Spire STL Pipeline Project

Resource Report 6
Geological Resources

FERC Docket No. CP17-40-_ _ _

Amendment to FERC Application
April 2017

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) section (§) 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 and Table 6.4-1.
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 and Table 6.2-1.
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 and Table 6.1-1.
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.

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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
MDNR	Missouri Department of Natural Resources
MP	milepost
M&R	metering and regulating
NMSZ	New Madrid Seismic Zone
PHMSA	Pipeline and Hazardous Materials Safety Administration
PGA	peak ground acceleration
Project	Spire STL Pipeline Project
Spire	Spire STL Pipeline LLC
USACE	United States Army Corps of Engineers
USDA-NRCS	United States Department of Agriculture-Natural Resources Conservation Service
USEIA	United States Energy Information Administration
USGS	United States Geological Survey

Geologic Resources

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.

6.1 Geologic Setting

Both the 24-inch pipeline and the North County Extension are located within the Interior Plains Division, Central Lowland Province, and the Till Plains and the Dissected Till Plains Sections (United States Geological Survey ["USGS"] 2004).

The Central Lowland Province is the largest physiographic province extending from western New York to North Dakota and south to Texas. Characteristic features of the Central Lowlands are flat lands with geomorphic remnants of glaciation. The majority of this province is bounded by higher relief, with elevations in the region being 2,000 feet or less (United States Department of the Interior 2015).

Project facilities at the 24-inch pipeline in Illinois and in Missouri from milepost ("MP") 55.3 to 57.7, and those located east of the North County Extension MP 1.2 in Missouri, are within the Till Plains Section. The Till Plains are characterized by level to gently rolling till-plain (glacial ground moraine), with broad bottomlands and associated terraces with meander scars along major river valleys. This section is overlain by a series of low, undulating ridges (glacial end moraines). Relief along the floodplain margins of major rivers and larger tributaries can be 150 feet and greater. Elevation ranges from 600 to 1,000 feet, and local relief is predominantly three to 100 feet, but can range up to 165 feet along bedrock bluffs near major streams. This section is almost entirely covered by Pleistocene till and stratified drift up to 400 feet thick. The tills are of Kansan, Illinoisan, and Wisconsinan age (oldest to youngest, exposed west to east). Up to 25 feet of loess covers till and bedrock on bluffs overlooking the Mississippi's floodplain; the loess thins to the east. Bedrock beneath the drift is composed of lower Mississippian limestones, shales, and sandstones, which is well exposed on the uplands between the lower Illinois River and the Mississippi's floodplain, and in the bluffs overlooking the rivers. Silurian and Devonian carbonates crop out along the floodplain margins farther north. Mississippian and Pennsylvanian limestones, siltstones, and sandstones are exposed in erosional windows through the till along the Wabash River and its major tributaries [United States Department of Agriculture ("USDA")-Forest Service].

Project facilities located in the Dissected Till Plains section include the 24-inch pipeline from the Mississippi River to MP 55.3 and MP 1.2 to 6.0 on the North County Extension. The Dissected Till Plains are characterized by moderately dissected, glaciated, flat to rolling plains sloping gently toward the Missouri and Mississippi River valleys, with local relief at 20 to 65 feet. Elevation ranges from 500 to 1,500 feet. According to the Missouri Department of Natural Resources' ["MDNR"] *Generalized Geology Map of Missouri*, the Project in Missouri crosses primarily Quaternary but also Pennsylvanian and Mississippian aged bedrock (MDNR 2009). Though, characteristic of the Central Dissected Till Plains, Quaternary loess (unconsolidated aeolian silt) can be up to 25 feet thick,

Pleistocene (pre-Illinoisan) till and stratified drift underlie the loess and cover most bedrock areas up to 300 feet deep, and the Mississippi and Missouri floodplains have up to 150 feet of unconsolidated Tertiary and Quaternary alluvium (gravel, sand, silt, and clay) overlying bedrock (USDA-Forest Service). This section is mainly underlain by Pennsylvanian shale, limestone, and minor coal; and bedrock is exposed locally along the deeper drainages and in windows eroded through the unconsolidated surficial material (USDA-Forest Service). According to the USDA-Natural Resources Conservation Service ("NRCS") Web Soil Surveys for Greene, Jersey, and Scott Counties, Illinois, and St. Charles and St. Louis Counties, Missouri, the Project is not anticipated to cross areas of shallow bedrock (i.e., areas where bedrock may be found less than five feet below the surface) (2015a and 2015b).

MDNR (Stout 2017) indicated that "the uppermost bedrock in the project area is the Mississippian-age Ste. Genevieve Limestone", which is included on USGS's *Bedrock Geologic Map of the St. Louis 30' x 60' Quadrangle, Missouri and Illinois* (Harrison 1997), in addition to bedrock of the Cherokee Group and Alluvium. As discussed in Section 6.4.4 and Table 6.4-1, one sink area (an indicator of karst terrain) has been field-verified on the North County Extension. Spire is completing geotechnical investigations of the proposed HDDs on the North County Extension to determine the depth at which karst is present. Spire's Karst Mitigation Plan is provided as Appendix 6-A to address unanticipated karst findings during construction. Based on the results of the remaining geotechnical investigations, Spire will evaluate if route adjustments or mitigation measures should be considered.

For topographic details including elevations relative to mean sea level along the route, see the USGS 7.5-minute series topographic quadrangle maps, located in Resource Report 1, Appendix 1-A.

6.2 Blasting

The 24-inch pipeline portion of the Project may require blasting in non-glaciated areas such as along river bluffs and bases of steep slopes in drainage ways. A Blasting Plan has been developed for the Project in order to minimize the potential for blasting-related adverse impacts, as well as address safety concerns; this plan is provided as Appendix 6-C. Though areas of shallow bedrock are not anticipated to be encountered, if 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. The explosive products selected will 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 provide 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.

As further discussed in the Blasting Plan, in lieu of blasting in areas of shallow bedrock, rock encountered during trenching would be removed using one of the following techniques: conventional excavation with a backhoe, hammering with a pointed backhoe attachment or pneumatic rock hammer followed by backhoe excavation, or

ripping with a bulldozer. Rock removal techniques would depend upon rock properties such as relative hardness, fracture susceptibility, expected volume, and location.

Table 6.2-1 provides the locations along the Project where blasting is anticipated.

Table 6.2-1. Locations of Proposed Blasting

County, State	Begin MP	End MP	Soil Type	Utilities within Blasting Radius (400 feet)[1,2]
24-Inch Pipeline				
Jersey County, Illinois	44.94	44.95	Rock Outcrop, Limestone-Lacrescent Complex	• One Nustar ammonia pipeline is located approximately 65 feet west of the proposed pipeline
St. Louis County, Missouri	58.24	58.62	Pits, Quarry	• Utility overhead lines would run along the quarry road in close proximity to the proposed pipeline; and • There are four locations where the overhead lines would cross the proposed centerline.
North County Extension[3]				
St. Louis County, Missouri	N/A	N/A	N/A	N/A

Notes:

The delineation to identify locations where blasting is anticipated was performed using desktop analysis of the USDA-NRCS Web Soil Surveys for Scott, Greene, and Jersey Counties, Illinois and St. Charles and St. Louis Counties, Missouri. Blasting was not assumed to be required in loam soils.

1 A trench width of 10 feet is assumed.

2 Confirmed by civil survey.

3 N/A = Not Applicable; no blasting is anticipated.

6.3 Mineral Resources

6.3.1 Illinois

According to the United States Energy Information Administration ("USEIA"), Illinois' fossil fuel resources include substantial coal reserves and some crude oil (USEIA 2016a). Illinois' crude oil production and reserves are modest and are generally located in the southern half of the state (USEIA 2016a). Production peaked in the middle of the 20th century and most wells now operating in the state produce less than two barrels of crude oil per day. According to the Illinois Department of Natural Resources ["IDNR"], approximately 800 drilling permits for oil, gas,

and injection wells are issued each year, with most of the production located in the southern portion of the state (2016). The oil producing area of Illinois is part of a geologic structure known as the Illinois Basin, which covers southern Illinois, western Kentucky, and western Indiana (IDNR 2016). The Project is located on the fringe of the formation (Illinois State Geological Survey ["ISGS"] 2016e).

Illinois has few producing natural gas wells and minimal production, but is second only to Michigan in total natural gas storage capacity, with 28 natural gas fields located within the state (USEIA 2016a).

Five percent of United States coal is produced from Illinois' 24 active bituminous coal mines (USEIA 2016a).

6.3.2 Missouri

According to the USEIA, Missouri has little fossil fuel production, but does have fossil fuel resources that have not been fully developed such as tar sands, coalbed methane, and oil shales (USEIA 2016b). Crude oil production in the state is less than 0.01 percent of the United States totals (USEIA 2016b). Presently there are three areas of current oil and gas production in Missouri - the Forest City Basin in northwestern Missouri, the Bourbon Arch in western Missouri, and the Lincoln Fold in northeastern Missouri; the Project is located within the Lincoln Fold (MDNR 2016a).

Missouri does not have natural gas reserves and only a small amount of natural gas production (USEIA 2016b). Approximately one-third of the state is underlain by coal seams that potentially could produce coalbed methane, with deposits located in the northwest, north-central, and west-central portions of the state. Missouri has one natural gas storage field located near St. Louis (USEIA 2016b). Little to no gas is produced for commercial sale in Missouri; however there are 45 registered wells for private use and two large wells produced gas for a private company (MDNR 2016a). According to the MDNR, no new wells are under construction within St. Charles and St. Louis Counties (2016b). The last recorded active wells in St. Charles and St. Louis Counties were drilled in 1975 and 2012, respectively (MDNR 2016b).

