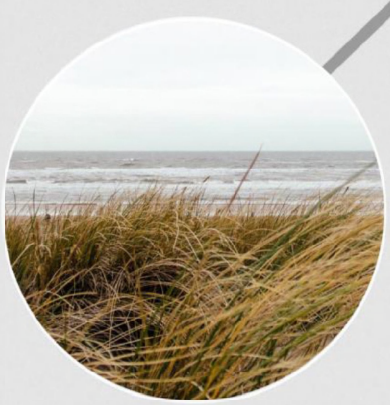
NewFields

Prepared Expressly For:

NOAA



Technical Memorandum

Inundation Analysis at Coastal Wetland Vegetation Sites

Jacob Oehrig; Shahrokh Rouhani; Michael Michalski, NOAA

September 4, 2015

• Deepwater Horizon Oil Spill •

NewFields LLC, 1349 West Peachtree St NW #2000, Atlanta, GA 30309

TECHNICAL MEMORANDUM

SUBJECT: Inundation Analysis at Coastal Wetland Vegetation Sites

DATE: September 4, 2015

TO: Marla Steinhoff, NOAA; Mary Baker, NOAA

FROM: Jacob Oehrig, NewFields; Shahrokh Rouhani, NewFields; Michael Michalski, NOAA

Introduction

The National Oceanic and Atmospheric Administration (NOAA) Center for Operational Oceanographic Products and Services (*CO-OPS)* generated information on the duration, frequency and magnitude of inundation events in 2010 at coastal wetland vegetation (CWV) sites situated in Louisiana and along Mississippi Sound. For each group of nearby CWV sites, CO-OPS produced a representative hourly hydrograph of water levels at an arbitrary but proximal location, referred to as "TCARI (*Tidal Constituent and Residual Interpolation*) Interpreted[1]" station. These created TCARI interpreted stations were located in Barataria Bay, Timbalier/Terrebonne Bay, Biloxi Marsh, Chandeleur Islands, as well as the Mississippi River Delta basins[2] (CO-OPS, 2013a; CO-OPS, 2013b; CO-OPS, 2013c; CO-OPS, 2013d; CO-OPS, 2013e). TCARI interpreted stations were situated such that all CWV sites were within 10 km (3.6 km on average) of a representative station. Anywhere from one to 27 CWV sites were assigned to each specific TCARI interpreted station. Figure 1 displays an example of a created TCARI interpreted station surrounded by a number of CWV sites to which it was assigned and Figure 2 shows the location of all Louisiana CWV sites and their proximal TCARI interpreted stations.

[1] TCARI is a method used to provide tidal corrections to hydrographic data to account for non-tidal effects (wind, river influence or changes in long term sea level datum). See http://www.nauticalcharts.noaa.gov/csdl/tcari.html for more information about TCARI analysis. Also see Lindley *et al*. 2011.

[2] The final CO-OPS TCARI reports for each region are provided in Appendices A through E. A compendium of standard operating procedures (SOPs) related to these analyses is provided in Appendix G.

Figure 1 Examples of CWV Sites in Terrebonne Bay and their Assigned TCARI Interpreted Station

