Completion Report

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

USACE PERMIT: SPK-2011-00755
UDWQ CERTIFICATION: SPK-2011-00755

January 10, 2022

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Acronyms

AMSL	above mean sea level
CMMP	Updated Final Compensatory Mitigation and Monitoring Plan
DBL	deep brine layer
MOU	Memorandum of Understanding
NGVD 29	National Geodetic Vertical Datum of 1929
OHWM	ordinary high water mark
POC	parameter of concern
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
SAP	Sampling and Analysis Plan
TDS	total dissolved solids
UBL	upper brine layer
UDWQ	Utah Division of Water Quality
UP	Union Pacific Railroad
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WRI 4221	Water-Resources Investigations Report 00-4221
WSE	water surface elevation

1.0 Introduction

1.1 Executive Summary

Union Pacific Railroad (UP) submits this completion report in compliance with Special Condition 1.d of the U.S. Army Corps of Engineers (USACE) Individual 404 Permit (No. SPK 2011-00755) issued September 9, 2015 (USACE 2015a), and modifications, and Condition 4 of the Amended Utah 401 Water Quality Certification with Conditions (No. SPK 2011-00755) which was issued to UP by the Utah Division of Water Quality (UDWQ) on September 13, 2017 (UDWQ 2017), for the Great Salt Lake Permanent East Culvert Closure and Bridge Construction Project, Great Salt Lake, UT. These authorizations require the submittal of a completion report that documents meeting Project performance standards to terminate the monitoring and adaptive management period.

The authorizations required the compensatory mitigation to duplicate the water and salt transfer (aquatic function) of the closed Great Salt Lake causeway culverts for average lake conditions. Mitigation included constructing a new 180-foot-long railroad bridge, earthen control berm, and south channel, which was completed in December 2016 (Project).

UP conducted 5 years of post-construction monitoring and reporting of the mitigation site and Great Salt Lake North and South Arm water quality and confirmed that the Project is meeting the geometry and salinity performance standards. Monitoring parameters include bathymetric and topographic surveys, average water depth at the causeway opening, and water quality (salinity) parameters. Quarterly and annual reports documenting the monitoring results were submitted to the regulating agencies and confirmed that the Project met the performance standards and that the Project will continue to allow the transfer of water and salt to meet salinity performance standards into the future.

This Completion Report requests the cessation of the monitoring and adaptive management period, and documents that UP conducted 5 years of monitoring, submitted the required quarterly and annual data monitoring reports, and successfully met the Project geometry and salinity performance standards. The appendices to this report include agency authorizations, executed memoranda of understanding, the Project mitigation and monitoring plan, the Project sampling plan, and previously submitted quarterly and annual data monitoring reports and approvals.

1.2 Background

UP submits this Completion Report pursuant to Special Condition 1.d of the USACE Individual 404 Permit (No. SPK 2011-00755) issued September 9, 2015 (USACE 2015a), and modifications, and Condition 4 of the Amended Utah 401 Water Quality Certification with Conditions (No. SPK 2011-00755), which was issued to UP by UDWQ on September 13, 2017 (UDWQ 2017), for the Great Salt Lake Permanent East Culvert Closure and Bridge Construction Project. This Completion Report requests the cessation of the monitoring and adaptive management period per the USACE Permit and the UDWQ Certification and requests that the monitoring and adaptive management period be terminated.

The Project consisted of the permanent closure of the Great Salt Lake causeway east culvert and the construction, operation, maintenance, and monitoring of a new Great Salt Lake causeway opening located at milepost 739.78 along the Great Salt Lake causeway (Figure 1). The Project constructed a new causeway opening, made up of a new 180-foot-long railroad bridge, earthen control berm, and south channel. This causeway opening was designed to allow the transfer of water and salt between the North and South Arms of the Great Salt Lake to duplicate, as closely as possible, the transfer of water and salt for average lake conditions as compensatory mitigation for closing the east and west culverts (Figure 22). The west culvert was closed under separate USACE and UDWQ authorizations, namely USACE Nationwide Permit 14, dated August 29, 2012 (USACE 2012). The east culvert was temporarily closed under a separate USACE and UDWQ authorization, namely a USACE Nationwide Permit 14 dated December 6, 2013, and a Utah 401 Water Quality Certification dated December 16, 2013 (USACE 2013; UDWQ 2013).

Construction of the Project began in October 2015 and was completed in December 2016. Mitigation monitoring began in January 2017, after construction was completed, and 5 years of monitoring and reporting were completed in December 2021. Mitigation monitoring was conducted in accordance with the *Updated Final Compensatory Mitigation and Monitoring Plan* (CMMP; UP 2016a) and the *Sampling and Analysis Plan* (SAP) and *Quality Assurance Project Plan* (QAPP) (UP 2016b).

Because the Project geometry and salinity performance standards were met, no adaptive management measures were required during the 5-year monitoring period.

The mitigation monitoring objectives were to (1) facilitate a determination of whether the performance standards described in the CMMP were being met and (2) provide additional information for salinity modeling and lake management as needed. UP and the U.S. Geological Survey (USGS) collected the data required to meet monitoring objectives. The CMMP defined the Project geometry and salinity performance standards related to South Arm average salinity and identified monitoring parameters required to determine consistency with these standards (Appendix B).

1.3 Completion Report Requirements

As described in Special Condition 1.d of the USACE Individual 404 Permit and Condition 4 of the Amended Utah 401 Water Quality Certification, this Completion Report achieves the following:

- Document the results of the mitigation monitoring during the agreed upon monitoring period after the completion of bridge and berm construction (Chapter 2).
- Describe any long-term changes in flow and salt transfer associated with the Project in relation to mitigation objectives (Chapter 3).
- Describe any long-term changes in flow and salt transfer associated with the Project in relation to lake salinity and the beneficial uses of the Great Salt Lake, antidegradation policy, numeric criteria, and narrative standards (Chapter 4).

In addition, Special Condition 1.l of the modified USACE Individual 404 Permit and Condition 5 of the Amended Utah 401 Water Quality Certification required the execution of a Memorandum of Understanding (MOU) between UP and UDWQ before the termination of the monitoring period (UDWQ 2017; USACE 2018). The executed UP and UDWQ MOU is provided in Appendix A.

Also included in Appendix A is the separate, but related, executed MOU between UDWQ and the Utah Division of Forestry, Fire and State Lands.

2.0 Mitigation Monitoring Results

Mitigation monitoring began in January 2017 after the construction of the Project, which was completed in December 2016. Five years of monitoring and reporting were completed in December 2021.

The 2017, 2018, 2019, 2020, and 2021 quarterly and annual data monitoring reports were previously submitted to the regulating agencies (UP 2017a, 2017b, 2017c, 2018a, 2018b, 2018c, 2018d, 2018e, 2019a, 2019b, 2019c, 2019d, 2019e, 2020a, 2020b, 2020c, 2020d, 2020e, 2021a, 2021b, 2021c, 2021d, 2021e, 2022a, 2022b). In accordance with UDWQ Certification conditions, the 2017, 2018, 2019, and 2020 annual data monitoring reports were approved by UDWQ (Appendix D; UDWQ 2018, 2019, 2020, 2021a). The 2021 annual data monitoring report was submitted on January 5, 2021 and is pending approval at the time of this report submittal.

