APPENDIX H

ADAPTIVE MANAGEMENT PLAN

PORT EVERGLADES, FLORIDA PROJECT

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H INTRODUCTION

Adaptive Management is a rational and evidence-based system for evaluating and avoiding environmental risk and impact in sensitive environments. In this case, it is being employed in association with dredging operations. In a successful dredging campaign, all adaptive management activities will occur before the minimum acceptable biological outcome is reached. This requires an observation-based knowledge of local habitats and conditions; a tiered-response system of project-specific operational states capable of providing advanced warning of a trajectory of deterioration; surveillance methods capable of providing timely feedback; and courses of action for dredging ('means and methods') to be implemented in response to alerts provided by the monitoring program. Adaptive management of any activity can be characterized as a cycle of observing and responding.

Dredging in coral reef habitats has become an activity where regulating agencies cannot afford to provide contractors with complete operational flexibility while relying solely on performance-based contracting requirements. This is because risks to the Permittee are high (much higher than the basic risk of delivering the dredged channel) and dredging contractors rarely have sufficient in-house expertise in local coral reef ecological processes to enable timely management and protection of reef ecosystem health. Dredging impacts in these highly sensitive environments can and should be effectively managed by the application of adaptive management processes designed specifically for the project's location and conditions.

The Adaptive Management Plan (AMP) presented herein outlines the adaptive monitoring plans (Sections H.7 and H.8), data collection techniques and analyses, communication platform and portal, and the Dredge Operation System State (DOSS, Section H.4) proposed for implementation for the Port Everglades, Florida (PEV) Project so that dredging can be managed within a transparent and formal decision-making framework. The main goal of this plan is to prescribe the process by which information will be collected, managed, analyzed, communicated, and used to adaptively manage construction operations to minimize impacts to natural communities and degradation of water quality.

H.1 PLAN OBJECTIVES

The objective of this document is to identify adaptive management strategies and approaches relevant to protecting coral reef habitats adjacent to the Port Everglades Harbor that are potentially at risk from proposed dredging and channel deepening activities. In this plan, the Corps developed a set of water quality and biological indicators to be used as initial triggers (see Table H-1 and Table H-2) to determine the appropriate state at which dredging should operate (green, yellow or red states, see Section H.4). In addition, Section H.4.3 details proposed management measures that shall be applied to reduce levels of suspended sediment reaching benthic resources. The specific strategies that will be used will be coordinated with the Interagency Working Group (IWG) with the goal of developing a consensus of practical steps that can be taken to evaluate and implement adaptive management protocol.

There are several objectives for this plan, including but not limited to the following:

- Early identification of key risks and uncertainties associated to the project
- Minimize risk of impacts occurring without being detected
- Minimize decision-making time lags during construction
- Regulate or further restrict dredging operations to minimize risk of impacts

- Obtain continuous, real-time data during construction
- Help provide oversight during construction
- Proof of concept for an instrumentation-focused plan with an automated alert system and ecological forecasting tool
- Refine triggers, as we gain a better understanding of natural conditions in the area.
- Identify dredge management measures (i.e., corrective actions) available when a trigger is met.
- Include a diver-based in-situ monitoring focused on sediment depth measurements and indicators of sediment stress on corals, octocorals, and sponges.

H.1.1 Conceptual Framework

The Corps, in collaboration with the Army's Engineer Research and Development Center (ERDC) Coastal and Hydraulics Laboratory (CHL), and NOAA's Atlantic and Oceanographic Meteorological Laboratory (AOML) and National Marine Fisheries Service (NMFS), intends to collect water quality and oceanographic data in near real-time and assess this data for the likelihood of ecological impacts using an existing operationally-focused expert systems tool (NOAA's Environmental Information Synthesizer for Expert Systems or EISES) (**Figure H-1**, Section H.7). This tool can generate and send reports and/or alerts to designated stakeholders automatically via the web, email or SMS text subscription These alerts can help determine the appropriate Dredge Operation State System (DOSS) to use (green, yellow or red; see Section H.4) if water quality or biological-based triggers have been tripped. Raw data and EISES ecological forecast alerts would be also available to stakeholders in a web portal in near real-time.

Biological data collected on a bi-monthly basis from the Diver-based monitoring protocol developed in collaboration with NMFS (described in detail in Section H.8), will also be integrated with EISES (**Figure H-1**) on a rolling availability (after each survey is completed), by coding data in an appropriate format (e.g., numeric stress index).

Turbidity data collected from the Vessel-based Compliance Turbidity Sampling will not be integrated with EISES (separate communications and reporting, see Section H.2.1.1), but will be available every 4 hrs in a web portal, similar to the water quality data collected near real-time. Turbidity data collected from the Vessel-based monitoring will also be used separately to determine the appropriate DOSS to use (green, yellow or red; see **Figure H-1** and Section H.4).

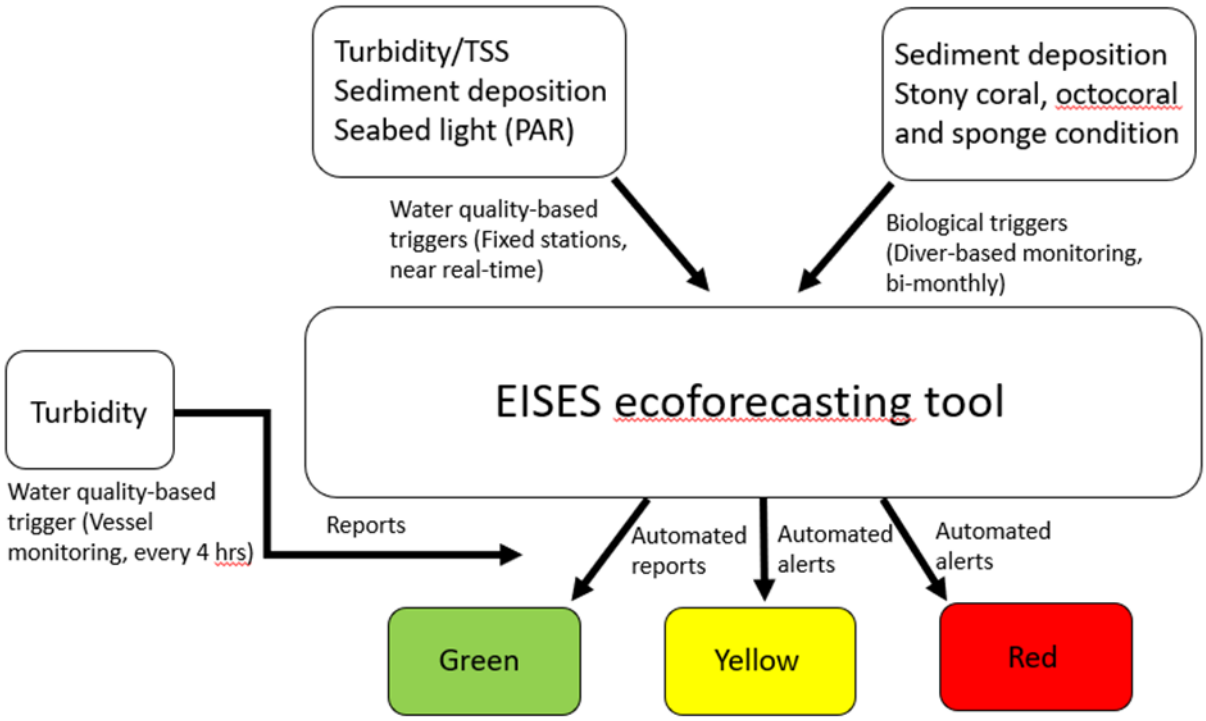

Figure H-1. Conceptual diagram for determining the appropriate DOSS to use (green, yellow or red, see Section H.4).

H.2 DATA COLLECTION METHODS

H.2.1 Water Quality and Oceanographic Data

H.2.1.1 Vessel-based Compliance Turbidity Sampling

The vessel-based turbidity monitoring contractor will be hired independently from the dredging contractor and will perform turbidity sampling adjacent to the dredging operations for compliance with the Water Quality Certification / State permit. The Corps will coordinate details of this plan with the Florida Department of Environmental Protection (FDEP). Samples to be analyzed for turbidity shall be taken every 4 hours, during daylight hours only, and at the surface, mid-depth, and bottom of the water column. The samples shall be retained and provided upon request. The samples should be labeled by day, time, and Nephelometric Turbidity Units (NTU) reading reported. The turbidity monitor will be required to instantaneously upload the NTU readings into the water quality web portal. The following locations are required sampling:

a. Station 1 (Compliance Turbidity): No more than 150 meters down-current of the dredge or point of discharge and in the direction of any visible plume. Down-current (and up-current, see b) below) must be measured and recorded accurately using either a vessel mounted ADCP (Acoustic Doppler Current Profiler) to log current velocity and direction throughout the water column simultaneously or a single point Direct Read Current Meter (DRCM) or similar that records current velocity and direction at a single depth at a time. If the Contractor uses a

DRCM or similar, measurements of up-current and down-current must be measured at the surface, mid-water column and 1 m above the seabed, with the depth and time always recorded. The Contractor will need to demonstrate to the Corps that currents have been measured and recorded up-current and down-current of the dredge and dredging plant with the GPS position of both, time and position of the dredger and any other active dredge related plant (scow/hopper) recorded at the same time. The Contractor will also coordinate with Contracting and Construction. All recorded data whether using an ADCP or DRCM must be provided to the Corps for all measurements.

b. Station 2 (Background Turbidity): At least 300 meters up current from the dredge or point of discharge and outside of any turbidity generated by the project.

Sampling Protocol

Sampling shall be conducted as follows:

1) Collect discrete water samples at specific measured water depths and use the samples to accurately calibrate a turbidity logger to convert units from NTU to Total Suspended Solids (TSS, mg/L) and then use the instrument to measure turbidity (or TSS) in collected samples. Additional information will be provided with details on the calibration process and how it will be implemented before and during dredging. Samples obtained for turbidity analysis shall be shaken well before analysis and analyzed within 30 minutes of collection. Water samples shall be taken with a sampler obtaining samples uncontaminated by water from any other depth, such as a Niskin or Nansen bottle sampler or equivalent. The setup of the sampler must allow a sample to be collected at a known depth with a depth sensor fitted to record the depth of the sample collected. The sampler must be capable of collecting a sample no higher than 0.5m above the sediment bed.

OR

2) Use a profiling turbidity sensor combined with depth sensor (for example a Conductivity Temperature Depth – CTD – logger) to carry out a measurement profile throughout the water column. Discrete water samples must be collected from the monitoring site and analyzed for Total Suspended Solids (TSS - units mg/L) to accurately calibrate the turbidity sensor over a range of concentrations with data converted from NTU to TSS.

Turbidity Monitoring Equipment

Monitoring required for turbidity shall be measured in Nephelometric Turbidity Units (NTU) using a standard Nephelometer. Discrete water samples must be collected from the study site and analyzed for TSS to convert all measured data from NTU to TSS (mg/L). The Corps will discuss with FDEP the specific contents of the electronic data sheet (e.g., dredge location, dredge name, etc.) and data deliverables.

Reporting

The monitoring data shall be immediately input via computer tablet on the boat onto the water quality monitoring portal. In addition, the data shall be recorded in the daily quality control (QC) test in the Corps' Resident Management System (RMS).

Notification

If turbidity compliance exceeds background levels by more than 29 NTU in Station 1 surface, mid-depth or bottom, the Contractor shall immediately input this into the water quality portal which would generate a Red DOSS state (see Section H.4), this in turn will provide immediate notification to all subscribers, including the dredging contractor. In addition, all dredging and/or disposal activity shall cease immediately and measures to reduce turbidity shall be taken. Dredging or disposal shall not resume until corrective measures (see Section H.4.3) have been taken and turbidity has returned to acceptable levels as determined by proper testing and in accordance with the DOSS response and restart criteria.

H.2.1.2 Fixed-Station Water Quality and Oceanographic Data Monitoring

The Corps, in collaboration with ERDC, NMFS, and AOML, intends to deploy bottom-mounted instruments and collect (near) real-time water quality and oceanographic data at 8 channel-side stations (**Figure H-2**). All real-time stations (stations 5-12 denoted in yellow in **Figure H-2**) will be distributed close to the Outer Entrance Channel (OEC) to monitor and respond to rapidly changing water quality and sedimentation impacts which may occur during dredging. An additional 8 stations (including 4 reference stations) will be deployed to collect continuous data across the project area (stations 1-4 and 13-16 and denoted in blue in **Figure H-2**). However, data from these stations will have to be manually downloaded during scheduled maintenance trips (every ~45 days), OR as part of a Rapid Response Technique during the DOSS Red State (see Section H.3.4), if triggered by automated alerts from data collected at real-time channel-side stations. Details on this protocol (including specific list of instruments to be deployed per station, sampling frequencies, and GPS locations of station) are provided in Section H.7.

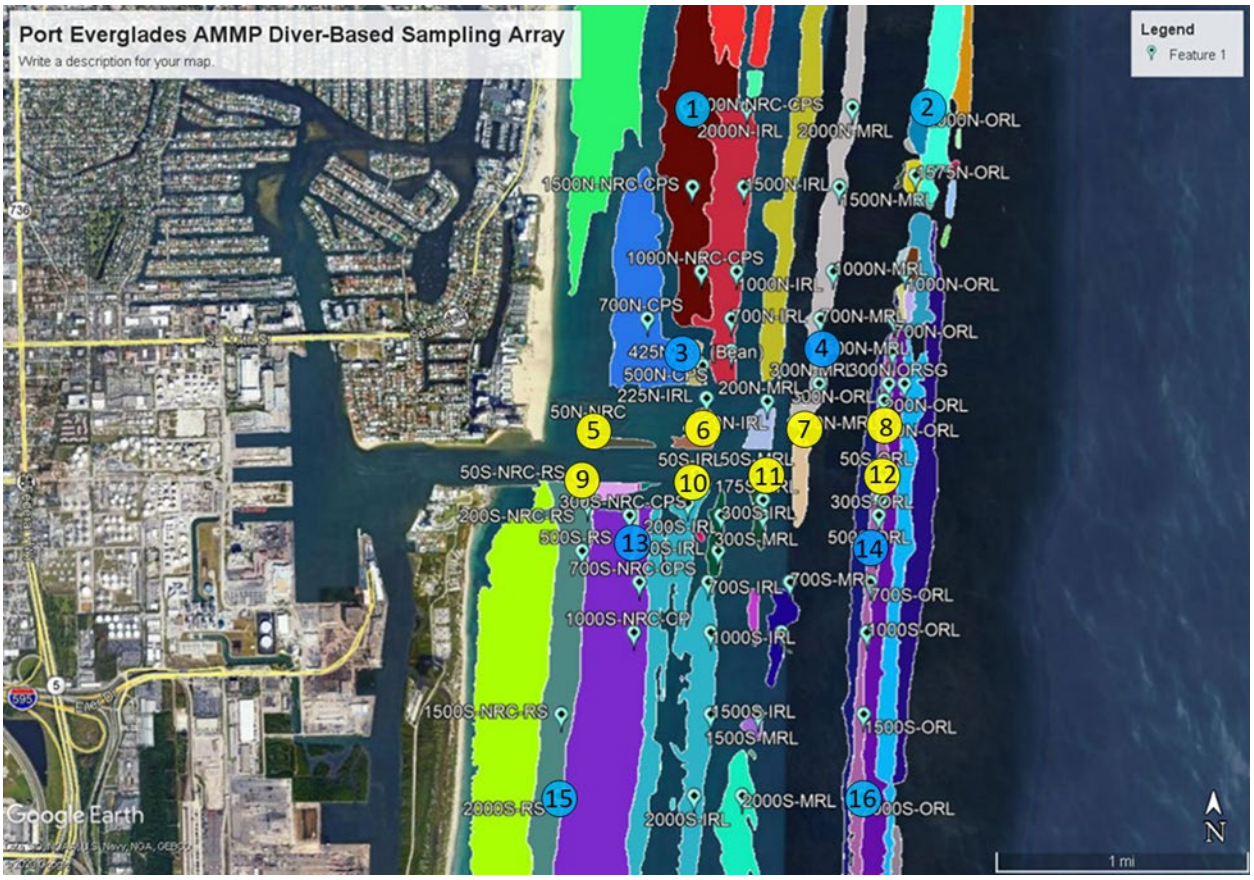

Figure H-2. Proposed array of fixed water quality stations in the project area. Stations denoted in yellow will have near real-time data collection capabilities. All stations (project area and reference reefs) are meant to overlay stations that will be monitored as part of the Diver-based monitoring depicted in Figure H-3 and described in Section H.8.

H.2.2 Diver-Based Monitoring

The development of a multi-season biological baseline prior to construction is essential in effectively executing adaptive management and monitoring of dredging projects conducted near coral reef habitats. NMFS developed and conducted an array of seasonal sampling at Port Everglades (winter of 2017 and summer of 2019) to better understand the existing sediment depths and biological composition over various reef habitats in anticipation of the proposed harbor deepening project. The Corps is collaborating with NMFS to continue support of this effort by implementing similar sampling methodologies and analyses in order to establish a more frequent biological dataset to quickly assess potential adverse conditions and trigger adaptive management responses or corrective actions, when necessary.

