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Carbon Market Opportunities for Louisiana's Coastal Wetlands

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Dedication

This work is dedicated to the late J. Stephen Mack for his contributions towards Tierra Resources' mission of bringing wetland carbon credits to market.

Acknowledgements

Tierra Resources gratefully acknowledges Entergy Corporation for its support of this project through the Environmental Initiatives Fund.

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Photo of the Luling Wetland Assimilation System Carbon Pilot. The wetland assimilation system is located in Luling, Louisiana and operated by St. Charles Parish. Photo by R. Lane

Executive Summary

Background

Restoration of the Mississippi River Delta is of national significance, and Louisiana currently accounts for almost 90% of all coastal wetland loss in the United States (Couvillion et al., 2011). The Mississippi River Delta's wetlands and waterways contribute tens of billions of dollars to the national economy annually, support millions of jobs, and provide hurricane protection and valuable fish and wildlife habitat that are vital to Louisiana's sustainability. One of the major challenges for coastal restoration is finding financing on a scale which all stakeholders find to be sufficient.

Carbon finance shows significant potential to be leveraged with current restoration programs to fund wetland restoration projects. The carbon sequestered in vegetated coastal ecosystems, specifically mangrove forests, seagrass beds, and salt marshes, has been termed "blue carbon" (Mcleod et al., 2011). In coastal Louisiana, blue carbon also refers to carbon sequestered in soils and trees of tidally influenced cypress-tupelo forests and freshwater marshes. Wetland restoration enhances carbon sequestration and avoids carbon releases that occur as wetlands convert to open water. A carbon offset (mtCO2e), also referred to as a carbon credit, is a metric ton reduction in emissions of carbon dioxide or greenhouse gases made in order to compensate for, or to offset, an emission made elsewhere. Allowing entities to privately invest in wetland restoration projects to offset greenhouse gas emissions elsewhere holds promise as a new carbon offset sector.

Approach and Methods

The objective of this study was to evaluate the commercial potential of blue carbon in Louisiana and to identify information needs for future scientific investigation that support wetlands' inclusion in current and future carbon offset programs. Existing restoration techniques were analyzed to identify scalable restoration methods that show commercialization potential as wetland offset projects. The predicted carbon offset yield for the various restoration techniques was modeled based upon current peer reviewed literature on carbon sequestration and greenhouse gas emissions. These values were then refined in line with carbon market rules to reflect a 20% buffer deduction that guards against the risk of reversal. The final carbon offset yields were applied to the amount of corresponding area that can be restored for each restoration technique as determined by Louisiana's Comprehensive Master Plan for a Sustainable Coast (CWPRA, 2012). Restoration techniques that were not detailed in the master plan were analyzed separately to determine the potential applicable area of the restoration technique. Finally, possible price scenarios were evaluated to account for low- and high-end ranges of expected prices in both compliance and voluntary carbon markets (Appendix C).

Findings

The final results revealed that ***coastal wetland restoration in Louisiana has the potential to produce over 1.8 million offsets per year - almost 92 million offsets over 50 years***. Restoration techniques that were identified as having potential as wetland carbon offset projects include river diversions, hydrologic restoration, wetland assimilation, and mangrove plantings. Of the restoration techniques, forested wetlands that receive treated municipal effluent, referred to as wetland assimilation systems, have the highest net offset yield per acre. However, it was concluded that river diversions and mangrove plantings have the potential to generate the largest volume of offsets in Louisiana due to the large amount of acreage upon which these restoration techniques can be implemented (Figure 1). It should also be noted that carbon credits from wetland assimilation systems and river diversions show potential to be stacked with water quality credits, should these markets evolve in Louisiana.

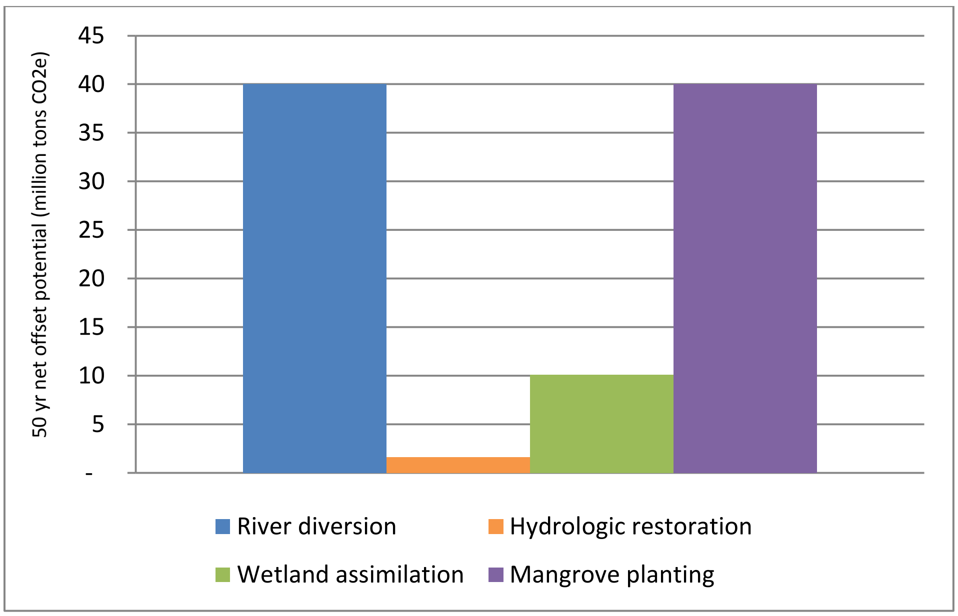

Figure 1: Net offset potential in Louisiana by wetland restoration type including a 20% buffer deduction

Wetland restoration techniques identified in this study could potentially generate $400 million to almost $1 billion in offset revenue depending on the price achieved for the carbon offset. Currently, preventing the emissions that occur during wetland loss is not included in wetland carbon accounting methodologies. If included, this prevented loss could provide an additional $140 million to almost $630 million, depending on the price of the carbon offset, rates of wetland loss, subsidence, and sea level rise. Conservative estimates, taking into consideration those factors that impact carbon offset prices and yields, determine that ***carbon finance has the potential to bring a total of $540 million to almost $1.6 billion to assist with wetland restoration in the coastal areas of the Mississippi River Delta*** (Figure 2).

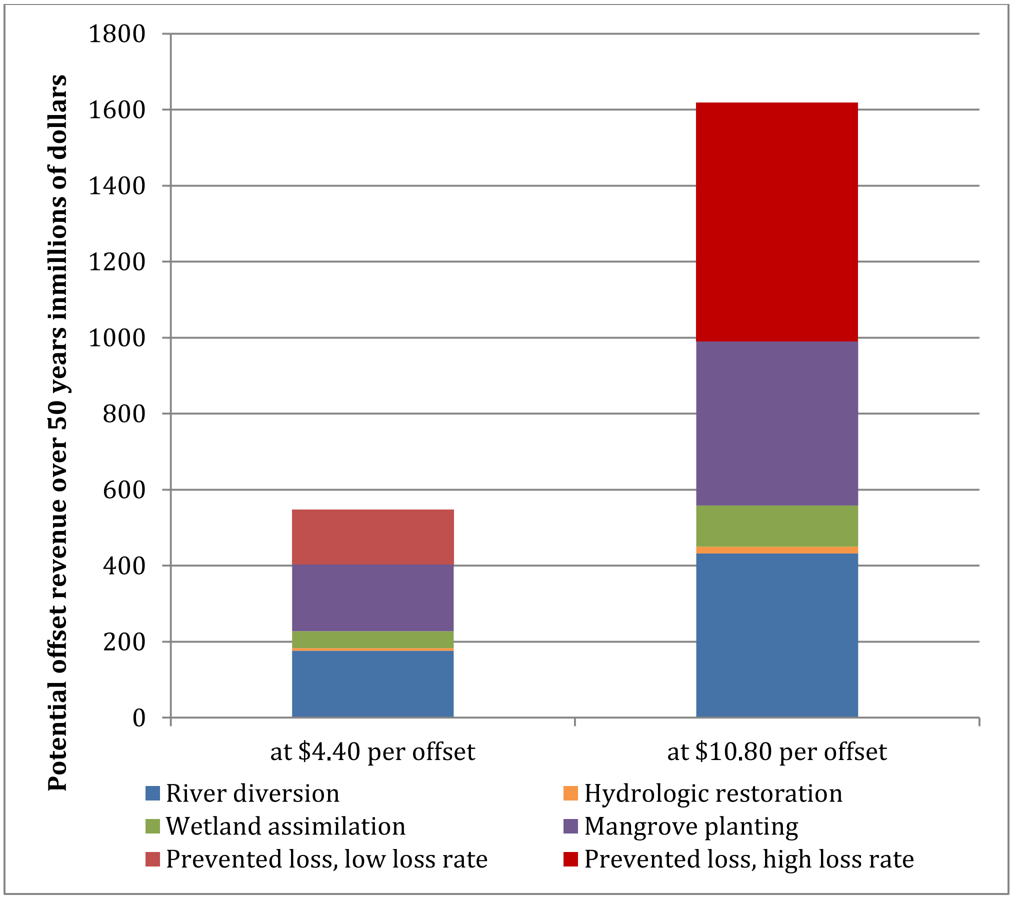

Figure 2: Total projected revenue potential of wetland carbon offsets in Louisiana from wetland restoration and prevented wetland loss including a 20% buffer deduction.

Recommendations

The recommended next steps to increase the commercial viability of wetland carbon offsets and realize the significant potential of wetlands to sequester carbon include:

- Undertaking efforts to reduce project development costs and simplify monitoring, reporting and verification including:
    - Furthering research to either justify the exclusion of GHG emissions in wetland carbon accounting or the development of regional emissions factors by restoration project type.
    - Modifying Louisiana's Coastwide Reference Monitoring System (CRMS) to include carbon offset monitoring parameters.
    - Developing wetland carbon and GHG emission models.
    - Creating a technology tracking database that allows for the management of large volumes of information associated with wetlands in a systematic fashion.
- Furthering research to determine the carbon impacts of prevented wetland loss and incorporating results into current wetland carbon accounting methodologies. The large offset potential from prevented wetland loss demonstrates the importance of creating a mechanism

to quantify the carbon benefit of preventing wetland loss in order to optimize the amount of offsets that can be achieved out of a specific restoration project.

- Publishing lessons learned from existing pilot projects including:
  - Analyses of costs and benefits,
  - Public-private paradigms that demonstrate the ability to leverage carbon finance with government restoration dollars.
- Advocating with carbon standards on issues that impact the viability of wetland carbon projects including:
  - Allowing use of federal funds considering the high cost and multiple co-benefits of wetland restoration,
  - Environmental credit stacking,
  - Types of conservation easements eligible for carbon projects,
  - Rules and processes for project aggregation, and
  - Crediting period length for wetland restoration projects.
- Establishing funding pools that will allow wetland project development to scale up to meet future carbon demands in the compliance market.
- Modifying existing wetland methodologies and protocols to fit the compliance market for potential inclusion of wetlands in California's compliance market to provide sustained demand for offset credits at higher offset prices.

Conclusion

The results of this assessment demonstrate that carbon finance has substantial potential to generate important revenue to support wetland restoration that will likely lead to new public-private paradigms that leverage carbon finance with government restoration dollars. This study points to Louisiana as an innovator of creative financing strategies for wetland restoration, and as creating new investment opportunities that will yield significant economic and environmental benefits. Beyond the Gulf Coast this work can be expanded to address other critical wetland areas such as the Sacramento-San Joaquin Delta, Florida's Everglades and wetlands in Virginia, Maryland and the Carolinas. Carbon markets could be influential in conserving other areas of the world such as the Amazon, Congo, and Mekong deltas.

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1.0 Introduction

The Mississippi River Delta is one of the most productive ecosystems in the world, providing essential goods and services at a variety of temporal and spatial scales, including carbon sequestration (Smith et al., 1983; Hussein et al., 2004; Mitra et al., 2005). Healthy wetlands also help reduce coastal flooding and improve water quality while providing habitat for thousands of species of flora and fauna, of which many are unique to wetland ecosystems. At a rate of one football field of area per hour, Louisiana has lost 1,900 square miles of land since the 1930's (Barras et al., 1994; Barras et al., 2003; Couvillion et al., 2011; Dunbar et al. 1992). The Mississippi River Delta's wetlands and waterways contribute tens of billions of dollars to the United States economy every year and support millions of jobs. Much of the U.S. economy depends on sustaining the navigation, flood control, energy production, and seafood production functions of the Mississippi River Delta and river system. Each of these functions is currently at severe risk due to coastal wetland loss. One of the largest challenges is finding sufficient financing to complete coastal restoration that is on a scale that all stakeholders agree is needed. Because wetlands sequester large amounts of carbon in soils and plants, the growing carbon market provides a potential funding source to support restoration and conservation of these valuable ecosystems.

The Mississippi River delta is a complex coastal system. Like most deltas, it is made up of several interdistributary hydrologic basins that are separated by current or abandoned river distributary channels (Roberts, 1997). The delta consists of two physiographic units, the active Deltaic Plain to the east and the Chenier Plain to the west (Roberts, 1997). Active deltaic lobe formation took place in the deltaic plain. The Chenier Plain was created by a series of beach ridges and mud flats that formed by periods of westward drift of sediments from the river. The delta is also characterized by a series of vegetation zones (saline, brackish and fresh marshes and freshwater forested wetlands, from the coast inland) that are determined primarily by salinity and soil conditions. The total area of the delta is more than 6 million acres (25,000 km^2), including wetlands, shallow water bodies, and low elevation ridges formed by current and abandoned distributary ridges and beach ridges. 4 million of these acres (16,000 km^2), show potential for improved wetland management and restoration.

Emissions trading is a market-based approach that provides economic incentives for reducing pollution. Today's carbon markets have foundations in earlier emissions trading systems, including the U.S. Acid Rain Program, which from 1990 through 2007 successfully used emissions trading to reduce the emissions from power plants that were causing acid rain. Carbon markets are similar to this program which put a price on the emissions of sulfur dioxide and nitrogen oxides. They are designed to work by assigning a price to greenhouse gas emissions. Under a compliance emissions trading system, regulators establish a 'cap' on the total amount of emissions that will be allowed, and carbon emitters must acquire permits covering each ton of greenhouse gases they produce. The exchange of permits on an open market allows emitters to choose whether it is more cost-effective to purchase these permits at market prices or reduce their own emissions internally by retrofitting their facility. These emissions trading programs are collectively referred to as carbon markets. Currently the carbon market is comprised of compliance markets, made up of emitters who by law are obligated to reduce their emissions (e.g. California) and voluntary markets in which organizations voluntarily reduce their emissions often to abide by sustainability plans supported by company shareholders or board members.

Projects which reduce greenhouse gas emissions generate "carbon offsets". A carbon offset ($mtCO_2e$), also referred to as a carbon credit, is a metric ton reduction in emissions of carbon dioxide or greenhouse gases made in order to compensate for, or to offset, an emission made elsewhere. To ensure quality and offset validity, protocols and methodologies must be certified and provide a transparent accounting procedure for the development, verification, and monitoring of offset projects. Methods to develop a carbon offset can align with voluntary guidelines or specific standards set by federal, regional, or state entities. Carbon offset projects themselves are diverse, and include renewable energy projects, energy efficiency projects, projects that destroy industrial pollutants, and projects that protect or restore forests and improve land use among others.

Environmental credit markets, especially carbon markets, provide an important and innovative approach to support environmental restoration and conservation. For a variety of financial, environmental, and political reasons, substantial interest exists for carbon offsets derived from terrestrial landscapes. For more than a decade, evolving and maturing carbon markets have supported forest restoration projects. Governments, environmental organizations, private companies, and carbon funds, appear to be driven by the potential that carbon offsets may obtain a premium price in the future. In 2013, globally, buyers purchased 32.7 million $mtCO_2e$ of carbon offsets from land use projects including forestry and agriculture. This was tied with 2010 for the highest volume in history (Peters-Stanley et al., 2013). In addition, forest project benefits beyond carbon sequestration are increasingly being quantified, with researchers claiming these projects led to the protection of 13 million hectares for endangered species, an additional 9,000 jobs worldwide and $41 million in benefits to education, infrastructure and health care.

The past two years have been strong for carbon markets and for forest carbon projects. At a national level, the US National Climate Action Plan, released in June 2013, focused energy and attention on climate change, including the role forests hold in mitigating climate change and a call for new approaches to protect and restore forests, grasslands and wetlands. Developments in the California compliance market indicate a strong and continuing regulatory structure, and private sector companies have increased their focus on their climate impacts (Appendix B). During this time, a new carbon market in China weighed inclusion of forest carbon offsets into their program. This energy for innovative solutions, combined with trends in voluntary markets that favor high-quality land use and forestry projects, and the continued progress of the California compliance market, provide strong potential for support of high-quality, scientifically rigorous offset projects in wetland restoration.

Recent developments pave the path for carbon markets to support wetland restoration. In 2012, the American Carbon Registry (ACR), a leading carbon market standard, certified the first wetland offset methodology. This methodology, "Restoration of Degraded Deltaic Wetlands of the Mississippi Delta," created the first route-to-market, opening the potential of carbon market investment into wetland restoration projects (Mack et al., 2012).[1] Other recent developments also show the growing recognition

[1] This methodology was developed by Tierra Resources and funded by Entergy Corporation through its Environmental Initiatives Fund.

of the importance of leveraging ecosystem markets for wetland restoration and improved management for climate benefits including:

- In 2010 an analysis of wetlands and land use change was included in the National Assessment of Ecosystem Carbon Sequestration and Greenhouse Gas Fluxes (Zhu et al., 2010).
- In 2013 the Intergovernmental Panel on Climate Change expanded guidance on wetlands in climate accounting (Blaine et al., 2013).
- In December 2013 the first global methodology for Tidal Wetlands and Seagrass Restoration was submitted for approval to the Verified Carbon Standard (VCS) (Silvestrum and Crooks, 2014).
- In February 2014 the VCS approved a methodology to quantify the greenhouse gas benefits of wetland creation activities in the United States (CH2MHILL and EcoPartners, 2014).

1.1 Wetlands and Carbon Sequestration

"Carbon Sequestration" refers to the removal of atmospheric carbon by plants or other storage mechanisms, which can mitigate greenhouse gases released as a result of changes in land use and the burning of fossil fuels. The carbon sequestered in vegetated coastal ecosystems, specifically mangrove forests, seagrass beds, and salt marshes, has been termed 'blue carbon' (Mcleod et al., 2011). In coastal Louisiana, blue carbon also refers to carbon sequestered in soils and trees of tidally influenced cypress-tupelo forests and freshwater marshes. Wetland restoration is an effective climate change mitigation strategy because it enhances carbon sequestration and avoids carbon releases that would occur in the absence of restoration activities.

There are five general carbon storage pools in wetlands (1) aboveground trees; (2) aboveground herbaceous vegetation; (3) surface litter; (4) dead wood; and (5) belowground organic soil that include all organic matter from belowground productivity and some organic matter produced aboveground that is buried as detritus. Wetland restoration techniques enhance carbon sequestration via increased vegetative productivity, carbon burial, and avoided carbon release. Increased productivity and accretion result in enhanced aboveground biomass and root production, leading to enhanced organic soil deposition and carbon sequestration (Day et al., 2004). Geological subsidence of this organic soil results in significant permanent carbon burial. Overall, the amount of carbon sequestered is highly dependent on the health and productivity of the wetland, as large amounts of previously stored carbon can be re-released to the atmosphere if the wetland deteriorates (Davidson and Janssens, 2006).

Wetlands can also emit greenhouse gases (GHGs). Methane production tends to occur in low salinity and freshwater tidal flats and marshes because of the high organic matter content of the soils at anoxic depths. As salinity increases, methane emissions decrease or cease completely due to the availability of sulfate, the reduction of which inhibits methane formation. Small amounts of nitrous oxide can also be emitted by wetlands during nitrification and denitrification. In general, wetland emissions can contribute to GHG impacts and require further investigation. The Intergovernmental Panel on Climate Change (IPCC) requires land use change assessments to quantify only those emissions resulting from direct human impacts. For the purposes of quantifying and valuing carbon sequestration in wetlands, it is the change of emissions beyond what is naturally occurring that must be quantified.

