey Turnpike Authority (2001). *Operational and Traffic Benefits of E-ZPass Development to the New Jersey Turnpike.* UC Berkeley Transportation Library, PATH Record Number 24583, Berkeley, CA.

Countermeasure	Scope	Climate-Related Impact(s)
		↑Express Lane Speed: 57%
	Upgrading toll plazas to ETC in Baltimore, Maryland	↓Environmentally Harmful Emissions: 16 to 63%
	Compilation of 13 U.S. Cities	↓Travel Time: 1.5 to 15%
	Metro Rapid BRT Service in Los Angeles, California	↓Transit delay: 33 to 36%
		↓Travel Time: 7.5%
	Dallas, Texas	↓Vehicle delay: 4%
		↓Person delay: 6%
		↓Bus Travel Time: 11%
		↓Car Travel Time: 16%
Improved Freight Movements[12]	Nationwide strategy of using B10 fuel for truck and rail fleets, doubling rail and truck fleet fuel efficiency, and growing the rail mode share by 20%.	↓Million Metric Tons CO_2-Equivalent: 54%
Improvements to Conventional Vehicle Technologies[13]	Efficiency potential of U.S. Conventional Vehicles	↑Fuel Economy: • 2-stroke engines: 15 to 20% • 4-stroke direct injection stratified charge engines: 18 to 23% • Direct-injection diesel engines: 25 to 40% • Continuously variable transmissions: 3 to 1-% • Lightweight materials – aluminum, magnesium, plastics, composites, powdered metals: 10 to 20% (assuming 30% weight reduction) • Reduced rolling resistance: 5 to 8% (assuming 30% rolling resistance reduction) • Improved aerodynamics: 5 to 15% (assuming 30% wind resistance reduction)
Use of ITS for Incident Management[8]	Peak Period Freeways	↓Delays: 1 to 22%
	Simulation study integrating traveler information with traffic and incident management systems for Seattle, Washington	↓Emissions: 1 to 3%
		↓Fuel Consumption: 0.8%
		↑Fuel Economy: 1.3%
	NaviGAtor incident management program in Georgia	↓Fuel Consumption: 6.83M gal/yr
		↓CO: 2,457 tons
		↓HC: 186 tons
		↓NO_x*: 262 tons
Safety Service Patrols[8]	Florida's Road Ranger service patrol in 2004	↓Fuel Consumption: 1.7M gal/yr
Surveillance and Detection[8]	Lane sensors and freeway video cameras added by the Maryland Coordinated Highways Action Response Team (CHART) program	↓Non-Recurrent Congestion: 5%
Ramp Metering Systems Error! Bookmark not defined.	Synthesis of mainline data	↑Traffic Speeds: 13 to 26%
		↑Throughput: 5 to 30%
	Eight second metering cycle in Salt Lake Valley, Utah	↓Peak Period Delay: 36% (54 seconds) per vehicle
	Simulation study of two corridors under varying travel demand on the Minneapolis-St. Paul, Minnesota system	↑Fuel Savings: 2 to 55%
Traffic Adaptive Signal Control[8]	Synthesis of simulation results	↑Traffic Volume Handling: 3 to 7%
	Application of ATCS	↓Travel Time: 12.7%
		↓Average Stops: 31.0%
		↓Average Delay: 21.4%
	Simulation of adaptive vs. fixed-time signal control	↓Delay: 18 to 20%
	Floating car studies	↓Travel Time: 7.4%

[12] Facanha, C., Ang-Olson, J. (2010). *Policies to Reduce Greenhouse Gas Emissions Associated with Freight Movements.* ICF International prepared for the Federal Highway Administration, Washington, D.C.
[13] U.S. Department of Energy – Office of Energy Efficiency and renewable Energy (September 1997). *Scenarios of U.S. Carbon Reductions: Potential Impacts to Energy Technologies by 2010 and Beyond.* Prepared by Interlaboratory Working Group on Energy – Efficient and Low – Carbon Technologies, September 22, 1997.

