GREAT SALT LAKE NORTH ARM SALT CRUST MONITORING, SPRING 2017 UPDATE

by Andrew Rupke and Taylor Boden

OPEN-FILE REPORT 714
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
2020

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Cover photo: *Salt crust exposed along the north arm of Great Salt Lake near the Spiral Jetty.*

Suggested citation:

Rupke, A. and Boden, T., 2020, Great Salt Lake north arm salt crust monitoring, spring 2017 update: Utah Geological Survey Open-File Report 714, 13 p., https://doi.org/10.34191/OFR-714.

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EXECUTIVE SUMMARY

While monitoring nearshore salt crust thickness in the north arm of Great Salt Lake from summer 2015 through early spring 2017, we observed seasonal changes and response to a causeway modification. The exposed salt crust, above water level, primarily exhibited dissolution; however, during late summer 2016 a minimal amount of growth may have occurred at the base of the crust. Where inundated, the salt crust showed more substantive responses to seasonal changes and lake events. As noted and discussed in our previous study (Rupke and others, 2016), measurements of salt crust below the water line exhibited thickness loss of up to 0.46 ft between late summer 2015 and early spring 2016. Monitoring during summer 2016 showed seasonal salt crust growth of up to 0.49 ft. Also, because of historical low lake levels in the north arm during summer 2016, extensive crust was exposed at the north end of the lake and we recorded the thickest nearshore salt crust measurement of 2.88 ft. By early spring 2017, much of the nearshore salt crust had dissolved and we recorded crust dissolution as much as 0.54 ft. Crust dissolution between summer 2016 and early spring 2017 occurred in response to both seasonal lake rise and increased flow through the causeway bridge which opened on December 1, 2016.

INTRODUCTION AND BACKGROUND

Great Salt Lake (GSL) is divided by a rockfill railroad causeway that limits the flow of brine between the north and south arms of the lake. The rockfill causeway was completed in 1959 and the resulting restriction of flow has caused different salinity levels in each arm. Salinity levels in the south arm are more variable, but the north arm has been at or near saturation with respect to halite (sodium chloride) for most of the time since the causeway was constructed. These high salinity levels have resulted in a salt crust precipitating on the floor of the lake in the north arm. The salt crust has been a consistent presence in the north arm with the likely exception of the late 1980s and early 1990s when lake levels were high (Loving and others, 2000; Mohammed and Tarboton, 2012). The salt crust is important because it can sequester a large amount of the total salt load of GSL (over 20%) thereby having a significant effect on overall lake salinity.

The purpose of this study was to monitor the thickness of the salt crust over time, in particular how the crust changed from summer 2016 through spring 2017. This study expands upon work reported in Rupke and others (2016) that included nearshore thickness measurements of the salt crust. Three transects and corresponding measurement sites used in the previous study were used as a baseline for monitoring crust thickness changes in this study. The crust measurement methods outlined in Rupke and others (2016) were also used in this study.

Observing how the salt crust changes over time provides data that helps us understand how GSL's salinity cycle functions. More specifically, we can better understand how the salt crust responds to changes in the GSL system. Also, our data collection provides a reference for understanding how the salt crust responded to the new railroad causeway bridge that opened on December 1, 2016.

METHODS

As previously noted, we used the same crust measurement methods developed and reported in Rupke and others (2016). When re-occupying a site, we used a Wide Area Augmentation System-enabled GPS to locate the site. In some cases we were able to locate the previous hole used. In that event, we did not measure the previous hole, but drilled and measured a new hole within a foot or two of the previous one. Old holes often appeared to have experienced enhanced dissolution, so re-measurement had potential to be inaccurate.

During the study we also collected water/brine samples and measured the density. The procedures we used for measuring density are consistent with procedures used for the Great Salt Lake brine chemistry database that is maintained by the Utah Geological Survey and posted on the survey's website (https://geology.utah.gov/docs/xls/GSL_brine_chem_db.xlsx). The brine densities were measured using an Anton Paar DMA 35 density meter.

MONITORING RESULTS AND DISCUSSION

Transects 1, 2, and 3 established by Rupke and others (2016) were monitored during the course of this study (figure 1). Transects 1 and 2 were revisited three times each and transect 3 was revisited twice. Lake conditions for all monitoring dates of each

transect, including those from 2015 and early 2016 are summarized in table 1. Measurement data for transects 1, 2, and 3 are presented in the appendix and figures 2, 3, and 4. The changes we observed are illustrated in figures 5, 6, 7, and 8.

The salt crust generally experienced dissolution and thickness loss while exposed above the water line. Transect 2 illustrates this well (figures 6 and 8a). However, from July 20, 2016, to September 20, 2016, several stations well above the water line apparently experienced slight thickness growth (figure 8a). We are aware of no mechanism to increase the thickness of the exposed salt crust at the surface above the water with the possible exception of accumulation and assimilation of detrital/loose salt, but this would only be viable very near the water's edge (station 24 is a likely candidate for this). However, given that brine is generally just below the surface of the crust, the salt crust may have experienced some growth through precipitation of salt at its base. Because thickness increase was consistently observed at several stations (20, 21, 22, and 23; figure 8a), the crust probably did experience some growth and the results are not due to measurement variability or error.