Missouri's current coal production is modest and equals only approximately one percent of the coal consumed within the state (USEIA 2016b).

6.3.3 Existing Resources

A review of the publicly available geographic information systems ("GIS") data for Scott, Greene, and Jersey Counties in Illinois, and St. Charles and St. Louis Counties in Missouri, identified oil and gas wells within 0.25-mile of the Project facilities, as identified in Table 6.3-1. No oil and gas resources were identified within the proposed REX Receipt Station, the Laclede/Lange Delivery Station, or the Chain of Rocks Station.

Locations of existing wells within the Project workspace will be field verified prior to construction. Spire will work with the well-operator and landowner to make minor deviations to the line to avoid impact on any oil and gas well within the Project workspace, therefore no negative affects to these wells are anticipated as a result of the Project. 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 shallow, and the impacts on oil and gas resource recovery also are anticipated to be minimal.

When present in a project area, 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. Mineral resources that are crossed or are located within 0.25-mile of the proposed Project are also listed in Table 6.3-1, based on a review of the ISGS and 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[1]	Distance (feet)/Direction from Construction Work Area
24-Inch Pipeline				
0.0R	Scott, Illinois	Coal Slope	Abandoned	1,097/Northeast
0.0R	Scott, Illinois	Coal Strip Mine	Abandoned	1,035/Northwest
0.0R	Scott, Illinois	Clay Mine	Abandoned	0/East
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
24.8R	Greene, Illinois	Oil/Gas Well	Unknown	1,033/West
36.7R	Jersey, Illinois	Oil/Gas Well	Unknown	34/South
42.3	Jersey, Illinois	Oil/Gas Well	Unknown	941/West
42.3	Jersey, Illinois	Oil/Gas Well	Unknown	Within the Workspace
44.2	Jersey, Illinois	Oil/Gas Well	Unknown	1,140/East
45.0	Jersey, Illinois	Oil/Gas Well	Unknown	13/East
53.3	St. Charles, Missouri	Oil/Gas Well	Abandoned	713/Southwest

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

Approximate MP	County, State	Mineral Resources	Status[1]	Distance (feet)/Direction from Construction Work Area
24-Inch Pipeline (continued)				
54.3	St. Charles, Missouri	Oil/Gas Well	Plugged	1,010/Southwest
55.3	St. Charles, Missouri	Oil/Gas Well	Abandoned	391/Southwest
56.9	St. Charles, Missouri	Oil/Gas Well	Plugged	444/East
57.1	St. Charles, Missouri	Oil/Gas Well	Active	1,080/West
57.1	St. Charles, Missouri	Oil/Gas Well	Active	1,091/West
58.2	St. Louis, Missouri	Mine - Sand and Gravel Quarry	Producer	227/North
58.3	St. Louis, Missouri	Oil/Gas Well	Active	196/South
58.4	St. Louis, Missouri	Mine - Limestone Quarry	Open Pit	410/East
58.5	St. Louis, Missouri	Mine - Limestone Quarry	Producer	420/East
58.8	St. Louis, Missouri	Oil/Gas Well	Abandoned	636/West
58.8	St. Louis, Missouri	Oil/Gas Well	Active	534/Northwest
58.8	St. Louis, Missouri	Oil/Gas Well	Unknown	1,242/Northwest
North County Extension				
1.3	St. Louis, Missouri	Oil/Gas Well	Unknown	1,189/South
1.9	St. Louis, Missouri	Oil/Gas Well	Unknown	1,078/Northeast
3.8	St. Louis, Missouri	Oil/Gas Well	Unknown	448/Southwest
4.9	St. Louis, Missouri	Oil/Gas Well	Unknown	161/East

Note:

Data is sourced from Illinois GIS sources included: Oil and Gas Fields (2016), Mines-Active (2016), Mines-All (2016), and Wells-Boring Location (2016). Missouri GIS sources included: Industrial Mineral Mines (2014), Inventory of Mine Occurrences and Prospects (2014), State Permitted Oil and Gas Wells (2014) and Wells (2015).

1 "Producer" refers to an active mine and "Past Producer" refers to a mine no longer in operation or abandoned (Mulvany 2016).

Based on Spire's review of publically available databases and maps, no known planned mines or expansion of planned mines were located in the Project areas. Based on consultations with the Central Stone quarry at MP 58.8, no expansion plans of their facility are planned in the foreseeable future. In addition, Spire reviewed the IDNR (2017) Illinois Coal Mine Permits viewer, which displays spatial data such as permit boundaries, National Pollutant

Discharge Elimination System points for mine permits, affected areas, surface mine areas, underground mine areas, mine shaft and facilities, aggregate sites, and abandon mined lands; no planned, current, or abandoned mine locations are in the vicinity of the Project. Spire also reviewed the United States Army Corps of Engineers ("USACE") St. Louis District public notices to determine if any planned mining projects were located in the vicinity of the Project area. Based on a review of this information, no active coal mining activities were identified within the vicinity of the Project.

If an unknown well (orphan well) is uncovered within the Project area, Spire would have the well pre-inspected by a professional to determine the condition of the well. Minimizing the equipment traffic and vibration in the area as well as maximizing the offset distance are precautions that may help alleviate well disturbance. After construction is complete, another post-inspection would be conducted to verify if any damage has occurred.

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 0.25-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/Direction from Construction Work Area (feet)[2]
24-Inch Pipeline				
13.5	Greene	Illinois	Karst	1,020 W
40.0-45.1	Jersey	Illinois	High Susceptibility for Landslides with Moderate Incidence	0[4]
40.0-45.1	Jersey	Illinois	High Susceptibility for Landslides with Low Incidence	0[4]
43.1-44.1	Jersey	Illinois	Karst	0[3]
46.0-58.8	St. Charles, St. Louis	Missouri	Moderate Susceptibility for Landslides with Low Incidence	0[4]
58.4	St. Louis	Missouri	Sink Area	1,078 W
58.4	St. Louis	Missouri	Sink Area	1,156 W
58.8	St. Louis	Missouri	Sink Area	0[3], 289 N, 296 N, 442 W, 625 NW
North County Extension				
0.0-6.0	St. Louis	Missouri	Moderate Susceptibility for Landslides with Low Incidence	0[4]
0.3	St. Louis	Missouri	Sink Area	954 W
0.5	St. Louis	Missouri	Sink Area	0[3]
1.6	St. Louis	Missouri	Sink Area	103 N[5]

Table 6.4-1. Geologic Hazard Areas (Continued)

Nearest MP[1]	County	State	Hazard Type	Distance/Direction from Construction Work Area (feet)[2]
North County Extension (continued)				
1.6	St. Louis	Missouri	Sink Area	705 NE
1.7	St. Louis	Missouri	Sink Area	48 NE, 539 NE
1.8	St. Louis	Missouri	Sink Area	206 SW, 587 NE
2.0	St. Louis	Missouri	Sink Area	05, 6
2.4	St. Louis	Missouri	Sink Area	1012 N
2.5	St. Louis	Missouri	Sink Area	03,75 SW
2.6	St. Louis	Missouri	Sink Area	73 NE3
3.2	St. Louis	Missouri	Sink Area	1220 S
3.8	St. Louis	Missouri	Sink Area	250 NE
4.0	St. Louis	Missouri	Sink Area	03, 468 SW
4.3	St. Louis	Missouri	Sink Area	655 NE
4.5	St. Louis	Missouri	Sink Area	44 NW7
6.0	St. Louis	Missouri	St. Louis Fault	174 E

Notes:

Hazard areas shown in the table are a combination field delineation and desktop review of the following public data sources: USGS Earthquake Hazards Program, Missouri Spatial Data Information Service (MSDIS), and Illinois State Geological Survey Data Clearinghouse. Data available from these sources for Illinois included earthquakes, faults, and sinkhole and karst. Spatial data relative to flash flooding, or volcanism were not present or available in the data sources used. Data available from these sources for Missouri included earthquakes, sink areas, and tectonic fault structures. The Project crosses a karst area identified in desktop review; a portion of which has been surveyed and no surface evidence of karst was identified.

1 Nearest MP indicates the closest MP from where direction and distance to workspace was measured.

2 Where desktop data shows a cluster of sink area data points, they are shown on one row as they are assumed to be associated to the same geologic feature.

3 Sinkholes are not anticipated to be a concern to Project activities due to a combination of field reconnaissance and review of aerial imagery. Field surveys have been conducted at the 24-inch pipeline's MP 43.1 to 43.9 and 58.8 and the North County Extension's MP 0.5 and sinkholes were not located. Aerials at MP 43.9 to 44.1 do not appear to have sinkholes and will be field verified during surveys once landowner permission has been obtained. MSDIS desktop data indicates sinkhole areas at are located along the North County Extension near MP 2.5, 2.6, and 4.0; however, field survey indicates wetlands in these locations which suggests the area is stable enough to hold water. Desktop data was not investigated outside of the permissible study area which generally ranged from 200 to 300 feet along the North County Extension.

4 Landslide susceptibility is based on USGS mapping and MPs are approximate (Godt 1997). The pipeline has been routed to avoid slopes where possible.

