Spire STL Pipeline Project

Draft Resource Report 6
Geological Resources

FERC Docket No. PF16-9-000

Pre-filing draft
October 2016

Public

RESOURCE REPORT 6 - GEOLOGICAL RESOURCES	
SUMMARY OF FILING INFORMATION	
Information	**Found in**
1. Identify the location (by milepost) of mineral resources and any planned or active surface mines crossed by the proposed facilities - Title 18 Code of Federal Regulations (CFR) part (§) 380.12 (h)(1 & 2)	Section 6.3 and Table 6.3-1.
2. Identify any geologic hazards to the proposed facilities - 18 CFR § 380.12 (h)(2)	Section 6.4.
3. Discuss the need for and locations where blasting may be necessary in order to construct the proposed facilities - 18 CFR § 380.12 (h)(3)	Section 6.2.
4. For liquefied natural gas (LNG) projects in seismic areas, the materials required by "Data Requirements for the Seismic Review of LNG Facilities," National Bureau of Standards Information Report 84-2833 - 18 CFR § 380.12 (h)(5)	Not applicable.
5. 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 - 18 CFR § 380.12 (h)(6)	Not applicable.
INFORMATION RECOMMENDED OR OFTEN MISSING	
1. Identify any sensitive paleontological resource areas crossed by the proposed facilities. (Usually only if raised in scoping or if the project affects federal lands.)	Section 6.6.
2. Briefly summarize the physiography and bedrock geology of the project.	Section 6.1.
3. If proposed pipeline crosses active drilling areas, describe plan for coordinating with drillers to ensure early identification of other companies' planned new wells, gathering lines, and aboveground facilities.	Section 6.3 and Table 6.3-1.

RESOURCE REPORT 6 - GEOLOGICAL RESOURCES	
INFORMATION RECOMMENDED OR OFTEN MISSING	
Information	**Found in**
4. If the application is for underground storage facilities: Describe monitoring of potential effects of the operation of adjacent storage or production facilities on the proposed facility, and vice versa; Describe measures taken to locate and determine the condition of old wells within the field and buffer zone and how the applicant would reduce risk from failure of known and undiscovered wells; and Identify and discuss safety and environmental safeguards required by state and federal drilling regulations.	Not applicable.

Table of Contents

Geologic Resources 6-6

6.1 Geologic Setting 6-6
6.1.1 MLRA 115C - Central Mississippi Valley Wooded Slopes, Northern Part 6-6
6.1.2 MLRA 108B - Illinois and Iowa Deep Loess and Drift, East-Central Part 6-7
6.1.3 MLRA 114B - Southern Illinois and Indiana Thin Loess and Till Plain, Western Part 6-7
6.1.4 MLRA 115B - Central Mississippi Valley Wooded Slopes, Western Part 6-7
6.2 Blasting 6-8
6.3 Mineral Resources 6-8
6.4 Geologic and Other Natural Hazards 6-11
6.4.1 Earthquakes/Seismic Risk 6-12
6.4.2 Underground Mining/Subsidence 6-15
6.4.3 Landslides 6-15
6.4.4 Karst 6-15
6.4.5 Flooding and Scour 6-17
6.5 Liquefied Natural Gas Facilities in Seismic Risk Areas 6-17
6.6 Paleontology 6-17
6.7 Geotechnical Investigations 6-18
6.8 References 6-18

Tables

6.3-1 Mineral Resources in the Vicinity of the Pipeline 6-9
6.4-1 Geologic Hazard Areas 6-11

Figures

6.4-1 USGS Forecast for Damage from Natural and Induced Earthquakes in 2016 6-13
6.4-2 USGS Forecast for Ground Shaking Intensity from Natural and Induced Earthquakes in 2016 6-14

Appendices

6-A Karst Mitigation Plan

6-B Geotechnical Investigation Report (to be provided in the FERC application)

Acronyms and Abbreviations

CFR	Code of Federal Regulations
FERC	Federal Energy Regulatory Commission
GIS	Geographic Information Systems
HDD	horizontal directional drill
ISGS	Illinois State Geological Survey
LRR	Land Resource Region
MDNR	Missouri Department of Natural Resources
MLRA	Major Land Resource Areas
MP	milepost
NMSZ	New Madrid Seismic Zone
Project	Spire STL Pipeline Project
Spire	Spire STL Pipeline LLC
USDA-NRCS	United States Department of Agriculture, Natural Resources Conservation Service
USGS	United States Geological Survey

Geologic Resources

6.1 Geologic Setting

This resource report identifies and describes the geological resources within the Spire STL Pipeline LLC ("Spire") Spire STL Pipeline Project ("Project"), the associated characteristics and limitations, and the proposed mitigation for impacts that may occur as a result of construction or operation of the Project. The Project is located in the Central Feed Grains and Livestock Region of the Interior Plains in Illinois and Missouri. The land surface of this Land Resource Region ("LRR") is typically nearly-level to gently-sloping dissected plain. The Project is located within four Major Land Resource Areas ("MLRAs") within this LRR. The MLRAs of the Project area are 115C- Central Mississippi Valley Wooded Slopes, Northern Part; 108B - Illinois and Iowa Deep Loess and Drift, East-Central; Part 114B - Southern Illinois and Indiana Thin Loess and Till Plain, Western Part; and MLRA 115B - Central Mississippi Valley Wooded Slopes, Western Part (USDA, 2006).

The 24-inch pipeline and its proposed facilities cross each of the four MLRAs, and Line 880 and its facilities is within one MLRA, as described below.

6.1.1 MLRA 115C - Central Mississippi Valley Wooded Slopes, Northern Part

From approximate milepost ("MP") 0.0 to MP 17.3, MP 30.7 to MP 31.8, MP 33.2 to MP 34.9, MP 37.3 to MP 44.6, and MP 44.9 to MP 48.9, the 24-inch pipeline is within the Central Mississippi Valley Wooded Slopes, Northern Part, MLRA. This MLRA is described as having well defined valleys with broad floodplains with numerous stream terraces along major streams and rivers. Floodplains along smaller streams are relatively narrow. Broad summits are nearly level to gently sloping. Elevation in this MLRA ranges from 420 feet along the Mississippi to 885 feet along the highest ridges. Local relief ranges from approximately 10 to 20 feet, but can range from 50 to 100 feet along drainageways and streams. Bluffs along the Illinois and Mississippi Rivers are up to 250 feet above valley floors.

