Indian River Lagoon Basin Management Action Plans Muck Removal Project Credit Guidance

Florida Department of Environmental Protection

Revised Draft June 6, 2022

Overview

Projects that remove muck overlying the natural, sandy substrate of Indian River Lagoon (IRL) and its tributaries are beneficial to the recovery of seagrasses, a critical habitat within the IRL system. Muck deposits contain nutrients that flux into the water column, increasing the abundance of phytoplankton, drift macroalgae, and epiphytes that attenuate light and constrain seagrass growth and propagation. Even for deep-water areas where seagrass coverage is not expected, muck deposits are a major source of nutrients and turbidity that readily spreads affecting the broader, shallower seagrass areas of the IRL. For these reasons, DEP considers the control and removal of muck deposits within the IRL as a beneficial nutrient reduction strategy.

Most IRL muck originates from upland soils and vegetation. For this reason, stringent watershed soil-erosion control and soil/vegetation containment measures are needed. Without such measures in place, muck removal will need to be frequently repeated, which is neither cost-effective nor time efficient. Ideally, muck removal projects should be performed in conjunction with soil and vegetation retention programs, including public awareness activities, which limit the amount of muck material deposited into the IRL.

Muck removal projects are required to meet applicable permitting requirements along with any evaluation and tests of the muck as specified by state and federal regulatory agencies. The data supporting this guidance, and the guidance itself, are specific to and only applicable to the IRL system with respect to determining Basin Management Action Plan (BMAP) nutrient reduction credit for muck removal. This guidance is best applied to the IRL proper and to downstream marine or estuarine tributary reaches open to the IRL and canals.

Guidance Items for Muck Removal Project Credit

Muck removal projects must meet the following guidance items or criteria to receive BMAP credit for nutrient reductions:

1. Definition of Muck and Minimum Thickness for Credit.

Definition of IRL muck: To be considered IRL muck (Trefry and Trocine, 2011), the sediment must be dark grey to black in color (2.5 – 4, Munsell scale) and contain > 75 % water by weight and ≥ 10 % organic matter (on a dry weight basis) as measured by percent loss on ignition (LOI) at 550° C. Another typical characteristic of IRL muck that can set it apart from other organic sediments is that it contains clay and silt that is ≥ 50 % of the sample by dry weight. This latter characteristic is provided as an informational item only and does not necessarily need to be quantified for the sediment in question to be considered IRL muck.

Minimum muck thickness relative to conventional dredge methods: Presently, the minimum sediment depth or layer thickness that the common or more conventional methods of dredging sediment (e.g., hydraulic, mechanical bucket) can achieve is about 30 centimeters (cm) (~ 1 foot). Therefore, if no other technologically or economically feasible method of removing muck that is capable of shallower and more precise dredge depths is available, then a median muck deposit thickness of 30 cm or greater is allowable for credit. There would be a high risk for significant over-dredge into the natural substrate if a conventional dredge method is planned for any project area in which the median muck thickness is less than this 30 cm thickness.

Minimum muck thickness relative to non-conventional dredge methods: Non-conventional dredge methods are defined here as more "surgically" precise methods capable of removing sediment at sediment depths or sediment-layer thicknesses that are less than 30 cm. If a non-conventional method is planned for a project, then a minimum median muck thickness for a project area can be 10 cm (~ 4 inches). Any deposit or proposed project area that contains muck (as defined above) but is less than 10 cm thick (as a median) is regarded as a less important, long-term nutrient-source threat to the IRL (J. Trefry, personal communication, 7/3/2018).

The thickness of the deposit can be manually measured using a graduated pole (pole specifications are found in Appendix A, under "Equipment") that is pushed into the sediment to the point of refusal. An estimate of the area of muck material to be removed that meets the above definition of muck is also needed and is required to calculate BMAP credit. Other survey methods (e.g., remote sensing) can be used, but must be approved by DEP; and, for the sake of data quality control, should be statistically validated by the manual pole method.

Scientific evidence indicates that very thin deposits of 10 cm or less can flux nutrients (if there is a fairly constant carbon input and a concentration gradient of nutrients in the sediment) and that layers of muck ≤ 5 cm may even cease to have a net flux of nutrients within 5 – 10 years (J. Trefry, Florida Institute of Technology [FIT], personal communication, 7/3/2018). However, it has also been observed to date that ~ 90 % of the sediment samples taken Lagoon-wide less than 30 cm thickness of probe-penetrable sediment fall below the minimum technical criteria that constitute the definition of IRL muck (> 75 % water by weight and ≥ 10 % organic matter dry weight). In other words, probe-penetrable deposits that are < 30 cm are more than likely NOT to be IRL muck, as technically defined in this guidance document. This may be because such thin layers are readily mixed with natural substrate sands and incoming sands and clays that decrease the overall organic content. Thicker organic-rich deposits (≥ 30 cm) are more likely to be IRL muck as defined and as supported by the data (A. Fox, FIT, personal communication, 8/6/2019; Trefry et al., 2019). Finally, the cost of removing shallow (< 30 cm) deposits and the higher risk of over-dredging to do so may be prohibitive unless performed in conjunction with the removal of thicker deposits adjacent or nearby.

2. Removal to the Natural Substrate.

Regardless of thickness, BMAP credit will be considered for removal of muck deposits if the permitted dredge-depth target is to or within the background or natural substrate (e.g., sandy, muddy sand, or sand-shell sediment). Muck must be completely removed down to the natural substrate throughout the proposed project area to the maximum *areal* extent possible, with consideration to safety and engineering limitations, to maximize the nutrient reduction benefits of the project.

The intent of this guidance is to encourage environmental dredging that maximizes muck removal by area as well as by depth. It may not be possible to remove sediment close to docks, stream banks, and canal walls for environmental or structural liability reasons. The effect of structures and banks on dredging credits will vary by situation, but in general, the portions of the project area not dredged are not included in the muck removal area requested for credit. The muck that cannot be removed within or adjacent the project area increases the likelihood that the dredged bottom will be re-covered by the muck left behind, reducing or negating the benefit of the dredge project. Any applied BMAP credits may be subject to change if the project is not providing sufficient removal of nutrient fluxing muck (if muck thickness is ≥ 30 cm).

3. Upstream Limit for Tributaries and Canals.

A salinity ≥ 1 practical salinity unit (PSU) will be used to delineate potential BMAP-credited muck removal projects within any given reach or segment of a tributary or canal waterway that is hydrologically open to the IRL. The presence of a dam or other water control structure that bisects an IRL tributary or canal waterway will also be considered as a reasonable upstream limit or boundary for muck removal projects that can receive BMAP credits.

The minimum salinity limit is imposed because fine-grain material and organic matter suspended in the water column and transported from a freshwater reach of the waterway to its estuarine reach will start to flocculate and settle to the bottom as salt concentration increases to about ≥ 1 PSU. As these flocs settle out of the water column, they form fresh deposits of sediment including muck.

