UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD PANEL

Before the Licensing Board:

E. Roy Hawkens, Chair
Dr. Michael F. Kennedy
Dr. William C. Burnett

In the Matter of	)	
	)	Docket Nos. 52-040 and 52-041
Florida Power & Light Company	)	
	)	ASLBP No. 10-903-02-COL-BD01
Turkey Point, Units 6 and 7	)	

PREFILED INITIAL TESTIMONY OF MARK A. QUARLES RERGARDING JOINT INTERVENORS' CONTENTION 2.1

Q1: Please state your name and your employment.

A1: My name is Mark A. Quarles. I am the Principal/Owner of Global Environmental, L.L.C. My business address is P.O. Box 58302, Nashville, Tennessee 37205. I am also a licensed Professional Geologist in the State of Tennessee. I have approximately thirty years of experience as an environmental consultant, most of it relating to hydrogeologic investigations.

Q2: In what capacity are you providing testimony today?

A2: I am providing testimony as an expert in the field of planned and accidental releases of environmental pollutants into the environment. A copy of my curriculum vitae is attached as **Exhibit INT001.** Other exhibits to my testimony are also attached, and a list of all my exhibits is provided at the end of this testimony. To summarize my expert qualifications, I received a B.S. degree in Environmental Engineering Technology from Western Kentucky University, and an M.B.A. from Vanderbilt University. My education in environmental engineering focused on water and wastewater treatment and solid waste disposal. My education in geology focused on

hydrogeology, which is the study of groundwater. That hydrogeology focus also involved performing environmental investigations specific to karst geologic environments that are characterized by sinkholes, caves, and conduit groundwater flow. Most of my experience since 1990 has involved performing environmental investigations to determine the nature and extent of chemical contamination in soil and fractured limestone bedrock in karst terrains. For example, in 2001, I interpreted local karst geologic and hydrogeologic data while serving as Senior Geologist for a project led by the U.S. Environmental Protection Agency (EPA) in Dickson, Tennessee regarding groundwater contamination from a landfill. That landfill was subject to an extensive investigation because of the occurrence of a cluster of birth defects that were believed to be associated with a one-time ingestion of contaminated drinking water that was obtained from a potable water supply well that served an entire county. I also presented "A Case Study in Karst Hydrogeology and Contaminant Fate and Transport" at the National Groundwater Association 51st Annual Convention and Exposition in December 1999. I have been recognized as an expert in hydrogeology and groundwater contamination in a variety of venues, and I have provided written or oral testimony on groundwater contamination on ten occasions.

Q3: What is the purpose of your testimony?

A3: The purpose of my testimony is to provide expert support for Joint Intervenors' Contention 2.1 in this combined license (COL) proceeding for two proposed reactors at the Turkey Point site near Homestead, Florida. Contention 2.1 challenges the adequacy of the Final Environmental Impact Statement (FEIS) prepared by the U.S. Nuclear Regulatory Commission (NRC) to address the potentially significant environmental impacts of Florida Power & Light Co.'s (FPL) proposal to inject municipal wastewater into the Boulder Zone, a cavernous karst limestone bedrock formation that is located beneath the Lower Floridan Aquifer underlying the site, after using it to cool the reactors. Intervenors are concerned that the injected wastewater, which contains potential or probable carcinogenic constituents, may migrate upwards from the Boulder Zone into the Upper Floridan Aquifer, a designated underground source of drinking water (USDW), causing the Upper Floridan Aquifer to become contaminated. As admitted by the Atomic Safety and Licensing Board (ASLB), the contention states:

> The [FEIS] is deficient in concluding that the environmental impacts from FPL's proposed deep injection wells will be "SMALL." The chemicals ethylbenzene, heptachlor, tetrachloroethylene, and toluene in the wastewater injections at concentrations listed in [FEIS] Table 3-5 may adversely impact the groundwater should they migrate from the Boulder Zone to the Upper Floridan Aquifer.

Florida Power & Light Co. (Turkey Point Nuclear Generating Plant, Units 6 and 7), LBP-16-03, 83 NRC 169, 186 (2016). As explained in more detail below, it is my expert opinion that the concerns raised by the contention have not been addressed.

Q4: What materials have you reviewed in preparation for your testimony?

A4: I have reviewed the Final Environmental Impact Statement for Combined Licenses (COLs) for Turkey Point Nuclear Plant Units 6 and 7 (2016) (**Exhibit NRC008A-D**), relevant portions of the Draft Environmental Impact Statement for Combined Licenses (COLs) for Turkey Point Nuclear Plant Units 6 and 7 (2015) (**Exhibit NRC__)**, and relevant portions of the initial and revised Environmental Report submitted to the NRC by FPL. Additionally, I have reviewed the expert declarations filed in motions submitted by all the parties during this proceeding. I have also reviewed relevant technical studies related to groundwater migration that are referenced in the FEIS.

Q5: Have you given affidavits or declarations in support of or in connection with any of Joint Intervenors' contentions in this COL proceeding?

A5: I have prepared four such documents for this proceeding: (1) Affidavit of Mark A. Quarles (Jan. 23, 2012) (filed in response to the Environmental Report, Turkey Point Plant, Units 6 and 7, Revision 3 (ER) prepared by FPL (hereinafter "First Quarles Aff.", attached as **Exhibit INT002**); (2) Second Affidavit of Mark. A. Quarles (Feb. 17, 2012) (filed in response to FPL's Response to Joint Intervenor's Motion to Amend Contention 2.1 (Feb. 10, 2012)) (hereinafter "Second Quarles Aff.", attached as **Exhibit INT003**); (3) Declaration of Mark A. Quarles in Support of Joint Intervenors' Answer to FPL's Motion for Summary Disposition of Joint Intervenors' Amended Contention 2.1 (Aug. 3, 2012) (hereinafter "Quarles Dec.", attached as **Exhibit INT004**); and (4) Third Affidavit of Mark A. Quarles (Feb. 2, 2016) (filed in response to FPL's Statement of Material Facts As To Which No Genuine Issue Exists, in support of FPL's Motion for Summary Disposition of Intervenors' Amended Contention 2.1 (Dec. 15, 2015)) (hereinafter "Third Quarles Aff.", attached as **Exhibit INT005**).

Q6: What analytical process did the NRC follow in preparing the FEIS, and what conclusions did it reach regarding the impacts of injecting wastewater into the aquifer underlying the Turkey Point site?

A6: According to the NRC, "[t]he purpose of the evaluation of deep well injection presented in the FEIS is to determine the impacts to water resources that might reasonably occur if Units 6 and 7 are licensed." FEIS 5-21. The FEIS describes the review process as follows:

> To evaluate the impacts of deep well injection at the Turkey Point site, the review team 1) reviewed studies that characterized the confining ability of the [Middle Confining Unit] and the causes and extent of upwelling at other deep well injection sites, 2) compared hydrogeological conditions and parameters at the sites at which upwelling occurred to conditions and parameters at the proposed site, 3) evaluated numerical

modeling of flow of injected wastewater presented by the applicant and performed confirmatory calculations, and 4) considered the injection well testing and groundwater monitoring requirements of the FDEP UIC program.

FEIS 5-21. "As a result of this evaluation," the NRC review team concluded in the FEIS that "significant upwelling of injected wastewater is not likely at the Turkey Point site and that, if upwelling did occur it would not noticeably impact overlying USDW aquifers." *Id.* The same conclusion is presented at page 5-26, *i.e.*, that "enhanced vertical flow through the confining units to the Upper Floridan Aquifer is extremely unlikely." Therefore, the FEIS asserts that the environmental impacts of any upward migration would be "SMALL." FEIS 5-42.

Q7: Please summarize your testimony with respect to the NRC's review process and conclusions.

A7: In my expert opinion, the NRC has failed to provide a reasonable amount of technical support for the conclusions in the FEIS that (1) upward migration is "extremely unlikely" to occur from the underground injection of wastewater at the Turkey Point site, and that (2) the environmental impacts of the upward migration of injected wastewater containing tetrachloroethylene, ethylbenzene, heptachlor, and toluene (constituents) will be "SMALL." Not only are these conclusions unsupported by the necessary data, but they are also contradicted by some of the documents on which the NRC relies.

