Turkey Point Cooling Canal System Nutrient Management Plan

September 16, 2016

1.0 Executive Summary

1.1 Background

Florida Power & Light Company (FPL) and Florida Department of Environmental Protection (FDEP) entered into Consent Order OGC No. 16-0241 (Consent Order) on June 20, 2016 to address certain issues related to the Turkey Point Power Plant (Plant) Cooling Canal System (CCS). Paragraph 21.b of the Consent Order requires FPL to submit, within 90 days of execution of the Order (September 18, 2016), "a detailed report outlining the potential source of nutrients found in the CCS, including chemical products used for plant operations." Paragraph 21.b of the Order also requires FPL to include in the report a "plan for minimizing nutrient levels in the CCS."

FPL submits this Nutrient Management Plan in compliance with the requirements of Paragraph 21.b of the Consent Order.

1.2 Introduction

The CCS provides multiple functions, and is subject to a wide range of environmental, thermal and hydraulic influences. The interaction of many factors creates a very dynamic system that can result in both gradual and rapid water quality changes. The CCS, at over 5,900 acres and approximately 5 billion gallons of surface water, is its own ecosystem supporting a dual role as an industrial waste water facility and a living habitat for a wide range of plant and animal species.

Despite the demands on the system, it has historically performed its dual role capably. The system is closed to external surface water influences, but subject to interaction with ambient weather phenomena, groundwater inflows and outflows, and a lesser input of industrial effluents from the power plants located at the site. It is a subtle balance.

In recent years the system lost that balance through a sequence of events that was primarily driven by the gradual (decades long) increase in CCS salinity. Following an extensive review, FPL has reconstructed the sequence of events that resulted in a large release of nutrients from plant biomass into the CCS water column. It was this nutrient release from decaying plant biomass that impacted the water quality balance of the CCS. This report summarizes the nutrient sources to the CCS, the biological changes that occurred due to the increase in salinity, and FPL's path to restore the balance of the system.

1.3 Summary of Events Causing CCS Water Quality Transition

Prior to 2010, the CCS operated as a sea grass based biological system with healthy sea grass (*Ruppia maritima*) meadows covering over 50 percent of the CCS, providing habitat, natural filtration, and utilization of nutrients from the water column. This ecosystem helped to maintain good water quality and low nutrient concentrations in the water column. During this time period, nutrient sources to the CCS water column primarily included berm vegetation biomass and soil erosion, groundwater inflows, and atmospheric deposition (of Nitrogen) along with a relatively low level of effluents from power plant operations. Nutrient mass removal from the CCS included the sea grass photosynthesis and growth, harvesting of sea grasses as a CCS maintenance activity, removal of biological material impinged on the plant intake screens, and groundwater outflows.

Salinity levels in the CCS have always been subject to seasonal variation, peaking at the end of the dry season (nominally July), and falling at the end of the wet season (nominally December). Between 2000 and late 2009 the peak seasonal salinities steadily increased to close to 70 practical salinity units (psu). By 2010 sea grass meadows were stressed by the high salinities and dying off in the CCS. By 2012 few if any sea grass beds remained. The system-wide sea grass die-off and subsequent decomposition of the sea grasses, released a significant volume of the previously bound and sequestered nutrients into the CCS water column over a multi-year period.

The increase of nutrient levels in the CCS water column facilitated seasonal algae blooms, resulting in high water turbidity and generally degraded water quality. Initial reports of algae blooms date back to isolated observances in 2011 and 2012, with multiple verified events in 2013, followed by continuously elevated and sustained algae concentrations from the summer of 2014 to the present. As explained further below, this phenomenon initiated by increased salinities closely resembles similar events observed with the Florida Bay algal blooms in the 1980's (Zieman, et. al., 1999) and a recent sea grass die-off event (Rudnick, 2016).

1.4 Summary of Findings

This Nutrient Management Plan provides a review of potential nutrient sources to the CCS and a plan for minimization of those sources.

Part A of the plan summarizes the status of the current nutrients in the CCS based upon a comprehensive evaluation of the nutrient sources and sinks, and the operating history of the CCS prior to the recent change in biology. In summary, the findings are:

- The major source of nutrients in the CCS water column came from the die-off and decomposition of sea grasses between 2010 and 2013, caused by elevated CCS average salinities above 55 psu steadily increasing over the period 2004 – 2010.
- Additional sources of nutrients are primarily environmental in nature and driven by the large scale of the CCS (5,900 acres; 5 billion gallons of water).
- To a lesser degree, controlled water sources contributed to nutrient concentrations, while industrial sources related to plant operations were a minor contributor to total loading.

Part B of the plan provides a discussion of how the nutrient levels in the CCS will be managed and minimized. The plan presents near term and long term initiatives and describes how those initiatives are expected to be implemented.

- Near term activities will focus on three areas: 1) nutrient/algae removal, 2) review of CCS practices including sediment and vegetative management, and 3) continued reduction of CCS salinity.
- Long term activities will focus on re-establishing sea grass meadows to provide stabilizing nutrient reduction and habitat for other aquatic species.

2.0 Part A – Evaluation of Potential Sources of Nutrients in the CCS

Table 2.1 Summary of Nutrient Source Inflows and Outflows to the CCS (all sources)

	Source Type (Industrial/ Environmental)	Flow Type (Continuous/ Batch/Natural)	Daily Flow (MGD)	Average Annual Flow (MG)	Nitrogen Concentration (mg/L)	Phosphorus Concentration (mg/L)	Nitrogen Mass	Percentage of N Reduction or Loading (%)	Phosphorus Mass	Percentage of P Reduction or Loading (%)
Outflows (Nutrient Mass Reductions)							**Reduction (lb/yr)**		**Reduction (lb/yr)**	
CCS Sediments (Absorption)	Environmental	Natural	-----	-----	-----	-----	100,000	19%	16,000	88%
Groundwater (East and Bottom)	Environmental	Natural	20	7,300	6.8	0.035	410,000	79%	2,000	11%
CCS Sediments (Removal)	Industrial	Batch	-----	-----	3,843 mg/kg	66 mg/kg	7,000	1%	100	1%
Inflows (Nutrient Mass Loadings)							**Loading (lb/yr)**		**Loading (lb/yr)**	
CCS Sediments (Diffusion)	Environmental	Natural	-----	-----	-----	-----	80,000	17%	15,000	85%
Groundwater (Bottom & South) [1]	Environmental	Natural	10	3600	0.7	0.01	21,000	4%	300	2%
Groundwater (East) [2]	Environmental	Natural	5	1800	1.35	0.011	20,000	4%	165	1%
Berms (Weathered)	Environmental	Natural	-----	-----	3,955 mg/kg	44 mg/kg	91,000	19%	500	3%
Berms (Dredged)	Environmental	Natural	-----	-----	3,843 mg/kg	66 mg/kg	3,500	1%	30	0%
Nitrogen Fixation [3]	Environmental	Natural/Episodic	-----	-----	8 mg/m2/day	-----	115,000	24%	-----	-----
Atmospheric Deposition	Environmental	Natural	-----	-----	1 mg/m2/day	-----	15,000	3%	-----	-----
Marine Wells	Industrial	Batch	-----	4900	1.35	0.011	56,000	12%	500	3%
Interceptor Ditch	Industrial	Batch	-----	2800	1.57	0.015	37,000	8%	400	2%
L-31 Pumping	Industrial	Batch	-----	3500	0.97	0.012	29,000	6%	400	2%
Floridan Wells [4]	Industrial	Batch	3	1000	0.225	0.006	2,000	0%	50	0%
Water Treatment Plant (WTP)	Industrial	Continuous	-----	71	3.42	0.529	2,000	0%	300	2%
Blowdown (Units 1, 3, 4 & 5)	Industrial	Continuous	-----	200	4.62	0.002	7,000	1%	3	0%
Outages (Units 3 & 4)	Industrial	Batch	-----	0.0006	105669	0.015	600	0%	0	0%
Unit 3 & 4 Waste Tanks	Industrial	Batch	-----	1	8.65	1.02	90	0%	9	0%
Sewage Treatment Plant (STP) Effluent [5]	Industrial	Continuous	-----	-----	-----	-----	0	0%	0	0%
Stormwater – Point Drains	Environmental	Natural	-----	0.01	4.21	0.117	0	0%	0	0%

[1] Groundwater source concentrations estimated from terrestrial data points of 0.7 mg/L and 0.01 mg/L for nitrogen and phosphorus, respectively.