According to the United States Department of Agriculture, Natural Resources Conservation Service ("USDA-NRCS"), uplands in this area are covered mostly with Wisconsin loess underlain dominantly by glacial drift consisting of distinct till units (USDA, 2006). Illinoian glacial drift is the dominant drift in Illinois. Pre-Illinoian drift is in the parts of this MLRA in Missouri. Unglaciated areas are in the southwestern portion of the part of the MLRA in Illinois. Wisconsin outwash deposits and sandy eolian material are on some of the stream terraces along the major tributaries. The glacial drift and loess deposits are underlain by several bedrock systems - the Pennsylvanian System occurs in the eastern part of the MLRA, the Mississippian System occurs along the Mississippi and Illinois Rivers, the Silurian System occurs in the northern and southern parts of the area, the Devonian System occurs only in the northern part of the area, and the Ordovician System occurs only in the southern part. Bedrock outcrops are common on the bluffs along the Mississippi River and its major tributaries and at the base of steep slopes along minor streams and drainageways.

6.1.2 MLRA 108B - Illinois and Iowa Deep Loess and Drift, East-Central Part

From approximate MP 17.3 to MP 30.7, and MP 31.8 to MP 33.2, the 24-inch pipeline crosses the Illinois and Iowa Deep Loess and Drift, East-Central Part MLRA. According to the USDA-NRCS, this entire MLRA was glaciated and has deposits of loess in varying thickness. This area is on a relatively young, moderately dissected to strongly dissected, rolling plain where stream terraces are adjacent to broad floodplains along major streams and rivers (USDA, 2006). Elevation generally ranges from 660 feet in the eastern and southern parts of the area to about 985 feet in the western and northern parts. The maximum local relief is about 160 feet along the major streams and along the dissected drainageways into the uplands. Relief is generally much lower in much of the area - typically three to 10 feet on the broad, flat uplands.

The area is underlain by Pennsylvanian shales, siltstones, limestones, and Ordovician and Silurian limestone. Coal beds are found to occur in the northern part as well as east of the Illinois River. Glacial drift covers the entire area, except for the bluffs along major streams. Glacial till in these parts is from the Illinoian age and consists of both distinct till units and sorted, stratified outwash from the Wisconsin age. The entire area is covered by a thick to moderately thin layer of Wisconsin loess, and in a few areas this loess directly overlies the bedrock.

6.1.3 MLRA 114B - Southern Illinois and Indiana Thin Loess and Till Plain, Western Part

From approximate MP 34.9 to MP 37.3, the 24-inch pipeline is located within the Southern Illinois and Indiana Thin Loess and Till Plain, Western Part MLRA. This MLRA is described as having well defined valleys with broad floodplains with numerous stream terraces along major streams and rivers. Floodplains along smaller streams are relatively narrow. Broad summits are nearly level to gently sloping. Elevation in this MLRA ranges from 350 feet along floodplains to 1,190 feet on the highest ridges. Local relief generally ranges from 10 to 50 feet, but can range from 50 to 100 feet along drainageways and streams.

According to the USDA-NRCS, the area is mainly covered with loess and Illinoian till (USDA, 2006). Meltwater outwash, and lacustrine and alluvial deposits can be found along streams and terraces along major tributaries. The glacial till and loess deposits are underlain by several bedrock systems - Middle and Late Mississippian bedrock occurs in the eastern part of the area, and Early and Middle Pennsylvanian bedrock occurs in the western part. Bedrock outcrops are common on the bluffs along the large rivers and their major tributaries. They also occur at the base of steep slopes along minor streams and drainageways.

6.1.4 MLRA 115B - Central Mississippi Valley Wooded Slopes, Western Part

From approximate MP 44.6 to MP 44.9, and MP 48.9 to MP 57.9, the 24-inch pipeline is within the Central Mississippi Valley Wooded Slopes, Western Part MLRA. Line 880 is located entirely within this MLRA. This MLRA consists mainly of deep dissected, loess-covered hills bordering the Missouri and Mississippi Rivers, their adjacent flood plains, and several relatively smooth, loess-mantled karst plains. The nearly level to very steep uplands are dissected by both large and small tributaries of the Mississippi River. Well defined valleys with broad floodplains and numerous stream terraces are along the major streams and rivers. The flood plains along the smaller streams are narrow. Broad summits are nearly level to gently sloping. Karst topography is common in this MLRA.

The well-developed karst areas have hundreds of sinkholes, caves, springs, and losing streams. Elevation ranges from 320 feet on the southernmost flood plain along the Mississippi River to 1,020 feet on the highest ridges. Local relief is mainly 10 to 50 feet, but is as much as 50 to 100 feet along drainageways and streams (USDA, 2006).

According to the USDA-NRCS, the uplands in this area are covered almost entirely with Wisconsin loess and underlain by Illinoian glacial drift. Wisconsin outwash deposits, alluvium, and sandy eolian material are on some of the stream terraces along the major tributaries in the area. The glacial deposits are underlain by several bedrock systems. The Mississippi System is the most extensive. Cherty dolostone and limestone are the most common rock types in this system. The Ordovician System is most common in more dissected areas and consists mostly of sandstone, dolostone, and limestone. Shale, sandstone, limestone, and coal in the Pennsylvanian System occur in the northeastern part of the MLRA, in both Illinois and Missouri. Bedrock outcrops are common on the bluffs along the Mississippi River and its major tributaries, and at the base of steep slopes along minor streams and valleys. Karst areas have formed where Mississippian or Ordovician limestone is near the surface. Many limestone and dolomite quarries are throughout the MLRA (USDA, 2006).

6.2 Blasting

The proposed Project may require blasting in non-glaciated areas such as along river bluffs and bases of steep slopes in drainageways. A Blasting Plan will be developed for the Project if it is determined that blasting is necessary, in order to minimize the potential for blasting-related adverse impacts, as well as address safety concerns. If blasting becomes required, Spire's construction contractor will be required to prepare a site-specific Blasting Plan for each blasting location. Where required, blasting/removal of bedrock will be conducted to a depth sufficient to install the pipeline, typically six to eight feet below the ground surface. Blasting charges will be limited to the minimum number and force necessary to fracture or loosen rock to the desired depth. Explosive products will be selected that have the appropriate water resistance for the site conditions to minimize the potential for adverse effects of the products on groundwater.

Testing for water quantity and quality parameters will be conducted for water wells located within 200 feet of proposed blasting areas where Spire has been granted access permission by the landowners. Spire will conduct testing prior to and after construction, and a qualified independent laboratory will analyze the results of the testing. Property damage resulting directly from blasting will be repaired or replaced. Spire is not aware of water main lines located within the vicinity of the potential blasting areas.