The 5 years of data summarized in this Completion Report, and previously submitted, were collected in accordance with the CMMP (UP 2016a) and the SAP and QAPP (UP 2016b), which were approved by UDWQ (UDWQ 2017) (Appendix B). The results of each monitoring event as well as the quality assurance and quality control (QA/QC) reviews and discussions regarding meeting the Project performance standards were submitted in the five annual data monitoring reports (Appendix D; UP 2018b, 2019b, 2020b, 2021b, 2022b). Data quality packages (Level 2) and other QA/QC supporting documentation were also provided in the quarterly data monitoring reports submitted to the regulating agencies (Appendix C; UP 2017a, 2017b, 2017c, 2018a, 2018c, 2018d, 2018e, 2019a, 2019c, 2019d, 2019e, 2020a, 2020c, 2020d, 2020e, 2021a, 2021c, 2021d, 2021e, 2022a).

Figure 1 shows locations of the Great Salt Lake sampling sites. Table 1 lists the monitoring events that were conducted to determine adherence to the Project performance standards and to collect additional data for the 5-year monitoring period. To characterize lake conditions during normal weather conditions, monitoring events were generally conducted when the wind was calm.

Sampling variances and corrective actions are summarized in Section 2.1. Monitoring data are summarized for parameters related to the confirmation of the salinity performance standard in Section 2.2. A summary of North and South Arm salinity calculations is provided in Section 2.3. Survey monitoring parameters related to the confirmation of the geometry performance standards are summarized in Section 1.1. Additional data collected are summarized in Section 2.5.

Figure 1. Great Salt Lake Sampling Site Locations

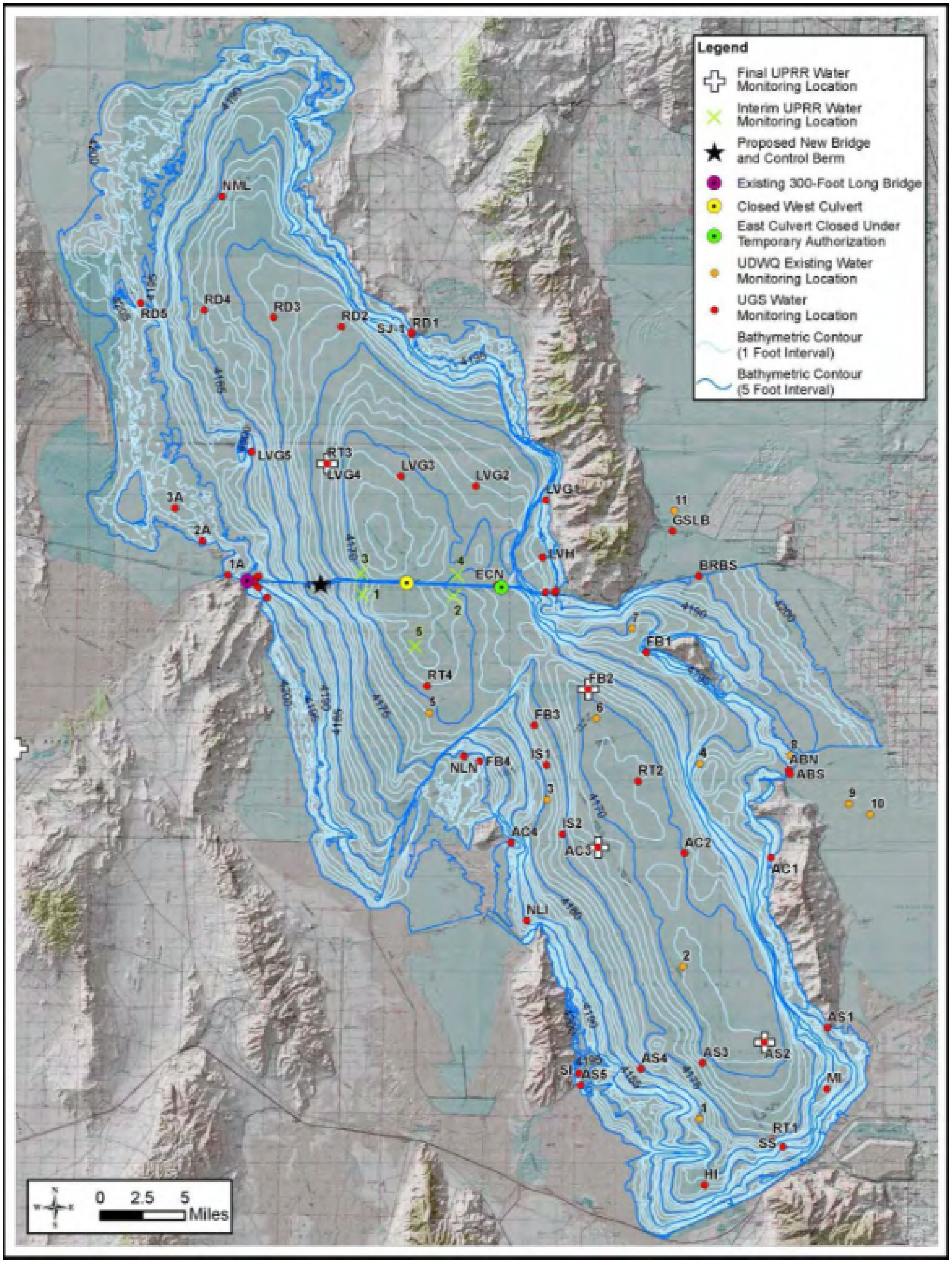


Table 1. Project Monitoring Event Dates

Quarter	Data for Project Performance Standards		Additional Data Collected	
	North and South Arm Lake Chemistry Monitoring	Causeway Opening Geometry (Bathymetric and Topographic Surveys)	Causeway Opening Water Quality Monitoring	USGS Flow Measurement at the Causeway Opening
First Quarter	**2017** – 2/13, 2/14 **2018** – 2/6, 2/7 **2019** – 3/15, 3/18 **2020** – 2/10, 2/12 **2021** – 3/17		**2017** – 1/24, 2/13, 3/2 **2018** – 1/3, 2/6, 3/7 **2019** – 1/8, 2/12, 3/18 **2020** – 1/7, 2/12, 3/5 **2021** – 1/6, 2/24, 3/25	**2017** – 1/17, 2/13, 3/2 **2018** – 1/4, 2/7, 3/8 **2019** – 2/8, 3/5 **2020** – 1/15, 2/12, 3/11 **2021** – 1/6, 2/2, 3/2
Second Quarter	**2017** – 5/9, 5/11 **2018** – 5/3, 5/4 **2019** – 6/4 **2020** – 5/28, 5/29 **2021** – 5/13	**2017** – June **2018** – June **2019** – May	**2017** – 4/11, 5/11, 6/7 **2018** – 4/11, 5/3, 6/7 **2019** – 4/9, 5/13, 6/4 **2020** – 4/7, 5/21, 6/10 **2021** – 4/12, 5/19, 6/2	**2017** – 4/6, 5/3, 6/15 **2018** – 4/3, 5/10, 6/7 **2019** – 4/4, 5/13, 6/5 **2020** – 4/3, 5/6, 6/4 **2021** – 4/1, 5/5, 6/1
Third Quarter	**2017** – 8/8, 8/10 **2018** – 8/7, 8/8 **2019** – 8/14, 8/15 **2020** – 8/12, 8/13 **2021** – 8/11	**2020** – August **2021** – August	**2017** – 7/5, 8/10, 9/6 **2018** – 7/12, 8/7, 9/5 **2019** – 7/9, 8/14, 9/10 **2020** – 7/8, 8/12, 9/15 **2021** – 7/7, 8/19, 9/2	**2017** – 7/6, 8/3, 9/7 **2018** – 7/12, 8/8, 9/6 **2019** – 7/9, 8/7, 9/5 **2020** – 7/10, 7/29, 8/5, 9/3 **2021** – 7/7, 8/5, 9/7
Fourth Quarter	**2017** – 11/8, 11/9 **2018** – 11/6, 11/7 **2019** – 10/15, 10/16 **2020** – 11/5 **2021** – 10/21[a]	**2017** – December **2018** – November	**2017** – 10/3, 11/9, 12/7 **2018** – 10/2, 11/6, 12/6 **2019** – 10/15, 11/11, 12/3 **2020** – 10/6, 11/5, 12/8 **2021** – 10/15, 11/3, 12/1	**2017** – 10/13, 11/1, 12/12 **2018** – 10/3, 11/7, 12/6 **2019** – 10/2, 11/1, 12/5 **2020** – 10/1, 11/5, 12/3 **2021** – 10/7, 11/4, 12/2

