Public Comments Received on the Triennial Review of State Surface Water Quality Standards

Public Comment Period: September 10-24, 2024

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Everglades National Park

From: Donatto Surratt, Water Quality Team Lead, Everglades National Park

Subject: Everglades National Park Comments on the Florida Department of Environmental Protection Triennial Review of Water Quality Standards

Water Quality Standards Rulemaking Team:

The Everglades National Park appreciates the efforts to update the water quality standards and clarify technical approaches to evaluating water quality conditions for compliance. We also appreciate the time that was dedicated to the Public Workshop on September 10, 2024. The staff was clearly informed and attempted to address several of the questions we raised during the meeting.

Here, we provide our review of the modifications to the water quality standards. Our comments, questions, and suggestions are aimed at improving clarity of the proposed changes. We welcome any follow-up dialogue regarding the topics raised in this review if any clarifications would assist in addressing these topics.

Comments, Questions, and Suggestions.

Chapter 62-302:

Chapter 62-302 @ 19: All of the requirements for the numeric nutrient standards rules defined in 62-302.531 and 62-302.532 were replaced by NPDES permits. However, the referenced codes (62-4.160(10), 62-620.610(12), and 62-620.620(6)) do not provide the same details provided in 62-302.531 focused on Class I, II, and III waters and there is no specific statement about preventing imbalance in flora and/or fauna in these references. Assurances that these levels of protection are still in place would provide some security that protection for these water bodies is not being lessened. If striking the reference to the 62-302.531 and 62-302.532, consider referencing Chapter 62-302, detailing the Classes and the required protection.

Chapter 62-302 @ 17: In reading the additions and deletions of water body sections, it is not clear what is driving these decisions. Consider providing a reference that describes why these water body sections are changing.

Chapter 62-302 @ 19: Utilizing “water quality modeling” was added to determine “Natural background”. Consider explaining how water quality modeling can determine “natural background” and provide some references.

Chapter 62-302 @ 19: “or other scientifically valid approaches” was also added to define “Natural background”. Consider providing examples and references for the other valid approaches.

Chapter 62-302 @ 28: “Pollution” definition, “human-induced impairment of air or waters” was added. Why are geological materials (i.e., soil and subsurface rock) not included?

Chapter 62-303:

Chapter 62-303: It is suggested to use a minimum of four annual geometric means to perform a Mann-Kendall trends test. Kendall (1975) and Mann (1945) showed that the normal approximation is excellent even for samples as small as n = 10 when using the continuity correction. Is this considered for this test when applying for sample sizes even lower than 10 by the protocol established in this chapter? In other words, how was a minimum of four samples deemed enough to be statistically significant? Please provide a reference.

Implementation of Florida's Numeric Nutrient Standard for Streams:

Title page – Does the removal of "EPA submittal" step indicate EPA is no longer required to approve these modifications? An explanation of this modification would be helpful.

Given the determination of floral health is based on a reference site data distribution, providing references describing requirements for establishing a reference site, would be helpful.

Section 1.1 Evaluating algal mats

- When considering the two most recent surveys with different results, please explain why there is no option for the water body to be moved to the Study List.
- When the RPS rank 4-6 coverage is >= 20%, an evaluation of the algal species composition must be conducted to provide additional information on flora imbalance, does this occur for any single instance of 4-6 coverage > 20% or does it still require two exceedances at independent times? Please consider being explicit here given the preceding paragraph is calling for two most recent surveys.

Section 1.2 Evaluating dominant algal species composition

- "A stream is considered to have a balanced periphyton community if two consecutive temporally independent samples do not include dominance by taxa known to be nutrient enrichment indicators or produce toxins."
    - How is dominance defined?
    - If the species of concern are growing in, but have not become the dominant yet, is there a trigger to go on the Study List?

Section 1.2.1 RPS and algal species composition decision key

- How come these decision paths terminate at 'Stop' when sites are showing impairment or impacts instead of going on a list? For example, number 4, it makes since to 'Stop' after the site attains the expectations for algal mats, but the same 'Stop' when the site does not meet expectations for algal mat occurrence, is challenging to understand.

General for the decision trees: Consider adding a reference or explaining what happens after impact/impairment is determined but 'Stop' is the end of the decision tree.

Section 1.3 Evaluating the presence or absence of nuisance macrophyte growth

- "To determine an LVS threshold for streams that would 'clearly support aquatic life'. How is 'clearly' support aquatic life defined? Right now, it sounds subjective.
- "Because invasive exotic or tolerant species can occur even in the absence of anthropogenic nutrient enrichment…" Is there a way to move a site under these conditions directly to the impaired list? Is there a way to merge the LVS, RPS, and nutrient data to determine the impairment designation immediately without the lengthy Study Listing process? Impairment evidence should be able to guide this decision.

Section 1.4.1 Chlorophyll a/algal bloom decision key

- "Typical conditions include flow between 10th and 90th percentile of long-term discharge…" Consider adding a baseline period unless the period of record expands every time data are added.

Section 2.1.3 Use of geomorphology to identify candidate sites

- "If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the second letter should be used in the calculation." Consider adding a description of the methods used to determine soil drainage capacity or a reference to the required method for these purposes.

Section 2.2 Tidally influence segments

- "The presence of 'typical' hydrologic conditions may be shown by tide and flow data temporally coupled with water quality sampling events." Consider defining 'typical' as it was done earlier with the percentile distribution range of 10 to 90%.

Appendix I: Protection of Threatened and Endangered Species in Portions of the Suwanne, Withlacoochee, Santa Fe, New, and St. Johns Rivers

Section 4. Where the change was to add the words "generally applicable" DO criteria…

- Consider adding the DO value.

MANASOTA — 88

A Project for Environmental Quality 1968 - 2088

WQS_Rulemaking@FloridaDEP.gov

2600 Blair Stone Road
Mail Station 6511
Tallahassee, Fl 32399-2400
September 22, 2024

Sent via email and USPS mail

Re: Triennial Review of Florida's Water Quality Standards

ManaSota-88, Inc. (hereinafter, "ManaSota-88") is a public interest conservation and environmental protection organization, which is a Florida not-for-profit corporation and citizen of the State of Florida. The corporate purposes of ManaSota-88 include the protection and preservation of water quality and wildlife habitat in Manatee and Sarasota Counties and, therefore, commenting on the Triennial Review of Florida's Water Quality Standards falls within ManaSota-88's general scope of interest and activity.

General Comments

The FDEP in general has abandoned many of the intensive water quality monitoring programs used in the past, including permit conditions and requirements for sampling and analyses. Unfortunately, this has resulted in misleading TMDL's and other information.

The Triennial Review is suggesting that mixing zones be amended to allow nutrients, but the Review provided no further information that could be found. Is FDEP proposing to exempt nutrient point discharges from mixing zone requirements?

The Grizzle Figg legislation needs to be specifically referenced with its relevance to bio limiting nutrients.

Specific Comments

Slide No. 8 - Recommend deleting reference to "water quality modeling" due to use of variables and concerns associated with inherent deficiencies of modeling. Unless models are frequently verified and calibrated with actual field data over multiple storm events and antecedent wet/dry environmental conditions they will be subject to questions of accuracy used to derive numerical standards. Use of "scientifically valid and accepted" approaches used in establishment of natural background could be provided as part of the definition without adding water quality modeling that has

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demonstrated concerns with regard to realistic outcomes and legal standing. Modeling may be used as a qualitative predictive tool but its sole use to establish set physical, biological and chemical background conditions as referenced by codified rule is a Pandora's Box.

Slide No. 8 - What is meant by clarifying the definition of nutrient and why is this being considered?

Slide No. 9 - Rather than removal of reference to fluctuating hydrologic conditions recommend addition of "naturally occurring hydrologic conditions".

Slide No. 14 - Fecal coliform criteria must apply to all surface waters of the State. Would this eliminate the criterion in Class III waters designated for recreation or subject to illicit wastewater discharge?

Slide No. 15 - Clarification procedures for when a nutrient total maximum daily load (TMDL) would be considered a site-specific interpretation should use "site-specific" data. Many TMDL's are derived from unverified and uncalibrated models and/or apply "similar" land use data that have proven unrepresentative of actual site conditions.

Slide No. 18 - Evaluation of algal mats should include language that specifies observations be performed only by a credentialed aquatic biologist familiar with algal taxonomy. Add photo documentation to be made part of algal mat and other reports.

Slide No. 19 -Clarifying that samples not dominated by specific taxa may indicate a balanced periphyton community may ignore excessive nutrient inputs. Recommend accompanying reference to water quality measurements, unauthorized discharges, etc.

Slide No. 20 - Evaluating the presence or absence of nuisance macrophyte growth should also include language that specifies observations be performed by a credentialed botanist. Also add photo documentation to accompany reports.

Slide No. 21 - Evaluating algal blooms, chlorophyll a, and phytoplankton taxonomic data should include language that specifies observations and analyses be performed by a credentialed biologist. Upstream sources should be specifically identified and assessed for compliance with applicable permits. Rather than remove language regarding trend assessments, include reference to details in Chapter 62-303, FAC.

Slide No. 22 - Waterbodies being assessed for nutrient impairment that use "other information and trends" should include reference to acceptable algal assays (e.g. Printz Algal Assay Bottle Test) to best determine nutrient thresholds, ratios, etc. References to macroinvertebrate taxa should cross-reference Section 62-302.530(10)(a,b), FAC surface water quality criteria using the Shannon-Weaver diversity index.

Slide No. 23 - Soils data should be included as a primary method to demonstrate that a segment is non-perennial, a critical metric used to determine jurisdictional wetlands.

Slide No. 24 - The assessment of physical alteration limitations to habitat should include historic and recent aerial and site photographic comparisons, stratigraphy (e.g. benthic) or other scientific measurements.

Slide No. 34 - If not referenced, include temperature, pH and water column depth in addition to time-of-day adjustments for ambient dissolved oxygen (DO) data. Naturally dystrophic conditions or anthropogenic inputs contributing to low DO should be referenced.

Slide 44 - Will proposed permitting of the discharge associated with an environmental restoration and enhancement project (as defined in subsection 62-4.020(6), F.A.C.) still need to meet applicable water quality standards and criteria through compliance monitoring and conditions for remediation?

Slide No. 50 - Specifying that temporal independence between Biological Health Assessment samples are 90 days apart may also include reference to seasonal wet and dry conditions. It's possible for seasonal conditions to extend beyond 90 days.

Slide No. 60 - A reasonable expectation that the water will become impaired within 10 years seems unrealistic due to any number of factors. A tighter timeframe is recommended.

Slide No. 61 - Adding existing TMDLs through BMAPs or a department enforcement order that rely solely upon models that have not been calibrated or verified with actual discharge data is not recommended. Also, listing LVS results can be linked to anthropogenic nutrient inputs through dye or other monitoring exercises.

Slide No. 63 - DEP's site-specific assessments to determine potential causes of the nuisance macrophyte growth should include aerial, drone and ground-level photographic documentation, in addition to evaluation of discharge permit monitoring data.

Slide No. 66 - The reasonable expectation that the water will become impaired within 4 years, as noted earlier for 10 years, is subject to interpretation and invites water quality degradation that may otherwise have been prevented. Predictions of water quality degradation should require active planning and implementation of preventive measures without a waiting period. Also, total maximum daily loads (TMDL's) for a given nutrient, nutrient trend, or nutrient response variable should be field-verified and not rely upon models unless they have been calibrated with site-specific data.

Slide No. 68 - Subsection 62-303.500(1), FAC should clarify how the TMDL prioritization process will be used only if TMDLs rely upon accurate, site-specific data, with models that have been calibrated and verified.

Slide No. 69 - Evaluation of pollution control programs must include permit monitoring and compliance, enforcement, remediation and all other regulatory records and data. The WMD's, FDEP, counties and others with approved quality assurance/quality control (QA/QC) plans may be included in the evaluation process.

Sincerely,

Glenn Compton

Chairman, ManaSota-88, Inc.

City of Tallahassee
Your Own Utilities℠

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September 24, 2024

Florida Department of Environmental Protection
Standards Development Section
2600 Blair Stone Road, MS 6511
Tallahassee, FL 32399-2400

Re: Triennial Review of Florida's Water Quality Standards

Sent Via Email to: WQS_Rulemaking@FloridaDEP.gov

The City of Tallahassee (City) appreciates the opportunity to provide comments on the Florida Department of Environmental Protection's (DEP) triennial review process, which addresses changes to water quality standards identified in 62-4, 62-302 and 62-303 of the Florida Administrative Code (F.A.C.). The City supports this rulemaking effort and the Department's goal of ensuring state water quality standards reflect the best available scientific information. The City hopes that these comments will lead to the refinement and practicable implementation of State water quality standards.

We appreciate your consideration of these comments and look forward to working with DEP staff. In the interim, should you have any questions, please do not hesitate to contact Mark Heidecker at 850-891-6825.

Respectfully submitted,

Mark Heidecker

Mark Heidecker
City of Tallahassee
Stormwater Management

Enclosures: Comments on Florida's Triennial Review of Water Quality Standards

City of Tallahassee Comments on Triennial Review of Water Quality Standards

The following comments are from the City of Tallahassee (City) for the public comment period regarding the triennial review of water quality standards as identified in chapters 62-4, 62-302, 62-303 and 62-304 of the Florida Administrative Code (F.A.C.) and the Numeric Nutrient Implementation Document.

62-302.530(6)(b) – Water Quality Criterion RE: Bacteriological Quality (*Escherichia* coli)

Existing water quality standards for *Escherichia coli* (*E. coli*) allow for direct measurement and statistical analysis methods. Membrane filter (MF) procedures generate directly measured results (reported as colony forming units—CFU). Statistical methods produce estimated results (reported as most probable number—MPN). While both methods are currently approved for use, statistical methods (SM 9223B/QT) tend to result in false positive results or increased levels of bacteria when compared to direct measurements of CFU (EPA Method 1603).

Per the 2012 *Recreational Water Quality Criteria Document* (Office of Water 820-F-12-058), which is the basis for Florida's adoption of bacteria criteria, EPA recommends EPA Method 1603. Shortcomings of statistical methods are well documented in numerous scientific articles and publications, some of which are outlined below. Based on this information, the City recommends DEP modify the criteria to exclude statistical methods that yield MPN results.

Suitability of the traditional microbial indicators and their enumerating methods in the assessment of fecal pollution of subtropical freshwater environments
https://europepmc.org/article/med/14723262
Sub-Tropical Freshwater - 80% of samples analyzed via Colilert-18/QuantiTray were equal to or greater than the counts obtained by membrane filtration.

Evaluation of Colilert-18 for the detection of coliforms and Escherichia coli in tropical freshwater
https://academic.oup.com/lambio/article/42/2/115/6703369
Tropical freshwater - Colilert-18/QuantiTray produced a 34% higher false-positive rate than membrane filtration.

Evaluation of Colilert-18 for detection of coliforms and Escherichia coli in subtropical freshwater
https://journals.asm.org/doi/full/10.1128/AEM.70.2.1242-1244.2004
Sub-Tropical Freshwater - Colilert-18/QuantiTray produced a 7.5% false-positive rate.

Equivalency testing of TTC Tergitol 7 agar (ISO 9308-1:2000) with five culture media for the detection of E. coli in water samples in Greece
https://pubmed.ncbi.nlm.nih.gov/20057092/
Colilert-18/QuantiTray produced higher E. coli counts than other methods in the study, with a mean relative difference 18.9% higher compared to the reference method. Other methods produced E. coli #s that were not statistically different from the reference method.

Marine bacteria cause false-positive results in the Colilert-18 rapid identification test for Escherichia coli in Florida waters
https://pubmed.ncbi.nlm.nih.gov/11823188/
In Florida, marine water samples collected in Pinellas County showed that Colilert-18/QuantiTray had a false-positive rate of 1-3 orders of magnitude greater than membrane filtration. The author hypothesizes that dilution issues may be the cause of the false positives.

62-302.530 Water Quality Criterion RE: Cyanotoxins (Microcystins and Cylindrospermopsin)

The City recommends DEP consider adoption of EPA's recommendations for Ambient Water Quality Criteria or Swimming Advisories (AWQC/SA) from *Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories for Microcystins and Cylindrospermopsin* (EPA 822-R-19-001). EPA recommendations accurately reflect the latest scientific knowledge on the potential human health effects from recreational exposure to cyanotoxins. Primary contact recreation is considered protected in water bodies at or below threshold concentrations of microcystins and cylindrospermopsin, which are 8 µg/L and 15 µg/L respectively.

Currently, waterbodies throughout Florida are routinely issued health alert notifications based solely on the presence of algal toxins regardless of magnitude. While such an approach provides conservative protection, it's not based in science and results in unnecessary limitations.

62-303.330 Biological Assessment RE: Linear Vegetation Survey (LVS) and Rapid Periphyton Survey (RPS) Certification

In reference to biological health assessment procedures it is stated in 62-303.330 "*Because these Biological Health Assessment procedures require specific training and expertise, persons conducting a BioRecon, SCI or LVI must comply with the quality assurance requirements of Chapter 62-160, F.A.C., attend at least eight hours of Department field training and pass a Department audit that verifies the sampler follows the applicable SOPs, as set forth in Chapter 62-160, F.A.C., before their Biological Health Assessment data will be considered valid for use under this rule*". However, at present DEP does not require similar certification for performing LVS and RPS evaluations. While these assessments are not listed in 62-303, their use is outlined in DEP's 2013 *NNC Implementation* Report. The 2013 Report states "*if any one of these floral measures indicates an imbalance, then the Department would conclude that the stream does not attain the NNC. Floral measures alone can provide evidence that the nutrient standard at Rule 62-302.531(2)(c) is not achieved, leading to the waterbody being placed on the Florida Verified List and Clean Water Act 303(d) list*". Given that LVS and RPS evaluations have the power of rule to place waterbodies on the verified list, the City strongly recommends DEP develop similar certification requirements.

62-303.360(5) Primary Contact and Recreation Use Support RE: Algal Toxins

The proposed addition of waters to the planning list related to county health department alert notifications due to the presence of algal toxins totaling 21 days in a calendar year is not science based. As discussed in relation to 62-302.530, EPA has issued national recommendations for

AWQC/SA and the recommended exceedance magnitudes for microcystins and cylindrospermopsin are 8 µg/L and 15 µg/L, respectively.

As technology improves, the detection limits of cyanotoxins will correspondingly decrease. Current advisory standards will result waterbody closures that are not science based. The City recommends that DEP reference the EPA recommended magnitudes and work with county health departments to issues alert notifications consistent with EPA recommendations. Suggested Rule Language:

(5) A Class I, I-Treated, II, III, or III-Limited water shall be placed on the Planning List for evaluating primary contact and recreation use support based on health alert notifications issued by a county health department due to the presence of algal toxins exceeding EPA recommended magnitudes for microcystins (8 µg/L) and cylindrospermopsin (15 µg/L). The health alert notifications shall total at least 21 days during a calendar year.

62-303.370 Listings Based on Fish Consumption

The proposed language in Chapter 62-303.370 includes the following: *"A Class I, II, III, or III-Limited water shall be placed on the Planning List for fish consumption if the Department of Health (DOH) has issued an advisory to limit consumption of any fish species from that water to one meal per week or less frequent consumption."* Additionally, DEP has proposed lowering the minimum number of fish required for tissue sampling for fish consumption compliance from 12 to eight (8), without providing any scientific basis for this change. The original minimum of 12 was established through statistical analysis that demonstrated 12 samples produced sufficiently accurate results for regulatory purposes, which led to its adoption in DEP Standard Operating Procedures (SOP) for fish tissue sampling (DEP SOP FS 6000). Unless DEP has completed additional analyses proving that a sample size of 8 is now adequate, the proposed change seems arbitrary and conflicts with the previously conducted analysis. The City recommends the continued use of the original standard: a minimum of 12 samples.

62-303 Process for Establishing, Subdividing and Altering WBID Boundaries

The City recommends DEP develop a standardized process for establishing, subdividing, and altering WBID boundaries. DEP periodically revises WBID boundaries, yet no documented standard operating procedure (SOP), criteria, nor opportunity for stakeholder input exists. Such an SOP should include a sound scientific basis for how WBID boundaries are established, subdivided, and altered. The City also recommends the SOP be incorporated into Chapter 62-303 by reference.

Implementation of NNC for Streams – Weight of Evidence Approach

DEP acknowledges that there is no clear evidence of floral or faunal responses to human-induced nutrients in streams. In 2013, they adopted a reference site approach for NNC in streams, using minimally disturbed sites as benchmarks. Due to the lack of biological responses to nutrient levels and to avoid arbitrary impairment designations, DEP initially implemented a weight-of-evidence approach for stream floral assessments. However, to date DEP has still not established cause-effect relationships between nutrient levels and biological responses in streams. Additionally, no floral thresholds have been updated or newly derived from reference sites based on data collected since 2013. Despite this, DEP has removed references to the weight-of-evidence approach the NNC Implementation Report and now treats reference-based floral thresholds as though they are definitive impairment criteria. Reference-based floral metrics, however, are not true impairment thresholds as they are based on the 90th (or 80th) percentile of reference site distributions, meaning 10% (or 20%) of minimally disturbed streams could be incorrectly listed as impaired.

Also, while the Stream Condition Index (SCI) was calibrated using the EPA's Biological Condition Gradient approach, the floral thresholds were not designed to measure the effects of human nutrient inputs but were instead arbitrarily set at the 90th or 80th percentiles of reference sites. While DEP's efforts to make stream impairment determinations more definitive and streamlined are commendable, removing the weight-of-evidence requirement without addressing the lack of a clear stressor-response relationship between nutrients and biological responses is problematic. Any changes in this regard should be based on sound science, not solely simplification. Accordingly, the City recommends DEP establish a clear and scientifically based methodology for assessing floral health before removing the weight-of-evidence requirement.

Additionally, the current data requirements for using floral and faunal metrics to place streams on the planning or verified lists need revision. Unlike water quality data, where DEP has conducted statistical analyses to determine a minimum sample size (requiring at least 20 samples with a 10% exceedance rate under the binomial method with 90% confidence), no such analysis has been conducted for biological data. Presently, a single failed SCI sample can place a stream on the planning list, and only two fails are needed for verified impairment. Therefore, the City recommends DEP establish a scientifically based minimum sample size for floral and faunal assessments before listing a WBID as verified impaired.

2024 Triennial Review of State Surface Water Quality Standards
Comments submitted by the Florida Department of Transportation
September 24, 2024

Rule 62-303.450, F.A.C

FDOT is concerned about the updates to this rule proposed by FDEP. By shortening the timeframe from 5 years to 4 years in designating an anticipated impairment as category 5, undue pressure and burdens could be inflicted onto stakeholders and under a time constraint which many public entities or unable to comply with. Additionally, the second update to the rule in which a downstream waterbody being impaired could cause the upstream waterbody to be on the Verified List in spite of the upstream waterbody not being impaired seems overly cautious and carries the potential to demand finite resources in addressing concerns that may not be warranted.

idexx.com/water

Ms. Nia Wellendorf
Florida Department of Environmental Protection
Water Quality Standards Program
3900 Commonwealth Boulevard
Tallahassee, Florida 32399-3000
Nijole.Wellendorf@FloridaDEP.gov

Re: Florida Triennial Review

September 12, 2024

Dear Ms. Wellendorf,

IDEXX applauds the Florida Department of Environmental Protection's Division of Environmental Assessment and Restoration for conducting a Triennial Review of the state's Water Quality Standards, and we appreciate the opportunity to participate in the public comment period.

At this time, we support those revisions made to the named chapters of the Florida Administrative Code (F.A.C.) and commend the DEP for their continued prioritization of providing clean and safe water, in all its forms, to Florida residents. It is of the utmost importance that states continue to focus on additional ways to strengthen these standards and better protect public health. IDEXX appreciates the opportunity to provide these comments and we look forward to the next steps in the regulation process.

Respectfully submitted,

Nina Fraulini

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cc Patsy Root, Sr. Manager, Government Affairs

Revised Comment Letter Submitted by Rick Cantrell from Stantec on September 16, 2024

First, consider revising the definition in 62-302.200(36), F.A.C. to include the perennial flow duration minimum within the RULE and indicate a hierarchal use of bioassessment information which in my opinion, is a stronger position legally. Also, consider changing the definition from "Stream" to "Perennial Stream". It could read:

"Stream" or alternatively "Perennial Stream" shall mean, for purposes of interpreting the narrative nutrient criterion in paragraph 62-302.530(48)(b), F.A.C., ~~62-302.530(47)(b), F.A.C.,~~ under paragraph 62-302.531(2)(c), F.A.C., a predominantly fresh surface waterbody with perennial flow in a defined channel with banks during typical climatic and hydrologic conditions for its region within the state. During periods of drought, portions of a stream channel may exhibit a dry bed, but wetted pools are typically still present during these conditions. For a flowing waterbody or waterbody segment to be considered perennial it must exhibit measurable flow for at least 180 consecutive days in greater than 50% of years. Flowing waterbodies or segments of flowing waterbodies that exhibit lesser flow duration shall be considered non-perennial unless there is site-specific bioassessment information based on the resident flora or fauna that an aquatic community is present that would require perennial flow. Streams do not include:

(a) Non-perennial flowing waterbody segments where site specific bioassessment information or flow data indicate ~~fluctuating hydrologic conditions, including~~ periods of desiccation;~~,~~ typically result in the dominance of wetland and/or terrestrial taxa (and corresponding reduction in obligate fluvial or lotic taxa);~~,~~ wetlands;~~,~~ portions of streams that exhibit lake characteristics (e.g., long water residence time, increased width, or predominance of biological taxa typically found in non-flowing conditions);~~,~~ or tidally influenced segments that routinely reverse the direction of flow~~s~~ or fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions; or

(b) Ditches, canals and other conveyances, or segments of conveyances, that are man-made, or predominantly channelized or predominantly physically altered; and

1. Are primarily used for water management purposes, such as flood protection, stormwater management, irrigation, or water supply; and

2. Have marginal or poor stream habitat or habitat components, such as a lack of habitat or substrate that is biologically limited, because the conveyance has cross sections that are predominantly trapezoidal, has armored banks, or is maintained primarily for water conveyance.