6.3 Mineral Resources

Based on review of the Project area, five surface mines are within 0.25 mile of the Project facilities, none of which cross the pipelines. No active surface mining or underground mining is within the construction right-of-way or Line 880 workspaces. Underground mining may have occurred from MP 0.0 through approximate MP 0.3 according to the Coal Mines in Illinois Viewer (ILMINES).

Mining activities could constitute a threat to the integrity of the proposed pipeline by way of surface subsidence and soil strains, as well as affect restoration efforts if mitigation measures are not implemented. Because of the narrow construction footprint of the proposed Project, impacts to the recovery of aggregates are anticipated to be minimal. The proposed Project facilities are surficial, and the impacts on oil and gas resource recovery also are anticipated to be minimal.

There are several gas and oil wells located near the proposed Project as this area has shallow natural gas and oil fields. A review of the publically available geographic information systems ("GIS") data for Scott, Greene, and Jersey Counties in Illinois, and St. Charles and St. Louis Counties in Missouri, identified a total of 23 oil and gas wells within 0.25 mile of the Project facilities. Of these, one is crossed by Project facilities in Illinois, and one is crossed by Project facilities in Missouri. Locations of existing wells within the Project workspace will be field verified through civil surveys prior to construction. Spire will work with the well-operator and landowner to make minor deviations of the line to avoid impact on any oil and gas well within the Project workspace. No negative affects to these wells are anticipated as a result of the Project.

Mineral resources that are crossed or are located within 0.25 mile of the proposed Project are listed in Table 6.3-1, based on a review of the Illinois State Geological Survey ("ISGS") and Missouri Department of Natural Resources (MDNR) GIS databases and maps (ISGS, 2016a; ISGS, 2016b; ISGS, 2014a-c; and MDNR, 2014a-d).

Table 6.3-1. Mineral Resources in the Vicinity of the Pipeline

Approximate MP	County, State	Mineral Resources	Status	Distance (feet)/Direction from Construction Work Area
24-Inch Pipeline				
0.0	Scott, Illinois	Mine	Unknown	836/Northeast
11.6	Greene, Illinois	Oil/Gas Well	Unknown	366/West
11.7	Greene, Illinois	Oil/Gas Well	Unknown	177/East
11.7	Greene, Illinois	Oil/Gas Well	Unknown	1,026/West
11.8	Greene, Illinois	Oil/Gas Well	Unknown	177/East
12.2	Greene, Illinois	Oil/Gas Well	Unknown	406/Southwest
12.4	Greene, Illinois	Oil/Gas Well	Unknown	1,275/Southwest
13.6	Greene, Illinois	Oil/Gas Well	Unknown	980/West
36.2	Jersey, Illinois	Oil/Gas Well	Unknown	343/South
41.8	Jersey, Illinois	Oil/Gas Well	Unknown	941/West
41.9	Jersey, Illinois	Oil/Gas Well	Unknown	Within the workspace
43.6	Jersey, Illinois	Oil/Gas Well	Unknown	1,184/East
44.5	Jersey, Illinois	Oil/Gas Well	Unknown	13/East

spire

Table 6.3-1. Mineral Resources in the Vicinity of the Pipeline (Continued)

Approximate MP	County, State	Mineral Resources	Status	Distance (feet)/Direction from Construction Work Area
24-Inch Pipeline (continued)				
53.6	St. Charles, Missouri	Oil/Gas Well	Abandoned	437/Southwest
53.6	St. Charles, Missouri	Oil/Gas Well	Plugged	295/Southwest
54.6	St. Charles, Missouri	Oil/Gas Well	Abandoned	Within the workspace
56.2	St. Charles, Missouri	Oil/Gas Well	Plugged	444/East
56.4	St. Charles, Missouri	Oil/Gas Well	Active	1,080/West
56.4	St. Charles, Missouri	Oil/Gas Well	Active	1,091/West
57.5	St. Louis, Missouri	Mine - Sand and Gravel Quarry	Producer	227/North
57.6	St. Louis, Missouri	Oil/Gas Well	Active	196/South
57.7	St. Louis, Missouri	Mine - Limestone Quarry	Open Pit	430/East
57.7	St. Louis, Missouri	Mine - Limestone Quarry	Producer	410/Southeast
57.9	St. Louis, Missouri	Oil/Gas Well	Abandoned	860/Southwest
57.95	St. Louis, Missouri	Oil/Gas Well	Active	571/West
Line 880				
0.5	St. Louis, Missouri	Mine - Limestone Quarry	Open Pit	430/East
1.1	St. Louis, Missouri	Mine - Limestone Quarry	Past Producer	1,218/East
1.7	St. Louis, Missouri	Oil/Gas Well	Active	867/Northeast
Redman Delivery Station				
5.4	St. Louis, Missouri	Oil/Gas Well	Plugged	82/West
Contractor Yard				
(N/A	Madison, Illinois	Indefinite Mine Boundary	Unknown	1,003/North
N/A	Madison, Illinois	Indefinite Mine Boundary	Unknown	1,091/West
N/A	Madison, Illinois	Mine	Abandoned	1,306/North
N/A	Madison, Illinois	Indefinite Mine Boundary	Unknown	1,030/West
N/A	Madison, Illinois	Mine	Abandoned	Within the workspace
N/A	Madison, Illinois	Mine	Unknown	1,109/Southwest
N/A	Madison, Illinois	Oil/Gas Well	Unknown	1,169/Southeast
N/A	Madison, Illinois	Mine	Abandoned	526/East
N/A	Madison, Illinois	Mine	Abandoned	672/East
N/A	Madison, Illinois	Mine	Abandoned	825/Northeast
N/A	Madison, Illinois	Indefinite Mine Boundary	Unknown	665/Southwest

Table 6.3-1. Mineral Resources in the Vicinity of the Pipeline (Continued)

Approximate MP	County, State	Mineral Resources	Status	Distance (feet)/Direction from Construction Work Area
Contractor Yard (continued)				
N/A	Madison, Illinois	Indefinite Mine Boundary	Unknown	912/South
N/A	Madison, Illinois	Indefinite Mine Boundary	Unknown	117/East
N/A	St. Charles, Missouri	Oil/Gas Well	Plugged	345/West
N/A	St. Charles, Missouri	Oil/Gas Well	Plugged	911/West

6.4 Geologic and Other Natural Hazards

Below is a discussion on geologic hazards that may exist or may potentially develop within the Project area. Geologic hazard areas that are crossed by or are located within a quarter-mile of the proposed Project are listed in Table 6.4-1.

