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Change in the Length of the Northern Section of the Chandeleur Islands Oil Berm, September 5, 2010, through September 3, 2012

By N.G. Plant and K.K. Guy

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Introduction

On April 20, 2010, an explosion on the Deepwater Horizon oil rig drilling at the Macondo Prospect site in the Gulf of Mexico resulted in a marine oil spill that continued to flow through July 15, 2010. One of the affected areas was the Breton National Wildlife Refuge, which consists of a chain of low-lying islands, including Breton Island and the Chandeleur Islands, and their surrounding waters. The island chain is located approximately 115–150 kilometers (km) north-northwest of the spill site (fig. 1). A sand berm was constructed seaward of, and on, the island chain. Construction began at the northern end of the Chandeleur Islands in June 2010 and ended in April

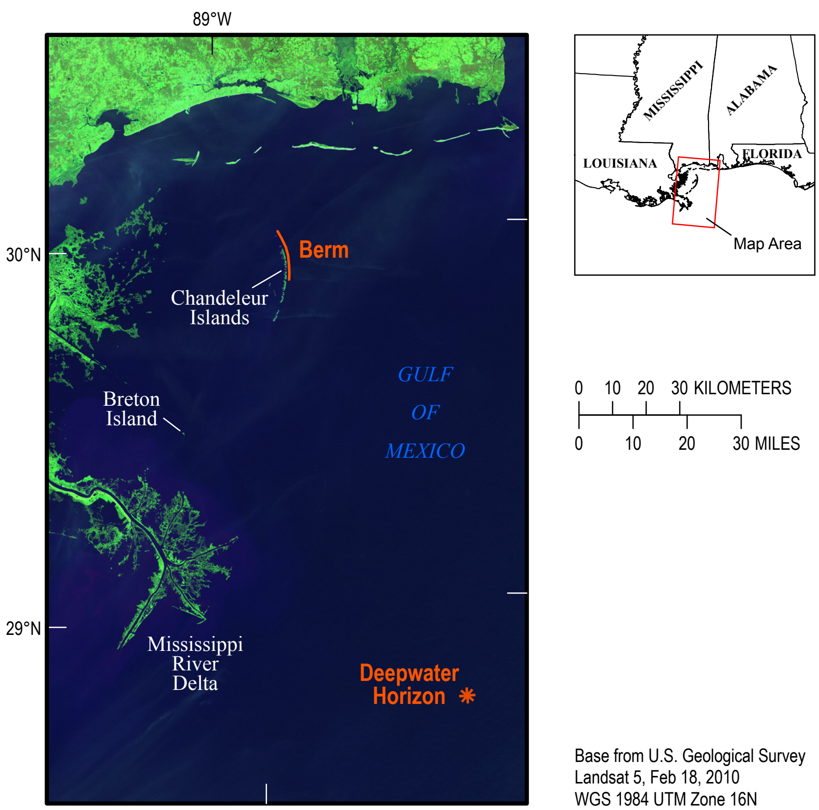

Figure 1. Chandeleur and Breton Islands (part of the Breton Island National Wildlife Refuge), the Mississippi River Delta, the site of the Deepwater Horizon oil spill, and the location of the full extent of the Chandeleur Islands berm. The background image is U.S. Geological Survey Landsat 5 taken February 18, 2010, prior to the start of berm construction.