2.0 Restoration Techniques and Carbon Modeling

The objective of wetland restoration is the restoration of hydrology, vegetation, and wetland functions to sites where wetlands previously existed or are currently degraded. Various techniques are used to achieve wetland restoration, and not all approaches are suitable for all wetland systems. As part of this study, existing restoration techniques were examined to identify restoration methods that show commercialization potential as wetland offset projects. The restoration techniques that were identified as having potential as wetland offset projects include the following:

- River diversions (also referred to as sediment diversions and freshwater diversions) - use of new channels and/or structures to divert sediment and freshwater from the Mississippi and Atchafalaya Rivers into adjacent basins.
- Hydrologic restoration - installation of features that restore natural hydrologic patterns either by conveying freshwater to areas that have been cut off by man-made features or by preventing the intrusion of salt water into fresh areas through man-made channels and eroded wetlands.
- Marsh creation - creation of new wetlands in open water areas, including bays, ponds, and canals, through sediment dredging and placement. Most projects involve pipeline conveyance of sediment.
- Wetland assimilation - the introduction of treated municipal effluent into impounded and degraded wetlands to provide freshwater and nutrients for restoration purposes.
- Mangrove plantings - assisted natural regeneration, seeding, or tree planting of black mangroves (Avicennia germinans).

The predicted carbon offset yield was determined for each offset restoration technique based upon currently available empirical data on carbon sequestration and GHG emissions from various types of wetland systems in the Mississippi River deltaic plain, as well as in other areas of the world (Appendix C). The amount of carbon sequestration that can be counted toward carbon offsets depends on the difference between the carbon sequestration rate of an approved baseline, which represents "business-as-usual" practices, and the rate that results from the restoration activity. Tree and soil carbon pools were conservatively selected to represent the amount of carbon being sequestered. Appendix C provides additional detail how the baseline and project carbon stocks, emissions, and offsets were estimated.

The sequestration rates for river diversions and hydrologic restoration were analyzed together since both involve the introduction of freshwater or the prevention of saltwater intrusion. Marsh creation was eliminated from the study based upon a lack of empirical data to model carbon yields, concerns over the permanence of the restoration technique, and the need to deduct significant fossil fuel emissions that occur during the pipeline conveyance of sediment. None of the projects increased GHG emissions beyond what occurred under the baseline scenario.

As summarized in Table 1, forested wetland assimilation had the highest net offsets at 7.0 $mtCO_2e$/ac/yr, followed by forested river diversions and hydrologic restoration (3.8 $mtCO_2e$/ac/yr), emergent wetland assimilation (3.1 $mtCO_2e$/ac/yr), mangrove planting (2.0 $mtCO_2e$/ac/yr), and emergent river diversions and hydrologic restoration (0.8 $mtCO_2e$/ac/yr). While the offset potential from river diversions is somewhat lower than some other approaches, its lower price per acre restored (less than half the cost per acre of hydrologic restoration, and less than one eighth the cost of beneficial dredging), may make these projects attractive in some circumstances (CWPRA, 2012). Diversions and wetland assimilation systems also have the potential to be stacked with water quality credits as these markets develop.

	Project C Seq.	Baseline C Seq.	Net Offset
Hydro / Diversion - forested	8.5	4.7	3.8
Hydro / Diversion - emergent	4.0	3.2	0.8
Marsh creation		data unavailable	
Wetland assimilation - forested	11.7	4.7	7.0
Wetland assimilation - emergent	6.3	3.2	3.1
Mangrove planting	5.8	3.8	2.0

Table 1. Preliminary estimate of offset potential (units in $mtCO_2e$/ac/yr).

2.1 Carbon Modeling Discussion

The net difference between the baseline scenario and the restoration activity is what can be transacted as wetland carbon offsets. Restored wetlands demonstrate an enhanced sequestration rate through enhanced plant growth and accumulation of organic matter in soils. The literature review suggests that for many wetland restoration projects, the baseline scenarios have higher emissions of GHGs than the project. While this is good in terms of carbon sequestration, it should not be viewed as a measureable phenomenon, but rather as an expression of the inherent high variability of GHG emissions by wetlands. There were generally many more baseline measurements compared to project measurements in the dataset used for this analysis, and given the high variability of GHG emissions, there was a greater chance for the baseline average to include some very high emission rates that raise the baseline mean.

High natural GHG emissions from wetlands, coupled with very high spatial and temporal variability regardless of anthropogenic effects, make the inclusion of GHG emissions in carbon sequestration calculations questionable. In addition, for projects that introduce water with high nutrient concentrations, such as assimilation systems, the inclusion of GHG emissions may not be necessary since the highly nitrified water would have to be discharged someplace else (i.e., river, bayou or canal) where the same GHG emissions would likely occur. Greenhouse gas emissions of methane (CH_4) are primarily an issue for fresh and low salinity wetlands, as there is a strong inverse relationship between CH_4 emissions and salinity. At salinities above about 5 practical salinity units (PSU), CH_4 emissions are very low because of the presence of sulfate (SO_4) in seawater, which when it undergoes sulfate reduction, inhibits CH_4 release. Nitrate (NO_3) behaves similarly as SO_4 by inhibiting CH_4 emissions. Projects that introduce nitrate into wetlands, such as wetland assimilation and river diversions, are also likely to have reduced CH_4 emissions compared to baseline. In the case of river diversions, the high nitrate concentration of diverted water inhibits methane production while the low nitrogen loading-rate, high organic carbon levels, optimum pH, high ambient temperatures, and an anaerobic zone close to the sediment surface encourages complete denitrification to dinitrogen, which does not contribute to global warming. The literature review confirmed that wetland restoration projects have no measurable net increase in GHG emissions.

The overall question is not whether wetland carbon sequestration projects emit CH_4 or nitrous oxide (N_20) per se, but whether the rate of these emissions is higher than what would occur given the baseline scenario. The high inherent spatial and temporal variability of GHG emissions by wetlands may make the monitoring of greenhouse gases, to reach confidence intervals required by emissions trading markets, cost-prohibitive. The final results of the restoration technique analysis determined that river diversions, mangrove plantings, and wetland assimilation projects show the most potential for carbon offset development in the Mississippi River Delta.

2.2 Prevented Wetland Loss

Unfortunately, many wetlands in Louisiana are deteriorating, resulting in the re-release of large amounts of previously stored carbon. Providing wetland offset credits for prevented wetland loss in the Mississippi River Delta may be essential to providing a strong business case for carbon investment into wetland restoration projects. Restoration projects may demonstrate that their implementation is preventing wetland loss rather than increasing rates of above and below-ground sequestration. Restoration techniques that can prevent the conversion of land to open water prevent the re-release of previously stored carbon when the wetland deteriorates (Davidson and Janssens, 2006). When vegetation death occurs, organic carbon undergoes complex cycling, with the fate dependent on the specific type and source of carbon (Reddy and DeLaune, 2008); part of the soil organic carbon is decomposed, resulting in GHG emissions, and part is buried, either in situ or exported and buried elsewhere. The top 50 cm of the wetland soil horizon generally includes the living root zone, which is most geomorphically unstable, most susceptible to erosion, and can be decomposed and volatilized when the vegetation dies. Based on values derived from the scientific literature, on average, the top 50 cm of wetland soil contains 206 $mtCO_2e/ac$ (Appendix C).

The potential exists for this carbon to be claimed as carbon offsets if restoration efforts are successful in preventing the loss of the wetland soil horizon. Research initiatives are currently underway to determine the proportion of the root zone that becomes volatilized as greenhouse gases.[2] While this information is being developed, a conservative estimate of 25% (51.6 $mtCO_2e/ac$), 50% (103.2 $mtCO_2e/ac$), and 75% (154.7 $mtCO_2e/ac$) of the carbon contained in the root zone were used for the purpose of estimating potential wetland carbon offsets.

Appendix C provides additional detail how the baseline carbon stocks, emissions, and offsets were estimated.

[2] ConocoPhillips and Tierra Resources are currently performing research on the fate and transport of carbon (prevented wetland loss) at saline, brackish, and fresh emergent sites.

3.0 Financial Evaluation of Potential Wetland Restoration Carbon Projects

The potential for a wetland restoration project to benefit from the carbon market depends not only upon the potential of the project to increase sequestered carbon, but also upon the rules of the carbon standard applied, the costs of monitoring, documenting, and selling verified carbon offsets to market, and on the price of carbon offsets achieved (Appendix A). Costs of developing and reporting of a carbon project can be substantial, often in excess of $200,000 in initial development costs before offsets can be sold. Some of these costs may decrease over time as project developers apply lessons learned in pilot projects to improve efficiency in later projects.

At this time, there are only two approved methods to transact wetland carbon offsets through voluntary markets (Mack et al., 2012; CH2MHILL and EcoPartners, 2014). However, California's Air Resources Board (ARB) may adopt wetland restoration projects into their compliance market in the future (Appendix B). In this preliminary assessment, the assumption was made that an approved protocol under ARB rules would yield the same volume of offsets - that there would be no additional buffer withheld or any additional deductions because of different rules for land eligibility or carbon accounting from the ACR "Restoration of Degraded Deltaic Wetlands of the Mississippi Delta" methodology (Appendix C). However, it is important to note that standards and methodologies can differ, impacting marketable volumes of offsets such as:

- Methods of carbon accounting
- Project crediting period
- Methods of establishing risks and additionality
- Carbon pools that are included or excluded
- Project boundaries
- Eligible project start dates
- Eligibility rules

3.1 Offset Volumes

The volume of offsets that can be counted and qualified under a standard depends on the difference between the carbon sequestration rate of an approved baseline, which represents "business-as-usual" practices, and the rate which results from the restoration activity. However, carbon market standards require that a percentage of carbon offsets from each project are not sold on the carbon market and, instead, are kept in a reserve buffer pool to guard against risk of reversal. The required buffer is based on assessed risk of reversal of carbon sequestration for each project, and may decrease the volume of offsets available for sale by 10 percent (the lowest buffer requirement under ACR rules) to more than 50 percent. In this study, a buffer of 20 percent was deducted from offset yield estimates from the scientific literature review previously described.

The carbon offset yields, refined to include this buffer deduction, were then applied to the amount of corresponding area that can be restored for the various restoration techniques as determined by Louisiana's Comprehensive Master Plan for a Sustainable Coast (CWPRA, 2012). Restoration techniques that were not detailed in the Master Plan (i.e., wetland assimilation, mangrove plantings) were analyzed separately to determine the potential applicable area of the restoration technique. Restoration acreage estimates were categorized into current, planned, and potential restoration areas. Because carbon market rules exclude many projects with early start dates from claiming offsets, offset estimate projections only include post-2000 project areas.[3] For simplicity, in this study, projects were all assumed to have a 50-year length to correspond with predicted acreage in Louisiana's Comprehensive Master Plan for a Sustainable Coast. The volume of offsets generated per acre was also assumed to be the same each year for the full 50-year project period. It is important to note that carbon project life and crediting periods differ from this 50-year timeframe. The ACR requires that wetland restoration projects utilize a 40-year crediting period and 40-year project life. In contrast, the ARB requires that forest carbon projects have a 25-year crediting period and the project must continue monitoring and reporting offset project data for 100 years after offset issuance (Appendix A). The results are summarized in Appendix D, which portrays annual net offsets for current wetland restoration projects, planned projects, and potential restoration areas.

Coastal wetland restoration in Louisiana has the potential to produce over 1.8 million offsets per year - almost 92 million offsets over 50 years. As shown in Figure 3, river diversion wetland restoration projects and mangrove plantings have the potential to generate the largest volume of offsets in Louisiana. These estimates do not account for the potential of including prevented wetland loss carbon benefits.

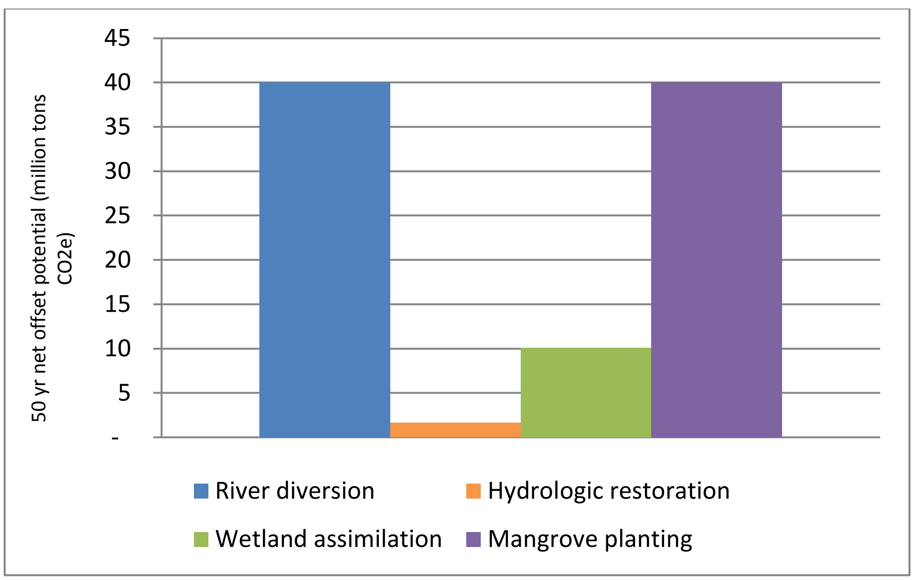

Figure 3: Net offset potential in Louisiana by wetland restoration type including a 20% buffer deduction

[3] In ACR, eligible projects may start as early as 1997, but this will change to 2000. See Appendix A.

3.2 Prevented Wetland Loss Carbon Project Potential

Louisiana's Comprehensive Master Plan for a Sustainable Coast utilized predictive models to evaluate a 'future without action' over a 50-year timeframe (CWPRA, 2012). Ranges of high and low values for each environmental uncertainty were chosen, forming two scenarios described as 'moderate' and 'less optimistic' in the Louisiana's Comprehensive Master Plan for a Sustainable Coast. To improve readability the authors of this report renamed the moderate scenario as the 'low loss rate' scenario, and the less optimistic scenario as the 'high loss rate' scenario. Figure 4 shows that under the low loss rate scenario, their analysis predicted 770 square miles (492,800 acres) of wetland loss over the next 50 years, which increases to 1,750 square miles (1,120,000 acres) of wetland loss under the high loss rate scenario.

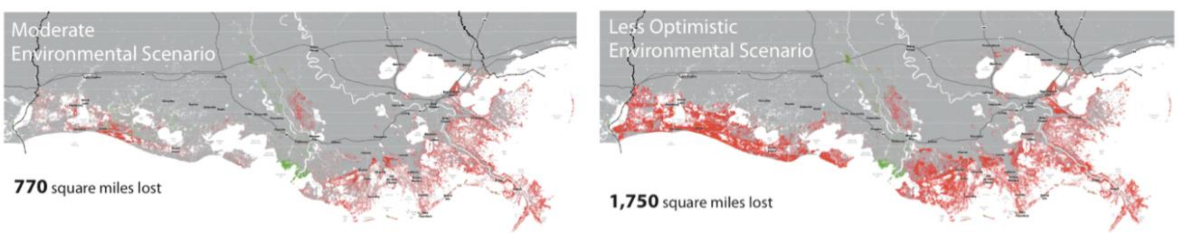

Figure 4: A comparison of estimated land change along the Louisiana coast at year 50 under moderate (low loss rate) and less optimistic (high loss rate) scenarios of future coastal conditions. Green indicates areas of natural new land creation and red indicates land that is likely to be lost (CWPRA, 2012).

Louisiana's Comprehensive Master Plan for a Sustainable Coast evaluated river diversions and other restoration techniques to maximize land building over 50 years. The results indicate that approximately 620 square miles (396,800 acres) in the low loss rate scenario and approximately 1100 square miles (704,000 acres) in the high loss rate scenario would be prevented from converting to open water (Appendix D). Assuming that 25-75% of the carbon in the top 50 cm of sediment would be prevented from releasing greenhouse gases results in over 20,000,000-100,000,000 mtCO_2e over 50 years before buffer deductions. Figure 5 portrays the substantial offset volume potential, highlighting the importance of incorporating the prevention of wetland loss into carbon accounting methodologies.

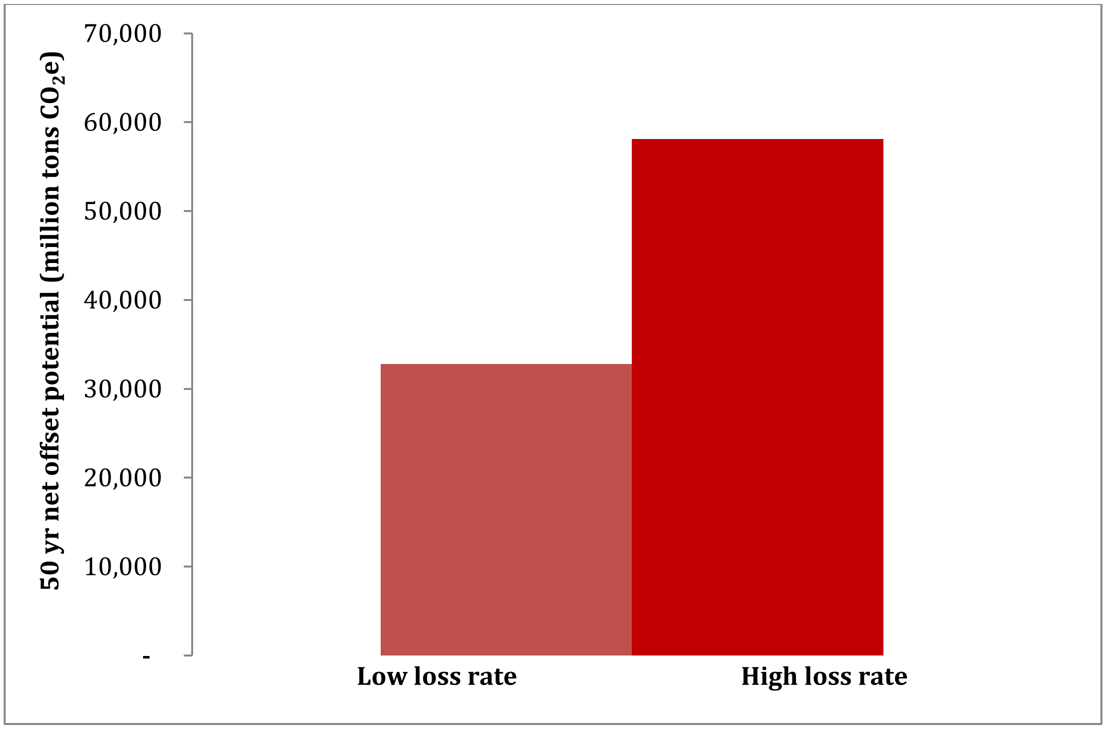

Figure 5: Net offset potential for prevented wetland loss in Louisiana including a 20% buffer deduction
*Note: assumes maximal land building and 50% of carbon stored in the top 50 cm of sediments is released as CO_2

3.3 Carbon Prices

Drivers of price, demand, and buyer motivation differ significantly between compliance and voluntary markets as well as from project to project. Ecosystem Marketplace and Bloomberg New Energy Finance noted that in the voluntary carbon market there is often a premium for quality, co-benefits, and charismatic value, for example, when a forest has Forest Stewardship Council certification, or a project achieves Climate, Community, and Biodiversity Alliance certification (Peters-Stanley et al., 2013). Voluntary offset projects can range from less than $1 per offset to more than $8 per offset depending on the charisma of the voluntary offset projects. Forest Carbon offset prices in 2012 in voluntary markets averaged $8.40 for ACR, $8.90 for Climate Action Reserve offsets, and $7.50 for Verified Carbon Standard offsets. California compliance offset price predictions have ranged from $7.50 to $10 in the first compliance period ending in 2014 to $38 to $51 per offset by the end of the third compliance period. Predictions vary greatly, and recent trends have led some to predict a slower increase in compliance market offset price.[4,5]

In this analysis, ranges of possible price scenarios were evaluated to account for conservative low- and high-end ranges of expected prices in both compliance and voluntary carbon markets (Appendix D). The low-price scenario, of $4.40 per offset (based on average price reported historically for ACR offsets) was used to represent a situation when offsets are not eligible for compliance market and have low charismatic value perceived by buyers. The high price scenario, of $10.80 per offset, was used as a

[4]There is a lot of uncertainty in the California market post 2020, making estimates of offset price beyond 2020 quite conjectural.
[5] https://pointcarbon.com/research/promo /research/1.2200807?&ref=searchlist.

conservative estimate of compliance offset prices in California or a somewhat less conservative estimate of a high-quality charismatic voluntary carbon offset.

