Review of the Louisiana Department of Environmental Quality's Wetland Assimilation Program

Prepared for:

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February 2020

This report '*Review of the Louisiana Department of Environmental Quality's Wetland Assimilation Program*' was developed for Louisiana House Concurrent Resolution 42 issued on June 4, 2019.

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Executive Summary

The Louisiana Department of Environmental Quality (LDEQ) began allowing the discharge of secondary treated wastewater into deteriorating natural wetlands to improve the sustainability of coastal wetland ecosystems. The intent was for the nutrients and solids present in the secondary treated wastewater to increase wetland health, offset subsidence, and provide an influx of freshwater to help combat saltwater intrusion. These wetlands have been termed assimilation wetlands and there are, currently, thirteen assimilation wetlands approved through LDEQ's assimilation wetland program under the Louisiana Pollutant Discharge Elimination System (LPDES) permit program. Three more assimilation wetlands have submitted permit applications for consideration of a LPDES permit. This report was generated in response to House Concurrent Resolution Number 42, which passed on June 4, 2019. The resolution requested the study of overall impacts of wetland assimilation projects.

Assessments of net primary productivity (NPP) and reviews of all data have occurred for each existing approved wetland. Two different assessment methods were used to assess assimilation wetlands with enough data (greater than five years of data). A five-year assessment from 2012 to 2016 conducted for the 2018 Water Quality Integrated Report found Thibodaux, Mandeville's Bayou Chinchuba, and Hammond to be impaired (Section 2.1), while a long-term assessment conducted by the Water Permits division found Breaux Bridge to be failing (Section 2.2). A site is considered impaired when the site has experienced a 20% decrease in NPP in comparison to a reference site. Each wetland also undergoes an annual review and letters discussing these results are sent out to the permittee. Permittees with a failing NPP assessment or other issues (e.g., loading rates above the permitted limit) are requested to submit a plan to address the failures.

LDEQ's assimilation wetland program has undergone evaluation both internally and externally in the past few years. The external review was performed by Naturally Wallace Consulting and was specific to the City of Hammond, though general recommendations for all wetlands projects were included. Currently, Hammond's permit is in-house for a renewal and LDEQ will be considering incorporation of new requirements to their renewal permit should the Department determine the renewal is appropriate. For all wetland projects, multiple changes and updates have been made to program guidance and methods to provide more consistent and detailed instruction. Starting in 2017, updates were incorporated into each permit during the renewal process. The updates included detailed guidelines for all methods and the requirement to create an Adaptive Management Plan. Planned updates to the LDEQ's Water Quality Management Plan (WQMP) include more detailed requirements for both the feasibility and baseline studies, detailed guidelines for all sampling methods, and the number of sites needed per total assimilation acreage. LDEQ may consider future updates for additional criteria to determine wetland health, particularly in marshes; requirements for the hydrological regime (e.g., requiring new wetland assimilation projects to have an alternative outfall outside of the wetland); and the use of a new model for determining the active assimilation area.

Of the thirteen wetlands permitted under the assimilation wetland program, only one (Breaux Bridge) is considered to be failing long-term. The external review of the assimilation wetlands recommended the program be continued, though with some changes. The internal review also found some changes and improvements could be made to the program. Some of these improvements have been incorporated into the program already and some are planned for future updates. LDEQ will continue to review the permit reports annually and work with each facility to ensure the goals of the program are met.

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1) Introduction

Coastal land loss is a significant problem in the State of Louisiana, with more than 4,800 km^2 of land (mostly wetland) lost since 1930 (Couvillion, et al., 2011). In an effort to help stem the loss of coastal wetlands, the Louisiana Department of Environmental Quality (LDEQ) began allowing the discharge of secondary treated wastewater into deteriorating natural wetlands to improve the sustainability of coastal wetland ecosystems. The intent was for the nutrients and solids present in the secondary treated wastewater to increase wetland health, offset subsidence, and provide an influx of freshwater to help combat saltwater intrusion.

Currently, thirteen assimilation wetlands have been approved through LDEQ's assimilation wetland program under the Louisiana Pollutant Discharge Elimination System (LPDES) permit program. Three more assimilation wetlands have submitted permit applications for consideration of a LPDES permit. The thirteen approved wetlands and three proposed wetlands are primarily freshwater swamp or a mix of freshwater swamp and marsh, although a proposed assimilation wetland is a bottomland hardwood forest (Table 1). All assimilation wetlands are located in the southern portion of the state, with the majority of the sites located within the Louisiana Coastal Zone (Figure 1). Freshwater marshes are wetlands inundated by water of salinity 2 parts per thousand (ppt) or less with vegetation that is primarily grasses. Saltwater marshes are wetland inundated by water of salinity 16 ppt or more with vegetation that is primarily grasses. Swamps are forested freshwater wetlands that are typically inundated for a majority of the year and primarily populated by bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*) vegetation. Bottomland hardwood forests are forested freshwater wetlands typically only flooded seasonally and less than six months out of the year and found primarily on alluvial floodplains (Mitsch and Gosselink, 2015).

1.1. Applicable Criteria and Assessment

The criteria were proposed initially through use attainability analyses (UAAs) submitted for each wetland and then codified into the state regulations (Conner and Day, 1989; Day, et al., 1994; Day, 1997; Day, et al., 2000a; Day, et al., 2000b; Day, et al., 2004a, b, 2005a, b; Day, et al., 2005c; Day, et al., 2006). As each UAA required a regulations update, the process was lengthy and ultimately repetitive. Therefore, a rule and *Water Quality Management Plan, Volume 3, Permitting Guidance Document for Implementing Louisiana Surface Water Quality Standards* (WQMP) update were proposed in 2006 and promulgated in 2007 seeking to streamline the permitting process for future assimilation wetlands. The rule and accompanying update to the WQMP, which was supported and approved by the U.S. Environmental Protection Agency (USEPA), defined specific types of wetlands, monitoring and assessment methods, and set forth consistent requirements to be implemented in each permit. Since this rule went into effect, each new wetland has to submit a feasibility and baseline study, which are comparable to UAAs, and then follow with the standardized permit process, which is based on the requirements in the WQMP (LDEQ, 2006, 2007, 2010).

LDEQ organizes the state's watersheds by basin (of which there are twelve, Figure 1). Each basin is then split into subsegments, allowing the state's waters to be managed in discrete hydrologic units. Designated uses are a use designated by the state and used to establish water quality standards that are protective of human health and the environment. Louisiana has seven designated uses: primary contact recreation, secondary contact recreation (SCR), fish and wildlife propagation (FWP), drinking water supply, oyster propagation, agriculture, and outstanding natural resource waters. Each wetland that was approved through a UAA was issued their own subsegment in the regulations (see LAC 33:IX.1123). Each of these

Table 1. List of all approved and proposed assimilation wetlands with their receiving wetland, year of first permittance, and wetland type.

Facility	Receiving Wetland	First Permitted	Wetland Type
City of Breaux Bridge	Cypriere Perdue	1997	Swamp
City of Hammond	South Slough	2010	Swamp and Freshwater Marsh
City of Mandeville	Chinchuba/ E. Tchefuncte	2004/2009	Swamp and Freshwater Marsh
City of New Orleans	Bayou Bienvenue Wetlands Triangle	2010	Swamp and Freshwater Marsh
City of St. Martinville	Cypress Island Coulee	2007	Swamp
City of Thibodaux	Pointe Au Chene	1992	Swamp
Guste Island Utility Co	Lower Tchefuncte	2008	Swamp and Freshwater Marsh
Harveston Wastewater District LLC	Selene Bayou	proposed	Bottomland Hardwood Forest
St. Bernard Parish	Poydras-Verret	2018	Saltwater Marsh
St. Charles Parish	Luling	2004	Swamp
St. James Parish-Vacherie	Bayou Chevreuil	proposed	Swamp
St. Martin Parish-Stephensville	Bayou Milhomme	proposed	Swamp
St. Mary Parish	Bayou Ramos	2002	Swamp
Tchefuncta Club Estates	Lower Tchefuncte	2008	Swamp and Freshwater Marsh
Terrebonne Parish	Ashland Wetlands	2013	Swamp and Freshwater Marsh
Town of Broussard	Cote Gelee	2003	Swamp

subsegments were required to meet the designated uses of SCR and FWP. All assimilation wetlands approved after 2007 were automatically assigned SCR and FWP as designated uses through LAC 33:IX.1109.J.3. The SCR designated use is protected through fecal coliform limits issued in the permit (Section 1.2). The FWP is protected through assessing each wetland for above-ground productivity as outlined in LAC 33:IX.1113.B.12.b. Above-ground productivity, more commonly termed net primary productivity (NPP) in literature, is a measure of the vegetative growth occurring in one year. Assessing the NPP allows LDEQ to evaluate the wetland health and profile the vegetative community in order to determine overall wetland condition. Using the vegetative community as a tool to evaluate wetland health is possible due to the interconnectedness between the plant community and a wetland's biological (e.g., faunal communities), chemical, and physical properties (Cronk and Fennessy, 2001; USEPA (and references therein), 2016).

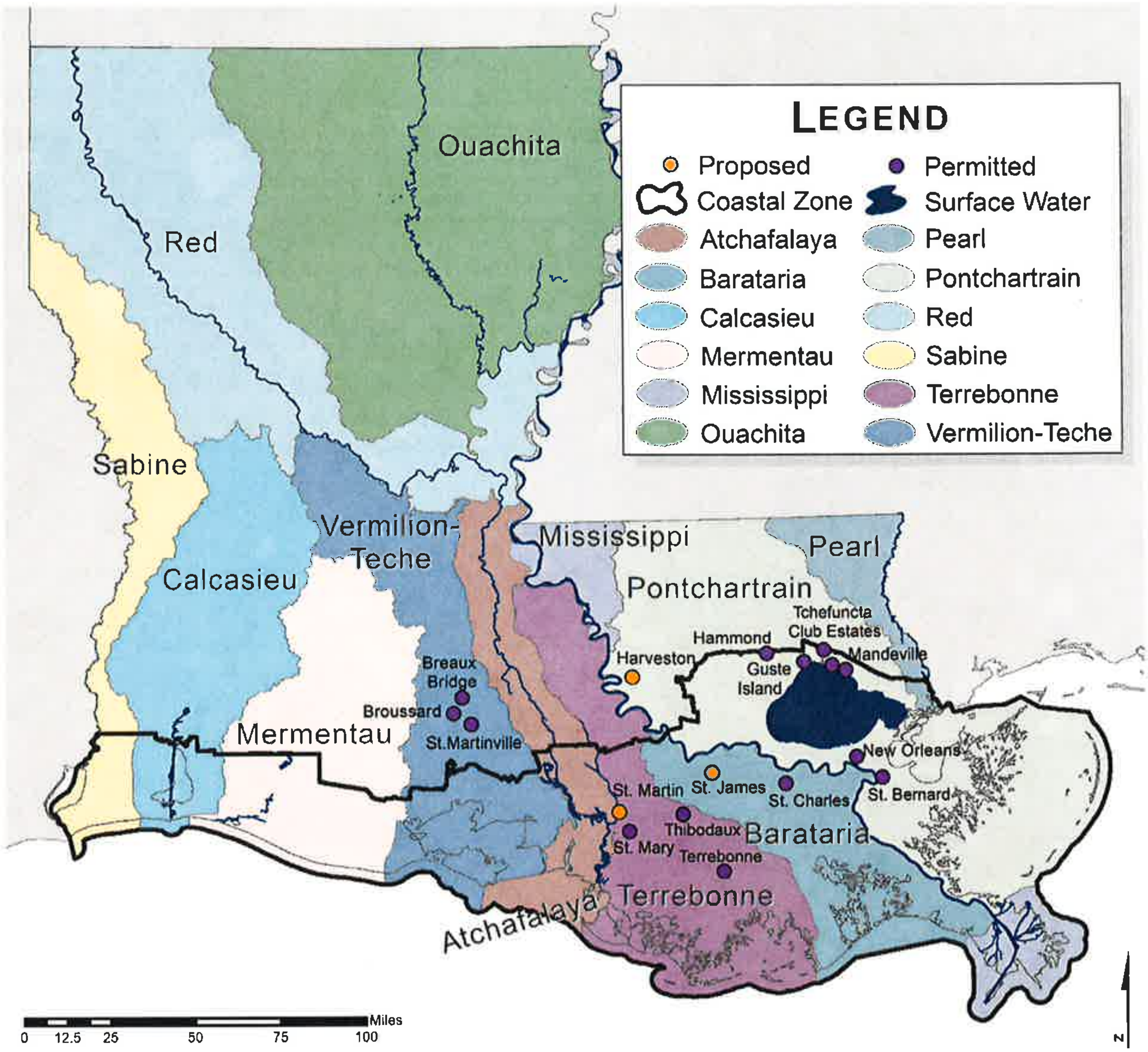

Figure 1. Location of thirteen permitted assimilation wetland sites and three proposed assimilation wetland sites. The City of Mandeville has two wetlands, which are both shown above.

