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2.5.3 SURFACE FAULTING

PTN COL 2.5-4 This subsection evaluates the potential for tectonic and non-tectonic surface deformation within a 25-mile radius (site vicinity) of Units 6 & 7. Information contained in Subsection 2.5.3 was developed in accordance with RG 1.165, *Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion*, and RG 1.208, *A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion*, and is intended to demonstrate compliance with 10 CFR 100.23, *Geologic and Seismic Siting Criteria*. RG 1.208 contains guidance on characterizing seismic sources, and it defines a “capable tectonic source” as a tectonic structure that can generate both vibratory ground motion and tectonic surface deformation, such as faulting or folding at or near the earth’s surface, in the present seismotectonic regime.

This section contains information on:

- Potential surface deformation associated with capable tectonic sources
- Potential surface deformation associated with non-tectonic processes, such as collapse structures (karst collapse), subsurface salt migration (salt domes), volcanism, and man-induced deformation (e.g., mining collapse and subsidence due to fluid withdrawal)

The conclusions developed in this subsection as well as Subsections 2.5.1 and 2.5.2 regarding the potential for surface deformation are summarized as follows:

- There are no capable tectonic fault sources or bedrock faults and no potential for tectonic fault rupture within the site, site area, or site vicinity.
- There is no evidence of Quaternary tectonic surface faulting or tectonic deformation within the site, site area, or site vicinity.
- There are non-tectonic surface deformation features within the site area and at the site. These features are most likely related to surficial dissolution of carbonate strata in the area.

The following subsections contain the data, observations, and references to support these conclusions.

2.5.3.1 Geological, Seismological, and Geophysical Investigations

Geological, seismological, and geophysical investigations have been performed at the site to characterize the local Quaternary tectonics, structural geology, stratigraphy, paleoseismology, and geological history. The results of these investigations, including site and regional geologic maps and profiles that illustrate lithology, stratigraphy, topography, and structure are presented in Subsections 2.5.1 and 2.5.4. Investigations relevant to the evaluation of surface faulting are presented in this subsection.

Information regarding the potential for surface faulting for the site has been summarized below from the following investigations and sources:

- Compilation and Review of Existing Data and Literature: The UFSAR for Units 3 & 4 provides information about the stratigraphy and structure within the site area (Reference 209). Consequently, emphasis has been placed on published maps and literature pertaining to the structure, tectonics, and stratigraphy of the region published since the UFSAR (Reference 209). Such materials include geologic mapping published by the Florida Geologic Survey and articles published in refereed journals and field trip guidebooks.

- Interpretation of Aerial Photography: Pre- and post-construction aerial photographs were obtained from the U.S. Geological Survey and Florida Department of Environmental Protection. Coverage includes black and white, color infrared, and true color photographs and stereo-pairs. These photographs cover the entire onshore portion of the site area and beyond and were examined specifically for evidence of tectonic or non-tectonic (e.g., karst or dissolution features) surface deformation. This analysis included mapping and identifying lineaments, or linear features, in the site vicinity. No lineaments were identified within the site area.

- Review of Seismicity Data: A comprehensive catalog of instrumental and historical earthquakes was compiled and analyzed (see Subsection 2.5.2.1). No earthquakes with estimated body wave magnitude, Emb, ≥3.0 have occurred within the Turkey Point site vicinity.

- Field and Aerial Reconnaissance: Geologic field reconnaissance was conducted as part of the Units 6 & 7 characterization activities. Field reconnaissance included visiting type localities for key geologic units, detailed geologic mapping of the site, and visiting geomorphic features and key outcrops of interest in the region. Aerial reconnaissance was focused on

features closest to the site area but included assessment of lineations identified from the aerial photography study as well as two potential geomorphic features described in the literature. No evidence of faulting or seismic activity (such as paleoliquefaction features) was found.

- Geologic reconnaissance and aerial photo analysis: Numerous ellipsoidal or circular features with a higher concentration of vegetation as well as water-filled areas that are generally less than 1 foot lower in elevation than the surrounding areas within the site and site area were identified; however, many of these surficial depressions observed on pre-construction photographs have been obliterated by construction, particularly of the Units 3 & 4 cooling canals.

- Integrated Multimethod Geophysical Survey: An integrated, multi-method geophysical investigation program was conducted on and around the area of Units 6 & 7. The geophysical investigation program was focused on identifying the potential for subsurface dissolution features that consisted of high-resolution microgravimetric, seismic refraction, and multichannel analysis of surface waves techniques obtained in collocated lines. The results of this survey found no evidence for cover-subsidence or cover collapse hazard for the site (see Subsection 2.5.4.4.5).

