APPENDIX D3

Other Reports and Related Documents

Environmental Assessment
Operation and Maintenance Dredging and Dredged Material Placement for Miami Harbor Navigation Project in Miami-Dade County, Florida

U.S. Army Corps of Engineers
JACKSONVILLE DISTRICT

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Operation and Maintenance Dredging and Dredged Material Placement for Miami Harbor Navigation Project in Miami-Dade County, Florida

OTHER REPORTS AND RELATED DOCUMENTS LIST

The following items are provided in Appendix D. These items may also be viewed and/or downloaded from the U.S. Army Corps of Engineers, Jacksonville District's (Corps) Environmental planning website, under "Dade", which can be accessed by visiting the link:
http://www.saj.usace.army.mil/About/Divisions-Offices/Planning/Environmental-Branch/Environmental-Documents/

- Corps. 2004. Miami Harbor General Reevaluation Report (GRR) Study and Final Environmental Impact Statement (EIS).

- Corps. 2018. Miami Harbor O&M Spillage Analysis.

- Corps. 2018. Initial Appraisal Report, Miami Harbor Navigation Improvement Project, Miami-Dade County, Florida.

- Water and Air Research, Inc. 2017-2018. Task 1 of the Miami Harbor Sediment Transport, Dispersal and Deposition Study – Outer Entrance Channel of Miami Harbor – Lessons Learned from the recent construction of the Miami Harbor Navigation Project.

- Water and Air Research, Inc. 2017-2018. Task 2 of the Miami Harbor Sediment Transport, Dispersal and Deposition Study – Outer Entrance Channel of Miami Harbor – Miami Harbor Sediment Tracer Study.

The following items are available for download via the provided link:

- National Marine Fisheries Service (NMFS). 1997. Amendment to SARBO
https://www.fisheries.noaa.gov/webdam/download/91875716

- NMFS. 1995. Regional Biological Opinion on Hopper Dredging of Navigational Channels and Borrow Areas Along the Southeast U.S. Atlantic Coast (SARBO)
https://www.fisheries.noaa.gov/webdam/download/91825981

- U.S. Environmental Protection Agency (USEPA). 2008. Miami ODMDS, SMMP
https://www.epa.gov/ocean-dumping/site-management-and-monitoring-plan-smmp-miami-ocean-dredged-material-disposal-site-fl

- USEPA. 2011. Revisions to the Miami Ocean Dredged Material Disposal Site (ODMDS) Site Management and Monitoring Plan (SMMP) https://www.epa.gov/ocean-dumping/site-management-and-monitoring-plan-smmp-miami-ocean-dredged-material-disposal-site-fl

Other reports and related documents listed in the EA are available by request.

Disclaimer: This review has not considered or examined previous data in the context of political, contractual, commercial and port operational aspects. In addition, the timescales and deadlines all parties were working within, both inside the United States Army Corps of Engineers, Jacksonville District (SAJ) and externally, have not been taken into account. It is recognized that all of these factors are likely to have influenced the project.

Executive Summary

This report has been produced under Call/Contract W912EP-15-A-0002-0003 for the Miami Harbor Sediment Tracer Study. Task 1 of this study included review of relevant existing data, reports, and scientific literature pertaining to the Miami Harbor Phase III Dredging Project (MHIII), which was implemented by the United States Army Corps of Engineers, Jacksonville District (SAJ) to deepen and widen the outer entrance channel to Miami Harbor. Relevant information was reviewed for three time-frames 1) Pre-Dredging, 2) During-Dredging, and 3) Post-Dredging.

Pre-Dredge

Very little background information exists for the Outer Entrance Channel or its wider environs, including the adjacent areas of Biscayne Bay, in terms of physical oceanography, metocean conditions, general or specific circulation, and net sediment transport or processes. In contrast to the physical data, much more background data are available for marine benthic resources in this area.

This disparity in information was consistent throughout all aspects of the project, with a disproportionate emphasis placed on biological data compared to physical data, resulting in a non-multidisciplinary approach.

In addition, there also appears to have been a belief (or lack of acknowledgement) by all parties that dredging would not create turbidity or a sedimentation problem. There was a lack of scientific rigor in assessing any potential impact from dredging in terms of turbidity and sedimentation, including review of previous examples from within the USA and around the world; the only reference appears to be limited to the previous dredging campaign in Miami Harbor (Phase II). This was despite strong evidence that dredged material may be advected over large distances (kilometers) as a result of tidal currents, wind-driven circulation, and wave-driven circulation, in particular in the lower water column and especially near-bed (lower 1 to 2 m of the water column), where no turbidity plume monitoring was carried out for MHIII (it should be noted that near-bed turbidity monitoring was not required in the permit).

Given the longevity of the project from inception to commencement of construction (over 10 years), availability of emerging science, and enactment of new legislation concerning endangered and threatened species, the Environmental Impact Statement (EIS) (2004) and other key documentation should have been reviewed, updated, and re-issued. In addition, there were no modeling studies performed, particularly for sediment transport and insufficient industry/dredge consultant input in advance to assess dredging impacts prior to construction (it is unknown by this author if those types of consultations are able to be conducted by the Corps of Engineers under federal law).The Florida Department of Environmental Protection's (FDEP)

environmental resources permit (Permit No. 0305721-001-BI) was somewhat prescriptive in terms of benthic monitoring requirements, but much less so in terms of physical monitoring including turbidity and sedimentation. Despite this, SAJ adopted it in full and passed it along to the dredging contractor, Great Lakes Dredge and Dock Company (GLDD), without reinforcing it and providing adequate levels of protection to the environment or SAJ interests. GLDD promised environmental resources would be a priority, but failed to enact more conservative Best Management Practices (BMPs), in particular those learned and complied with on other international dredging projects prior to MHIII, for example in Wheatstone, Western Australia (Chevron Australia, 2016).

Various tests were conducted on the rock core borings prior to dredging, however unfortunately for the context of this study, geophysical tests were limited with the density of the rock "assumed" to have a Specific Gravity (SG) of 2.65, rather than being tested. Based on the data and reports reviewed, no testing of the rock core borings was undertaken to determine the effect of various dredge types on the rock material which was subject to crushing or grinding, nor was there any analysis of the resultant material in terms of particle size.

Pre-dredge baseline data collection was not complete at the time dredging started and continued for at least 40 days into the dredging program. Therefore the baseline dataset was wholly inadequate both in terms of temporal extent, scientific robustness and statistical significance. It did not provide the Corps with adequate knowledge of typical conditions for any of the parameters measured prior to dredging, including sediment transport processes, and very importantly, it did not enable an accurate and rigorous assessment of the impacts that resulted during dredging or a post-construction evaluation. Photographs taken during baseline monitoring surveys show little to no sediment accumulation on corals surveyed before dredging began versus sediment accumulating on coral tissues with increased duration of dredging activities.

There was little consideration of sedimentation due to dredging operations versus natural processes and how to differentiate these. No truly adaptive management strategies including temporary cessation of dredging were in place to abate sedimentation impacts to benthic resources when they did occur, and this was compounded by the inconclusive and temporal brevity of the pre-dredge baseline data collected in 2013.

There is confusion in both the FDEP environmental resource permit and the Environmental Protection Plan (EPP) (SAJ, 2012) regarding the coral stress index to be utilized for baseline, during-construction, and post-construction coral health monitoring. These documents describe a binary system (0 or 1) for assessing presence/absence of coral stress parameters. The EPP states that presence of 2 or more stress parameters was required to designate a coral as stressed; however, this was not the protocol followed in coral health monitoring for MHIII. Coral stress parameters were not additive and corals were designated as "stressed" with presence of 1 or more stress parameters (DCA, 2014). The Broward County Segment III Coral Stress Index was also referenced in both documents, which is not the coral stress index that was utilized for MHIII. The Key West Dredging Project Resource Health and Sedimentation Monitoring (RHSM) Plan (CSA, 2003) was the intended model for MHIII, but it was not followed correctly, and

adaptations were made by DCA and/or the SAJ that were not described in the permit or EPP monitoring protocols.

During-Dredge

During dredging, several major aspects of the physical and biological monitoring programs were flawed. Turbidity and sedimentation monitoring data were inadequate for the following reasons:

- There was no calibration of the turbidity sensor with actual suspended sediments created by the dredging operations or suspended solids data in order to measure actual real-time dredge suspended solids rather than turbidity, despite collection and analysis of these samples. (This correlation was not required by the FDEP permit).
- Turbidity monitoring was meant to be carried out by an "experienced" operator, but was entirely subjective in nature in terms of: i) having no current velocity data in order to assess what the FDEP permit described as "down/up-current"; ii) no data on water-column stratification to determine if there was shear or reverse flow in the water column; iii) the operator deciding visually where the densest part of the turbid plume was; and iv) no measurements in the lower water column where it is extremely likely the majority of the suspended sediment and near bedload sediment would be and where the bulk of the sediment transport would occur.
- There was no meaningful qualitative/quantitative sedimentation data collected from the sediment accumulation blocks during weekly compliance surveys. The sediment blocks failed to accumulate sediment, possibly due to strong currents. Despite this being recognized early on, during the pre-dredge baseline monitoring surveys, the same method was utilized for sediment accumulation compliance monitoring throughout the entire dredging project. This eliminated the 1.5 mm sediment accumulation above control "sediment stress violation", which was a key threshold established for the monitoring program.
- The sediment traps used were potentially (or likely) to have been unsuitable in terms of collecting quantitative data due to high currents in the area, resulting in turbulence occurring around the mouth of the trap, reducing the trapping efficiency of the trap. Additionally, there were significant time-lags in the availability of these data, as traps were only collected monthly, and laboratory analyses took another month. Therefore, no recently-collected sediment accumulation data were available during dredging, or throughout the entire monitoring program.

SAJ provided notices of the "exceedances" in terms of turbidity monitoring. Given the overall observed outcomes and impacts, there were very few exceedances, although considering the points listed above regarding the inadequacy of the turbidity and sedimentation monitoring, this lack of exceedances is not surprising.

Several problems were also apparent in the biological monitoring. The dates on the weekly coral stress and sediment block compliance reports were consistently a week behind the monitoring period, indicating a delay in terms of official documentation to identify potential coral stress, which could delay implementation of adaptive management strategies. The "Adaptive

Management" and "Recommendations" sections of these reports were also relatively sparse and not very informative.

Because the coral stress index utilized was not additive, and presence of 1 or more of 24 possible stress parameters designated a coral as "stressed", the ability to differentiate significant project-related sedimentation stress from natural background stress was likely reduced. "High" coral condition scores (percent of stressed corals out of total number monitored per station) were reported for both channel-side and control stations during dredging.

Significantly high coral condition scores due to sedimentation were reported very early in the dredging program for the Hardbottom (Week 1) and Middle Reef (Week 9) areas. Significantly high coral stress scores for the Outer Reef were not reported until Week 30.

Trends from the weekly compliance monitoring reports show that significantly high coral stress was repeatedly reported for the Hardbottom and Middle Reef areas from Week 11 through Week 40, with partial mortality occurring in Week 32, despite several adaptive management measures performed in this timeframe. High coral condition scores due to bleaching were not reported until Week 34 (July, 2014) and due to disease until Week 52 (November, 2014). This information leads to major concerns pertaining to enforcement of coral "sediment stress violations"/thresholds, regard for natural marine resources, and effective adaptive management practices employed during dredging.

Although they were loosely defined, the EPP established several "stress violations" for the monitoring program. These were based on frequency of coral bleaching, excessive mucus production by corals, covering of benthic community components by sediment such that death or degradation occurred, or a maximum sediment accumulation rate of 1.5 mm per day above the analogous reference station as measured on the sediment accumulation blocks. Once dredging operations were underway, it is unclear from the weekly compliance reports if and how these thresholds were enforced. Adaptive management actions, as documented in the weekly reports, were slow to respond. Therefore, the coral stress and sediment accumulation "sediment stress violations" were either not enforced or significant time-lags in adaptive management, as a result of violations, failed to protect benthic resources.

Post-Dredge

The results and value of information in the post-construction reports are over-stated for several main reasons:

1) The pre-dredge baseline dataset was temporally and spatially limited as well as compromised by the initiation of dredging activities prior to completion of these baseline monitoring surveys;
2) local hydrodynamics, metocean conditions and natural sediment transport processes were not studied prior to and throughout the dredging project;
3) sediment accumulation data from traps were too high off the substrate (18 inches as required by the permit) and may have been influenced by higher current movement

than the substrate, thus failing to represent the condition on the substrate and therefore not comparable in “real-time” to coral stress and benthic monitoring data;

4) the sediment blocks did not function at Miami Harbor as they had at Key West possibly due to stronger currents and as such should have been replaced very early on in the project with an alternative method of assessing real time sedimentation rates approved by either FDEP or SAJ; and

5) methods of conducting coral stress assessments may have led to under-representation of significant dredge-related sedimentation stress on coral communities.

For these reasons and others detailed in this report, comparing pre-dredge baseline and post-construction datasets is invalid for sedimentation. Therefore, drawing scientifically-based conclusions from multidisciplinary data sets surrounding potential impacts from dredging activities is not possible. However, the datasets do allow for a pre- and post- dredging functional group assessment, which was a requirement of the permit.

Similar to the pre-dredge baseline monitoring surveys, the integrity of the one-month post-construction monitoring surveys was also compromised by dredging activities. Spot-specific “clean-up” dredging occurred within Cuts 1 and 2 of the outer entrance channel at the time post-construction monitoring surveys were being conducted. Additionally, the one-month post-construction monitoring surveys were performed in summer (June and July) compared to pre-dredge baseline monitoring surveys performed in winter (October through December), and as such under extremely different metocean and biological conditions (i.e. sediment transport rates are typically higher in winter and coral bleaching is more prevalent in summer). Although the timeframes of monitoring data collection was dictated by the permit, the contrasting seasonality of the two datasets further complicates their comparison for sedimentation values, which appears to have a significant seasonal variability.

Therefore, the authors consider that the scientific integrity of all datasets (pre-, during-, and post-dredge) collected for MHIII was compromised. A list of “lessons learned” based on the information reviewed for this report is provided in Section 3.0. This identifies recommendations relevant to the team and personnel, multi-disciplinary baseline data, permits and contracts, environmental monitoring, and public relations in the context of a large-scale dredging campaign.

1 INTRODUCTION

This report has been produced under Call/Contract W912EP-15-A-0002-0003 as part of Task 1 – Information Review and Report for the Miami Harbor Sediment Tracer Study. This Study is being performed by the team of Water and Air Research, Inc. (WAR) with subcontractors Environmental Tracing Systems (ETS) and CSA Ocean Sciences Inc. (CSA) for the United States Army Corps of Engineers, Jacksonville District (SAJ).

The Miami Harbor Phase III Dredging Project (MHIII) was implemented by the SAJ to deepen and widen the outer entrance channel to Miami Harbor and was constructed to accommodate larger Panamax vessels. Great Lakes Dredge and Dock Company (GLDD) was the dredging contractor who constructed MHIII from November 20, 2013 to September 20, 2015. GLDD was responsible for executing the environmental monitoring program, which included monitoring and

mitigation of marine benthic resources in the vicinity of the dredge footprint, which included seagrass beds in northern Biscayne Bay and hardbottom and coral reef communities adjacent to the outer entrance channel in coastal waters offshore Miami, Florida. Dial Cordy and Associates, Inc. (DCA) was subcontracted by GLDD to perform the majority of marine benthic resource monitoring required for MHIII.

The primary focus of Task 1 was to review information acquired before, during, and after dredging for MHIII as well as other relevant reports and scientific literature for the study site and its environs. Another sub-task for Task 1 included preparation of a list of “lessons learned” in order to identify data gaps and assess the adequacy of the regulatory requirements and monitoring program and provide recommendations for improving monitoring programs for future dredging projects. Another sub-task was to develop a conceptual model for regional and localized sediment transport processes in the Miami Harbor area. The last sub-task was to refine the Task 2 scope of work to deploy and monitor sediment tracers in the Miami Harbor area and monitor metocean and hydrological conditions to gain a better understanding of natural and potential dredge-related suspended solids on adjacent benthic marine resources.

This Task 1 Report summarizes the main findings following the information review; it is not completely exhaustive due to the vast amount of data spanning more than 10 years generated by the MHIII and provided by the SAJ. Data provided by the SAJ for each pre-dredging, during-dredging, and post-dredging timeframe was reviewed in terms of general information such as dredging practices and industry standards; physical environmental information such as metocean conditions, sediment transport processes and turbidity; and biological information pertaining to coral resources, with emphasis on the Middle Reef habitat.

This review was conducted by Dr. Jon Marsh of ETS and Erin Hodel of CSA Ocean Sciences Inc. as independently as possible without any pre-conceived ideas or views as to the project and the problems and impact summarized in Section 2. Both reviewers have carefully considered data and reports provided by SAJ, which focused on the Outer Entrance Channel (Cuts 1 and 2) and also conducted a literature search of available and relevant data over a wider geographical area around Miami including Biscayne Bay. It is not a literature review of the subject area, however, and where particularly relevant, both authors have incorporated references to support points made. Each reviewer has considered the data and reports within their area of expertise and have worked mostly independently of one another. This has led to a degree of “overlap” in terms of comments and observations made. However, this “overlap” has been left in the report as it is seen as affirming the concerns raised, especially those of Best Management Practices, international standards, and robustness of scientific data.

Dr. Jon Marsh has over 25 years of experience working on dredge monitoring projects worldwide including hydrodynamics, metocean data acquisition, numerical modeling, sediment transport processes, sedimentation monitoring, dredge operations, and impact assessments from dredging.

Erin Hodel has over 14 years of experience working on coral monitoring programs with an emphasis on coral health and sedimentation stress in south Florida and the Pacific. She has conducted numerous coral health assessments for benthic monitoring programs associated with

beach nourishment and dredging projects using both histopathological and gross morphological coral stress indices. She has worked on coral and other benthic resources monitoring and mitigation programs associated with three major federal dredging projects: MHIII, Key West Ship Channel Dredging, and the proposed Apra Harbor, Guam Dredging Project. She has conducted several laboratory-based sedimentation experiments on various species of Caribbean and Pacific corals aimed at defining sediment stress indicators and/or thresholds.

This review was initially intended to consider all data and reports provided to the reviewers comprising pre-dredging (e.g. the EIS and the 2013 pre-dredge baseline survey), impact assessment monitoring during dredging operations, and post-dredge monitoring. However, both reviewers identified key concerns and significant data-gaps during the pre-dredge phase, including the quality and very limited temporal and spatial baseline data from 2013 that was acquired, the regulatory/SAJ guidelines for monitoring, and the proposed methods for monitoring during dredging. As a result of these compounding concerns and data-gaps, both reviewers focused much of their attention on the pre-dredge data and reports in order to identify what caused the observed impacts to the marine flora and fauna in the during-dredging and post-dredging phases and to help identify and formulate “lessons learned”. Therefore the focus of Section 2 is on the pre-dredge phase, particularly on the turbidity monitoring, sedimentation, and coral health monitoring.

2 DATA REVIEW

2.1 Pre-Dredging

This section has been compiled in an approximate chronological order leading up to the commencement of dredging on 20 November 2013. However, given the period of time between the decision to deepen the channel from -44 feet (ft) to -52 ft Mean Lower Low Water, termed Miami Harbor Phase III (MHIII), until dredging got under way, many documents were produced by and on behalf of SAJ in support of dredging. To follow an approximate timeline, the sections are as follows:

- 2.1.1 Background Information on the Site
- 2.1.2 Supporting Documents by and on behalf of SAJ
- 2.1.3 FDEP Permit 0305721-001-BI
- 2.1.4 Proposed Coral Stress Parameters
- 2.1.5 Proposed Coral Stress Index
- 2.1.6 Coral Stress “Triggers” or Thresholds
- 2.1.7 GLDD Proposal
- 2.1.8 Baseline Monitoring and Report
- 2.1.9 QA/QC of Coral Condition Scores

2.1.1 Background information on the site

As outlined above, the information summarized below has been identified as relevant to this particular study and/or the Outer Entrance Channel for MHIII. Background information regarding the understanding the general hydrodynamics and sediment transport in the Outer Entrance Channel area or its environs was limited to the information available in the Feasibility Study completed in 2004, even though dredging commenced in 2013. This is despite the recognized environmental sensitivity and resources in the hardbottom and coral reef habitats areas seaward of the port, the previous capital dredging campaigns, a significant urban population, and the complexity and demands this concentrates on the area (SAJ, 2004). Typically for projects of this nature, physical monitoring and numerical modeling studies are carried out in order to assess the potential effect of capital dredging on both the local and wider environment including navigation, environmental impacts, change in circulation patterns, etc. Given the numerous marine academic institutes and organizations located in South Florida alone, the level of knowledge in terms of marine flora and fauna and biological resources is extremely notable. However, there is little evidence of a multidisciplinary approach including physical data gathering prior to MHIII, which has resulted in very little monitoring, knowledge, or understanding of the physical environment of the area. This pattern was observed in all documents and assessments by federal and state organizations and stakeholders with respect to MHIII.

2.1.1.1 Biscayne Bay

Much of the previous work identified comprised studies in the southern section of Biscayne Bay. These studies focused on observed changes in the nearshore salinity as a result of changes in terrestrial freshwater and groundwater flow and the resultant impact on the marine flora and fauna (Stabenau et al., 2015) and attempts to restore the nearshore waters to more brackish/estuarine conditions (Lirman et al., 2003). Lirman et al. did measure sedimentation rates in the area generally south of Elliot Key, using sediment traps and endeavored to distinguish between sedimentation on corals associated with high boating activity areas versus seasonal trends and processes. Lirman et al. concluded that increased boating in certain areas led to increased sedimentation with up to 575 mg/cm^2/day of sediment measured in sediment traps and commonly encountered coral covered with 3 cm of sediment in the field. Lirman et al. suggests in area where >10-15 cm of sediment exist, seagrass becomes more dominant, although this is also a function of water depth. Rogers (1990) predicts that habitats with heavy sediment loads (proposed at >10 mg/cm^2/day) lead to low coral species diversity, cover, and dominance of species more tolerant of smothering and reduced light levels.