The criteria LDEQ utilizes to provide insight into the health of the vegetative community is found in LAC 33:IX.1113.B.12.b, which states,

> "Assessment of Biological Integrity for Wetlands Approved for Wastewater Assimilation Projects Pursuant to the Water Quality Management Plan, Volume 3, Section 10, Permitting Guidance Document for Implementing Louisiana Surface Water Quality Standards. Wetland biological integrity will be guided by above-ground wetland vegetative productivity with consideration given to floral diversity. Due to effluent addition, the discharge area of a wetland shall have no more than a 20 percent reduction in the rate of total above-ground wetland productivity over a five-year period as compared to a reference area. The *discharge area* is the area of a wetland directly affected by effluent addition. For each location, the discharge area will be defined by the volume of discharge. The *reference area* is the wetland area that is nearby and similar to the discharge area but that is not affected by effluent addition. Above-ground productivity is a key measurement of overall ecosystem health in the wetlands of south Louisiana. Primary productivity is dependent on a number of factors, and the methods for measurement of above-ground productivity and floral diversity are found in the current Water Quality Management Plan, Volume 3, Section 10, Permitting Guidance Document for Implementing Louisiana Surface Water Quality Standards (LAC, 2019)."

Utilizing the rate of NPP, as opposed to individual productivity values, allows each site to be normalized to itself. A five-year period of data provides a better representation of the overall wetland productivity for each site by minimizing extremes. The decision to use no more than a 20% reduction in the NPP rate was intended to allow for natural fluctuations in data between ecosystems, as environmental data is inherently variable. A 20% reduction in NPP is not equivalent to a 20% loss of wetlands. Rather, the 20% reduction is the criterion at which the facility must instigate corrective measures, modifying their management methods as necessary to ensure appropriate productivity. If the facility continually exceeds the 20% reduction criterion, LDEQ reserves the right to reopen and modify or revoke the permit as it deems necessary.

Beginning in the 2018 Integrated Report (IR), which was approved by USEPA on November 20, 2019, assimilation wetlands with at least five years of data were assessed for NPP. Additionally, starting in 2019, annual reviews of each assimilation wetland have begun. Annual wetland reports, which are a requirement of each permit, are reviewed for completeness and accuracy and long-term NPP data is analyzed. Further details of NPP review and assessment are provided in Section 2).

1.2. Permit Requirements

Permit limits are required to ensure each permittee discharges effluent in compliance with water quality standards. The minimum limits for assimilation wetland permits are presented in Table 2. Monitoring frequency and type (i.e., grab, 24-hour composite) are based on the facility's design capacity and compliance history. Facilities may also require specific limits of other parameters, which are based on an evaluation of the effluent data and receiving wetland data. Permitted facilities with a design capacity of 1 million gallons per day (MGD) or greater are also required to conduct whole effluent toxicity (WET) testing. Meeting WET testing limits ensures the effluent does not have a toxic effect on receiving waters.

Table 2. Standard permit limits for sanitary wastewater dischargers into an assimilation wetland.

Effluent Characteristic	Discharge Limitations			
	lbs/d (unless otherwise stated)		mg/L (unless otherwise stated)	
	Monthly Avg.	Weekly Avg/ Daily Max	Monthly Avg.	Weekly Avg/ Daily Max
Flow (MGD)	Report	Report	---	---
BOD_5	*	---	30	45
TSS	*	---	30	45
Fecal coliform (colonies/100 mL)	---	---	200	400
pH (standard units)	---	---	6.0 min	9.0 max
Total Nitrogen	Report	---	Report	Report
Total Phosphorus	Report	---	Report	Report
Total Magnesium	Report	---	Report	Report
Total Lead	Report	---	Report	Report
Total Cadmium	Report	---	Report	Report
Total Chromium	Report	---	Report	Report
Total Copper	Report	---	Report	Report
Total Zinc	Report	---	Report	Report
Total Iron	Report	---	Report	Report
Total Nickel	Report	---	Report	Report
Total Silver	Report	---	Report	Report
Total Selenium	Report	---	Report	Report

*Values are dependent on the design capacity of the facility.

Five-day biochemical oxygen demand (BOD_5) and total suspended solids (TSS) are permitted according to LAC 33.IX.1109.J.6, which requires that "discharges to wetlands approved by the administrative authority for wastewater assimilation projects will only be permitted following procedures pursuant to the Water Quality Management Plan, Volume 3." The WQMP states, "the Department may allow the discharge of the equivalent of secondarily treated effluent into wetlands for the purposes of nourishing and enhancing those wetlands." Secondary treatment is defined at LAC 33:IX.5905 (

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Currently, LDEQ addresses pathogens through fecal coliform and enterococci limitations. The current designated use dealing with pathogens in assimilation wetlands is SCR, which is addressed through fecal coliform limitations of 1,000 colonies/100 mL and 2,000 colonies/100 mL for a monthly geometric average and weekly geometric average (or daily maximum), respectively. However, most permitted facilities have been given fecal coliform limits equivalent to primary contact recreation or 200 colonies/100 mL and 400 colonies/100 mL for monthly geometric average and weekly geometric average (or daily maximum), respectively. These limits are based on the demonstrated ability of existing facilities to comply with these limits using present available technology and best professional judgement (BPJ) in order to ensure that the water body standards are not exceeded.

Metals are also monitored in the discharge: magnesium (Mg), lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), zinc (Zn), iron (Fe), nickel (Ni), silver (Ag), and selenium (Se). Sampling of metals in the surface water, sediment, and vegetation is also required within the wetland area. In wetland environments, many metals sorb to soil particles due to the anoxic environment and essentially become locked into the subsurface, thus preventing their movement out of the wetland. Therefore, they accumulate in the wetland soil. Provided conditions do not change, the metals eventually become buried. Continued discharge into the wetland of a metal can allow it to accumulate to levels considered toxic. Thus, periodic monitoring for these metals allows the permittee and LDEQ to assess any potential impacts from discharges of these metals.

Total Nitrogen (TN) and Total Phosphorus (TP) are included as report requirements. This allows LDEQ to monitor nutrients in the discharge to Louisiana waterbodies. The Louisiana Nutrient Management Strategy, in place since 2014, seeks to manage nutrients within the state's waterbodies. Quarterly monitoring for TN and TP is included in all assimilation wetland permits in accordance with the Point Source Implementation Strategy to allow for gathering of nutrient information. Additionally, monitoring of TN and TP allows for the calculation of TN and TP loading rates into the assimilation wetland. All facilities are permitted to discharge no more than 15 $g/m^2/yr$ TN or 4 $g/m^2/yr$ TP. Data from Reddy and DeBusk (1987) and Kadlec and Knight (1995) shows that these loading rates are well within the range of wetland plants to take up nitrogen and phosphorus without reaching levels that are harmful (Table 4).

Assimilation wetland permits also require additional monitoring within the wetland assimilation area. Basic monitoring requirements include monitoring of: vegetation through species classification (relative diversity, relative dominance, relative frequency, and importance value), percent whole cover, and growth studies; surface water through monitoring of water level, nutrients (ammonium (NH_4), nitrate/nitrite (NO_x), total Kjeldahl nitrogen (TKN), orthophosphate (PO_4) and TP), metals, and BOD_5, TSS, pH, dissolved oxygen (DO), and salinity; and soil through metals, nutrients, and accretion rate (Table 5).

Table 3. Secondary treatment wastewater effluent limitations

Parameter	30-day average	7-day average

BOD_5	30 mg/L	45 mg/L
TSS	30 mg/L	45 mg/L
pH	within the limits of 6.0–9.0	

Table 4. Potential nutrient uptake rates of common wetland plant species (Reddy and DeBusk, 1987; Kadlec and Knight, 1995).

Scientific Name	Common Name	Nitrogen Uptake ($g\ m^{-2}\ yr^{-1}$)	Phosphorus Uptake ($g\ m^{-2}\ yr^{-1}$)
Alternanthera philoxeroides	alligator weed	140-450	17.5-57
Eichhornia crassipes	water hyacinth	195-585	35-112.5
Hydrocotlye spp.	pennywort	54-320	13-77
Juncus spp.	rush	80	11
Lemna minor	duckweed	35-120	11.6-40
Phragmites spp.	reed	22.5	3.5
Pistia stratiotes	water lettuce	135-511	30-110
Salvinia spp.	watermoss	35-170	9.2-45
Scirpus spp.	bulrush	12.5	1.8
Typha spp.	cattail	60-263	7.5-40.3
	Cypress swamp	1.04-21.3	0.33-2.3
	Hardwood swamp		0.07-0.87

Beginning in 2017, permits were issued with more consistent monitoring requirements. Table 5 outlines current requirements. Specific methods for each analysis are also outlined in detail in the permit and the WQMP. The development of an Adaptive Management (AM) Plan is now required for all wetland assimilation projects, which are discussed in Section 1.4.

1.3. Feasibility and Baseline Studies

Potential dischargers are currently required to follow procedures outlined in the WQMP, which include a feasibility assessment and baseline study to be submitted for review by LDEQ prior to permit issuance. The feasibility assessment includes a delineation and description of the proposed wetland, list of landowners with any necessary agreements, a proposed reference area, and hydrology of the proposed area. The baseline study requires initial measures of the proposed assimilation area and the reference area.

Table 5. Monitoring requirements and frequency for assimilation wetlands.

Monitoring Requirement	Wetland Component Monitoring Frequency		
	Flora	Sediment	Surface Water
Flora Species Diversity	P_2		
Above-Ground Vegetative Productivity	A_1		
Water Level Measurements			M
Metals Analysis: Hg, Pb, Cd, Cr, Cu, Zn, As, Ni, Ag, Se	P_1	P_1	P
Nutrient Analysis I: TKN, TP	$P_{1,2}$	$P_{1,2}$	Q
Nutrient Analysis II: NH_4, NO_x, PO_4		P_1	Q
Others: BOD_5, TSS, pH, DO, Salinity, Temperature			Q
Accretion Rate		P	
Nutrient Loading Rates			A
Adaptive Management Practices			A

A: Annually. Once per year at all Wetland Areas. A_1 – Stem growth and litter fall.
M: Monthly. Once per month at all Wetland Areas.
Q: Quarterly. Once per three months at all Wetland Areas.
P: Periodically. Must be made once during the fourth year of the permit period for all Wetland Areas.
P_1 – Preservation, handling, and analysis must meet the specifications of the Test Methods for Evaluating Solid Waste Physical/Chemical Methods, third edition (USEPA Publication Number

SW-846, 1986, or most recent revision) or an equivalent substitute as approved by the administrative authority.
P_2 – To be conducted in summer (August to September) to reflect peak growth.

Measurements required includes a flora classification; vegetative productivity; metal and nutrient concentrations of sediment; water level; water quality measurements including, salinity, dissolved oxygen, conductivity, and nitrogen and phosphorus parameters; and accretion.

LDEQ has submitted an updated WQMP to USEPA for review and plans to include more updates in the near future. Among the changes proposed to the WQMP are more detailed requirements for the feasibility and baseline studies. The feasibility study is now to include proposed monitoring sites, a description of the current and historical health of the proposed wetland, a description of the proposed discharge distribution system layout, and a description of the anticipated management strategies. Language has also been proposed in the WQMP indicating the feasibility assessment may be public noticed. Additionally, the permittee is not to initiate implementation of the baseline study or preparation of the permit application prior to receiving LDEQ's approval of the feasibility assessment. Baseline study requirements now include a listing of the specific parameters to be measured. For example, instead of "sediment analysis for metals," the specific metals to be analyzed are listed (e.g., Cd, Cr, Co, Pb, Zn, etc.). Sampling of Mg and Fe are being replaced with mercury (Hg) and arsenic (As) as mercury and arsenic are more toxic than Mg and Fe.

1.4. Water Quality Management Plan

In addition to the updates addressed above, the WQMP update includes the following:

- language specifying the feasibility study must be approved before a permit application can be submitted;
- language stating the baseline study shall be submitted and approved by LDEQ before a final permit is issued allowing for the discharge into proposed wetland;
- a more detailed description of acceptable statistics, which includes the use of nonparametric statistics when statistical groups have unequal variances;
- requirements for the number of sites per the total size of the assimilation wetland;
- a more detailed method for measuring productivity in both forests and marshes, including acceptable equations;
- methods for measuring relative density, relative dominance, relative frequency, and importance values for wood vegetation with acceptable equations;
- methods for percent whole cover with detailed descriptions for when samples will be collected and how percent cover will be calculated, including indicating if any of the site is flooded with no vegetation present;
- methods for accretion, including a method to be used when a site is too submerged for the standard feldspar method; and
- requirements for what should be included in an AM Plan.