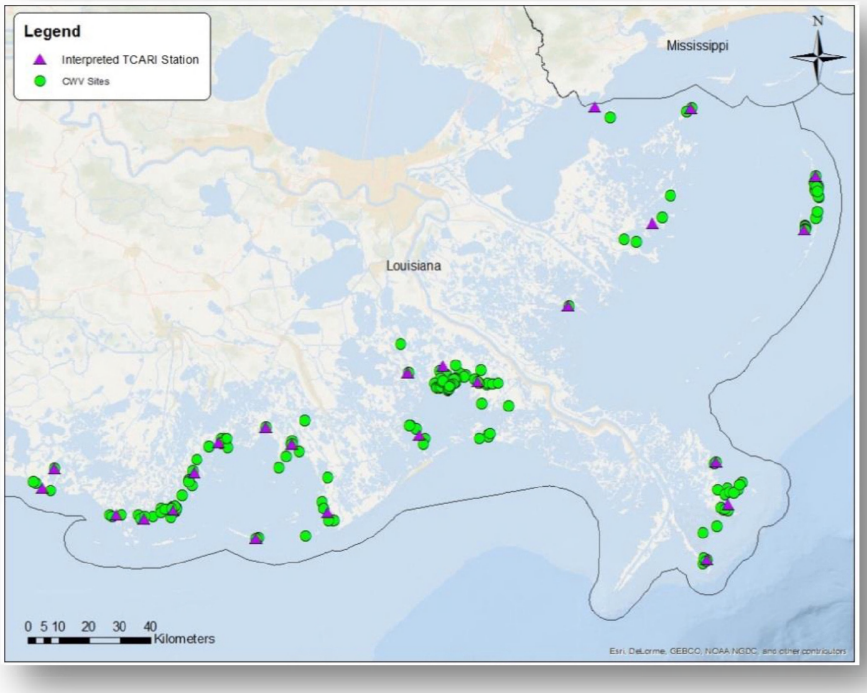


Figure 2 Location of all Louisiana CWV sites and their proximal TCARI interpreted stations

In this specific analysis, representative hydrographs at created TCARI Interpreted stations were generated based on tidal characteristics, harmonic constituents, and residual signals of hourly water levels observed at nearby National Water Level Observations Network (NWLON) stations as well as twenty-four Coastal Response Monitoring System[3] (CRMS) stations.

Inundation characteristics at each zone within each CWV site were then calculated by superimposing the zone elevation[4] on its corresponding representative TCARI hydrograph, as displayed in Figure 3. In this figure, seven (7) inundation periods with specific durations and magnitudes have been identified at zone 2 of the CWV site during the period of January 4, 2010 through February 1, 2010. More information is provided by CO-OPS (Appendices A through E).