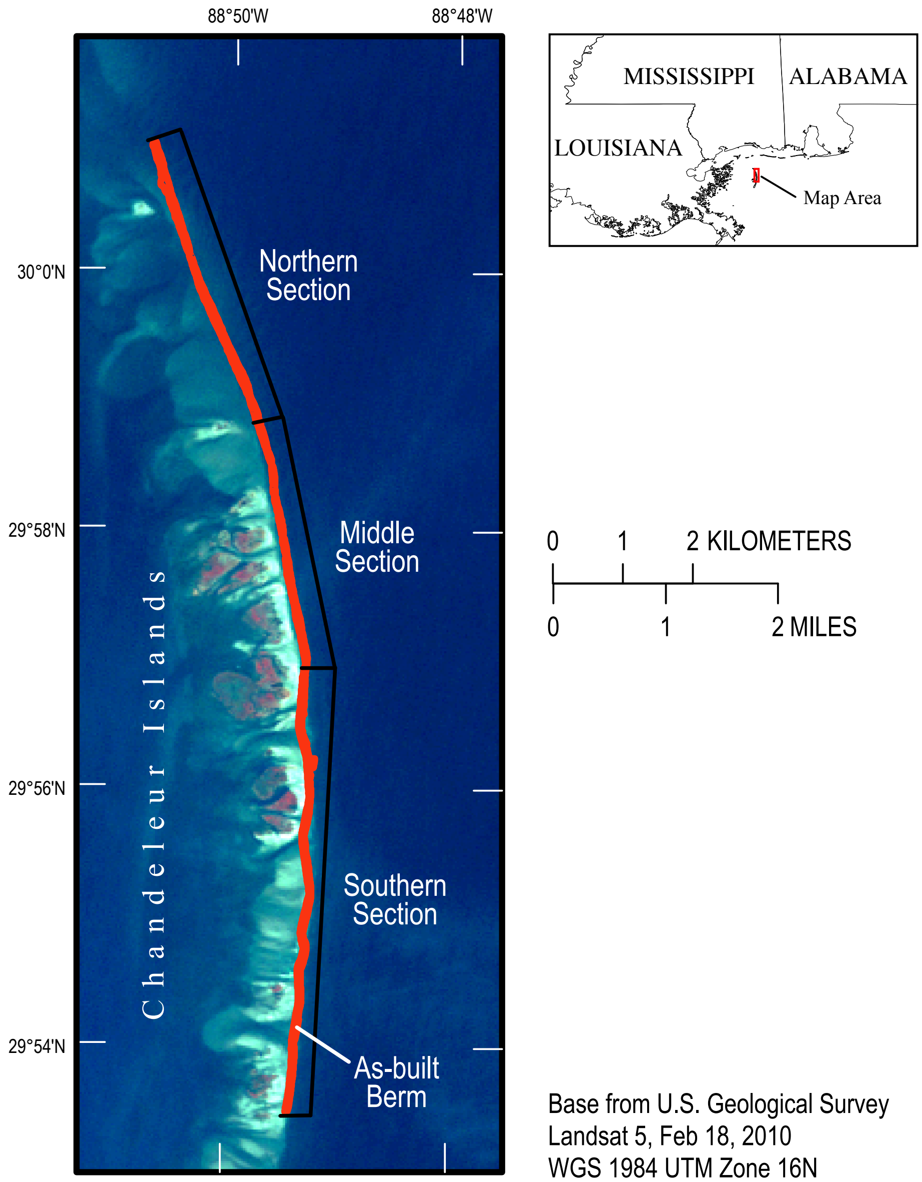

Figure 2. The Chandeleur Islands berm divided into northern, middle, and southern sections. The as-built berm footprint is shown in orange. The background image is U.S. Geological Survey Landsat 5 taken February 18, 2010, prior to the start of berm construction.

2011. The berm consisted of three distinct sections based on where the berm was placed relative to the islands (fig. 2). The northern section of the berm was built in open water on a submerged portion of the Chandeleur Islands platform. The middle section was built approximately 70–90 meters (m) seaward of the Chandeleur Islands. The southern section was built on the islands' beaches. Repeated Landsat and SPOT satellite imagery and airborne lidar were used to observe the disintegration of the berm over time. The methods used to analyze the remotely sensed data and the resulting, derived data for the northern section (fig. 3) are reported here.