1.0 No change
1.1

If a stream site exhibits a percent coverage of periphyton ranks 4-6 of 25% or less for two consecutive, temporally independent samples collected ≥90 days apart, the RPS results indicate evidence of a balanced periphyton community unless the site exhibits a percent coverage of periphyton ranks 4-6 of 25% or less but ≥ 20%, and an evaluation of the algal species composition indicates the dominance of an algal species that produces toxins or is associated with nutrient enrichment. If a stream site exceeds an RPS 4-6 coverage of 25% for two consecutive, temporally independent samples (≥90 days apart), the Department considers this as evidence that the numeric nutrient standard for streams is not achieved.

A complete RPS sample includes 99 observations (DEP SOP FS 7230), but sometimes site conditions prevent access to all 99 points. Samples with ≤ 90 valid observations pursuant to the SOP are inconclusive unless the sampled points are sufficient to evaluate the evidentiary threshold (e.g., ≥ 25 points with rank 4-6 coverage among the ≤ 90 observations would indicate a floral imbalance). A valid observation is one that does not require an X on the data sheet as specified in the SOP.

1.2

~~For example, n~~Nutrient enriched Florida springs (comment: How about data from the reference streams used to establish the nutrient thresholds?) are typically characterized by an abundance of one or more of the following taxa: Plectonema wollei (formerly Lyngbya wollei), Vaucheria sp., Dichotomosiphon spp, Aphanothece spp., Caloglossa spp., Chaetomorpha spp., Cladophora spp., Compsopogon spp., Enteromorpha spp., Hydrodictyon spp., Lyngbya spp., Oscillatoria spp., Rhizoclonium hieroglyphicum, Spirogyra spp. Information on potential toxin-producing taxa is located in the Department's Statewide Biological Database (SBIO) Florida Taxonomic Lists. Please contact the Florida DEP Laboratory for more information about specific taxa. The dominance of such taxa at a stream site where the RPS rank 4-6 ≥ 20% would be evidence that the numeric nutrient standard is not achieved.

2.0 BASIC INFORMATION NEEDS FOR DISTINGUISHING FLOWING WATERS UNDER RULE 62-302.200 ~~(36)~~, F.A.C.

The numeric nutrient standard for streams only applies to "flowing waters" meeting the stream definition in subsection 62-302.200(36), F.A.C. While **the default assumption is that any flowing water**body or segment of a flowing waterbody **meets this definition**, (comment: Since the definition of "Stream" in 62-303.200 (27) F.A.C. is much more inclusive and clearly includes streams not covered by subsection 62-302.200(36), F.A.C. this statement seems much too broad) permittees or other interested parties may want to provide the information necessary to demonstrate that a waterbody meets one of the exclusions in the definition for streams. Information can be submitted to the Department prior to or during the Watershed Assessment Cycle, or as a component of a permit application. The Department will review the submitted information, and all approved exclusions will be tracked by the Water Quality Standards Program including a GIS record of all stream exclusions.

The definition of stream in subsection ~~Rule~~ 62-302.200(36), F.A.C., states:

(36) "Stream" shall mean, for purposes of interpreting the narrative nutrient criterion in paragraph 62-302.530(48)(b), F.A.C., ~~62-302.530(47)(b), F.A.C.,~~ under paragraph 62-302.531(2)(c), F.A.C., a predominantly fresh surface waterbody with perennial flow in a defined channel with banks during typical climatic and hydrologic conditions for its region within the state. During periods of drought, portions of a stream channel may exhibit a dry bed, but wetted pools are typically still present during these conditions. . For a flowing waterbody or waterbody segment to be considered perennial it must exhibit measurable flow for at least 180 consecutive days in greater than 50% of years. Flowing waterbodies or segments of flowing waterbodies that exhibit lesser flow duration shall be considered non-perennial unless there is site-specific bioassessment information based on the resident flora or fauna that

an aquatic community is present that would require perennial flow. Streams do not include:
(a) Non-perennial water segments where site specific bioassessment information or flow data indicate ~~fluctuating hydrologic conditions, including~~ periods of desiccation;~~,~~ typically result in the dominance of wetland and/or terrestrial taxa (and corresponding reduction in obligate fluvial or lotic taxa);~~,~~ wetlands;, portions of streams that exhibit lake characteristics (e.g., long water residence time, increased width, or predominance of biological taxa typically found in non-flowing conditions);~~,~~ or tidally influenced segments that routinely reverse the direction of flow~~s~~ or fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions; or
(b) Ditches, canals and other conveyances, or segments of conveyances, that are man-made, or predominantly channelized or predominantly physically altered; and
1. Are primarily used for water management purposes, such as flood protection, stormwater management, irrigation, or water supply; and
2. Have marginal or poor stream habitat or habitat components, such as a lack of habitat or substrate

that is biologically limited, because the conveyance has cross sections that are predominantly trapezoidal, has armored banks, or is maintained primarily for water conveyance.

The Department applies relevant water quality standards when ~~while implementing programs such as~~ assessing waterbodies for attainment of water quality standards under section 403.067, F.S., or implementing the NPDES permitting programs. When applying the nutrient standards adopted in subsection ~~Rule~~ 62-302.531(2), F.A.C., the Department will make clear whether the numeric nutrient standards for streams adopted in paragraph ~~Rule~~ 62-302.531(2)(c), F.A.C., apply ~~are applicable~~. ~~In implementing water quality standards and evaluating whether a particular waterbody meets the provisions of paragraph 62-302.200(36)(a) or (b) F.A.C.,~~ When preparing draft lists of impaired waters under the IWR, the Department provides ~~will provide~~ public notice of the draft lists and requests information relevant to ~~making the determination~~ determining whether a flowing waterbody or waterbody segment meets one of the exclusions in the streams definition ~~the application of water quality standards~~, including the purpose of the waterbody, such as flood protection, stormwater management, irrigation, water supply, navigation, boat access to an adjacent waterbody, or frequent recreational use relevant to a stream exclusion ~~62- 302.200(36)(b)1. F.A.C~~. The Department considers ~~will consider~~ all relevant information in implementing water quality standards and maintain the administrative records of such decisions, which ~~will be~~ are available to the public.

For waters~~s~~bodies or waterbody segments that meet one of the exclusions ~~the definition~~ of paragraph 62-302.200(36)(a) or (b), F.A.C., the narrative nutrient criteria will apply and the Department shall assess the ~~stream~~ waterbody or waterbody segment using the nutrient impairment thresholds in subsection 62-303.351(4), F.A.C. (AGM chlorophyll a of 20 ug/L), subsection 62-303.351(3) (algal mats or blooms), and subsection (5) (increasing trends in nutrients or chlorophyll a), F.A.C. ~~and follow the Impaired Waters Rule at 62-303 F.A.C.~~

2.1 Non-Perennial Flowing Waterbody Segments

The ~~stream~~ numeric nutrient standard for streams meeting the definition in paragraph 62-302.200(36)(a) or (b), F.A.C., was ~~water quality standards adopted by the Department are~~ not designed to apply to wetlands, or uplands, or non-perennial ~~streams~~ waterbodies or waterbody segments. The duration and frequency of surface flow in ~~streams~~ a flowing waterbody must be understood to avoid confounding effects of natural drying events when assessing the ecological integrity of ~~flowing waters~~ aquatic resources present. Some knowledge of flow permanence is critical and may be the key variable influencing the communities in many small ~~streams~~ flowing water bodies in Florida and in determining the applicability of the stream definition in paragraph 62-302.200(36)(a) or (b), F.A.C. Different ecological expectations and sampling procedures are needed when assessing the condition of perennial streams versus ~~temporary~~ non-perennial (routinely intermittent) streams which are not included in the definition of paragraph 62-302.200(36)(a) or (b), F.A.C. The drying process causes changes in the physical and chemical conditions (e.g., loss of wetted habitat, reduced dissolved oxygen), which can exclude some species while allowing others to thrive.

These effects are not related to nutrients and therefore need to be controlled for in nutrient evaluations. Geophysical, hydrological, and biological information may be used individually or in combination to make a demonstration whether a flowing waterbody segment is non-perennial. Specific information to be included in a demonstration is discussed below.

There are two methods for demonstrating that a segment is non-perennial: 1) site specific gage and discharge data, 2) biological demonstration based on the resident flora or fauna. Either method can be used to independently establish whether a flowing waterbody or waterbody segment is non-perennial~~ity~~. **If both lines of evidence are available and the results conflict, the biological demonstration will take precedence.** (comment: The actual RULE definition as proposed does not say this. It is proposed to say: (a) Non-perennial water segments where site specific bioassessment information **or** flow data indicate……. Comment:The use of **or** indicates either one, and there is no hierarchy implied. While the proposed stream rule definition states: Evaluation of waters considered streams shall be consistent with the *"Implementation of Florida's Numeric Nutrient*

Standard for Streams" (Effective date, Link), which is incorporated by reference herein., this speaks to **evaluation** of flowing waterbodies already **considered streams.** This evaluation would be consistent with 62-302.531(2)(c) F.A.C. that states: The narrative nutrient criterion in paragraph 62-302.530(48)(b)~~62-302.530(47)(b)~~, F.A.C., shall be interpreted as being achieved in a stream segment where information on **chlorophyll *a* levels**, **algal mats or blooms, nuisance macrophyte growth**, and **changes in algal species composition indicates there are no imbalances in flora or fauna** as described in the document titled "*Implementation of Florida's Numeric Nutrient Standard for Streams*," (Effective Date, Link), which is incorporated by reference herein…. and 62-303.351 (1) FAC that states: The applicable numeric interpretation of the narrative nutrient criterion for streams established in subsection 62-302.531(2), F.A.C., is exceeded for any parameter, taking into consideration the **floral metrics** for the **Rapid Periphyton Survey (RPS), Linear Vegetation Survey (LVS), and chlorophyll *a*, the nutrient thresholds for TN and TP, and SCI** results for **the stream**, consistent with the document titled

"*Implementation of Florida's Numeric Nutrient Standards for Streams*," (Effective date, Link), which is incorporated by reference herein.; Neither says anything about further defining **what is a stream for the purposes of the NNC.** This creates the situation where a referenced support document supersedes what will be an adopted Rule. If you want to have a hierarchy, it should be in the adopted Rule definition.

2.1.1 STREAM FLOW CHARACTERISTICS AS AN INDICATOR

~~Perenniality~~ Perennial flow has been defined in several ways, including threshold-based definitions (such as 90% flow durations) and biologically-based criteria (such as 180 consecutive days of flow to support macroinvertebrate taxa). The terminology used here combines both elements. **Perennial streams are defined for NNC purposes** as those that have non-zero flow for at least 180 consecutive days (i.e., 6 months) in at least 90% of years in the available period of record. (Comment: Where is this definition located? Perhaps it should be cited. Since the purpose of the "stream" definition is to identify which flowing waterbodies are subject to certain NNC thresholds and specified biological assessments, perhaps this definition should be the sole criteria for perennial flow.)

The period of record must consist of at least 5 years of flow data. Likely perennial steams have measurable flow for at least 180 consecutive days in greater than 50% of years. ~~Seasonally perennial streams achieve 90-day (i.e., 3 months) flow spells in at least 75% of years, and~~ Non-perennial ~~streams~~ flowing waterbodies do not meet the flow thresholds for perennial, or likely perennial. ~~Streams that are seasonally perennial or non-perennial fit the non-perennial exclusion for the stream numeric nutrient standard.~~ (Comment: Since the purpose of this section seem to be the determination of which systems are entitled to an exclusion from the "Stream" definition based on flow, the concept put forth as "Seasonal perennial" appears to have no reason for existing as it would be included as qualifying for the non-perennial exclusion).

2.1.2 BIOLOGICAL INFORMATION AS INDICATORS

Macroinvertebrates

If available, macroinvertebrates will also be used to distinguish perennial from non-perennial /wetland systems. ~~Many~~Most rheophilic invertebrates ~~(rheophyllic taxa)~~ require relatively consistent inundation and water velocity to complete their life cycle, although ~~they~~ many have mechanisms to survive extreme drought conditions~~, when~~ if perennial streams reduce ~~may be reduced~~ to a series of pools. These pools typically exhibit slow flowing water with connecting flows between the pools existing in the sediments below the temporarily non-inundated sections of the stream bed. Other ~~(~~mostly wetland~~)~~ taxa are adapted to survive the frequent (generally annual) periods of desiccation associated with non-perennial streams or wetlands. Some invertebrate species could be classified as facultative, able to occupy both perennial streams and non-perennial ~~streams~~ flowing waterbodies. This ~~similarity in fauna~~ is due in part to the colonization of non-perennial ~~streams~~ flowing water segments by movement of invertebrates from nearby perennial waters, especially those with adaptations that allow them to survive in ~~temporary~~short hydroperiod environments, such as a multivoltine life cycle, highly mobile adults, and rapid growth during the wet season. Some ~~rarely inundated~~ non-perennial ~~streams~~ flowing waterbodies that have only a short hydroperiod may be ~~either~~

completely lacking in aquatic invertebrates (terrestrial animals may be present) or have a limited number of ~~facultative~~ species that can complete their life cycles rapidly before the stream dries.
The Department has compiled a taxa lists ~~of taxa~~ to distinguish ~~assist with distinguishing~~ perennial streams from non-perennial ~~streams/~~water segments or wetland systems (**Table~~s~~ 2~~8~~ ~~and 3~~9**). Paragraph ~~Rule~~ 62-302.531(2)(c), F.A.C., does not apply to non-perennial waterbody segments where there is a dominance of wetland and/or terrestrial taxa (with a ~~and~~ corresponding reduction in obligate fluvial or lotic taxa) or to wetlands. Paragraph ~~Rule~~ 62-302.531(2)(c), F.A.C., does apply to perennial streams where drought conditions may result in portions of a stream channel temporarily exhibiting a partially dry bed, but where wetted pools are typically still present.

SCI Stream Condition Index ("SCI") sampling, the method normally used to collect stream invertebrate taxa, requires certain hydrologic conditions to distinguish the effects of natural drought from water quality issues. SCI sampling (following DEP Standard Operating Procedure SCI 1000 as set forth in Rule

62-160.210, F.A.C.) is conducted during periods when water velocity has been 0.05 m/sec or greater for at least 28 days or after a 6-month period if the site has gone completely dry. Following these SOPs ensures that perennial streams are typically dominated by taxa from **Table 2~~8~~**, while non-perennial systems (which tend to transition into linear wetland strands) either would usually not be sampled for SCI or would typically not be dominated by taxa in **Table 3~~9~~**. The presence of long-lived aquatic species (benthic macroinvertebrates that require water for their entire life cycle) is another reliable method to determine if a stream is more characterized by perennial flow or wetland/terrestrial conditions. A list of long-lived taxa is included in DEP SOP SCI 2100 as set forth in Rule 62-160.210, F.A.C. However, several of the long-lived taxa such as crayfish (Decapoda-Cambaridae) are also dominant members of some longer duration wetland systems, and grass shrimp (Decapoda-*Palaemonetes*) are often abundant in marshes seasonally connected to more permanent waterbodies and may be present in otherwise non-perennial flowing waterbodies during wetter periods.

(Coment: It seems to me that proving the negative (non-perennial) with a positive demonstration (the presence of) using the aquatic macroinvertebrates is very difficult. I would propose eliminating Table 3~~9~~. Instead develop a more robust Table 2~~8~~ and use the absence of these taxa as for the determination. Further, the real concern as I see it is those flowing waterbody segments that might fall slight below the measurable flow for at least 180 consecutive days in greater than 50% of years, but which may exhibit a perennial fauna.

2.1.3 USE OF GEOMORPHOLOGY TO IDENTIFY CANDIDATES SITES

Given the large number of potentially non-perennial ~~streams~~ flowing waterbodies, the Department plans to use GIS resources to help identify candidates for the collection of biological data or flow monitoring. Drainage area and dominant water source (surface versus groundwater), which rely on readily available GIS layers, provide insight into the typical flow regime and degree of flow permanence in a stream. Drainage area in this context refers only to the contributing area upstream of a sampling location. As drainage area increases, groundwater storage increases and approaches the streambed level, ensuring a more continuous flow. (Exceptions to this include springs and seepage streams where even the upper reaches sustain year-round surface flow.) Similarly, as groundwater's relative contribution versus surface water increases, so does the permanence of flow in a system.

Florida's geology results in three distinctly different water delivery systems for Florida streams (karst, highlands, and flatwoods). Karst systems are those with abundant and steady groundwater discharged through limestone springs under pressure. The steady groundwater flow typical of karst systems exempts them from further non-perennial discussion. Highlands systems have unconfined lateral groundwater seepage through thick columns of sand through relict dunes, and flatwoods streams are dominated by surface water runoff seasonally coursing through and over combinations of flat, shallow, organic, and sandy soils. Accurately determining the dominant water source for highlands and flatwoods systems requires calculating the percentage of ~~well-~~ better drained soils (NRCS classifies these soils as moderately well drained, well drained, somewhat excessively drained, and excessively drained) in the watershed of a given site. Surrogates for this information, such as the presence or absence of tannins in the water, *i.e*. color, is highly variable and not a reliable long-term indicator.

To determine the hydrologic soil groups in the drainage area of a given site, a Geographic Information System (GIS) layer (*e.g.* NRCS, SSURGO) with hydrologic soil content is required. The percent of ~~hydric~~ better drained soils in the drainage area of interest should be calculated by adding up the soil types A and C in the PFCP region and the soil types A and B in the NEFCP and NWFCP regions. In GIS, this feature is typically designated as “HYDRGRP” or something similar in the attribute table of the soil layer. The percent thresholds in **Table 4** should be used to determine whether the site is highlands or flatwoods.

Additional Comments from Rick Cantrell Submitted September 13, 2024

62-303.351 Nutrients in Freshwater Streams.

A stream or stream segment shall be included on the Planning List for nutrients if:

(1) The applicable numeric interpretation of the narrative nutrient criterion for streams established in subsection 62-302.531(2), F.A.C., is exceeded for any parameter, taking into consideration the floral metrics for the Rapid Periphyton Survey (RPS), Linear Vegetation Survey (LVS), and chlorophyll *a*, the nutrient thresholds for TN and TP, and SCI results for the stream, consistent with the document titled "*Implementation of Florida's Numeric Nutrient Standards for Streams*," (Effective date, Link), which is incorporated by reference herein.;

(2) For streams meeting the definition in subsection 62-302.200(36), F.A.C., that do not have a site specific numeric interpretation of the narrative nutrient criterion, the nutrient thresholds in subparagraph 62-302.531(2)(c)2., F.A.C., are exceeded and insufficient Biological Health Assessment data are available to fully assess achievement of the nutrient provisions in subparagraph 62-302.531(2)(c)1., F.A.C., or if there is an annual geometric mean chlorophyll *a* greater than 3.2 ug/L; ? More than once in three consecutive years

(3) Algal mats or blooms are present in sufficient quantities to pose a nuisance or hinder reproduction of a threatened or endangered species, or other information is available, pursuant to Rule 62-303.350, F.A.C., indicating an imbalance in flora or fauna due to nutrient enrichment;

(4) An annual geometric mean chlorophyll *a* is greater than 20 ug/l, or

(5) There is a statistically significant increasing trend in the annual geometric means at the 95 percent confidence level in TN, TP or chlorophyll *a* over the assessment~~planning~~ period using the Mann-Kendall~~'s one-sided, upper-tail~~ Trend T~~t~~est~~. for trend, as described in Nonparametric Statistical Methods by M. Hollander and D. Wolfe (1999 ed.), pages 376 and 724, which are incorporated by reference herein. Copies of these pages may be obtained by writing to the Florida Department of Environmental Protection, 2600 Blair Stone Road, MS #6511, Tallahassee, FL 32399-2400.~~ To calculate the trend there must be a minimum of four annual geometric means in the assessment period.

Rulemaking Authority 403.061, 403.067 FS. Law Implemented 403.062, 403.067 FS. History–New 6-10-02, Repromulgated 1-2-07, 7-2-12, September 6, 2024

Florida Department of Environmental Protection
Attn: Kaitlyn Sutton
Division of Environmental Assessment and Restoration
2600 Blair Stone Road MS# 3555
Tallahassee, FL 32399-3000

Re: Comments on the Triennial review of Water Quality Standards

Dear Ms. Sutton:

On behalf of Florida Pulp and Paper Association Environmental Affairs ("FPPAEA" or "the Association"), I thank you for the opportunity to submit comments related to the Triennial Review of Water Quality Standards. We appreciate the hard work and dedication that you and others at the Florida Department of Environmental Protection (the "Department") have demonstrated to maintain the appropriate standards for protection of Florida's surface waters.

The Florida Pulp and Paper Association Environmental Affairs, Inc., known as FPPAEA, is the State trade association representing the majority of Florida's Forest Products industry, including pulp, paper, packaging, and wood products manufacturers. The Forest Products industry is ranked in the top 5 manufacturing sector employers for both number of jobs and employee compensation. The industry is also Florida's leading manufacturer in sustainability and providing green jobs. The industry employs over 30,000 Floridians in high-paying jobs, leads the way on recycling and renewable energy generation, and sustainably manages Florida's forests. The FPPAEA companies own and operate manufacturing facilities in the State of Florida that will be affected by these regulations.

The Association's comments in this submittal are directed toward a need to repeal the standards for aluminum and iron in a marine water. Aluminum and iron are the 3rd and 4th most abundant elements in earth's crust accounting for 8.1% and 5% of earth's crust, respectively. As such, the occurrence of aluminum and iron in soils, waters, and sediments is to be expected. However, to support the adoption or continuation of a standard, it is necessary to demonstrate that the occurrence of aluminum and iron in the marine environment is bioavailable and toxic to biota.

Toxicity of Aluminum and Iron

The science showing the toxicity of aluminum and iron in marine waters is very limited, but generally accepts that both of these elements are innocuous in marine waters. Aluminum is extremely common throughout the world and is innocuous under circumneutral or alkaline conditions (Sparling, D.W., Lowe, T.P. 1996). For iron, toxicity and bioavailability are limited due to high pH of marine waters (pH ~8.2). In this environment, very little iron remains dissolved in the marine waters.

History of Aluminum and Iron Standards

The Association's primary concerns are the standards for aluminum and iron in predominately marine waters. It is my understanding that the criteria for iron and aluminum in marine waters was based on an EPA document from the early 1970s. In its subsequent Red and Gold Books, EPA concluded that a recommended criterion for either iron or aluminum could not be supported by the available science. EPA has not reviewed the science necessary to recommend criteria for iron in marine waters since 1976 and previously concluded that *"the effects of iron on marine life have not been investigated adequately to determine a water quality criterion. Dissolved iron readily precipitates in alkaline sea waters. Fears have been expressed that these settled iron flocs may have adverse effects on important benthic commercial mussels and other shellfish resources"* (p. 155, EPA 1976). The EPA did review criteria for aluminum on several occasions, but never recommended a criterion for aluminum in marine waters. In its 2017-2018 review of Aluminum the EPA concluded the following.

> ***Acute -*** *The 1985 Guidelines require that data from a minimum of eight families are needed to calculate an estuarine/marine FAV. Notably, no acceptable test data on fish species were available (Figure 9). Since data are available for only five families, an estuarine/marine FAV (and consequently, the EPA cannot derive an estuarine/marine acute criterion).*
>
> ***Chronic -*** *There are no estuarine/marine chronic toxicity data that meet the test acceptability and quality assurance/control criteria in a manner consistent with the 1985 Guidelines in Appendix D (Acceptable Chronic Toxicity Data of Aluminum to Estuarine/Marine Aquatic Animals)*

Aluminum and Iron Standards in Other Coastal Jurisdictions

In a review of criteria for iron and aluminum in the other 21 coastal jurisdictions of the United States, it was determined that there are no numeric criteria in these coastal states for either metal. Some coastal states have implemented narrative aquatic life criteria for iron in estuarine/marine waters (EPA 1988b; Appendix B), but none for aluminum.

Numeric aluminum and iron criteria have not been developed for marine waters in Canada (Environment and Climate Change Canada 2019, 2022). For iron, in particular, provincial regulators have determined that there are insufficient data to establish an appropriate guideline, and it is not anticipated that iron toxicity would be a concern because the relatively high pH of marine waters (pH ~8.2) causes precipitation, leaving little iron to remain in solution (Phippen et al. 2007). It has also been determined that metals found in marine estuaries tend to form complexes with the abundant organic and inorganic ligands rendering the metals less bioavailable to aquatic organisms.

A review of environmental quality standards (EQS) for the European Union show that numeric criteria for aluminum and iron in marine waters do not exist. Similarly, numeric criteria for aluminum and iron have not been developed for marine waters in Australia and New Zealand.

For aluminum the guideline states the following:

There were limited marine data and procedures for calculating an Environmental Concern Level (ECL) (ANZECC & ARMCANZ 2000 Section 8.3.4.5) were used to calculate a low reliability marine trigger value of 0.5 µg/L derived for aluminum using an AF of 200. This figure should only be used as an indicative interim working level but could be revisited as more data become available. The factor of 200 was used because the ECL factor of 1000 was considered excessive for such a commonly found element.

