2015 Annual Interim Monitoring Report

Union Pacific Railroad Great Salt Lake Causeway Culvert Closure and Bridge Construction Project

SPK-2011-00755

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Prepared for
Union Pacific Railroad
Omaha, NE 68179

Prepared by
HDR, Inc.
3949 South 700 East, Suite 500
Salt Lake City, UT 84107

Contents

Tables

Figures

Acronyms

AWAL	American West Analytical Laboratories
CMMP	Compensatory Mitigation and Monitoring Plan
EPA	U.S. Environmental Protection Agency
GIS	geographic information systems
IMP	Interim Monitoring Plan
MDL	method detection limit
MRL	method reporting limit
NELAP	National Environmental Laboratory Accreditation Program
NGVD	National Geodetic Vertical Datum
NWP	Nationwide Permit
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
TDS	total dissolved solids
UDWQ	Utah Division of Water Quality
UGS	Utah Geological Survey
UPRR	Union Pacific Railroad
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WSE	water surface elevation

1.0 Introduction

In 2015 Union Pacific Railroad (UPRR) monitored the ambient water quality in the Great Salt Lake in accordance with UPRR's Interim Monitoring Plan (IMP) for Temporary Closure of the East Culvert, Great Salt Lake Causeway (UPRR 2014). The IMP was developed pursuant to the requirements of Special Conditions 2a and 2b of the U.S. Army Corps of Engineers' (USACE) Nationwide Permit 14 verification (USACE NWP 14) issued December 6, 2013 (SPK-2011-00755) and Condition 3 of the Utah Division of Water Quality's (UDWQ) 401 Water Quality Certification (No. SPK 2011-00755) issued December 16, 2013 (USACE 2013, 2014; UDEQ 2013).

The IMP described the scope and frequency of the both the water quality monitoring and its reporting. After USACE and UDWQ approved the IMP in May 2014, UPRR conducted four monitoring events during February, May, July, and September 2015. As required in the USACE NWP 14, UPRR submitted interim monitoring event reports after each monitoring event in 2015. These reports were submitted on May 11, 2015; August 18, 2015; October 16, 2015; and December 21, 2015 (UPRR 2015a, 2015b, 2015c, 2015e).

This report reviews and summarizes the ambient lake monitoring results for the monitoring events conducted in 2015. With the submittal of this report, UPRR is fulfilling the Utah 401 Water Quality Certification requirement to submit an annual interim monitoring report by January 1 of the year following data collection.

2.0 Interim Monitoring Goals and Objectives

Interim monitoring goals and objectives are provided in Table 1 below. The monitoring focused on characterizing the open waters of Gilbert Bay and Gunnison Bay near the project site. The monitoring consisted of four elements: (1) compiling water surface elevation (WSE) data for each monitoring event, (2) collecting in-situ water profiles, (3) collecting grab sample water quality samples for analyses at an off-site laboratory, and (4) collecting brine shrimp samples for analyses and counts by off-site laboratories. The activities of compiling WSE data (element 1) and collecting salinity gradient data (part of element 2) meet the USACE NWP 14 interim monitoring requirements (USACE 2013). Elements 2, 3, and 4 meet the UDWQ 401 Water Quality Certification interim monitoring requirements (UDWQ 2013).

Table 1. Interim Monitoring Goals and Objectives

Element	Goals	Objectives
1. Water surface elevations	Capture temporary hydrologic impacts resulting from closure of the east culvert.	Obtain WSEs for the North Arm and South Arm of the Great Salt Lake from USGS reporting stations located at Saline and Saltair.
2. Surface water profiles and conventional water quality	Collect Great Salt Lake total depth, depth to deep brine layer[a] (if present), ambient Secchi depth, pH, temperature, and salinity data set.	Collect salinity data consistent with UDWQ and USGS methods and reporting limits.
3. Surface and bottom water metals, sulfate sampling and dissolved oxygen	Collect Great Salt Lake ambient metals, sulfate, hardness, and dissolved oxygen data set in surface water.	Collect metals, sulfate, and dissolved oxygen water samples at specified locations consistent with UDWQ reporting limits.
4. Brine shrimp counts and tissue sampling	Collect Great Salt Lake ambient brine shrimp population data and tissue metals and percent moisture data set at co-located South Arm water quality stations.	Collect brine shrimp for taxonomic identification, counts, and tissue analysis at specified locations in accordance with UDWQ-approved reporting limits.

UDWQ = Utah Division of Water Quality; USGS = U.S. Geological Survey

[a] *Deep brine layer depth* refers to the vertical zone in a water column in which salinity changes rapidly with depth. For the purpose of this annual interim monitoring report, *deep brine layer depth*, *halocline*, and *chemocline* are synonymous.

3.0 Methods

The methods used for the monitoring events are described in the IMP and in each interim monitoring event report and so are only summarized below. UPRR conducted ambient lake monitoring at three locations in Gilbert Bay and two locations in Gunnison Bay, including locations to the south and north of the UPRR Great Salt Lake causeway in the vicinity of the east and west culverts and a location in Gilbert Bay in the basin between the causeway and the rest of Gilbert Bay (see Figure 1 and Table 2 below). These sampling sites were located in the open waters of Gunnison and Gilbert Bays at locations specified in the Utah 401 Water Quality Certification and in the USACE NWP 14. In-situ measurements and water quality samples were collected at each site (see Table 3 on page 6). Brine shrimp parameters were collected at the Gilbert Bay sites only.

Figure 1. Interim Monitoring Sampling Sites and USGS Gage Locations

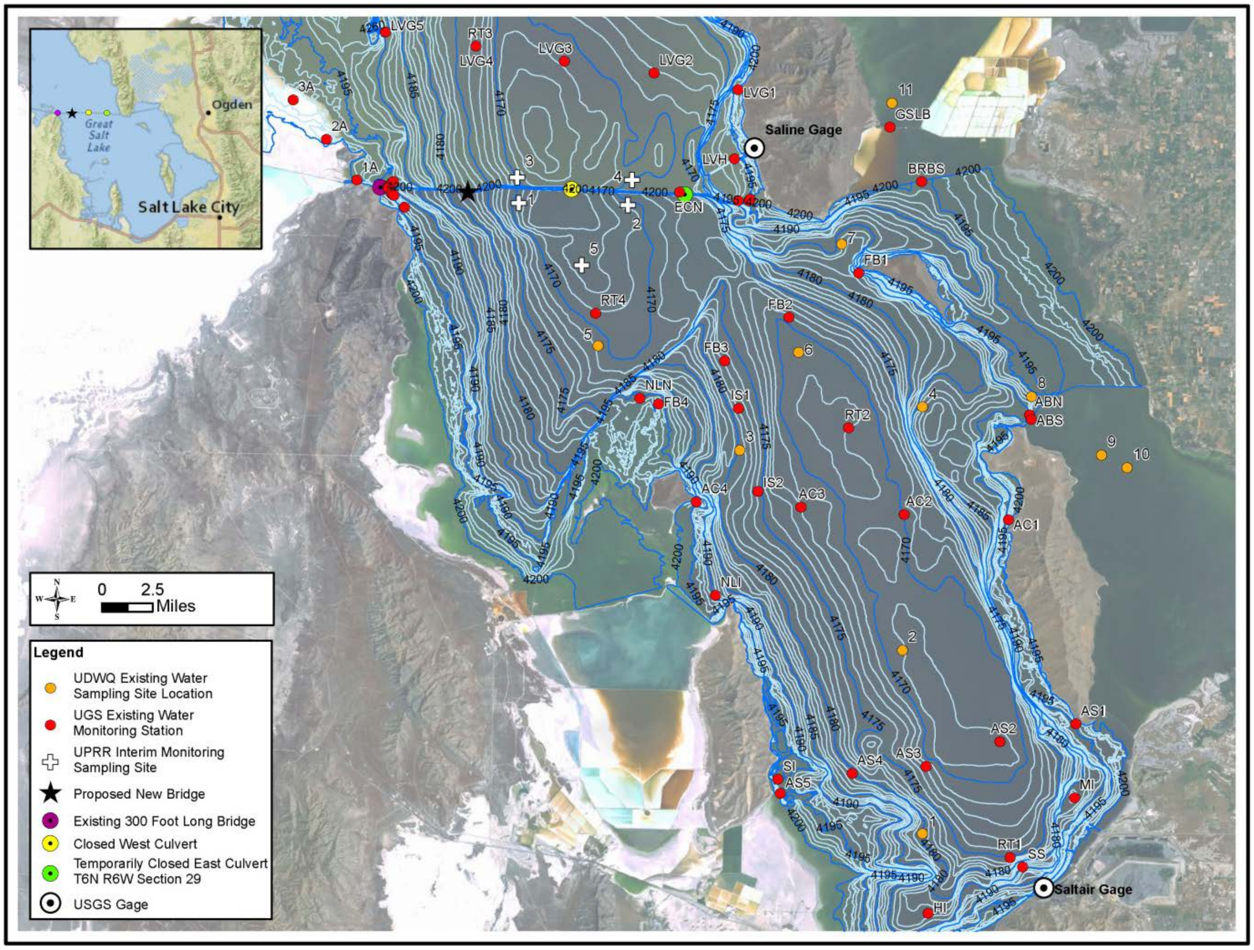


Table 2. Sampling Site Coordinates and Descriptions

Site Name	Latitude	Longitude	Description
Gilbert Bay			
Sampling site 1	41° 12' 49.65" N	112° 43' 4.82" W	Halfway between the proposed bridge and the west culvert; 1 km south of the UPRR causeway
Sampling site 2	41° 12' 47.86" N	112° 36' 52.62" W	Halfway between the west and east culverts; 1 km south of the UPRR causeway
Sampling site 5	41° 10' 9.65" N	112° 39' 25.81" W	6 km south of the west culvert
Gunnison Bay			
Sampling site 3	41° 13' 54.62" N	112° 43' 11.77" W	Halfway between the proposed bridge and the west culvert; 1 km north of the UPRR causeway
Sampling site 4	41° 13' 34.84" N	112° 36' 40.64" W	Halfway between the west and east culverts; 0.5 km north of the UPRR causeway

km = kilometers; UPRR = Union Pacific Railroad

Table 3. Interim Monitoring Locations and Frequency

Parameter	Number and Sample Depth	Frequency	Field Duplicate[a]	Field Blank[a]	Equipment Rinsate[a]	Sampling Site				
						1	2	3	4	5
Total water depth	One measurement taken from water surface to bottom of lake.	Four times per year	NA	NA	NA	X	X	X	X	X
Depth to deep brine layer	One location inferred from conductivity profile.	Four times per year	NA	NA	NA	X	X	X	X	X
Secchi depth	Measurements taken from water surface and averaged.	Four times per year	NA	NA	NA	X	X	X	X	X
Temperature, pH, conductivity	Vertical profile; measurements taken *in situ* every 0.5 m. The field conductivity measurements will establish whether there is a deep brine layer present.	Four times per year	NA	NA	NA	X	X	X	X	X
Total dissolved solids, density	Vertical profile; grab samples taken every 1.5 m in upper brine layer; samples taken every 0.5 m in the deep brine layer.	Four times per year	10% of samples	10% of samples	10% of samples	X	X	X	X	X
Total metals (As, Cu, Pb, Se, Hg, Zn), SO_4, hardness, and DO	Grab samples taken 0.2 m from the water surface and 0.5 m from the bottom.	Four times per year	10% of samples	10% of samples	10% of samples	X	X	X	X	X
Brine shrimp count	One sample from one vertical tow.	Tri-annually (May, July, and September)	1 per quarter	NA	NA	X	X	NA	NA	X
Brine shrimp tissue, percent moisture	Composite sample from up to three vertical tows.	Tri-annually (May, July, and September)	1 per quarter	NA	NA	X	X	NA	NA	X

m = meters
NA = not applicable
X = parameter measured at this site
As = arsenic
Cu = copper
DO = dissolved oxygen
Hg = mercury
Pb = lead
Se = selenium
SO_4 = sulfate
Zn = zinc

[a] Field duplicate, field blank, and equipment rinsate samples were collected as part of the field quality assurance program, the results of which are described in the three individual interim monitoring event reports.