[a] Sampling at site RT3 in the North Arm was not conducted due to limited boat access (UP 2022a).

2.1 Sampling Variances and Corrective Actions

Water quality monitoring during the 5-year monitoring period (January 2017 to December 2021) was completed in accordance with the CMMP and the SAP and QAPP (Appendix B; UP 2016a, 2016b). Over the course of the 5-year monitoring period, field conditions, data accuracy considerations, and equipment challenges made it necessary to revise and document the following sampling variances and corrective actions. These variances and corrective actions have been previously reported in the appropriate annual data monitoring reports and are summarized below.

- During the first quarter of 2017 open-water sampling event, floating sheets of ice precluded safe access to the open-water South Arm sampling site AC3. An accessible location about 2 miles south of site AC3 was chosen as an alternate location.
- During the 2019 monitoring period, there were data discrepancies in some of the monthly bidirectional flow samples collected and analyzed at the causeway opening. UP believes that these samples might not have adequately characterized the north-to-south flow due to seasonal variations in field conditions. In response to these data discrepancies, the field monitoring team revised the sampling methodology to collect a duplicate sample of the south-to-north flow and the north-to-south flow at the causeway opening. The SAP requires only one duplicate to be collected at the causeway opening during each monthly monitoring event; however, this additional sample

allowed the field monitoring team to field-evaluate the results during sample collection to avoid future discrepancies.

- As the open-water field monitoring team was calibrating the sampling equipment prior to the trip in August 2020, the team noticed that the conductivity probe was not calibrating correctly. As a result, specific conductivity measurements were not taken during the third quarter of 2020 at the open-water sampling sites or at the causeway opening. The field monitoring team worked with the conductivity probe vendor to order a replacement, and all other specific conductivity calibrations and measurements were successfully made and taken since.
- The open-water field monitoring team was unable to access the North Arm to sample at site RT3 during the fourth quarter of 2021 because the lake's water surface elevation (WSE) was at a historically low level. As the lake level lowered, land masses extended above the water surface near the causeway opening. Consequently, the open-water field monitoring team and the boat charter captain determined there was a navigational risk and safety concern in accessing the North Arm sampling site through the causeway opening. UP contacted Compass Minerals to investigate launching the boat into the Behren's Trench, as had been done before the causeway opening was completed, as an alternative way to access the North Arm sampling site. The open-water field monitoring team and the boat charter captain visited the Compass Minerals facility and determined that this access point was not suitable.

2.2 North and South Arm Lake Water Quality Parameters

Consistent with CMMP Section 3.10, the following water quality monitoring parameters were collected at each sampling site in the North Arm (site RT3) and South Arm (sites FB2, AC3, and AS2) for each quarterly monitoring event conducted during the 5-year monitoring period (UP 2016a):

- Water temperature
- Density
- Total dissolved solids (TDS)
- Specific conductivity
- Cations and anions

The data for water temperature, density, TDS, and specific conductivity are summarized below and are shown in Figure 2 through Figure 17. Cation and anion data were previously reported in the quarterly data monitoring reports and are not summarized in this section (UP 2017a, 2017b, 2017c, 2018a, 2018c, 2018d, 2018e, 2019a, 2019c, 2019d, 2019e, 2020a, 2020c, 2020d, 2020e, 2021a, 2021c, 2021d, 2021e, 2022a). The quarterly data monitoring reports are included in Appendix C for reference.

2.2.1 Water Temperature

Water temperature data were collected in the field generally at the following depth intervals: every 4 inches for the first 3 feet of the profile; every 1 foot from 3 feet deep down to the beginning of the deep brine layer, if present; and every 6 inches in the deep brine layer. These field-collected data are shown in profiles for each of the open-water sampling sites (Figure 2 [site AS2], Figure 3 [site AC3], Figure 4 [site FB2], and Figure 5 [site RT3]). The following observations are made:

- Generally, lake water temperature variation was seasonal, with the coldest temperatures generally occurring each year during the first-quarter monitoring event and the warmest temperatures generally occurring each year during the third-quarter monitoring event.
- Before the lake density stratified (that is, before the deep brine layer [DBL] and upper brine layer [UBL] developed at the South Arm sampling sites in the fourth quarter of 2017 (sites FB2 and AS2) and the second quarter of 2018 (site AC3), the water temperature was generally constant throughout the water column at the three South Arm sampling sites.
- Water temperatures began to indicate the presence of the DBL and UBL in the South Arm, since the DBL was generally warmer than the UBL in the colder seasons and colder than the UBL in the warmer seasons during much of the 5-year monitoring period.
- Temperature measurements indicated that the thickness of the DBL detected at the South Arm sampling sites varied seasonally. During 2021, temperature measurements indicated that the thickness of the DBL was reduced at sites AS2 and FB2, and, in the fourth quarter of 2021, the DBL was not present at site AC3.
- Temperature measurements in the North Arm (site RT3) varied seasonally and were generally constant with increasing depth for all quarterly monitoring events.

2.2.2 Density

Lake water samples were collected in the field generally at the surface, at every 5 feet of additional depth, and at the last whole foot depth increment above the lake bed. The density of each discreet sample was analyzed in the field using an Anton-Paar density meter and are shown in profiles (Figure 6 [site AS2], Figure 7 [site AC3], Figure 8 [site FB2], and Figure 9 [site RT3]). The following general observations are made:

- North and South Arm density measurements naturally varied with seasonal hydrologic influences. Over the 5-year monitoring period, the South Arm density measurements generally increased during the summer and fall months as WSEs decreased and generally decreased during the winter and spring months as WSEs increased.
- Density measurements at the South Arm sampling sites (AS2, AC3 and FB2) generally indicated the presence of a DBL corresponding with other water quality data for most of the 5-year monitoring period.
- The average density of the DBL at the South Arm sampling sites, in general, was about 60% of the density of the North Arm brine.
- Density measurements indicated that the thickness and concentration of the DBL detected at the South Arm sampling sites varied seasonally. The 2021 density measurements indicated that the thickness of the DBL was reduced at site AS2 and FB2, and, during the fourth quarter of 2021, the DBL was not present at site AC3.
- Density measurements in the North Arm (site RT3) varied seasonally and were generally constant or gradually increased with depth for all quarterly monitoring events.