A tiered sampling array will be used to monitor up to 76 sites (including 8 reference sites) in 8 habitats ranging between 50m and 2000m north and south of the existing channel edge in the vicinity of Port Everglades (**Figure H-3**). A systematic sampling grid was designed to sample an Outer Reef, Middle Reef Inner Reef and Nearshore Ridge Complex habitat on each distance interval from the existing channel edge. Monitoring will be conducted on a bi-monthly basis (every 2 weeks after completion of each survey) throughout the project duration (assuming that near-real time stations are functioning and transmitting

data; if not, more frequent monitoring may be conducted). Details on this protocol (including tiered sampling array of sites) are provided in Section H.8.

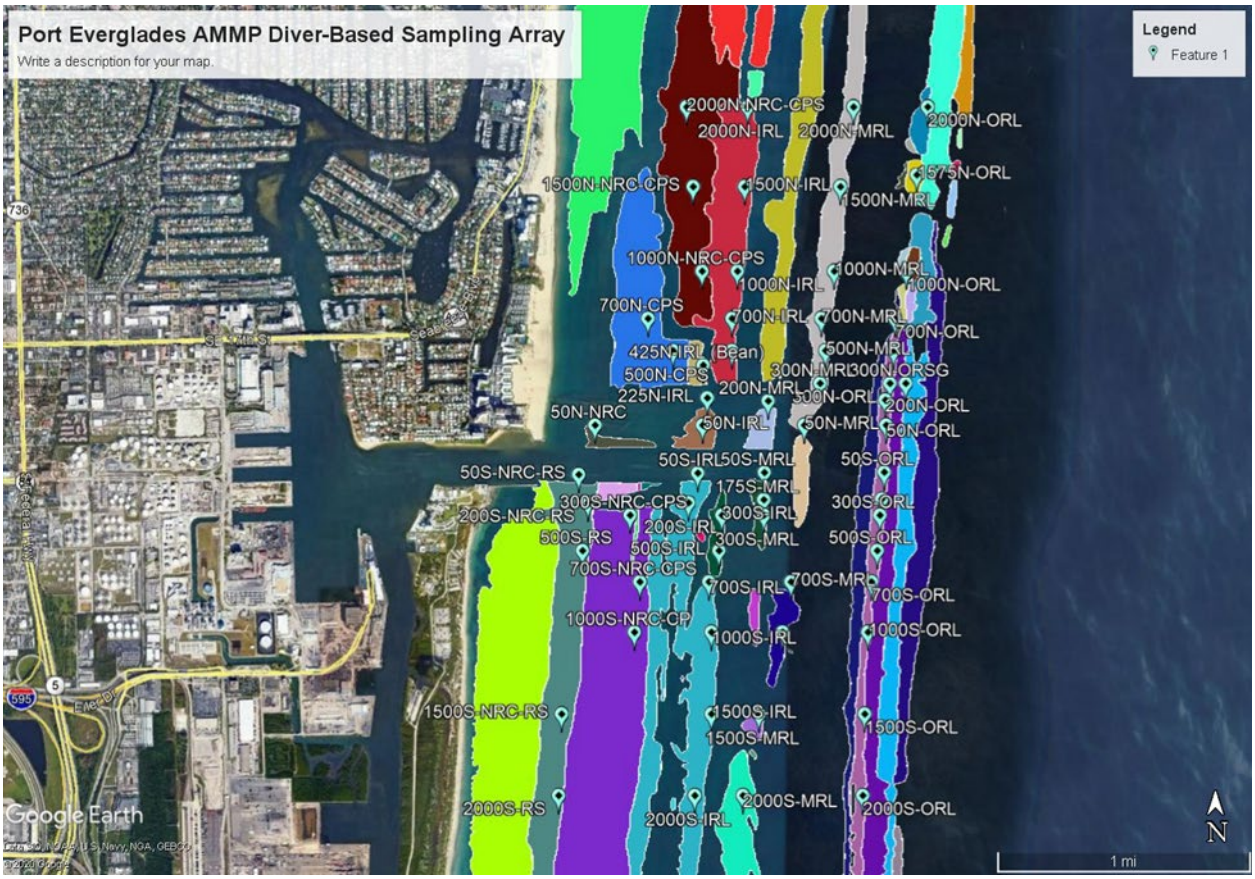

Figure H-3. Study domain with location codes describing distance and direction from channel edge and mapped habitat. Distance from the channel edge was measured for most sites using Google Earth in 2017. Reference sites will be determined and added to the AMP in-situ monitoring array at a later date.

H.3 DATA PROCESSING AND GENERATION OF ALERTS

H.3.1 Establishing Baseline Conditions (DOSS Green State)

To successfully establish the appropriate triggers and thresholds to use for adaptive management of this project (Section **Error! Reference source not found.**), a comprehensive baseline will be established prior to dredging operations to compare background conditions against with-project measurements that may require adaptive responses (e.g., yellow or red DOSS states). The Corps proposes to compile baseline (pre-construction) data from all the water quality, oceanographic and biological data collection protocols described above to describe natural (background) conditions, local hydrodynamics, and seasonal patterns in the data in anticipation of the dredging. The Corps will also compile other relevant data collected from the area by other agencies and contractors (e.g., Sediment Morphodynamics project, expected to be complete in the summer of 2021), as well as any peer-reviewed reports or surveys of benthic communities in the project area for this purpose.

H.3.2 Automated Reports and Alerts Using EISES

NOAA's EISES Artificial Intelligence-based Ecoforecasting System is a software tool which integrates data in near real-time into a single stream of information, and applies complex if-then rules, based on the input of human experts, to automatically assess the possible meaning of that information for ecosystems. The system has been applied to monitoring of coral reefs for bleaching (Gramer et al. in prep), spawning, and upwelling, as well as the in-situ detection of Harmful Algal Blooms (HABs). It has also begun to see application in other areas of environmental monitoring.

EISES can inform stakeholders that an adaptive management action is necessary. EISES is particularly useful, as receiving data from multiple in-water sensors may be difficult to interpret, especially when combined with other data sources such as biological data collected in-situ by divers. Rules can be implemented or refined in EISES to automatically assess a complex situation, and report the conditions to the managers - or perhaps not report them yet, until further rules (or triggers) based on additional data have been "fired" to indicate that a report is appropriate.

In a large-scale, well-instrumented monitoring project, an overabundance of data may be a serious issue, as it can overwhelm decision makers in near real-time. The field of artificial intelligence and expert systems like EISES can assist decision makers by filtering these streams of data, allowing the humans to focus on the data which stands out as most significant for their decisions in the moment.

The EISES coding project has been separated into four subsections of the software to be implemented. These sections of the program are, in procedural order: data feed processing, fact generation from these data feeds, rule evaluation of the facts, and alert distribution from the rules that were fired (see Error! Reference source not found.). An example of an automated visual report for alert subscribers from EISES is displayed in Figure H-5 showing multispecies coral bleaching threshold indicators (green, yellow, red) in geographic context, based on pre-defined triggers.

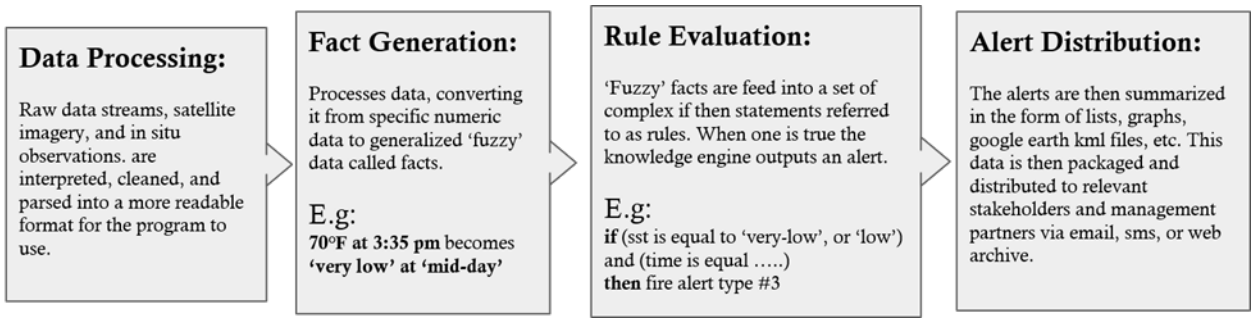

Figure H-4. EISES coding subsections of the software to be implemented for this adaptive management plan.

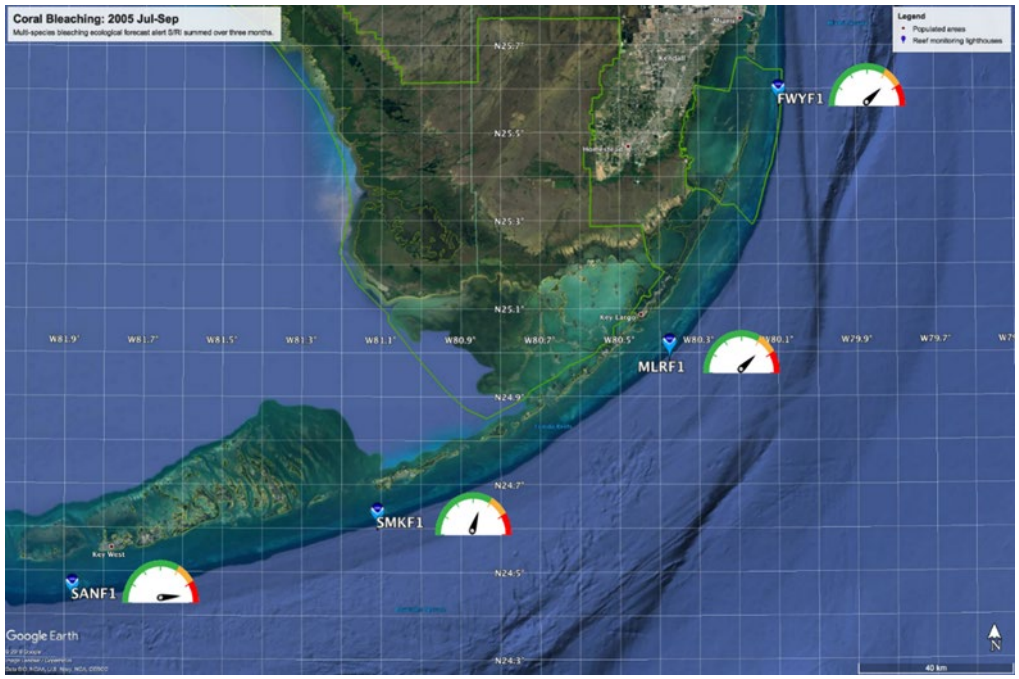

Figure H-5. Example of an automated visual report for alert subscribers from NOAA's EISES (Gramer et al. in preparation).

To successfully implement EISES for this project, the Corps has deployed a trial water quality monitoring buoy which will be collecting data during and post-construction of the O&M dredging at Port Everglades. The buoy will be equipped with instrumentation to provide information on hydrodynamics, and water quality, and telemetry to allow real-time data acquisition. Using historic large water quality data sets from Florida and other coral reefs areas, as well as pre-defined triggers (**see Section H.3.3**), preliminary rules will be developed for EISES and tested to help alert managers about any water quality conditions that may appear to lead to irreversible coral loss. These rules will likely have to be refined after collection of baseline data, and further refined throughout the project as more information is gained about hydrodynamics and sediment transport in the area.

H.3.3 Development of Water Quality-Based and Biological Triggers

The Corps, in collaboration with NMFS Habitat Conservation Division, developed a set of water quality and biological indicators to be used in this plan as initial triggers (see Table H-1 and Table H-2) to determine the appropriate state at which dredging should operate (green, yellow or red states, see Section H.4). A few important assumptions were made in this approach, including:

- Triggers are based on the most sensitive benthic group – stony corals – to allow ample time for detecting impacts before it is too late. Also, most of the relevant literature available to date have been focused on this benthic group.
- When information was available, triggers were focused on ESA-listed coral species present in the vicinity of Port Everglades (*Acropora cervicornis* and *Orbicella annularis* complex) and their responses to turbidity and/or sedimentation.
- Conditions/triggers are not mutually exclusive. Multi-parameter triggers were also developed.

- Triggers are likely to be refined after collection of baseline data, and further refined throughout the project as we gain more information about hydrodynamics and sediment transport in the area.
- Chronic (long-term) triggers will be used to determine appropriate dredge corrective actions (see Section H.5.3), while acute (short-term) triggers will be used for awareness and to help determine if additional monitoring requirements (tiered sampling array, see Section H.8), are needed.

Table H-1. Proposed water quality-based triggers (acute and chronic) to use for adaptive management of the project during dredging operations, as well as the scientific justification/rationale for each trigger.

Trigger	Yellow	Rationale	Red	Rationale
Turbidity acute	daily average of ≥ 25 NTU	Survival of coral recruits and juveniles is greatly reduced after 1-week exposure to 25-33 NTU (Fourney and Figueiredo 2017).	daily average of ≥ 25 NTU at the same station for 3 days in any running 7-day window	Survival of coral recruits and juveniles are greatly reduced after 1-week exposure to 25-33 NTU (Fourney and Figueiredo 2017).
Turbidity chronic	daily average of ≥ 4 NTU at the same station for 18 days in any running 90-day window	2x natural background (~2 NTUs) (Gramer and Hendee, 2018).	daily average of ≥ 7 NTU at the same station for 18 days in any running 90-day window	Sublethal effects in most coral species if exposed to 7-40 NTU for hours to weeks (Erftemeijer et al. 2012); survival of coral larval recruits and juveniles is greatly reduced at ≥ 7 NTU when exposed for about 3 weeks or longer (Fourney and Figueiredo 2017); time periods defined in Nelson et al. (2016), but no correlation to NTUs, only suspended sediment concentration; same values and studies used to justify SARBO PDCs limiting equipment type, dredge duration, and sediment composition.
Turbidity chronic	daily average of ≥ 15 NTU at the same station for 10 days in any running 21-day window	Survival of coral recruits and juveniles is greatly reduced after more than 2 weeks exposure to 14-15 NTU (Fourney and Figueiredo 2017).	daily average of ≥ 15 NTU at the same station for 14 days in any running 21-day window	Survival of coral recruits and juveniles are greatly reduced after more than 2 weeks exposure to 14-15 NTU (Fourney and Figueiredo 2017).
Total Suspended Solids (TSS) acute	150 mg/L mean daily	Sub-lethal responses observed in various species (including *A. cervicornis* and *O. annularis*) at 150 mg/L for 96 hrs (Thompson, 1980)	150 mg/L mean daily for 3 consecutive days	Mortality observed in various species (including *A. cervicornis* and *O. annularis*) at 476 mg/L for 96 hrs (Thompson, 1980).

Trigger	Yellow	Rationale	Red	Rationale
TSS chronic	10-20 mg/L mean daily for 18 days during a 90-day running window	Response matrix in Erftemeijer et al. 2012 has lethal effects for **sensitive** coral species from 20-40 mg/L. Nelson et al. 2016 coral status indicator for moderate stress is < 20 mg/L for any 18 days in any 90-day dredging window.	> 20 mg/L mean daily for 18 days in a 90-day running window	Response matrix in Erftemeijer et al. 2012 has lethal effects for **tolerant** coral species from 40-100 mg/L. Nelson et al. 2016 coral status indicator for mortality > 20 mg/L for any 18 days in any 90-day dredging window.
Photosynthetically Active Radiation (PAR) chronic	0 – 1.1 mol photons m-2 d-1 (mean every 2 weeks)	Bessell-Browne et al. 2017a observed mortality at light levels of 0 – 1.1 mol photons m-2 d-1 for various coral species after ~20 days.		
	Turbidity or TSS is yellow and light levels are < 2 mol photons m-2 d-1 (mean weekly)	Bessell-Browne et al. 2017a observed mortality at light levels of 0 – 1.1 mol photons m-2 d-1 for various coral species when turbidity ≥ 30 mg/L.		
Sediment depth acute (Pre-Project mean sediment depth on reef framework of 0.4 cm; diver measurement, mean per event)	0.6 cm	50% increase in mean sediment depth on reef framework over pre-project.	0.8 cm	Twice the background (100%) increase of mean sediment depth on reef framework over pre-project.
Sediment depth acute (Pre-Project mean sediment depth on reef framework of 0.4 cm; altimeter)	0.2 cm	0.2 cm deposition would be equivalent to diver measurement of 0.6 cm.	0.4 cm	Twice the background (100%) increase of mean sediment depth on reef framework over pre-project.

