NRC RAI Letter No. PTN-RAI-LTR-040

SRP Section: 02.05.04 - Stability of Subsurface Materials and Foundations

QUESTIONS from Geosciences and Geotechnical Engineering Branch 1 (RGS1)

NRC RAI Number: 02.05.04-1 (eRAI 6006)

FSAR Section 2.5.4.1.2.1 presents a discussion on dissolution activity in the limestone formation, including potential cavities at depths. Among the data sets used to assess the potential existence of cavities is the microgravity data presented in Figures 2.5.4-224 through 231 which provide insights into the existence of potential cavities in at the site. Based on the analysis of gravity data analyses, this section concludes that there are no large cavities underneath the site. In accordance with NUREG-0800, Standard Review Plan, Chapter 2.5.4, "Stability of Subsurface Materials and Foundations," and Regulatory Guide (RG) 1.132, "Site Investigations for Foundations of Nuclear Power Plants" please provide additional discussion on the adequacy of the assumptions used in the microgravity data analyses. Since only profile measurements were made and large gaps remain between profiles throughout the site area, please justify your assumption that no large cavities exist throughout the site. Also, please provide additional references and data sources used to reach this conclusion.

FPL RESPONSE:

FPL has reached its conclusions that the likelihood for encountering extensive dissolution beneath the power block is small based on the integration of geological/geotechnical data collected during the subsurface investigation program as well as the use of three concurrent geophysical surveys (microgravity, seismic refraction, and multi-channel analysis of surface waves). The seismic refraction and multi-channel analysis of surface waves (MASW) data are helpful in removing the effects of the overlying less dense muck in the interpretation of the microgravity survey data. As shown in FSAR Figure 2.5.4-227 and Figure 1, the MASW survey data also indicate that the muck is thicker above surficial solution features (vegetated depressions) that appear to be floored by continuous Key Largo limestone.

The geotechnical subsurface investigation program comprised 64 borings in the power block area and 24 borings outside the power block. FSAR Subsections 2.5.4.1.1, 2.5.4.1.2.1, 2.5.1.2.2, and 2.5.1.2.4 describe the locations and number of borings, the relatively small number of rod drops, and the vertical extents of those rod drops. Figure 2 shows the locations of all boreholes and identifies those boreholes with documented rod drops. Table 1 identifies the rod drop depth, the rod drop length and the stratigraphic unit in which the rod drop occurred. Boring logs (FSAR Reference 2.5.1-708) indicate the:

- 3-foot drop in B-805 occurred within the Miami Limestone.
- 2-foot drop in B-637 occurred within the Miami Limestone.
- Rod drops in borings B-738, B-811 and B-814 occurred in sandy zones within the Fort Thompson Formation.
- 1-foot drop in B-714 occurred at the base of the Fort Thompson Formation immediately before penetrating the sands of the Tamiami Formation.

No rod drops occurred within the nuclear island footprint of either Unit 6 or Unit 7. Boring B-714 is located within the footprint of the Unit 7 Annex Building and this rod drop might have been due to the process of drilling from the hard limestone of the Fort Thompson Formation into the underlying silty sand of the Tamiami Formation.

The subsurface investigation and testing program and the aerial photo analysis and geologic reconnaissance, described in FSAR Subsection 2.5.3.8.2.1, produced the data used to support the conclusion that the likelihood for encountering extensive dissolution beneath the power block is small. FPL did not rely on offsite data or publications, as the extent or absence of karst is generally site-specific and a function of mineralogy, lithology, groundwater elevation, groundwater gradient, and geochemistry.