3.1 In-situ Measurements

In-situ water quality measurements included total depth, depth to deep brine layer, Secchi depth, and vertical profiles of water temperature, conductivity, dissolved oxygen, and pH. These measurements are described in Table 4. Secchi depth was measured first. Then, water temperature, conductivity, dissolved oxygen, and pH were measured every 0.5 meter with a multiprobe water quality meter. The water quality meter was calibrated using the manufacturer's recommended calibration methods. These water quality measurements were used to determine the depth, if present, of the deep brine layer. The depth of the deep brine layer was used to determine the frequency of the grab samples for total dissolved solids and density according to the following rules:

- If a deep brine layer is present:
  - Collect samples above the deep brine layer every 1.5 meters
  - Collect samples below the deep brine layer every 0.5 meter
- If a deep brine layer is not present:
  - Collect samples every 1.5 meters

Specific gravity was determined via hydrometer for the interim monitoring events. The two Fisher-brand hydrometers used were calibrated for 60 degrees Fahrenheit, one for specific gravities of 1.100–1.220 and one for specific gravities of 1.200–1.420. Hydrometer readings were conducted on samples collected at the HDR office. Three readings were obtained per sample and averaged. Temperature corrections were applied, if appropriate.

3.2 Surface Water Samples

Surface water samples were sent to Brooks Rand Laboratories in Seattle, Washington, for metals analyses as described in Table 4. Surface water samples were sent to ChemTech Ford in Salt Lake City, Utah, for density, hardness, sulfate, and total dissolved solids (TDS) analyses as described in Table 4. Both laboratories are certified under the National Environmental Laboratory Accreditation Program (NELAP).

Each laboratory sample was collected into laboratory-supplied clean containers. Water samples were collected at depth with a Kemmerer sampler. Water samples to be analyzed for metals were collected using "clean hands" methods consistent with the U.S. Environmental Protection Agency's (EPA) Method 1669 (EPA 1996) and the UDWQ standard operating procedure for "Trace Metals Sample Collection (Clean Hands/Dirty Hands), Decontamination, and Multiprobe In-situ Monitoring Procedures."

The samples were preserved (as appropriate), stored, and delivered to the laboratory for analyzing the laboratory parameters listed in the IMP (see Table 4; UPRR 2014). A chain-of-custody record was maintained with the samples at all times. Shared sampling equipment used to collect the deep-water quality samples was decontaminated between sampling sites.

Table 4. Water Quality Parameters and Constituents To Be Measured and Methods, with Detection Limits, Reporting Limits, and Laboratory Hold Time

Parameter		Method [a]	Method Detection Limit	Method Reporting Limit	Hold Time
Field Measurements – Surface Water					
Lake elevation [b]	—	USGS automated gage	—	—	—
Total water depth	—	Troll 9500 field measurement	—	0.1 m	Field
Depth to deep brine layer [c]	—	Troll 9500 field measurement	—	0.1 m	Field
Secchi depth	—	—	—	0.1 m	Field
pH	—	SM 4500H	0.1 su	0.1 su	Field profile
Specific conductivity	—	SM 2510A	0.001 μmhos	0.001 μmhos	Field profile
Temperature	—	SM 2520	0.1 °C	0.1 °C	Field profile
Dissolved oxygen	DO	In-Situ, Inc., Method 1002-8-2009	0.2 mg/L	0.2 mg/L	Field profile
Specific gravity	--	ASTM 1429 [g]	0.001 (unitless)	0.001 (unitless)	—
Laboratory Analyses – Surface Water [d,e]					
Hardness	—	SM 2340C	—	1 mg/L as $CaCO_3$	14 days
Sulfate (total)	SO_4^{2-}	EPA 300.0	—	1 mg/L	28 days
Total dissolved solids [f]	Salinity [f]	SM 2540C	—	5 mg/L	7 days
Arsenic (total)	As	EPA 1640	0.05 μg/L	0.15 μg/L	180 days
Copper (total)	Cu	EPA 1640	0.04 μg/L	0.12 μg/L	180 days
Lead (total)	Pb	EPA 1640	0.003 μg/L	0.013 μg/L	180 days
Mercury (total)	Hg	EPA 1631E	0.15 ng/L	0.40 ng/L	28 days
Selenium (total)	Se	EPA 1640	0.070 μg/L	0.210 μg/L	180 days
Zinc (total)	Zn	EPA 1640	0.26 μg/L	0.75 μg/L	180 days

(*continued on next page*)

Table 4. Water Quality Parameters and Constituents To Be Measured and Methods, with Detection Limits, Reporting Limits, and Laboratory Hold Time

Parameter		Method [a]	Method Detection Limit	Method Reporting Limit	Hold Time
Laboratory Analyses – Gilbert Bay Brine Shrimp [e]					
Percent moisture	—	SM 2540G	—	1.0%	—
Arsenic (total)	As	EPA 1638	0.014 mg/kg	0.040 mg/kg	180 days
Copper (total)	Cu	EPA 1638	0.03 mg/kg	0.16 mg/kg	180 days
Lead (total)	Pb	EPA 1638	0.004 mg/kg	0.040 mg/kg	180 days
Mercury (total)	Hg	EPA 1631	0.12 ng/g	0.4 ng/g	28 days
Selenium (total)	Se	EPA 1638	0.06 mg/kg	0.15 mg/kg	180 days
Zinc (total)	Zn	EPA 1638	0.20 mg/kg	1.00 mg/kg	180 days
Laboratory Counts – Gilbert Bay Brine Shrimp					
Brine shrimp (*Artemia franciscana*)		Dissection microscope	Not applicable	Not applicable	Not applicable

°C = degrees Celsius
$CaCO_3$ = calcium carbonate
EPA = sampling method from EPA
µmhos = micromhos
m = meters
SM = Standard Methods for the Examination of Water and Wastewater

g/mL = grams per milliliter
mg/L = milligrams per liter
µg/L = micrograms per liter
ng/L = nanograms per liter
mg/kg = milligrams per kilogram
ng/g = nanograms per gram
su = standard units

[a] Laboratory Analytical Method or field equipment

[b] See Section 4.1, Water Surface Elevation.

[c] Deep brine layer depth refers to the vertical zone in a water column in which salinity changes rapidly with depth. The location of the deep brine layer is determined from abrupt changes in conductivity, temperature, and dissolved oxygen.

[d] Estimated by ChemTech Ford Laboratories and Brooks Rand Laboratories (metals). Due to the nature of Great Salt Lake water, reporting limits might be elevated for some analyses.

[e] Estimated by Brooks Rand Laboratories. Due to the nature of brine shrimp tissue, reporting limits might be elevated for some analyses.

[f] Total dissolved solids are measured to estimate salinity.

[g] Standard operating procedure is provided in Appendix H, Standard Operating Procedure for Specific Gravity Determinations Using a Hydrometer, of each interim monitoring event report.

3.3 Brine Shrimp Samples

One vertical plankton tow was performed at each of sites 1, 2, and 5 to obtain brine shrimp for analytical laboratory analysis. Brine shrimp samples were sent to Brooks Rand Laboratories for metals analysis (see Table 4). One additional plankton tow was performed at each of these sites to collect brine shrimp samples which were sent EcoAnalysts, Inc., for taxonomic life stage identification and counts.

Each tow was from the bottom of the water column to the water surface, using a 165-micrometer net with a 50-centimeter-diameter opening and a screened sample bucket attached at the bottom of the net. The net was lowered to the desired depth and raised at an approximate rate of 0.5 meter per second to collect brine shrimp from the water column. The analytical sample was concentrated into the sample bucket and transferred to a labeled and laboratory-supplied sample jar. The procedure was repeated to collect a sample for brine shrimp taxonomic analysis. The samples were stored and recorded on separate chain-of-custody forms (one for the analytical laboratory and one for the taxonomic laboratory).

3.4 Quality Assurance

All data were collected in accordance with the IMP's Quality Assurance Project Plan (QAPP) (UPRR 2014). After each monitoring event, UPRR subjected all data to quality assurance/quality control (QA/QC) procedures including but not limited to spot checks of transcription, review of electronic data submissions for completeness, comparison of geographic information systems (GIS) maps with field notes on locations, and identification of any inconsistent data. As a result of this process, UPRR observed the following:

- The dissolved oxygen sonde calibration was outside of acceptable limits for the dissolved oxygen probe on February 11, 2015. Further, dissolved oxygen data profiles were inconsistent with previous measurement patterns, and calibration had not been confirmed in the field for the September 2015 sampling event. Consequently, all dissolved oxygen results for the February 2015 Gilbert Bay sites 1, 2, and 5 and for the September 2015 Gilbert Bay and Gunnison Bay sites were rejected (R). Calibration records for the field instruments are provided in Appendix F of each report.

UPRR also evaluated the analytical data for their consistency with the data quality objectives in the QAPP. The QAPP specifies representativeness, accuracy, precision, comparability, and completeness objectives for data acquisition (UPRR 2014, Table 7-1).

- **Representativeness.** Representativeness was ensured via the location of sample sites as well as the monitoring event intervals. Representative locations and measurement intervals were prescribed by USACE and UDWQ and are listed in Table 2, Sampling Site Coordinates and Descriptions, of this report.
- **Accuracy.** Accuracy for field and laboratory measurements is defined as the degree of conformity of a measured or calculated quantity to its actual (true) value. The accuracy objective provided in the QAPP for the monitoring events (UPRR 2014) was met by using standard methods and calibrated instruments. Field instrument calibration records and laboratory Level 2 data packages are provided in Appendix F, Data Quality Assurance Documentation, and Appendix G, Field and Analytical Laboratory Data Reports, of each interim monitoring event report. QA samples (method blanks, laboratory control samples, method spikes, and others) were analyzed as appropriate for each method. In the few instances when laboratory QC analyses were

outside acceptable limits, the laboratory qualified the data as biased high or low and flagged the data accordingly.

