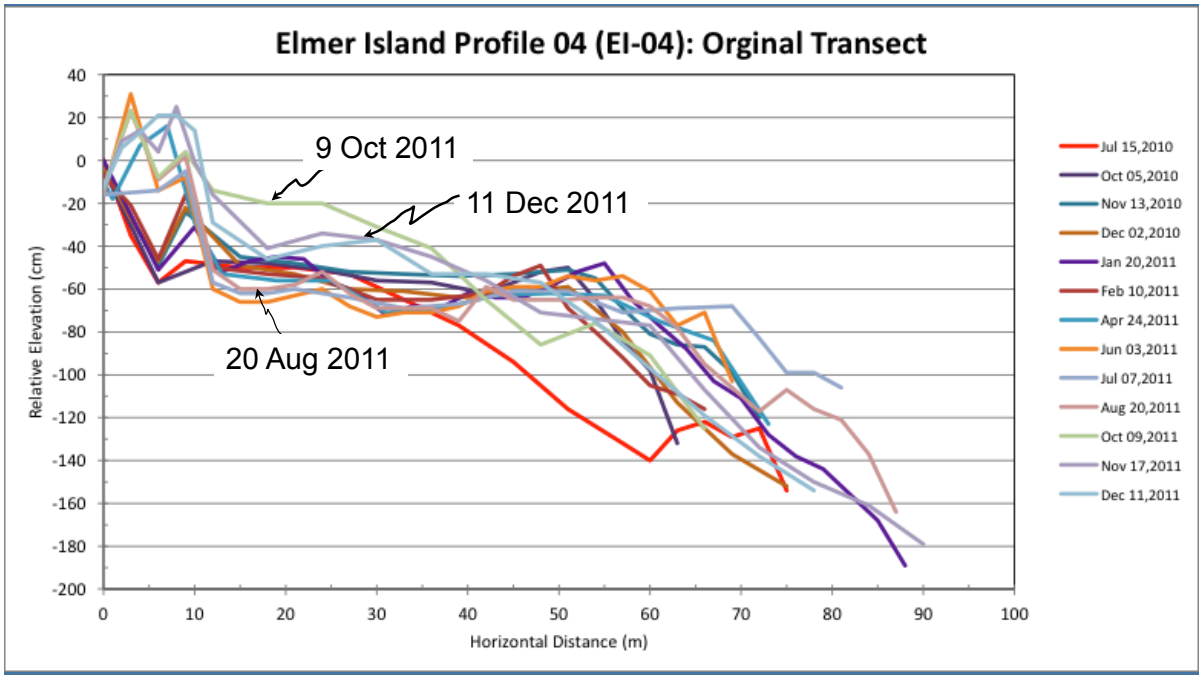
Appendix C: Use of Beach Profile Data for Interpreting Beach Morphological Changes and for Planning Purposes

Use of Beach Profile Data for Interpreting Beach Morphological Changes and for Planning Purposes



By

Duncan FitzGerald, Mark Kulp & Shannon MacDonald

Polaris/SCAT

8 November 2013

INTRODUCTION

A total 112 beach profile stations were set-up along 11 barriers on four of Louisiana's barrier arcs (Appendix 1; Table 1). There are 5 to 16 stations on each barrier and surveys were run every one to three months (Table 2). Two additional profiles were established on Grand Isle at Wild Beach and two on Elmers Island at Caminada Pass in February 2013. These new survey sites were established to track morphological changes of the beaches in the vicinity of SR mat removal sites. This report discusses the beach profile network, oil burial, and how the beach profile data were used to assess possible locations of subsurface oil and plan exploration programs, such the Louisiana Augering and Sequential Recovery (LAASR), Louisiana Buried Oil Project (BOP), and Snorkel SCAT.

Buried oil can be primary or secondary in origin and can exist in a number of environments (Figure 1). Primary oil is oil that came ashore, grounded to the substrate, and was subsequently buried. Secondary oil consists of surface residue balls and patties that broke off from oil residue mats and were buried, generally in the nearshore, but also along the beachface and in the supratidal zone. Although burial of secondary oil was commonly due to sand moved by waves, wind also played an important role in covering primary and secondary oil in the supratidal zone. The erosional-depositional history of the beach determined if buried oil was subsequently excavated by a storm and exposed along the beach or nearshore. The repetitive beach profile surveys recorded the morphological changes to the beach and became a valuable tool to search for possible buried oil.

Table 1. List of Barriers and Beach Profile Sites

1. Barataria:	*Fourchon Beach*
	Elmers Island
	Grand Isle
	Grand Terre I
	Grand Terre II
	Grand Terre III
2. Timbaliers:	*West Timablier*
3. Isle Derniers:	*Trinity Island*
	Whiskey Island
4. Delta:	*Southwest Pass*
	South Pass Spit

Table 2. Beach profile locations

Location	# of Profiles	Distance Between Profiles (m) (Approximate)	Initial Survey Date	Latest Survey Date
Elmers Island	12	500	2010/07/15	2013/10/12
Fourchon Beach	16	1000	2010/08/28	2013/10/12
Grand Isle	12	500	2010/08/27	2013/10/12
Grand Terre 1	12	500	2010/11/23	2013/08/06
Grand Terre 2	10	500	2010/08/25	2013/08/22
Grand Terre 3	5	500	2010/11/23	2013/08/07
South Pass	7	150	2010/12/21	2012/07/12
Southwest Pass	6	900	2011/03/25	2012/04/20
West Timbalier	5	1700	2011/08/01	2013/08/13
Whiskey Island	7	1100	2011/04/03	2012/06/04
Trinity Island	10	1000	2011/04/10	2012/12/01
Caminada Pass (Elmers Island)	2	80	2011/02/16	2013/08/21
Wild Beach (Grand Isle)	2	20	2013/02/16	2013/08/18

Mat Formation

A Surface Residue mat (SR mat) is a cohesive layer of sand and oil residue. Mats are found in a variety of environments and are formed by three primary mechanisms related to oil (emulsified oil called mousse) coming ashore:

A. Oil moved into the swash zone and mixed with sand that was entrained and suspended from seabed by wave swash and backwash on the beachface. The sand and oil slurry formed by this process was deposited in a variety of environments (Figure 1):

   1) transported to washover fans
   2) stranded in the supratidal zone at the base of dunes
   3) ponded in berm runnels of ridge and runnel systems
   4) grounded along the intertidal and sub-tidal zones
   5) attached to lower and subtidal remnant marsh and mangrove exposures

B. Floating oil washed ashore and became stranded by the falling tide. In the warm sun the oil seeped into the sand and stabilized in the upper to lower intertidal zone.

