Analysis of Aerial Extent, Volume, and Mass of the Gay Stamp Sands Calculated Using 2008 and 2016 LiDAR Elevation Data

Initial Findings

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Introduction:

This study addresses the erosion of stamp sands from the original Gay tailings pile and deposition of the stamp sand alongshore and into Keewenaw Bay. LiDAR data from 2008 and 2016 were used to calculate the extent, volume, and mass of terrestrial stamp sands in the northern region where the original pile was deposited by the mills and in the region south of the original pile where the sediment was transported alongshore. Since the shoreline has been highly dynamic in previous years, quantifying the erosion from 2008 to 2016 indicates the additional erosion of stamp sand into Keewenaw Bay, which has the potential to negatively impact biology in Buffalo Reef.

Methods:

Terrestrial stamp sand volume estimates were computed for years 2008 and 2016 using the 2008 USACE Lidar downloaded from NOAA Digital Coast. The 2008 Lidar was converted from NAVD88 to height by subtracting the water level on June 23, 2008 at local noon, 183.345 m, and the 2016 NCMP Lidar from the U.S. Army Corp was converted from IGLD85 to height by subtracting 183.794 m, the water level at local noon on September 20, 2016. While the height of stamp sands only indicated the onshore thickness of stamp sand above water level, a value of 2 m was added to the height to account for the stamp sand deposition from bedrock to the water to create a raster representing terrestrial stamp sand thickness, based on a comparison to historical bathymetric values (as was done in Yousef et al. 2013). Pond areas where there were empty (missing) values in the Lidar data were filled in with a value of 2 m. Note this assumes that in addition to the depth scoured by the ponds, there was also an additional 2 m of stamp sands below the pond, which is likely a relatively small overestimation of stamp sands. To convert stamp sand thickness to volume, the 2008 and 2016 thickness layers were multiplied by the area of an individual pixel (2 m x 2 m for 2008 and 0.838 m x 0.838 m for 2016).

The zonal statistics tool was used to sum the volume of onshore stamp sands. The 2008 and 2016 terrestrial stamp sand shoreline extent polygons were separated into three regions: the northern original Gay stamp sands tailings pile, the area south of the Gay pile to the coal dock, and the southern shoreline extent south of the coal dock.

Results:

Shoreline erosion is apparent, as both the area of the Gay pile and the area of stamp sands deposited along the shoreline decreased from 2008 to 2016, thus increasing the amount of stamp sands in Keewenaw Bay. Figure 1 shows the dynamic nature of the shoreline from 2008 to 2016. The greatest area of erosion is by the original Gay pile, totaling 6 Ha or 21% shoreline extent loss (table 1). The area extent decline of terrestrial stamp sands south of the Gay pile was much less than the erosion that occurred in the Gay pile area. The area between the Gay pile and the coal dock lost 3% of its extent from 2008 to 2016 and the shoreline extent south of the coal dock lost 2% of total area (table 1). The decreased aerial extent of onshore stamp sands corresponded to a decrease in amount of terrestrial stamp sands over time, where the Gay pile decreased from 14% of the original pile in 2008 to 11% in 2016, the area from the Gay pile to the coal dock declined from 20% to 17%, and the southern shoreline from 11% in 2008 to 10% in 2016 (table 2; figure 2). The erosional state from 2008 to 2016 resulted in an additional 1.6 Tg of stamp sands entering Keewenaw Bay during that time period.

