# NEXUS GAS TRANSMISSION PROJECT

***RESOURCE REPORT 6***

*Geological Resources*

*FERC Docket No. PF15-10-000*

**Pre-filing Draft**
**June 2015**

## NOTICE TO PUBLIC STAKEHOLDER REVIEWERS

This Draft Resource Report for the NEXUS Gas Transmission Project ("Project") is being filed as part of the Federal Energy Regulatory Commission's ("FERC's") pre-filing process. The pre-filing process allows interested stakeholders, FERC, and regulatory agency staff to engage in early dialogue to identify affected stakeholders, facilitate early issue identification and resolution, provide multiple opportunities for public meetings (e.g., open houses), and support the preparation of high-quality environmental Resource Reports and related documents that describe the Project, assess its potential impacts, identify measures to avoid and mitigate impacts, and analyze alternatives to the Project.

Since the initial filing of Draft Resource Report 1 (Project Description) and 10 (Alternatives) on January 23, 2015, NEXUS hosted eight Open Houses along the proposed pipeline route to inform stakeholders about the proposed Project and to answer questions. FERC staff also hosted six independent Public Scoping Meetings along the proposed route in April and May of 2015, as part of the National Environmental Policy Act ("NEPA") compliance process. This Draft Resource Report may contain items that are highlighted in grey that will be filed when NEXUS files its NGA 7(c) Certificate Application with the Commission in November 2015.

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| **Filing Requirement** | **Location in Environmental Report** |
| ☐ For underground storage facilities, how drilling activity by others within or adjacent to the facilities would be monitored, and how old wells would be located and monitored within the facility boundaries. | N/A |
| ☒ Discuss the need for and locations where blasting may be necessary in order to construct the proposed facilities. | Section 6.3 |
| ☒ Identify the location (by milepost) of mineral resources and any planned or active surface mines crossed by the proposed facilities. | Section 6.4 |
| ☒ Identify any geologic hazards to the proposed facilities. | Section 6.5 |
| ☐ For LNG projects in seismic areas, the materials required by "Data Requirements for the Seismic River of LNG Facilities," NBSIR84-2833 | N/A |

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| Dawn | Dawn Hub in Ontario, Canada |
| FERC | Federal Energy Regulatory Commission |
| MP | milepost |
| NEXUS | NEXUS Gas Transmission, LLC |
| Project | NEXUS Gas Transmission Project or Project, NEXUS Transmission, LLC |
| ROW | right-of-way |
| Spectra Energy | Spectra Energy Partners, LP |
| U.S. | United States |
| USGS | United States Geological Survey |

# 6.0 RESOURCE REPORT 6 – GEOLOGICAL RESOURCES

## 6.1 Introduction

NEXUS Gas Transmission, LLC ("NEXUS") is seeking a Certificate of Public Convenience and Necessity from the Federal Energy Regulatory Commission ("FERC") pursuant to Section 7(c) of the Natural Gas Act authorizing the construction and operation of the NEXUS Gas Transmission Project ("NEXUS Project" or "Project"). NEXUS is owned by affiliates of Spectra Energy Partners, LP ("Spectra" or "Spectra Energy") and DTE Energy Company. The NEXUS Project will utilize greenfield pipeline construction and capacity of third party pipelines to provide for the seamless transportation of 1.5 billion cubic feet per day of Appalachian Basin shale gas, including Utica and Marcellus shale gas production, directly to consuming markets in northern Ohio and southeastern Michigan, and to the Dawn Hub in Ontario, Canada ("Dawn"). Through interconnections with existing pipelines, shippers on the NEXUS Project will also be able to reach the Chicago Hub in Illinois and other Midwestern markets. The United States ("U.S.") portion of the NEXUS Project will traverse Pennsylvania, West Virginia, Ohio and Michigan, terminating at the U.S./Canada international boundary between Michigan and Ontario. The Canadian portion of the Project will extend from the U.S./Canada international boundary to Dawn. A more detailed description of the Project is set forth in Draft Resource Report 1.

This Draft Resource Report 6 describes the geologic setting and resources of the Project area for the pipeline facilities and the new aboveground facilities (Section 6.2) and addresses the potential for blasting (Section 6.3), use of mineral resources (Section 6.4), and geological hazards that may affect the construction and operation of these new facilities (Section 6.5). Where appropriate, mitigation measures intended to reduce the impact of the Project on geological resources and/or reduce the impact of geological hazards on Project facilities are identified. A checklist showing the status of the FERC filing requirements for Draft Resource Report 6 is included after the table of contents. Tables and figures for this Draft Resource Report are provided in the Tables and Figures Sections at the end of this report.

Project drawings, maps, alignment sheets, and aerials are provided in Appendix 1A of Draft Resource Report 1.

## 6.2 Geologic Setting

The Project pipeline facilities will cross from the Appalachian plateaus through the Great Lakes plains. The underlying geology of the Project includes relatively flat-lying Paleozoic (geologic era spanning 542 million years ago to 251 million years ago) sedimentary strata overlain by varying amounts of unconsolidated Pleistocene (1.65 million years ago to 10,000 years ago) deposits. The landscape of the Project is a result of the inundation of the area by seas in the Paleozoic era, the advance and retreat of continental ice sheets in the Pleistocene era, and fluvial erosion in the Holocene era (10,000 years ago to present).

### 6.2.1 Physiography and Topography

The U.S. is categorized into divisions, provinces, and sections (listed in decreasing scale) based on geologic structure, climate, and geomorphic history. The resultant topography of the various categories often vary noticeably from those adjacent. In 1928, Fenneman defined physiographic designations across the United States on a map titled "Physical Divisions of the United States," and these designations are still in use today. Using these designations, the Project is set in the Appalachian Highlands and Interior Plains divisions, with further description, as follows.

| NEXUS Pipeline Segments | Physiographic Region | | |
|---|---|---|---|
| MP (to nearest tenth) | Division | Province | Section |
| 0 – 14.5 | Appalachian Highlands | Appalachian Plateaus | Kanawha |
| 14.5 – 75.7 | Appalachian Highlands | Appalachian Plateaus | Southern New York |
| 75.7 – 105.3 | Interior Plains | Central Lowland | Till Plains |
| 105.3 – 249.0 | Interior Plains | Central Lowland | Eastern Lake |

***Appalachian Highland Division*** – area characterized by altitude but does include related lowlands in places.

Appalachian Plateaus Province – elevated, flat-lying sedimentary rocks with varying degrees of stream dissection.

Kanawha Section – dissected plateau comprised of fine sedimentary strata showing moderate to high relief.

Southern New York Section – mature, dissected plateau showing moderate relief that was covered by continental glaciers in the Pleistocene.

***Interior Plains Division*** – the vast middle of the continent with low relief locally.

Central Lowland Province – the low eastern portion of the interior plains.

Eastern Lake Section – the area around the Great Lakes that is characterized by the prevalence of glacial features (e.g., moraines, lakes, lacustrine plains).

Till Plains Section – flat areas with very little stream dissection, no natural lakes, and covered by glacial drift deposits.

### 6.2.2 Bedrock Geologic Materials of the Project Area

Figures 6.2-1a and 6.2-1b present bedrock geologic materials along the Project pipeline and aboveground facilities. Table 6.2-1 summarizes the bedrock geologic materials along the Project pipeline facilities and aboveground facilities by milepost. Those materials are further described below. Ohio descriptions from Nicholson *et. al.*, 2005. Michigan descriptions were taken from Milstein, 1987.

#### 6.2.2.1 Ohio

**Connemaugh Group (IPc)** – Lithologies include shale, siltstone, and mudstone. IPc shales are black, gray, green and red; have clayey to silty textures; and contain marine fossils in places in lower half of the unit, and is partially calcareous. Siltstones are gray, green and red, locally variegated; have clayey to sandy texture; and thinly bedded to nonbedded. IPc mudstones are black, gray, green, red, and yellow, variegated in part; have clayey to silty textures; are locally calcareous; and are commonly nonbedded. IPc sandstone tends to be green-gray weathering to yellow-brown; are mostly very fine to medium grained, but locally conglomeratic; are thin to massive to cross bedded; and are locally calcareous. Limestone and coal in this group are thin and discontinuous. IPc limestones are black, gray and green, micritic to coarse grained, and thin bedded to concretionary with marine fossils common in lower half of interval and thin to medium bedded, nonmarine limestone common in upper half of unit. Coal in the unit tends to be thin, bituminous, impure and very locally thick enough for economic development. Lateral and vertical lithic variability and gradation is common. The unit as much as 500 feet thick.

**Allegheny and Pottsville Groups, undivided (IPap)** – Lithologies include shale, siltstone, and underclay IPap shales are black, gray, and olive; clayey to silty; locally contain marine fossils; and are calcareous in part. IPap siltstones are gray, greenish and olive; clayey to sandy; thin bedded to medium bedded; and locally contain marine fossils. IPap underclay is gray and olive; generally 3 feet or less in thickness; clayey to silty; commonly rooted and underlying coal beds; nonbedded; and locally varies from flint to plastic clay IPap sandstone is light to medium gray weathering to yellow-brown; mostly very fine to medium grained, locally quartzose and conglomeratic in lower one-third of unit; thin to massive to cross bedded; and locally calcareous. IPap limestone is black to light gray; micritic to medium grained; locally grades into flint; and thin to medium bedded with discoidal concretions containing marine fossils. Locally nonmarine, micritic limestones occur beneath coal beds in upper one third of IPap. IPap coal is mostly banded bituminous, locally cannel; thin to locally as much as 12 feet thick; generally in discrete beds but locally contain shale partings and split into multiple beds. Lateral and vertical lithic variability and gradation is common. IPap is as much as 700 feet thick.

**Maxville Limestone; Rushville, Logan, and Cuyhoga Formations, undivided (Mlc)** – Mlc lithologies include interbedded shale, siltstone, and sandstone of various shades of gray, yellow to brown. Mlc sandstones are silty to granular with local stringers of quartz pebbles. Mlc shale is clayey to silty and locally fossiliferous. Medium to dark gray, thin to thick bedded limestone locally preserved at top of interval where Mlc crops out in southern half of state. Lithologies percentages vary in different areas where unit crops out with lateral and vertical gradation common at a regional scale.

**Berea Sandstone and Bedford Shale, undivided (Dbb)** – Lithologies include sandstone and shale. The upper portion of Dbb is brown sandstone weathering to light brown to reddish brown, thinly to thickly bedded (planar to lenticular bedding) with minor shale interbeds. The sandstone is 5 to 75 feet thick, locally 100 to 125 feet thickness in Lorain, Cuyahoga, and Medina Counties. The lower portion of Dbb is gray to brown shale, locally reddish brown; thin to medium bedded (planar to lenticular bedding); interbedded siltstone and sandstone, ripple marks in siltstone beds; 80 to 180 feet thick, locally thin to absent where Berea Sandstone is thick.

**Ohio Shale (Do)** – Do is a brownish black to greenish gray shale, weathers brown that is carbonaceous to clayey, laminated to thin bedded (fissile parting) with carbonate and/or siderite concretions in the lowermost 50 feet, petroliferous odor, and 250 to 500+ feet thick.

**Prout Limestone (Dp)** – An olive gray hard, siliceous limestone, dolomitic in part with irregular bedding; pyrite, glauconite and phosphatic bone fragments at upper contact; 0 to 9 feet thick. Contains corals superficially similar to those of lower part of Jaycox Shale Member of Ludlowville Formation in NY.

**Plum Brook Shale (Dpl)** – Dpl lithologies include shale and argillaceous limestone; gray; thin bedded fossiliferous; 0 to 40 feet thick.

**Delaware Limestone (Dd)** – Dd is a gray to brown Limestone that is thin to massive bedded with argillaceous partings, nodules and layers and carbonaceous, petroliferous odor. It is as much as 45 feet thick.

**Columbus Limestone (Dc)** – Dc lithologies include gray to brown limestone and dolomite, weathering brown with massive bedding. The upper 2/3 of Dc are fossiliferous, gray limestone; the lower 1/3 is brown dolomite. Dc is up to 105 feet thick.

**Salina Group (Ss)** – Gray, yellow-gray to olive-gray dolomite; laminated to thin bedded; occasional thin beds and laminae of dark gray shale and anhydrite and/or gypsum; brecciated zones in part.

**Tymochtee and Greenfield Formations, undivided (Stg)** – Olive-gray to yellowish- brown dolomite that is thin to massive bedded, in which the upper two-thirds commonly contains brownish-black to gray shale laminae and locally developed brecciated zones in lower one third.

**Lockport Dolomite (Sl)** – Dolomite has been observed in shades of white to medium gray, is medium to massive bedded, fine to coarse crystalline; fossiliferous; and vuggy.

**Detroit River Group (Ddr)** – Ddr is primarily brown to gray dolomite that is medium to thick bedded, laminated, with nodules or interbeds of anhydrite and/or gypsum. The basal part of Ddr becomes sandy dolomite or fine-grained sandstone. Ddr is as much as 170 feet thick.