Table 6.4-1. Geologic Hazard Areas

Nearest MP[1]	County	State	Hazard Type	Distance (feet)/Direction from Construction Work Area
24-Inch Pipeline				
0.0	Scott	Illinois	Abandoned Slope	836/Northeast
13.4	Greene	Illinois	Karst	1,018/West
42.5	Jersey	Illinois	Karst	0
57.7	St. Louis	Missouri	Sinkhole Area	1,021/ Northwest
57.8	St. Louis	Missouri	Sinkhole Area	1,005/Northwest
57.9	St. Louis	Missouri	Sinkhole Area	93/North
57.9	St. Louis	Missouri	Sinkhole Area	1,232/Northwest
57.9	St. Louis	Missouri	Sinkhole Area	514/Northwest
57.9	St. Louis	Missouri	Sinkhole Area	165/West
57.9	St. Louis	Missouri	Sinkhole Area	569/West
57.9	St. Louis	Missouri	Sinkhole Area	231/Southwest
Line 880				
0.7	St. Louis	Missouri	Sinkhole Area	0
1.8	St. Louis	Missouri	Sinkhole Area	824/Northeast

Table 6.4-1. Geologic Hazard Areas (Continued)

Nearest MP[1]	County	State	Hazard Type	Distance (feet)/Direction from Construction Work Area
Line 880 (continued)				
1.8	St. Louis	Missouri	Sinkhole Area	172/Northeast
1.8	St. Louis	Missouri	Sinkhole Area	231/East
1.9	St. Louis	Missouri	Sinkhole Area	545/East
1.9	St. Louis	Missouri	Sinkhole Area	0
2.1	St. Louis	Missouri	Sinkhole Area	0
4.4	St. Louis	Missouri	Sinkhole Area	888/Southwest
4.4	St. Louis	Missouri	Sinkhole Area	542/Southwest
Contractor Yard				
N/A	Madison	Illinois	Karst	1,040/South
N/A	Madison	Illinois	Underground	0

Note:

[1] For the 24-inch pipeline, nearest MP indicates the closest MP at the first instance of the Geological Hazard Area. For Line 880, nearest MP indicates the closest MP from where direction and distance was measured.

Sources: USGS Earthquake Hazards Program, Missouri Spatial Data Information Service, and Illinois State Geological Survey Data Clearinghouse.

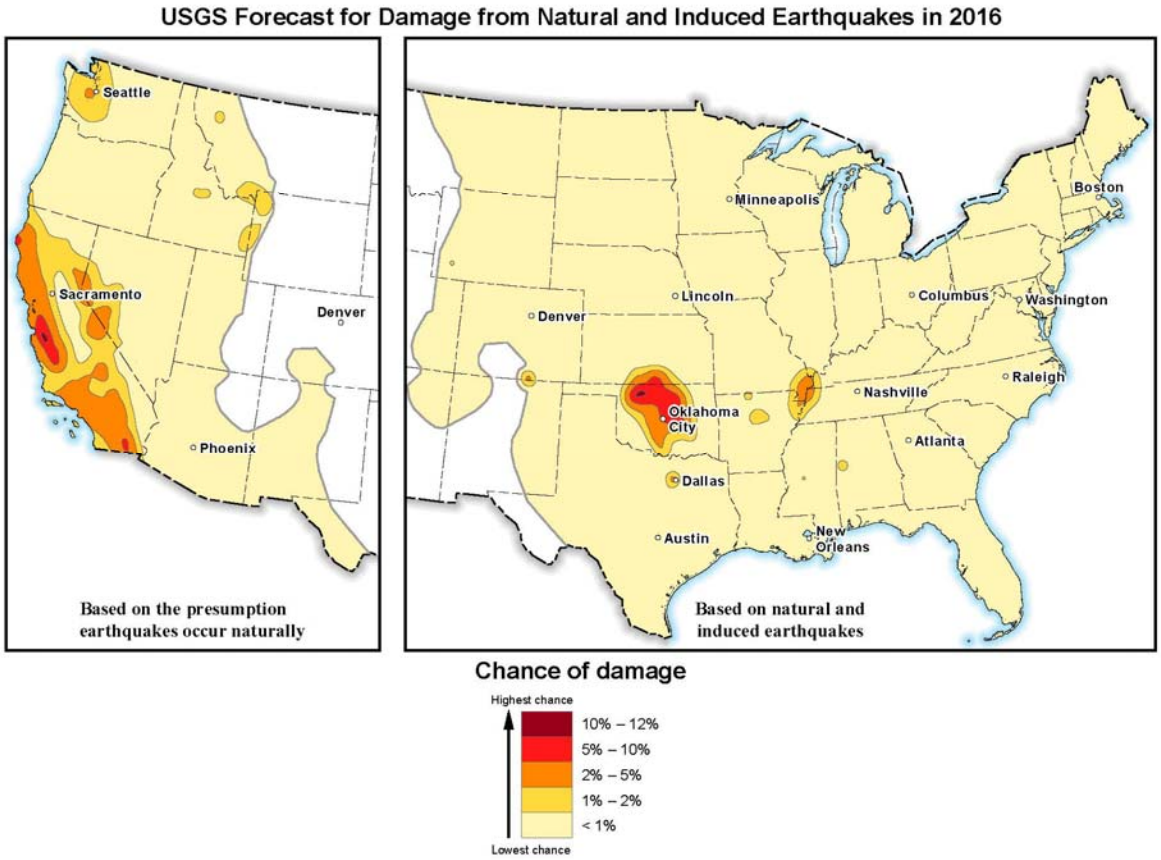
Data available from these sources for Illinois included earthquakes, faults, and sinkhole areas (karst). Information relative to flash flooding, volcanism, or landslides were not present or available in the data sources used. Additional information will be presented in subsequent filings if new information is identified.

Data available from these sources for Missouri included earthquakes, sinkhole areas, tectonic fault structures, and inventory of landslide incidences. Information relative to flash flooding and volcanism were not present or available in the data sources used. Additional information will be presented in subsequent filings if new information is identified.

6.4.1 Earthquakes/Seismic Risk

Seismic hazards in the Project area are relatively low, with mapped peak ground acceleration levels corresponding to the two percent in 50-year probabilities of exceedance, ranging from eight to 20 percent of gravity in Illinois, and 20 to 30 percent of gravity in Missouri (USGS, 2014). According to the United States Geological Survey (USGS) 2016 figure (Figure 6.4-1) depicting the forecast for damage from natural and induced earthquakes, portions of the Project are within an area with less than one percent chance of damage (USGS, 2016).