5 Field confirmed sinkhole.

6 Area is proposed to be crossed by HDD.

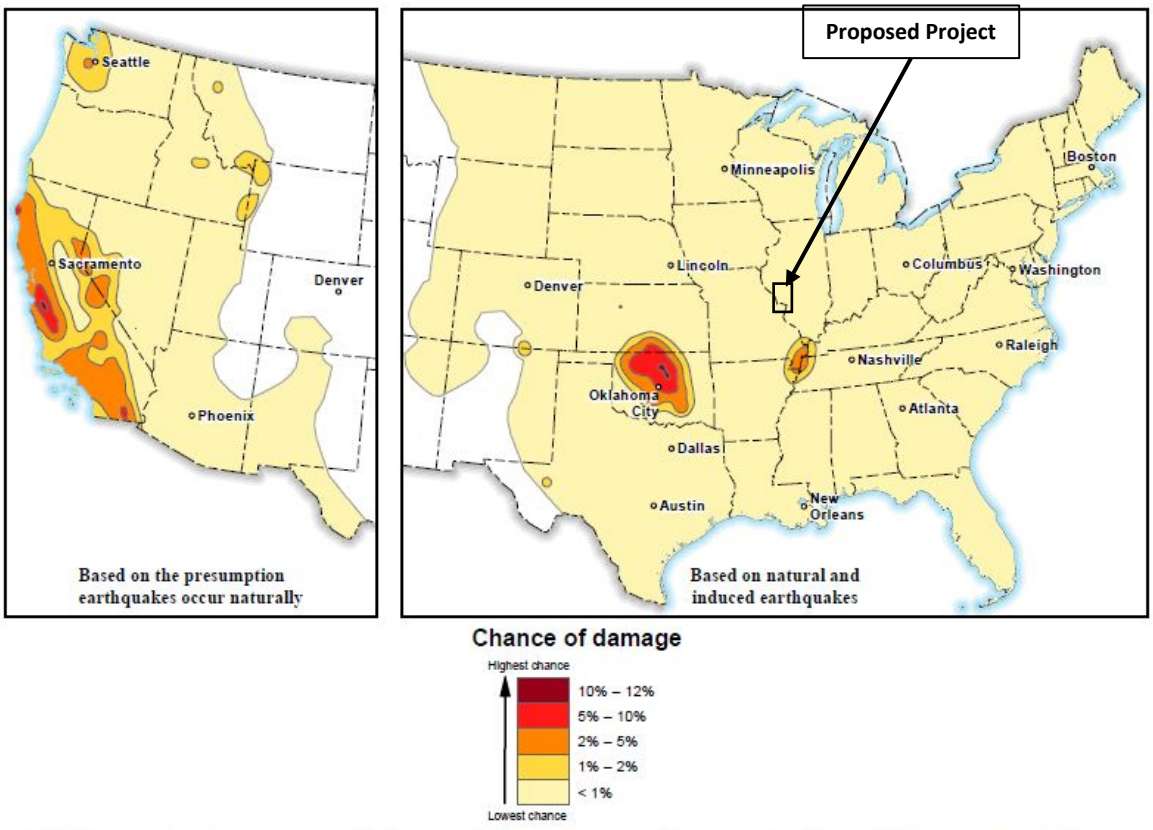
7 MSDIS desktop data sinkhole area was within the field crew's study area, and no sinkhole was located by the survey crew.

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 USGS 2017 figure (Figure 6.4-1) depicting the forecast for damage from natural and induced earthquakes, the Project is within an area with less than one percent chance for damage from natural and induced earthquakes and therefore damages occurring to the pipeline are not anticipated to be a major concern (USGS 2017).

Additionally, the pipeline will be built to 49 CFR Part 192 standards (Pipeline and Hazardous Materials Safety Administration ["PHMSA"] 2016) which provide adequate protection for hazards that may cause the pipeline to move or sustain abnormal loads (US Government Publishing Office 2016).

Figure 6.4-1. USGS Forecast for Damage from Natural and Induced Earthquakes in 2017

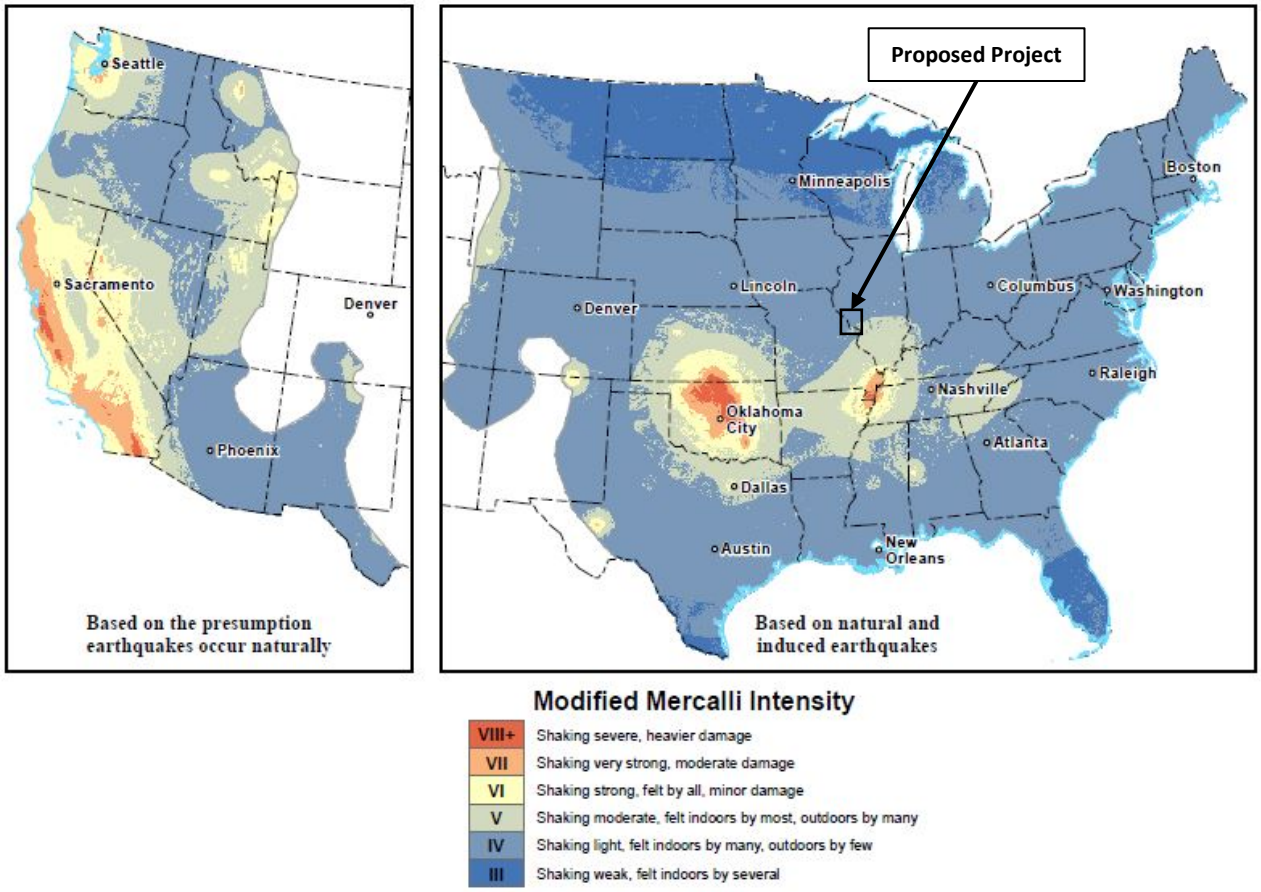


USGS map displaying potential to experience damage from natural or human-induced earthquakes in 2017. Chances range from less than 1 percent to 12 percent.

The Project is located approximately 100 miles northwest of, and was routed to avoid, an area of seismic activity referred to as the New Madrid Seismic Zone ("NMSZ") (United States Department of the Interior 2009). 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 2017 figure (Figure 6.4-2) depicting ground shaking intensity from earthquakes, the Project ranges from IV to V in Modified Mercalli Intensity. Areas of the Project may experience light 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". Because the potential for damage in the area of the Project is considered none to very light, damage to the Project from potential earthquakes is not anticipated to occur. Earthquakes that could occur would happen within sufficient distance away from the Project to pose significant issues or cause interruption with the service of the proposed pipelines. According to the ISGS, recent earthquakes in Illinois occurred in January 2012 and February 2010 however, these earthquakes occurred in the northeastern part of the state, and are not located near the Project area.

Figure 6.4-2. USGS Forecast for Ground Shaking Intensity from Natural and Induced Earthquakes in 2017

