2.5.3 SURFACE FAULTING

The U.S. EPR FSAR includes the following COL Item in Section 2.5.3:

> A COL applicant that references the U.S. EPR design certification will investigate site-specific surface and subsurface geologic, seismic, geophysical, and geotechnical aspects within 25 miles around the site and evaluate any impact to the design. The COL applicant will demonstrate that no capable faults exist at the site in accordance with the requirements of 10 CFR 100.23 and of 10 CFR 50, Appendix S. If non-capable surface faulting is present under foundations for safety-related structures, the COL applicant will demonstrate that the faults have no significant impact on the structural integrity of safety-related structures, systems or components.

This COL Item is addressed as follows:

{This section provides information about site-specific field and literature studies of the potential for faults or other tectonic features (including evidence of paleoliquefaction and prehistoric major earthquakes) that have the potential to affect operation of Callaway Plant Unit 2. Results of the investigations indicate that there is no evidence of Quaternary tectonic surface faulting or fold deformation and there are no capable tectonic sources within a 25 mile (40 km) radius of the Callaway Plant Unit 2 Site. In addition, no non-capable surface faulting has been identified under or near the foundations for safety-related structures. Information contained in these sections was developed in accordance with RG 1.208 (NRC, 2006), and is intended to satisfy 10 CFR 100.23, "Geologic and seismic siting criteria" (CFR, 2007a) and 10 CFR 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants" (CFR, 2007b).

2.5.3.1 Geological, Seismological, and Geophysical Investigations

Quaternary tectonics for the Site Region and Area are discussed in detail in Section 2.5.1.1.4 (Regional Tectonic Setting) and 2.5.1.2.4 (Site Area Structural Geology), and are summarized in this Section 2.5.3.

Lithologic, stratigraphic, and structural geologic conditions of the Site Region and Area are discussed in detail in Section 2.5.1.1.3 (Regional Stratigraphy) and 2.5.1.2.3 (Site Vicinity and Site Area Stratigraphy).

The Geologic History of the Site Region and Area is presented in detail in Section 2.5.1.1.2 (Regional Geologic History) and 2.5.1.2.2 (Site Vicinity and Site Area Geologic History).

The seismicity and the seismic hazard analyses performed for the Site Region and Area, including studies and information related to paleoseismology, are discussed in Section 2.5.1.1.4.2 (Regional Folding, Faulting, and Jointing) and 2.5.1.2.4.2 (Site Faulting), and are discussed in detail in Section 2.5.2. Site Area and Vicinity seismicity is summarized in Section 2.5.3.1.4 below.

The locations of the Site structures located relative to the geologic units are presented in Section 2.5.4. The following reviews and investigations were performed during 2007 and 2008 to specifically assess the potential for tectonic and non-tectonic deformation and surface fault rupture within a 25 mile (40 km) radius of the Callaway Plant Unit 2 Site:

- Compilation and review of existing geologic and seismologic data and references (Section 2.5.3.1.1).

- Review and interpretation of previous Callaway Plant Site investigations (Section 2.5.3.1.2).
- Current shear wave reflection seismic studies (Section 2.5.3.1.3).
- Determination of current Site seismicity characteristics, including review of USGS earthquake catalog and supporting data for the Callaway Plant Unit 2 Site Region, updated in 2007 (Section 2.5.3.1.4).
- Current field reconnaissance and paleoliquefaction studies (Section 2.5.3.1.5).