- **Comparability.** The comparability objective provided in the QAPP for the monitoring events (UPRR 2014) was ensured by meeting the target reporting limits provided in Table 4 of this report. Though the brine matrix did require dilutions, method reporting limits (MRL) and method detection limits (MDL) were met. Per the IMP, metals observed at concentrations between the MDL and MRL are provided "as is" in Appendix C, Surface Water Analytical Results, and Appendix G, Field and Analytical Laboratory Data Reports, of each interim monitoring event report but were reported as non-detect at the MRL in the main text of each report.
- **Precision.** Precision is an assessment of reproducibility under a particular set of conditions. The precision objective provided in the QAPP for the monitoring events consisted of the laboratory meeting all of its QA requirements and field duplicate results within 10% to 50%, as appropriate (UPRR 2014). Equipment rinsates and field blanks also provide insight into the sampling results' precision.
  - Level 2 data packages are provided in Appendix G, Field and Analytical Laboratory Data Reports, of each interim monitoring event report. QA samples (method blanks, laboratory control samples, method spikes, and others) were analyzed as appropriate for each method. In the few instances when laboratory QC analyses were outside acceptable limits, the laboratory qualified the data as biased high or low and flagged the data accordingly.
  - In September, brine shrimp metals analyses were all qualified as estimated (H) because they arrived warmer than 4 degrees Celsius, which is outside the laboratory's acceptable limits.
  - Duplicate agreement for detected metals exceeded acceptance percentages in some surface water and brine shrimp analysis, and the results were qualified as estimated (V) during the verification review.
  - Equipment rinsate results in February and May 2015 had elevated mercury levels, and mercury results for the lower-water-column samples were qualified as estimated (V) during the verification review.
  - All field blank results were trace or non-detect.
- **Completeness.** The completeness objective provided in the QAPP for the monitoring events was 90% (UPRR 2014) and is defined as the number of valid measurements divided by the number of measurements collected. For each monitoring event, 41 analytes were measured for each of the 5 water samples, and 14 analytes were measured for each of the 3 brine shrimp samples. Though some project variances and non-conformances resulted in data loss or qualification (see Section 5.0, Summary of Variances from the Interim Monitoring Plan, of this report and Section 2.6, Study Variances and Corrective Action, of each monitoring report), the completeness objective of 90% was met for each monitoring event for both surface water and brine shrimp.

Documentation of this process is provided in Appendix F, Data Quality Assurance Documentation, of each interim monitoring event report.

4.0 Summary of Results

The results of each 2015 monitoring event as well as the QA/QC review are presented in the four 2015 interim monitoring event reports, which were submitted on May 11, 2015; August 18, 2015; October 16, 2015; and December 21, 2015 (UPRR 2015a, 2015b, 2015c, 2015e). Data packages (Level 2) and other supporting documentation are also provided in these three reports. A summary of the results is provided below.

4.1 Water Surface Elevation

This section summarizes the WSE data and in-situ measurements collected during 2015.

Water Surface Elevation Data. UPRR acquired WSE data in 15-minute increments for Gunnison and Gilbert Bays from the U.S. Geological Survey's (USGS) website (USGS 2015; see Appendix A, Surface Water Elevation Data, of each interim monitoring event report). South Arm WSEs were obtained for USGS station 10010000 (Saltair gage), and North Arm WSEs were obtained for USGS station 10010100 (Saline gage; see Figure 1, Interim Monitoring Sampling Sites and USGS Gage Locations, of this report). The difference between the North and South Arm WSEs is referred to as the head difference; it is obtained by subtracting the North Arm WSE from the South Arm WSE (see Table 5). The USGS data presented in this report are reported by USGS as preliminary and will be updated when available.

Table 5. Water Surface Elevation and Computed Head Difference

Sampling Date	Water Surface Elevation (feet NGVD 29)		Head Difference (feet)
	South Arm	North Arm	
South Arm Sampling Date			
February 10, 2015	4193.9	4192.6	1.3
May 20, 2015	4194.1	4192.4	1.7
July 22, 2015	4193.6	4191.8	1.8
September 22, 2015	4192.7	4191.0	1.7
North Arm Sampling Date			
February 11, 2015	4193.9	4192.6	1.3
May 21, 2015	4194.1	4192.3	1.8
July 16, 2015	4193.7	4191.9	1.8
September 23, 2015	4192.7	4191.0	1.7

NGVD 29 = National Geodetic Vertical Datum of 1929

4.2 Vertical Profiles

The range of WSEs, total water depth, and depth to brine layer for all monitoring events are summarized in Table 6 below. Temperature, pH, dissolved oxygen, TDS, and salinity profiles are provided in Figure 2, Figure 3, Figure 4, Figure 5, and Figure 6, respectively.

Depth to Brine Layer. Total water depth, Secchi depth, and Gilbert Bay brine layer depth ranges observed in 2015 are summarized in Table 6 below. The following general observations are made:

- The range in lake-bottom elevations at sampling sites (see Figure 2 through Figure 6) can be attributed to varying field conditions; that is, sampling when there was significant wave action.
- For each monitoring event, a deep brine layer was observed at Gilbert Bay site 5.
- A deep brine layer was not observed at Gilbert Bay sites 1 and 2.
- A deep brine layer was not observed in Gunnison Bay.
- Secchi depths for Gilbert Bay were less than for Gunnison Bay in February and May and were greater than for Gunnison Bay in July and September.

Table 6. Water Level, Total Depth, Secchi Depth, and Brine Layer Depth Ranges – 2015

Parameter	Units	Gilbert Bay (Sites 1, 2, and 5)		Gunnison Bay (Sites 3 and 4)	
		Minimum	Maximum	Minimum	Maximum
Average WSE of sampling day	feet NGVD 29	4192.7	4,194.1	4,191.0	4,192.6
Secchi depth	meters (feet)	0.4 (1.1)	4.1 (13.5)	0.6 (2.0)	1.3 (4.3)
Total water depth	meters (feet)	7.0 (23.0)	9.0 (29.5)	5.9 (19.4)	7.3 (24.0)
Depth from water surface to deep brine layer	meters (feet)	7.5 (18.0)	8.5 (24.6)	Not found	Not found
Deep brine layer thickness	meters (feet)	0.1 (0.3)	0.5 (1.6)	Not found	Not found

NGVD 29 = National Geodetic Vertical Datum of 1929

Temperature. Temperature profiles for each monitoring event and each sampling site are shown in Figure 2 on page 15. The following observations are made:

- Gunnison Bay was consistently warmer than Gilbert Bay, though, as the year progressed, temperatures became more consistent.
- Reduced temperatures were observed in the Gilbert Bay deep brine layer at site 5 during May and July.
- General temperature variation corresponds seasonally, with the coldest temperatures during the winter (February event) and the warmest temperatures during the summer (July event).

pH. pH profile data for each monitoring event and each sampling site are shown in Figure 3 on page 16. The following general observations are made:

- Gilbert Bay sites had pH levels higher than those at Gunnison Bay sites for all sampling events.
- Reduced levels of pH were observed in the Gilbert Bay deep brine layer at site 5.

Dissolved Oxygen. Dissolved oxygen profile data are shown for the February, May, and July events and each sampling site in Figure 4 on page 17. Calibration of the sonde was suspect, so September results are not presented. The following general observations are made:

- Dissolved oxygen concentrations were similar among sites in May and July, except for higher values at site 3 in July.
- Lower dissolved oxygen conditions were observed near the lake bed at Gilbert Bay sites 1, 2, and 5. The lowest values were in the site 5 deep brine layer.

Total Dissolved Solids (TDS). TDS profile data are shown for each monitoring event and each sampling site in Figure 5 on page 18. The following general observations are made:

- TDS concentrations indicated that a deep brine layer was present at site 5, since the lower-water-column TDS concentration values were elevated relative to the upper-water-column TDS concentration values in May and July. The deep brine layer thickness was only 0.3 to 0.5 meter thick, based on laboratory TDS data.
- TDS concentrations in Gunnison Bay (sites 3 and 4) were similar, both spatially and vertically.

Salinity. Salinity profile data are shown in Figure 6. Hydrometer-measured specific gravities were used to determine sample densities, which in turn were used in combination with laboratory-reported TDS values to calculate salinity. Density and salinity results are provided in Appendix C, Surface Water Analytical Results, of each interim monitoring event report. Salinity profile data are shown for each monitoring event and each sampling site in Figure 6. The following general observations are made:

- Salinity in Gunnison Bay was greater than in Gilbert Bay.
- Higher salinities were observed in the Gilbert Bay deep brine layer than in its upper water column at site 5 in May and July.
- Because of the calculation of salinity (using hydrometer and laboratory TDS results), the salinity profiles mirror the general nature of the TDS profiles.
- TDS values have increased in the South Arm over the course of the 2015 sampling events.
- Average South Arm salinity, calculated from hydrometer and laboratory-reported TDS values, ranged from about 12.5% in February to 15% in September.

