FERC Pre-Filing Review
Draft Resource Report 6 – Geological Resources
AES Sparrows Point LNG Terminal & Mid-Atlantic Express Pipeline

Submitted: September 2006

SUMMARY OF REQUIRED FERC REPORT INFORMATION		
TOPIC	**FERC Reference**	**Report Reference or Not Applicable**
1. Identify the location (by milepost) of mineral resources and any planned or active surface mines crossed by the proposed facilities. • Describe hazards to the facilities from mining activities, including subsidence, blasting, slumping or landsliding or other ground failure.	§ 380.12(h)(1), (2)	Section 6.5 & Table 6.5-1
2. Identify any geologic hazards to the proposed facilities. • For the offshore this information is needed on a mile-by-mile basis and will require completion of geophysical and other surveys before filing.	§ 380.12(h)(2)	Section 6.6 & Table 6.3-1 (Not Applicable)
3. Discuss the need for and locations where blasting may be necessary in order to construct the proposed facilities.	§ 380.12(h)(3)	Section 6.4 Table 6.3-1
4. For LNG projects in seismic areas, the materials required by "Data Requirements for the Seismic Review of LNG Facilities," NBSIR84-2833.	§ 380.12(h)(5)	Section 6.6.1 & Resource Report 13
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.	§ 380.12(h)(6)	Not Applicable

Additional Information

Identify any sensitive paleontological resource areas crossed by the proposed facilities. (Usually only raised in scoping or required by land-managing agency.)	Section 6.8
Briefly summarize the physiography and bedrock geology of the project area.	Section 6.3 Table 6.3-1
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

LIST OF TABLES

LIST OF FIGURES

6. GEOLOGICAL RESOURCES

6.1 Introduction

AES Sparrows Point LNG, LLC proposes to construct, own, and operate a new liquefied natural gas (LNG) import, storage, and regasification terminal (LNG Terminal) at the Sparrows Point Industrial Complex situated on the Sparrows Point peninsula east of the Port of Baltimore in Maryland. LNG will be delivered to the Sparrows Point LNG Terminal via ship, offloaded from the ship to shoreside storage tanks, regasified on the Sparrows Point LNG Terminal site (Terminal Site), and transported to consumers via pipeline. The LNG Terminal will have a regasification capacity of 1.5 billion cubic standard feet of natural gas per day (bcsfd), with potential to expand to 2.25 bcsfd. Regasified natural gas will be delivered to markets in the Mid-Atlantic Region and northern portions of the South Atlantic Region through the Mid-Atlantic Express Pipeline (Pipeline), which is an approximately 87-mile, 30-inch outside diameter natural gas pipeline to be constructed and operated by Mid-Atlantic Express, LLC. The Pipeline will extend from the LNG Terminal to interconnections with existing natural gas pipeline systems near Eagle, Pennsylvania. Together the Sparrows Point LNG Terminal and Mid-Atlantic Express Pipeline projects are referred to as the Sparrows Point Project or Project. Both AES Sparrows Point LNG, LLC and Mid-Atlantic Express, LLC (hereinafter collectively referred to as AES) are subsidiaries of The AES Corporation.

AES is considering the possibility of building a combined cycle cogeneration power plant (Power Plant) on the Terminal Site. The Power Plant will be configured with one F-Class combustion gas turbine, one steam turbine, and associated auxiliaries. The Power Plant will operate only on natural gas, and will produce approximately 300 MW of clean electric power within an area of high energy demand. The Power Plant will be connected to the local utility electric system via an overhead transmission line. For purposes of this Resource Report, the Power Plant will be considered part of the Project. The Power Plant is addressed more fully in Section 1.10 of Resource Report 1.

The Project footprint is located in the counties of Baltimore, Harford, and Cecil in Maryland and the counties of Lancaster and Chester in Pennsylvania. The Terminal Site, which is located entirely within Baltimore County, is a former shipyard. The route proposed for the Pipeline (Pipeline Route), which crosses all of the listed counties, includes industrial, commercial, agricultural, and residential lands. Together, the Terminal site and the Pipeline Route comprise the Project Area.