Potential revenue from these offsets, if all potential restoration projects were undertaken, range from $8.1 million per year under the low price scenario to over $19.8 million per year if the higher offset price is achieved. These values include the 20 percent buffer contribution. Acreage predictions according to the Louisiana Comprehensive Master Plan are for 50 years. Assuming that the crediting period for the carbon projects could be extended, and carbon offset yields are steady over the 50 year period, potential offset revenues could total about $400 million under the low price scenario to almost $1 billion if the higher offset price is achieved. These financial values do not deduct the costs of restoration or carbon commercialization costs, which can be considerable, as noted in Appendix D, but show that wetland restoration has substantial potential to generate important revenue to support restoration.

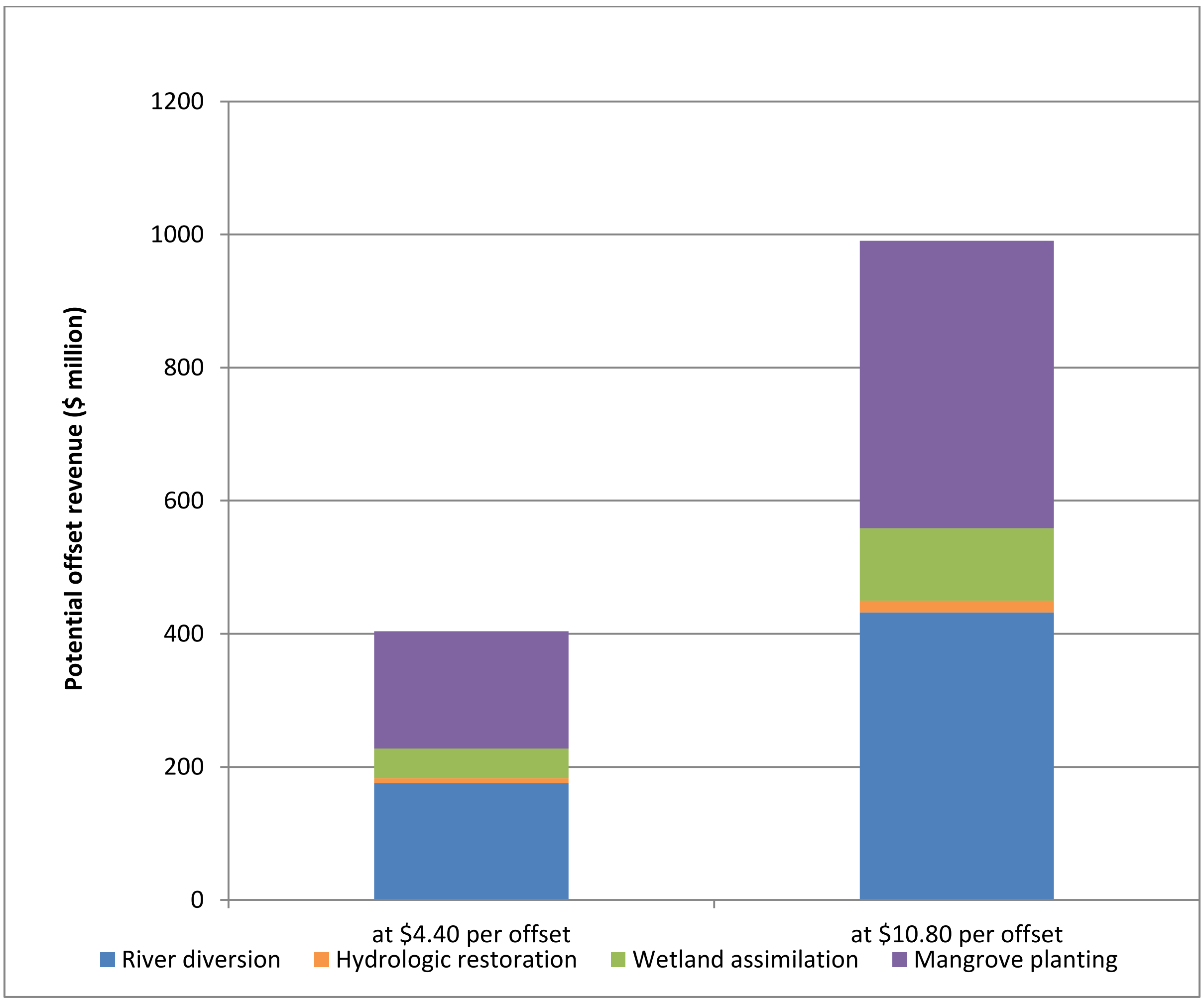

Figure 6: Projected revenue potential of wetland carbon offsets in Louisiana due to wetland restoration including a 20% buffer deduction.

Including the prevention of wetland loss in carbon monitoring and accounting may provide stronger financial incentives to develop wetland offset projects. Currently, the percentage of carbon that is released as GHGs during wetland loss is unknown but many research initiatives are under way. The financial proceeds from projected potential offsets from prevented wetland loss according to what is perceived as possible in the Louisiana Master Plan ranges from $72 million (25% of carbon released as GHGs, low loss rate, low price) to almost $1 billion (75% of carbon released as GHGs, high loss rate, higher price). For the purposes of this study an assumption was made that half of the carbon contained in the top 50 cm of sediment can be prevented from being released as greenhouse gases and that these offsets would be additional to those estimated above. If these prevented emissions could qualify as offsets, they could produce an additional 32.8 million offsets valued at over $140 million (low loss rate, low price) to over 58.1 million offsets valued at nearly $630 million (high loss rate, higher price) over a 50 year time period (Figure 7). The large offset potential from prevented wetland loss demonstrates the importance of creating a clear mechanism for quantifying and monetizing the carbon benefit of prevented loss. Including prevented wetland loss in carbon accounting will significantly increase the wetland carbon offset yields thus increasing the rational for private investment in wetland restoration projects.

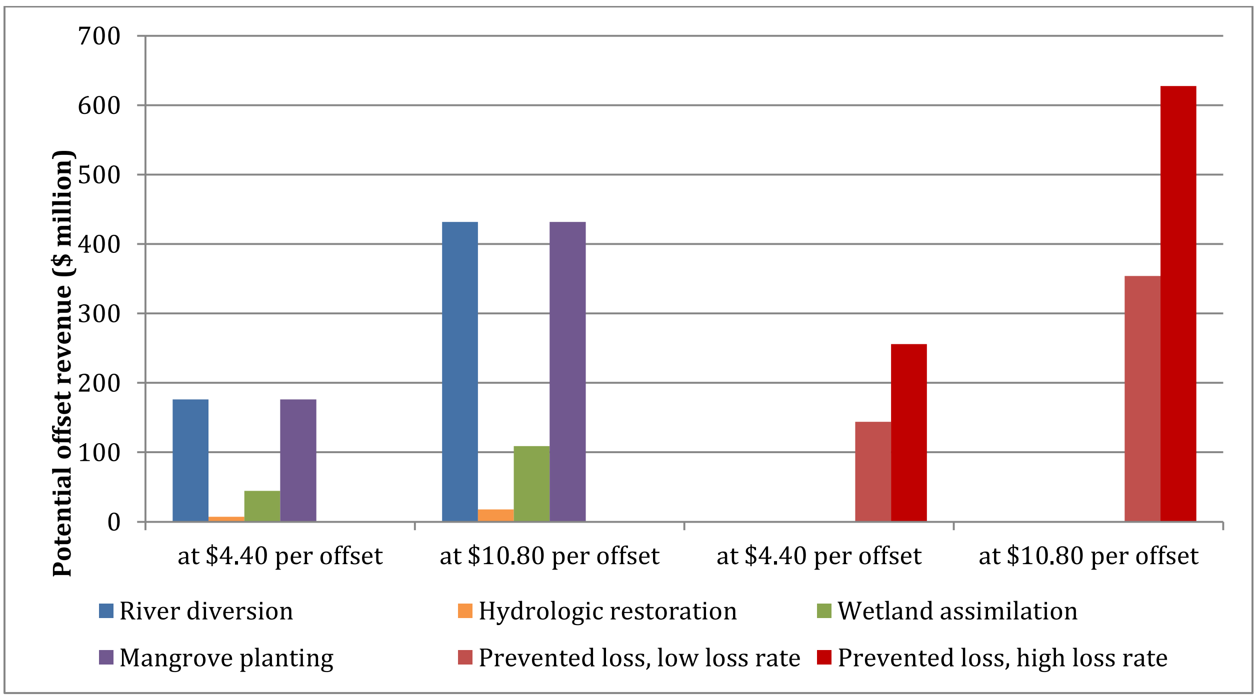

Figure 7: Projected revenue potential of wetland carbon offsets in Louisiana due to wetland restoration and prevented wetland loss including a 20% buffer deduction[6]

In summary, there are many factors that may influence the ultimate amount of funding that carbon finance will contribute to wetland restoration in the Mississippi River Delta. Major factors include the price of the carbon offset, whether prevented wetland loss can be included in carbon accounting methodologies, and finally the amount of wetlands that can be successfully restored for the project life. Eligibility rules for inclusion of projects in carbon market participation, including issues of start date, easement type, standardized emissions factors, use of federal funding in project implementation, and

[6] For the purposes of this study an assumption was made that half of the carbon contained in the top 50 cm of sediment can be prevented from being released as greenhouse gases and that these offsets would be additional to restoration offsets.

required buffer deductions will also be important. Wetland restoration techniques identified in this study could potentially generate $400 million to almost $1 billion in offset revenue depending on the dollar value of the carbon offset. Including prevented wetland loss in carbon accounting may provide an additional $140 to almost $630 million depending on the dollar value of the carbon offset, and rates of wetland loss, subsidence, and sea level rise. Considering the various factors impacting carbon offset prices and yields, carbon finance has the potential to bring a total of $540 million to almost $1.6 billion to assist with wetland restoration in the coastal areas of the Mississippi River Delta (Figure 8).

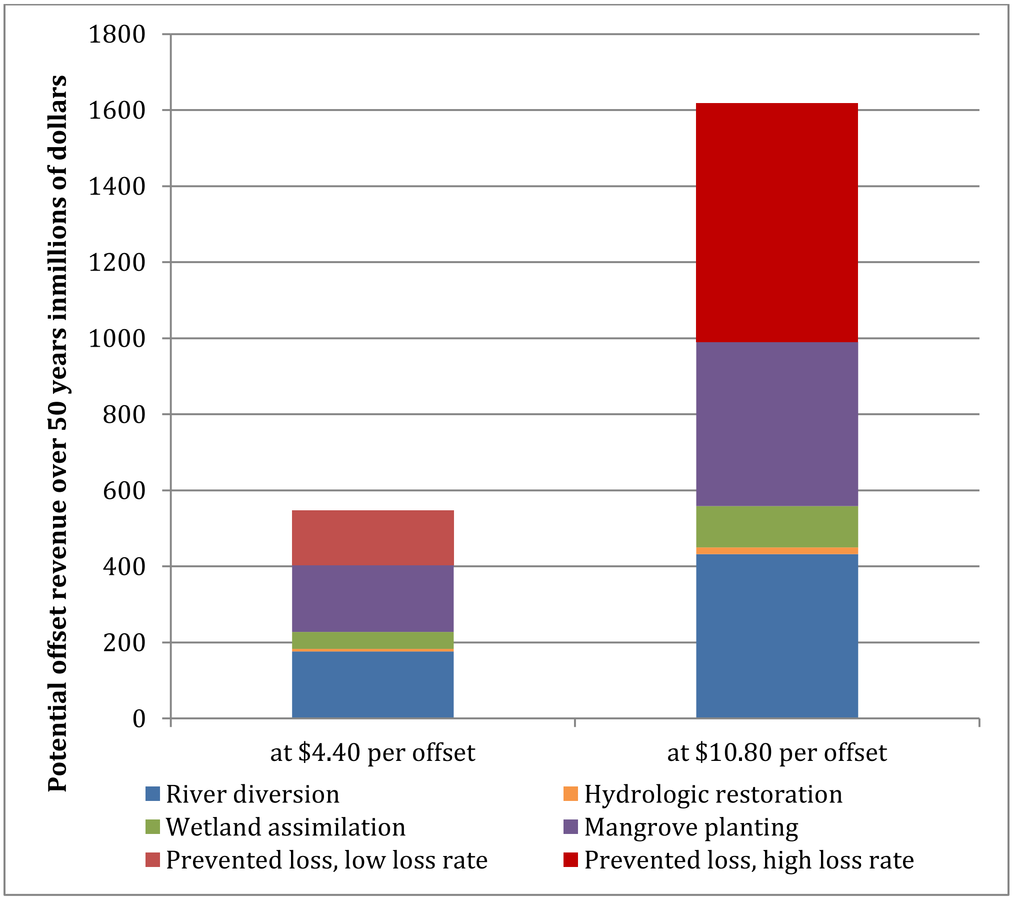

Figure 8: Total projected revenue potential of wetland carbon offsets in Louisiana due to wetland restoration and prevented wetland loss including a 20% buffer deduction

Carbon markets have the potential to provide a revenue stream to support restoration, but project development costs as well as the long-term commitments to project monitoring and reporting are important factors to consider when deciding if a project will be financially viable. Carbon projects require long-term commitment to the restoration activity and to reporting. Therefore, long-term costs are an important consideration for project developers and landowners that are assessing project feasibility and viability. While there are many commonalities across the multiple standards, rules on eligible project start dates, the permissible length of time between project start and first verification, the required frequency of verification, offset prices, and other differences can impact the number of offsets a project will be able to verify and sell. The costs of carbon market participation across the project life, and ultimately, whether the project will be financially viable contributes to the final determination. In general, in developing a carbon project, larger projects are more likely to be viable, since many of the project costs are relatively fixed. However, smaller projects can potentially be aggregated to achieve an economy of scale.

In most cases the costs of restoration will exceed potential carbon revenue streams. Capital intensive restoration projects will likely need to leverage carbon finance with traditional state and federal restoration programs. This may present challenges where state and federal programs are not allowed to be used in a way that results in profits for privately held entities. However, carbon finance may prove to be ideal for paying for parish or state cost-shares where it can be demonstrated that carbon funds were used directly towards project costs or long-term monitoring and maintenance, (which is usually not budgeted into state and federal programs). Considering that 80% of wetlands in Louisiana are privately owned, the remaining challenge will be negotiating win-win agreements with government agencies and private landowners that entice landowners to participate in programs instead of causing further conflicts between private landowners and governmental entities. In some instances, restoration projects may be able to be fully funded by carbon revenues and implemented by private landowners thus expediting coastal restoration. However, even in these instances it is likely that the projects will need to be aggregated.

4.0 Landowner Identification and Expressed Interest

It is clear that wetland restoration has substantial potential to generate climate benefits and to produce carbon offsets that can be sold to support restoration and monitoring. However, without willingness of stakeholders to undertake restoration projects and to commit to long term monitoring and maintenance, wetland carbon projects cannot succeed. During 2012 and 2013, an initiative began to identify wetland landowners and provide outreach about emerging opportunities to restore wetlands via carbon offsets. To date, approximately 50 wetland landowners who collectively own over 2.3 million acres of the nearly 4 million eligible acres were identified. One-on-one meetings were held with landowners who collectively own approximately 1.7 million acres. Landowners representing approximately 1.5 million acres expressed interest in exploring wetland carbon project participation. Tierra Resources has identified multiple landowners interested in public-private partnerships, substantial viable acreage for restoration projects, and several possible physical locations for potential project sites. These efforts demonstrate that there is substantial interest among landowners, and provides a strong foundation for future carbon project development in the region.

5.0 Commercializing Carbon: Carbon Market Trends and Developments

Carbon markets include both voluntary and compliance markets. There are important differences between the two, but trends in both favor high-quality land-based projects, such as wetland restoration offset projects (Appendix B).

The voluntary carbon market is fundamentally driven by the demand for carbon offsets from private sector companies who see offsets as a means to reduce their company's environmental footprint, to demonstrate corporate social responsibility, and enhance public relations. There are also smaller voluntary buyers-small companies or individuals- that desire to offset emission from personal activities, such as airline travel or miles driven. In practical terms, the voluntary carbon market is a buyer's market. The primary objective for offset projects in this space is to find a buyer that is voluntarily willing to pay a high price for offsets. Voluntary buyers assign higher value to projects based primarily on the perception of their quality or charismatic appeal. Voluntary buyers also focus on projects with strong - and perhaps more importantly, easily communicated - social or environmental outcomes beyond carbon reductions. These carbon projects are often most appealing if near the company's operation territory. Voluntary buyers may buy offsets generated from either voluntary or compliance driven market standards and methods. Demand for offsets in the voluntary market is inherently variable and uncertain, and prices paid for offsets vary substantially based on their perceived quality, value, and fit with buyer desire for project type, location, or other factors.

Compliance carbon markets are fundamentally driven by the demand for allowances and offsets by regulated GHG emitters. The criteria for offset project development and accounting in a compliance market are controlled entirely by the program's regulator. The primary concern for buyers is acquiring allowances and/or offsets at the lowest possible compliance cost. Concerns remain over strong verification and carbon accounting primarily to mitigate a buyer's liability should regulators invalidate specific offsets or projects. There is virtually no price distinction between offsets in terms of project charisma or co-benefits. In contrast to voluntary markets where buyers are price-setters, compliance markets offer a more level playing field where offset supply, demand, and prices are relatively more predictable.

5.2 California's Compliance Market

In 2006, California passed the first economy-wide climate law in the United States that aimed at reducing greenhouse gas emissions to 1990 levels by 2020 utilizing varied mechanisms which included an emissions trading structure. The cap is the aggregate limit on GHG emission from carbon sources from 2013, to 2020 and, enters its second phase in 2015, which will cover 85% of California's greenhouse gas emissions. The program uses a phased approach, expanding to cover more entities and to lower the cap over time. Covered entities include entities with over 25,000 mtCO_2e emissions annually, such as Investor Owned Utilities (IOU's), Publicly Owned Utilities (POUs), oil and gas companies, and more.

The California compliance market includes two compliance instruments: California Carbon Allowances (CCAs), issued by the California Air Resource Board (ARB) to emitters or otherwise marketed by auction, and California Carbon Offsets (CCOs) that are generated by qualifying carbon offset projects. CCOs are designed to be a cost containment mechanism that covered entities can use to offset up to 8 percent of their compliance requirement. Presently, only five offset project types have been approved for the compliance market by ARB. These include Forestry, Urban Forestry, Livestock Methane, and Ozone Depleting Substances, and Mine Methane. Rice Cultivation is another project type that is expected to be added in 2015. Another noteworthy point is that CCOs can be generated from projects in California, or in any location throughout the contiguous U.S. As a result, offset projects are now being developed throughout the lower 48 states, including Louisiana.

Entry into the California compliance market is a priority to receive large financial investments in wetland offset projects. The compliance instrument demand in the California market is driven by regulation, and consequently it is expected to produce a more predictable, stronger demand. California's carbon market entered its first compliance period January 1, 2013 and ended on December 31, 2014. Several important milestones were achieved setting the stage for continued growth and success in the final two compliance periods currently scheduled to end in 2020. Important strategic market linkages were formed during the first compliance period that strengthened California's position, further positioning the overall market for growth geographically, in volume, and in climate impact (Appendix B). Furthermore, the California compliance market has established a relatively consistent price for its offsets, which, by law are supported by an escalating price floor, rising at 5% annually, adjusted for inflation. The strength and expected growth of the California market, and the likelihood that the market may serve as a model or foundation for expanded regulated markets in other areas, makes entry into the California compliance market of paramount importance.

