Report on Results of Data Documentation Audits Conducted 6, 9, 10 June 2011 and 25-27 October 2011 to Review the Compiled Geologic Map Report for CNS Unit 1 (Lee Nuclear Site Unit 1) in Relation to the Lee Nuclear Site COL Application

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The primary purpose of the two data documentation audits conducted by NRO Senior Geologist, Dr. Gerry L. Stirewalt, on 6, 9, and 10 June and 25-27 October 2011 was to review Revisions 0 and 1 of the following report, which presented the geologic map compiled from data initially collected in the 1970s to characterize lithologies and geologic features in the excavation for former Cherokee Nuclear Site (CNS) Unit 1 (i.e., Lee Nuclear Site Unit 1):

> Project Report DUK-001-PR-01, Revision 2, Cherokee Nuclear Station Final Foundation Geologic Map Record: Duke Power Company, October 2011, prepared by Fugro Consultants, Inc.

Because CNS Unit 1 (Lee Nuclear Site Unit 1) lies under concrete poured during initial construction activities at the CNS site, it has not been possible for NRC staff to directly examine lithologies and geologic features (including faults, shear and breccia zones, and fractures) in that co-located excavation to confirm that no potentially capable (i.e., Quaternary, 2.6 Ma to present) tectonic structures or detrimental non-tectonic features occur in foundation bedrock at Lee Nuclear Site Unit 1. Regulatory requirements in 10 CFR 100.23(d) explicitly state that geologic and seismic siting factors related to design must include determination of the potential for tectonic and non-tectonic surface deformation. Regulatory Guide 1.208 indicates that faults exposed in site excavations should be mapped and assessed in regard to rupture potential while walls and floors of the excavations are exposed, to include assessment of non-tectonic surface and near-surface deformation.

Although the requirements and guidance defined above were effectively followed for the CNS site, results of the unpublished geologic mapping activities conducted in the 1970s for CNS Unit 1 needed to be documented for the Lee Nuclear Site COL application in order to satisfy a geologic mapping License Condition for Lee Nuclear Site Unit 1. This License Condition states that an applicant shall undertake the following actions: (a) Perform detailed geologic mapping of the excavation for nuclear island structures; (b) Examine and evaluate geologic features discovered in excavations for safety-related structures other than those for the nuclear island; and (c) Notify the Director of the Office of New Reactors, or the Director's designee, once excavations for safety-related structures are open for examination by NRC staff. Therefore, the applicant prepared and made available for review the 2011 report containing copies of the original geologic map panels, developed based on original field notes and geologic maps initially prepared in the 1970s to characterize site location geology in the CNS Unit 1 excavation; the compiled digital final geologic map and associated data; detailed descriptions of the quality assurance procedures exercised to produce the final digitized map compilation; and discussions of lithologies and geologic features that occur in the CNS Unit 1 (Lee Nuclear Site Unit 1) excavation. The goal of the report was to document the similarity of rock types and orientations

and ages of tectonic structures in the CNS Unit 1 (Lee Nuclear Site Unit 1), CNS Unit 2, and CNS Unit 3 (Lee Nuclear Site Unit 2) excavations in order to effectively fulfill the geologic mapping License Condition for Lee Nuclear Site Unit 1, which is now buried under concrete, and ensure that no capable tectonic structures or potentially detrimental non-tectonic features occur in foundation level bedrock in the Lee Nuclear Site Unit 1 excavation.

In regard to review of Revision 0 of the report, conducted during the June 2011 data documentation audit, G. Stirewalt made the following observations on report content:

1. Revision 0 of the report contained descriptive text; 5 tables; 16 figures; Plate 1, as a CD, presenting the final compiled digitized geologic map for the CNS Unit 1 excavation as a map with dimensions of 119 inches x 99 inches at full size; and Appendices A through G.

2. The report was prepared in accordance with QA procedures defined in FCL QAP 03B (2011) and the project-approved FCL Project Planning Document (FCL PPD, 2010).

