GREAT SALT LAKE BRINE CHEMISTRY DATABASE, 1966–2011

by Andrew Rupke and Ammon McDonald

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Cover photo: *The Southern Pacific Railroad rock causeway. The view is to the east, and the north arm of Great Salt Lake is on the left.*

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ABSTRACT

Great Salt Lake's salinity levels are dynamic, and the Utah Geological Survey has systematically sampled the Great Salt Lake brine since 1966 in an effort to monitor salinity levels and chemistry. The Utah Geological Survey collects samples in both the north and south arms of Great Salt Lake, and at each site samples are taken at regular intervals through the water column. Samples are analyzed for chemistry, total dissolved solids, and density. Early in the sampling program numerous sites were sampled, but data indicated that fewer sample sites were sufficient to characterize the lake so currently only two to three sites are sampled during each run. At a few sites in the north and south arms, a fairly continuous record of chemical analyses is available from 1966 through 2011. This report contains an updated version of the sample database containing all data from 1966 through 2011. The database has also been reorganized into a single Excel spreadsheet for ease of use.

INTRODUCTION

The salinity level of Great Salt Lake (GSL) is quite dynamic due to natural lake level fluctuations and man-made barriers within the lake. Salinity in the lake tends to be a function of surface lake level—as lake level rises salinity decreases and as lake level drops salinity increases. Another primary influence on salinity levels in GSL is the Southern Pacific Railroad rock causeway that was completed across the lake in 1959. Because of the restricted flow across the railroad causeway, it effectively divides GSL into two distinct bodies of water—the north arm (Gunnison Bay) and the south arm (primarily Gilbert Bay). The north arm, which receives very little freshwater input, essentially functions as the terminal part of GSL with minor return of water to the south arm. The south arm, however, receives significant freshwater input from the Bear River, Jordan River, and Weber River (through Bear River and Farmington Bays) and significant amounts of water flow from the south arm to the north arm. Over time, these conditions caused the north arm to become significantly more saline than the south arm. Also, the north-to-south flow through the causeway, although limited, has formed, at times, a dense brine layer at the bottom of the south arm of the lake. In an effort to monitor and understand the dynamic conditions created by lake level fluctuation, the railroad causeway, and other factors, the Utah Geological Survey (UGS) began a systematic brine sampling program in 1966. At a number of sites throughout the lake the UGS takes samples at various depths through the water column and analyzes the samples for chemistry, total dissolved solids, and density. This sampling program has largely been funded by the Utah Division of Forestry, Fire, and State Lands.

The UGS has released data from this sampling program in a number of publications. Prior to this release, the chemistry data were published in two major reports by Sturm (1986) and Gwynn (2007). Interpretive reports of this data by the UGS include those of Whelan (1973), Whelan and Petersen (1975), Whelan and Petersen (1977), Sturm (1980), Gwynn and Sturm (1987), and Gwynn (2002). Gwynn (2007) provided information on a number of additional publications on GSL brine chemistry, including an appendix presenting sources containing brine chemistry from before 1966. The UGS was involved in GSL sampling prior to 1966 as well, and Sturm (1986) summarized those sampling efforts.

This publication includes the UGS sample database in its entirety with all data from 1966 through 2011 (appendix A). Some of the updates for this release include a reorganization of the database for ease of use, updating all lake elevations in the database to reflect elevation corrections by the U.S. Geological Survey, and creation of a table summarizing sample dates for each sample site.

GREAT SALT LAKE SAMPLING

Sampling Sites

The UGS has sampled GSL brine at 57 different sample locations over the course of the sampling program (figure 1). Early in the sampling program's history, numerous sites were sampled in an effort to determine salinity and chemical variations within different areas of the lake. Lateral chemical variation within the arms of the lake was recognized to be minimal, and this information along with cost and time required to sample numerous sites led to a reduction of sampling sites over the years (Sturm, 1986; Gwynn, 2007). Currently, the UGS typically samples two to three sites in the south arm of GSL and two to three sites in the north arm of GSL during sampling runs.

