Appendix E

Aerial Imagery Acquisition and Processing

Source imagery immediately prior to or coincident with initial oiling/stranding (May/June 2010) was acquired by the NOAA National Geodetic Survey (NGS) Remote Sensing Division, which utilized a Trimble DualCam Model 439 Digital Sensing System (DSS). The DualCam DSS utilizes two separate camera heads with one collecting three-band frame data in the visible red, green, and blue domain, and the other filtered to collect coextensive frame data as a single near-infrared band. Most of the rapid/emergency response imagery collected by NOAA NGS in connection with the MC252 spill was acquired at an approximate altitude of 7,500 feet above ground level (AGL) yielding a nominal ground sample distance (GSD) resolution of 1 foot. Post processing of onboard global positioning system/inertial measurement unit (GPS/IMU) data enabled direct geo-referencing and subsequent ortho-rectification of individual image frames (planimetric, 2-dimensional image [2D]). End and side lap of the frames (approximately 60 percent and 30 percent, respectively) further facilitated stereoscopic analysis/compilation (topographic, 3D). Given the season and the very limited time from initial release to potential oil landfall, favorable/preferred environmental conditions for aerial image acquisition, particularly in regard to sun glint, clouds and cloud shadows, tides, and wind and wave conditions, were not always available.

Subsequent to initial oil landfall, and pursuant to a cooperative agreement reached by the Trustees and BP representatives on the Natural Resource Damage Assessment (NRDA) Aerial Imaging Technical Work Group (AITWG), a consecutive series of Fall and Spring aerial image-acquisition efforts was undertaken to provide high-resolution, four-band, aerial image data and derivatives over the Eastern states (Mississippi, Alabama, Florida) Area of Responsibility (AOR). The original scope for acquisition, processing, and deliverables was designed to support the needs of the NRDA Shoreline and Submerged Aquatic Vegetation Technical Work Groups[1]. Five epochs of NRDA-related imagery have been acquired to date (Table E.1): Fall

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

2010, Spring 2011, Fall 2011, Spring 2012, and Fall 2012 (with a sixth being acquired exclusively by BP in Spring 2013 to be shared with the Federal and state resource managers and Trustees.

MC252 Spill Response Aerial Imagery Acquisition		
NRD Project Name	**Acquisition Start Date**	**Acquisition Completion Date**
NOAA MC252 2010 *	5/5/2010	6/14/2010
NRDA Fall 2010	10/7/2010	10/21/2010
NRDA Spring 2011	4/28/2011	7/30/2011
NRDA Fall 2011	9/27/2011	11/11/2011
NRDA Spring 2012	4/23/2012	6/3/2012
BP-Sponsored NRDA Pre-Isaac 2012	8/25/2012	8/27/2012
NOAA Post-Isaac 2012	8/31/2012	9/3/2012
NRDA Fall 2012	8/25/2012	10/30/2012
Composite Date Range	5/5/2010	10/30/2012
* Note that this listing does not reflect all NOAA NGS pre-oiling acquisitions. The referenced imagery can be found at Environmental Response Management Application (ERMA®) Gulf Response interactive viewer, at *http://resources.geoplatform.gov/news/mapping-response-bp-oil-spill-gulf-mexico* NRDA imagery collected by AeroMetric, Inc.		

Table E.1 Imagery used in evaluation of potential SOM formation and persistence.

Additionally, BP sponsored a limited acquisition effort over selected coastal regions (including the Mississippi Barrier Islands and Alabama and Florida Gulf-facing beaches to Fort Walton Beach) immediately prior to landfall of Hurricane Isaac on Aug. 29, 2012. NOAA NGS also acquired post-Isaac imagery over limited coastal areas (including the Mississippi and Alabama mainland coast west of Mobile Bay, the Mississippi Barrier Islands, and the Alabama Gulf-facing beaches to Perdido Key) in the days immediately following landfall (Aug. 31 to Sept. 3, 2012).