**Dundee Limestone (Ddu)** – Ddu is olive gray to brown limestone. The upper part is thin bedded, and the lower part is medium to thick bedded. Fossiliferous characteristics in upper part becomes cherty dolomite in lower part. Ddu is as much as 105 feet thick.

**Traverse Group (Dts)** – Dts is dolomite and shale interbedded with limestone. The upper part is gray to light brown, thin to medium bedded dolomite with abundant chert. The lower part is olive gray, thin to medium bedded shale interbedded with limestone that is very fossiliferous. Dts is as much as 170 feet thick.

**Antrim Shale (Da)** – Da is dark brown to black, carbonaceous, thinly laminated Shale that is 0 to 230 feet thick.

**Sunbury and Bedford Formations, undivided (MDsd)** – MDsd lithologies include shale and siltstone. MDsd shale is black to brownish-black, carbonaceous in upper one third of interval, gray to bluish-gray, clayey with occasional siltstone lamina and thin beds in lower two-thirds of interval.

#### 6.2.2.1 Michigan

**Bedford Shale (Dbd)** – Dbd is a bluish to light gray, silty shale that becomes sandy in its upper part and has a gradational contact with the overlying Berea Sandstone. It is commonly 50 to 100 feet thick and thins and becomes fine grained to the west.

**Berea Sandstone (Db)** – The Berea attains a thickness of 260 feet in Huron Co. but thins northwestward, westward, and southwestward away from the thumb area and is absent in the eastern half of the Michigan basin. Unit is generally 50 to 100 feet throughout its extent. Consists predominantly of light gray sandstone that is fine grained in the lower and upper parts of the formation but medium to coarse grained in the middle. It is silty and pyritic in its lower part.

**Sunbury Shale (DMs)** – Sunbury shale is the youngest of the regionally extensive black gas shales. It is typically fissile black shale that weathers into small discoidal sharp-edged chips. Pyrite is common, particularly near the base where it separates a zone of small inarticulate brachiopods and SIPHONODELLA conodont fauna from the underlying Berea. The unit is present only in the western part of the basin. Crops out at many places along the eastern flank of the Cincinnati arch in Ohio and northeastern Kentucky and ranges there from 10 to 40 feet thick.

**Coldwater Shale (Mc)** – The Coldwater conformably overlies the Sunbury and Ellsworth Shales and conformably underlies the Marshall Sandstone. Maximum thickness is about 1,200 feet in Iosco and Arenac Cos just north of Saginaw Bay, but is generally 1,000 feet in the eastern two-thirds of the basin and thins to about 550 feet in the western third. Unit consists predominantly of gray to bluish gray shale. Its clay minerals are chiefly illite and kaolinite with minor chlorite. Other lithologies occur in the Coldwater and their distributions divide the formation into distinct eastern and western facies. In the eastern half of the basin, beds of silty and sandy shale, siltstone and fine-grained sandstone are common, and increase in abundance and coarseness to the west and up section. In the western half of the basin the Coldwater shales are more calcareous and beds of glauconitic, fossiliferous limestone and dolostone occur frequently especially in the middle and upper portions of the formation. Two marker beds can be traced over long distances: the Lime and the Red Rock beds. The Lime occurs throughout the western part of the basin and is commonly 18 to 3 feet thick. The Red Rock is more extensive and occurs in all parts of the basin except the extreme northeast. It is typically 9 to 18 feet thick and locally reaches 50 feet.

**Traverse Group (Dts)** – See description provided previously for Ohio.

**Dundee Limestone (Ddu)** – See description provided previously for Ohio.

### 6.2.3 Surficial Geologic Materials of the Project Area

Surficial geology of the Project area is comprised of unconsolidated sediments deposited in the Quaternary period, which includes the Pleistocene (1.65 million years ago to 10,000 years ago) and Holocene (10,000 years ago to present) epochs. Quaternary deposits in the Project area can be broken out into three general categories, based on their depositional environment: deposits laid down by advancing Pleistocene ice sheets (moraines and most tills); glacial melt deposits (stratified deposits from glacial streams and lakes); and recent deposits (alluvium in existing floodplains and swamp deposits). Quaternary geologic materials may be categorized by their depositional environment (e.g., swamp), grain size (e.g., sand and gravel), formation type (e.g., moraine), or a combination of these (e.g., lacustrine sand).

During Pleistocene glacial periods, advancing continental ice sheets rounded uplands, widened stream valleys, laid down a layer of till atop bedrock, and mounded till near the ice margins (moraines). The deposits of advancing ice, including till-covered uplands, moraines, and ground moraine (till plain), consist of till. Till is a dense diamict deposit generally consisting of gravel and fine silt and clay. There is little to no stratification of till deposits as the ice carried virtually all particle sizes (from boulders to clay) and meanwhile ground the material plucked from the underlying bedrock into ever smaller particles (rock flour).

Material laid down by glacial melt water can be generally referred to as stratified drift. The stratification of these deposits is due to the energy of the water that deposited the material. Coarser materials indicate faster flows (e.g., deltas and outwash streams), and finer deposits are interpreted to indicate standing or slow moving water (e.g., lakes). The multiple advances and retreats of the intercontinental ice sheets in the Pleistocene created a complex fabric in which the last glacial maximum (the Wisconsin glaciation) largely erased indications of prior glacial advances but, in places, left traces of older deposits behind. Adding to the complexity are the various and dynamic depositional environments created by glacial advance and retreat. For example, an area once covered by the last ice sheet may have subsequently been a glacial lake around the margins of the receding ice that later drained when the ice dam that created the lake failed, and there may be a stream running through the area today with localized swamps. In this hypothetical circumstance the area may have till atop bedrock overlain by lacustrine silts or sands with stream alluvium and swamp deposits overlying the glacial lake deposits in some locations.

The surficial geology of the Project is generally comprised of till in the shape of ground moraine, ground moraine, and thin till overlying an upland with lesser subglacial sands and gravels in the form of kames and eskers and outwash sands and gravels in northeast to north-central Ohio (ODGS, 2005). From north central Ohio (around milepost ("MP") 105) to the northern terminus, the surficial geologic deposits are wave-planed till, fines (silt and clay) and sandy deposits all related to glacial lakes Maumee (3 stages), Arkona, Whittlesey, Warren (3 stages), and Wayne, which covered the area about 14,000 years ago to 12,000 years ago (Stierman *et. al.*, 2005). These glacial lakes preceded the formation of Lake Erie and extended further to the south and west of the current lake (Kelley and Farrand, 1967). Lacustrine clays were deposited across the area when the lakes were present, and as these ancestral lakes receded toward modern-day Lake Erie, beach and eolian sands were deposited atop the clay in places. Of particular significance is the Oak Openings region (approximate MP 181.6 to 191.0) where the beach ridge sands overlie lacustrine clays, creating a unique ecosystem of sand dunes, swamp forest and wet prairies. Additional details about the Oak Openings region are provided in Draft Resource Reports 2 and 3.

A review of surficial geology maps provided information regarding the nature of deposits expected in the Project area. Figures 6.2-2a and 6.2-2b depict the surficial geology in the Project area, and Table 6.2-2 summarizes surficial geology in the vicinity of the proposed pipeline and aboveground facilities.

### 6.3 Rock Removal and Blasting

Based on NEXUS' experience, field reconnaissance and review of soils and geologic maps of the Project area, shallow bedrock (less than 5 feet from the surface) may be encountered at various locations along the Project alignment. In Draft Resource Report 7, Table 7.2-2, the depth to bedrock is presented, where available, based on the U.S. Department of Agriculture, Natural Resources Conservation Service digital Soil Survey Geographic Database.

Rock encountered during trenching will be removed using one of the techniques identified in Section 1.7.1.8 of Draft Resource Report 1. The technique selected is dependent on the relative hardness, fracture susceptibility, and expected volume of the material. Techniques include:

- Conventional excavation with a backhoe;
- Ripping with a dozer followed by backhoe excavation;
- Hammering with a pointed backhoe attachment followed by backhoe excavation;
- Blasting followed by backhoe excavation; or
- Blasting surface rock prior to excavation.

The NEXUS Project Blasting Plan (*see* Appendix 1B3 in Draft Resource Report 1) identifies the impact avoidance and minimization measures employed by NEXUS if blasting is determined necessary and will contain special provisions that will be taken to monitor and assess blasting within 150 feet of private or public water supply wells, should that situation arise.

Large rock not suitable for use as backfill material will either be windrowed along the edge of the right-of-way ("ROW"), with permission from the landowner, used to construct ATV barriers across the ROW, or buried on the ROW. NEXUS will negotiate with landowners and will obtain permission to permanently store rock along, over, through or across the ROW. Otherwise the excess rock will be hauled off-site and disposed of in an appropriate manner. NEXUS is evaluating the need for specifying blast rock disposal areas in the Project vicinity. Any remaining rock will be used to backfill the trench to the top of the existing bedrock profiles.

### 6.4 Mineral Resources

Mineral Resources in the Project area include non-fuel resources (limestone, sand and gravel, clay, *etc.*) along the entire Project route and fuel resources (coal and oil and gas) in the Allegheny Plateau portion of the Project in Ohio.

#### 6.4.1 Non-fuel Mineral Resources

Non-fuel mineral resources were assessed in the Project area by a review of government mine databases and a review of aerial photographs (2011-2014). Table 6.4-1 presents non-fuel surface mines located within ¼ mile of the Project pipeline. No non-fuel mine or mine leases were identified as being crossed by the current route. Avoidance was the primary method to prevent an impact to mines. There were no non-fuel surface mines identified within ¼ mile of the aboveground facilities.

The types of minerals commercially mined in the general geographic area of the proposed Project are summarized below.

**<u>Ohio (USGS, 2013b and ODNR, 2013)</u>**

- <u>Columbiana County</u> – sand and gravel, clay
- <u>Stark County</u> – sand and gravel, crushed stone

- Summit County – sand and gravel, salt
- Wayne County – sand and gravel, salt
- Medina County – sand and gravel
- Lorain County – sandstone
- Erie County – crushed stone, sandstone, sand and gravel, limestone
- Sandusky County – crushed stone, limestone
- Wood County – crushed stone, limestone
- Henry County –limestone
- Lucas County – crushed stone, limestone
- Fulton County – sand and gravel

**Michigan (USGS, 2013a)**

- Lenawee County – sand and gravel
- Monroe County – limestone, clay
- Washtenaw County – sand and gravel

### 6.4.2 Fuel Resources

#### 6.4.2.1 Coal

Southeast Ohio has been involved in the commercial production of coal since as early as 1800. Since that time, approximately 2.35 billion tons of coal have been produced in Ohio. Early mining operations were largely underground mines. Technological advances in the mid-20th century made the extraction of coal from strip mines an economically viable option, and surface mining was predominant. In the last approximately 20 years, coal extraction in Ohio has switched back toward underground mines as surficial coal deposits have been exhausted (ODGS, 2012).

Underground mining may be room-and-pillar mining or longwall mining. Since room-and-pillar mining has been used for much longer, it is the most common method historically used in Ohio. Room-and-pillar mining leaves pillars of mineable material to support the room. Roof rock can also be supported by timbers in some instances. This method results in long-term risk of collapse and surface subsidence hazards. Longwall mining is in greater practice in modern coal mines because it yields a much greater percentage of the minable resource. The longwall method uses temporary hydraulic roof support that is removed as the coal bed is mined away. As a result, longwall mining is susceptible to more immediate collapse than room and pillar mining (Gordon, 2009). Mapped active and abandoned underground mines within ¼ mile of the Project are summarized in Table 6.4-2. No active underground mines were identified in Table 6.4-2. A mapped abandoned underground mine underlies the Project between MP 51.4 and 51.5. There are no mapped underground abandoned or active mines within ¼ mile of aboveground facilities.

Mapped surface coal mines within ¼ mile of the Project are summarized in Table 6.4-3. There are no mapped active surface coal mines within ¼ mile of the Project. The Project does not intersect mapped former surface coal mines.

## 6.5 Geologic Hazards

Geologic hazards are natural physical conditions that, when active, can impact environmental features and man-made structures. Utilization of collocating the pipeline alignment with existing infrastructure such as power lines and other pipelines where practical, the flat to gently rolling terrain of the majority of the pipeline alignment and geological investigation performed by the Project's engineers during the design phase, allow geological hazard areas to be mitigated using modern construction techniques and ROW restoration techniques. Geologic hazards assessed and methods for mitigating these potential hazards are presented below.

### 6.5.1 Karst

According to USGS, the Project traverses a karst area between MP 119.9 and 184.9 and then again from MP 221.5 to 241.9 (Weary and Doctor, 2014). Mapped karst terrain data are presented as Figure 6.5-1 and illustrate karst terrain that has been identified along the Project route.

Karst topography is a landscape formed by the dissolution of soluble bedrock. Karst features form as the result of minerals dissolving out of the rock through rainwater. Slightly acidic rainwater leaches through the soil zone becoming more acidic. This acidic groundwater slowly dissolves the soluble bedrock, a process that commonly occurs along fractures, bedding planes, and layers of rock more prone to dissolution, where groundwater may be flowing through continuously.