3. Section 1.0 (“Introduction”) stated that detailed geologic mapping of unexcavated areas will be completed as part of the licensing process, including an area of approximately 530 square feet in the westernmost portion of the Lee Nuclear Site Unit 1 nuclear island and the Lee Nuclear Site Unit 2 excavation, which is currently at top of sound rock and not foundation grade level.

4. Section 1.0 explained that the original hand-drawn 11 x 17-inch geologic field maps for the CNS site, produced as 62 geologic map panels by Dr. Malcolm Schaeffer and his original geologic mapping team in the 1970s, were scanned and georectified to create the 62 digitized individual geologic map panels combined to generate the 7 geologic map sheets of Appendix G that were used to produce the final compiled geologic map presented in Plate 1.

5. Appendix A of the Project Report presented details of the CNS geologic mapping procedures implemented by Dr. Schaeffer and his original geologic mapping team in the 1970s.

6. Appendix B contained information on classification, mineralogy, and textural descriptions of rock samples from the CNS site area.

7. Appendix C presented copies of the original 62 hand-drawn 11 x 17-inch CNS final foundation grade geologic field map panels prepared by Dr. Malcolm Schaeffer and his geologic mapping team during the field work conducted at the CNS site in the 1970s.

8. Appendix D contained the georectified 62 geologic map panels of final foundation grade level bedrock at the CNS site, developed from the original 11 x 17-inch hand-drawn field

geologic maps presented in Appendix C, which were used to produce geologic Map Sheets 1 through 7 comprising the final compiled geologic map of Plate 1.

9. Appendix E qualified the documentation of the historic geologic mapping records for the CNS site.

10. Appendix F included the digitized 62 CNS final foundation grade geologic map panels, which made up the plates assembled into geologic Map Sheets 1 through 7.

11. Appendix G contained the 7 individual geologic map sheets that were generated from the 62 geologic map panels and used to produce the final compiled geologic map presented in Plate 1.

G. Stirewalt performed the following activities during the data documentation audit by systematically examining the final compiled geologic map of Plate 1 and the associated data used to construct it as presented in the report appendices:

1. Compared, by detailed visual inspection, the original field data on the hand-drawn 11 x 17-inch geologic field maps (included in Appendix C) with the final georectified and digitized geologic map records contained in Appendices D (the 62 geologic map panels as georectified), F (the 62 geologic map panels as digitized), and G (the 7 individual geologic map sheets generated from the 62 geologic map panels). He confirmed that any discrepancies between the original hand-drawn geologic field maps, the georectified and digitized 62 geologic map panels, and the 7 individual geologic map sheets were minor and posed no problems in regard to quality of the mapping results presented in the final compiled geologic map of Plate 1. Therefore, he documented that all original field data had been transferred accurately and incorporated into the final compiled geologic map of the CNS site as presented in Plate 1 of the report.

2. Confirmed that shears were common, and that there was much quartz in veins and pods and infillings in shear zones and fractures. The FSAR stated that the veins exhibited various states of deformation, ranging from undeformed to slightly deformed to folded and bent, with stringers both subparallel to the dominant foliation and ground up in the brittle matrix. These field relationships, also noted by NRC geologists during field audits conducted at the Lee Nuclear Site, indicated that the veins were both syn- and post-kinematic relative to ductile and brittle deformation phases as indicated in FSAR Section 2.5.1.2.5.4 (pg 2.5-62).

3. Documented that all rock units were strongly fractured (i.e., both the felsic gneiss and the mafic gneiss) by examining all 62 geologic map panels and all 7 geologic map sheets and noted the following relationships on the 7 geologic sheets:

   (a) A long NW-trending shear zone, which anastomosed to the NE in places, crossed Panels 44 and 45 in Map Sheet 2, although Sheet 2 was dominated by the NE-

trending shears. The metamorphosed dikes (i.e., the mafic gneiss unit) generally trended NNE also. The NW-trending shear also passed into Map Sheet 1, which was likewise dominated by NNE-trending shears.