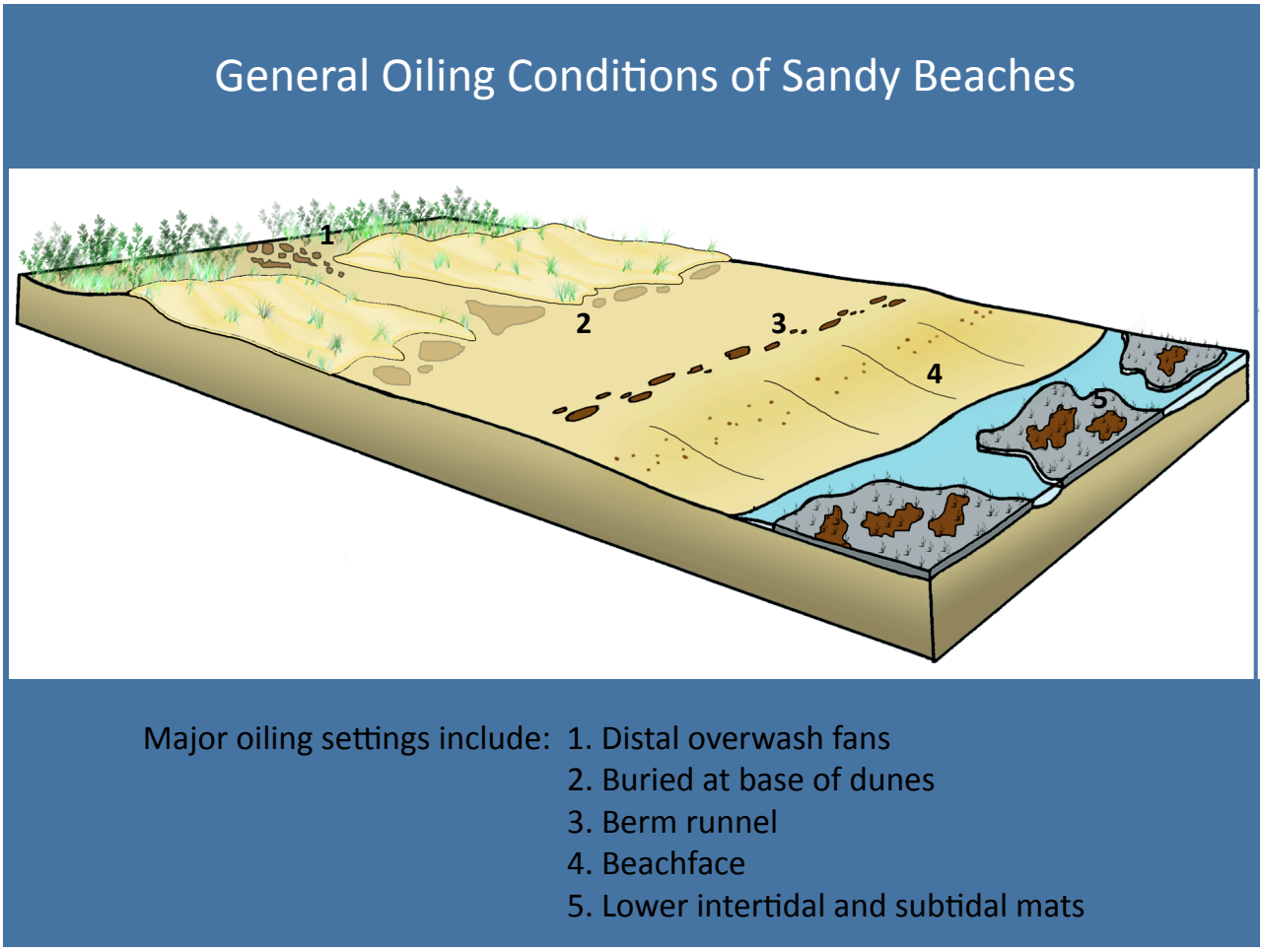


Figure 1. Conceptual diagram showing environments where the oil came ashore and was stranded (see text for discussion)

C. The turbulence produced by plunging breaking waves suspended sand from the seabed moving it vertically toward the water surface and mixing it into floating oil. This sand and oil slurry gradually increased in density as more sand was added, eventually reaching a threshold when it became denser than seawater and sank to the bottom.

Due to variability in bottom topography, height of the waves, type of wave, secondary flow interaction, and range in seabed conditions (e.g., existence or absence of bedforms, variability in grain size, presence of shell or organic matter), the concentration and rate of sediment mixing into the floating oil was non-uniform. Thus, the density threshold at which the sand oil agglomerate sank to the bottom was certainly variable, both spatially and temporally. It is likely that the density threshold occurred on a small scale and globules rather than large agglomerates sank to the bottom. Once reaching the bottom, the globules recombined to form discontinuous and variable dimension agglomerates. As more sediment was added to the agglomerates, mats formed and stabilized to the substrate.

Beach Profile Method

Beach profile surveys utilized the Emery Method, a simple but accurate technique that coastal geologists have been using since it was first introduced in 1961. It relies on two graduated stakes and a measured distance between them. As shown in Figure 2, the stakes are aligned and the reader notes where the horizon intersects one of the rods (read off back stake means an elevation drop and off the front stake means a rise in elevation). A detailed description of the method is given in Appendix 2.

Quality Assurance/Quality Control

The QA/QC process is used to verify that the profile data are reliable and it involves a number of steps. As data are entered into the database, an initial screening is performed to ensure the stake heights are logical and that data have been entered accurately. Data are plotted against previous surveys, which helps to confirm that it represents the profile indicated in the field notes and any anomalies are checked against the comments. For example, sand piles created by Operations during the cleanup process may appear unnatural in plotted data, but the notes make it clear why the irregularity exists. A more rigorous QA/QC process is undertaken periodically that involves a detailed review of the data. Each profile is examined systematically

Figure 2. Photograph illustrating the beach profile method.

by comparing the plotted data to all previous surveys. Stake resets, stake re-positioning, and storm events are all taken into account and any corrections to the data are made at this time. At this stage, decisions are also made to accept or reject individual data sets. Data may be rejected for a variety of reasons, such as systematic errors by the field team or a poor horizon on the day of the survey. A record is kept of the rejected datasets and no data are ever deleted from the database. A record is kept of any corrections made to the field notes and the person who made the corrections initials the changes.