2.2.3 Total Dissolved Solids

Lake water samples were collected in the field generally at the surface, at every 5 feet of additional depth, and at the last whole foot depth increment above the lake bed. Samples were evaluated by a state-certified analytical laboratory, and reported TDS data are shown in profiles (Figure 10 [site AS2], Figure 11 [site AC3], Figure 12 [site FB2], and Figure 13 [site RT3]). The following general observations are made:

- North and South Arm TDS concentrations varied with seasonal hydrologic influences. Over the 5-year monitoring period, the South Arm TDS concentrations generally increased during the summer and fall months as WSEs decreased and generally decreased during the winter and spring months as WSEs increased.
- TDS concentrations at the South Arm sampling sites (AS2, AC3, and FB2) generally indicated the presence of a DBL when other data also indicated the presence of a DBL for most of the 5-year monitoring period.
- The average TDS concentration of the DBL at the sampling sites, in general, was about 60% of the TDS concentration of the North Arm brine.
- TDS concentrations indicated that the thickness of the DBL detected at the South Arm sampling sites varied seasonally. In 2021, TDS concentrations indicated that the thickness of the DBL was reduced at site AS2 and FB2, and, in the fourth quarter of 2021, the DBL was not present at site AC3.
- TDS concentrations at the North Arm site (site RT3) varied seasonally and were generally inconsistent with depth for all quarterly monitoring events.

2.2.4 Specific Conductivity

Specific conductivity data were collected in the field generally at the following depth intervals: every 4 inches for the first 3 feet of the water column, every 1 foot from 3 feet deep down to the beginning of the DBL, and every 6 inches in the DBL. The specific conductivity data were generally used to determine the presence of the DBL due to the increased number of available data points. These field-collected data are shown in profiles for each of the open-water sampling sites (Figure 14 [site AS2], Figure 15 [site AC3], Figure 16 [site FB2], and Figure 17 [site RT3]). The following general observations are made:

- North and South Arm specific conductivity measurements varied with seasonal hydrologic influences. Over the 5-year monitoring period, the South Arm specific conductivity measurements generally increased during the summer and fall months as WSEs decreased and generally decreased during the fall and spring months as WSEs increased.
- Specific conductivity measurements at the South Arm sampling sites (AS2, AC3, and FB2) were generally constant before the lake stratified. Once South Arm density stratified, specific conductivity measurements increased, generally 10% to 25%, at the greatest depths for most of the 5-year monitoring period. Increased specific conductivity measurements, which is an indication of the formation of a DBL, were first evident at the following times by site:
    - during the fourth quarter of 2017 at site FB2,
    - during the fourth quarter of 2017 at site AS2, and
    - during the second quarter of 2018 at site AC3.
- The specific conductivity of the DBL at the sampling sites, in general, was about 85% of the specific conductivity of the North Arm brine.
- Specific conductivity measurements indicated that the thickness of the DBL detected at the South Arm sampling sites varied seasonally. In 2021, specific conductivity measurements indicated that the thickness of the DBL was reduced at sites AS2 and FB2, and, in the fourth quarter of 2021, the DBL was not present at site AC3.
- Specific conductivity measurements in the North Arm at site RT3 were generally constant with increasing depth for each event throughout the monitoring period.