The proposed WQMP updates will provide a more detailed and thorough feasibility and baseline study to better enable LDEQ to make a more informed decision. Clearer and more detailed descriptions of expected methods ensure more consistency between sites and ensure the data LDEQ receives is accurate. Though each site requires the same basic measurements, how each wetland is managed will be different depending on the wetland type present, the hydrological regime, and site-specific environmental factors. Management of each wetland assimilation site is crucial to the success of the wetland assimilation project. Therefore, the permittee is required to develop and implement an AM Plan. This Plan shall include all management practices necessary to ensure the health of the wetland assimilation area. This shall include, but is not limited to, the following:

- *Historical and current conditions of the wetland assimilation areas* – The AM Plan shall include the historical and current conditions of the wetland assimilation areas. This may include a record of plant species, current state of degradation, probable cause of the degradation, etc., as applicable.
- *Discharge distribution plan* – This shall be an established procedure describing how the effluent will be distributed into the wetland assimilation area, promoting restoration and sustainability of the wetland ecosystem while, at the same time, assimilating nutrients. Healthy wetlands typically experience a natural pulsing, or fluctuation, of floodwaters. Therefore, the discharge distribution plan must establish a method to discharge effluent into the wetlands in a manner that ensures uniform coverage and to the maximum extent possible simulates natural healthy conditions, within the wetland assimilation area.
- *Use of water control structures* – as necessary, the use of water control structures should be used in areas to avoid short-circuiting to maximize the assimilation potential of the wetland.
- *Extension of water distribution system* – The extension of the water distribution system may be necessary to ensure uniform coverage across the assimilation area.
- *Control of invasive species* – The introduction of nutrient enriched effluent may invite many invasive species (flora and fauna) into the wetland assimilation area, which may cause a negative impact to the area. Therefore, a program designed to control these invasive species should be developed and implemented, as necessary to prevent a negative impact.
- *Plantings of trees and other vegetation* – In some cases, the wetland assimilation areas are heavily degraded and are permanently flooded. In these areas, the planting of seedlings may be advantageous to ensure new growth, thus enhancing the longevity and sustainability of the wetland assimilation area.
- *Hydrologic studies* – As treated wastewater is discharged into the wetland assimilation area, changes within the area are expected. A negative impact could be channelization of the effluent, reducing the assimilation potential of the area. Therefore, periodic studies, such as dye studies or tracer studies, shall be conducted once within the permit cycle to ensure that uniform coverage over the wetland assimilation area is being maintained. Please note any dye or tracer used requires approval from the Water Permits Division prior to use.

Some sites may be required to include site-specific management strategies. Part of the goal of the AM Plan is to have permittees consider potential issues and consider solutions before they arise and to have a plan already in place if they do arise.

2) Wetland Assessment and Reviews

The Water Planning and Assessment Division (WPAD) of LDEQ has assessed NPP of the assimilation wetlands in the 2018 IR. The NPP for the most recent five years is assessed to determine each wetland's ability to meet the NPP criteria. Additionally, the Water Permits Division (WPD) of LDEQ oversees the individual sites and ensures each permittee submits a completed Annual Wetland Report. Along with ensuring the reports are submitted, WPD is reviewing each site's report, long-term NPP data, and concentrations of nutrients and metals in sediment and vegetation. The WPD is sending a review of report completeness and any potential problems found in the long-term NPP data or nutrient or metal concentrations to each permittee. This review will ensure the permittee is aware of any issues and they are addressed in a timely manner.

2.1. Integrated Report Assessment

LDEQ is required to provide, every two years, an analysis of the state's waterbodies in regard to their support of recreational activities and fish and wildlife propagation. This analysis is presented as the Integrated Report. In the 2018 IR, LDEQ compiled and assessed data from the Annual Wetland Monitoring Reports received from 2013 to 2017, which presents data from 2012 to 2016. LDEQ used the perennial (stem growth) and ephemeral (litterfall) productivity to calculate total NPP data for forested sites. Marsh sites used the end-of-season live biomass as their NPP. The Near (site closest to point of effluent addition) and the Reference sites were used to calculate the outcome of the criterion. If a site had multiple wetland types, the nearest sites to the effluent addition for each wetland type were used to calculate the criterion. The assessments were used to address the FWP designated use. The following assessment process was performed for the assessment:

1. Productivity data was compiled for the years 2012-2016 for the Near, and/or nearest sites of each wetland type, and corresponding Reference sites for each assimilation wetland.
2. Calculate the NPP for each site using the following equations:
   a. For a Forest Wetland site,
      NPP=perennial productivity + ephemeral productivity
   b. For a Marsh Wetland site,
      NPP=end-of-season live biomass
3. Calculate the year-to-year percent change for each site. If multiple sites were present for any site type (e.g., near, mid, etc), then the percent change was calculated using the average of year-to-year percent change for the combined sites.
4. The following decision tree was then used to determine impairment:
   A. For each year-to-year comparison is there a reduction in growth at the Test Site as indicated by a negative growth percentage?
      a. No (e.g., > 0% growth) – **Not impaired for that year-to-year comparison**
      b. Yes (e.g., < 0% growth)
         If yes, is there a reduction or increase at the Reference Site?
         i. Reference Site <u>Reduction</u> – Is the Test Site reduction less than the Reference Site reduction?
            a) Yes (e.g., Reference Site -30% and Test Site -10% = Lower rate of reduction at Test Site – **Not impaired for that year-to-year comparison**
            b) No – See next step
         ii. Reference Site Reduction – Is the Test Site reduction more than 20 percentage points less than the Reference Site reduction?

a) Yes (e.g., Reference Site -5% and Test Site -30% = 25 percentage points (>20%) reduction below Reference Site) – **Impaired for that year-to-year comparison**; also,
b) No (e.g., Reference Site -5% and Test Site -20% = 15 percentage points (<20%) reduction below Reference Site) – **Not impaired for that year-to-year comparison**

iii. Reference Site Increase – Is the Test Site reduction more than 20 percentage points less than the Reference Site increase?
a) Yes (e.g., Reference Site +5% and Test Site -20% = 25 percentage points (>20%) reduction below Reference Site) – **Impaired for that year-to-year comparison**
b) No – (e.g., Reference Site +5% and Test Site -10% = 15 percentage points (<20%) reduction below Reference Site) – **Not impaired for that year-to-year comparison**

B. Over the five-year period, how many year-to-year impairments occurred?
a. One year-to-year impairment – **Not impaired for the IR assessment**
b. Two or more year-to-year impairments – **Impaired for the IR assessment** and request further investigation by the facility to determine possible cause for the reduction in growth.

Subsegments where impaired assimilation wetlands were present were reported as impaired for FWP and have been placed in IR category 4b. A summary of each assessed site's findings for NPP are presented in Table 6, with more details of each year's data found in Table 7.

Table 6. Summary of assimilation wetland assessments from the 2018 Integrated Report.

Facility	2018 IR	Year Range
City of Breaux Bridge	Not Impaired	2012-2016
City of Thibodaux	Impaired	2012-2016
St. Mary Parish	Not Impaired	2012-2016
Town of Broussard	Not Impaired	2012-2016
City of Mandeville-Bayou Chinchuba	Impaired	2012-2016
City of Mandeville-Tchefuncte Marsh	Not Impaired	2012-2016
St. Charles Parish	Not Impaired	2012-2016
City of St. Martinville	Not Impaired	2012-2016
City of Hammond	Impaired	2012-2016

Table 7. Individual results of assimilation wetland assessments from the 2018 Integrated Report.

Year	% Change Near Site	% Change Ref Site	Assessment of Year-to-Year Support
			St. Charles Parish – Luling Wetland
			Forested Site (Near Site)
2012 to 2013	2.1%	-20.2%	Meet - Positive growth at test site
2013 to 2014	129.3%	72.6%	Meet - Positive growth at test site
2014 to 2015	-24.3%	-22.0%	Meet - Test percent loss is within 20 percentage points of reference site
2015 to 2016	6.0%	22.0%	Meet - Positive growth at test site

Year	% Change Near Site	% Change Ref Site	Assessment of Year-to-Year Support
			No annual failure over four years - Supports FWP
City of Hammond – South Slough Wetland			
Marsh Site (Near Site)			
2012 to 2013	106.2%	78.1%	Meet - Positive growth at test site
2013 to 2014	-17.1%	-44.0%	Meet - Test percent loss at lower rate than reference site loss
2014 to 2015	-14.5%	32.7%	Not Meet - Test percent loss >20 percentage points below reference site
2015 to 2016	61.7%	-14.5%	Meet - Positive growth at test site
City of Hammond – South Slough Wetland (con'd)			
Forested Site (Mid Site)			
2012 to 2013	-22.1%	16.9%	Not Meet - Test percent loss >20 percentage points below reference site
2013 to 2014	3.0%	40.4%	Meet - Positive growth at test site
2014 to 2015	37.6%	7.5%	Meet - Positive growth at test site
2015 to 2016	-19.1%	6.0%	Not Meet - Test percent loss >20 percentage points below reference site
			Three annual failures over four years - Impaired for FWP
City of Mandeville – Chinchuba Swamp			
2012 to 2013	-52.5%	-5.1%	Not Meet - Test percent loss >20 percentage points below reference site
2013 to 2014	87.8%	26.5%	Meet - Positive growth at test site
2014 to 2015	12.2%	-23.2%	Meet - Positive growth at test site
2015 to 2016	-5.8%	49.1%	Not Meet - Test percent loss >20 percentage points below reference site
			Two annual failures over four years - Impaired for FWP
City of Mandeville – East Tchefuncte Marsh			
Forested Site (Near Site)			
2012 to 2013	-49.0%	-5.1%	Not Meet - Test percent loss >20 percentage points below reference site
2013 to 2014	121.9%	26.5%	Meet - Positive growth at test site
2014 to 2015	-29.7%	-23.2%	Meet - Test percent loss is within 20 percentage points of reference site
2015 to 2016	26.0%	49.1%	Meet - Positive growth at test site
			One annual failure over four years - Supports FWP
City of Broussard – Cote Gelee Swamp			
2012 to 2013	-39.6%	62.6%	Meet - Test percent loss at lower rate than reference site loss
2013 to 2014	81.4%	89.6%	Meet - Positive growth at test site
2014 to 2015	-10.3%	-2.2%	Meet - Test percent loss is within 20 percentage points of reference site
2015 to 2016	-10.4%	-0.6%	Meet - Test percent loss is within 20 percentage points of reference site
			No annual failures over four years - Supports FWP
City of Breaux Bridge – Cypriere Perdue Swamp			
2012 to 2013	-14.2%	-26.1%	Meet - Test percent loss at lower rate than reference site loss
2013 to 2014	-31.0%	-21.7%	Meet - Test percent loss is within 20 percentage points of reference site
2014 to 2015	21.8%	47.0%	Meet - Positive growth at test site
2015 to 2016	-10.8%	-17.2%	Meet - Test percent loss at lower rate than reference site loss
			No annual failures over four years - Supports FWP

Year	% Change Near Site	% Change Ref Site	Assessment of Year-to-Year Support
St. Martinville – Cypress Island Coulee Swamp (mean of three Near sites)			
2012 to 2013	-45.1%	-50.5%	Meet - Test percent loss is within 20 percentage points of reference site
2013 to 2014	94.6%	52.4%	Meet - Positive growth at test site
2014 to 2015	31.6%	14.2%	Meet - Positive growth at test site
2015 to 2016	-44.6%	-6.2%	Not Meet - Test percent loss >20 percentage points below reference site
			One annual failure over four years - Supports FWP
City of Thibodaux – Pointe Au Chene Swamp			
2013 to 2014	-33.8%	45.3%	Not Meet - Test percent loss >20 percentage points below reference site
2014 to 2015	16.9%	6.2%	Meet - Positive growth at test site
2015 to 2016	-20.4%	-36.3%	Meet - Test percent loss at lower rate than reference site loss
2016 to 2017	-39.5%	24.6%	Not Meet - Test percent loss >20 percentage points below reference site
			Two annual failures over four years - Impaired for FWP
St. Mary Parish – Bayou Ramos Swamp			
2012 to 2013	640.5%	292.0%	Meet - Positive growth at test site
2013 to 2014	-51.3%	22.5%	Not Meet - Test percent loss >20 percentage points below reference site
2014 to 2015	9.4%	-4.2%	Meet - Positive growth at test site
2015 to 2016	18.4%	7.3%	Meet - Positive growth at test site
			One annual failure over four years - Supports FWP

2.2. Annual Wetland Reviews

The Annual Wetland Report is required every year by April 15th for major facilities (> 1 MGD) or 28th for minor facilities (< 1 MGD) for new and recently renewed permittees. A handful of permittees are still required to submit their reports by the date of their last permit issuance, but will be required to move that date to April 15th or 28th the next time their permit is renewed. The WPD reviews the reports for completeness, accuracy, areas of concern (e.g., elevated metals in soil), and any permit violations (e.g., failure of NPP criterion or high loading rates). Beginning in 2019, letters of review have been sent, outlining any areas of concern and requesting reports to address any permit violations. As part of this review, the long-term NPP is analyzed to determine the long-term trend for the period of record at each site as opposed to a five-year assessment required for the IR. The NPP for each year an assimilation wetland has data is plotted against time and the slope for each line is calculated. The slope of the line is equivalent to the rate of NPP change over time. Calculating the slope of all the data provides a mean of the long-term NPP rate and any extreme years are buffered by using all the data points. The slope of the reference site is used to calculate a 20% decrease using the following equation:

$$NPP_{80} = NPP_{ref} - |NPP_{ref} * 0.2|,$$

where NPP_{ref} is the mean of all reference site slopes and || is the absolute value. The slope of each site is then compared to the NPP_{80} of a reference site of the same wetland type. If a site is less than the NPP_{80} it is considered to be failing. If a site is more than the NPP_{80}, it is considered to pass. Using this method in conjunction with the IR assessment method, provides a more robust look at each assimilation wetland's long-term health. Permittees with failing sites are required to develop a study and test procedures to determine the origination of the cause(s) within 180 days. A summary of the results is in Table 8 and graphs of all sites are presented in Figure 8 through Figure 4.

Table 8. Summary of long-term assimilation wetland annual evaluation. The NPPs presented in the table are the slopes of all data.