If a hydrologic barrier (e.g., dam, weir, or some structure that impedes tidal flow) is present in the waterway, then it is likely that freshwater exists upstream of the barrier. Moreover, the waterway upstream of the barrier and its maintenance (including debris removal and sediment dredging) is the responsibility of a local or regional agency that has the budgetary and permitted authority to clean out accumulated debris and sediments upstream of the barrier and should do so periodically as a watershed muck and nutrient source control measure. Therefore, the award of BMAP credit will be limited to muck removal projects downstream of hydrologic barriers and where salinity is ≥ 1 PSU.

4. Sediment Nutrient Flux Rates and BMAP Credit Determination.

Nutrient flux rates from both muck and its proximal natural substrate will be used to determine BMAP credit for muck removal projects. Flux rates are estimated from the muck organic matter content measurement described in Appendix A. Sediments, organic enriched or not, have a potential to release nutrients. However, organic-enriched sediments such as muck, have the greater potential to release considerably more nitrogen (N) and phosphorus (P) than the less organic, sandier sediments that make up the natural bottom or substrate of the IRL. Compared to sandy or sand-shell sediments, muck has higher nutrient (carbon [C], N, and P) content and larger microbial populations that degrade or break down organic matter (mineralization), readily diffusing dissolved N (mostly as ammonia) and P (mostly as phosphate) to the overlying water column. Muck susceptibility to resuspension can exacerbate nutrient release to the water column due to its greater exposure to dissolved oxygen (oxidation mineralization). Temperature may also play an important role in flux rates (Fox, A.L. and J.H. Trefry. 2018) and should be considered during the planning stages of muck removal activities when seeking BMAP credit.

Literature-derived nutrient flux rates: Published or reported estimations of nutrient flux rates from sandy (natural) sediments and from muck sediments are presented in **Table 1**.

Reported ammonia-N flux rates from natural substrate sediments range from 220 kilograms per square kilometer per year (kg/km^2/yr) (Montgomery et al., 1979) to 4,700 kg/km^2/yr (Reddy et al., 2001). In strong contrast, ammonia-N flux rates from muck ranged from 9,800 kg/km^2/yr (Trefry et al., 1992) up to 40,000 kg/km^2/yr (Fox and Trefry, 2018).

Reported P flux rates for natural substrate sediments range from 40 kg/km^2/yr (Reddy et al., 2001) to 400 kg/km^2/yr (Trefry et al., 1992); and for muck, the range is 1,000 kg/km^2/yr (Trefry et al., 2016) up to 10,000 kg/km^2/yr (Fox and Trefry, 2018).

Table 1. IRL Sediment Flux Rates from Literature

1 South Central IRL
2 Throughout IRL system
3 North IRL
4 Turkey Creek
N/A: Not applicable

Source	Muck Ammonia Flux (kg/km2/yr)	Natural Substrate Ammonia Flux (kg/km2/yr)	Muck Phosphorus Flux (kg/km2/yr)	Natural Substrate Phosphorus Flux (kg/km2/yr)
Montgomery et al., 1979$_1$	N/A	220	N/A	N/A
Trefry et al., 1992$_2$	9,800	1,230	2,170	400
Reddy et al., 2001$_2$	N/A	4,730	N/A	40
Trefry et al., 2016$_3$	10,000 – 30,000	N/A	1,000 – 5,000	N/A
Fox and Trefry, 2018$_4$	20,000 – 40,000	N/A	5,000 – 10,000	N/A
Average for Natural Substrate	N/A	2,100	N/A	200

BMAP Credit Determinations for Current or New Projects: Nutrient flux rates from both muck and from natural substrate sediments will be applied as a difference between the two in the determination of a net flux rate and annual loadings and, conversely, potential nutrient reduction. As such, this determination of potential nutrient reduction is considered the BMAP credit that can be awarded to a muck removal project. The net flux rate is determined from the flux rate from the muck minus the flux rate from the natural, sandy substrate. Site-specific sediment measurements and calculated flux rates per project area are requirements to determine BMAP credits. Muck sediment sampling and other requisite measurements are specified in **Appendix A**.

The calculations to be conducted are based on the strong relationship between benthic fluxes of N and P and the organic matter content or the % LOI of the sediment (Fox and Trefry, 2018). The primary permittee or stakeholder of the project shall follow the method prescribed in **Appendix A.** to conduct the necessary field and laboratory measurements and calculate N and P fluxes from the project area.

This method relies on site-specific data, collected from the project area pursuant to methods described or cited in **Appendix A**, which will serve as the data input to the method equation for calculating a flux rate. For the sake of convenience, without having to run the equation calculation, one can instead refer to the "look up" table of flux-rate values (**Table 2**) that has been developed based on the expected % LOI ranges for IRL muck. The values in **Table 2** are based on an equation that describes the strong correlation of % LOI with IRL muck N flux and P (Fox and Trefry, 2018).

Table 2. Fluxes of Nitrogen and Phosphorus from IRL Muck Sediments as a Function of Sediment % LOI @ 550°C

% LOI @ 550°C	Ammonia-N Flux ($kg/km^2/yr$)	Phosphorus Flux ($kg/km^2/yr$)
10.0 – 10.9	8,000	400
11.0 – 11.9	9,000	500
12.0 – 12.9	10,000	700
13.0 – 13.9	11,000	800
14.0 – 14.9	13,000	1,000
15.0 – 15.9	15,000	1,200
16.0 – 16.9	17,000	1,500
17.0 – 17.9	20,000	1,800
18.0 – 18.9	25,000	2,300
19.0 – 19.9	31,000	3,000
≥20	41,000	3,900

At this stage it is advised to adjust the flux calculations for any temperature changes that may occur with depth or time. The adjustment method described by Fox, A.L. and J.H. Trefry. 2018, and used in **Equation 1.**, normalizes temperature conditions between monitoring periods. The calculation uses both the difference between in-situ temperature to a standard of 25° Celsius and the Q_{10} constant derived for each nutrient parameter.

EQUATION 1.

$$Flux_{Adjusted} = 10^{\left[\frac{\log Flux}{\frac{10}{Temperature - 25°C}}\right] + [\log Q_{10}]}$$

In Equation 1, the Q_{10} values for ammonium and phosphate are 2.9 and 3.0, respectively (Bailey, 2005). Both the $Flux_{muck}$ and the $Flux_{natural}$ values in Equation 2 (below) should be adjusted for temperature conditions at the time the measurements were taken. An example of how to apply all of the equations may be found in **Appendix B.**

The flux rate determinations and calculation of BMAP credits can be calculated using the following equations:

EQUATION 2.

$$\text{Flux}_{net}\ (\text{kg/km}^2/\text{yr}) = \text{Flux}_{muck}\ (\text{kg/km}^2/\text{yr}) - \text{Flux}_{natural}\ (\text{kg/km}^2/\text{yr})$$

$Flux_{muck}$ is the *median* flux value of all samples based on the sample site % LOI, as can be referenced in **Table 2**. $Flux_{natural}$ is the *average* of the literature values for natural substrate sediment, rounded to the nearest 100, as presented in **Table 1**.

