Gay Stamp Sands 2016 Trough Volume Estimates from LiDAR Elevation Data

Initial Findings

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Introduction:

This study addresses the encroachment of stamp sands towards Buffalo Reef in recent years. LiDAR data from 2008, 2013, and 2016 were used to trace the migration of stamp sands as well as quantify the amount of stamp sands deposited and the annual rate of deposition in a potential dredging area north of the reef, further referred to as the "dredging area" (figure 1).

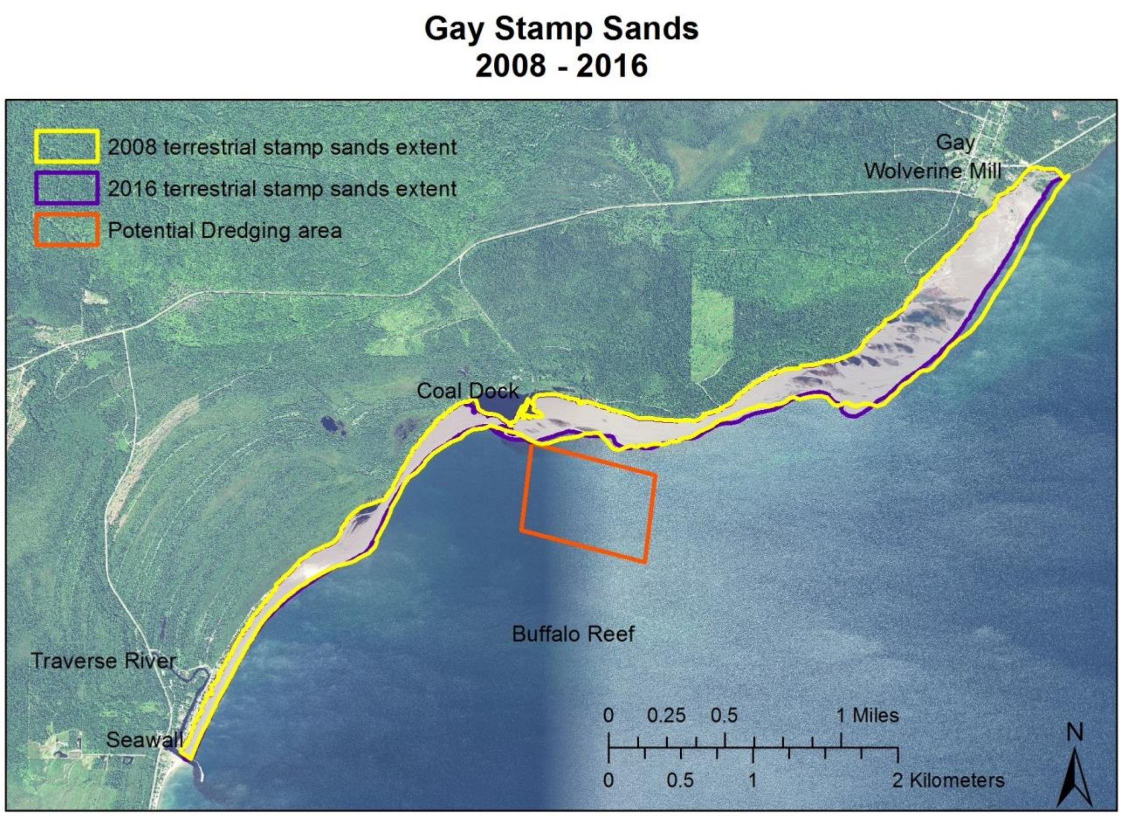

Figure 1. Shoreline stamp sand extent from 2008 to 2016 overlayed on 2016 NAIP Imagery.