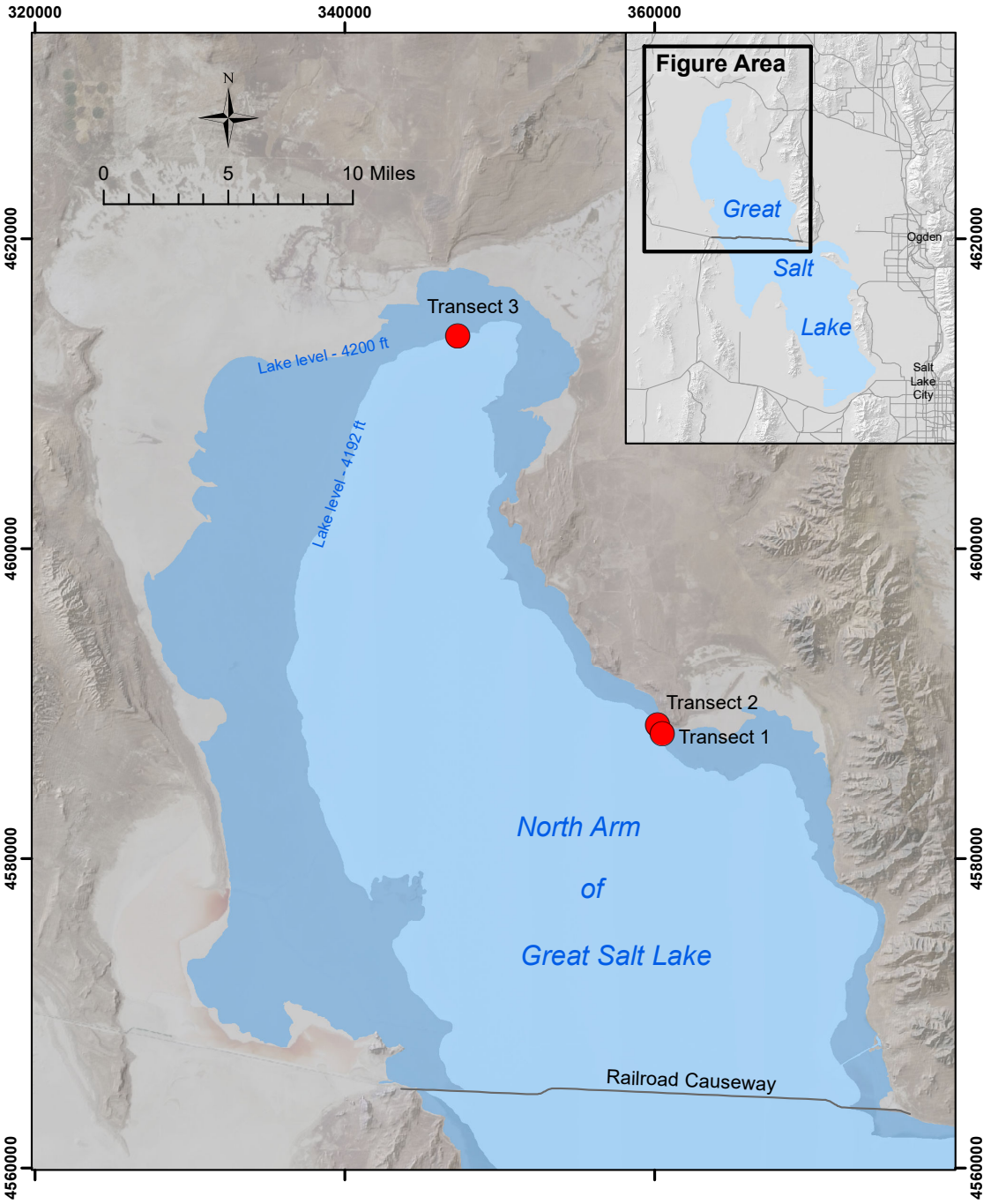

Figure 1. *Salt crust monitoring transect locations. Grid coordinates are UTM Z12 NAD83 (m). Base imagery is from August 2014 and June 2015 and is provided by Google.*

Table 1. *Lake conditions during study. Surface water elevations from U.S. Geological Survey gage at Saline, Utah.*

Date	Event	North Arm Surface Water Elevation (feet)	Measured Density of North Arm Brine (g/cm^3)
August 13, 2015	transect 1 measured	4191.40	--
August 21, 2015	transect 2 measured	4191.34	--
August 25, 2015	transect 3 measured	4191.26	--
March 4, 2016	transect 2 measured	4190.86	1.218
April 7, 2016	transects 1 and 2 measured	4190.91	1.223
July 20, 2016	transects 1 and 2 measured	4189.97	1.230
September 15, 2016	transect 3 measured	4189.10	--
September 20, 2016	transects 1 and 2 measured	4189.03	1.232
December 1, 2016	causeway breach opened	4189.20	--
March 9, 2017	transects 1 and 2 measured	4192.75	1.185
April 6, 2017	transect 3 measured	4193.32	--
April 12, 2017	probing for crust near transect 2	4193.60	1.191

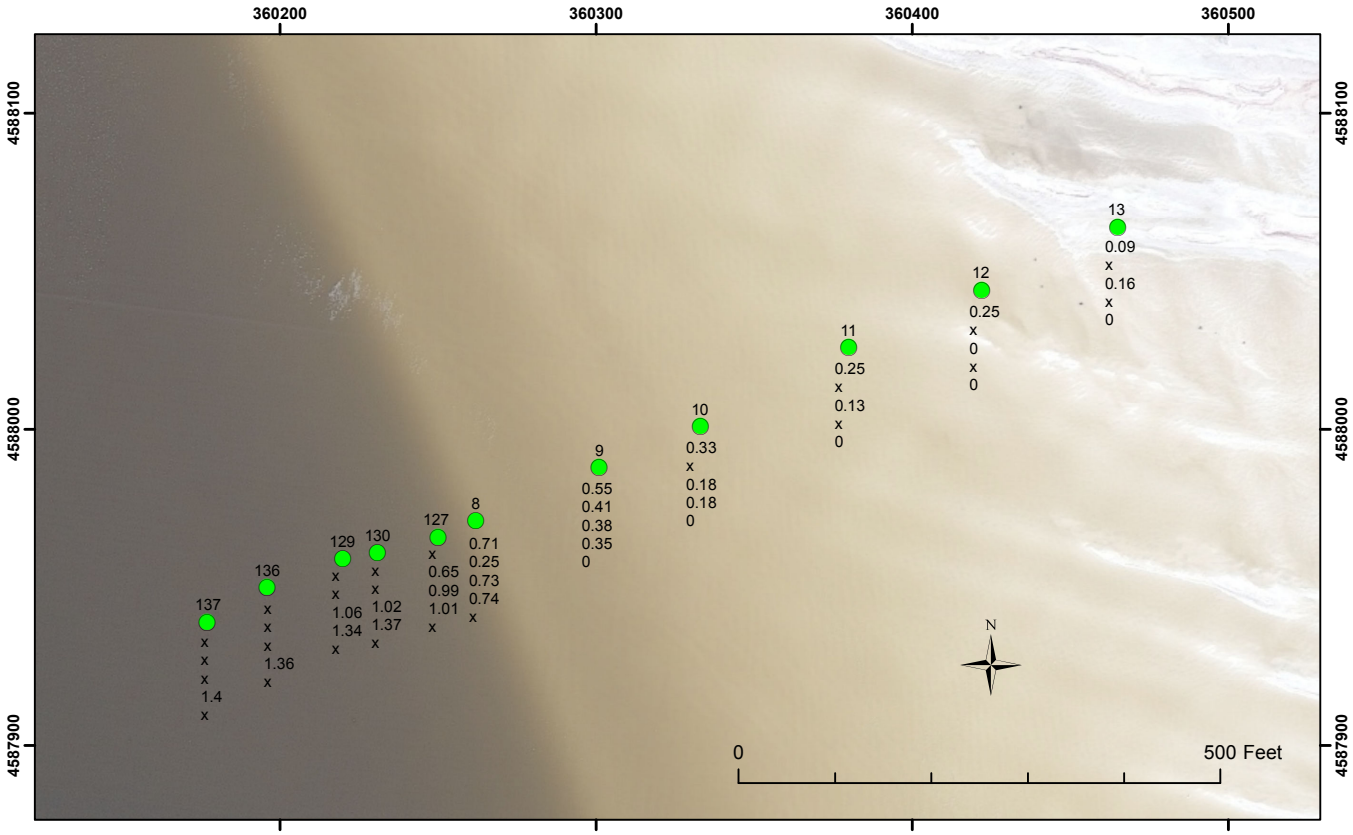

Figure 2. *Salt crust monitoring station locations along transect 1 (figure 1). Label above point indicates station number. Labels below point indicate salt crust thickness in feet on the following dates (in descending order): Aug. 13, 2015; Apr. 7, 2016; Jul. 20, 2016; Sep. 20, 2016; and Mar. 9, 2017. An "x" indicates a measurement was not taken on that date. Grid coordinates are UTM Z12 NAD83 (m). Base imagery is from August 2014 and is provided by Google.*

