SACE Hearing Request
Attachment 4

UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT COURT OF FLORIDA
Miami Division

Case No.: 1:16-cv-23017-DPG

SOUTHERN ALLIANCE FOR CLEAN ENERGY
TROPICAL AUDUBON SOCIETY INCORPORATED,
and FRIENDS OF THE EVERGLADES, INC.,

Plaintiffs,

v.

FLORIDA POWER & LIGHT COMPANY,

Defendant.

EXPERT REPORT OF WILLIAM NUTTLE, PH.D, PEng (Ontario)

I have been retained by the Plaintiffs in this matter to offer expert testimony. Pursuant to Fed. R. Civ. P. 26(a)(2)(B), the following is my written report.

My opinions are based on data on hydrogeology, hydrology, hydraulics, and water quality of both surface water and groundwater available to me as of May 14, 2018, and on my prior investigation described in the attached technical report.[1] I will continue to search for new data to inform my opinions as set forth below.

OPINIONS

1. The CCS is an industrial waste facility that is not a closed-loop system.

The Cooling Canal System (CCS) at the Turkey Point Power Station provides cooling for two nuclear-powered thermo-electric generating units, Units 3 and 4. The Turkey Point plant is located on the shore of Biscayne Bay, immediately adjacent to Biscayne National Park and about 25 miles southwest of Miami. The CCS consists of a system of shallow canals that cover an area of approximately 6,100 acres, two miles wide by five miles long, Figure 1. The surrounding landscape is flat and low-lying. Wetlands occupy the area immediately adjacent to the CCS, to

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[1] Nuttle, W.K., 2017. Review of the Water Budget for the FPL Turkey Point Cooling Canal System: Regional Impacts and Discharge to Groundwater. Prepared for the Southern Alliance for Clean Energy, 7 June 2017.

the west and south, and the Biscayne National Park visitor center and Homestead Bayfront Park are north, along Biscayne Bay. Florida City and Homestead, Florida are located 4.5 miles northwest of the site.

The CCS functions as a “closed-loop” system for the purposes of providing cooling for the power plants at Turkey Point, its primary function. For this reason, the CCS is classified as an industrial waste water facility by the State of Florida.[2] Water is recycled continuously within the system of canals and through the power plants to cool steam condensers. Heated water discharged from the power plants enters the CCS through a canal running east-west along its north boundary. From this canal, the water enters and flows south through a series of shallow, parallel canals. At the south boundary of the CCS, the circulating water is collected in a single, large canal that carries it east and into a smaller set of parallel canals, which then carry the cooled water north, back to the intake bay of the circulating water pumps at the power plants.

However, the CCS functions as an open system from the point of view of water supply. Water in the canals actively exchanges with the atmosphere and with groundwater in the underlying Biscayne aquifer and the surface water of Biscayne Bay, Figure 2. The Biscayne aquifer is a surficial, i.e. water-table, aquifer comprised of very porous limestone that has a thickness of about 100 feet at the location of the CCS. The Biscayne aquifer is the major source of drinking water for Monroe County and communities in south Miami-Dade County.

Active exchange with groundwater plays an important role in maintaining the water balance in the cooling canals. Water loss by evaporation is the largest component of the water balance. Rainfall and the addition of water from other sources balance losses from evaporation over the long term, but rainfall is highly variable. South Florida can go long periods of time with little or no rainfall. Over the long term, the net contribution of groundwater to the water budget is small, but exchange with the aquifer plays an important role offsetting day-to-day fluctuation in the shifting balance between rainfall and evaporation.

Evaporation - 40 MGD

Evaporation from the CCS removes waste heat produced by the power plants, and due to this evaporation from the CCS is 10 mgd greater than would occur under natural conditions. The cooling provided by the elevated rate of evaporation is essential both for generating electricity and for safe operation of the nuclear power plants.

Rainfall - 20 MGD

Rainfall is the major source of freshwater currently available to the CCS to replace evaporation. On average, rainfall provides enough water to replace only about half of the water removed by

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[2] Permit number FL0001562

evaporation. But, on days with of heavy rainfall can add over half a billion gallons of water to the CCS, causing water levels to rise rapidly.

Net Seepage Input from Biscayne Bay – 8 MGD
Saline water from Biscayne Bay seeps into the CCS to replace some of the water removed by evaporation. Water moves freely through the porous limestone that separates the CCS from Biscayne Bay. On a daily timescale seepage occurs both into and out of the CCS in response to fluctuations in water levels in the CCS and in Biscayne Bay.

Other Inputs of Water - 20 MGD
Other inputs of water for the CCS includes blowdown, i.e. water discharged by the power plants in addition to cooling water, water pumped from the Interceptor Ditch, and new inputs of water added beginning in 2014. New inputs of water include fresh water pumped from the L-31E canal, water from shallow saline wells, and brackish water pumped from the deep Floridan aquifer.

Groundwater Discharge from the Cooling Canals
FPL has measured and reported on the water and salt budgets for the cooling canals every month since September 2010. These data show that under current operations the cooling canals discharge more than 10 million gallons per day through the bottom of the canals into the Biscayne aquifer. These data also show that periods of groundwater flow out of the canals toward Biscayne Bay have occurred regularly throughout the period for which data are available.

Impact to Regional Water Resources
Continued operation of the CCS impacts regional fresh water resources in two ways. First, operation of the ID withdraws fresh water from the Biscayne aquifer at rates comparable to pumping from nearby public water supply wells. Second, active exchange between the CCS and the underlying aquifer feeds the growth of a plume of hypersaline water that accelerates the intrusion of saltwater toward well fields used for public water supply.

Current plans to remediate the pollution of the Biscayne aquifer and protect Biscayne Bay are inadequate. The volume of contaminated water that can be extracted using the recovery well system is barely adequate to offset the rate at which continued operation of the cooling canals adds water to the plume.

2. The functioning of the CCS depends on active exchange of water between the CCS, the underlying aquifer, and adjacent surface water.

The amount of water contained in the CCS varies constantly as a consequence of its exposure to the effects of weather and, through its connection to the aquifer, to fluctuations in water levels in Biscayne Bay and the adjacent wetlands. Water is added daily by rainfall and from other sources, including groundwater flow, and water is lost by evaporation and groundwater flow. Beginning in 2010, FPL has conducted extensive monitoring[3] of water levels and water quality in the CCS, the Biscayne aquifer, Biscayne Bay and adjacent wetlands. During this period the volume of the CCS has fluctuated between 4 billion and 8 billion gallons,[4] Figure 3. Data collected by FPL's monitoring program provide the raw information needed to evaluate the magnitude of water exchange in and out of the CCS via groundwater flow.

The active exchange of water between the CCS and the underlying aquifer plays three roles that are essential to maintaining the functionality of the CCS:

a) Groundwater flow into the CCS canals serves as an ultimate source of water that prevents the CCS from drying out during periods of little or no rainfall. Evaporation is the main mechanism for water loss from the CCS. Evaporation is also one of the principle mechanisms that cool the heated water from the power plants. The addition of heat from the power plants causes evaporation to be about 50 percent greater than would occur from the same area of natural wetlands.[5] Without a reliable source of water to replace the loss from evaporation the CCS would dry up and cease to function.

   Rainfall replaces about half of the water lost from evaporation, over the long term. But, rainfall in South Florida is highly variable, and there can be long periods with little or no rainfall. Water added to the CCS from other sources, such as the Interceptor Ditch (ID) and water sources used for freshening, also account for about half the water loss from evaporation, but these are variable as well. Groundwater is always available to make up the difference when needed.

b) Active exchange of water between the CCS and the aquifer regulates water levels and changes in the volume of the CCS. During periods of little or no rainfall, evaporation reduces the amount of water in the CCS, and water levels drop. Groundwater begins to flow into the CCS as water levels drop below the water-table in the surrounding wetlands and the level of water in Biscayne Bay. Groundwater flow into the CCS increases as

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[3] SFWMD, 2009. FPL Turkey Point Power Plant Groundwater, Surface Water, and Ecological Monitoring Plan. October 14, 2009.

[4] FPL calculates the volume of the CCS daily, based on measured water levels, as part of their compilation of the water and salt budgets in the post-uprate monitoring program.

[5] "The estimate of potential evapotranspiration (ETp) from open water and wetlands in the LEC Planning Area is 53 inches" (page 187; 2011–2014 Water Supply Plan Support Document September 2014), which is equivalent to a flux of 28 mgd over the total CCS area of 6100 acres when the potential evapotranspiration rate is applied to the water surface area within the CCS.

water levels continue to drop until groundwater flow has increased sufficiently so that evaporative losses are balanced. At that point water levels stabilize.

Likewise, water accumulates in the CCS during periods in which water inputs exceed losses from evaporation. This increases the volume of water in the CCS, and water levels rise. As the water levels rise above the water-table in the surrounding wetlands and the level of water in Biscayne Bay, wastewater flow out of the CCS and into the aquifer begins. Water levels and flow into groundwater and adjacent surface waters increase until outflow and evaporation are sufficient to balance the water inputs, and water levels stabilize or begin to decline.

The discharge of wastewater from the CCS into the aquifer is an important influence on water quality in the CCS. Dissolved substances, such as salt, accumulate in the CCS as the result of the evaporative loss of water. Biscayne Bay has been the major source of groundwater inflow to the CCS. Typical values of salinity in the CCS, at least since 2010, are between 2 and 3 times the salinity of Biscayne Bay. Groundwater flow out of the CCS removes this higher-concentration water, effectively flushing salt and other dissolved substances into the aquifer and into Biscayne Bay. This flushing is the only mechanism that limits the accumulation of salt and other dissolved substances in the CCS.

3. Evidence for the presence of water from the CCS in the Biscayne aquifer and nearby surface water relies on 1) the distinctive chemical characteristics of water in the CCS and 2) the occurrence of physical conditions required for flow out of the CCS through the aquifer.

Tritium is a reliable indicator of water discharged from the CCS.[6] Water in the CCS contains tritium in concentrations[7] hundreds of times greater than the background concentration of tritium in the aquifer and surrounding surface waters. No other source of tritium at such high concentrations exists in the region. Therefore, measured concentrations of tritium above background levels indicates the presence of water from the CCS. For this reason, the agencies cooperating in the design of FPL's monitoring program for the CCS agreed to include tritium as a water quality constituent that is routinely measured.

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[6] Janzen, J., and S. Krupa, 2011. Water Quality Characterization of Southern Miami-Dade Nearby FPL Turkey Point Power Plant. Technical Publication WS-31, South Florida Water Management District, July 2011.

[7] Typical values for tritium concentration in the CCS are between 2000 to 18000 pCi/l.

Water in the CCS also contains salt in high concentrations, due to the evaporation concentration of groundwater inflow from Biscayne Bay.[8] Conductance, total dissolved solids, chlorinity, and sodium measure other characteristics of CCS water directly related to salinity. The CCS is located in an area in which freshwater, from the Biscayne aquifer and surface water runoff, mixes with salt water from Biscayne Bay. Background concentrations vary from zero salinity, in groundwater fed by rainfall, to 40 psu in shallow, near-shore areas of Biscayne Bay. Therefore, using high salinity values as evidence to indicate the presence of CCS water requires additional information to establish the appropriate background levels and to rule out possible contribution from other sources of high-salinity water.