Trigger	Yellow	Rationale	Red	Rationale
Sediment depth chronic (Diver or altimeter-based)	> 0.5 cm and < 1 cm above background	Nelson et al. 2016 coral status indicator for moderate stress; NMFS *in-situ* observations	> 1 cm total sediment accumulation	Nelson et al. 2016 coral status indicator for mortality.
	Sediment depth ≥ 0.5 cm when sediment is > 5% fines. Sediment depth ≥ 1 cm when sediment is ≤ 5% fines.	Permanent inhibition of coral recruitment.	> 0.5 cm total sediment accumulation (2 weeks during spawning)	Designated critical habitat excludes areas that have >0.5cm total sediment accumulation.
MULTI-STRESSOR ACUTE			Any trigger above is yellow and average daily water temperature exceeds 29°C.	Stressor effects are often amplified at high water temperatures.
MULTI-STRESSOR CHRONIC Example: Increase in mean % sediment cover + Biotic sediment stress indicators + Turbidity greater than 4 NTUs			Any three of the triggers above are yellow	Cumulative effects are likely to lower tolerance thresholds compared to single stressor effects.
Data loss	Data loss (no transmission) in 2 or more real-time stations.	Real-time data acquisition is essential for generation of alerts.		

Table H-2. Proposed biological triggers (acute and chronic) to use for adaptive management of the project during dredging operations, as well as the scientific justification/rationale for each trigger.

Trigger	Yellow	Rationale	Red	Rationale
Diver observations acute Sedimentation Index 1: Sediment deposition not visually apparent, 2: Sediment deposition visually apparent on reef framework with sediment accumulation on scleractinians, buried holdfasts of octocorals or sediment visible in sponge tissues sediment on reef framework, but mean sediment depth remains less than 0.5cm and no coloidal sediment observed; 3: Partial burial of scleractinian corals, including halo or non-halo burial (less than 10 percent of colony covered by sediment), buried holdfasts and sediment accumulation on octocorals (e.g. adhering to seafans, rods and plumes), sediments clogging *Xestospongia muta* water passages or accumulating in atrial cavities, Mean sediment depth 0.5 to 0.6cm, Still mostly medium grains size or larger no Coloidal component; 4: Same biotic indicators as 3, Mean sediment depth 0.7 to 0.8cm, elevated fraction of fine sediments with Coloidal component; 5: Partial burial of scleractinian colonies (Greater than 10 percent coverage), Partial mortality of octocorals with sediment, turf or macroalgae adhering to colonies, sea fans, plumes and rods observed with eroded axis or loose on the bottom, Partial mortality of *X. muta*, Mean sediment depth greater than 0.8cm elevated fraction of fine sediments with Coloidal component.	Sedimentation index = 2-4	Effects of sediment deposition on benthic coral reef organisms remains below lethal.	Sedimentation index = 5	Biotic sediment stress is observed at lethal levels causing observed partial mortality of scleractinian corals or octocorals.

Trigger	Yellow	Rationale	Red	Rationale
Diver observations acute Biotic Sediment Stress Index 1: No visually apparent stress in scleractinian, octocoral or sponge assemblages; 2: Sediment accumulation visible on scleractinian corals and octocorals but no partial mortality, sediment visually apparent in tissues of 4 or less X. muta; 3:Partial mortality from sediment of scleractinian or octocorals (less than 10 percent of colony). Buried holdfasts, but no eroded axis of octocorals, no loose octocorals on bottom, sediments accumumulating in atrial cavities of X. muta; 4: Partial burial (less than 10 percent of colony covered) of scleractinian corals (halo or non-halo burial), buried holdfasts with eroded axis, more than 3 loose octocoral colonies on seabed or sediment accumulation on octocorals (e.g. adhereing to seafans, rods and plumes), sediments clogging X. muta water passages or visible in atrial cavities; 5: Partial burial of scleractinian colonies (Greater than 10 percent coverage by burial, halo or non-halo), Partial mortality of more than 5 octocorals with sediment, turf or macroalgae adhering to colonies, sea fans, plumes and rods observed with eroded axis and more than 5 octocoral colonies loose on the bottom, Partial mortality of X. muta,	Biotic sediment stress index = 2-4	Effects of sediment deposition on benthic coral reef organisms remains below lethal.	Biotic sediment stress index = 5	Biotic sediment stress is observed at lethal levels causing observed partial mortality of scleractinian corals or octocorals.
Diver observations acute	Signs of sediment accumulation on ESA-listed species	NMFS *in-situ* observations		
Diver observations chronic	Partial burial based on frequency of dose (monthly)	NMFS *in-situ* observations	Recent partial mortality, whole colony mortality or complete burial.	NMFS *in-situ* observations
			Bleaching and sedi-ment accumulation >0.5cm above back-ground	Bessell-Browne et al. 2017b found that bleached corals are less capable of removing

Trigger	Yellow	Rationale	Red	Rationale
				sediments from their surfaces compared to normally pigmented corals.
			Bleaching and sediment accumulation on coral tissue	Same as above
			Sediment accumulation then disease	Stony Coral Tissue Loss Disease (SCTLD) has already resulted in ~30% regional tissue loss (Walton et al. 2018). Sediment and turbidity associated with dredging have been associated with increased coral disease prevalence by Pollock et al. 2014.
MULTI-STRESSOR ACUTE			Any trigger above is yellow and average daily water temperature exceeds 29°C.	Stressor effects are often amplified at high water temperatures.
MULTI-STRESSOR CHRONIC Example: Increase in mean % sediment cover + Biotic sediment stress indicators + Turbidity greater than 4 NTUs			Any three of the triggers above are yellow	Cumulative effects are likely to lower tolerance thresholds compared to single stressor effects.

H.3.4 Rapid Response Techniques to be used during Yellow or Red Operation States

H.3.4.1 Additional Turbidity Sampling

During the Red Operation state or within the first 48 hours of a sustained Yellow Operation state, additional turbidity sampling will be required via the independent vessel operated turbidity contractor. In addition to the routine adjacent to the dredge monitoring (every 4 hours for compliance), the turbidity contractor will collect 10 additional samples from farther field locations every 48 hours while remaining in Yellow Operation State. This additional sampling will provide information relative to tracking the dredge plume and providing feedback to the agencies to inform the adaptive management decision making. The contractor will utilize the fixed monitoring station data and running trends, understanding of local hydrodynamics of the project site, and potentially aerial imagery to determine potential locations to sample. The turbidity contractor will deploy a vessel-mounted ADCP with CTD and turbidity logger profiling and collecting water samples to calibrate to TSS (mg/L) and measuring surface plume TSS (mg/L) concentrations to compare with pre-dredge values. The turbidity contractor shall monitor the overflow from the dredge and/or scow, if any, collecting samples to determine TSS (mg/L) and grain size distribution of overflow material for different loads and determine the start concentration being discharged including fines content. The Corps will coordinate with FDEP to coordinate standard procedures for turbidity related shutdowns and associated monitoring and reporting requirements.

H.3.4.2 Fixed-Station Monitoring – Data Retrieval from Non-Real-Time Stations

During the Red Operation State, a Rapid Response Team (see Section H.5.4) can be deployed to manually download the water quality and oceanographic data from the 8 non-real time stations distributed across the project area (Figure H-2) instead of waiting for the next scheduled maintenance trip. Data downloads would be gathered ashore, archived, and made available to stakeholders in a web portal and can be integrated with near real-time data from the channel-side stations in EISES, as described in Figure H-1.

In addition, protocols will be developed in conjunction with the IWG to address data loss from non-real time stations, which would not be downloaded until scheduled maintenance trips. The first step is to identify how much data is missing (temporal and spatial assessment). In the case of significant data loss (>15 consecutive days) for one or more stations, the Corps may implement a tiered data analysis approach (see below) which will include a more in-depth analysis of the water quality and biological data collected, and may entail additional monitoring requirements (e.g., Triage Monitoring, see Section H.8) where applicable, to ensure no significant project-related impacts have occurred during that time period.

H.3.4.3 Tiered Data Analysis

The Corps will develop an appropriate tiered data analysis approach for the water quality and biological data in coordination with the IWG. The goal is to identify events that may have led to the trigger being exceeded, such as:

- Determining where/if dredging is occurring
- Check previous data (temporal assessment)
- Check previous data collected from other stations across the project area (spatial assessment)

- Check other data collected by the sensors (e.g., temperature and salinity to assess if observations are likely caused by natural conditions)
- Pair water quality data with biological data

H.3.4.4 Sediment Sampling

The objective for the sediment sample collection and analyses is to discern between dredge-related sedimentation and naturally occurring sedimentation within the project area. A pilot study will be conducted in collaboration with ERDC during the ongoing O&M dredging needed to help determine if the proposed methods are able to distinguish dredge-related materials from native sediments. Methods used to accomplish this objective are described in the Dredging-Related Sedimentation Monitoring Plan (Appendix G of the DSEIS) and consist of sediment physical characterizations (grain size), and geochemical and microbial characterizations (if triggered by other data suggesting a project-related impact). In addition, the Corps is currently exploring the best methods for collection of sediment samples from turbidity plumes, barges, and/or scows, pending discussion with ERDC and the IWG.

H.4 DREDGE OPERATION SYSTEM STATE (DOSS)

The goals of the Dredge Operation System State (DOSS) is to provide;

- a tiered responsive management program of the dredging operations which is based on water quality and biological indicators at monitored reef sites across project area
- a detailed system of rapid feedback monitoring designed to inform dredge managers of any trend towards exceeding formal triggers.
- a formal field monitoring and management program including a hierarchy of three operation levels with required responses, directed towards adaptively managing the dredging project.
- a streamlined communication plan for each operation level and ready tools for evaluating data trends and making informed decisions as rapidly as possible.

The water quality and biological data will be utilized to continuously provide an automatic feedback loop to inform the DOSS and provide automatic triggering of one of the three operation states; green, yellow, or red.

Green Operation State: is defined as dredging in accordance with the contract plans and specifications without additional restrictive requirements imposed. This means that required vessel-based compliance turbidity sampling around the dredging activities is remaining within acceptable levels and no water-quality-based nor biological indicators are triggered.

Yellow Operation State: is the first operation level of potential concern based on one or multiple indicators. Yellow operation state requires immediate action to minimize turbidity levels to reduce potential sedimentation concerns. Within the first 6 hours of this operation state (equal to one tidal cycle), the contractor will be allowed to perform self-elected restrictions, adaptations, and management techniques to try and return to acceptable turbidity and/or sedimentation levels. By 12 hours, if the contractor remains in yellow operation state, the contractor must also implement Government-mandated corrective actions (see Section H.4.3) in an attempt to further reduce turbidity and/or sedimentation levels.

Red Operation State: is defined as the operation level of unacceptable turbidity, sedimentation or seabed light levels which could also include or be independently triggered by unacceptable water quality-based or biological indicators. Under the trigger of this state, the contractor must implement Government-mandated corrective actions (see Section H.4.3), which may include ceasing dredging until further notice.

In cases where dredging ceases, the following must be achieved prior to resuming dredging;

1. Turbidity and/or sedimentation levels have returned to yellow or green operation states and no other biological indicators have been triggered.
2. Turbidity and/or sedimentation levels have returned to yellow or green operation states and biological evaluations have been conducted and determined to be sufficient to proceed with dredging. The dredging can restart in green operation state.
3. Turbidity and/or sedimentation levels have returned to yellow or green operation states, but biological evaluations have not been conducted or are not complete. In this case, dredging can resume under the yellow operation state until the biological evaluation has been conducted and determined to be sufficient to proceed with dredging.

In addition, the Corps plans to work with industry to develop and include a dashboard mounted inside the dredge with one of the three colors always lit (**Figure H-6**). At a minimum, the operation state will be viewable on a web portal, along with near-real time water quality and oceanographic data collected by each station (example in **Figure H-7**).

Figure H-6. Image portraying inside dredge with stoplight dashboard.

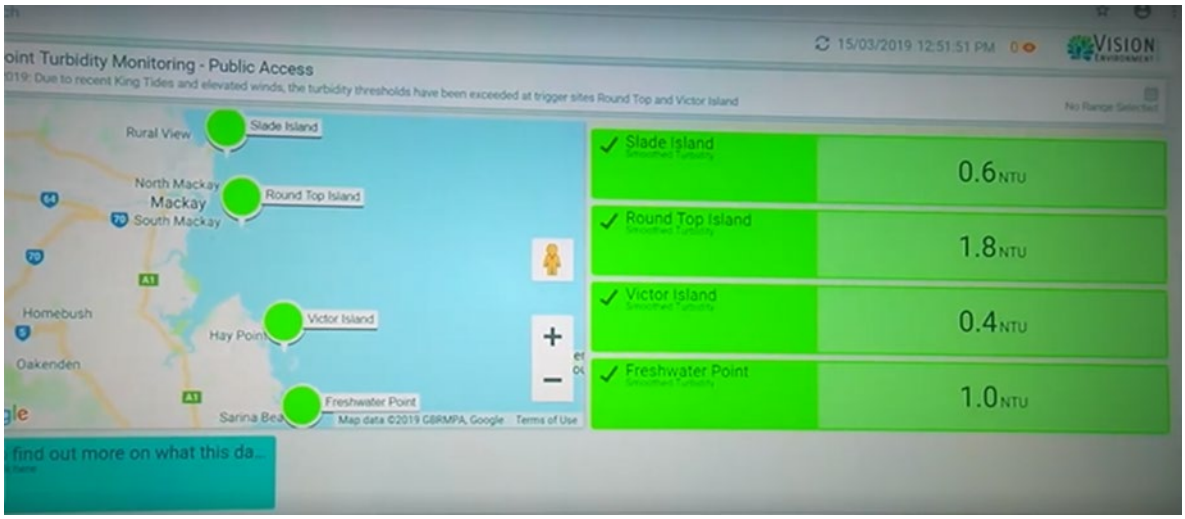

Figure H-7. Example image showing a web portal displaying data from each monitoring station.

H.4.1 Data Communications and Decision-Making

The DOSS will be programmed to automatically change the dredge operator's dashboard light when the Dredging Operation State has changed. In order to avoid an overly burdensome amount of e-mail notifications to the stakeholder/agency group, the following communications plan is proposed (**Table H-3**).

Table H-3. Communications plan for each DOSS state (Green, Yellow or Red).

Green	Yellow	Red
Stakeholders can view the dredge operation state at any time via the web portal.	Immediate e-mail notification provided when yellow operation state is triggered. EISES will automatically send this to subscribers.	Immediate e-mail notification provided when red operation state is triggered. EISES will automatically send this to subscribers.
The construction office will have someone available 24/7 (typically the Port Everglades Environmental Manager, see Section H.5.1).	The contractor shall be required to provide an e-mail within **6** hours (one tidal cycle) of a yellow trigger documenting the contractor elected techniques employed to reduce elevated water quality or biological indicators, and any outcomes achieved.	The contractor shall be required to implement government-mandated corrective actions, which may include ceasing dredging until further notice.
Weekly progress meeting calls for overall project updates.	Within **12** hours if water quality indicators remain elevated, the contractor shall be required to implement government-mandated corrective actions which can be prioritized prior to implementation.	The contractor shall be required to provide an e-mail within **24** hours of a sustained red operation state documenting all techniques employed to reduce elevated water quality or biological indicators, and any outcomes achieved.
	The contractor shall be required to provide another e-mail within **24** hours of a sustained yellow operation state documenting all	If the red operation state is held consistently (meaning the system doesn't default back to yellow over the course of

	techniques employed to reduce elevated water quality or biological indicators, and any outcomes achieved.	**48** hours) then the contractor shall hold a teleconference meeting to discuss remedial actions.
	If the yellow operation state is held consistently (meaning the system doesn't default back to green over the course of **48** hours) then the contractor shall hold a teleconference meeting to discuss remedial actions.	If dredging ceases, Contracting Office (COR) verbal approval will be required to restart dredging operations. Notifications to subscribers will be sent when dredging resumes.

H.4.2 Decision-Making Management Procedures

The Corps will coordinate internally and with the IWG to develop decision-making flow charts to guide management procedures during dredging operations for each DOSS and Operational Thresholds (**Figure H-8, Figure H-9, Figure H-10,** and **Figure H-11**).

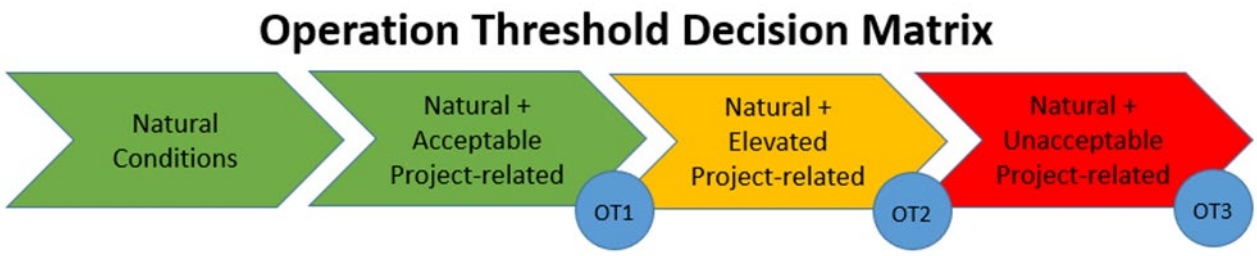

Figure H-8. Operational Thresholds (OTs) for each of the DOSS states (Green, Yellow or Red).