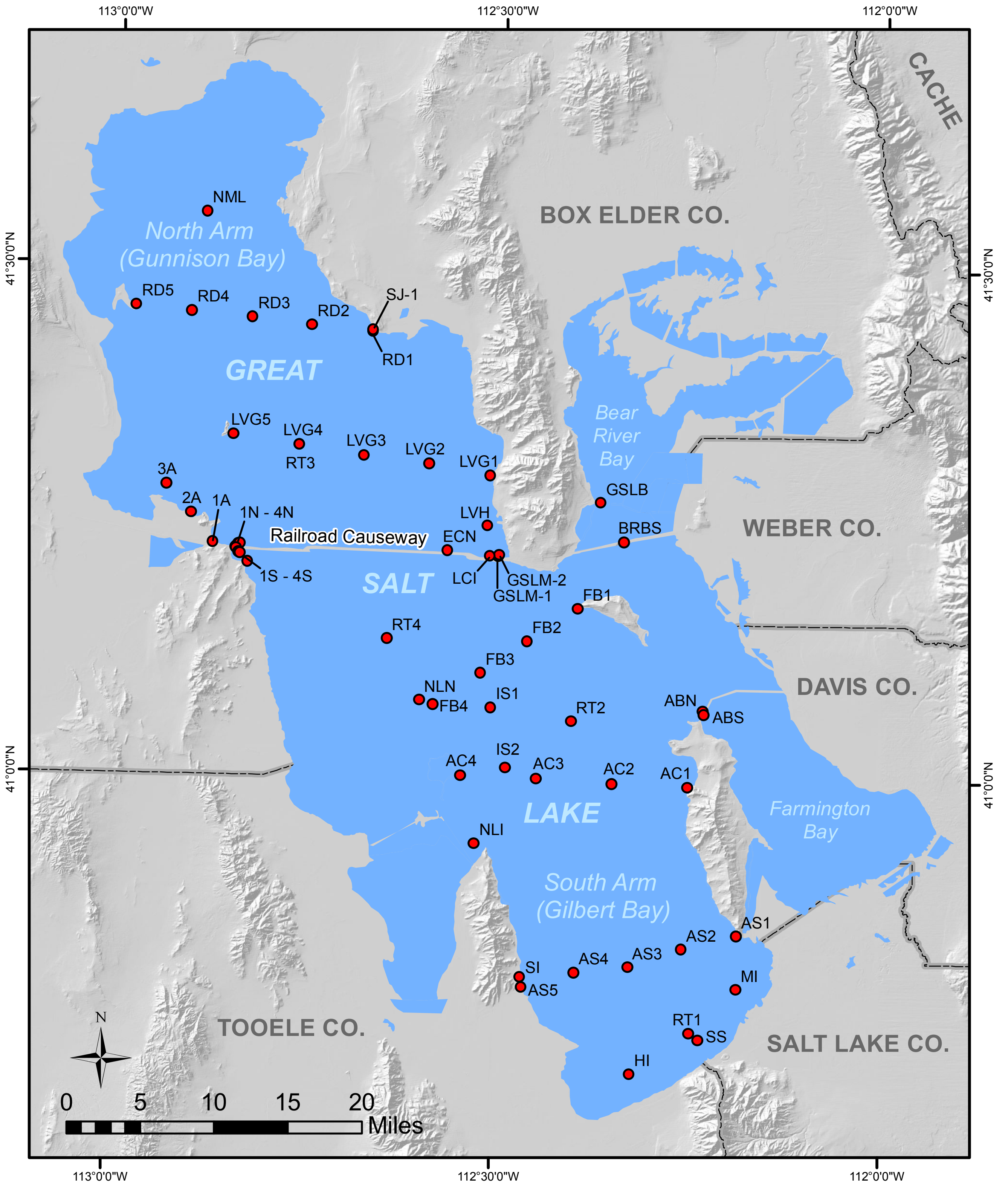

Figure 1. *Great Salt Lake brine sample locations. Great Salt Lake is represented at its extent when the water level is at 4200 feet (approximate average historical surface elevation).*

In the south arm of GSL, sites AS2 and FB2 have the most continuous records of analyses (figure 1); they have been sampled at least once a year from 1966 through 2011. In the north arm, sites LVG4 and RD2 have the most continuous sampling records. However, LVG4 and RD2 were not sampled from 2008 to 2010 due to access restrictions, and RD2 was also not sampled from 1990 to 1993. Recently, we have added a surface sampling location in the north arm at the Spiral Jetty (site SJ-1) if boat access to the lake is unavailable (figure 1). Table 1 summarizes the chemical and density data available for each sample location. Sampling locations were updated for accuracy in this release of the sample database, but locations should be considered approximate in general. Table 2 includes latitude, longitude, and UTM coordinates of sample sites.