Karst terrains have surface drainage systems that are established by sinkholes, springs, caves, disappearing streams, and underground drainage channels and caverns. The collapse of a cavern over a large area can create a solution valley or basin. Downstream of a karst drainage system is typically a spring where the system reaches the surface. These springs typically discharge in a valley and are commonly near the valley bottom, but can occur anywhere.

Dissolution sinkholes result from rainfall and surface water flowing through fractures in the soluble bedrock. In these instances a small depression gradually forms. The topographic expression of this feature is gently rolling hills and shallow depressions.

Cover-subsidence sinkholes result when overlying unconsolidated granular materials (sands) settle into void spaces in the underlying soluble bedrock. Dissolution of the soluble bedrock and the filling with the overlying material continues, forming a noticeable depression at the ground surface. In areas where the unconsolidated material is thick or the material contains more clay, the process is slow and relatively uncommon.

Cover-collapse sinkholes occur in areas where the unconsolidated material is clay-rich. In these cases, the void spaces are filled but a depression is not formed, rather the clay acts like a "bridge" and the cavity migrates toward the surface as the underlying clay fills the void. Eventually the bridge fails, forming a sinkhole.

Sinkholes can be a combination of these types or may form in phases with various karst features.

The type and thickness of the unconsolidated material over soluble rock is related to the frequency and type of sinkhole that can form. USGS states that surface expression of sinkholes is unlikely in areas where bedrock is covered by greater than 50 feet of unconsolidated glacial material (Weary and Doctor, 2014). A study conducted in the vicinity of a portion of the Project found that areas with 25 feet or more of glacial drift overlying soluble bedrock showed little to no surface expression of sinkholes (Aden, 2013). Figure 6.5-1 shows the karst areas of the Project where carbonate bedrock is covered by more or less than 50 feet of glacial drift. All of the carbonate bedrock in Michigan is covered by more than 50 feet of glacial sediment.

Aden, 2013 identified and mapped karst features in the area known as the Bellevue-Castalia Karst Plain. Those identified within 1,500 feet of the Project pipeline and aboveground facilities are summarized in Table 6.5-1. Field surveys by staff trained in karst feature identification and mitigation measures are on-going to identify karst features along the Project Route. These surveys have included conservations with engineers with Erie County, Sandusky County, Ohio Department of Transportation, and the Ohio Turnpike

Authority. None of the engineers contacted were aware of any pavement distress as a result of karst impacts within the Bellevue-Castalia Karst Plain. The Erie County Engineer, Sandusky County Engineer and Ohio Turnpike Authority reported no experience of pavement distress as a result of karst impacts anywhere within their systems. Ohio Department of Transportation District 2 reported karst impacts in gypsum north of the Project area along the shore of Lake Erie in Sandusky County, and Ohio Department of Transportation District 3 reported karst impacts south of the Project in Ashland County.

According to the County Engineers in both Erie and Sandusky Counties, the only karst-related issue in the vicinity of the Project was surface flooding due to groundwater rising and flowing from karst springs. This phenomenon is well described in the Ohio Department of Natural Resources map "Karst Flooding in Bellevue, Ohio, and Vicinity - 2008" (Pavey *et. al.*, 2012). The concentration of flooding in 2008 was located south of the proposed alignment of the NEXUS pipeline. Investigations of this event are on-going to evaluate whether buoyancy control measures should be implemented on the pipeline in closed depressions within the Bellevue-Castalia Karst Plain.

##### 6.5.1.1 Karst Sensitive Areas – Ohio

According to Weary and Doctor (2014) the Project is underlain by carbonate bedrock and less than 50 feet of glacial drift from: MP 119.9 to 129.4, MP 133.7 to 135.0, MP 142.6 to 143.4, MP 144.0 to 170.9, MP 172.2 to 172.8, and MP 175.8 to 180.4. The Waterville Compressor Station is the only compressor station in the Project that is underlain by carbonate bedrock and less than 50 feet of glacial drift. The primary identified karst sensitive area in the vicinity of the Project is the Bellevue-Castalia Karst Plain, as described above.

##### 6.5.1.2 Karst Sensitive Areas – Michigan

Portions of the Project in Michigan in mapped karst areas are underlain by greater than 50 feet of unconsolidated glacial drift. The presence of this thick layer of glacial sediment means that there is little to no surface expression of karst features in Michigan.

##### 6.5.1.3 Karst Mitigation

NEXUS will conduct awareness training for karst-like features during Supervisor Staff environmental training, including buffer zone requirements for known karst features. The Chief Inspector, Craft Inspectors, Safety Inspector, Lead Environmental Inspector and Environmental Inspectors will be aware of the potential for sinkhole formation during construction and trained to identify the signs of sinkhole formation.

In addition, as required by 49 Code of Federal Regulations, Part 192.613, NEXUS will conduct route surveillance during construction and operation of the facilities, along with training of surveillance personnel, to monitor the pipeline ROW for evidence of subsidence, surface cracks, or depressions which could indicate sinkhole formation. Should either be identified, the Project geotechnical engineer will be notified. In extreme instances, the affected pipeline segment will be excavated, repositioned, or replaced to a stress-free state, and properly bedded and backfilled to pre-construction contours.

#### 6.5.2 Seismic Environment and Risk

Seismic risk is associated with large earthquake events. The Project is located in an area of very little seismic activity.

The USGS produces hazard probability peak ground acceleration maps. Peak ground acceleration values are represented as factors of “g”, the acceleration of a falling object due to gravity. The USGS Seismic Hazard Maps (USGS, 2008) indicate that there is a 2 percent probability of reaching 5-7 percent “g” in 50 years. From this, it is noted that earthquakes and seismic hazards are unlikely to interfere with the Project.

It should be noted that O'Rourke and Palmer (1994) performed a review of the seismic performance of gas transmission lines in southern California. The authors found that electric arc-welded pipelines constructed post-World War II in good repair have never experienced a break or leak as a result of either traveling ground waves or permanent ground deformation during a southern California earthquake. The authors further concluded that modern electric arc welded gas pipelines in good repair are generally highly resistant to traveling ground wave effects and moderate amounts of permanent deformation.

### 6.5.3 Active Faults

The USGS Quaternary Fold and Fault Database was searched to identify any Quaternary faults that would be crossed by the proposed pipeline. None were identified (USGS, 2006). The Project crosses the Bowling Green Fault System near MP 175.5, near the horizontal directional drilling crossing of the Maumee River. This fault system has been identified in basement rock. The surface of the basement rock in these areas ranges from approximately 2,200 to 2,300 feet below ground surface (Baranoski, 2013).

Underground injection wells are used as a means of disposing of waste water in Ohio. In late 2011 waste water injection along a dormant fault zone in northern Ohio may have caused a magnitude 4.0 earthquake. The buildup of hydrostatic pressure along the faults could have triggered fault slip and the resulting release of energy, though this cannot be conclusively shown. The Ohio Division of Natural Resources has since prohibited the drilling of injection wells into Precambrian basement rock, where old fault zones are located. Based on the actions of the Ohio Division of Natural Resources and the depth of ancient fault zones, enhanced seismicity from fluid injection wells is not anticipated to be a significant concern.

### 6.5.4 Areas Susceptible to Soil Liquefaction

Soil liquefaction is the process by which stress exerted on soil during an earthquake can cause it to flow like a liquid. For liquefaction to occur, a relatively shallow water table, rapid strong ground motion, and non-cohesive soils all must be present (University of Washington, 2000).

Likelihood of strong shaking is low and no modern occurrences of soil liquefaction due to earthquake shaking in Ohio have been documented. Furthermore, pipelines are installed below ground, reducing their susceptibility to any potential damage caused by liquefaction.

### 6.5.5 Areas Susceptible to Landslides

Landslides occur when rock, sediments, soils, and debris move down steep slopes. Landslides are often triggered by heavy rains, erosion by rivers, earthquakes, or human activities (e.g., man-made structures or pilings of rock). The Landslide Overview Map of the Conterminous United States (Radbruch-Hall *et. al.*, 1982) indicates that the first approximately 8.7 miles of the Project (including the Hanoverton Compressor Station) are located in an area of high landslide susceptibility but moderate landslide occurrence. Moderate landslide incidence indicates that 1.5 percent to 15 percent of the area showing evidence of landslides.

Underlying geology and high relief make eastern Ohio prone to landslides, particularly in the form of rotational slumps and earthflows (Hansen, 1995). Fine-grained clastic bedrocks (e.g., shale and mudstone) are prone to slide along exposed slopes. Red mudstones known as "red beds," which are identified in the Conemaugh Group, weaken when wet and may result in landslides.

A buildup of hydrostatic pressure in colluvium may also result in debris avalanches. Hillside seeps can be an indication of potentially enhanced landslide susceptibility, due to the presence of a shallow water table in these locations. North-facing slopes are generally at higher risk for landslides due to greater moisture retention (Hansen, 1995). Prior to construction of the Project, Project personnel will be trained for the management of potential landslides. During the Project's Environmental Training Program, the Contractor's field supervisory personnel and the Company's supervisory personnel including the Chief Inspector, Craft Inspectors, and the Environmental Inspectors, will be trained on the potential for landslides to occur during construction. The training will also provide the appropriate protocol for work stoppage if a landslide occurs and a communication plan to alert the appropriate Company and Contractor Supervisors.

#### 6.5.5.1 Landslides Mitigation

Geotechnical investigations will be conducted during the design phase to identify (or further delineate) areas of landslide risk to allow for site specific measures to be developed. Mitigative and remedial measures will be implemented, as needed, to ensure slope stabilization and minimize the risk of landslides. For example, slope breakers constructed of materials such as sand bags may be installed on slopes with elevated erosion potential. In areas of side hill cuts, the right-of-way will be restored to preconstruction topography and erosion and sediment control measures will be installed to control surface water run-off, prevent scouring, and ensure slope stability.

The NEXUS Project Erosion and Sediment Control Plan in Appendix 1B1 of Draft Resource Report 1 provides field procedures associated with use of slope breakers, temporary and permanent trench plugs, matting, rip rap, and other erosion control measures.

In the areas the Project traverses where the potential landslide hazards may exist, the NEXUS Project team will coordinate with the construction contractor in regard to the site-specific conditions involved. The NEXUS Project will mitigate the potential risks using best construction practices to limit impacts. Prior to entering these areas, the Contractor's field supervisory personnel and the Company's supervisory personnel including the Chief Inspector, Craft Inspectors, and the Environmental Inspectors, will be trained on recognizing these conditions. In areas where geologic hazards have been identified, the same staff will be trained on the implementation and monitoring of the mitigation plans for these hazards. As conditions are identified, this team, based on the type of condition witnessed, will notify the Project Geotechnical Engineer for support, and reduce the amount of equipment in the area, or shutdown work in the area until additional measures can be implemented as directed by the Project Geotechnical Engineer.

During construction, measures will be implemented to minimize potential risks from landslides and soil erosion, especially in the areas of steep slopes. Where steep side slopes are encountered along the pipeline alignment, the upslope side of the construction ROW will be cut during grading and used to fill the downslope side of the ROW, thereby providing a safe and level surface on which to operate heavy equipment. Construction along hillsides may require additional temporary workspace downslope to accommodate the storage of excavated material. During grade restoration, the spoil will be placed back in the cut, compacted to restore original contours, and reseeded. Once grade and drainage patterns have been reestablished, permanent erosion controls (e.g., slope breakers) will be installed as needed. These activities will minimize the potential for man-induced landslides and erosion in the Project area. The Project Alignment Sheets located in Appendix 1A of Draft Resource Report 1, Volume II-B show each additional temporary workspace proposed for the Project and include contour information depicting the existing topography.

### 6.5.6 Surface Subsidence – Underground Mines

Underground mining poses risks to engineered structures because of the potential for the overlying strata to collapse into the void formed by the extraction of minerals. As discussed in Section 6.4, a portion of the Project area has a significant history of underground coal mining that dates back to the beginning of the 19$^{th}$ century. Several mapped abandoned underground mines surround the first approximately 52 miles of the proposed Project route. One mapped abandoned underground mine underlies the project near MP 51.4. There are expected to be many small mines that are unmapped and unknown, as they predate accurate records kept on the subject. Old abandoned mines are expected to be of the room-and-pillar type. According to the ODGS, there are no active underground mines beneath the proposed Project route.

#### 6.5.6.1 Underground Mine Mitigation

If the final alignment traverses an abandoned mine location, a geophysical survey will be performed prior to the construction phase of the Project to determine the depth to the top of the mine. Depending on results of the analysis performed by NEXUS Geological Engineers, construction methodology can be altered to accommodate the subsurface conditions. These alterations may include, but are not limited to, reducing the amount of equipment that is allowed on the ROW in this area, changing the pipe lay direction, i.e., switching the working and spoil sides of the ROW, and/or dragging pipe sections into place using rollers.