6.2 Objective and Applicability

Resource Report 6, *Geological Resources,* describes the geologic setting and resources for the Project, and identifies potential geologic hazards that may be associated with its construction and operation. As appropriate, additional geologic and geotechnical data will be obtained for those facilities requiring site-specific geologic and geotechnical data for construction design. These will include, at a minimum, the LNG Terminal foundations and horizontal directional drill crossings for major waterbodies and streams (see Resource Report 2 – *Water Use and Quality*). A report summarizing the preliminary site-specific geotechnical design study for the LNG Terminal was included in the submittal with Resource Report 13, Appendix J on September 5, 2006. Site-specific geotechnical investigations will be performed for potential horizontal directional drill (HDD) crossings (at the Susquehanna and Back Rivers) either during design or prior to construction. Further evaluation for the feasibility of HDD at additional crossings (at the Gunpowder Falls, Deer and Octoraro Creek crossings) will be completed prior

to construction. These reports will be provided to the Federal Energy Regulatory Commission (FERC) as completed, which is expected at this time to be sometime in September 2007.

6.3 Geologic Setting

The Project is located within the Atlantic Coastal Plain Province (the Embayment Section – Western Shore Lowlands Region) and the Piedmont Physiographic Province (Upland and Lowland Sections). Specifically, the LNG Terminal is located completely within the Western Shore Lowlands Region (Embayment Section) of the Atlantic Coastal Plain while the Pipeline Route splits the provinces at the Fall Line that is generally coincident with the stratigraphic break in the vicinity of milepost (MP) 18. The Sparrows Point Project facilities, physiographic provinces, and geologic setting information are summarized in Table 6.3-1.

The Project Area begins within the Atlantic Coastal Plain Province at the Proposed LNG Terminal and extends north along the proposed Pipeline Route to approximately MP 18. The Atlantic Coastal Plain Province is a low-lying region with little topographic relief, ranging up to a few hundred feet of elevation above mean sea level. The Coastal Plain Province is dominated by unconsolidated to poorly-consolidated Triassic to Quaternary age sediment deposits (gravel, sand, silt and clay) which are up to 8,000 feet thick near the Atlantic Coast. These sediments thin out toward the northern and western limits, eventually pinching out at the Piedmont Province boundary at an irregular contact line known as the Fall Line. These deposits (included in the Potomac Group) range from poorly- to well-sorted and represent high to low-energy stream and mud or backwater flat environments which are the source of interbedded finer and coarser grain materials. These sediments were generally derived by erosion of former uplands and mountains to the west of this area. Additional limited areas of Quarternary age surficial sediments or deposits are present within this portion of the Project area. These include Alluvium (generally located in stream flood plains, upland gathering areas or estuarine marshes) and Fill (heterogenous material - sediments, rock, dredge spoil).

The balance of the Pipeline is located within the Piedmont Province (north of MP 18 to MP 87) in Maryland and Pennsylvania. The Piedmont Province is a low- to moderate-relief region characterized with broad, rounded to flat-topped hills and shallow valleys. The Upland Section contains slightly more relief (ranging upward to more than 1,000 feet of elevation), while the Lowland Section contains less relief (elevations of less than approximately 500 feet). The Uplands Section is characterized by folded and faulted crystalline igneous and metamorphic bedrock, including schist, gneiss, gabbro and quartzite. Surficial deposits of upland gravels (higher hilltop elevations MP 18 to 20) and Alluvium (generally stream flood plains) are present within this Section. The Lowlands Section (at MP 79.3 to 81.5) is generally characterized as a zone of carbonate-based (limestone or dolomite) and metamorphic (marble, schist or quartzite) rock. Soils or overlying sediments in the Piedmont Province have been generally derived from fluvial erosion and deposition. There are no glacial deposits within the limits of the Project Area because the southernmost advance of the glacial ice did not extend this far south.

6.3.1 Sparrows Point LNG Terminal

The LNG Terminal is proposed to be situated at MP 0.0 on the Sparrows Point Peninsula in Baltimore County, Maryland, a low-lying peninsula located at the eastern portion of the Baltimore Harbor that contains heavy industrial facilities. The Sparrows Point Peninsula is relatively flat, with a total relief of less than 15 to 20 feet.

The mapped sediments in the vicinity of the Sparrows Point Peninsula (both onshore and offshore) are identified as Quarternary-age Lowland Deposits and are consistent with the regional description of the Atlantic Coastal Plain Province, i.e., gravel, sand,

silt and clay. These deposits are likely to be several hundred feet thick in the vicinity of the Terminal Site, as the estimated depth to rock is more than 200 to 300 feet below ground surface (to the west in the City of Baltimore Inner Harbor area) and more than 800 to 900 feet below ground surface (to the east at the Back River Neck area).

