ADDENDUM TO:

LAKE MATTAMUSKEET WATERSHED RESTORATION PLAN

An anchor to the past, a path to the future

NOVEMBER 30, 2018

PREPARED BY: NORTH CAROLINA COASTAL FEDERATION

On behalf of: Hyde County, U.S. Fish and Wildlife Service, and N.C. Wildlife Resources Commission

The information provided in this addendum is included to supplement the content within the Lake Mattamuskeet Watershed Restoration Plan to sufficiently address the criteria requirements of the Environmental Protection Agency's (EPA) Nine Minimum Elements. The addendum was submitted to the N.C. Division of Water Resources for review on July 22, 2019.

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ESTIMATE OF POLLUTANT LOAD REDUCTIONS

The Lake Mattamuskeet Watershed is located within the Tar-Pamlico River Basin and drains to the Pamlico Sound (sub-basin 03020105). The Tar-Pamlico Nutrient Management Strategy includes a set of rules (15A NCAC 02B .0255 - .0261) designed to equitably regulate sources of nutrient pollution in the basin including wastewater, stormwater, and agricultural nutrient sources as well as protect riparian buffers and mandate training for professionals that apply fertilizer. The rules went into effect in 2001 and seek to reduce nitrogen levels in the estuary by 30% and cap phosphorus levels at a 1991 baseline. According to the Tar-Pamlico Basinwide Water Resources Management Plan 2014 Summary, "full implementation of the nutrient reduction strategy has been a measured process and was reached in 2006."

However, monitoring has identified excess amounts of nitrogen and phosphorus in the lake, which have caused problems including low oxygen levels, extensive fish kills, and harmful algal blooms. In 2016, Lake Mattamuskeet was listed on the state 303(d) list of impaired waters due to elevated levels of pH and chlorophyll-*a*. The concentration of chlorophyll-*a* within the lake has been measured close to 200µg/L during the peak growing season, and the pH value reached 11 s.u. in June 2019.

In addition, monitoring by the U.S. Fish and Wildlife Service (USFWS) indicates submerged aquatic vegetation (SAV) has not been present in the lake since 2017. Monitoring results also indicate algae blooms have become a more frequent occurrence and contain a cyantotoxin, cylindrospermopsin, at concentrations that can impair recreational use. In fact, USFWS staff posted warning signs about health risks associated with harmful algal blooms during the first day of boating season (March 1 – November 1) at the Mattamuskeet National Wildlife Refuge in 2019.

This water quality issue is complicated by a decline of drainage capacity throughout the watershed, and a passive drainage system for the lake that relies on gravity in an area with minimal topographic relief. These problems are exacerbated further by rising sea level. The initial priority actions identified within the watershed restoration plan stem around establishing active water-level management capabilities in the Lake Mattamuskeet watershed that maintain or improve drainage capacity of lands in the watershed and improve water quality through land use best management practices (BMPs), wetland restoration and sheet flow application of drainage waters.

Information about a) drainage management on the surrounding landscape and the associated flow rates as well as b) nutrient and sediment concentrations within drainage ditches are needed. This data will be used to quantify the pollutant loads from sources within the watershed and develop pollutant load reduction targets to meet water quality goals. A coarse nutrient load reduction of 80% is the estimated target required to reduce the concentration of chlorophyll-*a* from 200µg/L to 40µg/L based on a theoretical linkage (EPA, 2008). The coarse target will be used until the watershed characterization is better refined through the development of the hydrologic and hydraulic model for the watershed. Nutrient load reduction estimates have been generated for each of the proposed management actions. These estimates provide an initial step to quantify reductions that can be obtained from implementing this watershed restoration plan.

Hydrologic Restoration via Sheet Flow Application

The strategy being pursued aims to re-establish and replicate the natural movement of water from the lake towards the Alligator River rather than the Pamlico Sound. The preferred design alternative is to identify, design, and prioritize projects where water diverted from the lake could be sheet flowed over newly-created or restored wetlands. The sheetflow application would allow nutrients to be assimilated and sediment to fall out before eventually reaching a water body such as the Atlantic Intracoastal Waterway (AIWW). This restoration strategy has the dual benefit of 1) restoring historic flow paths and 2) directing drainage water to where it can sheetflow across restored wetlands as opposed to discharging in sensitive and already degraded shellfishing waters. To date, several locations have been identified for potential sheet flow applications both within and adjacent to the Lake Mattamuskeet Watershed.