Figure 2. Lake Water Temperature Profiles at Site AS2

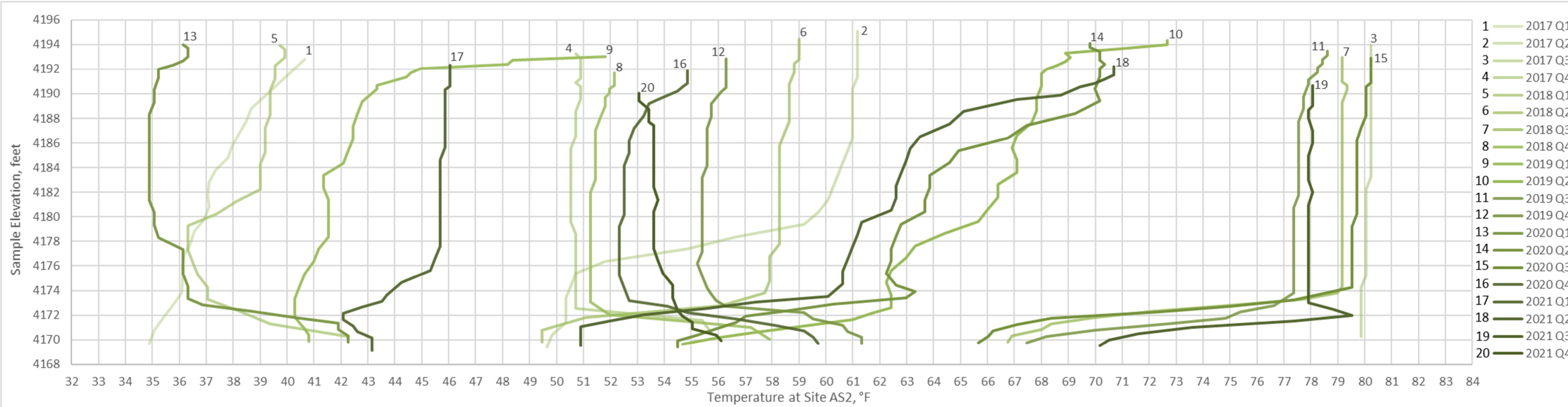


Figure 3. Lake Water Temperature Profiles at Site AC3

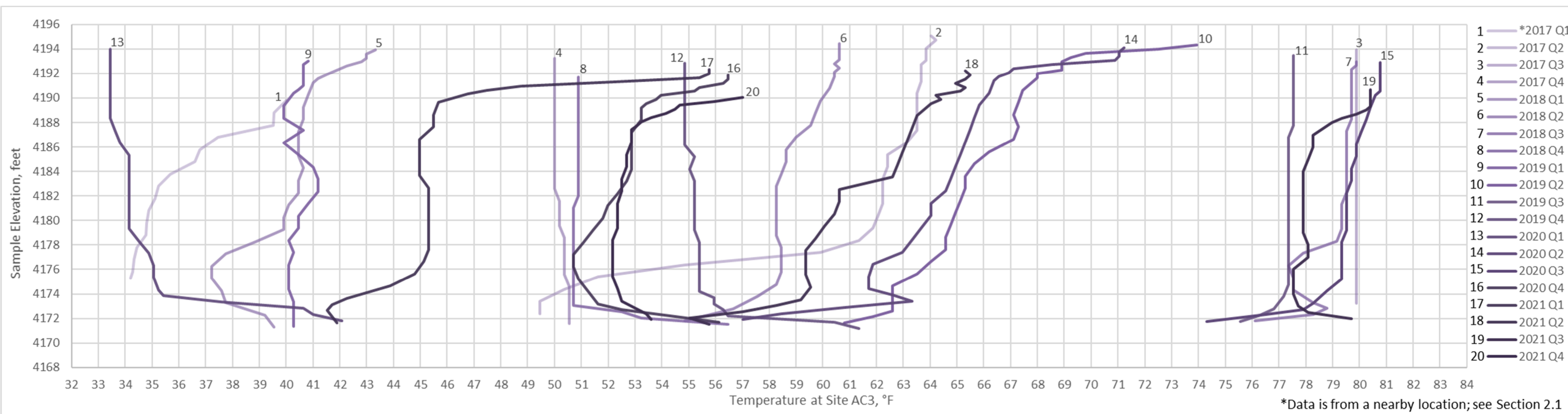


Figure 4. Lake Water Temperature Profiles at Site FB2

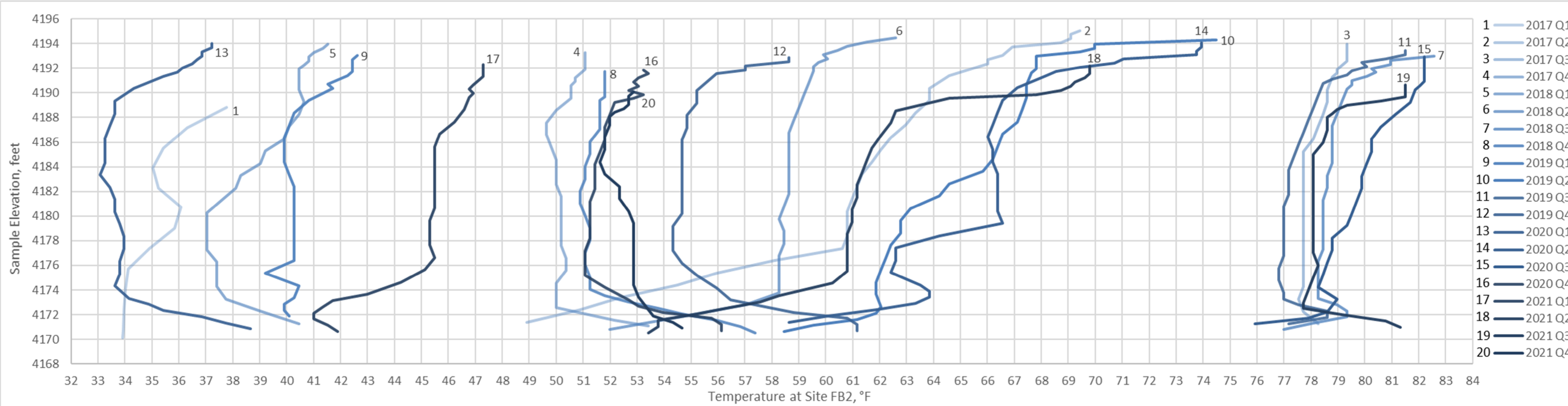


Figure 5. Lake Water Temperature Profiles at Site RT3