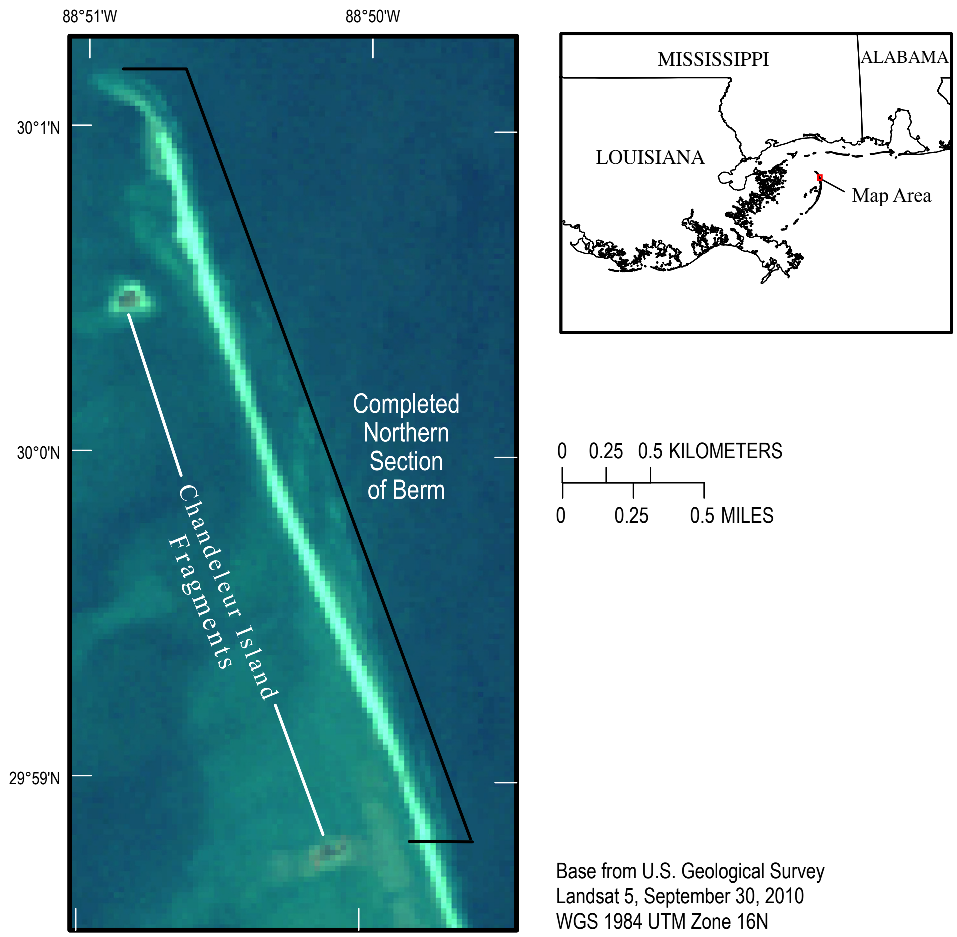

Figure 3. The completed northern section of the Chandeleur Islands berm. This U.S. Geological Survey Landsat 5 image was taken September 30, 2010.

Methods

The Chandeleur Islands berm was built approximately 50-m wide (above mean high water) and 2-m high relative to the North American Vertical Datum of 1988 (NAVD 88) and using the 1996 Geoid model (Geoid 96). Because of the large size of the berm combined with the highly reflective nature of sand, observations from satellite imagery were possible. Medium resolution (5–30 m) Landsat and SPOT satellite imagery (table 1) provided relatively frequent observation opportunities. Additionally, three high resolution lidar elevation datasets were used for measuring berm length. A total of 54 observations were made from September 5, 2010, the first date usable satellite imagery was available after the completion of the northern section of the berm, to September 3, 2012, when the berm no longer occupied its as-built footprint. For the purpose of these berm-length measurements, only those portions of the berm that occupied its as-built footprint (as estimated from a sequence of SPOT satellite images obtained during the construction period: September 5, 2010; October 1, 2010; December 7, 2010; and April 3, 2011) were measured.

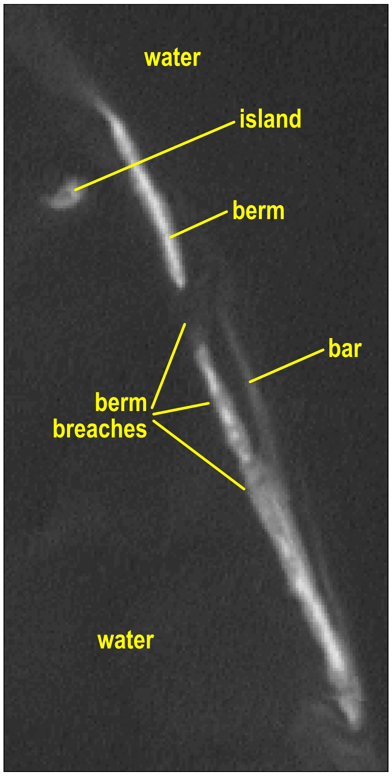

Figure 4. Example of a panchromatic image. Water, island, bar, berm, and breaches in the berm are labeled. The dry sand berm appears as light grays to white, the water as darker shades of gray, and the wet sand of the berm breaches as mid-tone grays.