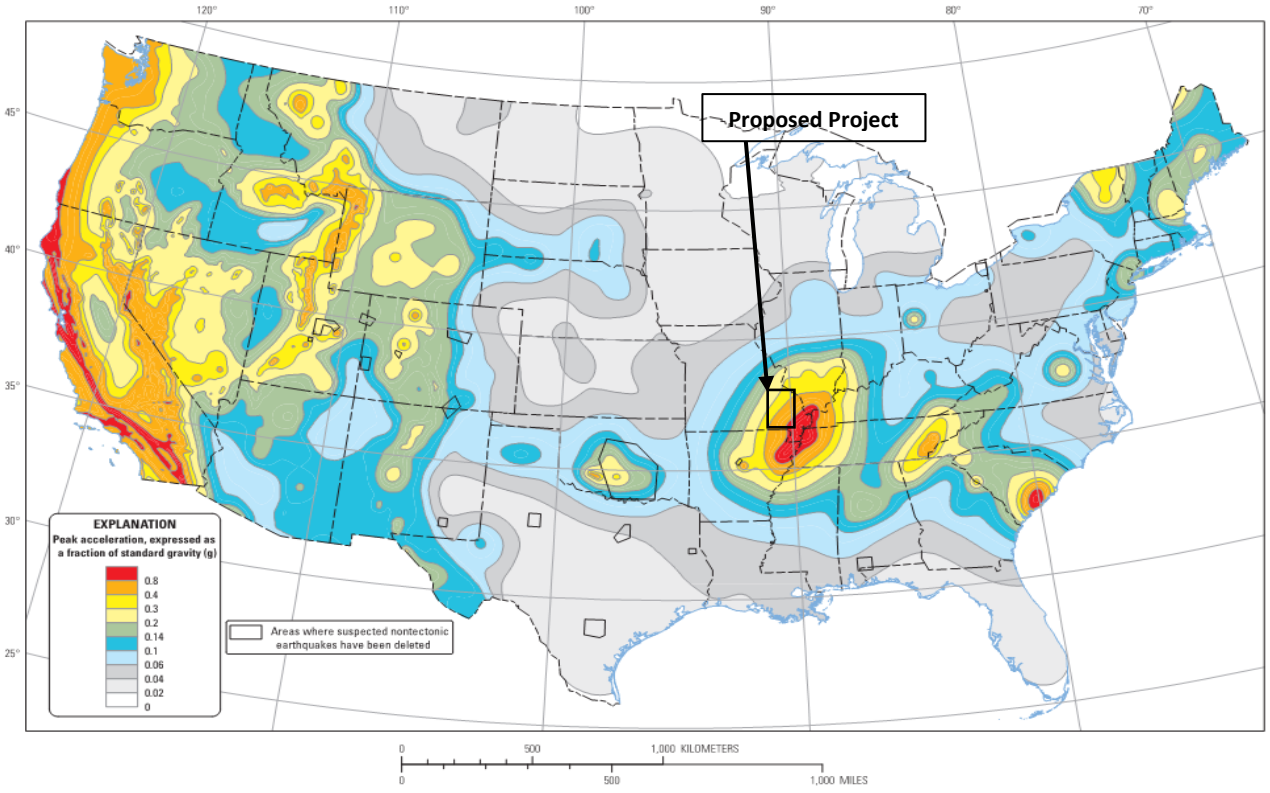


USGS map displaying intensity of potential ground shaking from natural and human-induced earthquakes. There is a small chance (one percent) that ground shaking intensity will occur at this level or higher. There is a greater chance (99 percent) that ground shaking will be lower than what is displayed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

According to the MDNR, small earthquakes and tremors occur frequently in the state, with thousands being noted since 1795. Most are typically too small to be felt and are more frequent in the NMSZ, but also occur on other faults located in Missouri and the surrounding states. Based on the history of past earthquakes, USGS seismologists in 2009 suggested that the chance of having a magnitude 7.0-8.0 earthquake in the NMSZ within the next 50 years is about 7 to 10 percent; smaller earthquakes have a greater change of occurring (MDNR 2015).

Spire has also reviewed available published National Seismic Hazard Maps Design prepared by USGS to calculate the peak ground acceleration ("PGA") of various return periods including two and 10 percent probabilities for exceedance in 50 years. PGA is equivalent to the maximum ground acceleration that occurs during earthquake shaking at a location (i.e., how hard the earth shakes at a given geographic point). As shown on Figure 6.4-3, the Project is within an area of PGA of 10 to 30 percent of standard gravity for two percent probability for exceedance in 50 years and, as shown on Figure 6.4-4, a PGA of 3 to 10 percent of standard gravity for ten percent probability for exceedance in 50 years.

Figure 6.4-3. USGS 2percent Probability of Exceedance in 50 Years Map of Peak Ground Acceleration in 2014

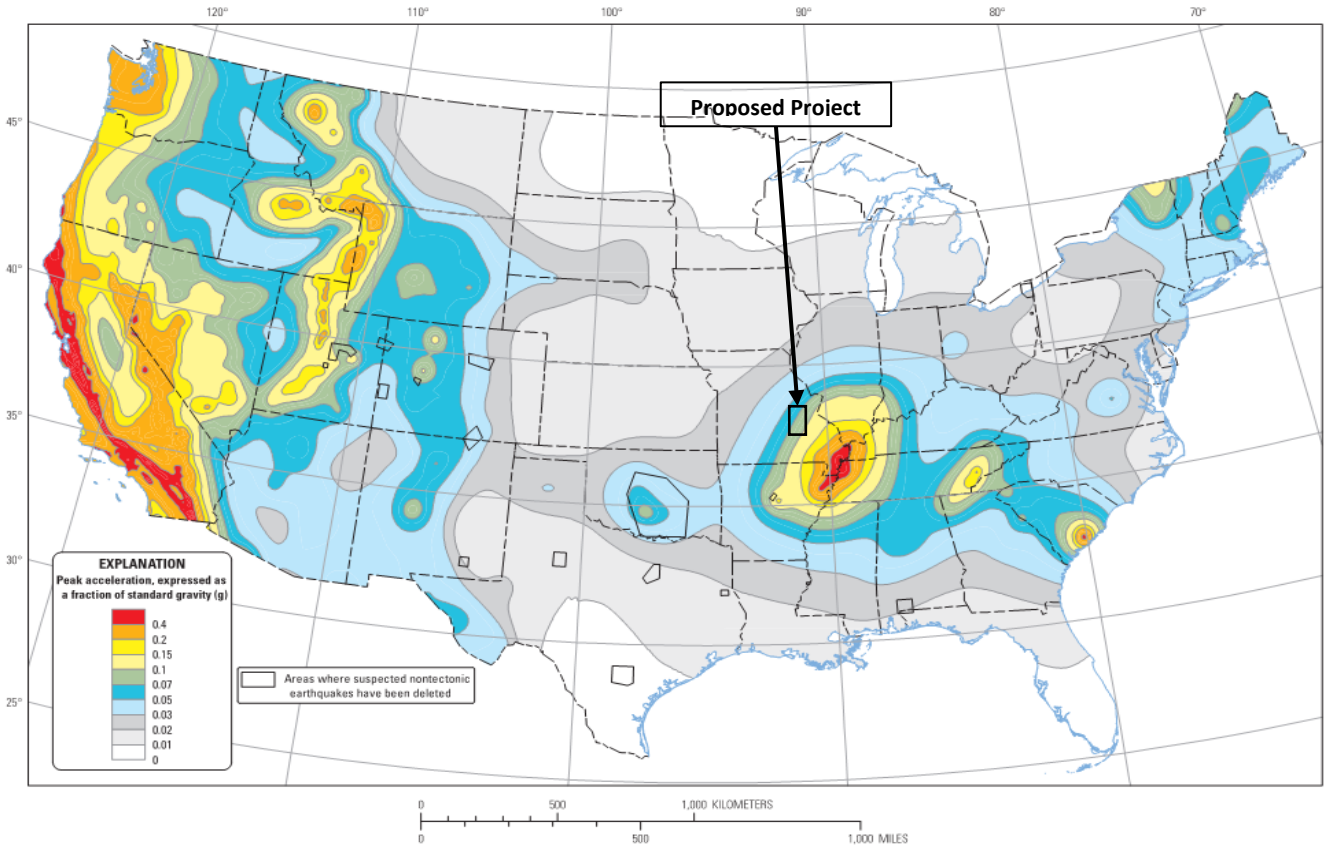


Two-percent probability of exceedance in 50 years map of peak ground acceleration

6.4.1.1 Active Faults

There are no active faults in the Project area in Illinois (ISGS 1995). The northern portion of the St. Louis fault is located east of the proposed Chain of Rocks Station in St. Louis County, Missouri (Missouri Spatial Data Information Service 2010). Most of the fault structure is beneath the Mississippi River, therefore little information is available. Displacement is greatest in the southern portion of the fault and dissipates northward. Activity on the fault has been inconclusive; two small earthquakes since 1974 (magnitudes 3.1 and 2.4) may be attributable to the St. Louis fault zone (Harrison 1994). Due to the USGS probabilities described in Section 6.4.1, the potential for damage in the area of the Project is considered none to very light, and damage to the Project from potential earthquakes is not anticipated to occur.

Figure 6.4-4. USGS 10percent Probability of Exceedance in 50 Years Map of Peak Ground Acceleration in 2014



Ten-percent probability of exceedance in 50 years map of peak ground acceleration

Spire concludes that proposed Project is not expected to be affected by seismic activity due to the low probability and low incidence/susceptibility of significant magnitude earthquakes within the Project area. Spire anticipates that the pipeline and associated aboveground facilities will not be affected by fault movements. The pipeline and associated facilities will be designed and constructed in accordance with applicable USDOT regulations (49 CFR 192) and constructed to standards that will allow them to withstand seismic events and the potential ground shaking caused from natural earthquakes should they occur.

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 light to moderate within portions of the Project area, according to the 2016 USGS Figure 6.4-2 depicting the forecast for ground shaking intensity from earthquakes. As previously mentioned, the Project is located outside of the NMSZ. During the winter of 1811-1812 the NMSZ experienced four earthquakes of about magnitude 8 which caused the area to experience significant disturbances that included soil liquefaction, landslides, and large fissures (Street 1990). However, the Project is located outside of the area of where significant disturbance was recorded as a result of these earthquakes and therefore this is not anticipated to be a concern to the proposed Project. Additionally, as discussed above, Spire has reviewed USGS national seismic hazard maps and determined that the Project is within an area of PGA of 10 to 30 percent of standard gravity for two percent probability for exceedance in 50 years and a PGA of 3 to 10 percent of standard gravity for ten percent probability for exceedance in 50 years. The southern portion of the Project is within an area evaluated by the USGS, and the study indicates that the geologic deposits in the area are relatively resistant to soil liquefaction (Pearce et al. 2008). Pearce et al. (2008) notes liquefaction potential at the 10 percent probability level is commonly utilized for building codes and complements the suspected recurrence interval for earthquakes in the NMSZ, which are estimated at 500 years. The study concluded that within the focus area, “the potential for liquefaction based on this probability and magnitude of seismic ground shaking is very low to none”, and would be insufficient to cause soil liquefaction. The estimated trigger PGA values are 40 percent or greater than PGA values that would be seen with this probability. Therefore, liquefaction within the Project area encompassed by this study would not be anticipated for an earthquake of this probability and magnitude.