The strength of elevated salinity as evidence for the presence of CCS water is increased by other information that establishes that physical conditions also occur for water to flow from the CCS to the point of interest. Water flow requires a pathway and the appropriate arrangement of forces to drive the movement of water along the pathway. The porous limestone of the Biscayne aquifer provides pathways for water flow in all directions around the CCS. The force to drive the movement of water through the aquifer is provided by a gradient in hydraulic head, as measured by a difference in the level of standing water. Generally, water moves in the direction from an area in which water level is higher toward an area where the water level is lower.[9]

4. The discharge of water from the cooling canal system (CCS) into Biscayne Bay occurs intermittently through multiple hydrological connections provided by the Biscayne aquifer.

The Miami-Dade Department of Environment Regulation and Management (DERM) deployed a sonde device to monitor salinity in a small cave in the shallow water of Biscayne Bay near the CCS for the period 14 October 2016 to 1 February 2017. On this occasion, measurements of water depth (for tides), salinity in the cave and salinity in the overlying water column at a reference site nearby were recorded hourly over a period of several days. Changes in salinity measured in the cave with the tides and with changes in the hydraulic gradient driving flow between the CCS and Biscayne Bay, Figure 4, illustrate the episodic nature of discharge from the CCS into Biscayne Bay.

The Biscayne aquifer provides a direct connection for the flow of water between the CCS and Biscayne Bay through multiple pathways. Geologists identify three types of voids occurring in the Biscayne aquifer: matrix porosity, touching-vug porosity, and conduit porosity. Water flow

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[8] Typical values for salinity in the CCS are 60 psu (practical salinity units) and above, about twice the concentration in Biscayne Bay. Daily salinity values range from 38 psu to 97 psu.

[9] Strictly speaking, this rule applies only where water is the same density. The rule can be applied where waters of different densities are present, as is the case around the CCS, as long as care is taken to convert measured water levels to a common density datum, i.e. equivalent freshwater head. For shallow groundwater flow, density differences require a relatively small adjustment in water levels, and these are neglected.

occurs primarily through the touching-vug porosity and the larger conduits.[10] Touching-vug porosity consists of centimeter-scale voids formed from animal burrows. Conduits are formed from extensive horizontal layers of touching-vug porous material, cracks in the limestone matrix, and solution cavities. Solution cavities found in the Biscayne aquifer include vertical pipes, which are 10s of centimeters (~ 1 foot) in diameter, and larger caves.[11]

The lower panel of Figure 4 tells a story of mixing and exchange of Biscayne Bay water and groundwater. The daily tides in Biscayne Bay are the mechanism driving mixing and exchange along a shallow groundwater pathway that connects the CCS with Biscayne Bay. Karst features similar to the cave are found throughout Biscayne Bay, where they are known to be points for groundwater discharge into the bay from the Biscayne aquifer. At the end of the 19th century, people relied on groundwater-fed springs beneath Biscayne Bay as a source for freshwater, Figure 5. Tritium in excess of background concentrations[12] has been found in this cave, indicating that a pathway exists for flow between the CCS and the cave through the Biscayne aquifer.

Salinity values measured in the cave (red trace in the lower panel of Fig.3) fluctuate with the tides. These fluctuations occur as the result of the reversing flow of water in and out of the cave.[13] At peak high tide, salinity in the cave is comparable to the salinity in the overlying bay water (green trace), indicating that water is flowing into the cave from the bay. During falling tides salinity in the cave increases above the salinity of bay water, and the increase continues until about the mid-point of the rising tide. This indicates that water is flowing out of the aquifer through the cave and into the bay. At around the mid-point of the rising tide, salinity in the cave drops rapidly to the salinity of bay water, indicating a reversal in the flow of water.

Also shown are salinity values measured in groundwater between Biscayne Bay and the CCS (TPGW-16S), Figure 1, and in the CCS. The peak salinities measured in the cave during outflow are what would be expected for a mixture of about equal parts groundwater, similar to the groundwater at TPGW-16S, and bay water. The groundwater measurements represent conditions along a shallow flow path, in roughly the upper 30 feet of the aquifer, connecting the CCS with Biscayne Bay. Tritium was measured in a sample of groundwater from this well with a concentration of 726 pCi/l on December 12/13, 2016, confirming the presence of CCS water. For both tritium and salinity the concentrations in the shallow groundwater are what would be expected for a mixture of about equal parts water from the CCS and water from Biscayne Bay.

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[10] Wacker, M.A., Cunningham, K.J., and Williams, J.H., 2014, Geologic and hydrogeologic frameworks of the Biscayne aquifer in central Miami-Dade County, Florida: U.S. Geological Survey Scientific Investigations Report 2014–5138, 66 p., http://dx.doi.org/10.3133/sir20145138.

[11] Cunningham, Kevin J. and Florea, Lee J... (2009). The Biscayne Aquifer of Southeastern Florida. Caves and Karst of America, 2009, 196-199. Available at: http://digitalcommons.wku.edu/geog_fac_pub/20

[12] 10.73 pCi/l tritium on Sep 20, 2016

[13] AOML (n.d.), Detection, Mapping, and Characterization of Groundwater Discharges to Biscayne Bay: Expanded Final Report. SFWMD Contract C-5870, Atlantic Oceanographic and Meteorological Laboratory.

Comparison between the upper and lower panels of Figure 4 illustrates the intermittent nature of groundwater discharge to Biscayne bay in response to changes in the hydraulic gradient between the CCS and Biscayne Bay. The hydraulic gradient is measured as the difference in daily average water level[14] (e.g. hydraulic head) in the CCS and in Biscayne Bay. Periods with a negative hydraulic gradient, indicating flow through the aquifer from Biscayne Bay toward the CCS, alternate with periods in which the hydraulic gradient is positive, indicating flow from the CCS toward Biscayne Bay. The direction of the hydraulic gradient correlates with changes in salinity in the groundwater at TPGW-16. Groundwater salinity decreases when flow is from Biscayne Bay, and it increases when flow is from the CCS.

The direction of the hydraulic gradient, evaluated as a daily average, affects the discharge of groundwater into Biscayne Bay through the cave. In effect, the direction of the hydraulic gradient between the CCS and Biscayne Bay regulates the amount of groundwater that discharges into the bay from the cave. When the daily-averaged direction of flow along the pathway through the aquifer is from Biscayne Bay, the peak salinity in the tidally-driven discharge from the cave is reduced. Because water discharging from the cave is a mixture of water from Biscayne Bay and groundwater, a decrease in salinity indicates that the higher-salinity groundwater makes up a smaller proportion of the mixture. Likewise, when the daily-averaged direction of flow through the aquifer is from the CCS, the peak salinity in the cave discharge is increased, indicating that groundwater from the CCS makes up a larger proportion of the flow discharging from the cave.

5. The discharge of water from the CCS into Biscayne Bay is large enough to impact water quality in Biscayne Bay.

In 2014, a proposal by FPL to pump water into the CCS from the L-31E canal prompted concerns that this would increase groundwater flow out of the CCS and impact water quality in Biscayne Bay. Responding to these concerns, Miami-Dade County required an expansion of water quality monitoring.[15] Results from the expanded monitoring program confirm that discharge from the CCS into Biscayne Bay occurs, and it is large enough to have an impact on water quality in the bay.

In January 2016, high concentrations of ammonia were detected in Biscayne Bay immediately adjacent to the CCS, Figure 6. This occurred during a period of sustained high water levels and following a time when the volume of water in the CCS was at or near its maximum, Figure 3. As in the previous example (Figure 4), the blue bar graph plots values of the hydraulic gradient

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[14] "Water level" refers to daily-average level, so the effect of diurnal tidal fluctuation in Biscayne Bay water level has been removed.

[15] Conditions included in Modification to Class I Permit CLI-2014-0312, May 2015.

between the CCS and Biscayne Bay, measured as the difference in daily-average water level (i.e. hydraulic head) in the CCS and in Biscayne Bay. In contrast with the previous example, the magnitude of the positive values of hydraulic head, driving flow through the aquifer from the CCS toward Biscayne Bay, is about twice as large, and the duration of flow toward the bay is measured in months, not days. The pattern of variation in ammonia concentrations measured at TPBBSW-7, beginning at a constant low value and rising to a higher, sustained value, follows the classic breakthrough curve for discharge of a plume of contaminant traveling in groundwater.

6. Water quality in the L-31E canal is impacted by the flow of CCS wastewater toward the west.

The L-31E canal runs parallel to the western boundary of the CCS. The canal extends from Palm Drive, near the northern boundary of the CCS, south beyond the southern extent of the CCS to connect with the Card Sound canal and Card Sound. Near the southern end of the CCS, the L-31E canal connects with the S20 canal through the S20 control structure. The S20 canal connects directly to Biscayne Bay. Flow between the L-31E and S20 canals is controlled by the S20 control structure. Around 2014, FPL installed flow barriers in the L-31E canal, near Card Sound, and in the S20 canal to prevent the intrusion of salt water in the canals. These canals are surface waters of the State.

FPL reports daily-averaged salinity at three locations along the L-31E canal as part of the regular reporting from its monitoring of the CCS. These data reveal numerous occurrences of the intrusion of salt water into the normally fresh water of the canal, Figure 7. In an initial survey in 2011,[16] tritium was found in the L-31E canal at a concentration above background levels, confirming the existence of a direct hydrological connection for flow between the CCS and the canal. It is also reasonable to assume that groundwater flow of Biscayne Bay water of saline water occurs from the S20 canal into the L-31E canal, by-passing the S20 control structure when water level in the S20 canal is higher than water level in the L-31E canal.

In almost every case, the appearance of salt water in the L-31E canal coincides with the occurrence of hydraulic gradients conducive of flow from the CCS toward the L-31E canal, Figure 7. Data for two hydraulic gradients are plotted: the hydraulic gradient for flow from the CCS into the L-31E canal (e.g. the difference in water level measured at CCS-1 and water level measured in the canal at SWC-1) and the hydraulic gradient between Biscayne Bay and the canal (e.g. the difference in tail water and head water levels measured at the S20 structure). Generally, conditions for flow from the CCS into the L-31E canal and from Biscayne Bay into the L-31E canal coincide, and these occur during the dry season, when the absence of recharge from rainfall and runoff lowers water levels in the L-31E canal.

In a few instances, a rise in salinity values in the L-31E canal occurs apparently in the absence of hydraulic gradients conducive of flow into the canal. However, a closer look at the data[17] shows that in these instances extreme high tides in Biscayne Bay created short-lived gradients for flow into the L-31E canal that are not reflected in the hydraulic gradients calculated from daily-averaged water level data.

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[16] Janzen, J., and S. Krupa, 2011. Water Quality Characterization of Southern Miami-Dade Nearby FPL Turkey Point Power Plant. Technical Publication WS-31, South Florida Water Management District, July 2011.

[17] Continuous data on water level in the L-31E canal and the S20 canal are recorded at the S20 structure by the South Florida Water Management District.