(1) UPWARD MIGRATION OF WASTEWATER CONTAINING CONTAMINANTS

Q8: Please explain how the FEIS describes the geology of the aquifers underlying the Turkey Point site, and FPL's proposal to inject municipal wastewater at the site.

A8: The FEIS accurately states that the Floridan aquifer system consists of three units, which are, from shallowest to deepest, the Upper Floridan Aquifer, the Middle Confining Unit (MCU), and the Lower Floridan Aquifer. FEIS 2-53. The Upper Floridan Aquifer is an important source of freshwater in Florida and is a designated USDW at the Turkey Point site. FEIS 2-54. The Lower Floridan Aquifer contains the Boulder Zone, the high-permeability geologic zone that has been identified for deep-well injection of water from proposed Turkey Point Units 6 and 7. FEIS 2-54. According to the FEIS, "the low-permeability dolomite and limestones of the MCU limits (sic) the upward migration of water from the Boulder Zone." *Id.*

Despite asserting that the MCU has low permeability, the FEIS also acknowledges that "[s]eismic-reflection studies performed by the USGS [U.S. Geological Survey] in southeastern Florida have identified both linear tectonic faults and "karst collapse" structures up to about 2 mi in diameter that may result in areas of increased vertical flow through the Floridan aquifer

confining units such as the MCU. . .” FEIS 2-55.[1]

Nevertheless, the FEIS concludes that:

> [I]n general the matrix of the MCU would confine injected effluent and that incidences of upwelling at other sites have been coincident with features that provide vertical pathways for upward migration such as fractures or improperly completed wells. Site data indicates that substantial fracturing of the confining layers is not evident at the Turkey Point site and well construction related issues are not expected to create potential for upwelling at the Turkey Point site because of improved understanding of the confining zones within the MCU and improved construction techniques. However, studies of other injection sites indicate that if rapid vertical migration occurs, it is not likely to reach the Upper Floridan aquifer and that, if it did, it would not noticeably impact drinking water quality.

FEIS 5-22.

Q9: In your expert opinion, does the FEIS support its conclusion that upward migration is “extremely unlikely”?

A9: No. It is my expert opinion that the studies relied on for the FEIS’ conclusion that upward migration is “extremely unlikely” do not support that conclusion. There are four key problems with the NRC’s analytical approach and conclusions. First, while the FEIS claims it can draw conclusions about the Turkey Point site by comparing it to “hydrogeological conditions and

[1] The FEIS cites four technical studies in support of the potential for vertical flow through geologic pathways:

- Cunningham et al 2012-TN4576: Kevin J. Cunningham, Cameron Walker, & Richard L. Westcott, *Near-Surface, Marine Seismic-Reflection Data Define Potential Hydrogeologic Confinement Bypass in the Carbonate Floridan Aquifer System, Southeastern Florida*, SEG Technical Program Expanded Abstracts 2012, (2012) (hereinafter “Cunningham 2012”, attached as **Exhibit INT006**).
- Cunningham 2013-TN4573: Kevin J. Cunningham, *Integrating Seismic-Reflection and Sequence-Stratigraphic Methods to Characterize the Hydrogeology of the Floridan Aquifer System in Southeast Florida*, U.S. Geological Survey Open File Report 2013-1181, (2013) (hereinafter “Cunningham 2013”, attached as **Exhibit INT007**).
- Cunningham 2014-TN4051: Kevin J. Cunningham, *Integration of Seismic-Reflection and Well Data to Assess the Potential Impact of Stratigraphic and Structural Features on Sustainable Water Supply from the Floridan Aquifer System, Broward County, Florida*, U.S. Geological Survey Open-File Report 2014–1136 (2014) (hereinafter “Cunningham 2014”, attached as **Exhibit INT008**).
- Cunningham 2015-TN-4574: Kevin J. Cunningham, *Seismic-Sequence Stratigraphy and Geologic Structure of the Floridan Aquifer System Near "Boulder Zone" Deep Wells in Miami-Dade County, Florida*, U.S. Geological Survey Scientific Investigations Report 2015-5013 (2015) (hereinafter “Cunningham 2015”, attached as **Exhibit INT009**).

parameters at the sites at which upwelling occurred" (FEIS 5-21), the NRC did not obtain nearly enough information about the specific characteristics of the Turkey Point site to make such comparisons. The FEIS relies on a single deep borehole test that provides very little information about the Turkey Point site characteristics. What little information *is* provided by the borehole test indicates that the layers of bedrock that were believed to be confining layers were actually quite permeable. Only by conducting a comprehensive, site-specific investigation that includes, among other analyses, seismic-reflection tests, could the NRC rule out vertical transport of injected wastewater into the drinking water aquifer. However, no seismic study was performed for the Turkey Point site.

Second, the FEIS incorrectly relies on broad generalizations about the "low-permeability" of the "confining units" that supposedly will contain the injected contaminants. *See, e.g.*, FEIS at 2-47. Time and again, unexpected vertical intrusions of contaminated water into the drinking water supply in South Florida have proved that generalization to be dead wrong. In fact, these recurring excursions impelled the USGS to begin conducting the seismic-reflection studies that now show the presence of faults and collapsed karst structures that may provide pathways for rapid upward migration of contaminated wastewater. The NRC has no reasonable basis to make such sweeping claims, having failed to support them with a seismic-reflection combined with other analyses of the Turkey Point site.

Third, the FEIS incorrectly minimizes the significance of known instances of upward migration of contaminated wastewater in the area of the Turkey Point site. There can be no doubt that contamination of drinking water sources with injected wastewater is a significant problem in South Florida, warranting a three-and-a-half year investigation. Cunningham 2013 at 2. The FEIS should have acknowledged that the number of occurrences of upward migration of wastewater through "confining layers" in the vicinity of the Turkey Point site is the appropriate indicator of its significance, not a general statewide survey.

Finally, the FEIS incorrectly attributes the known instances of vertical migration of contaminated wastewater to faulty wells, rather than geologic conduits such as faults and collapsed karst structures. The studies on which the FEIS relies do not support this proposition. Instead, these studies acknowledge that geologic characteristics of a given site are just as likely to be the cause of vertical migration.

Q10: Please describe the basis for your opinion that the FEIS is inadequate because the single site-specific well study on which the FEIS relies is completely inadequate to support the FEIS' general conclusion.

A10: In the FEIS, the NRC asserts that it compared the Turkey Point site to hydrogeologic conditions at other sites where upwelling occurred. FEIS 5-22. The FEIS cites only one study

conducted at the Turkey Point site to confirm or deny the presence of an adequate bedrock confining layers(s): the McNabb study conducted for FPL in 2012.[2] The McNabb study summarizes the construction and testing of a single on-site Exploratory Well (EW-1). EW-1 was constructed at Turkey Point to allow evaluation of the site hydrogeology for appropriate confining intervals and determine the presence of a zone below the confining interval that is suitable to accept injected fluids. *See* McNabb at 2.

The McNabb study is important because it is FPL's sole site-specific study to assess deep bedrock conditions that might be capable of being sufficient confining layers to prevent the upward migration of injected wastewater. The McNabb study does not support the conclusion that upward migration at that site is "extremely unlikely," but instead suggests the opposite. I discussed this in Third Quarles Aff. ¶ 9 – 24, and will explain it further below. In short, McNabb's data shows low percent bedrock recoveries, high percent porosity of bedrock intervals, and inconclusive straddle packer testing of bedrock intervals. All three of these characteristics indicate an ineffective confinement layer because they suggest significant fractures and weathering that may allow substantial vertical and horizontal migration of injected wastewater. Third Quarles Aff. ¶ 22.

Q11: What does the low percent recovery found in the McNabb study indicate about the "confinement unit" underlying the Turkey Point area?

A11: The low percent recovery indicates that the bedrock will not be an effective confinement layer, and therefore does not support the conclusion that upward migration of wastewater at the Turkey Point site is "extremely unlikely."