A two-dimensional (2-D) numerical modeling study was setup by Brown et al. (2003) to examine potential changes in Biscayne Bay in terms of hydrodynamics and salinity, in order to determine potential changes in the ecosystem and any impacts on flora and fauna. The study focused on assessing changes to freshwater inflow into the inner/nearshore coastal waters, via canals, levees, rainfall, and groundwater flows, although it was later used (unsuccessfully and as explained below, completely inappropriately) to consider general circulation patterns related to MHIII (see below). The model simulation was only carried out for a period of 2 weeks, far too short to determine the range of conditions including seasonal variability in the system from

summer and winter periods both in terms of environmental conditions, freshwater inflow, storms, etc. In addition, several key processes were omitted from the model.

Brown et al. 2003, noted that circulation in Biscayne Bay was influenced by both tidal-induced currents and wind-induced currents and that water-column stratification created vertical density gradients in the bay that varied spatially and temporally (as would be expected) due to a combination of factors including freshwater inflow, rainfall, and evaporation. The study concluded that the salinity had increased inside the bay due to the increased hydraulic volume of the bay associated with the construction of channels (i.e. widening and deepening for navigation purposes) and also the existence of a tidal node (an area with little tidal excursion) between Government Cut and Bakers Haulover Inlet to the north. This was predicted based on the tidal forcing observed, however the modeling carried out simulated a North-South slope or tilt offshore outside of the bay to “drive” or simulate the hydrodynamics rather than using actual bathymetry; this artificial feature simulated a “sweeping-current-inducing slope of the offshore area” which would undoubtedly have adversely affected predicted currents into the bay and circulation within the bay including the prediction of a tidal node. Despite a significant field monitoring campaign inside the bay comprising 12 Conductivity Temperature Depth (CTD) sensors and 5 acoustic doppler current profilers (ADCPs) collecting current velocity and direction throughout the entire water column, currents were depth-averaged. This approach could undoubtedly lead to net or residual currents being assessed as zero or very low, particularly in areas where stratified flow existed, for example wind-induced currents flowing above tidal-induced currents, leading to the assumption of limited water circulation overall. Not surprisingly, there were anomalies observed and disagreement between the field measurements and the model predictions indicating poor agreement. However, it is unlikely that there would be close agreement considering the lack of ocean circulation modeling to establish accurate boundary conditions in the model; the fact that no offshore wind and wave data were included; and that winds inside the bay were not considered sufficiently accurate in terms of direction, speed, or effective fetch. In addition, and very significantly, the vertical salinity data were depth –averaged in the model, despite clear evidence showing salinity stratification in the water column for a range of environmental and meteorological conditions.

Previous modeling was also carried out in the area by Fatt and Wang (1987), again to look at circulation and salinity changes related to changes in the ecosystem versus a better understanding of the hydrodynamics. They also observed anomalies between the synoptic data and model output assumed to be due to localized rainfall and wind-driven circulation. These parameters were not accurately reflected in the model. No evaporation function was used with the model tending to predict much lower salinities than field measurements.

A 3-D finite difference model was also developed by Sengupta et al. (1978), including for sediment transport, however this was only for a 1 day simulation; given the complexity of hydrodynamic processes for the area responding to tidal, metocean and seasonal variations, such a short time period would never simulate the general circulation accurately, and even less so the sediment transport processes.

As stated above, unfortunately and inappropriately, SAJ went on to use the Brown et al., 2003 model, or variations thereof, to evaluate the effect and potential impact of MHIII as part of the

EIS and also for navigational/ship movements, without any understanding of the modeling carried out or regard to its assumptions, short-comings, and inherent inaccuracies.

Continuing with the considerable bias and interest in ecological assessments in the area rather than a core understanding of the physical environment including hydrodynamics and sediment dynamics, Browder et al., 2005 developed a conceptual ecological model. Browder et al. note the poor water quality entering the bay via canals, storm water discharges, general runoff and groundwater and the fact that vessels (including recreational) disturb the sediment bed, however the ecological model does not consider it necessary for a multidisciplinary approach.

More recently, NOAA (2013) conducted a study (contracted and funded by SAJ) in Biscayne Bay to assess variations in turbidity and salinity. Field data were collected at 3 sites over a one year period including current velocities, turbidity, total suspended solids (TSS), and chlorophyll. Very low turbidities were recorded for much of the monitoring period excluding periods of phytoplankton activity and increased wind events. However, it should be noted that the details of the wind events were not adequately logged in terms of direction, effective fetch and waves which would all modify the wind characteristics and perhaps explain observed/visual patterns not matching measured data and results. NOAA concluded that turbidity could be elevated for up to a month associated with phytoplankton whereas wind events led to elevated turbidity for typically just one day.

Rather unusually, NOAA (2013) report good agreement between TSS and turbidity with phytoplankton being the main source, although NOAA report lower water column turbidity readings to be higher than surface readings by between 5-12% at the 3 sites; this is perhaps counter-intuitive given NOAA conclude the main source is phytoplankton and that these would typically be higher in the water column rather than lower. NOAA carried out statistical analysis between the various parameters measured to try to determine correlations between cause and effect, however differences were relatively small, insignificant, and inconclusive, suggesting a limited value in attempting to link or relate measurements to each other without regard for the various datasets, spatial and temporal variability, or localized effects. Given the absence of a general understanding of the circulation in the bay, the key processes that drive hydrodynamics, water-column stratification, and sediment dynamics including suspended sediment, it would be difficult to determine if or how the various parameters were interrelated and also draw any conclusions from the data. In addition, NOAA attempted to relate backscatter data, logged on an ADCP (Acoustic Doppler Current Profiler), to being proportional to the log of turbidity or TSS. This ignores the significant efforts required to produce a calibration curve in order to compare backscatter data with TSS and/or turbidity. It also seems to ignore the fact that other processes and parameters can significantly affect ADCP backscatter data including the presence of diatoms.

2.1.1.2 Government Cut

Despite the above, SAJ (2004) stated that the Brown 2003 numerical modeling study for Biscayne Bay “provides an evaluation of the impacts of Miami Harbor (MH) deepening on tidal current velocities and salinity in MH and on tidal current velocities along the coastal ocean shoreline around Government Cut”, even though the model “did not include coastal processes

such as littoral currents". The same model was later used to assist ship simulator assessments for vessel maneuvers into the Port of Miami. Given the background as to why the model was setup and the assumptions and shortcomings of the modeling approach, it is alarming to read in SAJ (2004) that the model suggests "negligible changes to current velocities and salinity throughout the [MHIII] project" although later in the same document there is a prediction that the proposed changes as a result of MHIII will lead to an increase in current velocities of 0.5 ft/s in Government Cut. Conversely, it is predicted that there will be no observable impact on the Atlantic Ocean side shoreline tidal velocities based on any of the simulations, and only subtle differences in salinity, which will remain within the "detection limits, confidence levels of present field data collection capability, and associated model assessments". The same paper concluded that "the modeled changes in the coastal environment are insignificant and no impacts would occur".

In conclusion, prior to MHIII, very little accurate background information existed in the Outer Entrance Channel or its wider environs, including the adjacent areas of Biscayne Bay, in terms of physical oceanography, metocean conditions, general or specific circulation, and net sediment transport or processes. Wave data are collected at adjacent NDBC sites offshore, however, in the absence of measured nearshore/inshore wave data or a correlation between offshore and nearshore/inshore wave conditions, it is not possible to draw any conclusions at this stage as to the wave climate for the study area; this assessment will be made as part of this study (see Section 5). However, it is noted in SAJ (2004) that swell waves (long period waves) from the north of the mid-Atlantic Ocean cannot reach the study area without modification of the wave pattern or wave energy associated with the shallows of the Bahama Banks or by refraction along the Florida shoreline.

2.1.2 Supporting Documents by and on Behalf of SAJ

Given the time period between the decision to proceed with MHIII and commencement of dredging, a significant number of reports were produced. Many of these were updates or supplements which often contained the same information in context with this particular review, namely turbidity, sedimentation, and any associated likely impacts from dredging operations including dredging, overflow and disposal. For clarity, the various elements associated with the above have been separated.

2.1.2.1 Sedimentology

The dredging operation for MHIII required the removal of surface sediment classed as "overburden" comprising sedimentary material on top of underlying rock. Methods outlined in section 2.1.4 indicate the dredging contractor removed the overburden using a different dredge type, a trailer suction hopper dredge (TSHD) compared with the underlying rock which was removed using a cutter suction dredge (CSD). Roessler and Beardsley (1974) indicated that the proportion of silica to carbonate in "overburden" sedimentary sediments increased from approximately 35:65 in the area near Miami versus 20:80 towards the south.

SAJ collected core borings of the overburden and underlying rock along the length of the channel to be covered by MHIII; the results are documented in Challenge Engineering and Testing 2011. In brief, SAJ concluded the sediment borings comprised shallow soft silty sand or

shell on the surface (overburden) with fossiliferous limestone or sandstone layers filled with shell and sand to termination. The thickness and depth of the various layers varied spatially along the length of the channel (SAJ, 2004). GLDD described the sediment and underlying rock to be dredged based on the core boring data as “seabed with soft or loose superficial sediments (thin veneer to several feet thick) with limestone below ranging from highly weather and poorly cemented to intact and moderately weak with stronger limestone lenses”. In terms of the limestone there were different structures as follows:

- very vuggy with large solution holes > 1” filled with sand, silt or calcite with solution voids up to 25% with 15% common
- bioclastic sandy limestone, similar to a coquina of sand, shell hash and larger shells, poorly or well cemented sometimes degraded to sand

Various tests were conducted on the core borings, however unfortunately for the context of this study, geophysical tests were limited with the density of the rock “assumed” to have an SG (Specific Gravity) 2.65, rather than being tested. Based on the data and reports reviewed, no testing of the core borings was undertaken to determine the effect of various dredging plant on the rock material which was subject to crushing or grinding, nor was there any analysis of the resultant material in terms of particle size.

This lack of information is perhaps a result of relatively recent dredging of similar rock material for the Miami Harbor Phase II Dredging Project and in neighboring sites in Florida (Key West Dredging Project) which indicated no apparent significant impact from dredging activities. However, this lack of data and no apparent significant impact could be due to the level and/or quality of monitoring and measurements that were carried out and how rigorous procedures were to assess any impact, rather than no impact occurring. For example, in other sites around the world, dredging of carbonate limestone very similar to that requiring to be dredged in the Outer Entrance Channel, particularly in Cut 1, has caused a significant impact (Wester and Babcock, 2005; Erftemeijer et al., 2012). In Geraldton, Western Australia, a visible dredge plume extending tens of miles up the coast was recorded in addition to deposits of a dense fine sediment “rock flour” on the seabed up to several feet thick being recorded that remained present for weeks/months after dredging.

Due to an unfounded and unsubstantiated assumption that sedimentation and turbidity would be “temporary” by SAJ and its contractors carrying out the review of capital dredging for MHIII, (see Section 2.1.2.2), no assessment was made nor was a detailed literature search carried out as part of the EIS process (SAJ, 2004). This assumption makes it clear that sediments were barely considered in SAJ 2004and any study was limited to predictions of the sediment budget in the vicinity of Government Cut which is predicted to be north to south at approximately 24,000 cubic yards (cy) per year, based on an estimate of 15,000 cy/yr deposited in the channel and 9,000 cy/yr in shoals on the outer reaches of the channel. Once again, no reference is provided in SAJ (2004) and this assumes: that no sand is transported directly across the channel; that no movement takes place from south to north, perhaps during seasonal changes in wind-wave events; or that deposition takes place elsewhere in the surrounding area. There appears to be no clear or overall understanding of sediment movement in the entire area with records

appearing to be presumably based on Operations and Maintenance dredging records. Given the lack of understanding of hydrodynamics and general circulation and sediment transport, making any assessment as to the fate and impact of sediment created during dredging and/or natural sediment transport, is extremely limited which should have been reflected in the EIS and ideally identified as a key data gap, but was not.

2.1.2.2 Turbidity

As early as the Environmental Baseline Study and Impact Assessment by Dial Cordy Associates (DCA) in 2001, indirect impacts associated with dredging were predicted to lead to "temporary changes to the habitats adjacent to the area being dredged…in particular reef and hardbottom habitats just outside the entrance channel or within the local area offshore of the port may be affected". In addition and in particular, related to turbidity, this report adds that "resuspension and deposition of sediments within the adjacent area will result in temporary periods of high turbidity" suggesting they believe that any effects will be short-term and return to previous conditions once dredging stops. In SAJ (2004) it states that "the Recommended Plan would cause temporary increases in turbidity however these levels would not exceed permitted variance levels outside of the mixing zone". Further comments by DCA in SAJ (2004) suggest a "temporary increase in turbidity during dredging may cause increased turbidity at the point of discharge from disposal sites", again stated with no qualification.

The statements go on to say, and presumably are based on the unqualified statement above, that there will be no indirect impact in the mid to far-field on seagrass, hardbottom communities, or coral, with the only impact being areas where direct removal will take place; for example, it is stated that "potential indirect impacts may include resuspension and deposition of sediments on nearby coral…this resuspension of sediments may result in temporary periods of increased turbidity within the area". Once again no qualification is given and is purely based on the naïve and uninformed assumption that the dredging operations will not cause significant or even moderate turbidity from any overflows or discharge, and in particular from a cutterhead and/or trailer suction dredge.

SAJ (2004) continues by stating that "environmental impacts from a cutterhead dredge will include localized suspended sediment along the bottom". This is consistent with the statement that "predicted suspended sediment around the draghead and overflow can be reduced…and that suspended sediment is expected to settle quickly because the overburden…is mostly sand" and "the majority of the materials within the project area include interbedded layers of sand and rock that are not expected to generate significant turbidity on removal". Further comments are added that since sensitive seagrass sites are 500 to 2,000 feet away from proposed dredging and "since the material to be dredged…principally comprises limestone, sandstone and clean quartz sand (USACE 2001), transport and deposition of fine sand/silt onto nearby seagrass beds is not expected".

The repetitive statements or claims listed above are numerous and re-affirm the view, incorrectly, that turbidity from any aspect of dredging operations (cutterhead, overflow etc.) was not expected. This is despite the weight of evidence to the contrary in the scientific community,

journals and publications, without any regard, understanding, or attempt to determine the fate or likely dispersal of any turbidity created or the pattern of sediment deposition.

It should be noted that detailed core borings were not collected until 2010, and that these showed that silt was present in virtually all overburden samples seaward of the breakwaters (CE and T, 2011).

It is also important to note that no clarification was given in SAJ 2004 as to the source of the turbidity, which can be both organic (phytoplankton, diatoms etc., see Section 2.1.1) and inorganic (suspended sediment), which could be a result of dredging and/or natural sediment transport processes due to tidal currents, wind-induced currents, and waves. No attempt was noted in this document to distinguish the constituent parts covered by the term “turbidity” or the primary source(s) further adding to the lack of accuracy or specificity (SAJ, 2004). However, other sources of turbidity are noted and indicated to have led to water quality degradation including storm water discharges, runoff, particularly from the Miami River, and resuspension of sediments due to tides, waves, wind and vessels leading to increased suspended sediment concentrations (SAJ, 2004). In the case of seagrass beds within Miami Harbor itself, it is stated that they already “experience chronic turbidity and sedimentation due to erosion, daily outflow from the Miami River, daily ship and tug activity in addition to natural turbidity sources including runoff, wind, or tide-driven shifting of shallow sediments”. It is hard to understand why the report did not recognize that if the above factors cause an impact including “chronic turbidity and sedimentation” how dredging of more than 2 million cubic yards of material would not be far worse, unless the parties were aiming to “play down” any impact. However, in their defense, it is stated that the proposed dredging activity will “comply with state water quality standards for turbidity, the additional turbidity and sedimentation would add to background sources already present at the Port. This is expected to place additional stress on adjacent seagrasses over the short-term”. No explanation is given as to why this would be short-term with the report going on to say that “dredging is not expected to result in long-term negative impacts to seagrass beds”.

Despite the claims and suggestions above which were repeated to state consultees indicating “little or no turbidity to be expected during construction” and that state water quality and turbidity standards will be met”, in the responses documented in SAJ 2004, FDEP indicated as early as February 2000 that the dredging will create “turbid water” with “silt particles [that] can also smother and suffocate animals and plants”. FDEP goes on to recommend that a 3-D model for 1 year should be run for currents and salinity only, although they do discuss using the model to look at cumulative effects. This recommendation from FDEP highlights the fact that it was not only DCA and SAJ that did not adequately consider sediment transport processes and impacts.

Similarly in 2004, NMFS highlighted that dredging in certain areas containing high fines contents, as identified by the Corps (USACE, 2001), could “redistribute suspended sediments in other areas both inside and outside the study area”. NMFS highlight that resuspended particulate matter and deposition of sediments in sensitive areas should “warrant water quality standards that exceed the State of Florida’s general water quality certificate for dredging…and recommend that sedimentation monitoring program be developed…and if sedimentation monitoring reveals lethal or sub-lethal effects to marine resources, additional mitigation may be warranted”.

Statements made by DCA in terms of the dredging having a limited and short-term impact, such as those above and similar, were repeated *ad nauseam* in numerous subsequent reports without any scientific justification, citation or reference. In addition, these statements were not limited to turbidity, but also included impact on wildlife, seagrass etc. without any idea on what the dispersal and fate of turbidity or deposition of sediment from dredging may be. As a result of these repeated statements, they almost became fact and were subsequently re-quoted by DCA and SAJ in later documents e.g. SAJ, 2004. The study and report from DCA in 2001 focused on the channel east of the breakwaters only (subsequently termed and known as Cuts 1 and 2) and up to 150 m (500 ft) either side (north and south) of the channel. Survey work included towed video and sidescan sonar surveys, diver transects and fish habitat characterization. No monitoring was carried out in terms of water quality or sedimentation and also nothing was done to predict the impact on or likely longevity of any impact or the spatial extent of any impact particularly given the relatively localized study area with respect to the channel. Unfortunately, these unqualified statements then propagated through and were compounded within subsequent documents issued by SAJ, for example in SAJ 2004 in response to concerns raised by NMFS, whose prime focus (as expected) was on the marine flora and fauna, rather than considering more multidisciplinary aspects. Many of the comments provided by SAJ in SAJ 2004 were often irrelevant, defensive in nature despite being reasonable suggestions, including considering a more cautionary approach, which was dismissed by SAJ.

In addition, part of the study (DCA, 2001) was to consider dredging and disposal options, although given the absence of details on the dredge volume, possible dredge methods, and dredge type to be used meant this assessment was limited. However, it was apparent that disposal would be at the existing Ocean Dredged Material Disposal Site (ODMDS) by whatever means, although no consideration was given to the potential impact from this disposal and the very strong possibility that fine sediment (clays, silts and fine sand) would not reach the spoil ground if dumped from the surface by scow or hopper given the water depth of 390 to 630 ft. Again DCA 2001 stated that dredge disposal at the ODMDS “would not result in any significant impacts to the area”, without any scientific justification or reference despite the majority of the capital dredge material likely to be deposited at the ODMDS (SAJ, 2004).

Similarly, DCA’s assessment of the potential beneficial use of the sediment including for habitat restoration or creation, concluded that “negative impacts on existing marine resources…would be minor…as long as turbidity controls are adhered to”. Due to a lack of any external review of other scientific literature, this unqualified statement is entirely consistent with earlier statements that as long as guidelines were followed then any impact from dredging will be non-existent or temporary. In addition, it is proposed in SAJ 2004 that following a “coordination process”, modifications to the proposed components resulted (past tense) in reduced environmental impacts to reef and seagrass areas, this is despite any clear understanding of the general circulation and hydrodynamics or sediment dynamics of the area (SAJ, 2004).

Consistent with the view that previous capital dredging in the port had not caused any concerns or observed impact, despite the fact that scientific knowledge and understanding had advanced, SAJ proposed protective measures and precautions similar to those applied in 1990, for the MHIII dredging in 2013. This is despite, Erftemeijer et al., 2012, referencing projects from the

1960s and 1970s onwards, including in the USA, where the international scientific community documents dredging projects that have impacted coral and hardbottom communities. This course of action further demonstrates a lack of consideration and appreciation, and also a literature search, by DCA and subsequently SAJ, in terms of responses to stakeholders including NMFS.

Despite NEPA requiring a multidisciplinary approach in decision making to ensure unquantified environmental values are also given appropriate consideration, SAJ 2004 states that impacts to natural systems off the South Florida shoreline (including estuaries, benthic communities, fisheries, maritime habitat…coral reef tract) have been considered in the formulation process. However, this was not comprehensive or based on a considered and appropriate scientific review. This is primarily because it appears no parties, in particular DCA and SAJ, and more laterally the dredging contractor GLDD (see Section 2.1.5), considered that there could or would be turbidity associated with the dredging which, in turn, would lead to sedimentation over time on the coral and hardbottom communities. Given turbidity was not anticipated, no adaptive management was put in place to address or deal with this when it occurred within a few weeks of dredging activities commencing, around approximately Week 9.

It is clear from the above that all parties (SAJ, FDEP, NOAA/NMFS and USFWS) believe that the State water quality standards for turbidity monitoring are and should be sufficient. It is also clear that SAJ are of the view that through good planning and design and adopting these standards, implementing Best Management Practices and agreeing to the monitoring, that any impact will be temporary. However, there is some discrepancy over the scale of any mixing zone with 150 ft (which is far too small an area) mentioned by USFWS whereas the final permit issued by FDEP refers to (as do other documents) of a mixing zone of 150 m (not feet; see Section 2.1.4). The only exceptions noted and relevant to this were:

- NMFS recommended that monitoring was more stringent and USFWS requested a contingency plan to halt dredging operations if suspended sediment concentrations exceeded acceptable levels; this was in place, but was insufficiently robust (see Section 2.1.4).
- USFWS also suggested that dredging should only take place when the environmental conditions would not contribute to siltation and sediment transport, which would minimize impact. In order to do this, it would be necessary to know what those environmental conditions were, which would require an idea of the current velocities, net residual transport and the fate of material from the cutterhead/draghead and any overflows. In detail, this would include and require an understanding of the key sediment transport processes; including transport pathways and rate of movement, dilution and dispersal (which in turn could affect the water quality, light attenuation etc.), whether sediment settles out and deposits and for how long and how much and also whether any subsequent resuspension occurs or whether this material remains and causes an accumulation over time leading to impact on the coral and hardbottom communities. USFWS made practical suggestions as to how to minimize or reduce potential impact from dredging by reducing the amount of fine sediment resuspended,

clearly recognizing and highlighting the risks on the environmental resources from the proposed dredging operations.

