A review of subsidence in the vicinity of The Biloxi Marsh Lands Property in St. Bernard Parish Louisiana

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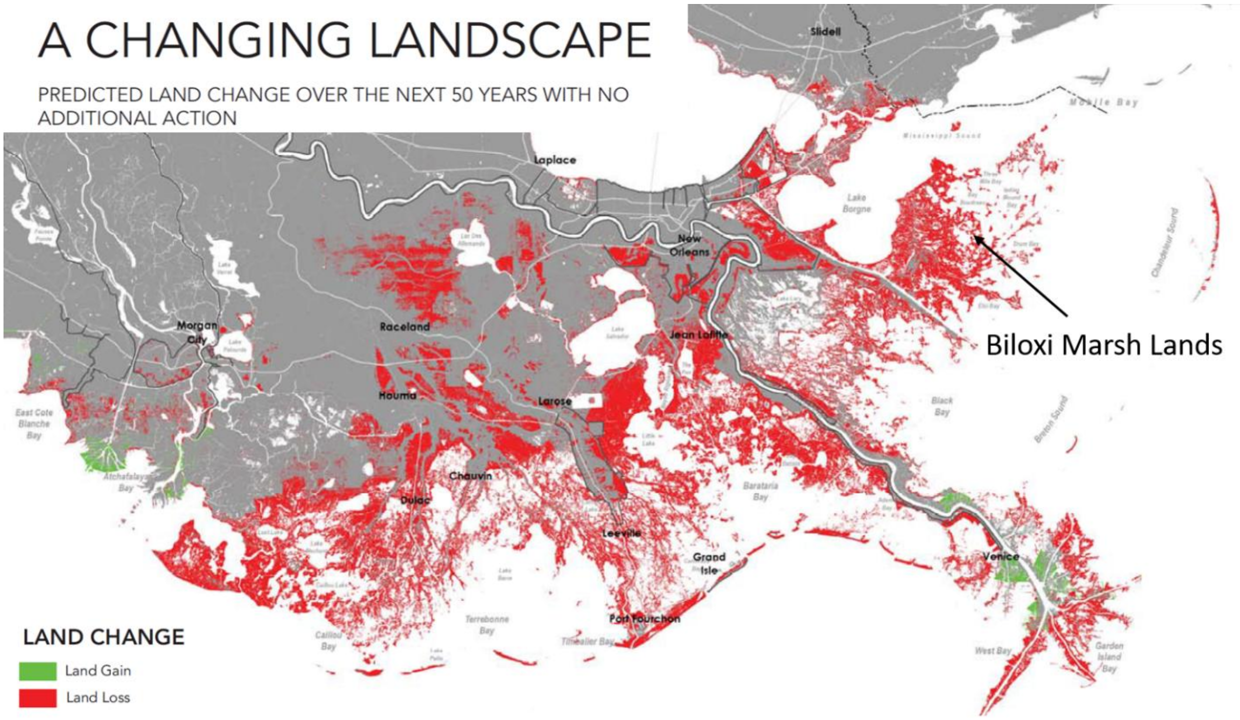
This report was prepared at the request of Mr. Louis Buatt on behalf of the Biloxi Marsh Lands Corporation to be attached with comments on the Draft Plan for 2017 Master Plan. The contents of this report are entirely the work of Chris McLindon. I am a professional geologist with a B.S. degree in Geology from L.S.U. in 1979 and 37 years of experience studying the geology of south Louisiana in the oil and gas industry. The contents of this report are consistent with technical presentations on subsidence in south Louisiana made by me to the Section Meeting of the Geological Society of America on March 22, 2016 and at the State of the Coast Conference on June 2, 2016, as well as comments provided to the America's Wetlands Foundation/C.P.R.A. Leadership Round Table meeting on October 26, 2016. The contents of this report are also consistent with recommendations for the Restore Act Center of Excellence Research Strategy submitted by me on behalf of the New Orleans Geological Society. The contents of this report also reflect my engagement with the earth science academic community acting as chair of the Special Projects Committee of the New Orleans Geological Society (NOGS). There are currently eight graduate-level research projects underway at U.N.O., Tulane, U.L.L. and L.S.U. that are utilizing oil and gas industry seismic data to study subsidence in coastal Louisiana. Access to this seismic data has been facilitated by the NOGS Research Proposal published in November 2015 of which I am a principal author. I am regularly engaged in conversations with students and professors about ongoing research on subsidence in the Louisiana wetlands.