2.5.3.1.1 Compilation and review of existing geologic and seismologic data and references.

The geologic and geotechnical information available for the Callaway Plant Site is contained in these principal sources:

- Detailed investigation performed for the existing Callaway Plant Unit 1 Site and complementary structures (AmerenUE, 2004 and Dames & Moore, 1980); the latter including excavation description and mapping for the Callaway Plant Unit 1 Site.
- Published and unpublished geologic mapping performed primarily by the Missouri Department of Natural Resources (MODNR) (MODNR 2007, Gentile 2004, Thompson 1986, 1991, and 1993).
- Seismicity data compiled and analyzed in peer-reviewed journal articles and, more recently, as part of Section 2.5.2.
- Information related to Quaternary faults, liquefaction features, and possible tectonic features in the Central and Eastern United States (Crone, 2000; Wheeler, 2005; Tuttle, 2005; USGS, 2000).
- Multiple references related to paleoliquefaction features and studies, and paleoseismicity, in the Central and Eastern United States (CEUS).

2.5.3.1.2 Review and interpretation of previous Callaway Plant Site investigations

The Site Area was extensively studied during the preparation of the FSAR for Callaway Plant Unit 1, (AmerenUE, 2004). The previous investigations documented the absence of Quaternary faults and other capable tectonic features at and within the Callaway Plant Site Area. The following sources were analyzed at that time to derive these conclusions:

- Interpretation of aerial pictures and topographic maps. This interpretation revealed no evidence of surface rupture, surface warping, or offset of geomorphic features indicative of active faulting.
- Approximately 170 exploratory boreholes drilled during Callaway Plant Unit 1 Site field investigation. Borehole data have provided evidence for the lateral continuity of strata across the existing Callaway Plant Site. The inspection of soil and rock samples revealed no adverse effects indicative of geologically recent or active faulting.
- Field reconnaissance of many surface outcrops at the Site and within the 5 mile (8 km) radius of the Site, coupled with geophysical surveys, provided no evidence for faulting at the Callaway Plant Unit 1 Site.

- Interviews with personnel from government agencies and private organizations. These interviews concluded that no known faults are present at the surface in or beneath the existing Callaway Plant Unit 1 Site Area.

These data sources support the conclusion that there is no evidence for faulting at the Callaway Plant Site. This conclusion remains valid as demonstrated by the Callaway Plant Unit 2 investigation described in the following sections.

2.5.3.1.3 Current Shear Wave Reflection Seismic Studies

Shear wave reflection seismic studies were performed at the Callaway Plant Unit 2 Site to locate geologic layers in the subsurface from reflected seismic waves. If present, subsurface features generate reflections of a shockwave of a known frequency band. The subsurface feature would reflect the wave to a line of sensors which can determine from the depth of the relevant feature the elapsed time. The locations of the shear wave reflection seismic studies performed for Callaway Plant Unit 2 are shown on Figure 2.5L-12.

Shear wave reflection seismic sections (Bay Geophysical, 2008) were interpreted as displayed in Figure 2.5L-12. In this figure interpreted seismic sections are identified by the correlation of the Graydon Chert Conglomerate and the Snyder Creek events traced across each seismic profile. The Graydon Chert Conglomerate is highlighted in orange and the Snyder Creek event is highlighted in yellow on each of the seismic figures.

The results show the presence of a minimal vertical time shift noted in Reflection Lines 1, 2 and 3 in Figure 2.5L-12. These time shifts have been interpreted by Bay Geophysical as non-significant offsets within the Snyder Creek Formation, and are not attributed to faulting. These offsets do not appear above or below the Snyder Creek Formation.

Post-depositional movements are not likely the cause of the offsets. It is probable that these apparent offsets could be a result of lenticular facies, erosion remnants, or a depositional feature within the Snyder Creek Formation (noted in Reflection Line 2 in Figure 2.5L-12). Other apparent offsets may be the result of low fold (low statistical redundancy) that occurs at the line ends of seismic reflection data, thus reducing the confidence of the interpreted apparent offsets. These offsets show minimal vertical time shift above the Snyder Creek event, and no evidence above the Graydon Chert Conglomerate event.