Facility	Year Range	Reference Site NPP	80% Ref Site NPP	Near Site NPP	Evaluation Result
			(g/m²/yr)		
City of Breaux Bridge	2007-2018	94.86	75.89	29.02	Impaired
City of Hammond	2007-2018	-41.39	-49.67	52.98	Pass
City of Mandeville-BC*	2007-2018	-4.43	-5.32	73.52	Pass
City of Mandeville-TM	2010-2018	-4.43	-5.32	29.77	Pass
City of St. Martinville	2011-2018	-89.32	-107.18	7.65 27.16 77.43	Pass
City of Thibodaux	2007-2018	-23.46	-28.15	-20.91	Pass
St. Charles Parish	2007-2018	6.78	-5.42	13.56	Pass
St. Mary Parish	2011-2018	-37.51	-45.01	127.53	Pass
Tchefuncta Club Estates	2009-2017	22.02	17.61	35.34	Pass
Town of Broussard	2008-2016	37.46	20.17	73.92 111.42	Pass

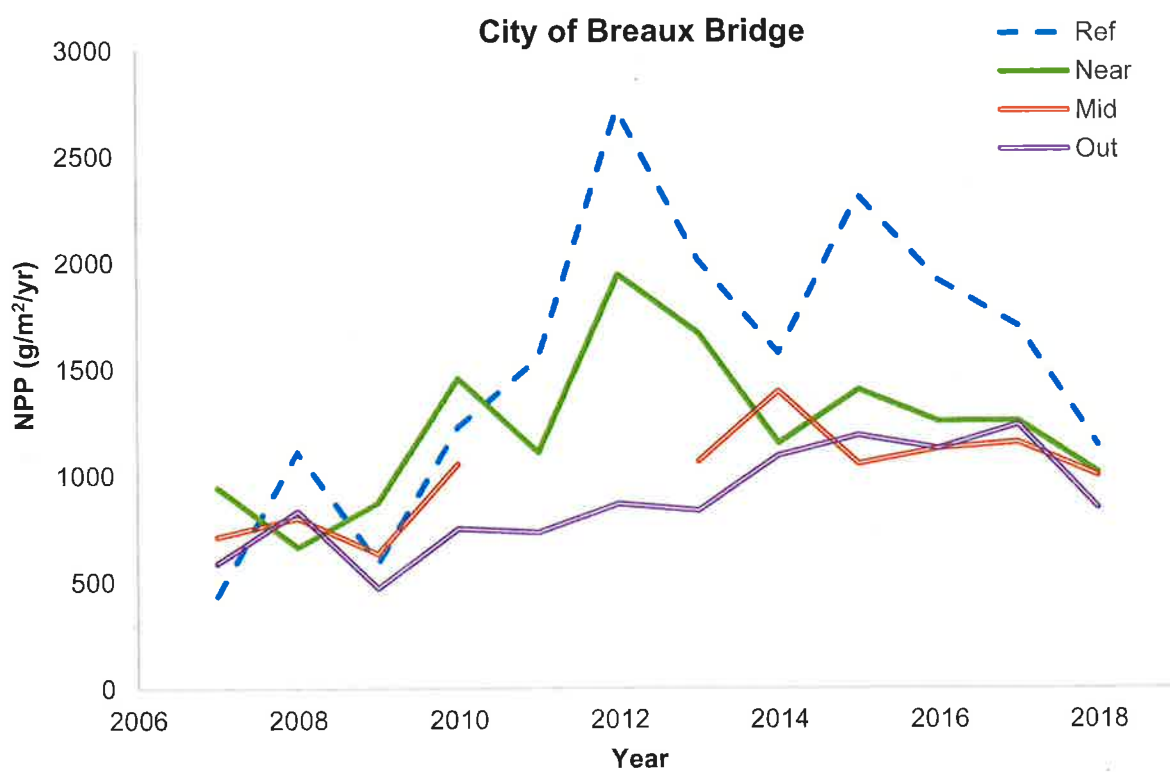

Figure 2. NPP for the City of Breaux Bridge from 2007-2018. NPP could not be calculated for 2011-2012 due to high water preventing the measurement of stem productivity.

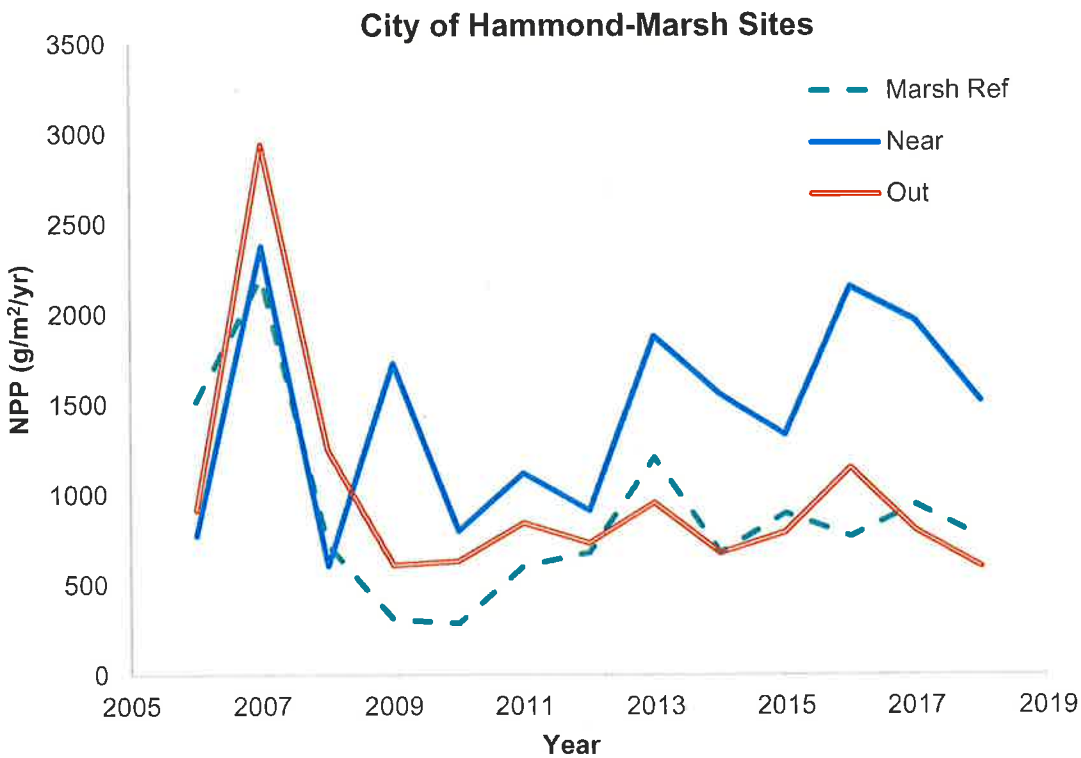

Figure 3. NPP for the City of Hammond's marsh sites from 2006-2018.

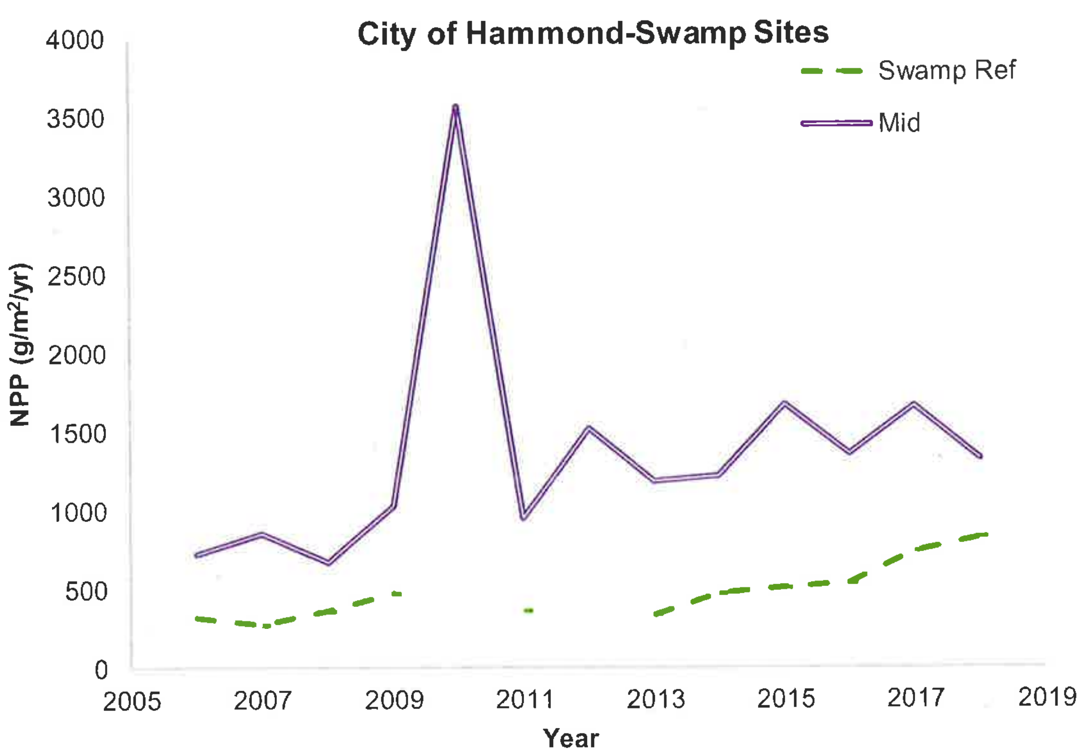

Figure 4. NPP for the City of Hammond's swamp sites from 2006-2018. NPP could not be calculated for 2010 and 2012 because tags marking trees for stem productivity had been stolen.

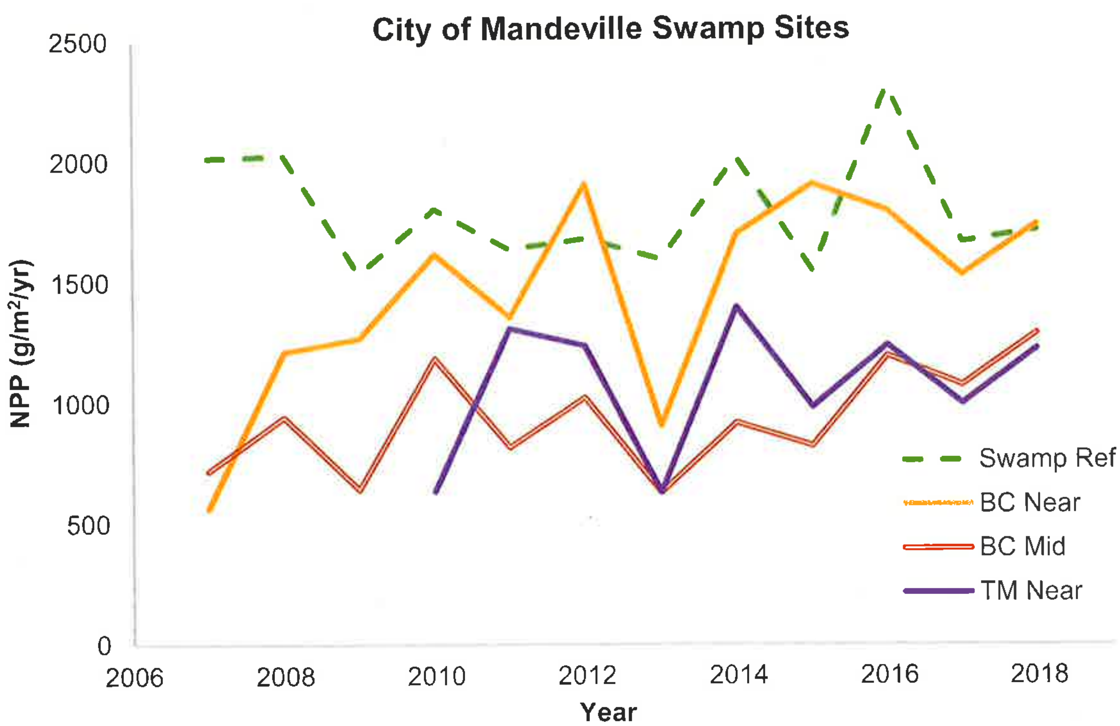

Figure 5. NPP for the City of Mandeville's swamp sites from 2007-2018. BC is Bayou Chinchuba and TM is Tchefuncte Marsh.