Figure 2. Temperature Profiles – 2015

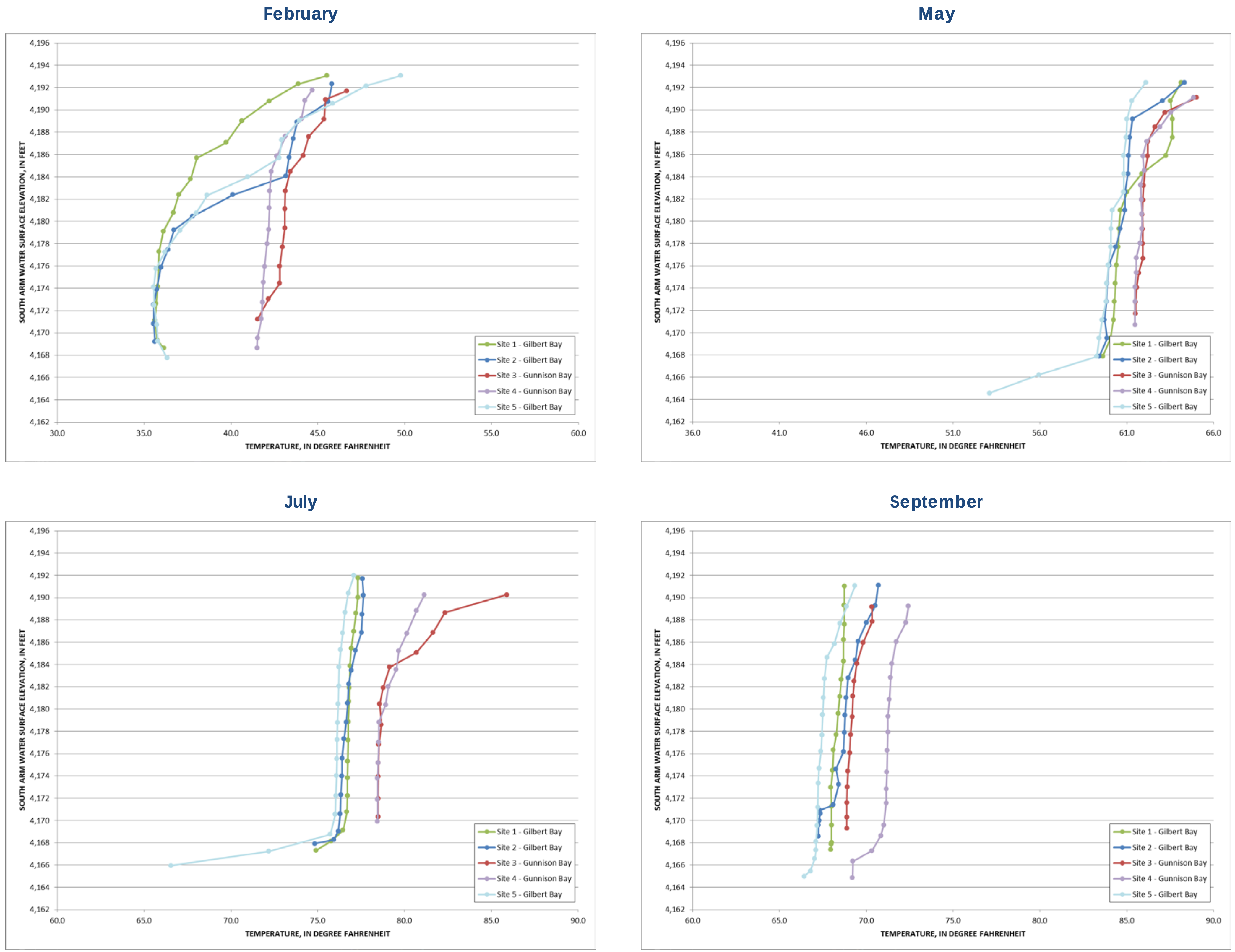
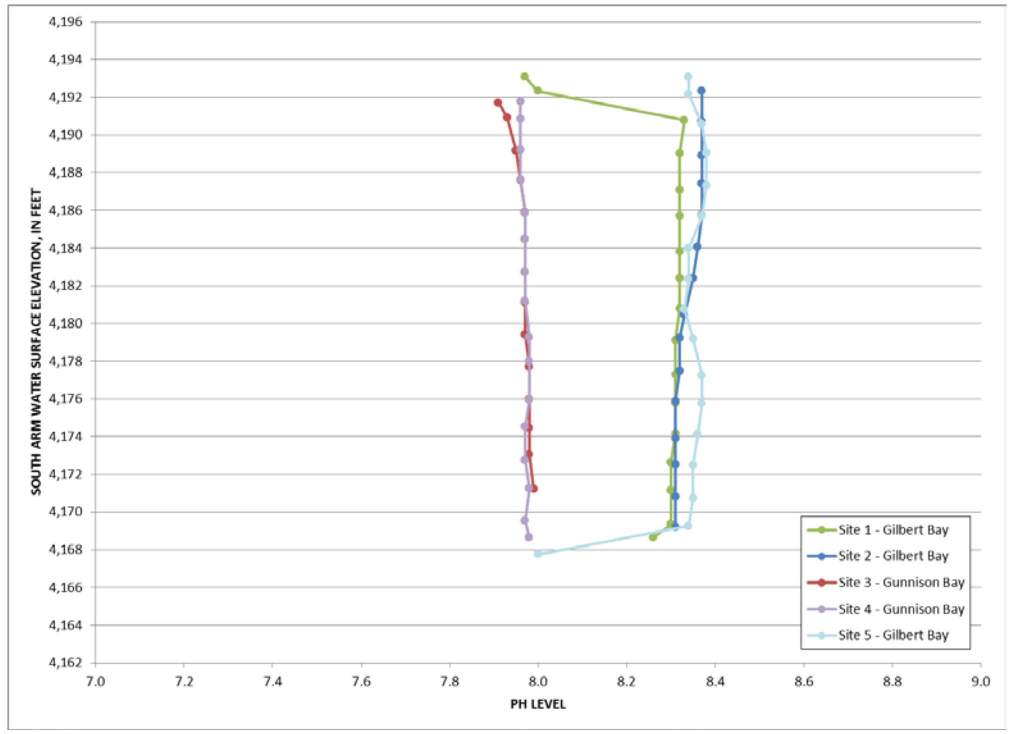
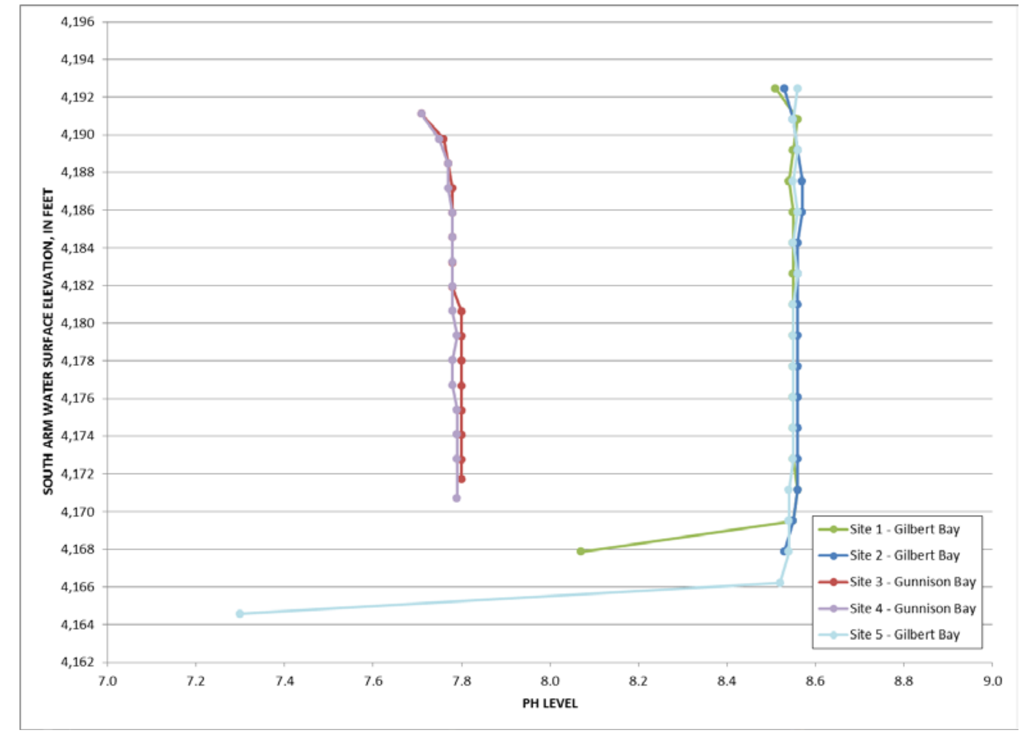