- Bob Hall at FDEP proposed that "additional prevention measures and consideration of limiting dredging to out-going tides should be considered".
- South Florida Water Management District proposed that a new study be conducted in terms of modeling in 3-D the hydrographic and salinity changes in the bay and wider area with a simulation period of over one-year. This was in response to the Brown et al. 2003 model that had a simulation period of only 2 weeks (see Section 2.1.1)
- Miami-Dade County DERM asked how SAJ was going to meet the water quality standards, given turbidity curtains proved ineffective at Miami Harbor and asked this to be clearly outlined.
- Tropical Audubon Society highlighted that the "RFP process is often seen as an opportunity for innovative technologies, cost efficiency, and project success. However, there is a long history of RFP process resulting in a low-bid winner whose only goal is to maximize profits utilizing short cuts to minimize costs. The focus of low-bid winners is cost-effectiveness not environmental protection."

Unfortunately these concerns or suggestions do not appear to have been recognized, accepted or proposed either by FDEP in the final permit (see Section 2.1.4), with only cursory comments made in these areas, or by SAJ in terms of improving on the FDEP permitting or specifications within the dredging contract. The regular or typical response from SAJ was Best Management Practices will be used, without any detail as to what this involved, although in SAJ 2004, DCA suggest that "some impacts are unavoidable even if the best planning efforts are adopted". In response to DERM's point, SAJ did acknowledge that turbidity curtains had been used successfully previously and that protection measures would be down to the dredging contractor including turbidity curtains, turbidity hoods on the cutterhead, dredging on an outgoing tide only, and the speed of the cutterhead and that it would be up to FDEP to establish the overall water quality standards. It is not clear how many of these were considered by GLDD; certainly few were imposed or recommended by FDEP in the permitting, resorting to monitoring turbidity levels rather than imposing specific conditions on dredging.

The only reference found where DCA recognize some degree of potential impact from dredging, is in the following statement in SAJ 2004. DCA state initially that any impact will be temporary and then on the very next page of the document reverse this statement. Initially, DCA state that "dredging may result in suspension of any fine carbonate materials that have settled on substrates or have been enclosed within reef structures ("powder pockets")…this resuspension of sediments may result in temporary periods of increased turbidity within the area". However, DCA then goes on to say that "where silt and/or silty sand are to be dredged, water quality impacts are expected to be significant, and take several weeks/months after cessation of dredging activities to return to background levels". Once again, no reference or qualification is made as to how this different conclusion has been made. In addition, in the same paragraph, DCA state "recent efforts to quantify real impacts of dredging incorporate only the waters directly above dredged substrates. However, due to the physical properties of water and the

complex hydraulics operating within the harbor and channels, these efforts greatly underestimate the extent of negative effects of dredging". Once again no reference or scientific citation or explanation of what has been measured, although what they appear to be proposing is that the potential impact from dredging could be far greater than previously indicated or expected.

Given the concerns and comments above, it is either up to the State regulator, FDEP, or alternatively SAJ to address these and take ownership of the project and all aspects associated with it. In addition, DCA and GLDD should've been cognizant of the risk and potential impact from dredging on coral and advised SAJ accordingly. Certainly DCA should have carried out a detailed review of the scientific literature in contributing to SAJ 2004 and GLDD would have been very aware of the risks and sensitivity from previous dredging operations including recent projects such as in north-west Australia (see Section 2.1.5).

2.1.2.3 Sedimentation

Further to the numerous statements in 2.1.2 regarding the temporary nature of turbidity being short-lived etc., there is no clarification or mention of the fate of any turbidity in the water column both in terms of organic matter or indeed suspended sediment either as a result of natural processes and/or dredging operations.

In terms of the EIS (SAJ, 2004) Appendix J Mitigation Plan there is mention that the "reef monitoring program will consist of both physical and biological components". For physical monitoring, this will assess the degree of settling of the [dredged] reef materials. However, no indication is provided in the document or subsequently how or if sedimentation associated with dredging will be separated from natural processes (see Section 2.1.6). This means that the pre-dredge baseline data collected 2013 in order to establish the impact of any observed sedimentation cannot be distinguished between dredging operations and what is natural littoral transport. This could result in anything from 0 to 100% sedimentation and everything in between being attributed to dredging operations or conversely natural sediment transport processes. This position creates a very difficult and un-defendable position for the Corps particularly in light of the pre-dredge baseline data being collected after commencement of dredging.

As is noted in Section 2.1.2, there was almost no consideration of sedimentation due to dredging operations (or natural processes and how to differentiate these) and therefore the potential impact on coral and hardbottom communities, despite the awareness and comments from different parties of the likely effects. As a result, no adaptive management plans, strategies, or additional monitoring were put in place to address this if, or (as it turned out) when it occurred, including ceasing dredging (see Section 2.1.5). This was further compounded by the sparse, inconclusive and temporally very short pre-dredge baseline data (see Section 2.1.6).

2.1.2.4 Coral Resources

The final Environmental Impact Statement (EIS) and General Reevaluation Report (GRR) for MHIII is dated February 2004 (SAJ, 2004). Pre-dredge baseline biological surveys occurred in the fall of 2013, with construction commencing on November 20, 2013, before pre-dredge baseline biological surveys were complete. Despite the nearly ten year time-span from completion of the final EIS to project construction, a supplemental EIS was not produced. The

National Environmental Policy Act (NEPA) states that a supplemental EIS is required when "there are significant new circumstances or information relevant to the environmental effects that have bearing on the proposed action or its impacts" (www.epa.gov/nepa/national-enviornmental-policy-act-review-process). From 2004 to 2013, significant new information with direct relevance to corals in the vicinity of MHIII became available. In this timeframe, the fields of climate change and ocean acidification (which directly affect coral survivorship) (See Hoegh-Guldberg et al., 2007; Pandolfi et al., 2011) coral stress and disease (See Weil et al., 2006; Miller et al. 2009), and reef resilience and restoration (See Bellwood et al., 2004; Precht, 2006) advanced rapidly. Additionally, in May, 2006, two species of corals, staghorn coral, *Acropora cervicornis* and elkhorn coral, *Acropora palmata*, became the first corals to be listed as threatened under the Endangered Species Act (ESA)(71 FR 26852). In 2009, five additional species of Caribbean corals were petitioned to be listed under the ESA, and later designated as threatened in 2014 (79 FR 53851). All seven species have geographic ranges that include the Florida Reef Tract offshore Miami-Dade County. Also in 2009, new, more detailed benthic habitat maps based on LIDAR data were published for coastal waters offshore Miami-Dade County (Walker, 2009).

2.1.3 FDEP Permit 0305721-001-BI

FDEP issued a Final Order Permit on May 22, 2012, stating there should be "no elevation of turbidity…authorized within the boundaries of the Biscayne Bay Aquatic Preserve, designated as Outstanding Florida Waters (OFW)" greater than a temporary mixing zone of 150 m and to establish a maximum allowable turbidity level above background within these OFW during project construction.

Overall, the terms and clauses in the permit relevant to this review, noted below, are very generic and lack specific details on what is meant or required which created ambiguity. It is assumed or possible that FDEP, and in turn SAJ, wanted to avoid being (overly) prescriptive and were therefore very much reliant on a very competent and professional contractor with the main focus being environmental protection to ensure conditions were monitored correctly and exceedances of the permit notified and addressed promptly. In the absence of a client (SAJ) representative on site ensuring compliance to the permit requirements, a lack of prescriptive conditions and a contractor focused on other more commercial aspects, including preventing dredge downtime, this could, and probably did, lead to shortfalls in the monitoring. By comparison to water quality/turbidity monitoring, the permit is much more prescriptive for coral, hardbottom resource monitoring.

Subject to any separate clarification agreed between FDEP and SAJ, which it is assumed did not exist and this review is not aware of, it is likely to lead and probably did lead to a very wide interpretation. Every indication, including SAJ's intention noted above in SAJ 2004 is that SAJ accepted and worked within the permit rather than made its own interpretation including tightening the monitoring requirements specified to the dredging contractor and its sub-contractors. In turn this would allow, and inevitably did allow, the dredging contractor and its sub-contractors to make their own interpretation, further compounding the problem in terms of the lack of specific detail provided in the FDEP permit.

In terms of specific clauses relevant to this review, the following are noted with comments added in italics relevant to the generic nature of FDEP's permit and ultimately SAJ's contract:

- "Best Management Practices (BMPs) shall be utilized where appropriate and maintained at all times…to minimize turbidity generation including when conditions appear conducive to the encroachment of a turbidity plume into the OFW and to prevent spillage of hazardous substances into waters from dredge or scows". *No indications were provided in terms of BMPs. It is not clear as to whether FDEP's definition of a "hazardous substance" includes the dredged sediment that is in the scow or hopper that is being collected and transported.*
- "Turbidity control devices shall be installed prior to commencement of construction in any given area and maintained daily to ensure integrity and functionality until post-construction clean-up of each work area is completed". *No details were provided as to what turbidity control devices FDEP was considering.*
- "Comply with barge monitoring protocol in EPA's and SAJ's September 2008 Miami ODMDS Site Management and Monitoring Plan (SMMP) including vessel tracking adding "if a scow is determined to be leaking, use of that scow will cease and repaired promptly".
- Contractor's Environmental Protection Plan including BMPs to be implemented to prevent erosion, turbidity etc." *Again no detail on BMPs.*
- "Turbidity monitoring shall be conducted by individuals with prior experience in turbidity monitoring for major dredging projects". *This review can find no details on International Towing and Salvage LLC or their experience or whether they are even in business. No details were provided as to the nature of experience, whether monitoring was deemed "successful", or the complexity or technical knowledge the contractor should have had.*
- Requirements for turbidity monitoring comprised measuring "background" in the "surface and mid-water column at least 300 m upcurrent of dredge and clearly outside of any influence generated by the project or other obvious turbidity plumes". *No details on how the contractor should assess "upcurrent" including and very importantly, any water-column stratification especially given flows could be reversed or flowing in different directions between the visible surface currents and lower water-column. No mention of near-bed measurements at all despite the TSHD or CSD operating at the bed and typically 20 to 30% or higher of the bed sediment/rock being dredged entering the water column in terms of stripping losses (see Section 2.1.3). This would create a very high suspended sediment layer near-bed. By its very nature, a heavily sediment loaded water mass (such as a dredge plume) is going to be dense, mix poorly (excluding areas of high current flow, turbulence or shear) and therefore have a tendency to only be in the lower water column and generally much closer to the sediment bed. Therefore measurements did not cover the entire water-column and critically did not include near-bed. With no understanding of the direction of flow or water column stratification it would be extremely difficult to explain the results and identify any anomalies. Given the above, it is unlikely that a true, representative or*

comprehensive assessment of background turbidity would be recorded making it harder to accurately determine turbidity related to dredging operations only.

- For what FDEP classed as the "Compliance" area subject to within or outside OFW, turbidity monitoring was required in "surface and mid-water column not more than 150 m down current from the dredge within the densest portion of the project-related turbidity plume, outside of OFW. Inside OFW at dredge sites, the same monitoring was specified not more than 750 m downcurrent within the densest part of the plume". *As above, no mention of how to measure "downcurrent", record water-column stratification and notably no requirement to monitor the lower water column where the greatest turbidity concentration and impact from dredging was likely. In addition, the "densest portion of the project-related turbidity plume" is highly subjective and ephemeral particularly if tidal currents, waves, wind-driven circulation are present and/or if there are multiple sources of project-related turbidity, i.e. from dredging, overflows, spillage or leakage from scows etc. Given the dynamic nature of the turbidity and source/s and the highly subjective nature of measuring the "densest part of the plume", it is very unlikely that turbidity measurements from dredging operations were remotely accurate or representative of what was actually being released into the water column and certainly in the lower water-column, in particular near-bed.*
- An intermediate area is also specified for an "expanded mixing zone within OFW and where the turbidity plume extends over known hardbottom and (or – presumably) seagrass resources requiring monitoring "at surface and mid-depth at 150, 300, and 500 m downcurrent from the dredge". *Similar issues as above.*
- "Water samples required with each compliance monitoring event". No specification as to whether these water samples should be analyzed, and if so, for what parameters. Importantly, no indication as to whether the samples or data should be used to calibrate the turbidity logger used for monitoring to convert turbidity data readings from NTU to mg/L.
- Compliance monitoring was required approximately every four (4) hours during daylight dredging, beginning approximately 30 minutes after the commencement of dredging or other construction activity. "Compliance monitoring shall also be conducted whenever a substantial plume (i.e. a plume that, in the monitors' professional judgement, may result in an exceedance of the turbidity standards) approaches the edge of the mixing zone (i.e. 150 m from the turbidity source) when working outside of OFW or 750 m from the dredge when plume extends into OFW…such that a water quality violation may exist". Reduced monitoring during night time dredging was outlined by FDEP. *There is no definition of a "substantial plume" in terms of turbidity concentration as a guidance or scale (diameter) leaving it ambiguous. In addition, during night time dredging, in the absence of comprehensive turbidity monitoring both vertically and horizontally through the water column, identifying upcurrent and downcurrent or the densest part of the plume, is even more subjective and likely to create all sorts of variations in the quality of the monitoring.*

- Notably, the permit notes that "transporting dredge and fill material does not qualify as a permitted turbidity source". It is not clear whether this means scows cannot leak, as in they are not permitted to leak, or that leakage does not fall under the turbidity monitoring requirements specified in the permit and therefore is less important. If the latter, this is in contrast to the comment above in terms of ensuring that "if a scow is determined to be leaking, use of that scow will cease and repaired promptly". This potentially means that if there is leakage from a scow or hopper, which did occur multiple times, unless this was classed as a "substantial plume" (which as above was not adequately specified), it would not be monitored even if or when it occurred near or over a hardbottom or seagrass resource.
- In terms of permitted turbidity concentrations, the permit indicates limits "outside OFW (seaward of Government Cut) turbidity at the edge of the approved mixing zones shall not exceed 29 NTU above background" and within the OFW not to exceed 9 NTU adjacent to the seagrass mitigation site or 13 NTU elsewhere. Calibration of the turbidity logger is to follow FDEP laboratory SOP; the link specified would not open at the time of this review. FDEP SOP as follows: "The instruments used to measure turbidity shall be fully calibrated within one month of the commencement of the project and at least once per month thereafter during project construction. Calibration shall be verified each morning prior to use, and after each time the instrument is turned on, using a turbidity "standard" that is different from the one used during calibration"; *presumably the original monthly calibration. As outlined above turbidity typically comprises a range of biological and physical material including natural sediments and importantly sediments related to dredging. Ideally background measurements, measured correctly, would reflect any natural sediment or background turbidity, however different particles/marine fauna respond in a variety of ways on a turbidity logger which is why the vast majority if not all similar operations require calibration of the turbidity logger using actual samples from the site from the water column where measurements are made. This allows calibration to the specific material being created, in this case dredged sediment, with water samples being analyzed for Total Suspended Solids to allow data to be expressed as mg/L rather than in more arbitrary units of NTU.*
- Additional measures specified include "whenever turbidity levels exceed the values states above, which would be indicative of a violation of state water quality standards, immediately cease all dredge or discharge operations that may be contributing to the water quality violation. Cessation of dredging or discharge operations shall continue until monitoring indicates that turbidity levels are meeting the applicable values stated…modify the work procedures that were responsible for the violation…installing additional BMPs. *This requirement in itself is relatively prescriptive however, the permit conditions above, for the reasons outlined, are likely to lead to few exceedances or occasions where it is clear and data comprehensive enough to lead to cessation of dredging and/or discharge operations. Given the monitoring requirements in the permit, unless turbidity was very significant resulting in plumes from the cutterhead*

dredge mixing sufficiently into the mid- or surface water column to be 'noticed' by the operator, particularly during night time, and then logged, it is unlikely this would result in cessation of dredging etc.

- Assessment of sedimentation on coral, hardbottom communities and/or seagrass was proposed using sediment traps and sedimentation blocks. Sediment traps were to be similar to the design used in the Broward County Shore Preservation Project (BCSPP) with a 1" diameter pipe and an 8" length tube with the top of the trap no more than 18" above the seabed. Sediment traps were to be emptied every 28 days with the weight captured measured in mg sediment. The sedimentation blocks were specified as 8" x 8" x 8" cement blocks with the sediment thickness deposited being recorded on each corner and in the center of the block. *No sedimentation was recorded on the blocks for the entire pre-dredge baseline survey (see Section 2.1.6), however, despite this, monitoring of the blocks continued throughout the period of dredging, again with no sedimentation observed throughout. Unfortunately, FDEP's specification of sediment traps "similar to those from BCSPP" suggests that these worked successfully and/or measured an accurate and representative quantity of sediment, however this ignores site specific conditions at MHIII and the most appropriate sediment trap type for this location and its efficacy. For example, if horizontal current velocities and/or wave-orbital velocities are high then a sediment trap open at the top, as per BCSPP, creates turbulence and distorts the circulation at the mouth of the trap which in turn affects the capture efficiency of sediment and also affects certain particle sizes. Given velocities and turbulence vary site to site, the data collected cannot be classed as quantitative, or comparable with each other given the spatial variability in these key parameters. In areas where there are high horizontal velocities (currents and/or waves), sediment traps should have apertures on the side with baffles to force the flow downwards into the collection chamber. Storlazzi et al., 2011 summarizes these factors highlighting that the turbulent nature of flow over the trap mouth creates eddies, the intensity of which and their frequency of shedding particles increases with increasing flow velocity toward and over the trap. Storlazzi et al., 2011 suggest that "where instantaneous combined current and wave-orbital speeds >10-20 cm/s, the trapped material should only be used to provide samples of suspended sediment for physical and chemical analyses to compare to seabed samples" rather than to assume data are quantitative. However, despite this, sediment traps approximately the same as those used in BCSPP were used throughout the pre-dredge baseline, dredging, and post-dredging period (see Section 2.1.6) even though there was no detailed understanding of the hydrodynamics and in particular bottom currents in the MHIII areas including at the control/reference sites. The only information available was modeled by Brown et al., 2003 which was wholly inaccurate. Therefore the sedimentation data cannot or should not be assumed to be quantitative and comparable spatially or temporally including between permanent monitoring stations and reference stations.*

- FDEP specify pre-dredge baseline monitoring of sedimentation etc. weekly for a minimum of 28 days prior to commencement of dredging. *Given the spatial and temporal variability likely for the site as a whole including localized and seasonal effects, this period of baseline monitoring is too short (see Section 2.1.6).*
- FDEP specify monitoring reports to be submitted within 1 week of analysis.

Finally, FDEP also requested a meeting 7 days before any dredging commenced to review conditions and monitoring requirements. It is assumed given the brief time period over which pre-dredge baseline data were requested by FDEP in the permit and delays in completing this with only 2 weeks of data collected out of the 4 weeks specified, that the meeting, if held, was unable to adequately review conditions and monitoring requirements certainly from the pre-dredge baseline surveys.

Notably, compliance and reference monitoring stations were pre-determined within the permit. During this review process, there has been no evidence that the monitoring stations were pre-determined based on any understanding of the hydrodynamics and circulation of the area, rate of movement of sediment or the likely fate of material created by the dredging operations, both the TSHD/CSD and overflow.

Neither the FDEP permit nor the USACE permit modification #1 (SAJ, 2012) include a stand-alone Biological Monitoring Plan which is typically required for large-scale projects of this nature. The USACE permit modification #1 does not include language pertaining to biological monitoring of marine benthic resources nor references either the FDEP environmental resource permit or the Environmental Protection Plan (EPP) (SAJ, 2013). The permits and the EPP do not clearly define all aspects of monitoring protocols, are vague, and could be misinterpreted due to lack of examples.

In conclusion, based on this review, the FDEP permit was vague, generic, and insufficiently prescriptive, particularly for the turbidity and sedimentation monitoring. This made it relatively easy to exploit, given the approach and monitoring adopted by the dredging contractor and the turbidity monitoring subcontractor (see Section 2.1.5). Unfortunately, SAJ simply passed the permit along to GLDD without adding or strengthening it or making it easier to make checks on performance and ensuring the protection of the environmental resources.

2.1.4 Proposed Coral Stress Index

There is confusion in both the FDEP environmental resource permit and the EPP regarding the coral stress index to be utilized for coral health monitoring. The FDEP permit Section 32.i.a.2 describes a binary coral stress index where stress parameters such as excessive mucus, disease, and bleaching are to each be assigned a health level or score of “0” for absence or “1” for presence. The permit directs the reader to “see example below” however no example is included. Later, in Section 32.ii.d, the permit states that “stress expressed above normal by corals and/or octocorals within transects (stress scale used for Broward County Segment III Project) will require an additional survey to outline the area(s) of impact”. However, the permit skips a crucial step in describing how coral stress scores will be tabulated per colony, per transect, or per station, nor describes how “stress expressed above normal” shall be assessed.

To add to the confusion, the Broward County Segment III Coral Stress Index is referenced which is not the coral stress index that was to be utilized for MHIII. The Broward County stress index is a severity ranking scale from 0 to 3, in which individual colonies were assigned a total stress rank, with 0 being healthy and 3 being severely stressed (See Fisher et al., 2008). Each rank from 0 to 3 was inclusive of a suite of primary stress parameters and severity; individual stress parameters such as bleaching or excessive mucus were not each assigned individual ranks or scores as described in the previous Section 32.i.a.2 of the FDEP permit.

The EPP includes coral health monitoring protocols for MHIII in Section 3.1.10.3.b. The EPP states that the following coral stress parameters shall be included: bleaching, excess mucus production, polyp extension, and disease, and refers the reader to an example in Appendix B. It does not include visible sediment accumulation on coral tissue as a mandatory parameter to be assessed. Sediment accumulation on coral tissue is one of the easiest parameters to assess and is a key indicator of sediment stress on corals (Rogers, 1983). Sedimentation rates in excess of what corals can actively manage via mucus production, tentacular and ciliary action, and swelling will eventually lead to energy depletion, sediment accumulation on tissue, tissue bleaching and anoxia via smothering, and eventual tissue death (Peters and Pilson, 1985; Erftemeijer et al., 2012). Sediment removal is energetically expensive for corals (Riegl and Branch, 1995; Anthony and Connolly, 2004) and therefore standing sediment on coral tissue is a critical parameter to monitor when increased sedimentation from dredging is anticipated.

Congruent with the FDEP permit, Section 3.1.10.3.b of the EPP describes a binary system (0 or 1) for assessing presence/absence of coral stress parameters. However, the EPP goes into more detail and states that “a coral receiving a score of a “1” for two or more stress parameters will be classified as declining in health”.