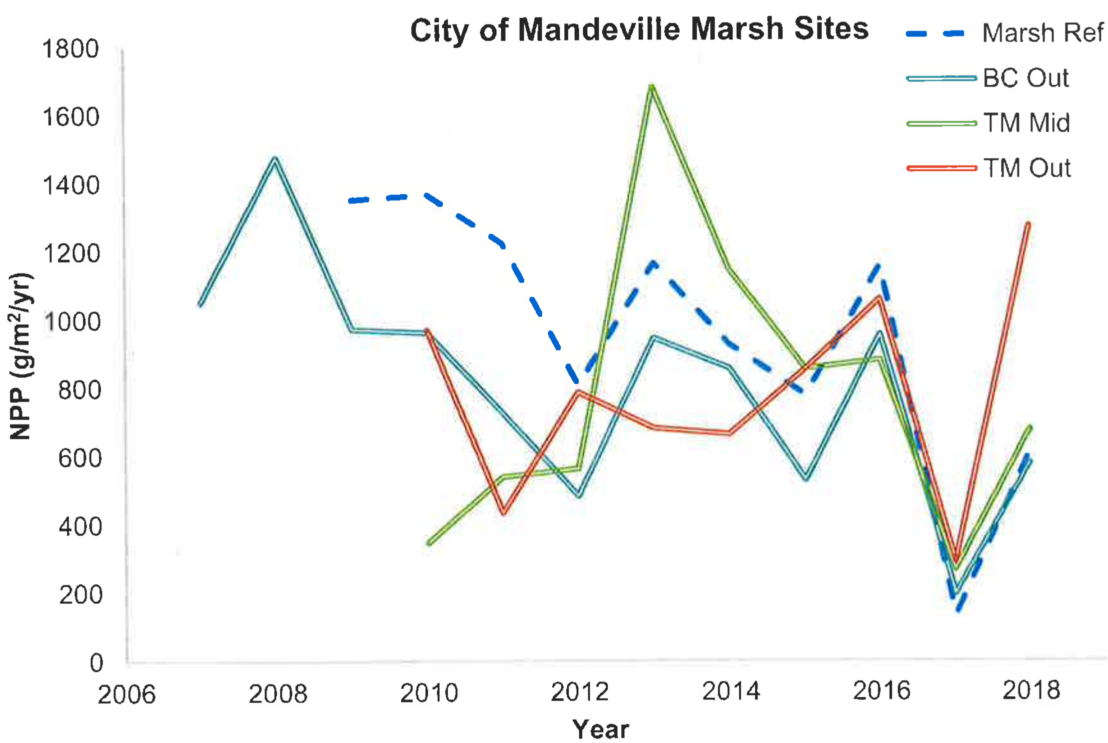

Figure 6. NPP for the City of Mandeville's marsh sites from 2007-2018. BC is Bayou Chinchuba and TM is Tchefuncte Marsh.

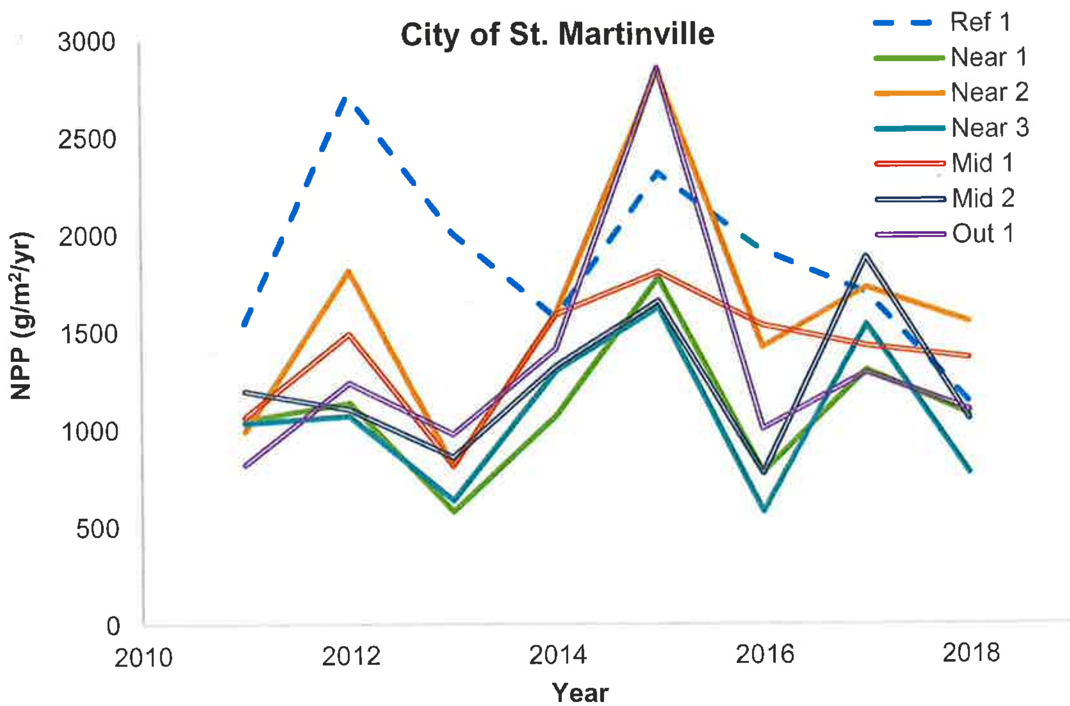

Figure 7. NPP for the City of St. Martinville from 2011-2018.

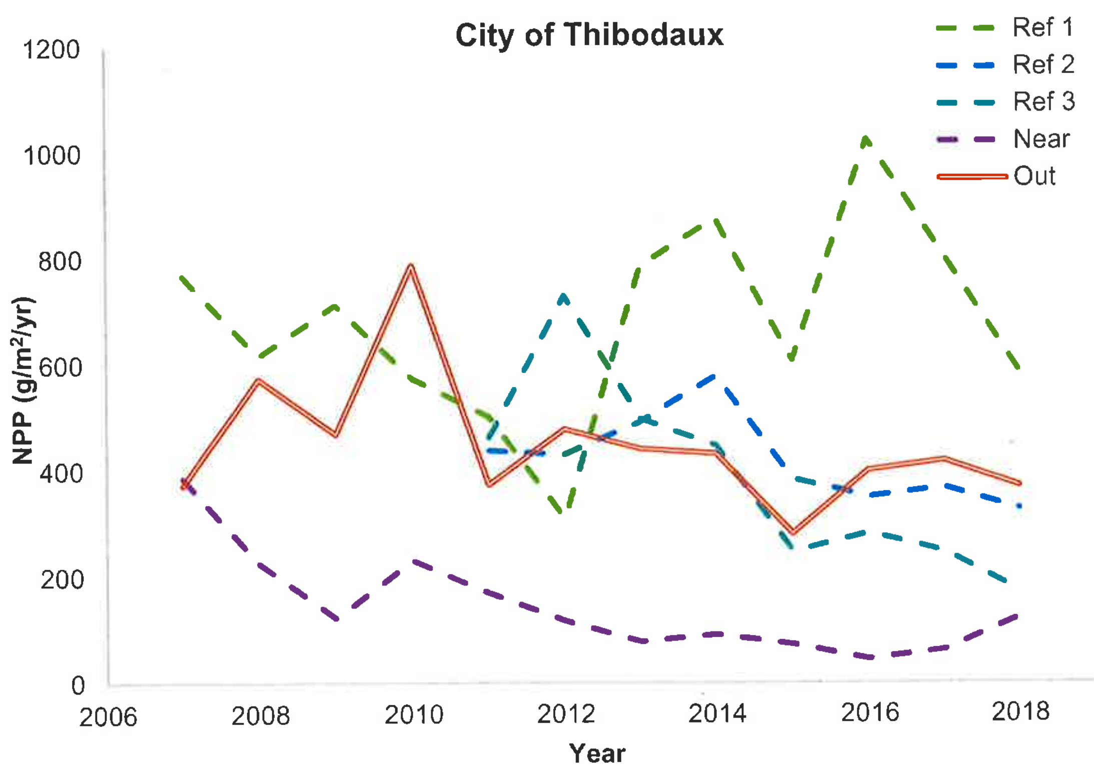

Figure 8. NPP for the City of Thibodaux from 2007-2018.

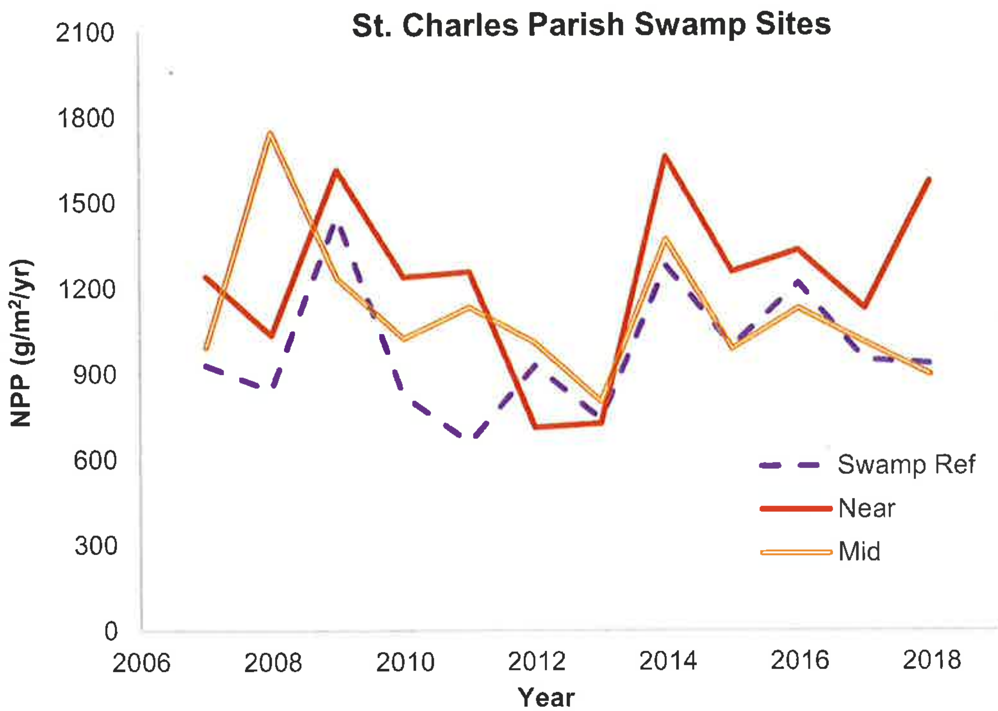

Figure 9. NPP for St. Charles Parish's swamp sites from 2007-2018.

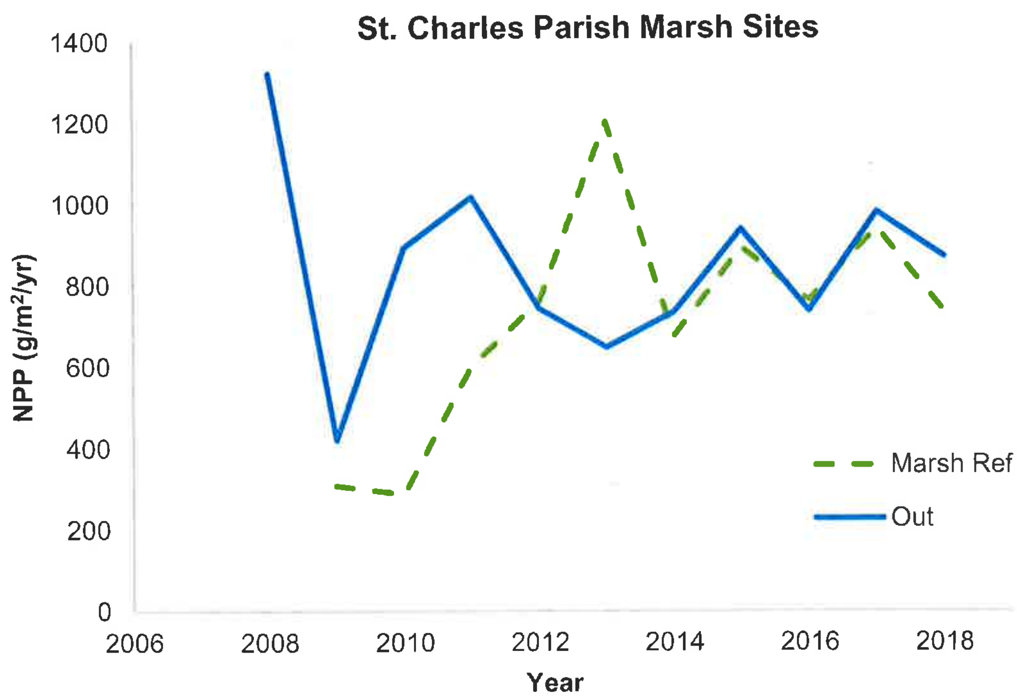

Figure 10. NPP for St. Charles Parish's marsh sites from 2007-2018.

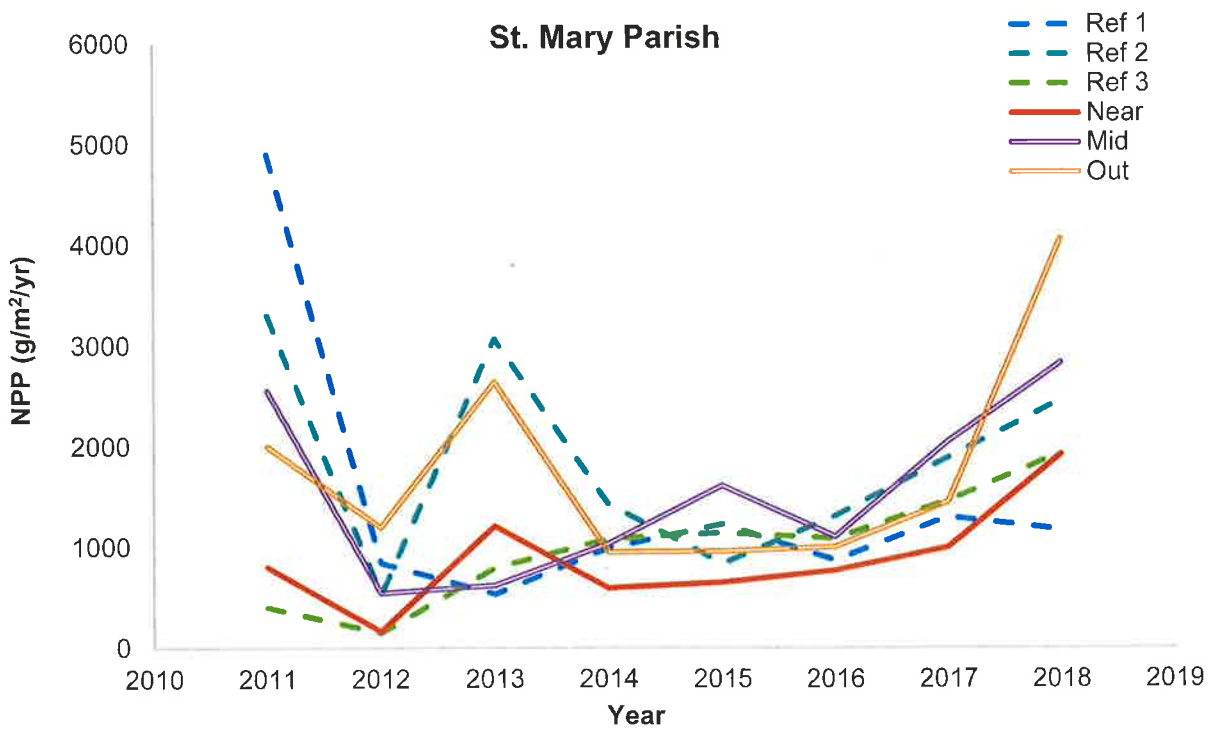

Figure 11. NPP for St. Mary Parish from 2011-2018.