Figure 3. pH Profiles – 2015

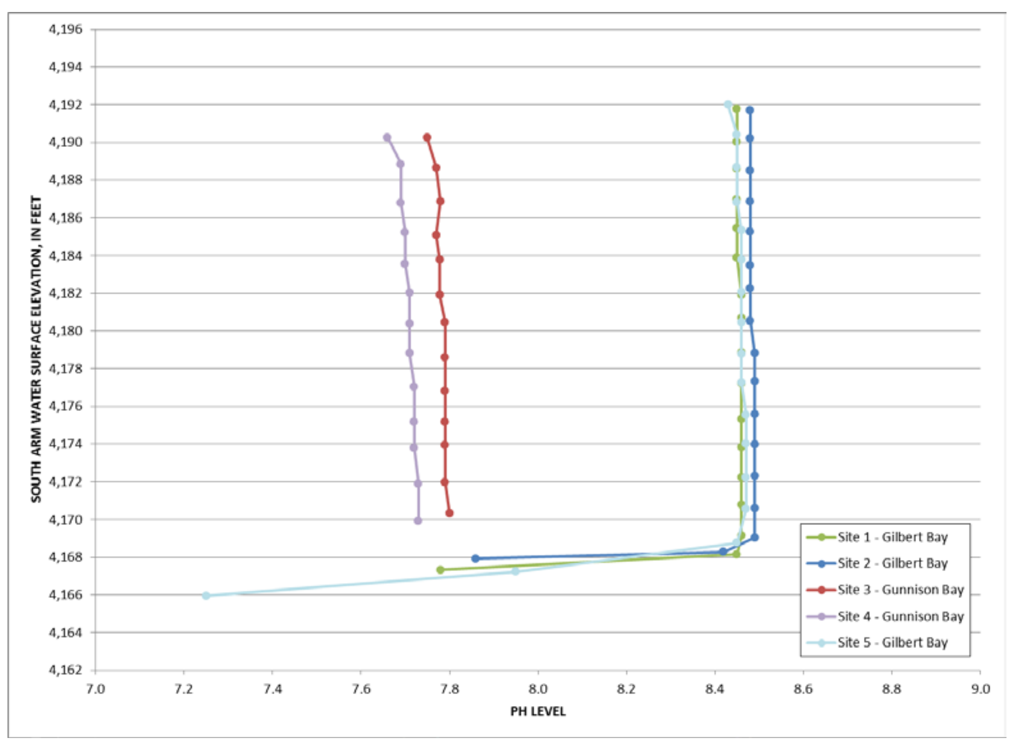
February



May



July



September

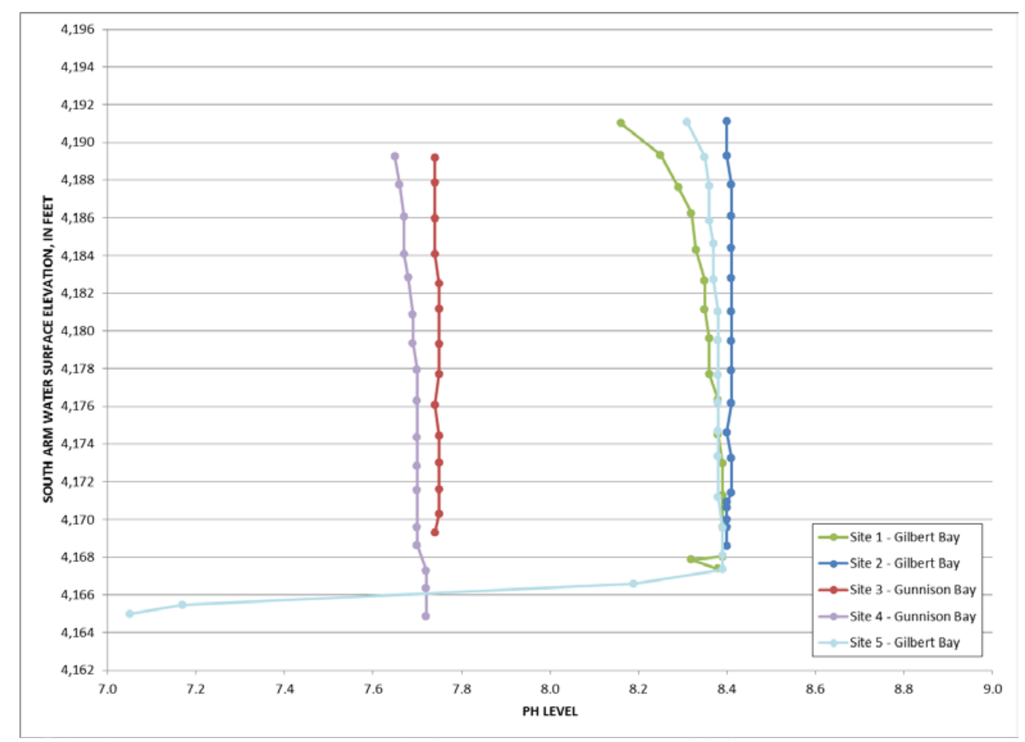
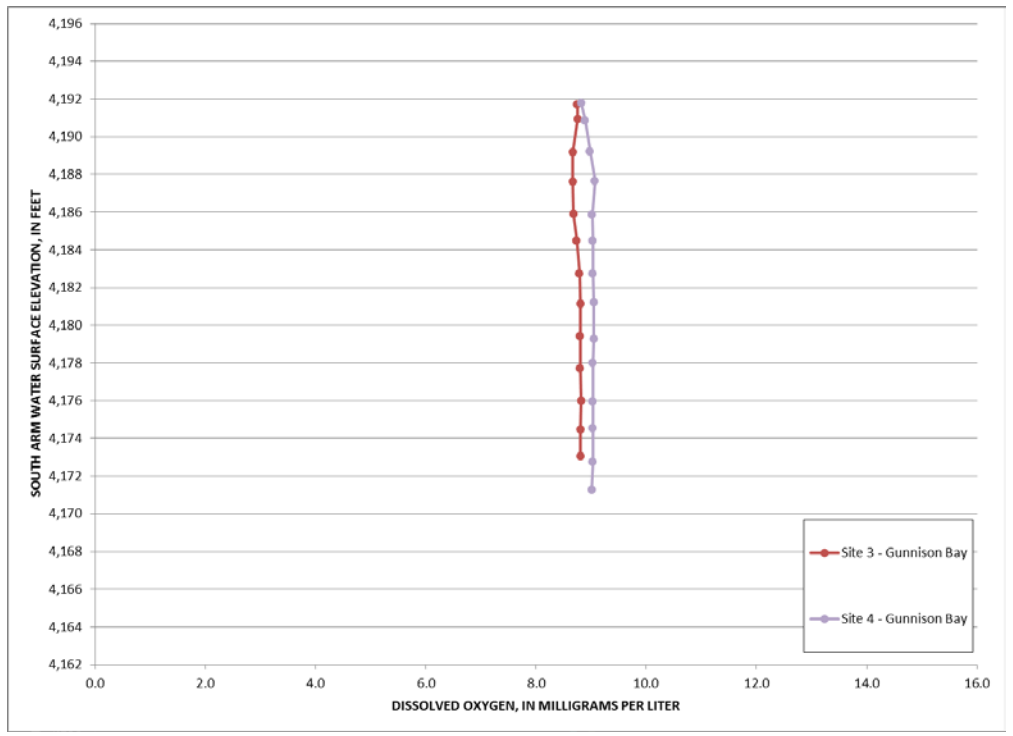
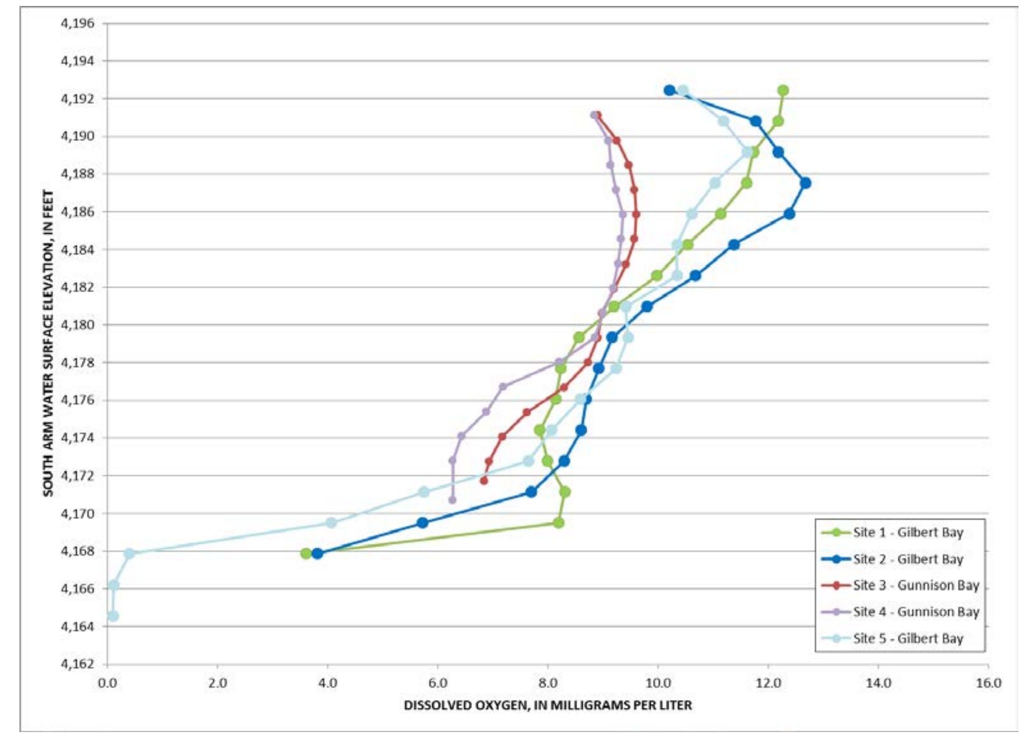


Figure 4. Dissolved Oxygen Profiles – 2015

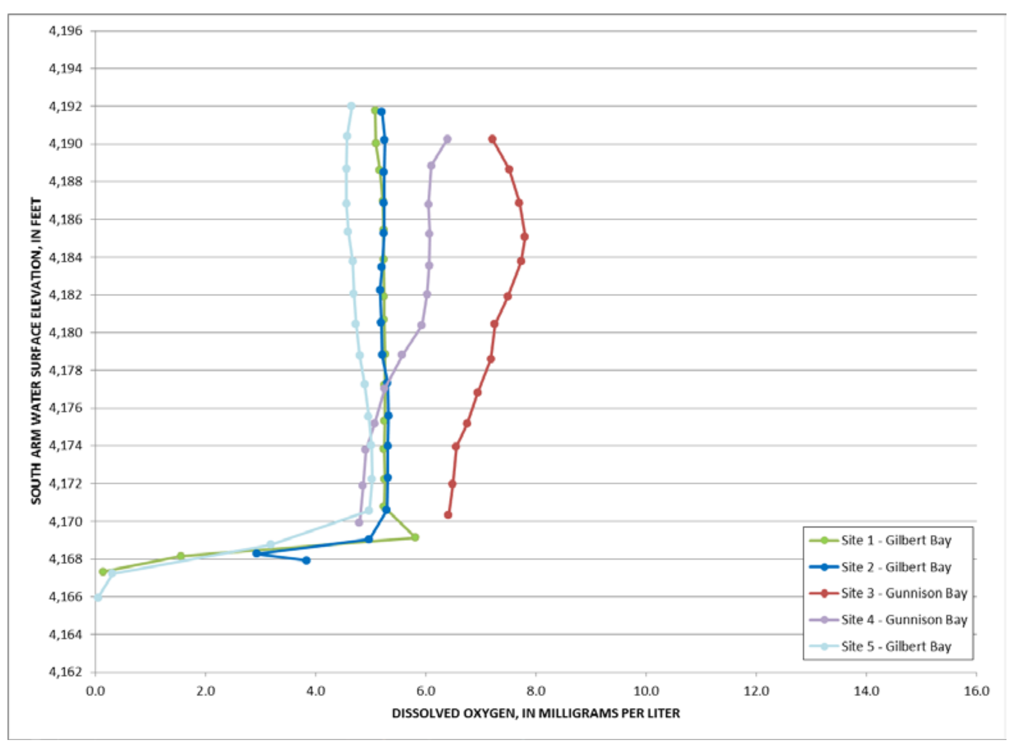
February



May



July



September

Sonde calibration was suspect. Data were rejected.