Land-based explorations in the form of rotary test borings revealed soil formations consisting of granular fill underlain by loose to medium-dense sands and clays, which are in turn underlain by medium dense to very dense sands and stiff clays. The land test borings extended to depths up to 126 ft. below existing grade. Detailed descriptions of the soil strata encountered in the explorations (generally in order of increasing depth) are as follows:

- *Miscellaneous Fill* – This stratum generally consisted of medium dense, gray-brown to dark brown silty to clayey sand containing fragments of wood, slag, cinders and ash.
- *Talbot Formation* – The Talbot Formation was encountered in all the recent test borings below the Fill layer and generally consisted of gray-brown sands along the southern side of the proposed tank locations to gray silts and clays over the remainder of the site. The thickness of this layer ranged from 35 to 115 ft.
- *Patapsco Formation (Potomac Group)* – Apparent Patapsco Formation deposits were encountered below the Talbot Formation to the final depth of the borings and consisted of gray sands to gray silts and clays.

Groundwater levels in the boreholes at the completion of drilling ranged from 4.5 to 10.3 ft below the existing ground surface. These water levels were measured in completed, cased test borings and were not obtained from observation wells; as such, the actual groundwater levels may vary from these observed depths and experience fluctuations due to tidal or seasonal influences. However, in relation to 2005 historic site investigation water level data (from ongoing Sparrows Point investigations) the site groundwater levels are generally consistent and it is not anticipated there would be more than one to two feet of variability.

Offshore exploration in the form of vibracore drilling was also performed for the Terminal Site. The vibracore borings were drilled to depths of up to approximately 63 ft. below the water surface. Each exploration encountered black or gray silt deposits beginning at the mudline. Those borings performed at distance from the shoreline (generally in or near the dredged shipping channel) encountered silts throughout the entire boring depths. Borings performed closer to shore also encountered interbedded sand and clay below the initial silt layers. The clay thickness was greatest in close proximity to the shore, and the sand occurrence was generally greatest in the borings located centrally between the shore and the shipping channel.

The subsurface conditions at the Terminal Site have been evaluated from a geotechnical standpoint to determine potential soil settlement characteristics, bearing capacity, dynamic loading response and other foundation design related factors. The offshore sediment conditions were investigated to support engineering for the dredging and spoil material management. These studies are summarized in the Preliminary Geotechnical Report on Sparrows Point included as Appendix J in Resource Report 13.

6.3.2 Mid-Atlantic Express Pipeline

The Pipeline Route is composed of an approximately 87-mile long corridor extending north from the Coastal Plain Province (Western Lowland Region) into the Piedmont

Plateau. A summary of the geologic conditions, stratigraphic formations, and physiographic provinces along the Pipeline Route is provided by county, state and milepost on Table 6.3-1.

As described in the geologic setting above, the mapped formations along the Pipeline Route generally include the following:

- *Unconsolidated Deposits* – present within the Coastal Plain Province section (MP 0 to 18) primarily consisting of clays, sands and gravels from the Talbot, Patapsco, Arundel, and Patuxent Formations with some areas of artificial fill and alluvium at or near water bodies.

- *Bedrock with overlying soils* – present within the Piedmont Province (MP 18 to 87) primarily consisting of folded and faulted crystalline igneous and metamorphic bedrock, including schist, gneiss, gabbro and quartzite. There are also mapped surficial deposits of upland gravels (along higher hilltop elevations MP 18 to 20) and alluvium (generally present in stream flood plains) present.

  The Lowlands Section of the Piedmont Province (at MP 79.3 to 81.5) is generally characterized as carbonate-based (limestone or dolomite) and metamorphic (marble, schist or quartzite) rock with overlying soils (of varying thickness locally).

Ground surface along the Pipeline Route is less than 20 feet above mean sea level at MP 0.0.[1] There is little relief along this segment of the Pipeline Route with the sole exception of some gently-rising, flat-topped hills at the north end. This relief ranges up to 100 feet at the point where the Coastal Plain Province transitions into the Piedmont Province. Within the Piedmont Province, elevations range from 100 to 200 feet (at MP 18 to MP 20) and to points further north, elevations generally range from 150 to 650 feet (MP 20 to MP 87). The Lowlands Section of the Piedmont Province (MP 79.3 to MP 81.5) represents a broad valley with an elevation of approximately 250 feet. This section of the Piedmont Province is characterized as gently-sloping hills with shallow valleys.

Slopes along the Pipeline Route break down as follows: 67% in areas of 0 to 8% slope; 25% in areas of 8 to 25% slope; 7% in areas of 15 to 25% slope; and 1% in areas with greater than 25% slope. In summary, the Pipeline Route can be characterized as generally low to moderate relief and flat to gently-sloping topography.