The "percent recovery" is a measurement of how much of the bedrock core sample from a specified sample interval actually contains bedrock rather than voids. The percent recovery can be used to determine the amount of air or water-filled voids in the bedrock because low percent recoveries are suggestive of voids when the bedrock has been weathered away. Voids indicate an ineffective confinement layer because they suggest significant fractures or weathering that may allow substantial vertical and horizontal migration of injected wastewater. Third Quarles Aff. ¶¶ 18, 22.

The low percent recoveries of the core samples reported by McNabb suggest there are voids in the bedrock at the Turkey Point site. Third Quarles Aff. ¶ 18; *see also* McNabb at 13. For the interval specifically within the McNabb-designated "primary confinement unit" (1,930 to 2,915

[2] The McNabb study is cited at page 2-47 of the FEIS as "FPL 2012-TN1577." The full cite to the McNabb Study is: McNabb Hydrogeologic Consulting, Inc., *Report on the Construction and Testing of Class V Exploratory Well EW-1 at the Florida Power and Light Company Turkey Point Units 6 & 7* (2012). A copy is attached as **Exhibit INT010.**

feet deep), the percent recoveries ranged from 8 to 92.9 percent, with an average of approximately 54 percent recovery. Such a low average percent recovery indicates that there is a significant amount of voids in the bedrock. Notably, the 8 percent recovery of one interval means that voids or very soft or fractured bedrock made up more than 90 percent of that bedrock core sample. The low percent recoveries of the core samples reported by McNabb indicate the presence of voids, which makes for an ineffective confinement layer. *See* Third Quarles Aff. ¶ 18.

Consequently, the low percent recovery found in the McNabb study suggests that upward migration may occur at the Turkey Point site.

Q12: What does the high percent porosity found in the McNabb study indicate about the "confinement unit" bedrock underlying the Turkey Point area?

A12: The high percent porosity found in the McNabb study indicates that the bedrock will not be an effective confinement layer, and therefore upward migration is not "extremely unlikely." Percent porosity is another measure of the quantity of voids within a specific portion of a bedrock core sample because the more porous the bedrock, the greater the quantity of voids contained in the bedrock. As discussed above, voids indicate an ineffective confinement layer. Third Quarles Aff. ¶ 22, citing McNabb at 24. The higher the percent porosity, the greater the quantity of voids contained in the bedrock, and therefore the less effective the confinement.

Porosity measurements collected by McNabb during the construction of EW-1 ranged from 27.5 to 43.4 percent and averaged 37 percent. Third Quarles Aff. ¶ 19, citing McNabb at 19. These numbers mean that up to 43.4 percent of the entire bedrock core section consists of voids. Furthermore, some core samples could not even be tested because "some of the core samples did not contain enough intact pieces to perform each of the laboratory analyses." Third Quarles Aff. ¶ 19, citing McNabb at 18-19. These measurements indicate that a significant amount of voids are present in the bedrock. Accordingly, the percent porosity measurements do not support a conclusion that upward migration is "extremely unlikely" to occur at the Turkey Point site.

Q13: What do the straddle packer test results in the McNabb study indicate regarding the bedrock underlying the Turkey Point area?

A13: The results indicate the bedrock layers are not sufficiently impermeable, and therefore that upward migration of wastewater is not "extremely unlikely" at the Turkey Point site. A straddle packer test evaluates how easily water flows across a layer(s) of bedrock that is thought to be within the "confining layer" above the injection zone and below the base of the lowermost underground source of drinking water. As described in my Third Aff., ¶ 20, packer tests are performed by inflating two balloon-like packers to isolate a section of the boring; filling that

interval with water; pumping that interval; and recording any water level changes within the interval and above the packer.

McNabb attempted to conduct nineteen straddle packer tests. Eight of the thirteen tests that were attempted within a designated "confinement unit" (1,930 to 2,915 feet) actually failed and were "[t]erminated due to packers not isolating test interval." McNabb at 21. McNabb concluded that the "only way" for a packer test to fail is by the packer not sealing against the wall of the geologic strata, thus allowing leakage. *See* McNabb at 19–20. However, this conclusion fails to recognize that the bedrock strata within the packer and more importantly above/below the packers could also be hydraulically connected through voids and fractures in the bedrock. Third Quarles Aff. ¶ 21. Such conditions would be consistent with the conditions that were demonstrated by low bedrock "percent recovery" tests and also by bedrock "percent porosity" results. Third Quarles Aff. ¶ 21.

In conjunction with the low percent recovery and high percent porosity of the confinement unit, the failed straddle packer test results indicate that the bedrock strata below and above the packers in the confinement unit could be hydraulically connected. Third Quarles Aff. ¶ 21. The failed straddle packer test results further cast doubt on the FEIS conclusion that upward migration is "extremely unlikely" to occur at the Turkey Point site.

Q14: Is the McNabb study technically deficient in any other respects?

A14: The McNabb study is outdated and inadequate to support the NRC's conclusion because of the McNabb study's limited scope and its methodological flaws.

First, the scope of the McNabb study is limited to data collected from a single well at the Turkey Point site. It is inadequate to assume, based on testing of a single well, that a confining layer with sufficient aerial extent, thickness, or lithological and hydraulic conditions exists to prevent horizontal and vertical migration of injected wastewater into underground sources of drinking water. Third Quarles Aff. ¶ 24. Vertical migration can occur by first migrating horizontally until vertical pathways are encountered to allow the more buoyant municipal wastewater that is injected under higher pressures to rise. Third Quarles Aff. ¶ 24. Vertical flow pathways such as faults or similar bedrock fractures might only be a few inches to a few feet wide. Thus, the likelihood that a randomly located single boring – or numerous other borings - can intercept a fault or vertical fracture is very low. Third Quarles Aff. ¶ 36. Given the limited scope of the McNabb study, the study cannot provide sufficiently thorough subsurface data at the site to support the FEIS conclusion that it is "extremely unlikely" that wastewater will upwardly migrate at Turkey Point.

Second, even if data from a single well were sufficient to support a conclusion about the

likelihood of upward migration, methodological flaws in McNabb's study render it inadequate to support the FEIS conclusion that upward migration is "extremely unlikely." McNabb determined the geologic bedrock type and the presence of aquifers and confining layers in part by interpreting pulverized drill cuttings. *See* McNabb at 5, 11. Pulverized drilling cuttings that are inspected on the ground surface from deep drilling depths do not provide adequate information to determine bedrock conditions such as the presence of voids, fractures, faults, hydraulic capacity, or the confining nature of the bedrock. Any determination of those findings would be a qualitative, general evaluation only. Third Quarles Aff. ¶ 13.

Third, McNabb only collected ten bedrock core samples that varied between 2 and 14 feet long from the entire 3,230-foot deep well. Given the number of cores and lengths of each, the core sampling program only included 122 feet of the entire 3,230-foot deep well, which is approximately 4 percent of the total depth. Thus, bedrock conditions reported by McNabb for the remaining 96 percent of the boring were generalized. Third Quarles Aff. ¶¶ 14-15. McNabb at 12–13.

Finally, as discussed in more detail below, neither McNabb nor any other party conducted any seismic investigation of the Turkey Point site. FEIS 2-55. In my expert opinion, FPL's failure to use this feasible and highly informative investigative method is unjustifiable.

By failing to address or correct these flaws in the scope and methodology of the McNabb study, the FEIS is rendered inadequate to support the conclusion that upward migration is "extremely unlikely" at the Turkey Point site.

Q15: Please explain the basis for your opinion that FPL's failure to use seismic stratigraphy to evaluate the FPL site is unjustifiable.

A15: Seismic stratigraphy, also referred to as seismic-sequence stratigraphy and seismic-reflection analysis, has become an important tool for evaluating the hydrogeology of South Florida – and specifically related to defining subsurface characteristics associated with deep well injection of municipal wastewater. Seismic stratigraphy is discussed and relied on in four USGS technical studies that are, in turn, relied on in the FEIS. *See* FEIS 2-55 and citations in footnote 1 above. The technique greatly improves upon methods that rely solely on investigations of boreholes, because it provides a much broader, three-dimensional picture of a site than a single – or even multiple – vertical boreholes.