Figure 5. TDS Profiles – 2015

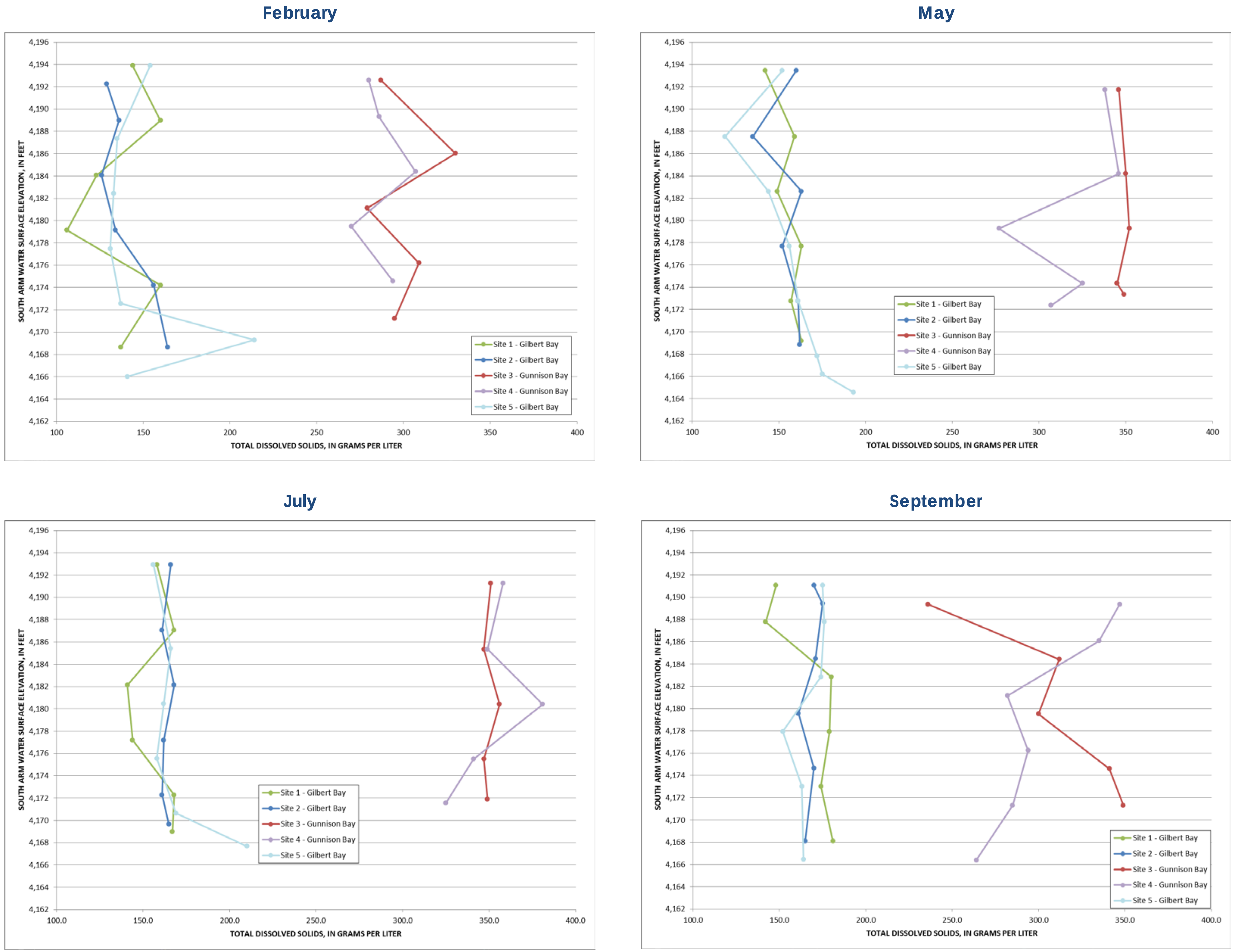
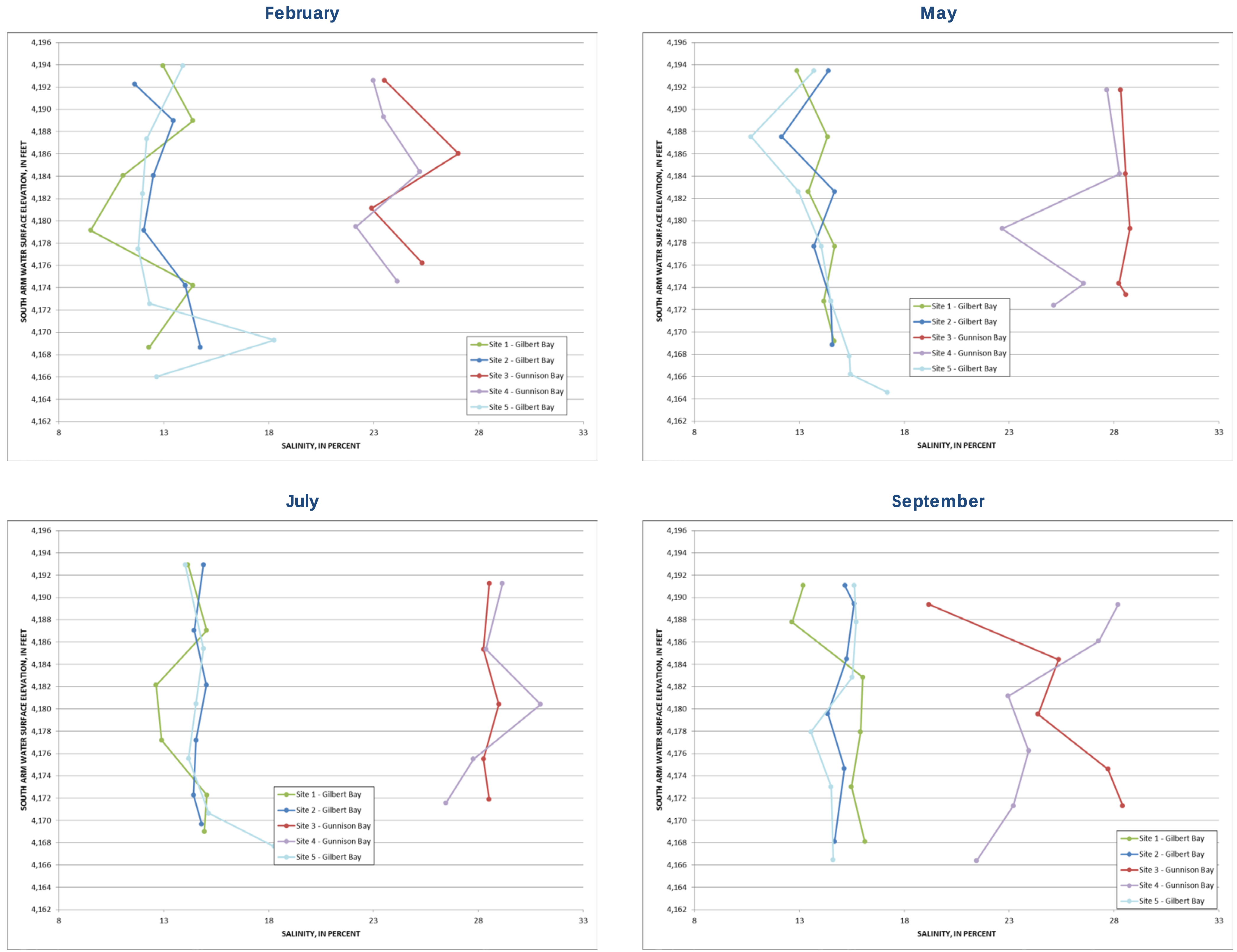


Figure 6. Salinity Profiles – 2015



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4.3 Surface Water Summarized Results

Analytical data collected from the three 2015 monitoring events are summarized in Table 8 below. These data were provided in their entirety in each of the 2014 interim monitoring event reports, which were published on May 11, 2015; August 18, 2015; October 22, 2015; and December 22, 2015 (UPRR 2015a, 2015b, 2015c, 2015e). The complete data set is also available in Microsoft Excel format on request.

4.4 Brine Shrimp Summarized Results

Brine shrimp metals data and sample life stage composition are summarized in Table 9 on page 23. These data were provided in their entirety in each of the 2015 monitoring event reports, which were published on May 11, 2015; August 18, 2015; October 16, 2015; and December 21, 2015 (UPRR 2015a, 2015b, 2015c, 2015e).

Life stages that contributed more than 1% to the overall sample population are included in Table 9 on page 23. Of note is the fact that less than 1% of each sample population was adult. However, there was still a noticeable increase in the percentage of eggs[1] between the July and September monitoring events. To summarize:

- The total brine shrimp count varied significantly among all sites for each monitoring event.
- In May 2015, total brine shrimp counts were observed with densities between 11,346 and 22,425 individuals per cubic meter. Most of the individuals were in the egg, nauplius, and early metanauplius life stages.
- In July 2015, total shrimp counts were observed with densities between 5,421 and 8,026 individuals per cubic meter. Nearly all individuals were in the egg and early metanauplius life stages.
- In September 2015, total shrimp counts were observed with densities between 8,246 and 35,142 individuals per cubic meter. Nearly all individuals were in the egg stage.
- The September data indicate that, while total counts varied, almost all individuals were classified as eggs.

4.5 Data Quality Assurance Summary

All data were collected in accordance with the IMP's QAPP (UPRR 2014). After each monitoring event, UPRR subjected all data to QA/QC procedures including but not limited to spot checks of transcription, review of electronic data submissions for completeness, comparison of GIS maps with field notes on locations, and identification of any inconsistent data.

In addition, UPRR evaluated the resulting data for their consistency with the data quality objectives. Data quality objectives were met for the majority of analytes and samples; in the instances where data were found to be outside of QAPP specifications, the data were qualified. Additional details can be found in Appendix F, Data Quality Assurance Documentation, of the associated 2015 interim monitoring event reports.

[1] For this report, the terms *cyst* and *egg* are synonymous. The laboratory includes *cyst* in the category *egg*.

Table 7. Results of Chemical Analyses for All Monitoring Events – 2015

Parameter	Units	Gilbert Bay				Gunnison Bay	
		Surface Water		Brine Shrimp (wet-weight)		Surface Water	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Upper Water Column							
Hardness, total	mg/L	20,100	25,300	—	—	5,290	51,200
Sulfate [a]	mg/L	9,560	11,100	—	—	20,700	26,800
Arsenic	µg/L or mg/kg	86.4 **V**	113	2.65	7.79 **H**	129	180
Copper	µg/L or mg/kg	1.45	2.73	2.28	7.45 **H**	0.71	9.12
Mercury	ng/L or ng/g	3.77	10.1	19.5 **H**	61.3	2.89	27.2
Lead	µg/L or mg/kg	1.21	1.56	0.163	1.07 **H**	0.169	0.64
Selenium	µg/L or mg/kg	< 1.05	< 1.05	0.34	1.05 **H**	< 1.05	1.35
Zinc	µg/L or mg/kg	< 3.75	< 3.75	12.5	30.2 **H**	< 3.75	14.4
Lower Water Column							
Hardness, total	mg/L	20,300	38,000	—	—	5,200	52,200
Sulfate [a]	mg/L	10,600	16,900	—	—	20,400	26,400
Arsenic	µg/L	83.2	177	—	—	134 **V**	188
Copper	µg/L	2.04	22.5	—	—	0.98	5.36
Mercury	ng/L	6.69 **V**	85.0 **V**	—	—	2.26 **V**	38 **V**
Lead	µg/L	1.17	10.3	—	—	< 0.065	0.492
Selenium	µg/L	< 1.05	1.42	—	—	< 1.05	1.23
Zinc	µg/L	< 3.75	20.4	—	—	< 3.75	4.88

[a] Data quality objectives for sulfate met quality assurance objectives (UPRR 2014); UPRR notes that historical Utah Geological Society data were analyzed to a greater level of resolution.

mg/L = milligrams per liter

µg/L = micrograms per liter

ng/L = nanograms per liter

< = Not detected at the method reporting limit.

H = Estimated. Samples warmed above 4 degrees Celsius during shipping.

N = Laboratory reports that quantity reported is estimated.

V = Upon data review and verification, determined to be estimated.