### 6.5.7 Flash Flooding

Streams that are typically prone to flash floods tend to have narrow river valleys, steep slopes, and rock-bottoms. Flash floods can also significantly increase the likelihood of landslides along the Project by weakening the bedrock material and undercutting already steep slopes.

Anthropogenic impacts on flooding potential include over-steepened slopes and reduced overburden from past strip mining in the area. These conditions exist only at the eastern end of the Project, mainly in Columbiana County, Ohio. As required, aboveground facilities and pipeline stream crossings will be designed to preclude impacts from high velocity flows, largely by controlling erosion, per the NEXUS Project Erosion and Sediment Control Plan. Measures will be implemented to provide the necessary equipment to handle waterbody flow increases during pipeline installation activities such as having additional pumps on stand-by for dam-and-pump crossings or appropriately sizing flumes to handle storm flows for flume crossings. In addition, equipment crossings will be designed to handle higher flow volumes that could be anticipated from storm events and flooding situations. After construction is completed, each crossing will be periodically inspected for signs of erosion and remediated, as necessary.

Designated Federal Emergency Management Agency flood plains along the Project route are discussed in Draft Resource Report 2.

## 6.6 Paleontological Resources

Paleontological resources potentially encountered along the Project include invertebrate fossils in Paleozoic sedimentary bedrock and Pleistocene bones in glacial sediments. Bedrock invertebrate fossils are common in Paleozoic strata and are not considered significant. Recorded findings of vertebrate Pleistocene fossil bones that have been identified in counties along the Project route include: mastodons, wooly mammoths, horses, birds, reptiles, deer, caribou, bison, elk, and flat-headed peccaries (Hansen, 1992). Some of the remains that have been found coincide with the identification of anthropological resources such as flint tools and arrowheads. No specific locations of these fossils are documented along the Project route.

Given the small footprint of the proposed trench excavation of the Project, it is unlikely that paleontological resources will be encountered by the Project. Should fossilized remains (e.g., animal bones potentially belonging to prehistoric creatures) be discovered during construction, Spectra Energy personnel will respond according to the Unanticipated Discoveries Plan included in Appendix 4C of Draft Resource Report 4.

## 6.7 References

Aden, 2013. Aden, D.J. Karst of the Bellevue Quadrangle and portions of the Clyde and Castalia Quadrangles, Ohio. Ohio Department of Natural Resources, Division of Geological Survey. Open File Report 2013-1. 4 p., 59 maps.

Fenneman, 1928. Fenneman, Nevin M. Physiographic Divisions of the United States. Annals of the Association of American Geographers Volume XVIII No. 4. December 1928. pp 264-353. Accessed at http://www.jstor.org/stable/2560726?seq=2#page_scan_tab_contents

Gordon, C.P., 2009. Mine Subsidence: Mitigating that Sinking Feeling: Ohio Department of Natural Resources, Ohio Geology No. 1

Hansen, 1992. Hansen, M.C. Bestiary of Pleistocene Vertebrates of Ohio. Ohio Geology. Division of Geological Survey. Winter 1992. pp 1-6.

Hansen, 1995. Hansen, M.C. Landslides in Ohio. Ohio Department of Natural Resources, Division of Geological Survey. GeoFacts No. 8. September 1995.

Kelley and Farrand, 1967. Kelley, R.W. and Farrand W.R. The Glacial Lakes around Michigan. Michigan Department of Natural Resources Geological Survey Division. Bulletin 4. 1967. Accessed at http://www.michigan.gov/documents/deq/BU_04opt_314532_7.pdf

Milstein, Randall L. (compiler), 1987. Bedrock geology of southern Michigan: Geological Survey Division, Michigan Dept. of Natural Resources, scale= 1:500,000

Nicholson et al., 2005. Nicholson, S.W., Dicken, C.L., Horton, J.D., Labay, K.A., Foose, M.P., Mueller, J.A.L. Preliminary Integrated Geologic map Database for the United States: Kentucky, Ohio, Tennessee, and West Virginia. United States Geological Survey Open-File Report 2005-1324.

ODGS, 2005. Glacial Map of Ohio. Ohio Department of Natural Resources, Division of Geological Survey, page-size map with text, 2 p., scale 1:2,000,000. Accessed at http://geosurvey.ohiodnr.gov/portals/geosurvey/PDFs/Glacial/glacial.pdf

ODGS. 2012. Abandoned underground mines of Ohio, Ohio Department of Natural Resources, Division of Geological Survey Map EG-3 with text.

[ODNR] Ohio Division of Natural Resources, 2014. Industrial Minerals Mining Operation GIS layer. Ohio Department of Natural Resources. Published: 3/11/2014. Last update: 3/11/2014.

Pavey et al., 2012. Pavey, R.R., Angle, M.P., Powers, D.M., and Swinford, E.M. with GIS and cartography by Powers, D.M. and Martin, D.R. Karst Flooding in Bellevue Ohio, and vicinity – 2008. Ohio Department of Natural Resources, Division of Geological Survey Map ED-5, scale 1:24,000. 2012.

Radbruch-Hall, Dorothy H., Roger B. Colton, William E. Davies, Ivo Lucchitta, Betty A. Skipps, and David J. Varnes. 1978. *Landslide Overview Map of the Conterminous United States*, U.S. Geological Survey, 1978.

Stierman et al., 2005. Stierman, D., Mitchell, B., Skubon, B., Krantz, D., Jol, H., and Fisher, T. Geophysical and GIS Investigations of the Oak Openings Sand Ridge in NW Ohio. Poster paper presented at the North Central meeting of the Geological Society of America, Minneapolis, May 19, 2005.

University of Washington. 2000. Soil Liquefaction. Internet: http://www.ce.washington.edu/~liquefaction/html/what/what1.html

[USEPA] – U.S. Environmental Protection Agency. 1989. Groundwater Monitoring in Karst Terrains, Recommended Protocols & Implicit Assumptions, EPA 600/X-89/050, February.

[USGS] – United States Geological Survey. 2006. Quaternary fault and fold database for the United States, accessed 4/29/2014, from USGS web site: http://earthquakes.usgs.gov/regional/qfaults/.

USGS. 2008. Documentation for the 2008 Update of the United States National Seismic Hazard Maps: U.S. Geological Survey Open-File Report 2008–1128, 2008. http://pubs.usgs.gov/of/2008/1128/, last accessed April 29, 2015

USGS. 2013a. 2009 Minerals Yearbook, Michigan [Advance Release]. US Geological Survey. December 2013.

USGS. 2013b. 2009 Minerals Yearbook, Ohio [Advance Release]. US Geological Survey. July 2013.

Weary and Doctor, 2014. Weary, D.J., Doctor, D.H. Karst in the United States: A Digital Map Compilation and Database. United States Geological Survey Open-File Report 2014-1156. 23 p. http://dx.doi.org/10.3133/ofr20141156

# TABLES

TABLE 6.2-1

**Bedrock Geology of the NEXUS Project**

| State, Facility | Milepost Begin | Milepost End | Map Symbol | Unit Age | Lithology 1 | Lithology 2 |
|---|---|---|---|---|---|---|
| **Ohio** | | | | | | |
| *TGP Interconnecting Pipeline* | | | | | | |
| | 0.00 | 0.89 | IPc | Pennsylvanian | siltstone | shale |
| *Mainline* | | | | | | |
| | 0.00 | 1.73 | IPc | Pennsylvanian | siltstone | shale |
| | 1.73 | 2.21 | IPap | Pennsylvanian | shale | siltstone |
| | 2.21 | 4.61 | IPc | Pennsylvanian | siltstone | shale |
| | 4.61 | 5.25 | IPap | Pennsylvanian | shale | siltstone |
| | 5.25 | 5.38 | IPc | Pennsylvanian | siltstone | shale |
| | 5.38 | 5.61 | IPap | Pennsylvanian | shale | siltstone |
| | 5.61 | 6.24 | IPc | Pennsylvanian | siltstone | shale |
| | 6.24 | 6.34 | IPap | Pennsylvanian | shale | siltstone |
| | 6.34 | 6.88 | IPc | Pennsylvanian | siltstone | shale |
| | 6.88 | 7.17 | IPap | Pennsylvanian | shale | siltstone |
| | 7.17 | 7.48 | IPc | Pennsylvanian | siltstone | shale |
| | 7.48 | 7.57 | IPap | Pennsylvanian | shale | siltstone |
| | 7.57 | 7.65 | IPc | Pennsylvanian | siltstone | shale |
| | 7.65 | 7.99 | IPap | Pennsylvanian | shale | siltstone |
| | 7.99 | 9.11 | IPc | Pennsylvanian | siltstone | shale |
| | 9.11 | 9.30 | IPap | Pennsylvanian | shale | siltstone |
| | 9.30 | 9.42 | IPc | Pennsylvanian | siltstone | shale |
| | 9.42 | 11.70 | IPap | Pennsylvanian | shale | siltstone |
| | 11.70 | 11.82 | IPc | Pennsylvanian | siltstone | shale |
| | 11.82 | 12.18 | IPap | Pennsylvanian | shale | siltstone |
| | 12.18 | 12.89 | IPc | Pennsylvanian | siltstone | shale |
| | 12.89 | 37.27 | IPap | Pennsylvanian | shale | siltstone |
| | 37.27 | 37.35 | Mlc | Mississippian | shale | siltstone |
| | 37.35 | 37.79 | IPap | Pennsylvanian | shale | siltstone |
| | 37.79 | 39.12 | Mlc | Mississippian | shale | siltstone |
| | 39.12 | 43.25 | IPap | Pennsylvanian | shale | siltstone |
| | 43.25 | 43.42 | Mlc | Mississippian | shale | siltstone |
| | 43.42 | 45.80 | IPap | Pennsylvanian | shale | siltstone |
| | 45.80 | 46.12 | Mlc | Mississippian | shale | siltstone |
| | 46.12 | 46.74 | IPap | Pennsylvanian | shale | siltstone |
| | 46.74 | 46.97 | Mlc | Mississippian | shale | siltstone |
| | 46.97 | 49.14 | IPap | Pennsylvanian | shale | siltstone |
| | 49.14 | 49.55 | Mlc | Mississippian | shale | siltstone |
| | 49.55 | 49.57 | IPap | Pennsylvanian | shale | siltstone |
| | 49.57 | 49.68 | Mlc | Mississippian | shale | siltstone |
| | 49.68 | 49.90 | IPap | Pennsylvanian | shale | siltstone |
| | 49.90 | 50.12 | Mlc | Mississippian | shale | siltstone |

TABLE 6.2-1

**Bedrock Geology of the NEXUS Project**

| State, Facility | Milepost Begin | Milepost End | Map Symbol | Unit Age | Lithology 1 | Lithology 2 |
|---|---|---|---|---|---|---|
| | 50.12 | 52.65 | IPap | Pennsylvanian | shale | siltstone |
| | 52.65 | 53.36 | Mlc | Mississippian | shale | siltstone |
| | 53.36 | 54.14 | IPap | Pennsylvanian | shale | siltstone |
| | 54.14 | 54.21 | Mlc | Mississippian | shale | siltstone |
| | 54.21 | 54.24 | IPap | Pennsylvanian | shale | siltstone |
| | 54.24 | 56.48 | Mlc | Mississippian | shale | siltstone |
| | 56.48 | 56.77 | IPap | Pennsylvanian | shale | siltstone |
| | 56.77 | 57.08 | Mlc | Mississippian | shale | siltstone |
| | 57.08 | 57.46 | IPap | Pennsylvanian | shale | siltstone |
| | 57.46 | 58.74 | Mlc | Mississippian | shale | siltstone |
| | 58.74 | 61.57 | IPap | Pennsylvanian | shale | siltstone |
| | 61.57 | 86.53 | Mlc | Mississippian | shale | siltstone |
| | 86.53 | 87.27 | Dbb | Devonian | sandstone | shale |
| | 87.27 | 88.19 | Mlc | Mississippian | shale | siltstone |
| | 88.19 | 91.87 | Dbb | Devonian | sandstone | shale |
| | 91.87 | 92.67 | Mlc | Mississippian | shale | siltstone |
| | 92.67 | 96.40 | Dbb | Devonian | sandstone | shale |
| | 96.40 | 96.59 | Do | Devonian | black shale | shale |
| | 96.59 | 97.54 | Dbb | Devonian | sandstone | shale |
| | 97.54 | 98.23 | Do | Devonian | black shale | shale |
| | 98.23 | 105.84 | Dbb | Devonian | sandstone | shale |
| | 105.84 | 106.06 | Do | Devonian | black shale | shale |
| | 106.06 | 108.09 | Dbb | Devonian | sandstone | shale |
| | 108.09 | 119.92 | Do | Devonian | black shale | shale |
| | 119.92 | 120.75 | Dp | Devonian | limestone | dolostone (dolomite) |
| | 120.75 | 121.30 | Dpl | Devonian | shale | limestone |
| | 121.30 | 121.91 | Dd | Devonian | limestone | |
| | 121.91 | 122.13 | Dpl | Devonian | shale | limestone |
| | 122.13 | 124.47 | Dd | Devonian | limestone | |
| | 124.47 | 127.73 | Dc | Devonian | limestone | dolostone (dolomite) |
| | 127.73 | 135.64 | Ss | Silurian | dolostone (dolomite) | shale |
| | 135.64 | 141.86 | Stg | Silurian | dolostone (dolomite) | shale |
| | 141.86 | 142.10 | Sl | Silurian | dolostone (dolomite) | |
| | 142.10 | 143.18 | Stg | Silurian | dolostone (dolomite) | shale |
| | 143.18 | 145.13 | Sl | Silurian | dolostone (dolomite) | |
| | 145.13 | 146.11 | Stg | Silurian | dolostone (dolomite) | shale |
| | 146.11 | 158.33 | Sl | Silurian | dolostone (dolomite) | |