The assumptions used in the microgravity data analysis include assuming that a spherical, water-filled cavity would have a sufficient density contrast with the surrounding limestone to produce a microgravity anomaly. The density contrast is based on laboratory test and published data summarized in the FSAR Subsection 2.5.4.4.5.4 and on experience conducting similar geophysical surveys in south Florida. A spherical cavity was used in the analysis as the most conservative approach since it represents the most compact form of "missing mass," and therefore produces the smallest gravity anomaly for a given cavity diameter. Other geometric distributions of a cavity, having the same diameter as the sphere, would produce a significantly larger gravity anomaly. The detectability of the anomaly varies with cavity size, depth, and location with respect to the survey line.

To further reduce any uncertainties in the resolution and interpretation of microgravity data with depth, and away from geophysical survey lines and boreholes, FPL proposes a commitment to conduct a microgravity survey on the base of the nuclear island (NI) excavation. The current excavation concept is to grout the excavation as part of the dewatering program. FSAR Subsection 2.5.4.5.4 describes the dewatering and excavation methods. The installation of a grout plug, approximately 25 feet thick, to prevent vertical seepage is described in FSAR Subsection 2.5.4.6.2 and, in more detail, in ER Subsection 3.9.1.7. The grout plug will be constructed from elevation -35 feet NAVD 88 to elevation -60 feet NAVD 88 by first drilling from the ground surface and then grouting. Vertical boreholes will be drilled in a grid pattern and grouted in an iterative process, which is estimated to consist of four rounds of drilling and grouting, prior to excavation. The grouting procedure described in ER Subsection 3.9.1.7 is expected to fill voids that may exist beneath the nuclear island excavation to an elevation of -60 feet NAVD 88. It is anticipated that the density of the grout will be similar to that of the foundation limestone and that the proposed microgravity survey will be designed to detect density anomalies below the grout plug that represent potential solution features with a diameter of 25 feet or greater if spherical and 12 feet or greater if cylindrical. Preliminary estimates indicate that a hypothetical solution feature with an approximate diameter of 30 feet at a depth immediately below El. -60 feet NAVD 88 will have a negligible effect on the stability of the nuclear island foundation, i.e., negligible effect on bearing capacity, settlement, or resistance to sliding. Such a cavity would cause an increase in stress levels in the vicinity of the cavity due to stress redistribution. However, the stresses from the design loading on the nuclear island at that depth are comparatively low (less than 50 psi) so that the effects are insignificant in the limestone of the Fort Thompson Formation with an average unconfined compressive strength of 2,000 psi (FSAR Table 2.5.4-209).

Table 1. Rod Drops at the Turkey Point Units 6 & 7 Area

Boring ID	From	To	Rod Drop	Stratigraphic Unit
	(Depth, FT)		(Length, FT)	
B-637	28.6	30.6	2	Miami Limestone
B-714	112	113	1	Fort Thompson Formation
B-738	71.9	74.5	2.6	Fort Thompson Formation
B-805	27	30	3	Miami Limestone
B-811	61.3	65.3	4	Fort Thompson Formation
B-814	87.6	88.1	0.5	Fort Thompson Formation

Note: No rod drops in the Nuclear Islands. B-714 is located in the Annex Building footprint in Unit 7.
Source: Reference 2.5.1-708