[2] Groundwater source concentrations estimated from Marine Well data of 1.35 mg/L and 0.011 mg/L for nitrogen and phosphorus, respectively

[3] Nitrogen fixation based on Lake Jessup (Florida) study; fixation rate dependent on N:P ratio (Gao, 2005)

[4] Existing Floridan wells provided 3 MGD during 2015 period. Nutrient loadings listed are estimated for a daily flow of 3 MGD.

[5] Tests for human trace constituents in site groundwater, CCS and remnant canal surface waters indicate no discernible link between the STP effluent and CCS.

2.1 Potential Nutrient Sources

The principal nutrients affecting the CCS water quality are nitrogen and phosphorous. Table 2.1 provides a listing of the sources, the concentration of nutrients, an estimate of the annual volumetric flow and a resulting annual nitrogen and phosphorous loading from each source. Where possible, source samples were taken to provide the concentration information. The largest sources of nutrients in the CCS are environmental in nature, originating in natural processes that impact the 5,900-acre system. These include groundwater inflows, absorption and diffusion from sediments, berm erosion and vegetative contributions, nitrogen fixation by blue-green algae, and atmospheric deposition. Lesser sources include controlled water resources pumped into the CCS for operations (interceptor ditch) or freshening (L-31). Finally, smaller but measurable sources come from specific industrial processes associated with power plant operations at the site. Groundwater outflow and absorption into sediments are the primary means of mass removal for nitrogen and phosphorous, respectively. Re-establishing sea grass meadows will provide a long term nutrient mass reduction in the CCS water column. Other means of facilitating nutrient mass reduction have been identified and will be discussed.

Table 2.1 provides a listing of all nutrient mass reductions (sinks) and mass loadings (sources) to the CCS, including their proportional contribution. The following sections discuss each nutrient loading source and mass reduction, followed by a discussion of the current and future nutrient balances. Nutrient balances for nitrogen and phosphorous are discussed in Tables 2.2 and 2.3, later in this section. The sea grass die–off will be described first to provide the setting for the CCS surface water changes observed.

2.1.1 Environmental Sources – Sea Grass Die-off

The largest single source of nutrients that impacted the CCS surface water and sediment pore water originated from the die-off and decomposition of sea grass beds that had thrived in the CCS prior to the period of elevated salinity. Over time, a portion of the inventory of decaying biologic matter and its nutrient content dispersed into the system and is the source for the increasing levels of nutrients observed in the CCS starting in 2010 and significantly increasing post 2013. Water turbidity increased starting in 2011; and algal blooms (and measured algal concentrations) in the CCS have continued to utilize this nutrient source. This nutrient mass moves in and out of the CCS water column based on algae bloom cycles. Due to the closed cycle nature of the CCS, the concentrations of nutrients are maintained largely within the system, with minimal opportunity to dissipate or dilute as occurs in natural systems.

The sea grass die-off due to hypersalinity and the subsequent algal blooms observed in the CCS closely resemble the well-documented increased salinities in Florida Bay during the 1980s and associated algal blooms following the sea grass die off (Zieman et al. 1999). The previous large-scale algal blooms in Florida Bay were mostly attributed to nutrient release from dead and decaying sea grass meadows. These massive sea grass die-offs were attributed in turn to sustained periods of hypersalinity due to a combination of reduced rainfall and the diversion of freshwater inflows away from their historical southward destinations. The ongoing sea grass die-off in Florida Bay is also attributed to hypersalinity (Rudnick 2016). The upper salinity tolerance range for *R. maritima* in South Florida is estimated to be near 55 psu (Koch et al. 2007). However, sea grasses also experience stress when exposed to salinity levels below 55 psu. Figure 2.1 summarizes the average salinity of the CCS since 1999.

The observed sequence of events leading to the sea grass die-off is as follows:

- Prior to 2010, CCS surface water quality was characterized by low turbidity, and a low and stable nutrient content. Sea grass meadows were prevalent in over 50 percent of the canal system, predominantly in the southern sections and the eastern return canals.

- Between 1999 and 2005 the peak seasonal salinity increased from approximately 55 psu to 65 psu, and average annual salinity increased from approximately 47 psu to 57 psu. Between 2005 and 2013 the annual and peak salinities leveled off. See Figure 2.1.

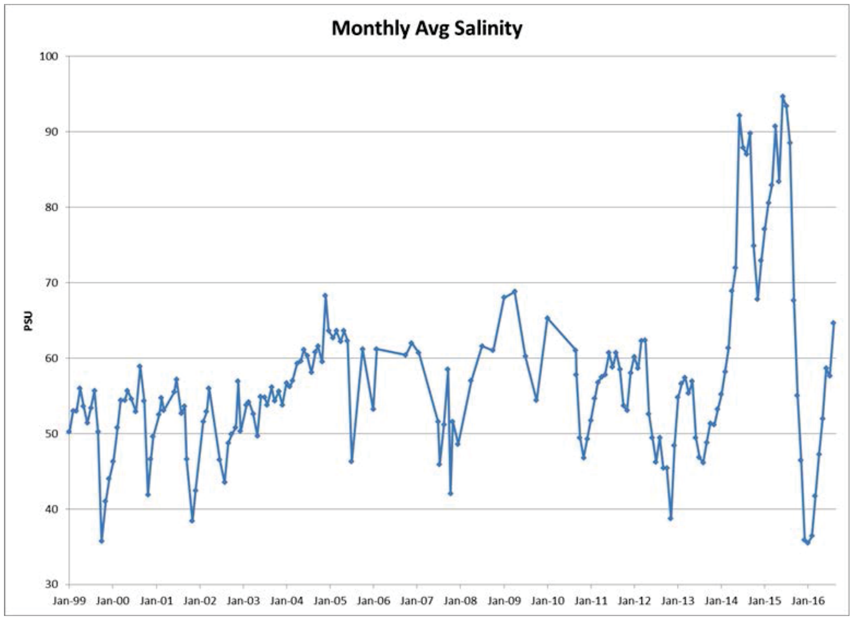

Figure 2.1 CCS Salinity (psu) Observations from 1999 to 2016

- The exposure of the sea grass meadows to elevated salinities resulted in stress periods (elevated salinity > 50 psu) followed by recovery periods (lower salinity < 50 psu). Throughout 2000 – 2005 the duration of the high stress periods increased while the duration of the recovery periods decreased. Between 2005 and 2010 system salinities averaged 55 psu, the high end of the tolerance range for *R. maritima*. By 2010 sea grass colonies were noticeably dying off in the system and water quality and clarity were beginning to degrade (See Figure 2.2). By 2012 few if any sea grass beds remained. This was confirmed by a review of aerial photography over the period 2000 –to present.

- The total nitrogen and phosphorous mass as a result of the die-off of the estimated 2,400 acres of sea grass has been estimated to be on the order of 10^5 pounds of total nitrogen and 10^4 pounds of total phosphorous. The release of this high level of nutrients during the die-off was the principal driver resulting in the algal-based system that now dominates the CCS. Observed peak nitrogen and phosphorous concentrations in the system are consistent with a large source of nitrogen and phosphorous entering the CCS between 2011 and 2013. Figure 2.3 provides an estimate of the total nitrogen and phosphorous mass in the CCS (assuming a 5 billion-gallon volume) from available nitrogen and phosphorous concentration data between 2010 and present.