One private landowner has volunteered tracts of land located within the northwest boundary of the watershed that would provide a pathway to sheet flow water over prior converted wetlands before eventually connecting to the AIWW. The particular parcel is 293 acres in size, and three-fourths of the parcel is currently enrolled in easement programs (through the Wetlands Reserve Program (WRP), and the Conservation Reserve Enhancement Program (CREP)). The owner is willing to enroll the remaining ~70 acres in the Emergency Watershed Protection-Floodplain Easement Program (EWP-FPE) or similar conservation program.

A roughly 600-acre parcel of actively farmed land, located to the south and immediately adjacent to the aforementioned parcel, belongs to the same property owner and currently drains to the lake. An engineering firm will be contracted, once funding is acquired, to develop an engineered design to redirect drainage water from the 600-acre parcel to the 293-acre parcel via sheet flow before connecting to the AIWW.

Calculating Nitrate Removal from Restored Wetlands

Dr. Tiffany Messer performed mesocosm experiments over a two-year time period from September 2012 to September 2014 as part of her dissertation research under the direction of Dr. Michael Burchell, North Carolina State University. This study evaluated the nitrate removal capacity of two restored wetlands receiving agricultural drainage water. The studies used Hyde County soils and loaded the wetlands at nutrient concentrations similar to what has been observed through monitoring efforts in and around Lake Mattamuskeet. Based on these mesocosm experiments, “utilizing restored wetlands to treat agricultural drainage water is a promising method to reduce N exports to downstream sensitive ecosystems,” (Messer et al., 2017).

Messer et al. (2017) found that nitrate removal rates ranged from 0.001 to 6.5 lbs/ac/d within mineral soils and 0.001 to 4.4 lbs/ac/d within organic soils during the growing season when water temperatures were above 53°F. However, when average water temperatures were below 53°F in both the growing and non-growing season the nitrate removal rates ranged from 0.05 to 1.4 lbs/ac/d and 0.03 to 2.5 lbs/ac/d in mineral and organic soils respectively.

Extrapolating this to estimate load reduction from potential sheet flow projects for Lake Mattamuskeet, the following was considered: for seven months of the year, during the growing season, the average daily low temperature is above 53°F. Meaning, the average daily low temperature is below 53°F for the remaining five months during the non-growing season. The soils of the potential sheet flow site are primarily organic and categorized as Pungo muck and Bellhaven muck according to the Natural Resources

Conservation Service (NRCS) Web Soil Survey. Based on this information it is estimated that the nitrogen load reduction that would occur from implementing the sheet flow strategy described above could range from a maximum estimate of 2,654 lbs/d of nitrate when temperatures are above 53°F, to 1,484 lbs/d of nitrate when temperatures are below 53°F. Therefore, the annual estimated load reduction that could potentially occur from redirecting the drainage water from the 600-acre parcel would be a maximum of 79,631 lbs/yr based on the average number of days pumping is thought to be needed per year. The federation and partners are seeking funding to perform a project site assessment and develop a preliminary engineered design for this priority management strategy.

Two other potential sheet flow application sites have been identified to date and are in need of further evaluation. The overall effectiveness of this strategy will be dependent on identifying sufficient areas for sheet flow application. Studies conducted by Chescheir et. al (1991) in neighboring Dare and Tyrrell County indicated that sheet flow application can reduce total nitrogen, total phosphorus and sediment by nearly 80 percent when the ratio of drained land to wetland area was 5:1. Even when the ratio of drained land to wetland was as high as 18:1, reductions of 30-60 percent were observed. (Chescheir et.al, 1991). By extension, this indicates that if stakeholders can identify ~1,000-4,000 acres for sheet flow application, 30-80% of nutrients and sediment currently draining to the lake can be reduced.