The *net* flux calculated from **Equation 2** is relevant to the mass reduction of N or P potentially fluxed in the IRL system upon completion of muck removal to the natural substrate. Sediments of the natural substrate have the potential to flux nutrients to overlying waters, but that rate of flux should be much lower than that of muck. Therefore, the difference between the fluxes from muck and from natural substrate should represent a net reduction in flux when the muck is removed from the system. Because of this relationship, the mass nutrient reduction benefit can be related to BMAP credit by using **Equation 3**:

EQUATION 3.

$$\text{BMAP Credit (lbs/yr)} = \text{Flux}_{net}\ (\text{kg/km}^2/\text{yr}) * \text{Project Area (km}^2) * 2.2\ (\text{lb/kg})$$

BMAP credit is equivalent to the net reduction in nutrient loading, expressed as pounds per year (lbs/yr), from the project area's sediments following project completion. For planning purposes, **Equations 2 and 3** can be used to calculate a *provisional* BMAP credit under pre-dredge conditions; however, it is the *post dredge* set of N and P net flux values that determines BMAP credits. Post dredge conditions must be assessed within six months of project completion.

Once BMAP credits are submitted, the nutrient reduction benefit must either be maintained or, if the reduction benefit over the lifespan of the project is determined to not be able to achieve the same level of reduction, additional projects equivalent to the initial credit must be submitted. At five-years post-dredge and nine-years post-dredge, the efficacy of the muck removal can be assessed.

EQUATION 4.

$$\text{Muck}_A\ (\text{cm/yr}) = [\text{Muck}'\ (\text{cm}) - \text{Muck}^0\ (\text{cm})]\ /\ 5\ \text{years}$$

At five-years post-dredge, the rate of muck accrual (Muck_A) is determined by comparing the current muck depth (Muck') to the post-dredge muck depth (Muck^0). If muck is accruing at a rate greater than 2.5 cm/yr, as determined by use of **Equation 4**, BMAP credits may need to be revised following the next assessment period and additional projects may need to be considered.

Similar to the five-year assessment, the nine-year post dredge assessment looks at muck accrual rate as well to determine if the assigned credit needs to be revised. In addition to assessing the accrual rate, additional measurements of % LOI must be taken at each site in the project area if median muck thickness is found to be ≥ 30 cm. Revised credits may be calculated using **Equation 5**, where the new load (Load_{9yr}) from the revised net flux based on the new % LOI measurements is subtracted from the existing BMAP credit.

EQUATION 5.

$$\text{Revised Credit (lb/yr)} = \text{BMAP Credit (lbs/yr)} - \text{Load}_{9yr}\ \text{(lbs/yr)}$$

A median, project-area muck thickness that is less than 30 cm will NOT be subject to a reduction in BMAP credits and those credits can be extended another 10 years. These guidance criteria apply to any project utilizing conventional dredging methods or nonconventional, thin-layer muck removal methods. An example project using these calculations is available in **Appendix B**.

5. Reporting Requirements.

Pre-Dredge Sampling Plan: Following delineation of the muck area to be dredged, a sampling plan is to be prepared in accordance with **Appendix A** and submitted to DEP for review. It is recommended that a cursory check on salinity and muck thickness be conducted in the project area prior to developing a sampling plan to ensure that those two measurements meet the criteria for project credit eligibility (i.e., ≥ 1 PSU and ≥ 30 cm thickness).

Upon review of the sampling plan by DEP, sampling may begin. It is important to note that the pre-dredge muck sample data (thickness, % LOI) are required for the calculation of BMAP credits, the estimation of muck accrual rates in the fifth-year post-dredge, and possible revision of BMAP credits by the tenth-year post-dredge.

Within 180 days Post-Dredge Request to Verify BMAP Credits: Post-dredge muck thicknesses and nutrient flux rates, both reported as medians over the project area, should be determined within 180 days following the project's completion date. These determinations are to be included in a formal request to DEP, initiating a review and approval process intended to establish the BMAP credits to be awarded for the first 10 years post-dredge.

Preventing sediment from entering waterways is preferable to repeated removal of muck deposits. Upland soil erosion has been identified as a prevalent source of muck (Pandit and Swain, 1992; Windsor and Steward, 1987; Trefry et al., 1987) and should be managed to prevent or slow the deposition of new muck. At the time a request is made for an award of credits, the requesting entity shall also provide a plan for how they will reduce the amount of sedimentary material entering waterways. A list of sedimentation prevention efforts either proposed or completed must be submitted with the request for final credits.

Fifth-Year Post-Dredge/Muck Accrual Rate: In the fifth-year post-dredge, a check of the project's median muck thickness is required and is to be reported to DEP. This should be done utilizing the same sampling site locations and methods as specified in the project's sampling plan. A check of muck thickness at the five-year mark will provide the data necessary to calculate a muck deposition or accrual rate. If that rate, based on the thickness differential between the medians of the < 180-day post-dredge and the fifth-year post-dredge, is > 2.5 cm, then it's likely that the median muck thickness by year nine or 10 could reach ≥ 30 cm, the threshold for credit revision.

Even though credit reduction or sustainment will not be considered based on the fifth-year check, its results can drive certain actions leading up to the tenth year. Such actions may entail identifying and mitigating sources of soil-borne sedimentation, including the possible need to rehabilitate old stormwater treatment systems, and would include preparing for the possible revision of the project's BMAP credits by the tenth year if soil inputs are not sufficiently abated. Details on credit agreement within the BMAP are described in Florida Statute 403.067(7)(b). In summary, the intervening years between the fifth year and tenth year would provide time for the project's managing agency to address necessary muck control and survey measures to ensure continued curtailment of fresh inputs of muck material and assess the need for eventual re-dredging.

Ninth-Year Post-Dredge/Report on Final Credits Status: In the ninth-year post-dredge, the primary permittee or managing agency for the muck-removal project is responsible for repeating the muck thickness measurements, muck sampling, and flux determinations in accordance with guidance item #4 above and methods in Appendix A and reporting those results to DEP.

Observations of land use changes, degraded stormwater treatment or erosion control efficiencies, other soil erosion phenomena in the project's watershed, and/or of any climatic events that could affect muck deposition depth and rate should be noted in the report. DEP shall use the report to evaluate within the ninth year whether project credit should be reduced or maintained in the tenth-year post-dredge and be in effect for up to an additional 10 years. The amount of credit may be reduced if the median thickness of re-deposited muck is ≥ 30 cm and would be based on a new muck loading as described in **Equation 3**.