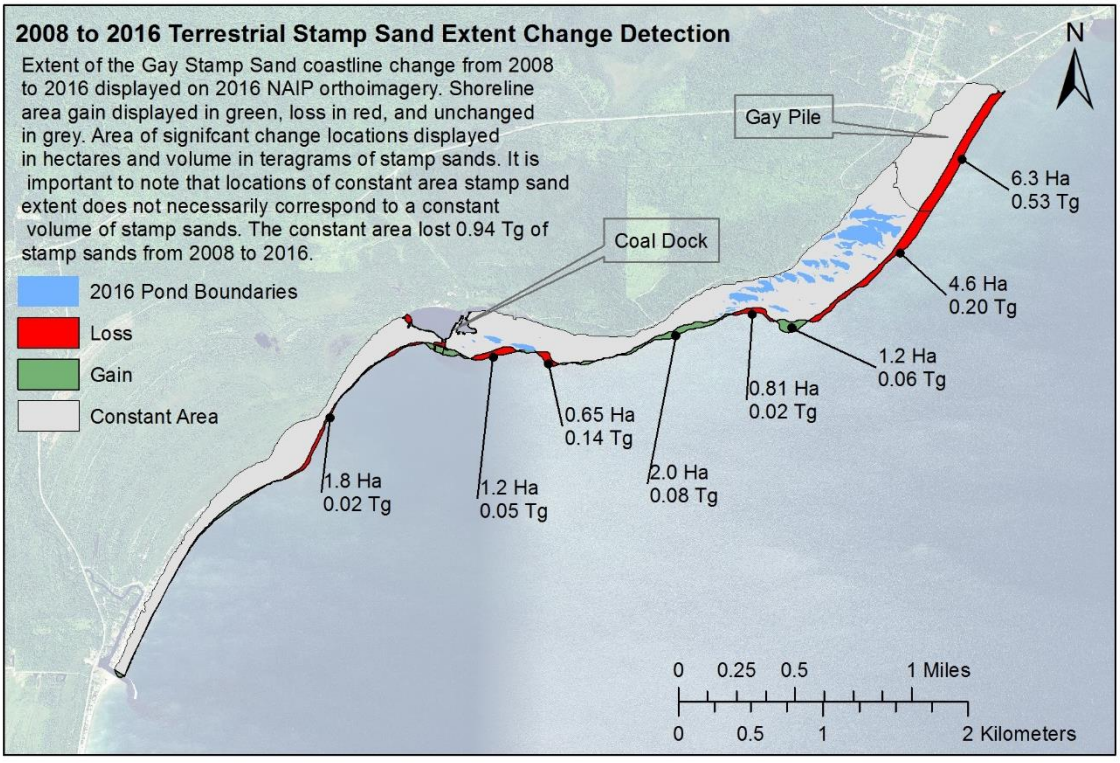

Figure 1: Changes in terrestrial stamp sand extent and mass using 2008 and 2016 aerial imagery and Lidar data.

Table 1. Preliminary onshore, Gay pile and shoreline, and eroded offshore stamp sand aerial extent from 2008 and 2016 Lidar.

Location	Year	Area (ha)	Percent Loss from 2008 to 2016 (%)
Gay Pile	2008	31	21%
	2016	25	
Shoreline: South of Coal Dock	2008	41	2%
	2016	40	
Shoreline: Between Gay Pile and Coal Dock	2008	95	3%
	2016	92	