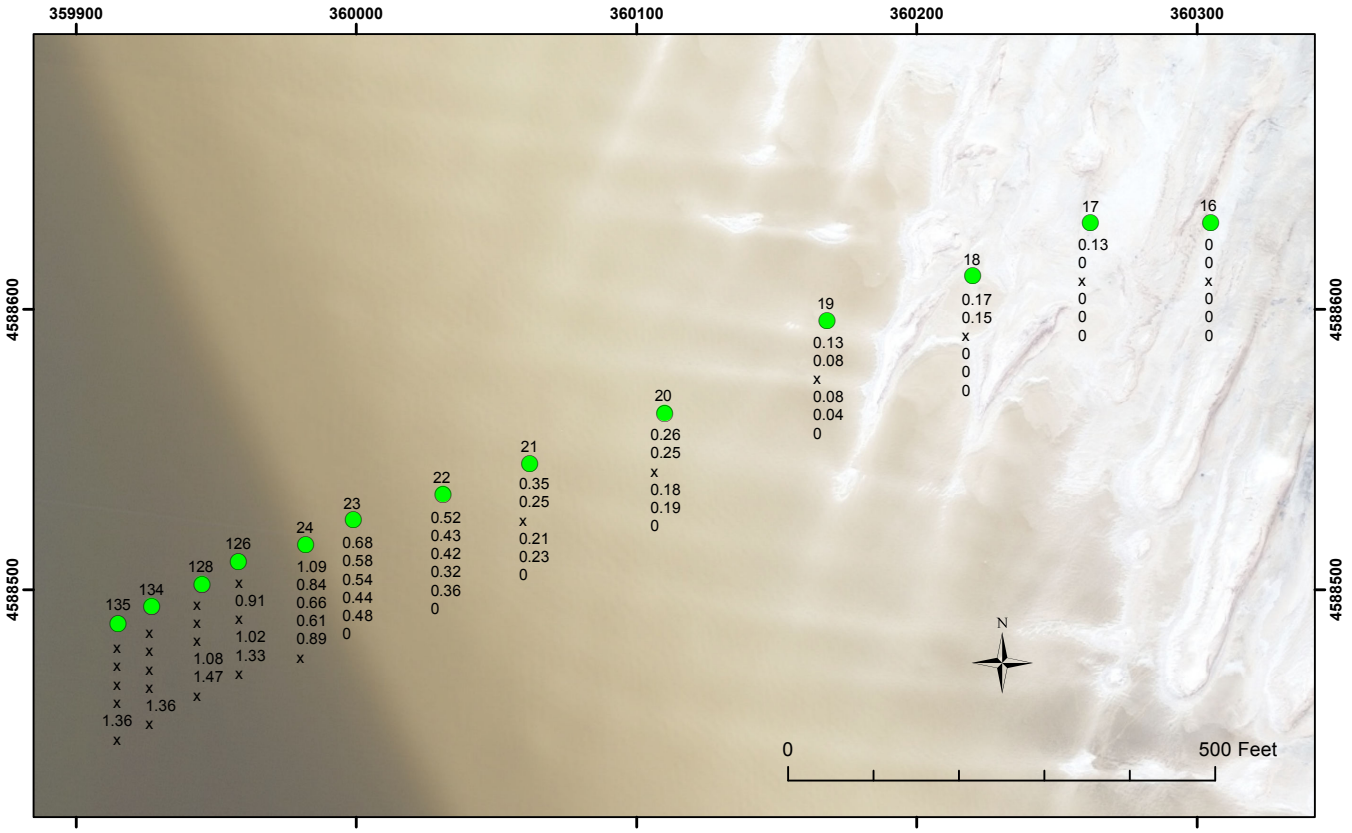

Figure 3. *Salt crust monitoring station locations along transect 2 (figure 1). Label above point indicates station number. Labels below point indicate salt crust thickness in feet on the following dates (in descending order): Aug. 21, 2015; Mar. 4, 2016; Apr. 7, 2016; Jul. 20, 2016; Sep. 20, 2016; and Mar. 9, 2017. An "x" indicates a measurement was not taken on that date. Grid coordinates are UTM Z12 NAD83 (m). Base imagery is from August 2014 and is provided by Google.*

The largest changes in thickness came from stations that were inundated at least part of the time. During late winter and early spring 2016 and 2017, substantial decreases in crust thickness were recorded, and during late summer 2016, significant crust thickness increases were recorded. Between August 2015 and April 7, 2016, we measured thickness reductions of 0.46 and 0.42 ft at stations 8 and 24 on transects 1 and 2, respectively. The largest increase we observed between measurements was at station 8 along transect 1 from April 7, 2016, to July 20, 2016, where the crust grew by 0.49 ft. From July 20, 2016, to September 20, 2016, we observed a thickness increase of 0.39 ft at station 128 along transect 2. We also recorded several other thickness increases at sites that were underwater for all or part of summer 2016. The largest decrease in thickness was at station 29 along transect 3 where 0.54 ft of crust dissolved between September 15, 2016, and April 6, 2017. Along transect 2 at station 23, 0.48 ft of salt crust dissolved between September 20, 2016, and March 9, 2017. Several other stations showed similar decreases in late winter and early spring 2017 compared to our previous measurements from late summer 2016.

The observed trends were basically consistent with lake conditions. Salt crust dissolved between summer 2015 and early spring 2016 during a time when the lake level rose slightly (0.3 ft) and significant precipitation events occurred that may have transiently and locally diluted nearshore brine (Rupke and others, 2016). Crust was added during summer 2016 as the north arm lake elevation dropped to record low levels (4189.0 ft above sea level at its lowest) and while water density was relatively high (1.232 g/cm^3 on September 20, 2016) (table 1). The salt crust increases we measured during summer 2016 were likely a result of salt raft accumulation and crystal growth on the floor of the lake. A significant change was evident in our measurements in spring 2017. This was partially a function of seasonal change, but the opening of the causeway breach on December 1, 2016, certainly played a role. By March 9, 2017, the north arm water level had risen 3.6 ft and the nearshore salt crust along transects 1 and 2 had dissolved completely at all stations where we were able to measure (figures 5 and 6). In deeper water, we noted some remnant crust, but the water depth prevented us from taking accurate measurements. On April 6, we measured the crust along transect 3. The crust there was also undergoing dissolution, but a remnant remained (figure 7). However, at the most southerly station (station 29; in the deepest water) we noted areas where the crust had completely dissolved away. Our water/brine density measurements from spring 2017 were notably lower at 1.185 and 1.191 g/cm^3 (table 1).