2.5.3.1.1 Previous Site Investigations

The results of previous geologic and seismologic investigations are presented in the UFSAR for Units 3 & 4 (Reference 209) and in a more detailed study of the 5-mile radius site area (Reference 205). Both studies conclude that no tectonic or non-tectonic surface deformation hazards exist at the site. In addition, the UFSAR states that “local depressions, some of which attain depths as great as 16 feet, are occasionally encountered in the surface of the limestone bedrock at the site. Such depressions are not sinkholes associated with collapse above an underground solution channel, but rather potholes, which are surficial erosion or solution features” (Reference 209). The UFSAR further explains that the Miami Limestone and Fort Thompson Formation have been susceptible to solution activity from groundwater during periods of low sea level (Pleistocene glacial advances), but that the “bedrock beneath the site is competent with respect to foundation conditions and is capable of supporting heavy loads” (Reference 209; see Subsection 2.5.4.4.5).

2.5.3.1.2 Regional and Local Geological Studies

Regional and local geologic mapping by the Florida Geologic Survey and other researchers have not identified any faults at the surface on the Florida peninsula within the 200-mile radius site region (References 212, 213, 225, 214, and 231) (Figures 2.5.1-201 and 2.5.1-224). Mapping indicates that the Miami Limestone, a Pleistocene unit approximately 20 feet thick, is exposed over an area greater than 50 miles wide in southern Florida (Reference 225). This outcrop pattern indicates that less than 20 feet of offset or differential erosion has occurred over a wide area and is evidence for the lack of geologic deformation in the region. Well data along a greater than 30-mile east-west transect indicate a maximum relief on the base of the Miami Limestone of 10 feet (References 212 and 213) and this variability is due to sedimentary variations in unit thickness. All geologic contacts within the site area and site are sedimentary in nature (Figures 2.5.1-227, 2.5.1-229, and 2.5.1-230).

In addition to the geologic mapping described above, the U.S. Geological Survey has published a compilation of all known or suggested Quaternary faults, liquefaction features, and possible tectonic features in the Central and Eastern United States (References 203 and 232) (Figure 2.5.3-201). These compilations do not identify any Quaternary tectonic faults or tectonic features within the site region or site area. One potential Quaternary feature, Grossman's Hammock, is located approximately 20 miles northwest of the site, but a ground-penetrating radar study provides evidence that the feature has no tectonic offset (Reference 216), Subsection 2.5.3.2 describes this feature in detail. The U.S. Geological Survey studies classified Grossman's Hammock as a non-tectonic feature (Figure 2.5.3-201).

2.5.3.1.3 Seismicity Data

The Florida peninsula is an area of extremely low seismic activity. The original EPRI seismicity catalog (Reference 206) does not record any earthquakes of Emb ≥3.0 within the Turkey Point site vicinity. Only three earthquakes in the EPRI catalog (Reference 206) occur within 200 miles of Units 6 & 7. The original EPRI catalog did not cover Cuba and large parts of the Gulf of Mexico.

As described in Subsection 2.5.2.1, the EPRI earthquake catalog for this COL investigation was updated to include earthquakes that occurred after the publication of the EPRI catalog. Moreover, this updated seismicity catalog extends south of the original EPRI catalog to include the entire site region and beyond.

The updated seismicity catalog contains a total of 697 events that occurred between March 1698 and December 2007 (Figure 2.5.3-201). Of these 697 earthquakes, a total of 66 are located within the site region. Of these 66 events within the site region, most are located in a zone of concentrated seismicity near Cuba, approximately 170 miles south of the site. There are no earthquakes with Emb ≥3.0 within the Turkey Point site vicinity (Figure 2.5.3-203).

2.5.3.1.4 Current Field and Aerial Reconnaissance

Aerial photography, satellite imagery, and topographic maps of varying scales and vintages reveal no evidence of geomorphic features indicative of the potential for tectonic surface deformation (e.g., faulting or folding) within the site area. Imagery reviewed as part of this COL investigation includes:

- 1:40,000-scale, black and white, stereo aerial photographs acquired in 1940 by the U. S. Geological Survey covering the entire site area (preconstruction)
- 1:40,000-scale, color infrared, photographs acquired in 1999 by the Florida Department of Environmental Protection covering the entire site area and much of southern Florida
- 1:40,000-scale, true color photographs acquired in 2004 by the Florida Department of Environmental Protection covering the entire site area and much of southern Florida
- 1:20,000-scale black and white photographs (vintage 1944) near Ft. Myers, Florida from the archives of the University of Florida
- 1:40,000-scale, color infrared photographs acquired in 2004 by the U.S. Geological Survey near the Shark River in Everglades National Park

Southern Florida is characterized by extremely subdued topography. In general, the only features on topographic maps with elevations greater than 5 feet within the site and site area are man-made roads or levees. To the north, the Atlantic coastal ridge (see Subsection 2.5.1.1.1.2.1) trends north-northeast to south-southwest and is up to 50 feet high and extends into the site vicinity (Reference 233). No topographic features within the site vicinity indicate the presence of surface faulting.