The NRDA and pre-Isaac image data sets described above were acquired by AeroMetric, Inc., under contract to BP. Consistent standards were maintained across all epochs in regard to sensor suite, environmental imaging constraints, processing requirements, geospatial accuracy standards, and final deliverables. Four-band (visible color and near-infrared) 12-bit depth digital frame photography was acquired with a Z/I DMC camera system flown at an altitude of 10,000 feet AGL yielding a nominal GSD of 1 foot. Post-processed onboard GPS/IMU data were submitted, together with available photo-identifiable ground control points, to bundleblock aerotriangulation adjustment, which provided enhanced positioning and orientation of each photo.

The resultant high-accuracy external orientation data of the exposure stations enabled the production of fully rectified and seamless ortho-image tiles and radiometrically-balanced Digital Ortho Quarter-Quarter-Quadrangles (DOQQQs) compiled to meet American Society for Photogrammetry and Remote Sensing Class 2, 1:2,400 scale accuracy requirement (planimetric, 2D root-mean-square error of 4 feet in X or Y for well-defined features). End and side lap of the frames (approximately 60 percent and 30 percent, respectively) further facilitated stereoscopic analysis/compilation (topographic, 3D mapping with an estimated one sigma vertical accuracy of 0.5 meters). All orthoimagery and planimetric mapping derivatives are in meters with respect to the Universal Transverse Mercator (UTM) grid system, Zone 16 North, North American Datum 1983 (2007, et seq.). All derived topographic elevations are in meters with respect to the North American Vertical Datum 1988 (indexed to local, high-accuracy, NAVD88 vertical control and/or terrain data).

Vector and Raster Derivatives from Aerial Imagery

The overall planimetric accuracy and horizontal co-registration of all epochs of ortho-rectified imagery (individual frames and/or DOQQQs) was such that the images could be efficiently viewed and evaluated in sequence. The quality of co-registration further enabled the capture and use of two key vector derivative data sets (geographic lines and polygons defined mathematically by the location of an ordered series of coordinates) in a semi-automated, multi-epoch assessment of shoreline change since initial oiling.

The first of these vector derivatives was the apparent land-water interface (LWI), which represented the apparent line of contact of the Gulf waters with Gulf-facing beaches and back barrier shorelines. These 2D vector features were digitized from the respective orthoimage data sets of each epoch at a constant interpretive scale of 1:1,200 (generalized on-the-fly to reflect best mean position, given wave run-up and retreat). This work was conducted by AeroMetric, Inc. for post-oiling imagery in Florida, Alabama, and the barrier islands in Mississippi and by the third Operational Science Advisory Team (OSAT-3) team in all other locations and epochs.

The second set of vector derivatives was generalized nearshore landforms along selected Gulf-facing beaches. These landforms were delineated as 2D polygonal/areal features and each was attributed with one of the nine generalized landform categories shown in Figure E.1 and Table E.2. For this analysis, “nearshore” was defined as approximately 100-150 meters from the LWI gulfward, and 10-25 meters landward of the LWI. These features were digitized at a scale of 1:1200 by staff at the U.S Geological Survey National Wetlands Research Center in Lafayette, Louisiana.