7. Under current operations, groundwater flow from the CCS into the aquifer amounts to 16 million gallons per day.

Groundwater flow and evaporation are the only two mechanisms that remove water from the CCS. When the volume of the CCS decreases by a known amount (c.f. Figure 3) the water lost leaves the canals either as groundwater flow into the aquifer or as evaporation. And, if the amount of evaporation is also known, then the amount of groundwater flow can be estimated by calculating the difference. A more accurate estimate of groundwater flow can be made by taking into account any water added by rainfall and other sources of water over the same period. This is the basis for using the water budget to calculate net groundwater flow.

The CCS water budget is an accounting of the amounts of water entering and leaving the CCS. Its components include water added by rainfall and from other sources, water removed by evaporation, and the net groundwater flow between the CCS and the aquifer. Other sources of water include "blowdown" water from the power plants, water pumped from the ID, and water added, beginning in 2014, from the L-31E canal and various wells for the purpose of reducing salinity in the CCS.

If the water budget accounting is complete, then the sum of all inflows minus all outflows must equal the change in the amount of water contained in the CCS, Equation 1.

$$\boxed{\text{Rainfall}} + \boxed{\begin{array}{c}\text{Other}\\ \text{inputs}\end{array}} - \boxed{\text{Evap}} - \boxed{\begin{array}{c}\text{Net}\\ \text{Flow}\end{array}} = \boxed{\begin{array}{c}\text{Change in}\\ \text{volume}\end{array}} \qquad \text{Equation 1}$$

By rearranging Equation 1, net (groundwater) flow can be calculated from the change in volume of water contained in the CCS and estimates of other components of the water budget, Equation 2. Net flow is the net of all groundwater exchange between the CCS across the bottom and sides of the canals that occurs within a given period of time, summing all outflows and subtracting all inflows.[18]

$$\boxed{\begin{array}{c}\text{Net}\\ \text{Flow}\end{array}} = \boxed{\text{Rainfall}} + \boxed{\begin{array}{c}\text{Other}\\ \text{inputs}\end{array}} - \boxed{\text{Evap}} - \boxed{\begin{array}{c}\text{Change in}\\ \text{volume}\end{array}} \qquad \text{Equation 2}$$

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[18] This approach to estimating the net groundwater flow does not rely on the calculated groundwater flow fluxes reported by FPL.

FPL compiles data and performs calculations to estimate components of the water budget with a daily time step as part of its ongoing monitoring. The data collected include pumping rates, water levels, salinity, rainfall, water temperature, and meteorological parameters related to evaporation. The calculated components of the water budget include rainfall (including runoff), evaporation, and the exchange of water by groundwater flow between the CCS and the Biscayne aquifer. The calculated rainfall input into the canals also accounts for runoff from the land surface around the canals. These calculations involve a number of adjustable parameters. The parameter values are determined by calibration, i.e. by selecting values of the adjustable parameters so that calculated values of CCS volume and salinity match observations.

I obtained FPL's reports on the water and salt budget for the CCS covering the period September 2010 through November 2017, Figure 8. Daily values for components of the water were compiled from four spreadsheet files that cover separate but overlapping periods of time: September 2010 through November 2015,[19] June 2015 through November 2016,[20] Jun 2015 through May 2017,[21] and May 2017 through November 2017.[22]

Example 1: net groundwater flow following the 2015/2016 high water event

Water levels in the CCS peaked in December 2015 following a period of six months of relatively high inflows from rainfall and the addition of water from other sources in an effort to lower salinity in the CCS. During the first three months of 2016, water levels returned to more normal values. Over this period, the volume of water contained in the CCS decreased by 2.2 billion gallons. Evaporation removed 2.9 billion gallons; rainfall added 1.5 billion gallons; and a negligible amount of water was added from other sources. The calculated net groundwater flow from the CCS into the aquifer is 1 billion gallons, for an average daily rate of 11 mgd (million gallons per day).

Example 2: net groundwater flow caused by Hurricane Irma storm surge

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[19] File contents are identified by this title on the "README" tab, "Water and Salt Balance Model of the Florida Power & light Cooling Canal System (CCS)," and this statement on the "Key" tab: "This model is based on the previously calibrated balance model (September 2010 through May2015) saved with filename Water&Salt_Balance_Thru_May2015_report.xlsx." The author of the file is identified as James Ross.

[20] File contents are identified by this title on the "README" tab, "Water and Salt Balance Model of the Florida Power & light Cooling Canal System (CCS)," and this statement on the "Key" tab: "This model is based on the previously calibrated balance model (September 2010 through May 2016) saved with filename Balance_Model_May2016_draftfinal_v2.xlsx." The author of the file is identified as James Ross.

[21] File contents are identified by this title on the "README" tab, "Water and Salt Balance Model of the Florida Power & light Cooling Canal System (CCS)," and this statement on the "Key" tab: "This model is based on the previously calibrated balance model (September 2010 through May 2016) saved with filename Balance_Model_May2016_draftfinal_v2.xlsx." The author of the file is identified as James Ross.

[22] File contents are identified by this title on the "README" tab, "Water and Salt Balance Model of the Florida Power & light Cooling Canal System (CCS)," and this statement on the "Key" tab: "This model is based on the previously calibrated balance model (June 2015 through May 2017) saved with filename Balance_Model_May2017_v3_draftfinal.xlsx." The author of the file is identified as James Ross.

The passage of Hurricane Irma across Key West and up the southwest coast of Florida in September 2017 caused a storm surge of 4.5 feet at Turkey Point, Figure 9. Over the period September 8 to 11 the volume of water in the CCS increased by about 3 billion gallons. Rainfall accounted for 2 billion gallons of this increase, and flooding by storm surge, which can be inferred from response of water levels in the CCS, accounted for the remaining 1 billion gallons.[23]

Following the storm surge, as the water drained from the adjacent wetlands and water levels receded outside the CCS, water added by the surge remained trapped within the CCS' levees until it could either evaporate or discharge into the underlying aquifer. Over a two-month period following the hurricane the volume of water in the CCS decreased by 2.1 billion gallons. Evaporation removed 2.1 billion gallons; rainfall added 1.3 billion gallons; and 1.4 billion gallons were added from other sources. The calculated net groundwater flow from the CCS into the aquifer is 2.7 billion gallons, for an average daily rate of 44 mgd.

Example 3: average net groundwater flow into the aquifer under current operations
January 2015 marks the beginning of the period of "current operations" for the CCS, Figure 3. Plant operations are a factor that influence the exchange of water between the CCS and the aquifer. The period of record from September 2010 through November 2017 spans a period in which plant operations changed in connection with work to increase the amount of power produced by the nuclear units 3 and 4. When this work was completed, in 2014, the cooling canals experienced a build-up in salinity and other water quality problems, prompting FPL to further modify operations by securing additional sources of water to replace losses from evaporation. These changes came online by the end of 2014.

Net groundwater flow can be a source of water inflow into the CCS as well, Figure 10. Equation 2 can be applied to calculate daily values of net groundwater flow from the data FPL reports from its monitoring program. Periods in which net groundwater flow is a source of inflow to the CCS alternate with periods in which net groundwater flow removes water from the CCS. These changes occur as constantly changing water levels both within the CCS and outside it, in Biscayne Bay and in the adjacent wetlands, alter the hydraulic gradients that drive flow through the aquifer.

For the period of current operations (January 2015 through November 2017), components of the water budget have the following average values: evaporation 39 mgd, rainfall 23 mgd, water input from other sources 23 mgd. The change in the volume of water in the CCS, averaged over the entire period January 2015 through November 2017, is small, 0.6 mgd. The net groundwater

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[23] FPL's report on the CCS water budget for this period does not account for the amount of water and salt added to the CCS by storm surge from Hurricane Irma. I have corrected this omission in my analysis of the water budget.

flow, averaging flows into the aquifer and flows into the CCS over all the days in this period, is 8 mgd into the aquifer.

The average rate of flow into the aquifer out of the CCS is of particular interest because of its importance in regulating water quality in the CCS. Groundwater flow into the aquifer is the only mechanism for removing dissolved substances and avoiding the build-up of excessive concentrations by evaporation. Also, groundwater flow into the aquifer is the mechanism by which the CCS impacts water quality by discharging hypersaline water and other pollutants into the aquifer and, via direct hydrologic connections provided by the aquifer, into Biscayne Bay and the adjacent wetlands.

The average value for net groundwater flow into the aquifer from the CCS is 16 mgd, computed as the sum over days in which the direction of groundwater flow is into the aquifer divided by the total number of days in the period. At this rate, the entire contents of the CCS empty into the aquifer every 11 months,[24] and at least 8 million pounds of salt, along with other pollutants, are flushed into the aquifer each day.[25]

8. Actions being taken by FPL with the objectives to cease harmful discharges from the CSS that threaten groundwater resources to the west, retract the hypersaline groundwater plume, and prevent releases of groundwater to surface waters connected to Biscayne Bay cannot achieve these objectives.

The 2016 Consent Order[26] with the Florida Department of Environmental Protection prescribes actions by FPL intended to remediate the damages by the hypersaline plume and protect Biscayne Bay. The order prescribes three main actions: installation of a recovery well system, freshening to reduce salinity in the CCS, and restoration projects along the Biscayne Bay shoreline. These actions are either demonstrably inadequate to the task or they work at cross purposes to each other and the stated objectives.

The actions being taken by FPL cannot achieve the objectives of the Consent Order because of (1) the failure of the interceptor ditch; (2) the inadequacy of the recovery well system; and (3) the increase in discharges from the CCS as a result of addition of fresher water. The actions being taken by FPL ignore the basic reality of the way the CCS interacts with groundwater and surface water.

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[24] This calculation is based on an average volume of the CCS of 5.0 billion gallons (range from 3.8 billion gallons to 7.8 billion gallons) and 16 mgd (range from 0 mgd to 225 mgd) average daily net groundwater flow out of the CCS; both of these figures are the average for the current operations period January 2015 through November 2017.

[25] In this calculation I assume an average salinity in the CCS of 67 psu (range from 38 psu to 97 psu).

[26] Consent Order 2016. State of Florida Department of Environmental Protection v. Florida Power & Light Company, OGC File No. 16-0241.

Failure of the interceptor ditch

Since 1974, a series of agreements with the South Florida Water Management District have prescribed the operation and monitoring of the Interceptor Ditch (ID). The ID was constructed to "restrict movement of saline water from the cooling water system westward of Levee 31E adjacent to the cooling canal system to those amounts which would occur without the existence of the cooling canal system"[27] This was in response to concerns that water discharged to the aquifer from the CCS could harm freshwater supplies. Failure of the ID to intercept water from the CCS is evident in by the development of the hypersaline plume extending west beyond the L-31E canal. Today, freshwater resources of the Biscayne aquifer are threatened both as a result of the failure of the ID to intercept water from the CCS as well as from adverse effects resulting from the continued operation of the ID.

Operation of the ID is supposed to prevent CCS water flowing west through the aquifer from reaching the L-31E canal. Water is pumped out of the ID as needed to maintain water levels in the ID lower than water levels in the L-31E canal. This is supposed to assure that the direction of groundwater flow is always from the west into the ID. In practice, the ID has failed to prevent the westward movement of the dense hypersaline plume along the bottom of the aquifer, ~ 100 feet below the land surface. The ID is too shallow, ~20 feet deep, to retard the horizontal movement of water deep in the aquifer, especially under the conditions where flow in the aquifer is stratified.