STORM EVENTS AND EROSION

In the spring of 2010 the beaches had undergone an extensive period of frontal storm erosion that was compounded by intense thunderstorms. These storms produced short period waves that continued to erode the beaches. After the oil came ashore and stranded, weather patterns changed and there was a prolonged period of low wave energy leading to sand movement back onto the beaches. During this period, beaches prograded and built vertically burying oil along different parts of the shore by as much as 80 cm of sand.

During the ensuing three years (2010-2013) the Gulf Coast was subjected to several major storm systems that eroded the beaches and exposed oil, including:

- Hurricane Alex, 28 June 2010
- Tropical Storm Bonnie, 22 July 2010
- Tropical Storm Lee, 2 September 2011
- Hurricane Isaac, 29 September 2012 (Figure 3)

Figure 3. Storm track of Hurricane Isaac. White dots indicate where it reached Category 1 status.

One of the more important storms, in terms of exposing previously undocumented buried oil, was Hurricane Isaac that impacted the Louisiana coast in late August of 2012. It formed in the mid-Atlantic and tracked west and then northwestward into the Gulf of Mexico. It reached hurricane status on 28 August when located approximately 115 km south-southeast of the mouth of the Mississippi River. Isaac made a landfall late on the 28th of August just southwest of the mouth of the Mississippi River with wind velocities exceeding 130 km/hr. After moving again over water, Isaac made a second landfall just west of Fourchon Beach on the morning of August 29th maintain its strength. Hurricane Isaac was a slow moving Category #1 storm that produced a 1.5 m high storm surge for a period lasting almost 24 hours. During this time, onshore winds generated 3-m high waves that pounded the central Louisiana coast causing extensive erosion and lowland flooding, widespread washovers and breaches, damage to numerous structures and facilities, and almost total shoreline retreat. A comparison of beach profile overlays provided a means of determining the impact of Isaac in eroding the beach to a depth beneath the Summer 2010 oiling horizon. Looking at a beach profile station El-03 at the eastern end of Elmers Island,

it is seen that the elevation of the beach when the oil was coming ashore (July 2010) is substantially below the beach level following Hurricane Isaac (Figure 4). This indicated that despite the substantial storm-induced erosion, oil could still have been buried along this section of beach, particularly in the lower portion of the beach and in the supratidal zone.

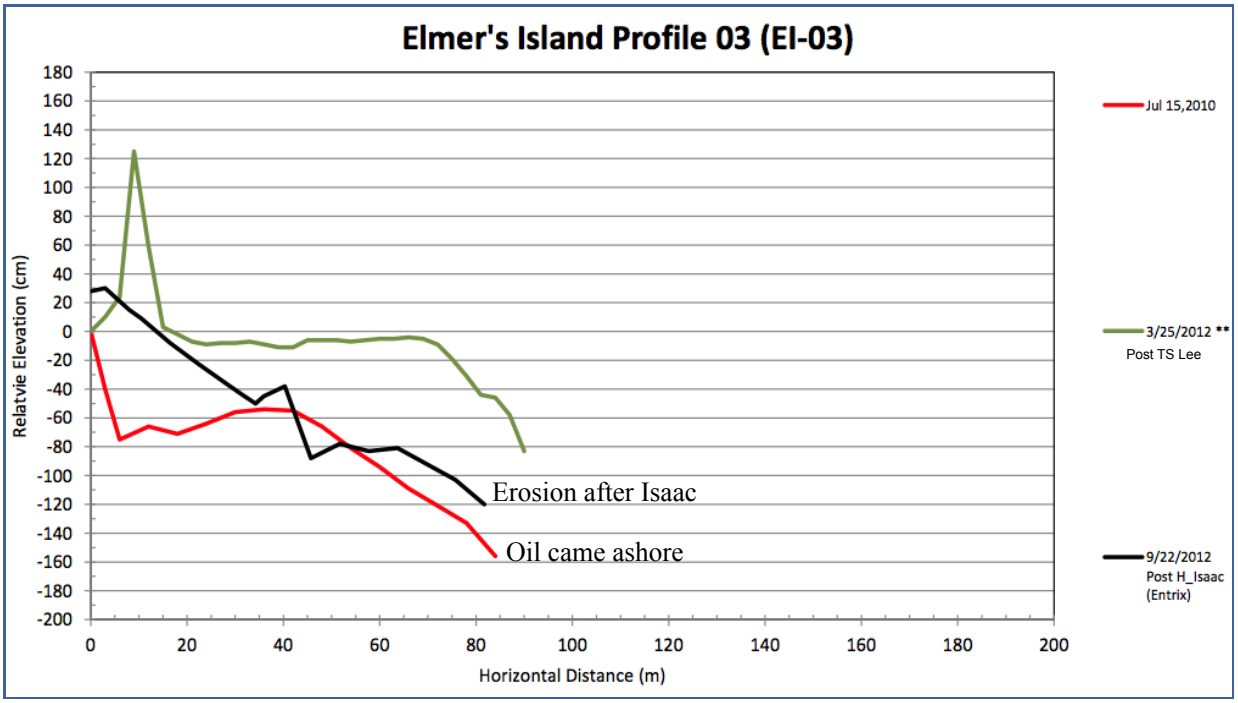


Figure 4. Beach profile overlays illustrating a location of possible buried oil.

When the beach profile overlays were analyzed following Hurricane Isaac, a close correlation was found to exist between the presence of unburied SR mats and areas along the barriers where profile data indicated that erosion levels had not penetrated the Summer 2010 oiling horizon. For example, SR mats were found on Grand Terre 2, Grand Terre 1, Grand Island, and Elmer's Isle in the lower intertidal along sections of beach where Isaac or previous storms had not deeply exhumed the lower beach (e.g., Grand Isle; Figure 5).