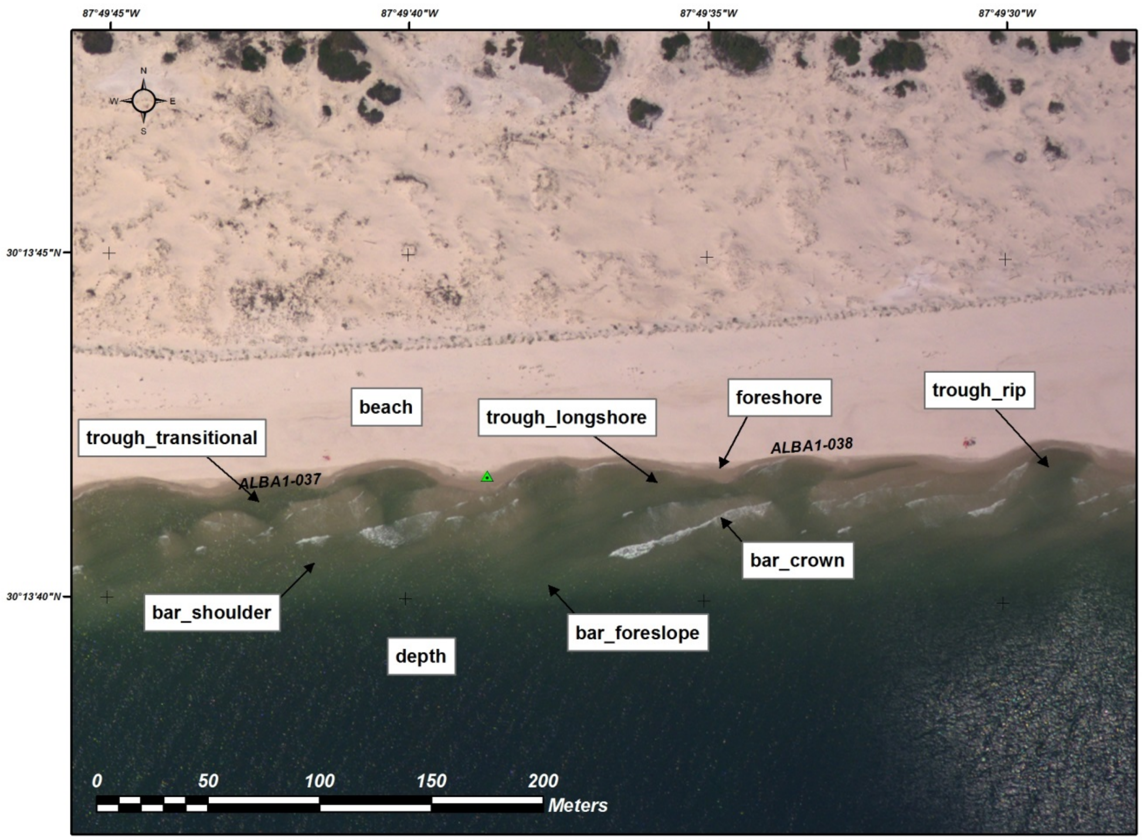

Figure E.1 Aerial image of ALBA1-037 and ALBA1-038 showing generalized nearshore landform features used in the OSAT-3 assessment. Definitions for the landforms are summarized in Table E.2.

As noted previously, the NOAA NGS image collections prior to initial oiling and post-Isaac landfall (as well the pre-Isaac AeroMetric, Inc. collection) were acquisitions of opportunity within limited time windows (and, therefore, often unfavorable environmental conditions for image collection), while the NRDA post-oiling imagery collected and processed by AeroMetric, Inc., was flown in accordance with specifications that provided for more favorable and consistent sun glint, water level, water clarity, and wind/wave conditions. Observed water levels at the time of exposure for each frame were retrieved from the three nearest NOAA tide gauges to assess the potential influence on the interpretation and capture of any given LWI or landform feature. In general, differences in water levels across all epochs utilized by the OSAT-3 team were deemed acceptable for the purpose of measuring changes in shoreline at the scale evaluated.