It is important to recognize that seismic-reflection analysis is an investigative tool favored by USGS to study the very question raised in the FEIS and Contention 2.1 – *i.e.*, whether wastewater injected into the Boulder Zone below the proposed Turkey Point reactors is likely to migrate into the drinking water supply above. In Cunningham 2012, the USGS described the

development of the technique between 2007 and 2011 and its usefulness to provide "a new perspective on the subsurface to depths of about 730 meters below the seafloor." Cunningham 2012 at 1. The USGS found the technique extremely useful to address the "immediate need for a subsurface assessment because at some wastewater treatment plants fresh wastewater injected by disposal wells into a saline lower part of the Floridan aquifer system has migrated into a shallow brackish-water part of the aquifer system called the USDW." *Id.*

The USGS reiterated the importance of seismic reflection analysis in Cunningham 2013, noting that legislation adopted by the State of Florida requires elimination of ocean outfalls of treated wastewater by 2025. Cunningham 2013 at 1. This legislation was, in part, the impetus for commencement by USGS of a three and a half year study (started in 2012) that would "include mapping of the geologic, hydrogeologic, and seismic-reflection framework of the FAS [Floridan Aquifer System], and identify[] structural and stratigraphic characteristics that would promote or preclude the successful use of the FAS as an alternate water supply or wastewater repository." *Id.* at 2.

The USGS further noted the importance and usefulness of seismic stratigraphy in Cunningham 2014, observing that it "allows, for the first time in southeastern Florida, a level of resolution in mapping of hydrogeologic units never before accomplished using well data alone." Cunningham 2014 at 3. In Cunningham 2015, the USGS further asserted that "[t]he relations between seismic-sequence stratigraphy and hydrostratigraphy allow for detailed mapping of permeable zones and semi-confining units of the Floridan aquifer system at a level of resolution never before accomplished using well data alone." Cunningham 2015 at 1. The USGS observed that use of high resolution seismic-reflection technologies "can be used to plan the development of future effluent-injection-well sites in other areas of southeastern Florida." *Id.* at 5.

The USGS collected seismic data in both the Cunningham 2012 and the Cunningham 2015 studies. The Cunningham 2012 study demonstrated that widespread fractures and faults exist in the area near Turkey Point, and those bedrock conditions render bedrock layers ineffective as confining layers. The USGS concluded that two types of subsurface geological structure systems have the potential for producing a breach in confining layers of bedrock in the Floridan aquifer system: 1) tectonic faults and 2) karst collapse structures. *See* Cunningham 2012 at 4. The Cunningham 2015 study confirmed the initial conclusions of the 2012 report by adding more site-specific subsurface data beneath actual deep well municipal wastewater injection sites. The latter study confirmed the presence of subsurface geologic faults and karst collapse structures that can transmit injected wastewater upwards into the Upper Floridan aquifer.

The Cunningham 2012 and 2015 studies used advanced subsurface seismic technologies to define hydrogeologic confining conditions and geologic structure that are relevant for Biscayne Bay-area deep well injection sites, in addition to traditional well and boring data. The studies

could evaluate both wells and subsurface bedrock conditions as potential root causes of upward contamination of the shallower Floridan aquifer.

The two USGS studies provide important clues to subsurface conditions that might also exist at the Turkey Point site, because the Turkey Point is located just 9 miles south of the South District Plant in the same geologic conditions. The studies also provide lessons learned regarding the root causes of aquifer contamination associated deep well injection of wastewater at both the Miami-Dade South District Plant and the North District Plant. Those clues and lessons are essential to understand the likelihood of upward migration of wastewater at the Turkey Point site.

The Cunningham 2012 study was performed in shallow-marine shelf of the Biscayne Bay. The Turkey Point site is positioned along the shoreline of the Biscayne Bay. The study acquired approximately 210 kilometers of marine seismic-reflection data north and east of Turkey Point between 2007 and 2011. It produced a high-resolution data set that provides an opportunity to evaluate geologic structures that cut across confining units of the carbonate rocks forming the Floridan aquifer system. The study identifies tectonic faults and karst collapse structures in the Biscayne Bay. Cunningham 2012 at 1. Cunningham found tectonic faults and karst collapse features, structural systems that "may serve as pathways for vertical groundwater flow across relatively low-permeability carbonate strata that separate zones of regionally extensive high-permeability rocks in the Floridan aquifer system." Cunningham 2012 at 4. Cunningham demonstrated that tectonic faults and karst collapse structures – where present in bedrock beneath the Biscayne Bay – cause fractures in multiple layers of bedrock that were originally thought to be "confining layers." Such fractures through those layers would not prevent injected wastewater from migrating upward. *See* Third Quarles Aff. ¶ 30-38.

The Cunningham 2015 study was performed specifically to acquire, process, and interpret seismic-reflection data near both the North and South District Plants to determine if geologic factors may contribute to upward migration of injected wastewater into the shallower underground source of drinking water. *See* Cunningham 2015 at 1. The 2015 study confirmed the presence of tectonic faults and karst collapse structures.

The Cunningham 2015 study provided even more essential geologic conditions because the study specifically used seismic-reflection surveys from both water-borne and land-based seismic reflections at both the North and South District Plants, where wastewater injection and Floridan aquifer contamination has occurred. *Id.* at 4 and 6. The study made these important findings relative to upward wastewater migration and connectivity to the Upper Floridan aquifer:

- Seismic-reflection data determined that both karst collapse structures and faults occur beneath the South District Plant. Karst collapse structures were present at three locations. *See* Cunningham 2015 at 1 and 24.

- Tectonic faults (one strike-slip and multiple reverse faults) exist in the area.
- The strike-slip fault and karst collapse structures "span confining units of the Floridan aquifer system and could provide high permeability passageways for groundwater movement." *Id.* at 24.
- Faults and karst collapse structures "represent a plausible physical system for the upward migration of effluent injected into the Boulder Zone to overlying US EPA designated underground sources of drinking water in the upper part of the Floridan aquifer system." *Id.* at 24.
- The Middle Confining Unit of the of the Florida Aquifer system, characterized in the FEIS as "less permeable" (FEIS 2-53) and having "low-permeability" (FEIS 2-54) is now characterized as consisting of two "*semi*-confining" units because of their tendency to leak. *Id.* at 5, Figure 4 (emphasis added).

The high resolution seismic-reflection technology is far superior to the results that are generated by well data alone, as performed by FPL. Investigations at the North and South District Plants demonstrate that use of the seismic-reflection technology is feasible for Turkey Point. Further, the USGS recognizes that seismic-reflection is a useful tool to use when considering any future deep well injection – such as what is proposed at Turkey Point. Given the outdated and limited horizontal scale of information collected from a single exploratory well, the McNabb report cannot be relied on for any conclusions about the likelihood that injected wastewater will not migrate upward into the Floridan aquifer at the Turkey Point site.

The results of the Cunningham 2012 and 2015 studies thereby strongly undermine the FEIS' conclusion that the Turkey Point area has an appropriate confining layer to prevent upward migration of injected wastewater. These results demonstrate a need to conduct a similar site-specific seismic study along with other traditional investigative methods at the Turkey Point site to determine whether or not sufficient confining layers exist. Third Quarles Aff. ¶ 38. Such a study has never been performed at Turkey Point. FEIS 2-55 and 5-25. Although NRC cited the Cunningham studies in the FEIS, NRC understated the significance of these essential reports relative to lessons that should have been made for Turkey Point and the need to complete a thorough site-specific analysis at Turkey Point.

Q16: Please explain the basis for your opinion that the FEIS incorrectly relies on broad generalizations about the "low-permeability" of the "confining units" that supposedly will contain the injected contaminants.

A16: As I discussed in response to Question 15, the FEIS characterizes the Middle Confining Unit of the of the Florida Aquifer system as "less permeable" (FEIS 2-53) and having "low-permeability" (FEIS 2-54). But the Cunningham 2015 study refutes this characterization. According to Cunningham 2015, the Middle Confining Unit consists of two "*semi*-confining"

units. *Id.* at 5, Figure 4 (emphasis added). This determination by the USGS directly and fundamentally contradicts the NRC's conclusion regarding the impermeability of the MCU.