LOUISIANA PLAN FOR FINDING BURIED OIL

In the fall of 2012, the Response in Louisiana began pursuing buried oil by using a variety of techniques depending on the area of the beach being explored, thickness of overburden, and depth to the marsh platform. By the winter of 2013, the search for SR mats buried beneath the sand and underwater was formalized into onshore (Auger) and nearshore (Snorkel SCAT) programs. The augering project, officially called the Louisiana Augering And Sequential Recovery (LAASR) program, relied heavily on the analysis of the beach profile data. In the spring of 2013, the Louisiana Buried Oil Project (BOP) was initiated, which was a program that continued the search and removal buried oil. The strategy in choosing BOP sites was largely based on the

Figure 5. Map showing portions of the barrier (yellow band) where buried oiled sediment may have occurred based on beach profile surveys. Note that all the SR mats that were found following Hurricane Isaac erosion coincided with the yellow band.

analyses of time-sequential aerial imagery and beach profile survey data. Additional information came from Operations activities including collection data (SRB weights collected during Patrol and Maintenance missions), the history of oiled sediment removed from an area, and geo-referenced photography. Aerial imagery was acquired immediately prior to and coincident with initial shoreline oiling (May/June 2010) by the NOAA National Geodetic Survey (NGS) Remote Sensing Division. In addition, the United States Department of Agriculture, Farm Service Agency conducted an aerial imagery that included the AOR as part of their ongoing National Agricultural Imagery Program (NAIP). After the initial oiling phase, acquisition of aerial imagery during the subsequent fall and springs during 2010-2013 period was undertaken by AeroMetric, Inc., under contract to BP (cooperative agreement reached by the Trustees and BP representatives on the Natural Resource Damage Assessment [NRDA] Aerial Imaging Technical Work Group[1]. Details on the image collection and processing are provided in Appendix G. BOP techniques used in exploring for buried oil included augering, hand-dug pits, and Snorkel SCAT. A brief description of these programs, how beach profile data were used to generate the sampling plans, and some results are discussed in the next two sections.

[1] [http://www.gulfspillrestoration.noaa.gov/wp.content/uploads/2011/02/2010_10_11_AERIAL_IMAGERY_Shoreline_and_SAV_Requests.redacted.pdf]

Augering Projects (LAASR & BOP)

The Augering program was initiated to find the remaining buried oil on the beaches as well as to demonstrate where buried oil did not exist. The field teams (2 to 6 teams) headed by SCAT Team Leads in conjunction with Operations, Safety, Agency, and Stakeholder personnel utilized a Cat Auger system to search for buried oil along a pre-designed grid that was based on the analysis of Beach Profile data.

1. Beach Area Determination- The beach profile data were integral in discerning where potential buried oil may have existed along sandy barrier shores and specifically, which tidal zones along the beach (subtidal, intertidal, supratidal) may have contained buried oil as well as at what depth (overburden thickness). For each barrier, we used the initial beach profile survey as the basis for defining the horizon when oil was coming ashore. For barriers in which the profile stations were established during early summer in 2010, the initial beach profile survey was an ideal surface upon which to base potential buried oil. For barriers in which profile stations were set up in late summer or fall when oil had already come ashore, the initial profile served as an indicator of potential buried oil. For example, beach profile stations on Grand Terre II were established in late August of 2010 after oil had grounded and while 2.7 million cubic meters of sediment were being pumped onshore as part of a beach restoration project. Likewise, our stations on Grand Terre 1 were not established until 25

September 2010. Under these types of circumstances, the totality of the beach profile history, identification of previous SR mats, and
beach erosional-depositional patterns were analyzed to formulate a sampling strategy.

Augering locations were largely based on sweep zones of profile surveys (overlays) that demonstrated previous erosional events had not proceeded to a depth recorded when the oil was
coming ashore. Potential buried oil is separated into *Primary Buried Oil*- mousse that came ashore early during the spill, formed mats that were subsequently buried within the beach and *Secondary Buried Oil*- oiled sediment (mostly SR mats) that was excavated and dismantled during storms and pieces of the mat transported to the upper beach and buried. Based on beach profile data, the beaches that showed the greatest likelihood of *Primary Buried Oil* included parts of Fourchon Beach,
Elmer's Island, Grand Isle, and Grand Terre II. On the basis of additional criteria (see above), portions of Grand Terre I, Grand Terre III, and West Timbalier were also identified. A lower threat of *Primary Buried Oil* was predicted for Trinity Island, South Pass Spit, Southwest Pass, and Whiskey Island.

2. Augering Delineation- The exact area along a barrier to be augered was determined by defining sections along beach overlays where erosion had not extended to the 2010 potential oiling horizon (see Appendix 3 for examples). Next, the depth to this horizon was calculated. These locations were then transferred to a map using a color scale to identify different overburden depths. Finally, a map was created that extrapolated the information from one profile station to the profile stations on either side. Examples of how beach profile sections were chosen for augering, how overburden depths were calculated, and how beach auger polygons were created are illustrated in Figures 6, 7 and 8. At Elmer's Station EI-3, most of the area along the profile showed a potential for buried oil at depths ranging from 10 to 90 cm (Figures 6 and 7). Because Profile Stations EI-4 and EI-5 exhibited similar patterns of potential buried oil, including the position along the beach and overburden depths, the auger polygon for Profile Station EI-3 was extended along the beach to Profiles EI-4 and EI-5 (Figure 8). This type of analyses for an entire barrier (Grand Isle) is provided in Appendix 4.

Areas designated for augering not only included the polygons defined by the beach profile data, but also supratidal regions that previously exhibited Secondary Buried Oil (concentrations of SRB's and SRP's) as well as washover fans that were not included in beach profile surveys. Some washover fans accumulated floating oil that washed onshore during storm and elevated tide events (e.g., Hurricane Alex). This oil was subsequently buried by overwash sedimentation and/or
aeolian deposition.