TABLE 6.2-1

**Bedrock Geology of the NEXUS Project**

| State, Facility | Milepost Begin | Milepost End | Map Symbol | Unit Age | Lithology 1 | Lithology 2 |
|---|---|---|---|---|---|---|
| | 158.33 | 158.49 | Stg | Silurian | dolostone (dolomite) | shale |
| | 158.49 | 163.52 | Sl | Silurian | dolostone (dolomite) | |
| | 163.52 | 165.36 | Stg | Silurian | dolostone (dolomite) | shale |
| | 165.36 | 167.82 | Sl | Silurian | dolostone (dolomite) | |
| | 167.82 | 168.94 | Stg | Silurian | dolostone (dolomite) | shale |
| | 168.94 | 172.79 | Sl | Silurian | dolostone (dolomite) | |
| | 172.79 | 175.46 | Stg | Silurian | dolostone (dolomite) | shale |
| | 175.46 | 177.21 | Ss | Silurian | dolostone (dolomite) | shale |
| | 177.21 | 180.88 | Ddr | Devonian | dolostone (dolomite) | evaporite |
| | 180.88 | 181.85 | Ddu | Devonian | limestone | dolostone (dolomite) |
| | 181.85 | 182.48 | Ddr | Devonian | dolostone (dolomite) | evaporite |
| | 182.48 | 183.21 | Ddu | Devonian | limestone | dolostone (dolomite) |
| | 183.21 | 184.88 | Dts | Devonian | dolostone (dolomite) | shale |
| | 184.88 | 197.81 | Da | Devonian | shale | black shale |
| | 197.81 | 202.81 | MDsd | Devonian and/or Mississippian | shale | black shale |
| **Michigan** | | | | | | |
| *Mainline* | | | | | | |
| | 202.81 | 204.97 | Dbd | Late Devonian | shale | sandstone |
| | 204.97 | 206.30 | Db | Late Devonian | sandstone | siltstone |
| | 206.30 | 207.26 | DMs | Mississippian-Devonian | black shale | |
| | 207.26 | 211.49 | Mc | Mississippian | shale | limestone |
| | 211.49 | 211.98 | DMs | Mississippian-Devonian | black shale | |
| | 211.98 | 214.82 | Mc | Mississippian | shale | limestone |
| | 214.82 | 215.52 | DMs | Mississippian-Devonian | black shale | |
| | 215.52 | 218.84 | Db | Late Devonian | sandstone | siltstone |
| | 218.84 | 219.78 | Dbd | Late Devonian | shale | sandstone |
| | 219.78 | 221.54 | Da | Late Devonian | black shale | limestone |
| | 221.54 | 225.18 | Dt | Middle Devonian | limestone | shale |
| | 225.18 | 228.08 | Dd | Middle Devonian | limestone | dolostone (dolomite) |
| | 228.08 | 230.01 | Dt | Middle Devonian | limestone | shale |
| | 230.01 | 230.21 | Dd | Middle Devonian | limestone | dolostone (dolomite) |

TABLE 6.2-1

**Bedrock Geology of the NEXUS Project**

| State, Facility | Milepost Begin | Milepost End | Map Symbol | Unit Age | Lithology 1 | Lithology 2 |
|---|---|---|---|---|---|---|
| | 230.21 | 241.92 | Dt | Middle Devonian | limestone | shale |
| | 241.92 | 249.03 | Da | Late Devonian | black shale | limestone |
| **Ohio** | **area (ac)** | **area (sf)** | **Map Symbol** | **Unit Age** | **Lithology1** | **Lithology2** |
| Clyde Compressor Station (CS-3) | 48.64 | 2,118,854 | Ss | Silurian | dolostone (dolomite) | shale |
| Hanoverton Compressor Station (CS-1) | 7.65 | 333,086 | IPap | Pennsylvanian | shale | siltstone |
| Hanoverton Compressor Station (CS-1) | 22.66 | 987,140 | IPc | Pennsylvanian | siltstone | shale |
| M&R-1 (TGP) | 2.07 | 89,989 | IPc | Pennsylvanian | siltstone | shale |
| M&R-2 (Kensington) | 2.58 | 112,562 | IPc | Pennsylvanian | siltstone | shale |
| M&R-3 (Open) | 1.89 | 82,203 | IPc | Pennsylvanian | siltstone | shale |
| Wadsworth Compressor Station (CS-2) | 19.91 | 867,204 | IPap | Pennsylvanian | shale | siltstone |
| Waterville Compressor Station (CS-4) | 35.88 | 1,563,063 | Ddr | Devonian | dolostone (dolomite) | evaporite |
| **Michigan** | | | | | | |
| M&R-4 (DTE / WillowRun) | 2.12 | 92,429 | Da | Late Devonian | black shale | limestone |

Sources:
Milstein, 1987 and Nicholson et al., 2005

TABLE 6.2-2

**Surficial Geology of the NEXUS Project**

| State, Facility | Milepost Begin | Milepost End | Lithology | Setting | Thickness (ft) |
|---|---|---|---|---|---|
| **Ohio** | | | | | |
| *TGP Interconnecting Pipeline* | | | | | |
| | 0.00 | 0.89 | NA | NA | NA |
| *Mainline* | | | | | |
| | 0.00 | 0.23 | NA | NA | NA |
| | 0.23 | 1.71 | T | Thin Upland | < 25 |
| | 1.71 | 2.24 | Fsg | Alluvial | 25 - 100 |
| | 2.24 | 4.72 | T | Thin Upland | < 25 |
| | 4.72 | 4.93 | T | Buried Valley | 25 - 100 |
| | 4.93 | 7.66 | T | Thin Upland | < 25 |
| | 7.66 | 7.78 | Fsg | Alluvial | 25 - 100 |
| | 7.78 | 9.49 | T | Thin Upland | < 25 |
| | 9.49 | 9.64 | Fsg | Alluvial | 25 - 100 |
| | 9.64 | 10.69 | Tsg | Buried Valley | > 100 |
| | 10.69 | 10.83 | Fsg | Buried Valley | > 100 |
| | 10.83 | 11.22 | Tsg | Buried Valley | > 100 |
| | 11.22 | 15.24 | Tsg | Thin Upland | 25 - 100 |
| | 15.24 | 16.83 | Tsg | Buried Valley | > 100 |
| | 16.83 | 17.50 | Tsg | Thin Upland | 25 - 100 |
| | 17.50 | 20.32 | Tsg | Buried Valley | > 100 |
| | 20.32 | 24.31 | Tsg | Thin Upland | 25 - 100 |
| | 24.31 | 24.46 | NA | NA | NA |
| | 24.46 | 25.90 | Tsg | Thin Upland | 25 - 100 |
| | 25.90 | 26.25 | SGf | Buried Valley | > 100 |
| | 26.25 | 27.25 | Fsg | Buried Valley | > 100 |
| | 27.25 | 28.15 | Tsg | Thin Upland | 25 - 100 |
| | 28.15 | 29.16 | Fsg | Buried Valley | > 100 |
| | 29.16 | 29.90 | Tsg | Thin Upland | 25 - 100 |
| | 29.90 | 30.09 | Fsg | Buried Valley | 25 - 100 |
| | 30.09 | 30.41 | Tsg | Thin Upland | 25 - 100 |
| | 30.41 | 31.46 | Fsg | Buried Valley | 25 - 100 |
| | 31.46 | 32.36 | Tsg | Outwash/Kame | 25 - 100 |
| | 32.36 | 33.06 | Fsg | Buried Valley | > 100 |
| | 33.06 | 33.39 | Tsg | Thin Upland | 25 - 100 |
| | 33.39 | 33.66 | Tsg | Outwash/Kame | 25 - 100 |
| | 33.66 | 35.08 | Tsg | Thin Upland | 25 - 100 |
| | 35.08 | 35.89 | Tsg | Outwash/Kame | 25 - 100 |
| | 35.89 | 39.17 | Fsg | Buried Valley | > 100 |
| | 39.17 | 39.98 | Tsg | Buried Valley | > 100 |
| | 39.98 | 40.32 | Tsg | Thin Upland | 25 - 100 |
| | 40.32 | 40.48 | Tsg | Buried Valley | > 100 |

TABLE 6.2-2

**Surficial Geology of the NEXUS Project**

| State, Facility | Milepost Begin | Milepost End | Lithology | Setting | Thickness (ft) |
|---|---|---|---|---|---|
| | 40.48 | 41.87 | Tsg | Thin Upland | 25 - 100 |
| | 41.87 | 42.23 | Tsg | Buried Valley | > 100 |
| | 42.23 | 42.39 | Tsg | Thin Upland | 25 - 100 |
| | 42.39 | 43.00 | T | Thin Upland | < 25 |
| | 43.00 | 43.17 | Tsg | Thin Upland | 25 - 100 |
| | 43.17 | 43.47 | Tsg | Buried Valley | > 100 |
| | 43.47 | 44.14 | Tsg | Thin Upland | 25 - 100 |
| | 44.14 | 44.17 | T | Thin Upland | < 25 |
| | 44.17 | 44.27 | Tsg | Thin Upland | 25 - 100 |
| | 44.27 | 44.38 | T | Thin Upland | < 25 |
| | 44.38 | 44.86 | Tsg | Thin Upland | 25 - 100 |
| | 44.86 | 45.78 | T | Thin Upland | < 25 |
| | 45.78 | 46.10 | Fsg | Buried Valley | > 100 |
| | 46.10 | 47.07 | Tsg | Buried Valley | > 100 |
| | 47.07 | 47.89 | Tsg | Thin Upland | 25 - 100 |
| | 47.89 | 48.62 | T | Thin Upland | < 25 |
| | 48.62 | 48.93 | Tsg | Thin Upland | 25 - 100 |
| | 48.93 | 50.22 | Tsg | Buried Valley | > 100 |
| | 50.22 | 50.37 | Tsg | Thin Upland | 25 - 100 |
| | 50.37 | 52.37 | T | Thin Upland | < 25 |
| | 52.37 | 53.31 | Tsg | Thin Upland | 25 - 100 |
| | 53.31 | 53.52 | T | Thin Upland | < 25 |
| | 53.52 | 53.89 | Tsg | Thin Upland | 25 - 100 |
| | 53.89 | 54.43 | T | Thin Upland | < 25 |
| | 54.43 | 54.70 | Tsg | Thin Upland | 25 - 100 |
| | 54.70 | 55.69 | SGf | Buried Valley | > 100 |
| | 55.69 | 56.13 | Tsg | Thin Upland | 25 - 100 |
| | 56.13 | 56.37 | T | Thin Upland | < 25 |
| | 56.37 | 57.71 | Tsg | Thin Upland | 25 - 100 |
| | 57.71 | 58.01 | Tsg | Buried Valley | > 100 |
| | 58.01 | 60.57 | Tsg | Thin Upland | 25 - 100 |
| | 60.57 | 61.33 | T | Thin Upland | < 25 |
| | 61.33 | 61.78 | Tsg | Thin Upland | 25 - 100 |
| | 61.78 | 62.00 | Tsg | Buried Valley | > 100 |
| | 62.00 | 62.17 | Tsg | Thin Upland | 25 - 100 |
| | 62.17 | 62.60 | Tsg | Buried Valley | > 100 |
| | 62.60 | 64.19 | Tsg | Thin Upland | 25 - 100 |
| | 64.19 | 65.08 | Tsg | Buried Valley | > 100 |
| | 65.08 | 65.16 | Tsg | Thin Upland | 25 - 100 |
| | 65.16 | 67.50 | Tsg | End Moraine | 25 - 100 |
| | 67.50 | 67.88 | Fsg | Buried Valley | > 100 |
| | 67.88 | 68.63 | Fsg | Buried Valley | > 100 |