2.5.3.1.4 Current Site Seismicity Characteristics

Earthquake epicenters through 2007, were identified as discussed in Section 2.5.2 and are shown in Figure 2.5L-5. There are no recorded earthquakes within the 25 mile (40 km) radius of the Callaway Plant Site. The Site is located in a region that has experienced only infrequent minor earthquake activity, with the closest epicentral location (a 3.0 to 3.9 m_b event) situated approximately 38 miles (61 km) southwest of the Callaway Plant Site, west of Cole County. The only other cataloged earthquake within 50 miles (80 km) of the Callaway Plant Site (also 3.0 to 3.9 m_b) was located approximately 45 miles (72 km) south-southeast of the Site, south of Gasconade County. Section 2.5.2 provides a full discussion on the seismicity and seismic hazard analysis for the Callaway Plant Site.

2.5.3.1.5 Current Field Reconnaissance and Paleoliquefaction Studies

To supplement existing information referenced in Section 2.5.3.1.1, a number of current Site specific studies were undertaken, including the following:

- Geologic studies were performed to develop a full understanding of the Site historical and structural characteristics, (to a radius of 0.6 mi (1 km)), utilizing data obtained from Site borings and geophysical surveys (Section 2.5.1.2 and Section 2.5.4).

- A study of current aerial and satellite photography and topographic maps was performed to evaluate the presence and distribution of faults and liquefaction features in the Site Area (5 miles (8 km)).

- Field reconnaissance within a 5 mi (8 km) radius of the Site was conducted by geologist teams to verify the results of the aerial study.

- Field reconnaissance of the rivers within the Site Vicinity (25 mi (40 km) radius) with an emphasis on the Site Area was conducted to locate potential areas where liquefaction of sediments may have occurred.

- Field reconnaissance was performed to visit the five faults mapped within a radius of 30 miles (48 km) of the Site.

Details of these activities are presented in the Site Area Paleoliquefaction and Surface Faulting Investigation provided in COLA Part 11G.

A search for evidence of paleoliquefaction and active faulting was conducted in the Site Area in three phases.

During Phase 1 remote imagery interpretation, followed by a detailed ground truthing investigation to a radius of more than 5 miles (8 km) from the Site, yielded no evidence of faulting or paleoliquefaction in the area of the Site. Most of the area around the Site has been impacted by agricultural activities or is wooded which might mask such features on remote imagery. However, no such features were found in non-developed areas, either. The Site Area Paleoliquefaction and Surface Faulting Investigation provided in COLA Part 11G contains a map of the sites visited by the team and a tabulation of the evaluation of each site.

The Phase 2 investigation involved a reconnaissance of the local rivers and streams within the Site Area and Site Vicinity to locate paleoliquefaction features that may be found there. Most sites on the streams were visited by boat, but some were visited by a land route because of shallow water conditions. The team found no conclusive paleoliquefaction evidence for strong ground motion in either the Site Area or Site Vicinity. The Site Area Paleoliquefaction and Surface Faulting Investigation provided in COLA Part 11G contains the results of that reconnaissance, including a map of the sites visited.

The USGS recently completed a compilation of all Quaternary faults, liquefaction features, and possible tectonic features in the Central and Eastern United States (Crone, 2000; Wheeler, 2005; Tuttle, 2005). The Phase 2 Site reconnaissance findings described here are consistent with the USGS findings, wherein the closest reported indication of paleoliquefaction is referred to in Crone, 2000 and Tuttle, 2005 as located about 16 miles (25 km) south-southwest from downtown St. Louis on the Meramec River (about 90 miles (145 km) east-southeast from the Callaway Plant Site).

Researchers in Tuttle, 2005 found no paleoliquefaction features along the lower Missouri River in a reach of 9 miles (15 km) upstream to 18 miles (30 km) downstream from St. Charles, Missouri (St. Charles is about 70 miles (112 km) east of the Callaway Plant Site). The lower 6 miles (10 km) of Femme Osage Creek, a tributary to the Missouri River near Defiance, Missouri (about 55 miles (88 km) east of the Callaway Plant Site), was also surveyed, and no paleoliquefaction features were found.