6.0 Targeting Compliance Approval for Wetlands Methodology

The ARB approved Compliance Offset Protocols, which currently only include five project types, have been developed from existing methodologies for GHG quantification that were vetted under rigorous voluntary standards. The expectation of sustained demand for offset credits and higher prices has attracted significant interest in lobbying the California Air Resources Board (ARB) to adopt additional offset project protocols from voluntary carbon standards active in the U.S. While there is no requirement that compliance offset projects take place in California, public pressure and political will suggest that projects that can demonstrate local benefits are more likely to be considered for adoption. California has a substantial need for innovative approaches to wetland restoration. In the San Francisco Bay Area, more than 80 percent of historic tidal wetlands disappeared in the last 150 years while the Sacramento-San Joaquin Delta has also suffered significant losses. The ACR-approved methodology for quantifying GHG emissions reductions from Restoration of Degraded Deltaic Wetlands of the Mississippi Delta provides a strong foundation for testing and expansion under ARB.

In December 2013, the American Carbon Registry formally announced the collaboration between Tierra Resources and other partners for expansion of the current ACR wetlands methodology to be eligible in California.[7] The overall objective is the potential adoption of the methodology as a compliance protocol by ARB. In order to adapt the ACR wetlands protocol to California, the scope of project activities is being expanded beyond the Mississippi Delta, particularly to address potential wetland conservation projects in the Sacramento-San Joaquin River Delta as well as tidal wetland restoration. The expansion will also require incorporating several regulatory criteria into the methodology. The ACR approval process for the methodology, which includes stakeholder workshops, a public comment period and a scientific peer review process, is expected to be completed in 2015.

The Climate Trust and Tierra Resources participated in an engagement strategy for the commercialization of the Restoration of Deltaic Wetlands of the Mississippi Delta Methodology that focused mainly on emissions reduction market players, carbon buyers, and greenhouse gas accounting protocols. The primary objective was to educate those involved and to allow for the recognition of the existing ACR wetlands method among counterparties that influence future compliance policies. A secondary objective was to position and promote the modification of a wetlands project type that could

[7] Partners include the Sacramento-San Joaquin Delta Conservancy, the California Coastal Conservancy, the California Department of Water Resources (DWR), the American Carbon Registry (ACR), the Nature Conservancy, and Hydrofocus.

ultimately be acceptable in the California compliance market. This was done in a series of carbon industry and stakeholder meetings in California, Washington DC, and Louisiana.

7.0 Conclusions and Recommendations

The objectives of this study were to; 1) evaluate the commercial potential of blue carbon in Louisiana, 2) identify information needs for future scientific investigation to support current and future wetland carbon offset programs, 3) identify scalable restoration methods that show commercialization potential as wetland offset projects, 4) determine the potential offset supply that can result from coastal restoration in Louisiana, and 5) provide financial estimates that carbon finance can contribute to coastal restoration.

Recent developments pave the way for carbon markets to support wetland restoration. In 2012, the American Carbon Registry (ACR), a leading carbon market standard, certified the first wetland offset methodology, "Restoration of Degraded Deltaic Wetlands of the Mississippi Delta", as developed by Tierra Resources, and funded by Entergy Corporation through its Environmental Initiatives Fund. This methodology created the first route-to-market, opening the potential of carbon market investment into wetland restoration projects. Other recent developments also show the growing recognition of the importance of leveraging ecosystem markets for wetland restoration and climate change mitigation.

Restoration techniques that were identified as having potential as wetland offset projects include river diversions, hydrologic restoration, marsh creation, wetland assimilation, and mangrove plantings. Marsh creation was eliminated from the study based upon a lack of empirical data to model carbon yields, concerns over the permanence of the restoration technique, and the need to deduct significant fossil fuel emissions that occur during the pipeline conveyance of sediment. Forested wetland assimilation systems have the highest net offset yield per acre. However, it was concluded that river diversions and mangrove plantings have the potential to generate the largest volume of offsets in Louisiana due to the large amount of acreage that these restoration techniques can be applied. It should also be noted that carbon credits from wetland assimilation systems and river diversions show potential to be stacked with water quality credits should these markets evolve in Louisiana.

The primary barrier to wetland carbon commercialization that was identified through this study is the high cost of wetland restoration. In most cases, wetland restoration costs that range from $20,000-$150,000 per acre far exceed potential carbon revenue streams. This will create challenges to incentivize business, government, and financial organizations to invest in wetland restoration projects when there is no obvious net-profit. High restoration costs will require that carbon finance be leveraged with government restoration funding programs, requiring new public-private partnership paradigms to stimulate investment into wetland projects.

The high cost of measuring variability of greenhouse gas emissions in wetlands adds to the challenge of creating a business case for investment into wetland restoration. Wetland GHG emissions can vary greatly depending on the season and hydrologic site conditions. This GHG variability may make the monitoring of greenhouse gases to reach confidence intervals required by emissions trading markets cost-prohibitive. The literature review performed as part of this study revealed that restoration projects have no measurable net increase in GHG emissions. The exclusion of GHG emissions in wetland carbon accounting or the development of regional emission factors could significantly expand this project type.

Carbon finance shows significant potential to be leveraged with current restoration programs to fund wetland projects. The final results of this study revealed that *coastal wetland restoration in Louisiana has the potential to produce over 1.8 million offsets per year - almost 92 million offsets over 50 years.* Wetland restoration techniques identified in this study could potentially generate $400 million to almost $1 billion in offset revenue depending on the dollar value of the carbon offset. Including prevented wetland loss in carbon accounting may provide an additional $140 to almost $630 million depending on the price of the carbon offset, and rates of wetland loss, subsidence, and sea level rise. Conservative estimates, considering factors impacting carbon offset prices and yields, indicate that carbon finance has the potential to bring a total of $540 million to almost $1.6 billion to assist with wetland restoration in the coastal areas of the Mississippi River Delta.

The recommended next steps to increase the commercial viability of wetland carbon offsets and realize the significant potential of wetlands to sequester carbon in the Gulf Coast and other areas of the U.S. include:

Technical Recommendations:

- Undertaking efforts to reduce project development costs and simplify monitoring, reporting and verification including:
    - Furthering research to either justify the exclusion of GHG emissions in wetland carbon accounting or the development of regional emissions factors by restoration project type.
    - Modifying Louisiana's Coastwide Reference Monitoring System (CRMS) to include carbon offset monitoring parameters.
    - Developing wetland carbon and GHG emission models.
    - Creating a technology tracking database that allows for the management of large volumes of information associated with wetlands in a systematic fashion.
- Furthering research to determine the carbon impacts of prevented wetland loss and incorporating results into current wetland carbon accounting methodologies. The large offset potential from prevented wetland loss demonstrates the importance of creating a mechanism to quantify the carbon benefit of preventing wetland loss in order to optimize the amount of offsets that can be achieved out of a specific restoration project.
- Publishing lessons learned from existing pilot projects including:
    - Analyses of costs and benefits,
    - Public-private paradigms that demonstrate the ability to leverage carbon finance with government restoration dollars.

Policy Recommendations:

- Advocating with carbon standards on issues that impact the viability of wetland carbon projects including:
    - Allowing use of federal funds considering the high cost and multiple co-benefits of wetland restoration,
    - Environmental credit stacking,
    - Types of conservation easements eligible for carbon projects,
    - Rules and processes for project aggregation, and
    - Crediting period length for wetland restoration projects.
- Establishing funding pools that will allow wetland project development to scale up to meet future carbon demands in the compliance market.
- Modifying existing wetland methodologies and protocols to fit the compliance market for potential inclusion of wetlands in California's compliance market to provide sustained demand for offset credits at higher offset prices.

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Appendix A: Carbon Market Terminology

ACR- American Carbon Registry, a U.S. carbon market standard and registry. ACR serves as a platform for development and registration of projects for the voluntary carbon market and also serves as an Offset Project Registry serving in review and listing of projects under the California compliance market.

Additionality- A key eligibility requirement for carbon offset projects. A project is additional if it can demonstrate that it creates emissions reductions or stores more carbon than in a business-as-usual scenario. A project cannot receive offsets for simply following local, state, or federal laws.

ARB- California Air Resources Board, the body that oversees design and implementation of California's compliance emissions trading system.

Baseline- An offset project must establish a carbon storage baseline, which represents the amount of carbon that would be stored (for example in the wetland plants and soil) without the carbon project. Additional carbon stored by the project is compared against this baseline using the rules of the carbon standard and methodology. The baseline may be based on historical practices or practices of similarly situated neighbors.

Blue carbon- Blue carbon is the carbon stored in mangroves, seagrass, and coastal wetlands.

Buffer- A pool of carbon credits that are held in case of reversals of stored carbon increases (for example, through a forest fire or hurricane). A percentage of carbon offsets from each project are not sold on the carbon market and, instead, kept in reserve to guard against risk.

Buffer deduction- A percentage of carbon offsets from a project that not sold on the carbon market to guard against risk. The percentage is determined by a risk assessment of the carbon project.

CAR- Climate Action Reserve, a U.S. carbon market standard and registry. ACR serves as a platform for development and registration of projects for the voluntary carbon market and also serves as an Offset Project Registry serving in review and listing of projects under the California compliance market.

Carbon allowances- Government issued permits to industries that allow them to emit greenhouse gases up to a certain limit.

Carbon finance- Carbon finance is a branch of environmental finance, and explores the financial implications of living in a carbon-constrained world, where carbon dioxide emissions and other greenhouse gases (GHGs) carry a price. The general term is applied to investments in GHG emission reduction projects and the creation (origination) of financial instruments that are tradable on the carbon market.

Carbon market- A financial market where government-issued permits that regulate greenhouse gas emissions are traded as a commodity.

Carbon offset- (carbon credit) is one metric ton reduction in emissions of carbon dioxide or greenhouse gases made in order to compensate for, or to offset, carbon dioxide or other greenhouse gas (GHG) emissions elsewhere.

Emissions trading- Emissions trading is a market-based approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants.

GHG- Greenhouse gas including carbon dioxide, methane, nitrous oxide and many refrigerants.

Greenhouse gas- A type of pollutant that scientists say contributes to global warming. The primary pollutant is carbon dioxide, but there is also methane, nitrous oxide and many refrigerants.

Leakage- A loss of carbon or increase of emissions outside of a project area. If a project causes leakage, it may not be eligible as a carbon project, or may have to deduct a corresponding volume of offsets generated by the project from those available for sale.

Permanence- Carbon offset quality standards require that climate benefits of an offset are 'permanent,' for example, that stored carbon in vegetation and soil in a wetland are not lost through a natural disaster or management change. To guard against this, project developers need to provide legal assurance as to the permanence of land use projects (for 40 years under ACR and 100 years under ARB rules), and contribute a portion of offsets to a required buffer (calculated depending on assessed risk of reversals).

VCS- Verified Carbon Standard, a global voluntary carbon market program.

Verification- Verification is the third-party audit of offsets calculated and claimed by a project. Carbon standards require offsets generated by a project to be verified before they can be transacted. Carbon standards set rules on the required frequency of verification, who is authorized to conduct a verification, and what verifiers will audit. For example, how data used in calculating baseline and project level carbon stocks are captured, recorded, and reviewed, or a site visit to measure soil carbon and ensure that reported values match those observed.

Wetland carbon sequestration- Wetland plants capture atmospheric CO2 through photosynthesis. As the plants die and decay, their root mats and other decayed material build up the soil, which results in permanent storage of carbon, or carbon sequestration. When wetlands degrade and turn into open water, the carbon stored in the soil can be released back into the atmosphere. Wetland restoration is a critical tool to combat wetland loss, as well as an effective climate change mitigation strategy as it enhances carbon sequestration and prevents carbon release resulting from wetland degradation and wetland loss. Therefore, wetland management and restoration projects can be measured as GHG offsets.

Appendix B: Carbon Market Trends and Developments

Critical Distinctions between Voluntary and Compliance Markets

Carbon markets include both voluntary and compliance markets. There are important differences between the two, but trends in both favor high-quality land-based projects, such as those in wetland restoration.

The voluntary carbon market is fundamentally driven by the demand for carbon offsets from private sector companies who see offsets as a means to reduce their company's environmental footprint, to demonstrate corporate social responsibility, and to enhance public relations. Large voluntary buyers typically purchase offsets as part of a corporate social responsibility (CSR) strategy, and many have an internal mandate to become climate neutral, either within a given time frame or for a particular product they manufacture. There are also smaller voluntary buyers-small companies or individuals- that desire to offset emission from personal activities, such as airline travel or electricity use. Major companies are increasingly adopting internal carbon pricing; this allows them to plan for the expectation of future regulation and to demonstrate climate leadership to their customers. Many of these businesses recognize that addressing climate change will be both a business cost and possible business opportunity regardless of the regulatory environment. Microsoft, Disney, and General Electric are among at least 29 companies incorporating a price on carbon into their long-term financial plans.

In practical terms, the voluntary carbon market is a buyer's market. The primary objective for offset projects in this space is to find a buyer that is voluntarily willing to pay a high price for offsets. Voluntary buyers assign higher value to projects based primarily on the perception of their quality. Voluntary buyers also focus on projects with strong—and perhaps more importantly, easily communicable—social or environmental outcomes beyond carbon reductions, called co-benefits. An improved forest management project, for example, may have co-benefits in watershed health, biodiversity or local economic development. Demand for offsets in the voluntary market is inherently variable and uncertain, and prices paid for offsets vary substantially based on their perceived quality, value, and fit with the buyer's purchase strategy. Project type, location, credit volume and charisma are all important considerations for voluntary buyers.

Compliance carbon markets are fundamentally driven by the demand for allowances and offsets by regulated greenhouse gas emitters. The primary concern for buyers in this type of market is acquiring allowances and/or offsets at the lowest possible compliance cost. Concerns remain over strong verification and carbon accounting, primarily to mitigate a buyer's liability should specific offsets or projects be invalidated by regulators. There is virtually no price distinction between offsets in terms of project charisma or co-benefits. In contrast to voluntary markets where buyers are price-setters, compliance markets offer a more level playing field where offset supply, demand, and prices are relatively more predictable.

The criteria for offset project development and accounting in a compliance market are controlled entirely by the program's regulator. Several initiatives are emerging to connect compliance programs between countries and states, but every compliance program currently sets its own rules and regulations for offset credits and projects, which significantly limits the fungibility of offset credits between compliance programs. For example, despite functioning within the scope of the Kyoto Protocol, the EU ETS chose to exclude the use of any Kyoto-compliant offsets from forestry or other land use projects in their own compliance program. Although international, regional, and state carbon markets approve the use of terrestrial carbon offsets, most programs only have provisions for upland forestry projects. However, in 2012 the American Carbon Registry (ACR) certified the first wetland offset methodology "Restoration of Degraded Deltaic Wetlands of the Mississippi Delta" developed by Tierra Resources, and funded by Entergy Corporation through its Environmental Initiatives Fund.

California Compliance Market Background

In 2006, California passed AB32- otherwise known as the California Global Warming Solutions Act- the first economy-wide climate law in the United States which aimed at reducing greenhouse gas emissions to 1990 levels by 2020 through varied mechanisms including an emissions trading system. The cap is the aggregate limit on GHG emission from carbon sources from 2013 to 2020 and, since the beginning of 2015, covers 85% of California's greenhouse gas emissions. The program uses a phased approach, expanding to cover more entities and to lower the cap over time. Covered entities include companies with over 25,000 $mtCO_2e$ emissions annually, such as Investor Owned Utilities (IOU's), Publicly Owned Utilities (POUs), producers and importers of transportation fuels, and natural gas producers.

The program includes two compliance instruments: California Carbon Allowances (CCAs), issued by the California Air Resource Board (ARB) to emitters or auctioned, and California Carbon Offsets (CCOs) generated by qualifying carbon offset projects. CCOs are designed to be a cost containment mechanism, which covered entities can use to offset up to 8 percent of their compliance requirements. CCOs can be generated from projects outside of California, so there are offset projects now being developed throughout the lower 48 states, including Louisiana. Presently, only five project types have been approved for the compliance market by ARB, including Forestry, Urban Forestry, Livestock Methane, Ozone Depleting Substances and Mine Methane Capture. In early 2015, it is expected that ARB will approve a protocol for Rice Cultivation- the first protocol to deal with an agricultural product type. It is also expected to approve an addition to its existing forestry protocol which will allow the eligibility of forested land in Alaska.

California's carbon market entered its first compliance period January 1, 2013 and has had a strong first two years, achieving important milestones for continued growth and success in 2015 and beyond. The program's first important linkage, to the Canadian province of Quebec, also strengthened and progressed, further positioning the market for growth geographically, in volume, and in climate impact. The concluding section of this appendix: *Carbon market update and trends*, provides additional detail.

Why the California Compliance Market?

The California compliance market is attractive for several reasons, but the relatively high price of offsets in the market and the expectation of growing demand driven by regulated GHG emitters are the primary factors. While the voluntary market is fundamentally driven by the demand for carbon offset credits from private sector companies who see offsets as a means to reduce their company's environmental footprint, demonstrate corporate social responsibility, and enhance public relations, compliance instrument demand in the California market is driven by regulation, and consequently is expected to produce more predictable, stronger demand. Current regulations allow 8% of an emitter's compliance obligation to be met through the use of offsets. This amounts to a maximum of about 200 million $mtCO_2e$ of offsets over the three compliance periods: 25.8 million $mtCO_2e$ in the first compliance period (2013-2014), 91.8 million $mtCO_2e$ in the second compliance period (2015-2017), and 83.1 million $mtCO_2e$ in the third compliance period (2018-2020) as additional entities are regulated (Figure 9 below, from ARB/ICF).

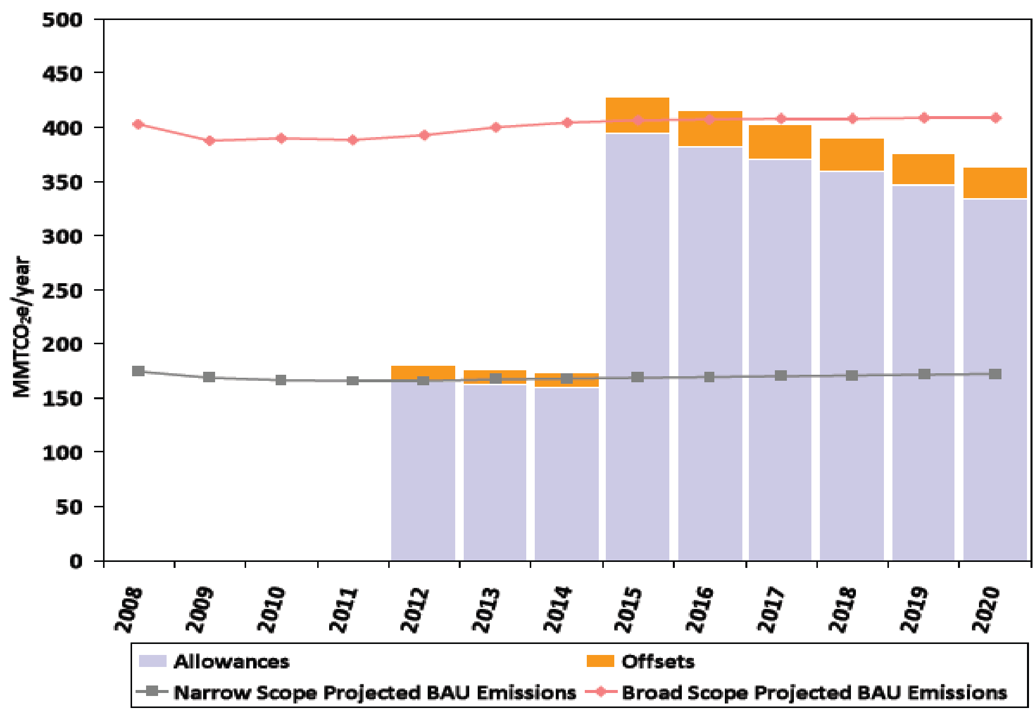

Figure 9: Projected emissions, caps, allowances and offsets in California

Further, allowances in the California market have historically traded at a relatively high price, and by law are supported by an escalating price floor, rising at 5% annually, adjusted for inflation. It is important to note that offsets in the system do not have a floor price and are expected to trade at a discount relative to allowances because of a limit on the offsets that can be used by each regulated entity and the added risk associated with offsets, most notably invalidation risk.