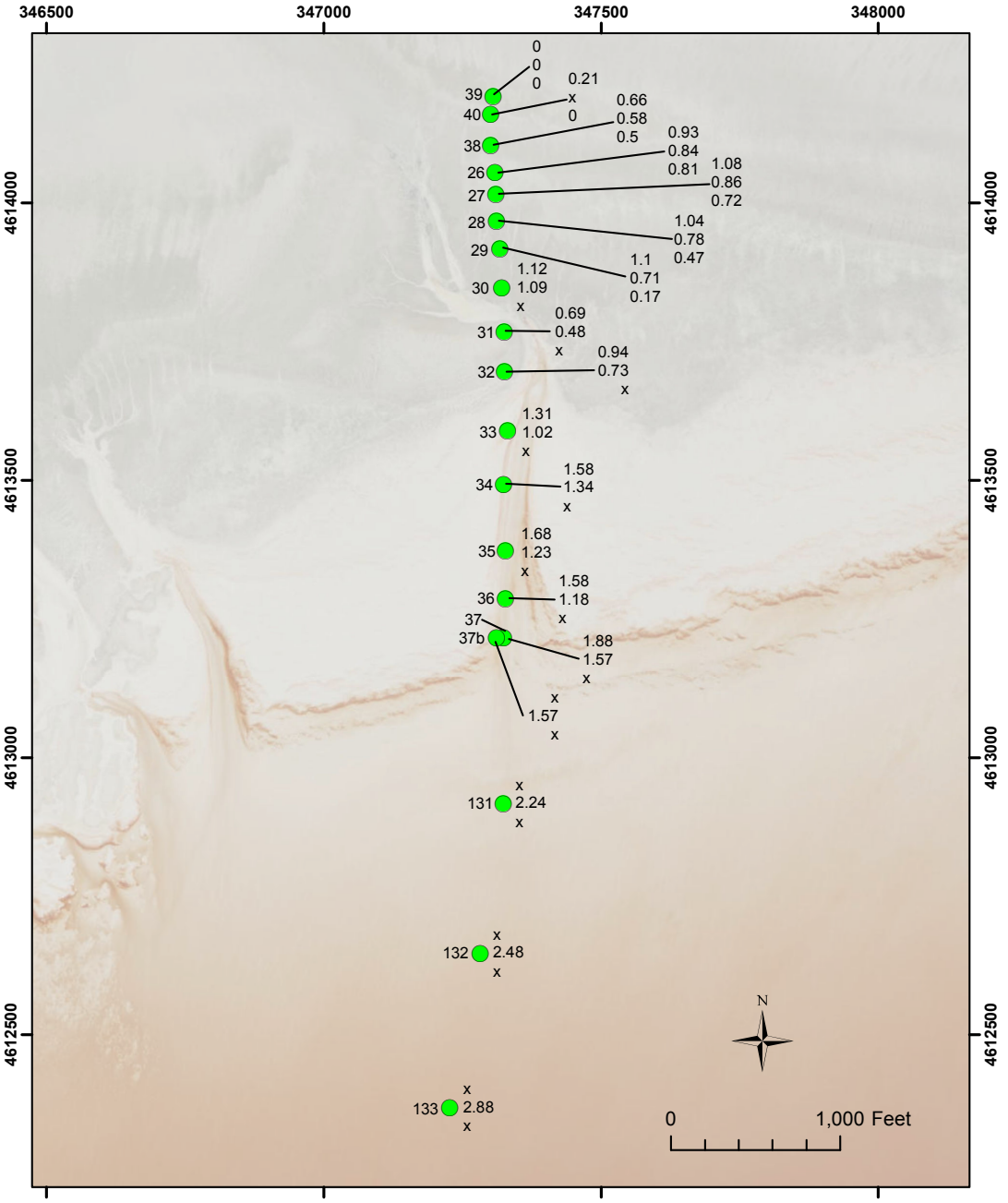

Figure 4. *Salt crust monitoring station locations along transect 3 (figure 1). Label left of point indicates station number. Labels right of point indicate salt crust thickness in feet on the following dates (in descending order): Aug. 25, 2015; Sep. 15, 2016; and Apr. 6, 2016. An "x" indicates a measurement was not taken on that date. Grid coordinates are UTM Z12 NAD83 (m). Base imagery is from August 2014 and is provided by Google.*

As the north arm water level reached record lows during late summer 2016, we were able to access areas of the crust that were previously inaccessible. As a result, our thickest crust measurement from this study and our previous study was obtained along transect 3 in September 2016 at station 133 where we measured 2.88 ft of salt crust. Notably, this measurement shows thick crust much farther north than Goodwin (1973) projected, which has potential implications for the total salt load sequestered in the north arm salt crust.

Our results are useful for observing the seasonal changes and other trends in the lake for measurement sites that are submerged for at least part of the time. Our measurements in spring 2016 demonstrated the winter/fall dissolution of salt crust at transects 1 and 2 related to seasonal freshening of the lake and perhaps short-term, local freshening from significant rain events. Measurements from summer 2016 showed precipitation of new salt crust in response to evaporation and concentration of lake brine, and measurements from late winter and early spring 2017 demonstrated a second year of winter/spring freshening

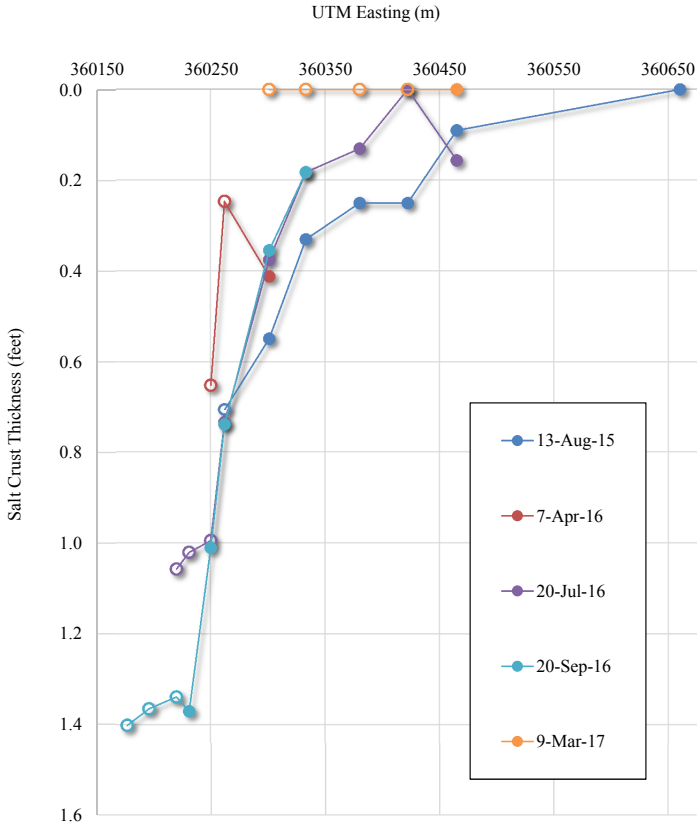

Figure 5. *Salt crust thickness measurements from transect 1. Solid circles indicate salt crust measurements above water/brine level, and open circles indicate measurements below the water/brine level.*