Based on an analysis of aerial imagery, three north-south-trending vegetation lineaments were identified more than 5 miles west of the site. These lineaments were investigated during aerial and field reconnaissance; no evidence for surface

rupture or geomorphic features indicative of active faulting was found. The lineaments were identified as linear swaths where vegetation had been cleared. Review of published literature in southern Florida identified four other features that were further investigated during fieldwork:

- Grossman's Hammock, a rock reef in Everglades National Park, approximately 20 miles northwest of the site (Reference 229)
- Tree lineations near the intersection of Flamingo Road and Ingram Highway in Everglades National Park, located 18 miles west of the site (Reference 233)
- A linear segment of the Shark River channel in Everglades National Park, approximately 34 miles west of the site (Reference 233)
- Faults identified with borehole data in the MacGregor Isles area near Ft. Myers, 120 miles northwest of the site (Reference 228)

Based on the geologic field reconnaissance, no geomorphic or other evidence for faulting or surface deformation is associated with any of these features. In addition, field and aerial reconnaissance did not identify any evidence for surface rupture, warping, or offset of geomorphic features indicative of active faulting within the site or site area. Field and aerial reconnaissance did identify several vegetated and some water-filled depressions (Figure 2.5.1-226 and 2.5.3-202) within the site and site area, which appear to be related to a process of surficial dissolution (see Subsection 2.5.4.4.5).Analysis of 1:40,000 scale aerial photos that were flown in the 1940's prior to construction at Turkey Point indicate that many of these surficial depressions have been obliterated by the construction of Units 3 & 4 cooling canals.

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

Field reconnaissance, a review and interpretation of aerial photography, and a review of published literature did not reveal any evidence for tectonic deformation within the site vicinity or site area. No faults or geomorphic features indicative of faulting have been mapped (Figures 2.5.1-229 through 2.5.1-235) in the site vicinity, site area, or the site. In addition, no seismic activity has been reported within the site vicinity (Subsection 2.5.2), and bedding is planar and undisturbed (Subsection 2.5.1). No salt domes, Quaternary volcanic features, or glacial sources of deformation occur in the site vicinity or in the 200-mile site region (Figures 2.5.1-201 and 2.5.1-212). Non-tectonic deformation features in the site

area appear to be “potholes” caused by surficial dissolution (see Subsection 2.5.4.4.5).

The site vicinity is located on the Florida carbonate platform, a tectonically stable region (Reference 218) that is characterized by extremely low rates of seismicity. The updated seismicity catalog includes no seismicity within the site vicinity (Subsection 2.5.2.1). Historic and late Holocene sea level data collected in central and southern Florida indicate tectonic quiescence during this period (Reference 211). Published geologic mapping at a range of scales indicates that no bedrock faults are mapped within the site vicinity (Subsection 2.5.1.1.4) (References 211, 212, 222, and 225).

Within the site vicinity, Grossman’s Hammock is the only geomorphic feature that has been speculated to be related to faulting (Figure 2.5.3-201). Grossman’s Hammock (sometimes referred to as rock reef) is 8 miles long and is similar to eight other ridges in southern Florida that have widths of approximately 300 feet and vertical relief of 1–5 feet. Steinen et al. (Reference 229) interpreted a fault to account for the apparent offset of a buried Quaternary erosion surface identified in a limited number of boreholes beneath Grossman’s Hammock. However, more recent work, including a ground-penetrating radar study showing no offset on the underlying Quaternary surface, documents that there is no faulting associated with this feature (Reference 216). Consequently, Crone and Wheeler (Reference 203) classified Grossman’s Hammock as a Class D feature, in that geologic evidence demonstrates that the feature is not a tectonic fault or structure (Figure 2.5.3-201). Other postulated explanations for Grossman’s Hammock include fracture-related preferential cementation, and preservation of paleo-shorelines or paleo-mud banks. While its origin is unresolved, tectonic faulting has been effectively ruled out as a hazard associated with this feature (Reference 232).