The EPP states that presence of 2 or more stress parameters was required to designate a coral as stressed; however, this was not the protocol followed in coral health monitoring for MHIII. Coral stress parameters were not additive and corals were designated as “stressed” with presence of 1 or more stress parameters (DCA, 2014). The EPP refers the reader to an example coral stress index in Appendix B, however, this example is incomplete in that it does not tally the total number of stressed corals (which should only be those colonies with 2 or more stress parameters present). Conversely, the Key West Resource Health and Sedimentation Monitoring (RHSM) Plan (CSA, 2003) included an example coral stress scoring worksheet (Figure 1). A lack of clearly-defined monitoring protocols and examples in the permits and plans may have contributed to misinterpretation of the intended monitoring protocol by the contractor. However, if any monitoring protocols were ambiguous, the contractor should have clarified them with the SAJ prior to project data collection.

EXAMPLE 1	Project Area Site A						Reference 1						Reference 2						Reference 3					
	Coral #						Coral #						Coral #						Coral #					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Bleaching	1	1	1	0	0	1	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	1
Excess mucus	0	1	0	0	1	0	0	0	1	0	0	1	1	1	1	0	1	0	0	0	0	0	1	0
Polyp extension	1	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1	0	0	1	0	1	0
Disease	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Declining	v	v										v	v	v									v	
	2 declining corals/site						Average of 1.33 declining corals/reference site 0.67 more declining corals at project area site versus reference sites = No further action																	

EXAMPLE 2	Project Area Site D						Reference 4						Reference 5						Reference 6					
	Coral #						Coral #						Coral #						Coral #					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Bleaching	1	1	1	1	0	0	1	1	1	0	0	0	1	0	0	1	1	0	1	0	0	1	0	0
Excess mucus	0	0	0	0	0	0	1	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0
Polyp extension	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1
Disease	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Declining	v	v					v												v					
	2 declining corals/site						Average of 0.67 declining corals/reference site 1.3 more declining corals at project area site versus reference sites = Initiate more detailed survey																	

Figure 1. Example coral stress index scoring worksheet included in the Key West Dredging Project RSHM Plan (CSA, 2003).

The EPP also describes additional coral bleaching and disease “triggers” or thresholds that were to be simultaneously monitored, in addition to parameters assessed with the stress index. The coral health monitoring protocol in the EPP emulates that utilized for the Key West Maintenance Dredging Project RHSM Plan (CSA, 2003) and indeed, this was the model intended for MHIII (pers. comm, T. Jordan-Sellers, SAJ). However, the same sentence that appears in the FDEP permit, erroneously referencing the Broward County Segment III Coral Stress Index, (“stress expressed above normal by corals and/or octocorals within transects [stress scale used for Broward County Segment III project] will require an additional survey to outline the area(s) of impact”) also appears in Section 3.1.10.4.4 of the EPP. The EPP does not reference the Key West Dredging Project RHSM Plan. It is possible that certain sections of the FDEP permit (and errors) were copied/pasted into the EPP. The intended coral stress index protocol (that used in Key West) was not what was cited in permits or plans by SAJ, FDEP, or GLDD or what was implemented by DCA during coral monitoring. Although the Key West Dredging Project RHSM Plan was the intended model for MHIII, it was not referenced, described, or followed properly in permits and monitoring for MHIII. The complete methodology employed in MHIII was not fully described until the Methods section in the Quantitative Baseline Monitoring Report for Middle and Outer Reef Benthic Communities (DCA, 2014).

2.1.5 Coral Stress Parameters

Twenty-four coral stress parameters were assessed during the pre-dredge baseline monitoring surveys for MHIII (See Table 2, DCA, 2014). While this list of stress parameters is thorough, it is problematic for several reasons:

Firstly, it includes many natural background stressors, such as overgrowth by sponges, signs of competitive interaction, and fish bites that are commonly observed in corals throughout southeast Florida at present. Coral communities and reefs in southeast Florida and worldwide have been in decline for decades due to multiple stressors including thermal stress induced bleaching, eutrophication, over-fishing, and disease (Pandolfi et al., 2005; Carilli et al., 2010). While it is important to incorporate background stress into a monitoring program, it is not practical to monitor every singlestressor, and especially those which are not unequivocally proven to be deleterious to coral health such as fish bites (See Mumby, 2009; Bythell et al., 1993) and polyp extension (expansion of polyp tentacles) which is a normal behavior for corals during heterotrophic feeding. These two parameters could have been noted, but should not have been included as parameters to designate a coral as “stressed”; which were scored as contributing to coral stress regularly during the coral monitoring for this project.

Secondly, because the coral stress index utilized was not additive, and presence of one or more of 24 possible stress parameters designated a coral as “stressed”, the ability to differentiate potential project-related sedimentation stress from natural background stress was masked. The coral health monitoring employed for MHIII did annotate the kinds of stress present on each tagged, monitored coral and later summarized in reports which stress parameters were most common at compliance versus control stations, but this method lacked a quantifiable component associated with potential sedimentation or other types of stress. Because coral communities in southeast Florida exhibit a fairly high degree of natural background stress, using a non-additive coral stress index runs the risk of finding no significant difference among compliance and control stations, as corals may be stressed for a multitude of different reasons. Inclusion of more “minor” stressors (such as overgrowth by sponges and fish bites) further increases the possibility of corals to be designated as “stressed” for one reason or another. While the intentions of the contractor may have been to be as thorough as possible and document all possible stressors, it led to high “coral condition scores” at both compliance and control stations. The coral condition score was the total number of “stressed” corals divided by the total number of colonies monitored at a given monitoring station. High scores at both compliance and control stations detracted from the ability to detect differences between the two. An additive coral stress index, where presence of each particular stressor contributes numerically to an overall “condition score”, would have increased the range of possible scores and the likelihood of finding potentially significant differences between compliance and control stations.

Thirdly, it is highly important to consider and include background stressors such as bleaching and disease in a monitoring program, as they reduce coral immunity and the capacity of corals to tolerate additional stresses (Schoepf et al., 2015) such as sedimentation from dredging. The reverse may also be true, whereby stress from sedimentation may increase susceptibility of

coral to bleaching and disease (Meehan and Ostrander, 1997; Wesseling et al.,1999; Sutherland et al., 2004). However, in order keep monitoring protocols practical, cost-effective, and capable and focused on detecting project-related stress, background stress parameters should be carefully selected and relevant.

2.1.6 Coral Stress "Triggers" or Thresholds

The FDEP permit did not include or define coral stress "triggers" or thresholds (i.e. pre-determined levels of coral stress that once reached, require additional surveys or adaptive management of dredging activities). Both the FDEP permit and the EPP state that "stress expressed above normal will require additional surveys to outline the areas of impact" but does not define or assign a value to the threshold itself. Ideally, thresholds for coral stress (or sediment accumulation) are established pre-project based on pre-dredge baseline data and/or pilot studies (See Shafer Nelson et al., 2015; Jones et al., 2016) which safeguard against permanent "impacts" and the need for "impact delineation surveys".

Again, using the example of the RHSM Plan from the Key West Dredging Project (CSA, 2003), various types of soft and hard "triggers" were defined in the monitoring protocol based on coral stress scoring or sediment accumulation and duration (Figure 2). Regional background stresses were acknowledged as important factors affecting coral health and therefore separate "triggers" for each coral bleaching and coral disease were also included. If 3 or more corals (50%) at a given monitoring station exhibited bleaching or if 50% were diseased, this constituted a "soft trigger" and additional coral stress surveys were required in the immediate vicinity of the monitoring station. Section 3.1.10.3.c of the EPP included the following similar language, "if three or more corals at any project area site show evidence of either bleaching or disease during a survey, this will indicate declining health at the site." This language was directly copied and pasted from the RSHM Plan as it mentions "three corals". Monitoring stations for the Key West RSHM only included 6 coral colonies total per station, and the threshold level established for bleaching and disease was 50%. A 50% target threshold for MHIII would have been approximately 15 corals per monitoring station (out of 30 total), not 3.

The EPP does mention a "stress violation" based on frequency of coral bleaching, excessive mucus production by corals, and/or covering of benthic community components such that death or degradation have occurred. The EPP also includes a maximum sediment accumulation rate of 1.5 mm per day above the analogous reference station as measured on sediment accumulation blocks (Section 3.1.10.5.b); however, the sediment blocks failed to accumulate sediment likely due to strong currents throughout the project. Therefore the pre-determined sediment accumulation threshold was ineffective.

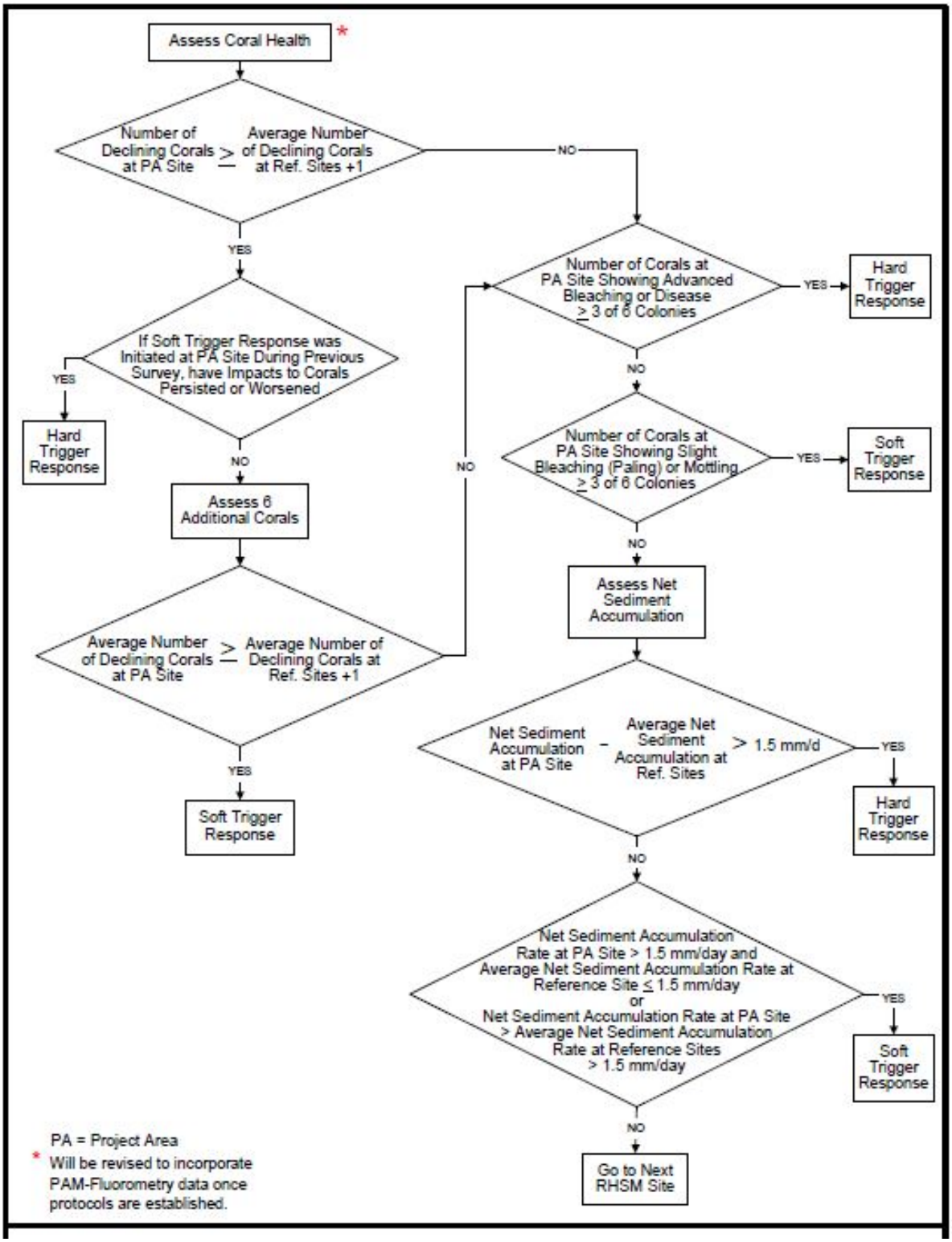


Figure 2. Example of coral stress flowchart defining soft and hard "triggers" and resulting management actions in the Key West Dredging Project RSHM Plan (CSA, 2003).

2.1.7 GLDD Proposal

GLDD submitted a tender proposal with sub-contractors Tetratech, DCA, and CSA, and were awarded the dredging contract, along with International Towing and Salvage LLC (ITS) who carried out the turbidity monitoring. Very little detail can be found as part of this review on ITS and certainly, given their core business and listed experience, it is not obviously apparent that they have expertise in turbidity monitoring, despite FDEP's stipulation that this work "shall be conducted by individuals with prior experience in turbidity monitoring for major dredging projects".

In GLDD's tender, the following statements were made to indicate their commitment to protecting the environment:

- There will be "extensive environmental monitoring of hardbottom communities and seagrass in close proximity to the dredging areas and have potential to be affected by the dredging process".
- "These resources will be continuously monitored and compared to background areas to make sure the dredging process in (*presumably is*) not causing any adverse impact to these important natural resources".
- "There will be other environmental observations and protection measures…[including] turbidity monitoring".
- They "successfully" did MHII with many of the same environmental concerns.
- "In fact, many techniques and methods specified were developed and successfully implemented by GLDD on previous projects to address environmental and safety concerns".
- GLDD's "ability to monitor and minimize impacts to the aquatic ecosystem throughout the project lifecycle is key".
- GLDD proposed an "environmental management program developed to ensure each objective (scope, schedule, budget and level of quality) is met to the highest level achievable".
- Structure and purpose "of QA activities to ensure quantitative monitoring data produced are known and of an acceptable quality and to provide a dataset that produces necessary signal that allows evaluation of whether environmental protection measures are accomplishing intended effects. This will allow objective decisions on compliance within the permit including water quality standards for turbidity and sedimentation".

The statements above, and similar ones regularly stated throughout the document, indicate a clear understanding of the importance and environmental sensitivity of the site. However, in practice and on the ground, having reviewed the approach, methodology, and ultimately the monitoring and data collected suggests that commercial interests were far more important. This may in part be a result of the lack of a prescriptive permit from the FDEP (certainly with respect

to turbidity and sedimentation compared with biological monitoring) and then from SAJ. However, it is clear that GLDD did not seek to put the environment and protection of environmental resources at the forefront of its operations. It is clear that they followed the permit/contractual requirements only.

GLDD would be very aware that the stripping losses or percentage spill of material from a CSD could typically be in the order of 20 to 30% of the material cut by the cutter head. This is material not drawn into the suction pipe during dredging. It is very likely that GLDD would be aware that stripping losses could also be as high as 50% when cutting hard rock formations (Dekker et al., 2003, Den Burger 2003 and Vlasblom 2005) as summarized in Mills and Kemps, 2016. This percentage is significantly influenced by the nature of the in situ material, cutter design, and operation (including rotation speed, depth of cut and swing), speed, cut type and ladder angle, all of which GLDD can control to some degree, in addition to particle size distribution and density of cut material and other metocean conditions (waves, tides) as dredging occurs (Lorenz, 1999, Den Burger, 2003, Palermo et al., and Henriksen, 2010). Given many of the studies and projects listed were approximately 10 years earlier or more than MHIII, including studies by the USACE, it is hard to assume that GLDD was not aware of the above. It is also unlikely that GLDD were not aware of a dredge project very similar to Miami where a catastrophic environmental impact occurred 10 years prior in Geraldton, Western Australia, particularly given GLDD's involvement in Wheatstone, Western Australia (Chevron Australia, 2016). Capital dredging in Geraldton was done by CSD removing approx. 4.1M m^3 of limestone rock substrate. The dredging took place between October 2002 and October 2003, which resulted in a turbid plume that stretched for up to 70 km along the coast and created layers of "rock flour" several feet thick in places which smothered the seabed over wide areas (Westera and Babcock, 2005) with the seabed requiring years to recover. The examples above clearly demonstrate the significant impact of dredging limestone with a cutterhead dredge. In addition, GLDD carried out roller-chopping in Miami to "pre-treat" or break up the rock without any suction which caused particularly high levels of suspended solids (pers. comm., L. Reichold, SAJ). Based on the studies listed above, roller-chopping could have created stripping losses of dredged sediment to the environment in excess of 50%.

(Note: Very crudely, considering a dredge volume of approximately 2 million yd^3 (assuming approximately only 33% was broken apart by CSD/roller-chopping into fines in the vicinity of Middle Reef, rather than the total estimated volume of 4.4M m^3 or 5.8M yd^3) spread over an estimated 216 acres (the area assessed by DCA to indicate sedimentation) at an average of 20% stripping losses, this would approximately equate to a deposition on the hardbottom communities of 13 inches or 33 cm, which is comparable with some reported observations of sedimentation on Middle Reef. Unfortunately, given no details were recorded of dredge volumes disposed at the ODMDS and the likelihood that a proportion of the fine sediment (silt and sand) probably did not make it to the bed within the vicinity of the ODMDS site, it is not possible to corroborate these volumes).

Despite likely knowledge of at least some or all of the above, GLDD accepted the FDEP permit requirements, passed on by SAJ as stated, and did not consider or advise or recommend additional or more comprehensive monitoring even though GLDD recognized the importance

and sensitivity of the environmental resources. It is possible, even highly probable, that this position was adopted to avoid any down-time or cessation of dredging (at GLDD's cost and impact on profit). Undoubtedly the lack of more prescriptive and comprehensive permit requirements allowed this position to be exploited and certainly does not agree with GLDD's statements listed above to have an "environmental management program developed to ensure each objective (scope, schedule, budget and level of quality) is met to the highest level achievable". Considering GLDD's experience immediately prior to MHIII in 2012-2013 with DEME for Chevron's Wheatstone (Chevron Australia, 2016) project near Onslow, Western Australia, which had much more stringent environmental monitoring, the standard of operations in Miami were highly questionable. The project for Chevron Australia required capital dredging of similar carbonate limestone rock and had a much more stringent and adaptive management and monitoring systems, which GLDD successfully worked within. Therefore, GLDD demonstrated that they can work within these stringent environmental constraints and conditions if or when required by the client or permit.

The Wheatstone project had a tiered "trigger level" approach to water quality monitoring created robust thresholds to manage any potential impacts on corals and seagrass habitats etc. surrounding the dredging area. Trigger levels were set for turbidity above which different levels of management were necessary including:

- adapt method of dredging (i.e. rate of dredging, overflow management);
- adapt method of disposal (i.e. placement location, rate of discharge);
- relocating dredge area within specific zones; and
- cease dredging if in non-compliance.

Importantly, water quality was monitored at regular intervals throughout the day using satellite-telemetered water quality instruments to provide near real-time data for use in proactive management. Assessment against the trigger levels occurred on a daily basis for the duration of the dredging activity. Review of the trigger values occurred through regular monitoring of the benthic communities using remotely operated vehicles (ROVs) throughout the project with comparisons drawn against the pre-dredge baseline and reference communities to detect any changes to the status. In addition, daily forecast modelling was used as a valuable tool to predict potential future impacts to water quality, including cumulative impacts, enabling proactive management to address issues before they occur. Hindcast modelling (using known source terms) was also a valuable tool to differentiate the relative contribution of various dredging activities when changes to water quality occurred as well as to differentiate between dredging related and natural effects. Monitoring in tiered levels ensured that warnings were available in sufficient time to enable management of operations to avoid reaching the threshold of unacceptable impact that would have stopped the dredging activity (Chevron Australia, 2016).

GLDD proposed to put adaptive management strategies in place with respect to environmental monitoring and to make management decisions based on monitoring results including coral condition, functional group cover, and sedimentation rates. However, very few details on adaptive management were provided. GLDD mention that "data information will be updated

constantly…facilitating the proactive protection of hardbottom and coral reef resources…a number of provisions will be made to ensure that unauthorized hardbottom impacts do not occur". It is not clear what "unauthorized" impacts were, but certainly no details were provided and clearly recent experiences in Western Australia were not proposed for MHIII. In addition, GLDD state that "hard coral condition and sedimentation rate limits will be used as measures to trigger corrective actions" and "data from these (in-situ) surveys may be used immediately (same day) to inform decisions on whether or not corrective action must be taken". In practice this is not something that was done or done on a daily basis. GLDD proposed that in the event of a turbidity exceedance, the SAJ "Environmental Compliance Coordinator would be notified and construction activities will cease immediately and not resume until corrective measures have been taken and turbidity back to acceptable levels". It is not clear as part of this review, how often, when, or even if this ever took place.

One example of adaptive management that GLDD proposed as part of the environmental monitoring of hardbottom communities and coral was that "hard corals exhibiting two or more condition parameters will be classified as declining in health. If three or more hard corals exhibit any conditions listed in Table 5, this will indicate declining health at the monitoring station. These results will be reported immediately to the Environmental Manager who will coordinate a corrective action (e.g., move dredge). Additional surveys may be necessary". It is not clear from this review whether this was ever done. However, GLDD goes on to state that a "verbal notification of sediment stress will be followed by a written report to be submitted within 24 hours to the agencies and agencies will be notified immediately of the possibility of unacceptably high sediment levels on the reefs. If stress is recorded, the dredging operation may be required to move to a new location, at least 400 ft away; until effected (presumably affected) organisms have recovered (signs of stress are no longer visible)". Given the significant spatial impact of dredge plumes from TSHD, overflows and in particular CSD and roller-chopping, as referenced in the literature above from the previous decade or earlier, it is naïve to assume, and misleading to state, that moving the dredge by 400 ft would have any measureable keffect on the coral and/or hardbottom affected or allow any recovery in the short to medium term.

As per the FDEP permit, GLDD reported turbidity monitoring data in NTU, despite the industry standard for dredge material being measured in mg/L for total suspended solids including, tests they carried out on the scow/hopper loads, which were measured in mg/L. More importantly no attempt was made to calibrate the turbidity monitoring equipment using the water samples collected. This would have allowed measurement of water quality data specifically related to dredged suspended sediment rather than all turbidity, which could be affected by biological material and also natural suspended sediment. In the case for the CSD dredging of carbonate limestone rock, this would be notably different from the dredging of ambient seabed/overburden material. Calibration of the turbidity monitoring equipment should have been done and is typically done on a regular/daily basis for the specific material being dredged and the dredge plumes being created to avoid or minimize the effects of other more natural material affecting the results. Given water samples were being collected and tested, it would not have been very costly or burdensome to carry this out and should have been done as standard practice. Instead, GLDD proposed to inspect and certify the instruments annually using formazin and

then a secondary standard on a daily basis. Neither “standards” would reflect or compare with any of the dredged suspended sediment created during MHIII. As part of this review, no comparison or calibration between the dredged sediment and the instrument readings was identified.