The GREEN Operation State Communications flow chart is shown in **Figure H-9**. The Operational Threshold (OT) 1 refers to the first indicator of project-related influence being picked up by the water quality monitoring and or biological monitoring but remaining within acceptable levels. The Contractor and USACE would discuss the observations and data during the routine weekly progress calls which are open to participation by the IWG. Daily reports will be generated in RMS with the referenced data.

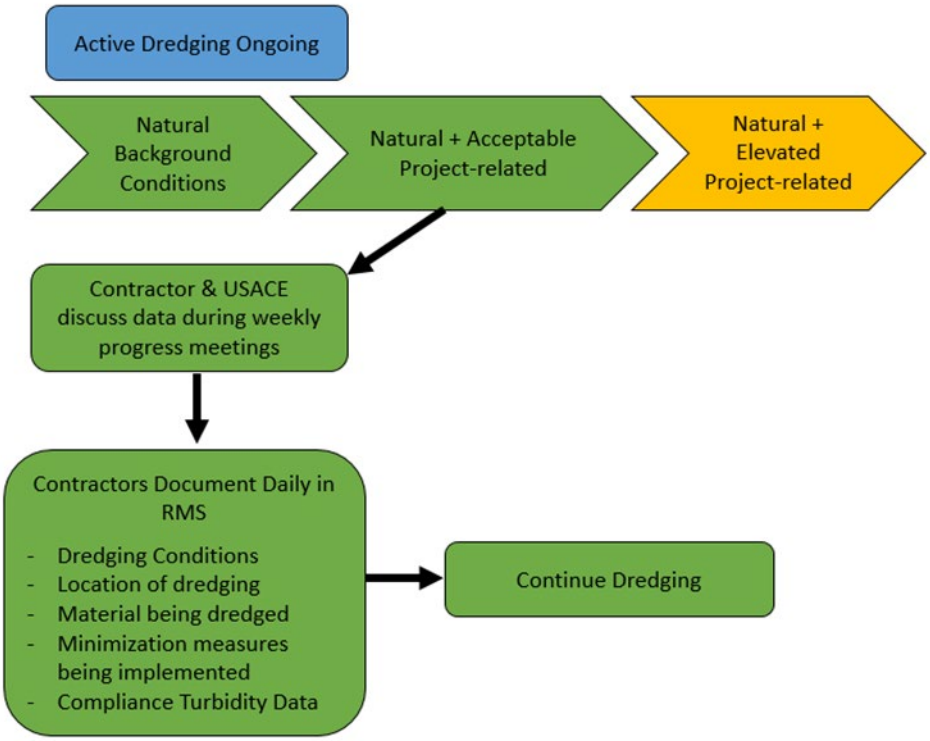

Figure H-9. GREEN Operation State and Communication Flow Chart under normal dredging conditions.

The YELLOW Operation State Communications flow chart after a yellow trigger/alert has been fired by EISES is depicted in **Figure H-10**. The OT2 refers to transition from green to yellow, but prior to red operation state. This is an indication that there is project-related elevated water quality and or biological indicators and requires an immediate adaptive management response. The DOSS system will provide immediate notification that the Yellow state has been triggered, and the contractor will be required to take a self-elected action within 6 hours (or government-mandated corrective actions within 12 hours if there is no improvement, see Section H.4.3), and provide an email notification regarding actions taken within 24 hours. This could lead back to a Green operation state based on monitoring data, or sustained yellow operation state requiring additional coordination, communication and action. While on the Yellow Operation state, monitoring data will be under elevated scrutiny (i.e., inspected in more detail or frequency).

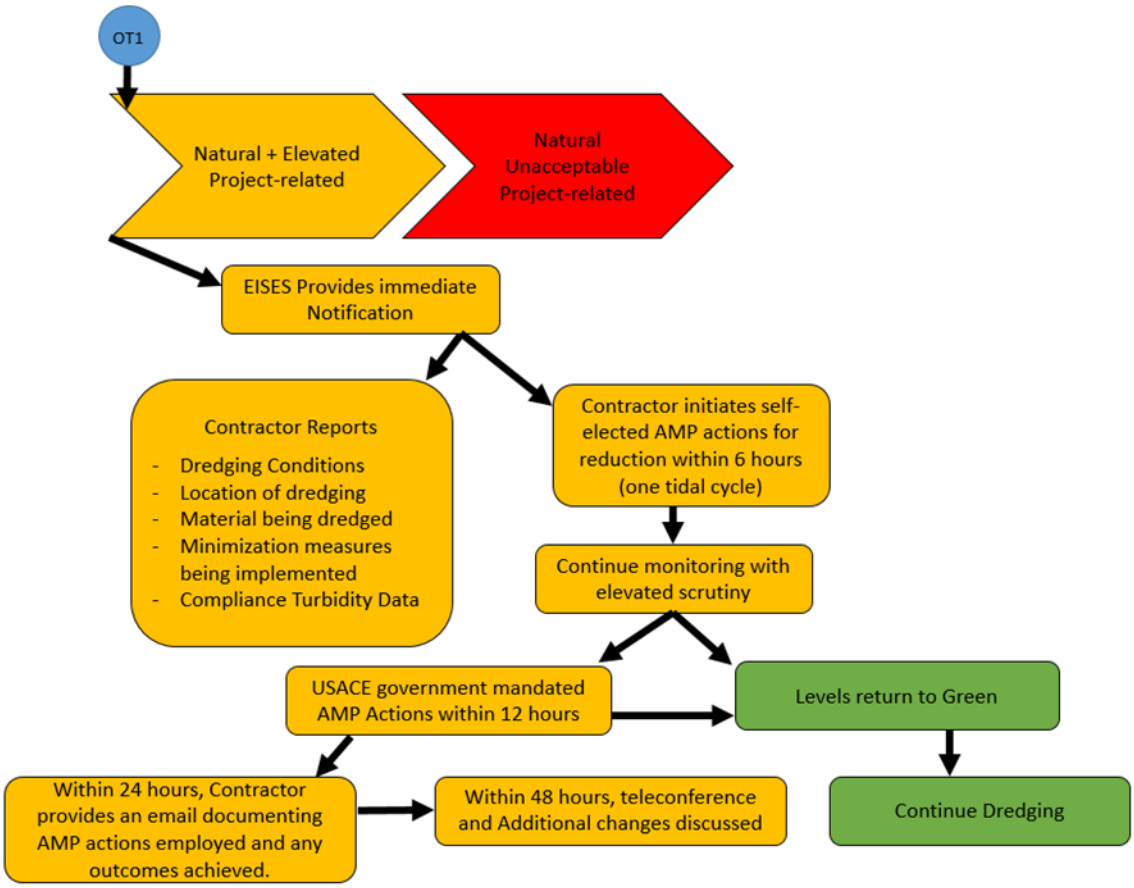

Figure H-10. YELLOW Operation State and Communication Flow Chart after a yellow trigger/alert has been fired by EISES.

The RED Operation State and Communication Flow Chart is shown in **Figure H-11**. The OT3 refers to transition from yellow to red operation state. This is an indication that there is unacceptable project related water quality and or biological indicators and requires an immediate adaptive management response. The DOSS system will provide immediate notification that the Red state has been triggered, and the contractor will be required to implement government-mandated corrective actions (see Section H.4.3) and provide an email notification regarding actions taken within 24 hours. While on the Red Operation state, monitoring data will be under elevated scrutiny (i.e., inspected in more detail or frequency).

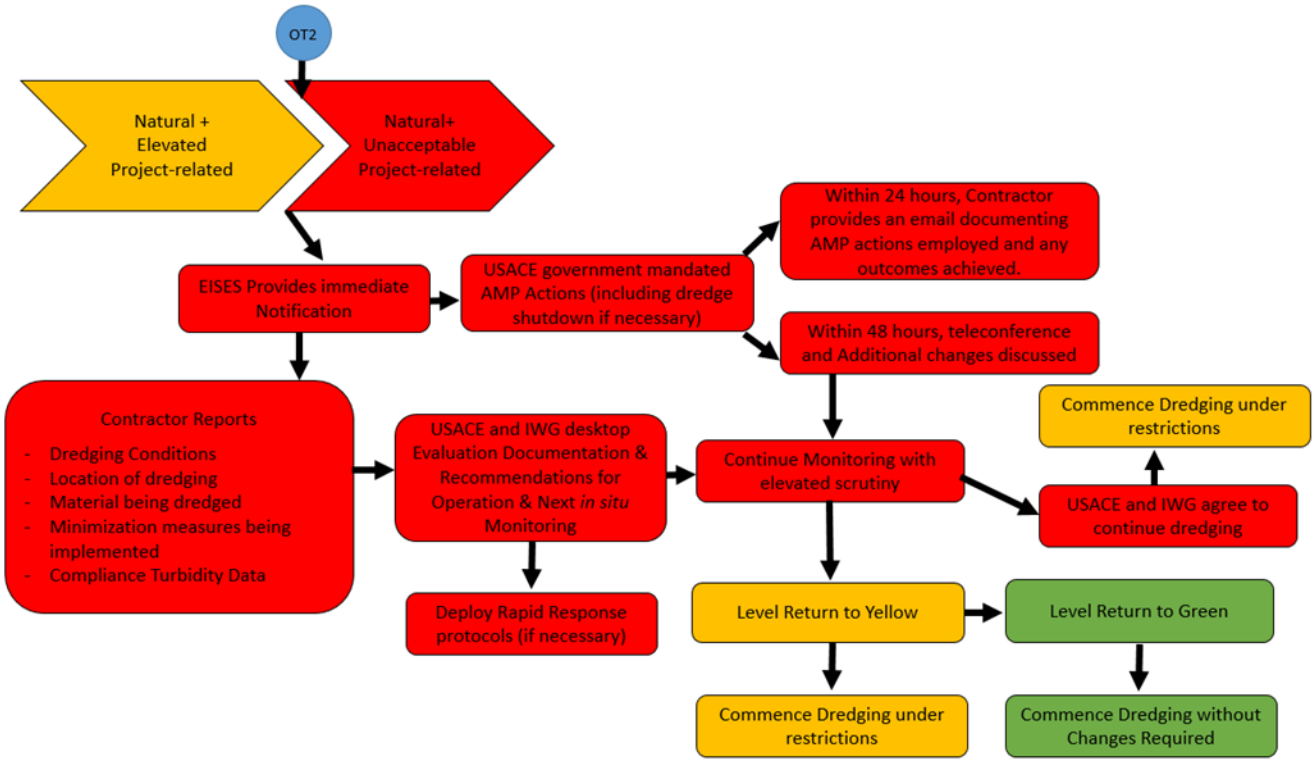

Figure H-11. RED Operation State and Communication Flow Chart after a red trigger/alert has been fired by EISES.

H.4.3 Dredge Management Measures

The following management measures shall be applied to reduce levels of suspended sediment reaching benthic resources. The Corps plans to engage industry during the draft and final SEIS phases to inform them of the measures to be imposed on the contractor.

H.4.3.1 Preventative Management Measures (DOSS Green State)

The Green Operation State assumes that all minimization measures [detailed in Section 2 (Alternatives) of the DSEIS] are in place and deployed. These management measures will be implemented where relevant and practicable and may be implemented even when additional responsive management measures (i.e., government-mandate corrective actions) apply. These include:

All dredges

- GPS, monitoring and automation systems on specified equipment
- Well-maintained, repaired and properly calibrated equipment

Trailing Suction Hopper Dredge (TSHD) and Split-Hopper Barges

- Ensure TSHD bottom doors and split-hopper barges hull seals inspected prior to mobilization and operated appropriately to prevent and reduce sediment loss during transit

- Optimizing under-keel clearance to reduce sediment re-suspension caused by propeller wash, where practicable

Cutterhead dredges

- Employ optimized cutterhead for differences in soil types to reduce spillage and suspended solids
- Optimize swing speed of the dredge head (e.g. reduce RPMs)

H.4.3.2 Government-Mandated Corrective Actions (DOSS Yellow and Red States)

Responsive management measures will be implemented on a case-by-case basis during the yellow and red states to help reduce excessive levels of suspended sediments from reaching benthic communities. The list of all the actions that may be implemented during the project is described below. However, the Corps will develop a plan to help expedite internal decisions regarding which corrective actions are more appropriate to use under different scenarios (i.e. depending on which trigger has been triggered).

All dredges

- Dredge shutdown until further notice (if necessary)
- Increase settling time for materials prior to decanting (the Corps will work with ERDC to develop a draft protocol and recommendations the contractor can use)
- Reduce or eliminate overflow allowances [beyond minimization measures, see Section 2 (Alternatives) of the DSEIS], especially when dredging near sensitive areas.
- Refine dredging and/or disposal operations based on forecasted metocean conditions (e.g. consider tidal cycles and strength of Florida currents). Dredging in the OEC could be avoided during periods of strong currents. This requires increased communication with the dredge contractor.
- Move to an alternate work area to continue dredging
- Deploy Air Bubble Screen (ABS) – The Corps will determine specific areas where this would be effective, but it is expected that the best potential may be to redirect currents around the dredging operation.
- Deploy turbidity curtains – The Corps will determine specific areas where this would be effective.

TSHD and Split-Hopper Barges

- Raising the overflow pipe to avoid spillage during transit
- Confining hopper dewatering to areas away from reef areas where practicable.
- TSHDs can be fitted with a turbidity reducing valve (environmental valve) within the overflow pipe.

Cutterhead dredges

- Discharge near the bottom

Mechanical dredges

- Optimize bucket fill (including minimizing the accent and decent speeds of the bucket)

H.5 PROJECT PERSONNEL

H.5.1 Port Everglades Environmental Manager

The Port Everglades Environmental Manager (PEEM) shall oversee all environmentally-related project actions including, but not limited to, resource and water quality assessments; monitoring; QA/QC of all data; will serve as the Point of Contact (POC) for environmental portions of the Adaptive Management Plan, Mitigation Plan, water quality compliance; and POC for all internal coordination (Corps) and external coordination for environmental matters. The PEEM will also be the POC for the IWG, primary monitoring teams and third-party monitoring team.

H.5.2 EISES Programmer

The Programmer's primary responsibility consists on building automated (expert-systems based) assessment capabilities for near real-time monitoring data. This position requires extensive experience making and analyzing automated in-situ measurements in surface and underwater reef environments and experience with telemetry using cellular, satellite, and acoustic transmission.

H.5.3 Data Collection Teams

H.5.3.1 Turbidity Vessel Monitoring Team

The Corps intends to hire an independent turbidity monitoring team to conduct the vessel monitoring turbidity sampling and dredge plume tracking. This team will be evaluated for demonstrated experience, technical approach plan, and overall best value to the government during procurement. This contractor will serve as the Corps' first warning system and is crucial to the success of this project. They will be required to incorporate data from the network of real-time turbidity sensors to inform the dredge plume tracking and be constantly posting live data when making observations in the field which could lead to immediate changes in the dredging operations. This team will be procured prior to construction (during the same time as the dredging contractor is being procured) but will remain independent from the dredging contractor.

H.5.3.2 Fixed-Station Monitoring Team

Deployment of the real-time buoys and/or bottom-mounted instrument packages will require an appropriate vessel with a crane and hoist capabilities, as well as an operations team designated for this purpose. Regular maintenance of stations after deployment consists of (1) manually download the data from sensors (frequency is expected to be between 30-60 days, regulated primarily by fouling of the optical sensors), (2) swapping or replacing any bad sensors and (3) replacing instrument batteries. Instrument troubleshooting and data processing/analyses will all be conducted upon returning to land. These operations are intended to be accomplished in collaboration with ERDC and AOML, though this

work may be contracted to a third party. Keeping these operations in-house constitutes a significant cost-saving measure to the Corps and provides the potential for future project applications for projects located near sensitive hardbottom resources.

H.5.3.3 Diver-Based Monitoring Team

The Corps intends to utilize a combination of the Jacksonville District's sub-contractors and resource agency personnel for scientific sampling and data collections. The Corps will collaborate with NMFS to ensure sampling methodology, protocol, and station locations are followed according to the agency baseline data collections presently in-progress.

H.5.4 Rapid Response Team

Data collection response teams will be locally situated for immediate deployment during alert stages. The Corps is still investigating options, but this could include personnel from NOVA, the U.S. Navy, or the Port Everglades.

H.5.5 Data Management Team

A Data Management team, comprised of an outside Jacksonville District source, shall be responsible for pre-construction, during construction and post-construction data storage, version control, accessibility of data (web portal), database design, long-term storage (archiving) and management of data throughout the project. The team shall be of sufficient size and capability to handle the amount of data expected from the monitoring efforts detailed in this plan.

H.6 References

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H.7 Addendum 1 - Water Quality and Oceanographic Data Collection (Fixed-station Monitoring Plan)

H.7.1 Introduction

The Port Everglades, Florida (PEV) Project is expected to deepen and widen the federal navigation channel to various authorized depths, and as a result, potentially cause direct and indirect impacts in nearby coral reef and seagrass habitats due to direct removal and/or project-related turbidity and sedimentation. The monitoring efforts here described are one of the main components feeding into the Adaptive Management Plan (AMP, detailed in this Appendix) and are focused on developing the appropriate methods for collecting relevant oceanographic and water quality data to facilitate adaptive management of the project during dredging operations.