Figure 1. Line 10 Geophysical Data

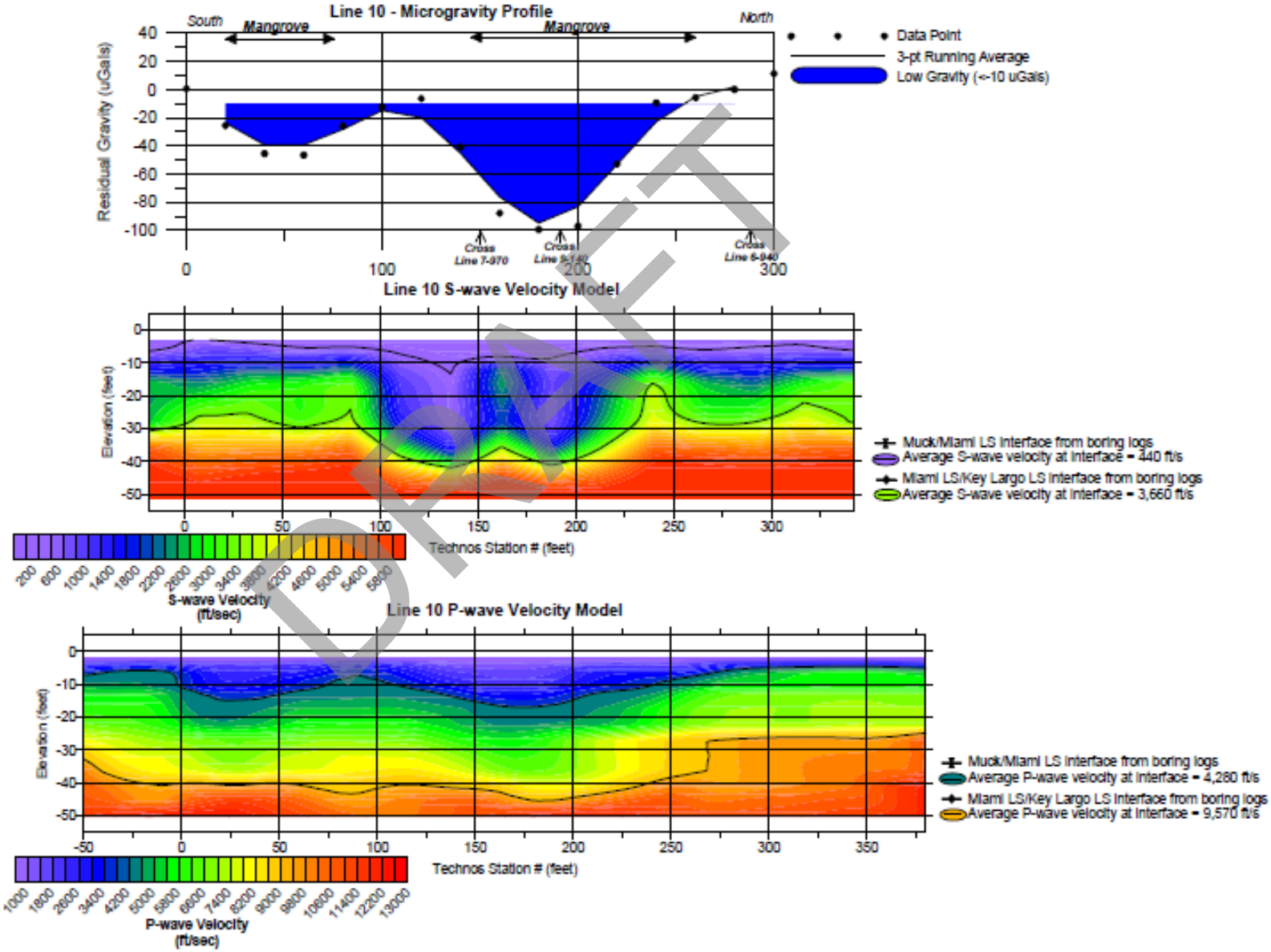