TABLE 6.2-2

**Surficial Geology of the NEXUS Project**

| State, Facility | Milepost Begin | Milepost End | Lithology | Setting | Thickness (ft) |
|---|---|---|---|---|---|
| | 68.63 | 72.52 | Tsg | Thin Upland | 25 - 100 |
| | 72.52 | 73.53 | Tsg | End Moraine | 25 - 100 |
| | 73.53 | 75.87 | Tsg | Thin Upland | 25 - 100 |
| | 75.87 | 82.07 | T | Thin Upland | < 25 |
| | 82.07 | 82.97 | Tsg | Thin Upland | 25 - 100 |
| | 82.97 | 83.34 | Fsg | Alluvial | < 25 |
| | 83.34 | 83.47 | Tsg | Thin Upland | 25 - 100 |
| | 83.47 | 85.90 | T | Thin Upland | < 25 |
| | 85.90 | 87.24 | T | Thin Upland | 25 - 100 |
| | 87.24 | 88.34 | T | Thin Upland | < 25 |
| | 88.34 | 88.86 | Tsg | Ground Moraine | 25 - 100 |
| | 88.86 | 89.03 | Fsg | Buried Valley | 25 - 100 |
| | 89.03 | 89.29 | Fsg | Buried Valley | > 100 |
| | 89.29 | 90.74 | Tsg | Complex | > 100 |
| | 90.74 | 91.26 | Tsg | Ground Moraine | 25 - 100 |
| | 91.26 | 94.18 | T | Ground Moraine | 25 - 100 |
| | 94.18 | 96.00 | T | Thin Upland | < 25 |
| | 96.00 | 96.22 | Tsg | Thin Upland | 25 - 100 |
| | 96.22 | 96.91 | Tsg | Complex | > 100 |
| | 96.91 | 97.53 | Tsg | Complex | 25 - 100 |
| | 97.53 | 98.08 | Tsg | Complex | > 100 |
| | 98.08 | 99.14 | Tsg | Ground Moraine | 25 - 100 |
| | 99.14 | 100.35 | T | Thin Upland | < 25 |
| | 100.35 | 100.45 | Fsg | Alluvial | 25 - 100 |
| | 100.45 | 101.98 | T | Thin Upland | < 25 |
| | 101.98 | 102.13 | Tsg | Thin Upland | 25 - 100 |
| | 102.13 | 104.82 | T | Thin Upland | < 25 |
| | 104.82 | 104.95 | Tsg | Thin Upland | 25 - 100 |
| | 104.95 | 105.75 | T | Thin Upland | < 25 |
| | 105.75 | 106.05 | Tsg | Thin Upland | 25 - 100 |
| | 106.05 | 107.76 | T | Thin Upland | < 25 |
| | 107.76 | 108.93 | T | Lacustrine | < 25 |
| | 108.93 | 109.83 | T | Lacustrine | 25 - 100 |
| | 109.83 | 109.88 | Fsg | Alluvial | 25 - 100 |
| | 109.88 | 110.15 | Tsg | Lacustrine | 25 - 100 |
| | 110.15 | 110.47 | Fsg | Buried Valley | 25 - 100 |
| | 110.47 | 112.24 | Fsg | Buried Valley | > 100 |
| | 112.24 | 112.69 | Fsg | Buried Valley | 25 - 100 |
| | 112.69 | 112.94 | Fsg | Alluvial | 25 - 100 |
| | 112.94 | 115.18 | F | Lacustrine | 25 - 100 |
| | 115.18 | 122.58 | T | Lacustrine | < 25 |

TABLE 6.2-2

**Surficial Geology of the NEXUS Project**

| State, Facility | Milepost Begin | Milepost End | Lithology | Setting | Thickness (ft) |
|---|---|---|---|---|---|
| | 122.58 | 122.68 | SGt | Beach Ridge | < 25 |
| | 122.68 | 127.41 | T | Lacustrine | < 25 |
| | 127.41 | 128.26 | T | Lacustrine | 25 - 100 |
| | 128.26 | 128.33 | SGt | Beach Ridge | < 25 |
| | 128.33 | 128.44 | T | Lacustrine | 25 - 100 |
| | 128.44 | 128.58 | SGt | Beach Ridge | < 25 |
| | 128.58 | 129.04 | T | Lacustrine | 25 - 100 |
| | 129.04 | 129.20 | SGt | Beach Ridge | 25 - 100 |
| | 129.20 | 132.47 | Tsg | Lacustrine | 25 - 100 |
| | 132.47 | 137.07 | F | Lacustrine | 25 - 100 |
| | 137.07 | 137.16 | F | Buried Valley | > 100 |
| | 137.16 | 137.34 | Fsg | Buried Valley | > 100 |
| | 137.34 | 138.55 | F | Buried Valley | > 100 |
| | 138.55 | 140.15 | F | Lacustrine | 25 - 100 |
| | 140.15 | 140.87 | F | Lacustrine | 25 - 100 |
| | 140.87 | 141.31 | Fsg | Alluvial | 25 - 100 |
| | 141.31 | 141.53 | F | Lacustrine | 25 - 100 |
| | 141.53 | 144.38 | F | Lacustrine | 25 - 100 |
| | 144.38 | 148.24 | T | Lacustrine | < 25 |
| | 148.24 | 148.44 | Fsg | Alluvial | < 25 |
| | 148.44 | 156.29 | T | Lacustrine | < 25 |
| | 156.29 | 157.17 | T | Lacustrine | 25 - 100 |
| | 157.17 | 157.39 | T | Lacustrine | < 25 |
| | 157.39 | 157.50 | Fsg | Alluvial | < 25 |
| | 157.50 | 158.55 | T | Lacustrine | < 25 |
| | 158.55 | 158.91 | T | Lacustrine | 25 - 100 |
| | 158.91 | 162.62 | T | Lacustrine | < 25 |
| | 162.62 | 164.19 | T | Lacustrine | 25 - 100 |
| | 164.19 | 164.96 | T | Lacustrine | < 25 |
| | 164.96 | 166.62 | T | Lacustrine | 25 - 100 |
| | 166.62 | 167.12 | Tsg | Lacustrine | 25 - 100 |
| | 167.12 | 167.93 | T | Lacustrine | 25 - 100 |
| | 167.93 | 168.89 | T | Lacustrine | < 25 |
| | 168.89 | 175.14 | T | Lacustrine | 25 - 100 |
| | 175.14 | 176.07 | Tsg | Lacustrine | 25 - 100 |
| | 176.07 | 176.51 | Fsg | Alluvial | 25 - 100 |
| | 176.51 | 177.83 | F | Lacustrine | 25 - 100 |
| | 177.83 | 178.69 | T | Lacustrine | < 25 |
| | 178.69 | 180.19 | T | Lacustrine | 25 - 100 |
| | 180.19 | 181.29 | F | Lacustrine | 25 - 100 |
| | 181.29 | 181.48 | SGf | Beach Ridge | 25 - 100 |
| | 181.48 | 190.98 | SGf | Beach Ridge | 25 - 100 |

TABLE 6.2-2

**Surficial Geology of the NEXUS Project**

| State, Facility | Milepost Begin | Milepost End | Lithology | Setting | Thickness (ft) |
|---|---|---|---|---|---|
| | 190.98 | 193.93 | F | Lacustrine | 25 - 100 |
| | 193.93 | 194.29 | F | Lacustrine | > 100 |
| | 194.29 | 195.51 | F | Lacustrine | 25 - 100 |
| | 195.51 | 195.67 | Tsg | Lacustrine | 25 - 100 |
| | 195.67 | 202.81 | Tsg | Lacustrine | > 100 |
| **Michigan** | | | | | |
| *Mainline* | | | | | |
| | 202.81 | 208.83 | Lacustrine clay and silt | No Data | No Data |
| | 208.83 | 214.87 | Lacustrine sand and gravel | No Data | No Data |
| | 214.87 | 243.70 | Lacustrine clay and silt | No Data | No Data |
| | 243.70 | 249.03 | Lacustrine sand and gravel | No Data | No Data |
| **Ohio** | | | | | |
| | **area (ac)** | **area (sf)** | **Lithology** | **Setting** | **Thickness** |
| Clyde Compressor Station (CS-3) | 0.01 | 360 | SGt | Beach Ridge | 25 - 100 |
| Clyde Compressor Station (CS-3) | 48.63 | 2,118,494 | Tsg | Lacustrine | 25 - 100 |
| Hanoverton Compressor Station (CS-1) | 4.85 | 211,134 | Fsg | Alluvial | 25 - 100 |
| Hanoverton Compressor Station (CS-1) | 25.46 | 1,109,092 | T | Thin Upland | < 25 |
| M&R-1 (TGP) | 2.07 | 89,989 | NA | NA | NA |
| M&R-2 (Kensington) | 2.58 | 112,562 | NA | NA | NA |
| M&R-3 (Open) | 1.89 | 82,203 | NA | NA | NA |
| Wadsworth Compressor Station (CS-2) | 11.97 | 521,270 | T | Thin Upland | < 25 |
| Wadsworth Compressor Station (CS-2) | 7.94 | 345,934 | Tsg | Thin Upland | 25 - 100 |
| Waterville Compressor Station (CS-4) | 35.88 | 1,563,063 | T | Lacustrine | < 25 |
| Clyde Compressor Station (CS-3) | 0.01 | 360 | SGt | Beach Ridge | 25 - 100 |
| Clyde Compressor Station (CS-3) | 48.63 | 2,118,494 | Tsg | Lacustrine | 25 - 100 |
| **Michigan** | | | | | |
| M&R-4 (DTE / WillowRun) | 2.12 | 92,429 | Lacustrine sand and gravel | No Data | No Data |

Notes:
F - fines; Fsg - fines over sand and gravel; SGf - sand and gravel over fines; SGt - sand and gravel over till; T - till; Tsg - till over sand and gravel
Source:
ODNR Glacial shape data layer

TABLE 6.4-1

**Industrial Mines within 0.25 mile of the NEXUS Project**

| Milepost | Distance (mi) | Direction | Resource | Producer |
|---|---|---|---|---|
| 124.0 | 0.22 | S | Limestone | Hanson Aggregate Midwest, Inc. |
| 154.8 | 0.04 | NE | Limestone | Olen Corporation |
| 243.1 | 0.04 | E | Sand & Gravel | J+T Aggregate, LLC |

Sources:
ODNR Industrial Minerals Mining Operation GIS layer. Last update: 3/11/2014
Mining and Minerals layer on Michigan DEQ GeoWebFace
http://ww2.deq.state.mi.us/GeoWebFace/#

TABLE 6.4-2

**Mapped Underground Mines within 0.25-mile of the NEXUS Project**

| Milepost | Distance (mi) | Direction | Mine Type | Status | API Number | Operator |
|---|---|---|---|---|---|---|
| 7.6 | 0.25 | SSW | Coal | Abandoned | 340298000602 | King & Perien |
| 33.9 | 0.17 | N | Coal | Abandoned | 341538003502 | R&T Coal Company |
| 34.1 | 0.22 | N | Coal | Abandoned | 341538003402 | Overholt Coal Company |
| 40.4 | 0.20 | N | Coal | Abandoned | 341538003202 | Massilon-Akron Coal Company |
| 42.7 | 0.17 | NE | Coal | Abandoned | 341538002702 | Akron-Massilon Coal Company |
| 43.7 | 0.19 | E | Coal | Abandoned | 341538001102 | Massilon Coal Mining Company |
| 48.6 | 0.21 | N | Coal | Abandoned | 341698001702 | J.D. Jones Coal Co. |
| 49.8 | 0.19 | NE | Coal | Abandoned | 341698000702 | H.E. Loomis |
| 51.4 | 0 | - | Coal | Abandoned | 341698000202 | Ohio Salt Co. |

Source:
ODNR's Mines of Ohio Interactive Map, last updated 3/8/2013

TABLE 6.4-3

**Surface Coal Mining Operations within 0.25-mile of the NEXUS Project**

| Milepost | Distance (mi) | Direction | Mine Status | Permittee | Permit Application Date | Application Approval Date |
|---|---|---|---|---|---|---|
| HCS | 0.06 | W | Inactive | General Mines, Inc. | 8/13/1979 | - |
| 1.7 | 0.05 | W | Abandoned | John Glenn Mining Co. | 12/14/1994 | 1/15/1993 |
| 1.9 | 0.21 | W | Inactive | Blum Coal Co. | 4/1/1981 | - |

Note:
HCS - Hanoverton Compressor Station
Source:
ODNR's Mines of Ohio Interactive Map, last updated 3/8/2013

TABLE 6.5-1

**Mapped Karst Features within 1,500 feet of the NEXUS Project**

| Approximate Milepost | Approximate Distance (ft) | Direction from Project | Feature |
|---|---|---|---|
| 122.28 | 240 | north | Field verified sinkhole |
| 123.58 | 130 | south | Spring |
| 124.20 | 700 | north | Field verified sinkhole |
| 125.87 | 800 | south | Suspect sinkhole - field visited |
| 126.03 | 250 | south | Field verified sinkhole |
| 126.53 | 900 | northeast | Suspect sinkhole - field visited |
| 126.54 | 1,475 | northeast | Suspect sinkhole - field visited |
| 126.55 | 250 | southwest | Suspect sinkhole - field visited |
| 126.56 | 1,350 | northeast | Suspect sinkhole - field visited |
| 126.57 | 350 | northeast | Suspect sinkhole - field visited |
| 126.68 | 510 | south | Suspect sinkhole - field visited |
| 126.68 | 830 | south | Field verified sinkhole |
| 126.68 | 1,285 | south | Suspect sinkhole - field visited |
| 126.91 | 990 | south | Suspect sinkhole - field visited |
| 127.10 | 1,475 | south | Suspect sinkhole - field visited |
| 127.14 | 1,175 | north | Field verified sinkhole |
| 127.28 | 360 | south | Suspect sinkhole - field visited |
| 127.28 | 1,400 | north | Suspect sinkhole - field visited |
| 127.30 | 1,400 | north | Suspect sinkhole - field visited |
| 127.76 | 85 | north | Spring |
| 129.42 | 1,300 | south | Spring |

Source:
Data and feature designations from Aden, 2013.