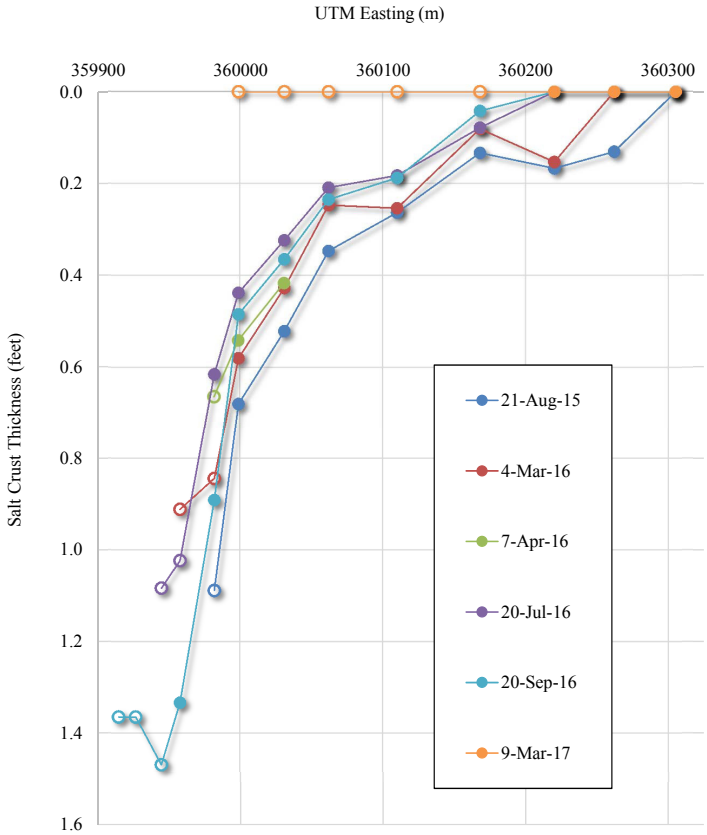

Figure 6. *Salt crust thickness measurements from transect 2. Solid circles indicate salt crust measurements above water/brine level, and open circles indicate measurements below the water/brine level.*

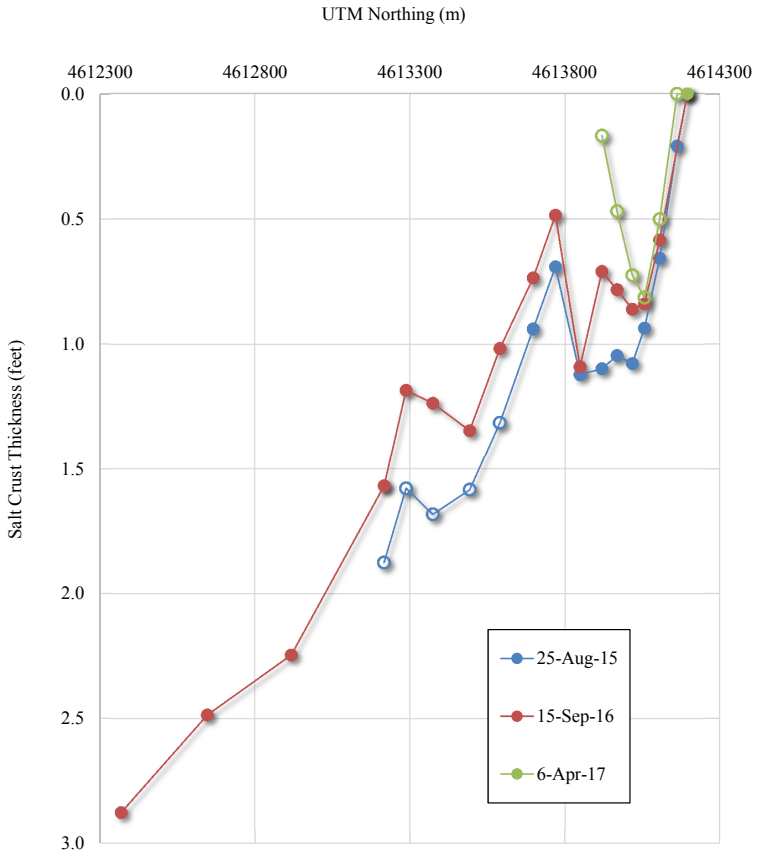

Figure 7. *Salt crust thickness measurements from transect 3. Solid circles indicate salt crust measurements above water/brine level, and open circles indicate measurements below the water/brine level.*

and dissolution. However, the timing of our measurements includes periods of unusual circumstances. Spring runoff in 2016 was minimal, and the north arm experienced unusually low water level rise (less than 0.6 ft in total). The exposed crust in spring 2016 also exhibited signs of significant heavy rain that may not be typical but may have contributed to nearshore crust dissolution (Rupke and others, 2016). Also, the opening of the causeway bridge on December 1, 2016, resulted in dramatic water level rise (over 3.7 ft between our September 20, 2016, and March 9, 2017, measurements) in early 2017. Unfortunately, because seasonal water level rise and opening of the causeway bridge were coincident, we cannot separate the two events in understanding the salt crust's response. However, we can safely assume that the salt crust experienced greater levels of dissolution because of the bridge opening.

Nearshore measurements and the limitations of our methods present some challenges in interpretation of trends. For instance, as mentioned in Rupke and others (2016), we are uncertain how much of an effect heavy rain events had on the nearshore crust by locally diluting the water nearest to the shore during heavy runoff. Also, as water level rises and falls, our ability to measure the crust at certain sites changes, disrupting the continuity of our records at important locations. Water level rise and fall presents the added complication of some measurement sites experiencing both exposure and inundation for undetermined amounts of time. Additionally, when the crust completely dissolves, as it did along much of transects 1 and 2, we do not have a full assessment of the amount of dissolution that could have occurred.

Although notable dissolution of the nearshore crust occurred during winter and early spring 2017, we assume that a significant amount of salt crust remains in more central, submerged parts of the north arm. This highlights the potential benefit of measuring salt crust thickness in deeper water if a reasonable method can be developed, thereby reducing the limitations listed above. However, we intend to continue monitoring the nearshore salt crust to continue to qualitatively observe trends and perhaps more substantive conclusions can be drawn from a longer record of observations.