6. Time Limitations and Time Extensions on Awarded Credits.

a. Re-evaluation at 10 years Post-Dredge: Muck deposition in the IRL system is a nearly continuous process due to upland runoff; therefore, credits assigned to a muck removal project are initially time-limited to a minimum of 10 years. One year prior to that 10-year time limit, the project area shall be surveyed for muck deposition and total nutrient loading (lb/yr) from muck-flux. The data collected from the survey will be used to assess whether project BMAP credits will be reduced or be sustained per guidance item #4.

b. Extension of 10-Year Post-Dredge Time Limit: The initial time limit of 10 years can be extended by an additional 10 years if the primary permittee or managing agency can meet the following two requirements: (1) Demonstrate that effective watershed source controls are in place or in progress and, (2) the median muck thickness over the project area is < 30 cm, for which full BMAP credit will be sustained for another 10 years. Otherwise, muck flux rates and corresponding muck loadings of N and P will be determined and used as specified in guidance item #4 above to determine reduced BMAP credits. If credits are reduced to 0 (per guidance item #4), then 6c below applies.

c. If credits are reduced to "0"at 10 years Post-Dredge: Project credits may effectively expire (be zeroed out) in the tenth-year post-dredge based on the field survey determinations explained in 6a and 6b above. This would be the case, in particular, if the ninth-year re-survey reveals that the newly accumulated muck loading in that year is equivalent to or exceeds that of the pre-dredge muck loading.

7. Dredged Material Stored Away from Surface Waters.

This item will be addressed through the regulatory permit process, but it is worth mentioning here as well. Dredged material from a muck removal project, whether contained at a temporary or permanent disposal management site, must be completely removed from contact with the surface waters of the IRL system, including any waterway conveyances that drain to the IRL or its tributaries. The distance from surface waters that the dredged materials are stored for *temporary* containment and handling will be determined on a case-by-case basis through the permitting process. Brevard County recommends a distance of at least 200 meters between a *permanent* containment site and surface waters of the IRL system. Again, permit requirements may dictate the manner and location of storage and handling of dredged muck and other associated sediment material.

8. Source Control Requirements.

An important consideration in the awarding of BMAP credit for muck removal projects is the implementation of actions that limit the deposition of upland soils and vegetation in the IRL and its tributaries. Many of the activities required by municipal separate storm sewer system (MS4) permitting also address control of upland erosion and are appropriate source control measures. Source control actions that can be considered as a minimum for credit include:

- Erosion and Sediment Control Ordinance;
- Landscaping Ordinance;
- Street Sweeping;
- Maintaining a Vegetative Cover on Banks of Drainage Features (canals, ditches, streams); and
- Outreach Program Informing Residential and Commercial Property Owners about sediment control.

The implementation of additional best management practices, including educational and training programs, which address erosion of upland soils and stabilization of shorelines is encouraged. Some examples of other actions include construction of riparian buffers along public waterways, citizen outreach programs that encourage construction and protection of riparian areas located on private property or provides training for property owners on how to manage their property that fronts a waterway, and construction of rain gardens or swales.

Vegetated buffers immediately upland of the waterway and aquatic emergent vegetation along upland/waterway margins are effective in controlling suspended solids and reducing nutrients both as surface and subsurface discharges (Mayer et al., 2006). Living shorelines where vegetation is mixed with structural material (living and nonliving) can be an enhancement of a vegetated buffer or riparian buffer (http://floridalivingshorelines.com/).

9. Report Documentation Needed for Project Evaluation and Award of BMAP Credit.

Appendix B provides an outline of an example project from beginning to end. A sampling plan in accordance with this guidance document may be provided to the Department prior to project implementation. In addition, a spreadsheet tool is also available for use in tracking project progress and may be used for determining BMAP nutrient reduction credits. Special thanks to Joel Steward for the creation of the spreadsheet tool.

10. Contact Information.

To submit muck removal projects for the IRL BMAP(s) or if you have questions, please contact the appropriate IRL Basin BMAP Coordinator at DEP, Division of Environmental Assessment and Restoration, Watershed Planning and Coordination Section, Tallahassee, Florida; phone # 850-245-7508.

11. Acknowledgements.

Our thanks to following staff and advisors who provided significant input into this guidance document; Joel Steward (Dredging & Marine Consultants), Austin Fox (FIT), Shailesh Patel (Dredging & Marine Consultants), Virginia Barker (Brevard County), Tiffany Busby (Wildwood Consulting), Mary Paulic (DEP) and Stacy Cecil (DEP).

12. References.

Bailey, E.M., 2005. Measurements of Nutrient and Oxygen Fluxes in Estuarine and Coastal Marine Sediments: Literature Review and Data Report. Prepared as a companion volume for *Nitrogen in Estuaries* by W. R. Boynton and W.M. Kemp in *Nitrogen in the Marine Environment*, 2006. Editors: D. G. Capone, D.A. Bronk, M.R. Mulholland, and E.J. Carpenter.

Fox, A.L. and J.H. Trefry. 2018. Environmental dredging to remove fine-grained, organic-rich sediments and reduce inputs of nitrogen and phosphorus to a subtropical estuary. Marine Technology Society Journal, 52(4):42-57.

Mayer, P.M., S. K. Reynolds, M.D. McCutchen, and T.J. Canfield. 2006. Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations. EPA/600/R-05/118. Cincinnati, Ohio, Environmental Protection Agency.

Montgomery, J. R., C. Zimmerman, and M. Price. 1979. The collection, analysis, and variation of nutrients in estuarine porewater. Estuarine and Coastal Marine Science. 9: 203-214.

Pandit, A. and H. Swain. 1992. Assessment of Stormwater BMPs in the Turkey Creek Basin Using a Hydrological Model. A report to the SJRWMD from Florida Institute of Technology. 146 pp. plus appendices.

Reddy, K. R., M. Fisher, H. Pant, P. Inglett, and J. White. 2001. Indian River Lagoon Hydrodynamics and Water Quality Model: Nutrient Storage and Transformations in Sediments. Final Report to St. Johns River Water Management District, Palatka, FL.

Trefry, J.H., K. Johnson, A. Fox, X. Ma. May 2019 DRAFT. Optimizing Selection of Sites for Environmental Dredging in the Indian River Lagoon System. A Report to Brevard County. Florida Institute of Technology, Melbourne, Florida 32901.

Trefry, J.H., A. Pandit, J.B. Martin. 2016. Sediment survey and fluxes of nutrients from sediments and groundwater in the northern Indian River Lagoon. Final Report to St. Johns River Water Management District, Palatka, FL.

Trefry, J.H. and R.P. Trocine. 2011. Metals in sediments and clams from the Indian River Lagoon, Florida: 2006–7 versus 1992. Florida Scientist 74:43–62.

Trefry, J.H., R.P. Trocine, R.D. Rember, C.R. Little. 2004. Post-Dredge Evaluation of Crane Creek: Sediment trapping Efficiency and Sediment Quality. Final report to St Johns River Water Management District, February 2004. Palatka, FL.

Trefry, J. H., H. Feng, R. Trocine, S. Metz, G. Grguric, R. Vereecke, and S. Cleveland. 1992. Concentrations and Benthic Fluxes of Nutrients from Sediments in the Indian River Lagoon, Florida (Project MUCK, Phase II). Final Report to the St. Johns River Water Management District, Palatka, FL.