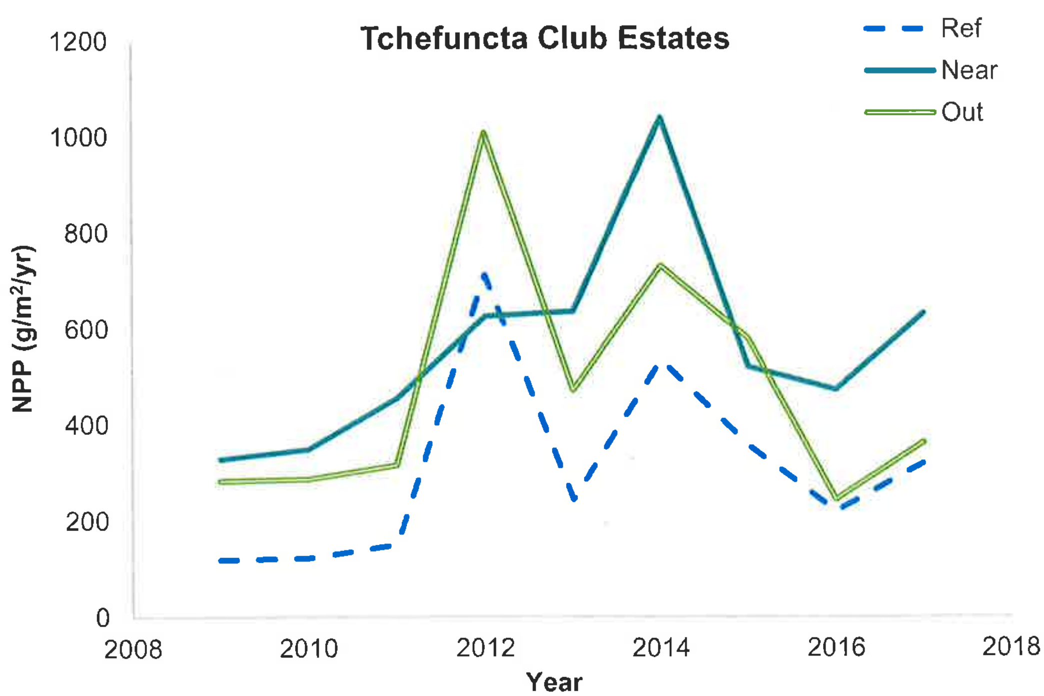

Figure 12. NPP for Tchefuncta Club Estates from 2009-2017.

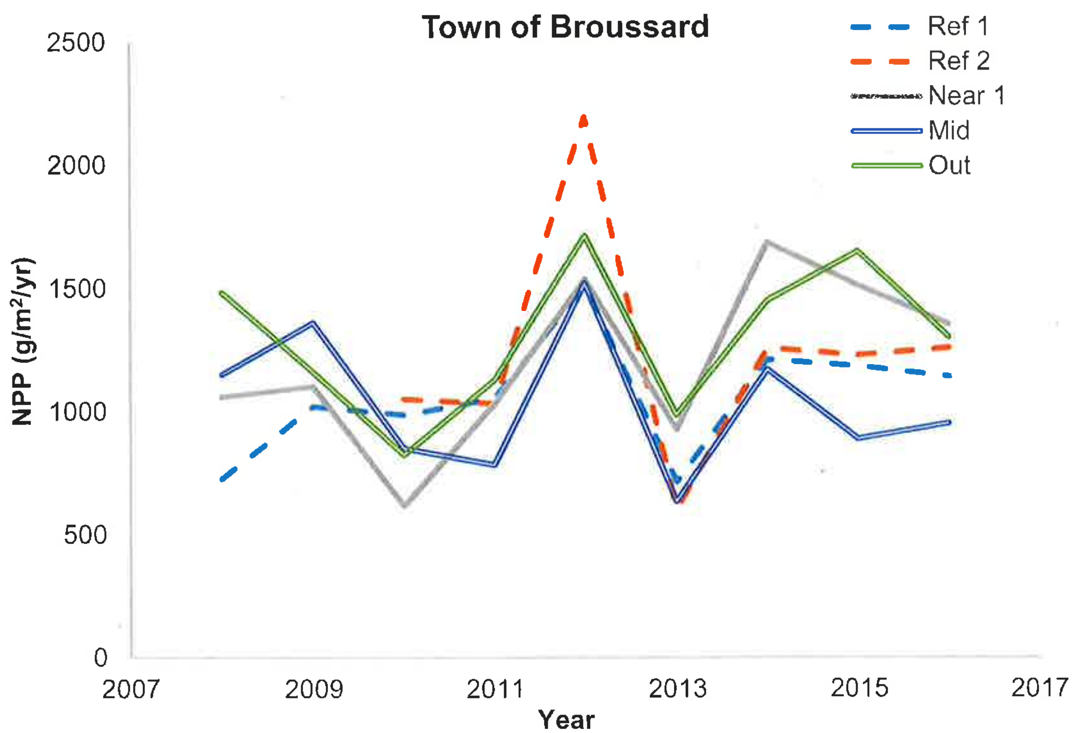

Figure 13. NPP for the Town of Broussard from 2008-2016.

All facilities are currently permitted for loading rates that are not to exceed 15 $g/m^2/yr$ TN or 4 $g/m^2/yr$ TP. Terrebonne Parish was originally permitted for loading rate limits of 25 $g/m^2/yr$ TN and 9 $g/m^2/yr$ TP from June 1, 2013 to May 31, 2019; however, their most recent permit, effective on June 1, 2019, reduced the loading rate limit to 15 $g/m^2/yr$ TN and 4 $g/m^2/yr$ TP. As part of the annual wetland review, loading rates are calculated for each facility from their discharge monitoring reports (DMR). Using the flow, TP, and TN data from the DMRs, annual loading rates and an overall mean were calculated (Table 9). Facilities exceeding their permitted loading rates were notified and required to provide a plan for reducing their discharge numbers within 30 days and the plan shall be implemented within 60 days of discovering these rates are too high.

In 2016, a flyover of all assimilation wetland projects was performed and photographs taken of each wetland. Prior to 2019, four of the assimilation wetlands were visited by WPD staff and, in 2019, six assimilation wetlands were visited by WPD staff. The Department intends to visit the remaining three permitted wetlands in 2020. Regular site visits will continue with the addition of drone flyovers, where access is available. In May 2019, WPD staff visited the Hammond assimilation wetland along with LDEQ's Unmanned Aircraft Systems (UAS) staff (Figure 14). The Program Manager for UAS was able to flyover Hammond's wetland providing WPD with a unique visual for the wetland's health. While NPP data from each wetland provides insight into the health of each wetland, the NPP data is only taken in specific areas. Utilizing information from flyovers provides LDEQ with an aerial image that shows the entire wetland and can show the amount of open water to wetland coverage. Additionally, flyovers are close enough to the surface (as opposed to GIS imagery) to allow the discernment between floating aquatic vegetation and rooted marsh vegetation. This is particularly beneficial for the Hammond wetland, as it recovers from a collapse of the marsh that occurred in 2009. The LDEQ UAS Program plans to obtain a fixed-wing aircraft, which will enable staff to acquire imagery that can be digitized and used to calculate percent cover.

Table 9. The mean loading rates for TN and TP for assimilation wetlands. Loading rates are not to exceed 15 g/m2/yr TN or 4 g/m2/yr TP. Those rates exceeding the 15/4 rates are presented in bold. The two loading rates for Hammond are based on the entire 10,000 acres and the estimated actual size of the active assimilation. More information is presented in Section 3.3.

Facility	Year Range	Mean Loading Rates TN (g/m2/yr)	Mean Loading Rates TP (g/m2/yr)
City of Breaux Bridge	2009-2018	1.39	0.29
City of Hammond	2010-2018	4.15*	0.81
		25.44§	**4.97**
City of Mandeville-BC	2010-2018	**22.93**	**4.21**
City of Mandeville-TM	2010-2018	3.16	0.56
City of St. Martinville	2011-2018	2.67	1.24
		5.76	1.34
		9.14	2.36
City of Thibodaux	2011-2018	3.71	0.62
Guste Island Utility Co	2009-2018	2.83	0.79
St. Charles Parish	2008-2018	3.74	0.88
St. Mary Parish	2011-2018	5.1	1.36
Tchefuncta Club Estates	2009-2017	12.55	1.5
Terrebonne Parish†	2016-2018	16.83	7.84
Town of Broussard	2010-2018	**38.79**	**11.49**

*data based on 10,000 acres
§data based on 1,630 acres
†Terrebonne was permitted for 25 $g/m^2/yr$ TN and 9 $g/m^2/yr$ TP in this time frame.

Figure 14. Aerial view of the marsh portion of the City of Hammond's assimilation wetland.

3) Assimilation Wetlands Reviews

The assimilation wetland program has been evaluated by LDEQ in the past three years, which has resulted in modifications and improvements to the permits and the annual report review process. The first evaluation was an internal review aimed at reviewing the literature available for questions about the program and providing summaries of the review along with suggestions for the best path forward when applicable. A second evaluation was performed by an independent contractor, specifically regarding the City of Hammond's wetland and the collapse of its marsh. This review was performed by Naturally Wallace Consulting, LLC (NWC) with little input from LDEQ. LDEQ's contract with NWC specified the report was to be as unbiased as possible, allowing NWC to reach their own conclusions. Along with specific recommendations for Hammond, the report provided some overarching recommendations for all assimilation wetlands.

3.1. LDEQ Literature Review

In May 2015, topics of interest related to the LDEQ's wetland assimilation program were identified by LDEQ staff for research through a review of available literature and program materials. The following are the identified topics and response for each question.

1) ***What are appropriate measures of overall health of wetland area documented in the literature?***

   The appropriate methods to estimate overall wetland health (or wetland condition) vary greatly and are highly dependent upon the specific needs and goals of those implementing them. Most methods require a variety of different measurements used collectively to determine the condition of a specific wetland. However, the primary objective of a long-term monitoring study needs to be determined. The primary objective should outline the desired outcomes and goals. Once the objectives have been explicitly defined, the appropriate methods used to estimate overall wetland health will become clearer.

2) ***What is the value in parameters included in the LPDES permit for overall health of wetland?***

   The vegetative measures (aboveground biomass and species classification) provide an overview of how the vegetative community is responding to the increased hydrologic and nutrient load. Aboveground biomass gives an indication of growth, while the species classification provides an overview of the plant community. Nutrients (TKN, TP, NO_x, NH_4, PO_4) and metals (Cd, Cr, Cu, Zn, Fe, Pb, Mg, Ni, Se, and Ag) are measured in plant tissue, soil, and water and provide knowledge of where the nutrients from the treated wastewater are moving through and within the wetland. *In situ* values for BOD_5, TSS, pH, DO, salinity, and temperature are measured in the water column to evaluate general water quality and ensure downstream designated uses are protected. Water level is measured to provide insight into the effects of the treated wastewater on hydrology, while soil accretion rates afford a measure for any increase in soil elevation. Metal concentrations in the water column can be used to assess for toxicity.

3) ***Are current criteria an appropriate measure?***

   The current criteria and required measures are relevant to determining wetland health; however, additional ones may be needed. The assessment of biological integrity for wetlands approved for wastewater assimilation projects in Louisiana is guided by the above-ground vegetation productivity as indicated by "there shall be no more than a 20% reduction in the rate of total above-ground wetland productivity over a five-year period as compared to a reference area (LAC, 2019)." Other criteria have also been outlined, but some are not frequently used, and some (e.g., faunal diversity) may no longer be relevant and are not measured. In order to ensure a more complete picture of wetland health, other factors may also be essential and need to be considered. Wetland health is dependent on more than the general productivity of vegetation. It would be prudent to review the outcomes and goals of the wetland assimilation program, determine if the criteria are still relevant, and research additional ones as needed.

4) Should any contribution from belowground, benthic, or faunal inputs be considered? If so, how should they be considered?