The Coastal Protection and Restoration Authority (CPRA) has released the Draft Plan for the 2017 Master Plan document. The Draft Plan includes Figure ES-2 - a map showing predicted land loss for the "Medium Environmental Scenario if no action is taken". This map predicts that the entirety of the Biloxi Marsh Lands will be lost to submergence due to subsidence and sea level rise over the next 50 years. This is an extraordinary and unprecedented claim to be made by a governmental agency. The Biloxi Marsh Lands are broadly recognized as one of the most stable and resilient marsh platforms in the Louisiana delta plain. The emergent marsh surface has supported the inhabitation by humans for centuries. The 2013 St. Bernard Parish Coastal Zone Management Program Report prepared by Coastal Environments, Inc. documents numerous archeological sites across the Biloxi Marsh Lands from the Coles Creek Cultural Period dating back to about 700 B.C. through the early 20th century. Any prediction that an entire marsh ecosystem of this size and importance will be completely submerged within the next 50 years should be supported by a very solid foundation of scientific data and research.

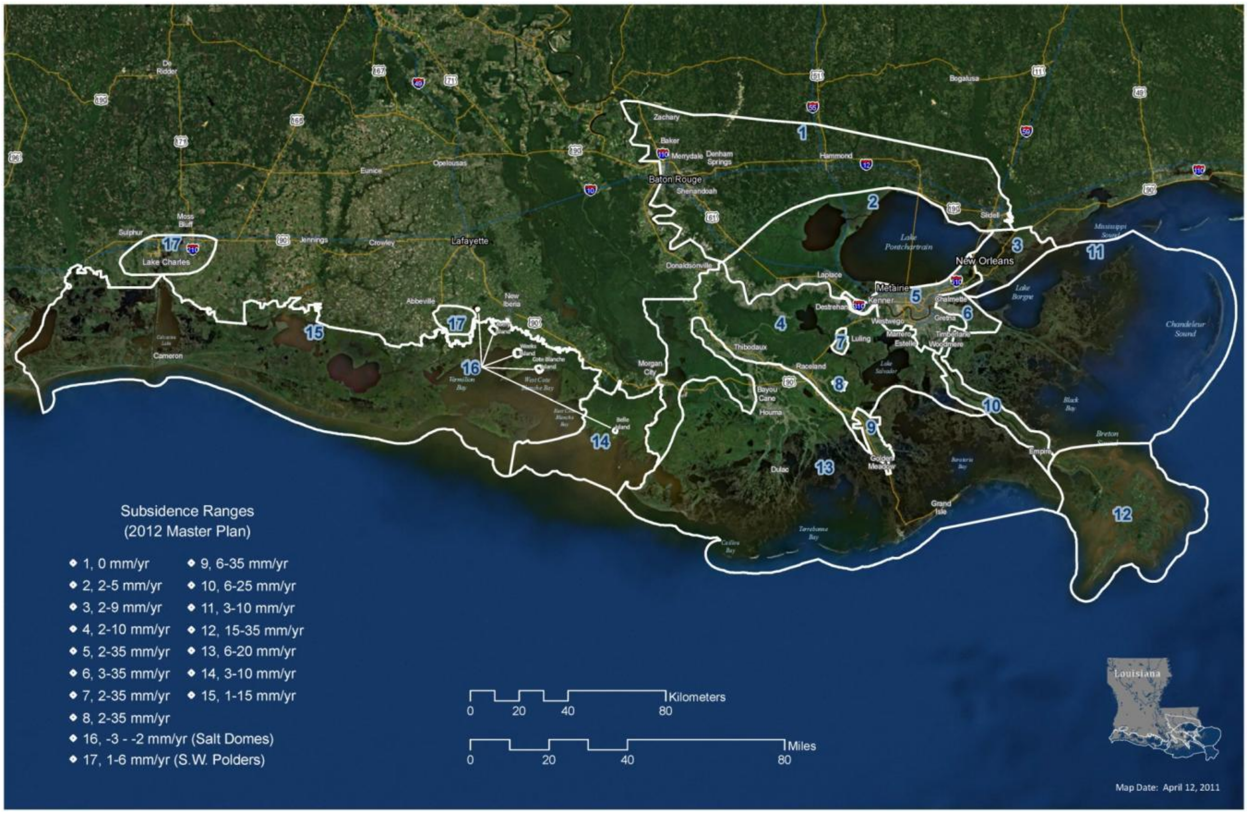


▲ FIGURE ES.2
Predicted land change along the Louisiana coast over the next 50 years under the Medium Environmental Scenario if we take no additional action. Red indicates areas predicted to be lost, and green indicates areas where land would be created.

These comments will provide an overview of the existing scientific research on factors affecting the submergence of the wetlands in south Louisiana, and a discussion of the degree to which research supports the CPRA prediction. Comments will be divided into the three fundamental factors that are controlling the submergence of the wetlands: subsidence, sea level rise, and vertical accretion of the marsh surface. In each case a simple common-sense assessment can be made of the predictions of the Draft Plan document by considering the projected outcome after 50 years relative to the changes that have occurred over the past 10 years. If the entirety of the Biloxi Marsh Lands is to be submerged over the next 50 years, then by extension roughly 20% of the total impact of that submergence should be obvious in changes that have happened over the past 10 years.