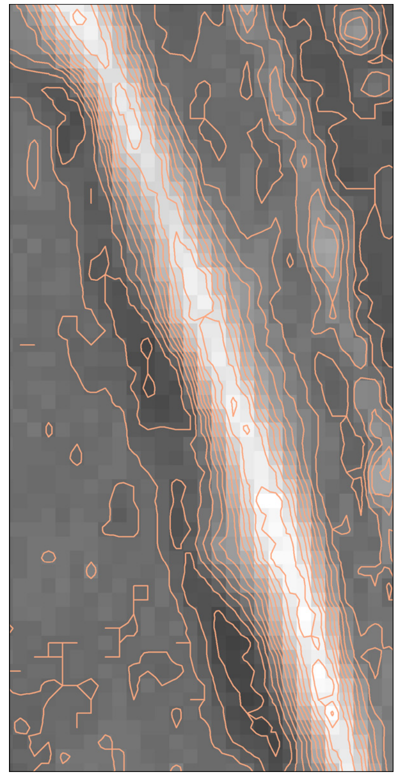

Figure 5. Example of isolines generated on the basis of pixel value. The isolines are drawn in pink on top of the U.S. Geological Survey Landsat 7 panchromatic image from which they were made. The berm is the wide, light streak of pixels running from the upper left to the lower right of the figure. The mid-tone grays in the upper right are waves.

Table 1. Satellite multispectral and panchromatic image resolutions.

Satellite	*Multispectral resolution*	*Panchromatic resolution*
SPOT 4	20 m	10 m
SPOT 5	10 m	5 m
Landsat 5	30 m	(none)
Landsat 7	30 m	15 m

Satellite images were selected on the basis of availability, clear view of the berm, and resolution (ground sampling interval or cell size). The sensors on Landsat 5, Landsat 7, SPOT 4, and SPOT 5 differ in their spectral bands and resolution (table 1). When available, panchromatic bands were used because of their higher resolutions. When not available, single bands from the multispectral images were selected. Band 5 (1.55 to 1.75 micrometers (µm)) at 30-m resolution was used for Landsat 5 images. Of the twelve 20-m resolution multispectral SPOT 4 images used, band 1 (0.50 to 0.59 µm) was used for 11 dates and band 3 (0.78 to 0.89 µm) was used for 1 date (table 2).

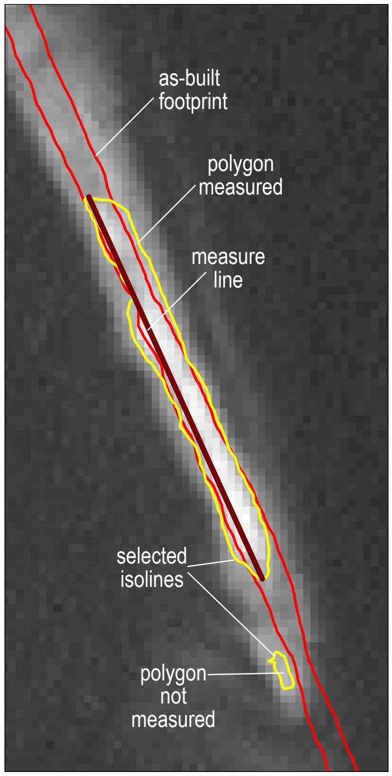

Figure 6. Example of berm-length measurement. The red line represents the berm's as-built footprint. One yellow line encloses a small area that appears to be on the berm; however, this area does not fall within the as-built footprint. Therefore, this area is no longer considered part of the berm and is not measured. A second yellow line encloses a larger area and mostly falls within the as-built footprint. The brown line represents the resulting berm-length measurement.

Water has lower reflectivity than sand in the satellite images and, therefore, has a lower pixel intensity value. In a typical gray-scale representation where low values are dark and high values are light, water will appear dark and sand will appear very light or white. Wet sand is less reflective than dry sand and appears in mid-tone grays (fig. 4). The relatively high pixel values of dry sand were used to delimit the berm footprint. This method is subject to bias errors caused by differences in water levels when different images were acquired, and no corrections for these biases have been made here. The water levels from a nearby location (Station 8761305, Shell Beach, Louisiana), referenced to the mean sea level datum, are included in this report (table 2).