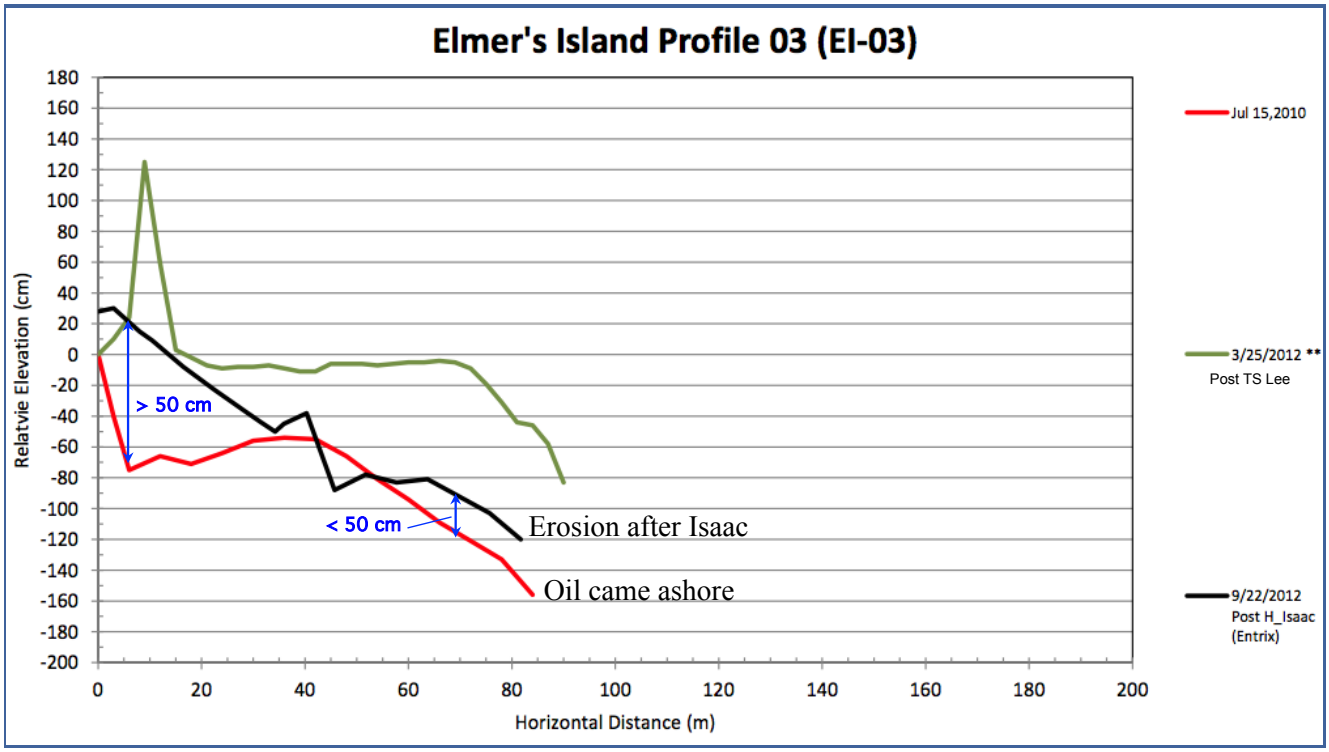


Figure 6. Beach profile overlays for station EI-3 illustrating the initial survey (red line) when oil was coming ashore compared to two storm events that significantly eroded the beach. The fact that these storms did not erode below the summer 2010 beach surface (red line) indicates that sections along this beach may have had buried oil.

Figure 7. Overburden information is transferred to maps so polygons can be constructed.

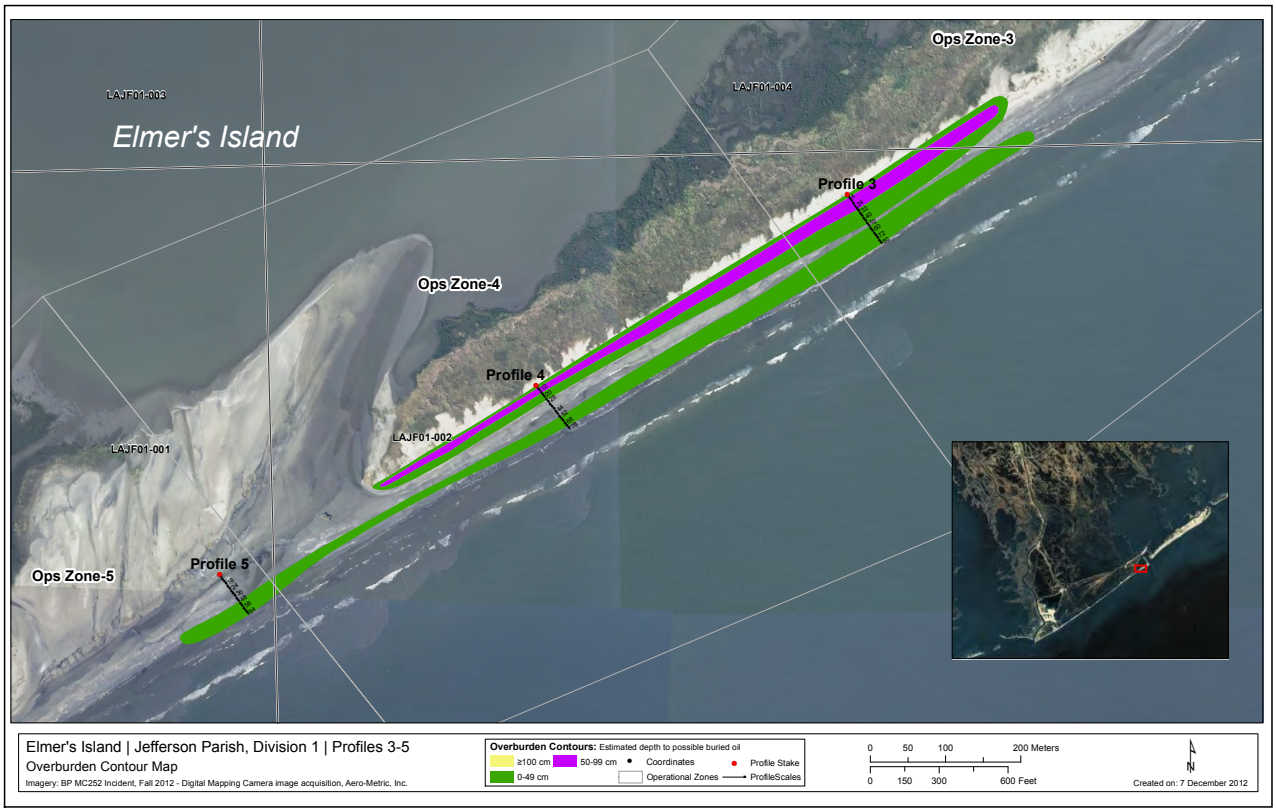


Figure 8. A section along Elmer's Island in which a polygon was produced from analysis of three beach profile stations (EI-3, EI-4, EI-5).

In most regions, auger holes had a 10-m spacing along a grid consisting of parallel and perpendicular lines. Exceptions to this pattern occurred where vegetation, tidal pools, and environmentally sensitive areas prevented transit by the auger-Cat. The density of holes was also sometimes modified, if oiled sediment, particularly an SR mat, was found in one of the holes. Under these circumstances, a 1 to 2-m spacing was used to clearly define the extent of the mat. In other instances, more distantly spaced grid systems were employed where extensive vegetation prevented augering or a lack of oil indicated a 20-m spacing was appropriate. An example of the grid system that was used at Elmer's station EI-3 and the results of the augering procedure are shown in Figure 9.