The two percent probability of exceedance of PGA was determined to be sufficient to trigger liquefaction, to about 10 percent liquefaction threshold exceedance. Pearce et al. (2008) notes that liquefaction is “not unexpected at this conservative probability level.” Loess deposits crossed primarily by the North County Extension have characteristics that are not susceptible to liquefaction, even under this model. Within the study area, Project facilities in areas susceptible to liquefaction at this probability and magnitude are located between the Mississippi and Missouri Rivers and at tributary crossings such as Coldwater Creek. Potential for liquefaction generally decreases as you move north, increasing in proximity from the NMSZ; and these areas crossed may have 10 to 30 percent potential to exceed the PGA that would trigger liquefaction.

6.4.2 Underground Mining/Subsidence

According to the Coal Mines in Illinois Viewer ("ILMINES"), no abandoned underground coal or industrial mines are located beneath the proposed 24-inch pipeline, the North County Extension, or the proposed facilities along these areas (ISGS 2015; ISGS 2016d).

One staging area and a portion of the REX Receipt Station are within a 1,000-foot mine subsidence buffer zone as designated by ISGS (2009). This area consists of an existing access road and cultivated fields. Heavy agricultural equipment would have been previously used, with no signs of subsidence at present. Therefore, impacts from mining or subsidence on the Project are not anticipated.

6.4.3 Landslides

Landslides, slumps, and rockfalls can occur in areas where there are bluffs and steep slopes of unconsolidated materials or thick soils, and are often triggered when surficial materials are moved or modified (MDNR 2015). The vast majority of the 24-inch pipeline, including the proposed facilities, is proposed in locations with low landslide incidence. Before crossing the Mississippi River, the 24-inch pipeline traverses approximately four miles with high susceptibility and moderate incidence, as well as approximately one mile with high susceptibility and low incidence. The Project area in Missouri crosses areas with moderate susceptibility and low incidence of landslides: approximately 12.8 miles along the 24-inch pipeline and six miles on the North County Extension (Godt 1997).

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, Section 1.3.1.2 Special Construction Procedures. Additionally, none of the proposed metering and regulating ("M&R") facilities along the 24-inch pipeline were located in areas of steep slopes.

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 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.

The Karst and Sinkhole Topography Map in Appendix 6-A illustrates mapped karst terrain data identified within the Project area (ISGS 2004 and MSDIS 2014). Table 6.4-2 further describes the potential for karst features crossed by the Project including facilities and other components as well as planned mitigation measures. The table includes public karst and sinkhole data up to 1,500 feet from the Project workspaces as well as field located data. As shown in the table, a majority of the surveyed areas did not reveal karst or sinkholes identifiable at the surface. Two sink areas were located during field surveys; both along or adjacent to the North County Extension route. One was

located 103 feet north of the Project workspace at MP 1.6; the other sink area was located at MP 2.0 which is proposed to be crossed by the HDD method.

Table 6.4-2. Karst Features Within 1,500 feet of the Project

Karst Feature[1]	Nearest MP[1, 2]	County, State	Identified Through Field or Desktop Review[3]	Planned Mitigation Measures
24-Inch pipeline				
Karst	13.5[8]	Jersey, Illinois	Desktop	If found pipeline will be rerouted. This region is in an agricultural region subject to the weight of farm equipment. Karst is not anticipated to be present within the depth at which the pipeline will be installed.
Karst	43.1-44.1[6]	Jersey, Illinois	Desktop	If encountered, Spire would coordinate with a geologic expert to evaluate the feasibility of completing construction in this area.
Sink Area	58.4	St. Louis, Missouri	Desktop	Area is within a portion of an active sand and gravel mining operation; the sink area is a planned, man-made depression.
Sink Area	58.8[8]	St. Louis, Missouri	Desktop	
North County Extension				
Sink Area	0.4[8]	St. Louis, Missouri	Desktop	Maintain rates of recharge and discharge in the subsurface at the desired natural levels.
Sink Area	1.6[4]	St. Louis, Missouri	Field	
Sink Area	1.7[8]	St. Louis, Missouri	Desktop	
Sink Area	1.8[8]	St. Louis, Missouri	Desktop	
Sink Area	2.0[5]	St. Louis, Missouri	Field	
Sink Area	2.5[8]	St. Louis, Missouri	Desktop	
Sink Area	2.6[7]	St. Louis, Missouri	Desktop	Maintain rates of recharge and discharge in the subsurface at the desired natural levels.
Sink Area	3.2[8]	St. Louis, Missouri	Desktop	
Sink Area	3.8[8]	St. Louis, Missouri	Desktop	
Sink Area	4.0[7]	St. Louis, Missouri	Desktop	
Sink Area	4.3[7]	St. Louis, Missouri	Desktop	
Sink Area	4.5[9]	St. Louis, Missouri	Desktop	

Notes:

1 Nearest MP indicates the closest MP from where direction and distance to workspace was measured.

2 Sink areas located within the limits of another known sink area are not shown. The larger of the sink areas is presented in the table.

3 For mainline construction, geotechnical hazard information was gathered utilizing Illinois Geospatial Data Clearinghouse. The information the Clearinghouse gathered is from multiple sources and compiled within their dataset. This dataset is considered general nature but provides a possibility that a geophysical formation may be present.

Table 6.4-2. Karst Features Within 1,500 feet of the Project (Continued)

[4] Sink area field verified 103 feet north of Project.

[5] Sink area field verified at centerline; crossed by HDD.

[6] Field surveyed from MP 43.1 to 43.5; no evidence of karst or sink area from the surface. Field surveys will be conducted as permission is granted at MP 43.5 to 44.1.

[7] Wetland/waterbody located in the field where desktop data indicated sink area.

[8] Outside of Project study area; desktop data (karst/sink area) not confirmed since it is located outside the Project area. No karst or sink features were identifiable at the surface by the field crew within Project study area.

[9] No features located in the field where desktop data indicated sink area.

Sources: Missouri Spatial Data Information Service, and Illinois State Geological Survey Data Clearinghouse.

Geotechnical investigations conducted at the river HDD crossings, the M&R facilities, and in certain locations in St. Charles County (for buoyancy evaluation) gave no indication of karst. Spire is completing geotechnical investigations of the proposed HDDs on the North County Extension to determine the depth at which karst is present.

Most of the hazards identified are small karst features (sinkholes) that, if encountered during construction, can either be avoided by small adjustments to the Project right-of-way or can be mitigated as described in the Karst Mitigation Plan. If encountered, the limits of the karst feature will be determined utilizing excavation equipment along the proposed route. The pipe selected for the Project can safely span across 25 feet of karst features. If the karst feature is 25 feet or less, the line can be constructed with no adjustment to the route. If a karst feature is greater than 25 feet, other engineering and/or route options would be considered. Engineering options may be considered to remediate/stabilize the void such as aggregate stowing, grouting, or a geotextile reinforced plug depending on the characteristics of the void and surrounding site conditions. In general, the pipeline may be installed near the proposed route utilizing an engineered technique. While an engineering solution could cause schedule delays thus impacting the surrounding areas, a route adjustment can usually be found within the 300-foot study corridor where the void can be safely spanned.

Public and private wells are discussed in detail in Resource Report 2, Section 2.1.2. Seven private wells are located within 150 feet of the proposed Project through Greene and Jersey Counties, Illinois. No private wells were located within 150 feet of the proposed Project in Scott County, Illinois, or in St. Charles and St. Louis Counties, Missouri. No springs are present at the Project area. Construction, operation, and maintenance of the proposed facilities are not expected to have long-term impacts on groundwater resources. If karst areas are encountered, stormwater will be diverted upland from the excavated karst areas utilizing approved erosion and control methods. If surface waters are present near the karst excavation, then water will be flumed to minimize the potential for storm water entering the void. Sand bags or similar materials would be utilized to withhold water from entering the excavation, and water levels will be monitored to determine whether it is entering the excavation.

Spire has prepared a Karst Mitigation Plan included in Appendix 6-A, describing the general measures to be implemented during construction to ensure that correct measures for construction in karst formations are taken. As described in the Karst Mitigation Plan, pre-construction review of the available datasets regarding karst information provides a possibility that a geophysical formation may be present in Illinois. The dataset for Missouri indicated the possibility of sink areas, but no indication of karst features. If an unanticipated karst feature is discovered during construction activities, work in the immediate area would stop and the appropriate contractor supervisors would be alerted. If karst mitigation is required, Spire will notify and coordinate with applicable agencies to ensure any necessary and appropriate agency review or approvals are acquired. 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.

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.

Within Illinois, portions of the 24-inch pipeline will be located within the 100-year FEMA floodplains of Apple Creek and Macoupin Creek in Greene County, Illinois, and Otter Creek and the Mississippi River in Jersey County, Illinois. Impacts are unavoidable due to the long linear nature of the floodplain and the route of the Project. Construction of the pipeline throughout these areas will not result in any permanent fill in the floodplains.

Within Missouri, a portion of the 24-inch pipeline will be located within the 100-year FEMA floodplain and FEMA regulatory floodway of the Mississippi River, Missouri River, and tributaries to the Missouri River. This includes the crossing of the Mississippi River and the crossing of the Missouri River, as well as the proposed 24-inch pipeline alignment approximately between MP 45.0 through MP 58.1. No permanent fill is associated with construction of the pipeline, and Spire will install the 24-inch pipeline with a minimum seven feet of cover within the floodplains of the Mississippi and Missouri Rivers. A portion of the North County Extension will be located within the 100-year FEMA floodplain and FEMA regulatory floodway of Coldwater Creek, however this is proposed to be crossed utilizing HDD techniques and no impacts are anticipated to occur within the floodplain. Additionally, no permanent fill associated with construction of the North County Extension is proposed in the floodplains.