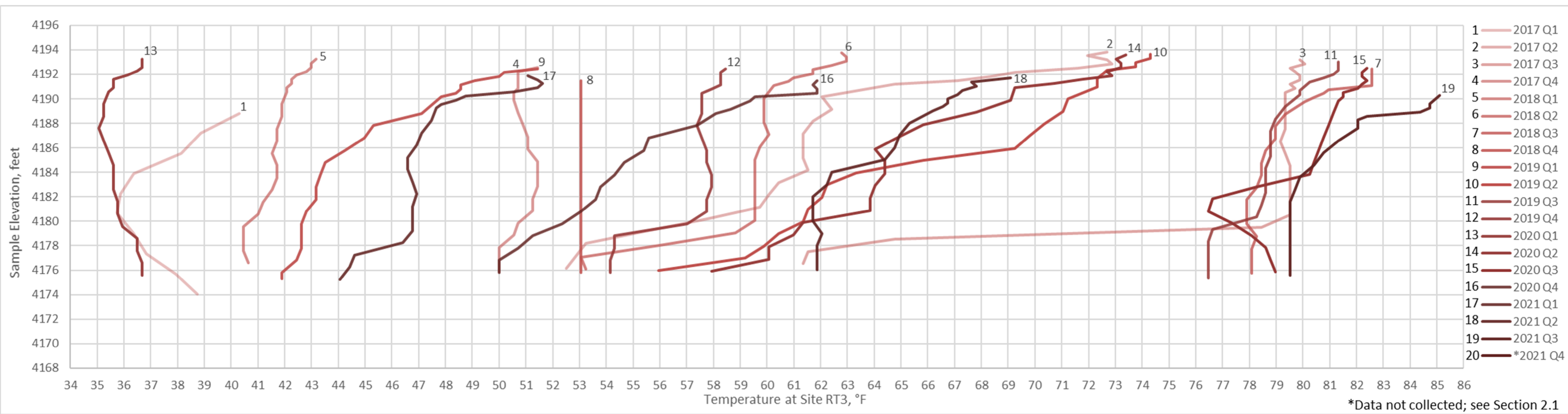


Figure 6. Lake Water Density Profiles at Site AS2

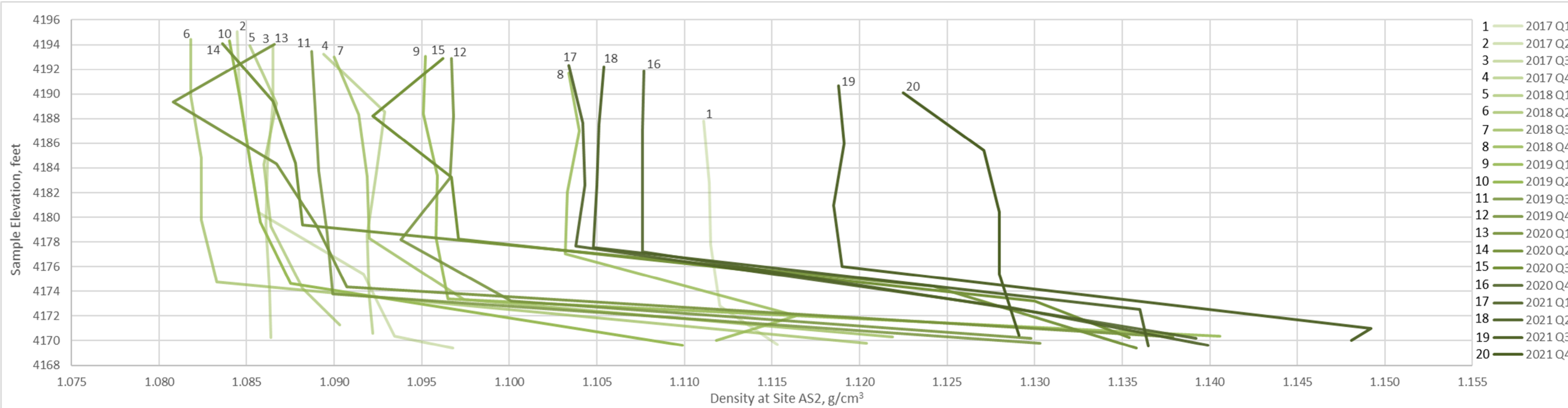


Figure 7. Lake Water Density Profiles at Site AC3

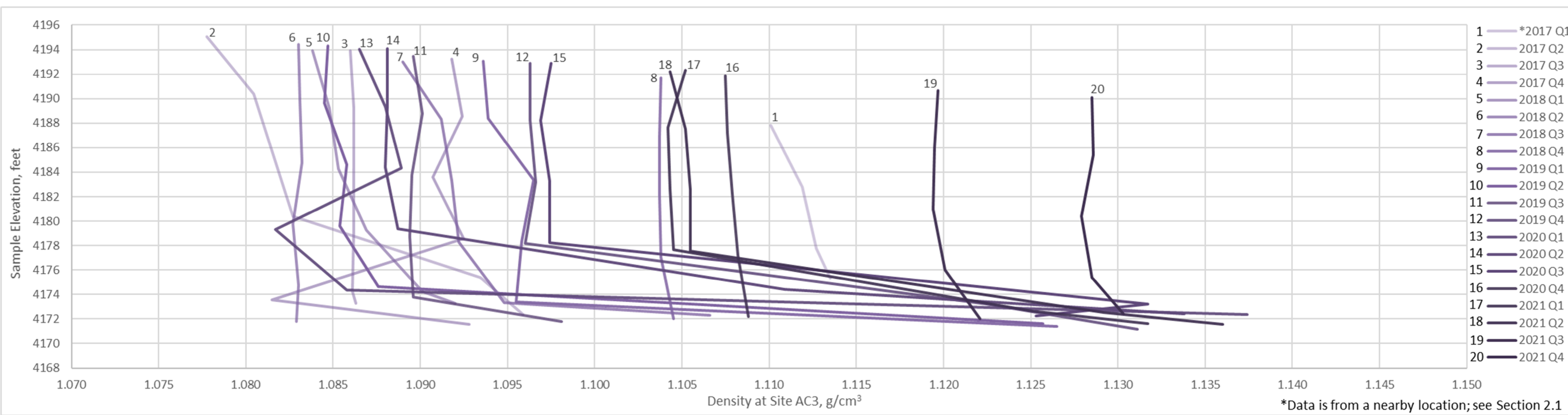


Figure 8. Lake Water Density Profiles at Site FB2

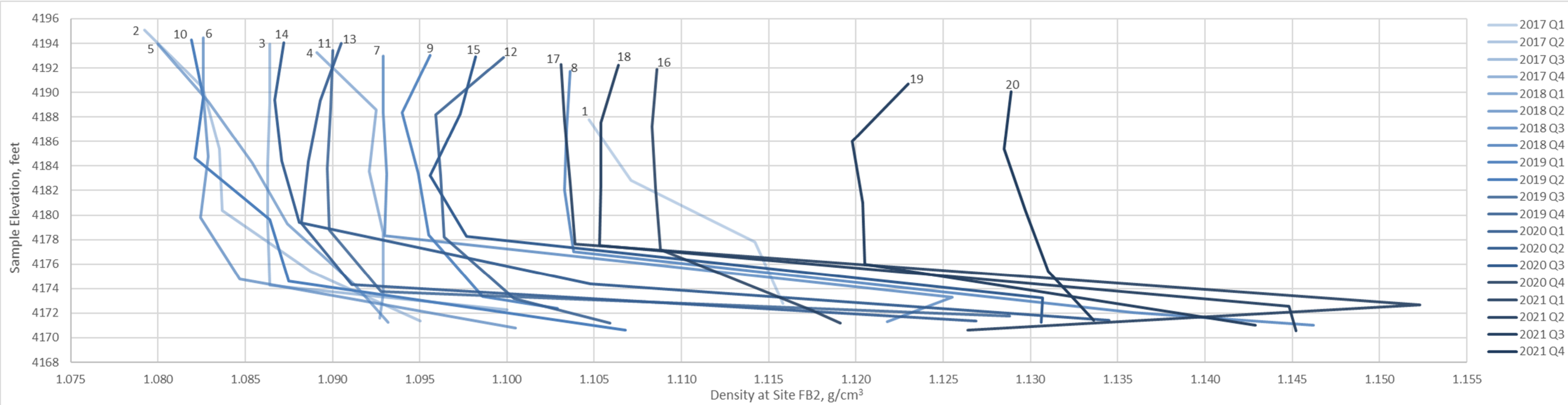


Figure 9. Lake Water Density Profiles at Site RT3