Density stratification in the aquifer means that it imperative to maintain conditions against vertical flow as well as horizontal flow. Water in the Biscayne aquifer west of the CCS is stratified. A layer of freshwater, fed by rainfall and groundwater flow from the west, overlies the plume of hypersaline water fed by flow out of the CCS and extending west beneath the ID and the L-31E.

The stability of the interface between the freshwater and salt water layers, in a coastal aquifer, depends on maintaining the level of the fresh water-table above sea level. Applying the Gyben-Herzberg principle, the depth to the interface between freshwater and salt water beneath the L-

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[27] Fifth Supplemental Agreement Between the South Florida Water Management District and Florida Power & Light Company, 16 October 2009

31E canal is calculated to be between 7 and 12 feet,[28] which coincides exactly with the bottom of the L-31E canal.[29]

Water is pumped out of the ID for the purpose of maintaining a hydraulic barrier to westward movement of CCS water in the shallow groundwater. Pumping lowers the water level in the ID and in the wetlands immediately adjacent to it. This decreases the height of the water-table in the freshwater lens, which also decreases the depth to the freshwater/salt water interface. Therefore, by lowering the watertable, ID operations also promote the vertical flow of the CCS water in the hypersaline plume upward into the upper area of the Biscayne aquifer.[30]

Beyond the threat arising from its failure to retard the westward movement of CCS water, operation of the ID represents a large, undocumented demand on the regional freshwater resource provided by the Biscayne aquifer. Water pumped out of the ID is a mixture of saline water discharged from the CCS and fresh groundwater flow from the west. The amount of freshwater withdrawn by ID operations can be estimated from the ID pumping rate and salinity data collected for the ID and the L-31E canal. The impact of pumping on the water table in the wetlands west of the CCS is exacerbated by the fact that pumping from the ID occurs predominantly during the dry season, January through May. This is when the amount of freshwater in the aquifer is at its seasonal low, and hydraulic gradients conducive for flow from the CCS into the L-31E canal exist.

On any day, the amount of water pumped from the ID, Q_{ID}, is the sum of an amount of water that has entered the ID from the west, from Q_{L31}, and an amount of water recycled from the CCS, Q_{RW};

$$Q_{ID} = Q_{L31} + Q_{RW}. \qquad \text{Equation 3}$$

---

[28] The Gyben Herzberg relationship calculates the depth to the interface between freshwater and salt water in a coastal aquifer, z, as the height of the freshwater water-table above sea level, h, multiplied by a factor computed from the densities of freshwater (nominally 1000 kg/m^3) and seawater (1025 kg/m^3); $z = \frac{\rho_f}{(\rho_s - \rho_f)} h$. For freshwater and sea water the multiplier is 40. In the situation of the L-31E canal and the hypersaline plume from the CCS, water level in the CCS plays the role of sea level. The water level in the L-31E canal is, on average, 0.3 feet above the level of the CCS; therefore the depth to the interface below the canal is computed to be 12 feet. However, the density of hypersaline water in the CSS and its plume can be higher than that of sea water; density of water with a salinity of 60 psu, roughly the long-term average for the CCS, is 1042 kg/m^3. Using this higher density, the multiplier is 24, and the estimated depth to the interface below the L-31E canal is 7 feet.

[29] "The depth of the L-31E canal is around 9 feet." Janzen, J., and S. Krupa, 2011. Water Quality Characterization of Southern Miami-Dade Nearby FPL Turkey Point Power Plant. Technical Publication WS-31, South Florida Water Management District, July 2011.

[30] Evidence for vertical migration of the plume was discussed at a meeting at the South Florida Water Management District in February 2017; PowerPoint presentation by Jonathon Shaw, Turkey Point Power Plant Interceptor Ditch Operations, Joint Agency Meeting – SFWMD/DEP/DERM, February 9, 2017.

Similarly, the amount of salt in the water pumped from the ID is the sum of an amount carried into the ID in groundwater flow from the west and in the flow of recycled water from the CCS;

$$Q_{ID}S_{ID} = Q_{RW}\,S_{CCS} + Q_{L31}\,S_{L31}. \qquad \text{Equation 4}$$

From these two equations, on can derive the following formula to calculate the portion of the total daily ID pumping that is fed by groundwater flow from the west:

$$Q_{L31} = Q_{ID}\,[(S_{CCS} - S_{ID}) / (S_{CCS} - S_{L31})] \qquad \text{Equation 5}$$

The daily rate of pumping from the ID, Q_{ID}, and the salinity of water in the ID, S_{ID} , are measured, Table 6. The salinity measured in the L-31E canal can be taken as representative of the salinity of water flowing into the ID from the west. Shallow groundwater west of the CCS is not totally fresh, as a consequence of infrequent flooding of the wetlands there by water from Biscayne Bay. The salinity of water below the CCS is taken to be 60 gm/l, which reflects the long-term, stable average of salinity measured in a shallow well in the center of the CCS[31].

Based on these data, calculations reveal that ID pumping removes about 3.5 mgd of mostly fresh groundwater from the Biscayne aquifer west of the CCS. This is the average of the amount of freshwater extracted calculated using Equation 5 applied with daily values of pumping rate and salinity, Table 1. The pumping rate varies from day to day, and salinity in the ID tends to be higher on days with higher rates of pumping.

This rate of extraction is large relative to other withdrawals from the aquifer. Nearby well fields operated by public water utilities[32] withdraw 2 mgd (Florida City), 11 mgd (Homestead), and 17 mgd (FKAA). The withdrawal of freshwater as a consequence of ID operations is not documented in current regional water supply plans.

Regional water supply plans include data on water use by power plants. The Lower East Coast water supply plan notes the water withdrawn from the Floridan aquifer for cooling for the gas-fired Unit 5 at Turkey Point, but it does not account for the extraction of water from the Biscayne aquifer to supply water for the CCS.[33] Since the latest update to the Lower East Coast plan, FPL has obtained permits to withdraw additional water for the CCS from the L-31E and from the Floridan aquifer.

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[31] TPGW-13

[32] Water use figures from Table A-8, 2013 LEC Water Supply Plan Update: Appendices, October 10, 2013.

[33] "FPL increased its power generation capacity at the existing Turkey Point plant by adding combined cycle generating technology to respond to significant population growth in South Florida. Unit 5 is a natural gas-fired combined-cycle unit that uses groundwater drawn from the Floridan aquifer while the other four units, Units 1–4, use water from the closed cycle recirculation canal system."

Table 1: Calculated rate of freshwater extraction from the Biscayne aquifer by pumping the Interceptor Ditch. Data are for the period January 2015 through November 2017.

	Calculated fresh water flow (mgd)	Measured ID Pump Rate (mgd)	ID salinity	L-31E salinity
Average	3.45	4.01	6.11	1.51
Standard deviation	8.53	9.63	3.85	1.44
Maximum	161.19	168.60	20.13	6.76
Minimum	0.00	0.00	1.92	0.27

Inadequacy of the recovery well system

The Consent Order prescribes that the recovery well system is supposed to “halt the westward migration of hypersaline water from the CCS within 3 years,” and “retract the hypersaline plume to the L-31E canal within 10 years.” To accomplish this, a series of 10 recovery wells will be sited along the western boundary of the CCS. These wells will remove water from the plume, which is to be disposed by deep well injection. Operation of the recovery well system is subject to the constraint that there be no “adverse environmental impacts.” This is assured by establishing an upper limit on the aggregate rate that the wells can withdraw water from the plume – 5.4 billion gallons per year, or 15 mgd.[34]

At the maximum rate pumping rate, it is highly unlikely that the recovery well system can succeed in retracting the plume within 10 years. In 2013, it was estimated that the western extent of the plume contained 123 billion gallons[35] of water originally discharged from the CCS. This is more than twice the volume of water that can be recovered if the recovery wells are pumped at their maximum rate for 10 years. And, it is certain that, through mixing with ambient water in the aquifer and the accumulated discharge from the CCS over the past 5 years, the volume of hypersaline water that now must be removed to retract the plume is much larger. CCS water added to the aquifer with a salinity of 60 psu can be diluted with nearly an equal volume of freshwater and still be considered hypersaline.

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[34] Water Use Individual Permit No. 13-0651-W, issued on February 27, 2017, by South Florida Water Management District

[35] This figure is based on calculations by SFWMD staff in 2013 of the total volume of CCS water in the mapped portion of the hypersaline groundwater plume, reported in Nuttle, W.K., 2013. Review of CCS Water and Salt Budgets Reported in the 2012 FPL Turkey Point Pre-Uprate Report and Supporting Data. Report to the South Florida Water Management District, 5 April 2013. The extent of the plume was mapped based on the presence of CCS water, even in diluted amounts, identified by its ionic and tritium chemical fingerprint. The mapped portion of the plume included only the western portion and the portion beneath the CCS. Including the unmapped portion that extends under Biscayne Bay could increase this number by a factor 1.5 to 2.

Freshening increases flow out of the CCS into the aquifer
To accomplish the objective of "cease discharges from the CCS that impair the reasonable and beneficial use of adjacent G-II ground waters to the west of the CCS," the Consent Order directs FPL to reduce the average annual salinity to 34 psu or below within 4 years. FPL is to conduct "freshening activities" to achieve this goal. FPL describes freshening activities as "using fresher water sources to replace freshwater evaporated from the CCS and thereby reduce the average annual CCS salinity."

Freshening activities, i.e. supplementing other inputs in the water budget to lower salinity in the CCS, distinguish the period of current operations (January 2015 through November 2017) from the preceding period in the record of data from the monitoring program (September 2010 through December 2014). Freshening activities have altered the water budget, Table 2. Water inputs from ID operation, and wells tapping the Upper Floridan aquifer and saline water beneath Biscayne Bay, have increased flows in the other inputs category by 17 mgd. Flows between the CCS and the aquifer have changed by a similar amount, from an average net inflow of 10 mgd in the earlier period to an average net outflow of 8 mgd under current operations. FPL recently reached a partnership agreement with Miami-Dade County[36] to secure to up to 60 mgd additional water for freshening activities. Any further increase in water inputs to the CCS will result in the same increase in average net groundwater flow from the CCS into the aquifer.

Table 2: Average daily values for components of the water budget (mgd)

	Sep 2010 to Dec 2014	Jan 2015 to Nov 2017
Evaporation	36.6	38.8
Rainfall	20.2	23.4
Other inputs	6.3	23.0
Volume change	-0.3	0.6
Net groundwater flow	-9.7	7.8

The effect of "freshening activities" is exactly opposite the usual meaning of the term "cease discharges from the CCS." In the context of the CCS water budget (Eq.'s 1 and 2), freshening activities increase the daily quantities of "other inputs." This has two effects. First, the volume of

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[36] Resolution approving joint participation agreements with Florida Power & Light Company providing for development of (1) an advanced reclaimed water project and (2) next generation energy projects; and authorizing the Mayor or his designee to execute the agreements and exercise the provisions contained therein, Resolution No. R-292-18, approved on April 10, 2018.

water in the CCS increases. Second, as the volume and water levels increase, the flow of water into the aquifer from the CCS increases until it balances the inflow provided by new sources of water. Likewise, the long-term reduction in salinity to 35 psu requires reducing the mass of salt in the CCS. The only mechanism that removes salt from the CCS is by flushing it into the aquifer.