The FEIS' conclusion that the MCU is generally impermeable is also contradicted by other studies. For example, the Reese and Richardson Study (cited at pages 2-47, 2-55, 2-71, 2-209, 2-210, 5-23, 7-17, and 9-255 of the FEIS), synthesized previous studies on the Floridan aquifer system in central and southern Florida and introduced a revised regional hydrogeologic framework.[3] Reese and Richardson identified the depths and thicknesses of the underlying bedrock for the entire State of Florida. FEIS 2-55. They concluded that the degree of confinement provided by confining units below the Upper Floridan Aquifer is "uncertain." *Id.* at 2.

Similarly, the FEIS' conclusion is contradicted by the Walsh and Price study, also cited repeatedly in the FEIS. *See* FEIS 2-57, 5-23, 5-25, 5-28, 5-40, and 7-17.[4] The Miami-Dade Water and Sewer Department conducted this study for the South District Plant and the North District Plant "to determine migration pathways of injected treated wastewater at two facilities in Miami-Dade County." It evaluated well logs and water chemistry data at the South District Plant. FEIS 5-25. Walsh and Price concluded that deep well injection into the Boulder Zone contaminated the Floridan Aquifer as a result of unintended vertical and horizontal migration of municipal wastewater into the aquifer from wastewater injection wells. *See* Walsh and Price at 1 and 14. *See also* FEIS 2-56 (noting that the Walsh & Price study found that flow within certain portions of the Middle Confining Unit was vertical, while flow within another portion was horizontal. Walsh and Price at 15.).

A report by Starr, et al. (cited at pages 2-53, 2-54, 2-56, and 5-23 of the FEIS) also contradicts the FEIS' conclusion that the MCU is generally impermeable.[5] The Starr study reviewed the existing information on the geology, hydrogeology, and geochemistry at the South District Plant. FEIS 5-23. It determined that groundwater in the Upper Floridan Aquifer is contaminated with

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[3] Ronald Reese & Emily Richardson, *Scientific Investigations Report 2007-5207, Synthesis of the Hydrogeologic Framework of the Floridan Aquifer System and Delineation of the Major Avon Park Permeable Zone in Central and Southern Florida*, U.S. Geological Survey Scientific Investigations Report 2007-5207 (2008) (hereinafter Reese & Richardson study). A copy is attached as **Exhibit INT011.**

[4] Virginia Walsh & René M. Price, *Determination of Vertical and Horizontal Pathways of Injected Fresh Wastewater Into a Deep Saline Aquifer (Florida, USA) Using Natural Chemical Tracers*, Hydrogeology Journal, 18(4): 1027-1042 (2009) (hereinafter Walsh & Price study). A copy is attached as **Exhibit INT012.**

[5] Robert C. Starr, Timothy S. Green, & Laurence C. Hull, *Evaluation of Confining Layer Integrity Beneath the South District Wastewater Treatment Plant, Miami-Dade Water and Sewer Department, Dade County, Florida*, Idaho National Engineering and Environmental Laboratory Accession No. ML14216A601INEEL/EXT-2001-00046, Idaho Falls, Idaho (2001) (hereinafter "Starr study"). A copy is attached as **Exhibit INT013.**

treated wastewater, which implies that contaminants are migrating through the Middle Confining Unit. Starr study at 39. Despite claiming that the MCU is generally impermeable, even the FEIS acknowledges the conclusion of the Starr study that: "the geologic data provided for review are not sufficient to demonstrate that the Middle Confining Unit is a competent, low hydraulic conductivity layer that is capable of preventing upward migrations of fluids from the Boulder Zone into the overlying underground source of drinking water." FEIS 5-23 – 5-24.

The conclusions by Cunningham 2015 (referenced in the first paragraph of this answer) and the Starr study also contradict other studies relied on in the FEIS for the proposition that the Middle Confining Unit is a "competent confining unit." For example, these reports undermine the assertion in the FEIS that sections of low permeability limestones and dolostones of the Middle Confining Unit "appear to act as a competent confining unit," due to high core recovery and low hydraulic conductivity. FEIS 2-56 and 5-24. Cunningham and Starr also undermine the FEIS' reliance on Robert G. Maliva et al., *Vertical Migration of Municipal Wastewater in Deep Injection Well Systems, South Florida, USA* (2007) (copy attached as **Exhibit INT014)**, for the proposition that "'matrix hydraulic conductivities of the limestone and dolostones that constitute the confining strata between the injection zone and the base of the USDW in South Florida are sufficiently low to retard significant vertical fluid movement' and that minimal vertical migration would occur through sections where vertical hydraulic conductivity was 10^{-6} cm/sec or less." FEIS at 5-24. The FEIS lacks a sound basis to rely on Maliva for this proposition because Maliva's study fails to consider the more likely vertical transport mechanisms associated with vertical leakage - bedrock vertical fractures and faults that can extend hundreds and thousands of feet, and well failures recognized by the Starr, Walsh and Price, and Cunningham studies. FEIS 5-24.

Q17: Please explain the basis for your opinion that the FEIS fails to adequately consider past breaches of confining layers in South Florida aquifers.

A17: The FEIS states that "[u]pward migration of treated municipal wastewater injected into the Boulder Zone has been observed at a minority of injection sites." FEIS 2-56. But there are 18 documented instances where deep well injection of wastewater has unintentionally migrated upward from the injection zone. Third Quarles Aff. ¶ 40; First Quarles Aff. ¶ 16. *See also* U.S. EPA Office of Water, *Relative Risk Assessment of Management Options for Treated Wastewater in South Florida*, 4-12 (2003) (hereinafter "EPA Risk Assessment Study") (**Exhibit INT015**). Out of those 18, three deep-well injection sites have caused confirmed fluid movement into USDWs in Pinellas, Dade, and Palm Beach counties. *Id.* at 4-12. An additional six injection sites have caused probable fluid movement in USDWs. *Id*. The confirmed instance of upward migration into a USDW in Dade County is particularly significant because Turkey Point is also located in Dade County. The FEIS does not adequately discuss these incidents or "lessons learned."

Two other site-specific studies confirm that deep well injection operations in the Boulder Zone have in fact contaminated the Floridan Aquifer as a result of unintended upward migration of injected wastewater into the aquifer. First, the Walsh & Price study, conducted by the Miami-Dade Water and Sewer Department for the South District Plant, concluded that deep well injection into the Boulder Zone contaminated the Floridan Aquifer as a result of unintended vertical and horizontal migration of municipal wastewater into the aquifer from nine injection wells. Walsh & Price at 1027, 1040-1041. Second, the Starr study, which I cited in my First Affidavit more than five years ago, determined that groundwater in the Upper Floridan Aquifer at the South District Plant is contaminated with treated wastewater. Starr study at iv. *See also* First Quarles Aff. ¶ 15. This finding implies that contaminants are migrating through the Middle Confining Unit. Starr at 38. The Starr study finds that the Middle Confining Unit at the South District Plant "is not a competent confining layer." *Id* at iv.

These past instances of upward migration at injection sites in this region fundamentally discredit the FEIS conclusion that upward migration of injected wastewater is "extremely unlikely" to occur at the Turkey Point site.

Q18: Please explain the basis for your opinion that the FEIS incorrectly characterizes the cause of known instances of vertical migration of contaminated wastewater as faulty wells, rather than geologic conduits such as faults and collapsed karsts.