The Corps, in collaboration with the Army's Engineer Research and Development Center (ERDC) Coastal and Hydraulics Laboratory (CHL), and NOAA's Atlantic and Oceanographic Meteorological laboratory (AOML) and National Marine Fisheries Service (NMFS), intends to deploy 16 bottom-mounted instrument stations and 8 buoys for continuous, near real-time environmental monitoring in the vicinity of the project area using existing, proven technologies. It is anticipated that instruments to be deployed throughout the duration of the project will include multi-parameter water quality sondes (measuring turbidity/temperature/salinity), Photosynthetically Active Radiation (PAR) sensors, acoustic backscatter instruments (LISST-ABS), acoustic altimeters, Acoustic Wave and Current Profilers (AWAC) or Acoustic Doppler Current Profilers (ADCP), and current tilt meters.

H.7.2 Plan Objectives

Sixteen instrument stations will be established throughout the study area for the purpose of collecting continuous water quality, hydrodynamic, wave, and bed elevation data. The data derived from these stations will be used for water quality monitoring and adaptive management during dredging operations; therefore, the 8 channel-side instrument stations are proposed to have near real-time capabilities.

There are three key objectives for this water quality and oceanographic data monitoring:

1. To provide data that are assessed against water quality-based triggers (see AMP) to inform management of dredging or dredge spoil placement activities.
2. To provide data to assist in inferring the cause of any potential changes in benthic organismal condition during dredging operations.
3. To collect data for a period between 6 months and 1 year prior to dredging to help establish baseline water quality and hydrodynamic conditions for the project area.

H.7.3 Methods

The main tasks to be conducted for this work include: 1) habitat characterization to identify deployment sites, 2) mobilization and deployment of bottom-mounted instruments, 3) connection of instruments to a moored buoy for near real-time data acquisition, and 4) data processing and reporting. Each of these tasks are described in more detail below.

H.7.3.1 Habitat characterization to identify deployment sites

The plan is to have a Corps / ERDC in-house dive team responsible for the mobilization, deployment, and maintenance/calibration of bottom-mounted instruments, with additional support from NOAA staff where applicable. Prior to deployment, the dive team will determine where to optimally position the instrument frames at each site. Efforts will be coordinated to determine an appropriate deployment location based on considerations of bottom conditions, proximity to traffic and infrastructure, water depth, and expected hydrodynamic environment, as well as the appropriate means to deploy instruments and cable the instruments to the buoy system. The goal is to deploy instrument frames adjacent to the reef in a manner that minimizes disturbance to the hard substrate and attached biota. Permitting requirements will be met prior to station establishment.

Once the area for instrument deployment has been selected, the dive team will photograph and record the physical condition of the surrounding environment in relation to the instrument location and arrangement. Physical characterization of the material present in the water column or in the seabed may also be conducted by divers at each site to help (1) understand the relationship between turbidity and sediment concentration, and (2) help distinguish native sediments from dredge-induced sediments. The Corps will discuss with the IWG appropriate methods for this task to ensure that the tasks described below (2-4) are accomplished.

H.7.3.2 Mobilization and deployment of bottom-mounted instruments

A total of 16 bottom-mounted instrument stations will be deployed across the project area to collect water quality and oceanographic data (Table H-4 and Figure H-12). Stations (project area and reference reefs) are meant to intersect stations that will also be monitored as part of the Biological Monitoring Plans (see Appendix G of the DSEIS), Dredging-related sedimentation monitoring). Data will be telemetered near real-time at the 8 channel-side stations to facilitate adaptive management of the project during dredging operations (Stations 5-12, Table H-4 and Figure H-12). The eight stations with near-real time data acquisition are meant to be distributed close to the Outer Entrance Channel to help monitor and respond to rapidly changing water quality, and assess any potential sedimentation impacts which may occur during dredging within the anticipated turbidity mixing zone (0-150 m). The remaining eight stations to be deployed (including reference stations) will capture water quality conditions beyond the 150 m zone. These stations will collect and store data internally, which will be manually downloaded during scheduled maintenance trips (every ~45 days, see below), OR as part of a Rapid Response Technique during the Dredge Operating State System (DOSS) Red State, if triggered by automated alerts from data collected at real-time channel-side stations (see AMP).

Reference stations will be located approximately 2000 m north and south of the channel (Figure H-12), in areas outside expected turbidity-generating activities associated with dredging operations. Reference reefs will be used for two main purposes in monitoring:

1. To help establish baseline conditions to use for the development and refinement of water quality-based triggers used in the AMP.
2. To help interpret any potential change observed in monitored variables at project area stations and to assist in inferring the cause of that change.

Table H-4. Proposed locations and habitat/zone type for each instrument station[1]. All stations (project area and reference reefs) are meant to overlay stations that will be monitored as part of the Diver-based monitoring described in detail in Section H-46, therefore, site names are the same.

Station	Site name	Latitude	Longitude	Real-time data acquisition
1	2000N-NRC-CPS	26 6.740	-80 5.759	No
2	2000S-ORL	26 4.468	-80 5.111	No
3	425N-IRL (Bean)	26 5.888	-80 5.698	No
4	500N-MRL	26 5.936	-80 5.248	No
5	50N-NRC	26 5.690	-80 6.096	Yes
6	50N-IRL	26 5.690	-80 5.700	Yes
7	50N-MRL	26 5.690	-80 5.326	Yes
8	50N-ORL	26 5.690	-80 5.025	Yes
9	50S-NRC-RS	26 5.527	-80 6.156	Yes
10	50S-IRL	26 5.532	-80 5.718	Yes
11	50S-MRL	26 5.534	-80 5.473	Yes
12	50S-ORL	26 5.535	-80 5.032	Yes
13	500S-IRL	26 5.276	-80 5.640	No
14	500S-ORL	26 5.276	-80 5.058	No
15	2000S-RS	26 4.468	-80 6.230	No
16	2000S-ORL	26 4.468	-80 5.111	No

[1] The Corps recognizes the low level of replication of instrument stations across the project area but believes the proposed efforts represent a valuable, feasible and economically viable plan. The Corps plans to design flexible instrument frames with the capacity to be relocated if needed based on consultation with the IWG, as we gain more information about hydrodynamics and sediment transport in the area, or in the case there are more appropriate areas that should be monitored as the project progresses. The Corps will also consider, if costs allow, including more real-time buoys across the project area.

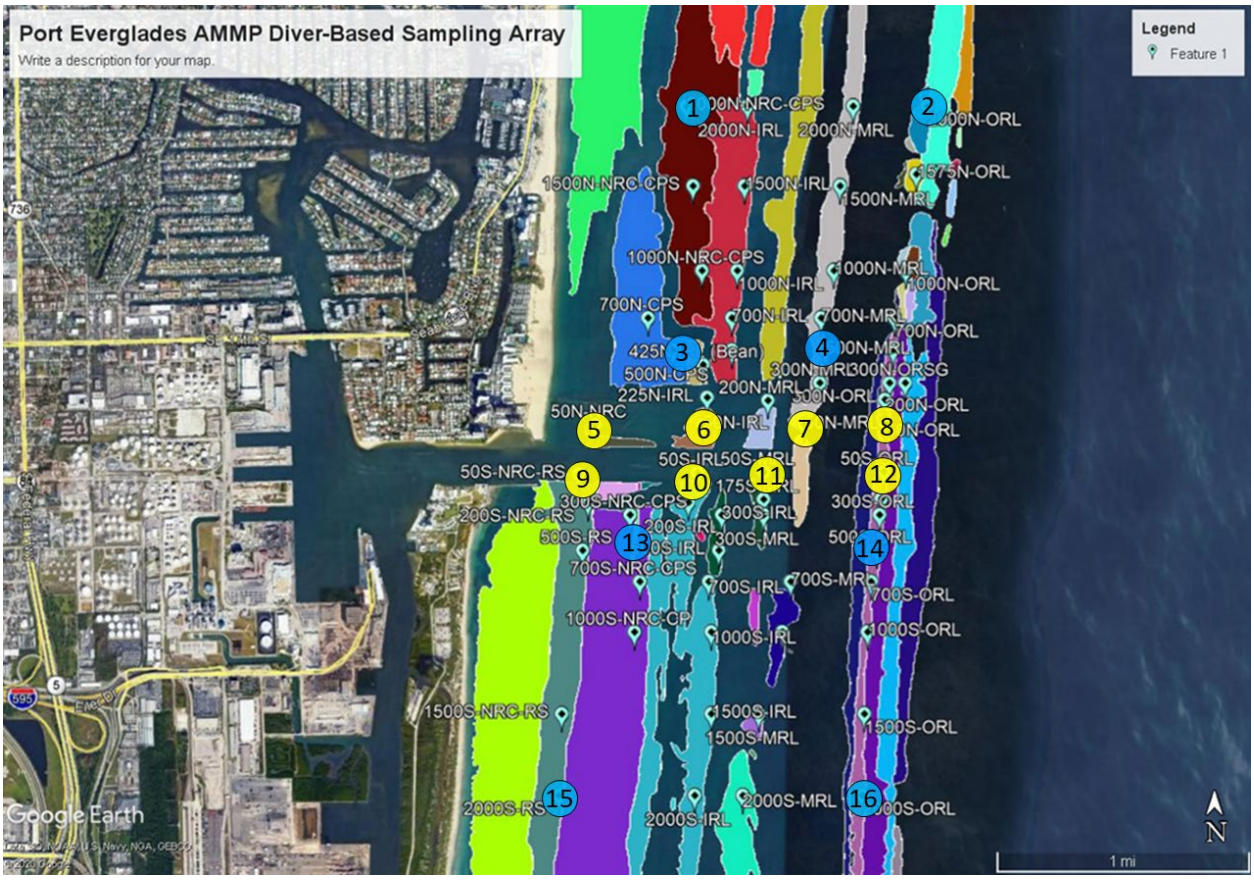

Figure H-12. Proposed array of fixed water quality stations in the project area. Stations denoted by yellow circles will have near real-time data acquisition capabilities, while data from stations denoted by blue circles will be manually downloaded during scheduled maintenance trips. Reference stations locations are denoted by station numbers 1-2 and 15-16. All stations (project area and reference reefs) are meant to overlay stations that will be monitored as part of the Diver-based monitoring described in detail in Section H.8).

The Corps will coordinate with the Navy's South Florida Ocean Measurement Facility (SFOMF) to ensure that stations south of the channel that fall within the Restricted Area (Figure H-13) do not have any acoustic instruments, or their locations are adjusted to avoid this area.

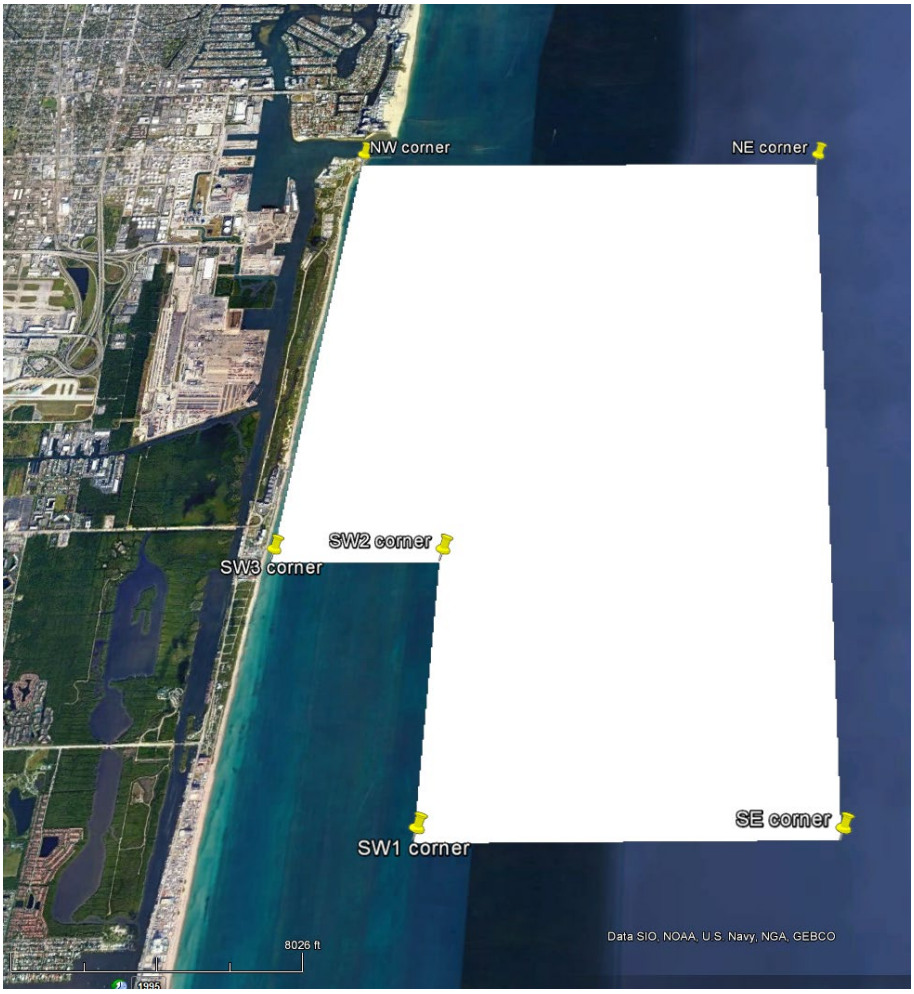

Figure H-13. Navy's Restricted Area boundaries denoted by the white polygon. Acoustic instruments cannot be deployed within this area.

H.7.3.2.1 Parameters to be measured

Water quality and oceanographic variables that will be measured at each station are listed in Table H-5, and include the following:

Turbidity (measured in Nephelometric Turbidity Units, NTU)
Turbidity will be measured using optical backscatter sensors (OBS), which provide an indirect measure of water clarity that may result from fine suspended particles and dissolved matter in the water column. With proper calibration, turbidity measurements can sometimes be used as a surrogate for the mass concentration of suspended solids; the response of the OBS measurements is more sensitive to particles less than 30 µm. Since they do not provide any information on the size distributions of the suspended particles, turbidity cannot be directly related to sedimentation potential. Additionally, these sensors are more prone to biofouling and are sensitive to air bubbles and changes in particle size.

Suspended Sediment Concentration (SSC, measured in mg/L)
The mass concentrations of suspended sediment will be approximated using acoustic backscatter instruments (LISST-ABS). Once calibrated, the LISST-ABS provides a surrogate measure of SSC in the range

of 1-30 mg/L depending on grain size. The instrument will also be used as a check for drift and errors in the optical turbidity measurements. The accuracy of the calibration function may diminish for particles less than 30 µm.

Sediment deposition (measured in cm)
Changes in seabed elevation will be monitored using high frequency acoustic altimeters. Laboratory tests (unpublished data, Coastal and Hydraulics Laboratory) show that changes in bed elevation can be resolved to better than 1mm for sandy to muddy sediments without bedforms. Coupled with turbidity, SSC, and hydrodynamic data, inferences can be made regarding deposition and erosion events. These data will be compared with diver-collected sediment depth measurements and sediment samples collected as part of the NMFS-developed biological data collection protocol described in the AMP.

Seabed light (PAR, measured in mol photons m^{-2} s^{-1})
The amount of light reaching the seabed provides a direct measurement of impacts from turbidity that is biologically relevant. Photosynthetically active radiation (PAR) is the range of the visible light spectrum available for photosynthesis (400-700 nm). PAR measurements are affected by cloud cover and sun angle, in addition to suspended solids concentrations. However, when combined with turbidity data, PAR measurements will help determine whether changes in photon flux density is a consequence of turbidity caused by dredging. PAR measurements will also be collected at the surface (in addition to the bottom-mounted sensors) to serve as reference values.

Water Temperature (measured in degree Celsius)
Water temperature is unlikely to be affected by dredging and/or dredging disposal operations. However, temperature will be recorded simultaneously with turbidity and salinity at all stations to identify natural thermal anomalies and differentiate potential dredging impacts on coral health from natural thermal anomaly events (e.g., coral bleaching). These measurements will be used to identify thermal stress events in conjunction with coral health outcomes.

Salinity (measured in ppt)
Salinity will be measured using the specific conductance of seawater, which is temperature corrected. Although salinity is unlikely be affected by dredging activities, salinity data may be useful for inference assessments. The salinity data can help differentiate the cause of an outgoing turbidity plume, which may result from high rainfall and terrestrial run-off, rather than dredging.

Waves and Currents (measured in m and m/s, respectively)
Waves and currents act to mobilize, suspend, and transport sediments from both the bed and at the site of dredging. Thus, characterization of the local hydrodynamic regime is important to determine the conditions for sediment mobility and deposition potential when sediment characteristics are also known, in addition to making inferences on sediment plume migration. This information is also required as input parameters for numerical sediment transport models.