3. AugeringTechnique- Augering is a sampling technique whereby an auger stem and bit were drilled into the sand to the former marsh platform or to a depth of 2m (Figure 10). A depth of 2m was deemed sufficient because buried oil was not found beneath this thickness of sand and beach profile data showed no erosion below this depth. A 45-cm diameter auger bit was used to drill the holes, because that width allowed ample room to scrape the sides of the hole and view possible buried oiled sediment. In addition to the investigation of the hole, the auger bit was also inspected for buried oil. The hole was re-entered and drilled until the marsh platform or 2-m depth was reached. Where the marsh platform was near the surface, pitting was done by hand in order to prevent penetration into the clay.

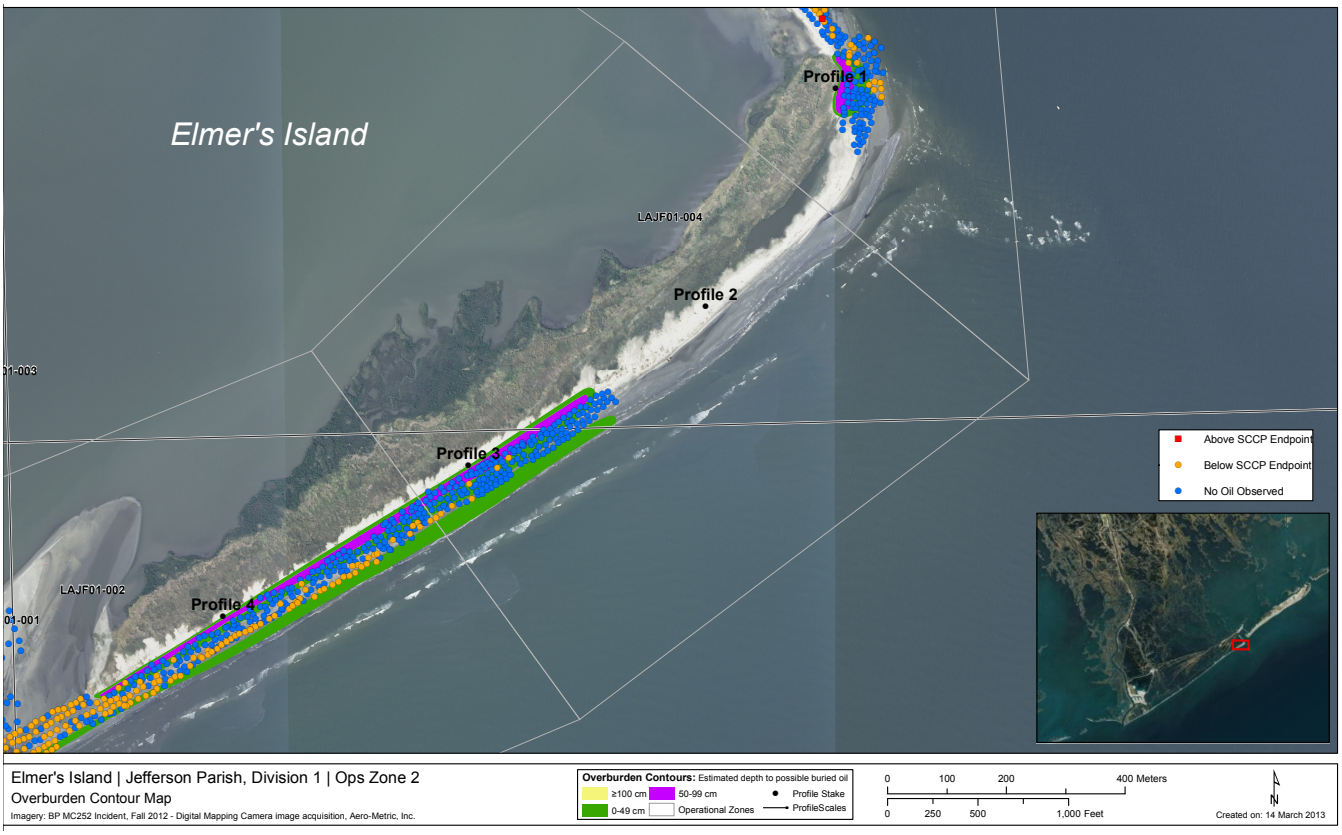


Figure 9. Map of eastern Elmer's Island showing the grid system and auger holes. Results of the sampling are given by the color scheme. Blue circles are holes having no observable oiled sediment, whereas the orange circles represent holes having oiled sediment below SCCP endpoint criteria. Note that portions of the polygons do not have auger holes, which is explained by the fact that auger holes were done in environmentally sensitive areas (e.g., vegetation, dunes, etc.).

4. Augering Results- Initially the augering procedure (LAASR) was employed on Fourchon, Elmer's Grand Isle, Grand Terre I, and Grand Terre II, totaling a combined 25 km length of shoreline covering 59% of the exposed portion of these beaches (Table 3). During these surveys, SR mats were identified on the barriers listed above with mat dimensions ranging from 4 m by 4 m to a maximum size of 35 m long and 5 m wide. The mats were 2 to 15 cm in thickness covered by 10 to 100 cm of sand. Augering was extended during the BOP program to other barriers, including the West Timbalier and Chaland barriers, as well as to new areas along barriers that had already been augered including Elmer's Island, Wild Beach in northern Grand Isle, Grand Terre 1, and Grand Terre II (see Appendix 5). Examples of auger hole coverage are shown in Figures 9 and 11. At Elmer's Island along the banks of Caminada Pass (Zone #2) several mats were discovered during the augering program. The red squares in Figure 11 depict auger holes where SR mats and heavily oil sand (oiled sand producing brown sheen) were recorded. If an SR mat was discovered, additional auger holes were drilled to define the extent of the mat; the final dimensions of the mat are represented by the red dashed polygons in the Figure 12. The mats were found by scraping and closely inspecting the inside of the auger hole and/or examining the tailings trapped on the auger bit (Figure 13). Pieces of the mat that came from the auger drill bit are shown in Figures 14 and 15.

Figure 10. Auger Cat with a 45-cm wide auger stem and bit. Tailings on the auger bit were examined in addition to a close inspection of the hole.