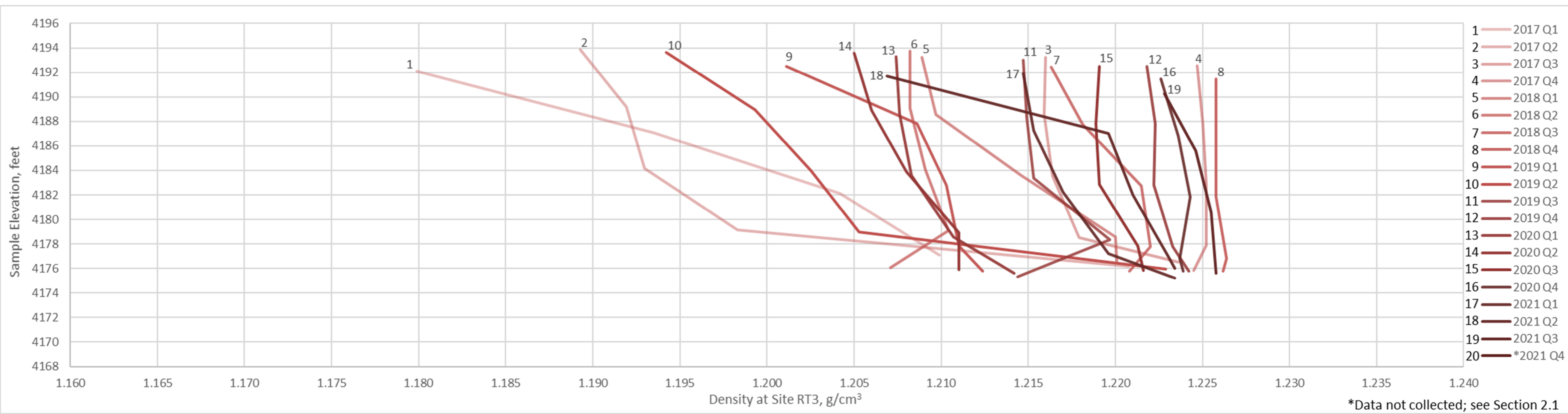


Figure 10. Lake Water TDS Profiles at Site AS2

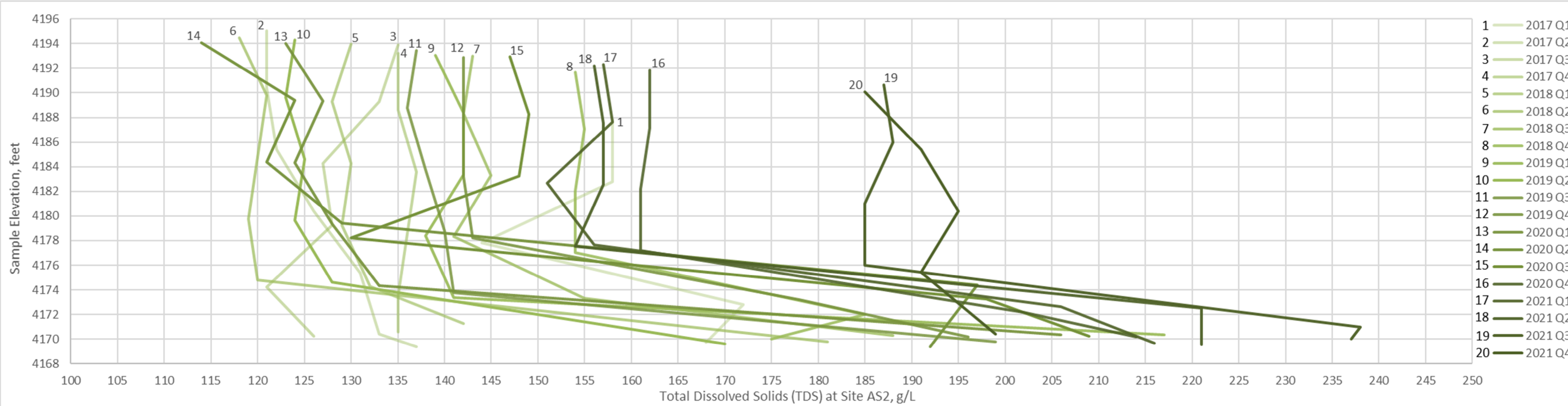


Figure 11. Lake Water TDS Profiles at Site AC3

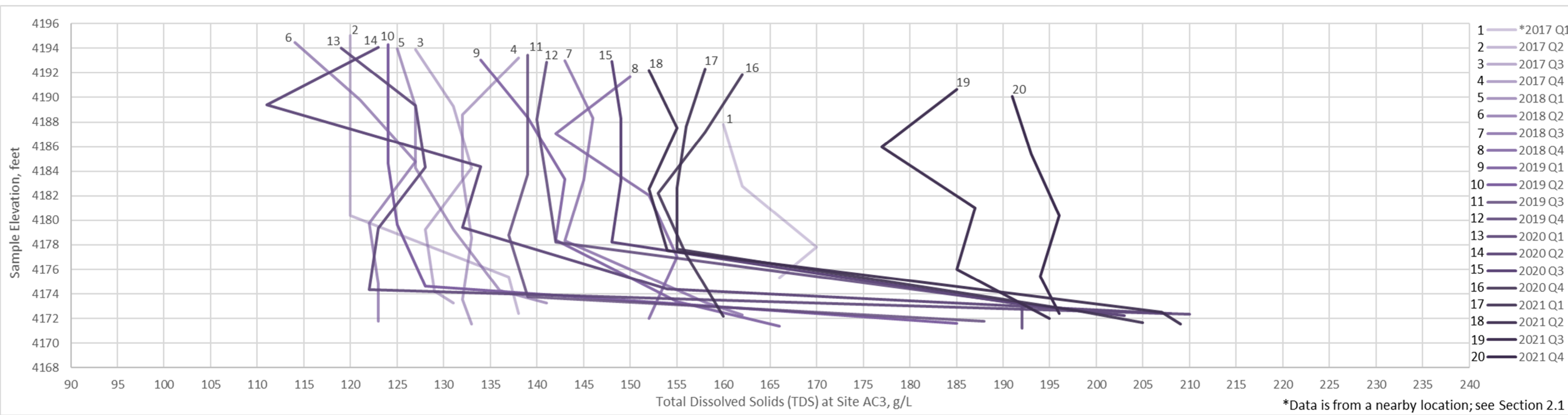


Figure 12. Lake Water TDS Profiles at Site FB2

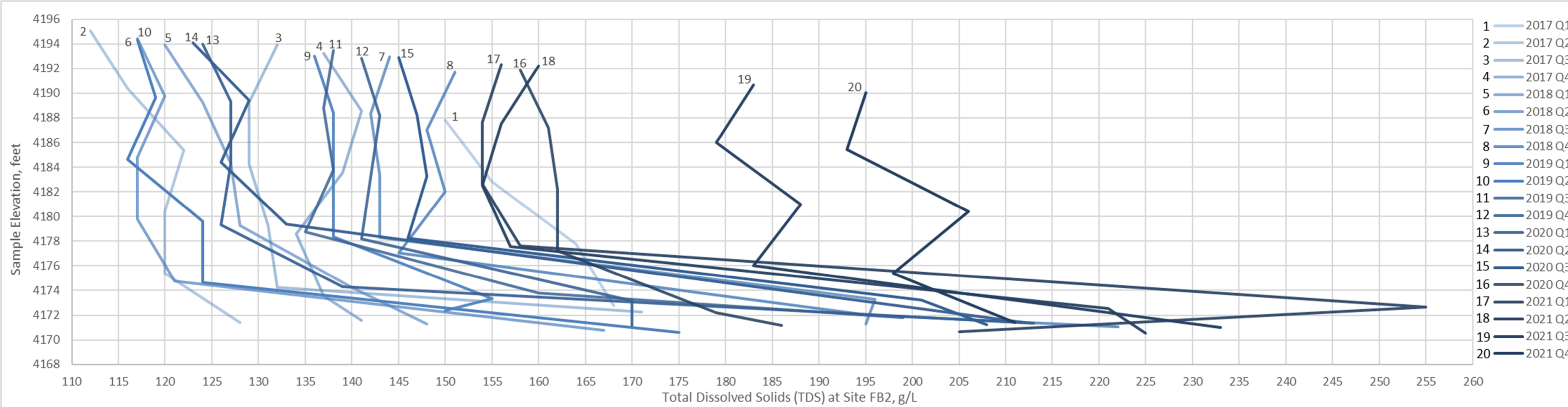


Figure 13. Lake Water TDS Profiles at Site RT3