Although the evidence is not conclusive as to timing, location, and magnitude; prehistoric earthquakes may have caused some of the paleoliquefaction features noted in the literature. Utilizing postulated locations, magnitudes, and recurrence intervals, sensitivity studies were performed as part of the development of the seismic hazard analysis for the Callaway Plant Unit 2, to determine the potential impact of these postulated prehistoric events on the seismic hazard at the Site. The hazard calculated using these postulated prehistoric events is enveloped by the seismic hazard resulting from the New Madrid Seismic Zone events, as well as the assumed background seismic source for the Callaway Plant Site. The inclusion of these postulated earthquakes has no impact on the PSHA in Section 2.5.2. The sensitivity studies and conclusions are discussed in Section 2.5.2.

The Phase 3 investigation confirmed locations for the 5 faults closest to the Site. Inspections of rock outcrops and road cuts found no evidence of recent movement on those faults, and confirmed the tectonically quiet nature of the Site Vicinity.

In summary, no surface faulting features that could represent a geologic hazard or which could impact the safety-related facilities of Callaway Plant Unit 2 were found in the area of the Site. No major geologic structures or faults in the Site Area have been identified that have the potential to affect operation of the plant.

2.5.3.2 Geological Evidence, or Absence of Evidence, for Surface Deformation

Folds shown in Figure 2.5L-6, and Figure 2.5L-9 are all pre-Pennsylvanian, and are more than 300 million years old, preceding the deposition of the Graydon Conglomerate. Descriptions are provided in Section 2.5.1.2.4.1 and none of these folds is expressed on the surface. The age of these deformations (300 Ma) demonstrates the stability of this Site Vicinity.

Linear features interpreted from remote imagery and topographic maps were investigated during the Phase 1 field reconnaissance discussed above in Section 2.5.3.1.5. These investigations did not reveal any evidence of surface deformation or faulting associated with either circular or linear features observed in the Site Area.

The Phase 2 field reconnaissance study found no conclusive paleoliquefaction evidence for strong ground motion along the streambanks within the Site Area, or Site Vicinity.

As discussed in Part 11G, the five faults located within 25 miles (40 km) of the Site and investigated in Phase 3 are inactive, non-capable tectonic sources and are incapable of generating earthquakes and/or ground deformation and shaking.

2.5.3.3 Correlation of Earthquakes with Capable Tectonic Sources

No reported historical earthquake epicenters have been associated with bedrock faults or other tectonic features within the 25 mile (40 km) radius of the Callaway Plant Site.

The Site is located in a region that has experienced only infrequent minor earthquake activity. There have been only two cataloged earthquake within 50 miles (80 km) of the Callaway Plant Site.

Neither of these events is associated with any known tectonic features as can be seen in Figure 2.5L-5.

2.5.3.4 Ages of Most Recent Deformations

As discussed above, there are no faults or other tectonic features within the 5 mile (8 km) Site Area that exhibit evidence of Quaternary activity. On the basis of a review of available

published geologic literature and field reconnaissance, it is concluded that deformations of geologic structures in the Site Area are constrained to the Pennsylvanian Period (300 Ma), do not affect Pleistocene deposits, and demonstrate the stability of the Site Vicinity.

2.5.3.5 Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures

As discussed in Section 2.5.1.2.4, no faulting or other tectonic deformation features are known to exist within 5 miles (8 km) of the Site, and no historic earthquake epicenters have been recorded within 38 miles (61 km). Therefore, there are no known or postulated relationships existing between the Site Area geologic regime and regional tectonic structures that are known to be capable sources for ground shaking and deformation.

2.5.3.6 Characterization of Capable Tectonic Sources

A "capable tectonic source", as defined by Regulatory Guide 1.208, is described by at least one of the following characteristics:

- Presence of surface or near-surface deformation of landforms or geologic deposits of a recurring nature within the last approximately 500,000 years, or at least once in the last approximately 50,000 years.
- A reasonable association with one or more large earthquakes or sustained earthquake activity that usually is accompanied by significant surface deformation.
- Structural association with a capable tectonic source having characteristics of either item above, such that movement on one could be reasonably expected to be accompanied by movement on the other.