Sampling Method

Currently, we travel to each sampling site using a boat owned and operated by the Utah Division of Wildlife Resources (DWR). We travel to each sampling site using the navigational equipment on DWR's boat. At each location, samples are taken at regular intervals (typically 5 feet) through the entire water column. A graduated hose weighted by a metal screen is used to take the samples at the appropriate depth. At each sample depth, sufficient water is pumped through the hose to remove the brine from the previous sample collection depth. The pump used for sampling is a 12-volt DC pump (Flojet 4300 series) powered by the boat's battery or a spare battery. Both the sample bottle and sample bottle lid are rinsed with brine from the appropriate sampling interval prior to being filled. We typically collect about 250 mL of brine at each depth interval.

Analysis Information

Brine samples are analyzed by a commercial lab for chemistry and density. The analytical suite includes the major ions that are found in GSL including sodium, magnesium, potassium, calcium, sulfate, and chloride. Early in the sampling program, lithium, boron, and bromine were part of the analytical suite, but these elements are not currently analyzed. The following laboratories have been used over the course of the sampling program:

1966–1974	Utah Geological and Mineralogical Survey Laboratory
1975–1978	Chemical and Mineralogical Services
1979–1981	American Chemical Research
1981–Present	Chemical and Mineralogical Services

Additional information on analyses and laboratory procedures is contained in Sturm and others (1980), Sturm (1986), and Gwynn (2007). As noted by Gwynn (2007), the quality of the analyses is somewhat variable and the more recent data are more reliable.

Sample Database

This publication includes a digital version of the sample database in Microsoft Excel spreadsheet format (appendix A). We reorganized the database since it was last published in 2007, and all the data are found in a single spreadsheet file named "Great_Salt_Lake_Brine_Chemistry_Database_Appendix_A.xls." Each tab in the spreadsheet corresponds to a particular sample location and provides all the data available for that sampling site. One tab in the spreadsheet contains coordinates for all the sample sites.

The database contains the following column headings for each site:

SITE – Name of sampling location.

LATITUDE – Latitude coordinate of site in NAD27 decimal degrees.

LONGITUDE – Longitude coordinate of site in NAD27 decimal degrees.

DATE – Date that the sample was collected.

DEPTH-FT – Depth of sample below water surface in feet. Some error is present in this measurement because if the boat is not completely still (on windy days, for example) the sample hose will not be completely vertical.

FIELD-DEN – Density of water measured in the field shortly after collection in g/cm3.

LAB-DEN – Density of water measured in the lab in g/cm3.

TEMP – Temperature of the sample recorded at the time of sampling in degrees Fahrenheit.

Na^{+} – Sodium concentration in g/L.

Mg^{+2} – Magnesium concentration in g/L.

K^{+} – Potassium concentration in g/L.

Ca^{+2} – Calcium concentration in g/L.

Cl^{-} – Chloride concentration in g/L.

$SO4^{-2}$ – Sulfate concentration in g/L.

Br – Bromine concentration in ppm.

Li – Lithium concentration in ppm.

B – Boron concentration in ppm.

TDS – Total dissolved solids in g/L.

WT%-TDS – weight percent of total dissolved solids.

LK-ELEV – Surface elevation of the lake at the time of sampling. Elevations are provided by the U.S. Geologi-