Methods:

To assess the migration of stamp sands in recent years, the volume of stamp sand deposition was computed from 2013 to 2016, 2008 to 2013, and 2008 to 2016. For the 2013 to 2016 change detection, LiDAR data from the U.S. Army Corp were reprojected into NAD 1983 UTM Zone 16N in ArcGIS. The 2016 layer was resampled to the resolution of the 2013 layer (from 0.838x0.838 m to 0.54x0.54 m). The raster calculator was used to compute the difference between the 2013 and 2016 layers. The difference raster was multiplied by the area of a pixel to obtain a volume layer and the zonal statistics tool was used to compute the volume total within the dredging area. The polygon used to define the dredging area was 529,541 m^2. To separate the highly dynamic region within the previously defined dredging area polygon from the more stable trough area, the dredging area polygon was divided into two regions defined as the "trough" and the dynamic "bars" regions. The separation was determined qualitatively based on the 2016 Lidar to separate areas of smooth from fluctuating bathymetry. The area of the trough is approximately 2/3 of the pre-defined dredging area, 361,319 m^2. Net deposition of stamp sands was also calculated for areas in the trough and dynamic bars area.

The same methods outlined above were followed for change detection from 2008 to 2016 and 2008 to 2013. For 2008 to 2016, the 2008 layer was resampled to the grid size of the 2016 LiDAR (from 2x2 m to 0.838x0.838 m) and for 2008 to 2013, the 2008 layer was resampled to the 2013 layer grid size (from 2x2 m to 0.54x0.54 m).While the 2013 and 2016 layers were both collected with the same sensor and contained the same vertical datum, the 2008 LiDAR was downloaded from NOAA Digital Coast in NAVD88 instead of IGLD85. The difference in vertical datum s was small relative to the 18.5 cm accuracy of the LiDAR because accuracy in datum conversion is typically within 10 cm[1]. A summary of LiDAR accuracy is provided in Table 1.

Table 1. Lidar collection years available and respective accuracy.

Lidar Year	Vertical Accuracy (m)	X-Y Accuracy (m)	Sensor
2016	0.185	3.5*	CZMIL[2]
2013	0.185	3.5*	CZMIL[2]
2008	0.25	0.75	Hawk Eye Mark II LiDAR[3]

*2013 and 2016 LiDAR X-Y accuracy is reported by Optech as a function of depth, d, where accuracy = 3.5 + 0.05 x d

Since the Lidar bathymetric measurement accuracy was nominally 18.5 cm, an additional analysis was conducted to remove any deposition or erosion values below or equal to 18.5 cm. NOAA tide gauges measure water level to 0.1 ft resolution, however water depth is factored into the vertical datum.

Results:

Change detection analysis from 2013 to 2016, 2008 to 2016 and 2008 to 2013 showed net deposition of stamp sands within the proposed dredging area (table 2). From 2013 to 2016, the annual deposition rate,12,905 m^3/yr was approximately half of the rate for 2008 to 2016, 24,196 m^3/yr for the entire dredging area (figures 2 and 3). During the recent period of change from 2013 to 2016 the dynamic bars had a greater percentage of total deposition than the trough section, unlike for the longer time-series from 2008 to 2016 (figure 4). However, the annual deposition rate of stamp sands is lower for more recent years from 2013 to 2016 than for 2008 to 2013. The declining rate of stamp sand deposition in recent years may indicate deposition as a function of severity of ice cover. Higher ice coverage in 2014 and 2015 suppresses wave action, which may result in less transport of stamp sands from bars into the trough region.

Removal of the deposition and erosion below the Lidar reported accuracy shows that the majority of the trough area for the 2013 to 2016 analysis is less than 18.5 cm and the longer time-series contains greater transport of stamp sands beyond the inherent uncertainties in vertical accuracy of the Lidar. For the 2013 to 2016 analysis, the net deposition calculation changed from 63,879 to 29,164 metric tonnes of stamp sands when excluding values lower than 18.5 cm in calculations (table 3; figure 3). Since 2013 to 2016 only spans three years, the lack of deposition greater than 18.5 cm is consistent with what we would expect, especially during a period of high ice coverage. For the 2008 to 2016 change detection, much of the deposition of stamp sands in the trough area was greater than 18.5 cm deposition and thus included in the analysis giving a total of 317,154 metric tonnes of stamp sands deposited within the total dredging area.