Local wave and current conditions will be monitored using bottom-mounted, upward-looking acoustic wave and current (AWAC) profilers. These instruments will report the average current speeds and directions measured through the water column with 1-meter vertical bin spacing. Additionally, the nearshore wave field will be characterized using the acoustic surface-tracking (AST) feature, which bypasses the depth limitations imposed by pressure measurements and does not require corrections for Doppler effects.

Standard statistical wave parameters (wave height, period, direction) will be derived from spectral analysis of the time-series data. Together, measurements of metocean conditions (e.g. wave height, current speed, current direction) will be collected at selected stations and resulting data will be used in the interpretation of changes in water quality and coral health. These measurements will identify important relationships between metocean conditions, dredging activity and location, and any subsequent impacts to water quality and coral health. Addendum A list known independent datasets which describe the physical environment in the vicinity of the project area.

The regional hydrodynamics are not expected to vary considerably throughout the study area. For this reason, and cost considerations, AWACs will be deployed at four near real-time stations, two north and two south of the harbor entrance channel. However, other low-cost options, such as tilt meters, could be considered for other bottom-mounted stations.

Digital video (collected only at a subset of near real-time stations)
Downward-looking, high-resolution cameras with autonomous wipers will be deployed at a subset of the near-real time stations to acquire digital video throughout the project duration. Video may be useful for inference assessments on sediment impact and will also help monitor the status of the bottom-mounted instruments. For example, collection of photographs during collection of each turbidity data point would allow for verification of genuine turbidity events and allow for a more accurate data analysis.

Table H-5. Data collection per station. Parameters measured near the seabed are denoted with an "X". Stations denoted with an asterisk (13-16) fall within the Navy's Restricted Area (Figure H-13) and will not have acoustic instruments (LISST-ABS or acoustic altimeters).

Parameter measured										
Station	Real-time	Turbidity	SSC	Sediment deposition	Light (PAR)	Currents (ADCP or AWAC)	Currents (Tilt meter)	Waves	Temperature	Salinity
1		X	X	X	X		X		X	X
2		X	X	X	X		X		X	X
3		X	X	X	X		X		X	X
4		X	X	X	X		X		X	X
5	X	X	X	X	X		X		X	X
6	X	X	X	X	X	X		X	X	X
7	X	X	X	X	X	X		X	X	X
8	X	X	X	X	X		X		X	X
9	X	X	X	X	X	X		X	X	X
10	X	X	X	X	X		X		X	X
11	X	X	X	X	X		X		X	X
12	X	X	X	X	X	X		X	X	X
13*		X			X		X		X	X
14*		X			X		X		X	X

Parameter measured										
Station	Real-time	Turbidity	SSC	Sediment deposition	Light (PAR)	Currents (ADCP or AWAC)	Currents (Tilt meter)	Waves	Temperature	Salinity
15*		X			X		X		X	X
16*		X			X		X		X	X

Table H-6 lists details of each proposed sensor to be deployed (manufacturer, model, parameter measured, etc). Data from the sensors will be logged internally as well as transmitted by telemetry. The instruments will be optimally configured and calibrated by trained technicians prior to deployment. Deployment of the instrument frame will need a marine vessel equipped with crane and hoist capabilities.

Table H-6. Specific details for bottom-mounted sensors to be deployed.

Instrument	Parameter measured	Units	Sampling frequency	Measurement interval	Service interval
InSitu AquaTroll (or similar)	Turbidity, Temperature, Salinity	NTU, ^{0}C, ppt	1 Hz	5 min	30-45 days
Sequoia 8 MHz LISST-ABS	SSC	mg/L	1 Hz	5 min	30-45 days
Echologger AA400, 450 kHz altimeter	Bed elevation	cm	1 Hz	15 min	30-45 days
Wetlabs PAR sensor (or similar)	Light (PAR)	mol photons m^{-2} s^{-1}	1 Hz	15 min	30-45 days
Nortek AWAC	Wave height/ direction, Water speed/ direction	m/s, m	2-4 Hz 6 min burst	30 min	30-45 days
Lowell TCM-1	Currents	m/s		15 min	30-45 days

H.7.3.2.2 Maintenance trips

Regular maintenance trips will be scheduled (approximately every ~45 days) in order to service the instruments; inspect, adjust, and/or perform any necessary repairs to the instrument frame; check connections to the moored buoy data system (see below); clean sensors due to bio-fouling; download data; and replace batteries. Data from the instruments will be downloaded and stored on an external hard drive for archiving or processing in the event of data gaps or failure of the telemetry system. A second set of sensors will be available to replace any fouled or malfunctioning instruments until troubleshooting and maintenance/calibration has been performed. Biofouling of the instrument sensors causes data degradation. Optical sensors are the most sensitive to biofouling and dictate the minimum servicing

interval. The optical sensors used in this work (PAR, turbidity) are equipped with wipers and copper guards to maximize the service interval and maintain data quality. Acoustic instruments have a longer service interval (see Table H-6) and are expected to need less frequent swap-outs. Finally, photos will be taken to document the condition of the station and surrounding environment and all activities and notable observations documented in a field report to be shared with the IWG on a rolling availability. Sediment samples will be also collected, and analyses conducted as deemed appropriate to characterize their composition and grain size distribution (as described in the AMP and the Sedimentation-related Monitoring plan in Appendix G of the DSEIS).

H.7.3.3 Connection of instruments to moored buoy for near-real time data acquisition

The Corps plans to collaborate with NOAA's AOML for mobilization and deployment of moored buoys at the channel-side near real-time stations (Figure H-12). To moor the buoy, the Corps plans to use a double-anchoring system near each proposed location, in hardbottom devoided of any large stony corals or octocorals. If feasible, the buoy will be moored in close proximity to coral reef or hardbottom habitat; alternatively, the buoy may be moored in sandy bottom in between the reef lines. The bottom-mounted frames will be flexibly designed, to simplify re-deployment at multiple distances from the buoy, if needed.

Pending results from the trial station planned during O&M dredging operations (see AMP), the goal is to have bottom-mounted instruments communicate remotely with the buoy via an acoustic modem pair (NOAA has used both LinkSys and Teledyne Benthos). The effective communications range (100-600 m) will depend on the ambient acoustic and oceanographic characteristics of the deployment environment and will be determined at a specified minimum hourly bandwidth. Electronics on each frame would gather appropriate data every hour, half an hour (as described in Table H-6) or more frequent (if possible), and transmit data acoustically to the buoy; the buoy would then multiplex data from instruments into an hourly data download via cellular modem. Data downloads would be gathered ashore, archived, and made available to stakeholders in raw and quality-controlled formats via the Web.

H.7.3.4 Data processing and reporting

H.7.3.4.1 Quality assurance and quality control (QA/QC)

All data collected by instruments will be subject to rigorous QA/QC procedures. Due to issues with biofouling of equipment, a regular maintenance schedule will be implemented, and all loggers retrieved, downloaded, cleaned and re-deployed or replaced as necessary to maintain the quality of data collected. Data will be analyzed using customized, automated Matlab data analysis programs which may include coordinate transforms, statistical analysis, and application of calibration coefficients. Real-time data QA/QC will follow Quality Assurance of Real-Time Oceanographic Data (QARTOD) standard methods to minimize errors (e.g., range limitation, de-spiking, signal to noise thresholds, and flat line tests).

H.7.3.4.2 Minimizing and dealing with data loss

Half of the instrument stations will have near real-time data acquisition capabilities; therefore, malfunctions or instrument losses/damage can be picked up almost immediately. Once a malfunction or instrument loss/damage is identified, equipment will be repaired or replaced within a maximum of 48 hours (weather permitting), or sooner where possible. In this case, a Rapid Response Team may be deployed to download data, and swap/replace any bad sensors or instrument batteries (see AMP). Data

loss in 2 or more near real-time stations will trigger a Yellow Operation State (see AMP) until sensors are transmitting data again.

Protocols need to be developed in conjunction with the IWG to deal with data loss from non-real time stations, which won't be picked up until scheduled maintenance trips. The first step is to identify how much data is missing (temporal and spatial assessment). In the case of significant data loss (>15 consecutive days) for one or more stations, the Corps may implement a tiered data analysis approach (see AMP) which will include a more in-depth analysis of the water quality and biological data collected, and may entail additional Rapid Response techniques (where applicable) to ensure no significant project-related impacts have occurred during that time period.

H.7.3.4.3 Data products

Data products per station will include a time-series of water quality parameters (turbidity, suspended sediment concentration, light attenuation, temperature, and salinity), changes in bed elevation, and standard wave parameters, mean current speeds and directions, and current profiles. Data from near real-time stations will be stored in a web portal for public access. This data will be assessed for the likelihood of ecological impacts using an existing operationally focused expert systems tool (EISES), and alerts shared with stakeholders via automatically generated reports as described in the AMP. Data from non-real-time stations will be submitted on a rolling availability to a public website and whenever possible integrated with near real-time data from the channel-side stations in EISES, as described in the AMP. In addition, after each maintenance trip, a summary field report will be generated for distribution to the IWG.

H.7.3.4.4 Data management

Given the large amount of data expected from this plan over the course of the project, the Corps will determine appropriate short- and long-term storage of the data. A Data Management team will be responsible for data storage, version control, accessibility of data, long-term storage, and management of data throughout the project as described in the AMP. The team shall be of sufficient size and capability to handle the amount of data expected from the monitoring efforts detailed in this plan.

H.7.4 Personnel

This work is intended to be accomplished by personnel from the Corps, ERDC, and NOAA, though this work may be contracted to a third-party. The dive team will consist of two divers, one dive supervisor/safety officer, and one boat captain/dive tender. The dive supervisor will be responsible for preparing and executing the dive safety plan in accordance to the Corps policies and procedures as outlined in EM 385-1-1. Team members shall have experience analyzing automated in-situ measurements using both optical and acoustic sensors, as well as experience with telemetry using cellular, satellite, and/or acoustic transmission.

H.7.5 Supplement: Existing datasets describing the physical environment of the project area

H.7.5.1 Currents

Two types of currents affect Port Everglades, offshore currents and currents within the harbor itself. Offshore currents affecting Port Everglades Harbor include littoral currents adjacent to the shoreline, inlet related tidal currents, and strong currents resulting from the proximity of the Florida Current, a component of the Atlantic Gulf Stream. Harbor currents arise from flood and ebb tides, river outflows, and power plant discharge.

Nearshore and Offshore Currents Observations

The Florida Current produces the strongest offshore current that affects Port Everglades. Currents shed from the Florida Current are highly variable in magnitude and unpredictable in occurrence. Research conducted in the Fort Lauderdale area indicates that the complex relationship between the Florida Current and the locally narrow continental shelf results in an inshore front that is dominated by horizontal wave-like meanders and sub-mesoscale eddies with strong horizontal shear (Shay et al. 1998). During a National Research Laboratory experiment conducted in 2001 both surface current mapping and bottom-mounted ADCPs captured significant current reversals and the presence of eddies in the vicinity of Port Everglades (Martinez-Pedraja et al. 2004).

A number of studies have been performed in the nearshore and offshore of Port Everglades studying local currents. As part of the Broward County Coastal Ocean Water Quality Study conducted by NOAA (Carsey et al. 2015) four ADCPs were deployed, two north and two south of Port Everglades. Measurements were collected between fall 2010 and winter 2012 / spring 2013. In a subsequent study, ADCPs and tilt current meters were deployed to measure currents. The ADCPs were deployed offshore of Hollywood in the same location as the 2010 – 2012 study, in a cross-shore array of measurements. This dataset covered a little over a year from September 2014 to November 2015.

Nova Southeastern University (NSU) collected current and wave data offshore of Port Everglades over a long timeframe from June 1999 to May 2013. The measurements were taken about 2.5 km south of the inlet in 11m water depth. During one month in the summer of 2010, an AWAC was also deployed at the same location to measure waves as well. An additional ADCP was deployed by NSU between January 2007 and November 2010 about 16.5km northeast of the inlet in about 240m water depth.

Florida Atlantic University (FAU) has also collected measurements in the area, primarily in the far offshore. Between 2011 and 2014 FAU deployed eight different instruments at various times and in over 300m water depth.

Harbor Currents: Observations

The combination of generally predictable flood and ebb currents with various other sources of flow intrinsic to Port Everglades creates a highly unpredictable environment where localized currents can develop unexpected with extreme magnitude and variable direction. NOAA conducted an extensive field study throughout the Port Everglades Harbor during 2009 (http://tidesandcurrents.noaa.gov/currents09). Five ADCPs were deployed as shown in Figure H-14 with the prefix “PEV”. These covered the inlet, main turning basin and south access channel. Measurements were generally taken over a two-month period between January and March 2009. Subsequent to this study the ADCP at the inlet throat was re-deployed between May 2009 and June 2011.

Taylor Engineering also collected about one month's worth of measurements within the basin during summer 2016. The stations with the prefix "T" are the four Taylor Engineering ADCPs within the basin (Figure H-14). Taylor additionally deployed another ADCP to the north near Hillsboro Inlet and to the south in Dumbfoundling Bay.

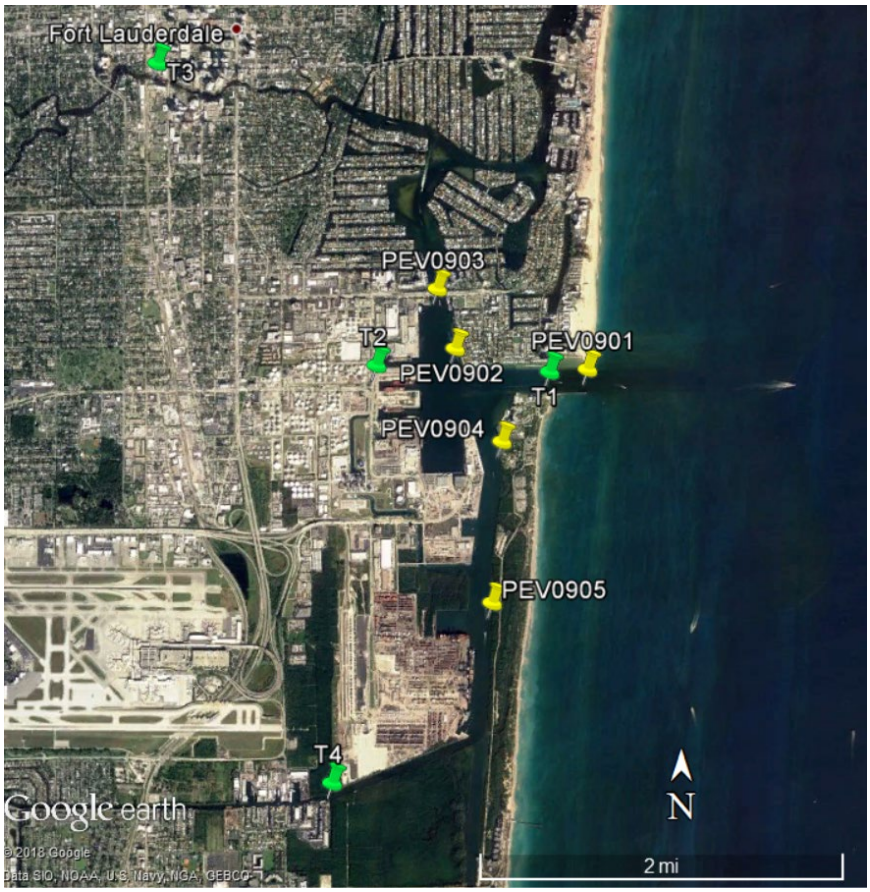

Figure H-14. Port Everglades Harbor ADCP locations used by NOAA in 2009.

Applied Coastal Research conducted a vessel mounted ADCP survey of the Port Everglades basin in April 2002 along lines depicted in Figure H-15.

Figure H-15. Port Everglades ADCP transects lines used by Applied Coastal Research in 2002.

H.7.5.2 Waves

There are not many direct wave measurements in the Port Everglades area. Deepwater wave conditions representative of Port Everglades can be obtained using hindcast data available from WIS station 63467 to define the wave climate. Similar to wind conditions, wave conditions in South Florida experience seasonal variability. Winter months show a marked increase in wave height due to Northeaster activity. The intensity and direction of these winter wave conditions are reflected in the dominant southward sediment transport and seasonal erosional patterns. Summer months experience milder conditions with a more shore normal propagation of incident waves.

Overall, wave conditions at Port Everglades are dominated by wind waves with limited exposure to open-ocean swell. Open-ocean swells originating from southeast through the northeast are blocked by two large shoals north and west of the Bahamas known as the Little Bahama Bank and the Great Bahama Bank, respectively. Water depths across the Bahama Banks average about 30 feet, so longer-period swells are reduced by bottom friction or the presence of land masses as they traverse the Bank. The minimum fetch between the western edge of the Banks and Port Everglades is about 50 miles, which allows ample

distance for the generation of shorter-period wind waves in the deep waters of the Florida Straits. During severe storm events such as hurricanes and tropical storms, high wind velocities can generate large, damaging waves over the relatively short distance between the Bahamas and Florida.