6.4 Blasting

An evaluation to identify locations within the Project Area with potential for bedrock less than five feet below ground surface was completed using the National Resources Conservation Service (NRCS) Soil Survey Geographic (SSUGRO) database, geologic map information and field reconnaissance. A summary of areas with the potential for shallow or outcropping bedrock has been identified on Table 6.3-1.

In areas of shallow bedrock, alternative trenching techniques may be used depending on rock characteristics and feasibility. These could include:

- Ripping and cutting with a backhoe;

[1] Unless otherwise noted, all elevations are provided in feet above mean seal level from United States Geologic Survey (USGS) topographic contour data.

- Hoe-ramming with a hydraulic ram that fractures rock with rapid percussive impacts;
- Trenching equipment, which is usually accomplished with cutting teeth on a large rotating wheel; or
- Non-explosive demolition agents such as S-Mite, which are placed in holes drilled in the rock and which can expand and fracture the rock.

Alternatively, controlled blasting techniques may be employed during construction in areas of shallow bedrock. Controlled blasting techniques would be employed to facilitate construction in a manner that will impact only near-surface materials, i.e. blasting would be limited in intensity to confine fracturing to shallow rock. Specific areas where blasting may be required would be determined during construction.

To minimize or avoid potential impacts associated with blasting activity, blasting will be completed by a licensed blasting contractor in accordance with applicable Federal, State and local regulations and in accordance with the Project Blasting Plan (attached as Appendix 6A). The Project Blasting Plan will include measures for avoiding or minimizing potential impacts, including the following:

- Contractor development of a Site-Specific Blasting Plan;
- Use of warning signs; site access control; audible warning signals before and after a blast;
- Procedures for safe blasting materials handling, storage and use;
- Performance of blasting in accordance with applicable guidelines and regulations;
- Location of buried utilities in the work area;
- Pre- and post-blast condition surveys on nearby structures or utilities;
- Seismograph vibration monitoring during blasting to assess vibrations generated by a blast;
- Optimization of blast charge size and delay timing to minimize vibration;
- Use of matting to contain fly-rock; and,
- Pre and post-blast surveys of water supply wells within 150 feet of the blasting area.

At a minimum, the following regulations will apply to use of explosives and blasting-related work:

- Occupational Safety And Health Administration (OSHA) 1910.109, “Explosives and Blasting Agents”;
- OSHA 1926.900 through 914, “Blasting and The Use of Explosives”;
- Maryland Code, Public Safety Article, Title 11, Subtitle 1, “Explosives”; and,
- Pennsylvania Code, Title 25, Part I, Subpart D, Article IV, Chapters 210 and 211.

Other local ordinances may also apply. All authorizations required by Federal, State or local regulations will be obtained prior to any construction-phase blasting activities.

If evidence of damage to structures or utilities is detected after blasting, repairs will be made to restore the structure or utility to pre-blast condition, including repair or replacement of water supply wells.

Since no bedrock is expected to exist within proposed dredging limits for the offshore shipping channel development at the Terminal site (based on explorations performed to date), no offshore blasting is anticipated.

6.5 Mineral Resources

An assessment of mineral resources in the Project Area and within approximately 0.25 miles of the construction right-of-way was conducted using aerial photographs, USGS topographic maps, field reconnaissance, land parcel ownership records, and publicly-available mineral resource information. Maryland and Pennsylvania Geologic Survey directories of mineral producers and oil and gas resource maps were reviewed in conjunction with the information sources described above. There were no resources such as oil or gas production, exploration or storage areas, bituminous coal or anthracite mining fields identified within 0.25 miles of the Project Area. Unconsolidated material (sand, gravel or clay) pits or rock quarry facilities were identified within 0.25 miles of the Project Area and are summarized on Table 6.5-1. The closest resources are two privately-owned rock quarries approximately 100 feet south of the construction right-of-way (across Quarry Road) at MP 48.9. Both facilities presently provide coarse Serpentinite aggregate at these locations. Details on the operations (e.g. mining methodology, potential mine expansion limits, etc.) will be further assessed as the proposed pipeline alignment is finalized and specific discussions with the owners/operators are conducted. It is not currently anticipated that these mining operations will present significant adverse impacts to the pipeline construction or operation.

6.6 Potential Geologic Hazards

6.6.1 Seismic Risk

The potential seismic ground motions for the Terminal Site and the Pipeline Route were evaluated using the National Earthquake Hazard Reduction Program (NEHRP) Spectral Acceleration Maps and information available from the United States Geological Survey (USGS). The USGS and NEHRP Spectral Acceleration Maps depict the estimated probability that certain levels of ground movement from a seismic event will occur at a particular location during a specified period of time. The USGS-NEHRP maps have been used in the development of the seismic provision for the International Building Code, which is the applicable building code in Pennsylvania and Maryland.