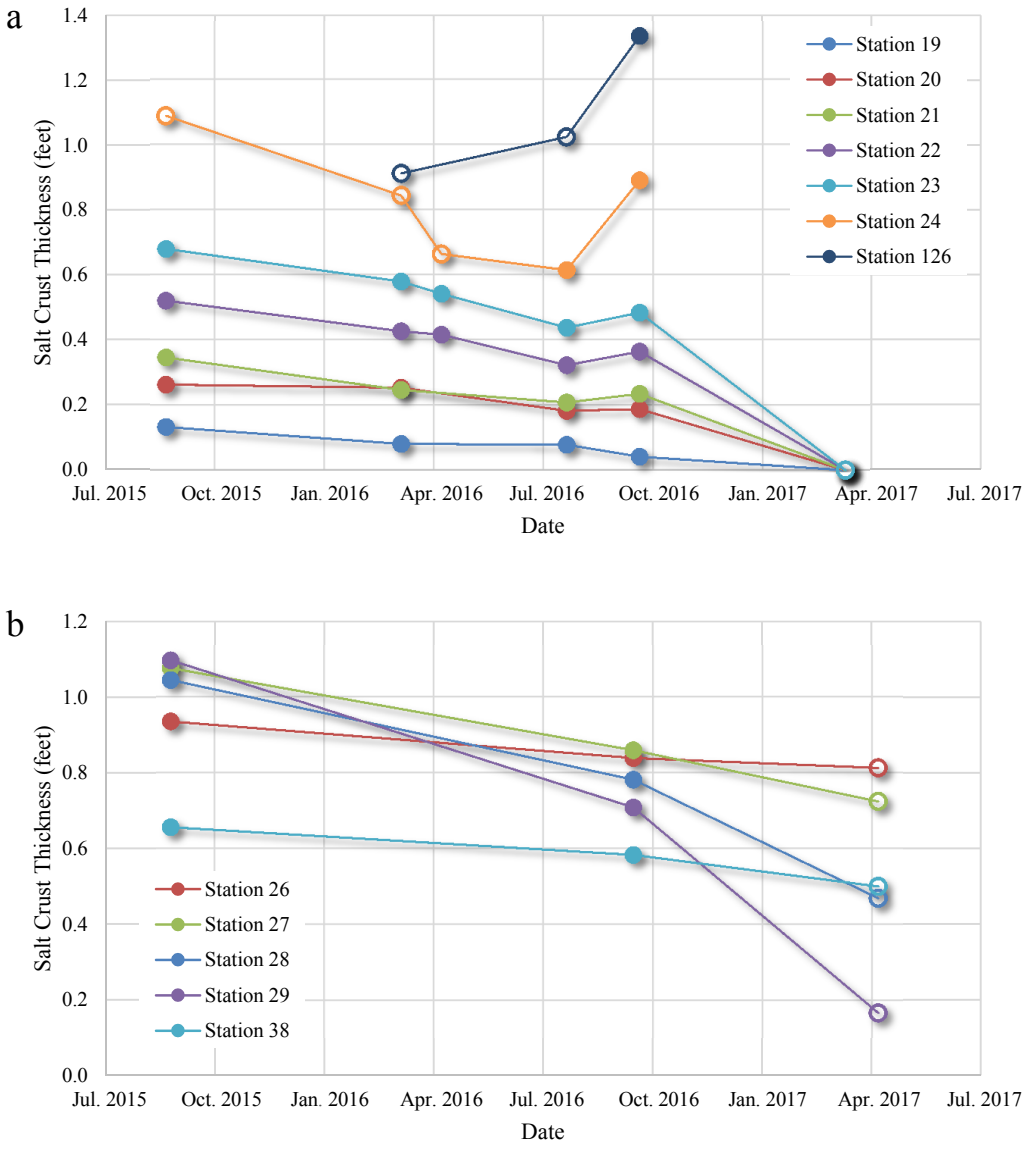

Figure 8. *Salt crust thickness measurements from stations along (a) transect 2 and (b) transect 3. Solid circles indicate salt crust measurements above water/brine level, and open circles indicate measurements below the water/brine level.*

CONCLUSIONS

Nearshore monitoring of the salt crust is useful for qualitatively observing trends caused by changing lake conditions. Both seasonal changes and causeway modifications were reflected in how the salt crust changed from summer 2015 through early spring 2017. Measurements from late winter and early spring in both 2016 and 2017 recorded notable dissolution of the salt crust in areas where it was below the water/brine level, and summer 2016 was marked by growth of the salt crust in areas where it was inundated. Somewhat unusual lake conditions were present during our period of monitoring, so future monitoring may help define more substantive conclusions on the usefulness of nearshore observations. More quantitatively useful observations would likely require monitoring of the salt crust in deeper water.

ACKNOWLEDGMENTS

We thank the Division of Forestry, Fire and State Lands for providing funding for this project. Michael Vanden Berg, Ken Krahulec, Craig Morgan, Stephanie Carney, and Mike Hylland provided helpful reviews of the report.