In addition, GLDD and its subcontractor did not have any mechanism to determine water velocities or water direction, with entries typically “N to S” (north to south) or “S to N” (south to north) or even “NA” (presumably Not Available); this is despite much of the dredging activity, and therefore turbidity monitoring, being in the channel where tidal currents were more likely to be east-west some or all of the time, orientated in line with the channel. No water column stratification data were recorded in order to assess whether any dredge plumes were moving in opposing directions in the water column. Based on the above, measurement logs provided by the contractor, including accurate recording of ambient data, tends to appear as cursory rather than detailed and comprehensive, and certainly not along the lines of the “highest level achievable” or similar as stated by GLDD. Given the subjectivity of identifying and measuring the “densest portion of the project-related turbidity plume” as per the FDEP permit, GLDD made little additional attempt to ensure this was done or achieved and based on a clear understanding or physical measurement of the ambient conditions, despite assurances stating that “turbidity will be closely monitored to assure (*presumably ensure*) that levels do not exceed compliance standards established in this permit”. Given the terms of the permit, no SAJ representative on site ensuring this was done systematically, it would be very easy for a less rigorous monitoring program to be adopted minimizing or removing the chance of any turbidity exceedances and perhaps explains anecdotal evidence that turbidity was seen as significant and yet turbidity monitoring data showed no concurrent exceedances. Had measurements been done in the lower water-column, as should have been the case with CSD and/or roller-chopping operations taking place, this would have undoubtedly led to exceedances and cessation of dredging, which GLDD would not have wished for. However, it would have certainly helped protect the environmentally sensitive resources GLDD proposed to do, as stated: “make sure the dredging process in (*presumably is*) not causing any adverse impact to these important natural resources” and “first and foremost…to devise a plan that was the most environmentally sensitive to both natural resources and endangered species”. In addition, GLDD stated under their proposals to ensure protection of the environment, presumably based on experiences such as the Chevron Wheatstone project, they list other “very environmentally sensitive areas” they have operated whilst “minimizing environmental impacts”.

One of the measures GLDD indicate they would put in place to ensure protection of the environment was to have sufficient volume capacity in terms of scows or dump barges to enable an “execution plan to utilize a sufficient number of barges to continuously load and tow barges without the need to overflow” whilst also ensuring that the dredge will “not experience delays due to unavailability of scows”. This was to ensure that GLLD can continue “performing work while ensuring the surrounding aquatic environment is protected”. However, on the very next page, they propose protocols to carry out overflowing; it is not at all clear why they propose to overflow having indicated otherwise and they had capacity or volume not to do so. It is also understood that GLDD discharged dredged material on several occasions with no scow or dump barge present, although no details were provided by SAJ on this.

GLDD noted that for MHII they "learned that turbidity can accumulate in a project" and that during this dredging operation, scows leaked. They proposed to ensure that all scows will be water tested and if they leak, be dry docked and re-tested before use. GLDD also stated that they would "verify scow seal integrity" and during transit to the ODMDS would "check the level and take a photo for each scow leaving the port from high rises to see if a plume…" and if a plume is seen on "two or more trips" the scow will be dry docked. However, the FDEP permit notes that "transporting dredge and fill material does not qualify as a permitted turbidity source", despite the fact that FDEP state that "if a scow is determined to be leaking, use of that scow will cease and repaired promptly". It is therefore not clear whether the FDEP permit was sufficiently clear to ensure compliance. The Environmental Protection Agency (EPA) and SAJ discussed a one foot threshold for "draft loss", equivalent to an allowable decrease in level in the scow between filling and arrival at the ODMDS pre-dumping, indicating loss of cargo in transit. SAJ indicated that was exceeded on approximately 31 occasions, representing 0.7 percent of the 4213 total scow movements (pers. Comm., L Reichold, SAJ). However, the actions taken by GLDD to rectify or address this have not been reviewed. These cargo losses, which included scows leaving with the hopper still open, would have created further turbidity plumes, which based on the FDEP permit requirements would have gone unmonitored; the fate of any suspended sediment spilled from the scow is unknown.

Given GLDD and its sub-contractor ITS were ultimately left un-supervised by SAJ to self-monitor turbidity, it is no surprise that monitoring was perhaps less than robust and certainly nowhere close to the monitoring conditions under which GLDD operated for the Chevron Wheatstone project despite very similar operations and material and despite assurances to the contrary from GLDD. It is therefore not surprising that there were very few exceedances identified and no dredge down-time, as far as is clear from this review, despite the observed sedimentation on the coral and hardbottom communities.

SAJ did propose in SAJ 2004 to use "environmental incentives as part of the RFP tender approach to "encourage the dredging contractor to avoid impacts to reef and seagrass areas" and "minimize environmental impacts". SAJ also proposed that the tender would be reviewed on the "technical portion of the contractor's proposal" by qualified staff. In SAJ 2004 the Tropical Audubon Society highlighted that the RFP process was of concern "resulting in a low-bid winner for the dredging contract whose only goal is to maximize profits by utilizing short-cuts to minimize costs. The focus of low-bid winners is cost-effectiveness not environmental protection". However, SAJ stated that the "RFP process showed the opposite with incentives to encourage potential contractors to develop a technical approach which will avoid or minimize impacts and ensure environmental protection".

In terms of GLDD's proposal, the only approach to reduce environmental impact, other than not using blasting, which ultimately may have been less environmentally damaging than roller-chopping and use of a CSD with no monitoring in the lower water-column, was the use of surge buoys in connection with anchor cables to minimize impacts to the reef.

Given the lack of acceptance or awareness by FDEP and SAJ that dredging operations would cause turbidity and potential sedimentation on the coral and hardbottom communities, and certainly the lack of advice or recognition by GLDD that roller-chopping and CSD would cause a

significant impact in terms of stripping losses and turbidity, no party including GLDD acknowledged or questioned the risks to the environment. As a result, no mitigation was planned for and the response mechanism or adaptive management plans were wholly inadequate.

2.1.8 Pre-dredge Baseline Monitoring (2013) and Report

The Baseline Monitoring Report (DCA, 2014) summarizes the pre-dredge monitoring of population dynamics, condition, and sedimentation environment of the benthic communities carried out by DCA on behalf of GLDD. These data were collected in order to compare with post-construction results "to document any change attributable to dredging while also considering other environmental or anthropogenic factors". As stated above, the FDEP permit required "protective measures" based on a "clear understanding and assessment" to ensure "preservation of natural resources, including hardbottom and seagrass". However, it indicated 28 days of pre-dredge baseline monitoring prior to dredging was adequate. For any site, 28 days is considered far too short. This is especially the case to obtain a "clear understanding and assessment", considering the variable conditions of the site, in particular seasonal variations, and the proposed duration of dredging.

DCA indicate that "quantitative sedimentation rates will be measured to test the null hypothesis", namely that "benthic communities in the indirect (channel side) sites will remain unchanged between the pre- and post-dredge surveys". This seems to be an unusual intent in terms of monitoring, rather than establishing whether there is any impact. In addition, as stated above, converting sediment trap data into quantitative data is potentially (and probably very likely) flawed and inaccurate based on the fact that the hydrodynamic conditions at the sites the traps were deployed was poorly understood and therefore the type of trap and setup was questionable. The data obtained from the sediment traps should have been used to collect suspended sediment samples for physical testing purposes only, rather than attempting to convert this into a sedimentation mass or rate per unit area over time.

Prior to the pre-dredge baseline survey, estimates had been attempted by SAJ from bathymetric survey data to try to assess sediment accumulation across Cuts 1 and 2 compared with nearshore hardbottom habitat. However, the accuracy or vertical resolution of such surveys would be questionable and is likely to lead to errors, especially when a change of 2 to 3% was being predicted over a period of years. These data and the comparisons made would also not highlight the flux or incremental change over the period between survey data or comparisons, which would provide different answers to sediment collected in a sediment trap.

In terms of the selection and location of continuous monitoring and reference sites, this appears to have been selected by FDEP setting the permit site polygons and then DCA using random point generation methods within the polygon to determine a target location, with divers identifying a high coral area rather than a sandy/barren seabed for the monitoring location. It does not appear that hydrodynamic/circulation, ecological or the likely fate of dredged sediment transport was used or considered in this process. Control or reference sites were then identified based on the same water depth and habitat type, although the reference sites to the north of the channel were approximately 9.3 km distance versus approximately 1.2 km for the south sites.

This bias or weighting is not clear and does not appear to be based on anything identified as part of this review, including for example, residual current velocities.

In addition, it is not clear why continuous monitoring sites were very close to the channel edges with no sites in more mid- or far-field locations in order to gain a better understanding of spatial variations and effects away from the dredging activities. This is consistent with earlier observations of a systematic almost entrenched focus on the biological aspects rather than considering, or ideally collecting data on, the likely dispersal, deposition and fate of turbidity and sediments resulting from the dredging. These data could be used to identify zones of high, low, and no impact, as is the case in other similar studies (e.g. Chevron Australia) in order to identify key monitoring sites and also ensure that reference sites are actually outside the impact of dredging and disposal operations.

Similarly, without this “clear understanding and assessment” and a more multidisciplinary approach, key processes including knowledge of the hydrodynamics and sediment dynamics at the site, it is possible that the reference sites, and possibly even mitigation sites, were impacted by the dredging and/or disposal operations. This could particularly be the case as turbidity and sedimentation accumulated over the duration of the entire construction project. Unfortunately, the pre-dredge baseline data, as specified in the FDEP permit and carried out by DCA, was insufficient in terms of spatial and temporal extent.

In addition to the sediment traps, DCA deployed sediment blocks as specified in the FDEP permit. Over the pre-dredge baseline survey period (and alarmingly over the entire dredging and disposal operations lasting 72 weeks), no sedimentation was recorded on these blocks. By comparison, sediment was recorded on adjacent corals and hardbottom areas, almost indicating the blocks preferentially or actively prevented sedimentation. Despite identifying that the blocks were not effectively recording any sedimentation at all during the pre-dredge baseline survey (or subsequently), no change whatsoever appears to have been made or suggested to this monitoring. No recommendation was noted in the documents reviewed to suggest alternatives or a discussion noted between DCA, GLDD, SAJ and/or FDEP to modify this monitoring approach or adopt a more informative monitoring system. It was suggested post-construction that “strong currents channel side swept all the sediment off the blocks” from the pre-dredge baseline through to the post-construction surveys; this is hard to believe and clearly indicates sediment blocks are not a suitable or reliable way to measure sedimentation offshore of Miami given the other data and evidence.

Even more importantly, despite FDEP specifying a 28-day pre-dredge baseline monitoring period with weekly data, only 2 datasets were obtained in total, with some data, including qualitative sedimentation assessments, only 2 to 4 days apart. In theory this monitoring was meant to represent two discrete datasets over the monitoring period between 13 October and 18 November 2013 before dredging commenced on 20 November 2013. Only two surveys were conducted before November 20 according to DCA due to bad weather. Surprisingly perhaps, given the brevity of the monitoring, DCA suggest a “natural sand event” occurred at one of the monitoring sites (HBN1-CR) adjacent to the north breakwater of Government Cut with a “sand wave…moving north to south as regional longshore drift” thereby concluding that “natural sand transport influences the sediment dynamics of nearshore hardbottom communities”. Given the

very brief period of monitoring, it is difficult to concur with this conclusion based on the evidence obtained.

DCA state that the pre-dredge baseline data was intended to "understand sediment dynamics at monitoring sites", however the monitoring proposed would not provide this, particularly since the sedimentation blocks recorded no sediment deposition at all and the sediment traps were emptied only once in Week 4. In addition, DCA deployed 3 sediment traps per monitoring site and at the time of collection combined all three samples into one composite sample, removing any ability to assess the variability in the sample collection. Several similar over-statements were made by DCA as to the information the pre-dredge baseline monitoring would provide. This was continued in the post-dredge assessments, which also over-stated what could be inferred, particularly quantitatively, as a result of comparing the pre- and post-dredging datasets.

DCA used the very limited sediment trap data to determine quantitative sediment rates expressed as g/day without any areal/spatial estimate (i.e. per cm^2). Given the concerns expressed above in terms of the accuracy or trapping efficiency of the sediment traps, particularly for different areas that might be subjected to varying horizontal tidal velocities and wave-orbital velocities affecting the turbulence around the mouth of the traps used at MHIII, estimating sedimentation rates is questionable. Relative to each trap and overall, it is possible some comparisons can be drawn.

Based on this review, it is not recommended that such a short duration of data (i.e. one single measurement) be used to make any comparisons as to the pre-dredge baseline sedimentation rates, versus those during and/or post-dredging. This very limited dataset does not enable or prove in anyway the null hypothesis proposed by DCA above or constitute a "clear understanding and assessment" pre-dredge or provide reliable quantitative data.

Furthermore and of grave concern, pre-dredge baseline monitoring continued in different areas through December 2013. DCA indicate that the later "pre-dredge" baseline monitoring was out on the Outer or Third Reef, however, TSHD were operating approximately 1 km away or less, with the TSHD and scows passing and operating throughout this area during this time, along with disposal of dredged material at the ODMDS approximately 2 km to the east. However, the fate of material dumped at the ODMDS, both material entrained in the water column during disposal and also material reaching the seabed, is unknown. Based on this review, it is therefore not possible to class these data as "baseline" monitoring given it is not possible to decipher whether any or all of any observations were due to dredging and/or related to background.

Regarding coral resources, four pre-dredge baseline monitoring weekly surveys were required for each of 8 compliance (channel-side) stations and 9 control stations, for a total of 17 stations for the Middle and Outer Reef monitoring areas. Pre-dredge baseline monitoring surveys occurred from October 18, 2013, to December 30, 2013. Four pre-dredge baseline monitoring surveys were completed for only 3 of 17 stations (17.6%) before dredging began on November 20, 2013. These same 3 monitoring stations were the only stations to receive all four baseline monitoring surveys; all other stations received only 2 or 3 surveys (See Table 1, DCA, 2014). All pre-dredge baseline monitoring surveys for the Outer Reef stations occurred after

dredging started. Baseline data collected after dredging activities had started provides no meaningful or true baseline condition from which to compare potential project-related impact and invalidates the scientific integrity of the entire study.

Results from pre-dredge baseline surveys for Middle and Outer Reefs show sediment stress was the most frequently observed stressor for all channel-side stations in contrast to a mix of polyp extension, excess mucus, and sediment stress (depending on the location) for control stations (See Figures 18, 19, 23, 24 in DCA, 2014). Time-series photographs of tagged coral colonies for stations where baseline monitoring was complete before dredging began show little to no sediment accumulation on corals surveyed before dredging began (Figure 3a). Conversely, time-series photographs of tagged coral colonies for stations where baseline monitoring was *not* complete before dredging show sediment accumulating on coral tissues with increased duration of dredging activities (Figure 3b). Coral monitoring data for stations monitored before *and* after dredging were both included in the pre-dredge baseline monitoring dataset and assessed together (DCA, 2014), therefore incorrectly skewing baseline data towards heavier sedimentation.

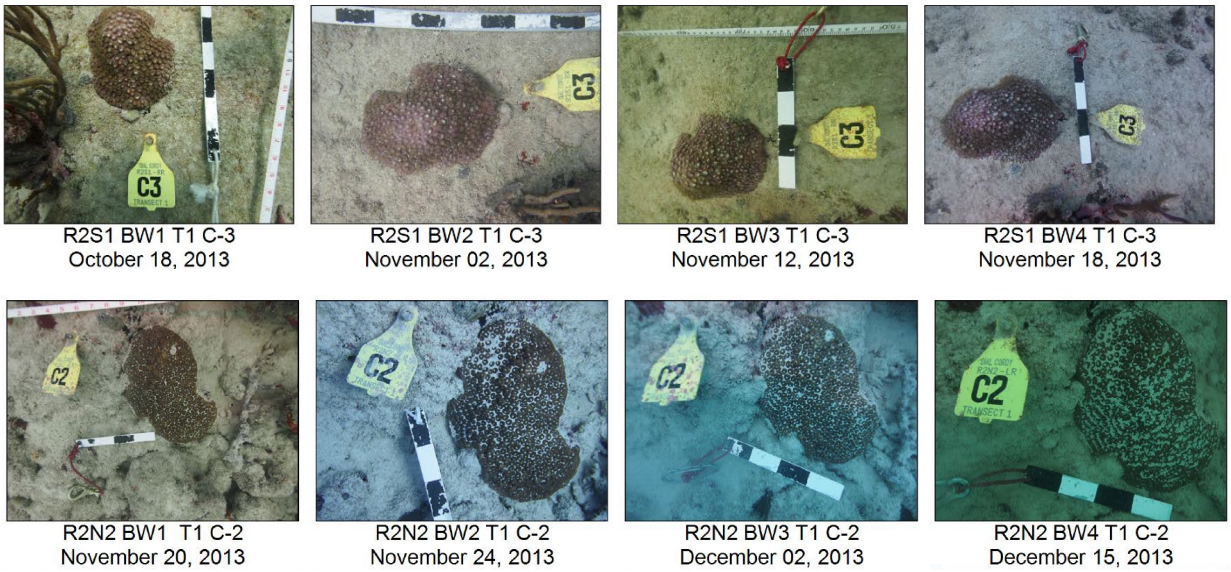


Figure 3. Baseline monitoring photographs of a) Coral C-3 on Transect 1 at Station R2S1 (*Montastraea cavernosa*), monitored prior to dredging; and b) Coral C-2 on Transect 1 at Station R2N2 (*Montastraea cavernosa*), monitored after dredging commenced. (Photos from Appendix B; DCA, 2015).

Pre-dredge baseline surveys which were completed before dredging began were compressed into a four-week timeframe, and therefore did not capture a wider range of normal conditions from various seasons and weather patterns (i.e. thermal stress in summer months and increased sedimentation in fall/winter months due to increased wave action). In some cases, the same station was surveyed twice in a 5-day period. The pre-dredge baseline data collection in 2013 was also collected only weeks before (and several weeks after) the dredging began, leaving no time for potential adaptive management of biological monitoring protocols and subsequent review by resource agencies. This is despite FDEP requesting a meeting seven

days before any dredging commenced to review conditions and monitoring requirements, presumably in light of pre-dredge baseline survey data.

Fall weather patterns and rough seas hindered diving activities during the pre-dredge baseline monitoring. No weather contingency was built in to the allotted timeframe for pre-dredge baseline surveys during a time of year well known for increased wind and wave action. Sedimentation levels recorded in traps and on coral tissues during the baseline period before dredging commenced were likely higher than average due to rough seas, the short duration of baseline data collection (lack of seasonality), and commencement of dredging activities, further undermining the baseline dataset.

This report includes several recommendations by DCA which were not subsequently followed in the monitoring program: 1) Based on results from a previous pilot study, a regression-based study design was recommended; however this is not the design employed in the baseline and subsequent monitoring surveys. The study design that was utilized and permitted by FDEP was a repeated measures design. 2) Elimination of sediment accumulation blocks, as they were shown to not accumulate sediments due to strong currents. However, the contractor did not adaptively manage in the field and utilize alternative methods to collect this type of data, such as sediment depth measurements along transects or rugosity measurements (to assess potential in-filling of hardbottom substrate). No alternative methodologies were recommended in the report. The sedimentation block data in the pre-dredge baseline report clearly showed no sediment accumulation and that the blocks did not work, yet their use continued throughout the dredge monitoring program (See Section 3.3.3; DCA, 2014).

The date of the report is March 13, 2014 for the draft and April 16, 2014 for the revised version, nearly 4 months into the dredging program. Per Section 3.2.4 in the EPP, the pre-dredge baseline report deadline was 15 days following completion of field surveys, which would have been approximately January 15, 2014. Therefore, SAJ, GLDD, nor regulatory agencies had the opportunity to review the pre-dredge baseline report before dredging began.

2.1.9 QA/QC of Coral Condition Scores

Four weeks of “pre-dredge” baseline coral monitoring photographs and data (coral condition scores) from Stations R2N1, R2N2, R2NC1, and R2NC2 were reviewed by E. Hodel as a quality assurance/quality control (QA/QC) exercise. Hodel had good agreement with the “QA/QC Condition Score” reported in Appendix A of the baseline monitoring report. Hodel agreed with stress scores and annotations relating to sedimentation parameters. She would not have normally included fish bites, polyp extension, or normal competitive reef species interactions in the analysis, but followed the same protocol as that described in the methods section of the baseline monitoring report.

Although Hodel agreed with presence or absence of coral stress parameters as scored by DCA, the non-additive total “condition score” for each coral was problematic. Presence of 1 or more of a multitude of stress parameters designated a coral as “stressed”. Therefore a coral with background stress from fish bites would be designated as stressed. However, a coral with background stress from fish bites, in addition to potential project-related sediment accumulation

on tissues would also be designated as “stressed”. Each of these corals would have received the same individual “condition score” of “1”.

The overall coral condition score for the monitoring station was the total number of “stressed” corals divided by the total number of colonies monitored. Because a coral colony could be designated as “stressed” for a multitude of parameters (including background stress), the coral data was not reflective of potential differences between compliance and control stations, nor capable of detecting potential project-related coral stress. An additive coral stress index, where presence of each particular stress parameter contributed numerically to an overall “condition score”, would have increased the range of possible scores and the likelihood of finding potentially significant differences between compliance and control stations, and also the likelihood of teasing out potential sedimentation stress.