For iron the guideline states the following:

There were insufficient data at this stage to derive a reliable trigger value for iron. The current Canadian guideline level is 300 µg/L, which could be used as an interim indicative working level but further data are required to establish a figure appropriate for Australian and New Zealand waters. ***Potential for iron deficiency needs to be considered in such studies.*** *No marine data were available.*

Related Environmental Concerns

There are recent field trials of nearshore kelps being purposefully grown offshore to help mitigate the effects of climate change, more specifically to help offset carbon dioxide emissions. However, there are concerns that the dissolved iron in the marine environment will limit the growth of healthy kelp (Paine, E.R., Boyd, P.W., Strzepek, R.F. et al., 2023). A recent analysis of ocean phytoplankton nutrient limitation indicates that iron is co-limiting the growth of ocean phytoplankton in many of the world's oceans (Browning, T.J., Moore, C.M., 2023). In its summary guidelines for iron triggers for marine environments, the Australian Government states that the potential for an iron deficiency needs to be considered when establishing an iron standard.

Developing Standards for Aluminum and Iron

EPA has specific data requirements and approaches for the development of numeric water quality criteria for the protection of aquatic life in fresh and marine waters. When data requirements for numeric criteria derivation are not met, the implementation of numeric criteria is inappropriate. EPA has not promulgated recommended marine numeric criteria for aluminum or iron because there is insufficient toxicity data available to ensure that criteria are accurate and protective. The use of limited funds and resources in Florida to assess marine waters for these metals and the consequences of placing waters on the 303(d) list is not prudent.

It is for these reasons that the Association requests that the Department repeal the standards for aluminum and iron in predominately marine waters until more information and data are available. If you have any questions regarding our comments, please do not hesitate to contact me. I can be reached by telephone at (813) 215-8856 or by email at rstewart@fppaea.org. Thank you for your time and attention to our concerns.

Best Regards,
Florida Pulp and Paper Association EA, Inc.

James R. Stewart, PE
Executive Director

cc: Nia Wellendorf
Greg Munson, Gunster Law
FPPAEA Board Members

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MIAMI WATERKEEPER®

September 24, 2024

Florida Department of Environmental Protection (DEP)
Division of Environmental Assessment and Restoration
c/o Nia Wellendorf, Program Administrator
2600 Blair Stone Road
Mail Station 6511
Tallahassee, FL 32399-3000
Sent via email to: WQS_Rulemaking@FloridaDEP.gov

Subject: Triennial Review of Water Quality Standards

Dear Ms. Wellendorf:

Please accept Miami Waterkeeper's comment letter in response to the Florida Department of Environmental Protection's (FDEP's) solicitation for public comments pursuant to state water quality rulemaking during the current triennial review period.

States are required under the Federal Clean Water Act (40 CFR 131.20) to conduct a comprehensive review of all water quality standards at least once every three years. As such, Florida has opened a public comment period for this triennial review where FDEP is undertaking rulemaking pursuant to water quality standards at Chapters 62-302, 62-303, and 62-4 of Florida Administrative Code. Pursuant to this rulemaking, Miami Waterkeeper submits the following comments:

Rules regarding state standards for turbidity limits are currently at 62-302.530, and therefore within one of the chapters proposed to be updated in this 2024 triennial review. Preceding the 2024 triennial review, FDEP had already published draft changes to update turbidity limits: In October 2020, the FDEP published draft standards (*DRAFT Implementation of the Turbidity Criterion for the Protection of Coral Reef and Hardbottom Communities*, **Attachment 1**) that propose implementation criterion more protective to coral and hardbottom community than what is currently in Florida Administrative Code. The implementation criterion is intended to help ensure that human-induced turbidity is not a limiting factor in the recovery of Florida's coral reefs. They are also intended to help implement Executive Order 19-12 by helping ensure that Florida's valuable and vulnerable coastlines and natural resources are protected. Despite the FDEP circulating the draft in the public domain, the agency did not conclude this effort. Therefore, the 2024 triennial review period presents an opportune time to finish coral and hardbottom turbidity criterion.

The current triennial review does not propose an update to the turbidity standard, leaving the existing 29 NTU criterion unchanged. This decision is particularly troubling given that the Florida Department of Environmental Protection (FDEP) had already identified in the 2019 "*DRAFT Revised Turbidity Criterion to Protect Florida Coral Resources*" (**Attachment 2**) that the current 29 NTU criterion above natural background levels is not sufficiently protective of sensitive coral and hardbottom species in South Florida. The 2019 draft acknowledged that while data is limited, the existing standard fails to adequately safeguard these vital ecosystems. It emphasized the need for further research and the exploration of alternative options to develop a more effective criterion for protecting Florida's coral reefs and hardbottom communities.

Miami Waterkeeper is therefore deeply concerned about the ongoing delay in revising Florida's turbidity standard, especially in the context of ongoing reef decline of the Florida Reef Tract and large-scale dredging projects such as the past PortMiami expansion and the upcoming Port Everglades and PortMiami expansion dredging proposals. We urge immediate action in updating this standard to address this critical issue and safeguard these vital resources.

Exposure to excess suspended sediments and sedimentation as a result of dredging can exert physical, chemical, and/or biological stressors on corals, imposing adverse effects to overall coral health and recruitment. These include increased energy expenditure in the form of mucus production and sediment clearance from the colony surface (May et al., 2023); reductions in ambient light for photosynthesis (Abdel-Salam and Porter, 1988); polyp retraction and impaired feeding due to sediment cover (Erftemeijer et al., 2012; Jones et al., 2016); reduced gas exchange (Jones et al., 2016); and in extreme cases, physical smothering and burial of coral colonies by sedimentation, resulting in mortality (Cunning et al., 2019). Dredging activities introduce fine sediments in tandem with chemical pollutants and pathogens, and as a result, can exacerbate coral diseases such as Stony Coral Tissue Loss Disease (SCTLD) (Studivan et al., 2022), which has caused widespread damage to Florida's reefs. Sublethal effects as a result of these stressors (e.g., bleaching; tissue damage; reductions in growth, photosynthetic efficiency, and calcification; etc.) (Erftemeijer et al., 2012) could potentially lead to mortality if confounding factors do not enable coral recovery. These anthropogenic sediments may also impede the survival and settlement of coral larvae, thereby inhibiting coral recruitment (Serrano et al., 2024). Recruitment success is essential for maintaining existing populations of corals and for the recovery of threatened or endangered species.

A 2023 federal report by the National Oceanic and Atmospheric Administration (NOAA) reveals that the PortMiami dredging alone resulted in over 278 acres of reef damage and at least 560,000 corals – likely millions – being buried or significantly damaged (NOAA's National Marine Fisheries Service, 2023; Cunning et al., 2019). As NOAA documented in 2016, fine sediment cover of up to 0.5 centimeters on hardbottom communities rendered areas surrounding the PortMiami Entrance Channel as unsuitable for coral recruitment. This underscores the urgent need for stronger turbidity protections to prevent further degradation of these critical marine ecosystems, as all of this damage occurred with only a handful of turbidity events exceeding the standard of 29 NTU above background.

Now, another major expansion dredging project is being proposed in Broward County, which also crosses the Florida Reef Tract and proposes enormous impacts. For example, the Army Corps of Engineers predicts 150,300 cubic yards of fine-grained sediment will be agitated during the proposed Port Everglades expansion, leading to indirect impacts on hardbottom ranging from 124 to nearly 178 acres–in addition to 26.34 acres of direct impact.[1] (Calculations are subject to change, and may increase, in the next Port Everglades expansion dredging Environmental Impact Statement to address uncertainty in modeling.) A large portion of the coral impacts are predicted to result from suspended sediments causing turbidity and eventually smothering corals at the benthos. Without an updated turbidity standard, Florida's coral reefs and hardbottom communities remain at substantial risk of further damage. An updated standard in this triennial review will be crucial for protecting corals and marine resources during this and future dredging projects.

Building on previous efforts, the FDEP's October 2020 "*DRAFT Implementation of the Turbidity Criterion for the Protection of Coral Reef and Hardbottom Communities*" represents a significant advancement in coral reef protection by proposing a narrative criterion to maintain turbidity within natural background conditions. It details methodologies for establishing baseline data and permit limits. Despite the progress made in this draft, it was never finalized, leaving the need for a revised turbidity criterion unresolved. Miami Waterkeeper provided feedback on this draft in May 2021 but has yet to receive a response or see any revisions to the draft.

Additionally, studies investigating the presence of per- and polyfluoroalkyl substances (PFAS) in Florida surface waters are occurring around the state (Holden et al., 2024; Camacho et al., 2024). In 2022, the U.S. Environmental Protection Agency (EPA) proposed Ambient Water Quality Criteria for two PFAS substances imposing acute and chronic aquatic toxicity on freshwater organisms. These Florida studies contain statewide data that could help FDEP establish state-level PFAS surface water quality standards if the EPA criteria is not adequate in addressing Florida's unique challenges. We urge FDEP to consider these and any future studies assessing PFAS in Florida surface waters in the development of a sufficient water quality standard pursuant to Chapter 62-302 of Florida Administrative Code.

In light of these issues, Miami Waterkeeper strongly urges the Florida Department of Environmental Protection to take immediate action. Specifically, we recommend the following: (1) Expedite the revision of the turbidity standard to reflect current scientific understanding and better protect coral reefs and hardbottom communities, with a clear deadline for finalization. (2) Promptly finalize the 2020 draft "*DRAFT Implementation of the Turbidity Criterion for the Protection of Coral Reef and Hardbottom Communities*" and integrate it into regulatory frameworks. (3) Incorporate feedback from Miami Waterkeeper and other stakeholders to ensure a robust and effective standard. (4) In finalizing the 2020 draft, we urge FDEP to collate any additional data published since the creation of the 2019 draft for the *Revised Turbidity Criterion to Protect Florida Coral*

[1] 2022 Revised Draft Supplemental Environmental Impact Statement (RDSEIS) for Port Everglades reports direct impacts to hardbottom and coral reef communities at 26.35 acres, with indirect effects ranging from 124 to nearly 178 acres (U.S. Army Corps of Engineers, February 4, 2022). Spillage analysis under Appendix I to the RDSEIS (Scenario 2) predicts an estimated total of 150,300 cy of fine-grained sediment throughout Port Everglades, as acknowledged under the proposed action in the 2024 Revised Supplemental Biological Assessment: Port Everglades, Florida Project.

Resources, that will further inform the revision of the current numeric criterion to a new protective standard. In the absence of robust dose-response data for Florida resident species, we urge FDEP to establish partnerships with researchers at Florida universities to inform a revised numeric criterion. Notably, future research should account for *Acropora spp.* and other corals protected under the Endangered Species Act to ensure the adoption of an adequately conservative criterion. (5) Should the FDEP find EPA's PFAS criteria insufficient for Florida's waters, consider studies assessing PFAS concentrations in Florida surface waters in the development of a sufficient state-level water quality standard for fresh and saltwater systems.

Further delay will only exacerbate the already severe threats to Florida's coral reefs and hardbottom communities, leading to potentially irreversible damage. The urgency of this matter cannot be overstated; we must act now to safeguard these vital ecosystems from further degradation. Thank you again for the opportunity to comment on this triennial review.

Sincerely

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Attachments:

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2. Florida Department of Environmental Protection. (July 2019). DRAFT Revised Turbidity Criterion to Protect Florida Coral Resources.

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DRAFT Implementation of the Turbidity Criterion for the Protection of Coral Reef and Hardbottom Communities

Division of Environmental Assessment and Restoration

Florida Department of Environmental Protection

October 2020

Contents

Section 1. Introduction

1.1 Purpose of Document

This document describes how the turbidity criterion for areas supporting coral reef and hardbottom communities will be implemented in Department permits. The criterion does not allow increases in turbidity above background levels but takes into account the variability in background levels. Key topics addressed in this document include how baseline (pre-project) levels will be established for permitted activities, how variability of baseline levels will be quantified, and how the variability will be used to assess compliance with the criterion.

1.2 Background Information

Florida is the only state in the continental United States with extensive shallow coral reef formations near its coasts. Coral reefs create specialized habitats that provide shelter, food, and breeding sites for numerous plants and animals. This includes species important to fishing like spiny lobster, snapper, and grouper. Coral reefs lay the foundation of a dynamic ecosystem with tremendous biodiversity. Most of Florida's corals occur in Florida's Coral Reef (FCR), which stretches approximately 360 linear miles from Dry Tortugas National Park west of the Florida Keys to the St. Lucie Inlet in Martin County (Figure 1). Roughly two-thirds of FCR lies within Biscayne National Park and the Florida Keys National Marine Sanctuary, a marine protected area that surrounds the Florida Keys island chain. The northern third of FCR (Miami-Dade to Martin County) was recently designated as the Southeast Florida Coral Reef Ecosystem Conservation Area (Coral ECA). Additionally, the state has extensive hardbottom habitats along its southeastern and southwestern coasts (Figure 2). Protection of these marine resources is critically important for preserving the State's marine biodiversity, protection of endangered or threatened species, and protection of fisheries, tourism, and coastal resiliency, including protection against the effects of sea level rise.

The implementation procedures presented in this document are intended to provide necessary protections to these critically important marine communities and help ensure that man-induced turbidity is not a limiting factor in the recovery of Florida's coral reefs. It is intended to help implement Executive Order 19-12 (Achieving More Now for Florida's Environment) by helping to ensure that Florida's valuable and vulnerable coastlines and natural resources are protected.

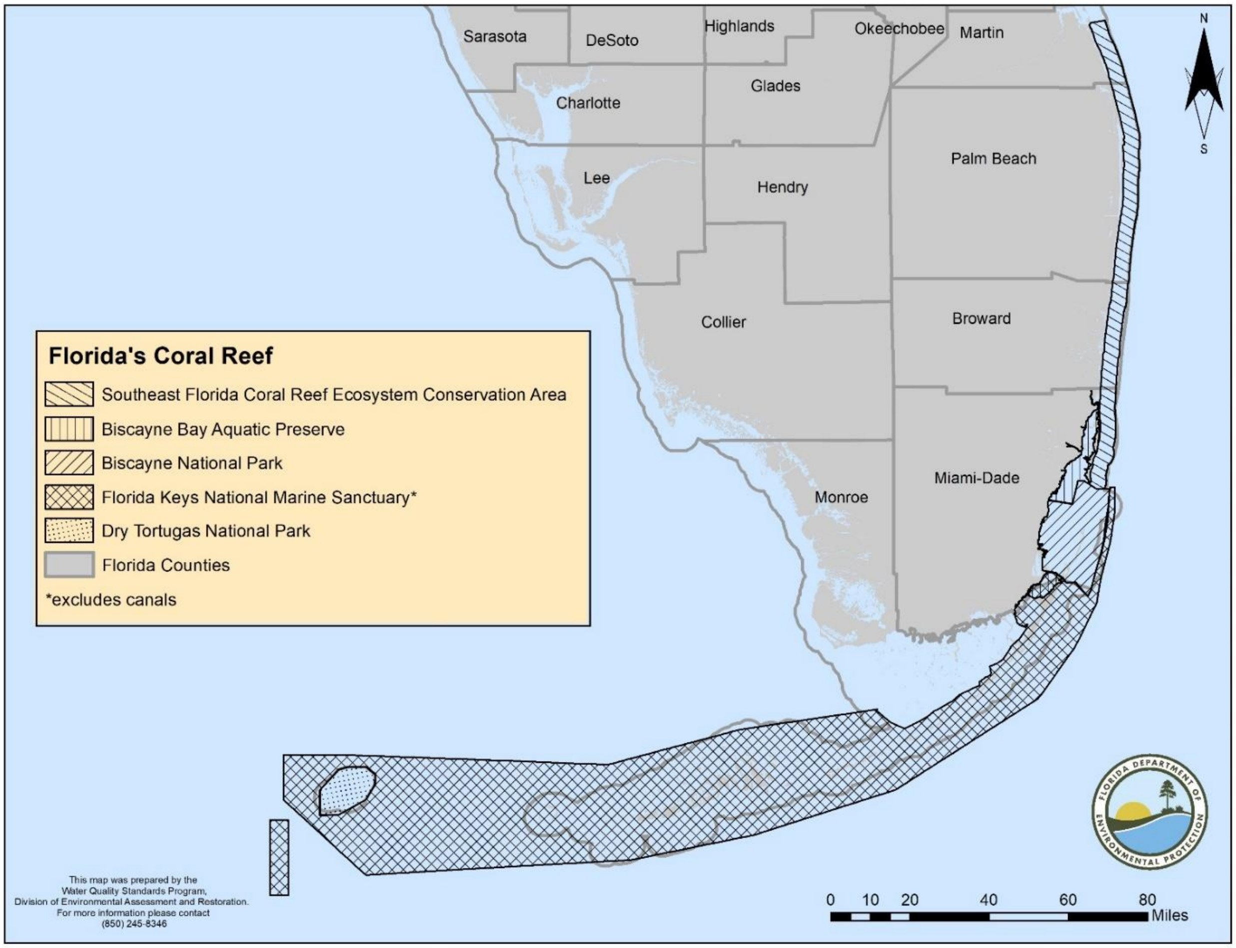

Figure 1. The location of Florida's Coral Reefs.

1.3 Proposed Criterion and Rule Language

As part of the Department's efforts to derive a turbidity water quality criterion that was specifically designed to be protective of coral reefs and hardbottom communities, Department staff conducted an extensive literature review of scientific studies addressing the effects of turbidity on coral reefs. During that literature review, the Department identified many different relevant studies and summarized the findings in a Technical Support Document (TSD) for *Turbidity Criterion to Protect Florida Coral and Hardbottom Communities*. While the data indicate that the current turbidity criterion (29 NTU above natural background) is not protective of corals and hardbottom communities, there are insufficient data to establish the magnitude of a specific numeric criterion that would be protective of all coral species.

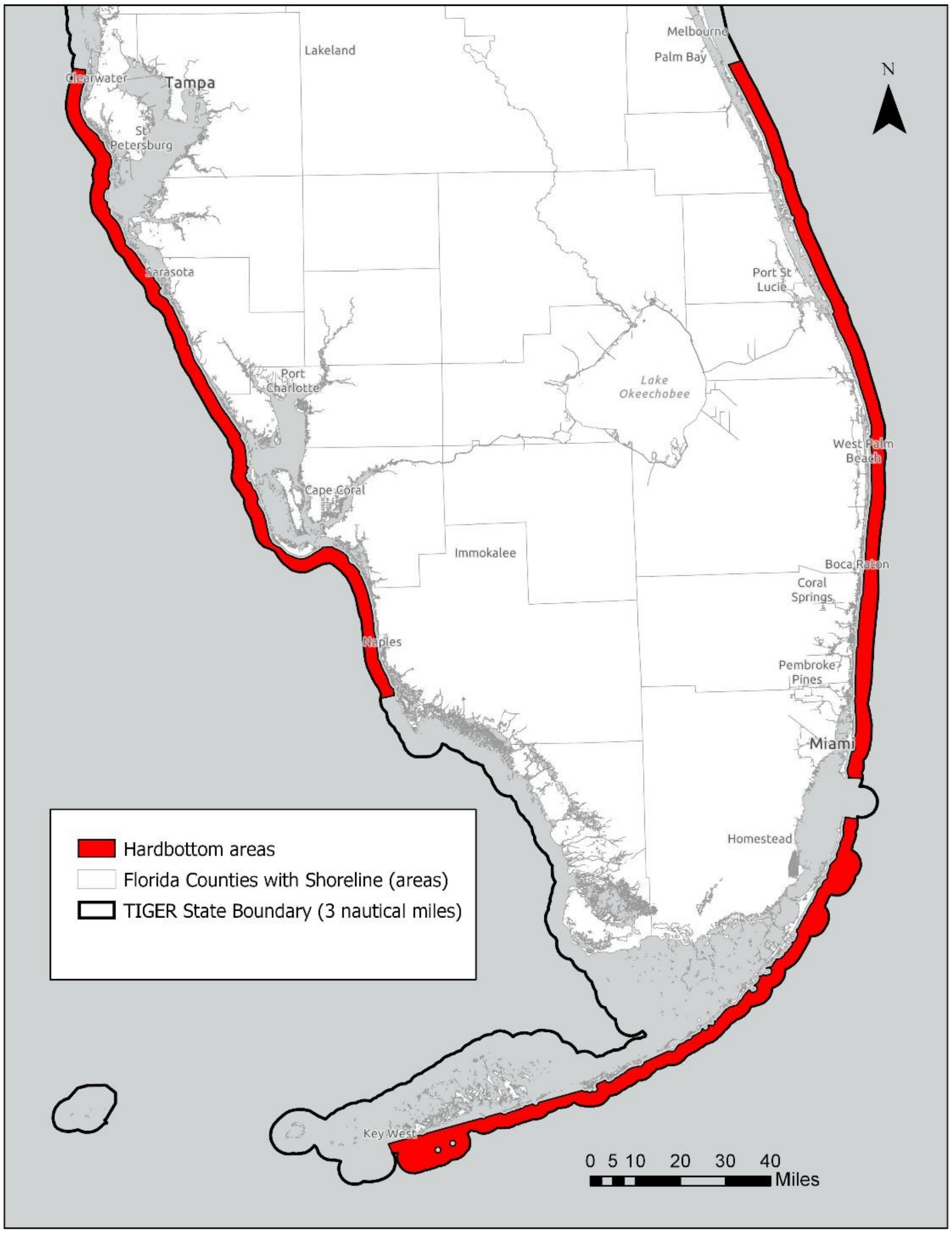

Figure 2: Distribution of Hardbottom areas within Florida's state waters.

However, the literature indicates that a) an appropriate magnitude of the criterion would likely fall between 3 and 7 NTU, depending on the species of coral, and b) the criterion would need to account for the natural variability in turbidity levels, which would need to be addressed in the duration and frequency component of the criterion. Given that the potential range of the magnitude of the criteria is generally similar to the range of the variability of natural background turbidity levels, the Department concluded that the best approach to establishing a turbidity criterion that is protective of corals is to adopt a criteria expressed and implemented in terms of maintaining turbidity levels within the range of background variability.

Paragraph 62-302.530(70)(b), Florida Administrative Code (F.A.C.), states:

b. Turbidity shall not be increased above background conditions within areas of the state where coral reef or hardbottom communities are currently found or have been demonstrated to have occurred since November 28, 1975. To evaluate this criterion, background conditions shall take into account the natural variability of turbidity levels and shall be established following the methods described in the document *Implementation of the Turbidity Criterion for the Protection of Coral Reef and Hardbottom Communities*, dated October 2020, which is incorporated by reference.

For the purposes of this criterion, "Coral Reef" shall mean a limestone structure composed wholly or partially of the living or dead skeletal remains of marine invertebrates in the Class Anthozoa and the Orders Scleractinia (stony corals), Stolonifera (organ-pipe corals), Antipatharia (black corals), and Hydrozoa (hydrocoral). "Hardbottom Coral Community" shall be defined as a consolidated hard structure with a living veneer of organisms characterized by the presence of corals, octocorals, and associated reef organisms. This definition of hardbottom does not include "worm reefs created by the *Phragmatopoma* species," which is included in the definition of "hard-bottom" in 403.93345 of Florida Statues for Coral Reef Protection. However, worm reefs are not included in the definition applicable to the turbidity criterion because worm reefs typically occur in environments with highly dynamic natural turbidity conditions (FDEP, 2020).

The majority of coral reef and hardbottom communities are expected to occur within FCR. It contains waters currently or historically known to support extensive coral reefs and hardbottom coral communities. The historical presence of coral is of critical importance because corals have the potential to re-colonize areas where they have experienced significant losses due to bleaching events and disease. In addition, due to climate change, it is expected that corals will migrate as waters closer to the equator become too hot. Therefore, protecting areas where ever they occur , including outside of FCR, is also important. The turbidity criterion is intended to ensure that turbidity is not a limiting factor to their survival, recruitment, growth, or recovery, regardless of whether these species currently occur within an area.

1.4 Threatened and Endangered Species Considerations

The criterion is also designed to protect threatened and endangered species of corals. The National Oceanographic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) currently lists *Acropora cervicornis* (staghorn coral), *Acropora palmata* (elkhorn coral), *Mycetophyllia ferox* (rough cactus coral), *Dendrogyra cylindrus* (pillar coral), *Orbicella annularis* (lobed star coral), *Orbicella faveolata* (mountainous star coral), and *Orbicella franksi* (boulder star coral) as threatened under the Endangered Species Act. All seven of these species occur within the waters of FCR. The NMFS has also designated most of FCR as critical habitat for staghorn coral and elkhorn coral. Given the presence of both critical habitat and threatened sensitive species, additional proactive protections are warranted.