Each image was visually examined to determine the footprint of the berm. Isolines based on pixel values were generated for each image using the Contour tool in ArcGIS® (fig. 5). A contour interval of 5 intensity units was used for Landsat 5 band 5, SPOT 4, and SPOT 5 images (fig. 5), and a contour interval of 2 intensity units was used for Landsat 7 panchromatic images. Because the pixel-intensity values for water, dry sand, and wet sand were not consistent between images, fixed contour levels were not used to delineate the berm. Instead, the contours were overlaid on the image and one of these contours was selected to represent the footprint of each berm segment as a polygon in the geographic information system (GIS). This footprint was then used to measure the length of the berm segment. Only those portions of the berm footprint that occupied the original as-built footprint were used to measure berm length (fig. 6). Once sand was moved beyond the as-built footprint by overwash, inundation, or breaching, it no longer contributed to the measured length of the berm.

The berm footprints obtained from three lidar elevation datasets were based on elevation rather than reflectivity. Contours were generated at 10-centimeter (cm) intervals and were compared to the berm footprints obtained from satellite imagery. The 100-cm (NAVD 88, Geoid 96) contour was selected to represent the subaerial portion of the berm. This level is well above the typical water level, allowing retrieval of topographic lidar from each survey. Similarly to the treatment of the satellite imagery, berm-length measurements were estimated where the 100-cm lidar-elevation contour fell within the as-built footprint. Some clusters of small polygons appeared in the lidar berm footprints. These clusters were measured as if they were one large polygon.

Results

The results from the satellite and lidar data analysis are presented in figure 7, which shows a time series of berm lengths derived from each of the sensors. The measurements are listed in table 2. The accuracy of the berm-length measurements was quantified from the differences between sequential length measurements, excluding the large length changes observed on September 6 and 9, 2011, that were associated with storm Lee. The root mean square difference was 243 m.