Geomorphic Feature	**Description**
Beach	The supratidal zone landward of the LWI above apparent high tide (i.e., continuous dry, white sand; backshore).
Foreshore	The intertidal zone at the LWI margin. In imagery it appears as light toned, continuous, exposed wet sand and slightly submerged, lower intertidal sands that are slightly darker.
Bar crown	The portion of the first or adjacent bar from shore that is or would be emergent within the ordinary tide range. These can be discontinuous features transected by rip troughs or may be anchored to the foreshore in places or may be separated from the foreshore by longshore trough features. Bar crowns generally have a greater longshore aspect ratio and typical cross-shore dimension of ~15 meters. In imagery they appear as light-toned exposed, wet sand and/or slightly submerged, slightly darker sand; typically indicated by breaking waves.
Longshore trough	Longshore trough features typically lie between the foreshore and bar crown (as described above), have a relatively large longshore aspect ratio. They may occasionally adjoin beach or bar-shoulder features. In imagery they appear as darker toned, submerged, lower intertidal or slightly subtidal.
Transitional trough	Neither longshore trough nor rip channel, but located between the foreshore and bar crown with an aspect ratio ~1. They are typically smaller than either longshore or rip features, and do not fully separate or transect a given bar feature.
Rip trough	Cross-shore channel formed by rip currents that transects the bar crown to/into the bar-shoulder. In imagery these are indicated by cusps at the foreshore/beach that are typically deeper/darker than longshore troughs.
Bar-shoulder	The subtidal zone, to a depth of ~1.5 meters, that are typically Gulfward of/adjacent to bar crown features. Bar-shoulders are generally continuous, but may be transected by rip troughs; may also adjoin foreshore or longshore troughs where a bar crown has not fully formed/emerged. In imagery they do not typically show breaking waves, and are where gentle sloping extends to abrupt change in tone.
Bar-foreslope	The subtidal zone from the bar-shoulder to the inflection at/near the base of the bar. Generally continuous; may have a steeper grade and typical depth from 2.0 to 4.0 meters. In imagery the foreslope extends from the bar-shoulder Gulfward, sometimes indicated by second abrupt change in tone at large trough feature between first and second bar.
Depth	The ~bottom of large trough feature between first and second bar (>3.5 -4 meters depth, indicated by darkest tones).

Table E.2 Generalized nearshore landform descriptions used by OSAT-3.

All of the referenced aerial image data sets were collected with sufficient overlap to support 3D stereoscopic compilation. A limited number of SCAT shoreline segments at which recurring oiling issues had already been identified by interested parties were chosen by the OSAT-3 team for more in-depth 3D analysis (see Table 2.3). At these selected segments, fixed collection boundaries were established that extended approximately 125 meters gulfward from the pre-oiling LWI and 75 meters landward of the pre-oiling LWI. Standard and through-water digital stereo-compilation of 3D terrain data was carried out at an interpretive scale of 1:800 to 1:1,200 by AeroMetric, Inc., based on the NOAA NGS pre-oiling imagery and five subsequent, seasonal NRDA collections (Fall 2010, Spring 2011, Fall 2011, Spring 2012, and Fall 2012). Water clarity and sun glint conditions for the NRDA imagery were usually such that through-water compilation (corrected for refraction) to a depth of 5 meters was possible.

SCAT Shoreline Segments
ALBA1-038 through ALBA1-044
ALBA2-002 through ALBA2-012
FLES1-003 through FLES1-008
FLES1-035, FLES1-036, FLES1-037
MSJK1-016 through MSJK1-021

Table E.3 MC252 spill response shoreline segments with digital elevation models (DEMs).

The digital terrain model (DTM) data, in the form of 3D mass points and break lines, were collected at a density sufficient to represent the detailed local vertical relief discernible in the stereo models. Coastal experts from the hydrodynamic modeling team worked with AeroMetric on identification and capture of important shoreline and subsurface features. Elevations from the DTM surfaces for each epoch were interpolated at a 2-meter horizontal sampling distance to produce raster digital elevation models (DEMs). Although the individual DEMs for each epoch maintained local vertical integrity, slight but discernible biases among the epochs with respect to one another and to NAVD88 were evident upon review. In order to achieve sufficient vertical co-registration of the DEMs and reference all to a common, absolute vertical reference system (i.e., NAVD88), each epoch was separately indexed to relatively permanent, stable, identifiable, and common features (e.g., hard surfaced road intersections) and their corresponding NAVD88 elevations as represented in LiDAR-based surface models acquired in the Spring of 2010 by the U.S. Army Corps of Engineers Joint Airborne Lidar Bathymetry Technical Center of Expertise and published by NOAA[2]. Final vertical alignment of the DEMs was further aided/confirmed by the presence and use of the Gulf water surface itself, which was ordinarily at or near local mean sea level (LMSL) at the time of image exposure (and, in this region of the Gulf of Mexico, a reasonable approximation of NAVD88 zero for this application).

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[2] http://csc.noaa.gov/dataviewer/webfiles/metadata/usace2010_al_fl_template.html
http://csc.noaa.gov/dataviewer/webfiles/metadata/usace2010_la_ms_template.html