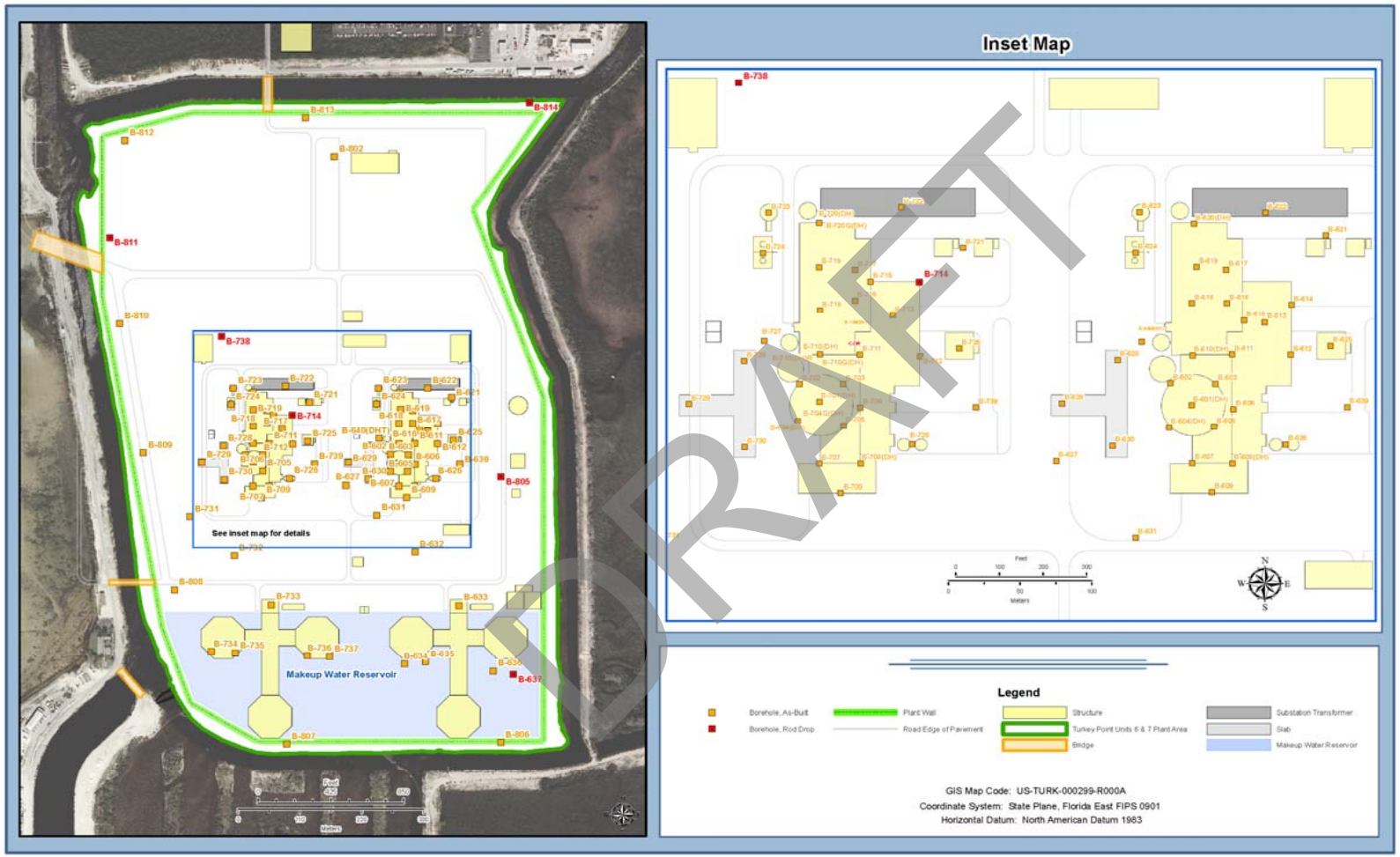