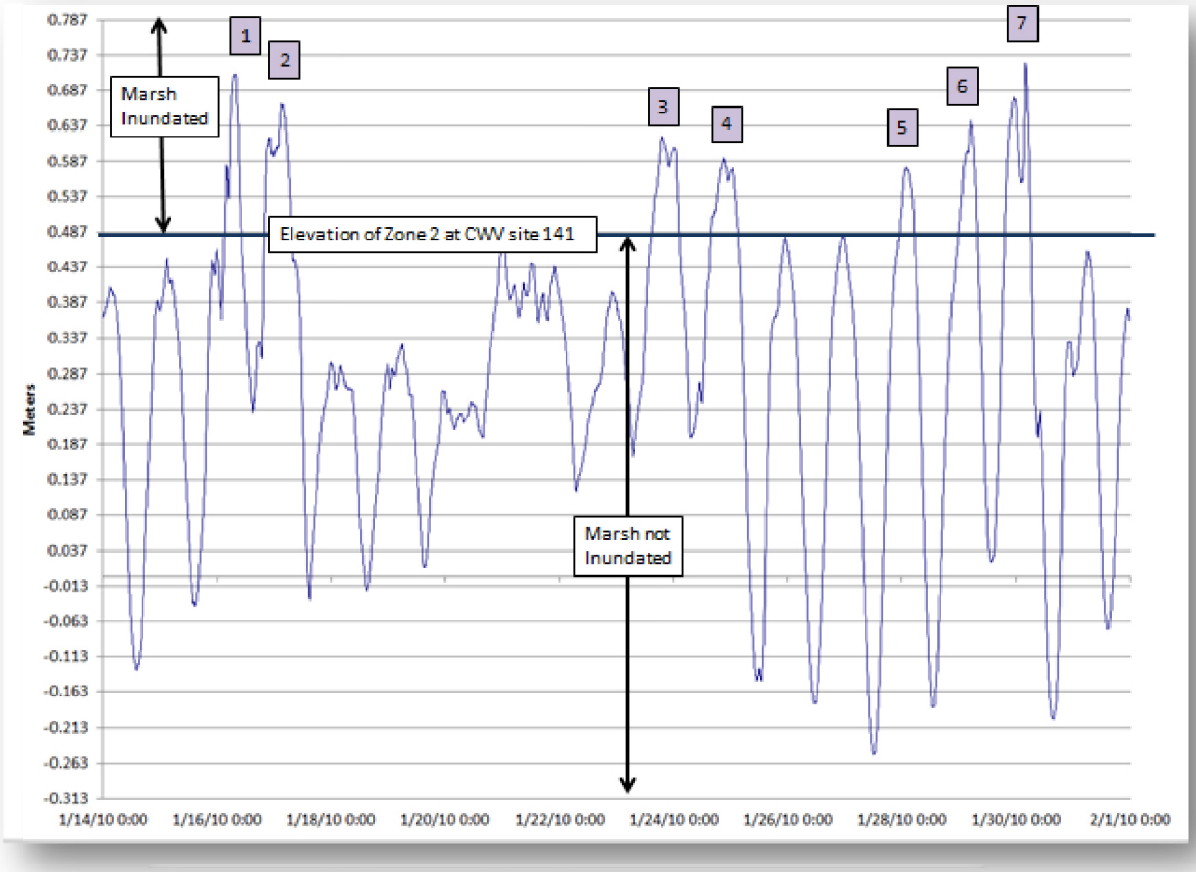


Figure 3. Example of a Predicted Water Level Hydrograph with a Superimposed CWV zone Elevation

[3] The CRMS stations function at a different operational standard than those installed and maintained by CO-OPS; therefore, it was necessary for CO-OPS to identify the relative performance difference between these two types of water level gauges prior to use (CO-OPS, 2013f). Appendix F includes a comparison study performed by CO-OPS.

[4] Each zone within a CWV site was comprised of a cover plot and a productivity plot, as shown in Figure 5(NOAA, 2011). The elevations of each plot within a zone were averaged into a single zone elevation.

The CO-OPS computed hourly hydrographs were based on elevations above the mean lower low water[5] (MLLW) datum. However, CWV site elevations were measured through real-time kinematic (RTK) procedures based on the North American Vertical Datum of 1988 (NAVD88). To address this difference, NAVD88 elevations above the MLLW provided by CO-OPS for each interpreted TCARI station were used to transform the reported RTK elevations at zones within each CWV site into elevations above MLLW.

Inundation Analysis

The hourly inundation data for each CWV site and RTK elevation data for each zone within the site were used to compute site- and zone-specific metrics.[6] Based on available water level data, TCARI interpreted stations had varying temporal extents for their computed hydrograph values. To accurately compare inundation values between CWV sites, the period of April 15, 2010 through November 26, 2010 was selected such that each site shared a full and common period of record, as displayed in Figure 4.