Belowground productivity of vegetation is difficult to measure and can be extremely variable depending on the time of year and species present. Additionally, separating live from dead material is extremely difficult due to the highly organic nature of wetland soils. Very little work has been done on belowground productivity, so it would be challenging to find comparison values (Cronk and Fennessy, 2001). Thus, belowground productivity should not be considered. Benthic and faunal inputs are typically measured using a diversity index; however, the methods would be time consuming, expensive, and potentially difficult to link to ecosystem changes due to the inherent variability in these measures. Some researchers have relied solely on the vegetative community to determine overall wetland condition due to the interconnectedness between the plant community and a wetland's biological (e.g., faunal communities), chemical, and physical properties (Cronk and Fennessy, 2001; USEPA (and references therein), 2016). While benthic and faunal measures may provide insight into overall wetland health and have well established measurements available, it may be more prudent to utilize a robust suite of vegetation measures. The current vegetation measures would need to be reviewed to ensure they are adequately capturing any benthic and faunal inputs.

5) Is 20% reduction comparison to reference wetland appropriate?

During the regulation update in 2006 and 2007, LDEQ, USEPA, and researchers determined that, "due to the variability inherent in natural systems, the margins of error expected in sampling methods and in statistical comparison, 20% is the best resolution at which differences in productivity between the discharge area and the reference area can be confirmed, and therefore attributed to impacts from the wastewater (LDEQ, 2006)." Significant strides have been made in the evaluation and assessment of long-term monitoring studies since the program first began in the early 1990s, and better methods may now be available. Consultation with a statistician familiar with long-term monitoring would help LDEQ determine the best model based on the desired power of detection.

6) If wetland type changes, should reference wetland also change?

The type of wetland and restoration goal would dictate whether a change in reference wetland type is warranted. If the goal were to restore a saltwater marsh to a freshwater marsh, then the reference wetland would need to change to a wetland of the new desired type. However, if the goal were to improve the sustainability of the current wetland present (swamp or bottomland hardwood forest) then a change to a marsh would indicate a problem and the reference type should not be changed.

7) *What is the growth turnover rate and life cycle of plants?*

For herbaceous wetland plants, it can take two to three years for the growth to turnover in temperate climates. However, in warmer climates where there is little, if any, freezing periods, marsh plant growth can turnover 3.5 to 10 times a year. Woody plants, however, take decades to turnover. Marshes harbor diverse plant communities that are primarily herbaceous, while forested wetlands are dominated by woody vegetation. All of these wetlands are dependent upon the water fluctuations occurring and an area's topography determines what species can grow. The turnover rate is highly dependent on the inflow rates, water depth, internal flow rates and patterns, timing and duration of flooding, and groundwater exchanges. Flood duration exerts control on the type of community present as well as species distribution. As flow increases, so does the species richness until the flow becomes too scouring and species richness declines. Additionally, drawdown periods are vital to some species, as their seeds will not germinate under standing water. The hydrology directly affects the species present and the stress each plant is experiencing, which, subsequently, affects its turnover rate (Cronk and Fennessy, 2001; Kadlec and Wallace, 2009).

When plants reach the end of their life, they begin to senesce. The dead parts fall to the soil/water surface becoming detritus, which is slowly decomposed by organisms. Because decomposition occurs in an anaerobic environment in wetlands, the plant detritus is not completely broken down and contributes to soil accretion and continued food for plant growth (Figure 15). As organisms break down the plants, some nutrients are returned to the soil and then fuel further plant growth.

8) *What is a good measure of growth?*

In general, the current methods are adequate. Growth, or an increase of biomass, in plants is typically considered synonymous with the term *primary production*. Net primary productivity (NPP) is the measured change in plant biomass over time, typically a year. Varieties of methods exist to measure

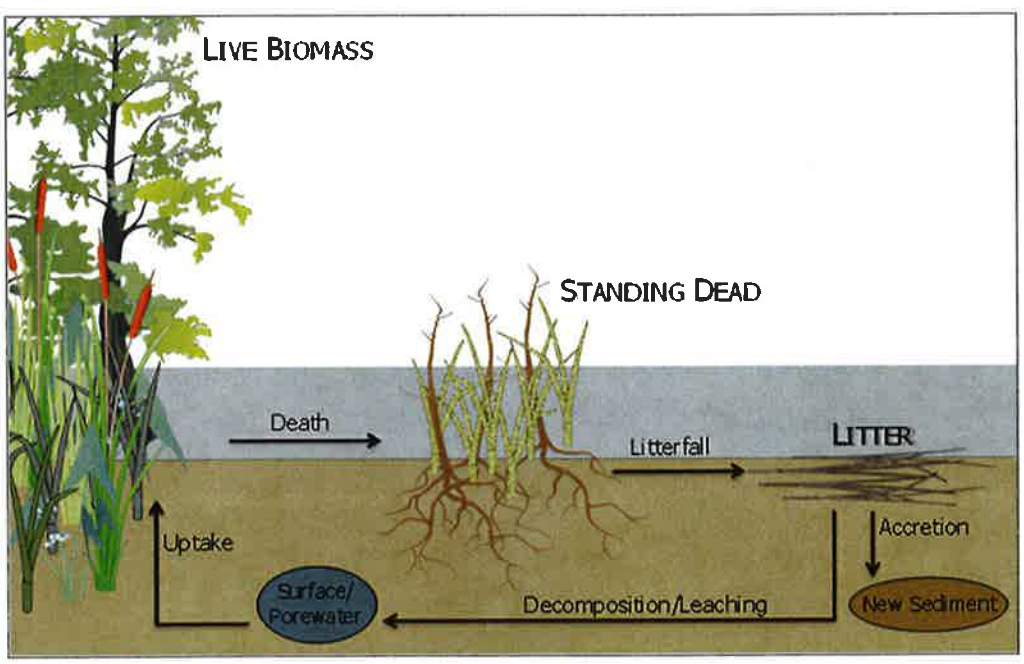

Figure 15. The plant life cycle.

NPP in plants. The end of season live biomass method (that is utilized for the assimilation wetlands) provides an underestimate of NPP, but when compared to a reference wetland measured in the same space and time it provides an adequate estimate. There is primarily one accepted method to estimate NPP in woody plants, utilization of allometric equations, and annual diameter at breast height measurements to estimate annual growth as outlined in the WQMP (Megonigal, et al., 1997; Cronk and Fennessy, 2001).

9) Is current measurement too broad? If so, what specific measurements might be more appropriate and why?

The specific parameters currently measured (Table 5) do provide information on wetland health in assimilation wetlands; however, a complete picture of wetland health may not be captured by current measures (Finding 3 above). More specificity in the criteria wording may help to more fully assess wetland health. Take the following criterion as an example, "There shall be no significant decrease in faunal species diversity and no more than a 20% decrease in faunal biomass." Specifics not included are the exact fauna to be included in faunal diversity, the method to measure diversity, and the statistical model to be used to evaluate significance. The lack of specificity makes it difficult for LPDES permittees to provide accurate information and for LDEQ to assess overall wetland health. The current measurements and criteria do provide a good starting point for the types of information that should be used to assess wetland health, but the wording may need refinement.

However, some criteria, such as fauna, may no longer be appropriate. Vegetative criteria may be able to replace faunal criteria if the measures for floral diversity are more clearly outlined and their robustness increased (Cronk and Fennessy, 2001). For example, the National Wetlands Condition Assessment utilized four vegetative measures (the Floristic Quality Assessment Index, Relative Importance of Native Plant Species, Number of Plant Species Tolerant to Disturbance, and Relative Cover of Native Monocot Species) to assess wetland condition and because of the interrelatedness between flora and fauna did not include a measure for faunal diversity (USEPA, 2016).

10) Does aboveground productivity account for new growth?

Yes, as growth is typically synonymous with primary productivity and aboveground productivity is typically the only part of growth that is measured. Refer to the answers to Findings of 4 and 7 for more information.

11) If the species composition of an assimilation wetland changes, will the new species still provide the same function?

New flora species will likely not provide the same function, though it depends on how function is defined. In general, wetland *functions* are the ecological processes taking place in a wetland (e.g., biogeochemical transformations), while wetland *services (or values)* are the benefits human populations derive from a wetland's functions (e.g., flood mitigation). Table 10 provides examples of each. If the wetland remains the same type (e.g., swamp, freshwater marsh, saltwater marsh) it would likely provide the same values. However, the wetland functions, as defined above, are more dependent on the specific vegetative species present and would likely be altered, though the extent of this alteration is unknown. Additionally, Keddy (2010) states that almost without exception higher nutrient

Table 10. Basic list of function and values commonly attributed to wetlands (Brinson and Rheinhardt, 1996; Mitsch and Gosselink, 2015).

Function	Value
Hydrologic	
Short and long-term surface water storage	Flood mitigation
Maintenance of water tables	Storm abatement/coastal protection
	Groundwater recharge
Biogeochemical	
Transformation and cycling of nitrogen, sulfur, and carbon	Improved water quality
Retention of toxics	Mitigation of global change
Decomposition of waste organics	
Sorption of phosphorus and heavy metals	
Accumulation of peat and inorganic sediments	
Habitat and Food Web Support	
Maintenance of plant and animal communities	Animal pelts
Maintenance of energy flow	Commercial fish/shellfish production
	Recreational hunting and fishing
	Timber production
	Maintenance of biodiversity
	Bird watching/aesthetics

concentrations (specific concentrations were not mentioned and will differ from species to species) cause plant diversity to decrease, so the likelihood of change occurring is high.

12) Should 20% reduction be limited to specific species?

No, all species present in a wetland ecosystem contribute to its overall health and should be included in the productivity measure. Inclusion of diversity measures may allow evaluations to be made as to the importance of any one species, but healthy wetlands include a diverse range of species. Typically, monocultures indicate system stress (Cronk and Fennessy, 2001).

13) What are documented nutrient uptake rates for the wetland plant species commonly found in Louisiana wetlands?

Nutrient uptake rates are presented in Table 4 and are dependent upon a myriad of variables, including but not limited to, type of soil, pH, temperature, and redox potential.

14) What are discharge levels in forested wetland vs. marsh? Is there a need to control the discharge at a level to allow the TYPE of wetland to act in a more natural fashion (e.g., uptake rates, wetting tolerance, etc.)?

Hydrologic inputs and outputs, such as water depth, water flow, or flooding frequency and duration, drive the biogeochemistry of the soils and biota present. This makes hydrology one of the, if not the single, most important determinant in the establishment and maintenance of wetland types and processes. When wetland hydrologic conditions change even a small amount, the biota may respond dramatically, altering species composition or richness, as well as ecosystem processes. Hydrology can limit or enhance species richness, primary productivity, and other ecosystem functions. Nutrient cycling and availability is also significantly influenced by hydrologic conditions (Mitsch and

Gosselink, 2015). Discharge levels vary among wetlands and are generally wetland-specific; thus, discharge levels should be controlled to allow for as natural a hydrological regime as possible. Each wetland is unique and levels should be determined individually for each wetland.

3.2. Literature Review Recommendations

The recommendations of this LDEQ review are as follows:

- The original goal of the program was to create sustainable wetlands to help offset coastal land loss. Other goals have been developed to leverage these wetlands in assimilating nutrient to aid in nutrient management in water bodies of the states (LNMS, 2019). Furthermore, designing an adaptive management program would provide LDEQ with the framework to review new and current LPDES permittees, modify requirements as needed, monitor for a specified period, evaluate and assess the results, and then make changes as needed and continue through this cycle in a clearly defined manner. This will help all stakeholders understand the program operation and provide a way for concerns to be addressed.
- Internally, LDEQ should develop clear, detailed guidance for baseline and feasibility studies and permitting requirements. This guidance may be developed with input from multiple water functions within LDEQ including water quality standards, assessment, and water permitting. Collaboration of the LDEQ water function involved in the assimilation wetland program is needed to ensure that each wetland is managed in a way that safeguards its continued health and sustainability while simultaneously optimizing nutrient assimilation and removal. Thus, the LDEQ water functions should work together to ensure that the assimilation wetland program can meet the goals for each water function.
- Hydrology is the primary feature that needs to be addressed for each wetland to ensure each ecosystem is experiencing the most appropriate hydrological regime. Many other problems (e.g., potential decline of vegetative growth) may be addressed by simply addressing the hydrology. Deciding the optimum approach to achieve the appropriate hydrological regime should include a hydrologist and engineer familiar with wetlands ecosystems.
- Originally, each wetland was required to have three site locations within the assimilation wetland. However, the sites at some wetlands are likely not capturing the wastewater flow through the wetland. Additionally, the size of an individual wetland may lend itself to more (or less) than three sites to ensure that adequate information is being captured. Thus, the placement and number of sites should be addressed, preferably with the assistance of a hydrologist (location) and statistician (number).
- The criteria and methods of assessing the criteria should be addressed as new advances in long-term monitoring have occurred recently. A statistician would help to modify current models or set up new models to ensure enough data is collected to detect changes at the desired level.

Of these recommendations, LDEQ has implemented the inclusion of an Adaptive Management Plan requirement into to all permits renewed since 2017 and more detailed guidance and requirements for the baseline and feasibility studies to the WQMP draft updates, which is currently with USEPA for review. Presently, LDEQ is working to determine guidelines for the number of sites needed per assimilation wetland. Once developed, these guidelines will be added to the WQMP, which is public noticed and the public is given the opportunity to comment, and individual assimilation wetlands will be evaluated during their next permit renewal.