Figure 2. Locations of Borings with Rod Drops at Turkey Point Units 6 & 7



Source: FSAR Reference 2.5.1-708

This Response is Site Specific

ASSOCIATED COLA REVISIONS:

The following text in FSAR Subsection 2.5.1.2.4, Site Geologic Hazards, ninth and eleventh paragraphs, will be revised in a future revision of the COLA.

Ninth paragraph:

Despite the presence of the aforementioned upper and lower secondary porosity zones, the number and magnitude of rod drops that occurred during drilling were negligible~~, as described in Subsection 2.5.4.1.2.1~~. **Boring logs (Reference 708) indicate the:**

- **3-foot drop in B-805 occurred within the Miami Limestone.**
- **2-foot drop in B-637 occurred within the Miami Limestone.**
- **Rod drops in borings B-738, B-811 and B-814 occurred in sandy zones within the Fort Thompson Formation.**
- **1-foot drop in B-714 occurred at the base of the Fort Thompson Formation immediately before penetrating the sands of the Tamiami Formation.**

No rod drops occurred within the nuclear island footprint of either Unit 6 or Unit 7. Boring B-714 is located within the footprint of the Unit 7 Annex Building and this rod drop might have been due to the process of drilling from the hard limestone of the Fort Thompson Formation into the underlying silty sand of the Tamiami Formation (Table 2.5.1-208, Figure 2.5.1-350).

Cavities observed during rock core operations were relatively small. The overall data collected during the Units 6 & 7 subsurface investigations are consistent with a communication with the FGS, which indicates that dissolution present in the site area is generally considered to be micro-karst with numerous small cavities. **This information is consistent with Cunningham (References 404 and 723) investigations in the Biscayne Aquifer in southeastern Florida.**

Eleventh paragraph:

An integrated geophysical survey focused on the Units 6 & 7 power block area and the small surface depressions identified within the site is discussed in Subsection 2.5.4.4.5. Based on **an integrated interpretation of the boring data (Subsection 2.5.4.1.2.1) and the integrated site geophysical survey** ~~all of the site characterization~~ data ~~collected from the site~~, there is no **apparent** evidence for sinkhole hazards or for the potential of surface collapse due to the presence of large underground openings. **The multi-channel analysis of surface waves (MASW) data indicate that the vegetated depressions at the site are underlain by continuous Key Largo Formation (Figures 2.5.4-227 and 241). These two figures show MASW data along survey lines 9 and 10 that intersect at a prominent vegetated depression. Within the limits of survey resolution, the microgravity data do not indicate the presence of large subsurface voids. To address uncertainties in the resolution of the geophysical data away from survey lines and at depth beneath the foundation, a microgravity survey will be conducted at the base of the Unit 6 and Unit 7 nuclear island excavations (Subsection 2.5.4.4.5.5).**

The following text in FSAR Subsection 2.5.3.8.2.1, Potential Sources of Non-Tectonic, Geologic Deformation, fifth paragraph, last sentence will be revised in a future revision of the COLA.

Based upon available **borehole and geophysical** data, there is minimal hazard posed by sinkholes and no evidence for potential surface collapse due to the presence of large underground openings.

The following text in FSAR Subsection 2.5.3.8.3, Summary of Potential Deformation at the Site, will be revised in a future revision of the COLA.

There is no evidence of potential tectonic faulting or tectonic deformation at the site. The only potential non-tectonic, geologic hazard at the site is surficial limestone dissolution. No **apparent** 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 is **partly** confirmed by the results of an integrated geophysical investigation focused on identification of subsurface dissolution features at the site (Subsection 2.5.4.4.5). No human-related deformation hazard exists at the site. **To address uncertainties in the resolution of the geophysical data away from survey lines and at depth beneath the foundation, a microgravity survey will be conducted at the base of the Unit 6 and Unit 7 nuclear island excavations (Subsection 2.5.4.4.5.5).**

The following text in FSAR Subsection 2.5.4.1.2.1, third paragraph, will be revised in a future revision of the COLA.