Table 8. Brine Shrimp Metals Results by Monitoring Event and Life Stage Composition – 2015

Parameter		Site 1			Site 2			Site 5		
		May	July	Sept	May	July	Sept	May	July	Sept
Life Stage Sample Composition (≥ 1% of at least one sample)										
Egg/cyst	Count per cubic meter	17,264 (77.0%)	5,636 (73.7%)	32,650 (92.9%)	12,630 (93.7%)	4,098 (75.6%)	11,407 (92.3%)	10,673 (94.1%)	6,599 (82.2%)	7,902 (95.8%)
Nauplius	Count per cubic meter	3,529 (15.7%)	252 (3.3%)	485 (1.4%)	505 (3.7%)	484 (8.9%)	131 (1.1%)	215 (1.9%)	290 (3.6%)	79 (1.0%)
Early metanauplius	Count per cubic meter	1,283 (5.7%)	1,511 (19.8%)	1,391 (4.0%)	186 (1.4%)	611 (11.3%)	492 (4.0%)	323 (2.8%)	910 (11.3%)	53 (0.6%)
Mid metanauplius	Count per cubic meter	233 (1.0%)	0 (0.0%)	194 (0.6%)	53 (0.4%)	25 (0.5%)	98 (0.8%)	27 (0.2%)	0 (0.0%)	0 (0.0%)
Total	Count per cubic meter	22,425	7,650	35,142	13,481	5,421	12,358	11,346	8,026	8,246
Percent Solids										
Total solids	%	13.43	15.89	16.25	13.14	14.70	15.47	12.45	15.11	15.85
Metals, Wet-Weight										
Arsenic	mg/kg	1.90	12.1	13.0 **H**	5.39	9.7	9.13 **H**	2.69	9.72	8.94 **H**
Copper	mg/kg	17.6 **V**	92 **V**	49.1 **H**	31.6 **V**	48 **V**	34.7 **H**	28.7 **V**	44.3 **V**	43.9 **H**
Mercury	ng/g	8.49	339	1.04 **H,V**	19.5	337	0.427 **H,V**	28.5	379	0.971 **H,V**
Lead	mg/kg	1.06	1.67	255 **H**	1.35	1.1	200 **H**	0.006	0.528	188 **H**
Selenium	mg/kg	0.22	2.67	2.00 **H**	0.48	2.42	1.78 **H**	0.46	2.64	1.77 **H**
Zinc	mg/kg	6.21	26.2	43.3 **H**	15.5	31	35.0 **H,M**	0.21	26.30	30.9 **H**

(*continued on next page*)

Table 8. Brine Shrimp Metals Results by Monitoring Event and Life Stage Composition – 2015

Parameter		Site 1			Site 2			Site 5		
		May	July	Sept	May	July	Sept	May	July	Sept
Metals, Dry-Weight										
Arsenic	mg/kg	14.1	1.92	2.12 **H**	41.0	1.38	1.41 **H**	21.6	1.47	1.42 **H**
Copper	mg/kg	131 **V**	14.6 **V**	7.97 **H**	240 **V**	6.8 **V**	5.37 **H**	230 **V**	6.70 **V**	6.96 **H**
Mercury	ng/g	63.2	53.8	0.169 **H,V**	148	47.8	0.066 **H,V**	229	57.3	0.154 **H,V**
Lead	mg/kg	7.87	0.265	41.5 **H**	10.3	0.15	31.0 **H**	0.050	0.080	29.8 **H**
Selenium	mg/kg	1.65	0.42	0.326 **H**	3.68	0.34	0.275 **H**	3.70	0.40	0.281 **H**
Zinc	mg/kg	46.2	4.16	7.04 **H**	118	4.3	5.42 **H,M**	1.67	3.98	4.89 **H**

H = Estimated. Samples warmed above 4 degrees Celsius during shipping.

M = Duplicate precision was outside of acceptance criteria. Result might be biased low and is estimated.

V = Determined during data review and verification to be estimated.

mg/kg = milligrams per kilogram

ng/g = nanograms per gram

5.0 Summary of Variances from the Interim Monitoring Plan

The 2015 monitoring was conducted in conformance with the IMP. Variances from the IMP were described in each monitoring event report. The three variances are summarized below.

1. In May, July, and September, brine shrimp sample collection for metals analysis was limited to one vertical plankton tow per site instead of three tows as specified in the IMP. This was a result of an abundance of brine shrimp biomass, in that one vertical tow yielded the required sample amount. Data quality was not reduced due to this variance.
2. Laboratory-measured density data collected in 2015 are considered valid results. However, to be consistent with previous monitoring events, hydrometer data were used for salinity calculations. As described in the May 2014 report, UPRR consulted with the Utah Geological Survey (UGS) (Rupke 2014) to identify the approach to determine density. In addition to laboratory measurements, specific gravity measurements of the samples were made with a hydrometer, and hydrometer data were used for salinity calculations. The hydrometer standard operating procedure is provided in Appendix H, Standard Operating Procedure for Specific Gravity Determinations Using a Hydrometer, of each report.
3. Laboratory measurements of dissolved oxygen, via the Winkler method, in May 2014 were suspected to be inaccurate due to an unknown interference during sample collection and preparation. Since then, to improve the accuracy of the results, dissolved oxygen sonde measurements, not laboratory measurements, were used to characterize dissolved oxygen.

Additional details can be found in Appendix F, Data Quality Assurance Documentation, of each interim monitoring event report.

5.1 Mercury in Equipment Rinsates

In general, the mercury concentrations in the equipment rinsate samples have been of the same order of magnitude as in the lower-water-column samples. Nevertheless, equipment rinsate results from the May, July, and September 2014 and February and May 2015 sampling events have had elevated mercury levels, suggesting that field sample handling might have introduced trace quantities of mercury into the deep brine samples. Hence, all deep brine mercury results from the first five monitoring events were qualified as estimated (indicated as V in Table 6 of each report).

The lower-water-column samples are the only samples collected using shared equipment and the only samples for which equipment rinsate samples apply. Equipment rinsates are collected in the following manner. Before taking the equipment rinsate sample, the sampling technician cleans the Kemmerer sampler with Alconox soap solution. The Alconox solution is agitated inside the sampler to ensure that the cylinder is coated with soap. Using a sprayer, the sampler is rinsed with copious amounts of distilled water and then, with the sampling technician pouring water directly from the jug, the sampler is given a last rinse with the distilled water. After this washing, lab-grade deionized water is poured directly onto the sampler; the deionized water used to rinse the sampler is collected and submitted to the laboratory as the equipment rinsate.

All sample bottles are certified as mercury free by Brooks-Rand Laboratories. Water used for rinsates is laboratory provided and certified free of mercury; the field blanks use the same water and have been non-detect for mercury in all events. The Kemmerer sampler was provided by the vendor for trace metals sampling; previous rinsates associated with fresh water samples collected with the Kemmerer sampler had been free of trace mercury concentrations.

A number of additional samples, beyond those specified in the IMP, have been collected in an attempt to isolate the source of mercury in the equipment rinsates.

- Two trip blanks accompanied the September 2014 samples, and were both non-detect.
- Eight trip blanks were sent on a “trip” that did not accompany samples in December 2014, and all results were non-detect.
- Alconox solution used to clean the Kemmerer sampler unit between sample collections was analyzed in December 2014, and mercury was found to be non-detect.
- In March 2015, distilled-water samples were collected from the tank sprayer used to rinse the Kemmerer sampler, and deionized water was poured over the sampler after it had been dry for a few months. Mercury was found in the sprayer water.

Because mercury was found in the sprayer water, a sprayer was not used to rinse samples for the May 2015 event, but all other procedures remained the same.

May 2015 equipment rinsates also exhibited mercury concentrations. At this point, despite earlier evidence that the Kemmerer sampler was suitable for trace metals analyses sampling, the Kemmerer sampler was sent to the laboratory for acid washing. Rinsates collected at the laboratory by laboratory personnel following the acid bath also contained mercury.

A new sampling apparatus (Kemmerer) was purchased for the July 2015 sampling event and was used again in September 2015. Mercury data did not require qualification in July 2015 or September 2015.

All data collected to inform the process described above are available on request.

6.0 Determination of No Adverse Effects

UPRR evaluated interim monitoring data collected and reported for South Arm salinity and WSEs for determination of no adverse effects to the beneficial uses of the Great Salt Lake because of the temporary closure of the east culvert. This evaluation is provided to support the data interpretation approach as described in Section 8.1, Data Interpretation Approach, of the IMP (UPRR 2014) and Special Condition 2(c) of the USACE NWP 14 for the temporary closure of the east culvert (USACE 2013).

The following sections compare the observed WSE, calculated head difference, and measured South Arm data to the historic WSE and UPRR/UGS salinity data to support this determination.

6.1 Water Surface Elevation and Head Difference

UPRR acquired real-time WSE data as recorded by the USGS gages located on the Great Salt Lake (see Figure 1, Interim Monitoring Sampling Sites and USGS Gage Locations, and Section 4.1, Water Surface Elevation, of this report). The North Arm’s WSE is monitored at the Saline gage at the southeast corner of the North Arm at USGS site 10010100. The South Arm’s WSE is monitored at the Saltair gage at the south end of the South Arm at USGS site 10010000. These data are available at ut.water.usgs.gov/greatsaltlake/elevations. UPRR has collected the historical real-time data for the WSEs over the last

10 years (USGS 2015). Using the WSEs at these USGS sites, UPRR: (1) computed weekly averages for the published USGS WSE data, and (2) calculated the head difference (in feet) between the South Arm WSE and the North Arm WSE (see Table 5, Water Surface Elevation and Computed Head Difference, and Section 4.1, Water Surface Elevation, of this report). UPRR then graphed the resulting data in Figure 7 below.