Figure 6.4-1. USGS Forecast for Damage from Natural and Induced Earthquakes in 2016

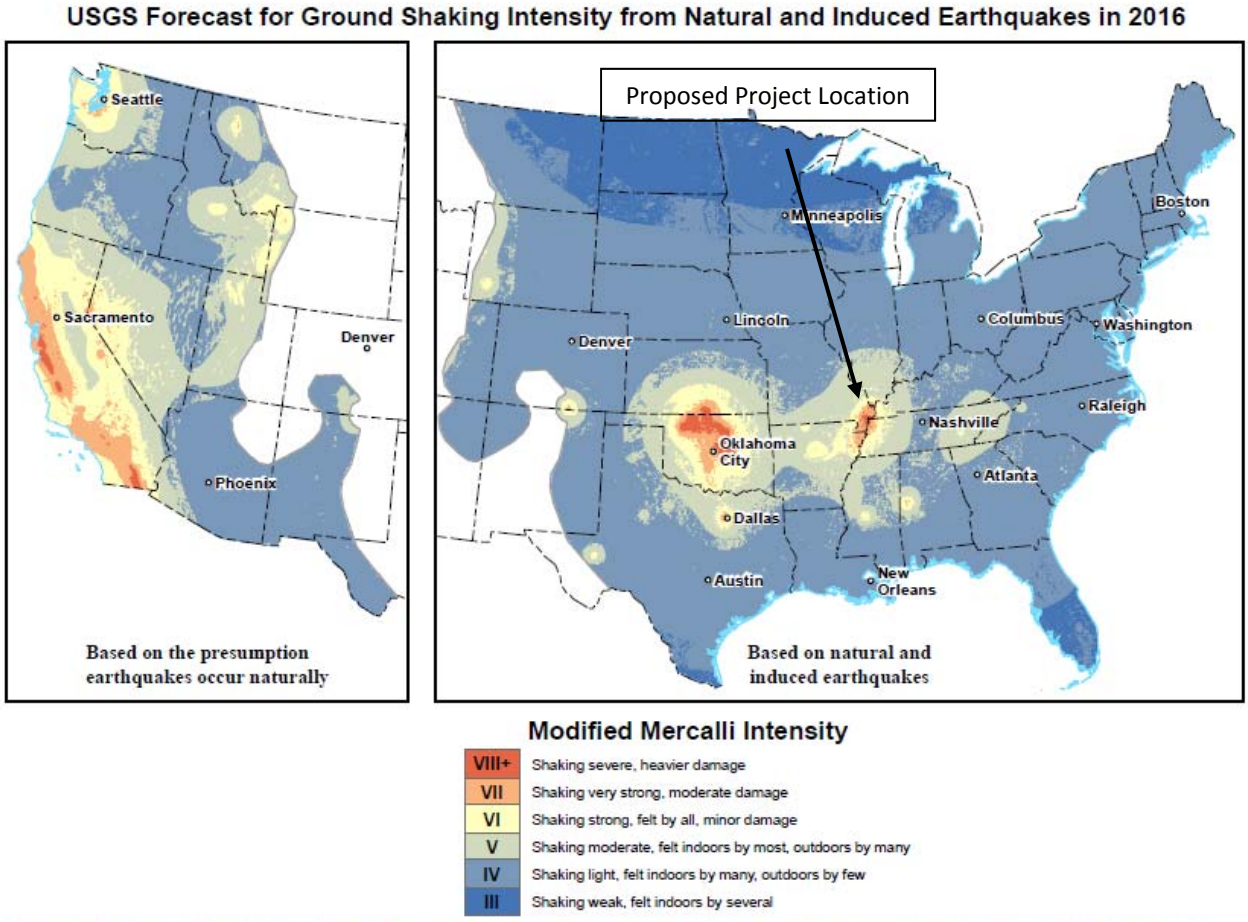


USGS map displaying potential to experience damage from natural or human-induced earthquakes in 2016. Chances range from less than 1 percent to 12 percent.

The Project is located northwest, and was routed to avoid an area of seismic activity referred to as the New Madrid Seismic Zone ("NMSZ"). According to the USGS, the NMSZ is the most active seismic area in the United States east of the Rocky Mountains. Due to the geologic conditions in the NMSZ, earthquakes in that region have the potential to damage an area approximately 20 times larger than earthquakes in California and most other active seismic areas. According to the USGS 2016 figure (Figure 6.4-2) depicting ground shaking intensity from earthquakes, the Project ranges from VI to V in Modified Mercalli Intensity. Areas of the Project may experience low ground shaking intensity described as "shaking light, felt indoors by many, outdoors by few" to moderate intensity, described as "shaking moderate, felt indoors by most, outdoors by many". According to the ISGS, recent earthquakes in Illinois occurred in January 2012 and February 2010. These earthquakes occurred in the northeastern part of the state, and are not located near the Project area.

According to the MDNR, small earthquakes and tremors occur frequently in the state, with thousands being noted since 1795.

Figure 6.4-2. USGS Forecast for Ground Shaking Intensity from Natural and Induced Earthquakes in 2016



USGS map displaying intensity of potential ground shaking from natural and human-induced earthquakes. There is a small chance (one percent) that ground shaking intensity will occur at this level or higher. There is a greater chance (99 percent) that ground shaking will be lower than what is displayed in these maps.

As depicted on Figure 6.4-1, the Project is within an area with less than one percent chance for damage. The pipeline will be built to 49 CFR Part 192 standards (PHMSA, 2016) which provide adequate protection for hazards that may cause the pipeline to move or sustain abnormal loads.

6.4.1.1 Active Faults

There are no active faults in the Project area according to the ISGS and MDNR GIS databases.

6.4.1.2 Soil Liquefaction

Soil liquefaction is the process by which stress exerted on soil during an earthquake can cause the soil to flow in liquid form. The probability of strong tremors from earthquakes ranges from low to moderate within portions of the Project area, according to the 2016 USGS figure above depicting the forecast for ground shaking intensity from

earthquakes. As previously mentioned, the Project is located outside of the NMSZ, which experienced four earthquakes of about magnitude 8 during the winter of 1811-1812. The NMSZ experienced significant area of disturbances that included soil liquefaction, landslides, and large fissures. The Project is located outside of the area of disturbance that occurred as a result of these earthquakes (Street, 1990).

6.4.2 Underground Mining/Subsidence

Underground mining may have occurred from MP 0.0 to MP 0.3 according to the Coal Mines in Illinois Viewer (ILMINES). Spire is verifying the location and coordinating with the landowner to determine if the Project is crossing this mine. Further information will be provided in the Federal Energy Regulatory Commission (FERC) application.