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APPENDIX

Salt thickness measurement data

Station	Transect Number	Thickness Average (ft)	Thickness Average (inches)	Thickness 1 (inches)	Thickness 2 (inches)	Thickness 3 (inches)	Thickness 4 (inches)	Standard Deviation (inches)	Standard Deviation (ft)	UTM Z12 NAD83 UTM Easting (m)	UTM Northing (m)	Date Measured	Measurement in water?	Number of holes used for measurement	Comment
8	1	0.71	8.47	8.500	8.500	8.500	8.375	0.06	0.005	360262	4587971	13-Aug-15	yes	3	
9	1	0.55	6.58	6.625	6.625	6.500		0.07	0.006	360301	4587988	13-Aug-15	no	3	
10	1	0.33	3.96	4.000	4.000	3.875		0.07	0.006	360333	4588001	13-Aug-15	no	3	
11	1	0.25	3.00	3.000	3.000	3.000		0.00	0.000	360380	4588026	13-Aug-15	no	3?	
12	1	0.25	3.00	2.625	3.250	3.125		0.33	0.028	360422	4588044	13-Aug-15	no	3?	
13	1	0.09	1.08	1.000	1.000	1.250		0.14	0.012	360465	4588064	13-Aug-15	no	3?	
15	1	0.00	0.00	0.000						360660	4588249	13-Aug-15	no	n/a	edge of salt crust
127	1	0.65	7.81	7.500	8.125			0.44	0.037	360250	4587966	7-Apr-16	yes	1	
8	1	0.25	2.96	2.750	3.000	3.125		0.19	0.016	360262	4587971	7-Apr-16	yes	1	only a few inches from shore
9	1	0.41	4.94	5.000	4.875			0.09	0.007	360301	4587988	7-Apr-16	no	1	
129	1	1.06	12.69	12.375	13.000			0.44	0.037	360220	4587959	20-Jul-16	yes	1	
130	1	1.02	12.25	12.125	12.375			0.18	0.015	360231	4587961	20-Jul-16	yes	1	
127	1	0.99	11.94	12.000	11.875			0.09	0.007	360250	4587966	20-Jul-16	yes	1	
8	1	0.73	8.81	8.750	8.875			0.09	0.007	360262	4587971	20-Jul-16	no	1	
9	1	0.38	4.50	4.500	4.500			0.00	0.000	360301	4587988	20-Jul-16	no	1	
10	1	0.18	2.19	2.000	2.375			0.27	0.022	360333	4588001	20-Jul-16	no	1	
11	1	0.13	1.56	1.500	1.625			0.09	0.007	360380	4588026	20-Jul-16	no	1	
12	1	0.00	0.00	0.000						360422	4588044	20-Jul-16	no		patchy in this area
13	1	0.16	1.88	1.875	1.875			0.00	0.000	360465	4588064	20-Jul-16	no	1	
137	1	1.40	16.81	16.875	16.750			0.09	0.007	360177	4587939	20-Sep-16	yes	1	
136	1	1.36	16.38	16.250	16.500			0.18	0.015	360196	4587950	20-Sep-16	yes	1	
129	1	1.34	16.06	16.375	15.750			0.44	0.037	360220	4587959	20-Sep-16	yes	1	
130	1	1.37	16.44	15.875	17.000			0.80	0.066	360231	4587961	20-Sep-16	no	1	at the edge of water
127	1	1.01	12.13	12.000	12.250			0.18	0.015	360250	4587966	20-Sep-16	no	1	
8	1	0.74	8.88	8.875	8.875			0.00	0.000	360262	4587971	20-Sep-16	no	1	
9	1	0.35	4.25	4.125	4.375			0.18	0.015	360301	4587988	20-Sep-16	no	1	
10	1	0.18	2.19	2.375	2.000			0.27	0.022	360333	4588001	20-Sep-16	no	1	
8	1									360262	4587971	9-Mar-17	yes	n/a	unable to measure, but some salt crust present; crust irregular and covered with sediment
9	1	0.00	0.00	0.000						360301	4587988	9-Mar-17	yes	n/a	
10	1	0.00	0.00	0.000						360333	4588001	9-Mar-17	yes	n/a	
11	1	0.00	0.00	0.000						360380	4588026	9-Mar-17	yes	n/a	
12	1	0.00	0.00	0.000						360422	4588044	9-Mar-17	yes	n/a	
13	1	0.00	0.00	0.000						360465	4588064	9-Mar-17	no	n/a	
24	2	1.09	13.06	13.000	13.125	13.000	13.125	0.07	0.006	359982	4588516	21-Aug-15	yes	2	
23	2	0.68	8.16	8.125	8.375	8.125	8.000	0.16	0.013	359999	4588525	21-Aug-15	no	2	sample SCI-1 collected
22	2	0.52	6.25	6.250	6.250	6.000	6.500	0.20	0.017	360031	4588534	21-Aug-15	no	2	
21	2	0.35	4.16	4.250	4.000	4.250	4.125	0.12	0.010	360062	4588545	21-Aug-15	no	2	
20	2	0.26	3.16	3.000	3.000	3.500	3.125	0.24	0.020	360110	4588563	21-Aug-15	no	2	
19	2	0.13	1.59	1.625	1.625	1.500	1.625	0.06	0.005	360168	4588596	21-Aug-15	no	2	
18	2	0.17	2.00	2.000	2.000	2.000	2.000	0.00	0.000	360220	4588612	21-Aug-15	no	2	
17	2	0.13	1.56	1.625	1.625	1.500	1.500	0.07	0.006	360262	4588631	21-Aug-15	no	2	
16	2	0.00	0.00	0.000						360305	4588631	21-Aug-15	no	n/a	edge of salt crust; patchy to east
126	2	0.91	10.94	10.875	11.000			0.09	0.007	359958	4588510	4-Mar-16	yes	1	
24	2	0.84	10.13	10.250	10.375	9.750		0.33	0.028	359982	4588516	4-Mar-16	yes	1	
23	2	0.58	6.96	6.750	7.000	7.125		0.19	0.016	359999	4588525	4-Mar-16	no	1	
22	2	0.43	5.13	5.250	5.125	5.000		0.13	0.010	360031	4588534	4-Mar-16	no	1	found previous hole, but measured a new hole
21	2	0.25	2.96	3.125	2.875	2.875		0.14	0.012	360062	4588545	4-Mar-16	no	1	
20	2	0.25	3.04	3.000	3.000	3.125		0.07	0.006	360110	4588563	4-Mar-16	no	1	
19	2	0.08	0.97	1.000	0.875	1.000	1.000	0.06	0.005	360168	4588596	4-Mar-16	no	2	
18	2	0.15	1.83	1.750	2.000	1.750		0.14	0.012	360220	4588612	4-Mar-16	no	1	
17	2	0.00	0.00	0.000						360262	4588631	4-Mar-16	no	n/a	patches of crust in this area
16	2	0.00	0.00	0.000						360305	4588631	4-Mar-16	no	n/a	
24	2	0.66	7.97	7.750	7.875	8.375	7.875	0.28	0.023	359982	4588516	7-Apr-16	yes	2	found previous hole, used both old and new holes
23	2	0.54	6.50	6.625	6.375			0.18	0.015	359999	4588525	7-Apr-16	no	1	found previous hole, but measured a new hole
22	2	0.42	5.00	5.000	5.000			0.00	0.000	360031	4588534	7-Apr-16	no	1	found previous hole, but measured a new hole
128	2	1.08	13.00	13.250	12.750			0.35	0.029	359945	4588502	20-Jul-16	yes	1	
126	2	1.02	12.28	11.625	12.125	12.375	13.000	0.57	0.048	359958	4588510	20-Jul-16	yes	2	