Subsidence

The Draft Plan for the 2017 Master Plan appears to over-estimate the rate of subsidence affecting the Biloxi Marsh Lands. The methodology of predicting subsidence is summarized in Attachment C2-2:Subsidence to the Draft Plan document. In this assessment coastal Louisiana was divided into 17 geographical regions to which varying ranges of "plausible subsidence rates" are assigned. Each geographical polygon was assigned a range of subsidence values, and Biloxi Marshlands is entirely contained within Polygon 11. The range of plausible subsidence values for Polygon 11 was determined to be 3 to 10 millimeters per year (mm/yr). The "Medium Environmental Scenario if no action is taken" model prediction that concluded that the Biloxi Marsh Lands would be completely submerged within 50 years was based on applying a subsidence value of 20% of the range of values (or 4.4 mm/yr) uniformly across the entire area of the polygon.



The rates of subsidence for each polygon in the Draft Plan assessment were originally determined by an expert advisory panel to be used as input for the 2012 Master Plan. These values were derived primarily from historical values of subsidence in the published scientific literature. Nearly all historical values of subsidence in coastal Louisiana have been determined from radiocarbon-based measurements from shallow cores, tidal gauge records, and geodetic measurements from the re-surveying of elevation benchmarks. Each of these methodologies measures historical values for average rates of subsidence over periods of time from centuries to a few years. Attachment C2-2:Subsidence recognizes that recent detailed examination of historical subsidence data (e.g. Kolker, et al. 2011) has shown that subsidence rates have been continuously decreasing over the past few decades, suggesting that “subsidence over the next 50 years may be at the lower end of the range”. Kolker, et al. also found that the continuously decreasing rate of wetlands loss over the past few decades is consistent with this determination of decreasing rates of subsidence. The range of subsidence values applied to each geographic polygon in the Draft Plan assessment should be reconsidered in light of these patterns of continually decreasing rates of subsidence and wetlands loss.