Table 3. Augered Shoreline

Fourchon	**Length (m)**
Total Beach Length	16011
Augered Length	9410 (59%)
Elmer's Island	**Length (m)**
Total Beach Length	5581
Augered Length	3848 (69%)
Grand Isle	**Length (m)**
Total Beach Length	12205
Augered Length	8542 (70%)
Grand Terre I	**Length (m)**
Total Beach Length	4713
Augered Length	1647 (35%)
Grand Terre II	**Length (m)**
Total Beach Length	4290
Augered Length	1661 (39%)

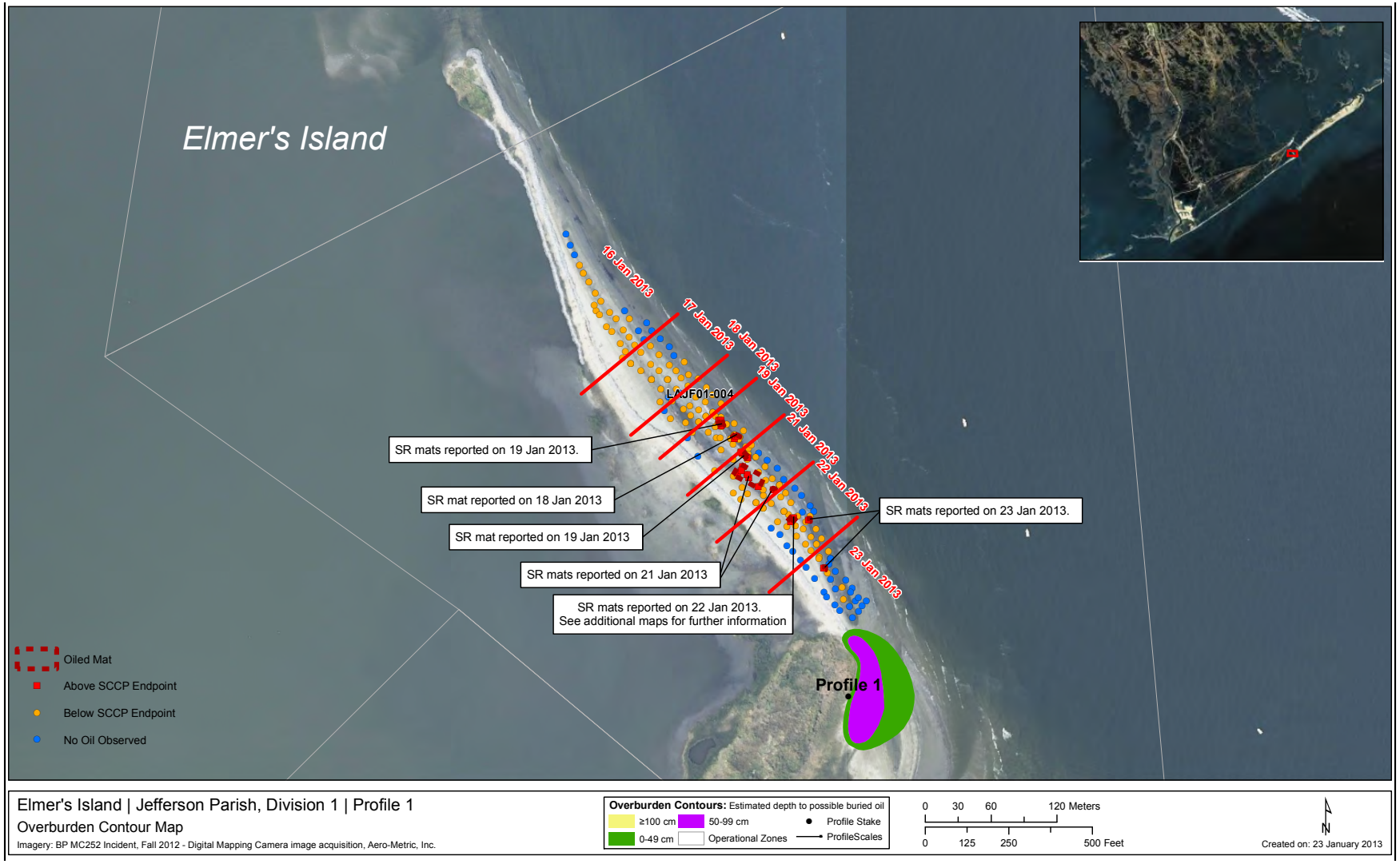
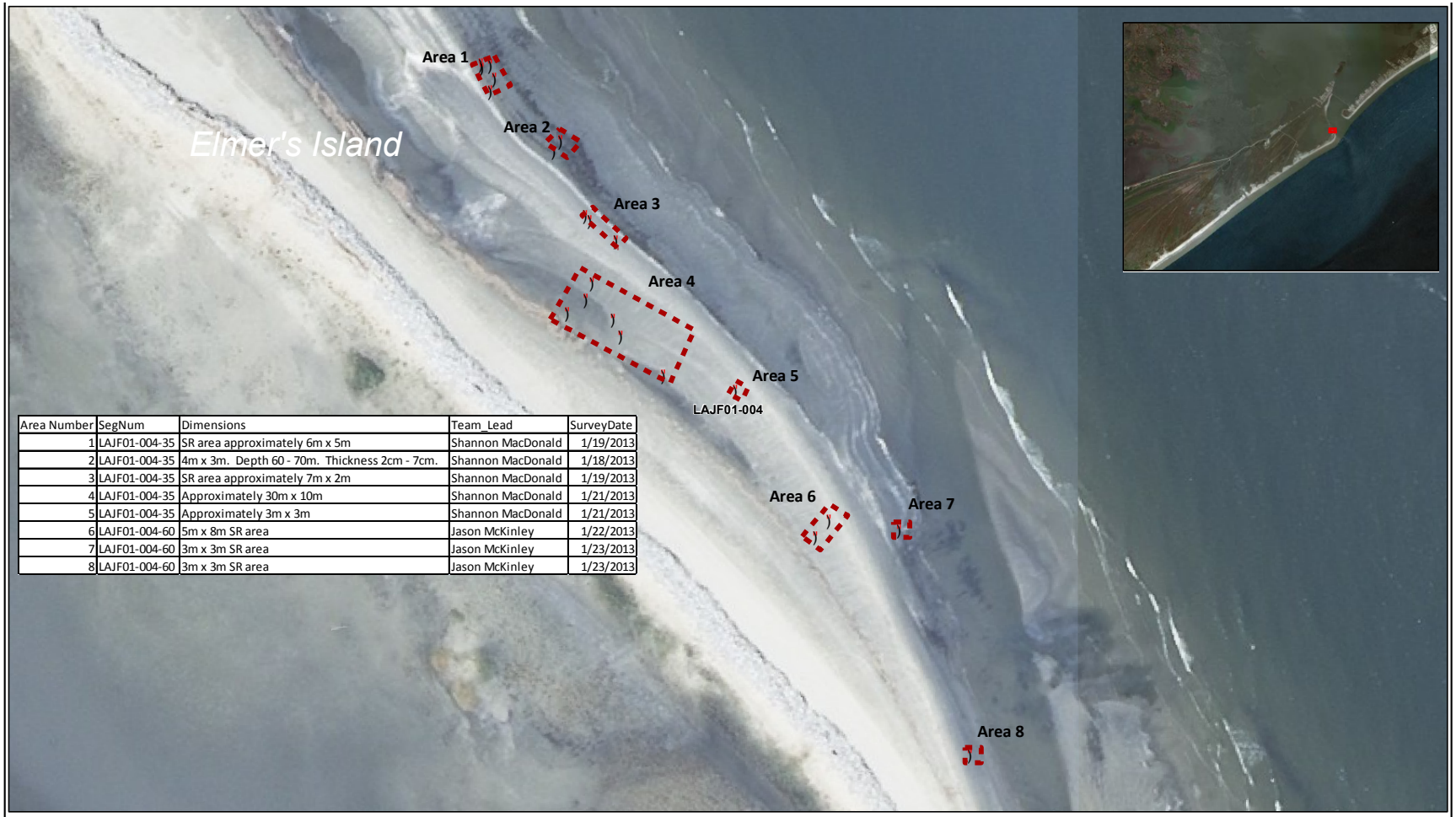