1.5 Outstanding Florida Waters (OFW) Considerations

Large portions of the areas with coral reefs and/or hardbottom communities are designated as Outstanding Florida Waters (OFW). As of May 2019, there are 32 separate designated OFWs within FCR, including Florida Keys, Biscayne National Park, Great White Heron National Wildlife Refuge, John Pennekamp Coral Reef State Park, Biscayne Bay Aquatic Preserves, Key Largo National Marine Sanctuary, and St. Lucie Inlet Preserve State Park (see Rule 62-30.700, F.A.C.). Projects regulated by the Department or a Water Management District that are proposed within an OFW may not lower (degrade) existing water quality, which is defined as the water quality at the time of OFW designation or the year prior to the permit, whichever is better (see paragraph 62-4.242(2)(c), F.A.C.). For activities that increase turbidity, the OFW requirements have generally been interpreted to not allow any increase above natural background (defined below) levels. However, Department rules allow for temporary increases in turbidity in OFWs within a mixing zone for certain permitted activities provided that turbidity at the edge of the approved mixing zone does not exceed natural background levels by more than the range observed through a normal tidal cycle, as described in paragraph 62-4.242(2)(b), F.A.C., which states:

> *(b) The Department recognizes that it may be necessary to permit limited activities or discharges in Outstanding Florida Waters to allow for or enhance public use or to maintain facilities that existed prior to the effective date of the Outstanding Florida Water designation, or facilities permitted after adoption of the Outstanding Florida Water designation. However, such activities or discharges will only be permitted if:*

1. The discharge or activity is in compliance with the provisions specified in subparagraph (2)(a)2.[1]*, of this rule, or*

2. For dredging beach-quality sand from inlets and related channels, or restoration/nourishment of beaches and the use of offshore borrow areas, the applicant demonstrates that:

a. Turbidity has been minimized for both magnitude and duration to the maximum extent practicable,

b. Turbidity at the edge of the approved mixing zone does not exceed natural background levels by more than the range in natural background turbidity levels measured throughout a normal tidal cycle for the applicable sand dredging or beach restoration/nourishment site; and in no case shall it exceed 29 NTUs above natural background; and,

c. Turbidity levels, both inside and outside of the mixing zone, are not expected to have an adverse impact on marine resources, recreational value or public safety, or

3. Management practices and suitable technology approved by the Department are implemented for all stationary installations including those created for drainage, flood control, or by dredging or filling; and there is no alternative to the proposed activity, including the alternative of not undertaking any change, except at an unreasonably higher cost.

The application of the turbidity criterion for coral reef and hardbottom communities (paragraph 62-302.530(70)(b), F.A.C.) is similar to the implementation of antidegradation standards for turbidity within designated OFWs. Implementation of both standards requires characterization of background turbidity conditions and only allows deviation from that level within the range of background variability. However, this document establishes more extensive data requirements for establishing background turbidity conditions, including sampling over more background tidal cycles, and provides a different statistical approach for determining attainment of the criterion.

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[1]Subparagraph 2(a)2., F.A.C., states:

2. The proposed activity of discharge is clearly in the public interest, and either:

a. A Department permit for the activity has been issued or an application for such permit was complete on the effective date of the Outstanding Florida Water designation, or

b. The existing ambient water quality within Outstanding Florida Waters will not be lowered as a result of the proposed activity or discharge, except on a temporary basis during construction for a period not to exceed thirty days; lowered water quality would occur only within a restricted mixing zone approved by the Department; and, water quality criteria would not be violated outside the restricted mixing zone. The Department may allow an extension of the thirty-day time limit on a construction-caused degradation for a period demonstrated by the applicant to be unavoidable and where suitable management practices and technology approved by the Department are employed to minimize any degradation of water quality.

Rule 62-302.200, F.A.C., defines the terms “background” and “natural background” differently. Background (subsection 62-302.200(3), F.A.C.) is defined as *the condition of waters in the absence of the activity or discharge under consideration, based on the best scientific information available to the Department*, while natural background (subsection 62-302.200(21), F.A.C.) is defined as *the condition of waters in the absence of man-induced alterations based on the best scientific information available to the Department. The establishment of natural background for an altered waterbody may be based upon a similar unaltered waterbody, historical pre-alteration data, paleolimnological examination of sediment cores, or examination of geology and soils* (note that additional language related to background in lakes is not shown). Although there is a difference between natural background and background conditions, in practice both the current turbidity criterion [*i.e*., 29 NTU (Nephelometric Turbidity Unit) above natural background] and antidegradation requirements in paragraph 62-4.242(2)(b), F.A.C., are typically assessed using the best available background conditions because data that can be used to characterize true natural conditions are seldom available, especially for turbidity. For instance, offshore south Florida was historically known for “gin clear water.” While offshore coral reef specific water quality monitoring in the Florida Keys goes back approximately 25 years and less than 5 years in the Coral ECA, only recently has turbidity been included in either program.

For implementation of this turbidity criterion, the Department will use the term “baseline,” which is based on pre-project turbidity data, to acknowledge the difference between baseline and true natural background conditions. Baseline conditions represent minimally or least disturbed background conditions that serve as the best available site-specific estimate of turbidity levels under natural background conditions. The variability in site-specific turbidity levels under baseline conditions, which is key to implementing the criterion, is expected to be an even more accurate estimate of the variability under natural background conditions. However, if there are sufficient historical data for a given site to establish that natural background conditions previously exhibited lower variability than current data, that historical data should be used to establish baseline conditions.

1.6 Natural Factors Influencing Background Turbidity Levels

Turbidity in coastal waters can be generated and influenced by natural events such as wind patterns, wave height and frequency, water currents, and land runoff. Sediments can be naturally resuspended in a system when exposed to wind-driven waves. The amount of sediment that is picked up varies based on the strength and duration of the wind creating the waves. Storms can also influence the amount of suspended sediment within the water column. As storms pass through an area, they block the normal wind patterns of an area and may result in alternating periods of low winds with small waves followed by large waves, which creates a highly variable amount of turbidity in different locations (Storlazzi and Jaffe 2008). The duration and severity of the storm are integral factors in the amount of suspended sediment introduced into the water column.

Tidal cycles can be another strong influencer of natural turbidity. Experiments performed in estuaries showed that turbidity was highest at or near low tide when the more turbid, lower salinity water from the upper estuary extended seaward (Ward 2004). The magnitude of the tidal range also impacts the amount of sediments suspended in the water column. Larger spring tides can cause higher amounts of sediment to be picked up during the low tide, subsequently making the water more turbid when the tide rises (Ward 2004). Tidal Stage can be very important near inlets as well.

Section 2. Implementation in Permitting

2.1 Permitting Information

The turbidity criterion for corals (paragraph 62-302.530(70)(b), F.A.C.) will affect dredging, beach nourishment, and other projects that may generate turbidity in coastal waters where coral and/or hardbottom communities are present. Documentation supporting the presence or absence of corals or hardbottom shall be based on current site-specific evaluation of the habitat, substrate, and epifaunal species present, which is required as part of the permit application process. The evaluation must be based on benthic surveys within the area affected by the project or construction area. If corals and hardbottom are present, the turbidity criterion could affect the boundaries (size) of allowable turbidity mixing zones, limits applied to permits, and associated water quality monitoring requirements for Joint Coastal Permits (JCP) and Environmental Resource Permits (ERP) in these areas whenever there is an expectation that the project will generate turbidity above the existing background.

Neither the criterion in paragraph 62-302.530(70)(b), F.A.C., nor this Implementation Document alter the opportunities or requirements for permittees to obtain mixing zones available under Rule 62-4.244, F.A.C., or variances. This document only affects how background is defined and determined. Compliance is still intended to be determined at the edge of an authorized mixing zone. However, turbidity levels, both inside and outside of the mixing zone, must not have an adverse or acute impact on marine resources, recreational value or public safety.

Activities that require a JCP include beach restoration or nourishment; construction of erosion control structures, such as groins and breakwaters; construction of public fishing piers; maintenance of inlets and inlet-related structures; and dredging of navigation channels that include disposal of dredged material onto the beach or in the nearshore area. Beach restoration and nourishment have been the main methods of managing beach erosion and maintaining beach habitat. Key rules and statutes that govern JCPs include: Chapter 161 Florida Statutes (F.S.), Chapter 62B-41, F.A.C., Chapter 62B-49, F.A.C., Chapter

18-20, F.A.C., Chapter 18-21, F.A.C., Chapter 62-4, F.A.C., Chapter 62-302, F.A.C., Chapter 62-330, F.A.C., Chapter 253, F.S., Chapter 258, F.S., part IV Chapter 373, F.S., and Chapter 403, F.S.

The ERP Program regulates activities in, on or over surface waters or wetlands, as well as any activity involving the alteration of surface water flows. The Program regulates almost any change to the landscape, including all tidal and freshwater wetlands and other surface waters (including isolated wetlands) and uplands. The ERP program deals with dredging and filling in wetlands and other surface waters (including ports and navigational channels), as well as stormwater runoff quality and quantity. The ERP Program is implemented jointly by the Department and four of the WMDs (all except the Northwest WMD). This program ensures that water quality is not degraded, and that wetlands and other surface waters continue to provide a productive habitat for fish and wildlife. Key rules and statutes that govern ERPs include Chapter 18-20, F.A.C., Chapter 18-21, F.A.C., Chapter 62-4, F.A.C., Chapter 62-302, F.A.C., Chapter 62-330, F.A.C., Chapter 253, F.S., Chapter 258, F.S., part IV Chapter 373, F.S., and Chapter 403, F.S.

2.2 Establishing Baseline (Pre-project) Levels

Permit applicants have the ultimate responsibility to provide the information needed to establish the baseline turbidity, including the natural variability in baseline turbidity levels, for the area where the permitted activity will take place. However, permittees have the options of a) using the interquartile range of values of existing available turbidity data for the area where the project is located (see Table A-1 in the appendix), b) using the interquartile range of baseline/background data from previously permitted projects in the area (see Section 2.4), or c) establishing natural baseline variability based on pre-project turbidity data collected specifically for the project at “baseline” stations. While this approach provides flexibility on how to establish baseline turbidity, applicants should be aware that the resultant permit limits will be more conservative if an applicant relies on existing turbidity data to establish baseline turbidity variability because a) the available historical data may not incorporate the full range of site-specific variability in turbidity levels as they are dominated by open water sites that generally have low turbidity levels, and b) the statistical methods used to establish baseline variability were specifically selected to be more conservative when relying on historical data.

Regardless of the option selected, pre-project baseline turbidity variability must be established for each project sub-area (*e.g.*, offshore borrow areas, nearshore placement stations, nearshore dredging areas, offshore dredging areas). Permit applicants have the option of choosing different methods to establish the baseline variability for different sites. All turbidity data and calculations (described below) provided by applicants will be reviewed by the Department and used to develop permit-required turbidity limits for use throughout the duration of the project. Compliance with these permit-required turbidity limits will constitute attainment of the turbidity criterion.

Also regardless of the option selected, turbidity data used to establish background variability must be taken using a hand-held Nephelometric Turbidity Meter in accordance with standard protocols (*i.e.*, DEP-SOP-001/01 FT 1600 Field Measurements of Turbidity) or data sonde meeting all applicable QA/QC requirements under Chapter 62-160, F.A.C. If the applicant uses data from a continuous monitoring sampling unit (sonde), the applicant must also meet the minimum calibration and quantitative or chronological bracketing requirements for continuous samples in the department document Continuous Monitoring SOP for Environmental Field Deployments.

2.3 Measuring Baseline (Pre-project) Levels

To qualify for the statistical methods for deriving the pre-project baseline turbidity variability using site-specific data as described in Section 2.2, the sampling must meet all of the requirements of this section.

1) If any living coral or hardbottom communities are within the area where the project has a reasonable potential to increase turbidity levels above the criterion, at least one of the pre-project baseline stations must be located above the living coral or hardbottom community. If coral or hardbottom communities are present at distinctly different areas within the overall project area, multiple baseline stations may be needed to address the different background conditions.

2) Projects expected to last longer than three months must provide data for the seasons in which the permitting activity is projected to occur and may have season-specific turbidity limits. Applicants are encouraged to have a pre-application meeting so that DEP permitting staff can provide site-specific guidance on the appropriate siting of pre-project baseline stations and seasonal requirements (if any).

3) The minimum duration over which background turbidity variation must be assessed to qualify for the measured turbidity option is four tidal cycles at each pre-project baseline station. The tidal cycles do not have to be consecutive; however, care must be taken to ensure that background turbidity data are collected at the same location for each tidal cycle. GPS coordinates must be provided to verify the baseline station location, and the location of each baseline station shall not differ by more than 10 meters between tidal cycle events.

4) Turbidity measurements must be collected at the surface (0.5 – 1 meter below surface) and bottom (0.5 – 1 meter off bottom) at a minimum of one representative baseline station for each project area. Total depths must also be recorded for checks in consistency and total depth must be recorded for each sample. For example, borrow areas and beach placement areas must each have representative baseline stations. In some cases, there may be more than one borrow area or placement area, and each of these areas must have at least one baseline station. Turbidity samples must be collected at a frequency of no greater than 4 hours apart throughout each tidal cycle, and applicants must report turbidity at the peak of each tidal stage. Pre-project turbidity samples may be collected more frequently (e.g., hourly) at the applicant's discretion to help ensure a more accurate and complete representation of the range of background variability. The measurement of turbidity may be started at any point in the tidal cycle and must end at the same point in the next cycle, such as from high to low to high, or from low to high to low.

5) The applicant must provide the Department with reasonable assurance that the collected turbidity data are representative of the natural variation in turbidity over a typical tidal cycle. This demonstration must include 1) tidal data (*i.e.,* tide charts, observed water levels) and other meteorological data (*i.e.*, current direction, wave height, wind speed and direction, precipitation) for the period over which baseline samples were collected; and, 2) longer-term tide and weather data for the project area. "Typical" shall mean that the height of the low and high tide are within the range of the 5^{th} and 95^{th} percentiles, respectively, of the historic data.

6) Because the pre-project data set requirements are relatively small in terms of sample size, the results are prone to undue influence from statistical outliers. Therefore, the turbidity results must be screened for outliers and any outliers shall be flagged for potential removal from the dataset before the calculation of background variability and calculation of permit-required turbidity limits. These outliers may be retained if the Department agrees that the values are representative of background conditions. For purposes of this analysis, an outlier shall mean any turbidity value that is greater than the mean of the data set plus three times the standard deviation, and the outlier analysis shall be conducted for each station and depth independently.

2.4 Calculation of Baseline Variability

The turbidity criterion in paragraph 62-302.530(70)(b), F.A.C., is intended to protect coral and hardbottom communities from deleterious effects associated with elevated turbidity levels. It is assumed that any sessile benthic organisms present within an area are adapted to the background turbidity in that area, including natural variability in background levels. However, increases in the magnitude, duration or frequency (*i.e.*, increased variability) of turbidity above background conditions have deleterious effects on the resident coral and hardbottom. Thus, the turbidity criterion is designed to maintain the pre-project background turbidity magnitude, frequency, and duration. Permits for dredging or other activities that may increase turbidity in waters subject to paragraph 62-302.530(70)(b), F.A.C., will be subject to permit-required turbidity limits based on pre-project variability. These permit-required turbidity limits will be established based on the observed turbidity range at the representative pre-project baseline station(s) and will be expressed as the allowable increase in turbidity between the project background and compliance stations.

If turbidity data from previously permitted projects are used to calculate the baseline variability, the applicant has the option of calculating the allowable increase in turbidity over background levels by a) calculating the interquartile range of all available baseline and background data from the project(s) or, b) if sufficient data are available to meet the tidal cycle requirement of Section 2.3, calculating the upper 90% confidence interval of the range over the tidal cycles, as described below.

When using data collected at project-specific baseline station(s), the allowable increase in turbidity over pre-project background levels and associated permit-required turbidity limit shall be calculated as an upper confidence interval of the mean difference between minimum and maximum turbidity over a typical tidal cycle. The allowable increase in turbidity shall be calculated using an upper 95% confidence based on a minimum of 4 pre-project tidal cycles and shall be calculated using the follow equation:

Allowable increase over Background Station = Upper 95% confidence interval $=\bar{X} + 1.96 \times \frac{S}{\sqrt{n}}$, where

(Equation 2)

$\bar{X}$= *Mean of differences between minimum and maximum turbidity over each baseline tidal cycle*
S = Standard deviation of the differences between minimum and maximum turbidity over all baseline tidal cycles
n = the number of baseline tidal cycles

Allowable increase over Background Station = Upper 95% confidence interval $=\exp\left(\bar{y} + 1.96 \times \frac{S_y}{\sqrt{n}}\right)$, where (Equation 2)

$\bar{y}$= *Mean of logarithms of differences between minimum and maximum turbidity over each baseline tidal cycle*

Sy = Standard deviation of the logartihms of the differences between minimum and maximum turbidity over all baseline tidal cycles
n = the number of baseline tidal cycles

The applicant must report and use all collected pre-project baseline turbidity data collected during l tidal cycles that passed applicable quality assurance requirements of Chapter 62-160, F.A.C., in the calculation of the confidence interval and cannot pick a sub-set of the pre-project baseline tidal cycles that provides the highest possible confidence interval. The calculated upper confidence intervals shall be applied in the determination of permit-required turbidity limits, as described in Section 2.5.

2.5 Assessment of Turbidity Levels During Construction Operations

To assess compliance with the turbidity criterion during construction, permittees must sample turbidity at both representative background and compliance stations. The background data collected during construction should be collected at station(s) located in an area clearly outside of the influence of any construction activities and may not necessarily be at the same location(s) as the pre-project baseline station(s). The locations of these compliance and background stations will generally not be fixed, but rather will change between monitoring events in response to changes in the plume direction as the work area (portion of the project area that is being dredged or filled) shifts or in response to changing tidal conditions over the course of the construction. Individual permits will specify the number of required stations, sampling frequency (minimum of 3 per day collected 4 hours apart), and specific conditions for siting compliance and background stations. However, there must be at least one background station and one compliance station at the edge of each authorized mixing zone, with turbidity samples collected at surface (0.5 to 1 m) and 0.5 to 1 m above the bottom at both locations unless the depth is less than 5 m, in which case only one mid-depth sample is needed. Individual permits will specify a minimum distance between the work zone and background station.

Typically, permittees are required to collect turbidity samples 3 times per day, 4 hours apart, during daylight hours only. The permittee shall report all turbidity data (*i.e.*, raw field sheets and processed data in an electronic database), and shall also report the following information:

a. Time of day samples were taken;
b. Dates of sampling and analysis;
c. GPS location of sample;
d. Depth of water body;
e. Depth of each sample;

f. Weather conditions, including wind direction and velocity;

g. Tidal stage and direction of flow;

h. Water temperature;

i. A map, overlaid on the most recent generally available aerial photograph, indicating the sampling locations, dredging and discharge locations, direction of flow, boundaries of natural resources (e.g., coral reefs, hardbottom, worm reefs, seagrass beds) and GPS coordinates for all vessels operating during the monitoring period.

j. A statement describing the methods used in collection, handling, storage and analysis of the samples; and

k. A statement by the individual responsible for implementation of the sampling program concerning the authenticity, precision, limits of detection, calibration of the meter, accuracy of the data and precision of the GPS measurements.

Each compliance sample shall be independently compared to the corresponding depth-specific background turbidity value, and any increase in turbidity at the compliance station above the background station must be equal to or less than the allowable increase in turbidity (*i.e.*, permit-required turbidity limit), as calculated using Equation 1 or 2. Dredging projects lasting longer than three months may have season-specific permit-required turbidity limits. The turbidity increase between the two stations shall be calculated as the measured compliance station turbidity minus the measured background station turbidity.

2.6 Example Application of the Permit Required Turbidity Limit

Table 1 provides an example calculation of the permit-required turbidity limit for a hypothetical dredging project. The hypothetical applicant collected turbidity measurements at a representative pre-project baseline station through five typical tidal cycles. No outliers were identified in the data set. The applicant tabulated the differences between maximum and minimum turbidity for each tidal cycle at both depths (*i.e.*, independently for samples collected at each the surface and bottom depth), calculated the mean and standard deviation of the difference independently for each depth, and then used Equation *2* to calculate the upper 95% confidence interval for each depth. The calculated upper 95 percent confidence intervals (*i.e.*, 2.1 and 2.6 NTU) will serve as maximum allowed increase between the background and compliance stations, and the permit shall specify permit limits for both surface (0.5 – 1 m) and bottom (0.5 - 1 m above bottom) depth samples.

Table 1. Pre-project baseline turbidity measurements collected to calculate the surface and bottom depth permit-required turbidity limits for a hypothetical dredging project within the Southeast Florida Coral

Reef Ecosystem Conservation Area. The baseline data were used to calculate upper 95% confidence intervals, which will serve as the applicable permit-required turbidity limits for the project.

Tidal Cycle	Surface Minimum Turbidity (NTU)	Surface Maximum Turbidity (NTU	Bottom Minimum Turbidity (NTU)	Bottom Maximum Turbidity (NTU)	Turbidity Difference Surface	Turbidity Difference Bottom
1	1.5	2.8	1.2	2.6	1.3	1.4
2	3.1	3.5	2.9	4.1	0.4	1.2
3	1.1	2.7	1.1	2.5	1.6	1.4
4	3.5	3.8	2.5	4.4	0.3	1.9
5	2.4	5.1	2.3	5.6	2.7	3.3
				Mean Difference	1.26	1.84
				Standard Deviation	0.981	0.856
				Sample size (n)	5	5
				Upper 95% C.I.	2.1	2.6

During construction, the permittee conducted the permit-required compliance and background station turbidity monitoring throughout the duration of the project. Turbidity measurements were collected at all monitoring stations three times per day at a frequency of every four hours at both surface and bottom depth at the background and compliance stations. **Table 2** provides an example background and compliance turbidity dataset collected over four days of the project. The pre-project baseline values calculated in **Table 1** (i.e., 2.1 and 2.6 NTU for the surface and bottom depth background measurement, respectively) were added to the turbidity values at the background (BG) sampling locations during construction to determine whether any of the samples taken at compliance stations during construction were out of compliance with the permit-required turbidity limits. In this example, one of the surface or bottom depth compliance measurements exceeded the applicable turbidity limits (see yellow highlighting).

Table 2. Hypothetical dredging project turbidity compliance data reported in NTU (Nephelometric Turbidity Unit). Turbidity measurements were collected at background and compliance stations at surface and bottom depth. Allowable increases in turbidity of 2.1 and 2.6 were added to the surface (BG_s) and

bottom depth (BG_b) background turbidity values, respectively, for each time and depth used to evaluate compliance with the permit-required turbidity limits.

Date	Time (HH:MM)	Surface Background Turbidity (NTU, BG_s)	Surface Turbidity Limit (NTU, BG_s + 2.1)	Surface Compliance Turbidity (NTU)	Bottom Background Turbidity (NTU, BG_b)	Bottom Turbidity Limit (NTU, BG_b + 2.6)	Bottom Compliance Turbidity (NTU)
5/27/2019	7:00	3.9	6.0	5.6	3.4	6.0	5.4
5/27/2019	11:00	3.2	5.3	4.1	3.3	5.9	4.9
5/27/2019	15:00	2.1	4.2	4.4	2.3	4.9	4.3
5/28/2019	7:00	3.7	5.8	5.5	4.0	6.6	6.0
5/28/2019	11:00	4.7	6.8	4.8	3.7	6.3	5.3
5/28/2019	15:00	2.5	4.6	4.2	2.5	5.1	4.5
5/29/2019	7:00	3.6	5.7	4.9	4.4	7.0	6.4
5/29/2019	11:00	2.9	5.0	5.0	2.1	4.7	4.7
5/29/2019	15:00	5.1	7.2	3.2	2.1	4.7	4.1
5/30/2019	7:00	4.7	6.8	4.1	5.0	7.6	7.3
5/30/2019	11:00	4.0	6.1	5.9	3.8	6.4	6.2
5/30/2019	15:00	3.9	6.0	5.7	4.1	6.7	6.7

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Appendix A

Purpose

This appendix provides summary statistics for baseline turbidity data that can be used to establish permit limits for dredging activities that have a reasonable potential to cause or contribute to violations of the coral turbidity criterion. It provides area-specific turbidity interquartile ranges for areas that have known coral or hard-bottom communities. Data were aggregated based on **w**ater**b**ody **id**entification (WBID) units used by the Department for impaired waters assessments. It should be emphasized that coral and hard-bottom communities do not occur throughout the entirety of these areas. Instead, they have been documented to have occurred somewhere within the area, and a permit applicant has the option of using these values to determine applicable permit limits for projects within these areas if they decide not to use site-specific data.

Data Processing

Data were obtained from the Department's IWR Run 57 database and DEP's Florida Reef Tract Nutrient Water Quality Assessment project for the Coral ECA[2]. Data were processed and analyzed in Excel and Systat 13. All turbidity data that passed quality assurance checks were included in the calculations, with the exception of data from stations within canals or within 200 meters of shore, which were excluded from the analysis to avoid biasing the results. Summary statistics (arithmetic mean. 10^{th}, 25^{th}, 75^{th} and 90^{th} percentiles, and the interquartile range) were calculated for each WBID with at least 20 turbidity measurements. In some cases, neighboring WBIDs were combined to attain the 20-measurements minimum. WBIDs 8077 and 8078 were split between waters within the Florida Keys National Marine Sanctuary (FKNMS) and outside the FKNMS (*i.e.*, Florida Bay portion of the WBIDs) to create homogenous (relative to turbidity) water segments. Sufficient turbidity data were available for most WBIDs in the area of interest with the exception of open ocean WBIDs along the Atlantic Coast north of Martin County.

Results

The mean, 10^{th}, 25^{th}, 75^{th}, 90^{th} percentile, and the interquartile range turbidity values for each WBID are summarized in Table A-1 and shown in Figure A-1. The table also provides the period or record used for each WBID. The periods of record are provided as a minimum date (earliest record) and maximum date (most recent record).

[2] The Florida Reef Tract Nutrient Water Quality Assessment is managed by the Office of Resilience and Coastal Protection. The data from this project were not loaded into WIN or the IWR database at the time of report preparation.

Table A-1. Summary of existing background turbidity (NTU) within WBIDs within FCR and open coastal WBIDs within Manatee, Sarasota, Charlotte, Lee, Collier, Monroe, Miami-Dade, Broward, Palm Beach, Martin, St. Lucie, Indian River, and Brevard (to Cape Canaveral) counties. The listed 90th percentile values shall be used for IWR assessments and listing decisions. The spatial extent of WBIDs was based on IWR Run 60.