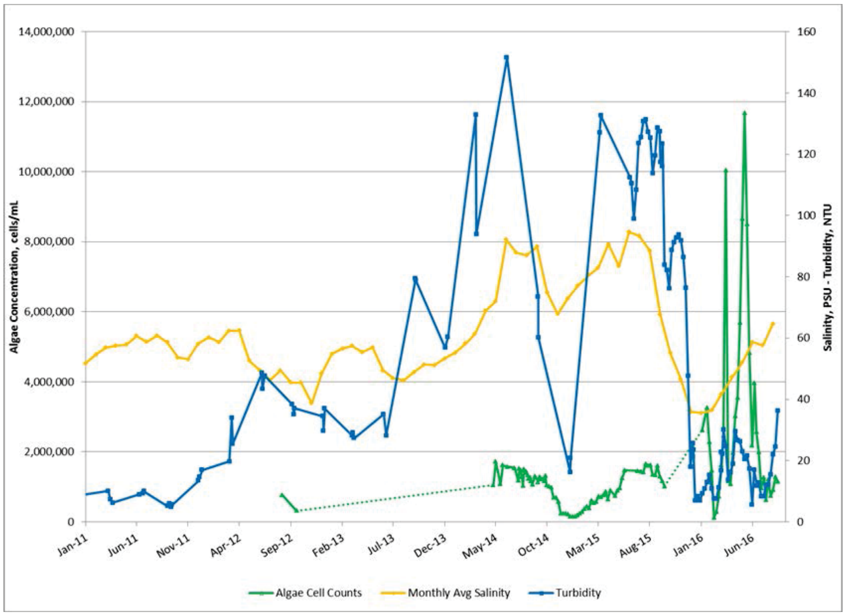

Figure 2.2 Changes in CCS Water Quality Marking Transition of System to Algal-Based

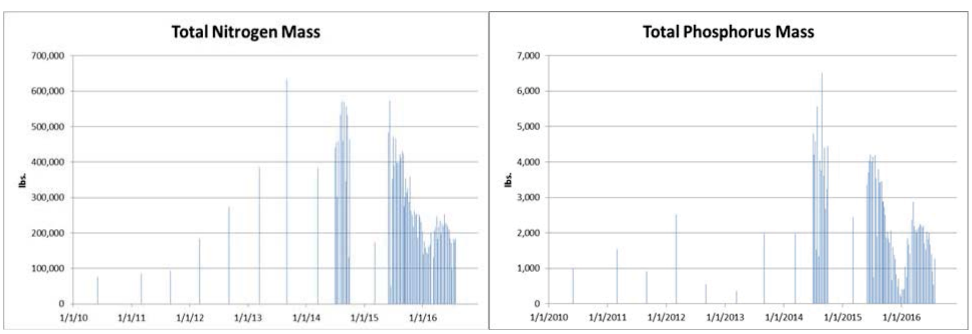

Figure 2.3 Estimates of Total Nitrogen and Phosphorous Mass in CCS (2010 – 2016)

2.1.2 Environmental Sources – Groundwater Inflows and Outflows

Groundwater impacts the CCS both as a source of nutrients and a sink. The magnitudes of the effects were estimated using the Tetra Tech Water Balance Model for groundwater that has been used with the Extended Power Uprate (EPU) monitoring program since 2009. The water balance information covers the period 2015 to 2016, representing the most recent water quality year. These flows are dependent on seasonal, ambient and water quality conditions in the system, so the impact on nutrient loading varies over time.

Table 2.1 provides a comprehensive listing of CCS mass removal and loadings, including concentrations and volumes/flows. Nutrient concentrations for groundwater outflows are estimated based on elevated CCS surface water quality data from 2015, at 6.8 milligrams per liter (mg/L) nitrogen and 0.035 mg/L phosphorous. Nutrient concentrations for ground water inflows differ based on the water source; terrestrial groundwater or marine groundwater. Terrestrial groundwater has estimated nutrient concentrations of 0.7 mg/L nitrogen and 0.01 mg/L phosphorous. These values are based on data collected in groundwater wells outside the CCS area (north and west), and are consistent with levels in regional studies. Marine source groundwater from the eastern face has estimated nutrient concentrations of 1.35 mg/L nitrogen and 0.011 mg/L phosphorous.

Under current assumptions groundwater flows act to reduce, representing a net annual movement of nutrients out of the CCS into the groundwater. In the coming years the effect of groundwater nutrient flows as a net sink is anticipated to decrease due to a lower volume moving out of the system as salinity decreases, and reduced nutrient concentration as water quality is improved.

2.1.3 Environmental Sources – Berm Erosion (Weathered and Dredged)

The CCS encompasses approximately 5,900 acres within its boundaries. Approximately 4,400 acres are water surface and another 1,500 acres are upland berms formed by the dredge spoils of the original CCS construction. The berms can be characterized as existing weathered berms, or berms recently compacted with dredge spoils. Erosion of these berms results in a noticeable input of nutrients and sediment. The nutrient loadings from berms are estimated based on nutrient runoff concentrations calculated using observed data for weathered berms and recently dredged material, rainfall averages, and nitrogen and phosphorous solubility values from the literature. Approximately 18% of the upland berm acreage is covered by recently (2015) dredged material, with the balance being weathered berms with a slightly lower nutrient concentration.

Vegetative debris from many sources, including the berms, is screened at the plant intakes to prevent flow obstruction in plant equipment. This material is required to be removed periodically. The material has historically been handled and hauled off for on-site composting or burn. Recently, the plant installed a macerator (grinder) that eliminates the need to haul off the debris, but directs the ground biomass back into the CCS through the discharge canal. In doing so, the macerator does not provide an additional nutrient source, but recirculates this biomass source and may influence the natural decay process (higher surface area for decomposition). This equipment will be a subject of future review, and is discussed in Section 3.0.

2.1.4 Environmental Sources – Nitrogen Fixation and Deposition

Atmospheric deposition provides a minor contribution of nitrogen (about 3%) to the CCS and it is included for completeness. Nitrogen deposition was estimated using the CCS wetted surface area and the nitrogen deposition rate from a site located 20 miles west of the CCS. While phosphorous deposition can also occur, estimates of these deposition rates are highly variable and driven by atmospheric and surface water conditions. For the current review, no phosphorous loading by atmospheric deposition is assumed.

Certain species of blue-green algae have been observed to be nitrogen-fixing; able to extract nitrogen at the water – air interface. The rates and overall contribution of nitrogen fixation to the CCS nutrient balance can be influenced by a wide range of conditions, including algal blooms. An estimate of the loading from this source was developed assuming that this phenomena occurred continuously during 2015 due to the persistent algal blooms (populations over 1 million cells/L) in the CCS. Nitrogen fixation rates observed in Florida lakes were used for these calculations. These estimates are included in Table 2.1 and the nutrient balances that follow.

2.1.5 Environmental Sources – Sediment Diffusion and Absorption

Movement of nutrients between the CCS water column and the sediment is driven by differing concentrations of nutrients in each location. As seasonal and biological changes in the system influence nutrient concentration in the water column, the rate and direction of nutrient exchange will shift. Estimates of diffusion (sediment to water) and absorption (water to sediment) rates were calculated from published studies, and sediments and water concentrations (Table 2.1). Application of these rates over the estimated water-sediment interface area in the CCS indicated that this phenomenon results in a net transfer of 20,000 lb/yr nitrogen and 1,000 lb/yr phosphorous from the CCS water column to the CCS sediment, but the nutrients remain within the CCS control volume. Therefore, for the purposes of the nutrient balances shown in Tables 2.2 and 2.3, this process is not included.