Table 1. *Summary of analyses available at Great Salt Lake sampling sites.*

Sample Site	Arm of Lake*	Years of available chemical analyses	Years of available density measurements
ABN	S	1976-1980, 1983	1976-1980, 1983
ABS	----	1976	1976
AC1	S	1966-1983	1966-1983, 2002
AC2	S	1966-1976, 1979-1983	1966-1976, 1979-1983, 2002
AC3	S	1966-1989, 1993, 2004, 2010	1966-1991, 1993-2006, 2009-2010
AC4	S	1966-1975, 1979-1983	1966-1975, 1979-1983
AS1	S	1966-1968, 1972	1966-1968, 1972
AS2	S	1966-2011	1966-2011
AS3	S	1966-1968	1966-1968
AS4	S	1966-1968	1966-1968
AS5	S	1966-1968	1966-1968
BRBS	----	1976-1983	1976-1983
ECN	N	1972, 1976-1988, 2003-2004, 2006-2007	1972, 1976-1988, 1990-2004, 2006-2007
FB1	S	1966-1967	1966-1967
FB2	S	1966-2011	1966-2011
FB3	S	1966-1967, 1969, 1978	1966-1967, 1969, 1978
FB4	S	1966-1967	1966-1967
GSLB	----	1979-1983	1979-1983
GSLM-1	N	2011	2011
GSLM-2	N	2011	2011
HI	S	1966-1967, 1974	1966-1967, 1974
IS1	S	----	1987-1992
IS2	S	----	1987-1993
LCI	N	1966-1967	1966-1967
LVG1	N	1966-1978	1966-1978
LVG2	N	1966-1977	1966-1977
LVG3	N	1966-1975	1966-1975
LVG4	N	1966-2007, 2011	1966-2007, 2011
LVG5	N	1966-1975	1966-1975
LVH	N	1972-1975	1972-1975
MI	S	1966-1967, 1969, 1974	1966-1967, 1969, 1974
NLI	S	1966-1968	1966-1968
NLN	S	1976-1989	1976-1995, 1998
NML	N	1971-1993	1971-1993
RD1	N	1967-1971, 1979-1983	1967-1971, 1979-1983
RD2	N	1967-1989, 1994-2007, 2011	1967-2007, 2011
RD3	N	1967-1971, 1979-1983	1967-1971, 1979-1983
RD4	N	1967-1971	1979-1983
RT1	S	1977-1984	1977-1984
RT2	S	1978-1986, 2007-2009	1978-2009
RT3	N	----	1983-2007
RT4	S	2010	1984-2004, 2007-2010
SI	S	1966, 1974	1966, 1974
SJ-1	N	2011	2011
SS	S	1971-1988	1971-1994, 1996-1998
1A	N	----	1984-1991
2A	N	----	1984-1985, 1987-1993
3A	N	----	1984-1985, 1987-1993
1N	N	----	1984-1991
2N	N	----	1984-1991
3N	N	----	1984-1992
4N	N	----	1984-1992, 1996
1S	S	----	1984-1991
2S	S	----	1984-1991
3S	S	----	1984-1992
4S	S	----	1984-1993