Also within the site vicinity, White (Reference 233) indicated that trees in the Everglades National Park form a local alignment near the intersection of the Main Park Road (previously called Flamingo Road) and Ingram Highway. Although a geologic cause for such an alignment is improbable, this feature was investigated as part of geologic field reconnaissance. Ground-based observations as well as satellite imagery and aircraft reconnaissance photographs did not reveal the presence of an alignment of trees nor any linear features that would be subject to further examination.

No geomorphic features or lineaments associated with faulting within the site area were identified during analysis of aerial imagery. The lineament analysis did

identify numerous linear and ellipsoidal/circular features associated with changes in vegetation within the 5- and 0.6-mile radii of Units 6 & 7 (Figures 2.5.1-226 and 2.5.3-202). These ellipsoidal or circular features are loci of more highly concentrated vegetation. These features are likely the result of the surficial dissolution of the limestone bedrock and are described in detail in Subsection 2.5.3.8.2. The linear features associated with these vegetated patches within the site area generally are an alignment of two to three vegetated patches connected by short, narrow drainage features. These features are oriented perpendicular to the coastline (oriented roughly east-west to northeast-southwest). The linear channels between the vegetated patches are interpreted to be tidally influenced (Reference 233). Fieldwork following the aerial imagery analysis indicated that the three north-south trending vegetation lineaments located 5-6 miles west of the site are simply areas where the vegetation has been cut down in wide swaths. There is no geomorphic expression of these features or other evidence that would indicate tectonic faulting associated with these vegetation lineaments.

2.5.3.3 Correlation of Earthquakes with Capable Tectonic Sources

The original EPRI earthquake catalog was updated to incorporate earthquakes that occurred between 1985 and 2007 (see Subsection 2.5.2.1.2). The updated earthquake catalog contains no earthquakes with estimated body wave magnitude, Emb, ≥3.0 within the site vicinity. No seismicity or capable tectonic sources exist within the site vicinity or site area; therefore, there is no spatial correlation of earthquake epicenters or capable tectonic sources (Figure 2.5.3-203).

2.5.3.4 Ages of Most Recent Deformation

Field reconnaissance, review and interpretation of aerial photography, and the review of published literature did not reveal any evidence for tectonic deformation within the site vicinity. In addition, results of the subsurface exploration program at the site indicates continuous, horizontal stratigraphy that precludes the presence of faults, folds, or structures related to tectonic deformation (Figure 2.5.1-227). Therefore, there is no correlation of geologic structures to ages of recent deformation (Figures 2.5.1-231 through 2.51-234).

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

Field reconnaissance, review and interpretation of aerial photography, and the review of published literature did not reveal any evidence for tectonic deformation

within the site area. In addition, results of the subsurface exploration program at the site indicates continuous, horizontal stratigraphy that precludes the presence of faults, folds, or structures related to tectonic deformation (Figures 2.5.1-231 through 2.5.1-234). Therefore, there is no correlation of geologic structures in the site area to regional, capable tectonic structures.

2.5.3.6 Characterization of Capable Tectonic Sources

Field reconnaissance, review and interpretation of aerial photography, and the review of published literature did not reveal any evidence for tectonic deformation within the site vicinity. In addition, results of the subsurface exploration program at the site indicates continuous, horizontal stratigraphy that precludes the presence of faults, folds, or structures related to tectonic deformation (Figure 2.5.1-227). Based on the above data and analyses, there are no capable tectonic sources within the site vicinity or site area.

2.5.3.7 Designation of Zones of Quaternary Deformation in the Site Region

Results of the subsurface exploration program at the site indicates continuous, horizontal stratigraphy that precludes the presence of Quaternary faults, folds, or structures related to tectonic deformation at the site (Figure 2.5.1-227). There are no other zones of Quaternary deformation associated with tectonic faults requiring detailed investigation within the site area (Figure 2.5.1-227). Field reconnaissance, review and interpretation of aerial photography, and the review of published literature performed did not reveal any evidence for Quaternary tectonic deformation, including paleoliquefaction, within the site, site area, or site vicinity. Within the site region, seismicity and potential Quaternary deformation are largely restricted to Cuba, approximately 170 miles south of the site. No sand blows or paleoliquefaction features have been identified in the published literature for the site region.

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

There are no sources for potential tectonic deformation at the site. The only evidence for non-tectonic deformation at the site are “potholes” that appear to be caused by surficial dissolution.