2.1.6 Controlled Sources – Water Resources [Interceptor Ditch (ID), L-31 canal, Marine Wells, Floridan Aquifer Wells]

Input water sources used for CCS salinity reduction (Marine wells, L-31, and Floridan Aquifer wells) are lesser, but notable contributors of nitrogen and phosphorous. During 2015, the L-31 and Marine wells provided significant flow (up to 40 MGD during operation). Future operations will limit or eliminate the use of these sources, and they will be replaced by a steady flow of 14 MGD of Floridan aquifer water. While higher in nitrogen concentration, the Floridan water is also lower in phosphorous.

Additional nutrients are introduced by the operation of the ID pumps, where seasonal adjustments are made to ensure an eastward gradient is maintained to control westward movement of the CCS water in the upper levels of groundwater. Future operations will limit use of and effects created by this source.

Nutrient concentrations for these sources were summarized from sample data taken during use of these sources in 2015 and are provided in Table 2.1.

2.1.7 Industrial Sources – Continuous Effluents (Blowdown, Water Treatment Plant Effluent, Sewage Treatment Plant)

Power plant operations involve several continuous effluent streams to the CCS. These include blowdown from the Unit 5 cooling tower, Units 1, 3 and 4 and effluent from a small demineralized water treatment plant. The concentrations and volumes associated with blowdown are relatively small in comparison to the volume of the CCS and are essentially negligible in the overall picture. The water treatment plant uses potable water from Miami-Dade County to provide demineralized water to Units 3 and 4. The system includes a reverse osmosis process that concentrates nutrients in the potable water source. The result is a notable phosphorous nutrient inflow, albeit minor in comparison to the environmental sources.

The site also has an on-site Sewage Treatment Plant (STP) that discharges through a shallow injection well to approximately 45 feet below ground surface. Significant surveys have been conducted to analyze CCS surface water, groundwater wells, and surface water monitoring stations in the adjacent deep artificial canals to determine if water originating in the STP discharge is making its way into the surrounding CCS. Samples were reviewed for elements common to human wastewaters, including aspartame, sucralose, sucrose, and caffeine. Those surveys show no indication of STP effluent reaching the CCS surface waters (below minimum detectable values), the artificial deep canals, or the plants groundwater wells in the vicinity of the STP.

However, as an illustrative exercise, the STP effluent nutrient concentrations and volumes were calculated to determine the order of magnitude introduction of this effluent could have if the full volume of STP effluent was released to the CCS. The results indicate such a hypothetical release would result in an annual loading of 2,400 pounds of nitrogen and 50 pounds of phosphorous.

Nutrient concentrations and annual flows are provided in Table 2.1, and are based on recent data samples for each stream.

2.1.8 Industrial Sources – Batch Effluents (Outages, Waste Tanks)

The reactor coolant systems of the nuclear units are continuously cycled through a filtration and demineralization system to maintain water quality. Maintenance of the nuclear plants results in periodic shutdowns (nominally every 18 months for each unit) to conduct needed maintenance. The units are cooled down during these periods, and upon returning to power and operating temperature, thermal expansion creates a volume of discharge waste water that is directed into holding tanks. These holding tanks are then subsequently discharged into the CCS. Similar to the Blowdown stream, the nutrient concentrations and total volumes are relatively low in comparison to the CCS and represent a minimal nutrient source. Table 2.1 provides nutrient concentration data and annualized flow amounts based on recent samples and operating logs.

2.1.9 Industrial Sources – Stormwater Point Drains

Stormwater point drains represent a minimal input, but their contributions were measured and the nutrient loading to the CCS was included.

2.1.10 Sediment Bulk Removal

Removal of the sediments through dredging does provide a net mass reduction, albeit minor. Future annual sediment maintenance is planned for the next several years, at a rate of approximately half of what was conducted in 2015. However, the magnitude of this maintenance activity will not appreciably reduce nutrient levels directly. The principal impact of the sediment maintenance is expected to be establishing and maintaining target CCS thermal efficiency to reduce evaporation and maintain a low and stable salinity in the CCS.

2.2 Nutrient Balances

Based on the above information, two nutrient loading balances were generated to capture two illustrative time periods for the CCS. The first time period captures the period (April 2015 – March 2016). During this period the CCS experienced a significant amount of activity bringing many of the nutrient sources discussed above into play. For example, in addition to sediment dredging, three external water sources (L-31 water, Marine wells and Upper Floridan Aquifer wells) were implemented. The resulting balance is presented in Table 2.2.

Table 2.2 Summary of Nutrient Balance in the CCS (circa 2015)

Nutrient Balance (circa 2015)	Nitrogen Mass	Percentage of N Reduction or Loading (%)	Phosphorus Mass	Percentage of P Reduction or Loading (%)	Notes
Net Outflows (Nutrient Mass Reductions)	**Reduction (lb/yr)**		**Reduction (lb/yr)**		
CCS Sediments (Diffusion - Absorption)	-	-	-	-	N/A, exchange occurs within CCS Control Volume
Groundwater (All Surfaces)	-369,000	98%	-1,535	94%	
CCS Sediments (Removal)	-7,000	2%	-100	6%	Based on 2015 activity
Net Inflows (Nutrient Mass Loadings)	**Loading (lb/yr)**		**Loading (lb/yr)**		
Berms (Weathered)	91,000	25%	500	23%	
Berms (Dredged)	3,500	1%	30	1%	
Nitrogen Fixation	115,000	32%	0	0%	
Atmospheric Deposition	15,000	4%	0	0%	
Marine Wells	56,000	16%	500	23%	
Interceptor Ditch	37,000	10%	400	18%	
L-31 Pumping	29,000	8%	400	18%	
Floridan Wells	2,000	1%	50	2%	
Water Treatment Plant (WTP)	2,000	1%	300	14%	
Blowdown (Units 1, 3, 4 & 5)	7,000	2%	3	0%	
Outages (Units 3 & 4)	600	0%	0	0%	
Unit 3 & 4 Waste Tanks	90	0%	9	0%	
Sewage Treatment Plant (STP) Effluent	0	0%	0	0%	
Stormwater – Point Drains	0	0%	0	0%	
Total	**-21,310**		**527**		Net reduction of N, net increase of P

This balance shows that over the 2015 period the net influence of all sources indicates decrease in nitrogen and an increase in phosphorous in the CCS. The balance is driven by the net outflow of nutrients (in part due to the conservatively high assumption of nutrient concentrations in the CCS water that flows out). However there are considerable nutrient inflows from berm erosion, atmospheric phenomena, and controlled water sources used to reduce salinity.

Table 2.3 illustrates a balance anticipated in the next several years following implementation of some of the planned nutrient minimization actions. For example, it is assumed that two controlled water sources (L-31 and Marine Well water) used to control and reduce salinity in 2015 are discontinued.

Table 2.3 Summary of Nutrient Balance in the CCS (Next 4 years)

Nutrient Balance (Next 4 Years)	Nitrogen Mass	Percentage of N Reduction or Loading (%)	Phosphorus Mass	Percentage of P Reduction or Loading (%)	Notes
Net Outflows (Nutrient Mass Reductions)	**Reduction (lb/yr)**		**Reduction (lb/yr)**		
CCS Sediments (Diffusion - Absorption)	-	-	-	-	N/A, exchange occurs within CCS Control Volume
Groundwater (All Surfaces)	-369,000	99%	-1,535	97%	
CCS Sediments (Removal)	-3,500	1%	-50	3%	Estimate 50% of 2015 activity over the next 4 years
Net Inflows (Nutrient Mass Loadings)	**Loading (lb/yr)**		**Loading (lb/yr)**		
Berms (Weathered)	81,900	38%	450	31%	Weathered area will decrease 10% per year
Berms (Dredged)	5,250	2%	45	3%	Dredge area will increase 50% per year
Nitrogen Fixation	57,500	27%	0	0%	Reduced by 50% based on expected algae reduction
Atmospheric Deposition	15,000	7%	0	0%	
Marine Wells	0	0%	0	0%	No marine well flows planned
Interceptor Ditch	37,000	17%	400	28%	
L-31 Pumping	0	0%	0	0%	No L-31 flows planned
Floridan Wells	9,333	4%	233	16%	Floridan source will increase from 3 to 14 MGD
Water Treatment Plant (WTP)	2,000	1%	300	21%	
Blowdown (Units 1, 3, 4 & 5)	7,000	3%	3	0%	
Outages (Units 3 & 4)	600	0%	0	0%	
Unit 3 & 4 Waste Tanks	90	0%	9	1%	
Sewage Treatment Plant (STP) Effluent	0	0%	0	0%	
Stormwater – Point Drains	0	0%	0	0%	
Total	**-162,077**		**-190**		Net reduction of N and P

Change to Assumption:

Reduction
Addition

However, the Floridan well flow of 3 MGD will be increased to 14 MGD in future years. The future year scenario includes continuation of dredging at a reduced rate for the next several years, and the resulting changes to berm erosion contributions as weathered berms are covered with new dredge material. Exhibit A provides a graphical representation of CCS nutrient inflows and outflows, consistent with the assumptions of Table 2.3.