A18: As I have previously discussed, the FEIS acknowledges that "[s]eismic-reflection studies performed by the USGS in southeastern Florida have identified both linear tectonic faults and "karst collapse structures" up to about 2 miles in diameter that may result in areas of increased vertical flow through the Floridan aquifer confining units such as the MCU. . ." FEIS 2-55. Nevertheless, the FEIS attributes past instances of vertical migration to well failure, ignoring the fact that the cause is just as likely to be the geological characteristics of the site. For instance, at page 5-40, the FEIS states that upward migration of wastewater at the Miami-Dade Southern District Wastewater Treatment Plant [SDWWTP] is "likely caused by a well construction problem." FEIS 5-40. But the seismic-reflection studies conducted by the USGS contradict those conclusions. As stated in Cunningham 2015:

> Recent studies by the [USGS] of seismic-reflection profiles acquired in onshore canals and offshore in Biscayne Bay and the Atlantic continental shelf have indicated the presence of tectonic faults (one strike-slip fault and multiple reverse faults) and karst collapse structures, and these studies substantiate the utility of this approach for locating feasible vertical-fluid flow pathways. *The strike-slip fault and karst collapse structures span confining units of the Floridan aquifer system and could provide high permeability passageways for groundwater movement. If present at or near wastewater injection utilities, these features represent a plausible physical system for the upward migration of*

> *effluent injected into the Boulder Zone to overlying U.S. Environmental Protection Agency designated underground sources of drinking water in the upper part of the Floridan aquifer system.*

Id. at 24 (emphasis added). The report concluded that karst collapse structures and associated faults may be present "at several locations" at the South District Plant. *Id.*

(2) ADVERSE IMPACTS TO USDWS

Q19: In your expert opinion, does the FEIS adequately support the conclusion that the environmental impact of the constituents from FPL's proposed deep well injection to the groundwater in the Upper Floridan Aquifer will be "SMALL"?

A19: No. The FEIS concludes that the impact will be "SMALL" because the concentration of any migration of the constituents would be low enough not to cause adverse impacts. FEIS 5-42. However, this is based on the incorrect conclusion that there is a safe concentration of the constitutes and any migration will sufficiently dilute the constituents to this low concentration. The FEIS also incorrectly concludes the impacts will be "SMALL" because the design and testing of the injection well will prevent any leaks, and the monitoring will identify any leaks before adverse impacts can occur. FEIS 5-41 – 5-42. Again, the FEIS fails to support these conclusions.

Q20: What potential adverse harms could the constituents have on the groundwater in the Upper Floridan Aquifer?

A20: The constituents could cause potential adverse harms to the groundwater in the Upper Floridan Aquifer. There is a risk of widespread contamination of drinking water aquifers with the constituents that could last long into the foreseeable future due to the sheer volume of water to be injected. Second Quarles Aff. ¶¶ 33, 36. According to the Starr study, up to 40 percent of FPL's injected fluids could contaminate the Upper Floridan Aquifer. Second Quarles Aff. ¶ 36. Additionally, the process of investigating and remediating the contaminated groundwater can be very long and costly. Third Quarles Aff. ¶ 46.

Q21: In your opinion, at what concentration level would the constituents cause adverse environmental impacts?

A21: Any concentration of the constituents above zero could cause adverse impacts. The EPA's Maximum Contaminant Level Goal (MCLG) should have been used to determine whether the environmental impact of the constituents would be "SMALL." The MCLG is the maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health

of persons would occur, and which allows an adequate margin of safety. Quarles Dec. ¶ 13.

The EPA set the MCLG at zero for both tetrachloroethylene and heptachlor. Quarles Dec. ¶¶ 15, 19. Heptachlor and ethylbenzene are possible human carcinogens, and tetrachloroethylene is a probable human carcinogen. *Id.*; First Quarles Aff. ¶ 31 (citing ATSDR Tox FAQ for ethylbenzene). Even at minute concentrations, tetrachloroethylene can cause nausea, liver damage, impaired heart function, and death, while heptachlor can negatively affect the immune and nervous systems. First Quarles Aff. ¶ 31 (citing ATSDR Tox FAQ for tetrachloroethylene and heptachlor). The ATSDR Tox FAQs for ethylbenzene, tetrachloroethylene, and heptachlor are compiled and attached as **Exhibit INT016.**

The FEIS determined the concentration of tetrachloroethylene would be 0.00359 mg/L and the concentration of heptachlor would be 0.000023 mg/L. FEIS 3-39. These concentrations are well above the EPA's MCLG and do not support the FEIS conclusion that the environmental impacts of the constituents to the Upper Floridan Aquifer will be "SMALL."

Q22: What studies does the FEIS rely on to conclude the impacts will be "SMALL" due to the low concentration of constituents?

A22: The FEIS concludes the impacts will be "SMALL" in part based on three studies that incorrectly suggest that the wastewater would be sufficiently diluted such that the constituents would only be in low concentrations and there would be no human health impact.

(1) The EPA modeled two flow scenarios of injected wastewater through the Middle Confining Unit to determine the final concentrations of constituents that would be found in the EPA Risk Assessment study. In both scenarios, the study concluded that overall risk to human health from deep well injection was low where there have been impacts to USDWs because the constituent concentrations would be below the maximum contaminant level (MCL) in all cases. FEIS 5-40 – 5-41.

(2) Dausman et al. modeled migration of two plumes from the South District Plant of wastewater injected into the Boulder Zone. FEIS 5-26, citing Alyssa M. Dausman, Christian Langevin, Michael C. Sukop, & Virginia Walsh, *Saltwater/Freshwater Interface Movement in Response to Deep-Well Injection in a Coastal Aquifer*, Proceedings of the 20th Salt Water Intrusion Meeting, June 23–27, Naples, Florida (2008) (hereinafter "Dausman study"). A copy is attached as **Exhibit INT017.** Dausman et al. concluded that over a projected 148-year injection period (from 1983 forward) the resulting plumes would extend "outward about 13 miles from the site in the MFA [Middle Floridan Aquifer], just beneath the UFA [Upper Floridan Aquifer]."

(3) Bloetscher et al. assessed the health risks of three effluent disposal alternatives currently

available to wastewater utilities in Southeast Florida: deep well injection, ocean outfalls, and surface water discharge. FEIS 5-29, citing Frederick Bloetscher et al., *Comparative Assessment of Municipal Wastewater Disposal Methods in Southeast Florida,* Water Environment Research 77(5):480–490, Alexandria, Virginia (2005) (hereinafter "Bloetscher study"). A copy is attached as **Exhibit INT018.** The Bloetscher study concluded that health risks associated with deep wells were generally lower than those of the other two alternatives. Bloetscher study at 480. It derived its conclusion that injected wastewater would be low from the presence of natural barriers between the injection point and population centers. *See* FEIS at 5-41.

Q23: Does the FEIS' reliance on the EPA, Bloetscher, and Dausman studies regarding the dilution of constituent concentrations provide sufficient support for the conclusion that environmental impacts of the constituents to the Upper Floridan Aquifer will be "SMALL"?

A23: No. My expert opinion is based on the failure of these studies to address the specific characteristics of the Turkey Point site, including the potentially high rate of vertical migration of wastewater into the drinking water aquifer. In addition, the studies were not specifically designed to address human health impacts of migrated contaminants.

For example, the Dausman study was not performed specifically for the Turkey Point site – it was performed for the South District Plant site where contamination has already occurred. Second, the study was not designed to predict constituent concentrations in any aquifer and as such, it should not be used to determine risks to human health. The study was instead designed to determine if the freshwater-saline interface layer would change over time due to wastewater injection.

Nevertheless, the Dausman study reached important conclusions relative to the absence of a geologic confining layer at the South District Plant and what effect that leakage has had on the drinking water aquifer beneath the site. The Dausman study concluded that: "water levels, in the protected drinking water aquifer above the zone of injection at a wastewater treatment plant, have increased over 20ft in the last 30 years." *See* Dausman at 50. According to that study, this rise in water level and also a rise in ammonia concentrations (a common indicator pollutant in municipal wastewater) in the drinking water aquifer is associated with "vertical migration" that is "probably due to salinity-induced buoyancy effects created by injection of the low-TDS [Total Dissolved Solids] effluent into the saline native waters into the LFA [Lower Floridan Aquifer]." Dausman at 51. This rise in water elevations demonstrates connectivity of the drinking water aquifer with wastewater injection into the much deeper Boulder Zone due to the absence of a geologic confining layer.