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, and appropriately sized flumes will be available to handle the storm flows as needed. After construction is completed, each crossing will be inspected periodically for signs of erosion and remediated as necessary.

A portion of the Chain of Rocks Station is located within a 100-year FEMA floodplain. A small area (less than 0.05-acre) will be fenced and permanently graveled within the LGC previously disturbed right-of-way adjacent to the existing Enable Mississippi River Transmission, LLC Chain of Rocks Station; the fenced and graveled area is within the limits of the floodplain.

Additionally, MLV 3 will be located within a 100-year FEMA floodplain, which is not expected to change the based flood elevation. Spire proposes to design aboveground facilities and pipelines as such to prevent and minimize impacts from potential high velocity flows. The REX Receipt Station and the Laclede/Lange Delivery Station are not located within a 100-year FEMA floodplain.

Additional information regarding floodplains, including anticipated permitting applications, is provided in Resource Report 2, Section 2.2.3 Floodplains.

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

Federal lands are crossed by the Project in Missouri. The United States Army Corps of Engineers ("USACE") property is held in fee title by the USACE St. Louis District and is located on the south side of the Mississippi River. 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.

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

In Illinois, the Project crosses areas where Mississippian age rocks, which can contain fossils of common prehistoric aquatic organisms such as bryozoans, trilobite, and brachiopods, may be located at outcrops or beneath drift (ISGS 2016f). Areas with underlying Pennsylvanian age rocks, which may commonly contain fossils of gastropods, trilobites, and corals, may also be crossed by the Project. The paleontological sites included by ISGS are not crossed by the Project, and other known paleontological sites publically available online are not located in the Project area (ISGS 2016f; Paleontology Portal 2016). However, there is record of a wholly mammoth fossil discovery on the campus of Principia College, which is located over one mile east of the Project (Principia News 2013).

Missouri's Code of State Regulations does not specify regulations for paleontological resources on state or local land. 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).

Should a potential paleontological find be discovered during construction, Spire would follow applicable regulations and coordinate with the appropriate agency(ies) pursuant to their applicable jurisdiction.

6.7 Geotechnical Investigations

Spire has conducted geotechnical investigations at the Mississippi and Missouri River crossings to determine the feasibility of conducting a HDD of these rivers. These geotechnical investigations included land and water bores. Spire filed the results of this investigation with FERC in January 2017 as part of i Volume IV - Privileged, Appendix 6-B. Based on these primary evaluations, the proposed Mississippi River and Missouri River were determined to be feasible with a high probability of successful completion.

While not anticipated, if an attempted HDD installation is unsuccessful, the proposed HDD alignment could be modified beneath the river using the same general location to accommodate an additional HDD attempt, depending on the condition/cause contributing to the original HDD failure. Prior to attempting a second HDD crossing, a risk mitigation workshop should be held with all parties to determine the cause of the initial failure and any mitigation measures that could be adopted to reduce the risk(s) during the second HDD attempt.

Additionally, four soil borings were performed in St. Charles County, Missouri at equal spacing between the proposed Mississippi and Missouri River crossings in support of the buoyancy evaluation for the pipeline. These borings are included in the geotechnical report filed with the FERC in January 2017.

Additional geotechnical investigations for the M&R facility sites were conducted. The results of this investigation are provided in Volume IV - Privileged, Appendix 6-B. Geotechnical investigations for the two HDD crossings on the North County Extension were initiated in March 2017. A portion of the geotechnical work has been conducted at the Coldwater Creek and Spanish Lake Park HDD crossing locations where survey access has been granted; remaining geotechnical work will be conducted as landowner permission is obtained.

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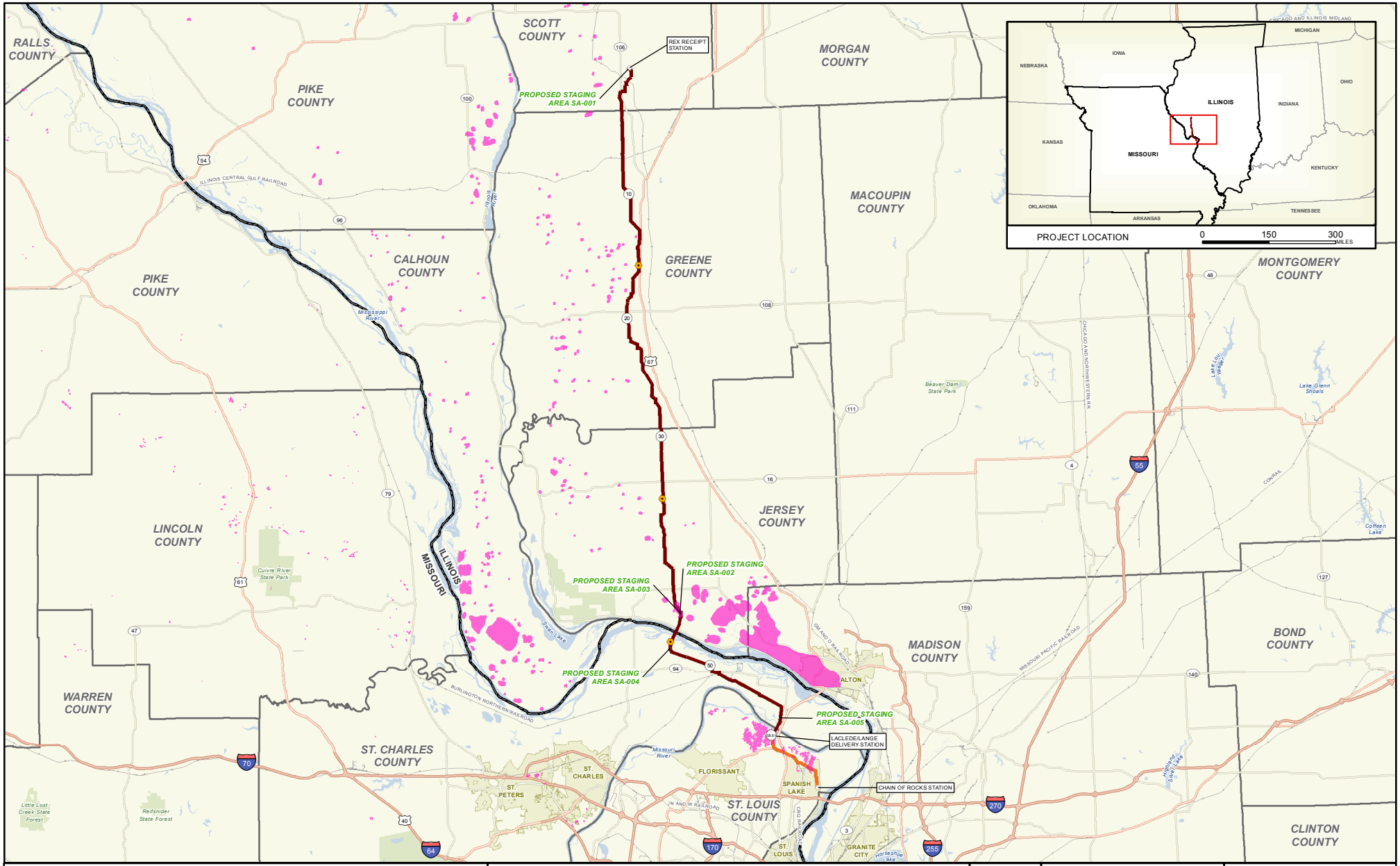
APPENDIX 6-A

Karst and Sinkhole Topography Map and Karst Mitigation Plan



- MILE POST
- PROPOSED M&R SITE
- PROPOSED MAINLINE VALVE SITE
- PROPOSED 24-INCH DIAMETER PIPELINE
- PROPOSED 24-INCH NORTH COUNTY EXTENSION
- INTERSTATE
- HIGHWAY
- MAJOR ROAD
- RAILROAD
- PROPOSED STAGING AREA
- KARST & SINKHOLE AREA
- PARK BOUNDARY
- WATERBODY
- COUNTY BOUNDARY
- STATE BOUNDARY

KARST DATA OBTAINED FROM THE ILLINOIS STATE GEOLOGICAL SURVEY & MISSOURI DEPARTMENT OF NATURAL RESOURCES.

SPIRE STL PIPELINE PROJECT

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: 1:633,806

REFERENCE SCALE: 1 IN = 10 MILES

Spire STL Pipeline

MOTT MACDONALD

DRAWN BY:	JTP 12/07/2016
CHECKED BY:	NDK 12/19/2016
APPROVED BY:	JW 12/19/2016
REV. DATE:	04/2017
REVISION:	2
DESC:	AMENDMENT TO FERC
PAGE:	1 OF 1

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Spire STL Pipeline Project

Karst Mitigation Plan

FERC Docket No. CP17-40-_ _ _

April 2017

Public

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Acronyms and Abbreviations

CFR	Code of Federal Regulations
NRCS	Natural Resources Conservation Service
Plan	FERC's Upland Erosion Control, Revegetation, and Maintenance Plan
Procedures	FERC's Wetland and Waterbody Construction and Mitigation Procedures
Project	Spire STL Pipeline Project
Spire	Spire STL Pipeline LLC
USDA	United States Department of Agriculture

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 in all work areas, including temporary workspaces and access roads. Additionally, this plan outlines the recommended records to be maintained onsite during construction.