Figure 11. Map showing the augering progress from 19 through 22 January 2013. The red squares indicate where a subsurface SR mat was found.



Area Number	SegNum	Dimensions	Team_Lead	SurveyDate
1	LAJF01-004-35	SR area approximately 6m x 5m	Shannon MacDonald	1/19/2013
2	LAJF01-004-35	4m x 3m. Depth 60 - 70m. Thickness 2cm - 7cm.	Shannon MacDonald	1/18/2013
3	LAJF01-004-35	SR area approximately 7m x 2m	Shannon MacDonald	1/19/2013
4	LAJF01-004-35	Approximately 30m x 10m	Shannon MacDonald	1/21/2013
5	LAJF01-004-35	Approximately 3m x 3m	Shannon MacDonald	1/21/2013
6	LAJF01-004-60	5m x 8m SR area	Jason McKinley	1/22/2013
7	LAJF01-004-60	3m x 3m SR area	Jason McKinley	1/23/2013
8	LAJF01-004-60	3m x 3m SR area	Jason McKinley	1/23/2013

Elmer's Island | Jefferson Parish, Division 1 | Profile 1

Overview Map

Imagery: BP MC252 Incident, Fall 2012 - Digital Mapping Camera image acquisition, Aero-Metric, Inc.

Oiled Area

Above SCCP Endpoint

0 5 10 20 Meters

0 25 50 100 Feet

1

Created on: 08 February 2013

Figure 12. Dashed red rectangles indicate subsurface SR mats defined along Caminada Pass at the northeast end of Elmers Island from the analysis of auger hole data.

Figure 13. The SR mat wrapped around the auger bit.

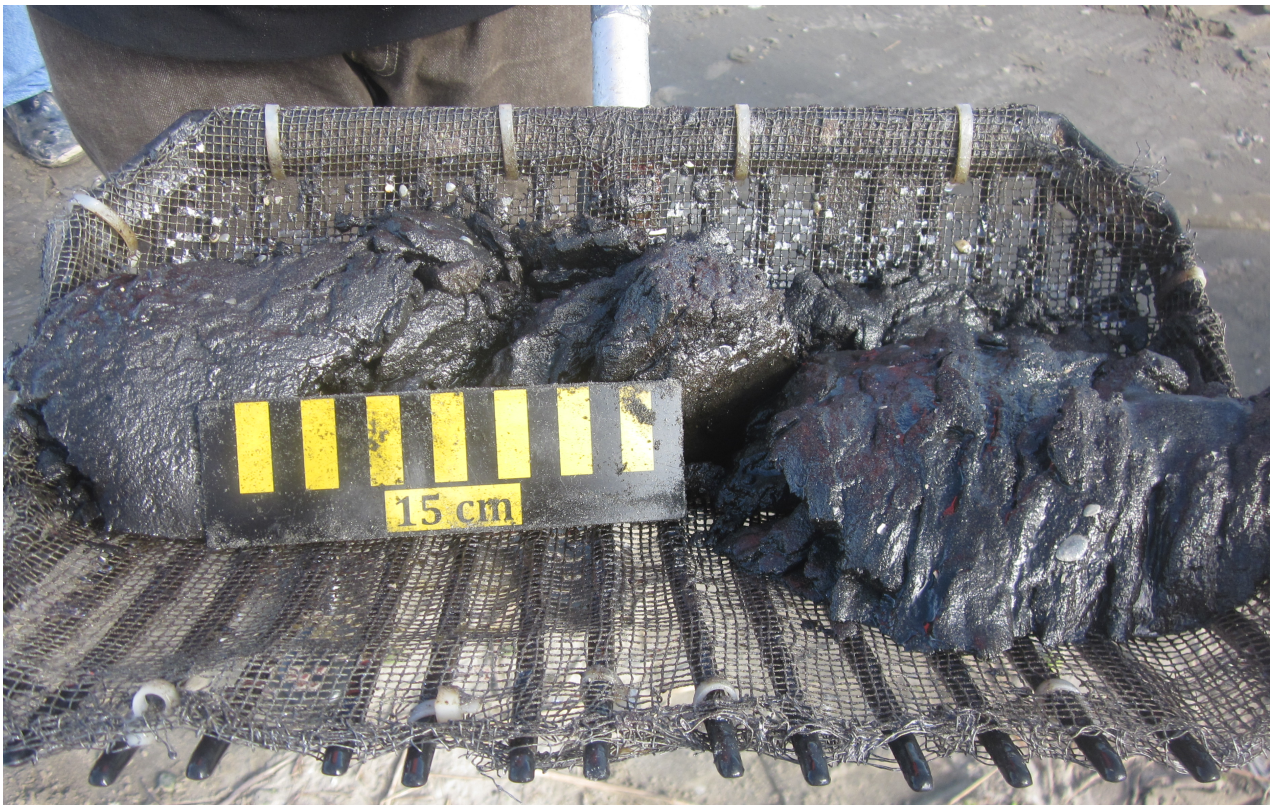


Figure 14. Chunks of SR mat removed from the auger drill bit. Sand was washed off using a screened rake.