H.7.5.3 Salinity

The Broward County Department of Planning and Environmental Protection maintains multiple monitoring stations throughout the waterways of Broward County. Three of these stations fall within Port Everglades Harbor (Figure H-16). Station 38 is located at the ICWW 100ft north of the east fender of the 17th street Causeway Bridge and 100ft west of the east bank. Station 39 is located 50ft west of the east bank. Station 47 is located at the Dania Cutoff Canal 200ft west of the ICWW. Changes in salinity levels may be attributed to fluctuations in local rainfall levels as well as variations in freshwater discharge levels from New River and the Dania Cutoff Canal.

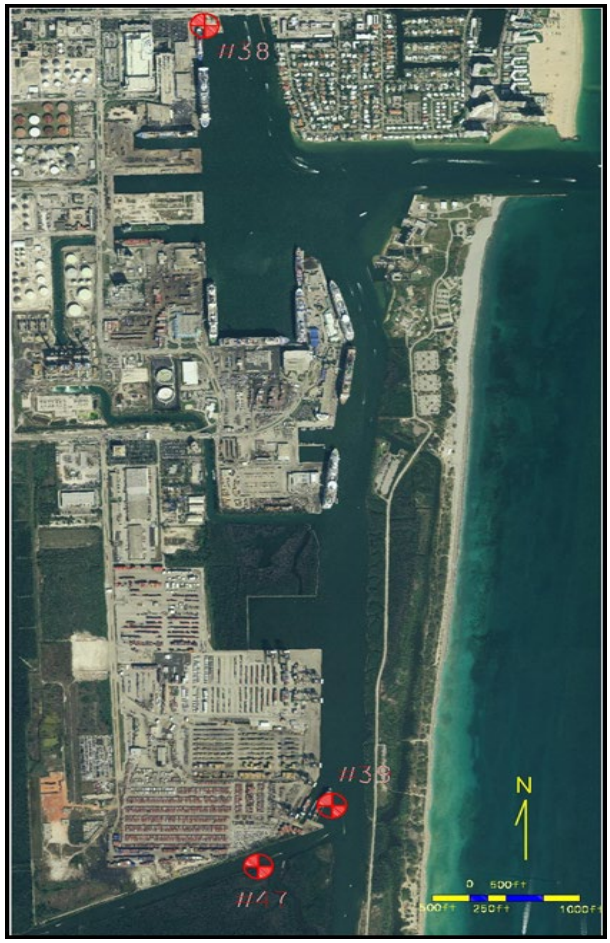

Figure H-16. Port Everglades Salinity Stations used by DEP.

H.7.5.4 Turbidity

Port Everglades through contract with Dial Cordy and Associates (DCA, 2018) collected one year's worth of turbidity measurements during 2017-2018 at two locations (Figure H-17) offshore of Port Everglades.

The nearshore location was in approximately 4.5 m water depth and the offshore sensor was located in approximately 10.5 m water depth. The overall turbidity levels varied with wave, rainfall, and freshwater canal releases, among other factors. Average values reported were 4.62 NTU (SD±6.99) offshore (excluding anomalous values) and 4.60 NTU (SD±12.30) nearshore (excluding anomalous values) over the course of the year. A significant spike in turbidity values was recorded during the passage of hurricane Maria in mid-September of 2017.

Figure H-17. Turbidity stations north of the Port Everglades channel used by DCA in 2017-2018.

H.7.6 References

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H.8 Addendum 2 - Port Everglades Adaptive Management Diver-Based Monitoring for Conservation of Coral and Coral Reef Habitats

H.8.1 Introduction

Sediment depth measurements are a reliable, inexpensive, and rapid way to determine if a dredging project has impacted coral reefs and reef habitats. Based on a review of literature from Atlantic/Caribbean and Pacific coral reef studies. Nelson et al. (2016) determined sediment depths measured during a dredging project less than 0.5 cm over reef would result in minimal stress to coral reefs, whereas sediment depths between 0.5 cm and less than 1.0 cm would result in moderate stress, and sediment depths greater than 1.0 cm would result in severe stress including coral mortality. In 2016, sediment depth measurements were collected at Port of Miami impact and reference areas (Miller et al. 2016, NMFS in preparation). While the reference-to-impact site comparisons are statistically different at sites (described in Miller et al. 2016), there is no baseline from before dredging began, with which to compare those measurements.

Having a reliable baseline of sediment depth measurements that is collected over different times of year, (and potentially over multiple years) can help facilitate effective adaptive management of dredging projects conducted near coral reef habitats. In December 2017 and June 2019, baseline interval sediment depth transect data were collected by National Marine Fisheries Service (NMFS) at 54 coral reef sites near Port Everglades, Fort Lauderdale, Florida (Figure H-18) (Swart 2018, NMFS in preparation). Average sediment depths were generally 0.4 cm along the Inner Reef, Middle Reef, and Outer Reef habitat sites, which is consistent with the findings in Nelson et al. (2016) (Swart 2018, NOAA in preparation). Based on the success of these pilot-scale interval sediment depth and mineralogy data collections in 2017, NMFS conducted additional sampling at Ports off southeast Florida in 2019 to help inform the understanding of ambient sediment depths and composition over various reef habitats and during different times of year (e.g. summer and winter) prior to the beginning of the PEV.

Effective adaptive management of dredging activities requires a combination of electronic instrumentation, vessel-mounted monitoring platforms and *in-situ* observations to help rapid decision-making and prevent adverse impacts to benthic resources while operations are being completed. Interval sediment depths and characterization transects, belt transects assessing biotic indicators of sediment stress and micro-transects of benthic coverage are being included as components of this *in-situ* Diver-based monitoring protocol[2], which is part of the Adaptive Management Plan for the PEV Project.

[2] This monitoring protocol was developed in collaboration with NMFS.

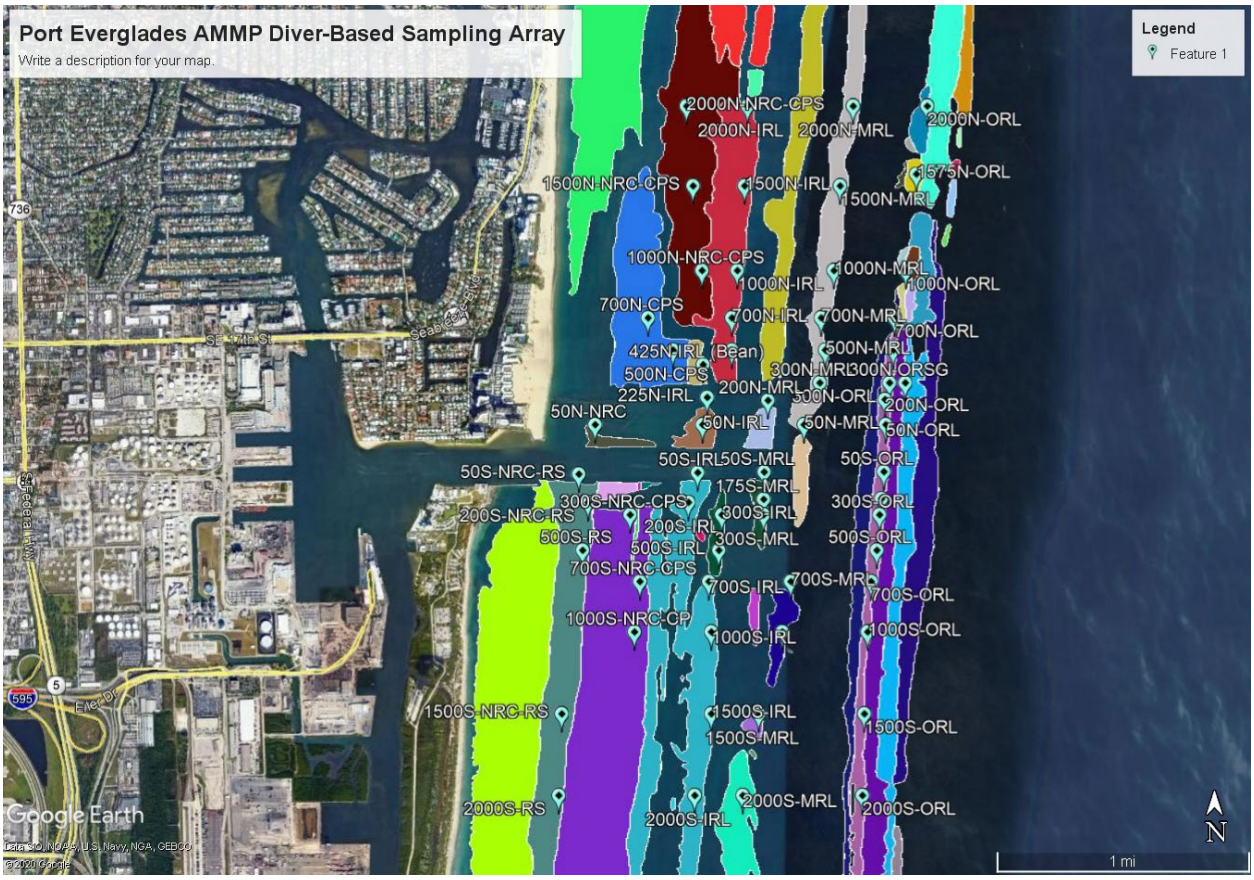

Figure H-18. Study domain with location codes describing distance and direction from channel edge and mapped habitat. Distance from the channel edge was measured for most sites using Google Earth in 2017. The image was updated in 2019 and 2020. Reference sites will be determined and added to the Adaptive Management in-situ monitoring array at a later date.

H.8.2 Plan Objectives

There are four main objectives for this Diver-based monitoring, which include:

1. Collect data to estimate sediment depths for use in adaptive management decisions to avoid and minimize environmental impacts of a large-scale port dredging project
2. Collect data on biotic sediment stress indicators for use in adaptive management decisions to avoid and minimize environmental impacts of a large-scale port dredging project.
3. Collect data to assess the status of sediment stress on ESA listed corals for use in adaptive management decisions to avoid impacts to listed species from a large-scale port dredging project.
4. Use information collected in Objectives 1-3 to inform adaptive management monitoring, assessment of adaptive management triggers and implementation of adaptive management actions to avoid and minimize adverse effects of future port deepening projects in the vicinity of sensitive ecological resources.

H.8.3 Methods

H.8.3.1 Adaptive management sampling array

The proposed adaptive management sampling array consists of up to 76 sites (68 plus 8 reference sites) in 8 habitats ranging between 50m and 2000m north and south of the existing channel edge in the vicinity of Port Everglades, Fort Lauderdale, FL (Figure H-18). Baseline sampling has been conducted at most of this array in 2017 and 2019. Assessment sites were added to the previously sampled 54-site array at approximately 200m north (4 sites) and 200m south (4 sites) of the channel. Appropriate reference sites (eight sites total) will be added to the sampling project area at a future date for each of the four primary coral reef habitats (nearshore ridge, inner reef, middle reef and outer reef), north and south of the channel. Reference site selection will be based on discussions with the IWG on prospective sites when they have been recommended as part of the overall project.

H.8.3.2 Personnel – Dive teams

Operations are planned for four divers onboard one vessel each day, consisting of two teams of 2 divers each. Eight dives are planned per day (four for each team), depending on depth profiles and scheduling. Dive teams on board the vessel will provide a safety diver, a designated person in charge/vessel operator and surface support while the other dive team is sampling.

A weighted float is deployed on the site coordinate. Divers enter the water and descend along the line to the weight.

Diver 1: Swims out 30m tape, Conducts two 10m biotic sediment indicator belt transects (including photographing examples of sediment stress); conducts three 1m micro-transects for sediment, algal and cyanobacteria coverage; and conducts one roving diver census of Endangered Species Act listed corals within 10m of the transect tape including both ends of the tape, Diver 1 reels up tape at end of sampling.

Diver 2: Conducts one interval sediment depth transect and sediment characterizations from 1 to 30m; videos benthos along transect tape at end of sampling. If a sediment sample is required because of sedimentation index or biotic sediment stress indicators are yellow or green at a site, the sample will be collected by Diver 2 near the 30m mark of the transect after completion of the ISD and sediment characterization data collection and before the video.

Figure H-19 depicts the sampling approach described above. Underwater operations are expected to consist of 30-35 minutes of bottom time (plus descent, ascent and safety stop). Based on prior experience, it is expected the two teams can sample 8 sites per day.

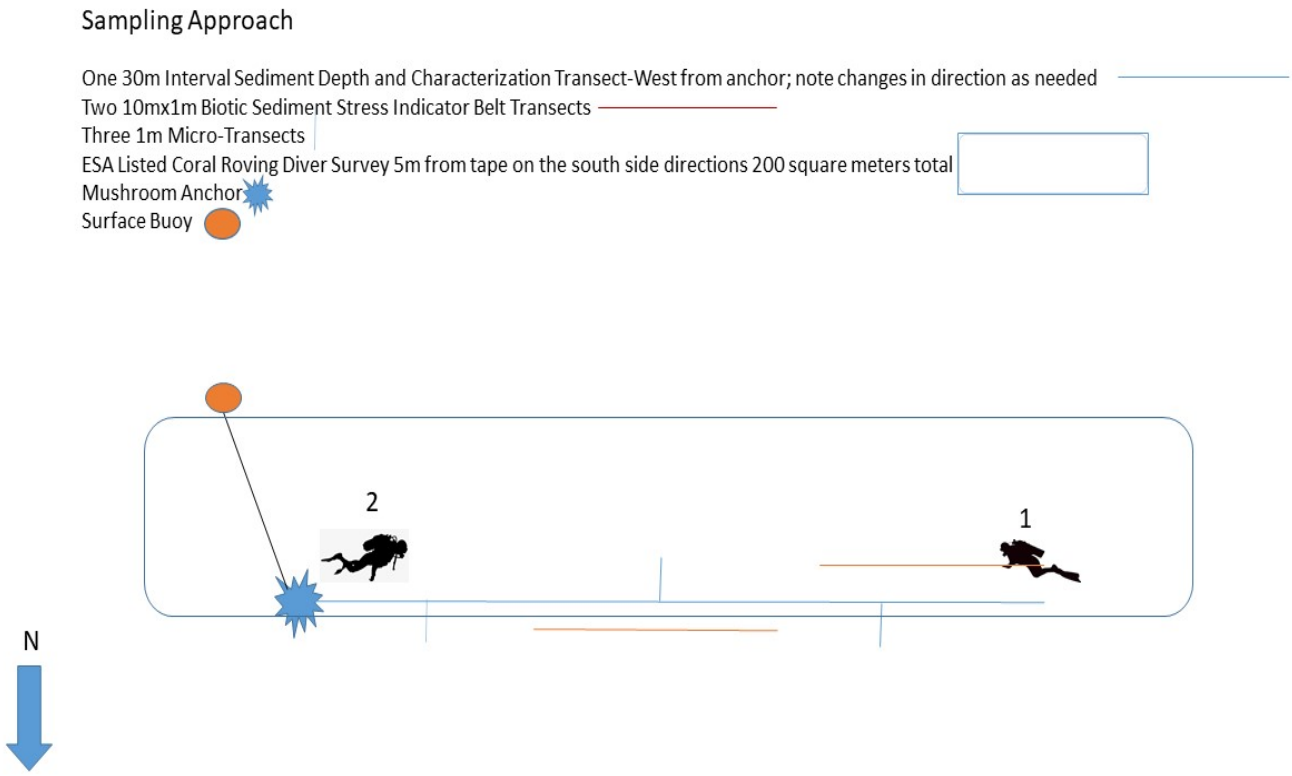

Figure H-19. Sampling approach to be used for the *in-situ* Diver-based monitoring

H.8.3.3 Monitoring Schedule

The Port Everglades AMP in-situ sampling plan is being designed to allow assessments as frequently as bi-monthly (every 2 weeks), of sedimentation on reef habitats and biotic indicators of sediment stress. Field sampling in the Port Everglades vicinity will be conducted bi-monthly at Tier 1 assessment sites (Table H-7) located approximately 100, 200, 300, and 500m north and south of the channel (30 sites). If the sedimentation index and biotic sediment stress index indicators are green, the survey event is complete. Adaptive Management reference sites (8 sites total, 4 north and 4 south of the channel; exact locations to be determined) will be sampled twice per calendar year (preferably June and December) if sedimentation index and biotic sediment stress index indicators remain green at all Tier 1 assessment sites.

Table H-7. Tier 1 sites (N = 30).