6.4.3 Landslides

In Illinois, the Project primarily crosses areas with a low landslide incidence. Before crossing the Mississippi River, the 24-inch pipeline traverses a short (less than one mile) area with high susceptibility and low incidence, as well as an area around five miles with high landslide incidence. The Project area in Missouri crosses areas with moderate susceptibility and low incidence of landslides (Godt, 1997).

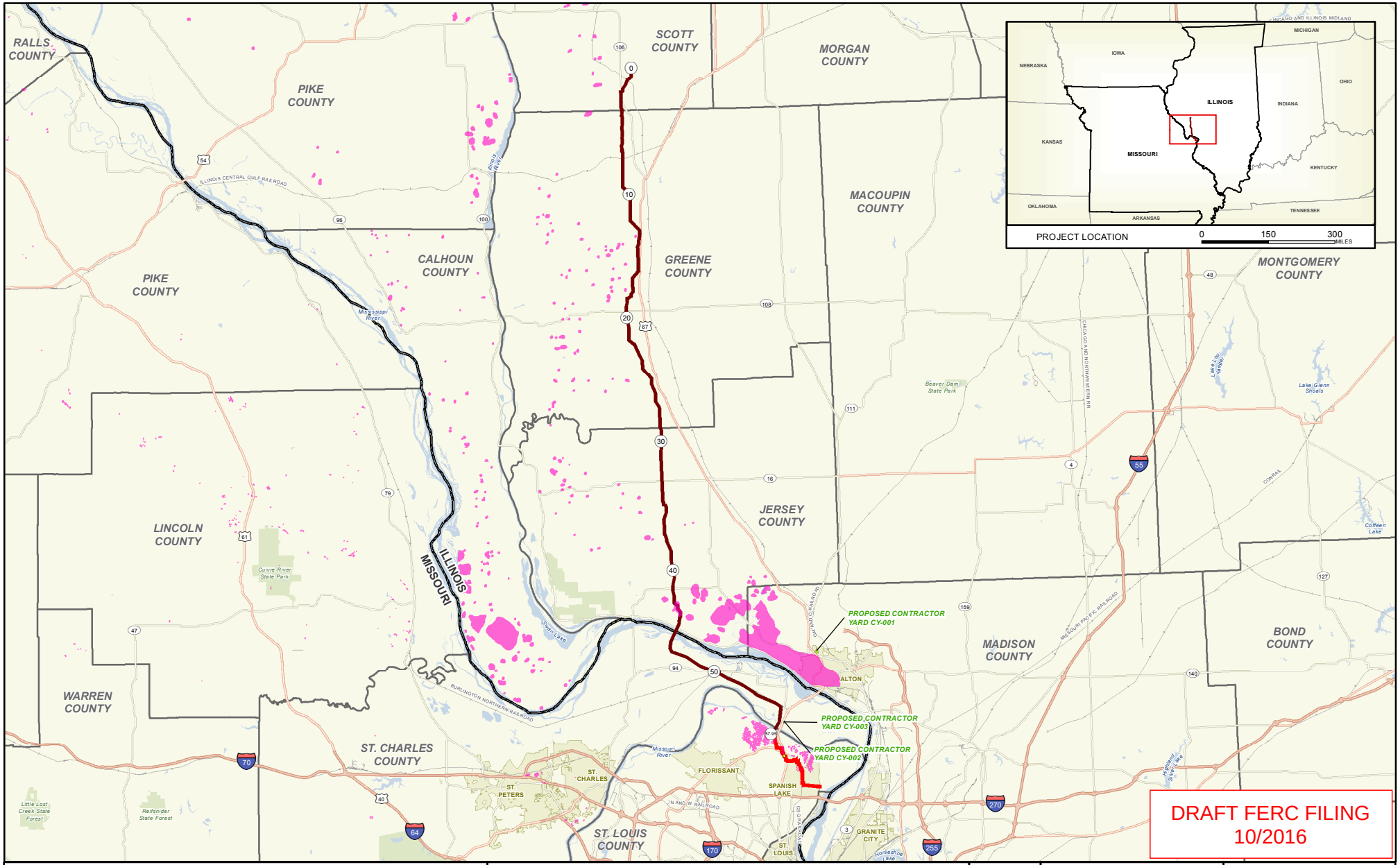
The vast majority of the 24-inch pipeline, including the proposed facilities, is proposed in locations with low landslide incidence. In areas with higher landslide incidence, Spire has routed the pipeline to avoid slopes where possible. Where steep slopes with a risk of landslide are encountered, Spire will follow the procedures for slope construction described in Resource Report 1. Existing facilities on Line 880 were designed and installed in accordance with 49 CFR Part 192 (PHMSA, 2016), which provides adequate protection from landslides and other hazards.

6.4.4 Karst

Karst is a landform that develops on or in limestone, dolomite, or gypsum by dissolution, and is characterized by the presence of characteristic features such as sinkholes, underground (or internal) drainage through solution-enlarged fractures (joints), and caves. Karst terrains develop due to the dissolution of carbonate bedrock. Karst features and resulting karst hazards are most common in areas where carbonate rocks either outcrop at the surface, or where they are shallow and buried with unconsolidated materials generally less than 50 feet thick. Hazards common to karst regions include sinkholes, springs, erratic surface water drainage and groundwater flow, and rapid movement of materials into and through the subsurface. Sinkholes and springs can also back up and cause local flooding during high-volume rain or snowmelt events.

Based on USGS Mineral Resources On-Line Spatial Database, the 24-inch pipeline traverses a karst area at approximate MP 42.5, and is located anywhere from approximately 93 to 1,232 feet from a sinkhole area from approximate MPs 57.7 to 57.9. The Line 880 traverses or ranges up to approximately 888 feet from a sinkhole area between MPs 0.7 to 4.4. Table 6.4-1 indicates mapped karst features within 1,500 feet of the Project and aboveground facilities. Figure 6.4-3 illustrates mapped karst terrain data identified within the Project area (ISGS, 2004).

Figure 6.4-3. Karst and Sinkhole Topography



- (1) MILE POST
- PROPOSED 24-INCH DIAMETER PIPELINE
- LINE 880 20-INCH DIAMETER RELOCATION
- EXISTING LINE 880 20-INCH DIAMETER PIPELINE
- INTERSTATE
- HIGHWAY
- MAJOR ROAD
- RAILROAD
- PROPOSED CONTRACTOR YARD
- KARST & SINKHOLE AREA
- PARK BOUNDARY
- WATERBODY
- COUNTY BOUNDARY
- STATE BOUNDARY

KARST DATA OBTAINED FROM THE ILLINOIS STATE GEOLOGICAL SURVEY.