Offsets may be invalidated for one of three reasons: material (greater than 5%) errors in credit calculation, double counting of credits, and noncompliance with state or federal regulations. In 2014, a portion of credits from an Ozone Depleting Substances (ODS) project listed by EOS Climate was invalidated by ARB for regulatory noncompliance, stemming from an improper handling of a byproduct of the destruction process. The invalidation caused an outcry in the market, and the exit of the Clean Harbors ODS destruction facility as a market actor.

To protect from invalidation, project developers may choose to attain additional verifications. A second verification within a three-year window from issuance will result in a CCO-3, a California-compliant offset with a three year, rather than eight year, invalidation window. If credits from a project are not invalidated within the three years, they become Golden CCOs, offsets that carry no invalidation risk. Since the Clean Harbors ruling, second verifications have become more common and attainment of CCO-3 status is on the rise.

As the market learns to adjust to potential risks, the strength and expected growth of the California market, and the likelihood that the market may serve as a model or foundation for expanded regulated markets, make entry into the California compliance market a priority.

Targeting Compliance Approval for Wetlands Methodology

The expectation of sustained demand for offset credits and higher prices has attracted significant interest in lobbying the California Air Resources Board (ARB) to adopt additional offset project protocols by voluntary carbon standards active in the US. ARB has a strong political interest in methodologies that enable projects to be developed in California. Tierra Resources and all project partners have a strong interest in ensuring the highest value for offset credits generated under the methodology, which leads directly to a goal of adapting the current ACR wetlands methodology for potential adoption as a compliance protocol by ARB.

Projects that produce California compliance offsets are not restricted to California, but rather may be from projects anywhere in the contiguous United States. However, all compliance offset projects must be developed according to ARB approved Compliance Offset Protocols, which currently only include five project types. However, wetland restoration projects may be a good fit for the California market for several reasons:

1) They come from a sector not covered by the regulation.

2) They produce offsets that are real, additional, quantifiable, verifiable, permanent and enforceable. The approved protocols built from existing methodologies for GHG quantification being developed and vetted under rigorous voluntary standards demonstrate that offsets meet these quality requirements. The ACR-approved methodology for quantifying GHG emissions reductions from Restoration of Degraded Deltaic Wetlands of the Mississippi Delta provides a strong foundation for testing and expansion under ARB (Mack et al, 2012).

3) They are well-suited for the long-term management required under California Offset Protocols. To ensure environmental integrity, ARB requires that forest projects produce lasting changes, requiring monitoring for a period of 100 years following the final issuance of any ARB or registry offset credits to meet permanence requirements. Wetlands can continue to increase stored carbon over time in soils and biomass, and are well matched with the long-term management requirements under the standard.

4) California has a substantial need for innovative approaches to wetland restoration. In the San Francisco Bay Area, more than 80 percent of historic tidal wetlands disappeared in the last 150 years. Degrading drained and cultivated organic soils continue to oxidize, subside and emit an estimated 1.5 to 2 million mtCO_2e annually. While there is no requirement that compliance offset projects take place in California, public pressure and political will suggest that projects that can demonstrate local benefits are more likely to be considered for adoption.

The Climate Trust and Tierra Resources participated in an engagement strategy for commercialization of the Restoration of Deltaic Wetlands of the Mississippi Delta Methodology focused mainly on emissions reduction market players, carbon buyers and greenhouse gas accounting protocols. The main objective was education and recognition of the existing ACR wetlands method among counterparties that can influence future compliance policy. Another goal was to position and promote the modification of a wetlands project type that could ultimately be acceptable in the California compliance market. This was done in a series of carbon industry and stakeholder meetings in California, Washington, D.C, and Louisiana.

In order to adapt the ACR wetlands protocol to California, the scope of project activities are being expanded beyond the Mississippi Delta, particularly to address potential wetland conservation projects in the Sacramento-San Joaquin River Delta as well as tidal wetland restoration. In December 2013, the American Carbon Registry formally announced the collaboration between Tierra Resources and other partners for expansion of the methodology for this region. This adaptation will also require incorporating several regulatory criteria into the methodology.

Carbon Market Update and Trends

The past two years have been strong for carbon markets and for forest carbon projects, with positive developments for the California compliance market and increasing commitment in the private sector to account for and mitigate climate impacts. At a national level, the US National Climate Action Plan, released in June 2013, focused energy and attention on climate change. This has included considering the role of forests in mitigating climate change and calling for new approaches to protect and restore forests, grasslands and wetlands. Challenges are inevitable in an evolving market, and ARB Rules on easements in forest carbon projects may set challenging precedent for some wetland restoration offset projects. However, this energy for innovative solutions, together with trends in voluntary markets favoring high-quality land use and forestry projects and the continued progress of the California compliance market, provide strong potential for support of high-quality, scientifically rigorous projects in wetland restoration.

Notable achievements and developments in the California compliance market for its first two years include:

- **Market signals growing confidence that the California compliance market is here to stay.** To date, California has conducted nine successful auctions, of which the most recent was the first joint auction with Quebec, with prices relatively stable despite some initial volatility. Demand was strong in the most recent auction, with all available current and future vintage allowances sold during the auction and almost two bids received for each available allowance, meaning strong demand exists among bidders. On average, 100% of current vintage allowances and 73% of future vintage allowances have sold at auction to date. While current vintage allowances have consistently cleared the price floor, future vintages have sold at the floor in several auctions, indicating that to date, entities are having little difficulty securing enough allowances to meet their compliance obligations, consistent with a long market where roughly 60% of allowances have been freely allocated.

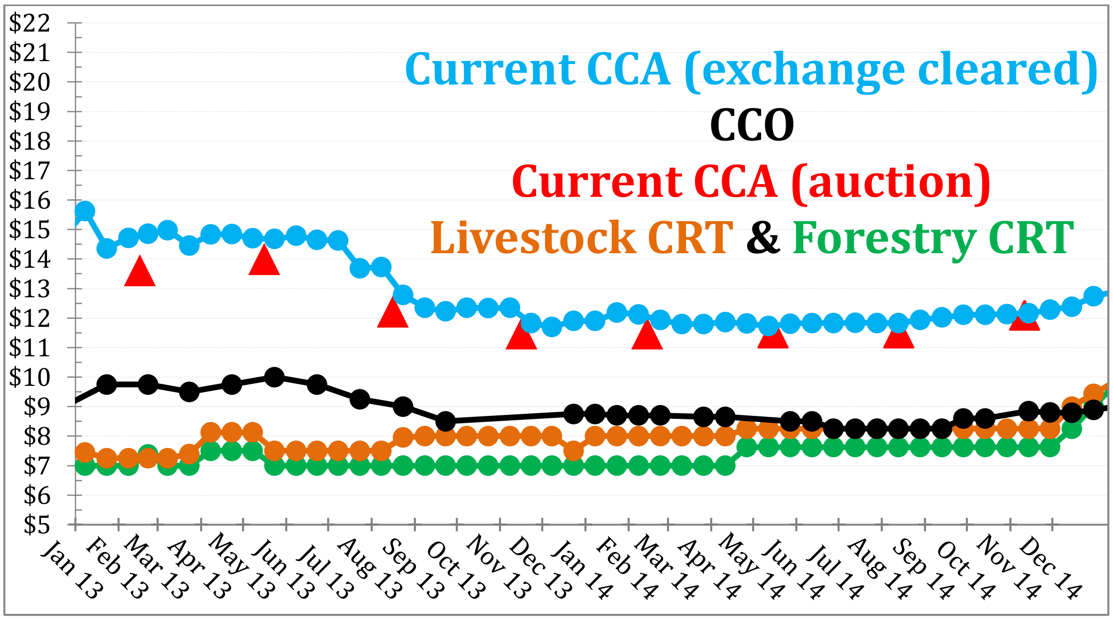

Figure 10: California carbon market allowance and offset prices have been relatively stable. (Note: CCA = California Carbon Allowances; CCO = California Carbon Offsets generated by qualifying carbon offset projects; CRT = Climate Reserve Tonne)

Strong interest in future vintage allowances was also displayed in the most recent auction, most likely in response to newly linked demand from Quebec, as well as the entry of transportation fuels under the cap at the beginning of 2015. Current and future vintage allowances cleared the price floor of $11.34 by $.76 and $.52, respectively, indicating that most entities under the cap have already "priced in" the new 2015 floor of $12.10. This shows strong confidence from the market that the compliance system will continue.

Please note: The carbon market information provided here is derived from price ranges offered by third party buyers. Prices can fluctuate based on energy markets, evolving CARB rules, and general supply and demand dynamics.

- **California Air Resources Board issues millions of offset credits.** In September 2013, ARB issued its first compliance offset credits to four projects developed under both ARB's compliance offset protocol and approved early action protocol. This demonstrated the successful organization of requisite support framework, including offset project registries and verifiers, to produce a steady flow of offset credits for the program. By February 1, 2015, 87 projects had been issued a total of over 16.7 million verified offsets.

- **Forestry Protocol accounts for nearly half of offsets**. Forest carbon projects have achieved broad success as an offset sector for the compliance program, to date making up nearly half of the available offset supply, with over 8.5 million credits listed to 14 projects. In early 2015, it is expected that ARB will approve the addition of lands in Alaska to its forestry protocol, increasing the potential for forestry to remain one of the key sources of offset supply into the future and confirming strong preferences toward land-based offsets in this market.

- **First compliance surrender occurs smoothly and with 100% compliance**. The program's first compliance surrender date passed on November 3, 2014, with entities required to surrender allowances and offsets equal to 30% of their obligations for the first compliance period. Over 360 entities participated in this surrender and all of them were 100% compliant, owing in part to the effort ARB has expended in educating firms about their obligations and how to comply. Offsets accounted for nearly 4% of surrendered instruments for all firms. Some entities surrendered higher percentages of offsets, signaling a preference among these firms for offsets as a lower-cost compliance option than allowances.

- **Linkage to other emissions trading programs provides basis for geographic and market expansion.** On January 1, 2014, California's carbon trading program officially linked with that of the province of Quebec, a long-anticipated linkage under which each jurisdiction can accept the other's carbon allowances and approved offsets for compliance under their respective emissions trading programs. This linkage may provide a pathway for other jurisdictions that may link, or provide a working model for other states and provinces that are seeking cost-effective approaches to reducing their greenhouse gas emissions, such as to comply with the newly announced rules for emission reductions from existing power plants under section 111(D) of the Environmental Protection Agency's Clean Air Act. Currently offsets are not allowed under section 111(D) but hopefully the agency will consider the option.

  In addition, in October of 2013, leaders of British Columbia, California, Oregon, and Washington formally joined forces to reduce emissions by signing the Pacific Coast Action Plan on Climate and Energy, committing to link and maintain their respective climate and renewable energy policies, and to harmonize their 2050 emissions reduction goals while developing shorter-term targets in the interim—an important first step toward larger linkage. The state of Washington has recently announced legislation to create a compliance program, while other carbon markets, including those in China and British Columbia, continue to explore linkage potential with California.

- **Market poised for continued growth, evolution, and innovation.** In addition to the highlights above, notables for 2015 and beyond include:
  - In January 2015, the minimum reserve price for allowances increased to $12.10.
  - The first triennial surrender- the first time entities will have to meet their obligation for a full compliance period- will take place in November 2015. Strong trading in both

allowances and offsets seems to indicate that entities under the cap are taking this obligation seriously.

- In January 2015, the emissions trading program expanded to include additional entities, including transportation fuel providers and commercial natural gas producers, bringing 85% of the state's total emissions under the cap.
- New offset protocols in the pipeline: four protocols were originally developed for the voluntary offset market and modified by ARB to ensure they meet the requirements of AB32. A new Compliance Offset Protocol for mine methane capture was adopted by ARB in April 2014 to supplement those currently approved: Forestry, Urban Forestry, Livestock Methane, and Ozone Depleting Substances. An additional new protocol for rice cultivation is anticipated to be approved in early 2015. Additional protocols, including additional agricultural protocols and a protocol for Wetlands are a second tier consideration.

Trends in the Voluntary Market Favor High Quality Land Use Projects

- **An increased focus on quality of offsets.** With increasing volumes of offsets being produced for compliance markets such as the California compliance system and the now-repealed Australia carbon tax, total traded volumes on the worldwide voluntary market declined in 2013, to 76 million mtCO_2e. Of this, 32.7 million mtCO_2e were produced by projects in the forestry sector, representing a 17% increase over 2012. Interest has continued to grow in forest carbon, particularly among companies purchasing offsets voluntarily as part of a climate commitment or corporate social responsiblity strategy, and interest has also grown in the co-benefits of forest projects, including biodiversity protection, local economic growth and watershed services. The significant increase in traded volume over the past year owes in part to a decrease in voluntary pricing for forestry offsets, as purchases in this sector are often highly price-sensitive, though Ecosystem Marketplace and Bloomberg New Energy Finance note that there is often a premium for quality, co-benefits, and charismatic value, for example, when a forest has Forest Stewardship Council certification, or a project achieves Climate, Community, and Biodiversity Alliance certification. This increased focus on quality has been coupled with increased awareness about both the ecosystem service benefits of forests and the crucial need to balance forest management strategies with the increased threat of climate change.
- **Major companies are adopting internal carbon pricing.** Many major publicly traded companies across various industry sectors have integrated an internal carbon price as a core element of ongoing business strategies, in expectation of future regulation, to demonstrate climate leadership, and in recognition that addressing climate change will be both a business cost and possible business opportunity regardless of the regulatory environment. Microsoft, Disney, Entergy, and General Electric are among at least 29 companies reported by the Carbon Disclosure Project to be incorporating a price on carbon into their long-term financial plans.

With Opportunity Comes Challenges

- **ARB Rules on easements in forest carbon projects may set challenging precedent for some wetland restoration projects.** In November 2013, ARB shared guidance on its rules, including that "land that is subject to a conservation easement with federal holders, including land enrolled in the USDA's Wetland Reserve Program (WRP) with a voluntary conservation easement is not eligible to participate in the ARB offset program" (http://www.arb.ca.gov/cc/capandtrade/protocols/usforest/resources/faq_102913_post.pdf). While this rule and guidance currently apply only to forest projects (as there is currently no wetland protocol for the California compliance market), this may set a challenging precedent for some wetlands restoration carbon offset projects. The primary issue identified that precludes projects with federally-held easements is that ARB defines the forest owner as "the owner of any interest in the real (as opposed to personal) property involved in a forest offset project" and thus includes easement holders, and mineral rights holders. Furthermore, there is a lack of clarity that federal agencies have authority to accept obligations that the ARB requires of owners of forest offset project lands. Despite this challenge, strong interest regionally, nationally, and globally from public and private sectors for innovative market-based approaches to restore and protect wetlands, forests, and grasslands suggest a collective will to overcome challenges to achieve these goals.

Appendix C: Wetland Carbon Sequestration Modeling Analysis

Wetlands and Carbon Sequestration

'Carbon Sequestration' refers to the removal of atmospheric carbon by plants or other storage mechanisms, which can mitigate greenhouse gases released as a result of changes in land use and the burning of fossil fuels. The carbon sequestered in vegetated coastal ecosystems, specifically mangrove forests, seagrass beds, and salt marshes, has been termed 'blue carbon' (Mcleod et al., 2011). In coastal Louisiana, blue carbon also refers to carbon sequestered in soils and trees of tidally influenced cypress-tupelo forests and freshwater marshes. Wetland restoration is an effective climate change mitigation strategy because it enhances carbon sequestration and avoids carbon releases that would occur in the absence of restoration activities.

There are five general carbon storage pools in wetlands: 1) aboveground trees; 2) aboveground herbaceous vegetation; 3) surface litter; 4) dead wood; and 5) belowground organic soil that include all organic matter from belowground productivity and also some organic matter produced aboveground that is buried as detritus. Wetland restoration techniques enhance carbon sequestration via increased vegetative productivity, carbon burial, and avoided carbon release. Increased productivity and accretion result in enhanced aboveground biomass and root production, leading to increased organic soil deposition and carbon sequestration (Day et al., 2004). Geological subsidence of this organic soil results in significant permanent carbon burial. Overall, the amount of carbon sequestered is highly dependent on the health and productivity of the wetland, as large amounts of previously stored carbon can be re-released to the atmosphere if the wetland deteriorates (Davidson and Janssens, 2006).

Wetlands can also emit greenhouse gases. Methane production tends to occur in low salinity and freshwater tidal flats and marshes because of the high organic matter content of the soils at anoxic depths. As salinity increases, methane emissions decrease or cease completely due to the availability of sulfate, the reduction of which inhibits methane formation. Small amounts of nitrous oxide can also be emitted by wetlands during nitrification and denitrification. However, denitrification can occur in organic bearing continental shelf sediments beyond the estuary. Though wetlands emit small amounts of nitrous oxide, the compound could be produced elsewhere in the estuarine or in the adjacent continental shelf and would likely occur without the presence of the wetland. Further research is needed to confirm whether nitrous oxide precursor compounds and their associated emissions would remain unchanged regardless of whether the wetlands are there or not. In general, wetland emissions can contribute to greenhouse gas impacts and require further investigation. The Intergovernmental Panel on Climate Change (IPCC) requires land use change assessments to quantify only those emissions resulting from direct human impacts. For the purposes of quantifying and valuing carbon sequestration in wetlands, it is the change of emissions beyond what is naturally occurring that must be quantified.

Restoration Techniques and Carbon Modeling

The objective of wetland restoration is the restoration of hydrology, vegetation, and wetland functions to sites where wetlands previously existed or are currently degraded. Various techniques are used to achieve wetland restoration, and not all approaches are suitable for all wetland systems. As part of this study, existing restoration techniques were examined to identify restoration methods that show commercialization potential as wetland offset projects. The analysis included the likely yield of carbon offsets for each restoration technique and the corresponding area of land suitable for restoration. The restoration techniques that were identified include:

- River diversions (also referred to as sediment diversions and freshwater diversions) - use of new channels and/or structures to divert sediment and freshwater from the Mississippi and Atchafalaya Rivers into adjacent basins.
- Hydrologic restoration - installation of features that restore natural hydrologic patterns either by conveying freshwater to areas that have been cut off by man-made features or by preventing the intrusion of salt water into fresh areas through man-made channels and eroded wetlands.
- Marsh creation - creation of new wetlands in open water areas, including bays, ponds, and canals, through sediment dredging and placement. Most projects involve pipeline conveyance of sediment.
- Wetland assimilation - the introduction of treated municipal effluent into impounded and degraded wetlands to provide freshwater and nutrients for restoration purposes.
- Mangrove plantings - assisted natural regeneration, seeding, or tree planting of black mangroves (*Avicennia germinans*).

A literature review was performed as part of this study to develop a database of currently available empirical data on carbon sequestration and GHG emissions from various types of wetland systems in the Mississippi River deltaic plain, as well as other areas of the world. The database was assembled from 47 peer-reviewed literature sources. Carbon sequestration from soils and trees, as well as methane (CH4) and nitrous oxide (N20) emissions, were the primary parameters of interest. Variables in the database included water inflow (none, diversion & wastewater), salinity (fresh, brackish & salt), type (forested, emergent & mangrove), and location (LA, gulf & world). Data were analyzed as applicable to wetland carbon offset projects and carbon market rules. The carbon impacts of preventing wetland loss were also analyzed. All values were converted to mtCO_2e/acre/year.

The likely carbon offset yield was determined for each offset restoration technique based upon results from the database. The amount of carbon sequestered that can be counted toward carbon credits depends on the difference between the carbon sequestration rate during an approved baseline, which represents "business-as-usual" practices, and the rate that results from the restoration activity. Tree and soil carbon pools were conservatively selected to represent the amount of carbon being sequestered. The net carbon offset yields were then applied to the amount of corresponding area that can be restored as determined by Louisiana's Comprehensive Master Plan for a Sustainable Coast. If the specific restoration technique (i.e., wetland assimilation, mangrove plantings) was not detailed in the master plan, an analysis was performed to determine the potential applicable area of the restoration technique.