Countermeasure	Scope	Climate-Related Impact(s)
		↓Delay: 16.5%
		↓Stops: 17%
	Synthesis of 11 U.S. cities	↓Delay: 5 to 42%
	Los Angeles, Broward County, Newark, and Oakland County in California	↓Delay: 19 to 44%
		↓Travel Time: 13 to 25%
		↓Stops: 28 to 41%
Traveler Information / Dynamic Message Signs[8]	Implementation of HAR and DMS in Detroit, Michigan	↓Delay: 22%
	Integration of freeway DMS with incident management systems in San Antonio, Texas	↓Fuel Consumption: 1.2%
Work Zone Management Systems[8]	Dynamic Lane Merge System deployed in a work zone outside Detroit	↑PM Peak Period Travel Speeds: 15%
		- AM Peak Period Travel Speeds: 0%
	Application of portable traffic management systems to two freeway work zones in Minneapolis-St. Paul, Minnesota during peak period	↑Throughput: 4 to 7%
	Automated work zone information zone on a California interstate	↓Maximum Average Peak delay: 50%
	Speed-activated DMS with warning messages in Virginia	↓Speeding Vehicles: 50%
	Radar equipped DMS	↑Travel Speed: 8 to 9 mph within work zone
	Average Clearance Time on the "BIG I"	↓Average Clearance Time: 44%
	Portable Traffic Management Systems in work zones	↓Approach Speed: 9 mph
		↓Speed Variability: 70%
Pricing Policies[14]	San Francisco Bay Area Metropolitan Transportation Commission	↓2035 CO_2 Emissions (Thousand Tons / Day)
		Non New Investments: 8%
		Freeway Performance: 6%
		HOT & Local/Express Bus: 8%
		Regional Rail & Ferry: 8%
Land Use[14]	San Francisco Bay Area Metropolitan Transportation Commission	↓2035 CO_2 Emissions (Thousand Tons / Day)
		Non New Investments: 8%
		Freeway Performance: 6%
		HOT & Local/Express Bus: 7%
		Regional Rail & Ferry: 7%

*Contributes to the formation of a GHG

Table 7: Estimated Fuel Cycle Carbon Dioxide Emissions per VMT

Fuel	Emissions during Vehicle Use (grams/mile)	Emissions due to Upstream Processes* (grams/mile)	Total Emissions (grams/mile)
Gasoline	272.4	74.9	347.3
Methanol from Natural Gas	270.4	112.7	383.1
Ethanol from Corn	301.1	24.4	325.5
Compressed Natural Gas	204.7	43.5	248.2
LPG from Oil and Gas	235.4	28.1	263.5

*Upstream processes associated with transportation include fuel extraction, processing, and distribution, vehicle manufacturing, and other transportation associated activities.[15]

[14] ICF International (July 2008). *Integrating Climate Change into the Transportation Planning Process.* Final Report prepared for the Federal Highway Administration, Washington, D.C.
[15] U.S. Department of Energy – Energy Information Administration (August 1996). *Alternatives to Traditional Transportation fuels 1994: Volume 2 Greenhouse Gas Emissions.* Page 16, Washington, D.C.

Table 8: Tools and Resources for Evaluating Climate Variability Mitigation Strategies