Table 2. Preliminary summary of change in stamp sand deposition with 2008, 2013 and 2016 Lidar[A]

Years	Value	Trough	Dynamic Bars	Total Dredging Polygon
2013-2016	Net Deposition Volume (m^3)	13,158	25,557	38,714
	Net Deposition Volume (metric tonnes)	21,710	42,169	63,879
	Percent Total (%)	34	66	--
	Annual Deposition Rate (m^3/yr)	4,386	8,519	12,905
	Average Deposition depth (cm)	4	15	7
2008-2016	Net Deposition Volume (m^3)	127,176	66,391	193,566
	Net Deposition Volume (metric tonnes)	209,840	109,545	319,385
	Percent Total (%)	66	34	--
	Annual Deposition Rate (m^3/yr)	15,897	8,299	24,196
	Average Deposition depth (cm)	35	39	37
2008-2013	Net Deposition Volume (m^3)	112,714	40,004	152,718
	Net Deposition Volume (metric tonnes)	185,979	66,006	251,985
	Percent Total (%)	74	26	--
	Annual Deposition Rate (m^3/yr)	22,543	8,001	30,544
	Average Deposition depth (cm)	31	24	29

A. Changes in net deposition volume from 2008 to 2013 plus 2013 to 2016 do not sum to the 2008 to 2016 analysis due to Lidar accuracy. Each change detection was computed separately with the Lidar from the respective years.