According to Attachment C2-2:Subsidence the subsidence values used in the Draft Plan for the 2017 Master Plan were not altered from those used in the 2012 Master Plan because “no new definitive studies on subsidence exist to provide coast wide predictions of future rates”. There have, however, been significant recent advances in the scientific study of subsidence and its relationship to near-surface geology. These studies could have been used to provide a more effective allocation of "plausible rates" of subsidence across the geographic polygons rather than the uniform attribution of a single value. Two primary studies from the last two years examined subsidence rates in detail – "Evaluating Land Subsidence Rates and There Implications for Land Loss in the Lower Mississippi River Basin" Lou, et al. 2015, and "Anthropogenic and geologic influences on subsidence in the vicinity of New Orleans, Louisiana, Jones, et al. 2016. Both studies showed that the variation of subsidence rates across the surface of the delta plain followed a very distinctive pattern of a concentration of the highest values of subsidence in relatively small and discrete "hot spots" and a distribution of the lower values across much larger areas. These studies both show that Geographic Polygon 11, which includes the Biloxi Marsh Lands, contains discrete hot spots of subsidence that affect only the very western edges of the polygon. These studies also both indicate that near subsurface geology, and in particular shallow-cutting geologic faults, are likely causes associated with concentrated areas of high subsidence. Other studies including the 2013 St. Bernard Parish Coastal Zone Management Program Report, Dixon et al. 2006 and Dokka 2011, have specifically interpreted the high subsidence areas along the western edge of Polygon 11 to be related to geologic faults. The Management Program Report and Dokka 2011 provided maps of near surface fault configurations showing faults oriented north-northwest to south-southeast near the western edge of Polygon 11 with the down-dropped direction to the west. In other words, the hot spots of high subsidence in the western portion of Polygon 11 appear to have been caused by the activity of geologic faults. The entirety of the Biloxi Marsh Lands is on the stable "upthrown" side of the faults, and away from the areas of high subsidence. Obvious common-sense comparisons can be made between the impacts of higher subsidence rates along the western edge of the polygon and the stable marsh platform in the Biloxi Marsh Lands. Old Paris Road north of Chalmette and the foundation Fort Proctor along the western shore of Lake Borgne have both subsided below the water's surface over the past few decades. These areas stand in stark contrast to the stability of the Biloxi Marsh Lands.

Attachment C2-2:Subsidence also mistakenly concludes that the data presented in the study "Influence of growth faults on coastal fluvial systems: Examples from the late Miocene to Recent Mississippi River Delta" by Armstrong et al. 2013 "may be helpful for differentiating areas prone to tectonic subsidence but they do not provide information that can be used to revise net subsidence rates or spatial variation." The faults mapped in this study clearly delineate boundaries of spatial variation in subsidence rates. Several examples of the 28 faults mapped in this study show that they form sharp linear boundaries between areas of emergent marsh and areas of open water formed by the complete submergence of the marsh surface. The Armstrong study states that faults in the area have been shown to have caused as much as 2 meters of subsidence at the surface. Several of the faults mapped by Armstrong et al. bound the southern edge of the Biloxi Marsh Lands separating it from the higher subsidence rates associated with the recent formation of open water in the southern portion of Polygon 11. The Biloxi Marsh Lands are clearly and distinctly separated from these areas of higher subsidence by the linear patterns of faults mapped in these studies. This geological configuration of the relatively high-elevation, stable Biloxi Marsh Lands bounded on two sides by fault systems causing higher subsidence rates to the south and to the west appears to have been persistent for very long periods of geologic time. Regional interpretations of sediment thickness and depositional activity from the Miocene, Pliocene, Pleistocene and Holocene Epochs consistently show that the area underlying the Biloxi Marsh Lands has been a geologically stable area for many millions of years. There is no salt basin or major regional fault systems underlying the Biloxi Marsh Lands. Given this configuration, it is a reasonable expectation that the Biloxi Marsh Lands will remain one of the more stable and persistent areas of the delta plain in the future.

The geological configuration of this area, combined with the recent studies showing the concentration of high subsidence rates in hot spots that appear to be controlled by geology, demonstrates a fundamental problem with methodology of assigning subsidence rates in the Draft Plan of the 2017 Master Plan. The higher values of the subsidence ranges used in each polygon have been shown to be exclusive to relatively small hot spots. The high-end values for the range of each polygon have also been derived from the highest historical values for subsidence ever recorded in the area. Generally speaking, there is no evidence that the current rates of subsidence in the hot spots are equivalent to the maximum historical values recorded in the area. Evaluations like Kolker et al. 2011 have shown that the high-end subsidence rates have dropped substantially over the past few decades. By allowing the higher subsidence rate values derived from historical measurements to skew the entire range of values, the 20% of range value that is applied to the entire polygon is well above the reasonable value that should be expected for most areas in the polygon. There is no obvious reason to assume that subsidence rates across the coastal plain would increase over the next 50 years.