Trefry, J.H., D.K. Stauble, M. Sisler, D. Tiernan, R. Trocine, S. Metz, C. Glasscock, and S.F. Bader. 1987. Origin, Composition and Fate of Organic-rich Sediment in Coastal Estuaries: Project Muck. Dept. of Oceanography and Ocean Engineering, Florida Institute of Technology, Melbourne, Florida. 147 pp.

Windsor, J.G. and J.S. Steward. 1987. Chapter 5. Water and Sediment Quality (p. 5-16). *IN*: Steward, J.S. and J.A. VanArman. 1987. *Indian River Lagoon Joint Reconnaissance Report*. SJRWMD, Palatka, FL; and SFWMD, West Palm Beach, FL. Report submitted to Florida Department of Environmental Regulation and Office of Coastal Resource Management, NOAA.

Appendix A.

Muck Sediment Survey and Sampling Strategy for Determining BMAP Nutrient Credit for Muck Removal

Sampling Strategy Objectives

The strategy prescribed for muck sediment sampling in the IRL system is intended to cover only the essential, minimum steps to (1) identify or verify within the boundaries of a proposed muck-removal project area that it is, indeed, muck as defined on p. 1 of this guidance document; and that muck covers the entirety of the project area; and (2) collect and interpret certain field measurements and sediment data for the purpose of delineating the project area boundaries, determining the areal extent (km^2) of the project area containing muck, the median muck thickness, and the median annual muck flux rates of nitrogen and phosphorus (based on % LOI of the sediment samples) from which potential BMAP credit for the project is determined.

Sampling Plan

The project lead (e.g., primary stakeholder or permit applicant) shall provide to DEP via BMAP Coordinator a plan that provides (with the aid of a map or maps as needed) introductory or background information on the project, the sampling approach (sampling design, number of sampling stations, the field measurements to be taken and at what stations), and the quality assurance/quality control (QA/QC) protocol. This sampling plan guidance addresses only the sampling objectives stated above; it does not include additional samplings and analyses that may be required for regulatory permits.

Introduction/Background – Minimum Information Required

Sampling Approach

Systematic design of sampling network: A systematic design is one in which the sampling sites are placed regularly or at equidistance from each other, generally within measurement grid cells or along measurement transects oriented in a manner that provides full coverage of the proposed project area from its perimeter boundaries to its center axis. This type of sampling network design is intended for a project area in which the entire area is subject to a common condition (Environment Canada, 2002); and in this case, that common condition is surficial muck sediment.

If the morphometry of the subject waterbody/project area is highly irregular (e.g., embayments, tributaries, or braided channels, etc.) it may be necessary to create sub-area sampling grids or transects. Each sub-area would have its own distinctive grid or transect network and/or spacing between sampling sites.

Number of sediment samples: The number and location of sampling stations necessarily conforms to the entirety of the sampling grid or transect network to ensure full or representative coverage. Toward that end, it is important to locate a sufficient number of the sampling stations along the expected perimeter boundaries of the project area (e.g., at the terminal ends of transects), as well as within the interior of the project area, in order to verify that the proposed dredge area is entirely covered with muck and that the samplings are representative of the entire muck dredge area.

The number of sediment samplings can be derived from **Equation A1** or a table of values (**Table A1**; the number of stations is calculated using the equation) known as the Balduck Method (Keillor, 1993). The Balduck Method estimates the minimum number of samples required to represent a dredge project area based on its areal coverage (km^2). Originally, the method, its **Equation A1** and **Table A1**, was set up to provide 3 different sample numbers depending upon its assigned Dredge Factor (Df), a unitless multiplier of 1, 2 or 3 applied to the equation that accounts for the project area's dredge history, the presence or absence of data on sediment contamination, and environmental issues related to pollution (e.g., fish advisory). However, given the fact that the sediment sampling described in this guidance is exclusively focused on the survey of muck presence, thickness, and the collection of muck grab samples (for color, odor, and LOI analyses), and not on metal or organic contaminants or whether the area had been dredged before, the Balduck's Method equation and table of values adapted for use here assumes a Df = 1; thus, Df as a multiplier is inconsequential and deleted from the equation.

Equation A1.

$$N = \cancel{(Df)}(30) \text{ x } ((W)(L))^{0.33}$$

where

N = number of sediment sampling stations;

W = width of a single dredge area or the widest dredge sub-area among the multiple sub-areas to be dredged; and

L = length of a single dredge area or the sum of the lengths of the sub-areas of a dredge (project) area.

Table A1. Minimum Number of Sediment Sampling Stations Based on Dredge Area

Dredge Area (km2)	Minimum Number of Samples
0.004 – 0.008	5- 6
0.008 – 0.017	6 – 7
0.017 – 0.025	8 – 9
0.025 – 0.042	9 – 10
0.042 – 0.054	11
0.054 – 0.071	12
0.071 – 0.083	13
0.083 – 0.108	14
0.108 – 0.133	15
0.133 – 0.167	16
0.167 – 0.192	17
0.192 – 0.233	18
0.233 – 0.275	19
0.275 – 0.317	20
0.317 – 0.367	21
0.367 – 0.417	22
0.417 – 0.483	23
0.483 – 0.542	24
0.542 – 0.625	25
0.625 – 0.692	26
0.692 – 0.775	27
0.775 – 0.858	28
0.858 – 0.938	29
0.938 – 1.000	30

Number and Type of Field Measurements

Field measurements of location (latitude and longitude), water depth, and muck depth or thickness should be taken at each of the sediment sampling stations.

Salinity measurements should be taken at 10 % of the sampling stations, at minimum, within a single project area or within each of its sub-areas. If the project area is within a tributary and the total number of sampling stations is determined to be < 10, then take at least two salinity measurements; one near or at the center of the project area or each of its sub-areas and the other measurement at project area's upper reach boundary (i.e., toward the freshwater reach).

QA/QC Protocol

At a minimum, field replicates and duplicates should be taken at 10 % of the total number of sampling stations. Of course, these are additional samples to the minimum number of sediment samples as determined by the Balduck Method.

A field replicate is a complete and separate collection of a sediment sample at a sampling station (perhaps taken off the side of the boat opposite the side where the first sample was taken so as not to take the replicate at a previously disturbed site). The purpose of replication is to assess intra-site variability and/or field sampling techniques.

A lab duplicate is collected by splitting a sample that has already been collected into two samples for analysis to help assess laboratory analytical variability.

If there is any transfer of samples to another entity (e.g., sampling entity passes samples on to a separate laboratory entity), a chain-of-custody protocol should be followed including the necessary forms for inclusion in a QA/QC section of a report.

[Note: DEP may require additional QA/QC measures but replicates and duplicates are the minimum QA/QC requirements recommended].