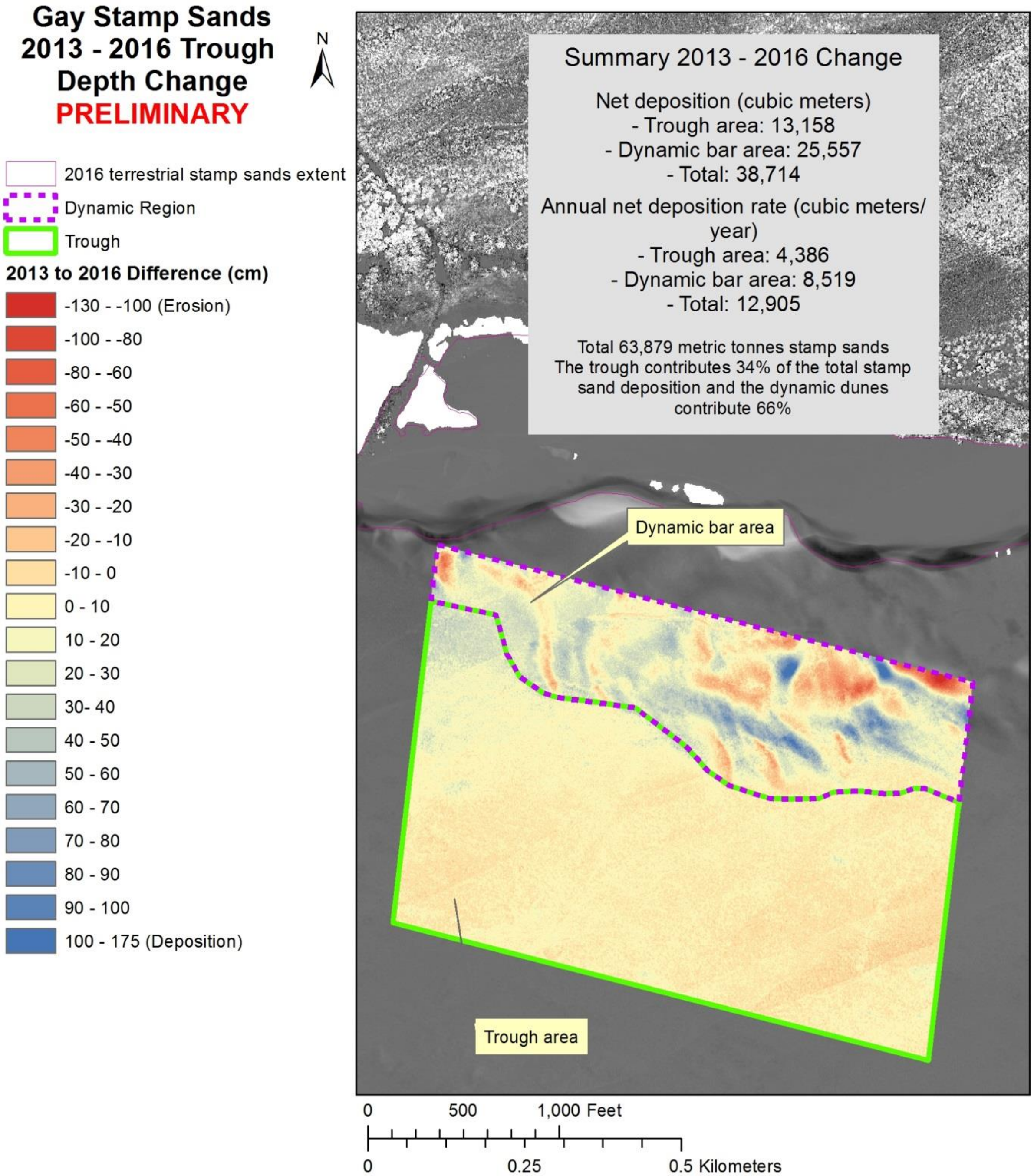

Figure 2. Difference in bathymetry between 2013 and 2016. Negative values indicate erosion of stamp sands and positive represent depositional areas.The original dredging area outline was split into two sections, the trough and the dynamic region.
The trough was 68% of the total dredging area volume, which was 529583 square meters. Thus the trough section was 361319 square meters.

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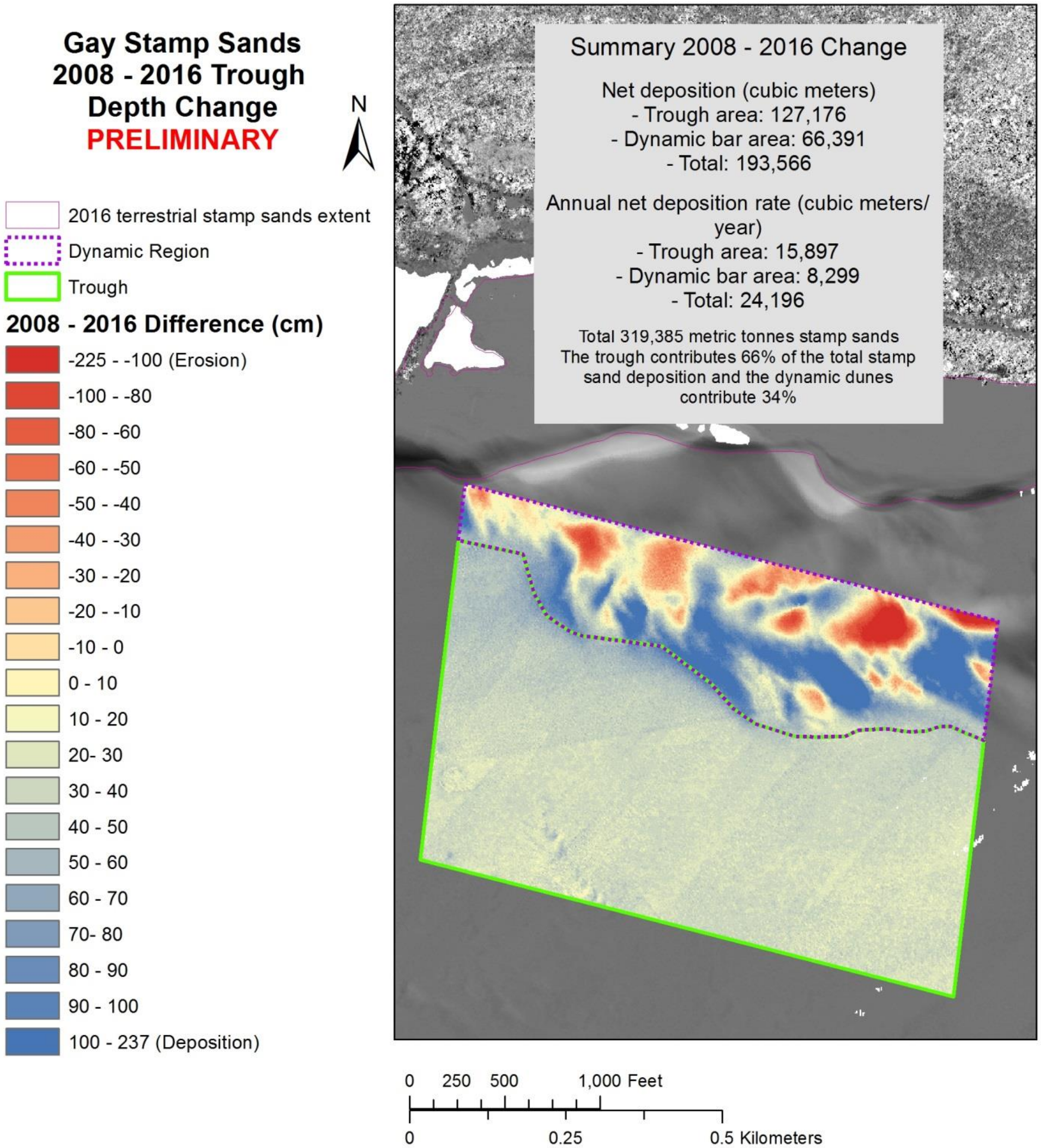