WBID	Area	POR Start	POR End	Sample Size (N)[1]	Mean	10th Percentile	25th Percentile	75th Percentile	90th Percentile	Interquartile Range
8065	10,000 Islands	10/19/92	9/23/19	131	4.9	0.7	1.4	5.3	8.6	3.9
8066	10,000 Islands	7/31/96	3/12/20	267	5.8	2.4	3.3	6.2	8.0	2.9
8067	10,000 Islands	2/25/15	10/21/19	15	5.4	1.6	2.0	3.9	6.0	1.9
8068	10,000 Islands	2/25/15	10/21/19	19	4.1	1.6	2.1	4.9	7.7	2.8
8069	10,000 Islands	9/15/92	3/3/20	202	4.4	1.4	2.0	5.3	8.6	3.3
8070	10,000 Islands	3/9/15	10/21/19	20	7.5	2.6	3.2	9.1	16.0	5.9
8103	Atlantic Coast			ID						
8104	Atlantic Coast			ID						
8105	Atlantic Coast			ID						
8106	Atlantic Coast			ID						
8107	Atlantic Coast			ID						
8108	Atlantic Coast			ID						
8109	Atlantic Coast			ID						
8110	Atlantic Coast			ID						
8111	Atlantic Coast			ID						
6001	Biscayne Bay	5/6/70	1/9/20	9701	1.3	0.3	0.4	1.6	2.9	1.2
8088	Biscayne Bay	3/28/95	8/21/19	345	1.3	0.2	0.3	1.1	1.8	0.8
8089	Biscayne Bay	5/6/70	11/13/19	322	1.7	0.2	0.3	1.2	2.6	0.9
8090	Biscayne Bay	9/30/93	11/13/19	210	2.0	0.1	0.3	1.0	1.9	0.7
3226H	Biscayne Bay	8/14/74	1/9/20	4102	2.4	0.4	0.7	3.1	5.2	2.4
3226H1	Biscayne Bay	3/19/79	1/6/20	496	1.2	0.4	0.6	1.6	2.2	1.0
3226H2[2]	Biscayne Bay	3/19/79	3/4/20	2111	2.5	0.5	0.7	3.1	4.6	2.4
3226H3[2]	Biscayne Bay	3/19/79	3/4/20	2111	2.5	0.5	0.7	3.1	4.6	2.4
6001C	Card Sound	5/6/70	1/8/20	2174	0.9	0.3	0.4	1.1	1.8	0.7
8091[3]	Coral ECA	5/6/70	3/5/20	275	0.6	0.2	0.3	0.7	1.2	0.4
8092[3]	Coral ECA	5/6/70	3/5/20	275	0.6	0.2	0.3	0.7	1.2	0.4
8093	Coral ECA	9/25/17	3/12/20	422	0.6	0.2	0.3	0.7	1.3	0.4
8094	Coral ECA	8/8/00	3/12/20	307	0.5	0.2	0.3	0.6	1.0	0.3
8095	Coral ECA	9/27/17	3/12/20	217	0.4	0.2	0.3	0.5	0.7	0.2
8096	Coral ECA	8/4/00	3/11/20	1430	0.4	0.2	0.3	0.5	0.8	0.3

WBID	Area	POR Start	POR End	Sample Size (N)[1]	Mean	10th Percentile	25th Percentile	75th Percentile	90th Percentile	Interquartile Range
8097	Coral ECA	9/28/17	3/23/20	93	0.2	0.2	0.2	0.3	0.3	0.1
8098	Coral ECA	9/28/17	3/23/20	279	0.5	0.2	0.2	0.5	1.0	0.3
8099	Coral ECA	9/21/17	3/23/20	180	0.8	0.2	0.3	0.5	1.5	0.3
8100	Coral ECA	9/21/17	3/23/20	120	1.0	0.2	0.3	0.5	2.0	0.3
8101	Coral ECA	9/20/17	3/18/20	278	1.4	0.2	0.3	1.3	2.9	1.0
8102	Coral ECA	1/18/19	3/17/20	135	3.3	0.4	0.7	3.8	10.7	3.1
8072	Dry Tortugas	5/26/95	10/5/11	363	1.3	0.2	0.3	0.8	1.2	0.5
8071	Florida Bay	7/15/92	4/1/20	377	11.6	2.4	3.8	12.7	25.6	8.9
6009	Florida Keys			ID						
6010	Florida Keys			ID						
6016	Florida Keys			ID						
6017	Florida Keys			ID						
6018	Florida Keys	3/23/95	6/24/13	132	1.5	0.3	0.5	1.2	1.8	0.7
6019	Florida Keys			ID						
8073	Florida Keys	3/22/95	12/17/19	904	2.1	0.3	0.5	1.8	3.3	1.2
8074	Florida Keys	4/5/95	5/3/13	425	2.5	0.5	0.8	2.1	3.6	1.3
8075	Florida Keys	3/26/95	5/3/13	684	2.3	0.5	0.7	1.8	3.3	1.1
8076	Florida Keys	3/26/95	4/10/13	470	1.7	0.5	0.7	1.4	2.1	0.7
8079	Florida Keys	3/22/95	12/17/19	739	1.6	0.2	0.4	1.4	2.2	1.0
8080	Florida Keys	3/23/95	12/16/19	297	1.6	0.3	0.5	1.4	2.3	0.9
8081	Florida Keys	1/17/89	6/24/13	272	1.5	0.3	0.4	1.4	2.4	1.0
8082	Florida Keys	3/24/95	1/23/13	60	1.1	0.1	0.2	0.6	1.4	0.4
8083	Florida Keys	3/24/95	1/23/13	264	1.8	0.3	0.5	1.4	2.6	0.9
8084	Florida Keys	3/24/95	1/22/13	257	1.6	0.2	0.3	1.4	2.8	1.1
8085	Florida Keys	3/27/95	1/22/13	367	1.5	0.1	0.2	1.1	2.1	0.9
8086	Florida Keys	3/28/95	4/9/13	264	1.5	0.2	0.3	1.1	2.2	0.8
8087	Florida Keys	3/28/95	1/17/13	324	1.5	0.3	0.5	1.2	1.9	0.7
6005A	Florida Keys	12/5/85	4/6/20	308	4.6	1.2	1.8	5.8	9.9	4.0
6005B	Florida Keys	10/19/89	4/6/20	215	1.2	0.3	0.5	1.4	2.1	0.9
6006A	Florida Keys			ID						
6006B	Florida Keys			ID						
6011A	Florida Keys			ID						
6011B	Florida Keys			ID						
6011C	Florida Keys			ID						
6012A	Florida Keys	12/29/82	2/27/20	101	1.7	0.5	0.7	1.8	2.4	1.1

WBID	Area	POR Start	POR End	Sample Size (N)[1]	Mean	10th Percentile	25th Percentile	75th Percentile	90th Percentile	Interquartile Range
6012C	Florida Keys			ID						
6012D	Florida Keys			ID						
6012E	Florida Keys			ID						
6013A	Florida Keys			ID						
6013B	Florida Keys			ID						
6013C	Florida Keys			ID						
6013D	Florida Keys			ID						
6014A	Florida Keys			ID						
6014B	Florida Keys			ID						
6014C	Florida Keys	4/5/95	10/5/11	60	2.1	0.8	0.9	1.9	2.2	1.0
8077 + 8078 Within FKNMS[4]	Florida Keys	6/7/78	4/10/13	277	1.9	0.4	0.7	1.7	2.7	1.0
8077 Outside FKNMS	Florida Keys	12/2/81	4/7/20	1952	7.3	0.7	1.2	7.8	16.6	6.6
8078 Outside FKNMS	Florida Keys	12/2/81	4/7/20	1029	7.2	1.1	1.8	6.8	15.8	5.0
8050	Gulf of Mexico	8/8/90	12/16/14	91	2.8	0.5	0.9	3.2	6.1	2.3
8051	Gulf of Mexico	8/8/90	12/16/14	364	2.7	0.8	1.1	2.9	5.8	1.8
8052	Gulf of Mexico	8/8/90	12/16/14	214	3.2	0.7	1.1	2.8	6.9	1.7
8053	Gulf of Mexico	8/8/90	12/16/14	152	3.0	0.7	1.1	3.2	6.9	2.0
8054	Gulf of Mexico	1/14/11	12/16/14	92	3.0	0.7	1.1	3.4	5.2	2.3
8055	Gulf of Mexico			ID						
8056	Gulf of Mexico	1/22/96	12/13/00	63	2.8	0.6	1.0	3.4	6.5	2.4
8057	Gulf of Mexico			ID						
8058	Gulf of Mexico	5/25/04	9/13/11	38	2.8	0.6	1.0	2.9	7.7	1.9
8059	Gulf of Mexico	9/22/83	12/17/18	27	3.4	0.3	1.0	3.4	11.5	2.4
8060	Gulf of Mexico			ID						
8061	Gulf of Mexico			ID						
8062	Gulf of Mexico	2/21/06	10/25/06	34	2.6	0.2	2.0	3.7	4.5	1.7
8063	Gulf of Mexico	1/26/99	3/17/20	92	2.6	0.7	1.1	3.1	4.8	2.0
6002	Manatee Bay – Barnes Sound	12/5/85	1/8/20	717	1.1	0.4	0.5	1.4	2.3	0.9
6003	Manatee Bay – Barnes Sound	1/9/86	1/8/20	1329	1.7	0.4	0.5	1.6	2.9	1.1

[1] Entries of "ID" in the Sample Size (N) column indicate that there were insufficient data to calculate the summary statistics.

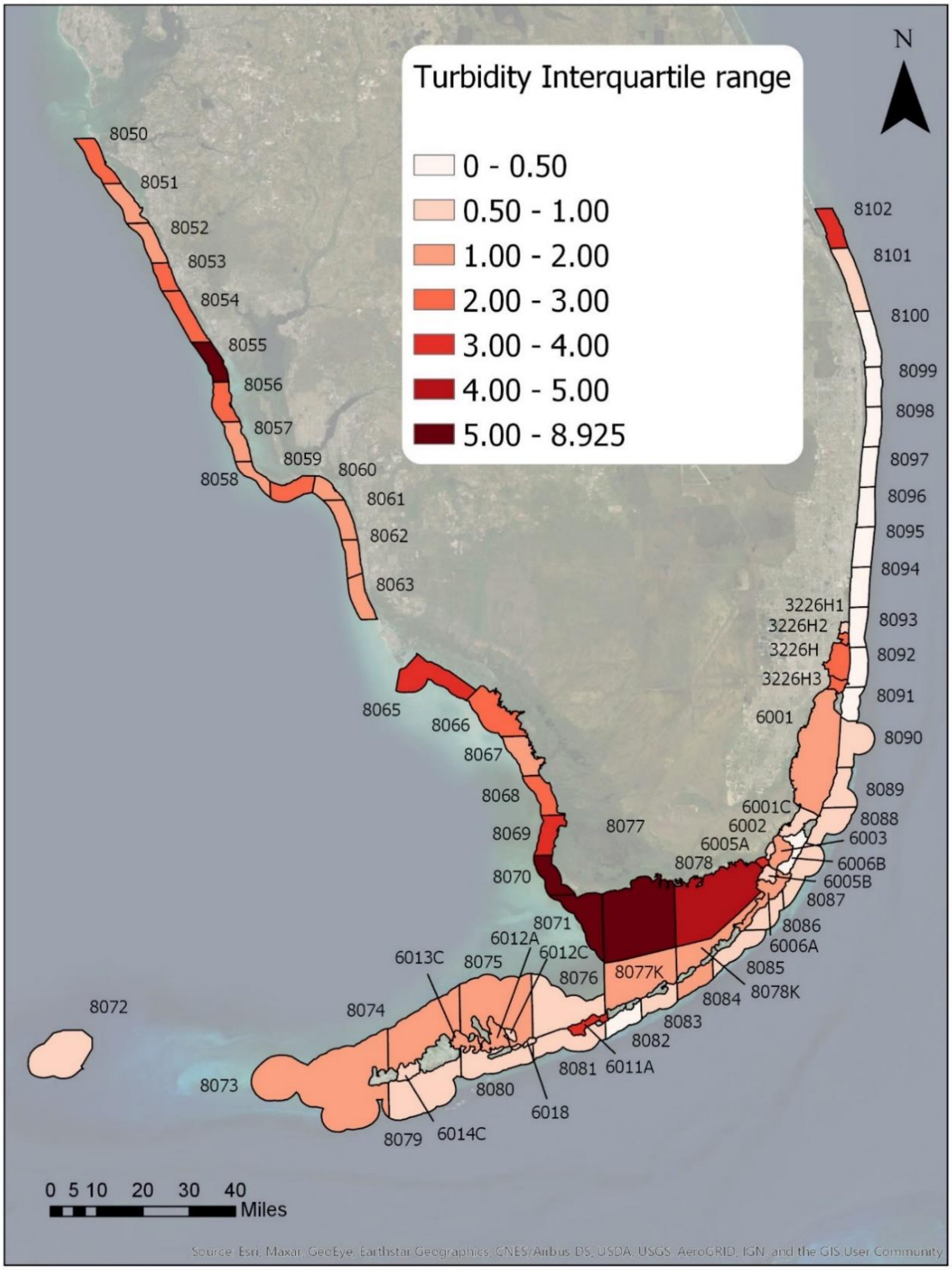
[2] Values were based on the neighboring WBID 3226H3 due to insufficient data in WBID 3226H2.

[3] Calculated based on combined WBIDs 8091 and 8092

[4] Values were based on combined WBID 8077 and 8078 stations within the FKNMS. These are displayed as WBID 8077K and 8078K on the maps..

1. Calculated based on combined WBIDs 8091 and 8092
2. Values were based on the neighboring WBID 3226H3 due to insufficient data in WBID 3226H2.
3. Values were based on combined WBID 8077 and 8078 stations within the FKNM.

Figure A-1. Map Displaying Interquartile Ranges from Table A-1.



DRAFT
Revised Turbidity Criterion to Protect Florida Coral Resources

Prepared by:
Florida Department of Environmental Protection
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Water Quality Standards Program

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1.0 Introduction

1.1 Purpose of the Report

The purpose of this document is to summarize the current scientific understanding of coral species sensitives and responses to turbidity and describe efforts to revise the generally applicable turbidity criterion to better protect coral reef and hardbottom communities that occur in South Florida. The document also provides recommendations for additional studies to further refine the numeric turbidity criterion in the future.

1.2 Proposed Criterion Revision

The Department recommends adoption of a two-part turbidity criterion. The first part of the criterion, which applies to all Florida waters, would add a narrative provision to the existing numeric turbidity criterion of 29 NTU above natural background. The second part of the criterion is intended to provide added protection for sensitive coral and hardbottom species in South Florida and would specify that there shall be no increase in turbidity levels outside of the range of natural variability. The second part of the criterion would only apply to coastal waters in areas specifically described and listed in the rule.

We recommend that the existing turbidity criterion in subsection 62-302.530(70), Florida Administrative Code (F.A.C.), be revised to include two paragraphs:

a. Turbidity shall not be increased more than 29 NTU above natural background, nor shall turbidity levels be increased to levels that negatively affect designated uses or result in increased sedimentation or reduced light transmission to the point that the normal growth, function, reproduction, or recruitment of aquatic life is impaired.
b. Turbidity shall not be increased above background conditions within the South Florida Coral Reef Ecosystem Conservation Area, Biscayne Bay National Park, Florida Keys National Marine Sanctuary excluding canals, and Dry Tortugas National Park, as shown on the map titled “South Florida Coral Reef Protection Area”, July 2019, which is

incorporated by reference herein, or other areas of the state where coral reefs, hardbottom communities, or Serpulidae reefs (worm rock) are currently found. For the purposes of evaluating this criterion, background conditions shall take into account the natural variability of turbidity levels and shall be established following the methods described in the document titled Implementation of the Turbidity Criterion for the Protection of Coral Reef Resources, dated July 2019, which is incorporated by reference.

The South Florida Coral Protection Area (SFCPA, **Figure 1**) is specifically listed and identified in the criterion because it contains waters, including marine sanctuary, state parks, and national parks, known to currently or historically support extensive coral reefs. Consideration of the historical presence of coral is of critical importance because the SFCPA has experienced significant declines in coral since 2014 due to Stony Coral Tissue Loss Disease (SCTLD). Coral and hardbottom organisms have a potential to colonize and grow throughout the SFCPA; the turbidity criterion is intended to ensure that turbidity is not a limiting factor to their survival, recruitment, growth, or recovery from SCTLD, regardless of whether these species currently occur within an area. Additionally, most of the SFCPA has been designated as critical habitat for Acropora, a genus of coral designated as endangered by the National Oceanographic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS), and such critical habitat warrants additional proactive protection.

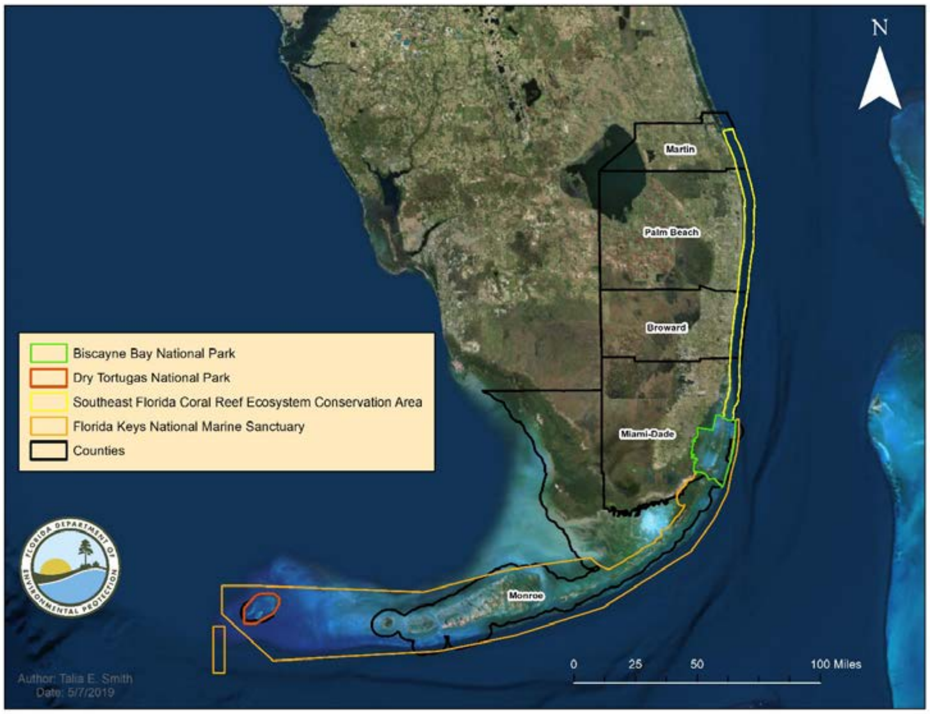

Figure 1. South Florida Coral Protection Area (SFCPA).

The spatial distribution of coral reefs, hardbottom, and worm rock (Serpulidae reefs) outside of the SFCPA is patchy, limited by other factors (e.g., lack of a hard rock substrate), and not well delineated (**Figure 2**). Therefore, paragraph 62-302.530(70)(b), F.A.C., only applies in areas outside of the SFCPA to waters where coral, reef, hardbottom, or worm rook communities are found. For purposes of interpreting the turbidity criterion in Paragraph 62-302.530(70)(b), F.A.C., "coral reef" shall mean a marine benthic community that includes hard coral species (Scleractinia), and "hardbottom" shall be defined as a marine habitat that includes benthic epifaunal organisms that are attached to a hard rock substrate. To be considered hardbottom, the epifaunal community of organisms must include either hard coral, octocorals, anemones, bryozoans, and/or sponge species.

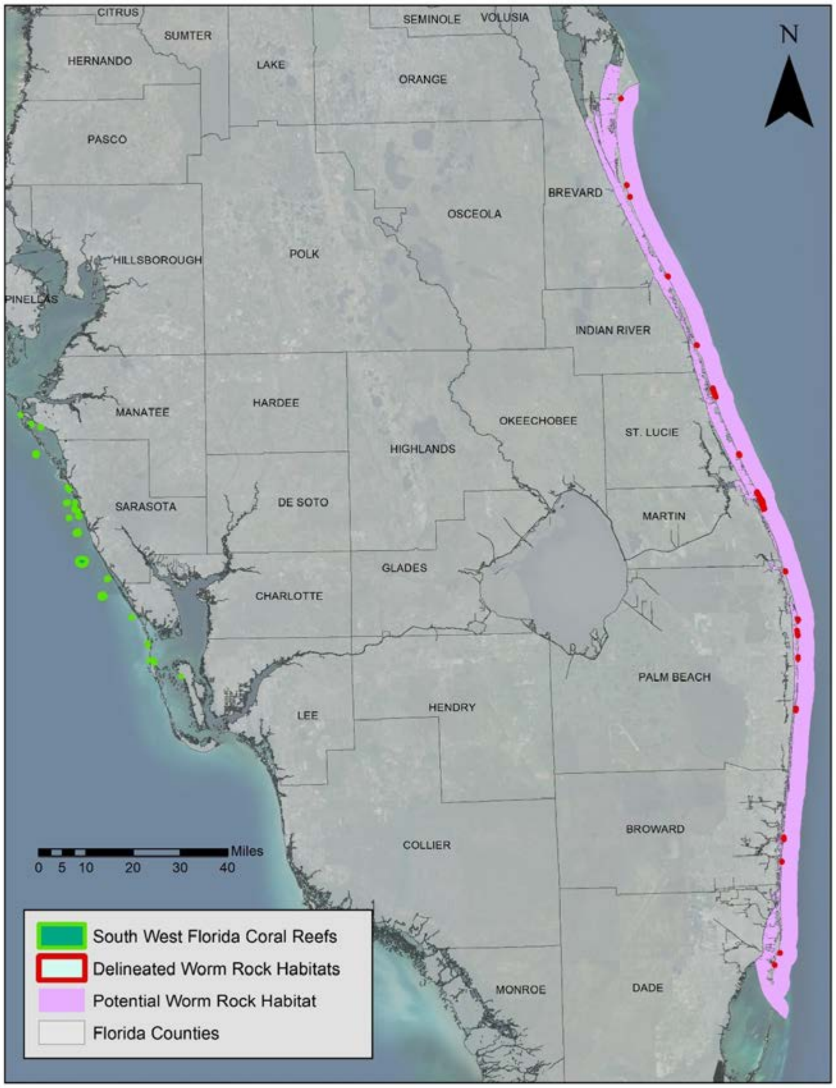

Figure 2. Spatial distribution of coral reefs and worm rock habitats on the southwest and southeast, respectively, coasts of Florida. Potential worm reef habitat is based on Kirtley and Tanner (1968) and shows where Serpulidae may potentially occur. Delineated worm rock reef habitats are from the Florida Fish and Wildlife Commission (FWC) (http://geodata.myfwc.com/datasets/dff9b71b85c04e47b8e54d0eed167205_2) and show the location of surveyed worm reefs.

2.0 Background

Turbidity is the optical property of a suspension that causes light to be scattered and absorbed rather than transmitted through the water column; it implies muddiness and lack of clarity and transparency. The more total suspended solids in the water, the higher the effect on light transmission and the higher the turbidity value. Although turbidity and suspended sediments are highly related, the turbidity value is influenced by sediment type, grain size, and the optical properties of the sediment. Turbidity is also influenced by algae and bacteria suspended in the water column; that is, there can be a non-sediment (algae and bacteria) fraction to turbidity.

The State of Florida established a water quality criterion for turbidity in subsection 62-302.530(70), Florida Administrative Code (F.A.C.), that applies to all waterbody classifications. In accordance with subsection 62-302.530(70), F.A.C., surface waters of the State of Florida shall not exceed 29 Nephelometric Turbidity Units (NTUs) above natural background conditions. The State's original turbidity criterion was 50 Jackson Candle Units, but in 1983 it was converted to 29 NTUs. The earlier 50 Jackson Candle Unit criterion dates back to the 1962 Sanitary Code of Florida, Chapter V (Rules of the State Board of Health). The basis of the criterion is only conjecture at this time because there is no available documentation supporting the 1962 Sanitary Code.

Stress from elevated suspended sediments, turbidity and reduced water clarity have been shown to cause significant adverse effects on coral and hardbottom ecosystems globally and in Florida waters. The source of the sediment may be natural or anthropogenic activities. Natural processes that cause suspended sediments and turbidity include resuspension processes related to wave action, tidal fluctuations, run-off from land, and storms. Anthropogenic activities that increase suspended sediments include dredging, beach nourishment, agricultural activities, urban runoff, construction, and resuspension from boat activity. Additionally, anthropogenic nutrient enrichment (nitrogen and phosphorus) can increase algal densities, which can result in reduced transparency and water clarity.

A review of the available literature strongly suggests that the existing 29 NTU above natural background turbidity criterion is not protective of sensitive marine habitats, particularly the coral reef communities of Southeast Florida and the Keys. In marine environments, dredging and construction activities increase suspended sediment concentrations[1] (SSC), sediment deposition, and turbidity, which result in reductions in light, reduced gas exchange, and physical smothering or even burial of benthic communities. The settlement of the re-suspended sediment in particular is a well-known stressor, requiring epi-benthic organisms to expend energy self-cleaning or become progressively smothered in sediments (Stark et al., 2017).