These modifications reduce the amount of nitrogen and phosphorous coming into the system. Under these assumptions, the balance shows an annual reduction in nitrogen and phosphorous. These balances do not include nutrient reductions that are anticipated by the application of active algae and nutrient capture and removal methods discussed in Section 3.0, nor does it include the effects of future sea grass re-establishment.

3.0 Part B – Nutrient Management Strategy

The CCS currently operates as an algal based biological system, with the algae life cycle primarily responsible for the movement of nutrients in and out of the water column. The nutrient inventory in the water column is also influenced by factors that impact the sources and sinks. The most influential sources are the result of natural processes, but some sources are under the control of FPL. FPL's strategy will address both the sources of nutrients, and nutrient bioavailability.

Review of the algae strains and nutrient loading indicates that the system is likely a phosphorous limited system, meaning that removal or binding of the bioavailable phosphorous would result in a reduction in growth of the algae population and algal blooms. Reduction of the algae population then may reduce nitrogen fixation by algal species. A reduced algal mass in the CCS will increase water clarity, improving the conditions for the re-establishment of submerged aquatic vegetation, such as *R. maritima*. Improved water clarity and lowered ambient salinities will provide the appropriate environmental conditions for submerged aquatic vegetation. Submerged aquatic vegetation can also provide a significant mechanism for uptake and retention of nutrients within the CCS.

Until relatively recently, the CCS contained a dense community of submerged vegetation (sea grass meadows) that assisted in nutrient control. Since the submerged vegetation die-off, the biologically sequestered nutrients were released back into the water column. A primary goal of the nutrient management plan for the CCS is to re-establish the submerged vegetation community. Submerged vegetation removes dissolved nutrients from the water column and provides long-term storage within the plant biomass. Unlike emergent aquatic vegetation, which primarily uptakes nutrients through root matter, many species of submerged vegetation can absorb nutrients directly through the plant leaves as well as through the roots. Re-establishing the submerged vegetation community within the CCS will reduce water column nutrients, likely result in a shift and reduction in algal species, and establish a more balanced water quality in the CCS.

Target nutrient levels have been developed for the CCS water quality. Achieving the target levels will reduce the severity and persistence of algae blooms and provide the environmental conditions necessary to support re-establishment of submerged aquatic vegetation in the system. Target levels are a management guide, and each parameter will be subject to variability based on seasonal and environmental factors and should be reviewed on an appropriate averaging interval.

Table 3.1 Target Nutrient Levels and Water Quality Parameters

Parameter	General Health	
	Good	Acceptable
Salinity (psu)	< 40	40 – 50
Water Clarity (ft)	> 10	2 - 10
Total Phosphorus (mg/L)	< 0.02	0.02 – 0.035
Total Nitrogen (mg/L)	< 2.5	2.5 – 5.0

This nutrient management plan includes both near term and long term initiatives. Near term efforts will focus on three areas:

- Active Algae/Nutrient Removal. Methods that will physically remove or reduce the bioavailability of phosphorous in the water column, as well as reduce algal biomass and phosphorous from the CCS have been investigated by FPL through some initial trials. This effort has included the use of aluminum-based flocculants and protein skimming methods. Several methodologies will be developed and proceed to implementation based on feasibility and efficacy. The use of chemical coagulants to reduce nutrients within the CCS could be achieved by in-situ applications or by treatment in an external system. Application of protein skimming technology will allow for harvesting of biomass without the use of flocculants. Exhibit B provides a summary of methods considered.

- Canal Practices Review. A review of canal maintenance practices will include, but is not limited to, vegetation and berm maintenance practices, use of the macerator, a comprehensive sediment and flow maintenance plan that will also serve the purposes of the pending Thermal Efficiency Plan (CO Sec. 20.b). The review will also include a nutrient monitoring program that will track nutrient and water quality information to enhance system management going forward. The nutrient monitoring program will include continued review and characterization of all effluent streams into the CCS and will identify opportunities for further minimization.

- Salinity Reduction and Controlled Flow Management. Continue efforts focusing on salinity reduction to achieve and maintain a CCS surface water quality that will support the re-establishment of sea grasses while minimizing the introduction of nutrients from these controlled water sources. This near term activity is critical to achieve the goals of the long term component of the nutrient management function. Operation of the Recovery Well System (currently in permitting and design) on the western boundary of the CCS will also minimize the inflow of groundwater from western face and bottom seepage.

Long term initiatives will develop strategies to accelerate the re-establishment and sustained growth of sea grasses to sequester nutrients in the CCS and create a stable system similar to historical conditions.

3.1 Active Algae/Nutrient Removal

Three methods are being evaluated for implementation in order to physically collect and remove algae and nutrients in the water column. These are: 1) direct application of flocculants into the CCS, 2) treatment of CCS water in an external system, and 3) the use of protein skimming methods. All methods implement technologies common to water treatment and algae management in Florida. Pilot tests have been conducted, or are ongoing, to evaluate the efficacy and controllability of the methods in treating the CCS system water and to determine the feasibility for future implementation at increased scale.

Based on a review of algae management practices in Florida, the two most successful methods involve chemical precipitation methods, which use metal salts to generate flocculent (floc) particles which remove dissolved constituents by physical adsorption onto the floc surface and removal of particulate solids by enmeshment into the floc particle. The use of chemical coagulants can be achieved by direct (in-situ) applications or by treatment in an external treatment system, similar to methods applied in traditional water treatment facilities.

Protein skimmers are used in large aquarium and tank environments to harvest natural occurring or mechanically induced foam that has collected nutrients and suspended solids in much the same manner as flocculants. These skimmers simply employ mechanical equipment to separate the foam material floating on the water body.

3.1.1 Flocculant Treatment

FPL consulted with a panel of experts and professionals familiar with algae management in Florida water bodies, both fresh water and salt water. The panel included aquatic biologists, toxicologists and environmental professionals. The combined opinion of the assembled panel was that the most immediately effective means of reducing algae and nutrient concentrations in large water bodies was the deployment of an aluminum-based flocculant. These flocculants have the ability to coagulate algae and nutrients, and reduce the bio-availability of phosphorous by binding the free phosphorous. Aluminum-based flocculants have been widely used throughout Florida and the Southeastern US to address algal blooms in shallow water bodies, principally in fresh water applications. In order to evaluate their efficacy in salt water, FPL conducted pilot studies using a commercial product, Green Bullet. This is a polymeric salt of aluminum chloride.

FPL is evaluating the application of flocculants under two approaches, an external treatment train and a direct application to the CCS itself. Both are being evaluated currently. The external treatment approach will extract and treat a volume of CCS water using a land based self-contained system isolated from the CCS. This approach will allow for controlled dosing of the CCS water volumes, flocculation, settling, and separation of waste streams and treated water streams. Direct application is the more common means of treating large water bodies, but may not be as efficient.