* S = south arm, N = north arm

Table 2. *Great Salt Lake sampling locations.*

	(NAD27)		(NAD83)		(NAD83)	
Site	**Longitude**	**Latitude**	**Longitude**	**Latitude**	**UTM Easting (m)**	**UTM Northing (m)**
ABN	112.2316	41.0683	112.2324	41.0682	396461	4547064
ABS	112.2300	41.0650	112.2308	41.0649	396590	4546696
AC1	112.2502	40.9933	112.2510	40.9932	394778	4538760
AC2	112.3483	40.9960	112.3491	40.9959	386531	4539183
AC3	112.4458	41.0000	112.4466	40.9999	378337	4539758
AC4	112.5443	41.0024	112.5451	41.0023	370057	4540166
AS1	112.1841	40.8483	112.1849	40.8482	400121	4522586
AS2	112.2550	40.8350	112.2558	40.8349	394123	4521193
AS3	112.3241	40.8166	112.3249	40.8165	388265	4519236
AS4	112.3933	40.8108	112.3941	40.8107	382419	4518683
AS5	112.4608	40.7958	112.4616	40.7957	376697	4517111
BRBS	112.3366	41.2333	112.3374	41.2332	387920	4565512
ECN	112.5653	41.2230	112.5661	41.2229	368732	4564686
FB1	112.3950	41.1675	112.3958	41.1674	382908	4558284
FB2	112.4600	41.1350	112.4608	41.1349	377394	4554765
FB3	112.5200	41.1033	112.5208	41.1032	372296	4551332
FB4	112.5816	41.0716	112.5824	41.0715	367059	4547905
GSLB	112.3675	41.2717	112.3683	41.2716	385398	4569815
GSLM-1	112.4996	41.2176	112.5004	41.2175	374229	4563991
GSLM-2	112.4984	41.2188	112.4992	41.2187	374331	4564123
HI	112.3200	40.7120	112.3208	40.7119	388436	4507620
IS1	112.5061	41.0696	112.5069	41.0695	373399	4547570
IS2	112.4863	41.0106	112.4871	41.0105	374951	4540992
LCI	112.5101	41.2176	112.5109	41.2175	373351	4564011
LVG1	112.5116	41.2966	112.5124	41.2965	373375	4572779
LVG2	112.5916	41.3075	112.5924	41.3074	366699	4574109
LVG3	112.6766	41.3146	112.6774	41.3145	359598	4575031
LVG4	112.7608	41.3241	112.7616	41.3240	352571	4576225
LVG5	112.8466	41.3330	112.8474	41.3329	345411	4577363
LVH	112.5140	41.2475	112.5148	41.2474	373079	4567331
MI	112.1841	40.7958	112.1849	40.7957	400042	4516759
NLI	112.5250	40.9360	112.5258	40.9359	371552	4532766
NLN	112.5992	41.0756	112.6000	41.0755	365589	4548376
NML	112.8865	41.5510	112.8873	41.5509	342599	4601638
RD1	112.6675	41.4366	112.6683	41.4365	360620	4588561
RD2	112.7475	41.4416	112.7483	41.4415	353947	4589248
RD3	112.8250	41.4483	112.8258	41.4482	347488	4590125
RD4	112.9041	41.4533	112.9049	41.4532	340893	4590823
RD5	112.9766	41.4583	112.9774	41.4582	334849	4591514
RT1	112.2441	40.7525	112.2449	40.7524	394912	4512022
RT2	112.4020	41.0570	112.4028	41.0569	382123	4546026
RT3	112.7608	41.3241	112.7616	41.3240	352571	4576225
RT4	112.6424	41.1356	112.6432	41.1355	362085	4555104
SI	112.4632	40.8058	112.4640	40.8057	376513	4518224
SJ-1	112.6676	41.4381	112.6684	41.4380	360615	4588727
SS	112.2322	40.7458	112.2330	40.7457	395906	4511264
1A	112.8705	41.2270	112.8713	41.2269	343157	4565637
2A	112.9000	41.2557	112.9008	41.2556	340754	4568877
3A	112.9323	41.2832	112.9331	41.2831	338113	4571990
1N	112.8413	41.2227	112.8421	41.2226	345595	4565108
2N	112.8398	41.2237	112.8406	41.2236	345723	4565216
3N	112.8373	41.2257	112.8381	41.2256	345937	4565434
4N	112.8358	41.2266	112.8366	41.2265	346065	4565531
1S	112.8408	41.2217	112.8416	41.2216	345634	4564996
2S	112.8373	41.2177	112.8381	41.2176	345918	4564546
3S	112.8353	41.2167	112.8361	41.2166	346083	4564431
4S	112.8252	41.2085	112.8260	41.2084	346911	4563503

cal Survey. In this release, the lake elevations within the entire spreadsheet have been updated to reflect the changes made to the lake level record by the U.S. Geological Survey in 2001 (Loving, 2002; U.S. Geological Survey, undated).

SAMP-ELEV – Estimated elevation of sample. This elevation is calculated by subtracting sample depth from the surface elevation of the lake. Some error will be present in this measurement as noted in DEPTH-FT description.

WT%-Na – dry weight percent sodium.

WT%-Mg – dry weight percent magnesium.

WT%-K – dry weight percent potassium.

WT%-Ca – dry weight percent calcium.

WT%-Cl – dry weight percent chloride.

WT%-SO_4 – dry weight percent sulfate.

At a few of the sample sites, chemical data are not available and the corresponding data columns are not present.

IMPORTANT DATES FOR INTERPRETING LAKE CHEMISTRY

Along with natural fluctuations in lake level and salinity, a number of human-caused events are important to consider when interpreting the data contained within this report. Some of the more important dates are listed below.

1959 – Construction of the Southern Pacific Railroad rock causeway separating the north and south arms of the lake was completed (Loving and others, 2002).

August 1984 – Construction of the 290-foot wide breach in the railroad causeway was completed. The bottom of the breach was at an altitude of 4200 feet (Loving and others, 2002; Gwynn, 2007). Figure 2 illustrates changes in salinity trends as a result of the breach.