Equipment

- Global Positioning System (GPS) for recording station location latitude/longitude.
- Graduated line with weighted 20 cm disc at the end for measuring water depth (cm).
- The simplest method uses a graduated polyvinyl chloride (PVC) pole for manually measuring muck thickness or depth. For the sake of consistency across projects in the IRL system, muck thickness surveys will be carried out using 1.25 inches outside diameter, capped PVC with 4-millimeter (mm) diameter holes at half-meter intervals along its length to maintain neutral buoyancy. The pole, marked in centimeter graduations, is lowered into the water column until the surface layer of sediment is encountered; this depth is recorded as the water depth. The pole is then pushed into the sediment until a firm bottom is struck and the total depth minus the water depth is recorded as the thickness of the muck layer. Water depths are validated at ~5 % of the sites by lowering a 20 cm diameter weighted disk (typically a 3 lb. weight) attached

to a calibrated rope until it settles onto bottom sediments. Other survey methods (e.g., remote sensing) can be used, but must be approved by DEP before credit is awarded; and for the sake of data quality control, shall be statistically validated by the manual pole method.

- Salinometer (hand-held optical salinometer, or some electronic instrument meter with a salinity probe). Pre-trip and post-trip calibrations should be performed and recorded.
- Eckman dredge sediment sampler or Petite Ponar sediment sampler are recommended. However, samples of muck can be collected using several different pieces of equipment including corers, scoops, as well as the dredge/grab samplers. DEP standard operating procedure (SOP)-001/01 FS 4000 Sediment Sampling describes the different sampling devices and collection methodologies. The DEP protocols are available at: http://publicfiles.dep.state.fl.us/dear/sas/sopdoc/2008sops/fs4000.pdf.
- Munsell color chart. The hues to look for are grays and blacks. The lower the numbers are for chroma and value the more likely the sample is in the gray to black color range.
- Remove sample from sampling device with a clean non-reactive utensil and transfer to sample container. DEP-SOP-001/01 FS 4000 describes different sampling methods. If needed, a large bowl, tray, or bucket to receive the sediment sampler contents for subsequent transfer to sample containers could be used.
- A clean scoop, spoon, or similar device to transfer sediment from the sampling device, bowl, tray, or bucket to sample container.
- A jug of distilled water for second and final rinsing of sediment sampler, bowl or tray or bucket, scoop or spoon following the first rinsing using project area's ambient water.
- Clean glass or plastic jars with screw-on lids to be used as the sediment sample containers for delivery to the laboratory.
- Field notebook and/or data sheets.
- Sample container labels and markers (labels note the station name, date, and time of collection).

All jars, samplers, and other equipment that may come into contact with a sediment sample needs to be cleaned prior to the sampling trip by first washing with phosphate-free Liquinox soap, then a tap water rinse followed by a distilled water rinse and allowed to air dry.

Laboratory Analysis – LOI %

LOI % @ 550º C on the sediment samples shall be determined using either the ASTM (American Society for Testing and Material, 1996) or the method described by Heiri et al. (2001).

References for Appendix A

Environment Canada. 2002. Sediment Sampling Guide for Dredging and Marine Engineering Projects in the St. Lawrence River. Vol. 1. Planning Guidelines. Environment Canada, Environmental Protection Branch, Quebec Region. Montreal, Quebec. Report 104 pages.

Heiri, O., Lotter, A.F., Lemcke, G. 2001. Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. Journal of Paleolimnology 25:101-110.

Keillor, P. 1993. *The Challenge of Describing a Contaminated Sediment Site,* In: *Managing Contaminated Sediments*, A Short Course, Department of Engineering and Professional Development, University of Wisconsin-Madison, April 13-15, 1993.

Appendix B.

Example Project Data and Calculations

Assessment for Pre-Dredge Muck Removal

1. Determine a list of existing best management practices (BMPs) already in place or create a scheduled plan to implement additional BMPs that will reduce sedimentation and muck accumulation at your site. E.g.
    a. Directed community outreach adjacent to dredge site for:
        i. Florida friendly yards and neighborhoods initiative.
        ii. County fertilizer ordinance.
    b. Plan for adjacent marina turnout to maintain vegetated buffers along shoreline by March 2022. See BMAP project CIRL BC-XX.
    c. Planned US Hwy 1 improvements conducted by FDOT September 2025.
    d. Planned improvements for baffle box and swale construction along Canal Drive, Main Street, and Riverview Drive by June 2024. See CIRL BMAP project BC-XX, BC-XX, BC-XX.
2. Determine the *total* area to be dredged: example (e.g.) 9.91 acres or 0.04 km^2.
3. Determine the *minimum* amount of sample sites that will be required based on the dredge area by using **Table A1** as a reference: e.g., 10 sites.
    a. More sites can achieve better results, the example uses 12 sites total rather than the required minimum in the assessment.
4. Determine the sites that will be sampled and create a map that shows the area to with the sampling sites. The example map in **Figure B1** also provides details that may be useful for obtaining State or Federal permits.
5. Determine if the site meets the *two minimum* muck criteria:
    a. If the *minimum* salinity is ≥ 1 PSU across the sample sites, then the salinity gradient criterion is met: e.g., 18 PSU.
    b. If the *median* muck thickness across the sample sites is ≥ 30 cm, then the muck thickness criterion is met: e.g., 35 cm.
6. Determine the % LOI at each sample site: e.g., a range of 10.1 % – 14.6 % across the sites. See **Figure B2** for site specific % LOI.

7. Use the % LOI of each sample site to determine the N and P flux, e.g., 9,000 $kg/km^2/yr$ N and 500 $kg/km^2/yr$ P where the Q_{10} values for ammonium and phosphate are 2.9 and 3.0, respectively, and the measured temperature was 32° C.
8. Calculate the adjusted *net* nutrient flux in the following manner:
    a. N:

$$\frac{18{,}964\,\frac{kg}{km^2}}{yr} = 10^{\frac{\log \frac{9{,}000\frac{kg}{km^2}}{yr}}{\frac{10}{32℃-25℃}} + \log 2.9}$$

    b. P:

$$\frac{1{,}075\,\frac{kg}{km^2}}{yr} = 10^{\frac{\log \frac{500\frac{kg}{km^2}}{yr}}{\frac{10}{32℃-25℃}} + \log 3}$$

9. Use the adjusted flux values to obtain the *median* N and P flux, e.g., 18,006 $kg/km^2/yr$ N and 1,077 $kg/km^2/yr$ P.
10. Calculate the *net* nutrient flux by subtracting the natural background substrate flux (**Table 1**) value from the median flux:
    a. N: 18,006 $kg/km^2/yr$ – 2100 $kg/km^2/yr$ = 15,906 $kg/km^2/yr$
    b. P: 1,077 $kg/km^2/yr$ – 200 $kg/km^2/yr$ = 877 $kg/km^2/yr$
11. Optional: for planning purposes, the net nutrient flux may be used as a provisional credit in the BMAP:
    a. Multiply the net flux by the dredge area to obtain the load to be removed by the dredge activity and the conversion factor to pounds:
        i. N: 15,906 $kg/km^2/yr$ * 0.04 km^2 * 2.2 lbs/kg = 1,404 lbs/yr
        ii. P: 877 $kg/km^2/yr$ * 0.04 km^2 * 2.2 lbs/kg = 77 lbs/yr