In addition, a variety of stakeholder groups, such as Our Florida Reefs (OFR), Coastal Ocean Task Force (COTF), US Coral Reef Task Force (USCRTF), and the South East Florida Coral Reef Initiative (SEFCRI), , have recognized the value of the coral reef resources in this area and the unique threats they face from maritime industry and coastal construction impacts, which will be in part ameliorated by a more protective turbidity standard as proposed. Examples of recommendations include:

1. OFR (Our Florida Reefs):
    a. S-104: Set new and appropriate water turbidity standards for marine construction to limit damage from coastal constructions to reefs and associated habitats.
    b. S-103: Create and enforce BMPs that eliminate destructive impacts to coral reefs from coastal construction projects (beach renourishment, port expansion, etc.) to eliminate burials, habitat removal, and excessive siltation and turbidity on coral reefs.
    c. N-98: Develop, fund, and implement a SEFCRI-wide beach management plan for sustainable management of beaches and to protect and minimize impacts to reefs from turbidity caused by erosion.
    d. N-127: Improve permit conditions and BMPs for coastal construction using recommendations from past monitoring (turbidity, sedimentation, and hardbottom) results to reduce negative impacts to reefs from future construction projects.
2. COTF (Coastal Ocean Task Force)

[1] Suspended Sediment Concentration (SSC) is equivalent to Total Suspended Sediments (TSS). The term “SSC” is most commonly used within the literature on coral responses and is therefore used in this document for consistency with these literature sources.

   a. Improve methods of offshore sediment dredging for beach nourishment to reduce muddy runoff turbidity and sediment stress on corals, eliminate damage from dredging "accidents," and enhance sea turtle nesting beaches.
   b. Set new and appropriate water turbidity standards for marine construction to limit damage to reefs and associated habitats from coastal construction projects.
3. USCRTF (US Coral Reef Task Force) Sedimentation and Turbidity Workshop
   a. The water quality threshold of 29 NTU above background for construction projects is too high to be protective of coral reef resources and needs to be revised. Monitoring turbidity through NTU alone is an outdated method, and should be complemented with diverse abiotic and biotic monitoring parameters.
   b. Construction near valuable benthic resources should occur during environmental windows that respect seasonal periods of biological importance and stress for those resources (i.e., spawning, bleaching, rainy season, etc.). These are not universal and may vary by location.

3.0 Stressor of Concern – Suspended Sediments

Suspended sediments originate from resuspended marine sediments, soil erosion, terrestrial runoff, discharges, and construction activities (i.e., dredging and fill placement). Suspended sediments are made up of organic and inorganic materials, although bacteria and algae can also contribute to the total SSC. Increased suspended sediments are a significant factor in reduced water clarity, reduced light attenuation, and increased turbidity, and can cause additional problems when they settle on the bottom (sedimentation).

A review of peer-reviewed literature on the environmental impacts of dredging (sedimentation and turbidity) was done by Erftemeijer et al., 2012, and impacts to coral reefs due to dredging events have been documented world-wide. The major problems arising from turbidity and sedimentation derived from coastal construction and dredging are related to the shading caused by decreases in ambient light and sediment cover on the coral's surface, as well as problems for the feeding apparatus under a sediment blanket and energy costs associated with mucus production, sediment clearance, and impaired feeding (Erftemeijer et al., 2012). The accumulation of sediment on coral reefs or "sedimentation" associated with coastal construction/dredging can have negative impacts on coral reefs and is a widespread cause of coral reef degradation (Rogers 1990; Riegl 1995).

In many cases, dredging operations have contributed to the loss of coral habitats, either directly due to the removal or burial of reefs or indirectly as a consequence of lethal or sublethal stress to corals caused by elevated turbidity and sedimentation (Erftemeijer et al 2012). For example, a large-scale dredging project and corresponding monitoring event was conducted off Miami Beach to observe the effects of dredging activities on a subtropical coral community beginning in 1977 (Marszalek 1981). Monitoring revealed that approximately one centimeter of sediment was deposited on the nearby reef surface in less than two hours (Marszalek 1981). Scleractinian corals suffered the most damage and were observed actively cleaning themselves of sediments; most were partly covered with a layer of mucus and sediment, and the polyps were distended and swollen (Marszalek 1981). Many of the small colonies of *Dichocoenia stokesii*, *Montastraea cavernosa*, and other hemispherical forms showed a band of dead tissue adjacent to the substrate, buried beneath the layer of silt (Marszalek 1981). In addition, there was a general increase in turbidity throughout the study area, with turbidity levels varying depending on proximity to the dredge, weather conditions, and tidal cycles. A transect survey completed during the winter of 1980 concluded that an average of 9.7% (range: 3% to 32.4%,) of coral colonies exhibited signs of coral stress, which was a large increase from the 5% measured in 1978 (Marszalek 1981).

Summaries of species sensitivities and responses to turbidity, suspended sediment, and sedimentation from dosing and *in situ* experiments are provided in **Section 5.0**. The preponderance of evidence from these studies indicate that corals are sensitive to suspended sediments and that the existing 29 NTU criterion is not adequately protective of these species. The next section, **Section 4.0**, presents a conceptual model that describes the stressor-response relationships to suspended sediments in coral species.

4.0 Conceptual Model

A conceptual model is a written description and diagram that provides a visual representation of predicted relationships between stressors and resulting ecological conditions (U.S. EPA, 1998). It can be used to describe predicted relationships between biological, physical, and chemical conditions of a waterbody; develop hypotheses regarding cause and effect relationships; determine the most sensitive end-point(s); and determine the most critical stressors.

The conceptual model shown in **Figure 3** summarizes natural and anthropogenic sources of suspended sediments, potential biological responses, and transport pathways on adult and early life-history stages of corals. The model links exposure characteristics such as low light availability, sedimentation (covering, smothering and deposition), and suspended sediment with detrimental outcomes. The stressor is the physical, chemical, or biological agent that directly causes one or more biotic responses of concern, which in this case are suspended sediment or turbidity, decreased light availability, and sedimentation.

4.1 Effects of Suspended Sediment on Corals

Corals are both autotrophs and heterotrophs. Ingestion of sediments by corals has been observed in many studies (Lewis and Price, 1975; Lewis, 1976; Logan, 1988; Marshall and Orr, 1931; Stafford-Smith and Ormond, 1992; Stafford-Smith, 1993) and appears to be part of a normal feeding mechanism. Suspended particulate matter constitutes a potentially diverse food source containing bacteria, microalgae, protozoa, detrital organic matter (Marshall, 1965), interstitial invertebrates, undissolved mucus (Wild et al., 2004), microbial exudates, and excretory products from other animals (e.g. from fish, Meyer and Schultz, 1985; Lopez and Levinton 1987; Houlbrèque and Ferrier-Pagès, 2009). Many studies have shown that corals are capable of assimilating and obtaining nutritional benefits from organic matter associated with ingested sediments (Anthony, 1999, 2000; Anthony and Fabricius, 2000; Mills and Sebens, 1997; Mills et al., 2004; Rosenfeld et al., 1999). However, Mills and Sebens (1997) suggested that high loads of clean sediments may cause polyps to stop feeding and reject sediments, reducing ingestion rates. Similarly, Anthony (2000) indicated that at concentrations >30 mg L^{-1} *Acropora millepora* and *Pocillopora damicornis* from clear water offshore environments showed a tendency to retract their polyps, which reduced the potential for energy gains from feeding.

Low SSCs may be beneficial for some corals in some circumstances and detrimental at higher concentrations, depending on organic content, water flow and coral morphology. A low dose stimulation and high dose inhibition has been reported in numerous studies (Anthony, 1999, 2000; Logan et al., 1994; Mills and Sebens, 1997; Mills et al., 2004; Mills and Sebens, 2004; Rosenfeld et al., 1999; Stafford-Smith and Ormond, 1992; Tomascik and Sander, 1985). While low SSCs can have beneficial effects, high SSC is one of the key stressors because it reduces feeding activity and increases energy expenditures to continually process and transport intercepted sediments (**Figure 3**).

4.2 Light Availability

Spectral composition and the quantity and quality of the submarine light field is fundamentally important for the physiology and ecology of coral-algal symbiosis. Light attenuation, mediated by absorption and scattering of light by suspended particles, is one of the key stressors to corals in the short- and long-term (Jones et al., 2016). In very low or zero light conditions, corals can enter a state of hypoxia and then anoxia due to reduced photosynthetic production of oxygen (Jones et al., 2016).

4.3 Sediment Covering

The initial response of corals to deposition of sediments on their surfaces is an attempt to self-clean by moving sediments to edges where they are dropped off the colony (Marshall and Orr, 1931). The principal sediment rejection mechanisms identified for a range of coral species, representing different families, are: ciliary action, hydrostatic inflation, tentacle movement, contractions, and mucus entrapment (Bak and Elgershuizen, 1976; Hubbard and Pocock, 1972; Logan, 1988; Marshall and Orr, 1931; Schuhmacher, 1977; Stafford-Smith and Ormond, 1992; Stafford-Smith, 1993; Vaughan, 1916; Yonge and Nicholls, 1931). These are usually referred to as active processes (requiring energy).

If sedimentation rates exceed the coral's sediment clearance rate, sediments will inevitability build up on a coral's surface and the coral becomes progressively buried in a sediment deposit. The fate of the underlying tissues is partial mortality (lesion formation), unless the sediment layer is removed by a storm.

One of the significant issues associated with smothering is tissue hypoxia, brought about by either light attenuation or a reduction in gas (solute) transfer across diffusive boundary layers. Corals are oxygen conformers and routinely experience pronounced diel changes in tissue oxygen concentrations ranging from super-saturation (hyperoxia) during the daytime associated with algal photosynthesis, to night-time oxygen shortage (hypoxia) or even anoxia by host and algal respiration (Jones and Hoegh-Guldberg, 2001; Kuhl et al., 1995; Shashar et al., 1996). In darkness or low flow conditions, oxygen concentrations can fall to levels where aerobic respiration and ATP generation is limited (Bailey-Serres and Voesenek, 2008; Fukao and Bailey-Serres, 2004).

4.4 Combined Effects of Proximal Stressors

The key pressure parameters identified above are highly interconnected, with suspended-sediments causing biological effects directly, and also causing changes in light quality and quantity (through attenuation and scattering in the water column). Similarly, high SSCs are a prerequisite for sediment deposition, mediated by the process of sedimentation in the water column. While the direct physical effects of coral smothering are generally more of an acute concern, accumulated sediments also have a longer-term effect as they reduce the amount of light reaching the coral surface and impact feeding processes (**Figure 3**).

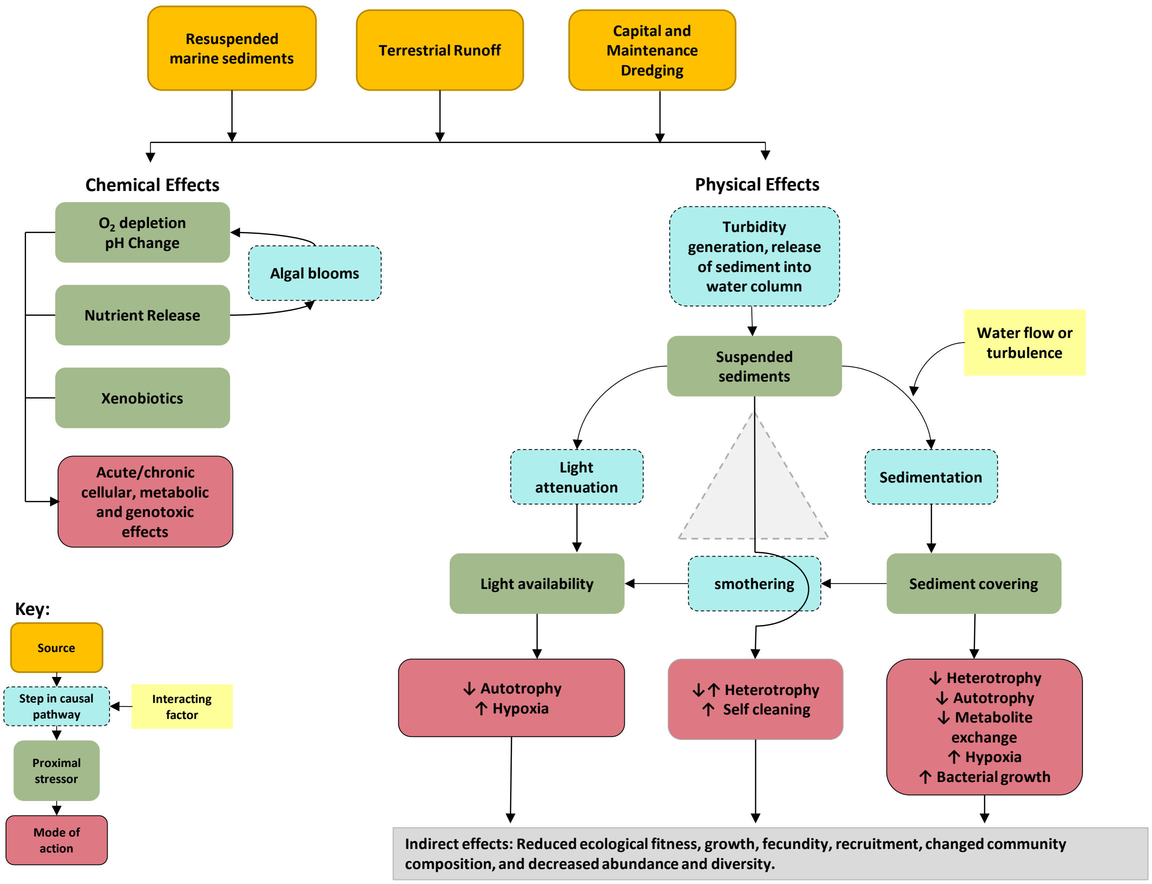

Figure 3. Conceptual model for dredging effects on coral larvae and adult energy expenditure (Adapted from Jones et al., 2016).

5.0 Assessment of Effects

There is limited literature available on the effects of turbidity and sedimentation on Florida reefs; however, many studies showing significant negative effects have been conducted in the Caribbean and many of the coral species commonly on Florida reefs are found across the Caribbean. These studies show sensitivity of different species to SSC, turbidity, light reduction, and sedimentation. This section describes the relative sensitivity of adult and early life stages of corals found in Florida to turbidity and sedimentation based on research conducted in Florida and the Caribbean. Biological responses to experimentally manipulated turbidity, SSC, light, or sedimentation are summarized in **Table 1**.

5.1 Sensitivity of Adult Florida Coral Species

Although information on the sensitivity of Florida's coral species to turbidity and associated stressors is limited, the available studies have demonstrated that several coral species, including the endangered *Acropora cervicornis*, are sensitive to turbid conditions and sedimentation. Conversely, other species such as *Sideastrea spp.* and *Meandrina meandrites*, are either adapted to naturally higher turbidity ranges or have the ability to tolerate limited duration exposures to elevated turbidity or increased sedimentation. However, the overall duration of exposure is critically important to all species and even the most tolerant species exhibit stress if exposed to high levels for prolonged durations.

Acroporids are particularly sensitive to sediment as they are among the least effective of the reef building corals at trapping and removing sediment from their surface (NOAA fact sheet; https://sero.nmfs.noaa.gov/protected_resources/outreach_and_education/documents/acropora_factsheet.pdf). *Acropora* spp. found in Florida depend heavily on wave action to clear sediment, making them highly sensitive to anthropogenic turbidity and sedimentation (Bak and Elgershuizen, 1976). *Acropora palmata* exhibited partial mortality when exposed to a single application of 200 mg/cm^2 of clean calcareous sediment (Rogers, 1983). When exposed to 600 mg of sediment[2], *A. palmata* photosynthetic rates dropped significantly (Abdel-Salam et al., 1988). *In situ* observations indicate that *Acropora* spp. are almost completely absent from reefs near influxes of terrigenous sediment (Acevedo et al., 1989).

Many studies have shown that *Acropora cervicornis* is sensitive to SSC. When exposed to moderate SSC (150 mg/L) for 96 hours, polyp retraction and mucus production occurred, while partial mortality occurred in colonies exposed to high SSC levels (476 mg/L) (Thompson, 1980). Physiological stress responses occurred at lower levels of SSC. Colonies exposed to 25 mg/L of drilling mud for 24 hours exhibited a 62% decrease in calcification rates, and colonies exposed to 100 mg/L showed a 50% decline in soluble tissue protein (Kendall et al., 1983). Exposure to 100 mg/L of kaolin reduced calcification rates and free amino acid content (Kendall et al., 1985). *A.*

[2] Sediment was dumped into a cup approximately the "size of a small 35 mm film canister"

cervicornis is also sensitive to sediment applications, experiencing major bleaching from a single application of 400 mg/cm^2 of clean calcareous sediment (Rogers 1983).

Kendall et al (1983) found that drilling muds and turbidity influenced the native coral *Acropora cervicornis* in Carysfort Reef, Florida in several ways. The study examined, *in situ*, the effects of exposure to used drilling muds and turbidity on the calcification rate, ninhydrin positive substance (NPS) content, and tissue protein content of corals. The study found that total soluble protein in the coral decreased significantly in 25, 50, 100 and 500 ppm drilling mud treatment, with a dramatic loss noted in the 500 ppm treatment. Soluble protein concentration was 50% lower after 24-hour exposure to 100 ppm and 68-92% lower in corals exposed to 500 ppm. Calcification rate also declined in response to increasing drilling mud concentrations, with calcification rates declining by 62, 83, 88, and 95% at 25, 50, 100, and 500 ppm, respectively (Kendall et al., 1983). Additionally, a loss of zooxanthellae was observed in the field in corals exposed to 500 ppm.

Montastraea annularis, *Acropora palmata*, and *Acropora cervicornis* are considered to be more sensitive to turbidity, sedimentation, and SSC than other species of corals found in Florida. Multiple studies have shown that, as the input of terrigenous sediment on reefs increases, *M. annularis* cover decreases (Torres and Morelock, 2002; Acevedo et al., 1989; Bégin et al., 2014). Physiological responses have been measured on colonies that inhabit highly turbid sites. *M. annularis* living in sites impacted by high turbidity and sedimentation have significantly lower skeletal extension rates than those on unimpacted reefs (Torres 2001). When exposed to 120 mg/mL of SSC, *M. annularis* exhibited significant decreases in photosynthetic rates (Abdel-Salam, 1988). When exposed to a single application of 400 mg/cm^2 of clean calcareous sediment, *M. annularis* showed mild discoloration, which is the first indication of bleaching (Rogers 1983). Chronic exposure (6 weeks) to low levels of SSC (100 mg/L) also produced minor sub-lethal effects, including reduced rates of respiration, photosynthesis, calcification and nutrient uptake (Szmant-Froelich et al., 1981). When exposed to 150 mg/L of SSC for 96 hours, *M. annularis* exhibited polyp retraction and mucous production, and when SSC was increased to 476 mg/L, all colonies showed mortality within 65 hours of exposure (Thompson, 1980).

Agaricia agaricites cover was significantly decreased at reefs near an influx of terrigenous sediment (Acevedo et al., 1989). When exposed to moderate SSC levels (150 mg/L) for 96 hours, *Agaricia agaricites* experienced polyp retraction and increased mucus production, while partial mortality occurred in colonies exposed to high SSC levels (476 mg/L) (Thompson, 1980).

Some coral species can tolerate short duration exposure to sedimentation and turbid conditions; however, these conditions are still stressful to the corals and longer-term exposure or increased concentrations of suspended sediments can adversely affect the corals. For example, *Montastrea cavernosa*, *Siderastrea radians*, *Siderastrea siderea*, and *Meandrina* meandrites were found to dominate highly turbid reefs in Puerto Rico (Loya, 1976). *M. cavernosa* can tolerate higher turbidity and sediment environments because they effectively remove sediment through active and passive rejection. The morphology and large polyps of *M. cavernosa* allowed them to passively shed most sediment and remove the rest with little energy input under laboratory conditions using fine and coarse sediment for five days and similar results were observed using existing natural sediment *in situ* (Lasker, 1980).

Sideastrea spp. are adapted to nearshore, stressful environments and can tolerate periodic high turbidities (Lirman and Manzello, 2009). Torres and Morrelock (2002) found that *S. siderea* populations in Puerto Rico at five different sites were unaffected by high inputs of terrigenous sediments onto reefs. Their *in situ* study was conducted under different natural sedimentary regimes, with sites ranging from no exposure to high exposure to terrigenous sediment. There were upward growth responses for a five-year period as well as changes in coral cover as a result of increased sediment influx (Torres and Morelock, 2002). *S. radians* showed only slight reductions in photosynthesis when subject to short-term burials (2-24 hours) and recovered quickly under laboratory conditions.

Only under extended chronic sediment burial (≥48 hours) and extreme salinity (15 or 45 psu) did colonies experience tissue mortality (Lirman and Manzello, 2009). Small colonies (2-3 cm) of *S. radians* in Biscayne Bay were able to survive 4 days of complete burial of natural sediment with only slight reductions in photosynthetic rates. After 7-10 days of burial at low salinity (15 ppt), colonies were thought to have experienced complete mortality, with no evident photosynthesis or respiration occurring; however, in 2-3 weeks, tissue began to regrow and in 6 weeks, colonies appeared healthy (Lirman et al., 2002).

Meandrina meandrites and *Dichocoenia stokesii* were shown to tolerate turbidity in short-term laboratory experiments, but adverse effects on these species were noted after only a few days of exposure to turbid conditions. When exposed to 28-30 NTU for three days, colonies experienced mucous production, reduced photosynthesis to respiration (P:R) ratios, and lesions; however, no bleaching or mortality was seen (Telesnicki and Goldberg, 1995). Colonies of *Meandrina meandrites* showed significant increases in respiration after day two, and *Dichocoenia stokesii* exhibited significant increases in respiration after three days. P:R ratios were significantly different from controls in both species when exposed to 14-16 NTU for seven days.

Porites astreoides and *Diploria strigosa* have also shown some tolerance to SSC in laboratory experiments. *Porites astreoides* exposed to moderate SSC levels (150 mg/L) for 96 hours in the laboratory had no physiological effects on colonies. Only under extended exposure to 476 mg/L did colonies show major sub-lethal stress responses, but there was no colony mortality (Thompson, 1980). Even when exposed to 1,000 mg/L for 65 hours, no mortality was seen (Thompson and Bright, 1980). *Diploria strigosa* exhibited no discoloration even when exposed to sediment applications of 800 mg/cm^2(Rogers, 1983). *Diploria strigosa* was able to clear sediment quickly, and photosynthetic rates were unaffected by 120 mg/ml of suspended sediment (Abdel-Salem, et al., 1988).

High turbidity levels produced by sediment resuspension was investigated to test the effects on the survival and growth rates of hard corals collected from the Gulf of Mexico patch reefs off west central Florida. This experiment was done under controlled laboratory conditions that were intended to simulate the levels of suspended sediment that might be expected to occur on the periphery of an ocean dredged material disposal site (Rice and Hunter 1992). Four different levels of suspended sediment (49, 101, 165, and 199 mg/L) were tested in 10-day survival and growth experiments. Eight species of hard corals were used for suspended sediment experiments. Loss of color associated with expulsion of zooxanthellae was a common response in *Manicina*, *Scolymia*, *Isophyllia*, and *Solenastrea* (Rice and Hunter 1992). Partial polyp death and/or polyp bleaching , shrinkage of soft tissue, and exposure of underlying skeletal features were observed in *Manicina*, *Scolymia*, and *Isophyllia* (Rice and Hunter 1992). The average coral growth rates for seven species exposed to 165 mg/L suspended sediment load for 10 days were significantly different in control and experimental treatments (Rice and Hunter 1992).

5.2 Early Life Stages

Suspended sediment and sedimentation have several effects on early life stages of coral, and these effects may be substantially more detrimental to coral recruits than adult corals. Coral settlement rates are significantly depressed by elevated turbidity and sedimentation because sediment covers the hard substrates that coral recruits require for settlement. Sediment deposition can also interfere with sexual reproduction and recruitment by sediments binding directly to egg-sperm bundles and causing them to sink. Several studies have reported that suspended sediments can reduce fertilization success at concentrations as low as 50 mg/L (Ricardo et al., 2015).

Because early life-history stages of corals are susceptible to elevated suspended sediments, high turbidity during spawning periods could lead to loss of the entire reproductive output for the year (Jones et al., 2015; Harrison et al., 1984; Hughes and Tanner, 2000; Hughes et al., 2000). Several studies have suggested that increased levels of sedimentation and/or suspended sediments can affect reproductive success (Erftemeijer et al., 2012; Perez III et al., 2014; Ricardo et al., 2015; Fourney and Figueiredo, 2017; Humanes et al., 2017; Moeller et al., 2017). However, the majority of these studies were conducted using non-Florida or Caribbean species.

Fourney and Figueiredo (2017) conducted the only published Florida study on the effects of suspended sediments on early coral life stages. *Porites astreoides* recruits were exposed to four levels of sedimentation (30, 60, 90, and 120 mg cm^{-2} of deposited sediment) and two temperature levels (26˚C and 30˚C). The experiment was conducted twice: first with large grained "natural" sediment, and a second time with small grained "anthropogenic" sediment typical of dredging conditions. The first experiment used 1,503 newly settled recruits and ran for three months, while the second experiment used eighty 5-month old recruits and ran for one month (Fourney and Figueiredo 2017). Between the two experiments, temperature and anthropogenic sedimentation additively affected the survival of *Porites astreoides* recruits; higher temperatures and anthropogenic sedimentation (30˚C and 60 mg cm^{-2}) displayed significantly higher mortality (Fourney and Figueiredo 2017). After 4 weeks of exposure to low turbidity (<7 NTU) levels, 80% of *Porites astreoides* recruits remained alive, but after 4 weeks at 29 NTU, survival dropped to 10%. Fourney and Figueiredo (2017) recommended that the Florida turbidity criterion be revised to < 7 NTU based on this result.