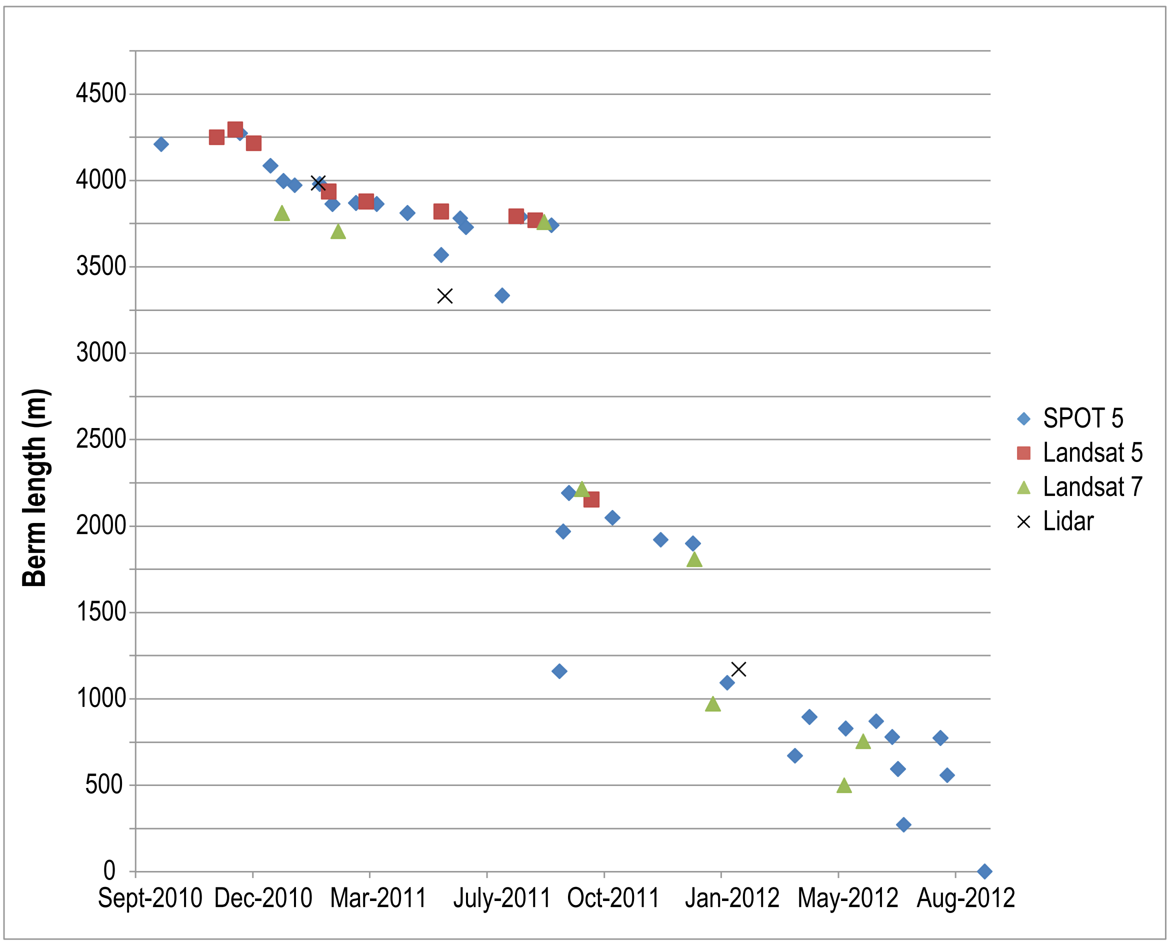

Figure 7. Time series of berm-length measurements from each data source.

Acknowledgments

The data collection and analysis presented in this report were conducted with support from the U.S. Geological Survey's Coastal and Marine Geology Program. The clarity of the report was improved by reviews from C. Sherwood and J. Flocks. We thank B. Boynton, T. Burress, and K. Naugle for editing, producing, and publishing the final document.

Table 2. Berm-length measurements.

Date (MDY)	Image Time (UT)	Sensor	Spectrum	Isoline	Number of Line Segments	Total Length (m)	Water Level (m)	Area of Isoline Polygons (m^2)	Area of Berm (m^2)
9/5/2010	16:34	SPOT 4	band 1	70	2	4287	0.60	236405	215662
10/1/2010	16:23	SPOT 4	band 1	120	3	4209	0.24	224530	170784
12/7/2010	16:33	SPOT 4	band 1	140	1	4274	-0.42	332030	226925
1/2/2011	16:32	SPOT 4	band 1	110	1	4086	-0.14	296380	212314
1/13/2011	16:20	SPOT 4	pan	165	1	3997	-0.32	201112	164848
1/23/2011	16:27	SPOT 4	pan	190	1	3973	-0.32	274364	207905
2/13/2011	16:22	SPOT 4	pan	170	2	3981	-0.67	276848	203383
2/24/2011	16:10	SPOT 4	band 1	220	2	3864	-0.22	250067	181192
3/16/2011	16:25	SPOT 4	pan	220	1	3871	-0.09	300387	206710
5/28/2011	16:18	SPOT 4	pan	225	4	3569	0.25	184313	152353
6/13/2011	16:09	SPOT 4	pan	50	2	3783	0.34	218465	171980
6/18/2011	16:13	SPOT 4	pan	65	2	3729	0.07	205332	169886
7/19/2011	16:15	SPOT 4	pan	175	5	3335	0.24	142460	128903
8/4/2011	16:06	SPOT 4	pan	200	1	3791	0.00	245299	183110
8/30/2011	16:05	SPOT 4	band 3	185	2	3740	-0.01	236669	144353
9/9/2011	16:13	SPOT 4	pan	220	11	1969	0.30	86258	77147
9/14/2011	16:16	SPOT 4	pan	235	11	2191	-0.18	124252	60368
10/21/2011	16:02	SPOT 4	band 1	140	8	2048	0.04	125974	69291
12/1/2011	16:12	SPOT 4	pan	215	13	1921	0.04	94628	55188
1/27/2012	16:12	SPOT 4	band 1	170	4	1094	-0.17	35988	35657
3/25/2012	15:53	SPOT 4	band 1	185	7	671	0.17	15855	15537
6/16/2012	15:51	SPOT 4	pan	60	9	780	0.64	21563	21126
6/21/2012	15:55	SPOT 4	pan	60	6	594	0.55	14432	14363
6/26/2012	15:58	SPOT 4	pan	45	6	271	0.65	4071	3953
7/27/2012	16:00	SPOT 4	band 1	80	4	774	0.27	30992	26120
8/2/2012	15:44	SPOT 4	band 1	190	4	558	0.10	21987	12036