In general, the plan will be developed in stages. The external treatment approach will be used to identify the dosage rates that will maximize coagulation of the algae and nutrients and minimize residual aluminum concentrations in the treated water stream. This approach allows for treatment of discharge water, if needed, prior to discharge back to the CCS. The direct application approach will build on the results of the external treatment method and the experienced gained from an earlier direct application pilot study conducted by FPL in the CCS during June 2016. The direct application approach utilizes a flocculant injection array in the CCS water column, followed by the capture and removal of the floating floc matter downstream of the injection point. (See Exhibit C).

Data Informing Flocculation Treatment

A small scale, short duration, direct application treatment pilot study was conducted in June 2016. The study demonstrated that direct application of a flocculant to the CCS can be successful in coagulating algae biomass, and concentrating total suspended solids and nutrients in buoyant floc. The buoyant floc was then removed from the CCS by scavenging pumps. In this pilot study, an aluminum-based flocculant was applied into a section of the main return canal using a floating injection manifold. The manifold delivered the flocculant at a depth of approximately 5 feet below the water surface to allow for mixing, interacting with the aeration stream and ultimately floating the coagulated material to the surface.

The concentration (application mixing ratio) of the flocculant was varied to determine the dosage that successfully coagulated the nutrients and algae and minimized the residual dissolved aluminum downstream of the collection point. The goal was to identify the lowest dose that would result in floc formation and removal. Dose concentrations ranged from 1000 parts per million (ppm) to 250 ppm. It was determined that a low dosage rate of 250 ppm provided effective coagulation, and minimized the amount of flocculant required. Samples were taken upstream, within the flocculation area, downstream of the floc plume (post floc material removal), and of the clarified treated water stream returning to the CCS. Disposal of the removed floc material was managed by using upland holding structures and directing the treated floc flow into geotextile bags prior to excess water being returned to the CCS.

Table 3.2 Results of Flocculation Pilot Test Water Chemistry

Analyte	Upstream	Downstream	Center of Floc Plume	Treated Stream Return	Floc (mg/kg)
Phosphorus as P (mg/L)	0.0341	0.00984*	0.0145*	0.00423*	114
Nitrogen Kjeldahl (mg/L)	4.68	4.81	4.64	3.95	2180
Turbidity (NTU)	7-8	3	2.2	NA	NA
TSS (mg/L)	39-115	62-186	36-305	77-140	4600
Algae Counts (Cell/mL)	787,351	669,339	1,415,250	311,440	NA
Total Aluminum (mg/L)	ND	0.763	3.45	2.05	72,150

ND = non detectable, NA = Not available

** The reported value is between the laboratory method detection limit and the laboratory practical quantification method*

Controls during Implementation

Results of the pilot study demonstrated that flocculant can be effectively introduced directly into the CCS to create a buoyant floc that can be removed with low aluminum concentrations in the downstream water and sediments. Based on the pilot study results and a review of relevant toxicity information, FPL is establishing dosage levels that will minimize the concentration of aluminum in the downstream water column and sediments. In the case where the flocculant is applied directly to the CCS, any floc not collected in the downstream water will migrate through the water column, and attract additional soluble phosphorus, particularly orthophosphate, onto the floc particle. The floc particle containing the dissolved and particulate nutrients would then settle onto the bottom of the canal and provide additional phosphorus uptake for phosphorus which may be released from anoxic sediments. The design to be used by FPL will minimize the amount of flocculant that will not be recovered. Dosage limitations will limit downstream dissolved aluminum to less than 1.5 mg/L in the water column.

The design of the large scale flocculation system for direct application to the CCS will address:

- Optimal concentration of flocculating agent based on bench testing, pilot testing and industry experience
- Location for injection system to optimize treated area, flocculation and floc material removal, including treatment of water to be returned to the CCS
- Methods and configuration for controlled injection and metering of flocculating product

Once the initial design is completed, a prototype will be constructed to ensure that all of the mechanical elements of the treatment system perform as expected and achieve the desired results with respect to flocculant delivery, collection and disposal. In addition, the rates of nutrient removal per volume of flocculant applied will be estimated.

When the system is in operation, sampling for the following parameters will be conducted:

- Total Suspended Solids (TSS)
- Total Nitrogen, Total TKN
- Phosphorous
- Algal concentrations
- Salinity, Specific Conductance
- Total and dissolved Aluminum upstream and downstream water column and sediments
- Residual polymers (if applicable)

3.1.2 Aeration Combined with Protein Skimming

Based on a review of technologies employed at other large operations, and within the waste water treatment industry, protein skimming technology using micro-aeration is a relatively benign process that is effective at concentrating algae and TSS in foam mats that can be harvested to remove the algae and associated nutrients from the water column. Another benefit of this approach is that it increases the dissolved oxygen in the water column. Disposal of the removed material can be managed similar to the flocculation methods discussed above. The following is the anticipated implementation of this technology at the CCS to evaluate its efficacy.

Controls during Implementation

No chemical addition is required for operation of the aeration/protein skimming technology, therefore no dosage or concentration limits apply. The design phase for this short-term measure will address the following attributes:

- The type of protein skimming system best suited for use in the CCS;
- System specifications, locations for implementation and site plans;
- Water quality monitoring during application of this method;
- Pumping capture system details including skimming system;
- Disposal system details; and
- Quantification of its efficacy.

A prototype will be constructed to test the equipment and confirm the efficiency of the system to remove solids (including algae) and improve dissolved oxygen in the CCS. If successful, the system can then be scaled up as necessary for longer term use. Constituents of the waste stream and CCS in the vicinity of the application will be monitored with a similar regime as described for the flocculant application. Disposal of the waste stream will be similar to the flocculant application.

3.2 Canal Practices Review

3.2.1 Vegetation and Berm Maintenance Practices Review

As discussed in section 2.1, berm erosion is estimated to be one of the largest single sources of phosphorous to the CCS. Properly executed, vegetative management practices can help minimize this source. While FPL has a robust vegetative management program in place, a detailed review will be carried out to evaluate the existing practices and to identify ways to decrease nutrient leaching from the berms.

Additionally, the plant operates a macerator (grinding unit) during periods of high biomass collection on plant intake screens. While operation of the macerator is not a source of nutrients, it can accelerate decay of existing biomass in the system. Plant practices for the implementation of this equipment will be reviewed.

FPL will conduct a review of all system vegetative and berm maintenance activities with the objective of minimizing nutrient release to the CCS surface waters or identifying additional bulk removal opportunities.

3.2.2 Sediment Management and CCS Flow Balance

Sediment maintenance and canal flow balancing activities are primarily required to maintain design hydraulic and thermal distribution in the CCS. This will maximize heat exchange efficiency and minimize CCS temperatures, thereby reducing the amount of water evaporated by the CCS process and helping to attain salinity reduction and maintenance goals. Bulk sediment removal can also provide a net nutrient management benefit, as identified in Section 2.0. Careful planning and execution of activities in the CCS are important to ensure disturbed sediments in canals under maintenance are isolated from the main CCS flow field and allowed to settle prior to restoring flow to those canals.

3.2.3 Nutrient Monitoring and Management Program

The monitoring activities implemented over the past six years have focused on data to address CCS salinity and hypersaline groundwater. FPL has leveraged that information, and augmented the monitoring process, to include periodic monitoring of CCS water quality and nutrient concentrations. Effluent streams into the CCS will be tracked and estimated on a periodic basis to ensure FPL has control of all potential nutrient sources. This information will continue to be used to monitor status and trends within the CCS. The program will include an appropriate level of oversight and monitoring to support achieving the goals of this plan.