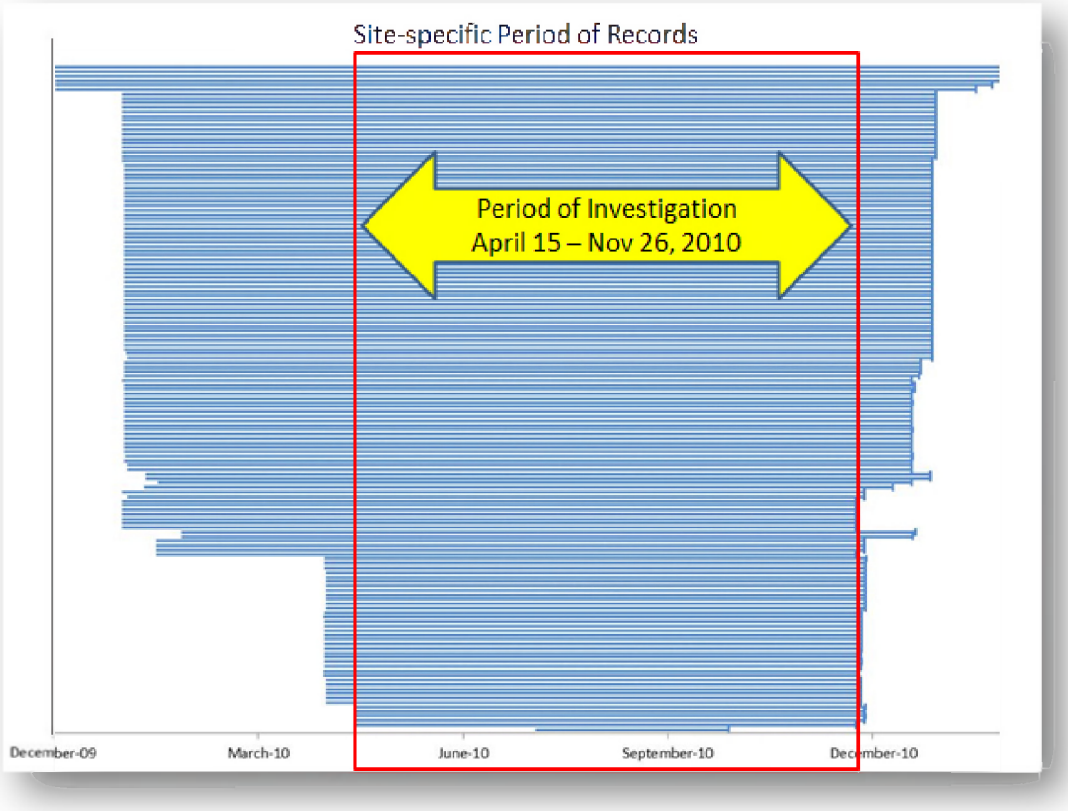


Figure 4. Site-specific Periods of Record
(Each CWV is displayed as one row)

[5] MLLW is the arithmetic mean of the lower low water heights of each tidal day observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). See http://tidesandcurrents.noaa.gov/datum_options.html for more information.
[6] Zone-specific metrics were calculated by applying plot-specific elevations to hourly water level time series for each CWV site.

The investigated metrics included:

- Average Flood Depth: Average water depths above CWV site/zone RTK average elevation over the selected period of investigation
- Flood Event Count: Count of flood events over the selected period of investigation[7]
- Average Event Duration: Average duration of flood events in hours over the selected period of investigation
- Total Inundation Duration: Total duration of flood events in hours over the selected period of investigation
- Flood Frequency: Percentage of time during the selected period of investigation when water elevation exceeded the CWV site average RTK elevation
- Weighted Average Flood Depth: Average flood depth weighted by the duration of flood events during the selected period of investigation

Results

Summary statistics of inundation metrics for Zone 1, Zone 2, and Zone 3 of CWV sites across various basin areas in Louisiana are listed in Table 1. Figure 5 provides a graphical representation of a typical layout of a CWV site and its respective transect and three zones. Zone 1 was typically located 1.5 meters inland from the shoreline whereas Zone 2 and Zone 3 were located at 50% and 80% of the CWV transect length, respectively (NOAA, 2011). Table 2 shows the average distance from shore for each CWV zone across the respective areas within Louisiana.

Results indicate that the Delta area was most often inundated and at higher flood depths than the other regions. Flood frequencies in Zone 1 during the time period analyzed averaged 64% for Barataria Bay and were as high as 96% in Delta Phragmites habitat. The average flood depth in Zone 1 ranged from an average of 11.2 cm in Timbalier/Terrebonne basin to an average of 86.5cm in the Delta region.

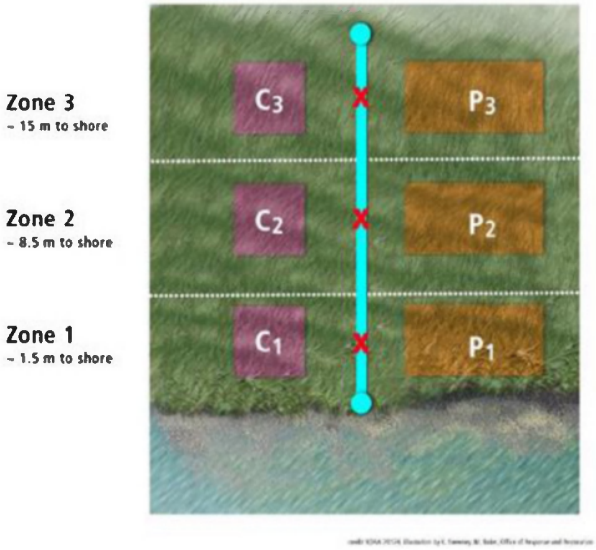


Figure 5. Typical layout of a CWV site with a central transect (in blue) which is divided into three zones. Zone 1 represents the area closest to the shoreline whereas Zone 3 is furthest inland. Representations of the Cover plots ($C_{1,2,3}$) and Productivity plots ($P_{1,2,3}$) are also shown.