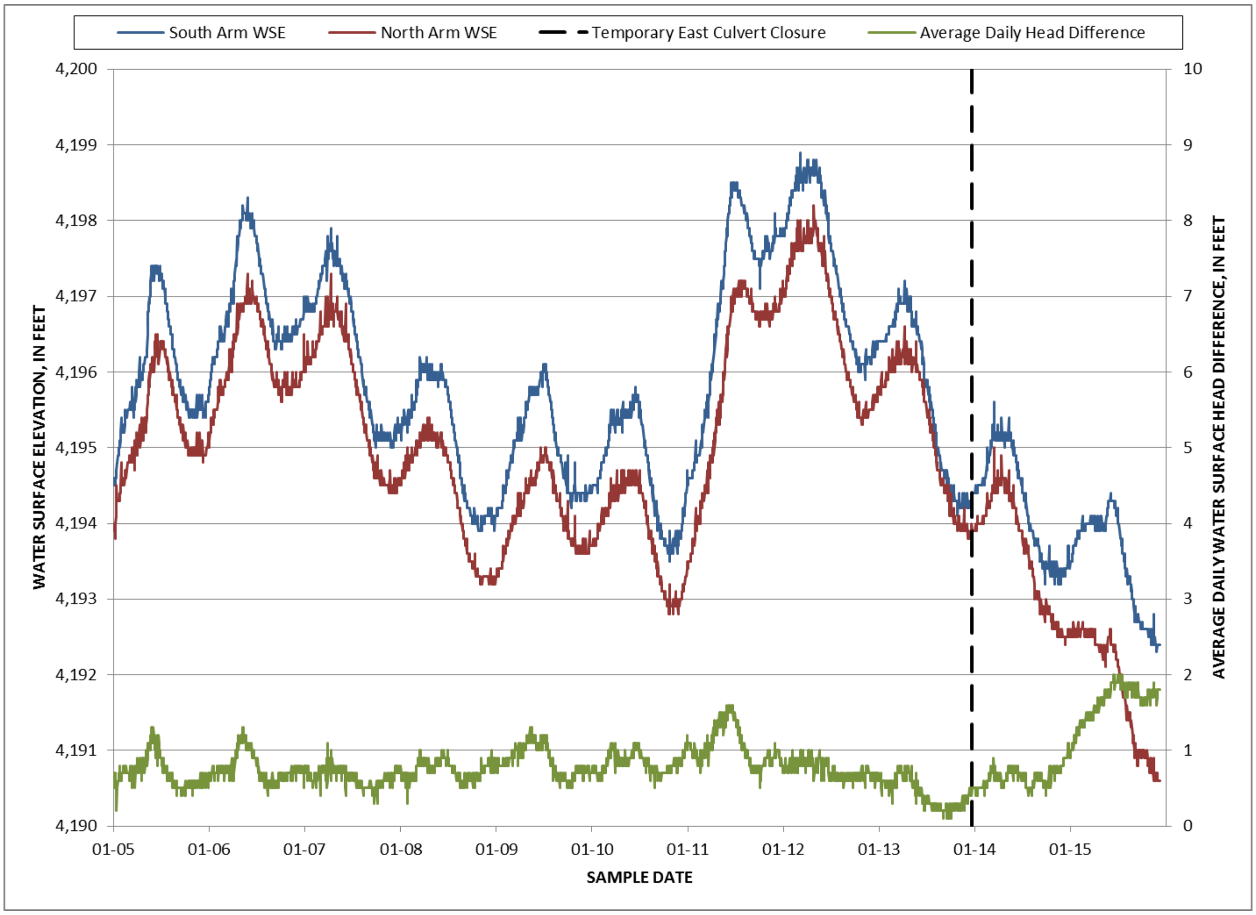
The WSE data collected and provided below indicate that, since the temporary closure of the east culvert, the South Arm WSE has dropped about 2 feet. As seen in Figure 7, after the temporary closure occurred in 2013, the previously recorded head difference remained relatively constant for about a year. However, as the South Arm WSE continued to drop, reaching about 4,193 feet in elevation and below, almost one year after the temporary closure of the east culvert, the head difference began to increase. This trend (increasing head difference) continues as the lake levels continue to drop.

For the monitoring event in September 2015, the South Arm WSE was recorded at 4,192.7 feet in elevation with a head difference of 1.8 feet. The South Arm WSE at that time was about 1.35 feet above the historic low of about 4,191.35 feet in elevation recorded in 1961. With a South Arm WSE of about 4,193 feet in elevation or lower, lake waters no longer flow through the existing 300-foot-long bridge, thereby eliminating flow between the North and South Arms through the bridge. This reduction or elimination of flow through the bridge can be corroborated by reviewing the data from the USGS gage that records bridge flow data, which is USGS Site 10010020, Great Salt Lake Breach at Lakeside, Utah (waterdata.usgs.gov/ut/nwis/uv/?site_no=10010020&PARAmeter_cd=00065,0).

Based on UPRR's review of the last 10 years of data, the following observations are made:

- The South Arm reached a high of almost 4,199 feet in elevation in 2011; since then, the WSE has continually declined due to drought conditions characterized by low precipitation and runoff volumes.
- As the lake waters drop below about 4,193 feet in elevation, the open-water flow between the North and South Arms is reduced as the lake waters can no longer flow through the existing 300-foot-long breach near Lakeside. This condition affects head difference and WSEs.
- The low lake levels have resulted in less water and salt transfer through the causeway, as the lake waters have receded away from the causeway and the overall length of causeway between the North Arm and South Arm open waters is less, resulting in a smaller area for water and salt to transfer through the causeway itself.

Figure 7. North and South Arm WSEs and Head Difference



Based on this analysis, UPRR determined that the temporary closure of the east culvert and the resulting WSEs and head difference have not resulted in adverse effects on the Great Salt Lake's beneficial uses. The two free-flowing water and salt conveyance structures (the east culvert and the 300-foot-long breach) that were in the causeway in November 2013 are no longer conveying water and salt. The east culvert was closed in December 2013 under an interim authorization to stabilize the causeway. Lake waters have receded from the existing 300-foot-long breach (since December 2014), and, because of drought conditions, open water is no longer flowing through the breach due to drought conditions.

Water and salt transfer through the causeway is still occurring in areas where lake surfaces meet the causeway. Although the lake WSEs and head differences have been affected by the temporary closure of the east culvert, these differences have also been exacerbated by the drought and the resulting elimination of flow through the breach. Taking account of the impact due to the drought, UPRR has determined that the temporary closure of the east culvert under the interim authorization is determined not to have adversely affected the beneficial uses of the Great Salt Lake.

6.2 South Arm Salinity

UPRR compared average salinities computed from interim monitoring event measurements to average historic UGS salinities.

UPRR used the UGS Great Salt Lake Brine Chemistry Database to define the historic South Arm densities (UGS 2012). By analyzing the UGS reported density and applying the USGS empirical formula, UPRR computed average lake salinities for the period 1966–2011. This UPRR/UGS historical salinity range was reported in the December 7, 2015, Compensatory Mitigation and Monitoring Plan (CMMP; UPRR 2015d).

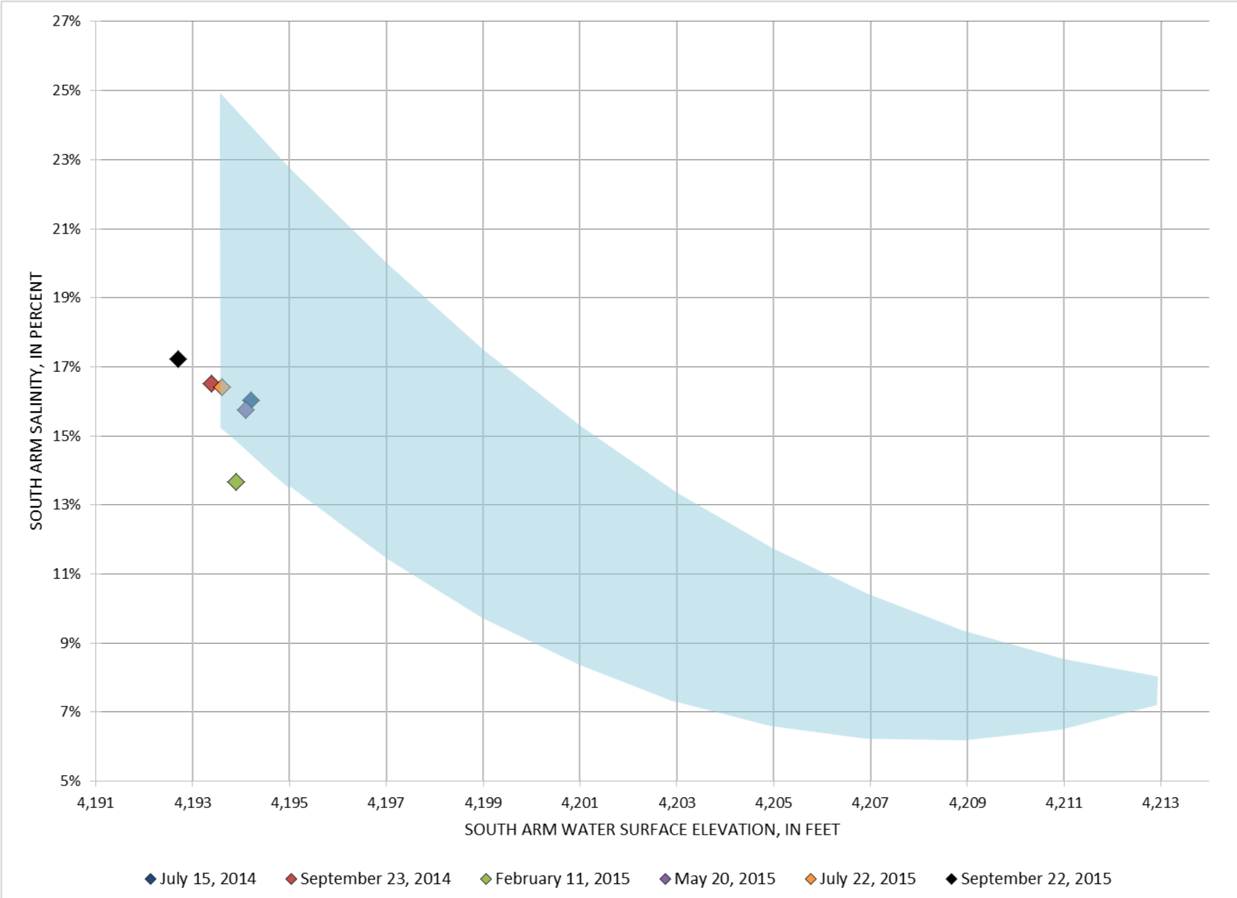
Consistent with the methodology described in the December 2015 CMMP, UPRR calculated average South Arm salinities for the monitoring events and compared these observed data to UPRR/UGS historic salinity ranges for the South Arm (UPRR 2015d).

At each UPRR sampling site, samples were collected at various depths, and hydrometer-specific gravity readings were measured in a controlled setting after returning from the field. Observed specific-gravity measurements were corrected for temperature and then used to estimate densities and calculate salinities, following the USGS-defined density-salinity relationships (USGS 1973). These discrete salinities were averaged bathymetrically in accordance with USGS methodology to produce an average South Arm salinity for each event (USGS 1973). Note that the salinity values calculated using the methodology consistent with the CMMP are used for this salinity determination only. They are not consistent with the salinity values calculated for the interim monitoring event salinity profiles, which are calculated using hydrometer- and laboratory-reported TDS values.

UPRR has plotted and compared the interim monitoring average South Arm salinity data for the 2014 and 2015 monitoring events to the UPRR/UGS average historic South Arm salinity range as represented by the blue shaded area in Figure 8 below. The historic collection of lake samples and analysis for salinity occurred over a South Arm WSE range of about 4,194 feet in elevation to about 4,212 feet in elevation. Because of the current low lake WSEs, the salinity data collected by UPRR in September 2014 and 2015 correspond to WSEs that are slightly lower than the historic data represented in Figure 8.

The South Arm interim monitoring salinity data and the comparative analysis indicate that South Arm salinities are generally consistent with the UPRR/UGS average historic South Arm salinities. Based on this analysis, UPRR determined that the temporary closure of the east culvert has not resulted in adverse salinity effects on the beneficial uses of the Great Salt Lake.

Figure 8. Interim Monitoring Results Compared to UPRR/UGS Historic South Arm Salinity Range



7.0 References

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[UGS] Utah Geological Survey

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[UPRR] Union Pacific Railroad

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2015a Interim Monitoring Report – May 2015 Monitoring Results. May11.

2015b Interim Monitoring Report – May 2015 Monitoring Results. August 18.

2015c Interim Monitoring Report – July 2015 Monitoring Results. October 21.

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