3.3. Hammond Wetland Evaluation Report

The City of Hammond was originally permitted through an Administrative Order to discharge into the South Slough Wetlands in 2006. The area Hammond was permitted into includes 10,000 acres, 1,800 acres of which is marsh, while the remaining 8,200 acres is forested wetland. The majority of the forested wetland area is included in the Joyce Wetland Management Area, which is overseen by the Louisiana Department of Wildlife and Fisheries (LDWF). Beginning in 2007, the marsh to which Hammond discharges began to collapse. Multiple studies were conducted by the city's consultants (Comite Resources, LLC or Comite) to determine the cause of the collapse. Comite determined the main contributor to the collapse was the numerous nutria in the area who were preferentially eating the nutrient enriched marsh plants in the assimilation area (Ialeggio and Nyman, 2014; Shaffer, et al., 2015). Other scientists who investigated have claimed the collapse was caused by increased degradation of belowground biomass combined with decreased production of belowground biomass leading to weakened soil strength (Turner, et al., 2018).

In 2018, LDEQ contracted with an independent reviewer to evaluate the city's assimilation wetland. The contractor submitted their final report May 22, 2019 (NWC, 2019). NWC provided a discussion of the potential causes of the collapse as well as recommendations for Hammond specifically and the assimilation wetland program as a whole.

In 2007, (approximately one year after effluent addition began) the marsh portion of the assimilation wetland at Hammond shifted to open mud flats (Bodker, et al., 2015; Shaffer, et al., 2015). Two primary theories have been proposed as the cause of this collapse:

1) Increases in nutrient loading from the discharge into the assimilation wetland led to increased degradation rates of organic matter within wetland soils. This also resulted in decreasing belowground biomass and subsequently led to soil instability, which in turn led to a collapse of the existing plant community (Darby and Turner, 2008; Bodker, et al., 2015; Turner, et al., 2017)

2) There was a major nutria "eat out" of the marsh vegetation. Nutria have been shown to prefer fertilized vegetation (Ialeggio and Nyman, 2014). As the marsh became fertilized by the discharge, nutria consumed the vegetation present, causing a conversion to open water and mud flats (Shaffer, et al., 2015; Day, et al., 2019).

Turner, et al. (2017) and NWC (2019) estimated the marsh at Hammond transitioned to open water between 2007 and 2010 over an area of 122 hectares. This assumes a phosphorus assimilation rate of 46 m^2/yr, which falls into the 86^{th} percentile of k-rate coefficients determined by (Kadlec and Wallace, 2009) at the upper range of observed rates in treatment wetlands. The time frame in which the transition occurred also equates to a speed development rate of 0.7 years (NWC, 2019). The speed development rate is the inverse of the annual plant biomass contributing to accretion. A rate of 0.7 years would require the entire plant biomass of the marsh to turn over approximately 20 times per year (or every 0.6 months). Other studies of marsh plants have shown turnover rates ranging from 0.6 to 6.8 months during the peak summer growing season (July and August). For nutrients to be the sole cause of Hammond's wetland collapse, the wetland would have needed to respond to nutrient loadings extremely rapidly, much more rapid than has been found in other wetlands (NWC, 2019).

Organic carbon is used by bacteria to reduce nitrite/nitrate (NO_x) nitrogen to gaseous forms (N_2 and N_2O). The stoichiometric requirement for this reduction, called denitrification, uses approximately 1.25 mol of C per mol of N (Reddy and Delaune, 2008):

$$5(C_6H_{12}O_6) + 24(NO_3^-) + 24H^+ \rightarrow 30\,(CO_2) + 12(N_2) + 42\,(H_2O).$$

Wetland organic matter typically has a low bulk density around 0.1 g/m^3 and is 95% organic matter. That organic matter is 44-48% carbon, which leads to 1 m^3 of wetland sediment containing approximately 45,600 g of stored carbon. Measurements of peat material in constructed wetlands have found a NO_3-N removal rate of approximately 2.4 g/d of NO_3-N per m^3. Using these assumptions, a carbon loss of approximately 2.6 g/d of C per m^3 of organic matter can be calculated. This equates to a carbon loss rate of 0.0056% per day (or 2% per year). This estimate is in agreement with studies at Hammond from various researchers that demonstrated soil carbon loss to be between 1.5 to 4.7% per year. Subsequently, if all the stored wetland organic matter could be broken down into bioavailable carbon, no new carbon was added from additional plant growth or from the effluent discharge, and there was an endless supply of NO_3-N, it would take approximately 50 years for all of the organic matter in the top 1 m of wetland sediment to be consumed via denitrification. This estimate makes it unlikely that the rapid and widespread vegetation changes reported were the result of soil decomposition.

One average-sized nutria can consume 72.4 kg of dry organic matter per year (Sasser, et al., 2018), which is equivalent to the annual biomass production in 24 m^2 of marsh or a biomass productivity of 3,000 g/m^2/yr. Productivity estimates from Hammond have been around 2,400 g/m^2/yr (NWC, 2019). Additionally, nutria are considered "wasteful feeders" and destroy approximately 10 times more vegetation than they consume. Around 2,000 nutria were killed in the Hammond wetland (Shaffer, et al., 2015), which equates to one nutria per 610 m^2 (NWC, 2019). If the vegetation eaten by nutria did not grow back, the entire 122 hectares of impacted area would have been consumed in approximately two years. Provided nutria are "wasteful feeders", the pre-existing marsh plant community was a relict system and not stable, and the nutria were attracted by the fertilized vegetation and existed in the densities reported, the idea that nutria caused an eat out leading to marsh collapse is plausible.

NWC (2019) used a biotic model to estimate the active assimilation area based on the vegetative community. Rate coefficients for N and P, flow and N and P concentrations from discharge monitoring reports, outlet concentrations of N and P based on best available tertiary treatment technologies, and background concentration of N and P from original studies of the wetland were used to calculate the area of active assimilation at the Hammond wetland. Yearly assimilation area estimates were calculated from 2006 to 2018 (Figure 16). The results of the model indicate the active assimilation area is much smaller (max of 1,630 acres) than the entire wetland area used in the permit (10,000 acres). Using the results from the model, new loading rates can be calculated for N and P by dividing the annual mass loads by the area of active assimilation. Table 9 shows the calculated loading rates for both Hammond's active assimilation area and the entire area included in the permit. Utilizing the entire permitted area, gives loading rates of 4.15 g/m^2/yr TN and 0.81 g/m^2/yr TP, which are well below the permitted loading rates of 15 g/m^2/yr TN and 4 g/m^2/yr TP. However, utilizing the active assimilation area, loading rates were found to be 25 g/m^2/yr TN and 5 g/m^2/yr TP, which are higher than the permitted loading rates.

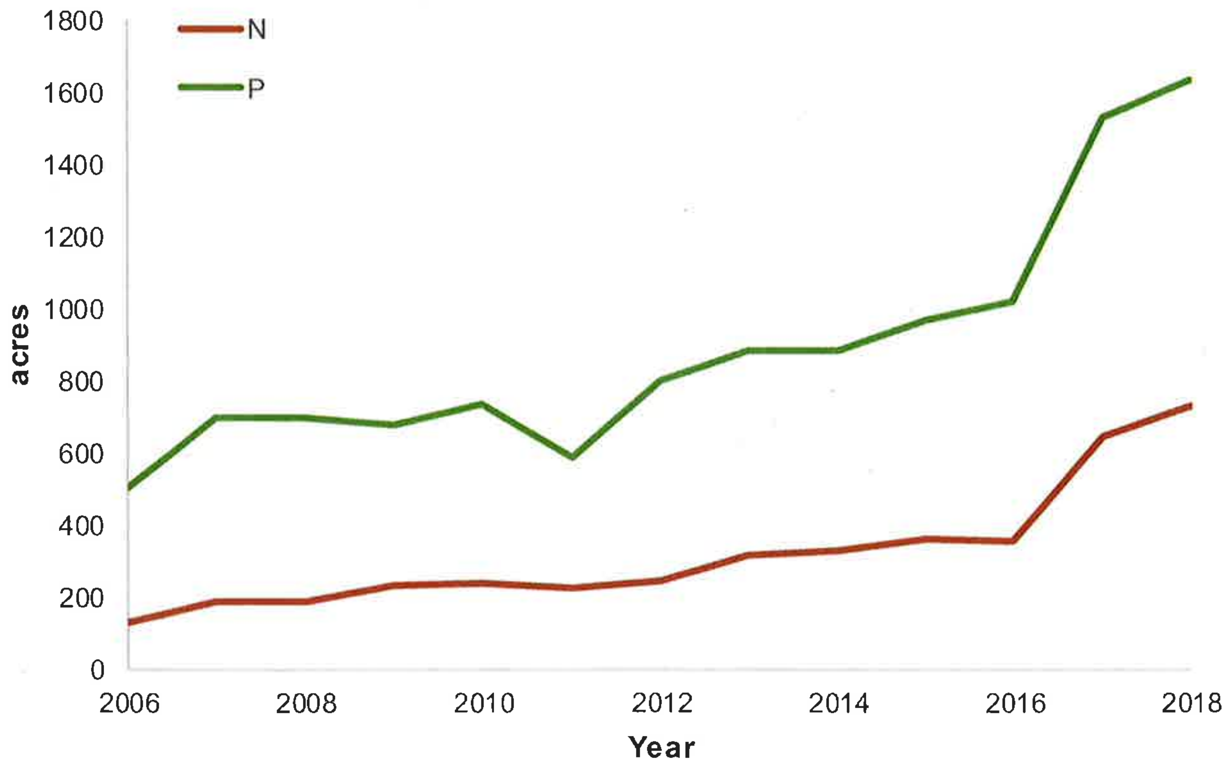

Figure 16. Estimated area required for nutrient assimilation in the City of Hammond's assimilation wetland.

3.3.1. Wetland Evaluation Report Recommendations

The NWC report on Hammond concluded that the marsh conversion was most likely due to nutria herbivory based on the assumptions considered and explained in the report. It also concluded that the outcome of continued discharge will likely result in a floating mat marsh as opposed to an anchored marsh. Given enough time, however, the floating mat could convert to an anchored marsh. The report also provided some specific recommendations for the Hammond wetland:

- Continuance of discharge is strongly recommended as the system is meeting its objectives of nutrient assimilation, salinity reduction, and productivity enhancement; assimilation is enhancing the growth of trees at the mid site; and discontinuing the discharge is highly unlikely to return the marsh to the pre-project state.
- Multiple monitoring sites should be located within the active assimilation.
- A comprehensive survey of the impacted region should be performed, including plant species, soil measurements, and water quality measurements.
- Field studies to better understand the flow should be performed along with the replacement of the two water controls.

In addition to the specific recommendations for Hammond, the NWC report also made some recommendation for all assimilation wetlands.

- Evaluation of future assimilation projects should consider what changes to the wetland would happen with effluent addition and what changes will occur without effluent discharge.

- Evaluation of future assimilation projects should consider stability of the pre-project vegetative community and likely changes that will occur both with and without effluent discharge.
- The use of more current design tools than the loading chart currently used is recommended. These tools should allow for an estimation of the size of the active assimilation.
- The assimilation area should have at least three monitoring points located in the anticipated area of active assimilation zone.
- Ongoing vegetation surveys should list major species and estimated percent cover for both swamp and marsh areas. This should be done at least every 4th year of the permitting cycle.
- Criteria specific to marsh plants should be developed.

4) Conclusion and Recommendations

LDEQ's assimilation wetland program has undergone evaluation both internally and externally in the past few years. Assessments of NPP and reviews of all data have occurred for each wetland. Multiple changes and updates have been made to program guidance and methods to provide more consistent and detailed instruction. Two different methods were used to review assimilation wetlands with enough data. A five-year assessment from 2012 to 2016 found Thibodaux, Mandeville's Bayou Chinchuba, and Hammond to be impaired based on 2018 Water Quality Inventory assessment protocols. (Section 2.1), while a long-term evaluation found Breaux Bridge to be impaired (Section 2.2). As each wetland is reviewed for their annual wetland review, letters discussing these results are sent out to the permittee. Permittees with a impaired NPP or other issues (e.g., loading rates above the permitted limit) are required to implement a plan to address the failures.

LDEQ WPD has updated their workflow so that a staff member is responsible for permitting and reviewing each wetland as part of their workload. The staff member currently in this role is a wetland expert and is applying their expertise when evaluating each wetland. LDEQ staff have worked towards making a number of updates to permits and the WQMP. Updates already incorporated into permits include detailed guidelines for all methods and the requirement for each facility to create an Adaptive Management Plan. Planned updates to the WQMP plan include more detailed requirements for both the feasibility and baseline studies, detailed guidelines for all methods, and determination of the number of sites needed per total assimilation acreage. LDEQ may consider future updates for additional criteria to determine wetland health, particularly in marshes; requirements for the hydrological regime (e.g., requiring new wetland assimilation projects to have an alternative outfall outside of the wetland); and the use of a new model for determining the active assimilation area. Hammond's permit is currently in-house for a renewal and LDEQ will be considering incorporation of new requirements to their permit. Potential new requirements specific to Hammond include an additional monitoring site in the assimilation area, a hydrological flow study within two years of permit issuance, a change in the size of the active assimilation area, additional methods to monitor the marsh vegetation, and additional monitoring of soil TN and TP. LDEQ will continue to review each wetland annually, making recommendations as needed, and work towards overall program improvements.

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