The maximum considered earthquake ground motion for the conterminous United States is shown with the Project Area on Figure 6.6-1. The estimations presented on the maps are based on past seismic history at a location and are used to develop provisions of building codes (e.g., for structures, bridges, highways and utilities such as natural gas pipelines). Values on these seismic maps are referred to as maximum seismic acceleration (S_a) values, and are presented as a relative percentage of gravitational acceleration. The data indicate the Project Area is located in a region of generally low seismic risk.

The following sections discuss specifics of the seismic risk analyses for the Terminal Site and Pipeline Route individually.

6.6.1.1 Sparrows Point LNG Terminal

An evaluation of the seismic risk associated with the LNG Terminal has been performed and is presented in a separate report entitled “Site Specific Design Response Spectra and Assessment of Liquefaction Potential,” which is included in its entirety as Appendix F to the Preliminary Geotechnical Report on Sparrows Point (Appendix J in Resource Report 13).

The evaluation took into consideration the characteristics of the overburden deposits present beneath the Terminal Site, with assumptions for depths to and type of (soft or hard) bedrock, which is anticipated to be in excess of 500 ft.

below ground surface. The natural soil deposits vary from north to south within the proposed LNG tank footprints – these variations were also accounted for in the evaluation.

In summary, the Terminal Site is located in an area that has experienced far fewer significant earthquakes than northern and southern areas of the East Coast; however, several lesser earthquakes have occurred in this area, and the area has also experienced some ground shaking from larger and more distant earthquakes. Published United States Geological Survey (USGS) maximum spectral acceleration (Sa; also referred to as the maximum seismic acceleration coefficient) data indicate the Terminal Site to be within a region of relatively low seismicity; specifically, the maximum value of S_a is *0.17g*, where *g* is the gravitational constant.

Ground motion analyses accounting for several variables relating to soil deposit thicknesses, bedrock depth and types, and empirically-derived shear wave (V_s) velocities were performed using the PROSHAKE computer program. The resulting design spectra have been evaluated for the Safe Shutdown Earthquake (SSE; the maximum earthquake potential for which certain structures, systems, and components important to safety, are designed to sustain and remain functional) and the Operating-Basis Earthquake (OBE; the vibratory ground motion for which those features of the plant necessary for continued operation without undue risk to the health and safety of the public will remain functional). The SSE is an approximately 2,500-year event; the OBE is a 475-year event.

The resultant design spectra curves included in the seismic assessment report will be utilized in Terminal structure design.

6.6.1.2 Mid-Atlantic Express Pipeline

Maximum seismic acceleration coefficients (S_a) ranging from approximately *a=0.20g* to *a=0.32g* were determined for the 0.2-second spectral response along the Pipeline Route. Further, S_a ranging from approximate *a=0.06g* to *a=0.08g* were determined for the 1.0-second spectral response along the Pipeline Route. As with the Terminal Site discussed above, these values represent the magnitude of a potential seismic event with a mean return period of approximately 2,500 years.

The geologic reference maps indicate the Pipeline Route passes through an area of faulted bedrock in the vicinity of MP 79 to 83. Regionally, this area includes numerous faults (Martic, Embreesville, Cream Valley, and several un-named). Based on the routing through this area, the faults anticipated to be intersected are the Martic thrust fault at approximate MP 79.2 and an unnamed strike-slip fault at approximate MP 82.5. The Martic thrust fault MP 79.2 represents the stratigraphic break between the Octararo Schist (uplifted side) and the Canestoga limestone. The strike slip is parallel to Brandywine Creek, which indicates it may be structurally related to and may control the local drainage patterns. These faults were likely active during orogenies of the Paleozoic era (estimated 400 to 500 million years ago) during the formation of this region's faulted and folded bedrock regime, but are not considered or suspected to be active.

Based on the seismic map and fault information identified during the geologic literature review, there appears to be a relatively low potential for seismic-related impacts associated with the Pipeline Route. Regardless, specific evaluation of relevant factors, such as seismic potential, surface topography and soil conditions along the Pipeline Route will be considered during the detailed pipeline design. The pipeline will be designed to meet or exceed the codes and standards identified in Resource Report 11, including the U.S. Department of Transportation Title 49, CFR Part 192, "Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards," as well as other industry standards (ASCE, ASME, ANSI, etc.) and applicable codes typically employed for the design of buried pipe. If necessary, to meet or exceed these codes, engineering measures will be incorporated into the pipeline design (for example, increased pipe wall thickness, increased yield strength, modified welding requirements or modified installation techniques).