Small dissolution features are present in limestone drill core samples collected during the subsurface investigation at the site and described in Reference 257. They occur in the form of vugs and moldic secondary porosity, particularly in the Miami and Key Largo ~~L~~**l**imestones. During the site subsurface investigation, six-rod drops, indicating the potential presence of voids, were noted during approximately 9000 feet of rock coring **(Table 2.5.1-208 and Figure 2.5.1-350)**. Two of the rod drops (B-637 and B-805) occurred within the Miami Limestone, which will be removed from beneath the nuclear island during construction. These two rod drops had magnitudes of 2 and 3 feet. One rod drop (B-714) occurred at the base of the Fort Thompson Formation immediately before penetrating the sands of the Tamiami Formation and had a magnitude of 1 foot. The remaining three rod drops (B-738, B-811, and B-814) occurred within sandy zones of the Fort Thompson Formation in the elevation range of –62.7 to –79.1. These three rod drops, which are all located outside the nuclear island footprint, had magnitudes ranging from 0.5 to 4 feet. **While** ~~C~~**c**aliper and acoustic logs from the 10 boreholes where downhole geophysical data were obtained do not indicate the presence of **large** voids**, they do support the interpretation of two preferential secondary porosity flow zones**. A more detailed discussion of the site geologic hazards is presented in Subsection 2.5.1.2.4. A description of the results of a geophysical survey using microgravity, seismic refraction, and multichannel analysis of surface waves methods to investigate the potential for solution features beneath the site is provided in Subsection 2.5.4.4.5.

The following text in FSAR Subsection 2.5.4.4.5.5 Conclusions re-titled "Summary and Commitment" will be revised in a future revision of the COLA.

2.5.4.4.5.5 ~~Conclusions~~ **Summary and Commitment**

Based on geophysical site characterization data, there is no **apparent** indication that sinkhole hazards exist at the site. There is also no **apparent** evidence for the presence of underground openings within the survey area that could result in surface collapse. Large low gravity anomalies with magnitudes less than –30 µGals are only detected outside the power block areas, primarily in areas associated with surface depressions containing vegetation. Once the effects of variations in muck thickness are removed from the residual gravity data, all the remaining low gravity anomalies can be explained by density variations within the Miami Limestone. **The results of the drilling program and borehole geophysical data (Subsections 2.5.1.2.4 and 2.5.4.1.2.1) indicate the existence of two preferential secondary porosity flow zones. The extent of rod drops in six of the 88 borings (approximately 9,000 feet of rock cores) integrated with the field geophysical data supports the interpretation that large voids are absent beneath the footprints of the Units 6 & 7 nuclear islands.**

However, considering the uncertainties related to resolution in the geophysical data at depth and away from survey lines, a microgravity survey will be performed on the excavation surface to detect the presence, or verify the absence of potential water-filled dissolution features beneath the power block. The microgravity survey will be designed to detect 25-foot diameter spherical voids and cylindrical voids as small as 12-feet in diameter at the base of the 25-foot thick grout plug at an elevation of approximately -60 feet NAVD 88. If present, microgravity anomalies may be further investigated by drilling and sampling to determine their origin.

Table 2.5.1-208 will be added to FSAR Subsection 2.5.1 in a future COLA revision:

Table 2.5.1-208. Rod Drops at the Turkey Point Units 6 & 7 Area

Boring ID	From	To	Rod Drop	Stratigraphic Unit
	(Depth, FT)		(Length, FT)	
B-637	28.6	30.6	2	Miami Limestone
B-714	112	113	1	Fort Thompson Formation
B-738	71.9	74.5	2.6	Fort Thompson Formation
B-805	27	30	3	Miami Limestone
B-811	61.3	65.3	4	Fort Thompson Formation
B-814	87.6	88.1	0.5	Fort Thompson Formation

Note: No rod drops in the Nuclear Islands. B-714 is located in the Annex Building footprint in Unit 7.
Source: Reference 2.5.1-708