Table 2. Berm-length measurements.—Continued

Date (MDY)	Image Time (UT)	Sensor	Spectrum	Isoline	Number of Line Segments	Total Length (m)	Water Level (m)	Area of Isoline Polygons (m^2)	Area of Berm (m^2)
4/3/2011	16:36	SPOT 5	pan	200	2	3864	-0.11	163295	155541
4/29/2011	16:35	SPOT 5	pan	220	1	3811	0.19	293933	198091
9/6/2011	16:34	SPOT 5	pan	180	15	1159	0.56	21958	21791
12/29/2011	16:40	SPOT 5	pan	180	11	1900	-0.17	54728	51267
4/6/2012	16:33	SPOT 5	pan	185	17	895	0.23	15599	15559
5/7/2012	16:36	SPOT 5	pan	220	13	828	0.45	14011	13999
6/2/2012	16:35	SPOT 5	pan	135	14	870	0.40	14779	14732
9/3/2012	16:44	SPOT 5	band 1		0	0	0.03	0	0
11/17/2010	16:15	Landsat 5	band 5	60	3	4251	0.19	213683	196434
12/3/2010	16:16	Landsat 5	band 5	60	1	4294	-0.48	327139	224936
12/19/2010	16:16	Landsat 5	band 5	65	1	4215	-0.19	308113	217324
2/21/2011	16:16	Landsat 5	band 5	75	1	3935	-0.17	325223	206750
3/25/2011	16:16	Landsat 5	band 5	65	1	3877	-0.01	364934	203410
5/28/2011	16:15	Landsat 5	band 5	80	1	3820	0.25	382134	199462
7/31/2011	16:15	Landsat 5	band 5	70	1	3793	0.23	283368	195406
8/16/2011	16:15	Landsat 5	band 5	110	2	3772	0.08	239345	177599
10/3/2011	16:14	Landsat 5	band 5	120	6	2154	0.21	103317	85999
1/12/2011	16:19	Landsat 7	pan - band 8	42	4	3813	-0.39	215844	186296
3/1/2011	16:19	Landsat 7	pan - band 8	52	4	3707	-0.20	300342	191166
8/24/2011	16:19	Landsat 7	pan - band 8	78	3	3759	0.35	204096	147228
9/25/2011	16:19	Landsat 7	pan - band 8	60	7	2213	0.22	120897	93973
12/30/2011	16:20	Landsat 7	pan - band 8	52	6	1809	-0.05	79836	64407
1/15/2012	16:20	Landsat 7	pan - band 8	60	7	972	-0.39	55414	34659
5/6/2012	16:21	Landsat 7	pan - band 8	78	6	501	0.47	11546	11536
5/22/2012	16:21	Landsat 7	pan - band 8	94	5	755	0.16	23029	22069

Table 2. Berm-length measurements.—Continued

Date (MDY)	Image Time (UT)	Sensor	Spectrum	Isoline	Number of Line Segments	Total Length (m)	Water Level (m)	Area of Isoline Polygons (m^2)	Area of Berm (m^2)
2/12/2011		Lidar	elevation - cm	100	1	3985		148019	127343
5/31/2011		Lidar	elevation - cm	100	15	3332		77453	71713
2/6/2012		Lidar	elevation - cm	100	11	1171		25314	24035

Date (MDY) = Date in month/day/year format.

Image Time (UT) = Universal Time that image was acquired in hours and minutes (HH:MM).

Sensor = Image source type.

Spectrum = The satellite image band used or, for lidar, the elevation used, in centimeters.

Isoline = Satellite image pixel value or lidar elevation of contour line used to delineate berm.

Number of Line Segments = Number of line segments in berm measurement.

Total Length (m) = Total length of berm, in meters.

Water Level (m) = Water level Shell Beach, Louisiana, tide station, at the time of image collection, in meters using Mean Sea Level as the datum.

Area of Isoline Polygons (m^2) = Area of isoline polygons falling, at least in part, within the as-built footprint, in square meters.

Area of Berm (m^2) = Area of the portion of the isoline polygons that fall within the as-built footprint, in square meters.