Site Name	Latitude	Longitude
50N-ORL	26 5.690	-80 5.025
50N-MRL	26 5.690	-80 5.326
50N-IRL	26 5.690	-80 5.700
50N-NRC	26 5.690	-80 6.096
200N-ORL	26 5.773	-80 5.028
200N-MRL	26 5.770	-80 5.459
225N-IRL	26 5.780	-80 5.683

425N-IRL (Bean)	26 5.888	-80 5.698
300N-ORSG	26 5.828	-80 4.953
300N-ORL	26 5.828	-80 5.011
300N-MRL	26 5.828	-80 5.268
500N-ORL	26 5.936	-80 4.997
500N-MRL	26 5.936	-80 5.248
500N-IRL	26 5.936	-80 5.592
500N-CPS	26 5.936	-80 5.809
50S-ORL	26 5.535	-80 5.032
50S-MRL	26 5.534	-80 5.473
50S-IRL	26 5.532	-80 5.718
50S-NRC-RS	26 5.527	-80 6.156
200S-ORL	26 5.446	-80 5.041
175S-MRL	26 5.444	-80 5.475
200S-IRL	26 5.434	-80 5.752
200S-NRC-RS	26 5.434	-80 6.122
300S-ORL	26 5.393	-80 5.048
300S-MRL	26 5.393	-80 5.475
300S-IRL	26 5.393	-80 5.629
300S-NRC-CPS	26 5.393	-80 5.967
500S-ORL	26 5.276	-80 5.058
500S-IRL	26 5.276	-80 5.640
500S-RS	26 5.276	-80 6.142

If a sedimentation indicator (sedimentation index or biotic sediment stress index) is yellow at one or more Tier 1 sites, sampling will also be conducted at Tier 2 assessment sites (Table H-8) located 700 and 1000m from the channel (north or south), as well as the adaptive management reference site for the same habitat that has sedimentation index or biotic sediment stress index in a yellow indicator. An applicable reference site is only sampled when a yellow or red trigger is observed for a Tier 2 array site of the same habitat in the same direction from the channel.

Table H-8. Tier 2 sites (N = 16).

Site Name	Latitude	Longitude
700N-ORL	26 6.042	-80 4.992
700N-MRL	26 6.042	-80 5.263
700N-IRL	26 6.042	-80 5.592
700N-CPS	26 6.042	-80 5.901
1000N-ORL	26 6.198	-80 4.950
1000N-MRL	26 6.198	-80 5.216
1000N-IRL	26 6.198	-80 5.572
1000N-NRC-CPS	26 6.198	-80 5.702
700S-ORL	26 5.173	-80 5.079

700S-MRL	26 5.173	-80 5.375
700S-IRL	26 5.173	-80 5.677
700S-NRC-CPS	26 5.173	-80 5.931
1000S-ORL	26 5.007	-80 5.092
1000S-MRL	26 5.007	-80 5.406
1000S-IRL	26 5.007	-80 5.668
1000S-NRC-CPS	26 5.007	-80 5.951

If any Tier 2 site has sedimentation indicators (sedimentation index or biotic sediment stress index) in the red, sampling will also occur at the Tier 3 assessment sites (Table H-9) including 1500 and 2000m (north or south of the channel) and all four adaptive management reference sites in the same direction as the red indicator site (north or south of the channel).

Table H-9. Tier 3 sites (N = 16).

Site Name	Latitude	Longitude
1575N-ORL	26 6.516	-80 4.912
1500N-MRL	26 6.477	-80 5.193
1500N-IRL	26 6.477	-80 5.545
1500N-NRC-CPS	26 6.477	-80 5.735
2000N-ORL	26 6.740	-80 4.872
2000N-MRL	26 6.740	-80 5.145
2000N-IRL	26 6.740	-80 5.534
2000N-NRC-CPS	26 6.740	-80 5.759
1500S-ORL	26 4.737	-80 5.104
1500S-MRL	26 4.737	-80 5.493
1500S-IRL	26 4.737	-80 5.668
1500S-NRC-RS	26 4.737	-80 6.219
2000S-ORL	26 4.468	-80 5.111
2000S-MRL	26 4.468	-80 5.552
2000S-IRL	26 4.468	-80 5.729
2000S-RS	26 4.468	-80 6.230

For project planning purposes, additional field sampling capacity should be identified and pre-positioned, so sampling activities triggered for Tier 2 or Tier 3 assessment and reference sites does not supersede the bi-monthly sampling at Tier 1 sites. Tier 1 sampling must occur when any dredging operations are occurring (with the understanding that dive operations are subject to weather and safety considerations). Triggered Tier 2 or Tier 3 sampling may also result in Triage field sampling to assess the causes, extent and severity of any red threshold sedimentation or turbidity exceedance.

Intervals north and south of the Port Everglades Entrance Channel will be sampled from east to west:

Tier 1:

50m

200m Sites 175m and 225m from the channel edge are included in the 200m grid line due to variation in habitat occurrence.

300m

500m 425N-IRL is included in the 500m grid line.

Tier 2:

700m

1000m

Tier 3:

1500m 1575N-ORL north was added to replace the 1500N-ORAPRD site in the original array to add consistency in sampling outer reef habitats and improve dive logistics. ORL habitats are generally shallower than ORAPRD habitats.

2000m

Four Habitat Groups: Seven Mapped Habitats (from east to west)
A systematic sampling grid is designed to sample an Outer Reef, Middle Reef, Inner Reef and Nearshore Ridge Complex habitat on each distance interval from the existing channel edge (Figure H-18). Not all habitats occur on each transect. Generally, sampling is planned on linear reef habitats and nearshore Ridge Complex. Alternate habitats, such as spur and groove or aggregated patch reef are sampled when linear reef habitat is not present on a particular interval distance from the channel edge.

Group	**Habitat**	**Habitat Code** (Walker et al. 2009)
Outer Reef	Outer Reef Linear	ORL
	Outer Reef Spur and Groove	ORSG
Middle Reef	Middle Reef Linear	MRL
Inner Reef	Inner Reef Linear	IRL
	Colonized Pavement Shallow	CPS
Nearshore Ridge Complex (NRC)		
	NRC-Ridge Shallow	NRC-RS
	NRC-Colonized Pavement Shallow	NRC-CPS

The location code for each site includes distance from the channel edge (as shown in Google Earth imagery from 2017), direction from the channel, and the habitat code as in the following examples: 50N-ORL: 50m North-Outer Reef Linear. 300S-IRL: 300m South-Inner Reef Linear. Middle Reef Linear and Inner Reef Linear have locations where two reef lines of the same habitat are encountered on a sample grid line from

east to west. Sampling is conducted on the most seaward occurrence of each habitat type, where two reef lines of the same habitat occur.

H.8.3.4 Interval Sediment Depth Transects

Divers enter the water at a weighted marker buoy deployed on the coordinates for each sample location. Once divers reach the bottom, Diver 1 attaches a 30m tape to the weight and swims the transect to the west. Diver 2 will begin the Interval Sediment Depth (ISD) data collection by recording sediment depth measurements to the nearest 0.1cm at each 1m interval starting at the 1m mark (Figure H-20). A total of 30 measurements will be recorded along each ISD transect.

Characterization of sediments is also recorded at each interval sediment depth location (each meter mark). Characterization categories include: S-sand, SF-Sand with fines, FS-Fines with sand and F-Fines. S includes less than 5% fines. SF is mostly sand with 5-49% fines. FS is mostly fines with 5-49% sand, F is fine sediments with less than 5% sand. The diver may palpate the sediment to feel for slickness (colloidal or organic sediments) or sand grains. The diver may release a handful of sediments into the water to visually assess the content of fine sediments versus larger sediments. These observations are expected to take less than 30 seconds at each meter mark.

H.8.3.5 Video Record

After completing the ISD transect, Diver 2 will record a slow 360-degree pan with a video camera at an appropriate oblique angle (~30 degrees above seabed) to view the reef habitat. Diver 2 will then slowly swim (approximately 5m per minute) from the 30m mark of the transect tape back to the weight with the video camera no more than 1.0m above the bottom, except to move over large sponges or octocorals, as needed. The camera will be oriented perpendicular to the bottom to record in the plan view. Video of the 0m mark end of the transect will be recorded in a 360-degree slow pan at an oblique angle to view the reef habitat. Video of interesting observations may be made by coming to the adjacent meter mark (perpendicular to the transect tape) and slowly moving the video camera to an oblique angle to show the item of interest. The video camera is then slowly moved back to the plan view at the same meter mark and the transect video continues from there.

H.8.3.6 Biotic Sediment Stress Indicators

Diver 1 will conduct two 10mx1m belt transects, one along the north side of the transect tape from 20-30m marks (Transect 1) and one along the south side of the transect tape from 10-20m marks (Transect 2). Sediment stress indicators observed in scleractinian, octocoral, and sponges will be recorded (NMFS in preparation) (Figure H-21). Presence or absence of visually apparent project-related sediments deposited on turf algae (e.g. colloidal sediments) will also be recorded. Diver 1 will photograph representative examples of sediment stress indicators observed in the belt transects. In the event a belt transect cannot be completed before the end of the dive, the length of the completed portion of the belt transect will be written on the datasheet. A shortened belt transect can still provide valuable data, even if it is not the full 10m.

H.8.3.7 Micro-Transects

Bottom cover by macroalgae, cyanobacteria, algal turf or sediment will be quantified by Diver 1 by placing a 1m measuring tool graduated at 10cm intervals perpendicular to the transect tape at 3 locations (25m, 15m and 5m marks) along the 30m tape. Presence of macroalgae, cyanobacteria, algal turf, bare hardbottom, sediment on bare hardbottom or other (e.g. benthic organisms) will be recorded at each 10cm interval along the 1m measuring tool (Addendum 2). The diver will make a note on the datasheet of the taxa of organisms that fall into the "Other" category (e.g. SCL, OCT, SPO). In the event the 25, 15 or 5m mark falls in a sand patch or sand channel, the micro-transect will be moved to the nearest meter mark falling on hardbottom and the actual meter mark of the new location will be noted on the datasheet.

H.8.3.8 ESA Coral Roving Diver Surveys

After completing the micro-transects, Diver 1 will conduct a roving swim to observe any ESA listed coral colonies within 5m of the transect tape, including both ends. The area observed will begin 5m east of the 0 mark on the transect tape and extend to 5m west of the 30m mark. Diver 1 will swim along the south side of the transect tape making meanders to visually assess coral colonies and identify ESA listed species. When an ESA listed colony is encountered within the 5m distance from the transect tape, Diver 1 will record the location and direction of the colony in relation to the transect tape on the datasheet (Example Notation: 1) Ofav 4m, mm 26; unabbreviated version: One) *Orbicella faveolota* four meters from the transect tape at meter mark 26). Diver 1 will then take a picture of the datasheet that clearly shows the ESA coral notation. Diver 1 will then place a scale bar on the seabed next to the coral colony and take a photograph in the plan view (looking directly down from above). Four additional photographs, one each from the east, north, west and south directions (in that order) to show all sides of the colony. One close-up of the colony to show the coral polyps and septa will be taken. The scale bar can be moved for each photograph, or a second scale bar can be used for the directional photographs. A minimum of six photographs of each ESA listed colony is required, in addition to the notation on the datasheet. Each photograph should be at the closest distance that shows the coral colony and a scale bar and be in focus. Additional close-up photographs of sediment, disease, bleaching or any other coral condition may also be taken. Once photographs of the ESA listed coral are completed, Diver 1 continues with the ESA coral roving diver survey until the south side and both ends of the transect tape have been assessed for the presence of ESA listed corals. Conducting the ESA coral roving diver survey in this manner will assess a total of 200 square meters of reef habitat for presence of ESA listed corals. Following completion of the ESA Roving Diver Survey, Diver 1 will reel up the transect tape from 30m back to the weight. The dive team will meet at the weight, then ascend to the safety stop together.

H.8.3.9 Sediment Sample Collection

One sediment sample will be collected at a site when sedimentation index or biotic sediment stress index indicators trigger Tier 2 or Tier 3 sampling. The sediment sample will be taken in a manner to not interfere with sediment depth measurements at the meter marks. Surficial sediments on the reef hardbottom will be collected by sliding a metal tool no more than ~0.3 cm below the sediment-water interface when sediments are greater than 1cm deep. Shallower sediments will be collected by scraping the metal tool along the reef framework and scooping the sediments into the sample tube. The sediment sample will be scooped into a certified-clean, HPDE 50ml sample tube. The scooping process will be repeated until 20ml of surficial sediments are collected; then the bottle will be capped by the diver. Sediment sample bottles will be labeled with the location code, date of collection, and initials of the diver who collected the sample.

Bottles will be inspected post-dive to ensure these markings remain legible and lids are secure. After returning to land, sediment samples will be dewatered by pipette or decanting after sediments have separated from the water and will be held at ambient temperature until delivery for processing and analysis.

H.8.3.10 Tiered Sampling Array

Sampling will be conducted at Tier 1 locations (50, 200, 300 and 500m north and south of the channel) bi-monthly (every 2 weeks). Tier 2 locations will be sampled when one or more sedimentation indicators at a Tier 1 location is yellow. Tier 3 locations will be sampled when any adaptive management trigger/index score at a Tier 2 location is red, or when multiple indicators (three or more) at Tier 2 are yellow. Tier 2 and Tier 3 locations will be sampled in the same direction from the channel as any observed yellow or red indicators (Tier 1 North: multiple yellow or single red indicator->Sample Tier 2 North; A Tier 2 South location indicator is red->Tier 3 South).

H.8.3.11 Triage Sampling

Triage sampling will be conducted when multiple locations in the Tier 2 or Tier 3 arrays are yellow or when any location in Tier 1, Tier 2 or Tier 3 is in a red status. Triage sampling consists of two activities:

1. A paired roving diver swim from a Tier 1, Tier 2, or Tier 3 site with a red indicator, away from the channel, to determine the northern or southern extent of the conditions that triggered a red indicator. Roving diver observations will be made with one or more channel parallel transects (number to be determined in consultation with the IWG).
2. Quantitative sampling using the same methods as the array locations will be conducted at additional locations within the triage survey area when observations of Sedimentation Index or Sediment Stress Indicator scores indicate effects of sediment stress are extreme (e.g. mean sediment depth at a location is greater than 1.0cm with a majority of fine with sand or fine sediment; Biotic indicators of sediment stress are two times greater in frequency of occurrence than baseline observations) at any Tier 1, Tier 2, or Tier 3 location. The naming convention for these locations will follow the convention used for naming locations in the array with T (for Triage) added to the end of the site name (e.g. 560N-ORL-T would indicate the data were collected 560m north of the channel on the outer reef linear habitat and was a triage location).

H.8.4 References

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H.8.5 Supplements: Field datasheets

Date:			
Buddy Team Initials: 1) Collection diver 2) Transect Diver 3) Biotic Indicators diver			
Location-Habitat Codes:			
Water Depth/Visibility(in feet)			
Sediment Depth Measurements to nearest 0.1cm Sediment characterization: S (Sand); SF (Sand with some Fines), FS (Fines with some sand), F (Fines)			
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9
10	10	10	10
11	11	11	11
12	12	12	12
13	13	13	13
14	14	14	14
15	15	15	15
16	16	16	16
17	17	17	17
18	18	18	18
19	19	19	19
20	20	20	20
21	21	21	21
22	22	22	22
23	23	23	23
24	24	24	24
25	25	25	25
26	26	26	26
27	27	27	27
28	28	28	28
29	29	29	29
30	30	30	30
*SC denotes sand channel within reef habitat; *SP denotes sand patch within reef habitat			

Figure H-20. Field datasheet for recording interval sediment depths[3]

[3] Each datasheet can accommodate up to four interval sediment depth transects

Site_____ Date_____ Diver_____ Meters Completed____

Transect 1 Transect 2 Biotic Sediment Stress Index 1-5:_____

		Micro-Transects			
Scleractinian corals:		5m	15m	25m	
No visually-apparent Stress NS					10cm
Dusting Dt					20cm
Sed. Accumulation: 0-50%+Loc SA					30cm
Partial Burial 51-99%+Loc PB					40cm
Burial 100% cover Bu					50cm
Partial mort.: Record %+Loc PM					60cm
Dead 100% Mortality Dd					70cm
Disease Ds					80cm
Bleaching Bl					90cm
Other Stressors OS					100cm
Octocorals:					
No Visually Apparent stress NS					
Dusting Dt					
Sed. Accumulation 0-50% +Loc SA					
Partial Burial 51-99% + Loc PB					
Burial 100% cover Bu					
Disease Ds					
Attachment Failure AF					
Partial mort. Record % +Loc PM					
Dead Dd					
Other Stressors OS					
Sponges:					
No Visually apparent stress NS					
Dusting DT					
Sed. Accumulation 0-50%: SA					
Partial Burial 51-99% cover PB					
Burial 100% cover Bu					
Attachment Failure AF					
Dead 100% Mortality Dd					
Fine sediment in Atrial Cavity AC					
Other Stressors OS					

M=macroalgae, T= Turf algae, C=Cyanobacteria, S=Sediment,
SCL, OCT, SPO, Paly
****
ESA Listed corals:
1.
Mm:
Condition:
2.
Mm:
Condition:
3.
Mm:
Condition:
4.
Mm:
Condition:
5.
Mm:
Condition:

****
Loc: Location Codes
T=Top, S=Side, B=Base
E=Entire Base,
A=Top, Side and Base
I=Inside Tissues

For OS Record P=Predation, C=Competition, M=Mechanical/Physical damage;
Modifiers in conjunction with SA, PB, and Bu: E-epiphytes with fine sediment; ST-fine sediment in tissues of sponges

Figure H-21. Field datasheet for recording biotic sediment stress indicators observed in scleractinian, octocoral, and sponges