Resource	Description
INVEST	FHWA's Sustainable Highways Initiative and Self-Evaluation Tool is a web-based self-evaluation tool, developed for CH2M HILL, for measuring sustainability over the life-cycle of a transportation project or program – from system and project planning through design and construction, to operations and maintenance.
GreenLITES	Green Leadership in Transportation Environmental Sustainability is a tool, used by the NYSDOT, which rates transportation projects and operations based on the extent to which they incorporate sustainable practices.
I-LAST	Livable and Sustainable Transportation rating system used by the IDOT (Illinois).
Greenroads	Greenroads Rating System is a points-based system to certify sustainable roadway and transportation infrastructure projects.
DEEPS	Dynamic Energy-Economic Policy Simulation is a tool used by the ODOT which predicts long-term effects of federal and state policies and environmental (CO_2 emissions and reductions) and economic (jobs created and GSP increase) indicators.
MOVES	Motor Vehicle Emission Simulator was developed by the EPA (replacing MOBILE-6) which estimates pollutants and GHG emissions from mobile sources.
CMIP 3[10]	Contains model projections used in the IPCC Fourth Assessment Report (AR4). <http://www-pcmdi.llnl.gov/ipcc.about_ipcc.php>
CMIP 5[10]	Contains model projections that will be used in the IPCC Fifth Assessment Report (AR5). <http://www-pcmdi.llnl.gov/cmip5/index.html>
National Center for Atmospheric Research – Earth System Grid[10]	Portal that contains output from various climate models, including those used by the IPCC and those under development. <http://www.earthsystemgrid.org/home.htm>
IPCC AR4, Chapter 8[10]	Report chapter "*Climate Models and Their Evaluation*" provides a high-level, technical discussion of the state of climate modeling and an evaluation of the models use by the IPCC. <http://www.ipcc.ch/pubclications_and_data/ar4/wg1/en/ch8s8-es.html>
North American Regional Climate Assessment Program[10]	Portal for dynamically-downscaled climate model output that can be requested in various formats, such as ASCII or GIS. <http://www.narccap.ucar.edu>
North American Climate and Hydrology Projections[10]	Portal for downscaled output from CMIP3 models and scenarios that can be requested in NetCDF or ASCII formats. The outputs are considered valid for the continental U.S. <http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html>
Cal-Adapt[10]	Web-based climate adaptation planning tool for the state of California that contains statistically-downscaled data which can be downloaded or manipulated in an embedded Google maps viewer. <http://cal-adapt.org>

3.4 Areas at Risk for Severe Weather

Data from the Spatial Hazard Events and Losses Database for the U.S. (SHELDUS) was used to assess climate variability risks in Ohio with respect to: increased storm intensity, higher flood levels, increased temperatures, and longer/more frequent droughts. SHELDUS includes county-level data of weather events that occurred between 2001 and 2009 in addition to reports on property and crop losses, injuries, and fatalities. Weather events included in the database are avalanches, coastal events, drought, earthquakes, flooding, fog, hail, heat, landslides, lightning, severe storms/thunderstorms, tornados, wildfires, wind, and winter weather. The data shows that tornados, severe storms, floods, and winter weather constituted the overwhelming majority of severe weather events in Ohio between 2001 and 2009.

Through an analysis of the data, counties with a significant history of extreme events were identified (**Figure**). These counties are defined as areas with more occurrences than the state average plus 1.5 standard deviations. For example, the counties identified in

Table 9 were found to have a large number of tornados, severe storms/thunderstorms, and floods; these counties are anticipated to be at greater risk for future extreme weather events. Winter weather events that occurred during that time were highly concentrated in the Lake Erie counties. It is expected that those counties in the northernmost part of the state will continue to be the most vulnerable to winter hazards.

Table 9: Counties at Risk for Severe Weather Occurrences

Source: National Atlas of the United States (Risk Assessment the Spatial Hazard Events and Losses Database for the United States, 2001 to 2009)

County	At Higher Risk for Tornados	At Higher Risk for Severe Storms/Thunderstorms	At Higher Risk for Floods
Van Wert	X		
Warren			X
Clinton	X		
Knox		X	
Athens			X
Lorain		X	X
Cuyahoga		X	X
Summit		X	
Stark	X	X	X
Ashtabula			X
Trumbull		X	
Columbiana			X

*Higher risk defined as areas with more historical occurrences between 2001 and 2009 than the state average plus 1.5 standard deviations (i.e., above the 86th percentile).