Like the Dausman study, the Bloetscher study was not designed or performed specific to Turkey

Point (or even the South District Plant). Instead, the Bloetscher study was a "comparative assessment" that evaluated, generalized, and compared wastewater disposal alternatives in the southeast Florida region. *See* Bloetscher at 480. The Bloetscher study concluded that risks to human health were the greatest nearest the wastewater injection site and that risks were reduced as the distance away from the site increases. *Id*. Of particular risk, according to that study, was the use of water in Aquifer Storage and Recharge (ASR) wells because that water is "withdrawn for distribution without further treatment." *See* Bloetscher at 489. The study assigned low risks to the use of ASR wells because it was assumed that any contamination would be detected during operational withdrawals and that withdrawals would then stop. *Id*. This conclusion therefore relies on samples being collected and analyzed for constituents of concern prior to use of the water.

The EPA Risk Study was also not designed to be a site-specific investigation of the subsurface conditions and wastewater effluent migration for the Turkey Point site. The study was a generic study that evaluated regional conditions that might be expected in Dade County. Although the EPA study included groundwater flow models to predict groundwater concentrations in the aquifer if leakage occurs, EPA admitted that the study has two significant limitations:

- "The presence and extent of preferential flow paths, or alternative wastewater migration pathways, is not adequately known. The significance of these pathways to both wastewater transport and risk can only be estimated."
- Substantial data gaps exist. There are limited data and information that may be used to develop and assign accurate values for some model input parameters. At present, this is an unavoidable source of remaining uncertainty."

EPA Risk Assessment Study at 4-40.

Q24: Do municipal wastewater treatment plants treat the wastewater to remove all contaminants that might be harmful?

A24: No. Constituents such as tetrachloroethylene, heptachlor, ethylbenzene, and toluene are just a few of the many constituents that are in the wastewater. FEIS 3-39. Those constituents are commonly associated with industrial or agricultural wastewater streams that are discharged into the sewerage system prior to reaching the treatment plant. The mere presence of these and other similar indicator constituents in the municipal wastewater effluent reported by FPL in the FEIS after treatment demonstrates that the municipal wastewater treatment plant is ineffective at removing all such constituents from the wastewater. Third Quarles Aff. ¶ 50-53.

Q25: What can cause vertical migration of wastewater into the Upper Floridan Aquifer and how would a faster rate of upward migration affect the dilution of constituent concentrations?

A25: Vertical migration of wastewater from the Boulder Zone and into the Upper Floridan aquifer can be caused by a leaking geologic confining layer, the absence of a geologic confining layer, by faulty well construction, and by a well construction that deteriorates over time to allow leakage. Third Quarles Aff. ¶¶ 27–29 (citing Reese and Richardson at 2), 32 (citing Cunningham study at 3), 39, 44.

The Dausman study concluded that vertical migration of wastewater into the drinking water aquifer occurred beneath the South District Plant site and has a relatively direct connectivity to that injection because of the 20-foot rise in groundwater elevations at the site. *See* Dausman at 50.

The Starr study of the South District Plant concluded that "the spatial patterns of contamination in the Upper Floridan Aquifer are consistent with migration of contaminated water through isolated conduits" and that those isolated conduits "could be either natural features or man-made features such as inadequately sealed wells." *See* Starr at 38. Walsh and Price concluded that the vertical migration was "rapid" through vertical pathways; that the "warmer injectate retained the temperature signal as it vertically migrated upwards"; contamination was widespread "throughout the site"; and the concentration of ammonia (an indicator of wastewater) correlated well in one aquifer monitor well with the injected wastewater concentrations. Walsh and Price at 1, 4, and Figure 5. These conclusions suggest a direct and quick vertical leakage rate.

The site-specific studies above for the South District Plant site therefore concluded that adequate confining conditions do not exist to prevent contamination of the shallow Upper Floridan Aquifer.

Groundwater contaminant migration that is rapid and follows such "isolated conduits" results in less dilution because the flow is concentrated along discrete vertical pathways. With a faster rate of upward migration along these discrete conduits, the contaminant concentrations of the constituents will be less diluted and will be more representative of the injected wastewater constituents at the point of connectivity with the drinking water aquifer. Second Quarles Aff. ¶ 39.

At least one groundwater flow model used by FPL in the FEIS predicted vertical migration of groundwater injected into the Boulder Zone would "likely be less than 300 feet" – but that model assumed there were no "well-developed pathways" that would enable rapid, conduit-like flow. FEIS at 5-27 and Appendix G. Such conduit-like flow conditions exist just to the north at the South District Plant.

NRC relied on a regional study of South Florida injection well sites by Maliva that evaluated the

permeability of bedrock layers to measure the vertical rate of groundwater flow. FEIS at 5-24. NRC relied on the results of that study to conclude that "minimal vertical migration would occur through sections where vertical hydraulic conductivity was 10^{-6} cm/sec or less" and used that generic conclusion to support its conclusion that the same conditions exist at Turkey Point "to prevent or limit vertical migration." FEIS at 5-24. This NRC conclusion is substantially flawed because it fails to consider the more likely vertical transport mechanisms associated with vertical leakage - bedrock fractures and faults that can extend hundreds and thousands of feet (see Cunningham 2015 at 13, 15, 17, 19 – 22) and well failures recognized by Starr, Walsh and Price, and Cunningham studies. *See* my Answer to Question 15 above.

A Turkey Point site-specific investigation that at a minimum includes a seismic analysis and other hydrogeological analyses is necessary to determine if confining conditions sufficiently exist vertically and horizontally to prevent migration and contamination of the drinking water aquifers.

Q26: Can groundwater contamination migrate far from the point of injection?

A26: Yes. The Dausman study concluded that wastewater that was injected at the South District site will migrate 13 miles horizontally. *See* Dausman at 52. The Bloetscher study concluded that distance from the site has a major impact on human risks – the closer the human exposure point (e.g. a drinking water well) to the site, the higher the risks. *See* Bloetscher at 489.

Q27: In your opinion, will the planned design and testing of the injection wells at Turkey Point prevent leakage of wastewater, and therefore prevent contamination of the Upper Floridan Aquifer?

A27: No. Seals and well casings can fail at any time and contaminate the groundwater before FPL is made aware. Third Quarles Aff. ¶ 44. As a result, even a wastewater injection well application that is reviewed and approved by the Florida Department of Environmental Protection (FDEP) and constructed to FDEP standards can fail. Third Quarles Aff. ¶ 39; FEIS at 2-56. Drilling an injection well to the near 3,000-foot depth of the Boulder Zone results in plenty of opportunities for human error and unknowns associated with voids in the bedrock and sealing multiple casings, for example.

Moreover, the FEIS relies on the lower injection rates planned for the proposed site relative to the South District Plant to limit formation pressures and ensure the integrity of the constructed well. FEIS 5-40. However, no formation pressure test was ever conducted on well EW-1 to monitor leakage between the concrete that is in contact with bedrock formations and all outer steel casings. Third Quarles Aff. ¶ 43. The contact between the bedrock and outer casing must be sealed for the entire depth of the well to prevent upward migration of wastewater along this

pathway. This is especially critical where the bedrock is significantly fractured or where voids are present. Without these tests, it is not possible to document whether cement coverage and seal would prevent leakage. Third Quarles Aff. ¶ 43. Furthermore, the FEIS fails to provide sufficient support that mechanical integrity tests performed every five years will be sufficient enough to detect stresses and strains on the injection wells that would allow for leakage. Third Quarles Aff. ¶ 44.

Q28: Will FPL's groundwater monitoring system be able to detect upward migration of constituents before they reach the Upper Floridan Aquifer?

A28: No. FPL's groundwater monitoring system is likely unable to detect upward migration in time because (1) sampling will not be frequent enough due to possibility of a rapid rate of migration and (2) the constituents may migrate horizontally before they migrate upward.

First, upward migration of wastewater along vertical pathways can occur in a matter of days. Second Quarles Aff. ¶ 21. However, FPL's groundwater monitoring of potential contamination in USDWs consist of quarterly or semi-annual sampling frequencies. Third Quarles Aff. ¶ 42. EPA's assessment of the Lower Floridan Aquifer "supports the existence of vertical joints and high rates of migration flow in the planned Boulder Zone injection formation," such that groundwater flow may occur "at extremely rapid rates." First Quarles Aff. ¶ 23 (citing EPA, Risk Assessment at ES-11). The Walsh & Price study also confirms a fast rate of upward migration near the Turkey Point site. Third Quarles Aff. ¶ 41; Walsh and Price at 1038. Therefore, the constituents are likely to reach the Upper Floridan Aquifer before FPL's monitoring system detects the contamination.