2.2 During Dredging

Based on the above, the quality of the data collected, the limited time available and the focus of this review, a reduced amount of time was spent analyzing the physical data obtained during dredging. The complexity of trying to piece together the dredging and monitoring activity into a coherent format that could be analyzed and interpreted would be very time-consuming. This may seem counter-intuitive given the scale of questions and concerns in terms of the accuracy, scientific rigor, and statistical significance over many aspects of the turbidity and sedimentation monitoring listed above, but it was not considered an efficient use of time to do so. Key questions and concerns related to the data collected include:

- No calibration of the turbidity sensor in order to measure actual dredge suspended solids rather than turbidity, despite collecting samples and carrying out analyses of these samples (refer to section 2.1.1).
- The entirely subjective nature of the turbidity monitoring in terms of i) having no current velocity data in order to assess down/up-current; ii) no data on water-column stratification to determine if there was shear or reverse flow in the water column; iii) the experienced operator deciding visually where the densest part of the turbidity plume was; and iv) no measurements in the lower water column where it is extremely likely the majority of the suspended sediment and near bedload sediment would be and the bulk of the sediment transport would occur.
- No qualitative/quantitative sedimentation data from the sediment accumulation blocks.
- Value of the pre-dredge baseline monitoring data both spatially and temporally in addition to being 1 or 2 datasets and continuing while dredging and transfer to the ODMDS was underway.
- The sediment traps used, potentially (or likely) were unsuitable in terms of collecting quantitative data, due to the turbulence around the mouth of the trap and therefore reducing the trapping efficiency of the trap.

SAJ did provide a notice of the “exceedances” in terms of turbidity monitoring. Given the overall observed outcomes and impacts, there were very few exceedances, although considering the

points above in terms of the turbidity monitoring, perhaps this is no surprise at all. The majority of exceedances were only 1 to 5 NTU above background with only 6 with higher exceedances recorded, mostly occurring at Julia Tuttle Mitigation Area. The highest exceedance (approximately 74 and 80 NTU above background in the surface and mid-water column, respectively) was on the 27 November 2013, approximately 1 week after dredging commenced and therefore did not occur during CSD and/or roller-chopping.

2.2.1 Weekly Offshore Coral Stress and Sediment Block Compliance Reports

The dates on the weekly coral stress and sediment block compliance reports are consistently a week behind the monitoring period. It was not clear during this review from information provided by SAJ, if other means of relaying this information (and potential stress violations) were utilized and how it was documented. A week's delay in preparing the data and submitting the report could be significant in terms of potential additional duration of coral stress and/or time-lag for adaptive management. Also, Section 3.2.4.d of the EPP states that any sediment stress violations "will be reported by phone, fax, or email then followed by a written report within 24 hours to be submitted to the agencies". It is not clear whether this occurred and if so if was it properly documented.

The "Adaptive Management" and "Recommendations" sections of the weekly reports are relatively sparse and not very informative. The majority of content in the "Adaptive Management" section is copied and pasted from the previous week's report; therefore, it becomes confusing when certain adaptive management strategies ended. New bullet points were added to this section of the reports as new strategies were implemented, but previous bullet points do not drop off. One of the adaptive management strategies first described in Week 16 was the movement of the dredge to the northern side of the channel, to abate sedimentation stress at the southern hardbottom channel-side stations. Given the channel is approximately 200 meters wide, moving the dredge to the other side of channel may not have been a sufficient distance, especially considering the potential advection of dredge plumes noted at other sites and based on the assumed zone of influence from dredging was up to 750 m (monitoring was required for any station located within 750 m of the working dredge). High coral condition scores for the southern hardbottom channel-side stations were still reported for three consecutive weeks (Weeks 18, 19, and 20) following this adaptive management strategy.

The "Recommendations" section of these reports is brief and was eliminated in all weekly reports from Week 42 through the last weekly report in Week 69. The only recommendation made specific to coral health in these reports, which was repeated in several reports from Weeks 1 to 25, was that "Species specific stress responses in corals reveal differing patterns in time and space. The long-term, repetitive monitoring at each of these sites may allow differentiation between background stresses and project related stress events". No other recommendations were made within approximately 70 weeks (17.5 months) of field data as it was being collected relative to observed species-specific sensitivities or geographic patterns of heightened coral stress. Following Week 25, the only recommendation that was made (through Week 42) was that "Hardbottom site HBN1 should be eliminated from future monitoring due to

burial by natural longshore drift during pre-dredge baseline monitoring, which was not associated with dredging operations".

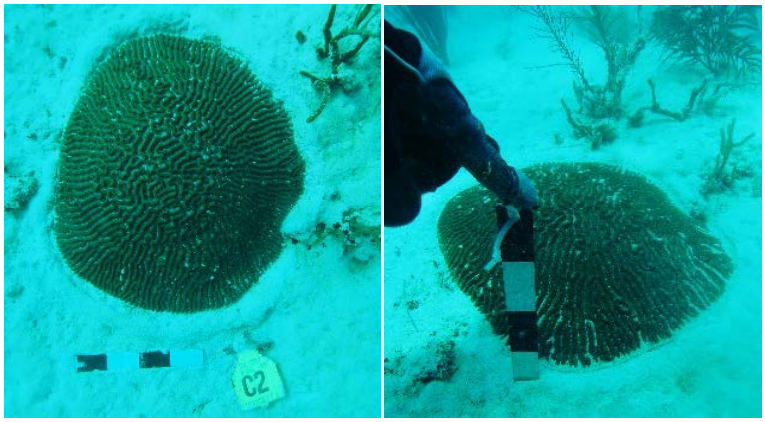
A t-test was used to compare coral condition scores between channel-side and paired control stations. If a given channel-side site displayed sedimentation stress, but its paired control displayed another type of stress (which was likely as many background stresses were included in assessments), "high" coral condition scores could result at each station, resulting in a failure of the t-test to detect statistically significant differences due to sedimentation, and thus failure of one of the sediment stress "triggers" or "thresholds". In Week 35, FDEP requested that coral condition scores due only to sedimentation-related parameters also be included in weekly compliance reports. Following this analysis, coral condition scores at channel-side stations are noticeably higher versus control stations; although it does not appear as though significance testing (t-test) was also performed for this set of condition scores. All subsequent weekly reports included this re-analysis of the sediment stress data, which was a worthwhile endeavor, but possibly further contributed to time-lags in reporting the data. An additive coral stress index may have provided an overall coral condition score more representative of the additive effects of multiple stressors and a more efficient means of quantitatively assessing a particular stress parameter independently. The non-additive stress index utilized in MHIII required re-sorting of the data and re-calculation of coral condition scores based on presence or absence of a particular stress parameter.

In Week 32, severe sedimentation stress was reported for both Hardbottom and Middle Reef channel-side stations. "Significantly elevated stress levels of permanently marked corals at channel-side stations [were] predominantly attributed to sediment accumulation, partial burial, excess mucus production, and/or extended polyps. Sedimentation on corals was documented at all channel-side sites. Partial mortality from sedimentation was also observed at HBS3 and HBS4 typically in areas where sediment has receded" (Week 32 Compliance Report, DCA, 2014). The data and qualitative descriptions in this report are of grave concern and reveal a failure to properly enforce "coral stress violations" outlined in the EPP and a failure in the monitoring and management protocols to protect coral resources before permanent impacts occurred. Once partial mortality of coral tissue happens, the change is not reversible. Less severe levels of sediment stress are reversible if sedimentation stress abates before tissue death (See Vargas-Ángel, 2007; Hodel, 2007). Sediment thresholds or monitoring "triggers" need to be conservative enough to guard against such irreversible changes (tissue death). Despite widespread impacts from sedimentation reported in Week 32, no adaptive management actions were reported in subsequent weekly compliance reports until Week 39.

Although it was recognized early in the monitoring program (during pre-dredge baseline surveys) that the sediment accumulation blocks were ineffective for measuring sediment accumulation, this method was still utilized for sediment accumulation compliance monitoring during active dredging. This resulted in meaningless datasets being reported week after week, a lack of "real-time" sediment accumulation data to pair with observations of sediment stress in corals throughout the entire project, inability to enforce the 1.5 mm sediment accumulation threshold above reference outlined in the EPP, and a missed opportunity to investigate and advance knowledge of sediment thresholds for corals in the area. Furthermore, the sediment

traps were only collected monthly, and subsequent laboratory analyses took approximately one month before results were available. This, coupled with the lack of weekly sediment accumulation measurements from field surveys resulted in a complete lack of quantitative sediment accumulation data for one-month timeframes during active dredging periods. Photographs taken during compliance monitoring in Week 32, when widespread impacts from sedimentation were reported, show up to approximately 2.5 cm of sediment accumulation at bases of corals (Figure 4); however, sediment accumulation block data reported this week was 0 mm for 20 out of 22 stations monitored and <1 mm for the remaining 2 stations (Week 32 Compliance Report, DCA, 2014).

a)



b)

Figure 4. Photographs taken during the Week 32 monitoring survey showing sediment accumulation at bases of a) Coral C-2, Transect 1 at Station R2N1 (*Pseudodiploria strigosa*) and b) Coral C-3, Transect 3 at Station R2N2 (*Solenastrea bournoni*) (Photos from DCA, Week 32 dataset).

2.2.2 Coral Stress Data Matrix

In order to help visualize patterns or trends during the active dredging phase, a matrix or large table was constructed in Excel to display when (in Dredging Weeks) each channel-side station exhibited coral condition scores significantly higher than the paired control (which constituted a “coral stress violation” and required additional surveys per the EPP) (See Miami Harbor Coral Stress Data Matrix provided in Excel file format). Adaptive management as reported in the weekly compliance reports was noted in the matrix as well as significant regional background stresses such as bleaching or disease. If ≥50% of channel-side stations for a given area

(Hardbottom, Middle, or Outer Reef) displayed high coral condition scores, that area was highlighted in red for the week.

Some alarming trends are revealed in this matrix. Significantly high coral condition scores primarily due to sedimentation were reported very early in the dredging program for the Hardbottom (Week 1) and Middle Reef (Week 9) areas. Significantly high coral stress scores for the Outer Reef were not reported until Week 30. For the Hardbottom area, From Week 11 to 32, 19 weekly surveys occurred, and coral condition scores were significantly higher versus controls at ≥50% of channel-side stations in 15 of the 19 surveys, at times up to 4 weeks consecutively. In this timeframe, adaptive management of dredging operations was reported 4 times but do not appear to have been sufficient to abate sedimentation stress. For the Middle Reef, from Week 29 through 40, 11 weekly surveys occurred and significantly higher coral condition scores were reported for ≥50% of channel-side monitoring stations versus controls in 9 of the 11 surveys. In this 12-week time-frame, only 2 adaptive management actions were reported: overflow on the Liberty Island dredge was stopped at least temporarily (Week 31) and an additional scow was added to the fleet to reduce overflow (Week 39).

Trends from the weekly reports show that significantly high coral stress was repeatedly reported for the Hardbottom and Middle Reef areas from Week 11 through 40. High coral condition scores due to bleaching were not reported until Week 34 (July, 2014) and due to disease until Week 52 (November, 2014). Out of a total of 55 weekly surveys that took place between November 2013 and March 2015, 28 weeks were highlighted “red”. Therefore, high coral stress was reported at ≥ 50% of channel-side monitoring stations approximately 50% of time. This strongly questions the integrity of the SAJ to fully protect coral and other natural hardbottom community resources during review of incoming field data. This raises several significant questions. How were “coral stress violations” handled and managed? Were additional impact surveys as required by the EPP always performed or only if required following review of data by the FDEP? Was the contractor aware of the gravity of the data and the potential consequences for coral resources and was this communicated to SAJ? The SAJ failed to enforce any “sediment stress violations” and to implement effective adaptive management practices throughout the dredging period, despite the coral data (even with its problems) indicating sedimentation stress.

2.3 Post-Dredging

For similar reasons explained in Section 2.2, effort examining data post-dredging has been limited. For example, DCA are currently undertaking a survey of the proposed impacted area primarily on Middle Reef, measuring total sediment thickness over hardbottom and describing the sediment as “Fine” or “Mixed”, which this review considers has little or no value, particularly given this survey has been conducted over multiple weeks/months (pers. comm., M Robbart, DCA). Datasets spread out over weeks or months make it impossible to draw conclusions on spatial patterns of sediment thickness if sediment is mobile, particularly if it is being resuspended periodically and deposited elsewhere within the same study area or outside the study area. In addition, given there is no comparable pre-dredge baseline data and the results are based on a thickness only and not composition, it is unclear as to what the results will be used for or conclude.

Similarly for other surveys done post-dredge, given the pre-dredge baseline data are essentially inconclusive or certainly statistically weak. Whether further post-dredge studies are done by a regulator, stakeholder, or litigant to demonstrate or prove that an impact occurred, or on behalf of or by SAJ to defend a case that no impact occurred, it is very difficult to draw any conclusions either way.

2.3.1 Quantitative Post-Construction Analysis for Middle and Outer Reefs Report

The date of the draft report is October 30, 2015, and revised final report is November 19, 2015 over three and four months, respectively, after post-construction surveys were complete (July 15, 2015). Per Section 3.2.5.c of the EPP, the post-construction report and raw data was due 15 days following completion of monitoring surveys (although an extension may have been granted by the FDEP).

The results and the value of the information in this report is over-stated. For example, “the Corps project monitoring before, during, and after dredging provides the best record of benthic community dynamics, structures, and the potential project effect” and “review and analysis can help scientists distinguish project related effects due to sedimentation and compare them with effects from regional warm water mass bleaching events followed by a coral disease outbreak”. Similarly it is also stated that “baseline surveys established information on the sedimentation environment and percentage cover of benthic resources” and “these baseline results used as comparison for impact assessment survey to document changes attributable to dredging 1 year after completion while considering other environmental and/or anthropogenic factors”. This is not the case given the sparsity of the pre-dredge baseline data collected in 2013. Care must be taken not to draw too many conclusions from the data and also “over-sell” it given the limitations. Stating that “sedimentation existed in the project area pre-dredging” is extremely likely and almost stating the obvious. However, it is the quantity, spatial distribution, and temporal variation that is most important and 28 days of monitoring, that was incomplete, is nowhere near sufficient to draw much more of a conclusion.

In addition, drawing conclusions from one site (HBN1 – CR), adjacent to the north breakwater, that showed sediment on coral in Week 1 and Week 4 of the pre-dredge baseline survey is not significant and cannot confirm therefore “that sediment is present along the reef”. Clearly some corals closer to the shoreline where longshore transport is more frequent, may perhaps survive more burial or burial for longer periods, but this cannot be extrapolated to all reef areas, particularly given the absence of reliable and long-term pre-dredge baseline data and therefore the ability to predict changes and impact over seasonal timescales.

Understanding the sediment dynamics of the area to assess resuspension, transport, and erosion is key as per the study outlined in Section 5. However, based on the above, it is not reasonable to state that “during 1 year post construction impact assessment surveys, sediment accumulation rates were found to be equal to or below pre-dredge baseline values at all channel side sites, except for rare weather events (Hurricane Matthew)” and subsequently “mean sediment accumulation rates over all channel side locations were below baseline values during 1 year post construction surveys…sediment accumulation indicate returned to levels observed

prior to dredging". Given the extremely limited pre-dredge baseline data this cannot be stated with any degree of confidence or certainty. Similarly, given the lack of understanding of natural sediment transport versus dredge sediment transport combined with lack of temporally and spatially robust pre-dredge baseline data, it is not possible to draw conclusions on the variations in sand cover between control sites and sites closer to the dredge site. It is also not reasonable to simply subtract the average sediment coverage for one area from another to demonstrate or suggest that there was a reduced or no impact from dredging.

Post-construction monitoring surveys were conducted for four weeks between June 17 and July 15, 2015. This timeframe is problematic for several reasons. Firstly, dredging of the outer entrance channel Cuts 1 and 2 was reported to be complete (dredging operations were deemed complete by the USACE on April 8, 2015) in the final weekly compliance report from Week 72 (April 1 to 7, 2015). However, spot-specific "clean-up" dredging occurred within both Cuts 1 and 2 through September 2015 (pers. comm., L. Reichold, SAJ). Therefore, the data from post-construction surveys, similar to pre-dredge baseline surveys, was potentially compromised by dredging activities. Although the amount of "clean-up" dredging was likely very small in comparison to that which occurred during pre-dredge baseline surveys, the scientific integrity of the post-construction dataset is still challenged. The monitoring program therefore lacked truly valid pre-dredge baseline and post-construction datasets, which were the two primary datasets compared in this report to inform potential project-related impact assessments by regulatory agencies.

Secondly, the post-construction surveys were conducted in a different season (summer) compared to pre-dredge baseline surveys (late fall) and as such under vastly different metocean conditions. Summer weather patterns in south Florida are characterized by light southeast winds, minimal wave activity, and low turbidity in contrast to late fall when high northeast winds, heightened waves, and increased turbidity are commonplace as a result of "nor-easter" storms, never mind any localized or more distant effects from hurricanes or tropical storms. As a result, background sedimentation accumulation levels on the reef would naturally be lower while prevalence of thermal stress (paling and/or bleaching) would be higher in summer months. The reverse would be expected in fall months, with heightened sediment accumulation and lower occurrence of thermal stress. The contrasting seasonality between the two datasets further complicates comparison. By comparison, in Florida, the FDEP requires that pre-dredge baseline and post-construction benthic monitoring surveys associated with beach nourishment projects be conducted in summer months, in order to reduce seasonal differences in sediment regime and biota between surveys (FDEP, 2016).

The fourth paragraph of the Executive Summary states that "baseline surveys established information on the population dynamics, condition, and sediment environment of benthic communities adjacent to the Federal Navigation Channel". This statement is not correct for the following reasons: 1) the pre-dredge baseline survey dataset from 2013 was incomplete and compromised by initiation of dredging activities; 2) local sediment transport processes, hydrodynamics, and metocean conditions were understudied prior to and throughout the dredging project, and 3) sediment accumulation data from traps and sediment accumulation blocks were not accurate or adequate.

The fact that pre-dredge baseline monitoring was conducted during dredging operations is never mentioned in this report. A reader with no prior knowledge of the project reading this report would not be informed of this important information. Data averages reported for the pre-dredge baseline survey include all surveys (not just those that occurred before dredging) and are therefore scientifically invalid and biased towards increased sedimentation.

2.3.2 Other Reports and Scientific Publications Related to MHIII

2.3.2.1 NMFS 2016 and Miller et al, 2016 - Port of Miami Entrance Channel Sedimentation Reports

The National Marine Fisheries Service (NMFS) conducted a survey to examine sedimentation impacts from MHIII (NMFS, 2016). This report and Miller et al. 2016 are based on a survey carried out in December 2015 that collected sedimentation data from coral and hardbottom communities for transects running north up to 700m from the channel. These data were compared with pre-dredge baseline data from October 2013 and post-construction survey data collected in July 2015. While the data show a pattern in terms of sedimentation away from the channel and suggest a significant quantity of sediment on the coral reef habitat and more than the reference sites to the north used for MHIII, Miller et al. acknowledge that “neither the dredging process nor the Port of Miami entrance channel environment was (presumably were) conducive to a simple sedimentation gradient leading away from the channel and into the coral reef habitat”.

This further highlights the lack of a multidisciplinary understanding of the study site in particular hydrodynamics and general circulation in the area and also very importantly the movement and fate of sediment, particularly from a very dynamic and complex dredging operation. In addition, understanding the natural sediment transport processes and movement is critical, however sediment transport, sedimentation patterns and sediment impact gradient are never “simple”. Trying to draw conclusions from the additional data reported by Miller et al., given the very limited data surrounding the dredging operation, and in particular 28 days of pre-dredge baseline data as requested in the FDEP permit, which was not even carried out comprehensively by DCA on behalf of GLDD, makes this task almost impossible. Having no understanding of the hydrodynamics and natural and dredged sediment dynamics makes this even harder.

Both the NMFS report and Miller, et al. include many photos showing partial burial of stony and soft corals; however, the source of sediment in these photos cannot unequivocally be determined as project-related, natural, or both. Some photos show patterns of coral partial mortality (sediment halos) and accumulation of fine sediments near bases of corals that suggest sedimentation impacts from the project (See Figures 8, 9, and 12 in NMFS 2016). Other photos show partial burial of corals in deep sediment of a coarser nature as denoted by sand waves (See Figures 7, 10, and 11 in NMFS 2016); sand waves are more typical of coarser as opposed to finer sediments, and the source of this sediment may be natural coarser sediments and are less likely to have resulted from dredging.

Miller et al. contend that corals at Middle Reef channel-side stations exposed to higher sedimentation stress were more susceptible to White Plague Disease (WP) or “sudden death”

(presumably by disease) versus controls. Risk of death was calculated as the percent of corals that died due to disease among those experiencing sedimentation stress. Because disease outbreaks are commonly associated with bleaching events (Muller et al 2008; Miller et al., 2009) and not commonly with sedimentation stress, this analysis should have also evaluated the risk of death for corals which manifested signs of thermal stress. Additionally, the entire dataset should have been utilized to substantiate results.

Miller et al. discusses local, project-related versus regional stressors and the importance of managing "controllable" dredging events. They advocate that these projects do not overlap with "uncontrollable" regional stressors such as thermal stress events or important spawning events for reef species. This management strategy for dredging operations is also recommended by Fraser et al. 2017 and referred to as "environmental windows". Environmental windows are already commonly adopted in many Best Management Practices to avoid impacts to threatened and endangered species. For example, beach nourishment projects in Florida are typically constructed outside of sea turtle or shorebird nesting seasons.

This paper also includes a list of recommendations for Port Everglades that are scientifically sound (See also NMFS letter to USACE dated April 6, 2017) and based on "lessons learned" from MHIII.

2.3.2.2 Swart 2016 – Port of Miami Sediment Sample Analysis Report

Another example is the work and report of Swart (2016) who used X-ray diffraction and isotopic composition to predict the source of sediment up to 1050 m north and 700 m south of the channel compared with the reference sites used for MHIII. In general terms, the reference site sediments had high aragonite, high High Mg Calcite (HMC) and lower Low Mg Calcite (LMC) and a higher C and O isotope value. This compares with sediments closer to the channel which had higher LMC and a more negative C and O content, which is described in Swart (2016) as a more allochthonous source of carbonate. Despite a number of assumptions made which are not clear from the document reviewed and some data in tables which do not appear to match those on the figures presented, it is possible that the data highlight material closest to the channel is different material and could be from the capital dredging of limestone. However, in the absence of understanding the circulation and sediment transport in the area, there is a degree of supposition in the results. Had this work been done prior to dredging as well, or samples collected and retained pre-, during and post-dredging, then a much more compelling argument or case could be made.

2.3.2.3 SAJ 2016 – MHIII After Action Report, ADDAMS Model

Dr. P. Schroeder of ERDC used the Automated Dredging and Disposal Alternative Modeling System (ADDAMS) to assess total suspended solids (TSS) and turbidity analysis associated with the different dredging equipment used for MHIII (SAJ, 2016). Dr Schroeder suggests that such an approach could be used for Port of Everglades given the similarities with Miami including hydrodynamics, wave climate and sediment characteristics. Given the shortcomings of the model and approach listed below, this is not recommended and would have very limited value and is likely to be misleading and inaccurate.