1.2 Pre-Construction Review

For the 24-inch pipeline construction, geotechnical hazard information was gathered utilizing Illinois Geospatial Data Clearinghouse. This information is from multiple sources and is compiled within their dataset. This dataset is considered general in nature, but provides the possibility that a geophysical formation may be present. A similar review was conducted utilizing the Missouri Spatial Data Information Service. While the dataset indicates the possibility of sink areas, only one sink area has been confirmed in the field at milepost 2.0 along the North County Extension. Geotechnical investigations near this area will be conducted as this location is encompassed as part of a proposed horizontal directional drill of Coldwater Creek. Additionally, Laclede Gas Company, a related company of Spire Inc., has a long history of working in the area and has not encountered issues related to sink holes or karst features.

For the trenchless crossings of the Mississippi and Missouri Rivers, a geotechnical investigation was conducted. Hazardous geological formations are not anticipated within the planned path of the horizontal directional drill installations. A portion of the geotechnical work has been conducted at the Coldwater Creek and Spanish Lake Park HDD crossing locations where survey access has been granted; remaining geotechnical work will be conducted as survey permission is granted.

1.3 Training and Awareness

Spire will conduct awareness training for karst-like features, including portals, voids, or sinkholes. Prior to construction, the contractor's field supervisory personnel and Spire's supervisory personnel, including the Chief Inspector, Craft Inspectors, and the Environmental Inspectors, will be trained on unanticipated karst features that could be discovered during trenching operations. The training will also provide the protocol for work stoppage if a karst feature is discovered in the immediate area and a communication plan to alert the appropriate Spire and contractor supervisors of such discovery. This training will comply with 49 Code of Federal Regulations ("CFR") Part 192.613 which requires the surveillance during construction.

1.4 Inspection, Monitoring, and Surveillance

As required by 49 CFR 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.

1.5 Construction Phase and Karst Remediation

If an unanticipated karst feature is discovered during trenching or other construction activities, work in the immediate area will be stopped immediately and the communication plan will be implemented to alert appropriate Spire and contractor supervisors. Erosion and sedimentation controls will be modified at the direction of an Environmental Inspector to install the measures necessary to minimize the potential for surface water runoff intrusion into the karst feature. A designated Project geotechnical engineer will be contacted and directed to the feature to conduct a detailed evaluation. The Project geotechnical engineer will develop specific design and mitigation measures depending on the site conditions and nature of the karst feature.

The mitigation methods detailed by the Project geotechnical engineer would provide enhanced stability to the void and increase the long term stability and integrity to the pipeline right-of-way. The principal approach to avoid aggravating dormant sinks, or possible areas of subsidence and karst activity, is to maintain rates of recharge and discharge in the subsurface at the desired natural levels. In this context, desired natural levels refer to the pre-development recharge and discharge rates. Final grading of contours and any necessary permanent erosion and sediment controls will be designed to prevent runoff from accumulating in the area of the void. In addition, during the discharge of any hydrostatic test water from the pipeline, a discharge location will be selected that will prevent the discharged water from encountering any unanticipated karst features discovered during trenching activities. These methods will help control the flow of water into underlying karst areas, which meets the intent of maintaining rates of subsurface recharge and discharge to pre-development conditions. Stormwater control measures in areas of known and verified karst terrain will be enhanced to include detention, diversion, or containerization to prevent construction influenced stormwater from flowing to the karst feature drainage point.

In the event that an unanticipated karst feature or void is discovered during construction or post-construction monitoring and karst mitigation is required, the Class 1 pipe specified for the 24-inch pipeline is capable of spanning a 28-foot void, should one unexpectedly occur, and continue to operate safely. During construction of the project, should an unanticipated cavern feature or sinkhole be encountered of size less than the maximum unsupported span length, a mitigation strategy as identified in Sections 1.5.1 or 1.5.2 below may be implemented by the Project geotechnical engineer. Should the karst feature approach or exceed the size of the maximum unsupported length, an investigation and mitigation strategy as identified in Section 1.5.3 may be implemented. It should be noted that the mitigation strategies identified below are provided as options, and each mitigation measure to be employed will be specifically selected by the Project geotechnical engineer at the time of intersection.

spire

1) Mitigation Measures for Sinkhole Throats

If new sinkhole throats develop within the construction area while work is commencing, work in the area will be halted and the sinkhole area will be isolated and cordoned off to an area extending 100 feet radially from the feature. The sinkhole will be inspected by a geotechnical engineer and remedial measures such as filling of the sinkhole using inverted filter approach or adjustment of the pipeline alignment may be implemented. The inverted filter approach is often used for sinkhole repair, especially when the sinkhole is not located near structures. The sinkhole area is excavated to expose either bedrock or the throat of the sinkhole. A course of rock large enough to bridge the throat of the sinkhole is placed at the bottom of the excavation. Courses of progressively finer rock and gravel are compacted above the base course. A geotextile fabric may be placed above the finest gravel course to prevent excessive loss of the uppermost course, which may consist of sand and/or soil. The inverted filter method provides filtration treatment of storm water and allows controlled storm water infiltration and groundwater recharge.

2) Mitigation Measures for Subsurface Voids and Caverns

If an existing subsurface void is intersected within the work area, work will similarly be halted and cordoned off for further evaluation by a qualified geotechnical engineer. As indicated earlier, the principal approach to maintain rates of recharge and discharge at pre-development conditions, a filter fabric secured over the void may be implemented in addition to an inverted filter.

Methods to mitigate sinkhole collapses and similar subsurface voids have been recommended by the United States Department of Agriculture ("USDA") Natural Resources Conservation Service ("NRCS"). These typical details are provided as Attachments A through C and may also be implemented depending on the karst feature encountered. The mitigation methods would provide enhanced stability to the void and increase the long term stability and integrity to the pipeline right-of-way. Final grading of contours and any necessary permanent erosion and sediment controls will be designed to prevent runoff from accumulating in the area of the void. In addition, during the discharge of any hydrostatic test water from the pipeline, a discharge location will be selected that will prevent the discharged water from encountering any unanticipated features discovered during trenching activities.

3) Mitigation Strategies for Karst Features Greater than Maximum Unsupported Span Length

If a karst feature greater than 50 feet long in largest measured dimension is intercepted during work activities including drilling, blasting, excavation, or trenching, all work within a 300-foot radius will immediately be stopped and Spire and Contractor Supervisors will be notified. The Project geotechnical engineer will be subsequently contacted and directed to the feature to conduct a detailed evaluation to review suspected features for evidence of areas of soft soils, highly fractured bedrock, ground subsidence, surface water flow toward the feature, and diminishing flow in nearby surface streams or waterbodies. At this time, Project geotechnical engineer may increase or decrease the work stoppage buffer based on the observation of site conditions and in consultation with state or regulatory agencies, as necessary.

Should any of the abovementioned indicators be identified, the Project geotechnical engineer will commence a characterization program to determine the full extents of the feature along and within proximity to the pipeline alignment. The characterization method may consist of, but not be limited to, one or more of the following strategies:

a. visual assessment (field inspection) or Aerial Assessment (drone or aerial);
b. LiDAR or field topographic survey;
c. installation of geotechnical instrumentation or survey monuments to determine movement;
d. geophysical investigation (microgravity, multi-channel analysis of surface waves, or electrical resistivity);
e. track drill probing and/or geotechnical drilling;
f. test pit excavation; and/or
g. infiltration or dye trace testing.

Once sufficient detail is achieved to delineate the extents of the feature, it is anticipated that several options may be considered as a mitigative strategy, including subsurface grouting within the right-of-way, structurally supporting (cradling) the pipeline on a deep foundation system, or relocating the pipeline to a less sinkhole-prone portion of an adjacent property. As each karst feature is unique, the mitigative strategy selected will be on a case-by-case basis by the Project geotechnical engineer and in consultant with project stakeholders.

Under any situation, in the event that an unanticipated karst feature or void is discovered during construction or post construction monitoring and karst mitigation is required, Spire will notify and coordinate with applicable agencies to ensure any necessary and appropriate agency review or approvals are acquired.

1.6 Post-Construction Monitoring

Spire will conduct visual post-construction inspections of the right-of-way to evaluate the success of any mitigation activities performed for any karst features or voids discovered and mitigated during construction. The frequency of inspections will generally comply with those required under the FERC's Upland Erosion Control, Revegetation, and Maintenance Plan ("Plan") and Wetland and Waterbody Construction and Mitigation Procedures ("Procedures"), but would more specifically be based on the severity of the mitigation activities and the Project geotechnical engineer recommendations with a decreasing frequency over the two year monitoring period. As required by the Plan and Procedures, monitoring will be conducted for up to two years after construction completion. If a new karst feature or void were to develop within the right-of-way as a result of Spire's subsequent construction activities, Spire would contact the Project geotechnical engineer to evaluate the feature and make additional remedial recommendations. Spire will provide updates on the status of all discovered and mitigated karst features or voids in its bi-weekly and quarterly activity reports. During operation of facilities, staff performing routine inspections of facility and related assets will be made aware in areas of carbonate formations that the potential for sinks and karst features exists, and that surface expressions of sinks, disappearing streams or runoff, and change in topography should be noted and brought to the attention of the Project geotechnical engineer for further review and consideration. Should the potential for karst be documented, a mitigation measure, as identified in Section 1.5, may be implemented.