6.6.2 Soil Liquefaction

Soil liquefaction can be caused by cyclic ground shaking typically associated with earthquakes in susceptible areas. The potential for soil liquefaction is influenced by multiple variables, including depth of groundwater, soil type, relative soil density, gradation of soil deposits, and depositional environment.

6.6.2.1 Sparrows Point LNG Terminal

The liquefaction potential for the Terminal Site was assessed as part of the seismic risk assessment referenced above. The assessment concluded:

- The majority of the field density (N-) values obtained during the geotechnical drilling program indicated the soil density exceeds the minimum required to safeguard against liquefaction;
- Eight of the N-values were below the minimum for liquefaction; the locations of these values indicate a *potentially* more susceptible soil layer near the southwestern-most proposed tank location.
- Additional boreholes should be drilled prior to detailed design to obtain a more detailed assessment of soil density to provide sufficient data for terminal design.

The Talbot Formation, which immediately underlies the fill soils at the Terminal Site is variable in nature and is characterized as interbedded clay, silt and sand. Soil types that are most susceptible to liquefaction are typically medium to fine sands, where significant pore-water pressure can develop during a significant cyclic shaking event. In the southern portion of the Terminal Site the underlying Talbot Formation is primarily sand. The “Site Specific Design Response Spectra and Assessment of Liquefaction Potential,” of the Preliminary Geotechnical Report on Sparrows Point recommended that prior to final LNG Terminal design that additional boreholes be completed in this area to confirm the presence of the loose sand layer and collect additional data proximate to the LNG tank locations to support the foundation design. If, during final design, it is concluded that there is a liquefiable sand layer, then the potential effects of liquefaction will be considered and factored into the H-pile design of the LNG tank foundations to compensate for potential effects associated with liquefaction, such as reduction of soil shearing strength and ground settlement.

6.6.2.2 Mid-Atlantic Express Pipeline

Based on the relatively low seismic potential within the Project Area, the existing bedrock or soil conditions, relative age of deposition, and lack of any documented incidence of soil liquefaction in the Project Area, the potential for soil liquefaction to occur along the Pipeline Route is considered to be relatively low and only one area of potentially susceptible soil has been identified at MP 3.0 to 4.1.

As indicated above, areas of underlying soils in the Talbot Formation were identified at the LNG Terminal during geotechnical investigation to be potentially susceptible to soil liquefaction. The Talbot Formation (in areas mapped with sand as the primary component) is also crossed by the Pipeline Route from MP 3.0 to 4.1. The soils in this formation coupled with other geophysical conditions (such as elevated water table or saturated soils), could be potentially susceptible to soil liquefaction during a seismic event. Specific evaluation of relevant factors, such as seismic potential, surface topography and reported soil conditions along the Pipeline Route will be considered during the detailed pipeline design. The pipeline will be designed to meet or exceed the codes and standards identified in Resource Report 11, including the U.S. Department of Transportation Title 49, CFR Part 192, "Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards." If necessary, to meet or exceed these codes, engineering measures will be incorporated into the pipeline design (for example, weighting the pipeline or increasing the flexibility or strength of the pipe). Under normal operating conditions, liquefaction of the surrounding soils is not the primary hazard to the pipeline, but rather buoyancy induced by liquefaction, which will be addressed during detailed design, if necessary based on soil conditions.

6.6.3 Landslides

The potential for landslides or slope failures in the Project Area is influenced by several factors including slope steepness, soil type and thickness, soil and bedrock structure and lithology, climate, hydrology, and geomorphic history. Clay deposits and deeply-fractured shallow or outcropping bedrock on steep slopes are generally the conditions that are most susceptible to landslide occurrence.

6.6.3.1 Sparrows Point LNG Terminal

The Terminal Site will be situated on Sparrows Point which is underlain by soils of the Potomac Group, a mixture of silts, sands and clays. This general area was identified on the National Landslide overview map of the United States as having moderate susceptibility/low incidence for landslides. This indicates there is a low reported incidence of landslides – specifically less than 1.5% of the mapped area. Although there is limited relief in this region, the LNG Terminal has been located where no steep slopes are present; this will essentially eliminate the potential for slope failures for the Terminal Site. To review localized conditions, an evaluation was completed of steep (greater than 25%) slope areas and soils with elevated (greater than 50%) clay content. No areas within or near the LNG Terminal location were identified as susceptible to landslides.