Agricultural Buffer Restoration

Riparian buffers and filter strips are an effective method of reducing nutrient inputs to waterways. According to NCDWR, nutrient offset credits for agriculture riparian buffer restoration is 75.76 pounds of N/acre/year load reduction, and 4.88 pounds of P/acre/year load reduction. However, due to a variety of factors, it is not common practice for farmers to implement vegetated buffers between cropland and a drainage ditch. Without a buffer strip, the farmer is able to maximize harvestable cropland and facilitate access for ditch maintenance purposes. Proper incentives are necessary to encourage implementation by landowners to offset a loss in revenue associated with a reduction in the acreage of harvestable cropland. The North Carolina Agriculture Cost Share Program provides such an incentive, and is locally administered through the Hyde Soil and Water Conservation District.

A GIS-based analysis was performed to estimate the linear length of primary drainage ditches within the watershed that are not buffered by vegetation. The National Hydrography Dataset was used to delineate the location of surface water ditches, and 2018 orthoimagery was used as a reference to identify whether or not vegetative buffers were present. Based on this desktop analysis, it was determined that there are four distinct geographic areas that cover the perimeter of the watershed where the use of vegetative buffers could reduce the nutrient and sediment load entering into those specific ditches that eventually drain to the lake (Figure 1) (Table 1).

The minimum flow length through a filter strip is recommended to be 20 feet as per the Natural Resources Conservation Service (NRCS) Conservation Practice Standard (Code 393). The linear length of the existing un-buffered ditches was multiplied by the minimum flow length to calculate the area where filter strips could be installed. The nutrient load reduction was then estimated for both nitrogen and phosphorus in the table below. One caveat of this estimate is that it only accounts for installing filter strips on one side of the drainage ditch. There may be instances where agricultural land drains to both sides of the ditch. Therefore, the nutrient load reduction estimate in the table below is conservative in nature.