# FIGURES

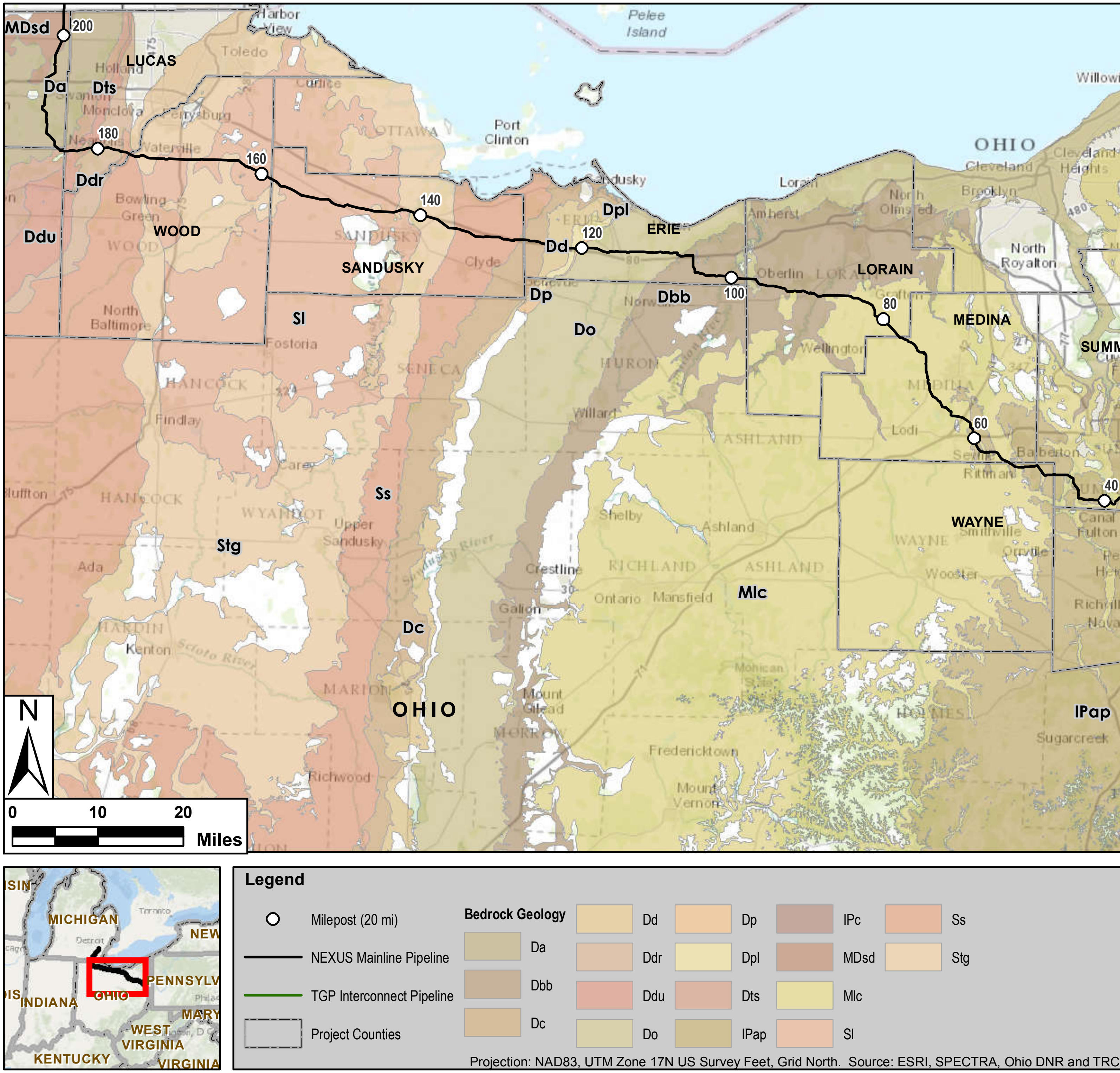


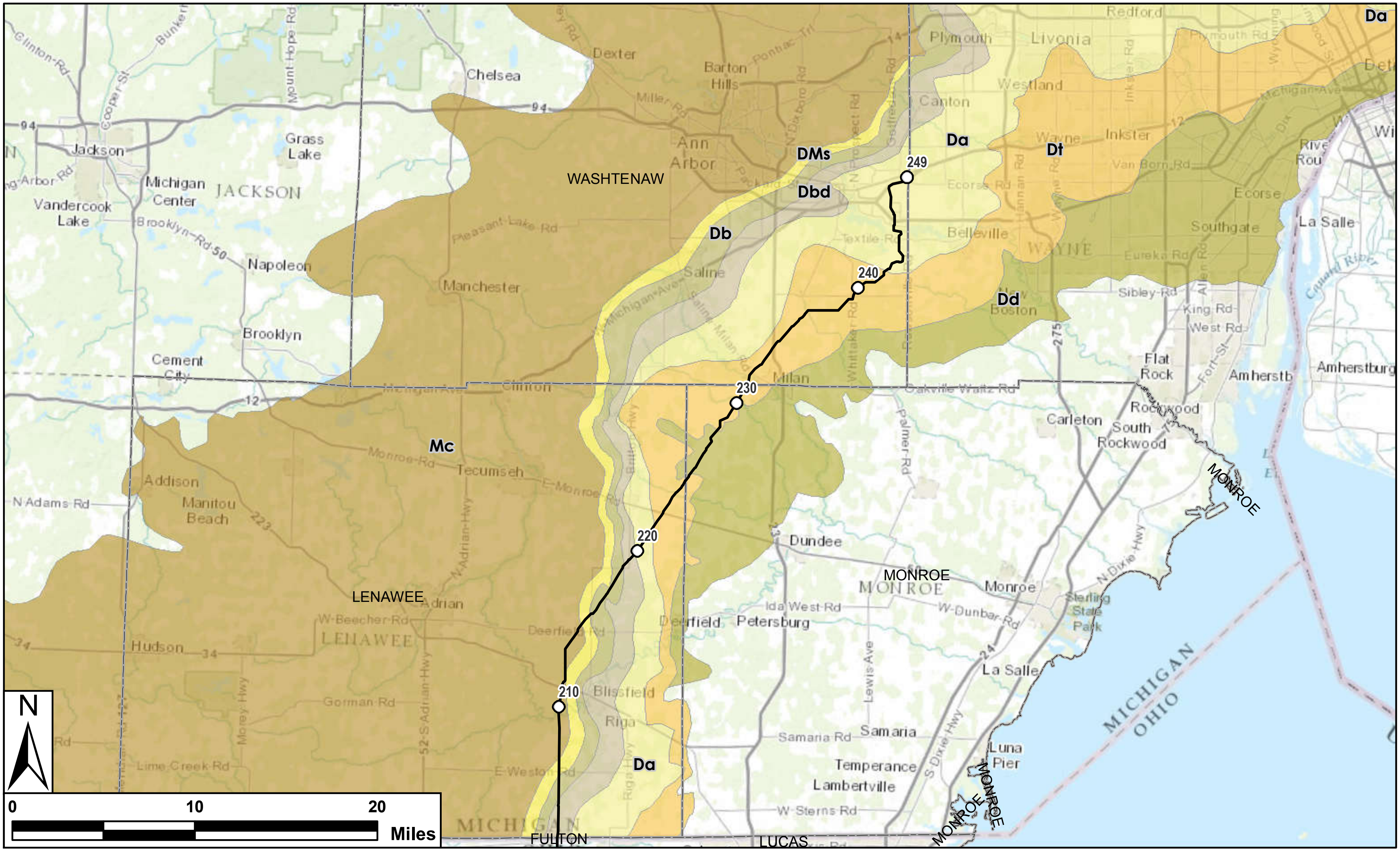

Figure 6.2-1a

**Bedrock Geology Crossed by Pipeline Facilities**

Ohio

NEXUS GAS TRANSMISSION

5/31/2015





## Legend

- ○ Milepost (10 mi)
- NEXUS Mainline Pipeline
- Project Counties

**Bedrock Geology**

- DMs
- Da
- Db
- Dbd
- Dd
- Dt
- Mc

Projection: NAD83, UTM Zone 17N US Survey Feet, Grid North. Source: ESRI, SPECTRA, MI GIS Open Data and TRC

Figure 6.2-1b

**Bedrock Geology Crossed by Pipeline Facilities**

Michigan

NEXUS GAS TRANSMISSION

5/31/2015

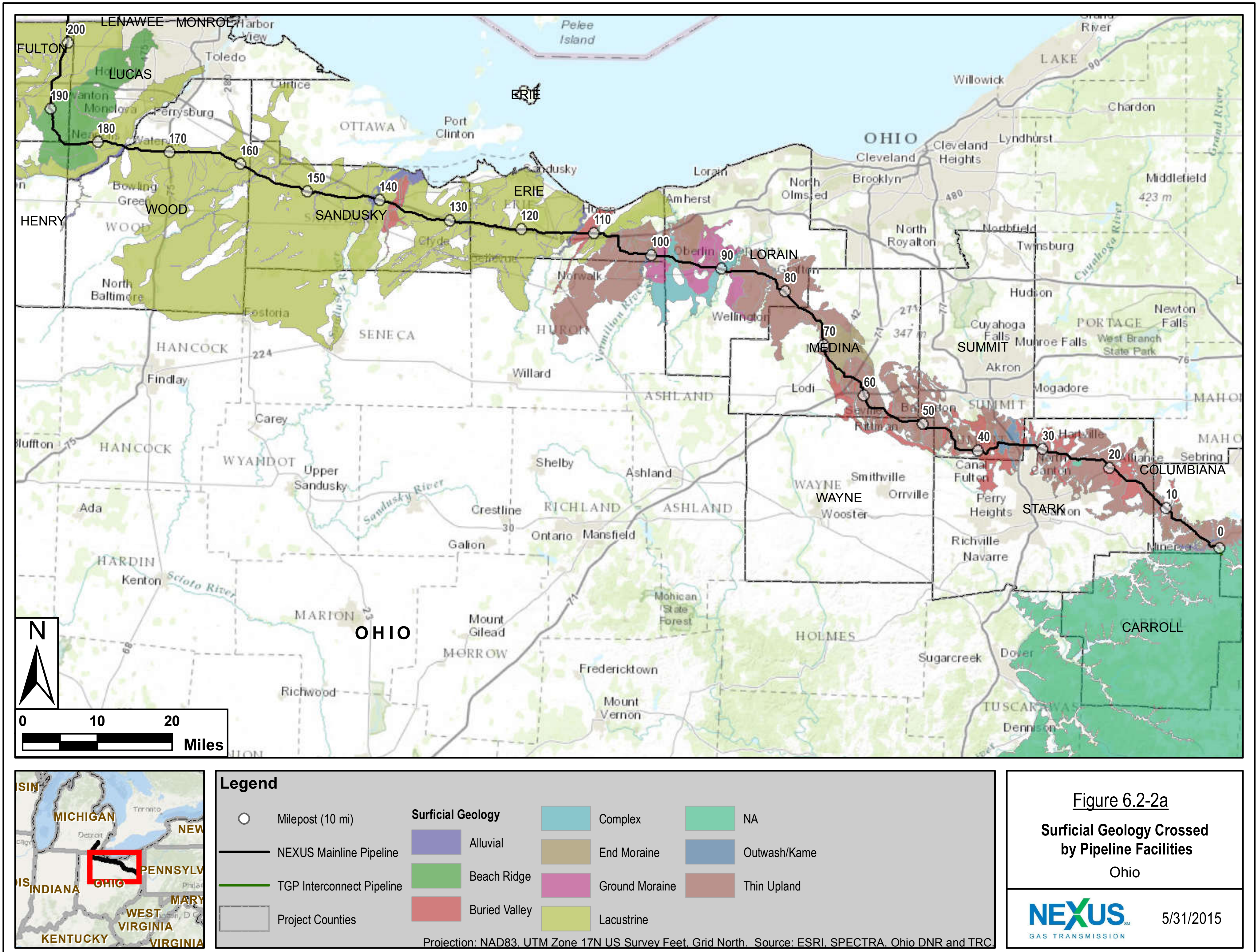
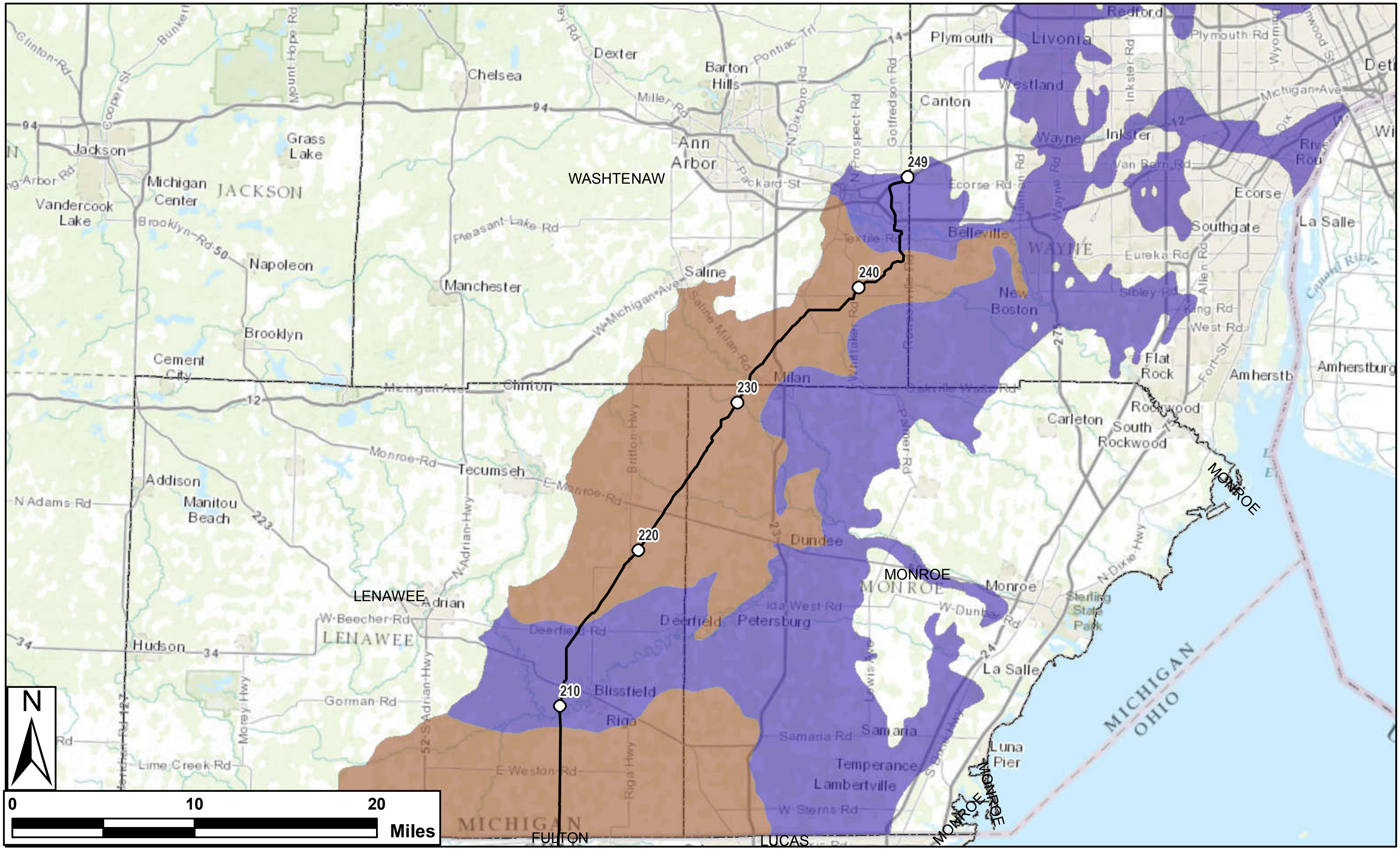