(b) Map Sheets 3 and 4 showed the NNE-trending pattern of shears to be dominant. The NNE-trending shears were also prominent on Map Sheet 5, although there was a strong NW-trending shear as well. Sheet 6 was similar to Sheet 5, and one NW shear appeared to be offset by a NE-trending shear around 98+90x and 95+80y.

(c) Sheet 7 reflected somewhat stronger NNW-trending fractures and dikes, and also contained bands of quartzite that appeared to outline isoclinal fold closures.

As a result of the data documentation audit, G. Stirewalt determined that the following the primary concerns needed to be addressed in Revision 1 of the report.

1. The compiled geologic map for CNS Unit 1 (Lee Nuclear Site Unit 1) must enable NRC staff to assess the similarities and differences between both lithologies and geologic features, including tectonic structures, which occur in foundation rock units for these two co-located units compared to CNS Unit 2 and Unit 3 (Lee Nuclear Site Unit 2). Revision 0 of the map compilation report primarily addressed only the lithologic similarities. It was deemed necessary for the report to document that faults and shear zones underlying CNS/Lee Nuclear Site Unit 1 are also similar to those structures revealed at CNS Unit 3 (Lee Nuclear Site Unit 2) or CNS Unit 2, which lies between Lee Nuclear Site Units 1 and 2. This documentation relates to providing assurance in the report that no capable tectonic structures or any potentially detrimental non-tectonic features underlie Lee Nuclear Site Unit 1 as a primary objective of the compiled geologic map report.

2. The report should address similarity of tectonic structures by ensuring that no geologic field evidence exists for any of the following geologic features: (a) Quaternary deformation in the CNS Unit 1 (Lee Nuclear Site Unit 1) excavation based on data derived by Dr. Schaeffer and his geologic mapping team in the 1970s, just as directly observed in the field for foundation grade level bedrock in CNS Unit 2 and top of sound rock in CNS Unit 3 (Lee Nuclear Site Unit 2) during field audits conducted by NRC geologists at the Lee Nuclear Site. (b) Unique orientations of faults and shear zones in the CNS/Lee Nuclear Site Unit 1 excavation, compared to foundation grade level bedrock in CNS Unit 2 and top of sound rock in CNS Unit 3 (Lee Nuclear Site Unit 2). Stereonet plots of the shear zones should be provided for comparing orientations of CNS/Lee Nuclear Site Unit 1 structures with those in foundation grade level bedrock in CNS Unit 2 and top of sound rock in CNS Unit 3/Lee Nuclear Site Unit 2, and eventually in foundation grade level bedrock in Lee Nuclear Site Unit 2. (c) Potentially problematical structures that cross-cut the site and pass from CNS Unit 2 or Unit 3 (Lee Nuclear Site Unit 2) toward and into the CNS/Lee Nuclear Site Unit 1 excavation, which now lies under concrete.

3. Section 6.0 (“Results”) of the report stated that the detailed final foundation maps, along with unpublished CNS evaluations, confirmed that foundation bedrock underlying CNS/Lee Nuclear Site Unit 1 and CNS 2 exhibited no geologic features interpreted as capable tectonic features, and that no data suggested the potential for tectonic or non-tectonic surface deformation underlying CNS/Lee Nuclear Site Unit 1 and CNS Unit 2. However, tectonic structures were not directly compared and evaluated in the report (i.e., only lithologies were), and there was little support provided for these very important conclusions, which comprise the kind of information needed to fulfill the geologic mapping License Condition for foundation rock units at Lee Nuclear Site Unit 1, although the compiled geologic map data readily showed similarity in orientation of the geologic structures, including shear zones and fractures, between the compared locations. It was more difficult to determine similarities in style, amount, and age of possible fault displacements by examining the compiled map data alone, and information addressing these aspects of the structures should be provided in the report to support the statements about a lack of capable tectonic features and potential for tectonic and non-tectonic surface deformation at CNS/Lee Nuclear Site Unit 1.

4. Section 2.5.1.2.5.4 of the FSAR generally qualifies, and quantifies when radiometric age dates are cited (e.g., undeformed K-feldspar collected from an undeformed igneous vein cutting across a shear zone gave minimum age of 219+/- 1 Ma using K/Ar), the antiquity of the shear zones. Additional information on this dated sample should be included in the report since it documents that shearing is pre-Quaternary in age and the shear zones are not capable tectonic features.