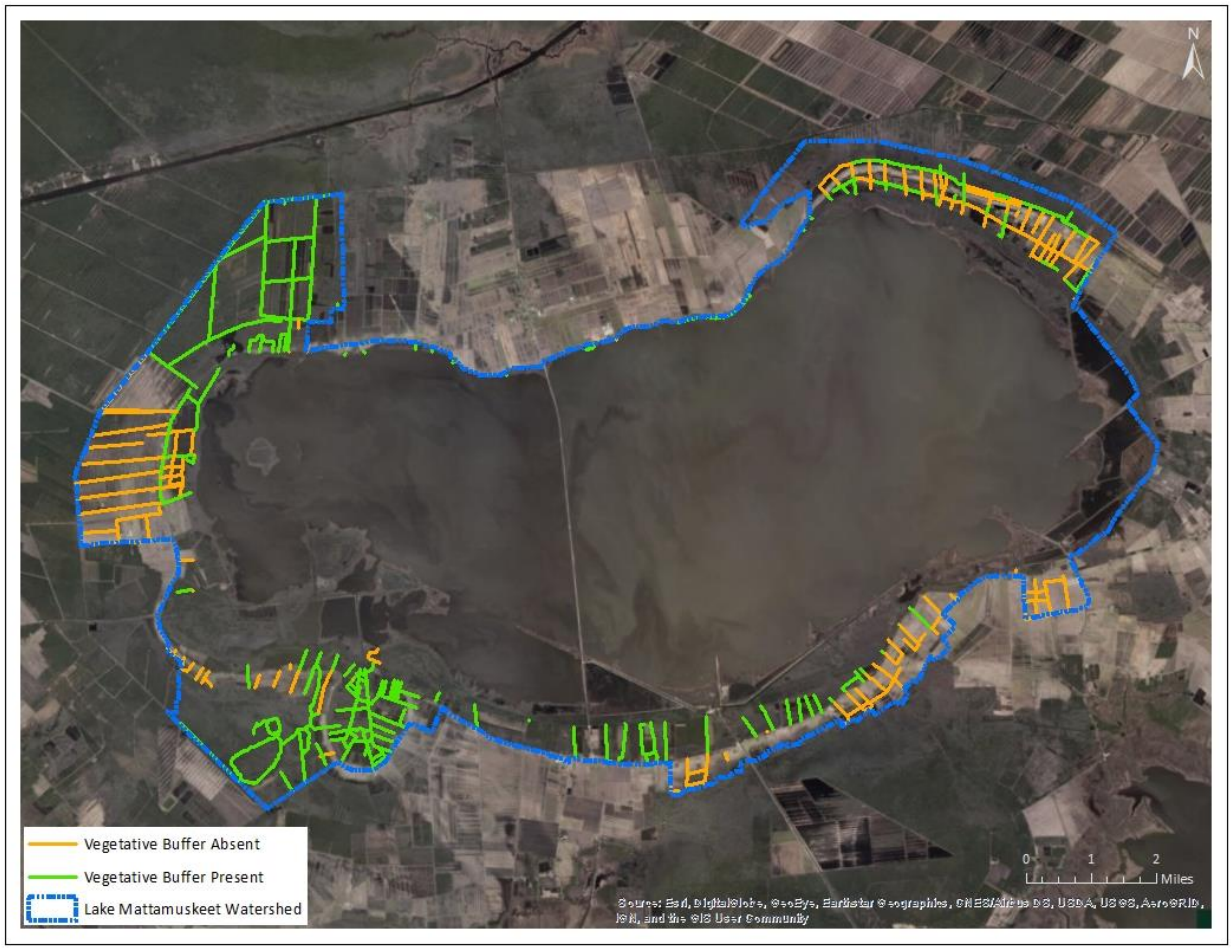

Figure 1. Classification of existing drainage ditches within the Lake Mattamuskeet Watershed.

Location	Un-buffered Ditch Length (miles)	Buffer Width (feet)	Area (acres)	Nitrogen Reduction (pounds/year)	Phosphorus Reduction (pounds/year)
Piney Woods Rd (NW)	17.3	20	41.9	3,177.33	204.66
North Lake Rd (NE)	14.8	20	35.9	2,718.18	175.09
New Holland (SE)	11.9	20	28.8	2,185.56	140.78
SR 1304 (SW)	3.6	20	8.7	661.18	42.59
Total	**47.6**	**20**	**115.4**	**8,742.25**	**563.12**

Table 1. Nutrient load reduction estimates (pounds/year) based on implementing vegetated filter strips on existing ditches within the watershed that are currently un-buffered.

The table below shows the compelling results on the effective widths of vegetated filter strips from a five-year study conducted in the Tar Pamlico Basin by North Carolina State University (Table 2) (Line and Osmond, 2007). Specific nutrient load reduction estimates could be generated using the table if water quality sampling and monitoring is conducted within targeted ditches that do not currently have a vegetated buffer to assist with determining the width that would be most appropriate to reduce the desired nutrient and sediment load in the most cost effective manner as possible.

	Runoff	TSS	TP	DP	TKN	NH_3	NO_3	TN
Width < 15 ft*								
number of studies	11	13	11	7	4	6	6	5
median (%)	20	58	54	4	69	57	24	58
mean (%)	22	57	47	6	67	40	28	38
Width 15-30 ft*								
number of studies	12	15	12	6	5	5	5	6
median (%)	46	81	68	48	76	67	57	62
mean (%)	47	82	68	28	76	43	49	66
Width >30 ft*								
number of studies	7	9	7	1	2	2	2	3
median (%)	65	91	90	90	89	88	82	82
mean (%)	66	85	86	85	89	88	40	84

*Table 2. Runoff and pollutant load reductions (%) for vegetated filter strip (Line and Osmond, 2007) (*measurements of width were converted from metric to standard units).*

Waterfowl Impoundment Management

Dr. Randall Etheridge, East Carolina University, is studying two waterfowl impoundments with different management regimes. One impoundment is managed by the Refuge to provide native, seed-producing wetland plants preferred by waterfowl (moist-soil management), and the other is a private impoundment planted with corn and managed by a local farmer. The objective of this study is to determine the potential nutrient input of these management regimes into Lake Mattamuskeet. The results will help to inform if the management of the impoundments can be altered to reduce the nutrients reaching the lake while also maintaining their food production for waterfowl.