The recommended solution to this problem would be to rework the methodology for estimating subsidence to more properly reflect the actual patterns of subsidence across the delta plain. This would first require significantly increasing the acquisition of current rates of subsidence by expanding the GPS measurement network. The average value of the 20% of range for the Geographic Polygons (excluding the salt domes) is 6.8 mm/yr. This average of the values used in the Medium Environmental Scenario is greater than the maximum value for current subsidence measured by any of the GPS stations in the CORS network (Karegar et al. 2015). In other words, the subsidence values used to predict the submergence of the Biloxi Marsh Lands and other wetlands areas across south Louisiana are not supported by any current GPS measurements of subsidence rate.

Secondly, reworking the methodology would require significantly improving the interpretation of near-surface geology across the polygons. By improving the density of direct subsidence measurements and the interpretation of the geologic structure that is likely to be controlling subsidence, the high-rate hot spots can be more accurately delineated. Outside of these hot spots it is likely that the average rates of subsidence across the polygons are generally at or near the low-end values for the ranges currently assigned to each polygon. The application of this reworked methodology to the Biloxi Marsh Lands would be likely to result in an estimate of average current subsidence rate of about 2 mm/yr.

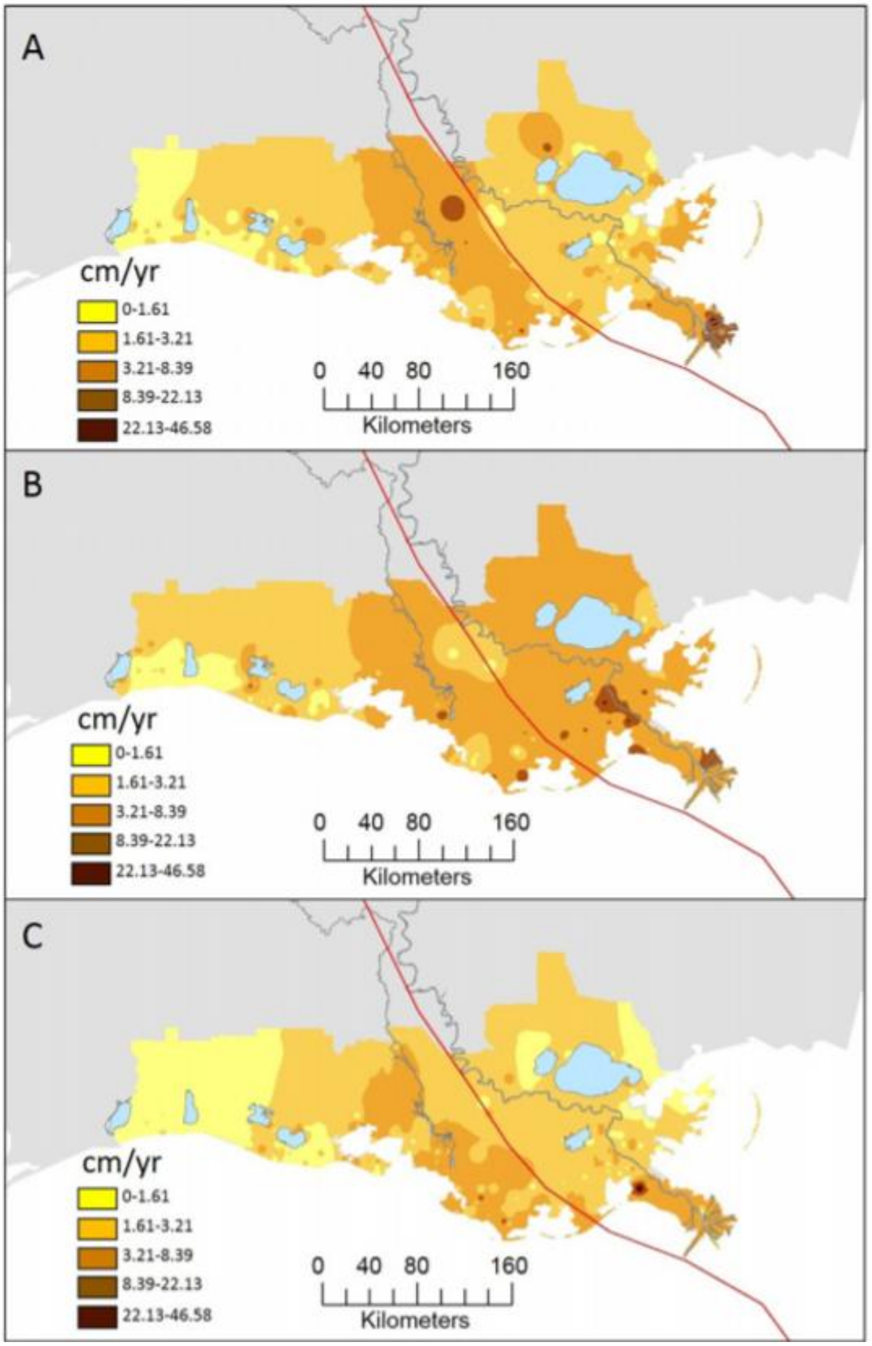
Sea Level Rise

The prediction that the Biloxi Marsh Lands will be fully submerged within the next 50 years by the Draft Plan of the 2017 Master Plan is also based in part on the prediction that global (eustatic) sea level will increase by 2.07 feet during that time span. This value is derived from Attachment C2-1:Sea Level Rise to the Draft Plan. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report in 2013 placed the current rate of global average sea level rise at a rate of 3.2 mm/yr. A 2.07-foot rise in sea level in the next 50 years would require an average rate of sea level rise of 12.62 mm/yr – almost four times the generally accepted current rate. The prediction of future sea level can be a very contentious subject, and there would be little value in drawing an evaluation of the potential submergence of the Biloxi Marsh Lands into the full debate. The better evaluation may be to consider the value of a 50-year projection of future sea level. Graphical representations of the range of potential future values of sea level are very similar to the representations of "cones of uncertainty" surrounding the projected paths of tropical cyclones. The ever-widening cone shows an ever-increasing uncertainty about the future location of the eye of the storm. The cone of uncertainty for a storm entering the Caribbean Sea may show a spread of potential landfall locations on the northern Gulf of Mexico from Galveston to Pensacola at some relatively distant point in the future. The value of these long-range projections is to alert residents of the northern Gulf that they may be in the future path of the storm. A wise response in this situation may be to stock up on batteries and bottled water. It would not necessarily be wise for residents between Galveston and Pensacola to board up windows or evacuate their homes when landfall of the storm is that far into the future. An experienced resident of the Gulf Coast will know to watch the path of storm, and to make necessary responses when landfall is much closer to being imminent at their location.

The general conception of the "Medium Environmental Scenario if no action is taken" prediction for the submergence of coastal Louisiana 50 years into the future is that the results of the prediction are imminent. One is left to deduce from the range of potential scenarios that the "medium scenario" has a relatively high probability of occurrence. The better concept for most residents of the coastal plain might be to maintain an awareness that complete submergence of broad areas of wetlands like the Biloxi Marsh Lands is in the realm of possibility. The responsible course of action would be to watch the path of the global sea level curve over time, and make necessary responses when impacts are more clearly imminent. Put another way, it may be better to consider the future impacts of global sea level rise in 10-year increments rather than in 50-year increments. A ten-year projection of the current rate of sea level rise would mean that sea level would be 32 millimeters (about 1.2 inches) higher than it is today. If the current rate of sea level rise were to double in the next 10 years, then sea level would be 2.4 inches higher. The Biloxi Marsh Lands would be minimally impacted by submergence under either of these scenarios. At the end of the 10-year period the future rates of sea level rise could be re-estimated, and projections of the potential impacts over the coming decade could be formulated. There is no inherent value to basing the design and implementation of the 2017 Master Plan on 50-year predictions that are so far into the future and encompassing such a wide range of uncertainty.

Accretion

The natural vertical accretion of the marsh surface is given no consideration in the Draft Plan assessments for the 2017 Master Plan. The Coastal Reference Monitoring System (CRMS) has been monitoring accretion in the marsh since 1996, and the values appear to be significant. The 2015 study "Wetland Accretion Rates Along Coastal Louisiana: Spatial and Temporal Variability in Light of Hurricane Isaac's Impacts" by Bianchette et al. examined vertical accretion rates from 390 CRMS sites across the coastal plain. It has been coming increasingly obvious since the installation of the CRMS system that marshes are able to maintain vertical elevation by the accretion of sediments that are redistributed by tropical storms. The Bianchette et al study looked specifically at accretion rates before and after Hurricane Isaac in 2012. They found that "that accretion rates averaged about 2.89 cm/year from stations sampled before Isaac, 4.04 cm/year during the period encompassing Isaac, and 2.38 cm/year from sites established and sampled after Isaac."



The study showed that accretion rates across the Biloxi Marsh Lands ranged from about 16 mm/yr before and after the storm to over 32 mm/yr during the period of the storm. These rates of vertical accretion are significantly higher than any measure of subsidence or sea level rise that has been attributed to the area by any assessment. It is strikingly obvious from the results of this study that accretion should be included in the predictive models for the 2017 Master Plan.

Conclusions

The values that were used to make the "Medium Environmental Scenario if no action is taken" that predicts the complete submergence of the Biloxi Marsh Lands over the next 50 years have been generally well understood for the past decade. The predictions of the Draft Plan of the 2017 Master Plan are based on the assumption that constant rates of subsidence and a progressively increasing rate of global sea level rise throughout the 50-year span of the model should progressively submerge the coastal wetlands. This progressive submergence should logically be manifest by a measurable decrease in the land area of the coastal wetlands. The reality of the last decade is that between 2008 and 2010 the total land area of the coastal wetlands has increased by 210 square miles. The total land area of the wetlands in the Breton Sound Hydrologic Basin that includes the Biloxi Marsh Lands has increased by 13 square miles. These are the last two years for which land areas were measured for U.S.G.S. Scientific Investigations Map 3164. Preliminary indications appear to show that land areas do no change substantially in the succeeding years.

The current rates of subsidence and sea level rise are not being manifest by a progressive decrease in land area. It is likely that actual current subsidence rates and sea level rise rates are lower than the values used in the Medium Environmental Scenario model. It is also likely that vertical accretion rates in the marsh are generally greater than or equal to the combined effects of subsidence and sea level rise. A more accurate prediction of future land areas in the coastal wetlands for the 2017 Master Plan could be accomplished by:

1. Reworking the methodology of assigning subsidence values across the coastal plain to include greater density and accuracy of current subsidence measurements and the integration of near-surface geological interpretation.
2. Restrict projections of future sea levels to 10 increments with the intention of recalibrating the models at the end of each 10-year period.
3. Including vertical accretion values in the predictive models.

The Biloxi Marsh Lands have been one of the most resilient and persistent marsh platforms in the Mississippi Delta Plain for several centuries. The prediction by the Draft Plan of the 2017 Master Plan that the Biloxi Marsh Lands will be submerged by subsidence and sea level rise in the Medium Environmental Scenario is based on estimates of subsidence rate and sea level rise rate that are too high based on current data. The Draft Plan also ignores the vertical accretion of the marsh surface, which has been demonstrated to have been occurring at rates equal to or greater than the combination of subsidence and sea level rise over the past few years. A valid prediction that the Biloxi Marsh Lands will be fully submerged in the next fifty years can only be made after the complete integration of a greater density of direct subsidence measurements and near-surface geological interpretation.

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