[7] A *flood* event is defined as a period during which water elevation is above the CWV site/zone RTK average elevation. The duration of the flood event lasts until the water elevation drops below the CWV site/zone RTK average elevation. If water elevations again rise above the CWV site/zone elevation, this is treated as a separate flood event.

Table 1. Summary Statistics of Inundation Metrics for CWV Sites in Louisiana at Zone 1, Zone 2 and Zone 3. Inundation metrics are calculated during the time period of April 15, 2010 through November 26, 2010

Metric/Area	Zone 1				Zone 2				Zone 3			
	Min	Max	Average	Std.Dev.	Min	Max	Average	Std.Dev.	Min	Max	Average	Std.Dev.
Average Flood Depth (cm)	**3.1**	**125.1**	**23.6**	**28.9**	**0.8**	**113.4**	**17.0**	**21.4**	**0.3**	**104.6**	**12.8**	**14.9**
Barataria Bay	6.3	32.2	13.0	4.9	5.3	23.6	10.4	3.8	4.8	22.5	10.0	3.1
Timbalier / Terrebonne	3.3	40.0	11.2	7.3	2.9	24.8	8.8	5.3	3.1	21.7	8.2	4.5
Biloxi Marsh	3.1	80.4	26.9	30.0	4.6	15.8	9.4	3.5	3.5	12.1	8.8	2.9
Chandeleur	3.3	29.1	13.5	7.4	3.7	18.8	8.2	4.7	3.2	14.8	7.4	3.6
Delta	5.6	125.1	86.5	26.1	0.8	113.4	60.6	26.2	0.3	104.6	40.8	28.1
Flood Event Count	**1**	**1464**	**231**	**280**	**1**	**1427**	**195**	**186**	**1**	**1585**	**212**	**196**
Barataria Bay	30	340	150	53	60	378	157	55	94	719	175	107
Timbalier / Terrebonne	14	1277	288	257	87	706	222	127	38	755	233	133
Biloxi Marsh	1	257	143	95	91	233	157	50	130	245	167	41
Chandeleur	11	1464	478	457	70	1427	410	319	153	1585	411	350
Delta	1	106	6	23	1	14	3	4	1	135	24	40
Flood Event Duration (hours)	**1**	**5425**	**827**	**1879**	**1**	**5425**	**629**	**1651**	**2**	**5425**	**267**	**1047**
Barataria Bay	10	2725	106	414	7	558	33	90	4	56	18	11
Timbalier / Terrebonne	1	572	32	97	1	46	11	9	3	34	10	6
Biloxi Marsh	3	5425	1196	2222	6	22	11	6	4	22	11	6
Chandeleur	1	529	39	104	1	29	8	8	2	17	7	5
Delta	7	5425	5064	1252	3	5425	4072	2047	3	5425	2013	2330
Total Inundation Duration (hours)	**353**	**5425**	**3484**	**1395**	**5**	**5425**	**2732**	**1605**	**3**	**5425**	**2587**	**1479**
Barataria Bay	1247	5425	3475	1062	823	5136	2766	1196	921	5212	2739	1056
Timbalier / Terrebonne	410	5373	2784	1148	337	4851	2049	1167	206	5289	2066	1143
Biloxi Marsh	659	5425	2945	1818	523	5382	2014	1675	671	5425	1963	1730
Chandeleur	353	5425	3659	1283	373	4866	2113	1221	520	3875	2174	1092
Delta	763	5425	5203	1017	5	5425	5130	1241	3	5425	4588	1834
Flood Frequency (%)	**7%**	**100%**	**64%**	**26%**	**0%**	**100%**	**50%**	**30%**	**0%**	**100%**	**48%**	**27%**
Barataria Bay	23%	100%	64%	20%	15%	95%	51%	22%	17%	96%	50%	19%
Timbalier / Terrebonne	8%	99%	51%	21%	6%	89%	38%	22%	4%	97%	38%	21%
Biloxi Marsh	12%	100%	54%	34%	10%	99%	37%	31%	12%	100%	36%	32%
Chandeleur	7%	100%	67%	24%	7%	90%	39%	23%	10%	71%	40%	20%
Delta	14%	100%	96%	19%	0%	100%	95%	23%	0%	100%	85%	34%
Weighted Average Flood Depth (cm)	**3.7**	**125.1**	**28.0**	**27.5**	**1.1**	**113.4**	**20.9**	**20.5**	**0.3**	**104.6**	**16.9**	**14.7**
Barataria Bay	9.1	34.5	17.5	6.0	7.8	31.0	14.6	5.4	8.4	29.0	14.3	4.8
Timbalier / Terrebonne	6.8	50.4	16.3	8.0	5.3	27.8	12.9	5.4	2.5	24.6	12.2	4.6
Biloxi Marsh	7.4	80.4	30.4	28.3	7.9	20.5	12.6	3.8	8.1	13.4	11.9	1.9
Chandeleur	3.7	46.2	20.3	9.6	5.6	28.5	13.1	6.0	4.9	21.6	12.8	4.7
Delta	7.1	125.1	86.8	25.5	1.1	113.4	62.4	24.6	0.3	104.6	44.3	27.2