Please note that units are important throughout this crediting procedure. The spreadsheet tool provided on the DEP website may assist with keeping track of all necessary calculations, however it is sensitive to the units of measurement. If sampling equipment is not designed for metric units or tracks in smaller units of measure, please be aware that conversions outside the tool may be necessary. Link to spreadsheet tool:
https://publicfiles.dep.state.fl.us/DEAR/DEARweb/BMAP/BMP_Efficiencies/Draft_BMAPCreditEligibilityCalculationsIRLMuckRemovalProjects_20220512.xlsx

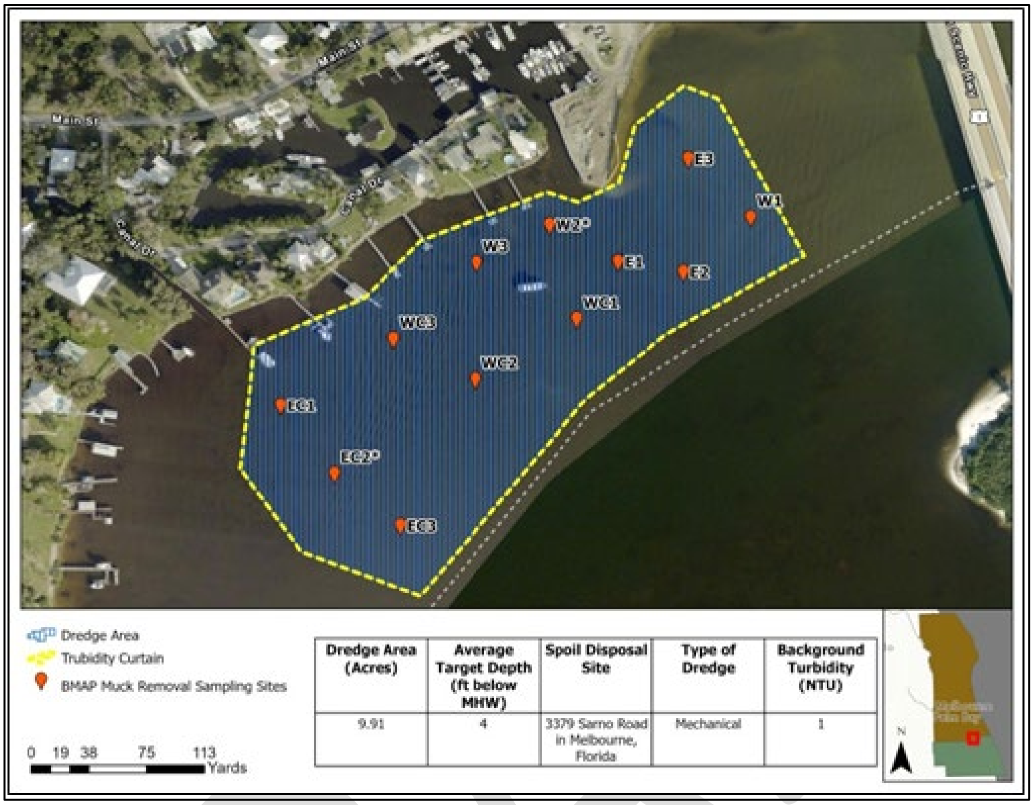

Figure B1. Dredge location and muck sampling sites

Project Area (ac)	0.04	Pre-Dredge Eligibility Criteria and Credit Planning						
Sampling Sites	Temperature (°C)	Salinity (psu)	Muck Thickness (cm)	Percent Loss on Ignition (% LOI)	Nitrogen (N) Flux $kg/km^2/yr$	Phosphorus (P) Flux $kg/km^2/yr$	Temperature Adjusted Nitrogen (N) Flux $kg/km^2/yr$	Temperature Adjusted Phosphorus (P) Flux $kg/km^2/yr$
W1	30.00	N/A	20.00	12.60	10,000	700	17,029	1,212
W2*	32.00	18	55.00	13.40	11,000	800	23,178	1,726
W3	32.00	N/A	30.00	11.80	9,000	500	18,964	1,079
WC1	30.00	N/A	45.00	11.00	9,000	500	15,326	866
WC2	30.00	N/A	50.00	11.90	9,000	500	15,326	866
WC3	34.00	N/A	40.00	10.10	8,000	400	20,857	1,075
EC1	31.00	N/A	10.00	11.50	9,000	500	17,048	967
EC2*	29.00	25	30.00	14.30	13,000	1,000	19,902	1,552
EC3	30.00	N/A	25.00	9.90	2,100	200	3,576	346
E1	30.00	N/A	55.00	8.10	2,100	200	3,576	346
E2	31.00	N/A	70.00	14.60	13,000	1,000	24,625	1,933
E3	34.00	N/A	30.00	14.00	13,000	1,000	33,892	2,688
10	Temperature for adjustment in °C	18	35.00	Q10 Constant TN	2.9	Median Total Flux	18,006	1,077
Is the Minimum Sample Sites Required (above) met?	25	Minimum salinity (≥ 1 PSU) met?	Mimimum Median Muck Depth (30 cm) met?	Q10 Constant TP	3	Net Pre-dredge Flux	15,906	877
YES		YES	YES					

Figure B2. Pre-dredge eligibility criteria

Credit Assessment for Post-Dredge Muck Removal

1. Return to the dredge area no more than six months after the dredge activity and determine the median muck thickness across the sample sites: e.g., 2.5 cm.
2. Determine the % LOI at each sample site: e.g., a range of 1.2 % – 15 % across sites. See **Figure B3** for site specific % LOI.
3. Use the % LOI of each sample site to determine the N and P flux, e.g., 2,100 kg/km^2/yr N and 200 kg/km^2/yr P.
4. Calculate the temperature adjusted *net* nutrient flux in the following manner where the measured temperature was 21° C:
    a. N:

$$\frac{1{,}372\,\frac{kg}{km^2}}{yr} = 10^{\frac{\log\frac{2{,}100\frac{kg}{km^2}}{yr}}{\frac{10}{21℃-25℃}}+\log 2.9}$$

    b. P:

$$\frac{129\,\frac{kg}{km^2}}{yr} = 10^{\frac{\log\frac{200\frac{kg}{km^2}}{yr}}{\frac{10}{21℃-25℃}}+\log 3}$$

5. Use the adjusted flux values to obtain the *median* N and P flux, e.g., 1,240 kg/km^2/yr N and 116 kg/km^2/yr P.
6. Calculate the *net* removal benefit by subtracting the total post dredge flux from the pre-dredge flux:
    a. N: 18,006 kg/km^2/yr – 1,240 kg/km^2/yr = 16,766 kg/km^2/yr
    b. P: 1,077 kg/km^2/yr – 116 kg/km^2/yr = 961 kg/km^2/yr
7. Multiply the net flux by the dredge area to obtain the load to be removed by the dredge activity and convert the nutrient flux values to pounds per year to determine the BMAP credit that can be submitted during the annual reporting period:
    a. N: 16,766 kg/km^2/yr * 0.04 km^2 * 2.2 lbs/kg = 1,480 lbs/yr
    b. P: 961 kg/km^2/yr * 0.04 km^2 * 2.2 lbs/kg = 85 lb/yr