2.5.3.8.1 Potential for Tectonic Deformation at the Site

Field reconnaissance, review and interpretation of aerial photography, and the review of published literature did not reveal any evidence for tectonic deformation at the site. In addition, results of the subsurface exploration program at the site

indicates continuous, horizontal stratigraphy that precludes the presence of faults, folds, or structures related to tectonic deformation (Figure 2.5.1-227). Therefore, there is no potential for tectonic surface deformation at the site nor are there any capable tectonic faults within the site vicinity. The subsurface exploration program indicated no evidence of folding or warping related to Quaternary tectonic activity (Figures 2.5.1-227 and 2.5.3-201). Quaternary volcanic activity has not been mapped in the site region (Figure 2.5.1-201). The field reconnaissance and review of published literature indicated no sand blows or paleoliquefaction features are identified in the site area.

2.5.3.8.2 Potential for Non-Tectonic Deformation

No salt domes, Quaternary volcanic features, or glacial sources of deformation occur in the 200-mile site region (Figures 2.5.1-201 and 2.5.1-212). No human activities occurring in the site area pose a hazard for surface deformation. The only evidence for non-tectonic deformation at the site are “potholes” that appear to be caused by surficial dissolution (see Subsection 2.5.4.4.5).

2.5.3.8.2.1 Potential Sources of Non-Tectonic, Geologic Deformation

There is no evidence of non-tectonic deformation within the site in the form of glacially induced faulting, or salt migration. Pleistocene continental glaciers did not extend as far south as the site region and there are no documented examples of glacially induced faulting in the site region. No piercement-type salt domes are located within the site region. The nearest salt dome is approximately 280 miles west of Units 6 & 7 in the eastern Gulf of Mexico (Reference 207). The Florida coastal plain is part of a stable continental region, and no Tertiary or Quaternary volcanic activity is found within the site vicinity. The nearest Cenozoic volcanic activity is recorded in early Tertiary tuffs, located 400 miles southeast of Units 6 & 7 in southeastern Cuba (Reference 217). The subdued topography indicates that no slopes are steep enough within the site area to pose a slope-stability hazard. However, deformation related to karst is noted in southern Florida (Reference 221) and limestone dissolution is evident in stratigraphic units, such as the Miami and Key Largo Limestones, that underlie the site (References 220 and 223).

Quaternary limestones in the region, including the Key Largo Limestone, the Miami Limestone, and portions of the Fort Thompson Formation, have been documented as exhibiting vugs and high permeability related to soluble, karstic limestone (References 204, 205, 209, and 215). In addition, an offshore U.S. Geological Survey study just southeast of the site vicinity has documented the

presence of a 600-meter-diameter sinkhole southeast of Key Largo (Reference 226). Furthermore, the UFSAR indicated that “local depressions, some of which attain depths as great as 16 feet, are occasionally encountered in the surface of the limestone bedrock at the site” (Reference 209). However, the UFSAR concluded that these features were “not sinkholes associated with collapse above an underground solution channel, but rather potholes, which are surficial erosion or solution features” (Reference 209). The conclusion has been substantiated by an integrated geophysical investigation (see Subsection 2.5.4.4.5).

Geologic reconnaissance and aerial photo analysis identified numerous ellipsoidal or circular features. These features consist of vegetation and water-filled areas that are generally less than 1 foot lower in elevation than the surrounding areas within the site and site area. Many of these surficial depressions observed on pre-construction photographs have been obliterated by construction of the Units 3 & 4 cooling canals (Figures 2.5.1-226 and 2.5.3-202). The underlying Miami Limestone is covered by recent deposits of organic-rich mud and silt approximately 2 to 6 feet thick. In these vegetated areas field and geotechnical work investigations have confirmed that the deposits of mud and silt reach thicknesses exceeding 6 feet, and appear to be wetter than the surrounding areas. Little information about the timing and style of formation of these features or their extent beneath the surface of the site is available. The Florida Geological Survey generally assesses a low hazard to karst features that form when limestone is exposed at the surface or beneath a thin veneer of permeable sediment, as is the case within the site area (Figure 2.5.1-238) (Reference 227). In these cases, such solution potholes are generally expected to be shallow and broad, and to develop gradually, rather than in a single, sudden collapse event. Additionally, these solution potholes are not expected to form large voids beneath the surface that would pose a hazard to the site (Reference 227). Based on information developed in this subsection and in Subsection 2.5.1, the possibility of dissolution features similar to the one reported southeast of Key Largo (Reference 226) existing at depth beneath this site area is unlikely (see Subsection 2.5.4.4.5).

Borings completed for the geotechnical exploration have not documented voids or significant rod drops or unusual drilling fluid losses indicative of underground cavities and core from below vegetated depressions exhibited high recovery percentages (Subsections 2.5.1.2 and 2.5.4). Furthermore, no collapse or settlement problems associated with karst-type dissolution of underlying limestones have been associated with Units 3 & 4 (Reference 209).