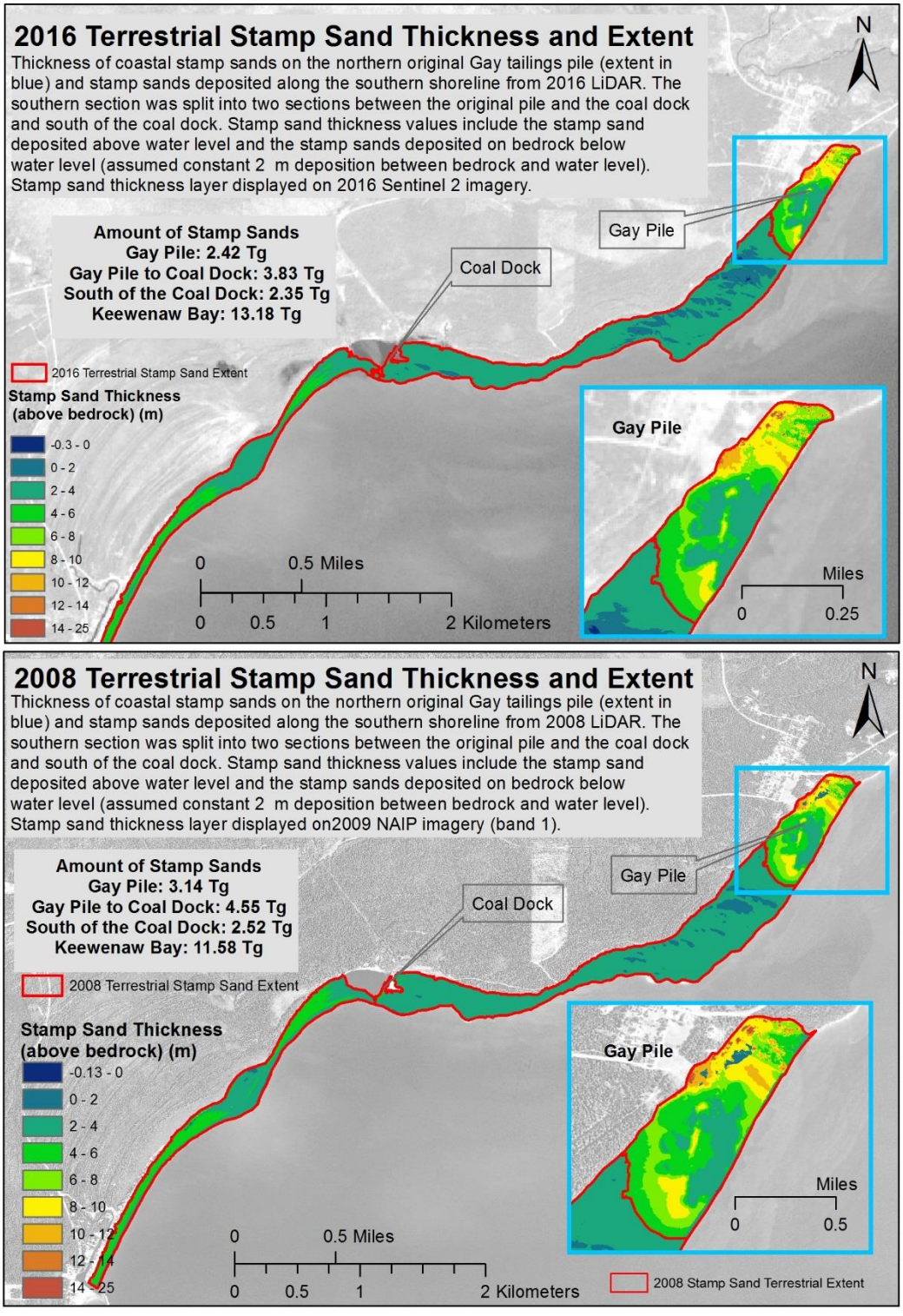

Figure 2: Detailed data on 2008 and 2016 terrestrial stamp sand thickness and extents

Table 2. Preliminary onshore, Gay pile and shoreline, and eroded offshore stamp sand volume estimates from 2008 and 2016 Lidar.

Location	Year	Stamp Sand Mass (Tg)	Percent of Original Pile (%)	Percent Change 2008 to 2016 (%)[A]
Gay Pile	1901-1932	22.79	100.0	NA
	2008	3.14	13.76	-22.95
	2016	2.42	10.60	
Shoreline: South of Coal Dock	2008	2.52	11.04	-6.50
	2016	2.35	10.32	
Shoreline: Between Gay Pile and Coal Dock	2008	4.55	19.95	-15.78
	2016	3.83	16.80	
Roads (sand used by local road commissions)	NA	1.01	4.4	NA
Keweenaw Bay	**2008**	**11.58**	50.82	13.82
	2016	**13.18**	57.84	

A. Negative value indicates percent loss and positive indicates percent increase. Stamp sand volume increased from 2008 to 2016 in Keewenaw Bay as the amount of terrestrial stamp sands decreased over time.

References:

Yousef, F., Kerfoot, W.C., Brooks, C.N., Shuchman, R., Sabol, B. and Graves, M., 2013. Using LiDAR to reconstruct the history of a coastal environment influenced by legacy mining. *Journal of Great Lakes Research, 39*, pp.205-216.