5. Examination of the compiled geologic map and the stereonet plot shown in FSAR Figure 2.5.1-231 revealed that the orientations of shear zones and shear planes are similar between the compared locations based on 241 data points collected on these tectonic structures at the CNS site. It would be useful to provide a stereonet plot using the detailed measurement data shown on the compiled geologic map to reinforce the concept that orientations of these geologic structures are similar between the compared locations. Such a stereoplot could be compared with data from Lee Nuclear Site Unit 2 once those data are collected during the geologic mapping program to satisfy the geologic mapping License Condition for that unit.

In regard to review of Revision 1 of the report during the October 2011 data documentation audit, G. Stirewalt determined that the applicant had made the following pertinent changes by incorporating additional text, tables, figures, and appendices in support of the compiled geologic map presented in Plate 1:

1. Revision 1 of the report documented very well the similarity of rock units and tectonic structures (i.e., similar orientations with age date control imposed from geochronology and consideration of cooling history for undeformed minerals in shear

zones) at CNS/Lee Nuclear Site Unit 1 and CNS Unit 2. The changes made to Revision 1 of the report (e.g., information in new Appendices H and I of Binder 5 and additional discussions in Binder 1) were exactly what was needed to support the conclusions made in the report regarding similarity of rock types and tectonic structures in CNS/Lee Nuclear Site Unit 1 and CNS Unit 2, and a lack of evidence for capable tectonic structures or potentially detrimental non-tectonic features at CNS/Lee Nuclear Site Unit 1 and CNS Unit 2. Appendix H provided discussions of CNS shear zones, including stereonet plots documenting orientations of these tectonic structures. Appendix I included discussions of shear zone fabric and geochronologic and kinematic constraints on timing of development of shear zones.

2. In Binder 1 of Revision 1 under the "Shear Orientation Measurement Comparison" heading, the correct statement was made that there is good agreement between data sets obtained for CNS geologic mapping and COLA geologic mapping. In Binder 1, which incorporated the requested information on orientations and ages of shear zones at CNS/Lee Nuclear Site Unit 1 and CNS Unit 2, stereonet plots of poles to shear planes (52 measurements) and joints (199 measurements) from Shear Zone 6 were presented on Appendix H pages H92 and H93, respectively. However, there was no summary discussion of Zone 6 in the report, as was done for other shear zones. G. Stirewalt directly examined the southeastern end of Shear Zone 6 during a site audit on 13-14 July 2011, and noted that it runs beneath the concrete covering Lee Nuclear Site Unit 1 foundation bedrock, dips steeply, and strikes about N45W. That orientation is shown by both shear planes and joints in the stereoplots illustrated on pages H92 and 93 of the report. G. Stirewalt recommended that a summary discussion of Shear Zone 6 be included in the report.

G. Stirewalt notes that the applicant incorporated all pertinent changes recommended from the data documentation audits conducted in June and October 2011 into Revision 2 of the report, dated October 2011, related to documentation of the similarity of lithologies and geologic features (including faults, shear and breccia zones, and fractures) in the CNS/Lee Nuclear Site Unit 1 and CNS Unit 2 foundation grade level excavations to confirm that no potentially capable (i.e., Quaternary, 2.6 Ma to present) tectonic structures or detrimental non-tectonic features occur in foundation bedrock at Lee Nuclear Site Unit 1. A summary discussion of Shear Zone 6, the largest fault evaluated at the CNS site, was specifically included. Therefore, the report presents data adequate to fully satisfy the geologic mapping License Condition for Lee Nuclear Site Unit 1.

References cited in this data documentation audit report:

Fugro Consultants Inc., "Project Planning Document Duke Energy COLA Program", Revision 1, 12 August 2010.

Fugro Consultants Inc., Nuclear Site Assessment Quality Assurance Manual, Quality Assurance Procedure No. 03B "Project Report," Revision 3, 1 January 2011.