Table 3. Sensitivity (dose-response thresholds) of Florida coral species to turbidity, suspended sediments, light limitation, or sedimentation. Growth forms: B = branching, L = laminar, E = encrusting, M = massive, S = solitary. Modified from Erftemeijer et al, 2012.

Coral species	**Experimental SSC, turbidity, or light level**	**Response**	**Growth Form**	**References**
Acropora cervicornis	Severe light reduction (shading) for 5 wks	Mass bleaching (3 wks), mortality/algal cover (7 wks), no recovery (8 months)	B	Rogers (1979)
	50 mg/l (96 h)	No effect		Thompson (1980)
	150 mg/l (96 h)	Polyp retraction, mucus production but no mortality		
	476 mg/l (96 h)	Partial mortality after 96 h.		
	25 mg/l (drilling mud) (24 h)	62% Decrease in calcification rate		Kendall et al. (1983)
	100 mg/l (drilling mud) (24h)	50% Decline in soluble tissue protein		
	50 and 100 mg/l (kaolin, 24h)	Reduced calcification rate and free amino acids at 100 mg/l (recovery in 48 h)		Kendall et al. (1985)
	1000 mg/l (for 65 h)	Mortality of colonies		Thompson and Bright (1980)
Acropora spp.	170 mg/l (hours) of marine snow/SPM	Mucus production in response to flocculation		Fabricius and Wolanski (2000)
Agaricia agaricites	Severe light reduction (shading) for 5 wks	Partial bleaching after 5 wks, recovery within wks	L	Rogers (1979)
	50 mg/l (96 h)	No effect		Thompson (1980)
	150 mg/l (96 h)	Polyp retraction, mucus production but no mortality		
	476 mg/l (96 h)	Mortality after 65 h		
	<1% SI (several days)	33% Decrease in calcification rate (for >1 month), but survival		Bak (1978)
	1000 mg/l (for 65 h)	Mortality of colonies		Thompson and Bright (1980)
Cladocora arbuscula	49, 101, 165 and 199 mg/l (10–20 days)	No effect on growth rate or survival (10 d), minor bleaching (20 d)	B	Rice and Hunter (1992)
Colpophyllia natans	Severe light reduction (shading) for 5 wks	Partial bleaching (5 wks), limited recovery & some algal growth (15 wks)	M	Rogers (1979)
Dichocoenia stokesii	0–2 NTU and 7–9 NTU (wks)	No effect on P:R ratio	M	Telesnicki and Goldberg (1995)
	14–16 NTU (wks)	Mucus production, P:R ratio <1 after 6 days exposure		
	28–30 NTU (wks)	Mucus production, P:R ratio <1 after 3 days exposure		
	50–150–476 mg/l (96 h)	No effect at 50 and 150 mg/l; extreme sub-lethal stress but survival at 476 mg/l		Thompson (1980)
	1000 mg/l (for 65 h)	No mortality		Thompson and Bright (1980)
Diploria labyrinth-iformis	Severe light reduction (shading) for 5 wks	Substantial bleaching (5 wks), no recovery & some algal growth (15 wks)	M	Rogers (1979)
Eusmilia fastigiata	Severe light reduction (shading) for 5 wks	No visible effects	M	Rogers (1979)
Isophyllia suniosa	49,101, 165, and 199 mg/l	No effect on growth rate or survival after 10 d, minor bleaching after 20 days	M	Rice and Hunter (1992)
Madracis auretenra	<1% SI (several days)	33% drop in calcification rate (for >1 month) but survived	B	Bak (1978)
Manicina areolata	49, 101, 165 and 199 mg/l	No effect on growth rate or survival after 10 d, minor bleaching after 20 days	M	Rice and Hunter (1992)

Coral species	Experimental SSC, turbidity, or light level	Response	Growth Form	References
Millepora alcicornis	Severe light reduction (shading) for 5 wks	Partial bleaching (5 wks), algal growth (6 wks), no recovery of damaged tissue	B	Rogers (1979)
Meandrina meandrites	0-2 NTU and 7-9 NTU (wks)	No effect on P:R ratio	M/E	Telesnicki and Goldberg (1995)
	14–16 NTU (wks)	Mucus production, P:R ratio <1 after 6 days exposure		
	28–30 NTU (wks)	Mucus production, P:R ratio <1 after 3 days exposure		
Montastraea annularis	severe light reduction (shading) for 5 wks	substantial bleaching (5 wks), partial recovery (6-8 wks), some algae/mucus	M/E	Rogers (1979)
	50 mg/l (96 h)	No effect		Thompson (1980)
	150 mg/l (96 h)	Polyp retraction, mucus production but no mortality		
	476 mg/l (96 h)	Mortality after 65 h		
	100 mg/l (6 wks)	Major sub-lethal effects (photosynthesis, respiration, calcification, and nutrient uptake)		Szmant-Froelich et al. 1981
	1-10 mg/l (6 wks)	only (some) effect on feeding response		
	525 mg/l	Decreased net production and tissue chlorophyll content, increased respiration and mucus		Dallmeyer et al. (1982)
	1000 mg/l (for 65 h)	Mortality of colonies		Thompson and Bright (1980)
Montastraea cavernosa	severe light reduction (shading) for 5 wks	No visible effects	M	Rogers (1979)
Mussa angulosa	Severe light reduction (shading) for 5 wks	No visible effects (1 colony showing minor bleaching after 8 wks)	M	Rogers (1979)
Phyllangia Americana	49, 101, 165, 199 mg/l	No effect on growth rate or survival (10 d), minor bleaching (20 d)	E	Rice and Hunter (1992)
Porites astreoides	50-150-476 mg/l (96 h)	No effect at 50 and 150 mg/l; extreme sub-lethal stress but survival at 476 mg/l	M/E	Thompson (1980)
	<1% SI (several days)	Bleaching and mortality		Bak (1978)
	1000 mg/l (for 65 h)	No mortality		Thompson and Bright (1980)
Porites astreoides	30–120 mg cm^{-2} d^{-1} (0.07–42 NTU)[1]	After four weeks of exposure to low turbidity (<7 NTU), 80% of *P. astreoides* recruits remained alive; exposure to turbidity levels above 29 NTU led survival to drop to 10%.	L	Fourney and Figueiredo (2017)
Porites divaricata	50-150-476 mg/l (96 h)	No effect at 50 and 150 mg/l; extreme sub-lethal stress but survival at 476 mg/l	B	Thompson (1980)
	1000 mg/l (for 65 h)	No mortality		Thompson and Bright (1980)
Porites Furcata	50-150-476 mg/l (96 h)	No effect at 50 and 150 mg/l; extreme sub-lethal stress but survival at 476 mg/l	B	Thompson (1980)
	1000 mg/l (for 65 h)	No mortality		Thompson and Bright (1980)
Porites porites	Significant light reduction due to eutrophication	Reduced reproductive success (ova maturation, larval development)	M	Tomascik and Sander (1987)
Scolymia cubensis	49, 101, 165, 199 mg/l	No effect on growth rate or survival after 10 d, minor bleaching after 20 days	S	Rice and Hunter (1992)
	49-199 mg/l (10 days)	Partial polyp death and partial bleaching (in some individuals)		Rice (1984)
Siderastrea radians	49-199 mg/l (10 days)	Partial polyp death and partial bleaching (in some individuals)	M/E	Rice (1984)
Siderastrea siderea	Severe light reduction (shading) for 5 wks	Partial bleaching after 5 weeks, partial recovery in 6–8 weeks	M	Rogers (1979)

Coral species	Experimental SSC, turbidity, or light level	Response	Growth Form	References
Solenastrea hyades	49, 101, 165, 199 mg/l	No effect on growth rate or survival after 10 d, minor bleaching after 20 d	M	Rice and Hunter (1992)
	49-199 mg/l (10 days)	Partial polyp death and partial bleaching (in some individuals)		Rice (1984)
Stephano-coeania intersepta	49, 101, 165, 199 mg/l	No effect on growth rate or survival after 10 d, minor bleaching after 20 d	M	Rice and Hunter (1992)
	49-199 mg/l (10 days)	Partial polyp death and partial bleaching (in some individuals)		Rice (1984)

1. Study was conducted as a sedimentation study. Turbidity was measured in the first 24 hours of the study.

6.0 Options for Criterion Revision

The primary challenge to revising the turbidity criterion to protect sensitive coral reef and hardbottom communities is the limited dose-response data (laboratory or *in situ*) on Florida species. The data on how turbidity effects the full life cycle of Florida corals are extremely limited, thus it is difficult to quantify the larval and recruitment sensitivities, which are critical to establishing a protective numeric criterion. Many of the available studies evaluated high turbidity levels over short durations that are not reflective of human-induced turbidity (*i.e*., long duration exposures). Corals are likely adapted to short-term turbidity perturbations because they evolved within ecosystems that experience periodic natural turbidity spikes associated with storms and hurricanes; however, longer term increases, even at much lower levels, are unnatural and potentially exert deleterious effects on coral health and recruitment.

Another challenge is that the majority of the available dose-response data are provided as SSC in mg/L rather than turbidity (NTU). Although SSC is a more direct measure of the proximal stressor, it is not the ideal water quality measure for permitted projects because it requires a relatively lengthy laboratory analysis. In contrast, turbidity provides an instantaneous measure of the potential stressor that can be used to quickly address problems if an environmentally relevant threshold has been exceeded.

There are several options for addressing the turbidity criterion given the existing challenges: a) develop additional narrative components to supplement and strengthen the existing turbidity criterion; b) propose a numeric criterion based on the limited Florida and Caribbean data; c) seek partnerships with Florida universities to design and implement dose-response studies on Florida resident species, or d) do nothing. The “do nothing” option is least protective and does not fulfill the Department’s obligation to adopt criteria for sufficient parameters or constituents to protect all designated uses. There is currently sufficient information to demonstrate that the existing turbidity criterion does not adequately protect sensitive aquatic life uses associated with Florida's coral reef tract; therefore, option "d" will not be discussed further.

6.1 Develop Additional Narrative Components

Water quality criteria must be based on a sufficiently sound scientific rationale. There are currently insufficient data and information to support specific numeric thresholds that are protective of sensitive coral community species including all life stages. However, as previously stated, there is clear evidence to demonstrate that the existing 29 NTU above natural background is not sufficiently protective of sensitive aquatic life uses. U.S. EPA encourages States and authorized tribes to establish narrative criteria where numeric criteria cannot be established or to supplement numerical criteria. Therefore, the currently best and most defensible alternative would be for the State to adopt additional narrative components to supplement and strengthen the existing turbidity criterion.

A number of states currently include narrative criteria for turbidity or related parameters in their state water quality standards, examples include:

- Connecticut Class AA Waters: Shall not exceed 5 NTU over ambient levels and none exceeding levels necessary to protect and maintain all designated uses. All reasonable controls or Best Management Practices are to be used to control turbidity.
- Connecticut Class SA Waters: (Turbidity) none other than of natural origin except as may result from normal agricultural, road maintenance, or construction activity, dredging activity or discharge of dredged or fill material provided all reasonable controls and Best Management Practices are used to control turbidity and none exceeding levels necessary to protect and maintain all designated uses.
- Louisiana: Turbidity other than that of natural origin shall not cause substantial visual contrast with the natural appearance of the waters of the state or impair any designated water use. Turbidity shall not significantly exceed background; background is defined as the natural condition of the water. Determination of background will be on a case-by-case basis.

- New Mexico: Turbidity attributable to other than natural causes shall not reduce light transmission to the point that the normal growth, function or reproduction of aquatic life is impaired or that will cause substantial visible contrast with the natural appearance of the water. Activities or discharges shall not cause turbidity to increase more than 10 NTU over background turbidity when the background turbidity, measured at a point immediately upstream of the activity, is 50 NTU or less, nor to increase more than twenty percent when the background turbidity is more than 50 NTU. However, limited-duration turbidity increases caused by dredging, construction or other similar activities may be allowed provided all practicable turbidity control techniques have been applied and all appropriate permits, certifications and approvals have been obtained.
- Tennessee: There shall be no turbidity, total suspended solids, or color in such amounts or of such character that will materially affect fish and aquatic life. In wadeable streams, suspended solid levels over time should not be substantially different than conditions found in reference streams.

The recommended revisions to Florida's turbidity criteria would include two components to address different issues associated with turbidity or suspended solids. The first component, which would apply to all Florida waters, would maintain the existing 29 NTU above natural background and add a narrative statement modelled after the narrative turbidity criteria from other states that addresses fully protection of aquatic life. The proposed language for paragraph 62-302.530(70)(a), F.A.C., is as follows:

> Turbidity shall not be increased more than 29 NTU above natural background, nor shall turbidity levels be increased to levels that negatively affect designated uses or result in increased sedimentation or reduced light transmission to the point that the normal growth, function, reproduction, or recruitment of aquatic life is impaired.

The second component would be designed to provide additional protection to sensitive coral species and reef habitat including endangered species in Southeast Florida. The provision would state that turbidity shall not be increased above background for coastal waters within the South Florida Coral Reef Ecosystem Conservation Area, Biscayne Bay National Park, Florida Keys National Marine Sanctuary excluding canals, and Dry Tortugas National Park (**Figure 4**) or within other areas of the state where coral reefs, hardbottom communities, or Serpulidae reefs (worm rock) are currently found. The proposed language for paragraph 62-302.530(70)(b), F.A.C., is as follows:

> Turbidity shall not be increased above background conditions within the South Florida Coral Reef Ecosystem Conservation Area, Biscayne Bay National Park, Florida Keys National Marine Sanctuary excluding canals, and Dry Tortugas National Park, as shown on the map titled "South Florida Coral Reef Protection Area", July 2019, which is incorporated by reference herein, or other areas of the state where coral reefs, hardbottom communities, or Serpulidae reefs (worm rock) are currently found. For the purposes of evaluating this criterion, background conditions shall take into account the natural variability of turbidity levels and shall be established following the methods described in the document Implementation of the Turbidity Criterion for the Protection of Coral Reef Resources, dated July, 2019, which is incorporated by reference.

The determination of background, under paragraph 62-302.530(70)(b), F.A.C., will include consideration of natural variability and allow for limited duration activities such as dredging or construction provided turbidity levels do not exceed an upper percentile of background levels (e.g., 90^{th} percentile). The logic behind the allowance of natural variability is that any corals present will be adapted to both the average turbidity levels as well as the range of natural variability around that average. However, longer duration (beyond natural variability) perturbations from the background condition may have deleterious effects on the resident coral. Thus, implementation of the criterion is intended to maintain the background turbidity magnitude, frequency, and duration.

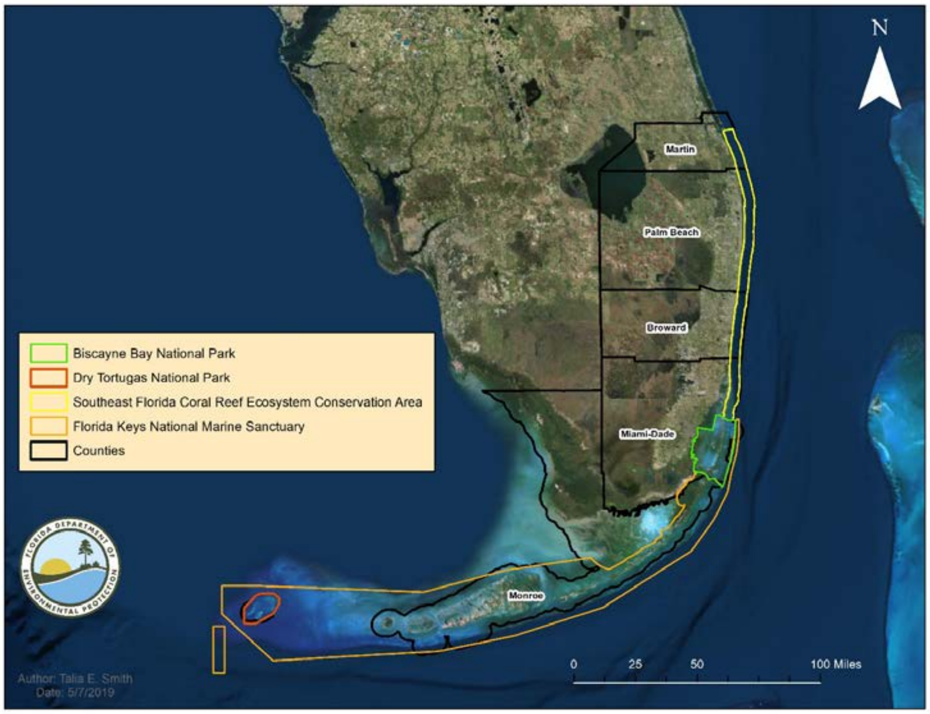

Figure 4. South Florida Coral Reef Protection Area.

6.1.1 Inclusion of Sabellariid Worm Reef Communities

The Department received public comments during the first round of Triennial Review workshops in May 2019 requesting that worm reef (Sabellariidae) communities along the Florida's southeast coast be considered in the revised turbidity criterion. Specifically, the commenters stated that worm rock communities were sensitive to turbidity increases and were threatened by activities that may smother these organisms. The main species of worm rock or tube worm found in Florida waters is *Phragmaopoma lapidosa*. These worm reefs thrive in high energy conditions and are distributed along a 320 km segment of the Southeastern coast of Florida from Key Biscayne to Cape Canaveral. Most sabellariid reefs are near landward edges in the intertidal and shallow surf zones (1-4 meters), however, some have been scarcely found up to depths of 100 meters and have also been found along channels of inlets with high tidal currents.

The biological processes of tube building by sabellariid worms serve important functions such as reef-building, accumulation of hardbottom and beach rock, and coastal protection (resiliency). The tube-worms help sort and lithify (petrify, change to stone) particles and are directly related to the accumulation of hardbottom beachrock. The tube-building activity of sabellariid worms promotes the formation of hardbottom substrate along Florida's southeast coastline, which supports the eventual formation of hardbottom epifaunal communities. Additionally, many species live among the worm reef structures, and the presence of these structures increases species diversity in the low diversity surf zone (Nelson and Main 1985).

Commented [JD1]: This sentence needs some work. It seems to combine several thoughts, but I'm hesitant to edit it myself as I'm not sure of the intended meaning.

The beachrock that is created by sabellariid worms has high material strength and can stand high energy waves, making this beachrock an important factor in the stability and development of a resilient coastline. Kirtley and Tanner (1968) recommend that sabellariid worm reefs should be protected and considered in future erosion control programs for beaches. Other studies that focused on the engineering aspects of worm reefs have found that they decrease wave action and trap sand on the landward side, reducing coastal erosion (Mehta 1973, Kirtley and Tanner 1968).

These worm rock communities are formed in high energy coastal environments that have naturally high turbidities; however, the sabellariid worms are sensitive to sediment burial and smothering over extended periods of time. Nelson and Main (1985) studied worm reefs under multiple burial conditions to assist with permitting decisions for beach nourishment projects. The study tested the effects of sediment burial on reef-building tubeworms under 5 different sediment types over durations ranging from 24 to 72 hours. The tested grain sizes ranged from coarse to fine sediments and included muddy sand with higher organic matter content. The percent survival was analyzed using two-way ANOVA tables with replication. The results of the burial experiment indicate that *P. lapidosa* can tolerate burial by any of the tested sediment types for up to 24 hours without suffering significantly increased mortality. Furthermore, at relatively cooler temperatures (17 - 23° C), burial by any of the sediment types resulted in no significant increase in mortality relative to controls. However, higher water temperatures (28 - 31°C), significantly increased mortality, which occurred after 48 hours for all sediment types. At higher temperatures, mortality due to burial by fine sediments greatly increased (Nelson and Main 1985).

P. lapidosa showed no adverse effects in high silt loads and high turbidity (e.g., up to 50 NTU) conditions (within a four-day period) if the silt did not bury the worms (Nelson and Main 1985). Silt is rapidly removed during beach nourishment in high energy conditions and dispersed via long-shore drift. However, if conditions do not allow for dispersal of silt, any type of burial of the worm reefs will likely result in the morality rates found in these experiments. The tolerance levels of the reef-building tubeworm larvae and other organisms that live alongside the worms have not been determined and may have higher sensitivities to silt and burial.

In conclusion, *P. lapidosa* can tolerate high silt load levels for at least four days, can only tolerate burial by sediment for 24 hours at high temperature, and may tolerate burial for at least 72 hours at cooler temperatures (17 - 23 °C). The available literate suggests that sabellariid worms are not particularly sensitive to turbidity or suspended sediments; however, they can be sensitive to sediment burial or smothering. There is an inherent relationship between turbidity and sedimentation, although it is highly dependent on water turbulence, flushing, and the characteristics of the suspended sediments. However, when all these factors are equal, there will be a greater likelihood of excess sedimentation and burial at higher turbidity levels. Therefore, the Department recommends applying the proposed narrative turbidity criterion for corals to worm rock to ensure the protection of this ecologically significant habitat. The Department expects that the background levels near the worm reefs will be higher than those typically found in coral communities, which will allow for beach nourishment projects, while still protecting the worm rock. Protection of the worm reefs will provide protection to the sabellariid worms; biological communities dependent on the habitat created by the worms; and promote coastal resiliency. Additionally, including worm rock habitats under the narrative turbidity criterion provides protection to the more turbidity sensitive hardbottom species, including hard and soft coral, that can colonize the hard substrate created by the sabellariid worms.

6.2 Propose a Numeric Criterion Based on Available Florida Data

The second alternative for revising the turbidity criterion is to adopt a criterion using the limited available data conducted in Florida and Caribbean (on species that exist in Florida). Although the data are currently limited and do not meet the data sufficiency requirements typically associated with derivation of aquatic life criteria, it can be argued that the existing criterion is not adequately protective and is allowing harm to critically important coral reef species and habitats in Florida. Therefore, the revision would represent a significant improvement in the level of protection afforded. One major technical limitation of this approach is the fact that a majority of the studies have been conducted using SSCs (mg/L), rather than turbidity (see **Tables 1** and **2**).

6.2.1 TSS, NTU, and Light Attenuation Translator Study

The Standards Development Section (SDS), the Coral Reef Conservation Program (CRCP) in the Office of Resilience and Coastal Protection (RCP), and BIPP have designed and are currently implementing a study to collect concurrent samples of total suspended solids (SSC, mg/L), turbidity (NTU) and light attenuation (PAR) in the vicinity of beach nourishment projects located in Southeast Florida. The primary objective of the study is to develop relationships between the three water quality parameters that, if determined to be sufficiently robust, would be used to either translate the literature-based thresholds from SSC (mg/L) to an equivalent NTU-based criterion; or, as translators that dredge and fill permittees could use to convert an SSC-based criterion to a protective NTU threshold for use during project implementation. If the latter options is used, the Department would include an option for a permittee to develop a site-specific translator based on the specific sediment characteristics of the site.

6.2.2 Potential Turbidity Threshold

As previously stated, the literature to support a specific turbidity or SSC threshold in Florida waters is limited; however, there are several specific studies that are currently or soon to be available that could be used as the basis for a best available science approach (**Table 2**). Telesnicki and Goldberg (1995) demonstrated significant differences in P:R in relatively tolerant *Meandrina meandrites* and *Dichocoenia stokesii* species at 14-16 NTU. Additionally, several articles state that SSC above 10 mg/L have the potential to cause significant sub-lethal and lethal effects to coral reef systems (Rogers 1990; Lirman et al., 2003; Flores et al., 2012; Erftemeijer et al., 2012). However, the SSC based thresholds from these papers would need to be translated to an NTU equivalent to be directly useful for criteria derivation.

The results of Fourney and Figueiredo (2017) suggest that turbidity levels less than 7 NTU near coral reefs will facilitate coral recruit survival. Additionally, a current graduate student at NOVA Southeastern University recently completed a study similar to Fourney and Figueiredo (2017) using a more sensitive *Acropora sp*. (Joana Figueiredo, personal communication). The data from this more recent study are still being analyzed and have not been published; however, a preliminary review of the data suggests a criterion in the range of 4 to 5 NTU would be protective of recruitment in the more sensitive *Acropora* (Joana Figueiredo, personal communication).

The best available science supports a revised turbidity criterion for areas with coral reef habitat at approximately <7 NTU, based primarily on the work by Fourney and Figueiredo (2017) and Telesnicki and Goldberg (1995). The value may be reconsidered based on pending study results from NOVA Southeastern University, which currently suggest a criterion of approximately 4 NTU. The recommended duration of the criterion is either an instantaneous value (single sample maximum) or daily average value. However, any criterion would need to account for natural variability. The recommendation is based on the duration of exposure used in the principle studies, particularly Fourney and Figueiredo (2017). Although Fourney and Figuerido (2017) conducted their study over 5 to 12 weeks, turbidity was only measured in the first 24 hours of the study, and thus represents an initial disturbance that was later linked to longer-term (5-12 week) sedimentation effects on settled larval polyps.

Table 4. Studies done with Florida and/or Caribbean species summarizing the sensitivity of coral and the response of corals and coral comminutes to different concentrations of sedimentation, suspended sediments, and turbidity.

Citation	Location	Species	Experimental turbidity levels	Summary
Fourney and Figueiredo, 2017	Florida	*P. Astreoides*	7 and 29 NTU for four weeks	Sedimentation reduced coral survival in increased temperatures. Dredged (fine) sediment reduced survivability. Natural sediment did not. Suggest to lower FL standard to <7 NTU.
Telesnicki and Goldberg, 1995	Hollywood, FL	*D. Stokesii*, *M. meandrites*	7-9 (7 days), 14-16 (7 days) and 28-30 NTU (28 days)	Exposure to 14-16 NTU (1 wk) reduced P:R ratios and increased mucous production. 28-30 NTU caused lesions on *M. meandrites*.