2.5.3.8.2.2 Potential Sources of Non-Tectonic, Human-Related Deformation

There is no human-related, permanent ground deformation hazard at the site. There are no underground mining activities within the site area that may produce man-induced surface collapse. The closest quarrying activities are located 8 miles from the site and include localized blasting and excavation. This surficial excavation is not expected to impact the site area. No oil or gas production-related activities occur within the site or site area. Some oil and gas exploration has been performed in southern Florida, and approximately six dry holes were drilled within the site vicinity (Reference 208). No ground-shaking or subsidence hazard is expected from these activities.

2.5.3.8.3 Summary of Potential Deformation at the Site

There is no evidence of potential tectonic faulting or deformation at the site. The only potential non-tectonic, geologic hazard at the site is surficial limestone dissolution. No indicators of collapse or settlement problems exist at the site, and the geotechnical investigation found no evidence for subsurface dissolution features that would cause such problems. This conclusion was confirmed by the results of an integrated geophysical investigation focused on identification of subsurface dissolution features at the site (see Subsection 2.5.4.4.5). No human-related deformation hazard exists at the site.

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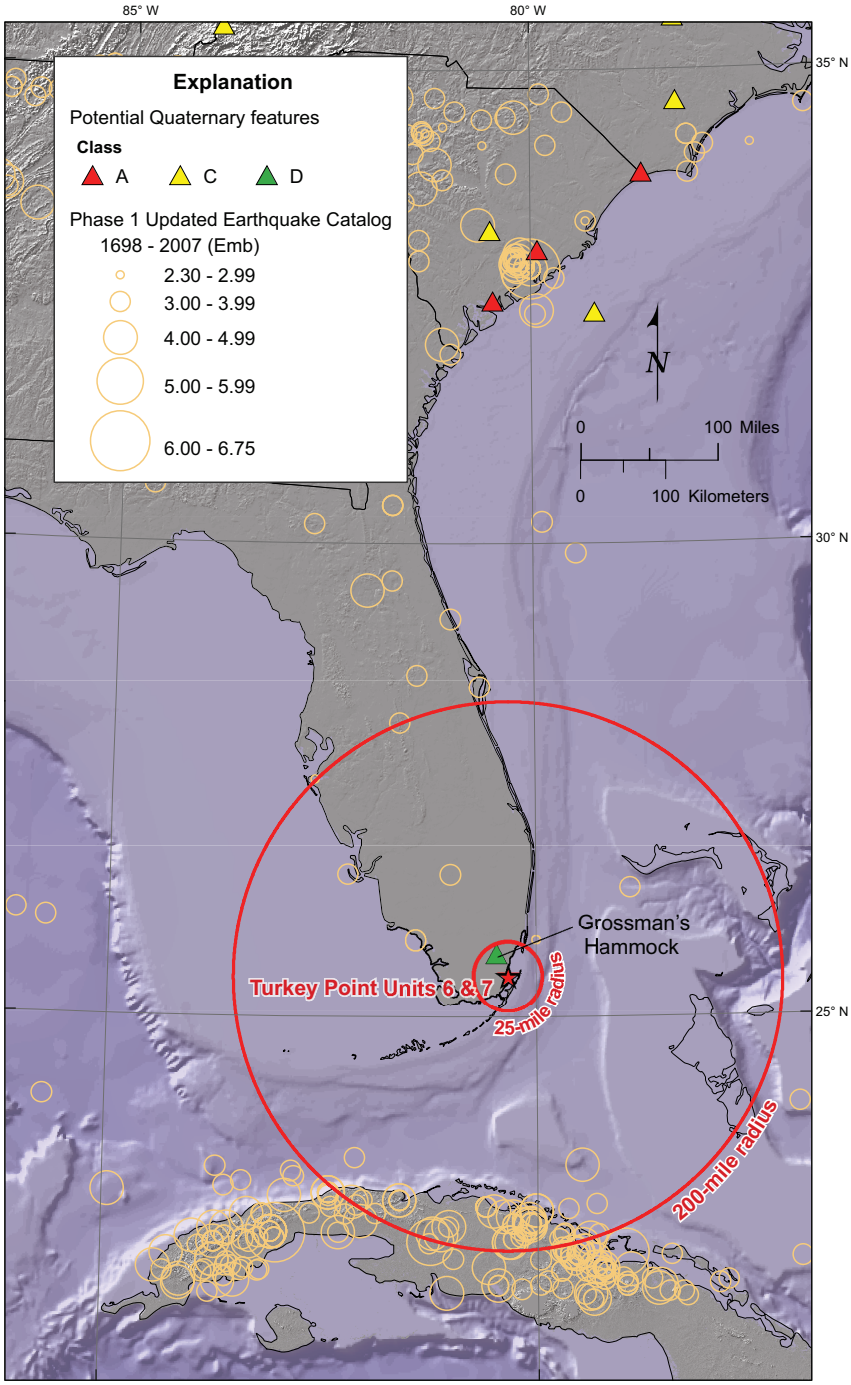
PTN COL 2.5-4