Figure 3. Difference in bathymetry between 2008 and 2016. Negative values indicate erosion of stamp sands and positive represent depositional areas.The original dredging area outline was split into two sections, the trough and the dynamic region.
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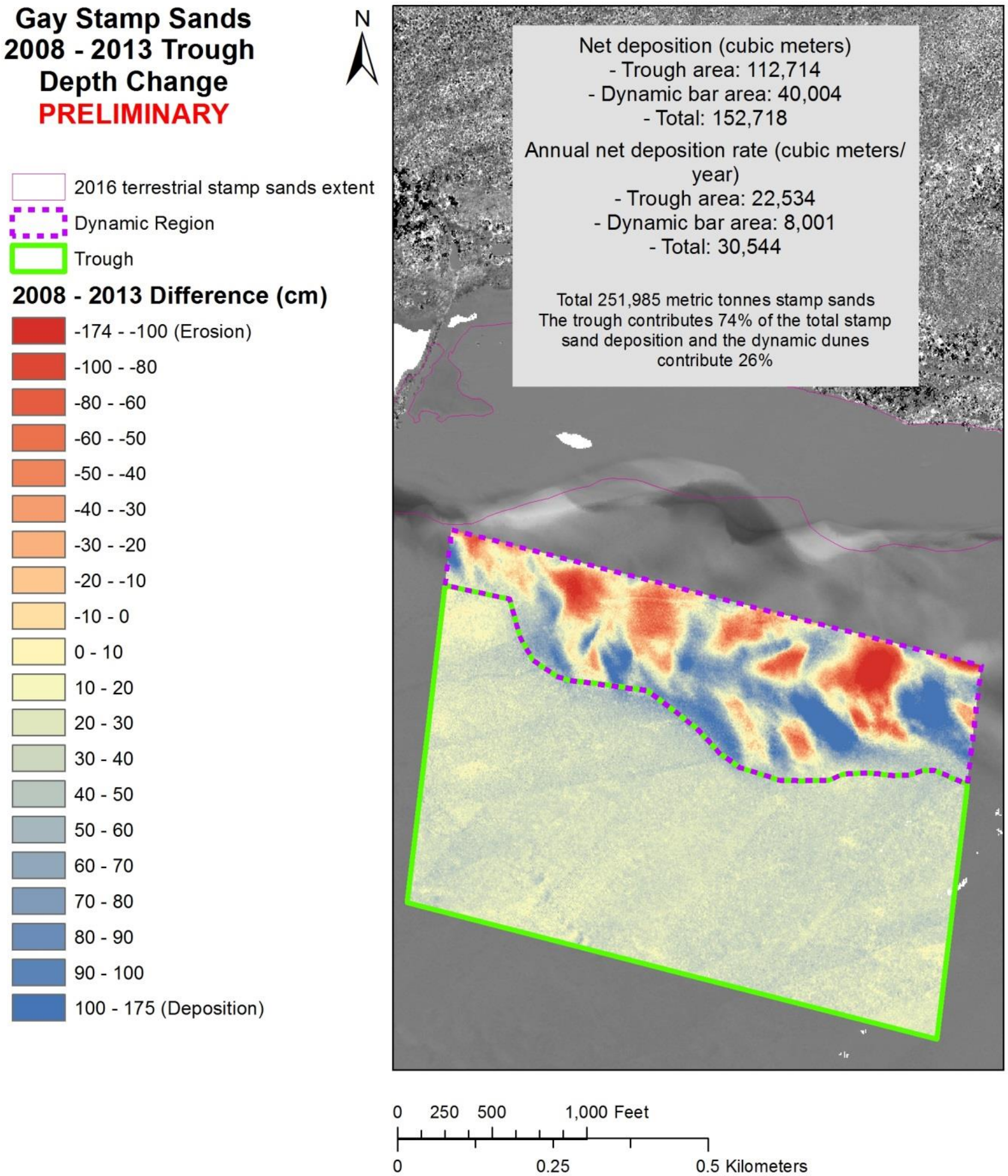