To gage the impact of freshening activities on the flow of CCS water feeding the hypersaline plume, I reviewed the monthly average groundwater flows that FPL compiles in its reporting on the CCS water and salt budgets, Figure 10. [37] [38] [39] [40] FPL computes groundwater fluxes separately across the bottom of the CCS and each of its sides based on hydraulic gradients derived from water level data. I examined only the groundwater flow computed out through the bottom of the CCS because this is directed downward, deep into the aquifer. Therefore, bottom flow is a better indicator of the flow from the CCS that feeds the hypersaline groundwater plume. By contrast, the net flow computed from the water budget (above), includes horizontal flow at shallow depths that more likely discharges into Biscayne Bay or a canal.

FPL's computed groundwater flow into the aquifer through the bottom of the CCS was much larger during this period, 11 mgd, compared with the average groundwater flow for the preceding period since 2010, 1 mgd. Other differences are apparent in the water budget between the two periods. In particular, water inputs from pumping the ID are much larger in the recent period; ID pumping accounts for a large portion of "other inputs." "Freshening activities' may or may not have had an effect on the increased ID pumping. Therefore, it is difficult to say what portion the increased from 1 mgd to 11 mgd is attributable to freshening.

Freshening activities work at cross purposes with the recovery well system. Any increase in groundwater flow from the CCS feeding the hypersaline plume degrades the performance of the recovery well system. At a rate of inflow of 11 mgd, over two thirds of the pumping capacity of the water recovery wells is required just to intercept and remove the water that groundwater flow

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[37] File contents are identified by this title on the "README" tab, "Water and Salt Balance Model of the Florida Power & light Cooling Canal System (CCS)," and this statement on the "Key" tab: "This model is based on the previously calibrated balance model (September 2010 through May2015) saved with filename Water&Salt_Balance_Thru_May2015_report.xlsx." The author of the file is identified as James Ross.

[38] File contents are identified by this title on the "README" tab, "Water and Salt Balance Model of the Florida Power & light Cooling Canal System (CCS)," and this statement on the "Key" tab: "This model is based on the previously calibrated balance model (September 2010 through May 2016) saved with filename Balance_Model_May2016_draftfinal_v2.xlsx." The author of the file is identified as James Ross.

[39] File contents are identified by this title on the "README" tab, "Water and Salt Balance Model of the Florida Power & light Cooling Canal System (CCS)," and this statement on the "Key" tab: "This model is based on the previously calibrated balance model (September 2010 through May 2016) saved with filename Balance_Model_May2016_draftfinal_v2.xlsx." The author of the file is identified as James Ross.

[40] File contents are identified by this title on the "README" tab, "Water and Salt Balance Model of the Florida Power & light Cooling Canal System (CCS)," and this statement on the "Key" tab: "This model is based on the previously calibrated balance model (June 2015 through May 2017) saved with filename Balance_Model_May2017_v3_draftfinal.xlsx." The author of the file is identified as James Ross.

out of the CCS continually adds to the volume of the plume. That leaves only 4 mgd of pumping capacity applied to reducing the existing volume and retracting the hypersaline plume. That's only 15 billion gallons that can be removed from the existing plume over 10 years. The current volume of the plume could easily be 10 times this amount.

Coastal restoration projects are inadequate to protect Biscayne Bay from discharges from the CCS.

The action prescribed in Consent Order in response to the objective "to prevent releases of groundwater from the CCS to surface waters connected to Biscayne Bay…" is clearly incommensurate with the scale of the challenge. The action that FPL will undertake is limited to restoring coastal habitat by partially filling two relic canals in the vicinity of the power plant. These two canals are far from the only direct hydrologic connections between the CCS and Biscayne Bay. The cave site, described above, is an example of what are likely numerous connections. In 1973, faced with a similar goal to "restrict movement of saline water from the cooling water system westward of Levee 31E"[41] FPL undertook the construction and operation of the ID to create a hydraulic barrier to shallow groundwater flow along the entire western boundary of the CCS. Given the track record of the ID, it is unlikely that something on the same scale as the ID, 5 miles in extent, would be an adequate hydraulic barrier to protect Biscayne Bay from discharges from the CCS.

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[41] Fifth Supplemental Agreement Between the South Florida Water Management District and Florida Power & Light Company, 16 October 2009

QUALIFICATIONS

My resume is attached hereto as Exhibit B and contains my qualifications and a list of all publications that I have authored in the past 10 years.

PRIOR TESTIMONY

During the past 4 years, I have testified in deposition and at trial in the following cases:

Altantic Civil, Inc. v. Florida Power and Light Company, et al. Case No. 15-1746 (Florida Division of Administrative Hearings, Nov. 2-4, 2015).

In re Florida Power and Light Company Turkey Point Power Plant Unites 3-5 Modification to Conditions of Certification. Case No. 15-1559EPP (Florida Division of Administrative Hearings, December 1-4, 2015).

COMPENSATION

I am being compensated as follows for my work in this matter: $175.00 per hour.

SIGNATURE

William K. Nuttle

Exhibit A: Figures

Figure 1: Turkey Point Cooling Canal System showing the main features and monitoring locations mentioned in the text.

Figure 2: The cooling canals at Turkey Point exchange water freely with the atmosphere, through rainfall and evaporation, and with the underlying Biscayne aquifer, which is the main source of freshwater for communities in south Miami-Dade County and the Florida Keys.

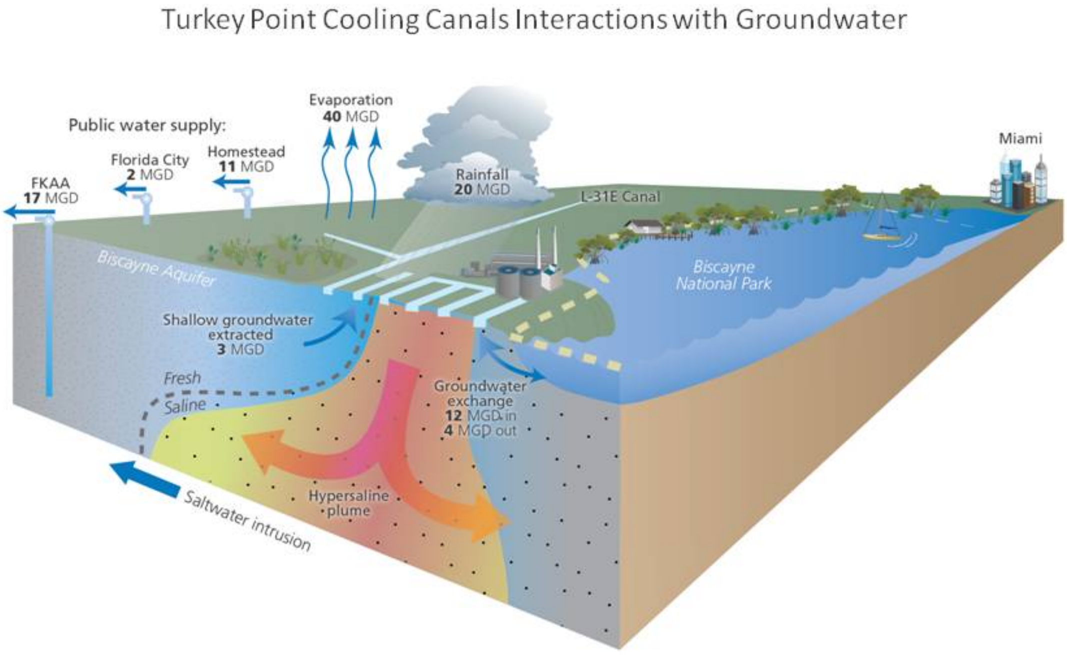

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Figure 3: The volume of water contained in the CCS changes constantly in response to rainfall, water inputs from other sources, and the loss of water through evaporation. Water exchange between the CCS canals and the underlying aquifer sometimes adds water and sometimes removes water from the CCS. Measured changes in CCS volume combined with measurements and estimates of rainfall, other water inputs, and evaporation make it possible to calculate the volume of water exchanged with the aquifer on a daily basis.

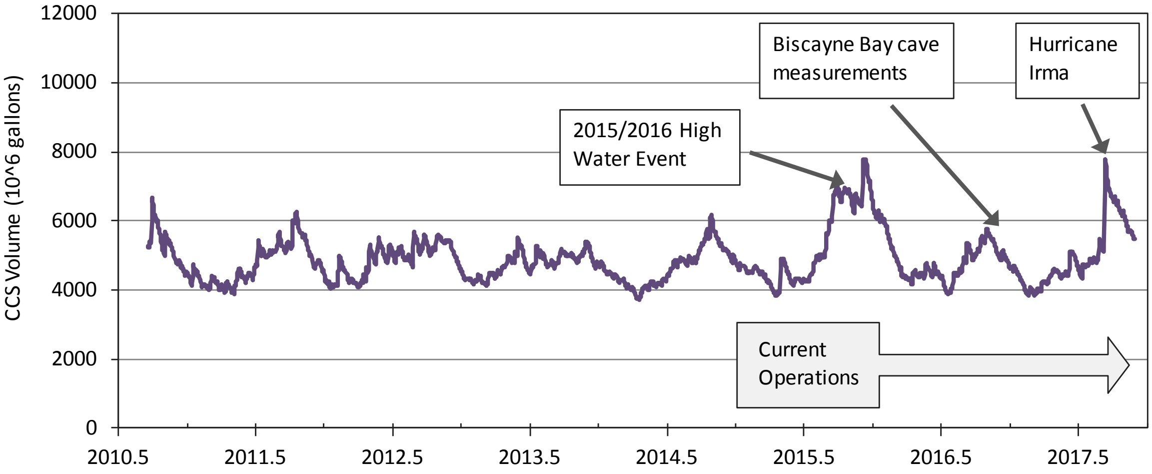


Figure 4: Changes in that direction of the hydraulic gradient between the CCS and Biscayne Bay (top panel) controls groundwater discharge into the bay through a submarine cave. The hydraulic gradient is calculated as the difference between daily average water levels in the CCS (TPSWCCS-5) and Biscayne Bay (TPBBSW-3); positive values indicate the direction of flow from the CCS toward the bay. Salinity (bottom panel) is reduced as high-salinity water from the CCS is diluted by mixing with ambient water in the aquifer as it flows from the CCS into the bay. Salinity of water inside the cave (red) fluctuates as tidal fluctuations drive water flow first into and then out of the aquifer through the cave. Inflowing water has the (lower) salinity of Biscayne Bay surface water, and outflowing water is elevated by mixing with higher-salinity water from the aquifer. Increased outflow from the aquifer, during periods in which the hydraulic gradient is positive, is reflected in higher salinity in the outflowing water in the cave.