Common Carp (*Cyprinus carpio*) Removal

Common carp are known as "ecosystem engineers" capable of causing stable state shifts in shallow aquatic ecosystems as a result of increased turbidity from carp grazing that results in a decline of SAV and subsequent shifts in biological assemblages. Modeling shows the loss of SAV is a result of a negative feedback mechanism between increased nutrient loading, increased harmful algal blooms, and increased turbidity, which is possibly exacerbated by an overabundance of invasive common carp.

Master's student April Lamb has been working with her advisor Dr. Jesse Fischer at North Carolina State University to evaluate the feasibility of common carp exclusion and targeted vegetation restoration within Lake Mattamuskeet. Population density estimates determined there to be 971,220 carp with a biomass of approximately 4,475,053 million pounds within the lake. Common carp are roughly 1% phosphorus and 6.5% nitrogen as measured by live weight. Therefore, the estimated nutrient load reduction associated with a large scale common carp removal program would be 44,750 pounds of phosphorus and 290,878 pounds of nitrogen. Carp exclusion fences will be installed at tide gates of each outfall canal and at the five culverts that pass under NC-94 causeway that bisects the lake to minimize the reinvasion threat of common carp. A long-term maintenance biomass removal program will also be explored.

The removal of common carp will not have an immediate impact on phytoplankton blooms since the removal will not immediately impact the nutrient bioavailability within the water column of the lake. However, the biomass removal will reduce a source of nutrients that concentrate within the sediment through decomposition and eventually interact with the water column through resuspension and bioturbation. The biomass removal is anticipated to drastically reduce bioturbation, which would then improve water clarity and provide a higher probability for SAV restoration to occur.

ESTIMATES OF REQUIRED TECHNICAL AND FINANCIAL ASSISTANCE

Monitoring and Research

The members of the Mattamuskeet Technical Working Group are comprised of staff scientist from USFWS and NCWRC. They work through a collaborative agreement to identify, prioritize, and conduct monitoring and research at the Refuge. The results of their efforts are used to inform current and future lake management actions. USFWS and NCWRC have dedicated staff and funding to allow this collaboration to continue. No new funds for this staff level coordination are needed. However, ensuring continued support of their existing monitoring efforts and new funding for identified research needs will be important.

Maintain Existing Efforts

Long-term monitoring datasets are essential to evaluating the effectiveness of management actions and developing research questions that can be addressed through scientific investigation.

Continuous monitoring of lake levels and water quality as well as precipitation and wind speed occurs at real-time monitoring stations located within each basin of the lake through a contract between USFWS ($35,000), NCWRC ($20,000), and USGS ($5,000). Total financial contributions of $60,000 per year are required to maintain this monitoring effort.

Monitoring of water levels, discharge, and water quality in the canals on the Refuge is performed on a weekly basis and monthly grab samples are collected by USFWS staff through regular operations at an annual cost of $4,000 and $5,000 respectively. The cost of maintaining this effort could increase if additional water quality parameters are analyzed or the sampling frequency increases.

Real-time monitoring of the water level at Rose Bay initially cost approximately $30,000 to install the water level station accomplished through coordination with the USFWS Refuge Inventory and Monitoring Branch in collaboration with North Carolina State University. Since March 2019, a new radar system to monitor real-time water depth was installed through grant funding and will be maintained by the North Carolina Flood and Inundation Mapping program.

In the spring, the NCWRC staff annually sample inland fish communities within Lake Mattamuskeet and associated canals within the Refuge boundary ($5,000). SAV monitoring is performed by the USFWS staff on an annual basis ($2,500) as part of the Refuge and USFWS migratory game bird program operations. Aerial waterfowl surveys are performed annually by both the USFWS as part of Refuge operations, and NCWRC staff as part of the mid-winter waterfowl survey. The cost of conducting the mid-winter waterfowl survey ranges between $7,000 - $15,000 per year and accounts for several hours of staff time and the use of aircraft provided by the USFWS.