SPIRE STL PIPELINE

KARST & SINKHOLE TOPOGRAPHY

SCOTT, GREENE, & JERSEY COUNTIES, ILLINOIS AND
ST. CHARLES & ST. LOUIS COUNTIES, MISSOURI

10 5 0 10 MILES

N W E S

ABSOLUTE SCALE: 1:633,600

REFERENCE SCALE: 1 IN = 10 MILES

Spire STL Pipeline

MOTT MACDONALD

DRAWN BY:	EAP 10/06/2016
CHECKED BY:	NDK 10/06/2016
APPROVED BY:	JW 10/19/2016
REV. DATE:	10/2016
REVISION:	0
DESC:	DRAFT FERC FILING
PAGE:	1 OF 1

G:\Spire\372453_StLouisPipeline\DataProd\Work\GIS\MXD\~FERC_FIGURES\SPIRE_STL_PIPELINE_FERC_S&K_MAP_8.5x11.mxd

Spire has prepared a Karst Mitigation Plan for construction in karst formations that describes mitigation methods, inspection and surveillance and staff training. This plan is included as Appendix 6-A

6.4.5 Flooding and Scour

Streams in the Project area may be affected by flash floods due to narrow river valleys, steep slopes, and rock-bottomed streams. Flash floods have the potential to cause damage to proposed facilities.

The MRT Bi-directional Station will be located within a 100-year FEMA floodplain. Additionally, MLV facilities 2 and 3 will be located within a 100-year FEMA floodplain. Spire will design aboveground facilities and pipelines to prevent and minimize impacts from high velocity flows.

For the pipelines, the trench will be excavated at least 12 inches wider than the diameter of the pipe, though the width may increase depending on the stability of the native soils. Spire is proposing to provide a minimum depth of cover of approximately five feet over the pipeline across waterbodies, with two feet of cover in areas of consolidated rock. The proposed cover will generally provide adequate scour protection from high flows and flooding. Prior to construction, field observations will be conducted to determine stability of the banks and appropriate bank stabilization techniques. In order to handle increased flows, additional pumps will be on standby for dam-and-pump crossings, or appropriately-sized flumes to handle the storm flows. After construction is completed, each crossing will be inspected periodically for signs of erosion and remediated as necessary.

6.5 Liquefied Natural Gas Facilities in Seismic Risk Areas

No Liquefied Natural Gas facilities are proposed as part of this Project, and therefore, this section is not required.

6.6 Paleontology

According to online resources, no paleontological sites appear to occur on the Project area (Paleontology Portal, 2016).

Illinois regulates paleontological resources on state and locally owned land, according to the Illinois Archaeological and Paleontological Resources Protection Act (20 ILCS 3435/.02) (from Chapter 127, paragraph 133c.02). Properties crossed by the Project that qualify for these conditions are state owned road right-of-ways; as these are previously disturbed, no impacts to these state regulated resources are anticipated.

Federal lands are crossed by the Project in Missouri. The USACE property is held in fee title by the USACE St. Louis District and is located on the south side of the Mississippi River at approximate MP 45.20. Spire is proposing to install the pipe via horizontal directional drill (“HDD”) at this property as part of its crossing of the Mississippi River. Construction workspaces will be placed outside of the property, therefore no earth disturbance of the USACE property is anticipated.

The MDNR indicates that fossils such as brachiopods, bryozoans, trilobite parts, etc. in shaly limestones of the Middle Ordovician Plattin and Decorah Formations, and bryozoans, brachiopods, etc. in shaly limestone of the

Meramecian Warsaw Formation may be present near the portion of the Project located in St. Louis County (MDNR, 2008).

Spire does not anticipate encountering significant areas of shallow bedrock on the Project, as discussed in Resource Report 7. The Project area is not located within a known paleontological site. Should a potential paleontological find be discovered during construction, Spire would follow applicable regulations and coordinate with the appropriate agency pursuant to their applicable jurisdiction.

6.7 Geotechnical Investigations

Spire intends to conduct geotechnical investigations at the Mississippi and Missouri River crossings to determine the feasibility of conducting a HDD of these rivers. It is expected that this data will assist Spire in avoiding potential geologic hazards related to the river crossings. These investigations will be summarized in a Geotechnical Investigation Report, included as Appendix 6-B, to be provided in the FERC application.

6.8 References

Godt, J. W. 1997. *Digital Representation of Landslide Overview Map of the Conterminous United States (U.S. Geological Survey Open-File Report 97-289-B)*. Accessed September 2016 from http://store.usgs.gov/b2c_usgs/b2c/usgs/netfile?file=//igskah cigssap05/mod/storefiles/PDF/19031_Digital_Landslide_Overview_1997.pdf.

Illinois General Assembly. *Illinois Compiled Statues.* Accessed October 2016 from http://www.ilga.gov/legislation/ilcs/ ilcs3.asp?ActID=375&.

Illinois State Geological Survey. 2014a. *Geographic Information Systems, GIS Mapping Services, Active Coal Mines in Illinois.* Data Set: GIS_Base.IL.ISGS_Mines_Active_2014_04.

Illinois State Geological Survey. 2014b. *Geographic Information Systems, GIS Mapping Services, Mines*. Data Set: GIS_Base.IL.ISGS_Mines_All_Point_2014_04.

Illinois State Geological Survey. 2014c. *Geographic Information Systems, GIS Mapping Services, Mines.* Data Set: GIS_Base.IL.ISGS_Mines_All_Poly_2014_04.

Illinois State Geological Survey. 2004a. *Geographic Information Systems, GIS Mapping Services, Sinkhole Areas*. Data set: GIS_Base.IL.ISGS_Sinkhole_Areas_2004_04.

Illinois State Geological Survey. 2004b. *Geographic Information Systems, GIS Mapping Services, Faults*. Data Set: GIS_Base.IL.USGS_Faults_2004.

Illinois State Geological Survey. *Illinois Quaternary Deposits*. Accessed September 2016 from http://isgs.illinois.edu/sites/isgs/files/maps/ statewide/quaternary-deposits-8x11.pdf.

Illinois State Geological Survey Prairie Research Institute. 2016a. *Coal Mines in Illinois Viewer (ILMINES)*. Accessed October 2016 from http://isgs.illinois.edu/ilmines.