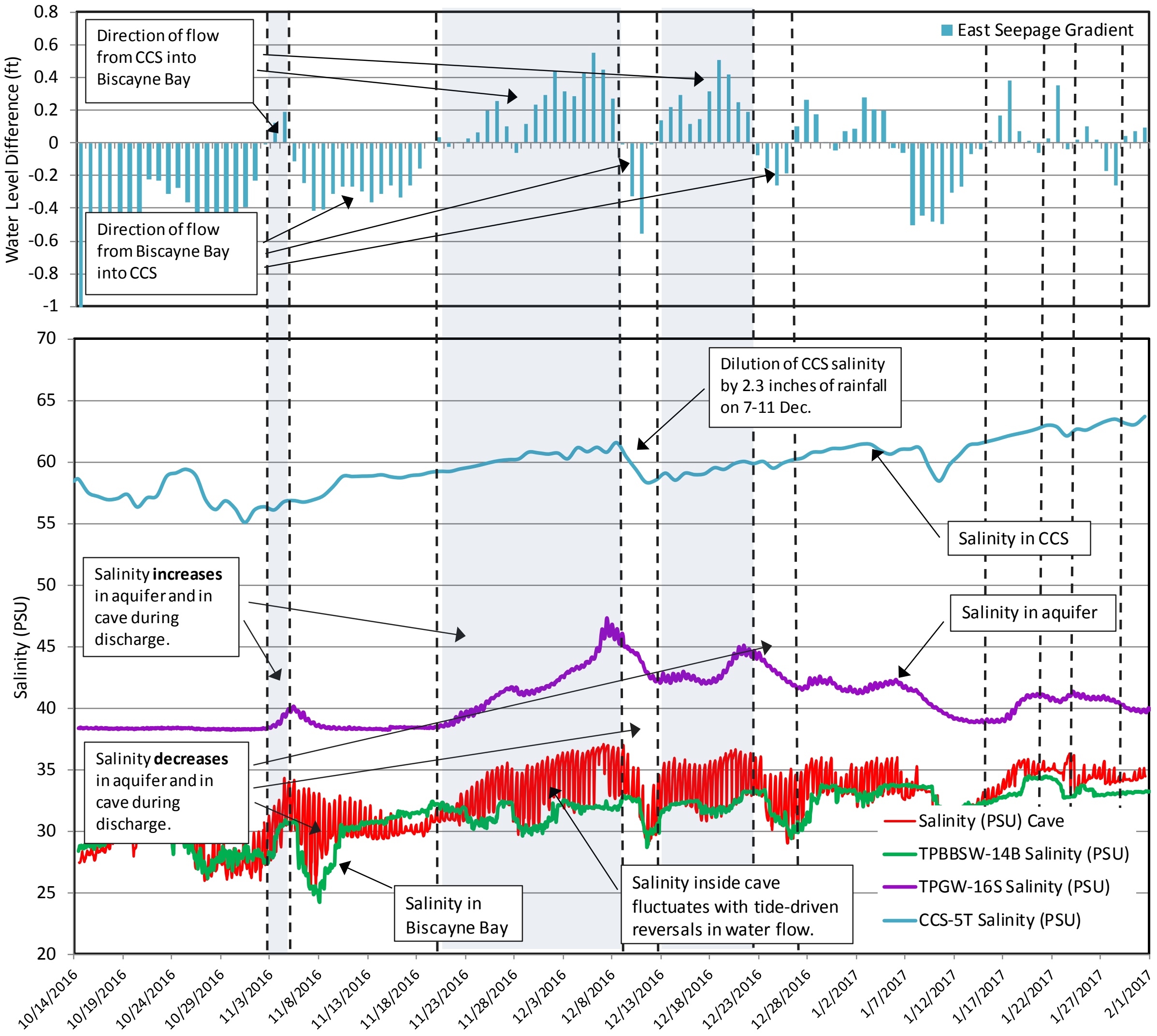
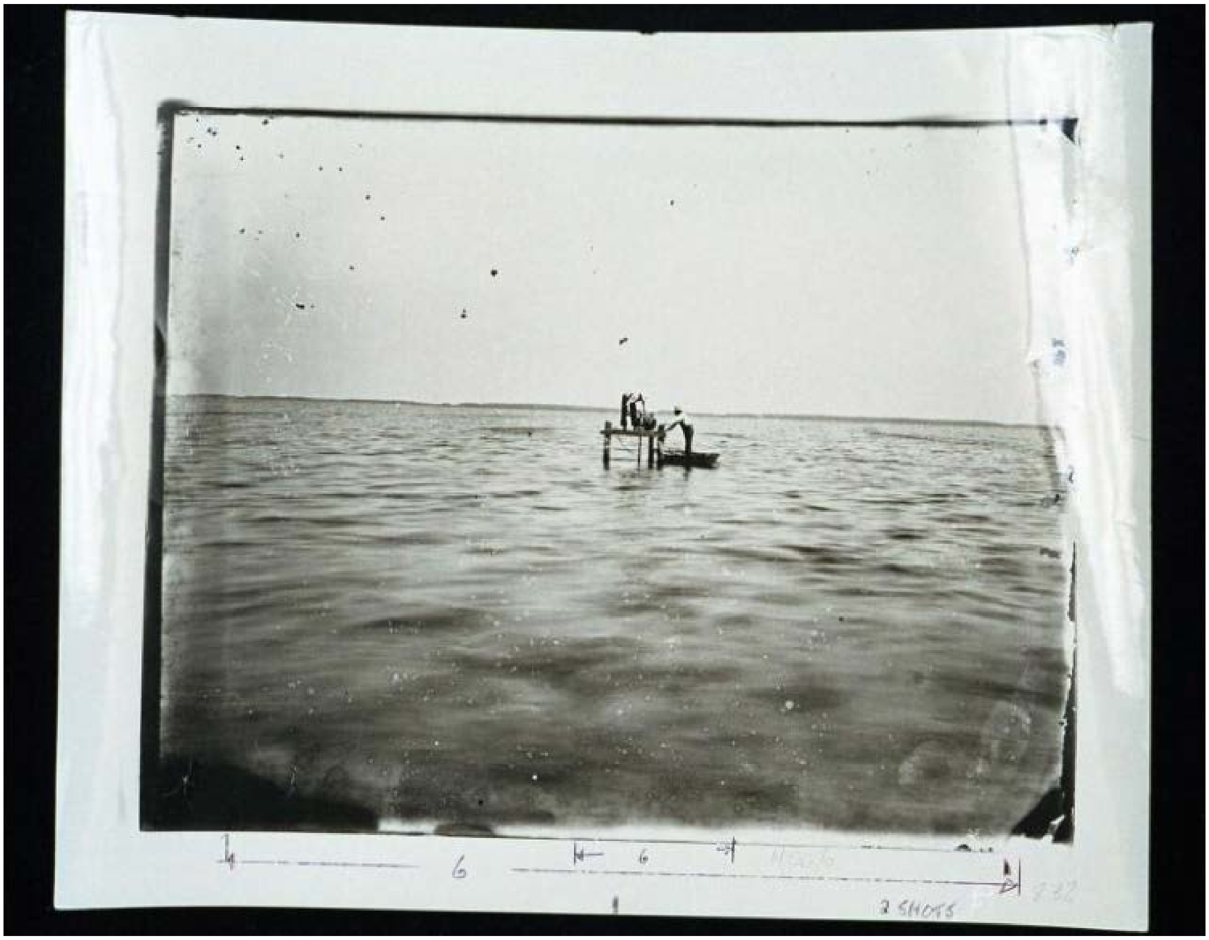


Figure 5: Groundwater discharging through cavities in the limestone Biscayne aquifer fed freshwater springs under Biscayne Bay that were used as a source of freshwater in the late 19th century. (Photo credit: Freshwater springs in Biscayne Bay, ca. 1890, Munroe, Ralph, 1851-1933)[42]



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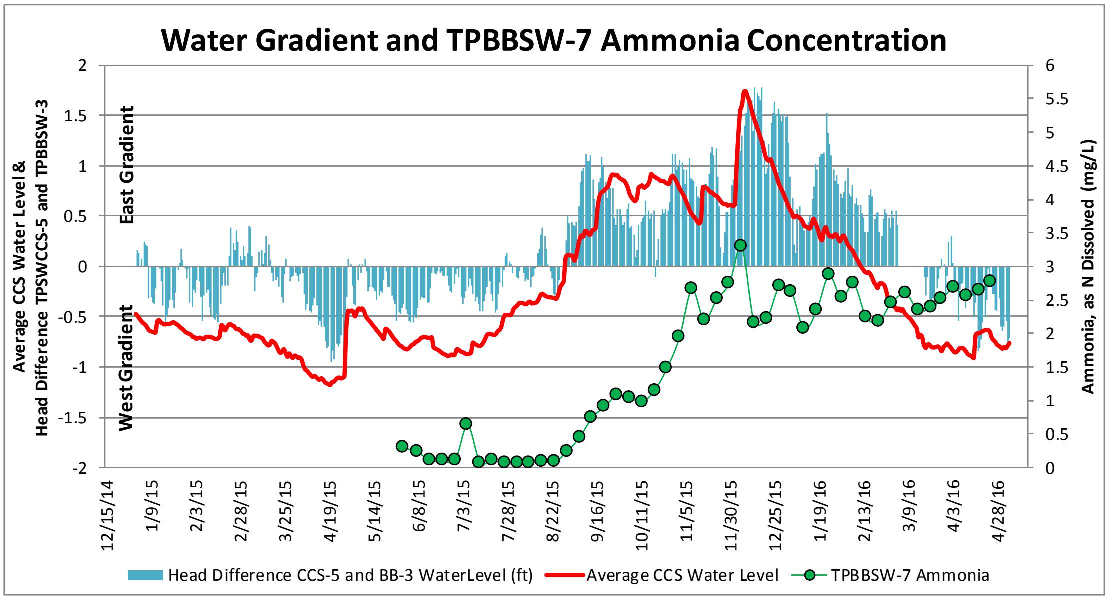
[42] Online: http://dpanther.fiu.edu/sobek/RM00010005/00001; accessed 14 May 2018

Figure 6: The high-water event in 2015/2016 (CCS water level shown in red) corresponded with an extended period of discharge from the CCS into Biscayne Bay through the aquifer. Positive values of the hydraulic gradient, measured as the difference in daily average water levels in the CCS (TPSWCCS-5) and in Biscayne Bay (TPSWBB-3), correspond with flow from the CCS into Biscayne Bay. The rise in ammonia concentrations measured in Biscayne Bay water (at TPBBSW-7) follows the classic pattern of a breakthrough curve for the discharge of a plume of contaminant moving in groundwater.[43]