Second, the wastewater may migrate horizontally within the Boulder Zone prior to migrating vertically. FPL's intent to use a "dual-zone" groundwater monitoring well (DZMW) to detect upward migration of wastewater may not provide an early indication of groundwater contamination because the DZMW is located 75 feet from the injection well. Third Quarles Aff. ¶ 47; FEIS at 5-39 – 5-40. Discrete vertical migration of wastewater can also bypass shallower monitoring wells through discrete vertical fractures in the upper-lying bedrock. The Walsh & Price study, for example, concluded that upward migration "likely resulted from issues related to well installation or failure because effluent appeared to bypass deeper monitored intervals before being detected at higher depths." FEIS 5-25. *See also* Walsh and Price**.** As a result, the FEIS failed to provide sufficient evidence that the DZMWs that FPL intend to construct will detect upward migration of wastewater.

Q29: Can a leaking injection well that was presumably properly installed allow vertical leakage of wastewater upward through bedrock layers and into the Floridan aquifer?

A29: Yes. Two studies at both the South District and North District Plant have documented that possibility. While regulations and well installation protocols must be following when drilling an injection well through an aquifer and multiple layers of bedrock, that process is risky.

As previously discussed, karst collapse structure, tectonic faults, and the cavernous nature of the Boulder Zone create extremely fractured bedrock with caverns and solution-enlarged fractures. Well installation procedures involve injecting "grout", a cement mixture, to adequately seal the exterior of a metal well casing with the surrounding bedrock. The more fractured the bedrock, the more difficult the process to inject the grout in a manner that fully encases the well casing and the surrounding bedrock to provide a seal to prevent upward migration of injectate. McNabb documented such highly weathered bedrock conditions with voids during the installation of well EW-1. See Quarles Third Affidavit ¶ 18 through 24. The Cunningham 2015 study that included seismic-reflection analyses confirmed that karst collapse structures and associated faults were present "within the upper part of the lowermost major permeable zone of the Lower Floridan aquifer" at the South District Plant. That study is geographically the closest completed seismic study in relative the Turkey Point site.

The Starr study concluded that Floridan aquifer contamination at the South District Plant was due to upward migration along "localized pathways such as wells that are not adequately sealed or natural conduits." *See* Starr at iv. That study recommended additional investigations to better define the subsurface geology and groundwater conditions. *See* Starr at 38.

The Walsh and Price study also concluded that a leaking well at the North District Plant allowed wastewater to migrate vertically into the overlying aquifers. That study concluded that "data provide strong evidence of a one-time pulse of injectate into the overlying aquifers due to improper well construction." *See* Walsh and Price at 1.

Q30: Does the FEIS provide sufficient support that any upward migration of the constituents from the injection well would be "SMALL" because leaks would be detected or mitigated before reaching the Upper Floridan Aquifer?

A30: No. As discussed above, the FEIS relies upon flawed data from McNabb, Dausman, and Bloetscher. The EPA's MCLG for heptachlor and tetrachlorethylene confirm that for the FEIS to reach a conclusion of "SMALL," the constituent concentrations should be zero. Moreover, the FEIS fails to provide sufficient support that FPL's monitoring programs, although in line with FDEP requirements, will detect leakage and prevent constituents from reaching the Upper Floridan Aquifer. The FEIS also fails to consider mitigation strategies in light of these deficiencies and past documented contaminations. As a result, the FEIS fails to provide sufficient support for its conclusion that the environmental impacts of the constituents to the Upper Floridan Aquifer would be "SMALL."

Q31: What data should the FEIS have analyzed to assess the environmental impacts of the constituents were the constituents to upwardly migrate to the Upper Floridan Aquifer?

A31: In making any determination on the environmental impact of upward migration of constituents into the Upper Floridan Aquifer, the FEIS should have evaluated the nature and extent of a potential contamination; the impact of such a contamination to the wastewater treatment plant; the cost and economic impact of the contamination; and the cost to modify treatment and effluent distribution methods. Third Quarles Aff. ¶ 46.

Q32: What is your overall conclusion of the FEIS conclusions that (1) upward migration is "extremely unlikely" to occur at the Turkey Point site, and (2) even if upward migration occurred, the environmental impacts of the constituents to the Upper Floridan Aquifer would be "SMALL"?

A32: In my expert opinion, neither of these conclusions made in the FEIS is supported by the studies the FEIS relied upon.

Q33: Does this conclude your testimony?

A33: Yes.

LIST OF EXHIBITS FOR PREFILED TESTIMONY OF MARK A. QUARLES REAGRDING JOINT INTERVENORS' CONTENTION 2.1

Exhibit Number	Document Name
INT001	Curriculum Vitae of Mark Quarles (current as of Mar. 2017)
INT002	Affidavit of Mark A. Quarles (Jan. 23, 2012) (filed in response to the Environmental Report, Turkey Point Plant, Units 6 and 7, Revision 3 (ER) prepared by FPL)
INT003	Second Affidavit of Mark. A. Quarles (Feb. 17, 2012) (filed in response to FPL's Response to Joint Intervenor's Motion to Amend Contention 2.1 (Feb. 10, 2012))
INT004	Declaration of Mark A. Quarles in Support of Joint Intervenors' Answer to FPL's Motion for Summary Disposition of Joint Intervenors' Amended Contention 2.1 (Aug. 3, 2012)
INT005	Third Affidavit of Mark A. Quarles (Feb. 2, 2016) (filed in response to FPL's Statement of Material Facts As To Which No Genuine Issue Exists, in support of FPL's Motion for Summary Disposition of Intervenors' Amended Contention 2.1 (Dec. 15, 2015))
INT006	Kevin J. Cunningham, Cameron Walker, & Richard L. Westcott, *Near-Surface, Marine Seismic-Reflection Data Define Potential Hydrogeologic Confinement Bypass in the Carbonate Floridan Aquifer System, Southeastern Florida*, SEG Technical Program Expanded Abstracts 2012, (2012) (cited in the FEIS as 2012-TN4576)
INT007	Kevin J. Cunningham, *Integrating Seismic-Reflection and Sequence-Stratigraphic Methods to Characterize the Hydrogeology of the Floridan Aquifer System in Southeast Florida*, U.S. Geological Survey Open File Report 2013-1181, (2013) (cited in the FEIS as 2013-TN4573)
INT008	Kevin J. Cunningham, *Integration of Seismic-Reflection and Well Data to Assess the Potential Impact of Stratigraphic and Structural Features on Sustainable Water Supply from the Floridan Aquifer System, Broward County, Florida*, U.S. Geological Survey Open-File Report 2014–1136 (2014) (cited in the FEIS as 2014-TN4051)
INT009	Kevin J. Cunningham, *Seismic-Sequence Stratigraphy and Geologic Structure of the Floridan Aquifer System Near "Boulder Zone" Deep Wells in Miami-Dade County, Florida*, U.S. Geological Survey Scientific Investigations Report 2015-5013 (2015) (cited in the FEIS as 2015-TN-4574)
INT010	McNabb Hydrogeologic Consulting, Inc., *Report on the Construction and Testing of Class V Exploratory Well EW-1 at the Florida Power and Light Company Turkey Point Units 6 & 7* (2012) (cited in the FEIS as FPL 2012-TN1577)

INT011	Ronald Reese & Emily Richardson, *Scientific Investigations Report 2007-5207, Synthesis of the Hydrogeologic Framework of the Floridan Aquifer System and Delineation of the Major Avon Park Permeable Zone in Central and Southern Florida*, U.S. Geological Survey Scientific Investigations Report 2007-5207 (2008)
INT012	Virginia Walsh & René M. Price, *Determination of Vertical and Horizontal Pathways of Injected Fresh Wastewater Into a Deep Saline Aquifer (Florida, USA) Using Natural Chemical Tracers*, Hydrogeology Journal, 18(4): 1027-1042 (2009)
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