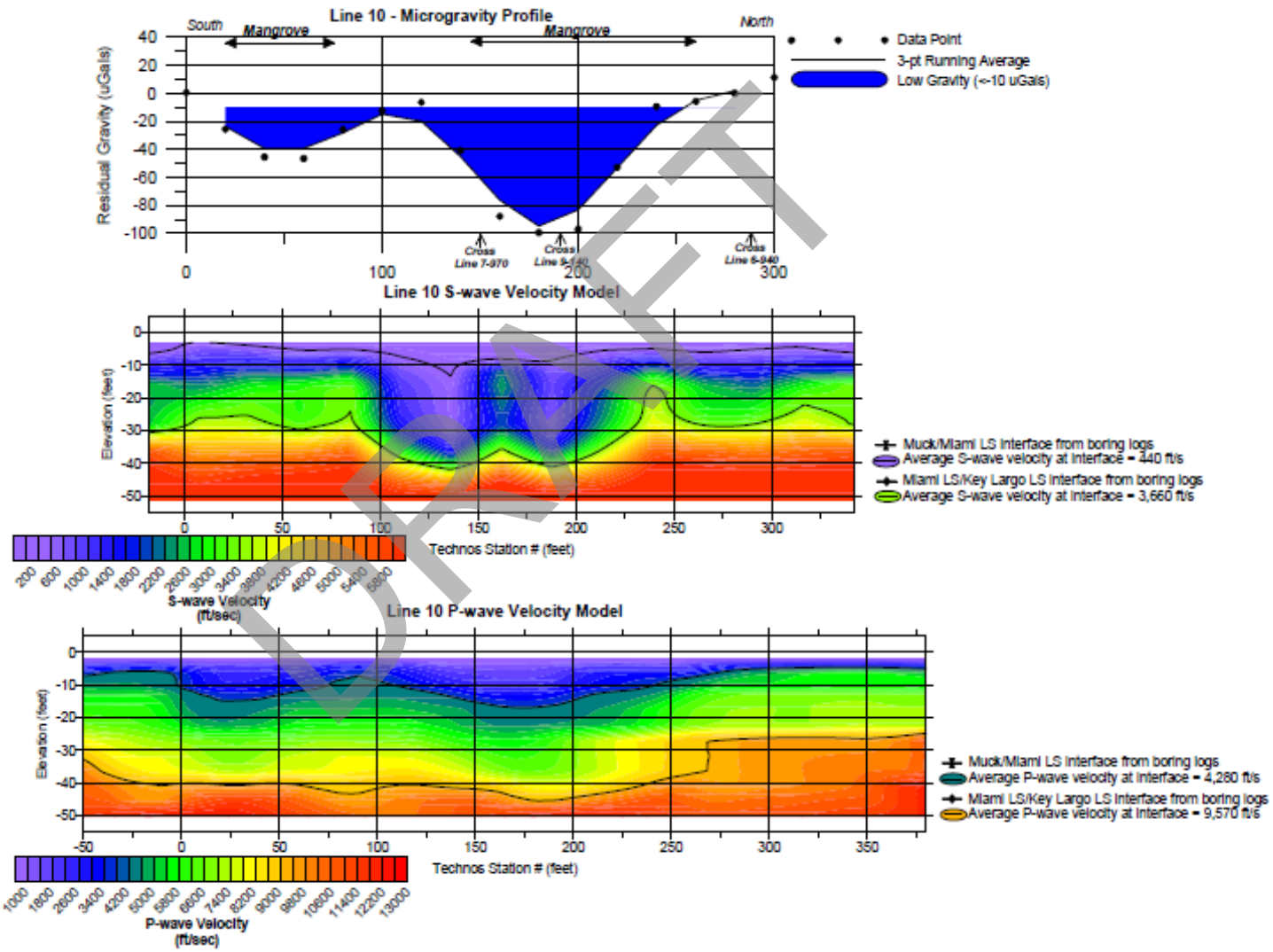
Figure 2.5.1-350 will be added to FSAR Subsection 2.5.1 in a future COLA revision:

Figure 2.5.1-350. Locations of Borings with Rod Drops at the Turkey Point Units 6 & 7

Source Reference 2.5.1-708

Figure 2.5.4-241 will be added to FSAR Subsection 2.5.4 in a future COLA revision:

Figure 2.5.4-241. Line 10 Geophysical Data



References:

None

ASSOCIATED ENCLOSURES:

None