3.3 Salinity Reduction and Controlled Flow Management

Achieving salinity reduction to an annual average of 34 psu is an important objective from multiple perspectives. In 2015 (as indicated in Table 2.2) FPL used controlled sources from the L-31 E canal, Marine wells, and flow from Floridan Aquifer wells to reduce the salinity in the CCS. The volumes applied in 2015 were on the order of 30-40 MGD for the L-31E and Marine wells, when they were in use and approximately 3 MGD from an existing Floridan well. However, in future years, it is expected that only Floridan wells, limited to 14 MGD, will be the controlled water source to be utilized for salinity reduction.

Operation of the Interceptor Ditch (ID) requires periodic pumping via the ID Operating Procedures (IDOP), as required by the Fifth Supplemental Operating Agreement and Industrial Waste Water Facility Permit. Close adherence to the requirements of the IDOP will minimize the contribution from this source.

3.4 Long Term Efforts

The near term activities described above will enable the return of stable, moderate salinity CCS surface water that will provide a suitable habitat for sea grasses. The freshening of the CCS to reduce salinities in the canals, coupled with nutrient minimization through flocculation and micro-aeration (decreasing the likelihood of algal blooms and potential for nitrogen fixation), will result in improved water clarity and environmental conditions favorable to the re-establishment of a sea grass-based ecosystem in many areas of the canals. The long-term Plan is to return the CCS to water quality conditions similar to those experienced prior to 2005.

3.4.1 Re-establishment of Sea Grass Meadows

Historically, CCS water was clear and with thriving sea grass meadows of *R. maritima*. This species was historically the dominant grass in the CCS. Sea grasses will help trap suspended solids in the water column, sequester nutrients from the water column and sediments, and help stabilize sediments. *R. maritima* grows fast and is more tolerant of salinity fluctuations than other sea grasses in Biscayne Bay (such as turtlegrass, *Thalassia testudinum*). Therefore the success of *R. maritima* in colonizing and repopulating the CCS is higher than other native sea grasses. When sea grasses thrived in the CCS, they required management systems due to their high productivity. Management activities such as sea grass harvesting can be re-established and if the sea grasses are removed from the CCS, this will provide an additional biologically-based nutrient minimization process.

When sea grasses thrived in the CCS, salinities were lower and ranged 30 to 45 psu, seasonally. The requirement to reduce annual average CCS salinities to 34 psu within 4 years through the ongoing freshening process (CO Paragraph 20.a) is consistent with this objective. *R. maritima* grows in a wide range of salinities from mesohaline to hypersaline environments. It is likely that, remaining in the CCS, is a dormant seed source for the *R. maritima* that once populated the CCS. Lower salinities and water clarity will provide the environmental conditions needed for natural sea grass reemergence. Cultivation (re-planting) programs may also be employed to accelerate the process, and to allow more control regarding the location of sea grass meadows to promote survivability and effectiveness. Careful consideration of planting locations within the CCS with appropriate water depth and substrate will be identified to ensure successful plant establishment, as this species grows best at depths between 2 and 3 feet. After plant populations become established, they will serve as a source for additional plants.

Over a period of several years, new plants should be re-established, and the water flow will carry seeds, rhyzomes and fragments downstream and assist in furthering the re-establishment of sea grasses.

A healthy sea grass population of approximately 50% of the canal water acreage is expected to continue to help balance the nutrients in the CCS and sequester nutrients in biomass. A healthy sea grass system will also provide fish and invertebrates a protected habitat to grow and reproduce. A reduction of nutrients in the CCS surface waters should also result in a reduction of nutrients entering the groundwater; this will reduce the nutrient mass load that could be transported via groundwater to external canals such as the Turning Basin.

Section 4.0 Conclusion

This Nutrient Management Plan provides a review of potential nutrient sources to the CCS and a plan for minimization of those sources.

Part A of the plan summarizes the status of the current nutrients in the CCS based upon a comprehensive evaluation of the nutrient sources and sinks, and the operating history of the CCS prior to the recent change in biology. In summary, the findings are:

- The major source of nutrients in the CCS water column came from the die-off and decomposition of sea grasses between 2010 and 2013, caused by elevated CCS average salinities above 55 psu steadily increasing over the period 2004 – 2010.
- Additional sources of nutrients are primarily environmental in nature and driven by the large scale of the CCS (5,900 acres; 5 billion gallons of water).
- To a lesser degree, controlled water sources contributed to nutrient concentrations, while industrial sources related to plant operations were a minor contributor to total loading.

Part B of the plan provides a discussion of how the nutrient levels in the CCS will be managed and minimized. The plan presents near term and long term initiatives and describes how those initiatives are expected to be implemented.

- Near term activities will focus on three areas: 1) nutrient/algae removal, 2) review of CCS practices including sediment and vegetative management, and 3) continued reduction of CCS salinity.
- Long term activities will focus on re-establishing sea grass meadows to provide stabilizing nutrient reduction and habitat for other aquatic species.

Literature Cited

Koch, M., Schopmeyer, S., Khyn-Hansen, C., Madden, C., and J. Peters. 2007. Tropical seagrass species tolerance to hypersalinity stress. Aquatic Botany 86: 14–24.

Rudnick, D. 2016. Florida Bay Seagrass Die-off Summary. Presentation to the South Florida Ecosystem Restoration Joint Working Group and Science Coordination Group Meeting. March 21, 2016

Zieman, J.C., Fourqurean, J.W., Frankovich, T.A., 1999. Seagrass Die-off in Florida Bay: long-term trends in abundance and growth of turtle grass Thalassia testudinum. Estuaries 22, 460–470.