Baseline Analysis

Table 2 presents baseline sequestration values derived from the database. This table contains baseline values for freshwater forested, freshwater emergent, brackish, and saltmarsh wetland types.

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	Mean	Min	Max	s.e.	n

Baseline Tree:	2.7	0.6	4.8	0.4	10	Conner & Day (1976); Conner et al. (1981); Day et al. (2006); Hunter et al. (2009); Megonigal et al. (1997); Shaffer et al. (2009)
Baseline Soil (Fresh - Forested):	2.0	.	.	.	1	Day et al. 2004
Baseline CH4 (Fresh - Forested):	8.3	0	28.2	4.2	6	Yu et al (2008)
Baseline N2O (Fresh - Forested):	17.1	-2.0	89.5	14.5	6	Yu et al (2008)
Baseline Soil (Fresh - Emergent):	3.2	0.9	4.6	0.3	8	DeLaune & Smith (1984); Feijtel et al. (1985); Hatton et al. (1982, 1983); Nyman et al. (2006); Rybczyk et al. (2002)
Baseline CH4 (Fresh - Emergent):	44.6	4.4	85.4	11.0	6	Crozier & DeLaune (1996); DeLaune & Smith (1984); DeLaune et al. (1983); Feijtel et al. (1985)
Baseline N2O (Fresh - Emergent):	0.1	-0.4	0.3	0.1	4	DeLaune et al. (1989); Smith et al. (1983a,b)
Baseline Soil (Brackish):	4.8	2.3	7.1	0.7	12	DeLaune & Smith (1984); Feijtel et al. (1985); Hatton et al. (1982, 1983); Nyman et al. (1995, 2006)
Baseline CH4 (Brackish):	60.4	1.5	136.6	17.1	9	Alford et al. (1997); Crozier & DeLaune (1996); DeLaune & Smith (1984); DeLaune et al (1983); Feijtel et al. (1985)
Baseline N2O (Brackish):	0.3	0.1	0.7	0.1	5	DeLaune et al. (1989); Smith & DeLaune (1983); Smith et al. (1983a)
Baseline Soil (Salt):	3.8	2.7	5.8	3.7	9	Feijtel et al. (1985); Hatton et al. (1983); Nyman et al. (2006); Perry & Mendelssohn (2009); Smith et al. (1982, 1983b)
Baseline CH4 (Salt):	6.8	0.4	34.1	5.5	6	Crozier & DeLaune (1996); DeLaune et al (1983); Feijtel et al. (1985); Smith et al. (1982)
Baseline N2O (Salt):	0.7	0	3.7	0.6	6	DeLaune et al. (1989); Smith & DeLaune (1983); Smith et al. (1982, 1983a)

Table 2: Baseline carbon sequestration values derived from the scientific literature (units in mtCO_2e/ac/yr). s.e.= standard error. Positive values denote carbon sequestration and negative values denote net GHG emissions.

Baseline with Prevented Wetland Loss

Unfortunately, many wetlands in Louisiana are deteriorating resulting in the re-release of large amounts of previously stored carbon. Many areas of coastal Louisiana face imminent wetland loss that can also be incorporated into the baseline scenario if the wetland loss can be abated through restoration. Wetland loss refers to vegetation death and conversion to open water. Currently, wetland carbon accounting includes the 'prevented loss' of future carbon sequestration capacity as a wetland area would decrease over time (Mack et al., 2012). However, providing wetland offset credits for the prevented re-release of carbon previously stored in soils may be essential to providing a strong business case for carbon investment into wetland restoration projects.

Many restoration techniques can prevent the conversion of land to open water thus preventing the re-release of previously stored carbon when the wetland deteriorates (Davidson and Janssens, 2006). When vegetation death occurs, organic carbon undergoes complex cycling, with fate dependent on specific type and source (Reddy and DeLaune, 2008); part of the soil organic carbon is oxidized resulting in GHG emissions and part is buried, either in situ or exported and buried elsewhere. The top 50 cm of the wetland soil horizon generally includes the living root zone, which is most geomorphically unstable, most susceptible to erosion, and can be oxidized when the vegetation dies. For example, Day et al. (1994) observed the presence of the chemoautotrophic bacterium (Beggiatoa sp.) in a dying salt marsh, and suggested that rapid decomposition of the roots by anaerobic sulfate-reducing bacteria led to collapse of the marsh substrate. In separate studies of the same marsh, DeLaune et al. (1994) and

Nyman et al. (1995) described the physical collapse of the marsh and oxidation of the peat root structure. On average, the top 50 cm of wetland soil contains 206 $mtCO_2e/ac$ (Table 3).

Literature Source	Wetland Type	Comment	Organic Matter (g/m2/yr)	Accretion (cm/yr)	Carbon in 50cm (Kg/m2)	C ($mtCO_2e/ac$)
Hatton et al. 1982	Fresh	Levee	477	1.06	11.3	166.9
Hatton et al. 1982	Fresh	Backmarsh	306	0.65	11.8	174.6
Nyman et al. 2006	Fresh	Stable	538	0.82	16.4	243.4
				Mean Fresh:	**13.1**	**194.4**
DeLaune & Pezeshki 2003	Brackish		406	0.85	11.9	177.2
DeLaune & Pezeshki 2003	Brackish		237	0.51	11.6	172.4
DeLaune & Pezeshki 2003	Brackish		302	0.6	12.6	186.7
Hatton et al. 1982	Brackish	Levee	797	1.35	14.8	219.0
Hatton et al. 1982	Brackish	Backmarsh	269	0.64	10.5	156.0
Hatton et al. 1982	Brackish	Levee	826	1.4	14.8	218.9
Hatton et al. 1982	Brackish	Backmarsh	348	0.59	14.8	218.9
Nyman et al. 2006	Brackish	Stable	604	0.88	17.2	254.6
Nyman et al. 2006	Brackish	Deteriating	542	0.96	14.1	209.5
				Mean Brackish:	**13.6**	**201.8**
Hatton et al. 1982	Salt	Backmarsh	675	1.35	12.5	185.5
Hatton et al. 1982	Salt	Backmarsh	435	0.75	14.5	215.2
Nyman et al. 2006	Salt	Stable	424	0.59	18.0	266.6
Nyman et al. 2006	Salt	Deteriating	618	0.98	15.8	234.0
Nyman et al. 1995	Salt	Burial	796	1.3	15.3	227.2
Nyman et al. 1995	Salt	Burial	434	0.85	12.8	189.5
				Mean Salt:	**14.8**	**219.6**
				Overall Mean:	**13.9**	**206.3**
					25% of overall mean:	**51.6**
					50% of overall mean:	**103.2**
					75% of overall mean:	**154.7**

Table 3: Carbon sequestrated in the first 50 cm of the wetland soil horizon of fresh, brackish and saltwater wetlands. Values derived from the scientific literature.

The potential exists for this carbon to be claimed as carbon offsets if restoration efforts are successful in preventing the loss of the wetland soil horizon. Research initiatives are currently underway to determine the proportion of the root zone that becomes oxidized as GHGs.[8] While this information is being developed, a conservative estimate of 25% (51.6 $mtCO_2e/ac$), 50% (103.2 $mtCO_2e/ac$), and 75% (154.7 $mtCO_2e/ac$) of the carbon contained in the root zone were used for the purpose of estimating potential wetland carbon offsets.

Prevented Wetland Loss Carbon Project Potential

Louisiana's Comprehensive Master Plan for a Sustainable Coast used predictive models to evaluate a 'future without action' over a 50-year timeframe (CWPRA, 2012). Ranges of high and low values for each environmental uncertainty (i.e., subsidence, sea level rise, rate of wetland loss) were chosen based on expert panel recommendations or by using best professional judgment, forming two scenarios described as 'moderate' and 'less optimistic'. To improve readability the authors of this report renamed the moderate scenario as the 'low loss rate' scenario, and the less optimistic scenario as the 'high loss rate' scenario. Under the low loss rate scenario, their analysis predicted 770 square miles (492,800

[8] ConocoPhillips and Tierra Resources are currently performing research on the fate and transport of carbon (prevented wetland loss) at saline, brackish, and fresh emergent sites.

acres) of wetland loss over the next 50 years, which increases to 1,750 square miles (1,120,000) of wetland loss under the high loss rate scenario (Figure 11).

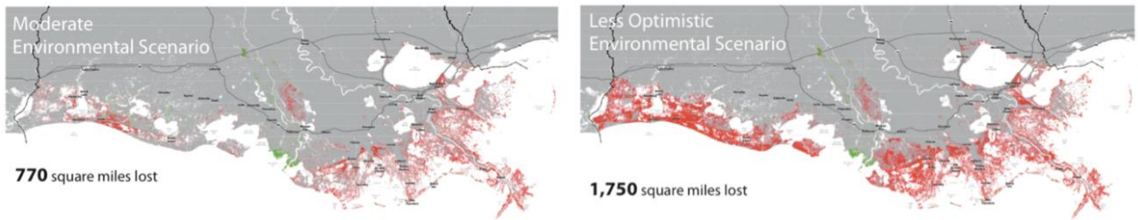

Figure 11: A comparison of estimated land change along the Louisiana coast at year 50 under moderate (low loss rate) and less optimistic (high loss rate) scenarios of future coastal conditions. Green indicates areas of natural new land created and red indicates land that is likely to be lost (CWPRA, 2012).

Louisiana's Comprehensive Master Plan for a Sustainable Coast evaluated river diversions and other restoration techniques to maximize land building over 50 years, using a 20-year river flow record of the Mississippi River. The results of the maximize land scenario indicated that approximately 4750 square miles (3,040,000 acres) in the low loss rate scenario and approximately 4250 square miles (2,720,000 acres) in the high loss rate scenario could be maintained (CWPRA, 2012; Figure 12).

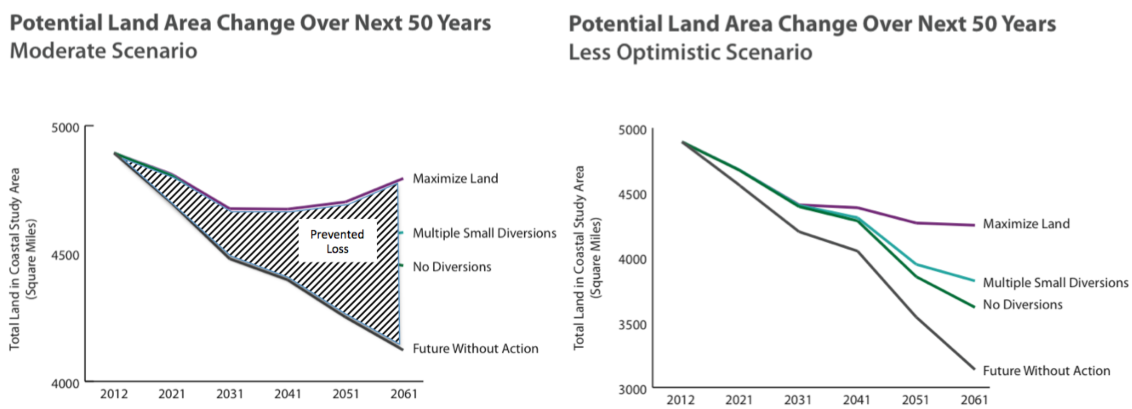

Figure 12: Comparison of land changes in the coastal study area using different restoration strategies under moderate (low loss rate) and less optimistic (high loss rate) scenarios of future coastal conditions. (modified: CWPRA, 2012).

Unfortunately, even with the maximize land building restoration techniques, some land loss will still occur. Subtracting the maximized land building scenario from the current wetland land area results in 150 square miles (96,000 acres) of land loss in the low loss rate scenario and 650 square miles (416,000 acres) of land loss in the high loss rate scenario. Subtracting the predicted wetland loss from the acres that will still be lost in the maximal land building scenario results in approximately 620 square miles (396,800 acres) in the low loss rate scenario and approximately 1100 square miles (704,000 acres) in the high loss rate scenario that would be prevented from converting to open water (Table 4). Assuming that 25-75% of the carbon in the top 50 cm of sediment could be prevented from releasing greenhouse gases would result in over 20,000,000-100,000,000 wetland carbon offsets over 50 years.

	Low Loss Rate Scenario	High Loss Rate Scenario
Predicted wetland loss with no action	492,800 acres	1,120,000 acres
Acres lost with maximal land building	96,000 acres	416,000 acres
Prevented wetland loss	396,800 acres	704,000 acres
Carbon impact 25%	20,474,880 mtCO_2e	36,326,400 mtCO_2e
Carbon impact 50%	40,949,760 mtCO_2e	72,652,800 mtCO_2e
Carbon impact 75%	61,384,960 mtCO_2e	108,908,800 mtCO_2e

Table 4: Estimated prevented wetland loss using values from CWPRA 2012.

Economic Flooding Damages

The additional risk of flooding can be calculated as coast wide expected annual damages, which are predicted to increase from $2.4 billion today to $7.7 billion by year 50 under the low loss rate scenario. If we experience the high loss rate scenario, the average annual flood damages could reach $23.4 billion by year 50 (CWPRA, 2012).

River Diversions & Hydrologic Restoration

A major focus of current wetland restoration strategies has been the reconnection of the Mississippi River with the delta using river diversions and siphons (Day et al., 2007, 2009; DeLaune et al., 2003, 2005; Lane et al., 2003, 2006; LDNR, 1998). Approximately 28.5% of the Mississippi River delta plain has been lost since 1956 (Barras et al., 2008). A major cause is believed to be due to flood control levees that prevent seasonal inputs of nutrients and sediments from the Mississippi River, which formed the delta over the past 6000-7000 years (Kesel, 1988, 1989; Mossa, 1996; Roberts, 1997). Other factors certainly exacerbate wetland loss, such as the proliferation of access canals and deep-well fluid withdrawal associated with the oil and gas industry (Turner et al., 1994; Morton et al., 2002; Chan & Zoback, 2007), intentional impoundment for waterfowl management (Boumans & Day, 1994), and herbivory by nutria (Evers et al., 1998). However, a major focus of current wetland restoration strategies has been the reconnection of the Mississippi River with the delta using river diversions and siphons (Day et al., 2007, 2009; DeLaune et al., 2003, 2005; Lane et al., 2003, 2006; LDNR, 1998), which are water control structures built into the Mississippi River levees that allow river water to pass through or over the levees into surrounding wetlands (Figure 13).

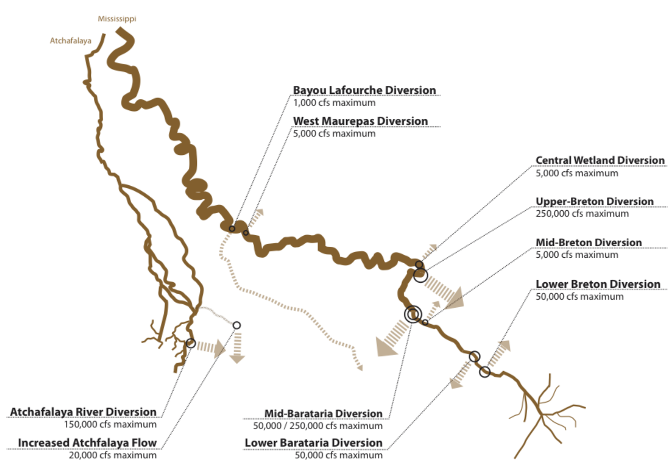

Figure 13: Schematic map of current and future river diversion projects (From CWPRA, 2012).

Wetlands in coastal Louisiana that receive river water have been shown to be more sustainable and to have lower land loss compared to wetlands without riverine inputs (Baumann et al., 1984; Barras et al., 2008; Day et al., 2000; Delaune & Pezeshki ,1988, 2003; Nyman et al., 1990, 1993). River diversions and siphons currently in operation (at maximum discharge) in Louisiana include Davis Pond (300 CMS), Caernarvon (225 CMS), Naomi Siphon (60 CMS), West Pointe a la Hache Siphon (60 CMS), and the Violet Siphon (14 CMS); and those in the planning stages include Bayou Lafourche (28 CMS) and Blind River (85 CMS). A total of 300,000 acres are currently receiving diverted river water, 200,000 acres are planned (i.e., lower Barataria Bay), and there is approximately 300,000 acres that have potential to be implemented that are currently not planned (CWPRA, 2012; Table 5).

	River Diversion	Hydrologic Management
Current	300,000	4,000
Post yr 2000	150,000	500
Forested	10,000	125
Emergent	140,000	375
Planned	200,000	16,000
Forested	50,000	4,000
Emergent	150,000	12,000
Potential	300,000	10,000
Forested	100,000	2,500
Emergent	200,000	7,500
TOTAL	800,000	30,000

Table 5: Current, planned, and potential areas (in acres) for river diversion and hydrologic management in coastal Louisiana.

Hydrologic restoration refers to projects that restore natural hydrologic patterns either by conveying freshwater to areas that have been cut off by manmade features, or by preventing the intrusion of saltwater into fresh areas through manmade channels and eroded wetlands. Such restoration includes the removal of spoil banks and other hydrological impediments, as well as the instillation of weirs, sills, locks and other water control structures. Sequestration rates for hydrologic restoration are the same as for river diversions, and were analyzed together due to the similar restoration mechanism of introducing freshwater and/or preventing saltwater intrusion (Table 6).

Diversions	Mean	Min	Max	s.e.	n	Refs
Baseline Tree:	2.7	0.6	4.8	0.4	10	Conner & Day (1976); Conner et al. (1981); Day et al. (2006); Hunter et al. (2009); Megonigal et al. (1997); Shaffer et al. (2009)
Baseline Soil (Fresh - Forested):	2.0	.	.	.	1	Day et al. 2004
Baseline CH_4 (Fresh - Forested):	8.3	0	28.2	4.2	6	Yu et al (2008)
Baseline N_2O (Fresh - Forested):	17.1	-2.0	89.5	14.5	6	Yu et al (2008)
Baseline Soil (Fresh - Emergent):	3.2	0.9	4.6	0.3	8	DeLaune & Smith (1984); Feijtel et al. (1985); Hatton et al. (1982, 1983); Nyman et al. (2006); Rybczyk et al. (2002)
Baseline CH_4 (Fresh - Emergent):	44.6	4.4	85.4	11.0	6	Crozier & DeLaune (1996); DeLaune & Smith (1984); DeLaune et al. (1983); Feijtel et al. (1985)
Baseline N_2O (Fresh - Emergent):	0.1	-0.4	0.3	0.1	4	DeLaune et al. (1989); Smith et al. (1983a,b)
Project Tree:	4.5	2.6	6.4	1.9	2	Conner et al. (1981); Shaffer et al. (2009)
Project Soil:	4.0	2.0	8.1	0.8	7	DeLaune et al. (2003); DeLaune & Pezeshki (2003
Project CH_4:	13.5	3.7	30.2	3.9	6	Altor & Mitsch (2006); Nahliik & Mitsch (2011)
Project N_20*:	2.3	.	.	.	1	Kadlec & Wallace (2009)

Table 6: Carbon sequestration values for river diversion and hydrological restoration scenarios derived from the scientific literature (units in $mtCO_2e$/ac/yr). s.e.= standard error.

* these values were taken from the 'Project N_20' row in Table 2 since appropriate literature values were not available.

Louisiana's Comprehensive Master Plan for a Sustainable Coast (CWPRA, 2012) indicates that for a $3.8 billion investment in river diversion projects, 300 square miles (192,000 acres) of new wetlands would be created ($19,800/acre; Table 7). In regard to hydrologic management, a total of 4,000 acres is currently under such management, 16,000 acres are planned, and there are approximately 10,000 acres more potential (Table 5). Louisiana's Comprehensive Master Plan for a Sustainable Coast (CWPRA, 2012) indicates that for a $0.7 billion investment in hydro-management projects, 25 square miles (16,000 acres) of new wetlands would be created ($43,750/acre).

	cost	area (acre)	$/acre	current (acre)	planned (acre)	potential (acre)
Diversions	$3.8 billion	192,000	19,800	300,000	200,000	300,000
Hydrologic Restoration	0.7 billion	16,000	43,750	4,000	16,000	10,000
Wetland Assimilation	.	.	.	17,000	13,500	30,000
Beneficial Dredging	20 billion	128,000	156,250	.	.	.