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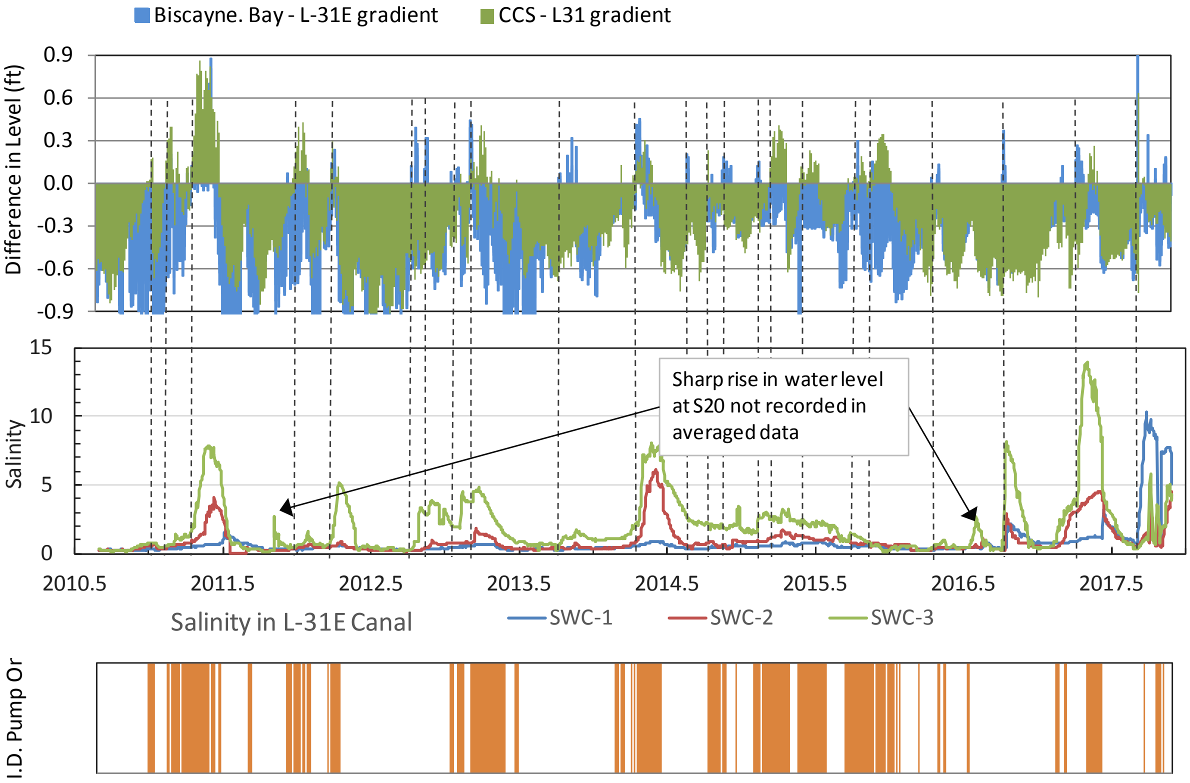
[43] This figure is taken from a spreadsheet obtained from Miami-Dade DERM. The author of the spreadsheet is indicated as Sara Mechtensimer. A LinkedIn profile for Sara Mechtensimer identifies her as an employee of FPL. [accessed 25 May 2017].

Figure 7: Salinity measured in the L-31E canal (middle panel) rises in response to intermittent groundwater discharge from the CCS and Biscayne Bay. Discharge is inferred from periods in which the hydraulic gradients are favorable for flow from the CCS and Biscayne Bay toward the L-31E canal (upper panel). The hydraulic gradients are calculated as the difference between daily average water levels in the CCS and the canal and between the tailwater and headwater levels at the S20 structure.[44] Positive values for the hydraulic gradients indicate flow is from the CCS or Biscayne Bay toward the L-31E canal. In the two instances in which a spike in salinity does not correspond to a positive hydraulic gradient, inspection of instantaneous water level data from the S20 structure confirms the short-term occurrence of a positive gradient not captured in the daily average data. Pumping from the Interceptor Ditch (ID; bottom panel) can contribute to the inflow of saline water into the canal by inducing vertical movement of the boundary between fresh and salt water in the aquifer.



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[44] The hydraulic heads are uncorrected for density differences. The difference in density between the saline water in the CCS and the (mostly) freshwater in the L-31E favors flow from the CCS toward the L-31E canal when the water levels are equal. The error introduced by neglecting the effect of density differences in calculating hydraulic head for flow toward the L-31E canal is in failing to identify conditions for flow toward the L-31E when they exist.

Figure 8: Daily values of the components of the CCS water budget measured by FPL's monitoring program: evaporation, rainfall, other inflow.

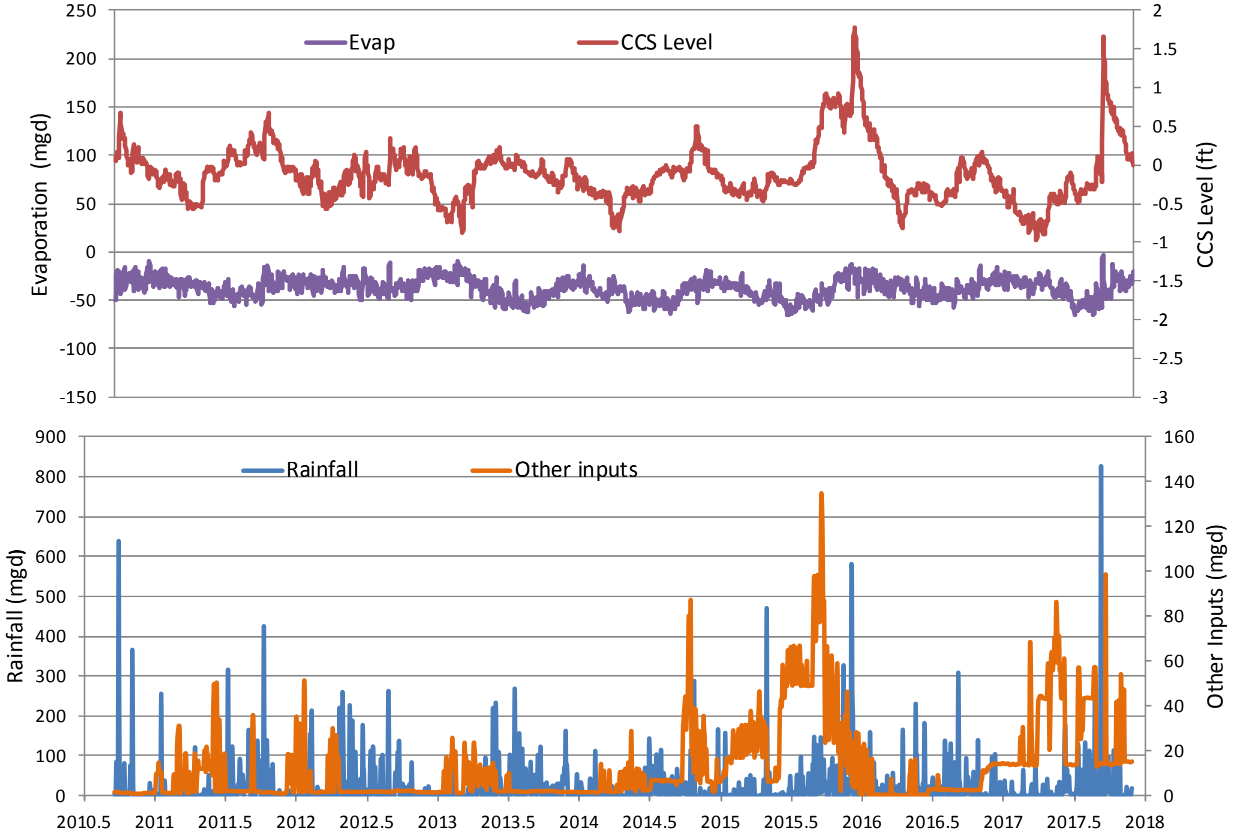

Figure 9: During Hurricane Irma, surface flooding from storm surge (inset) and rainfall during Hurricane Irma storm added about 3 billion gallons to the volume of the CCS. Rainfall accounted for 2 billion gallons of this increase, and flooding by storm surge accounted for the remaining 1 billion gallons.

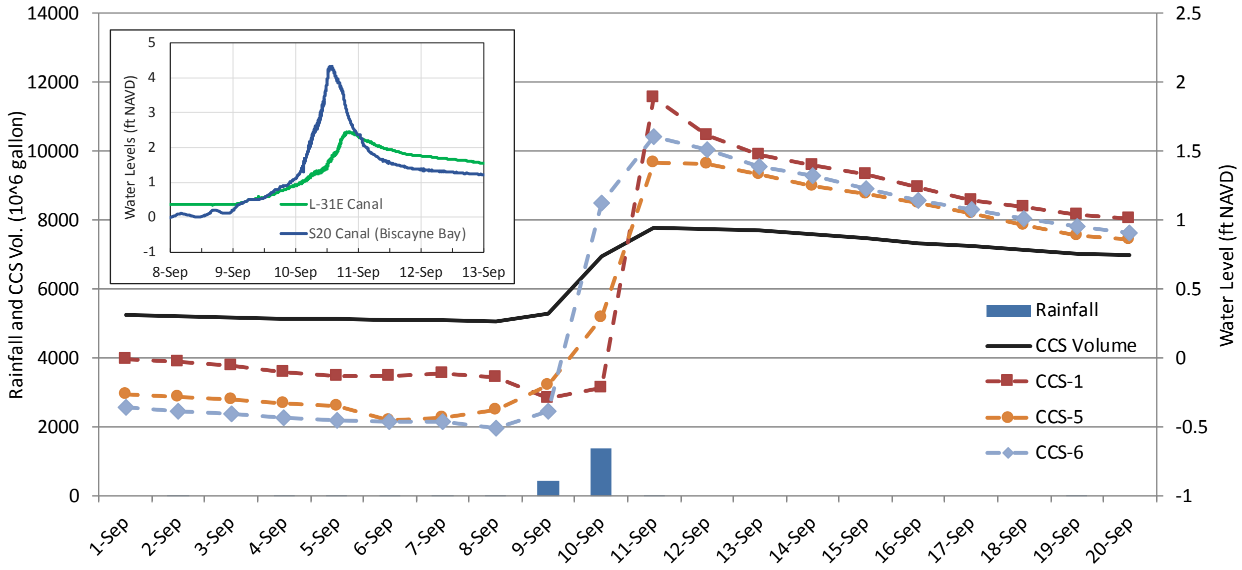

Figure 10: Upper panel: computed daily net groundwater flow into the aquifer (mgd). Positive values of net flow indicate flux into the aquifer. Negative values of net flow indicate flux into the CCS. Middle panel: monthly average groundwater flow (mgd) into the aquifer through the bottom of the CCS, computed by FPL as part of its regular monitoring and reporting on conditions in and around the CCS. Lower panel: daily inflow from “other sources.” Inflow from other sources includes the water pumped out of the ID, inputs from various sources for “freshening activities” and relatively much smaller inputs from plant blowdown. Water inputs for the purpose of freshening first occurred in the last half of 2014, and they occur regularly under “current operations,” defined as beginning in 2015.