6.6.3.2 Mid-Atlantic Express Pipeline

The Pipeline alignment is identified as having a moderate/low susceptibility for landslides. After reviewing data for localized conditions along the Pipeline Route, three areas were identified as potentially steep or susceptible to landslides. The three areas were identified along the Pipeline Route include:

north of Little Gunpowder Falls (MP 22.9); south of Deer Creek (MP 35.4); and south of Susquehanna River (MP 43.9). However, given the remaining localized factors – apparent bedrock competency, heavy vegetative cover and/or planned horizontal directional drilling installation methods (in the instance of the Susquehanna River) in these areas – there appears to be a relatively low potential for slope failures. It should also be noted that 99% of the route within Baltimore County, Maryland is along areas of less than 15% slopes.

To further minimize or avoid potential impacts from landslides or slope failure in areas of potential susceptibility, construction of the Pipeline will be completed in accordance with the Erosion and Sediment Control Plan (provided as Appendix 2A to Resource Report 2), including measures to ensure appropriate grading, limit undercutting or overloading slopes, and provide for appropriate revegetation and maintenance during operation.

6.6.4 Subsidence

Carbonate bedrock weathers uniquely and under certain conditions it can be dissolved by mildly-acidic soil, groundwater or precipitation. Such weathering can potentially result in features in rock such as depressions, voids or caves. Surface expression of these features in the form of ground subsidence is referred to as karst topography, which can include subtle surface depressions and in extreme cases sinkholes. Subsidence can also result if "loss of ground" occurs from underground mining operations.

6.6.4.1 Sparrows Point LNG Terminal

No potential karst features were identified at the proposed Terminal Site. No sinkholes or areas of underground mining were identified along the Terminal Site in the Mineral Resources geologic review (Section 6.5 above). Further, no evidence of subsidence or ground disturbance was recorded during the field surveys in this area. Based on the great depth to bedrock (estimated to be greater than 500 ft.) at the Terminal Site the potential for subsidence due to solution of bedrock is very low.

6.6.4.2 Mid-Atlantic Express Pipeline

During the geologic literature review, one area of potential karst features was identified along the Pipeline Route (at approximately MP 79.5 to 81), with a reported mapped density of approximately one feature per 10 acres within in this area. On a relative scale, the area of karst mapped features traversed by the Pipeline has a relatively low density of karst features. Further, during the routing and field surveys, consideration was given to avoiding any mapped, observed or documented features along this karstic area.

A review of regional sinkhole and karst feature mapping in Chester County, Pennsylvania identified only one specific mapped feature in this zone present along the project survey corridor – a closed or linear depression at MP 80.4. However, no evidence of subsidence or ground disturbance was recorded on the Pipeline Route during the field surveys in this area.

In this area of mapped karst features, if any additional documented features or field observations of karst-related conditions are identified along the Pipeline,

they will be evaluated during the detailed pipeline design. Accordingly, if necessary, engineering measures may be incorporated into the pipeline design (for example, increased pipe wall thickness, increased yield strength, modified weld requirements or modified backfill approaches).

Construction will be completed in accordance with the Sparrows Point Project – Environmental Construction Plan and Best Management Practices drawings, appended to Resource Report 2 (Appendix 2A and 2B, respectively). Use of proper erosion control devices and minimization of disturbance to surface drainage patterns will avoid or further minimize potential impacts within the area of karst topography.

During operation, routine right-of-way monitoring inspections will be completed as described in Resource Report 1. This monitoring will include visual ground surface inspection, as well as aerial fly overs, to confirm there are no new karst-related surface features which could potentially impact pipeline operations.

6.6.5 Other Geologic Hazards

Additional potential geologic hazards affecting construction or operation may include volcanism or flooding.

Volcanism:
Based on the geologic resource and reference materials identified above and an understanding of the Project Area, there is no indication of conditions conducive to volcanism in the vicinity of either the Terminal Site or the Pipeline Route, and no volcanic deposition has been documented. In general, the entire eastern seaboard of the United States is devoid of current volcanic activity due to the lack of the necessary conditions such as diverging or converging crustal plates, or the presence of an isolated, active or dormant volcano resulting from a "hot spot" in the mantle underlying the crust. As such, potential volcanism is not considered to be of concern for either the Terminal Site or the Pipeline Route.