Table 7: Summary table of cost/benefit analysis from CWPRA (2012), as well as estimations of current, planned and potential areas affected by projects.

Marsh Creation

This project type involves the creation of wetlands in open water areas such as bays, ponds, and canals using sediment dredging and placement and can also include the beneficial use of dredged material on degraded wetlands. Such restoration includes primarily marsh creation projects, but dredged material can also be a component of bank stabilization, barrier island/headland restoration, ridge restoration, and shoreline protection projects (see CWPRA, 2012 for definitions). Most projects involve pipeline conveyance of sediment where the material is placed in a deteriorated wetland or open water containment area at specific elevations for desired marsh plants to grow and colonize to form new marsh. Projects that use dredged material generally build most of their land as soon as the project is constructed, and then over time, that land erodes and subsides which can present a permanence issue for a commercial wetland carbon offset project with a lifetime of 40 to 100 years. Marsh creation projects in open water would not need to deduct a baseline. However, marsh creation projects will generally be less productive than other restoration techniques such as river diversions, and therefore overall offset potential will likely be slightly less than other restoration techniques. Furthermore, the GHG emissions from the combustion of fossil fuels (diesel fuel) during the dredge operation may result in a significant deduction from the carbon offset yield.

Some marsh creation projects involve the beneficial use of sediment that is dredged for maintenance of navigation channels and access canals. A great deal of sediment is dredged in south Louisiana, and much of it could be used to rebuild marshes. However, this sediment is usually pumped to upland disposal sites or dumped in the Gulf of Mexico. Beneficially using this dredged material to rebuild wetlands is a strategy that has been widely used and found successful. USACE is the nation's largest dredger, dredging and disposing of about 200 million cubic yards of sediment annually in constructing, operating, or maintaining civil works projects (http://el.erdc.usace.army.mil/dots/budm/budm.cfm). The USACE uses the concept of regional sediment management to coordinate dredging activities in coastal systems (e.g., navigation maintenance, beach nourishment, and habitat restoration) to foster balanced, natural system processes, and to reduce project costs. In these situations that beneficially use dredge, portions of the GHG emissions due to diesel combustion could be considered part of the baseline scenario. However, the permanence of these wetlands remains a concern.

Further research is needed to determine carbon sequestration rates from these types of projects. Insufficient data was available to model the potential carbon offset yield. Marsh creation was eliminated from the study based upon a lack of empirical data to model carbon yields, concerns over the permanence of the restoration technique, and the need to deduct significant fossil fuel emissions that occur during the pipeline conveyance of sediment.

Louisiana's Comprehensive Master Plan for a Sustainable Coast (CWPRA, 2012) indicates that for a $20 billion investment in marsh creation projects, 200 square miles (128,000 acres) of new wetlands would be created ($156,250/acre, Table 7). The major drawback of using dredged material for wetland creation is the high cost per acre compared to river diversions ($19,800/acre) and hydrological management ($43,750/acre), and as energy prices become more expensive over time, the cost of this management option will increase.

Wetland Assimilation

The introduction of treated municipal effluent into the highly perturbed wetlands of Louisiana is a major step towards their ecological restoration. Both natural and constructed wetlands have been shown to effectively treat wastewater to tertiary levels (Kadlec and Knight, 1996). The benefits of treating municipal effluent using wetlands rather than the business-as-usual practice of simply discharging into surrounding rivers and streams are multiple. These include improved water quality (Day et al., 2004), financial and energy savings (Ko et al., 2004), increased primary production (Hesse et al., 1998; Day et al., 2004; Brantley et al., 2008; Lundberg et al., 2011), and enhanced vertical accretion (Rybczyk et al., 2002; Brantley et al., 2008; Hunter et al., 2009). Increased productivity and accretion result in enhanced aboveground biomass and root production, leading to enhanced organic soil deposition and carbon sequestration (Day et al., 2004). Geological subsidence of this organic soil results in significant permanent carbon burial. Table 8 presents carbon sequestration values for wetland assimilation derived from the database. This table contains baseline values for freshwater forested and freshwater emergent wetland types.

WLWWT	Mean	Min	Max	s.e.	n	Refs
Baseline Tree:	2.7	0.6	4.8	0.4	10	Conner & Day (1976); Conner et al. (1981); Day et al. (2006); Hunter et al. (2009); Megonigal et al. (1997); Shaffer et al. (2009)
Baseline Soil (Fresh - Forested):	2.0	.	.	.	1	Day et al. 2004
Baseline CH_4 (Fresh - Forested):	8.3	0	28.2	4.2	6	Yu et al (2008)
Baseline N_2O (Fresh - Forested):	17.1	-2.0	89.5	14.5	6	Yu et al (2008)
Baseline Soil (Fresh - Emergent):	3.2	0.9	4.6	0.3	8	DeLaune & Smith (1984); Feijtel et al. (1985); Hatton et al. (1982, 1983); Nyman et al. (2006); Rybczyk et al. (2002)
Baseline CH_4 (Fresh - Emergent):	44.6	4.4	85.4	11.0	6	Crozier & DeLaune (1996); DeLaune & Smith (1984); DeLaune et al. (1983); Feijtel et al. (1985)
Baseline N_2O (Fresh - Emergent):	0.1	-0.4	0.3	0.1	4	DeLaune et al. (1989); Smith et al. (1983a,b)
Project Tree:	6.2	2.7	10.6	0.9	7	Day et al. (2004, 2006); Hunter et al. (2009)
Project Soil (Forested):	5.5	.	.	.	1	Day et al. 2004
Project Soil (Emergent):	6.3	.	.	.	1	Rybczyk et al. (2002)

Table 8: Carbon sequestration values for the wetland assimilation scenario derived from the scientific literature (units in $mtCO_2e/ac/yr$). s.e.= standard error.

The following wetland assimilation sites (and quantity of effluent assimilated) are currently functioning in Louisiana: Breaux Bridge (3800 m^3/d), Amelia (3000 m^3/d), Mandeville (8000 m^3/d), Thibodaux (12,000 m^3/d), Luling (6000 m^3/d), Broussard (5700 m^3/d) and Hammond (30,000 m^3/d), as well as several others. A total of 17,000 acres are currently in wetland assimilation, 13,500 acres are planned (i.e., central wetland unit), and there is approximately 30,000 acres more potential (Table 7).

Mangrove Planting

Mangrove plantings show potential as a significant long-term restoration technique throughout coastal Louisiana to reduce wetland loss and prevent further erosion of shorelines due to relative sea-level rise. Black mangroves (*Avicennia germinans*) were historically restricted to the southernmost barrier islands and beaches by winter freeze events (Penfound & Hathaway, 1938), however, recent freeze-free winters have facilitated a noticeable expansion of *Avicennia* northward into *Spartina sp.* marshes (Giri et al., 2011; Perry & Mendelssohn, 2009). This northward expansion is likely to continue if increases in temperature occur as predicted by climate change models (IPCC, 2007). The primary reason that mangroves are not established along a greater area of the coast is principally due to 'propagule limitation' from the limited natural availability of mangrove propagules due to hydrologic restrictions and blockages associated with the landward wetland complex that prevent waterborne transport of mangrove propagules (Lewis, 2005, 2009; Friess et al., 2012). Because of this, it is expected that mangrove seedlings will grow robustly once introduced into *Spartina sp*. dominated areas.

Baseline values for the mangrove planting scenario were derived from saltwater soils (Table 9). The project involves the planting of mangroves, therefore both tree and soil carbon sequestration rates were applied, though tree sequestration rates were derived from forested baseline rates since appropriate literature values were not available (Table 2). There are currently 15,000 acres of mangroves along the most southern edge of coastal Louisiana (Giri et al., 2011), but with climate change, there is a potential of 500,000 acres in the near future, especially with planting.

Mangrove	Mean	Min	Max	s.e.	n	Refs
Baseline Soil (Salt):	3.8	2.7	5.8	3.7	9	Feijtel et al. (1985); Hatton et al. (1983); Nyman et al. (2006); Perry & Mendelssohn (2009); Smith et al. (1982, 1983b)
Project Tree*:	2.7	0.6	4.8	0.4	10	Conner & Day (1976); Conner et al. (1981); Day et al. (2006); Hunter et al. (2009); Megonigal et al. (1997); Shaffer et al. (2009)
Project Soil:	3.1	3	3.2	0.1	2	Osl & et al. (2012); Perry & Mendelssohn (2009)
Total Cseq:	**2.0**	**0.9**	**2.2**	.	.	

Table 9: Carbon sequestration values for the mangrove planting scenario derived from the scientific literature (units in $mtCO_2e/ac/yr$). s.e.= standard error.

* these values were taken from the 'Baseline Tree' row in Table 2 since appropriate literature values were not available.

Carbon Modeling Discussion

The net difference between the baseline scenario and the restoration activity can be transacted as wetland carbon offsets. Restored wetlands demonstrate an enhanced carbon sequestration rate through enhanced plant growth and accumulation of organic matter in soils that can be transacted as wetland carbon offsets (Table 10).

The literature review suggests that GHG emissions exceed carbon sequestration values in wetland systems. The literature review also suggests that for many wetland restoration projects, the baseline scenarios have higher emissions of greenhouse gases than the project. While this is good in terms of carbon sequestration, it should not be viewed as a measureable phenomenon, but rather as an expression of the high inherent variability of GHG emissions by wetlands. There were generally many more baseline measurements compared to project measurements in the dataset used for this analysis, and given the high variability of GHG emissions, more chance for the baseline average to include some very high emission rates, thus raising the baseline mean. High natural GHG emissions from wetlands coupled with very high spatial and temporal variability, regardless of anthropogenic effects, makes the inclusion of GHG emissions in carbon sequestration calculations questionable.

	Project Net C Uptake	Project GHG Emissions	Baseline Net C uptake	Baseline GHG Emissions	Net Offset w/GHGs	Net Offset no GHGs
Diversion - forested	8.5	15.8	4.7	25.4	13.4	3.8
Diversion - emergent	4.0	15.8	3.2	44.7	29.7	0.8
Hydrological mgmt- forested	8.5	15.8	4.7	25.4	13.4	3.8
Hydrological mgmt- emergent	4.0	15.8	3.2	44.7	29.7	0.8
Marsh creation			data unavailable			
Wetland Assimilation - forested	11.7	18.1	4.7	25.4	14.3	7.0
Wetland assimilation - emergent	6.3	18.1	3.2	44.7	29.7	3.1
Mangrove planting	5.8	n/a	3.8	n/a	2.0	2.0

Table 10: Preliminary estimate of offset potential (units in $mtCO_2e/ac/yr$).

For projects that introduce water with high nutrient concentrations, such as assimilation systems, the inclusion of GHG emissions may not be necessary since the highly nitrified water would have to be discharged someplace else (i.e., river, bayou or canal) where the same GHGs emissions would likely occur. GHG emissions of CH_4 are primarily an issue for fresh and brackish wetlands, as there is a strong inverse relationship between CH_4 emissions and salinity. At salinities above about 5 PSU, CH_4 emissions are very low because the presence of SO_4 in seawater inhibits CH_4 release. Nitrate (NO_3) behaves similarly as SO_4 by inhibiting CH_4 emissions. Thus, projects that introduce nitrate into wetlands, such as wetland assimilation and river diversions, are also likely to have reduced CH_4 emissions compared to baseline.

The validity of including GHGs in carbon sequestration accounting is uncertain due to very high spatial and temporal variability. More research is needed to address GHG emissions from wetlands. Researchers performing this study decided to conservatively omit GHG emissions from the final carbon offset financial modeling due to the belief that emissions data presented in Table 10 may not be a measureable phenomenon, but rather an expression of the high inherent variability of GHG emissions by wetlands. Carbon sequestration values presented in Table 11 were conservatively used as a basis for financial modeling in this study (Appendix D).

	Project C Seq.	Baseline C Seq.	Net Offset
Hydro / Diversion - forested	8.5	4.7	3.8
Hydro / Diversion - emergent	4.0	3.2	0.8
Marsh creation		data unavailable	
Wetland Assimilation - forested	11.7	4.7	7.0
Wetland assimilation - emergent	6.3	3.2	3.1
Mangrove planting	5.8	3.8	2.0

Table 11: Preliminary estimate of offset potential used for financial modeling in this study ($mtCO_2e/ac/yr$).

The overall question is not whether carbon sequestration projects emit CH_4 or N_20 per se, but whether the rate of these emissions is higher than what would occur given the baseline scenario. The high inherent variability of GHG emissions by wetlands may make the monitoring of greenhouse gases to reach confidence intervals required by emissions trading markets cost-prohibitive. Of the restoration techniques, forested river diversions, forested hydrologic management projects, and forested wetland assimilation projects have the highest wetland offset yield per acre for carbon offset development. Clearly, the land area suitable for a given restoration technique also impacts wetland carbon project commercial potential. Appendix D includes the acreage potential in which projects may be implemented. In general, exclusion of GHG emissions has less impact on the offset yield for forested wetlands compared to emergent wetlands. Providing a path for quantifying wetland offset credits for prevented wetland loss in the Mississippi River Delta will be essential to provide a strong business case for carbon investment into wetland restoration projects.

Appendix D: Wetland Carbon Financial Implications

Carbon Standard Assumptions

The potential for a wetland restoration project to benefit from the carbon market depends not only upon the potential of the project to increase sequestered carbon, but also upon the rules of the carbon standard applied, the costs of monitoring, documenting, and selling verified carbon offsets to market, and on the price of carbon offsets achieved (Appendix A). At this time, there are only two approved methods to transact wetland carbon offsets through voluntary markets (Mack et al., 2012; CH2MHILL and EcoPartners, 2014). However, California's Air Resources Board (ARB) may adopt wetland restoration projects into their compliance market in the future (Appendix B). In this preliminary assessment, the assumption was made that an approved protocol under ARB rules would yield the same volume of offsets—that there would be no additional buffer withheld or any additional deductions because of different rules for land eligibility or carbon accounting from the ACR methodology "Restoration of Degraded Deltaic Wetlands of the Mississippi Delta" (Appendix C). However, it is important to note that standards and methodologies can differ, impacting marketable volumes of offsets such as:

- Methods of carbon accounting
- Project crediting period
- Methods of establishing risks and additionalility
- Carbon pools that are included or excluded
- Project boundaries
- Eligible project start dates
- Eligibility rules

Offset Volumes

The volume of offsets that can be counted and qualified under a standard depend on the difference between the carbon sequestration rate during an approved baseline, which represents "business-as-usual" practices and the rate that results from the restoration activity. However, carbon market standards require that a percentage of carbon offsets from each project are not sold on the carbon market and, instead, kept in reserve to guard against risk in a buffer pool. The required buffer is based on assessed risk of reversal of carbon sequestration by each project, and may decrease the volume of offsets available for sale by 10 percent (the lowest buffer requirement under ACR rules) to more than 50 percent. In this study, a buffer of 20 percent was deducted from restoration offset yield estimates modeled from the scientific literature in Appendix C.

The carbon offset yields, refined to include this buffer deduction, were then applied to the amount of corresponding area that can be restored for the various restoration techniques as determined by Louisiana's Comprehensive Master Plan for a Sustainable Coast (CWPRA, 2012). Restoration techniques that were not detailed in the Master Plan (i.e., wetland assimilation, mangrove plantings) were analyzed separately to determine the potential applicable area of the restoration technique. Restoration acreage estimates were categorized into current, planned, and potential restoration areas. Because carbon market rules exclude many projects with early start dates from claiming offsets, offset estimate projections only include post-2000 project areas (Table 12).

	River Diversion		Hydrologic restoration		Wetland assimilation		Mangrove Planting	
	Acres	Net annual offset potential ($mtCO_2e$)	Acres	Net annual offset potential ($mtCO_2e$)	Acres	Net annual offset potential ($mtCO_2e$)	Acres	Net annual offset potential ($mtCO_2e$)
Current	300,000		4,000		17,000		15,000	24,000
Post yr 2000	150,000		500		12,220		n/a	
Forested	10,000	30,400	125	380	2,720	15,232		
Emergent	140,000	89,600	375	240	9,500	23,560		
Current total		120,000		620		38,792		
Planned	200,000		16,000		13,500			
Forested	50,000	152,000	4,000	12,160	2,700	15,120		
Emergent	150,000	96,000	12,000	7,680	10,800	26,784		
Planned total		248,000		19,840		41,904		
Potential	300,000		10,000		30,000		500,000	800,000
Forested	100,000	304,000	2,500	7,600	15,000	84,000		
Emergent	200,000	128,000	7,500	4,800	15,000	37,200		
Potential total		432,000		12,400		121,200	500,000	
TOTAL	**800,000**	**800,000**	**30,000**	**32,860**	**60,500**	**201,896**	**500,000**	**800,000**

Table 12: Net annual offset potential in Louisiana by wetland restoration type including a 20% buffer deduction.

The financial implications of incorporating prevented wetland loss in carbon accounting methodologies were also determined. Louisiana's Comprehensive Master Plan for a Sustainable Coast evaluated river diversions and other restoration techniques to maximize land building over 50 years. The results indicate that approximately 620 square miles (396,800 acres) in the low loss rate scenario and approximately 1100 square miles (704,000 acres) in the high loss rate scenario would be prevented from converting to open water (Appendix C). Assuming that 25-75% of the carbon in the top 50 cm of sediment would be prevented from releasing greenhouse gases results in over 20,000,000-100,000,000 wetland carbon offsets over 50 years before buffer deductions. For the purposes of this study an assumption was made that half of the carbon contained in the top 50 cm of sediment can be prevented from being released as greenhouse gases and that these offsets would be additional to those estimated above. A 20% buffer deduction was then subtracted from the prevented loss offset yields.

Project Start Date, Length, and Crediting Period

Carbon standards require a minimum project length and define crediting periods for forestry and similar land use carbon projects. The project length is an important consideration for project developers and landowners who must commit to a restoration activity and to monitoring and reporting throughout the full project life, or incur penalties if they withdraw. For ACR, the minimum project life for a wetland restoration carbon project is 40 years from the project start date. For the California compliance market, the minimum project length is 100 years after the issuance of the last offset. Therefore, a project that generated offsets for 40 years would require reporting and monitoring for 140 years. Crediting periods are also an important consideration in carbon markets since they provide the project developer with greater certainty of the length of time for which offsets can be claimed against an approved baseline, even if carbon market rules change. The ACR requires that wetland restoration projects utilize a 40-year crediting period and 40-year project life. In contrast, the California ARB requires that forest carbon projects have a 25-year crediting period and the project must continue monitoring and reporting offset project data for 100 years after offset issuance. In this preliminary study, projects were all assumed to have a 50 year length to correspond to the timeframe of Louisiana's Comprehensive Master Plan for a Sustainable Coast. The volume of offsets generated per acre was also assumed to be the same each year for the full project life for each restoration type.

Carbon Project Costs

Carbon project development can have significant costs to collect, analyze, and document monitoring data as well as for documentation, registration, verification, and carbon sale. Costs of developing and reporting on a carbon project can be substantial, often in excess of $200,000 in initial development costs before offsets can be sold. Furthermore, carbon projects require a long-term commitment to the management change and to reporting, meaning that long-term costs are also an important consideration for project developers and landowners in assessing project feasibility and viability.

While there are many commonalities across standards, rules on eligible project start dates, the permissible length of time between project start and first verification, required frequency of verification, offset price, and other differences can impact the number of offsets a project will be able to verify and sell, and ultimately, whether the project will be financially viable. Lessons learned from pilot projects, and ease of aggregating large wetland restoration areas to achieve economies of scale has substantial potential to reduce the burden of these carbon project costs.