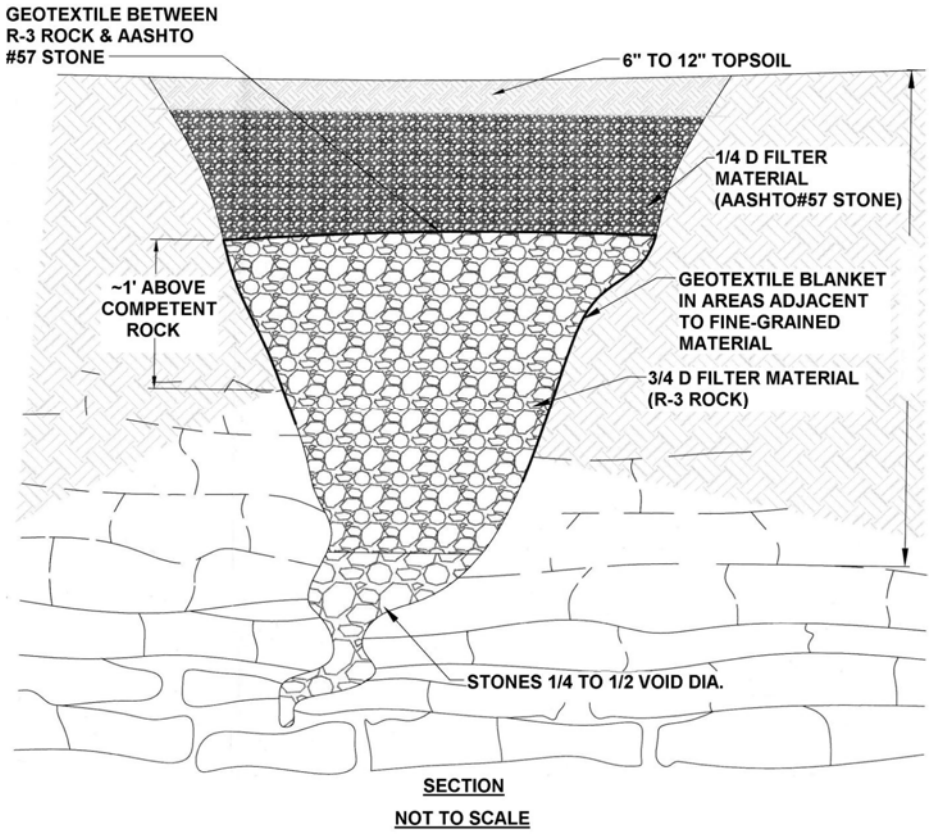
1.7 Plan Maintenance

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

ATTACHMENT A

USDA NRCS Sinkhole Repair with Pervious Cover Detail

USDA NRCS Sinkhole Repair with Pervious Cover Detail



Source: Adapted from USDA NRCS

Notes

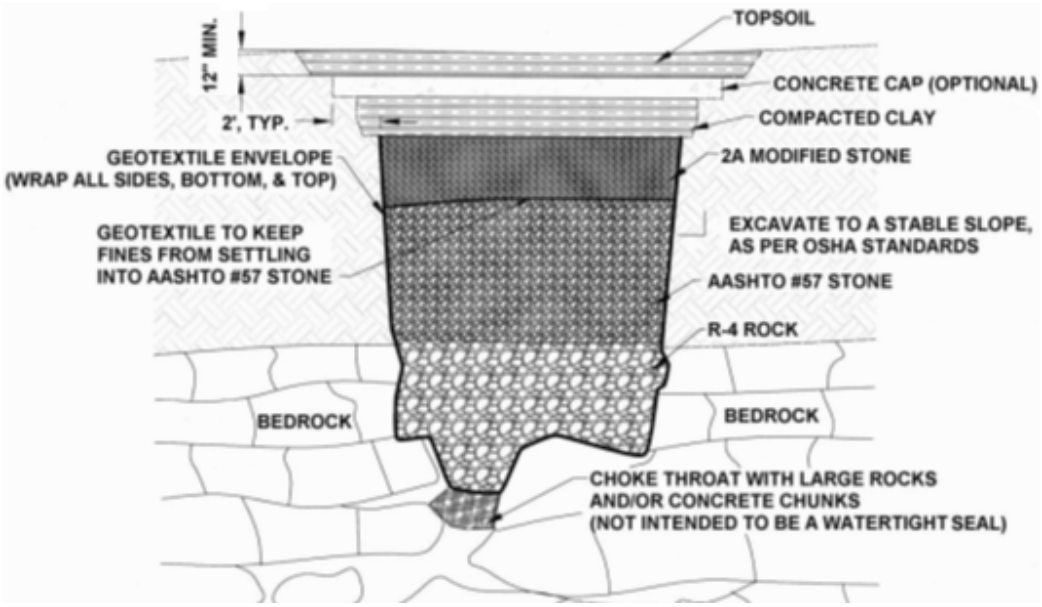
1. Loose material shall be excavated from the sinkhole and expose solution void(s) if possible. Enlarge sinkhole if necessary to allow for installation of filter materials. OSHA regulations must be followed at all times during excavation.

Stones used for the “bridge” and filters shall have a moderately hard rock strength and be resistant to abrasion and degradation. Shale and similar soft and/or non-durable rock are not acceptable.

ATTACHMENT B

USDA NRCS Sinkhole Repair with Impervious Cover Detail

USDA NRCS Sinkhole Repair with Impervious Cover Detail



Source: Adapted from USDA NRCS

Notes:

1. Loose material shall be excavated from the sinkhole and expose solution void(s) if possible. Enlarge sinkhole if necessary to allow for installation of filter materials. OSHA regulations must be followed at all times during excavation.

2. Geotextile shall be non-woven with a burst strength between 100 and 200 psi.

3. Select field stone(s) about 1.5 times larger than solution void(s) to form "bridge." Place rock(s) so no large openings exist along the sides. Stones used for the "bridge" and filters shall have a moderately hard rock strength and be resistant to abrasion and degradation. Shale and similar soft and/or non-durable rock are not acceptable.

4. Minimum thickness of R-4 rock is 18." AASHTO #57 stone thickness shall be ¼ to ½ that of the R-4 rock. Minimum thickness of 2A modified crushed stone shall be 9" AASHTO #57 stone and 2A modified crushed stone shall be compacted after each placement.

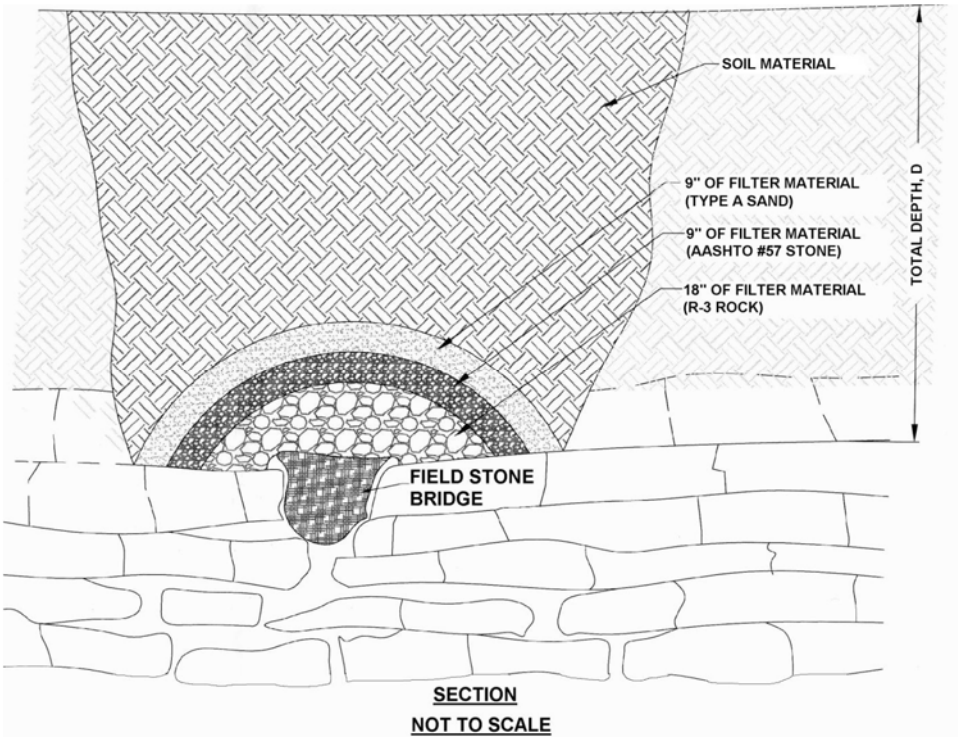
5. Compacted clay seal shall be a minimum of 12" thick. Clay shall be placed in 6" to 9" lifts and thoroughly compacted. Concrete cap, which is optional, shall be a minimum of 8" thick. Use 4,000 psi concrete with 6" X 6" - 6 gauge welded wire fabric, or # 3 rebar on 18" O.C. both ways.

Topsoil shall be a minimum of 12" thick. Grade for drainage away from sinkhole area.

ATTACHMENT C

USDA NRCS Sinkhole Repair with Soil Cover Detail

USDA NRCS Sinkhole Repair with Soil Cover Detail



Source: Adapted from USDA NRCS

Notes:

1. Loose material shall be excavated from the sinkhole and expose solution void(s) if possible. Enlarge sinkhole if necessary to allow for installation of filter materials. OSHA regulations must be followed at all times during excavation.

2. Select field stone(s) about 1.5 times larger than solution void(s) to form “bridge”. Place rock(s) so no large openings exist along the sides. Stones used for the “bridge” and filters shall have a moderately hard rock strength and be resistant to abrasion and degradation. Shale and similar soft and/or non-durable rock are not acceptable.

3. Minimum thickness of R-3 rock is 18” AASHTO #57 stone thickness shall be a minimum of 9” thick. Minimum thickness of type A sand shall be 9”. NOTE: A non-woven geotextile with a burst strength between 100 and 200 psi may be substituted for the AASHTO#57 stone and type A sand.

4. Soil shall be mineral soil with at least 12% fines and overfilled by 5% to allow for settlement. Suitable soil from the excavation may be used. Any available topsoil shall be placed on top surface.

APPENDIX 6-B

Geotechnical Investigations Report

CONTAINS PRIVILEGED INFORMATION - DO NOT RELEASE

APPENDIX 6-C

Blasting Plan