Figure 6.2-2a

**Surficial Geology Crossed by Pipeline Facilities**

Ohio





## Legend

- ○ Milepost (10 mi)
- NEXUS Mainline Pipeline
- Project Counties

**Surficial Geology**

- Lacustrine clay and silt
- Lacustrine sand and gravel

Projection: NAD83, UTM Zone 17N US Survey Feet, Grid North. Source: ESRI, SPECTRA, MI GIS Open Data and TRC.

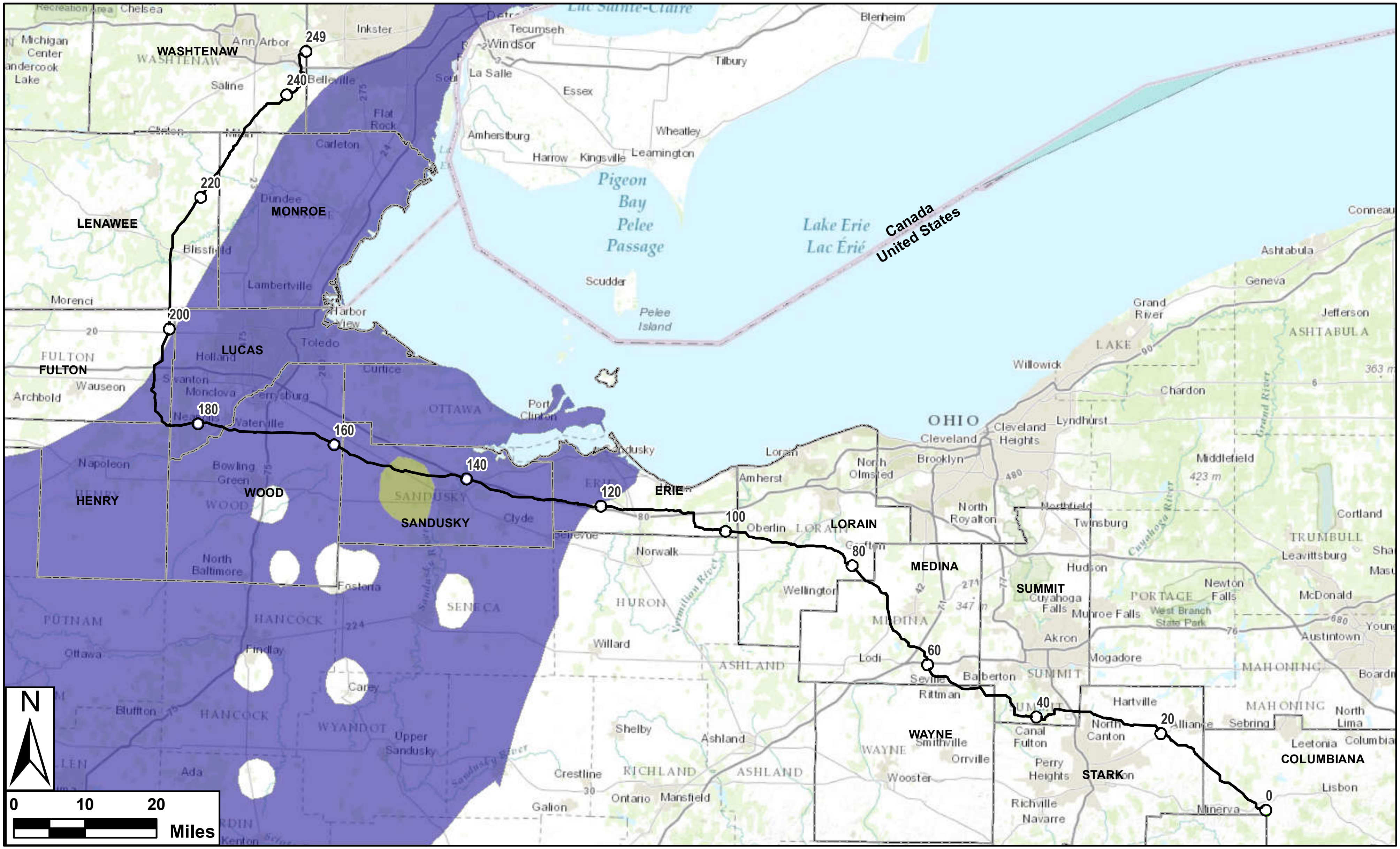
Figure 6.2-2b

**Surficial Geology Crossed by Pipeline Facilities**

Michigan

NEXUS GAS TRANSMISSION

5/31/2015





## Legend

- Milepost (20 mi)
- NEXUS Mainline Pipeline
- TGP Interconnect Pipeline
- Project Counties

**USGS Karst Type that Intersects Proposed Pipeline**

- Short 4
- Short 5

Projection: NAD83, UTM Zone 17N US Survey Feet, Grid North. Sources: ESRI, TRC, Ohio DNR, MI GIS Open Data and SPECTRA

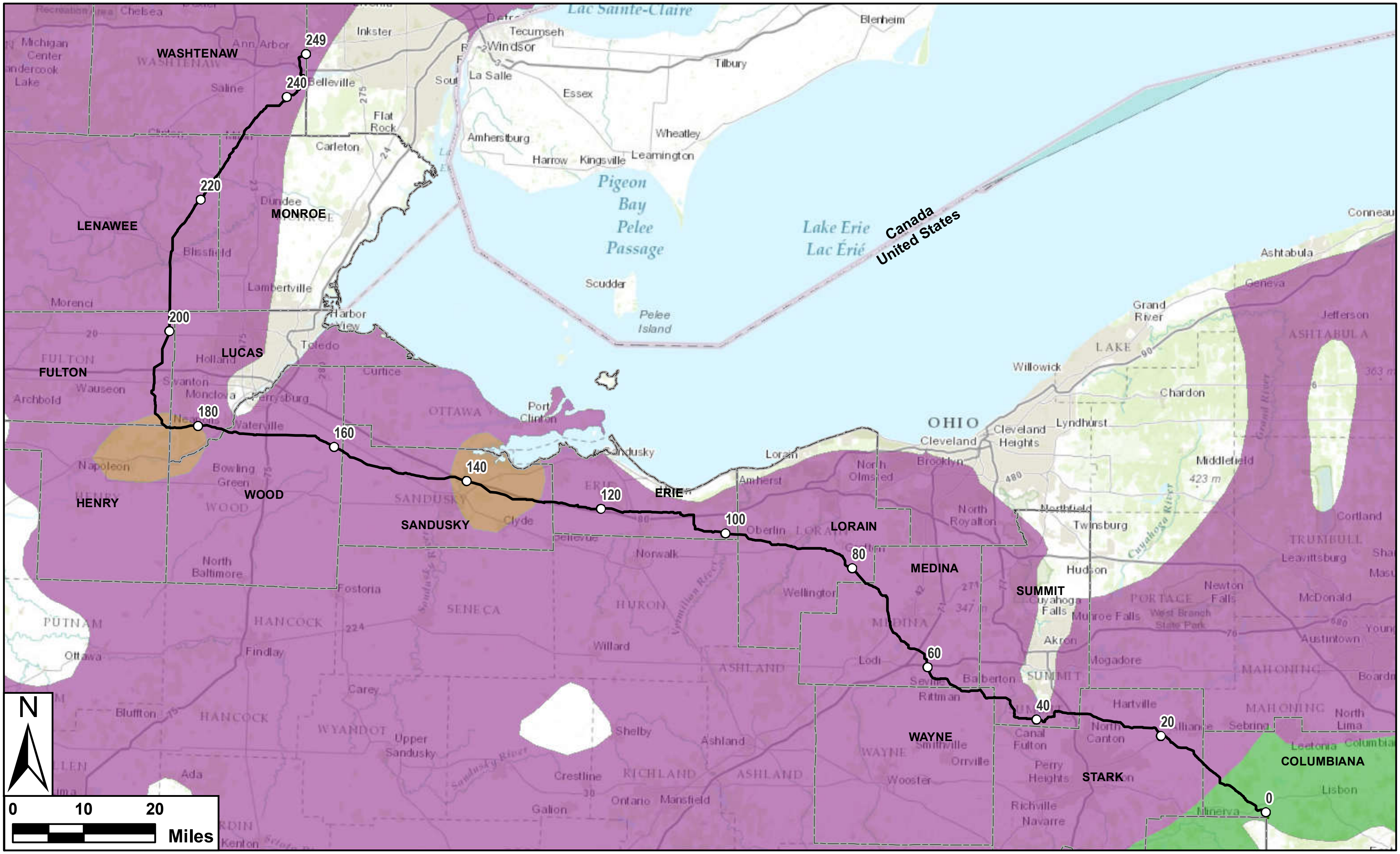
Figure 6.5-1

**Karst Areas Crossed by Pipeline Facilities**

Michigan and Ohio

NEXUS GAS TRANSMISSION

5/31/2015





**Legend**

- ○ Milepost (20 mi)
- NEXUS Mainline Pipeline
- TGP Interconnect Pipeline
- Project Counties

**Landslide Susceptibility Crossed by Proposed Pipeline**

- low
- sus-high
- sus-mod

Projection: NAD83, UTM Zone 17N US Survey Feet, Grid North. Sources: ESRI, Ohio DNR, TRC, USGS, MI GIS Open Data and SPECTRA

Figure 6.5-2

**Landslide Susceptibility Crossed by Pipeline Facilities**

Michigan and Ohio

NEXUS GAS TRANSMISSION

5/31/2015