Carbon Prices

Drivers of price, demand, and buyer motivation differ significantly between compliance and voluntary markets as well as from project to project. Ecosystem Marketplace and Bloomberg New Energy Finance noted that in the voluntary carbon market there is often a premium for quality, co-benefits, and charismatic value, for example, when a forest has Forest Stewardship Council certification, or a project achieves Climate, Community, and Biodiversity Alliance certification (Peters-Stanley et al., 2013). Voluntary offset projects can range from less than $1 per offset to more than $8 per offset depending on the charisma of the voluntary offset projects. Forest Carbon offset prices in 2012 in voluntary markets averaged $8.40 for ACR, $8.90 for Climate Action Reserve offsets, and $7.50 for Verified Carbon Standard offsets. California compliance offset price predictions have ranged from $7.50 to $10 for the first compliance period ending in 2014 to $38 to $51 per offset by the end of the third compliance period. Predictions vary greatly, and recent trends have led some to predict a slower increase in compliance market offset price.[9,10]

In this analysis, ranges of possible price scenarios were evaluated to account for conservative low- and high-end ranges of expected prices in both compliance and voluntary carbon markets. The low-price scenario, of $4.40 per offset (based on average price reported historically for ACR offsets), was used to represent when offsets are not eligible for compliance market and have low charismatic value perceived by buyers. The high price scenario, of $10.80 per offset, was used as a conservative estimate of compliance offset prices in California or a somewhat less conservative estimate of a high-quality charismatic voluntary carbon offset.

It should be noted that allowances in the California are supported by an escalating price floor, rising at 5% annually, adjusted for inflation. Offsets in the California system do not have a floor price and are expected to trade at a discount relative to allowances because of a limit on the offsets that can be used by each regulated entity (8% of their annual compliance obligation) and the added risk associated with offsets. This analysis conservatively assumed that offsets would sell for a 30% discount from the allowance price floor averaged from 2016 (the earliest date envisioned as feasible for inclusion of wetland restoration in the compliance market) to 2020, the time period for which this floor is currently established and defined.

Wetland Carbon Financial Implications

Potential revenue from wetland carbon offsets, if all potential restoration projects were undertaken, range from $8.1 million per year under the low price scenario to over $19.8 million per year if the higher offset price is achieved. These values include the 20 percent buffer contribution. Acreage predictions according to the Louisiana Comprehensive Master Plan are for 50 years. Assuming that the crediting period for the carbon projects could be extended, and carbon offset yields are steady over the 50 year period, potential offset revenues could total about $400 million under the low price scenario to almost $1 billion if the higher offset price is achieved (Figure 14). These financial values do not deduct the costs of restoration or carbon commercialization costs, which can be considerable, but show that wetland restoration has substantial potential to generate important revenue to support restoration.

[9]There is a lot of uncertainty in the California market post 2020, making estimates of offset price beyond 2020 quite conjectural.

[10] https://pointcarbon.com/research/promo /research/1.2200807?&ref=searchlist.

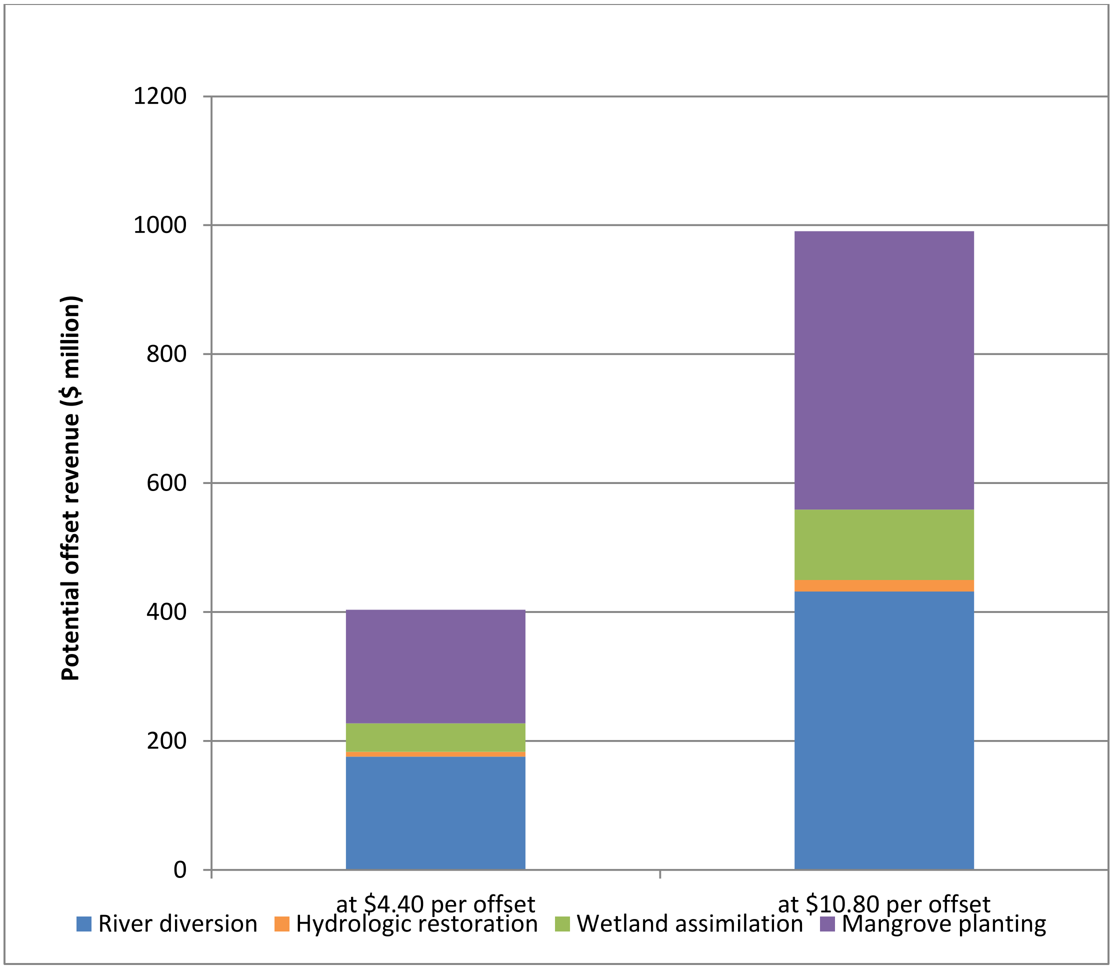

Figure 14: Projected revenue potential of wetland carbon offsets in Louisiana due to wetland restoration including a 20% buffer contribution.

Including prevented wetland loss in carbon monitoring and accounting may provide stronger financial incentives to develop wetland offset projects. Currently, the percentage of carbon that is released as GHGs during wetland loss is unknown. The financial proceeds from projected potential offsets from prevented wetland loss according to what is perceived as possible in the Louisiana Master Plan ranges from $72 million (25% of carbon released as GHGs, low loss rate, low price) to almost $1 billion (75% of carbon released as GHGs, high loss rate, higher price). For the purposes of this study an assumption was made that half of the carbon contained in the top 50 cm of sediment can be prevented from being released as greenhouse gases and that these offsets would be additional to those estimated above. If these prevented emissions could qualify as offsets, they could produce an additional 32.8 million offsets valued at over $140 million (low loss rate, low price) to over 58.1 million offsets valued at nearly $630 million (high loss rate, higher price) over a 50 year time period (Figure 15). The large offset potential from prevented wetland loss demonstrates the importance of creating a clear mechanism for quantifying and monetizing the carbon benefit of prevented loss. Including prevented wetland loss in carbon accounting will significantly increase the wetland carbon offset yields thus increasing the rational for private investment in wetland restoration projects.

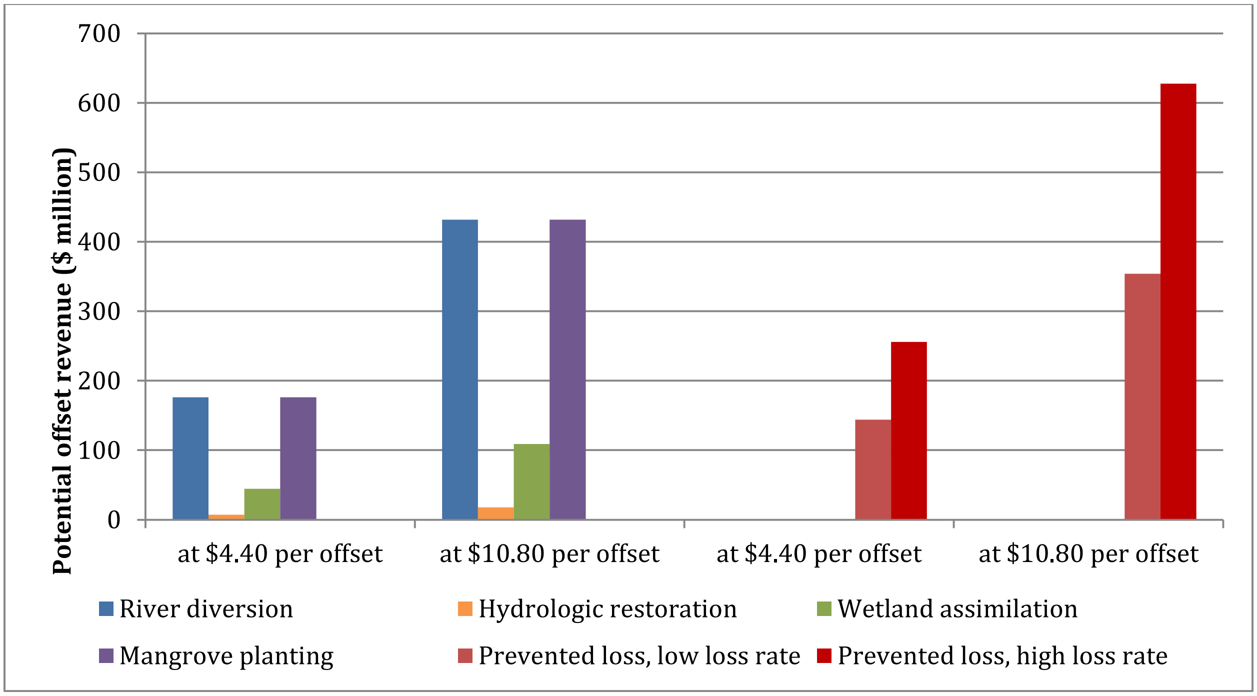

Figure 15: Projected revenue potential of wetland carbon offsets in Louisiana due to wetland restoration and prevented wetland loss including a 20% buffer.

In summary, there are many factors that may influence the ultimate amount of funding that carbon finance will contribute to wetland restoration in the Mississippi River Delta. Major factors include the price of the carbon offset, whether prevented wetland loss can be included in carbon accounting methodologies, and finally the amount of wetlands that can be successfully restored for the project life. Eligibility rules for inclusion of projects in carbon market participation, including issues of start date, easement type, standardized emissions factors, use of federal funding in project implementation, and required buffer deductions will also be important. Wetland restoration techniques identified in this study could potentially generate $400 million to almost $1 billion in offset revenue depending on the dollar value of the carbon offset. Including prevented wetland loss in carbon accounting may provide an additional $140 to almost $630 million depending on the dollar value of the carbon offset, and rates of wetland loss, subsidence, and sea level rise. Considering the various factors impacting carbon offset prices and yields, carbon finance has the potential to bring a total of $540 million to almost $1.6 billion to assist with wetland restoration in the coastal areas of the Mississippi River Delta (Figure 16).

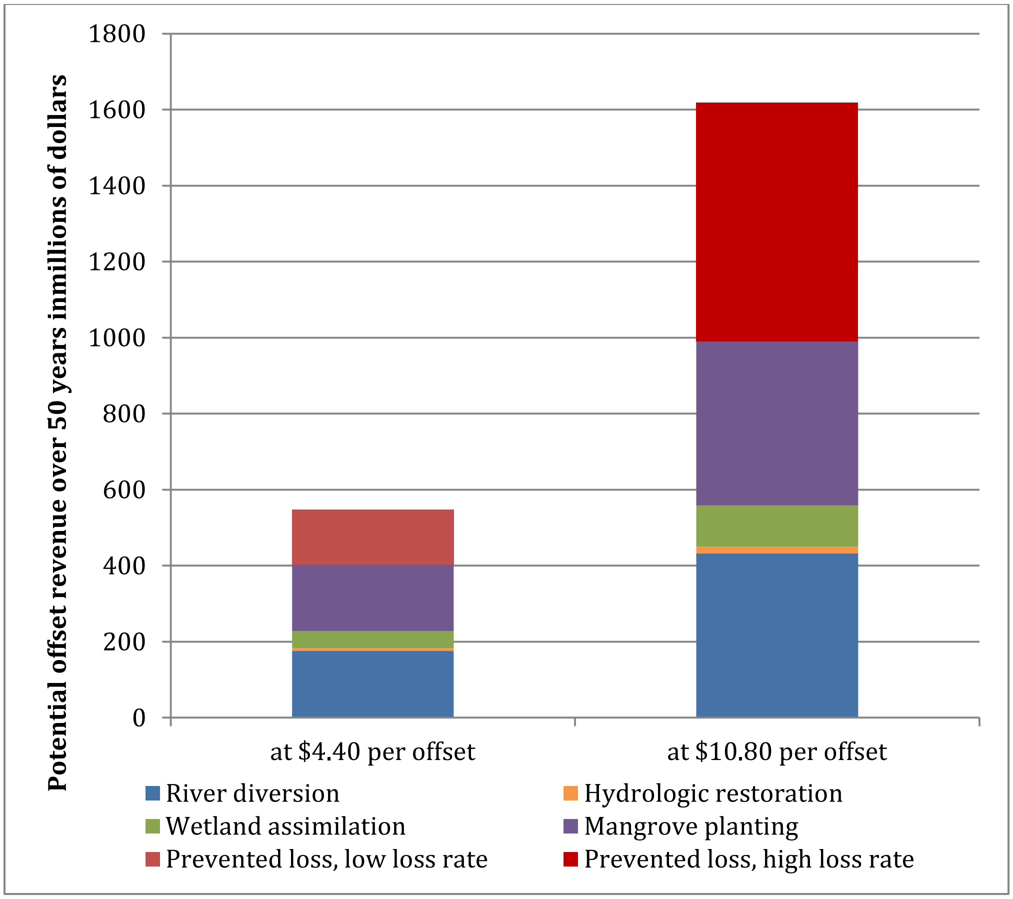

Figure 16: Total projected revenue potential of wetland carbon offsets in Louisiana due to wetland restoration and prevented wetland loss.

Carbon markets have the potential to provide a revenue stream to support restoration, but project development costs as well as the long-term commitments to project monitoring and reporting are important factors to consider when deciding if a project will be financially viable. Carbon projects require long-term commitment to the restoration activity and to reporting. Therefore, long-term costs are an important consideration for project developers and landowners that are assessing project feasibility and viability. While there are many commonalities across the multiple standards, rules on eligible project start dates, the permissible length of time between project start and first verification, the required frequency of verification, offset prices, and other differences can impact the number of offsets a project will be able to verify and sell. The costs of carbon market participation across the project life, and ultimately, whether the project will be financially viable contributes to the final determination. In general, in developing a carbon project, larger projects are more likely to be viable, since many of the project costs are relatively fixed. However, smaller projects can potentially be aggregated to achieve an economy of scale.

In most cases the costs of restoration will exceed potential carbon revenue streams. Capital intensive restoration projects will likely need to leverage carbon finance with traditional state and federal restoration programs. This may present challenges where state and federal programs are not allowed to be used in a way that results in profits for privately held entities. However, carbon finance may prove to be ideal for paying for parish or state cost-shares where it can be demonstrated that carbon funds were used directly towards project costs or long-term monitoring and maintenance, (which is usually not budgeted into state and federal programs). Considering that 80% of wetlands in Louisiana are privately owned the remaining challenge will be negotiating win-win agreements with government agencies and private landowners that entice landowners to participate in programs instead of causing further conflicts between private landowners and governmental entities. In some instances, restoration projects may be able to be fully funded by carbon revenues and implemented by private landowners thus expediting coastal restoration. However, even in these instances it is likely that the projects will need to be aggregated.

Appendix E: Study Assumptions

Carbon Modeling Assumptions

Tree and soil carbon pools were conservatively selected to represent the amount of carbon being sequestered.

GHG emissions were conservatively omitted from the final carbon accounting. The literature review confirmed that wetland restoration projects have no measurable net increase in GHG emissions beyond what occurred under the baseline scenario. In most cases including GHG emissions resulted in a higher offset yield. However, GHG emissions were conservatively omitted from the final carbon accounting as this may not be a measurable phenomenon.

The sequestration rates for river diversions and hydrologic restoration were analyzed together as both restoration techniques involve the introduction of freshwater or the prevention of saltwater intrusion.

Based on values derived from the scientific literature, on average, the top 50 cm of wetland soil contains 206 mtCO_2e/ac. The prevented wetland loss carbon modeling assumed that half of the carbon contained in the top 50 cm of the wetland soil horizon can be prevented from being released as GHGs and that these offsets would be additional to restoration offsets.

In this study projects were all assumed to have a 50-year length to correspond with predicted acreage in Louisiana's Comprehensive Master Plan for a Sustainable Coast. The volume of offsets generated per acre was also assumed to be the same each year for the full 50-year project period. It is important to note that carbon project life and crediting periods differ from this 50-year timeframe. The ACR requires that wetland restoration projects utilize a 40-year crediting period and 40-year project life.

In the Louisiana's Comprehensive Master Plan for a Sustainable Coast high and low values for each environmental uncertainty were chosen, forming two scenarios described as 'moderate' and 'less optimistic'. To improve readability the authors of this study renamed the moderate scenario as the 'low loss rate' scenario, and the less optimistic scenario as the 'high loss rate' scenario.

Financial Modeling Assumptions

The assumption was made that an approved protocol under ARB rules would yield the same volume of offsets as the ACR "Restoration of Degraded Deltaic Wetlands of the Mississippi Delta" methodology (Mack et al., 2012). It is assumed that there would no additional deductions withheld due to different rules for land eligibility or carbon accounting.

Carbon sequestration values presented in Table 13 were conservatively used as a basis for financial modeling in this study.

	Project C Seq.	Baseline C Seq.	Net Offset
Hydro / Diversion - forested	8.5	4.7	3.8
Hydro / Diversion - emergent	4.0	3.2	0.8
Marsh creation	data unavailable		
Wetland Assimilation - forested	11.7	4.7	7.0
Wetland assimilation - emergent	6.3	3.2	3.1
Mangrove planting	5.8	3.8	2.0

Table 13: Preliminary estimate of offset yield used for financial modeling in this study (mtCO_2e/ac/yr).

Many carbon markets exclude projects with early start dates from claiming offsets. The offset estimates included in the financial modeling only include restoration projects that are post-2000.

A buffer of 20 percent was deducted from the preliminary carbon modeling offset yield estimates. The buffer is based on assessed risk of reversal of carbon sequestration, and may decrease the volume of offsets available for sale by 10 percent (the lowest buffer requirement under ACR rules) to more than 50 percent. It should be noted that the 20 percent buffer is a simplifying assumption, and actual buffer deduction requirements will vary from project to project as risk is assessed.

The low-price scenario, of $4.40 per offset (based on average price reported historically for ACR offsets), was used to represent when offsets are not eligible for compliance market and have low charismatic value perceived by buyers. The high price scenario, of $10.80 per offset, was used as a conservative estimate of compliance offset prices in California or a somewhat less conservative estimate of a high-quality charismatic voluntary carbon offset.

It should be noted that allowances in the California are supported by an escalating price floor, rising at 5% annually, adjusted for inflation. Offsets in the California system do not have a floor price and are expected to trade at a discount relative to allowances because of a limit on the offsets that can be used by each regulated entity (8% of their annual compliance obligation) and the added risk associated with offsets. This analysis conservatively assumed that offsets would sell for a 30% discount from the allowance price floor averaged from 2016 (the earliest date envisioned as feasible for inclusion of wetland restoration in the compliance market) to 2020, the time period for which this floor is currently established and defined.

Financial estimates do not deduct the costs of restoration or carbon commercialization costs.