EXHIBITS

Exhibit A – Depiction of Nitrogen and Phosphorous Cycles in the Turkey Point CCS

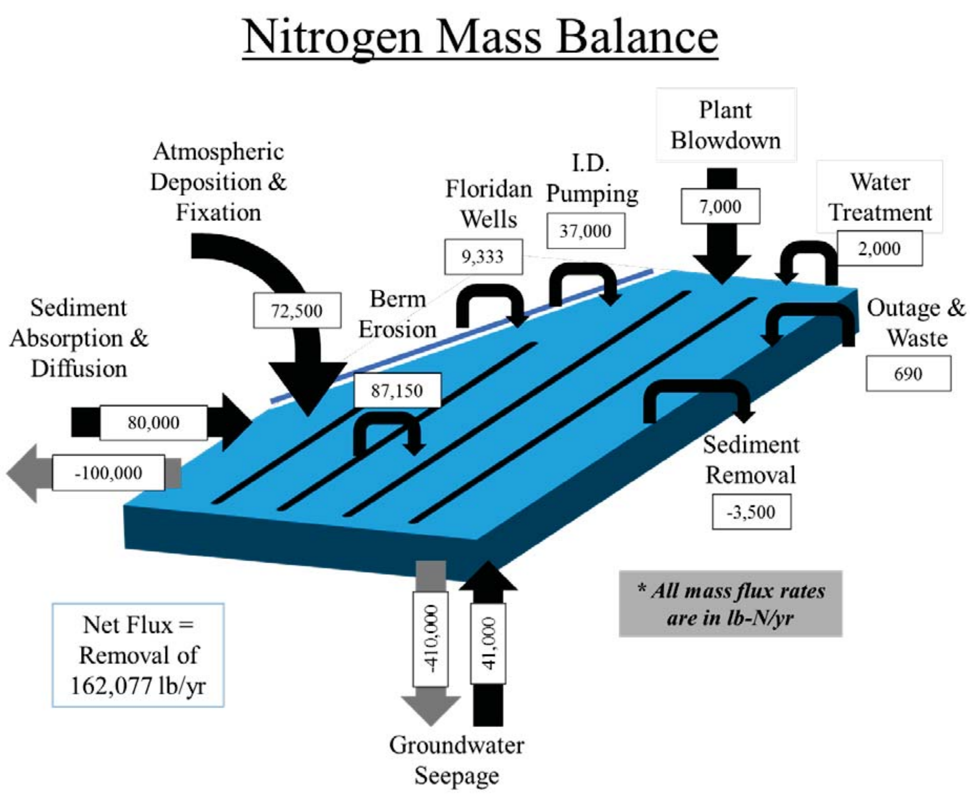

Figure A.1 – Nitrogen Mass Balance for Turkey Point CCS using data of Table 2.3

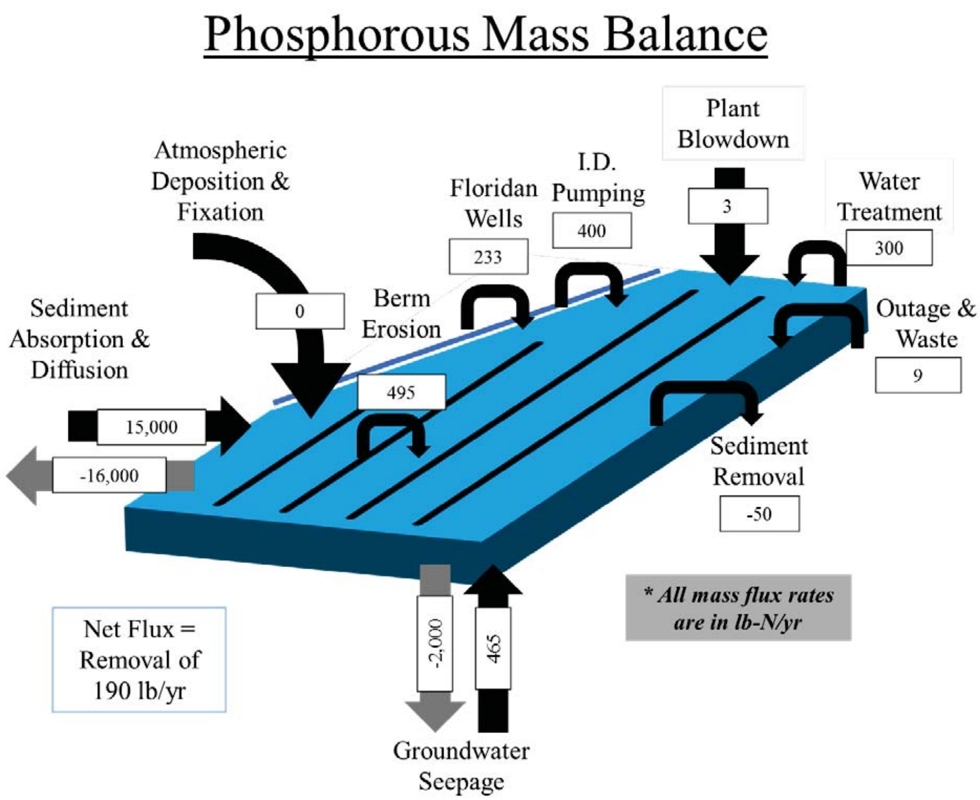

Figure A.2 - Phosphorous Mass Balance for Turkey Point CCS using data of Table 2.3

Exhibit B – Alternative Methods Considered for Nutrient/Algae Removal

Algae/Nutrient Removal Method	Description and Benefits	Challenges
Flocculation	Particulate nutrients and algae are removed using a chemical flocculant, most commonly an alum based compound. The flocculant acts to aggregate the suspended nutrients and particulates to facilitate filtration or direct removal.	Volume and flow of CCS surface water creates challenges in effectively treating the water column, and may result in excess dissolved aluminum. Must be teamed with a removal methodology to be most effective.
Protein Skimming	Similar to large scale aquarium cleaning systems. As air bubbles move through the column of organic-laden water, the proteins are attracted to the air/water interface of the bubble, producing a floating foam mat. The foam mat can then be collected and consolidated for disposal.	Volume and flow of CCS surface water creates challenges in effectively treating the water column. Must be teamed with a removal methodology to be most effective.
Disk Filters	Disk filtration technology achieves solids removal by forcing water through a series of stacked and compressed disks with increasingly smaller pore sizes	Bulk fabric/material filtration requires significant equipment and produces a solid waste stream.
Sand Filters	Sand filtration is an effective and highly efficient process for removing particles from water. The size of particles removed by the filtration process can be regulated by altering the grain size of the sand particles within the filter.	Bulk sand filtration requires significant equipment, flushing water and produces a solid waste stream.
Aeration / Circulation	This technique is designed to increase water column concentrations of dissolved oxygen and to provide an oxidized zone at the water-sediment interface that inhibits diffusion into the water column.	Volume and flow of CCS surface water creates challenges in effectively treating the water column. Application in other Florida industrial systems has been ineffective.
Physical removal of algae	Some species of algae that have a bulkier physical consistency can be removed by filtration using membranes, screens, or textiles. Can also be applied in combination with flocculation or protein skimming.	Variation in algae species indicates that opportunities, without the aid of flocculation or protein skimmers, would be of limited efficacy.
Removal of canal bottom sediments	One of the most common methods used to reduce water quality impacts from sediments is dredging. Net impact of dredging can remove and sequester nutrients, physically or in combination with flocculation.	Intensive physical activity requiring coordination of spoils placement, decant of spoils, berm compaction and post dredge berm vegetation/containment.
Submerged Aquatic Vegetation	Submerged aquatic vegetation has provided an effective mechanism for uptake and retention of nutrients within an aquatic environment.	Maintenance of sea grass beds and screening of biomass require proper material and staffing. Water quality requirements must be established for successful implementation of this alternative.
In-place Sediment Inactivation	Sediment phosphorus inactivation is a technique that reduces sediment phosphorus release by combining available phosphorus in the sediments with a flocculant to form an insoluble inert precipitate, rendering the sediment phosphorus unavailable for release into the overlying water column.	Volume and flow of CCS surface water creates challenges in effectively treating the full CCS, and may result in excess dissolved aluminum in the water column. Potentially conflicts with bulk sediment removal, but treatment of remaining sediment may provide additional benefits.
Chemical Algae treatment	Copper sulfate has been used as a means of killing algae, depending on algae strain and environmental conditions (i.e., salinity).	Large scale application has secondary effects on dissolved oxygen levels, and does nothing to remove the nutrient mass from the system.

Exhibit C – Flocculation System

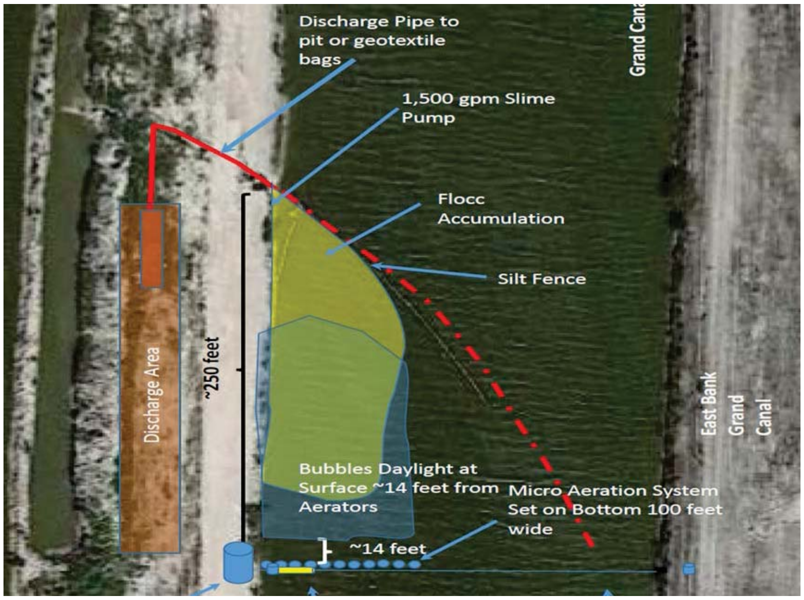

Figure C-1   Arrangement of Direct Treatment Pilot Study Equipment

Figure C-2. Flocculent Injection Manifold (on its side)