Flooding (Sparrows Point LNG Terminal):
The LNG Terminal area is to be located in a coastal setting and therefore the Terminal Site is subject to tidal fluctuations in surface and groundwater levels. National Oceanic and Atmospheric Administration (NOAA) tidal data for the 1983 to 2001 Tidal Epoch indicate the Mean Higher High Water (MHHW) level is Elevation 0.506 m (1.66 ft). This is equivalent to 0.83 ft above North American Vertical Datum-1988 (NAVD).

The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map indicates the 500-year (Zone "B") flood limits do not encroach onto the proposed Terminal Site. In addition, the grade of the Terminal Site will be raised during construction and a bulkhead will be installed at the waterline which will further reduce the potential for any flooding impacts at the Terminal Site.

Hurricane flooding has been known to occur in the area of the Terminal Site. Because such flooding represents the worst-case meteorological event in the area of the Terminal Site, it is used for the basis for determining the volume and velocity of flood control design efforts. The Terminal Site will incorporate appropriate flood control design elements, including establishment of shore protection features, to protect against hurricane flooding, and site storm water collection and drain systems, to allow

collection and removal of rain and flood waters from the site. Specifically, shore protection will be installed to protect against flooding and storm surges resulting from hurricanes and severe weather.

Flooding (Mid-Atlantic Express Pipeline):
Based on the geologic reference materials and field surveys along the Pipeline Route, there may be areas adjacent to the stream and wetland crossings that are susceptible to localized seasonal flooding. Specific measures will be employed to avoid or minimize potential construction or operation impacts related to flooding at these wetland and water bodies, including for example: specialized construction techniques in wetland areas, minimizing disturbance to vegetation along stream bank areas, avoiding (to the extent practical) paralleling water bodies or crossing at non-perpendicular angles, restoration measures at water body and wetland crossings (to restore pre-existing contours or hydraulic conditions, respectively). These construction techniques are outlined in Resource Report 2 and, more specifically, in the Sparrows Point Project – Environmental Construction Plan and Best Management Practices drawings, appended to Resource Report 2 (Appendix 2A and 2B, respectively).

6.7 Avoidance and Minimization of Adverse Effects

Avoidance and minimization of potential adverse effects on construction and operation of the project from geologic conditions or hazards was a primary consideration during the routing, siting and alternative analysis. The Pipeline Route was also selected and modified as necessary to avoid or minimize potential impacts to mineral resources, as described in more detail in Resource Report 10.

During the route selection process, including desktop analysis of map resources and survey activities in the field, specific effort was made to avoid areas of steep slopes and landslide susceptibility. These considerations have reduced the potential for slope stability issues during construction and operation.

In areas with potential shallow bedrock conditions which could not be avoided, efforts will be taken to minimize potential impacts during construction. As indicated in the section above, an evaluation of alternative construction techniques will be performed, including controlled blasting. Monitoring and engineering controls, as identified in the Blasting Plan (attached as Appendix 6A) guidance document, will be employed to avoid or minimize potential impacts during construction.

6.8 Paleontology Resources

Maryland:
Geologic reference materials indicate paleontological resources are present in southern, central and western Maryland, specifically dinosaur fossils present in the Mesozoic-age formations (dated between the Triassic and Cretaceous periods). Noteworthy specimen fossils found in Maryland include *Astrodon johnstoni* (official Maryland State dinosaur) and *Ecphora gardnerae gardnerae* (official Maryland State fossil shell). However, these are not recorded in the geologic formations encountered at the Terminal Site or along the Pipeline Route. Fossils of plants such as seeded ferns have been identified in northeastern Maryland, including Harford, and Cecil Counties, proximate to the Pipeline Route (however, as indicated below these do not appear to represent significant palentological resources requiring any action if encountered).

Pennsylvania:

In Pennsylvania, the trilobite, *Phacops rana,* is the Pennsylvania state fossil and can be found in Devonian age formations. Geologic reference materials indicate no significant vertebrate fossils such as dinosaur bones have been encountered in Pennsylvania, and mastodon bones have been found only in the northern tier of the state.

Potentially significant paleontological resources include bones, rare plant or animal species or "undiscovered" invertebrate fossils in the rock record. According to both the Maryland and Pennsylvania Geological Surveys, no requirements exist for notification if fossils of any type are encountered in an excavation; however, if apparently significant paleontological resources (i.e. obvious potential dinosaur bones) are discovered during construction the Maryland or Pennsylvania State Geologic Surveys, as appropriate, will be contacted as a courtesy.

6.9 Underground Storage Facilities

The Project will not involve the construction or operation of any underground natural gas storage facilities.

6.10 References

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APPENDIX 6A

Project Blasting Plan