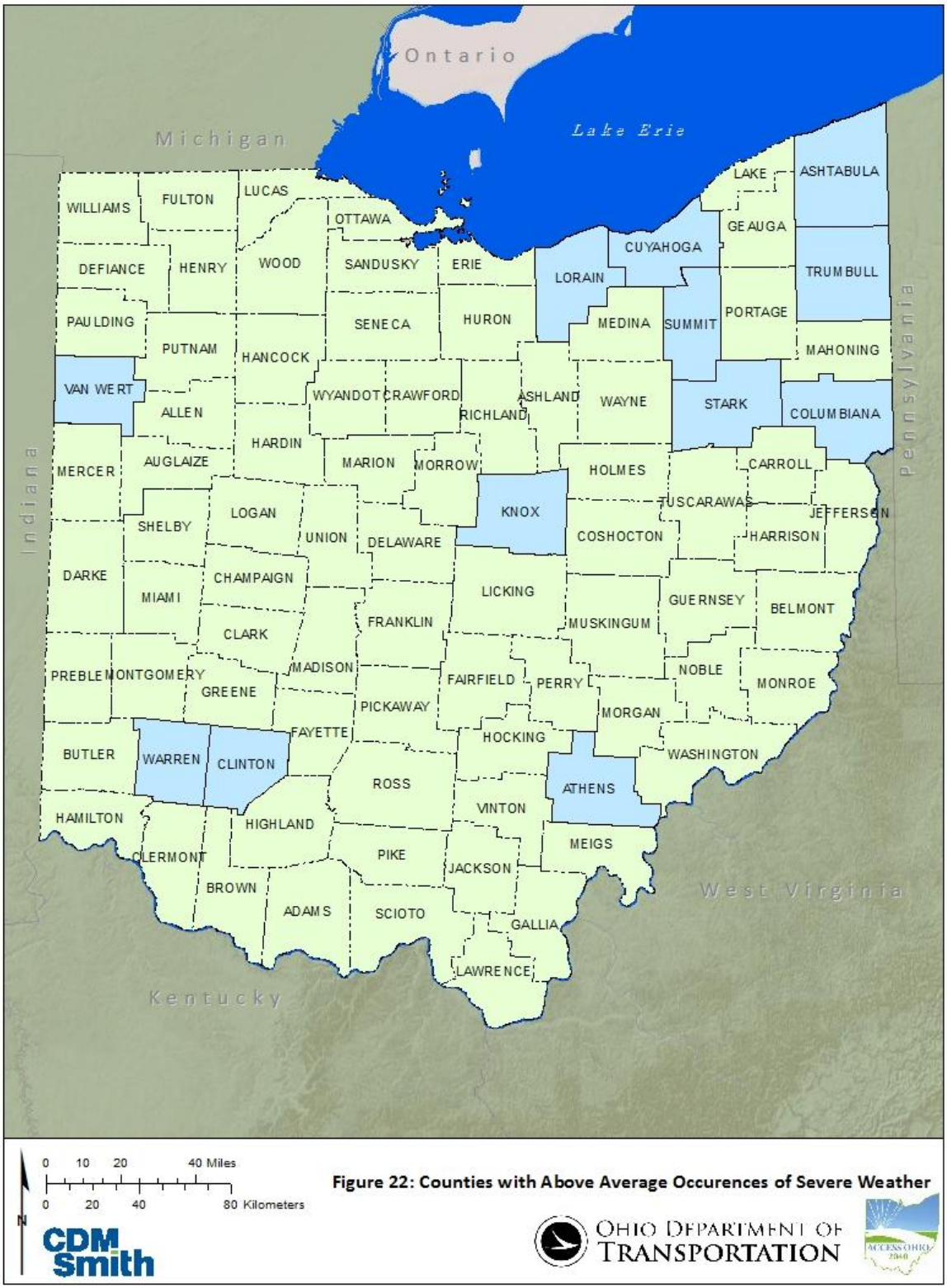


Figure 22: Ohio Counties at Risk for Severe Weather

Source: National Atlas of the United States (Risk Assessment the Spatial Hazard Events and Losses Database for the United States, 2001 to 2009)