Total cost to maintain existing monitoring efforts is estimated to be: $83,500- $91,500.

Future Research

Specific research efforts have focused on answering questions related to the drainage capacity within the four main outlet canals, effects of nutrient loading through sediment resuspension within the lake, common carp population and biomass estimates, concentrations of agricultural herbicides within drainage ditches, effectiveness of SAV restoration techniques, and nutrient concentrations of water discharged from both conventional and moist soil management style impoundments. Some of this research has already been completed while some remains ongoing. The information provided from these current and future studies is critical to the success of the watershed restoration efforts. However, providing a cost estimate for future research is challenging at this time as it will require information and recommendations generated from ongoing studies.

Based on previous research projects funded in the watershed and on the lake, it is estimated that $200,000 a year would provide sufficient funding to support future research priorities.

Modeling/Engineering Design

The strategy being pursued aims to re-establish and replicate the natural movement of water from the lake towards the Alligator River rather than toward the Pamlico Sound. The preferred design alternative is to identify, design, and prioritize projects where water diverted from the lake could be sheet flowed over newly-created or restored wetlands where nutrients and sediment can be absorbed before eventually connecting to a water body.

In order to systematically evaluate the various alternatives proposed to restore water quality a detailed engineering analysis is required to select the most cost-effective and most environmentally acceptable pathway(s) to provide an additional outlet for the lake via sheet flow applications that restore the natural hydrology of the region. The development of watershed scale model, evaluation of potential sheet flow sites, and engineered designs that could be used to obtain permits has a cost estimate of $250,000.

Private landowners have volunteered tracts of land that could provide a pathway to sheet flow water over prior converted wetlands. Each of these sheet flow projects will require engineered designs. It is estimated that each project will cost $100,000-$200,000 to fully design. It is not yet known how many total projects will come from this watershed restoration plan, but based on similar experiences in the neighboring

Mattamsukeet Drainage Association, an estimate of 10-15 projects is reasonable. Therefore, total engineering/design costs are roughly estimated to be $1.75M.

Infrastructure Improvements/Project Construction

In general, it is expected that infrastructure improvements and construction of the identified projects will cost 10 times the design cost. With design/engineering costs estimated at $1.75M, it is safe to estimate a $17-20M investment in implementing the infrastructure improvements. This estimate is in keeping with similar work being done to implement active water management and wetland restoration projects within the Mattamuskeet Drainage Association and North River Wetlands Preserve.

Establishment of a Service District

A cost estimate of $30,000 was suggested by Hyde County staff for the legal fees associated with title searches and preparation of documents and materials in advance of a public hearing for the establishment of a service district based on experience from the establishment of the Swan Quarter and West Quarter Special Service Districts, which are both located in Hyde County.

Operation and Maintenance

The details of the service district still need to be evaluated, but the general understanding among the stakeholders is that drainage services could be either contracted from the existing drainage entities or new drainage infrastructure and management could be developed to assist in meeting the drainage needs. The upfront infrastructure and development costs of establishing a new service district could likely be funded by grant or other funding opportunities. The service district would be responsible for using income generated from a levy on private property taxes for the operation and maintenance of drainage services within the district as well as capital improvement projects. The USFWS cannot cede management authority of the Refuge and therefore would not be included as a party of the service district. The Refuge could enter into an MOA with Hyde County as a collaborating partner to contribute to the implementation of the plan's management within the service district.

Representatives from the Mattamuskeet Drainage Association suggested using an assessment fee of $30 per acre/year as an average cost estimate to fund active water management within a newly established service district based on assessment fees that are used in adjacent drainage management entities. This cost estimate accounts for both operation, maintenance, and future upgrades. The area of land within the watershed but outside the Refuge boundary that would be incorporated into a service district totals 17,993 acres, and the total annual cost estimate would be $539,790 to operate and maintain.