Table 2. Average distance from shore for each CWV zone by region

Area	Average Zone 1 Distance (m)	Average Zone 2 Distance (m)	Average Zone 3 Distance (m)
Barataria Bay	1.9	8.1	14.2
Timbalier / Terrebonne	1.7	8.2	14.4
Biloxi Marsh	1.4	9.6	16.9
Chandeleur	2.1	8.9	15.9
Delta	1.8	9.2	14.9

References

Center for Operational Oceanographic Products and Services (CO-OPS). 2013a. *Barataria Bay TCARI Grids in Response to Deepwater Horizon Oil Spill, Gulf of Mexico*. NOAA.

Center for Operational Oceanographic Products and Services (CO-OPS). 2013b. *Biloxi Marsh TCARI Grids in Response to Deepwater Horizon Oil Spill, Gulf of Mexico*. NOAA.

Center for Operational Oceanographic Products and Services (CO-OPS). 2013c. *Chandeleur Island TCARI Grids in Response to Deepwater Horizon Oil Spill, Gulf of Mexico*. NOAA.

Center for Operational Oceanographic Products and Services (CO-OPS). 2013d. *Delta TCARI Grids in Response to Deepwater Horizon Oil Spill, Gulf of Mexico*. NOAA.

Center for Operational Oceanographic Products and Services (CO-OPS). 2013e. *Summary of the TCARI Work for the Terrebonne Bay and Vicinity*. NOAA.

Center for Operational Oceanographic Products and Services (CO-OPS). 2013f. Comparison of 9999618 CRMS 0292-H01 A with 8762075 Port Fourchon, Belle Pass LA. NOAA.

Lindley C, Gill S, Allen A, and Huang L. 2011. Utilizing Tidal Constituent and Residual Interpolation to Simulate Water Levels and Determine patterns of Inundation. Proceedings of the 2011 Solutions to Coastal Disasters Conference, June 25-29, 2011, Anchorage, Alaska: 491-501

NOAA, 2011, Sampling and Monitoring Plan for the Assessment of MC252 Oil Impacts to Coastal Wetland Vegetation in the Gulf of Mexico, August 4, 2011; http://www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data/

Attachments:

Appendix A: Barataria Bay TCARI Grids in Response to Deepwater Horizon Oil Spill, Gulf of Mexico

Appendix B: Biloxi Marsh TCARI Grids in Response to Deepwater Horizon Oil Spill, Gulf of Mexico

Appendix C: Chandeleur Island TCARI Grids in Response to Deepwater Horizon Oil Spill, Gulf of Mexico

Appendix D: Delta TCARI Grids in Response to Deepwater Horizon Oil Spill, Gulf of Mexico

Appendix E: Summary of the TCARI Work for the Terrebonne Bay and Vicinity

Appendix F: Comparison of 9999618 CRMS 0292-H01 A with 8762075 Port Fourchon, Belle Pass LA

Appendix G: Compendium of Standard Operating Procedures (SOPs) provided by CO-OPS