The model makes a significant number of assumptions in order to estimate the "mass rate at which bottom sediment becomes suspended as a result of hydraulic/mechanical dredging operations" and ultimately uses this mass rate to predict the resultant suspended sediment concentrations. Therefore the model considers "TSS associated with the dredging process itself", not TSS from stripping losses, considered to be very significant source during roller-chopping and CSD, or for a "discharge or scow overflow at the discharge end". In addition, "the model does not consider the resulting bottom sedimentation and sediment transport associated with a suspended solids plume". However, this is exactly what was being measured for MHIII. It is suggested that other models should be used to consider sedimentation and incorporate bathymetry, hydrodynamics, and wave and sediment characteristics.

In addition, the model was run assuming dredged sediment comprised "stiff clay-like sediments as a surrogate for limestone" due to the absence of information on dredging limestone. However as listed above, there are examples of similar capital dredging operations including cutter suction dredging of limestone rock around the world. Despite the above, Schroeder uses model output to make comparisons between TSS predicted from dredge operations at the bed, with turbidity monitoring data from MHIII, which was measured rather subjectively and inaccurately and only in the surface or mid-water column. Schroeder carried out this comparison without model functions on sediment transport, dispersal, deposition, or sedimentation. It is difficult to see how the datasets are comparable or accurate conclusions can be drawn and many of the conclusions that are made are tenuous and not supported by the model output and cannot be verified from the field data.

2.3.2.4 Barnes et al., 2015 – Satellite Imagery Data

Barnes et al. (2015) utilized satellite imagery to document increased size and duration of sediment plumes during the dredging project relative to a background period when no dredging took place. Although sediment plumes at the surface are not necessarily representative of sediment accumulation on the seafloor, this paper calls attention to the resourceful use of historic and recent remote sensing data (See also Petus et al., 2016). This paper highlights the ability to incorporate remote sensing techniques and utilize advanced technology from cameras, satellites, and other "automated" meters to collect more data to more comprehensively understand the effects of dredging projects.

3 Lessons Learned

The following represents an approximate chronological order of lessons learned combined with a recommended approach and actions to increase success of any subsequent large-scale dredging project and to avoid a recurrence of the problems encountered during MHIII.

3.1 Team

- It is imperative that SAJ hires a highly professional team (company or individuals) comprising subject-matter-experts in their respective fields who can demonstrate competence, including through references and/or recommendations, and who SAJ can use to obtain impartial advice that is reliable, well-informed, and current. Roles and responsibilities of team members should include identifying any risks SAJ are exposed

to, assumptions made for any work done, and making recommendations if shortfalls or problems are noted. Experts with international experience may be beneficial to provide insight regarding how dredging contractors and environmental monitoring is carried out in other countries. SAJ may consider it advantageous to hire independent parties.

- SAJ should consider having either a Corps employee or a suitably experienced Client Representative on site at all times to provide the “eyes and ears” for all Corps projects to ensure that the Corps interests are followed. This person would ensure that monitoring requirements are rigidly adhered to at all times and if modifications have to be made, someone is on site to appreciate and explain the problem and facilitate any temporary change until necessary permit modifications are in place.
- It is strongly recommended that SAJ reconsiders contractors currently used before further contracts are awarded, based on the quality of the work undertaken, with a much more rigid and technical screening process put in place to assess potential contractors. Scoring on price alone, or primarily, is a false economy and assessments need to be based on proven quality and technical ability by properly qualified personnel, including external consultants if suitable expertise is not available within SAJ.
- There also needs to be a culture and ability for SAJ to allow staff to recognize their own limitations or extent of expertise without criticism, in order to allow other qualified SAJ staff to be brought in or hire external consultants to assist.
- As much as possible, there must be continuity in the team for the duration of the project. If this is not possible, sufficient time needs to be allowed for handover and training, even if it delays the project, as opposed to having unrealistic timescales dictated.

3.2 Multidisciplinary Baseline Data

- Collect sufficient spatial and temporal measurements to observe natural system pre-project patterns, variations (including seasonal) and establish trends with statistically significant datasets to determine errors. Use these data to set quantifiable/measurable thresholds with contingency built in. Temporally speaking, baseline coral and hardbottom data should span 1 year minimum, with at least 2 datasets collected in opposite seasons (i.e. summer and winter, or wet and dry seasons). The same is recommended for turbidity, as long as highs and lows are captured. This data collection should be paired with coral/hardbottom data. For waves and currents, data collection over 1 year is ideal; however, a minimum of 6 months of data (3 months in each opposing seasons) is the minimum recommended. Spatially speaking, an area large enough to encompass that beyond the influence of dredging is recommended. An area of approximately 10 km in each direction is suggested for projects similar to MHIII; however this depends largely on the tidal excursion.
- Data must be current and from the project site, not based on historic information or from another site.

- Data should be multidisciplinary (i.e. biological, physical, sedimentological), and not solely or primarily focused on ecological/marine biological aspects.
- Understanding the sediment dynamics of the area to assess resuspension, transport, and erosion is key as per the study outlined in Section 5.
- Determine approximate dredge volume and nature of material to be dredged including detailed geophysical testing; collect a current bathymetric survey and core samples (overburden/maintenance and capital/rock). If required, hire in a dredging consultant to provide this to avoid a conflict of interest with potential dredging contractors.
- Measure and understand key circulatory, metocean, and sediment transport processes; pathways; and fate, in addition to boundary conditions for model development. Sediment transport data must include both dredge related and natural processes, in order to be able to separate the different sources and impacts and observe what marine flora and fauna are subjected to during natural storm events, for example.
- Discuss outcomes with a qualified dredging consultant to consider “optioneering” in terms of dredge type, operations, overflow, and limitations. For example, blasting was considered for a prolonged period only to be removed relatively late in the process. GLDD chose not to do that, although other contractors may have required it. SAJ should dictate dredge operations that are allowed; for example, SAJ may wish to ban all overflow or “roller-chopping” with dredger operating with no suction and no scows.
- Assuming a capital dredging program, establish a 3-D numerical model for hydrodynamics and sediment dynamics, that allows access to the code or is open-source (e.g. Delft 3D). Great care must be taken to use the most appropriate model including a careful analysis of both the model and the modeler’s capability and the assumptions (or “fudge factors”) that will go into the model and what is “hidden” behind the images. Often modelers describe “good agreement” between field data and model output, in some cases because the same dataset has been used to calibrate the model and then used to predict model output. In many cases including other scientific and technical disciplines, similar measurements and data would not be considered as “good agreement”. For example, ADDAMS model used by Dr. Schroeder of ERDC has significant limitations and assumptions, is very simplistic and in the case of MHIII was compared and essentially tried to be validated against data that the model cannot accept or is not setup to use.
- Calibrate and validate the model with actual and different field measurement data (not further modeling) and ensure it matches as closely as possible current real-life conditions. This must be achieved before using the model to predict any changes related to capital dredging activities.
- Once it can be demonstrated that the model can accurately reflect current conditions, run “optioneering” scenarios including beneficial use, avoid double-handling, nearshore disposal, ODMDS, efficient dredging and disposal.

- Use the model to establish zones of high, low, and zero impact and verify these zones with field data measurements.
- Identify the monitoring area and any reference control sites and mitigation that are outside the impact area.
- Use the above, based on a position of strength and being well-informed, to develop a suitable monitoring program, scaled appropriately and based on field data to control costs and the dredging program. Use this information to then discuss conditions in the permit with regulators, public etc. to "get them on-board". With a weight of evidence and high quality field data, it would be very hard for the regulator to argue or disagree and go against real-field measurements and a model that can be demonstrated to match real-life observations.
- Produce an EIS based on knowing ideally 90-95% of the project in terms of the details of the dredging (volume, area, material, dredge type, disposal), monitoring equipment, monitoring requirements (duration, locations, data provision), benthic monitoring, any mitigation requirements fully examined. Use the EIS to ensure nothing has been missed or not considered fully. It should be comprehensive enough to avoid unexpected events or surprises during the project with no stone unturned. The EIS must and should include an up to date literature search on the latest scientific knowledge, technology that could assist, industry standards etc. minimizing the possibility of responses from agencies/stakeholders requiring changes to the EIS, permit and monitoring requirements etc. leading to project delays.
- If there is a long delay between the EIS and commencement of the project, an updated or supplementary EIS must be issued taking into account any changes in legislation, environmental classifications, improvements or changes in scientific knowledge, standards or monitoring.
- Multidisciplinary baseline data and assessment should be sufficiently robust to ensure no last minute surprises, dredge downtime, project delays, cost overruns or environmental impact, and if there are, protocols and experts/team are in place to deal with them efficiently and cost-effectively. This will ensure that permits or authorizations don't expire or run out, incurring additional cost and delays, since the project should run to schedule.

3.3 Permits And Contracts

- SAJ must separate the environmental monitoring contract from dredging contractor to ensure they are independent; as above, ensure the environmental monitoring contractor is qualified and experienced.
- Verify whether the permit issued by FDEP is sufficient for SAJ purposes or needs to be made more stringent or prescriptive for SAJ interests and to allow defense if required; this includes imposing requirements if the permit is "watered down" based on tasks

being considered too onerous or costly (e.g. calibration of a turbidity sensor to TSS in mg/L using actual dredged sediment).

- Ensure that the permit and contract have clarity, sufficient flexibility for variations and a protocol if data or results indicate something unexpected that is not covered or monitoring needs to be modified quickly; agree to a protocol with regulators in advance for this contingency to protect the environment. The permit conditions and contract passed to the contractor must be enforceable and not ambiguous and open to interpretation or too subjective.
- Ensure permits include stand-alone Biological Monitoring Plans approved by regulatory authorities.
- Review the contracting method to ensure quality, experience, and technical ability are truly assessed and taken into account rather than the contract simply awarded to the lowest price, which is likely to be a false economy; this should include SAJ deciding to employ its own contractors rather than being forced to use the sponsors preferred contractor.
- Reconsider environmental incentives since they clearly did not work to protect the environmental resources.
- Consider whether down-time due to exceedances are at the dredge contractors risk; this is relatively common in the industry and is likely that the contractor would approach the contract and dredge type offered in a different way and may not necessarily be more expensive.

3.4 Environmental Monitoring

- SAJ should identify key data requirements and ensure where possible data are obtained in real-time and are made available to SAJ (and regulators and public if required) for transparency in order to avoid misinformation (e.g. problems with fake truth on social media) as quickly as possible. An early assessment of data requirements versus timescales to provide the data would be invaluable. There is no point in having an adaptive management plan that will get data days or weeks later. For example, turbidity loggers used for rapid assessment of dredge plume and therefore suspended solids and near-bed sedimentation impact, must be real-time to assess water quality exceedance in case there is a need to cease dredging. Other key monitoring data must be turned around and provided to SAJ much more rapidly.
- Instruments must be calibrated for the measurements intended or data to be collected in accordance with scientific/international standards; this should be demonstrated regularly to SAJ.
- Establish true adaptive management plans and procedures to ensure that monitoring provides a realistic accurate early-warning system that the dredging contractor works within and is aware immediately if an exceedance is likely or has happened. Recommend that this involves a review of adaptive management approaches from

around the world in advance, to establish what is meant by adaptive management in order that it can be defined and agreed by all parties. This should be (or become) a standard approach for SAJ that is commensurate and comprehensive and is incorporated into the separate dredging and monitoring contracts. Ideally, with the correct provision, it should be easy to be checked and supervised by the SAJ Project Manager and a Client Representative on site.

- Collect sediment and rock samples prior to, during, and post-dredging including natural sediment, overburden, dredged sediment created from the different dredge type and any samples identified as potentially causing an impact i.e. deposited on hardbottom communities. Carry out comprehensive testing of these samples including geochemical and physical properties. Catalogue and retain these samples for the duration of the project.
- If a significant time has elapsed between the baseline monitoring and commencement of dredging, re-collect key baseline data for a sufficient length of time and spatial area to be scientifically robust.
- Consider using or developing a benthic monitoring system that will allow more objective monitoring including a digital record that can be re-checked and corroborated, vetted or "policed" in terms of benthic impact rather than using a more subjective approach such as divers who may apply evidence differently or incorrectly. For example in Chevron Wheatstone's project, ROV surveys were carried out (Chevron Australia, 2016).
- Provide examples of benthic monitoring "stress indices" and scoring, and correct references to avoid misinterpretation on the monitoring protocol.
- Ensure proper interpretation and execution of monitoring protocols by the contractor performing the monitoring with regular independent checks carried out.
- Utilize an additive stress index for benthic resources and clearly define methods for determining the overall "condition score". Limit the suite of stress parameters being evaluated to those most relevant to potential project-related impacts and the most critical background stressors.
- Recommended stress parameters to include in coral stress indices: sediment-related signs of stress (increased mucus production, sediment accumulation on tissue, tissue swelling, sediment "halos"); severity of bleaching; and disease. Percent live tissue can be monitored through time using planimetry but requires standardization of photo collection techniques. Recommended coral stress parameters to eliminate: fish bites, polyp extension, abrasion, competitive interactions and overgrowths. Keep the index relatively simple.
- Clearly define coral stress "triggers" or thresholds from both natural and project-related sources based on baseline data and/or pilot studies, and define next-steps in protocols/management actions to be taken when thresholds are exceeded. Provide examples and/or flowcharts in monitoring plans.

- Allow more time for baseline monitoring, report review, and adaptive management of monitoring protocols before construction. Do not initiate dredging activities until all pre-dredge baseline data are collected. Suggest quarterly pre-dredge baseline surveys over a minimum 1 year period prior to dredge program versus the four weeks immediately before dredging adopted for MHIII.
- Anticipate potential changes in the monitoring protocol following pilot studies and be adaptive and utilize alternative methods. Allow sufficient time for all stakeholders to review/approve suggested changes.
- Do not use sediment blocks for sediment accumulation; instead measure sediment accumulation on substrate along transects at pre-determined, marked locations. Other methods to consider include rugosity and 3-D video mapping (See Storlazzi et al., 2016).
- Clearly define communication lines and protocols for reporting field data as it is collected. Consider a “preliminary report” submitted within 24 hours via email, or on-line submission of “threshold compliance” data, followed by written report to reduce time-lags in information availability associated with production of reports.
- Enforce “sediment stress violations” and clearly define field and management protocols, as well as dredging alternatives if violations occur. Employ more reliable means of sediment accumulation data via scientific divers and include meters/loggers on the seafloor in monitoring program (Consider use of the ASM-V sediment meter).
- Establish coral sediment stress thresholds that corals can tolerate without irreversible changes (before tissue death).
- Consider the use of software programs (can be customized in Excel) to help manage and summarize data as it is collected, and automate alarms or triggers.
- Perform pre-dredge baseline and post-construction monitoring surveys within the same season.
- Incorporate remote sensing techniques and utilize advanced technology from cameras, satellites, and other “automated” meters to collect more data to more comprehensively understand the effects of dredging projects.
- Consider environmental windows for dredging to avoid periods of vulnerability such as thermal stress events, disease epizootics, or important reef species spawning aggregations.
- Consider the use of a geoportal to quickly upload, organize, manage, and visually display large amounts of data, including geo-referenced spatial data. Geoportals can have multiple user groups with varying degrees of access, and therefore can provide varying levels of transparency.

3.5 Public Relations

It is recognized that construction and dredging projects create turbidity and no matter the monitoring and adaptive management strategies, this is unavoidable. However, if SAJ carries out a comprehensive multidisciplinary baseline assessment it will be possible to predict what might happen, when, where, what the impact might be, and how long it will last with a high degree of accuracy. This will allow appropriate mitigation to be put in place in areas that will not be impacted subsequently. It is essential to openly acknowledge this and act with transparency to avoid mistrust and misinformation, which will become more and more of a problem. Ultimately a detailed baseline assessment done more thoroughly with consideration of physical attributes to mechanical disturbances should lead to savings in terms of monitoring during- and post-dredging or and demonstrate that SAJ are in control.

4 Conceptual Sediment Transport Model

It was assumed that as part of the review for the Task 1 report, background data from scientific papers, previous studies, modeling, data and reports would be available to provide a conceptual sediment transport model. However, as outlined above, the sparsity of information that exists particularly both locally and regionally in terms of hydrodynamics, circulation, metocean characteristics and sediment dynamics is such that a conceptual model would be primarily guesswork and therefore cannot be done at this stage. This task will now be completed as part of the main sediment tracer study based on field data and measurements.

5 Proposal for Task 2: Sediment Tracer Study

W&A, CSA and ETS propose to carry out the sediment tracer study exactly as outlined in the tender document and contract, however, based on the review outlined above, there are a few clarifications or proposed minor modifications that are outlined below:

- Five (5) tracers will be released exactly as per the existing contract, in terms of locations, quantities, particle size etc. (see Figures 5 and 6), however it was anticipated as part of this review that information would be available on turbidity profiles or distribution emerging from Biscayne Bay. It was also assumed that these data would exist for sediment plumes created by dredging operations (dredging, overflow etc.). However, neither are clear. Therefore, for the blue silt—only tracer release between the north and south breakwater, it is proposed that background data will be collected in terms of current velocity profiles, stratification and turbidity over the ebb tide period for each release and the tracer particles will be released in the section of flow or water where the highest turbidity is present at that time. This will be reviewed and modified accordingly during the ebb tide. In the case of the orange silt tracer to be released at the edge of the channel to simulate suspended sediment from dredging operations, it is likely that the vast majority of any suspended sediment was released close to the bed, rather than in the surface or mid-water column. This is contrary to the position stated in the SAJ After Action Meeting Report that the vast majority of turbidity was potentially from hopper/scow overflow. Given the stripping losses from a CSD and reported TSS from roller-chopping, it is anticipated that >90% of the TSS associated with dredging would have been in the bottom 1 to 2 m of the water column. Therefore, it is proposed that the orange silt-tracer will be released in this section of water column

(0.1 to 2 m above the seabed, rather than on the seabed itself) from several outlets simultaneously.

- One of the key elements of the sediment tracer study is to ensure that the sediment tracers released have the same physical properties as the dredged sediment and/or native sediment since both aspects are being considered as part of the study. This is critical in order to ensure the tracer particles behave in the same way to try to retrospectively determine the possible or likely fate of dredged sediment versus natural sediment transport. Unfortunately, SAJ were unable to locate any of the dredged sediment internally or externally. Therefore SAJ obtained 9 rock/sediment samples from core borings comprising CB-MH09-03, 04, 08, 09, 10, 11, 14, 16, 17, primarily collected from Cuts 1 and 2. SAJ also created a composite sample of all 9 individual samples. Tests were carried out on the 10 total samples on behalf of SAJ by Maskel Laboratory, FL. who carried out the following tests:
    i) Sieve Analysis (Using Sieve Sizes No. 3/4", 3/8", 3.5, 4, 5, 7, 10, 14, 18, 25, 35, 45, 60, 80, 120, 170, 200, 230), ASTM D 6913
    ii) Hydrometer Analysis, ASTM D 422
    iii) Carbonate Content, Non-ASTM Method (no physical crushing of the material in the lab)
    iv) Specific Gravity for Soil, ASTM D 854

In addition, SAJ sent ETS part of the composite sample to conduct physical tests in the United Kingdom including a comparison with ETS sediment silt and sand tracers in stock prior to manufacturing material specifically for the study. Key information included the density or SG of the dredged sediment. Previous testing done (CE&T, 2011) had assumed an SG of 2.65, the same as silica, however given the material comprised carbonate limestone, this was likely incorrect.

Tests carried out by Maskel indicated an average SG of 2.72 for the 9 samples with the composite having an SG of 2.73, with individual values ranging from SG 2.65 to 2.81.

Based on the above information, ETS outlined to SAJ that it was intending to manufacture all the sediment tracers with the same SG of 2.65 to be consistent and also based on the fact that considerably more information, understanding and literature exists on the behavior of silica-based (SG 2.65) particles and silica is also present in many of the samples, based on the lab data approximately ranging from 5 to 74% with an average composition of 38%.

Discussions had been held previously with SAJ about the possibility of releasing an additional sediment tracer that had an SG closer to carbonate (termed the “6th tracer”), however given the relatively small difference between the SG of silica and the core borings, equivalent to 0.07, it was felt this was not necessary and the “6th tracer” has been dropped. A separate letter confirming this has been issued to SAJ for consideration.

Sampling Methodology: Sampling locations will include the 54 locations previously sampled during the background fluorescence sediment collection survey, in addition to approximately 96 additional stations, for a total of up to 150 sampling locations (Figures 5 and 6. Sampling locations include existing SAJ or NMFS monitoring station locations as well as haphazardly-selected locations on Middle and Outer Reefs and sand patches/plains along the edges of each reef feature. A 15 x 15 x 5 cm quadrat will be utilized for sediment sampling, analogous to that utilized during background sampling, but slightly smaller in order to decrease collection time per sample underwater. A plastic syringe will still be utilized to collect silt samples. Sediment and/or silt samples will be collected from within the quadrat from various “substrate types” including sand patches, standing sediment on the reef, at the base of coral heads, and within or including turf algae.