Citation	Location	Species	Experimental turbidity levels	Summary
Rice and Hunter, 1992	Florida sp, in lab	7 species	49, 101, and 165 mg/l for 10 days. Corals at 165 mg/l were exposed to 199 mg/l for 10 additional days	Colony survival was not impacted. Growth rates decreased at 165 mg/l for fastest growing species. Colonies died in 7-16 days under complete burial.
Kendall et al, 1983	Carysfort Reef, FL	*A. cervicornis*	25, 50, 100, 150 and 500 mg/l drilling mud for 24 hrs	Coral exposed to used drilling mud for 24 hrs showed decreased calcification rates (starting at 25 ppm), tissue protein (at 25 ppm), ninhydrin positive substance (at 100 ppm), zooxanthellae density (at 500 ppm).
Kendall et al, 1985	Carysfort Reef, FL	*A. cervicornis*	50, 100 mg/l kaolin for 24 hrs follower by 48 hr recovery	Coral exposed to 100 ppm showed reduced calcification rates and free amino acids (FAA). Calcification rates returned to normal after recovery period but FAA for 50 and 100ppm kaolin coral dropped after recovery
Rice, 1984	Florida	community study	49, 101, and 165 mg/l and 199 mg/l for 10 days.	Sub-lethal responses (bleaching, shrinkage of soft tissue, polyp death, decreased growth rates) to suspended sediments (165 mg/l) occurred in 10 days of exposure.
Vargas-Angel et al, 2007	Broward County, FL	*M. cavernosa*	Observations. control sites (24.7 and 29.2 $mg/cm^2/day$), dredging sites (58.4 and 40.9 $mg/cm^2/day$)	All coral showed mild to moderate stress and polyp retraction. High exposure led to tissue swelling, focal bleaching, mucous, reduced zooxanthella
Lirman and Fong, 2007	Florida Reef Tract	community study	*In situ* observations	reefs closer to shore have greater coral cover despite more stressors
Walker et al, 2012	Ports of Miami, Everglades and Palm Beach	community study	*In situ* observations	Dredging at 3 FL ports effected 176 hectares of reef through burial

Citation	Location	Species	Experimental turbidity levels	Summary
Jordan et al, 2010	Florida	community study	*In situ* observations	Sedimentation rates are higher and sediment is courser near shore. Resuspension is driven by waves. "Sand borrowing areas" had significantly higher sedimentation rates.
Miller et al, 2016	Port of Miami	several species	*In situ* observations	Dredging increased sedimentation on coral up to 200m away, increased coral mortality up to 700m away and increased sediment halos up to 300m away. Disease and bleaching occurred at impacted sites before controls
Malaio et al, 2008	Florida	25 species	*In situ* observations	Turbidity is one component driving keys wide variation in water quality. Macroalgae cover is increasing in coral communities
Fabricius, 2005	Literature review	several species	Various	Sedimentation: can severely degrade coastal reefs, exposure time, exposure amount and grain size/type affect impacts. Temperature organic content and bacterial activity confound. Affects settlement, recruitment and juvenile survival.
Dustan and Halas, 1987	Carysfort Reef, FL	community study	observations of benthic communities along transects	Coral living between 10 and 21 m showed decreases in abundance due to sediment. Some species shifted towards shallower waters due to light availability.
CSA, 2007	Key West, FL	community study	observations during dredging events	No significant change in coral cover occurred. Bleaching and paling occurred.

Citation	Location	Species	Experimental turbidity levels	Summary
Fisher et al, 2008	Broward County, FL	*M. cavernosa*, *S. bournoni*, and *S. siderea*	observations during dredging events	No significant change in coral cover occurred. Mild to moderate stress was seen on colonies, but recovery occurred post-dredging.
PBS&J, 2008	Florida	community study	observed outcomes of 26 dredging/filling projects in FL	Found 217 acres of reef were affected in total.
Lindeman and Snyder, 1999	SE Florida	community study	observed during beach widening events	Burial and loss of 5 hectares of near-shore hardbottom habitat. A 30x drop in fish density and 10x drop in fish diversity were observed.
Marszalek, 1981	Miami Beach	community study	observations during dredging event	1 cm of sediment covered nearby reef in less than 2 hours. Partial mortality and paling occurred. up to 32% of corals exhibited stress (near dredging).
Lirman and Manzello, 2009	South Florida	*S. radians*	burial of coral for 2, 4, 6, 24, 48 hr, 7 days and 21 days	Coral recovered quickly from 2-24 hrs of sediment burial at normal salinity levels. However, burial for >24 hours or burial under salinity stress led to slower recoveries, reduced growth rates, and, in some instances, mortality.
Lirman and Manzello, 2002	South Florida	*S. radians* (2-3cm diameter)	burial for 4, 7 and 10 days, under salinity of 20 psu and 15 psu	*S. radians* are highly tolerant and recover rapidly. At 20 psu and 4 days of burial coral showed slight reduction in photosynthesis. At 15 psu and 7-10 days of burial coral appeared dead but regrew tissue in 6 weeks.
Erftemeijer et al, 2012	Literature review	several species	effects of turbidity and sediment on corals	Dredging can have significant impacts on corals; however, the severity of the effects

Citation	Location	Species	Experimental turbidity levels	Summary
				depends on coral species and form; frequency, intensity and duration of turbidity, sediment type, and the presence of other stressors.
Lasker, 1980	Republic of Panama	*M. cavernosa*	*In situ* (5 days, 25 cm^{-2} per day) and laboratory (30, 60,120, 240, 360, 480 min, 74.4 mg dry weight cm^{-2} coarse and 18.5 mg cm^{-2} fine sediment) experiments	Field observations only small amounts of sediment accumulated on living tissue. Their morphology and large polyps allow them to passively shed most sediment and remove the rest with little energy input under fine and coarse sediment for laboratory experiment and existing natural sediment.
Rogers, 1983	Puerto Rico	*A. palmata*, *A. cervicornis*, *O. annularis*, *D. Strigosa*, *D. clivosa*	200, 400, and 800 mg/cm^2 of calcareious sediment appied 1 time. 200 mg/cm^2 applied daily, 3x a week, or 3x a month, for a month.	Single sediment application: at 200mg/cm^2 *A palmata* had algal growth, at 400mg/cm^2 *O. annularis* and *A cervicornis* had mild bleaching, *D. strigosa* was tolerant. *D clivosa* was damaged by repeated exposure other species were not
Abdel-Salam and Porter, 1988	USVI	*A. palmata*, *D. strigosa*, *M. annularis*	600 mg of sediment	All three species showed significant increases in respiration rates and photosynthetic rates for *M. annularis* and *A. palmata*. *Annularis* and *Strigosa* were better at clearing sediment than *A. palmata*.
Torres, 2001	SW Puerto Rico	*O. annularis*	Field sampling	Corals at high sedimentation sites had lower skeletal extension rates.
Torres and Morelock, 2002	Puerto Rico	*O. annularis, S. siderea, P. astreoides*	*In situ* observations	*M. annularis* cover decreased in reefs with high terrigenous sediments. Linear extension was

Citation	Location	Species	Experimental turbidity levels	Summary
				unaffected. *S. siderea* and *P. astreoides* have higher resilience to terrigenous sediments.
Acevedo et al, 1989	Ponce, PR	community study	*In situ* observations based on distance from terrigenous sediment influx	Species diversity and coral cover decreased with increased proximity to sediment influx. *M. cavernosa* dominated sites near influx and *A. palmata* were largely absent. *O. annularis* and *A. agaricities* were less common near influx.
Begin et al, 2016	Saint Lucia	community study	*In situ* observations, % terrigenous sediment of top 5 cm of sand	Percent terrigenous content in sediment loading was a significant indicator of coral cover, algal cover and % change in coral abundance.
Hernandez-Delgado et al, 2011	Vega Baja, PR	*Acropora palmata*	*In situ* observations	Turbidity from beach nourishment (10-50-fold higher than 10 NTU) along with sewage overflow led to average coral mortality of 52% in 2009. Mortality was highest near pollution sources, then nearshore, and lowest offshore.
Begin et al, 2013	Eastern Caribbean Islands	community study	observed benthic composition and %terrigenous sediment at 22 reefs on 11 islands	Increased % terrigenous content in sediment was linked with decreased coral and algae cover and increased sponge cover. Species assemblages were affected as well. *O. annualaris* decreased with increased terrigenous content.
Begin et al, 2014	Saint Lucia	community study	measured sediment accumulation and modeled sources	Over the 3-4 decades, input of terrigenous and calcareous sediment has increased 2-3x. Expansion of unpaved roads and road degradation plays a

Citation	Location	Species	Experimental turbidity levels	Summary
				large role in increased terrigenous input.
Carilli et al, 2009	Caribbean Reefs	*Faveolata*	measured skeletal growth rates at sites with varying effects from local stressors. Sedimentation was one of the local stressors included.	Corals exposed to high levels of local stressors maintained suppressed growth rates for 8 years post bleaching compared to 2-3 years for reefs with low stressors.
Dallmeyer et al, 1982	Jamaica	*O. annularis*	exposed to 525mg/L of suspended peat sediment for 2 hours. Received treatments during the day and at night	During the day exposure, reduced oxygen production but did not alter behavior. At night, respiration increased and clearing behavior occurred. Net production the following morning was significantly lower than pre-exposure levels.
Loya, 1976	Puerto Rico	*M. cavernosa, O. annularis, S. radians, S. siderea, M. meandrites*	Compared coral reefs at low (1.5 FTU or 3 $mg/cm^2/day$) and high (5.5 FTU or $14mg/cm^2/day$) turbidity sites	Coral diversity and % cover was lower at the high turbidity site. *M. cavernosa* dominated the high turbidity site. S. *radians*, *S. siderea* and *M. meandrites* were abundant, but *O. annularis* prevalence was low and colony sizes were smaller.
Nemeth and Nowlis, 2001	St. Thomas, USVI	community study	High sedimentation rates were 10-14mg/cm2/day. Low rates were 4-8mg/cm2/day.	During a bleaching event, 38% more coral bleached at high sedimentation sites compared to nearby low sedimentation sites.
Otero, 2009	SW Puerto Rico	N/A	sampled water quality indicators	Found sedimentation was rarely higher than $10mg/cm^2/day$ (only during storm events). Co-variation between sedimentation and turbidity was high.
Rogers, 1990	Review	N/A	Literature review	Mean sedimentation rates and suspended sediment concentrations for healthy reefs are <1-

Citation	Location	Species	Experimental turbidity levels	Summary
				10mg/cm^2/day and <10 mg/l, respectively. Chronic exposure to higher rates reduce coral cover, diversity, growth rates, calcification rates, and recruitment and increased branching morphology.

6.3 Coordinate with Universities to Collect Dose-Response Data

Given that the Department lacks the expertise and facilities necessary to carry out the necessary studies to produce dose-response data for the effect of turbidity on corals, DEP is investigating universities that have the needed capabilities. Potential university partners in Florida include NOVA Southeastern University, Florida International University, Florida State University, and University of Miami Rosenstiel School of Marine and Atmospheric Science (RSMAS). DEP staff have reviewed a substantial body of literature on studies that have been conducted throughout the world. Many of these studies could be replicated using Florida resident species. The additional studies would need to address effects on adult coral, larvae, and larval recruitment. Experiments involving larvae and larval recruitment must address both brooding and broadcast spawning species because the effects of elevated turbidity are likely different between the two reproductive strategies.

Dose-response studies can be modelled after similar studies previously conducted in Australia and NOVA Southeastern University. Bessell-Browne et al., (2017) described a well-controlled experimental design that could be used to evaluate the effects of turbidity and/or light reductions on coral species over varying durations (**Figure 5**). The experimental design used by Fourney and Figueiredo (2017) should also be considered for evaluating effects to settled larval polyps; however, the experimental design should be altered to include a control and the frequency of turbidity measurements should be increased (*i.e.*, daily measurements at a minimum).

Finally, the study design and associated analyses used by Ricardo et al, 2015 to assess the effects of suspended sediments on sperm availability for two Australian coral species (*Acropora millepora* and *Acropora tenuis*) should be evaluated for potential replication on Florida species.

Their study design allowed the calculation of fitted fertilization success curves (**Figure 6**) that were used to determine EC_{50} (Effective Concentration; Concentration of a substance that causes a 50% response) thresholds for fertilization success. Thresholds like an EC_{50} are typically used to develop acute and chronic water quality criteria. Most typically, a lower level of effect (e.g., EC_{20}) is used to develop protective criteria. The type of data provided by Ricardo et al. (2015) would be ideal for supporting the Department's efforts to revise the turbidity criterion.

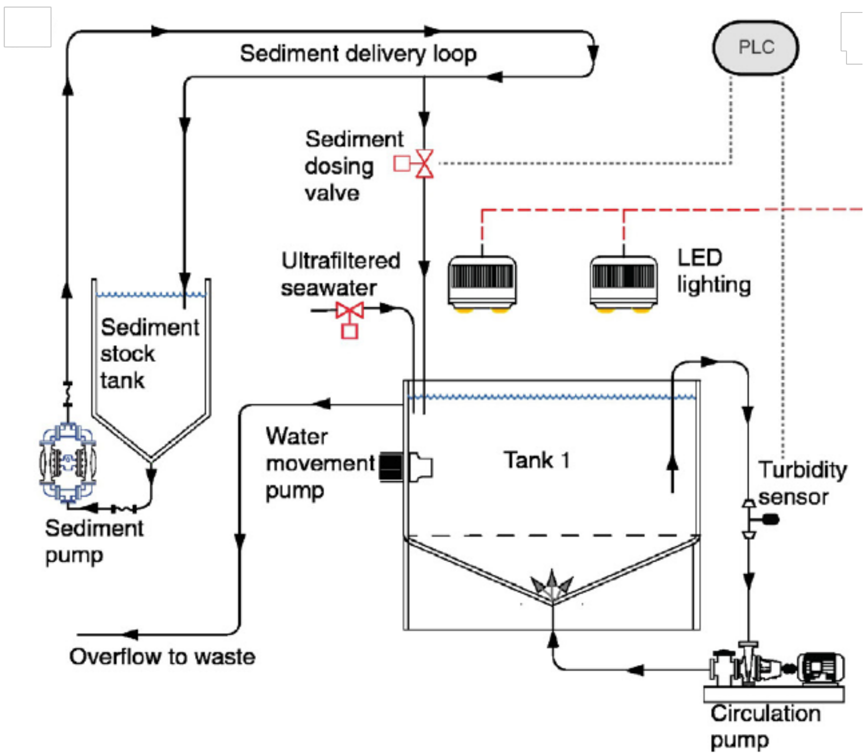

Figure 5. Schematic of the experimental dosing system used by Bessell-Browne et al. (2017) showing the sediment delivery (stock) tanks, and the position of the recirculation pump, water movement pump and in-line turbidity sensor. Delivery of sediment from the stock tanks was controlled by the programmable logic controller (PLC) system from input from the turbidity sensor. Figure taken from Bessell-Browne et al. (2017).

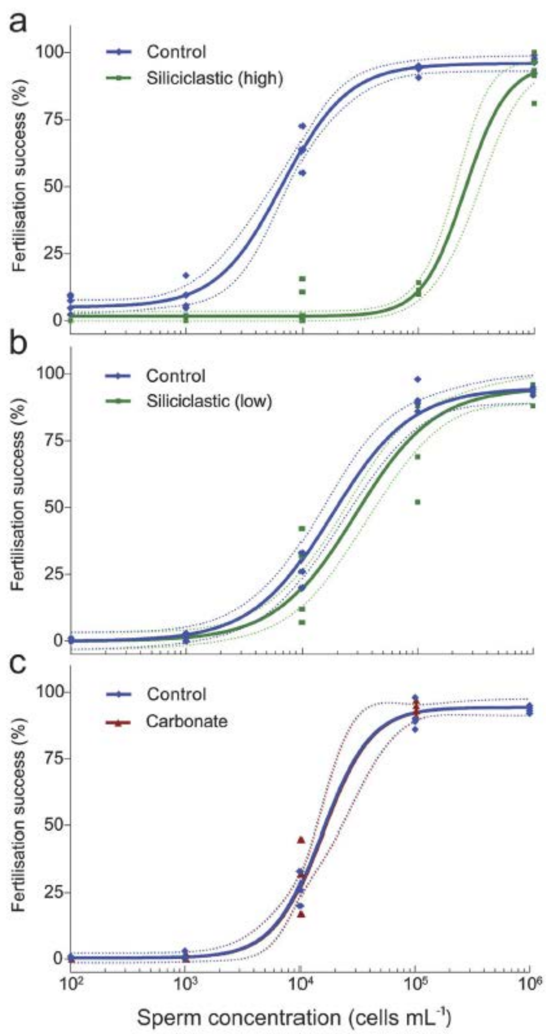

Figure 6. *Acropora tenuis* fertilization success (%) curves fitted to four-parameter logistic models plotted over a range of sperm concentrations (102–106 sperm m^{-1}). (a) Siliciclastic (high): 700 mg L^{-1}, green; control: 0 mg L−1, blue and (b) siliciclastic (low): 230 mg L^{-1}, green; control: 0 mg L^{-1}, blue) and (c) carbonate:230 mg L^{-1}, red; control: 0 mg L^{-1}, blue) suspended solid sediment concentrations. Dashed lines represent 95% confidence bands. Figure taken from Ricardo et al. (2015).

6.4 Recommend Option(s)

Three options were presented for moving forward with a revised turbidity criterion to protect coral reefs and hardbottom communities in Florida: 1) add narrative components to supplement and strengthen the existing turbidity criterion; 2) adopt a criterion based on the currently limited Florida and Caribbean data; or, 3) work with Florida researchers to design the appropriate studies to collect Florida specific data and move forward with a revised criterion once sufficient supporting research has been completed.

The Department recommends a combined approach that incorporates both near-term and longer-term revisions to the standard. First, we recommend moving forward with a revised narrative criterion (option 1) during the upcoming Triennial Review. Second, we recommend that the Department reach out, perhaps through the Coastal Office, to researchers in Florida universities in an attempt to encourage interest among the researchers in conducting the needed research and to adopt a numeric threshold, as described in **Sections 6.2 and 6.3**.

Pursuing option 1 acknowledges the fact that the existing turbidity criterion does not adequately protect sensitive aquatic species like corals. Although adoption of a numeric criteria would provide more regulatory certainty, more straightforward implementation, and be easier to assess in ambient waters under the Impaired Waters Rule, there is currently a lack of sufficient scientific studies to demonstrate a scientifically defensible threshold. There are currently only two Florida studies that can be used to develop a criterion. There is significant uncertainty regarding whether these studies, which only represent two species, provide representative information for all Florida species. It should be stressed that none of the three species are included among the list of NMFS endangered species, meaning that NMFS would most likely have concerns that the criterion is not sufficiently protective. Pursuit of a narrative criterion is currently the best option in the short-term.

Over the longer-term, SDS recommends pursuing partnerships with Florida universities to collect the dose-response data necessary to develop a numeric turbidity or SSC criterion to protect sensitive coral and hardbottom communities (Option 3). If successful, the Department could, in the future, revise the criterion to include more specific numeric thresholds linked to sensitive coral responses. Doing so will overcome the limitations of the narrative criterion listed above. It could also potentially allow for more complex expressions of duration and frequency than can be currently developed. The duration of exposure to elevated suspended solids or turbidity is critical to coral responses. Corals may be able to withstand very high concentrations of suspended solids for short periods of time, but conversely show sensitives to much lower concentrations over longer periods of exposure. The combination of concentration and duration are critical to the resultant response, as is the nature of sediment. Pursuing option 3 would afford an opportunity to fully investigate the critical durational component of the dose-response relationships.

7.0 Economic Benefits of Coral Reefs

Water quality criteria are established to protect the designated uses of a state's waterbodies, including aquatic life (flora and fauna). Economic costs are not a consideration when establishing criteria, although economic costs may be considered when establishing designated uses, antidegradation evaluations, and when applying moderating provisions such as variances and mixing zones. Even though economics is not considered in the establishment of criteria, it is important to understand the significant economic benefits Florida receives from a healthy reef ecosystem.

The economic value of an ecosystem is defined as the total value of the goods and ecological services that it provides. Coral reefs provide a number of economic and ecological benefits. In general, coral reefs serve as natural barriers and wave breakers against strong ocean waves and storms (*i.e.*, increase coastal resiliency), support ecotourism, and create a natural fishing resource.

When coral reefs frame a coastline, they provide protection from naturally occurring erosion, large waves, and intense storms. Reefs serve as natural breakwaters that absorb incoming wave energy, thereby protecting the infrastructure and habitat on the shore. For example, a study performed in Guam concluded that the average yearly damage to the island from typhoons is $4.3 million USD (Beukering et al., 2007). The same study estimated that the total cost would increase to an annual damage cost of $12.7 million USD without the services provided by coral reefs. Cesar et al. (2003) estimated that reefs annually provide $172 million and $9 billion in protective services in Florida and worldwide, respectively. Storlazzi et al., (2019) conducted an analysis of the value provided by U.S. coral reefs in coastal hazard reduction caused by flooding and erosion form extreme weather events. They estimated that coral reefs provide over $420 million in protective services to Florida on an annual basis (Table 5).

Table 5. Annual value of protection provided by coral reefs by Florida region (From Storlazzi et al., 2019).

Measure	Florida Peninsula	Florida Keys
Number of People Protected	4,947	716
Impacts to Buildings (2010 U.S. dollars)	323,835,761	32,125,237
Impacts to Economic activity (2010 U.S. dollars)	42,970,125	26,686,848

Ecotourism is an important source of revenue for many countries, including the U.S. Healthy coral reefs support a wide variety of animals that attract ecotourist visitors and other recreational users of the area. Millions of people flock to coastlines around the world every year to experience and participate in recreational activities. This large number of tourists creates a demand for services and amenities employing an entire tourism industry. Many visitors choose the location of their visit based on the appearance of beaches, proximity to coral reefs, and accessibility of various water sports. A healthy coral reef is essential to maintaining these qualities. For example, in Colombia, the average money spent by visiting divers on the coral reefs is $84.70 per person per day. The overall annual value of recreational diving on the reefs within the national park is $658,359.00 (Trujillo 2017). Similarly, 200,000 divers and three million snorkelers visit Hawaii each year, bringing the total recreational value of Hanauma Bay to $31,021,099 per year (Beukering 2004).

A five-year study found that the average visitor made 6.31 trips, at an average value of $463 per visit, to Florida's coral reefs for the purposes of diving, snorkeling, or glass bottom boat tours (Bhat 2003, Brander and Beukering 2013). Protecting the area, or adding marine protected areas, leads to a 200% increase in fish abundance, 100% increase in water visibility, and a 100% increase in coral quality. Protection also increases the number of times a tourist will visit the ecosystem. Protection allows for 4.99 more trips on average for divers, 3.88 more trips on average for snorkelers, and 2.70 more trips on average for glass bottom boat tours (Bhat 2003, Brander and Beukering 2013). Johns et al. (2001) reported that reefs generate 70,400 full time and part time jobs per year and $4.4 billion in local sales in South Florida. The coral reef ecosystem is an integral part of Florida's economy and can vary in influence based on location.

A 2001 study conducted by Johns et al. examined four different counties in South Florida for the amount of reef related sales, income generated by reefs, and employment created by reefs (Table 6). The total income of the reef related sales for the four counties was nearly $2 billion.

Table 6. Average sales, income, and employment for the year 2000 in four different South Florida counties. Number adjusted for inflation to reflect 2019[3] prices (Johns 2001).

County	Reef Related Sales (millions of dollars)	Income (millions of dollars)	Employment (number of full time and part time jobs)
Palm Beach	530.9	211.2	4,500
Broward County	1,647	853.6	19,000
Miami-Dade County	1,305	623.1	13,000
Monroe County	539.8	157.6	8,000

Brander and Beukering (2013) determined that Florida coral reefs provide a mean annual value of $10,428[4] per hectare (2007 prices) for all tourism and recreational activities, which equates to $12,714 per hectare ($5,145/acre) in 2019 when adjusted for inflation. Additionally, Brander and Beukering (2013) estimated that total annual recreation value of the Florida reef track is $174 million dollars (2007 prices) or $258.4 million dollars adjusted for inflation (2019). Their estimate was based on a total coral area of 36,000 hectares (88,958 acres) and included recreational fishing, scuba diving, snorkeling, and glass-bottom boat rides.

[3] All inflation adjustments were calculated based on the Consumer Price Index (CPI) Inflation Calculator (https://data.bls.gov/cgi-bin/cpicalc.pl) based on a comparison between December 2007 and May 2019.

[4] Equates to $4220 per acre.

Coral reefs support a vast diversity of life. Countless varieties of fish, invertebrates, and mammals use coral reefs for foraging, territory, nursery grounds, and cleaning stations. This high volume of life allows commercial and recreational fishing industries to flourish. Many people in countries with vibrant coral reefs are dependent on the fish that reside within the reef. Tourists are able to fish from land, boat or even dive the reef to spearfish. For, example, in Guam, the value of the fishing industry totaled $3.96 million USD per year. This included both the recreational and commercial fishing industries (Beukering 2007). Other estimates place the value of coral reef fisheries at $5.7 billion annually worldwide (Cesar 2003). By protecting coral reefs, the fishing industry benefits as the reef serves as vital nursery grounds for many large fish.

Coral reefs play an essential role in the health and economy of coastal areas. By adopting protective measures, corals can protect the shoreline and existing infrastructure from harmful waves and storm surges, create a thriving tourism industry, and promote local fisheries which boosts the local economy.

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