Figure 4. Difference in bathymetry between 2008 and 2013. Negative values indicate erosion of stamp sands and positive represent depositional areas.The original dredging area outline was split into two sections, the trough and the dynamic region. The trough was 68% of the total dredging area volume, which was 529583 square meters. Thus the trough section was 361319 square meters.

Table 3. Preliminary summary of uncertainty due to 18.5 cm Lidar accuracy in change detection of stamp sand deposition for total dredging area.[A]

Years	Value	Total Dredging Area	
		All Data	Exclusion[B]
2013-2016	Net Deposition Volume (m^3)	38,714	27,972
	Net Deposition Volume (metric tonnes)	63,879	46,155
	Annual Deposition Rate (m^3/yr)	12,905	9,324
	Average Deposition depth (cm)	7	5
2008-2016	Net Deposition Volume (m^3)	193,566	192,215
	Net Deposition Volume (metric tonnes)	319,385	317,154
	Annual Deposition Rate (m^3/yr)	24,196	24,027
	Average Deposition depth (cm)	37	36
2008-2013	Net Deposition Volume (m^3)	152,718	149,416
	Net Deposition Volume (metric tonnes)	251,985	246,537
	Annual Deposition Rate (m^3/yr)	30,544	29,883
	Average Deposition depth (cm)	29	28

A. Changes in net deposition volume from 2008 to 2013 plus 2013 to 2016 do not sum to the 2008 to 2016 analysis due to Lidar accuracy. Each change detection was computed separately with the Lidar from the respective years.
B. Uncertainties were values of erosion and deposition within 0 and 18.5 cm, thus values between -18.5 and 18.5 cm.