Illinois State Geological Survey Prairie Research Institute. 2016b. *Scott County Coal Data.* Accessed October 2016 from http://isgs.illinois.edu/research/coal/maps/county/scott

Illinois State Geological Survey Prairie Research Institute. 2016c. *Recent Earthquakes*. Accessed October 2016 from http://isgs.illinois.edu/recent-earthquakes.

Illinois State Geological Survey Prairie Research Institute. 2005. *Bedrock Geology of Illinois*. IMAP 14. Accessed September 2016 from http://isgs.illinois.edu/content/bedrock-geology-map-illinois.

Missouri Department of Natural Resources. 2014a. *Geographic Information Systems, GIS Mapping Services, Abandoned Mines.* Data Set: GIS_Base.MO.MO_2014_Abandoned_Mine_Land_Project_Boundaries_shp.

Missouri Department of Natural Resources. 2014b. *Geographic Information Systems, GIS Mapping Services, Industrial Mineral Mines*. Data Set: GIS_Base.MO.MO_2014_Industrial_Mineral_Mines_shp.

Missouri Department of Natural Resources. 2014c. *Geographic Information Systems, GIS Mapping Services, Inventory of Mines.* Data Set: GIS_Base.MO.MO_2014_Inventory_of_Mines_Occurences_and_Prospects_shp.

Missouri Department of Natural Resources. 2014d. *Geographic Information Systems, GIS Mapping Services, Oil and Gas Wells*. Data Set: OIL_GAS_WELLS.

Missouri Department of Natural Resources, Division of Geology and Land Survey. 2008. *Collecting Missouri Fossils.* Accessed October 2016 from https://dnr.mo.gov/pubs/pub665.pdf.

Missouri Department of Natural Resources. 2005. *Geographic Information Systems, GIS Mapping Services, Faults.* Data Set: GIS_Base.MO.MOfaults_dd.

Missouri Department of Natural Resources. Undated. *History of Earthquakes in Missouri*. Accessed October 2016 from https://dnr.mo.gov/geology/geosrv/geores/historymoeqs.htm.

Street, Ronald L., and Otto W. Nuttli. *The Great Central Mississippi Valley Earthquakes of 1811-1812*. Publication no. Special Publication 14, Series XI, 1990. N.p.: n.p., n.d. Web.

The Paleontology Portal. *Illinois, US*. Accessed October 2016 from http://paleoportal.org/index.php?globalnav=time_space &sectionnav=state&name=Illinois.

The Paleontology Portal. *Missouri, US*. Accessed October 2016 from http://paleoportal.org/index.php?globalnav=time_space &sectionnav=state&name=Missouri.

United States Department of Agriculture, Natural Resources Conservation Service. 2006. Major Land Resource Regions Custom Report, Data Source: *USDA Agriculture Handbook* 296. Accessed September 2016 from http://soils.usda.gov/MLRAExplorer.

United States Department of Transportation Pipeline and Hazardous Materials Safety Administration. Accessed October 2016 from http://phmsa.dot.gov/pipeline/regs/notices.

United States Geological Survey. 2016. *USGA Forecast for Damage from Natural and Induced Earthquakes in 2016*. Accessed September 2016 from http://earthquake.usgs.gov/hazards/induced/images/ProbDamagEQ.pdf.

United States Geological Survey. 2014. *Seismic Hazard Map*. Accessed August 2016 from http://earthquake.usgs.gov/earthquakes/ byregion/illinois-haz.php.

United States Geological Survey. 2011. *US Physiographic Regions*. Accessed September 2016 from http://www.arcgis.com/home/ item.html?id=aecc78431a1f4ad7a45c65c2e8d17a3b.

United States Geological Survey. *Minerals Information. 2010-2011 Minerals Yearbook, Illinois*. Accessed September 2016 from http://minerals.usgs.gov/minerals/pubs/state/2012_13/myb2-2012_13-il.pdf.

United States Geological Survey. *Minerals Information. 2010-2011 Minerals Yearbook, Missouri*. Accessed September 2016 from http://minerals.usgs.gov/minerals/pubs/state/2010_11/myb2-2010_11-mo.pdf.

APPENDIX 6-A

Karst Mitigation Plan

Spire STL Pipeline Project

Karst Mitigation Plan

FERC Docket No. PF16-9-000

Draft
October 2016

Public

Table of Contents

Karst Mitigation Plan 1

1.1 Introduction 1

1.2 Karst Mitigation Methods 1

1.2.1 Pipeline Construction Activities and Other Earth Disturbances 1

1.3 Inspection, Monitoring and Surveillance 1

1.4 Plan Maintenance 1

1.5 Staff Training 1

Acronyms and Abbreviations

Project	Spire STL Pipeline Project
Spire	Spire STL Pipeline LLC

Karst Mitigation Plan

1.1 Introduction

This Karst Mitigation Plan describes the general measures to be implemented by Spire STL Pipeline LLC ("Spire") and its contractors to ensure that correct measures for construction in Karst formations are taken during construction of the Spire STL Pipeline Project ("Project"). Measures identified within this Karst Mitigation Plan outline methods that will be used on all work areas including temporary workspaces and access roads and outlines the recommended records to be maintained onsite during construction.

1.2 Karst Mitigation Methods

1.2.1 Pipeline Construction Activities and Other Earth Disturbances

Where large voids are encountered near the surface, Spire will excavate and fill using a method that preserves their local drainage function and still provides support for the pipeline that is deemed necessary. Mitigative and remedial measures will be implemented as needed to minimize the risk of subsidence.

The high-grade steel (Grade X70 with a 0.353-inch wall thickness) to be used to manufacture the pipeline can withstand loss of subgrade support approximately 28 feet in length without being compromised based on an analysis prepared by Mott MacDonald. This analysis indicates that even if an unmapped sinkhole is identified or develops below the pipeline, the pipeline will be able to safely span the sinkhole. Construction of the Project will be in accordance with U.S. Department of Transportation standards.

1.3 Inspection, Monitoring and Surveillance

As required by 49 Code of Federal Regulations Part 192.613, Spire will conduct route surveillance during construction and operation of the facilities, along with training of surveillance personnel, to monitor the pipeline right-of-way for evidence of subsidence, surface cracks, or depressions which could indicate sinkhole formation. Should any of these conditions be identified, Spire will implement corrective actions.

1.4 Plan Maintenance

A copy of this Karst Mitigation Plan will be retained on-site, and it will be made available to the federal, state, and local agencies upon request.

1.5 Staff Training

Training will be provided for all Project supervisory and inspection staff to be aware of the potential for sinkhole formation during construction. Staff will be trained to identify the signs of sinkhole formation.

APPENDIX 6-B

Geotechnical Investigation Report
(to be provided in the FERC application)