Station	Transect Number	Thickness Average (ft)	Thickness Average (inches)	Thickness 1 (inches)	Thickness 2 (inches)	Thickness 3 (inches)	Thickness 4 (inches)	Standard Deviation (inches)	Standard Deviation (ft)	UTM Z12 NAD83 UTM Easting (m)	UTM Northing (m)	Date Measured	Measurement in water?	Number of holes used for measurement	Comment
24	2	0.61	7.38	7.250	7.500			0.18	0.015	359982	4588516	20-Jul-16	no	1	
23	2	0.44	5.25	5.125	5.375			0.18	0.015	359999	4588525	20-Jul-16	no	1	
22	2	0.32	3.88	4.000	3.750			0.18	0.015	360031	4588534	20-Jul-16	no	1	
21	2	0.21	2.50	2.500	2.500			0.00	0.000	360062	4588545	20-Jul-16	no	1	
20	2	0.18	2.19	2.125	2.250			0.09	0.007	360110	4588563	20-Jul-16	no	1	
19	2	0.08	0.94	0.875	1.000			0.09	0.007	360168	4588596	20-Jul-16	no	1	
18	2	0.00	0.00	0.000						360220	4588612	20-Jul-16	no	n/a	
17	2	0.00	0.00	0.000						360262	4588631	20-Jul-16	no	n/a	
16	2	0.00	0.00	0.000						360305	4588631	20-Jul-16	no	n/a	
135	2	1.36	16.38	16.250	16.500			0.18	0.015	359915	4588488	20-Sep-16	yes	1	
134	2	1.36	16.38	16.125	16.625			0.35	0.029	359927	4588494	20-Sep-16	yes	1	
128	2	1.47	17.63	17.500	17.750			0.18	0.015	359945	4588502	20-Sep-16	yes	1	
126	2	1.33	16.00	15.875	16.125			0.18	0.015	359958	4588510	20-Sep-16	no	1	at the edge of water
24	2	0.89	10.69	10.750	10.625			0.09	0.007	359982	4588516	20-Sep-16	no	1	an additional inch of detrital salt above crust
23	2	0.48	5.81	5.750	5.875			0.09	0.007	359999	4588525	20-Sep-16	no	1	
22	2	0.36	4.38	4.250	4.500			0.18	0.015	360031	4588534	20-Sep-16	no	1	
21	2	0.23	2.81	2.875	2.750			0.09	0.007	360062	4588545	20-Sep-16	no	1	
20	2	0.19	2.25	2.125	2.375			0.18	0.015	360110	4588563	20-Sep-16	no	1	
19	2	0.04	0.50	0.625	0.375			0.18	0.015	360168	4588596	20-Sep-16	no	1	
18	2	0.00	0.00	0.000						360220	4588612	20-Sep-16	no	1	spotty crust
17	2	0.00	0.00	0.000						360262	4588631	20-Sep-16	no	1	
16	2	0.00	0.00	0.000						360305	4588631	20-Sep-16	no	1	
24	2									359982	4588516	9-Mar-17	yes	n/a	unable to measure, but some salt crust present; crust irregular and covered with sediment
23	2	0.00	0.00	0.000						359999	4588525	9-Mar-17	yes	n/a	
22	2	0.00	0.00	0.000						360031	4588534	9-Mar-17	yes	n/a	
21	2	0.00	0.00	0.000						360062	4588545	9-Mar-17	yes	n/a	
20	2	0.00	0.00	0.000						360110	4588563	9-Mar-17	yes	n/a	
19	2	0.00	0.00	0.000						360168	4588596	9-Mar-17	yes	n/a	edge of water
18	2	0.00	0.00	0.000						360220	4588612	9-Mar-17	no	n/a	minimal spotty crust underneath sediment; up to 3/4 inch
17	2	0.00	0.00	0.000						360262	4588631	9-Mar-17	no	n/a	
16	2	0.00	0.00	0.000						360305	4588631	9-Mar-17	no	n/a	
37	3	1.88	22.50	22.125	23.000	22.375	22.500	0.37	0.031	347324	4613216	25-Aug-15	yes	2	
36	3	1.58	18.94	19.000	18.875			0.09	0.007	347328	4613287	25-Aug-15	yes	1	
35	3	1.68	20.19	19.875	20.500			0.44	0.037	347328	4613373	25-Aug-15	yes	1	possible small zone of mud (less than an inch?)
34	3	1.58	19.00	19.000	19.000			0.00	0.000	347324	4613492	25-Aug-15	yes	1	possible small zone of mud (less than an inch?)
33	3	1.31	15.75	15.750	15.750			0.00	0.000	347331	4613589	25-Aug-15	yes	1	possible small zone of mud (less than an inch?)
32	3	0.94	11.25	11.000	11.500			0.35	0.029	347326	4613696	25-Aug-15	no	1	
31	3	0.69	8.28	7.750	8.500	8.375	8.500	0.36	0.030	347325	4613768	25-Aug-15	no	2	probed for deeper salt, but none encountered
30	3	1.12	13.44	12.750	13.750	14.000	13.250	0.55	0.046	347321	4613847	25-Aug-15	no	2	may be about 1.5 inches of salt below about 2 inches of mud bed below the top salt
29	3	1.10	13.16	13.000	13.625	12.875	13.125	0.33	0.027	347317	4613918	25-Aug-15	no	2	
28	3	1.04	12.53	13.125	13.000	12.000	12.000	0.62	0.051	347311	4613967	25-Aug-15	no	2	
27	3	1.08	12.91	12.625	13.250	12.750	13.000	0.28	0.023	347310	4614016	25-Aug-15	no	2	
26	3	0.93	11.22	11.125	11.250	11.250	11.250	0.06	0.005	347309	4614055	25-Aug-15	no	2	
38	3	0.66	7.88	8.750	7.750	7.500	7.500	0.60	0.050	347301	4614104	25-Aug-15	no	2	may be a few inches of additional salt below top salt; measurements represent top salt
40	3	0.21	2.5	2.500	2.500			0.00	0.000	347301	4614160	25-Aug-15	no	1	
39	3	0.00	0	0.000						347305	4614193	25-Aug-15	no	n/a	
133	3	2.88	34.50	34.625	34.375			0.18	0.015	347227	4612369	15-Sep-16	no	1	
132	3	2.48	29.81	29.500	30.125			0.44	0.037	347282	4612647	15-Sep-16	no	1	possible thin mud zone based on probing and cuttings
131	3	2.24	26.94	26.750	27.125			0.27	0.022	347323	4612917	15-Sep-16	no	1	
37	3	1.57	18.81	18.500	19.125			0.44	0.037	347324	4613216	15-Sep-16	no	1	possible thin mud zone
37b	3	1.57	18.81	18.750	18.875			0.09	0.007	347311	4613216	15-Sep-16	no	1	added this location because when exposed 37 is in water drainage area; possible minor mud zone
36	3	1.18	14.19	14.000	14.375			0.27	0.022	347328	4613287	15-Sep-16	no	1	
35	3	1.23	14.81	14.625	15.000			0.27	0.022	347328	4613373	15-Sep-16	no	1	
34	3	1.34	16.13	16.000	16.250			0.18	0.015	347324	4613492	15-Sep-16	no	1	possible thin mud zone
33	3	1.02	12.19	12.250	12.125			0.09	0.007	347331	4613589	15-Sep-16	no	1	
32	3	0.73	8.81	8.875	8.750			0.09	0.007	347326	4613696	15-Sep-16	no	1	possible mud zone (less than 0.5 in?)
31	3	0.48	5.81	5.750	5.875			0.09	0.007	347325	4613768	15-Sep-16	no	1	

Station	Transect Number	Thickness Average (ft)	Thickness Average (inches)	Thickness 1 (inches)	Thickness 2 (inches)	Thickness 3 (inches)	Thickness 4 (inches)	Standard Deviation (inches)	Standard Deviation (ft)	UTM Z12 NAD83 UTM Easting (m)	UTM Northing (m)	Date Measured	Measurement in water?	Number of holes used for measurement	Comment
30	3	1.09	13.06	13.000	13.125			0.09	0.007	347321	4613847	15-Sep-16	no	1	mud zone from 8-12 inches deep
29	3	0.71	8.50	8.500	8.500			0.00	0.000	347317	4613918	15-Sep-16	no	1	
28	3	0.78	9.38	8.500	10.250			1.24	0.103	347311	4613967	15-Sep-16	no	1	possible thin mud zone
27	3	0.86	10.31	10.000	10.625			0.44	0.037	347310	4614016	15-Sep-16	no	1	possible thin mud zone; mud covers top of salt
26	3	0.84	10.06	9.875	10.250			0.27	0.022	347309	4614055	15-Sep-16	no	1	possible thin mud zone; mud covers top of salt
38	3	0.58	7.00	6.750	7.250			0.35	0.029	347301	4614104	15-Sep-16	no	1	additonal salt zone base at 12.75, but probably did not measure first time; mud covers top of salt
39	3	0.00	0.00	0.000						347305	4614193	15-Sep-16	no	1	drilled but found no salt
29	3	0.17	2.00	2.000	2.000			0.00	0.000	347317	4613918	6-Apr-17	yes	1	crust is completely dissolved away in some areas near this station
28	3	0.47	5.63	5.500	5.750			0.18	0.015	347311	4613967	6-Apr-17	yes	1	
27	3	0.72	8.69	8.875	8.500			0.27	0.022	347310	4614016	6-Apr-17	yes	1	mud covers top of salt; irregular surface; probably dissolving
26	3	0.81	9.75	10.375	9.125	9.75		0.63	0.052	347309	4614055	6-Apr-17	yes	2	mud covers top of salt; irregular and dissolving; bottom of crust somewhat indistinct
38	3	0.50	6.00	6.000	6.000			0.00	0.000	347301	4614104	6-Apr-17	yes	1	mud covers top of salt; mud (?) zone from 6 to 9.5 inches; salt lense from 9.5 to 10.75 inches
40	3	0.00	0.00	0.000						347301	4614160	6-Apr-17	yes	1	
39	3	0.00	0.00	0.000						347305	4614193	6-Apr-17	no	1	