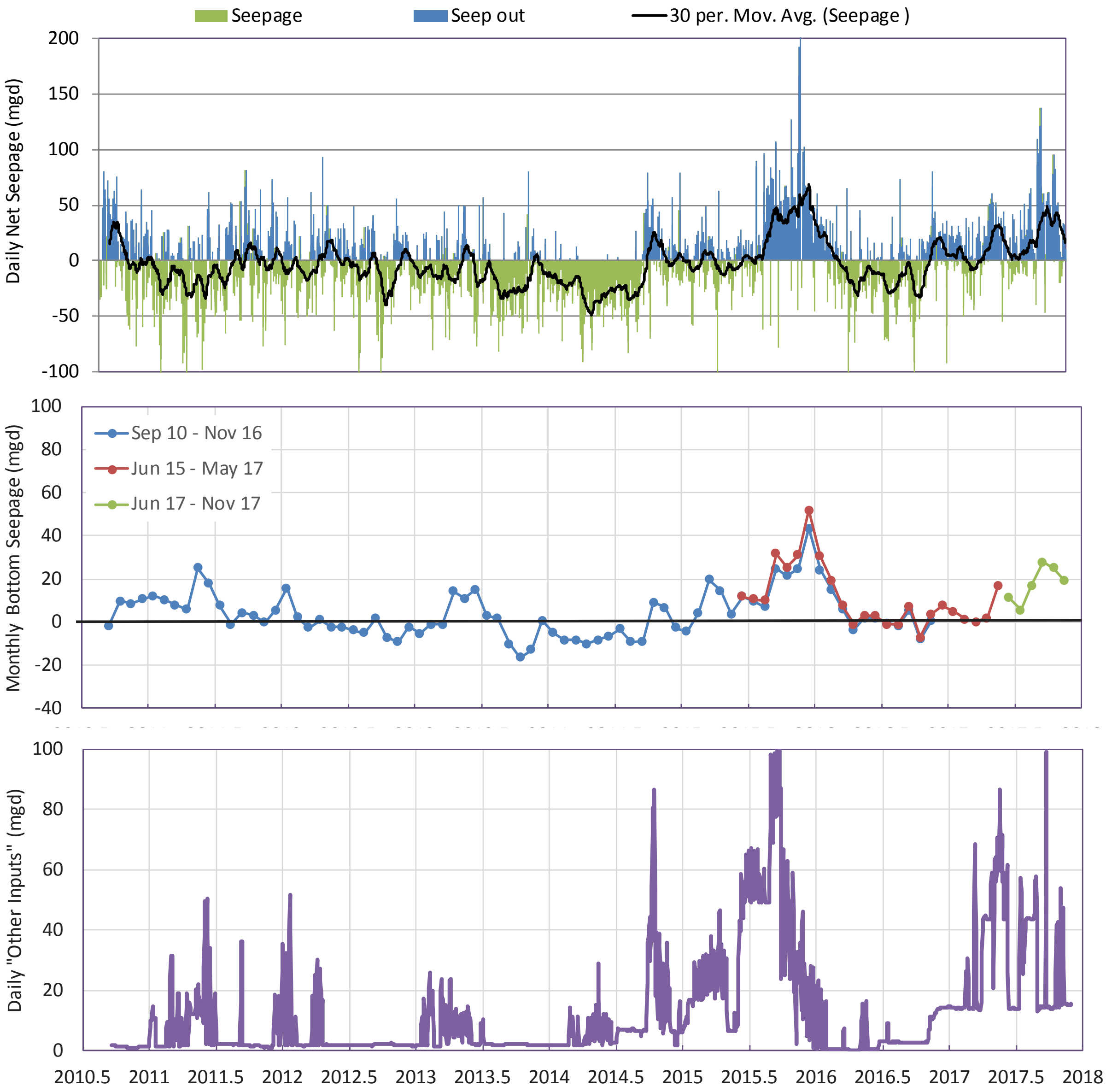

Exhibit B: Curriculum Vitae

William K. Nuttle, Ph.D, P.Eng

11 Craig Street
Ottawa, Ontario
Canada K1S 4B6
wknuttle@gmail.com

Profile

William K. Nuttle has 25 years of experience working with water managers, engineers, Earth scientists and ecologists in planning eco-hydrology research and applying the results of this research to ecosystem restoration and management of natural resources. Prior to joining the University of Maryland he coordinated ecosystem research programs directed at supporting large-scale ecosystem restoration activities and resource management in South Florida and Louisiana. He was director of the Everglades Department for the South Florida Water Management District in 2000-2001, and prior to that he served as Executive Officer for the Florida Bay Science Program. Dr. Nuttle received his M.S. and Ph.D. (1986) degrees in civil engineering from the Massachusetts Institute of Technology and his BSCE from the University of Maryland. He has previously worked as an expert on water and salt budgets for the Turkey Point Power Plant cooling canals for the South Florida Water Management District, and as an expert witness in Florida Division of Administrative Hearing cases.

Education

1986	PhD, Civil Engineering, Massachusetts Institute of Technology, 1986
1982	MS, Civil Engineering, Massachusetts Institute of Technology, 1982
1980	BS, Civil Engineering, University of Maryland, 1980

Career Summary

1986 -	Consultant in Environmental Science, Hydrology, and Water Resources
2013 -	Science Integrator, Integration and Application Network, Center for Environmental Science, University of Maryland
2009 - 2012	Executive Officer, South Florida Marine and Estuarine Goal Setting for South Florida (MARES) Project
2000 - 2001	Director, Everglades Department, Division of Watershed Research and Planning, South Florida Water Management District
1998 - 2000	Executive Officer, Science Program for Florida Bay and Adjacent Marine Systems
1997	Lecturer, Environmental Science Program, Carleton University, Ottawa, Ontario
1991 - 1993	Associate, Rawson Academy of Aquatic Science, Ottawa, Ontario
1990 - 1991	Assistant Professor (Research), Memorial University of Newfoundland
1986 - 1989	Assistant Professor, University of Virginia

Scientific Publications (last 10 years)

2014	J.S. Ault, S.G. Smith, J.A. Browder, W. Nuttle, E.C. Franklin, J. Luo, G.T. DiNardo, J.A. Bohnsack, Indicators for assessing the ecological dynamics and sustainability of southern Florida's coral reef and coastal fisheries, Ecological Indicators, Volume 44, September 2014, Pages 164-172, ISSN 1470-160X, http://dx.doi.org/10.1016/j.ecolind.2014.04.013. (http://www.sciencedirect.com/science/article/pii/S1470160X14001435)
2014	Pamela J. Fletcher, Christopher R. Kelble, William K. Nuttle, Gregory A. Kiker, Using the integrated ecosystem assessment framework to build consensus and transfer information to managers, Ecological Indicators, Volume 44, September 2014, Pages 11-25, ISSN 1470-160X, http://dx.doi.org/10.1016/j.ecolind.2014.03.024. (http://www.sciencedirect.com/science/article/pii/S1470160X14001265)
2014	Grace Johns, Donna J. Lee, Vernon (Bob) Leeworthy, Joseph Boyer, William Nuttle, Developing economic indices to assess the human dimensions of the South Florida coastal marine ecosystem services, Ecological Indicators, Volume 44, September 2014, Pages 69-80, ISSN 1470-160X, http://dx.doi.org/10.1016/j.ecolind.2014.04.014. (http://www.sciencedirect.com/science/article/pii/S1470160X14001447)
2013	Kelble CR, Loomis DK, Lovelace S, Nuttle WK, Ortner PB, Fletcher P, Cook GS, Lorenz JJ, Boyer JN. The EBM-DPSER Conceptual Model: Integrating Ecosystem Services into the DPSIR Framework. PLOS One 8 (8):e70766. doi:10.1371/journal.pone.0070766
2010	Lookingbill, T., T.J.B. Carruthers, J.M. Testa, W.K. Nuttle, and G. Shenk. Chapter 9: Environmental Models, in: Longstaff, B.J. and others (eds), Integrating and Applying Science: A Practical Handbook for Effective Coastal Ecosystem Assessment. IAN Press, Cambridge, MD.
2008	Habib, E., B.F. Larson, W.K. Nuttle, V.H.Rivera-Monroy, B.R. Nelson, E.A. Meselhe, R.R. Twilley. Effect of rainfall spatial variability and sampling on salinity prediction in an estuarine system. Journal of Hydrology 350:56-67.

Technical Reports (last 10 years)

2015	Nuttle W., America's Watershed Initiative Report Card for the Mississippi River Methods: report on data sources, calculations, additional discussion. [online: http://americaswater.wpengine.com/wp-content/uploads/2015/12/Mississippi-River-Report-Card-Methods-v10.1.pdf; accessed 1 May 2017]
2015	Nuttle, W.K. Review of CCS Water and Salt Budgets Reported in the 2014 FPL Turkey Point Pre-Uprate Report and Supporting Data. Prepared for the South Florida Water Management District, 8 June 2015.
2013	Nuttle, W.K., and P.J. Fletcher (eds.). Integrated conceptual ecosystem model development for the Florida Keys/Dry Tortugas coastal marine ecosystem. NOAA Technical Memorandum, OAR-AOML-101 and NOS-NCCOS-161. Miami, Florida. 92 pp.
2013	Nuttle, W.K., and P.J. Fletcher (eds.). Integrated conceptual ecosystem model development for the Southwest Florida Shelf coastal marine ecosystem. NOAA

Technical Memorandum, OAR-AOML-102 and NOS-NCCOS-162. Miami, Florida. 108 pp.

2013 Nuttle, W.K., and P.J. Fletcher (eds.). Integrated conceptual ecosystem model development for the Southeast Florida Coast coastal marine ecosystem. NOAA Technical Memorandum, OAR-AOML-103 and NOS-NCCOS-163. Miami, Florida. 125 pp.

2013 Nuttle, W.K. Review of CCS Water and Salt Budgets Reported in the 2012 FPL Turkey Point Pre-Uprate Report and Supporting Data. Prepared for the South Florida Water Management District, 5 April 2013.

2012 Day, J. and others. Answering 10 Fundamental Questions About the Mississippi River Delta. Mississippi River Delta Science and Engineering Special Team, National Audubon Society.

2010 Marshall, F., and W. Nuttle. Development of Nutrient Load Estimates and Implementation of the Biscayne Bay Nutrient Box Model. Final Report prepared by Cetacean Logic Foundation, Inc. for Florida International University Subcontract No. 205500521-01.

2008 Marshall, F., W. Nuttle, and B. Cosby, 2008. Biscayne Bay Freshwater Budget and the Relationship of Inflow to Salinity. Project report submitted to South Florida Water Management District by Environmental Consulting and Technology, Inc., New Smyrna Beach, FL.

2008 Nuttle, W.K, F.H. Sklar, A.B. Owens, M. D. Justic, W. Kim, E. Melancon, J. Pahl, D. Reed, K. Rose, M. Schexnayder, G. Steyer, J. Visser and R. Twilley. 2008. Conceptual Ecological Model for River Diversions into Barataria Basin, Louisiana, Chapter 7. In, R.R. Twilley (ed.), Coastal Louisiana Ecosystem Assessment & Restoration (CLEAR) Program: A tool to support coastal restoration. Volume IV. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA.

2008 Habib,E., W.K. Nuttle, V.H. Rivera-Monroy, and N. Nasrollahi. An Uncertainty Analysis framework for the CLEAR Ecosystem Model: Using Subprovince 1 as Test Domain and Skill assessment, Chapter 12. In, R.R. Twilley (ed.), Coastal Louisiana Ecosystem Assessment & Restoration (CLEAR) Program: A tool to support coastal restoration. Volume IV. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA.