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2017 Coastal Master Plan

Attachment C2-2: Subsidence

Report: Final

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Coastal Protection and Restoration Authority

This document was prepared in support of the 2017 Coastal Master Plan being prepared by the Coastal Protection and Restoration Authority (CPRA). CPRA was established by the Louisiana Legislature in response to Hurricanes Katrina and Rita through Act 8 of the First Extraordinary Session of 2005. Act 8 of the First Extraordinary Session of 2005 expanded the membership, duties and responsibilities of CPRA and charged the new authority to develop and implement a comprehensive coastal protection plan, consisting of a master plan (revised every five years) and annual plans. CPRA's mandate is to develop, implement and enforce a comprehensive coastal protection and restoration master plan.

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- Coastal Protection and Restoration Authority (CPRA) of Louisiana - Mandy Green, Angelina Freeman, and David Lindquist.

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Executive Summary

The 2012 Coastal Master Plan recognized that subsidence is a key driver of coastal change in Louisiana and the effects of subsidence should be incorporated into future planning. However, future subsidence rates are difficult to predict and subsidence was therefore treated as an uncertainty and included in the 2012 modeling as part of the future scenarios. The values used in those scenarios were derived from a map of plausible subsidence rates (ranging from 0 to 35 mm yr^{-1}) across coastal Louisiana that were differentiated into 17 geographical regions.

The objective of this effort was to identify and review recent technical literature, information and data that could improve the accuracy and spatial precision of the subsidence values to be used in the 2017 Coastal Master Plan, including data from tide gauges and Continuously Operating Reference Stations (CORS). However, no new definitive studies on subsidence exist to provide coast wide predictions of future rates, and there are issues of concern with the new data sets. For example, the CORS data are largely based on highway surveys, and the tide gauge data analysis likely better reflects relative sea level rise, not enabling the specific identification of subsidence.

Considering the lack of definitive data or new studies on which to justify modifying the spatial polygon boundaries or the plausible range of subsidence rates, the recommendation is for the 2017 Coastal Master Plan to use the same polygons and plausible ranges as the 2012 Coastal Master Plan.

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List of Abbreviations

CORS	Continuously Operating Reference Stations
CPRA	Coastal Protection and Restoration Authority
CWPPRA	Coastal Wetlands Planning, Protection and Restoration Act
GPS	Global Positioning System
MRHDM	Mississippi River Hydrodynamic and Delta Management (Study)
NOAA	National Oceanographic and Atmostpheric Adminstration
SPCMSC	St. Petersburg Coastal and Marine Science Center
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

1.0 Introduction

The 2012 Coastal Master Plan recognized that subsidence is a key driver of coastal change in Louisiana and the effects of subsidence should be incorporated into future planning. However, because future subsidence rates are difficult to predict, subsidence was one of several factors which varied among scenarios (CPRA, 2012). The values used in those scenarios were derived from a map of plausible subsidence rates (ranging from 0 to 35 mm yr^{-1}) for coastal Louisiana, differentiated into 17 geographical regions.

The 'plausible ranges' of subsidence rate values incorporated into the 2012 Coastal Master Plan were identified during an expert advisory panel meeting held on September 14, 2010. The objective of the panel meeting was to predict future subsidence rates for different regions of coastal Louisiana to use as an input into the models that were used to support the 2012 Coastal Master Plan. The predicted subsidence rates had to be indicative of conditions over the next 50 years to be useful to master plan modeling efforts, which meant assessments of subsidence rates over geological time scales could only be used with some substantial assumptions.

The upper and lower plausible subsidence rates identified by the panel were intended to bracket future subsidence rates and were informed by historical observations and geological understanding of the coast and the processes driving subsidence. The 2012 Coastal Master Plan 'moderate' scenario assumed that future subsidence rates would be 20% of the identified range of subsidence rates for each region. This value was selected based on observations (e.g., Kolker et al., 2011) that report historical subsidence rates are declining and thus suggesting that subsidence over the next 50 years may be on the lower end of the range. The 'less optimistic' scenario assumed that the recent decline in subsidence rates would not continue and the subsidence rate selected for the modeling was the median value of the range in each region.

The 2012 Coastal Master Plan included a list of additional technical references that were considered by expert panel members and that guided the definition of the plausible range of subsidence rates. These references, as well as the section of the master plan that discusses subsidence can be found in section 5.2 of Appendix C describing future scenarios (CPRA, 2012).

Figure 1 shows the different geographical regions used to differentiate subsidence rates, and Table 1 provides the range of subsidence rates identified for each region, and the rates that were used in the 2012 Coastal Master Plan for the 'moderate' and 'less optimistic' scenarios for each region.

The objective of this report is to review and identify recent technical literature that could improve the accuracy and spatial precision of the subsidence values to be used in the 2017 Coastal Master Plan.

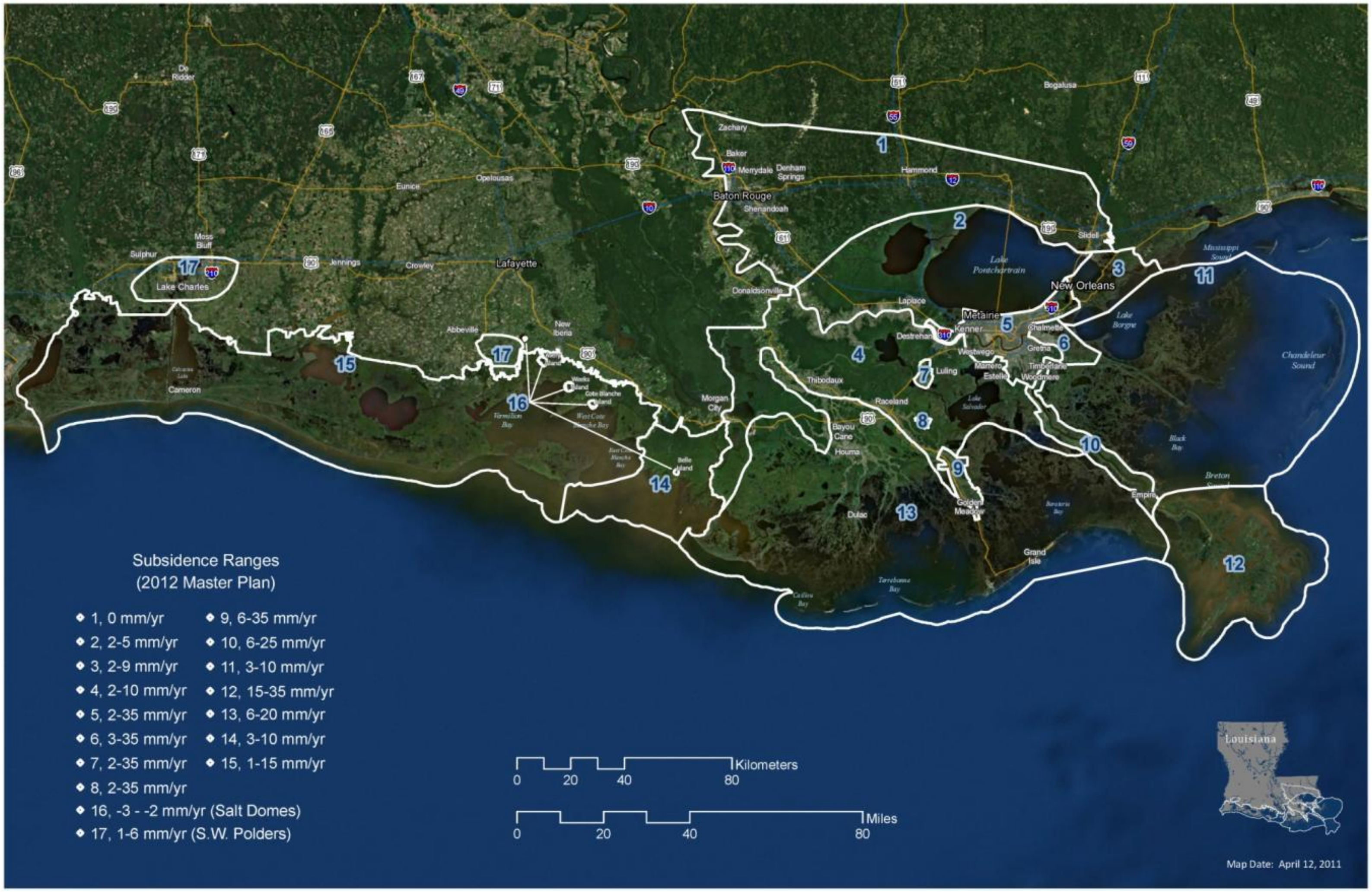

Figure 1: 2012 Coastal Master Plan - Plausible Future Subsidence Ranges in Coastal Louisiana.

Table 1: Subsidence Values Used in the 2012 Coastal Master Plan Modeling Effort.

	Region ID	Moderate Scenario (mm/yr)	Less Optimistic Scenario (mm/yr)
North Shore	1	0	0
Pontchartrain	2	2.6	3.5
New Orleans Land Bridge	3	3.4	5.5
Barataria and Terrebonne Marsh	4	3.6	6
New Orleans	5	8.6	18.5
New Orleans_East	6	9.4	19
Bayou Gauche	7	8.6	18.5
Gheen	8	8.6	18.5
GoldenMeadow	9	11.8	20.5
Miss River	10	9.8	15.5
Breton	11	4.4	6.5
Birdsfoot	12	19	25
Barataria and Terrebonne Bays	13	8.8	13
Atchafalaya	14	4.4	6.5
Chenier Plain	15	3.8	8
Salt Domes	16	-2.2	-2.5
Southwest Polders	17	2	3.5

2.0 New Subsidence Literature

Several new papers have been written on subsidence since the work was conducted to draft the 2012 Coastal Master Plan. These sources were reviewed to determine if they would be useful for improving the plausible range of subsidence rates and/or the spatial distribution used in the 2012 Coastal Master Plan either by providing new information on subsidence rates or the spatial variation across the coast. Short summaries are provided here to illustrate the types of new information available in the literature.

- Armstrong et al. (2013) examines how growth faults have influenced relic fluvial features present in the alluvial architecture underlying the modern Mississippi River delta. The study uses seismic measurements to map and characterize faults observed under the lower Mississippi River and Breton Sound. The data presented in this study may be helpful for differentiating areas prone to tectonic subsidence but they do not provide information that can be used to revised net subsidence rates or spatial variation.
- Bernier (2013) offers new interpretation of the spatial wetland loss data collected by the USGS St. Petersburg Coastal and Marine Science Center (SPCMSC) for coastal Louisiana. The dataset used by this study spans 1956 to 2004 and was initially published prior to the 2012 Coastal Master Plan. This report confirms that the observations of wetland loss are primarily due to subsidence rather than coastal erosion and that the highest rates of subsidence are spatially correlated to areas of historic hydrocarbon withdrawal. The results of this study support the hypothesis that future rates of wetland loss may be lower than the historical average because of the relative decline in regional hydrocarbon withdrawal. Although this study supports some of the assumptions made in the selection of rates for scenarios in the 2012 Coastal Master Plan, it does not provide information that would lead to modification of the existing rates or spatial variation.
- Simms et al. (2013) presents a method to predict long-term rates of subsidence at coastlines by comparing the elevation of modern coastal features (e.g., beach ridges) to the elevation of preserved paleo-shoreline features from the last interglacial period. Although this study presents data from the Texas gulf coast, it could be applied to the Louisiana shoreline. However, this has not yet been accomplished and although the long-term rates derived from such an approach may be useful in the future no information is currently available to alter the subsidence rates used in the 2012 Coastal Master Plan.
- Yu et al. (2012) uses geologic methods (e.g., AMS Carbon 14 dating of boring sediment) to define a relative sea level rise curve for the Louisiana Chenier Plain. Interpretation of this new dataset in relation to a previously derived relative sea level curve for the modern Mississippi River delta suggests that deep subsidence in coastal Louisiana is primarily due to glacial isostatic adjustment (0.45 mm yr^{-1}) and affected to a lesser degree by lithospheric flexure due to sediment loading (0.15 mm yr^{-1}). Deep subsidence refers to subsidence occurring in the Pleistocene basement and below. A previous study based on numerical modeling (i.e., Blum et al., 2008) suggests that lithospheric flexure produced subsidence rates of approximately 1.0 mm yr^{-1}. As the rates used in the 2012 Coastal Master Plan represent the sum of all subsidence processes, this additional information on a single factor cannot be used to modify the 2012 approach or rates.

3.0 New or Improved Data and Information

Since the 2012 Coastal Master Plan expert panel was convened in 2010, several additional or improved sources of subsidence data and other relevant information have become available. Below is a brief description of these new data sources.

Tide Gauge Data

Ayres (2012) reports a relatively long time series (~ 50 years) of relative sea level rise values derived from 19 tide gauges (Figure 2, Figure 3). A recent CPRA report (CPRA, 2013) details a method to integrate these tide gauge data into the existing 2012 Coastal Master Plan subsidence map, extrapolating the gauge data (deriving subsidence as the remainder of relative sea level rise minus eustatic sea level rise) to the existing subsidence regions which encompass each gauge. Although the proposed method adds substantial new insight based on quantitative measurements, the method maintains the master plan region boundaries despite the fact the regions do not reflect the distribution of subsidence rates as reflected in the tide gauge data. Also the proposed method assumes that tide gauge measurements capture total subsidence, which is only true at locations where no subsidence is occurring below the terrestrial benchmarks used as the geodetic control.

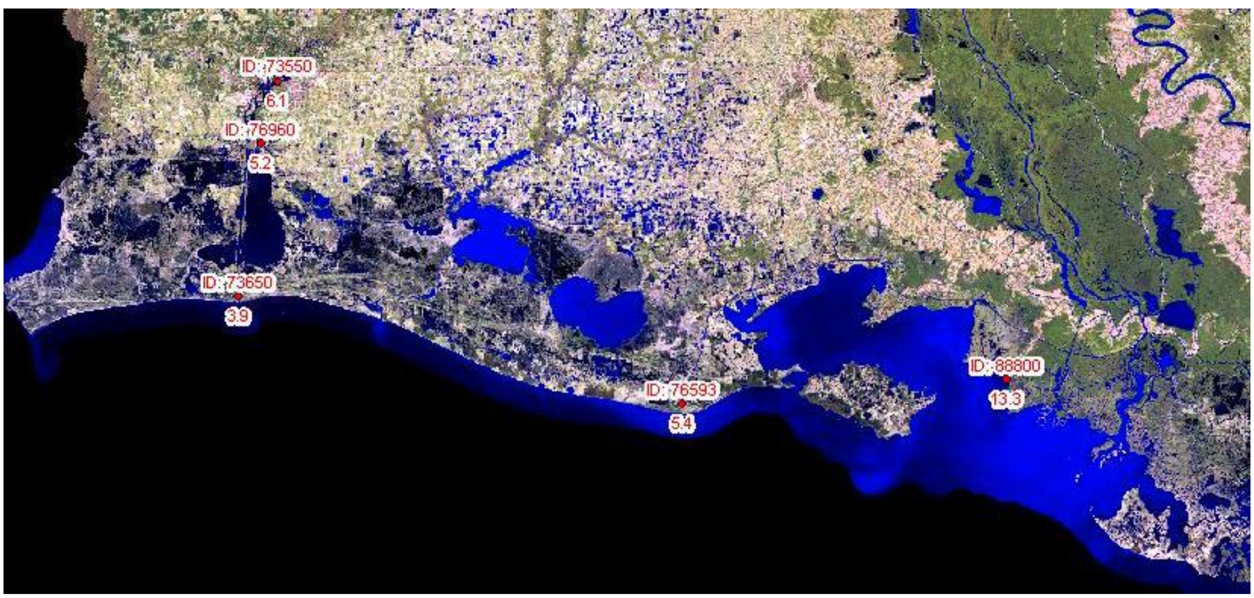

Figure 2: USACE Tide Gage Stations and Observed Relative Sea Level Trends in Western Louisiana (Ayres, 2012).

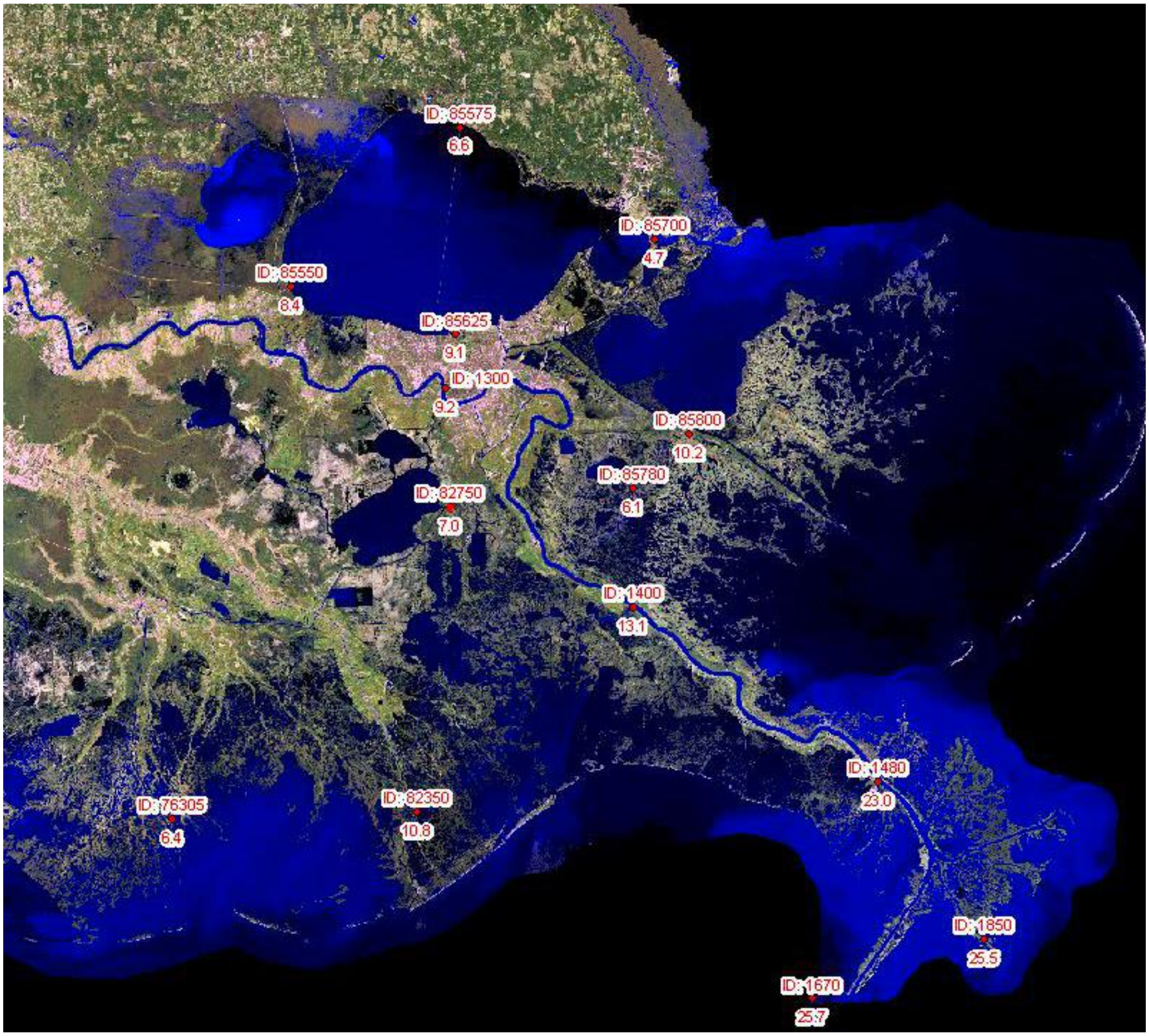

Figure 3: USACE Tide Gage Stations and Observed Relative Sea Level Trends in Southeastern Louisiana (Ayres, 2012).

Continuously Operating Reference Stations (CORS GPS)

Continuously Operating Reference Stations (CORS) collect elevation measurements using satellite-based geodetic measurements (i.e., GPS) and can resolve total subsidence at a location at very high precision. Although there are approximately 50 CORS stations in Louisiana, only approximately 12 collect freely accessible measurements along the coastal areas (Figure 4). Most CORS were installed within the last 10 to 15 years and do not have long enough time series to compute long term trends with a high degree of statistical confidence, in terms of elevation change (Josh Kent, pers. comm.).

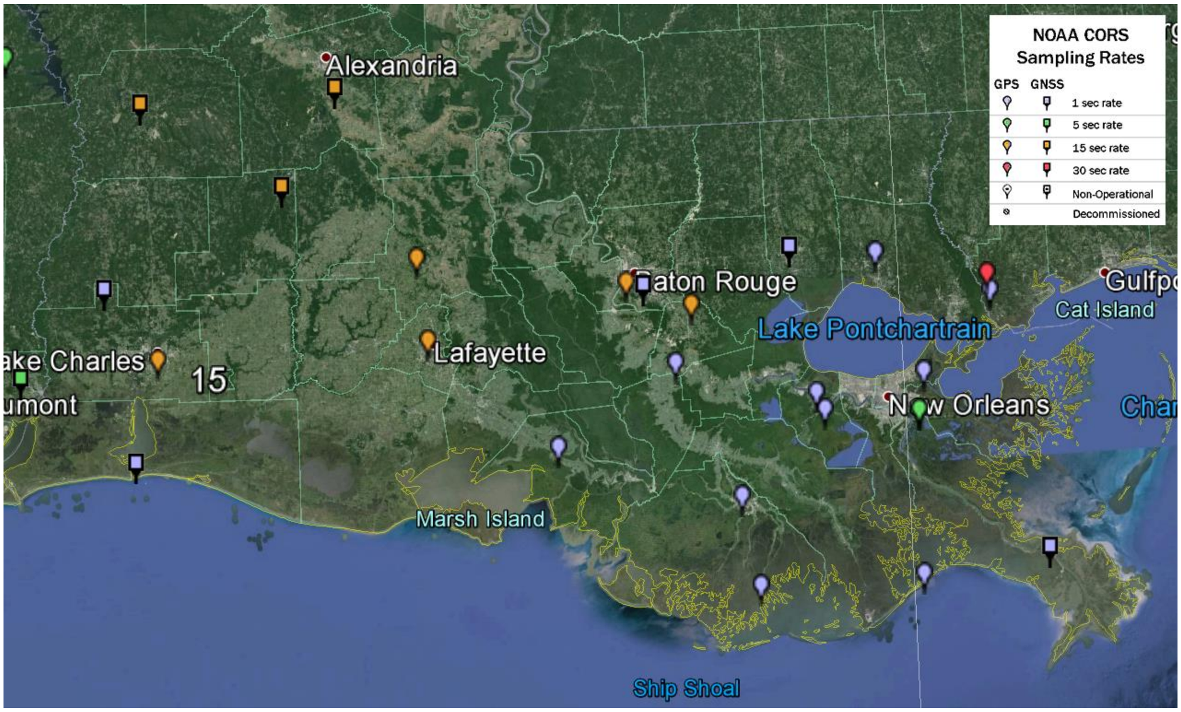

Figure 4: Continuously Operating Reference Stations (CORS) Locations in Coastal Louisiana.

4.0 Discussion

The topic of determining which subsidence values to use has also been addressed for other non-master plan efforts by CPRA and their partners. The recent U.S. Army Corps of Engineers (USACE) West Bay project analysis for the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) program utilized spatially-variable subsidence values. Those values, based primarily on observations of highway benchmark vertical displacement as outlined in Shinkle & Dokka (2004), declined moving upriver. This data was also used to inform future landscape condition for the Mississippi River Hydrodynamic and Delta Management (MRHDM) Study.

DeMarco et al. (2012) recommended some type of accounting be used for spatially-variable subsidence. The recommendation was to use the 2012 Coastal Master Plan rates and spatial variability and mirror the master plan 'Moderate' scenario of 20% into the ranges. However, DeMarco et al. (2012) was released prior to the final release of a recently-completed analysis of USACE gauges in coastal Louisiana (Ayres, 2012) that expands the potential list of tide gauges with long periods of record in the coastal zone that might inform a determination of historical subsidence. Currently a hybrid approach, using information from both the 2012 Coastal Master Plan approach and the Ayres rates, is being used for CPRA feasibility planning studies (CPRA, 2013). Given that 1) no new definitive studies on subsidence exist to provide coast wide predictions of future rates, 2) the Shinkle & Dokka (2004) data are largely based on highway surveys, and 3) the Ayres tide gauge analysis likely better reflects relative sea level rise within the aquatic environment, the proposed approach for the 2017 Coastal Master Plan is to use the same plausible range of subsidence rates as used in the 2012 Coastal Master Plan.

5.0 Recommendations for a Plausible Range

Given the lack of definitive data or studies on which to justify modifying the spatial polygon boundaries or the plausible range of subsidence rates, the recommendation is for the 2017 Coastal Master Plan modeling effort to use the same polygons and plausible ranges as the 2012 Coastal Master Plan (Figure 1, Table 1).

6.0 References

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