None of the faults or other tectonic features identified within a 25 mile (40 km) radius of the Callaway Plant Site is assessed to be a capable tectonic source. This conclusion is based on the following:

- No evidence of Quaternary deformation is reported in the literature or was observed during any phase of the field reconnaissance conducted for this study, as discussed in Section 2.5.3.1.5.
- There are no associated historical earthquakes or alignments of seismicity to suggest the presence of a capable tectonic source in the Site Area (refer to Section 2.5.1.2.4).
- All features noted during the field reconnaissance (Section 2.5.3.1.5) are associated with geologic structures that are pre-Quaternary, demonstrating that the features have not resulted from capable tectonic sources as defined above.

2.5.3.7 Designation of Zones of Quaternary Deformation in the Site

No zones of Quaternary deformation that would require additional investigation have been identified within the Callaway Plant Site Area (Section 2.5.1.2.4). Geologic investigations of the Site have not revealed any evidence of faulting affecting deposits younger than Pennsylvanian (Graydon Conglomerate Formation as well as Quaternary glacial and post-glacial deposits).

No paleoliquefaction features were noted in the alluvium along the Missouri River or its tributaries within the 5mile (8 km) Site Area. Only a single location of 95 sites visited in the Site Vicinity was noted to contain a possible feature of interest.

In addition, as discussed in Section 2.5.1.1.4.2.2, the USGS recently completed a compilation of all Quaternary faults, liquefaction features, and possible tectonic features in the Central and Eastern United States (Crone, 2000; Wheeler, 2005; Tuttle, 2005; USGS, 2000). Their findings indicate that the closest reported indication of paleoliquefaction is referred to in Crone, 2000, and Tuttle, 2005, as being located about 16 miles (25 km) south-southwest from downtown St. Louis on the Meramec River (about 90 miles (145 km) east-southeast from the Callaway Plant Site).

2.5.3.8 Potential for Tectonic or Non-Tectonic Deformation at the Site

The potential for tectonic and non-tectonic deformation at the Site is negligible. This is based on evidence discussed above and summarized as follows:

- A remote imagery interpretation, followed by a detailed ground truthing investigation, yielded no evidence of paleoliquefaction features or faulting in the Site Area.

- No Quaternary deformation has been identified in the Site Vicinity, and the closest reported indication of paleoliquefaction is referred to in Crone, 2000, and Tuttle, 2005, as located about 16 miles (25 km) south-southwest from downtown St. Louis on the Meramec River (about 90 miles (145 km) east-southeast from the Callaway Plant Site).

- The Site is located in a region that has experienced only infrequent minor earthquake activity, with the closest epicentral location (3.0 to 3.9 mb) situated approximately 38 miles (61 km) southwest of the Callaway Plant Site, west of Cole County. Additionally, there has been only one other cataloged earthquake within 50 miles (80 km) of the Callaway Plant Site. This earthquake (3.0 to 3.9 mb) was approximately 45 miles (72 km) south-southeast of the Site, south of Gasconade County.

- Shear Wave Reflection Seismic Studies at the Site indicate non-significant offsets within the Snyder Creek formation not attributable to faulting. Post-depositional movements are not interpreted as the cause of the offsets.

- Folds shown in Figure 2.5L-6, and Figure 2.5L-9 are all pre-Pennsylvanian, preceding the deposition of the Graydon Conglomerate. Descriptions are provided in Section 2.5.1.2.4.1.

- The extensive detailed mapping of the excavations for Callaway Plant Unit 1 revealed no evidence of folding or faulting, or any other feature that would adversely affect the safety of the plant (Dames & Moore, 1980).

2.5.3.9 References

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