Common Carp (*Cyprinus carpio*) Removal

The Mattamuskeet Technical Working Group is pursuing funding opportunities to perform the biomass removal through the submission of an application to the Fiscal Year 2022 National Wildlife Refuge System Large Invasive Species Project Allocation. The budget to perform the biomass removal identifies costs of $750,000 as payment to contracted fishermen for removal of 5 million pounds of common carp based on a rate of 15 cents per pound; and $250,000 for equipment, monitoring, and maintenance of common carp exclusion gates, monitoring equipment, nets, seine traps, etc.

INTERIM MILESTONES

One of the priority management actions includes conducting annual and five-year assessments for the purpose of adapting and evolving the watershed restoration plan based on results. These assessments

will specifically consider water management improvements on the lake and within the watershed, reductions in nutrients reaching the lake, improvements in lake water clarity, reduction in algal blooms within the lake, and preservation of the way of life in Hyde County. The following interim milestones have been identified as measures that can be used to evaluate the success of implementing priority management actions.

Active Water Management

The implementation of active water management capabilities within the lake and watershed is a critical component of the watershed restoration plan. There are several interim milestones associated with this goal that include:

- Perform hydrologic study of the watershed - May 1, 2020
- Create a formal body that provides managing authority for active water management within the watershed in coordination with the Refuge, which would be excluded as a party to the formal body since USFWS cannot cede management authority.
    - Hold public hearing by May 1, 2020 to take effect July 1, 2020.
- Design engineered plans for the pilot project to re-direct drainage from a 600-acre parcel that currently drains to the lake to an adjacent 293-acre parcel within the watershed via sheet flow before eventually discharging towards the AIWW - December 1, 2020
    - Complete construction - December 1, 2021
- Design engineered plans for active water management within the watershed - June 1, 2021

Water Quality Improvements

The actions of active water management and water quality improvements are intimately tied. By designing and installing sheet flow application projects to help with managing water volume, water quality will also be improved.

Since removing the lake from the 303(d) list is one of the goals of the watershed restoration plan, reducing the chlorophyll-*a* concentrations within the lake by 10µg/L per year until the water quality standard of 40µg/L is reached shall be used as an interim milestone to evaluate the effectiveness that both nutrient load reductions and active water management within the watershed has on water quality within the lake. This interim milestone will be used as benchmark once active water management activities are implemented. The pH value of the water within the lake should shift from basic to neutral as chlorophyll-*a* concentrations are lowered and subsequently fewer phytoplankton blooms.

Nutrient reductions and water quality improvements will be assessed annually and at 5-year intervals, and include:

- Increasing light attenuation coefficient (k) for the lake.
- Increasing secchi disk measurements for the lake.
- Gradual declining nitrogen (mg/L) and phosphorus (mg/L) levels overtime based on lake-wide grab samples (Total P is 100% greater than 1980 levels; Total N is 400% greater than 1980 levels).
- Completing up to three pilot projects on actively farmed lands to determine the efficacy of a variety of nutrient management BMPs (e.g. filter strips, no-till, check weirs, etc.) within the watershed.

The performance of a common carp (*Cyprinus carpio*) removal program is anticipated to not only remove a significant source of nitrogen and phosphorus within the lake, but also improve water clarity by reducing bioturbation and subsequent turbidity. A proposal to perform this removal has been submitted by the Mattamuskeet Technical Working Group for submission to the Fiscal Year 2022 National Wildlife Refuge System Large Invasive Species Project Allocation. The proposal targets as close to 100% common carp biomass removal as possible. An operational management plan will go into effect after the large scale removal, and an annual 5% biomass return rate will be used to measure the effectiveness of the management activities to keep the common carp population in control.

The return of SAV coverage will serve as a primary indicator of the lake ecosystem health and will be used as the principal metric to evaluate the effectiveness of each implemented management action/BMP to improve water quality within Lake Mattamuskeet. Since the SAV restoration component is anticipated to occur over the long-term, a goal of observing 25% coverage within the lake over the next decade will be used as the interim milestone. Afterwards, the same rate increase of 25% over five year increments will be used as an interim milestone until 100% coverage is reached.

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