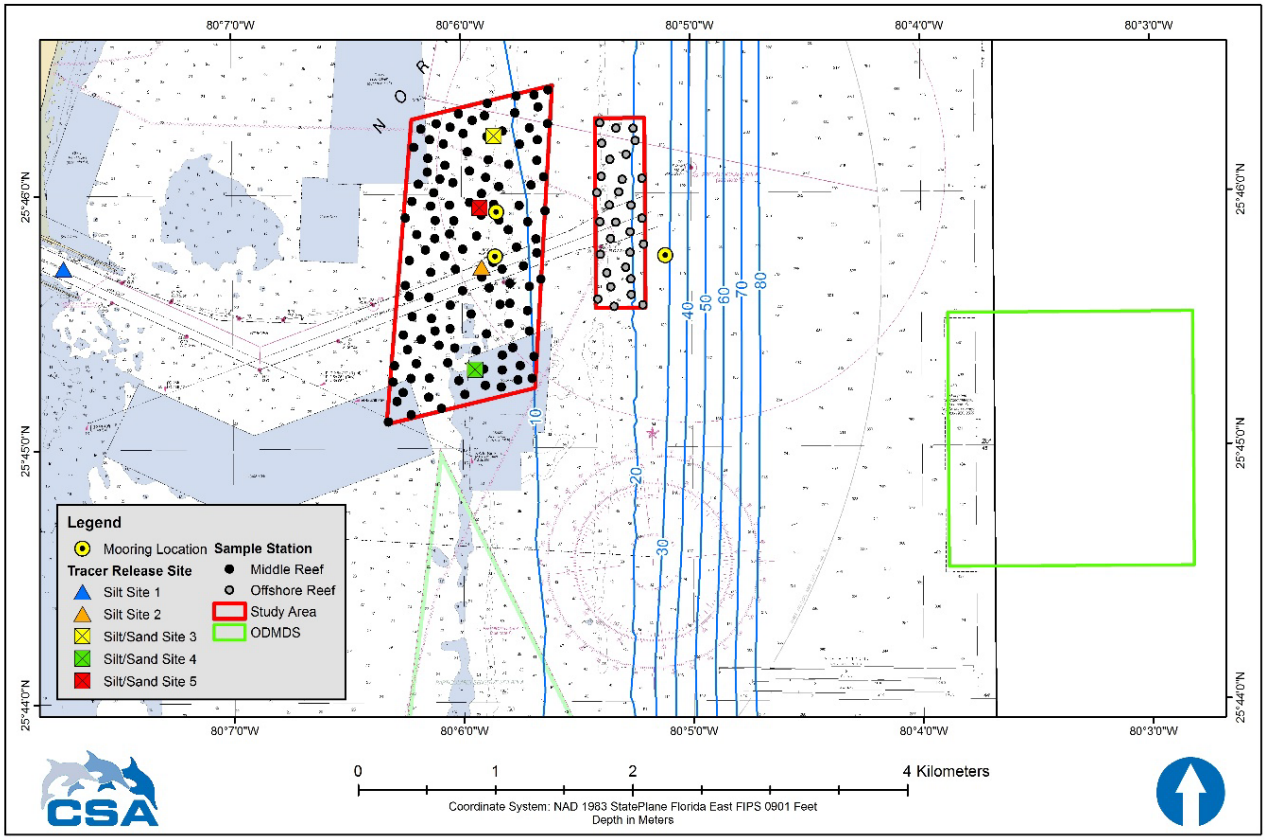


Figure 5. Overview of tracer release sites, mooring locations, and sediment sampling locations for the Miami Harbor Sediment Tracer Study.

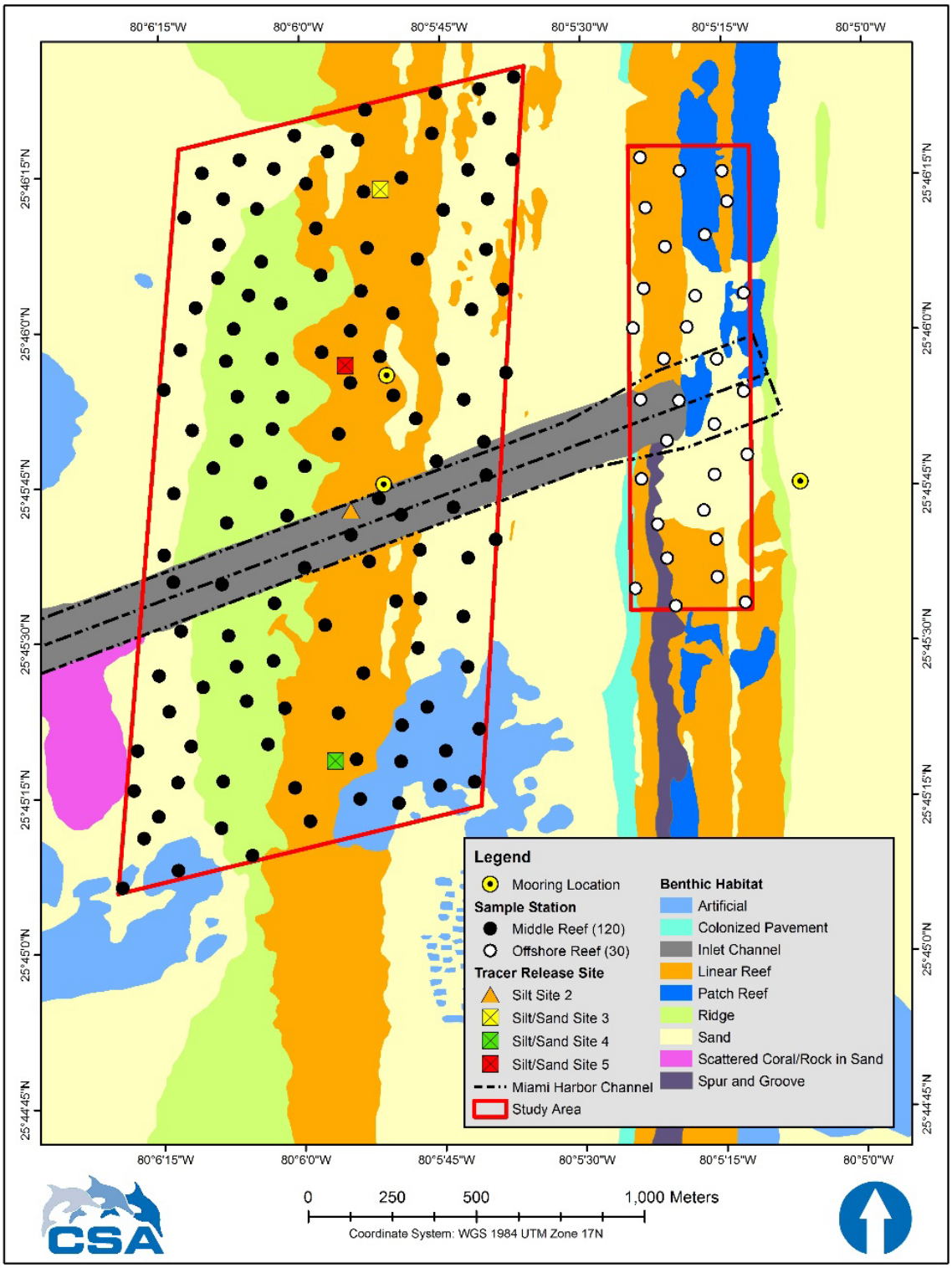


Figure 6. Close-up view of tracer release sites, mooring locations, and proposed sediment sampling locations for the Miami Harbor Sediment Tracer Study.

REFERENCES

Anthony, K.R.N. and S.R. Connolly. 2004. Environmental limits to growth: physiological niche boundaries of corals along turbidity–light gradients. Oeologia 141(3):373-384.

Barnes, B. B., C. Hu, C. Kovach, and R.N. Silverstein. 2015. Sediment plumes induced by the Port of Miami dredging: Analysis and interpretation using Landsat and MODIS data. Remote Sensing of Environment 170:328-339.

Bellwood, D. R., T. P. Hughes, C. Folke, and M. Nyström. 2004. Confronting the coral reef crisis. Nature 429:827-833. doi:10.1038/nature02691.

Browder, J.A., R. Alleman, S. Markley, P. Ortner, and P.A. Pitts. 2005. Biscayne Bay Conceptual Ecological Model. Wetlands Vol. 25, No. 4 December 2005, pp 854-869

Brown, G.L., R.T. McAdory, G.H. Nail, M.S. Sarruff, R.C. Berger, and M.A. Granat. 2003. Development of a two-dimensional numerical model of hydrodynamics and salinity for Biscayne Bay, Florida. U.S. Army Corps of Engineers Technical Report CHL-03-10.

Bythell, J.C., E.H. Gladfelter, and M. Bythell. 1993. Chronic and catastrophic natural mortality of three common Caribbean reef corals. Coral Reefs 12:143–152.

Carilli, J. E., R.D. Norris, B. Black, S.M. Walsh, and M. McField. 2010. Century-scale records of coral growth rates indicate that local stressors reduce coral thermal tolerance threshold. Global Change Biology, 16: 1247–1257. doi:10.1111/j.1365-2486.2009.02043.

Challenge Engineering and Testing Inc. 2011. Final Report Miami Harbor Deepening Project Core Borings and Laboratory Testing, Dade County, Florida, 2011 p 110.

Chevron Australia. 2016. Wheatstone Project. Dredging and Dredge Spoil Placement Environmental Monitoring and Management Plan. p230.

Continental Shelf Associates, Inc. 2003. Key West Maintenance Dredging Project Resource Health and Sedimentation Monitoring Plan. Prepared for Department of the Navy Southern Division, Naval Facilities Engineering Command. 14 pp.

DCA. 2001. Dial Cordy and Associates Inc. Environmental Baseline Study Impact Assessment for Miami Harbor, General Reevaluation Report to United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL. 56 pages

DCA. 2014. Dial Cordy and Associates Inc. Miami Harbor Phase III Federal Channel Expansion Project, Permit No 0305721-001-BI, Quantitative Baseline for Middle and Outer Reef Benthic Communities. Report to United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL. 62 pages

DCA. 2015. Dial Cordy and Associates Inc.. Miami Harbor Phase III Federal Channel Expansion Project, Permit No 0305721-001-BI, Quantitative Post Construction Analysis for Middle and Outer Reef Benthic Communities. Report to United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL. 134 pages

DCA. 2015. Dial Cordy and Associates Inc. Delineation of Potential Sedimentation Effect Area within Middle and Outer Reef Habitats, Port of Miami Phase III Federal Channel Expansion Project, FDEP Permit No 0305721-001-BI Final. Report to United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL. 60 pages

DCA. 2015. Dial Cordy and Associates Inc. Weekly Offshore Coral Stress Compliance Report 001, FDEP Permit No 0305721-001-BI – Port Miami Phase III Harbor Deepening Week 11/20-11/26 Terrapin Island Dredge Activity. Report to United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL. 4 pages

Dekker, MA, M.P. Kruyt, M. Den Burger, W.J. Vlasblom. 2003. Experimental and numerical investigation of cutter head dredging flows. Journal of Waterway, Port, Coastal and Ocean Engineering 129:203-209

Den Burger, M. 2003. Mixture forming processes in dredge cutterheads. PhD, TU Delft, Delft University of Technology, the Netherlands

Department of the Army, Jacksonville District Corps of Engineers. Permit No. SAJ-2006-06547 (IP-MLC) Modification #1. Issuance Date: July 25, 2012.

Erftemeijer, P.L.A, B. Riegl, B.W. Hoeksema, and P.A.Todd. 2012. Environmental impacts of dredging and other sediment disturbances on corals: A Review. Marine Pollution Bulletin, Vol. 64, Issue 9, 2012, 1737-1765.

Fatt, J.C. and J.D.Wang. 1987. Canal discharge impacts on Biscayne Bay salinities, Biscayne National Park. Research/Resources Management Report SER-89. National Park Service, Atlanta, Georgia.

Federal Register. 2006. Endangered and Threatened Species: Final Listing Determinations for Elkhorn Coral and Staghorn Coral. Federal Register 71(89):26852-26861.

Federal Register. 2014. Final Listing Determinations on Proposal to List 66 Reef-Building Coral Species and To Reclassify Elkhorn and Staghorn Corals. Federal Register 79:53851-54123.

Fisher, L., K. Banks, D.S. Gilliam, R.E. Dodge, D, Stout. 2008.Real-Time Coral Stress Observations Before, During, and After Beach Nourishment Dredging Offshore SE Florida.Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008.

Fisher, L., K. Banks, D. Gilliam, R. E. Dodge, D. Stout, B. Vargas-Angel, Brian K. Walker.Jones, R., Pia Bessell-Browne, Rebecca Fisher, WojciechKlonowski, MatthewSlivk. 2016. Assessing the impacts of sediments from dredging on corals. Marine Pollution Bulletin 102:9-29.

Florida Department of Environmental Protection. 2012. Permit No. 0305721-001-BI; Miami Harbor Phase III Federal Channel Expansion. Issuance Date: May 22, 2012.

Florida Department of Environmental Protection. 2016. Standard Operation Procedures for Nearshore Hardbottom Monitoring of Beach Nourishment Projects. 70 pp.

Fraser, M.W. J. Short, G. Kendrick, D. McLean, J. Keesing, M. Byrne, M. J. Caley, D. Clarke, A. R. Davis, P. L. A. Erftemeijer, S. Field, S. Gustin-Craig, J. Huisman, M. Keough, P.S. Lavery, R. Masini, K. McMahon, K. Mengersen, M. Rasheed, J. Statton, J. Stoddart, P. Wu. 2017. Effects of dredging on critical ecological processes for marine invertebrates, seagrasses and macroalgae, and the potential for management with environmental windows using Western Australia as a case study. Ecological Indicators 78:229-242.

Henriksen J, R. Randall, S. Socolofsky. 2012. Near-field resuspension model for a cutter suction dredge. Journal of Waterway, Port, Coastal, and Ocean Engineering 138:181-191

Hodel, E.C. 2007. Master's Thesis: Histopathological assessment and comparison of sedimentation and phosphate stress on the staghorn coral, Acropora cervicornis. Nova Southeastern University. 101 pp. + apps.

Hoegh-Guldberg, O., P. J. Mumby, A. J. Hooten, R. S. Steneck, P. Greenfield, E. Gomez, C. D. Harvell, P. F. Sale, A. J. Edwards, K. Caldeira, N. Knowlton, C. M. Eakin, R. Iglesias-Prieto, N. Muthiga, R. H. Bradbury, A. Dubi, M. E. Hatziolos. 2007. Coral reefs under rapid climate change and ocean acidification. Science 318(5857):1737-1742.

Hoegh-Guldberg, O. and J. F. Bruno. 2010. The impact of climate change on the world's marine Ecosystems. Science18 JUN 2010 : 1523-1528MEPS 266:273-302 (2004) - doi:10.3354/meps266273

Houk, P., R. Camacho, S. Johnson, M. McLean, S. Maxin, J. Anson, E. Joseph, O. Nedlic, M. Luckymis, K. Adams, D. Hess, E. Kabua, A. Yalon, E. Buthung, C. Graham, T. Leberer, B. Taylor, R. van Woesik, P. Houk, R. Camacho, S. Johnson, McLean. 2015. The Micronesia Challenge: Assessing the Relative Contribution of Stressors on Coral Reefs to Facilitate Science-to-Management Feedback. PLoS ONE 10(6):1-17. doi:10.1371/journal.pone.0130823.

Lirman, D., B. Orlando, S. Macia, D. Maqnzello, L. Kaufman, P. Biber, T. Jones. 2003. Coral communities of Biscayne Bay, Florida and adjacent offshore areas; diversity abundance, distribution and environmental correlates. AquConserv—Mar Freshwater Ecosyst 13:121–135

Lorenz, R. 1999. Spill from dredging activities. Proc Øresund Link Dredging & Reclamation Conference, Copenhagen

Meehan, W.J. and G. K. Ostrander. 1997. Coral bleaching: A potential biomarker of environmental stress. Journal Of Toxicology And Environmental Health Vol. 50, Iss. 6,1997

Miller, J., E. Muller, C. Rogers, R. Waara, A. Atkinson, K.R.T. Whelan, M. Patterson, B. Witcher. 2009. Coral Reefs 28: 925. doi:10.1007/s00338-009-0531-7.

Miller M.W., J. Karazsia, C.E. Groves, S. Griffin, T. Moor, P. Wilber and K. Gregg. 2016. Detecting sedimentation impacts to coral reefs resulting from dredging the Port of Miami, Florida USA. Peer. J. 4: e2711

Mills D, and H. Kemps. 2016. Generation and release of sediments by hydraulic dredging: a review. Report of Theme 2 - Project 2.1 prepared for the Dredging Science Node, Western Australian Marine Science Institution, Perth, Western Australia. 97 pp.

Mumby, P. J. 2009. "Herbivory versus corallivory: are parrotfish good or bad for Caribbean coral reefs?" Coral Reefs 28.3: 683-690.

National Marine Fisheries Servi ce (NMFS). 2016. Examination of Sedimentation Impacts to Coral Reef along the Port of Miami Entrance Channel, December 2015. Final Report. 58 pp.

Nelson, D. S., J. McManus, R.H. Richmond, D.B. King Jr., J.Z. Gailani, T.C. Lackey, D. Bryant. 2015. Predicting dredging-associated effects to coral reefs in Apra Harbor, Guam Part 2: Potential coral effects.Journal of Environmental Management 168:111-122. DOI: 10.1016/j.jenvman.2015.10.025

NOAA. 2013. Biscayne Bay Turbidity Study. NOAA Technical Report OAR-AOML-41

NOAA National Marine Fisheries Service. 2016. Examination of sedimentation impacts to coral reef along the Port of Miami Entrance Channel, December 2015

Palermo M.R., P.R. Schroeder, T.J. Estes, N.R. Francingues. 2008. Technical guidelines for environmental dredging of contaminated sediments. No ERDC/EL- TR-08-29. Environmental Laboratory, U.S. Army Engineer Research and Development Center, Vicksburg, MS

Pandolfi, J. M., J. B. C. Jackson, N. Baron, R.H. Bradbury, H.M. Guzman, T.P. Hughes, C.V. Kappel, F.Micheli, J.C. Ogden, H.P. Possingham, and E. Sala. 2005. Are US coral reefs on the slippery slope to slime?. Science, 307 5716: 1725-1726. doi:10.1126/science.1104258

Pandolfl, J.M., S. R. Connolly, D. J. Marshal, A. L. Cohen. 2011. Projecting coral reef futures under global warming and ocean acidification. SCIENCE 333(6041):418-422.

Peters, E.C. and M.E.Q.Pilson. 1985. A comparative study of the effects of sedimentation stress on symbiotic and asymbiotic colonies of the coral Astrangiadanae (Milne Edwards and Haime 1849). Journal of Experimental Marine Biology and Ecology 92:215-230.

Petus, C., M. Devlin, A. Thompson, L. McKenzie, E. Teixeira da Silva, C. Collier, D. Tracey, K. Martin. 2016. Remote Sensing 8(210). doi:10.3390/rs8030210.

Precht, W.F. ed., 2006. Coral reef restoration handbook. CRC Press.

Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008. Session number 1. Real-time coral stress observations before,during, and after beach nourishment dredging offshore southeast Florida, USA.

Riegl, B. and G.M. Branch. 1995. Effects of sediment on the energy budgets of four scleractinian (Bourne 1900) and five alcyonacean (Lamouroux 1816) corals. Journal of Experimental Marine Biology and Ecology 186:259-275.

Roessler, M.A. and G.L.Beardsley. 1974. Biscayne Bay: Its environment and problems. Florida Scientist 37:186-204.

Rogers, C.S. 1983. Sublethal and lethal effects of sediments applied to common Caribbean Reef corals in the field. Marine Pollution Bulletin 14(10):378-382.

Rogers C.S. 1990. Response of coral reefs and reef organisms to sedimentation. Mar EcolProgSer 62:185–202

SAJ, 2004. Final General Re-Evaluation Report and Environmental Impact Statement, pp 902

Schoepf, V., M. Stat, J. L. Falter & M. T. McCulloch. 2015. Limits to the thermal tolerance of corals adapted to a highly fluctuating, naturally extreme temperature environment. Scientific Reports 5, Article number: 17639 doi:10.1038/srep17639

Sengupta, S., .S. Lee, H.P. Miller. 1978. Three-dimensional numerical investigations of tide and wind-induced transport processes in Biscayne Bay Sea Grant Technical Bull. (July 1978) No. 39

Stabenau, E., A. Renshaw, J. Luo, E. Kearns and J.D. Wang. 2015. Improved coastal hydrodynamics model offers insight into surface and groundwater flow and restoration objectives in Biscayne Bay, Florida, USA. Bulletin of Marine Science 91(4): 433-454.

Storlazzi, C.D., M.E. Field, M.H. Bothner. 2011. The use (and misuse) of sediment traps in coral reef environments: theory, observations, and suggested protocols. Coral Reefs 30: 23. doi:10.1007/s00338-010-0705-3

Storlazzi, C.D., P. Dartnell, G.A. Hatcher, A.E. Gibbs. 2016. End of the chain? Rugosity and fine-scale bathymetry from existing underwater digital imagery using structure-from-motion (SfM) technology. Coral Reefs 35:889–894. DOI 10.1007/s00338-016-1462-8. Chevron Australia, 2016. Wheatstone Project. Dredging and Dredge Spoil Placement Environmental Monitoring and Management Plan. pp230.

Sutherland, K.P., J.W. Porter, C. Torres. 2004. Disease and immunity in Caribbean and Indo-Pacific zooxanthellate corals.MEPS 266:273-302. doi:10.3354/meps266273

USACE. 2001. Miami Harbor General Re-Evaluation Report-Miami Harbor Channel Deepening Widening Geotechnical Investigation. 6pp

USACE. Jacksonville District. 2013. Miami Harbor Phase III Dredging Project. RFP No. W912EP-12-R-0013. Project Specifications Section 01 57 20 – Environmental Protection. May 2013. 59 pp +apps.

Vargas-Ángel, B., E.C. Peters, E. Kramarsky-Winter, D.S. Gilliam, R.E. Dodge. 2007. Cellular reactions to sedimentation and teAmperature stress in the Caribbean coral Montastraea cavernosa. Journal of Invertebrate Pathology 95 (2):140-145.

Vlasblom, W. J. 2005. Chapter 3: Cutter suction dredger. CEDA Lecture Notes, Wb3408b

Walker, B.K. 2009. Benthic Habitat Mapping of Miami-Dade County: Visual Interpretation of LADS Bathymetry and Aerial Photography. Florida DEP report #RM069. Miami Beach, FL. pp. 47

Weil, E., G. Smith, D. L. Gil-Agudelo. 2006. Status and progress in coral reef disease research. Diseases of Aquatic Organisms 69:1-7.

Wesseling, I., A.J. Uychiaoco, P.M. Aliño, T. Aurin, and J.E. Vermaat. 1999. Damage and recovery of four Philippine corals from short-term sediment burial. Marine Ecology Progress Series 176: 11-15.

Westera, M. and R. Babcock. 2005. Post dredging recovery of seagrass in the Geraldton region - Interim Report October 2004 sampling. CSIRO Marine Research, Perth, Western Australia, pp. 22.

Unpublished as far as aware:

Swart, P.K. 2016. Report on the mineralogy and the stable carbon and oxygen sotope Composition of Samples Supplied by NOAA, June 2016, Peter K Swart, MGS, RSMAS, Univ. of Miami. In Port of Miami Sediment Analysis document sent from NMFS to SAJ.

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