3.5 Using the Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) to Evaluate Stewardship

Transportation officials must balance diverse, and often competing, objectives to achieve performance outcomes with limited funding. Having a clear, transparent, and repeatable process for guiding sustainable decisions amongst multiple criteria is critical for proper stewardship of Ohio resources. Towards this end, the FHWA Infrastructure Voluntary Evaluation Sustainability (INVEST) tool may be of value to Ohio DOT in promoting and communicating various performance outcomes.

INVEST, an FHWA analysis tool, is a web-based collection of voluntary best practices designed to help transportation agencies integrate sustainability into their programs and projects. INVEST supports agencies in self-evaluating three components, spanning the full life-cycle of transportation services, including System Planning, Project Development, and Operations and Maintenance.

Each of these modules contains performance criteria that can be used to evaluate potential projects. Given the larger corridor scale of the AO40 analysis, this list can be narrowed to focus on the following sustainability-related impacts, which can be used to facilitate prioritization at the system planning level:

- Access and Affordability
- Safety Planning
- Air Quality

System Planning Criteria 5 (SP-5): Access and Affordability - The goal of SP-5 is to enhance the accessibility and affordability of the transportation system for all users and all modes. This goal supports social and economic sustainability principles by offering transportation choices to the traveling public through:

- improving employment opportunities
- enhancing opportunities to interact with the community, and
- improving environmental sustainability

To obtain credit for this criterion, the project/corridor must meet a majority of access and affordability goals. Comparing and contrasting how well AO40 corridors satisfy these goals can be a useful evaluation tool for decision-makers to make balanced choices.

System Planning Criteria 6 (SP-6): Safety Planning - The goal of SP-6 is to integrate safety measures into the transportation planning process. This goal supports the social and economic sustainability principles by reducing the impacts associated with personal and public property damage, injury, and loss of life. To obtain credit for this criterion, the project/corridor must meet a majority of safety goals. Comparing and contrasting how well AO40 corridors satisfy these goals can be a valuable evaluation tool for decision-makers to make balanced choices.

System Planning Criteria 6 (SP-10): Air Quality - The goal of SP-10 is to plan, implement, and monitor multimodal strategies that reduce emissions, and to establish a process for documenting emissions reductions. This goal supports the environmental and social sustainability principles by reducing pollutants and improving quality of life. To obtain credit for this criterion, the project/corridor must meet a majority of the metrics relating to air quality. Comparing and contrasting how well AO40 corridors satisfy these goals can be a valuable evaluation tool for decision-makers to make balanced choices.

Through a quantifiable evaluation of AO40's performance towards sustainable best practices, decision-makers can align strategies and make progress towards meeting today's transportation needs, while also enhancing the ability of future generations to meet future needs.

4. SUMMARY

This Environmental Overview is intended to inform planning decisions that have the potential to impact Ohio's natural and human resources. The objective is to ensure compliance with NEPA and other federal regulations, so that the planning process aligns with Ohio's short and long-term environmental goals. As Ohio's population and economy continue to grow, this will include planning for and mitigating the effects of infrastructure development on ecosystems. With over 60,000 miles of streams, 120 endangered species, and eight national parks, Ohio is home to diverse environmental resources. In the midst of these resources, ODOT manages over 1,600 miles of highway- the 10th largest in the nation. The inclusion of climate variability considerations into existing transportation planning processes will position Ohio to best protect its environmental resources and plan for the future. As ODOT seeks to continually improve sustainable practices, tools such as INVEST and approaches such as Eco-Logical type planning can be used to self-evaluate current practices and integrate innovative techniques for incorporating environmental values into the infrastructure project development process.