Project Area (ac)	Less Than Six-Month Post Dredge Crediting						
Sampling Sites	Temperature (°C)	Muck Thickness (cm)	% LOI	N Flux kg/km^2/yr	P Flux kg/km^2/yr	Temperature Corrected N Flux kg/km^2/yr	Temperature Corrected P Flux kg/km^2/yr
W1	19.00	20.00	15.00	15,000	1,200	7,919	621
W2*	20.00	10.00	10.00	8,000	400	4,698	231
W3	21.00	0.00	3.50	2,100	200	1,372	129
WC1	19.00	10.00	3.00	2,100	200	1,109	103
WC2	19.00	0.00	2.50	2,100	200	1,109	103
WC3	22.00	5.00	7.00	2,100	200	1,526	144
EC1	19.00	0.00	1.90	2,100	200	1,109	103
EC2*	18.00	0.00	2.60	2,100	200	997	93
EC3	19.00	0.00	1.30	2,100	200	1,109	103
E1	19.00	0.00	1.20	2,100	200	1,109	103
E2	20.00	9.00	10.00	8,000	400	4,698	231
E3	22.00	20.00	14.00	13,000	1,000	9,445	719
10		2.50			Median Total Temperature Corrected Flux	1,240	116
Is the Minimum Sample Sites Required (above) met?					Change from Pre-Dredge Flux	16,766	961
YES					Credit	1,480	85

Figure B3. Less than six-month post-dredge

Five-Year Check in to Determine if Additional Sedimentation Treatment Is Required

1. After five years post-dredge activity, return to the dredge area and determine the *median* muck thickness across the sample sites: e.g., 10 cm.
2. Determine the muck accrual rate by subtracting the less than six-month post-dredge *median* from the five-year post-dredge *median* and dividing by number of years past, e.g., (10 cm – 2.5 cm) / 5 yr = 1.5 cm/yr
3. If the accrual rate exceeds 2.5 cm/yr, additional projects targeting sedimentation may need to be considered to maintain BMAP credit. **Figure B4** shows example thickness for each site.

Project Area (ac)	Five-Year Check
Sampling Sites	Muck Thickness (cm)
W1	20.00
W2*	5.00
W3	10.00
WC1	5.00
WC2	10.00
WC3	10.00
EC1	10.00
EC2*	20.00
EC3	10.00
E1	0.00
E2	20.00
E3	30.00
6	10
Is the Minimum Sample Sites Required (above) met?	1.50
YES	Yes, Credits on track

Figure B4. Five-year muck thickness check

Check in to Determine if Credit Requires Revision after Nine Years

1. After nine years post dredge activity, return to the dredge area and determine the *median* muck thickness across the sample sites: e.g., 30.5 cm.
2. Determine the muck accrual rate by subtracting the five-year post dredge *median* muck thickness from the nine-year post dredge *median* muck thickness and dividing by number of years past (four years), e.g., (10 cm – 30.5 cm) / 4 years = 5.13 cm/yr
3. If the *median* muck thickness across the sample sites is greater than 30 cm, the BMAP credit may need to be revised with the following method:
4. Determine the % LOI at each sample site: e.g., a range of 8 % – 12 % across the sites. See **Figure B5** for individual site information.

5. Use the % LOI of each sample site to determine the N and P flux, e.g., 9,000 $kg/km^2/yr$ N and 500 $kg/km^2/yr$ P.
6. Calculate the adjusted *net* nutrient flux in the following manner:
    a. N:

$$\frac{13{,}778\,\frac{kg}{km^2}}{yr} = 10^{\frac{\log\frac{9{,}000\frac{kg}{km^2}}{yr}}{\frac{10}{29℃-25℃}}+\log 2.9}$$

    b. P:

$$\frac{776\,\frac{kg}{km^2}}{yr} = 10^{\frac{\log\frac{500\frac{kg}{km^2}}{yr}}{\frac{10}{29℃-25℃}}+\log 3}$$

7. Use the adjusted flux values to obtain the *median* N and P flux, e.g., 11,629 $kg/km^2/yr$ N and 588 $kg/km^2/yr$ P.
8. Calculate the *net* removal benefit by subtracting the *median* 9-year post dredge flux from the *median* pre-dredge flux:
    i. N: 18,006 $kg/km^2/yr$ – 11,629 $kg/km^2/yr$ = 6,377 $kg/km^2/yr$
    ii. P: 1,077 $kg/km^2/yr$ – 588 $kg/km^2/yr$ = 489 $kg/km^2/yr$
9. Multiply the *net* flux by the dredge area to obtain the load to be removed by the dredge activity and convert the nutrient flux values to pounds per year to determine the revised BMAP credit:
    i. N: 6,377 $kg/km^2/yr$ * 0.04 km^2 * 2.2 lbs/kg = 563 lbs/yr
    ii. P: 489 $kg/km^2/yr$ * 0.04 km^2 * 2.2 lbs/kg = 43 lbs/yr
10. For this example, additional projects will need to be submitted to the BMAP as the project is not actually achieving the initial nutrient reduction amount observed in the initial crediting time frame.

Project Area (ac)	Nine-Year Post Dredge						
Sampling Sites	Temperature (°C)	Muck Thickness (cm)	% LOI	N Flux kg/km^2/yr	P Flux kg/km^2/yr	Temperature Corrected N Flux kg/km^2/yr	Temperature Corrected P Flux kg/km^2/yr
W1	27.00	30.00	12.00	10,000	700	12,373	872
W2*	29.00	30.00	10.00	8,000	400	12,248	621
W3	29.00	30.00	11.00	9,000	500	13,778	776
WC1	27.00	34.00	10.00	8,000	400	9,899	498
WC2	27.00	32.00	12.00	10,000	700	12,373	872
WC3	30.00	31.00	10.00	8,000	400	13,624	693
EC1	28.00	35.00	10.50	8,000	400	11,011	556
EC2*	28.00	31.00	11.30	9,000	500	12,387	695
EC3	27.00	31.00	10.80	8,000	400	9,899	498
E1	27.00	25.00	8.00	2,100	200	2,598	249
E2	28.00	20.00	8.00	2,100	200	2,890	278
E3	30.00	20.00	8.00	2,100	200	3,576	346
10		30.5			Median Total Flux	11,629	588
Is the Minimum Sample Sites Required (above) met?		5.13			Net Nine-Year Post Dredge Flux	6,377	489
YES		YES, proceed with revision process			Revised Credit	563	43

Figure B5. Nine-year post-dredge

Optional 10-yr BMAP Credit Renewal

1. Either the less than six-month post-dredge nutrient credit or the nine-year post-dredge revised credit may be renewed after 10 years post-dredge for an additional 10 years.
    a. If credits did not require revision at nine-year assessment, the less than six-month credit may be renewed
    b. If credits did require revision at nine-year assessment, the revised credit may be renewed if the revision does not equal zero, however additional projects to meet the original nutrient removal credit must be provided.