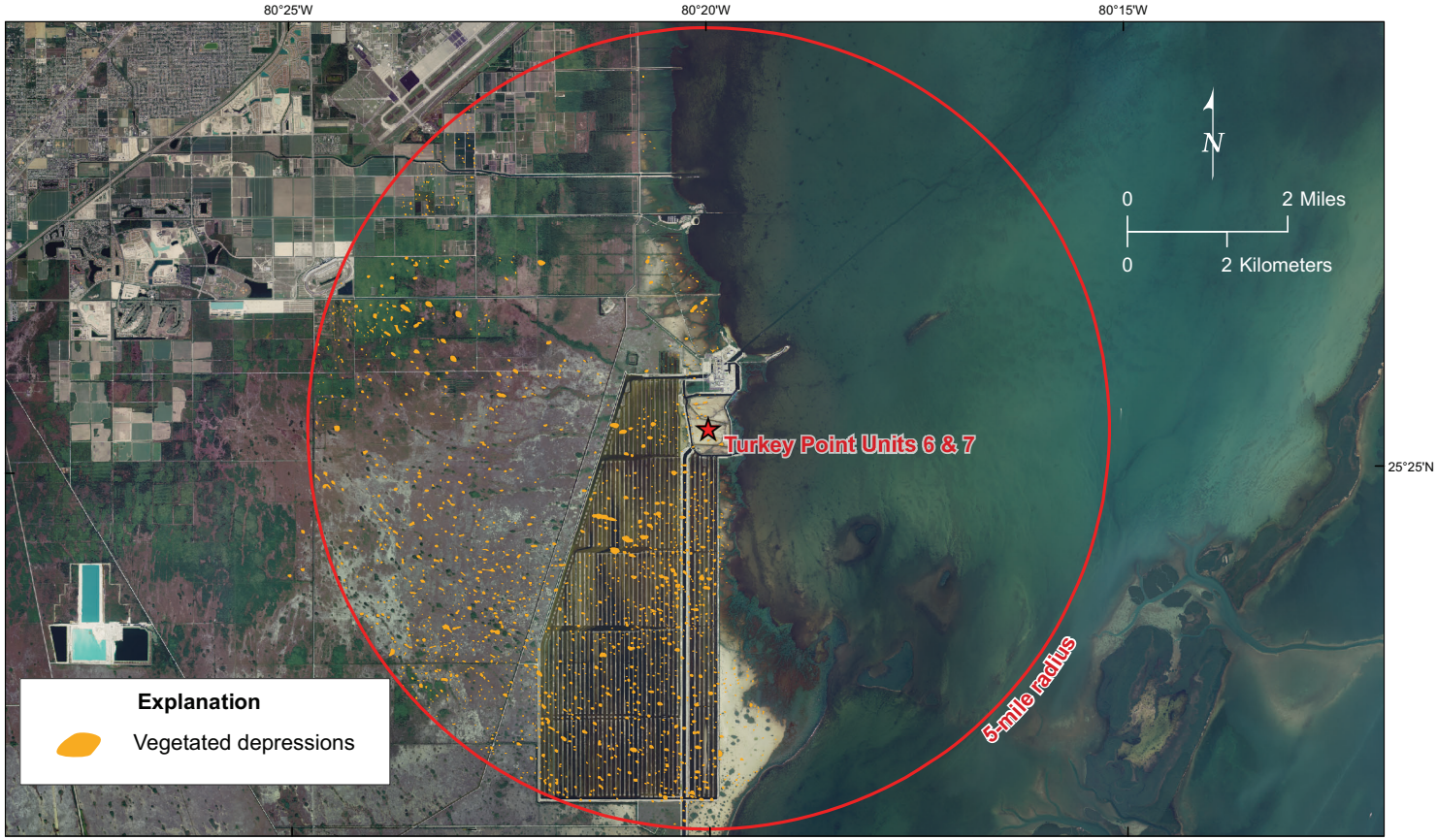
Figure 2.5.3-201 Potential Quaternary Features and Seismicity