April 1987 to June 1989 – The West Desert Pumping Project pumped water from the north arm of GSL moving from 500 to 600 million tons of salt to the West Desert (Loving and others, 2002; Gwynn 2002).

December 2000 – The breach in the railroad causeway was lowered to an elevation of 4193 feet (Gwynn, undated).

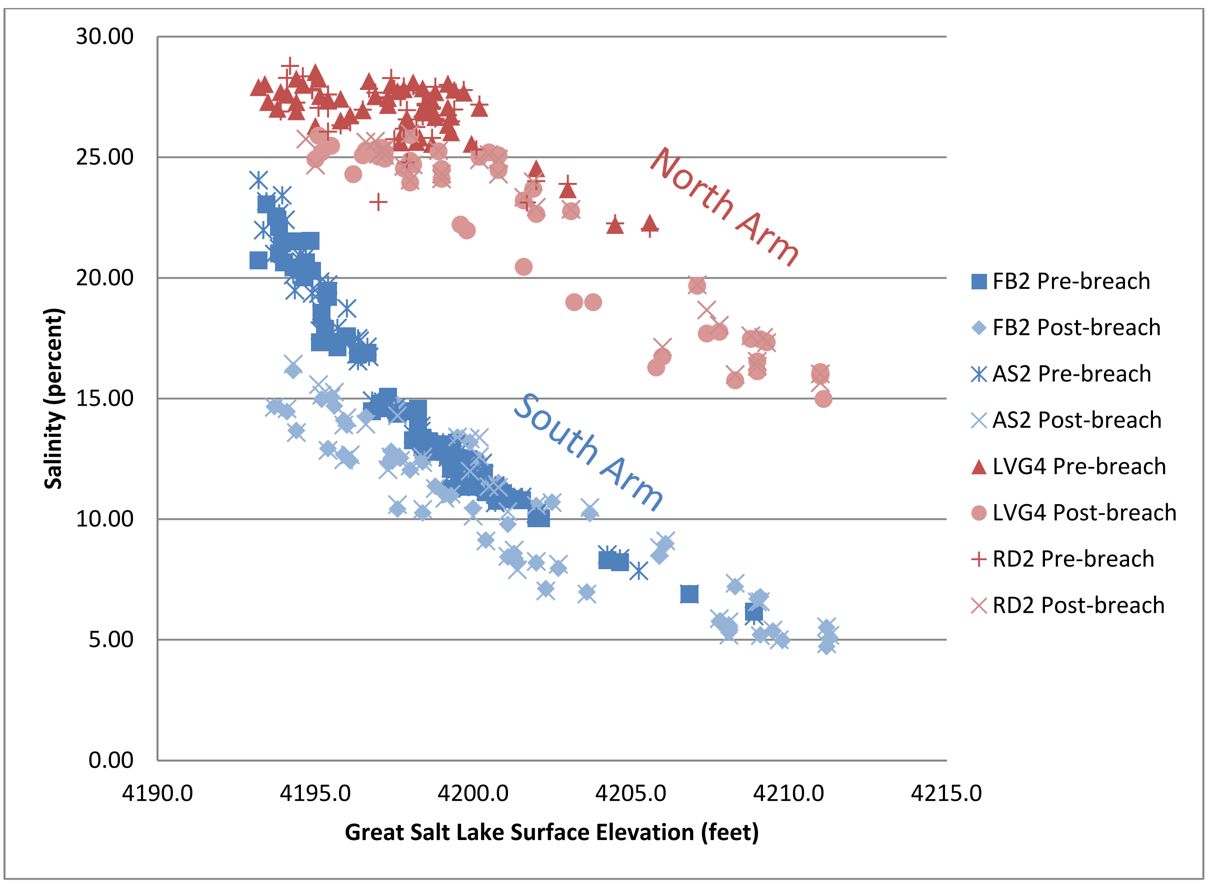

Figure 2. *Salinity of Great Salt Lake versus surface elevation of Great Salt Lake. Blue symbols represent data from the south arm of Great Salt Lake and red symbols represent data from the north arm. For each point, salinity of brine has been averaged from sample depths of 5 to 15 feet. Deeper sample depths were not included to remove effects of deep brine layer. For each sample site, the data before and after the railroad causeway breach in 1984 have been represented differently to highlight changes in salinity trends.*

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