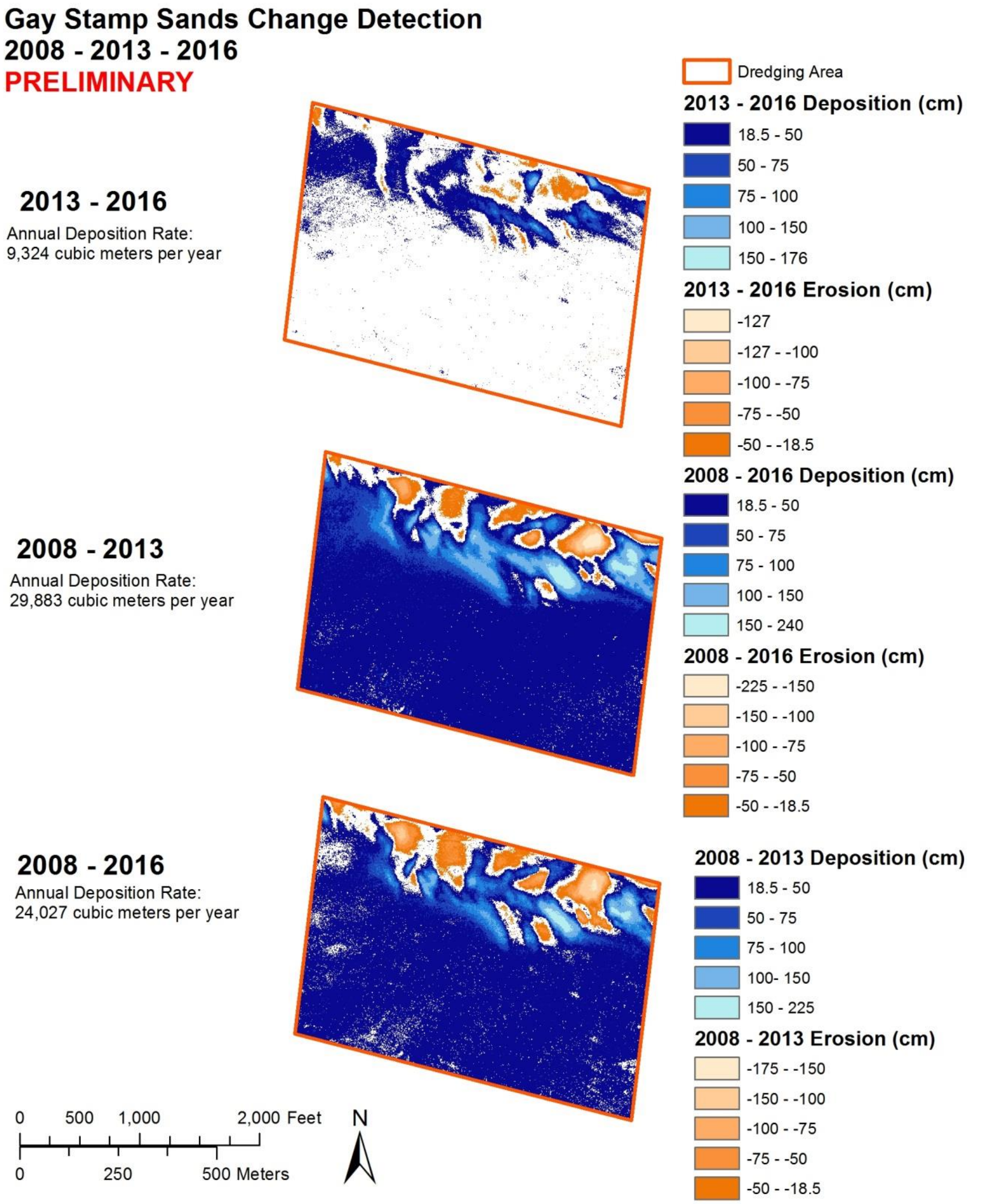

Figure 5. Change detection of stamp sand erosion and deposition within the potential dredging polygon from 2013 to 2016, 2008 to 2013, and 2008 to 2016 filered based on the accuracy of the lidar. Blue shows deposition and organge shows erosion of stamp sands. The white areas are values within the accuracy of the lidar, -0.185 to 0.185 m, and thus excluded from calculations of net deposition and annual deposition rates.

References

1. National Geodetic Survey, National Oceanic & Atmospheric Administration. (2017). International Great Lakes Datum of 1985. https://www.ngs.noaa.gov/TOOLS/IGLD85/igld85.shtml
2. Optech. Airborne Bathymetric Lidar Summary Specification Sheet. http://www.gstdubai.com/downloads/CZMIL-Specsheet-140814-WEB.pdf
3. National Oceanic & Atmospheric Administration. 2008 USACE NCMP Topographic Lidar: Lake Superior Metadata https://coast.noaa.gov/dataservices/Metadata/TransformMetadata?u=https://coast.noaa.gov/data/Documents/Metadata/Lidar/no_harvest/mi2008_usace_lakesuperior_m2517_metadata.xml&f=html