Base source: Reference 201
Source of Quaternary features: Reference 203

PTN COL 2.5-4

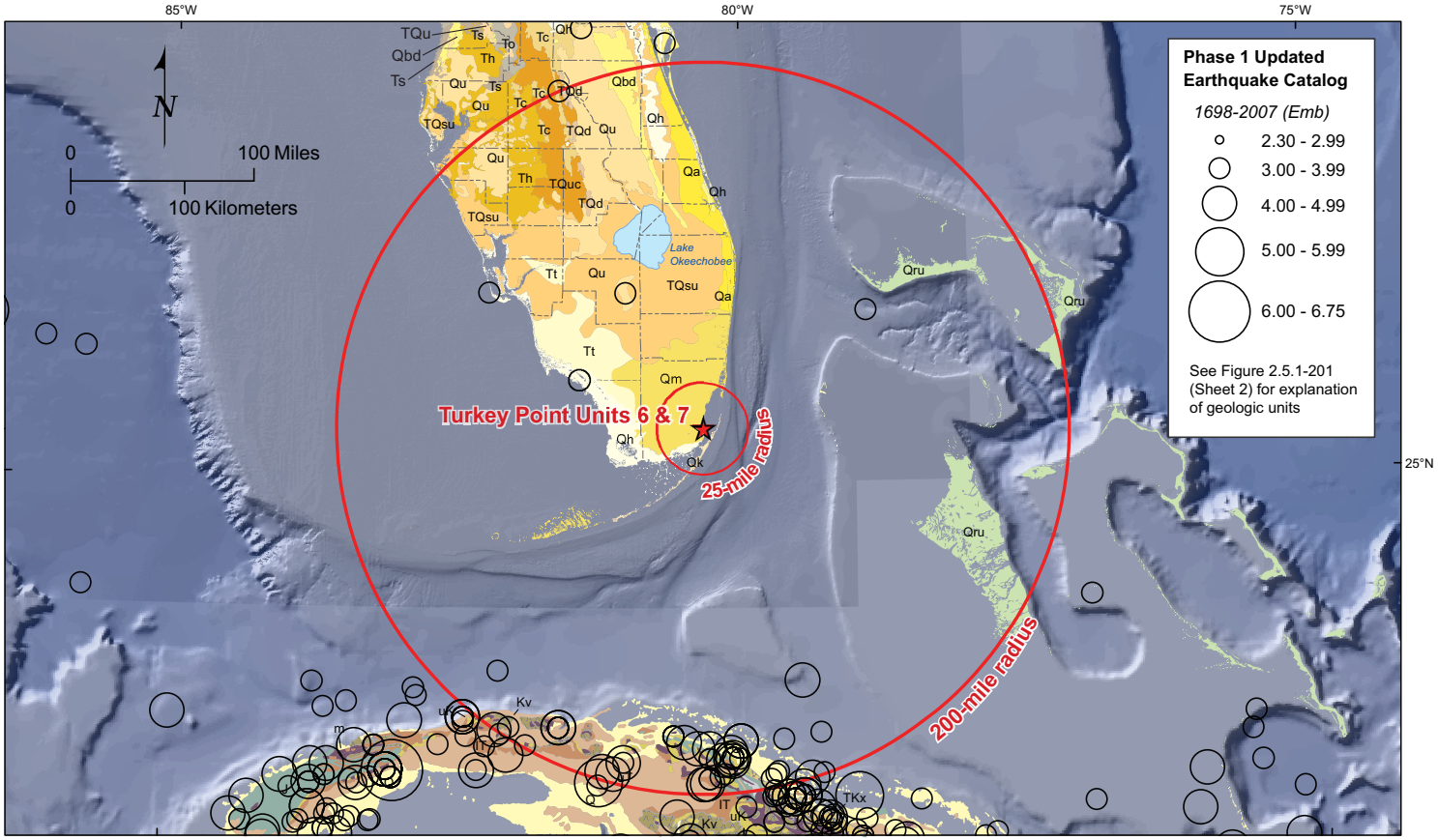
Figure 2.5.3-202 Vegetated Depressions Identified Within Site Area from Photographs Taken Before Construction of the Cooling Canals



Note: Reconnaissance mapping performed using 1940s 1:40,000 scale panchromatic stereo aerial photography (Reference 230), but shown on 2004 imagery (Reference 234) of the Units 6 & 7 site for reference.

PTN COL 2.5-4

Figure 2.5.3-203 Site Region Seismicity



Base sources: Reference 201 and 219
Geologic information sources: References 210, 202, and 224