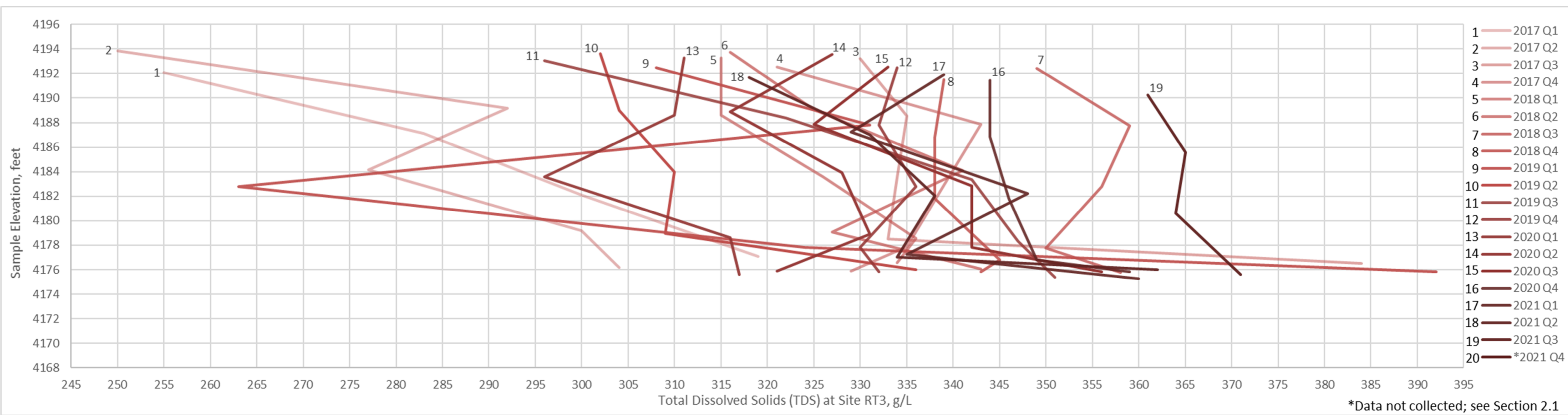


Figure 14. Lake Water Specific Conductivity Profiles at Site AS2

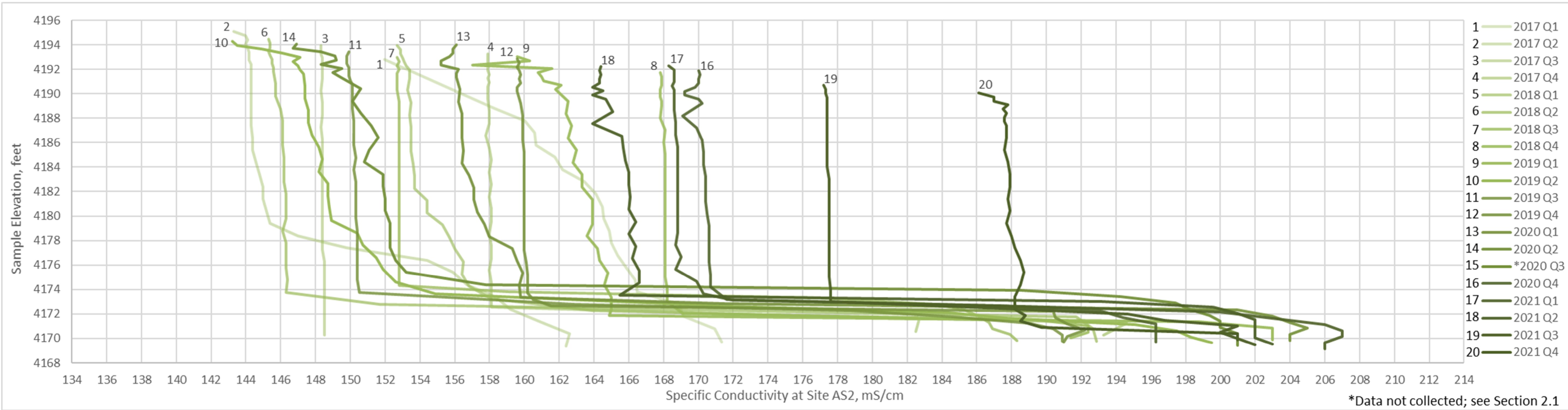


Figure 15. Lake Water Specific Conductivity Profiles at Site AC3

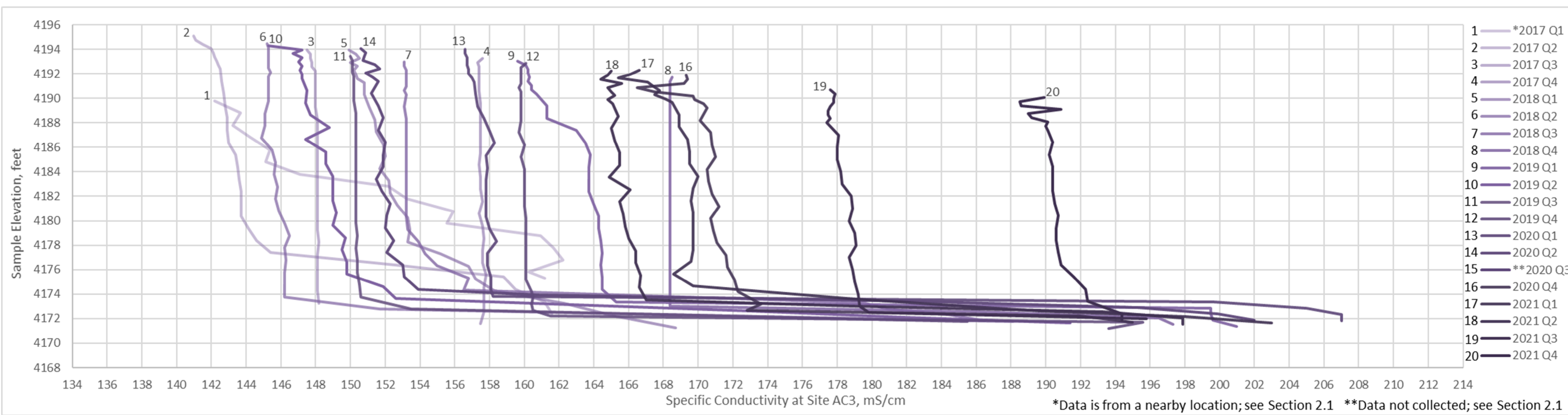


Figure 16. Lake Water Specific Conductivity Profiles at Site FB2

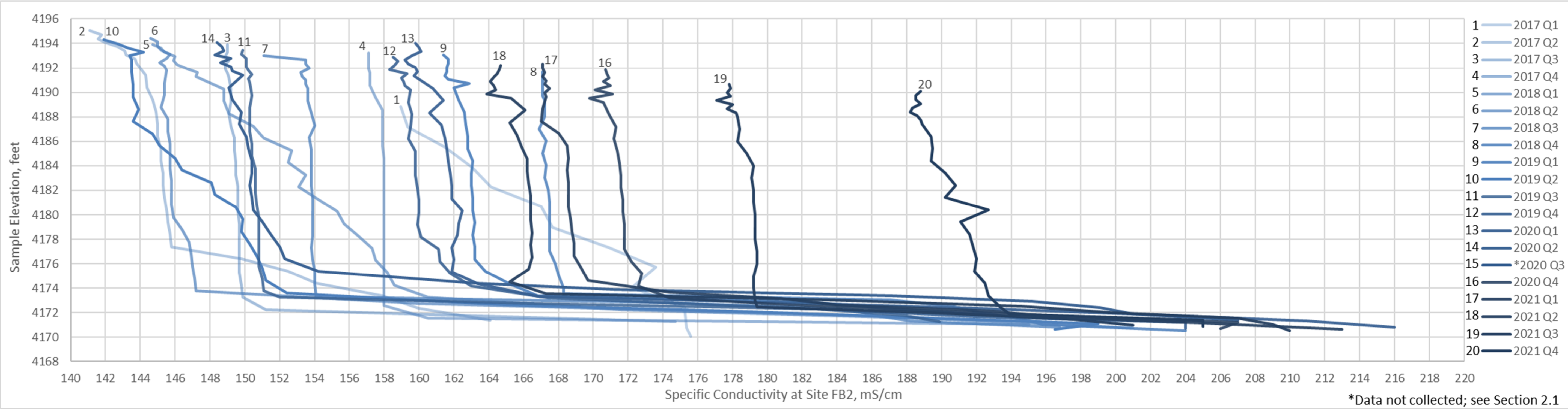
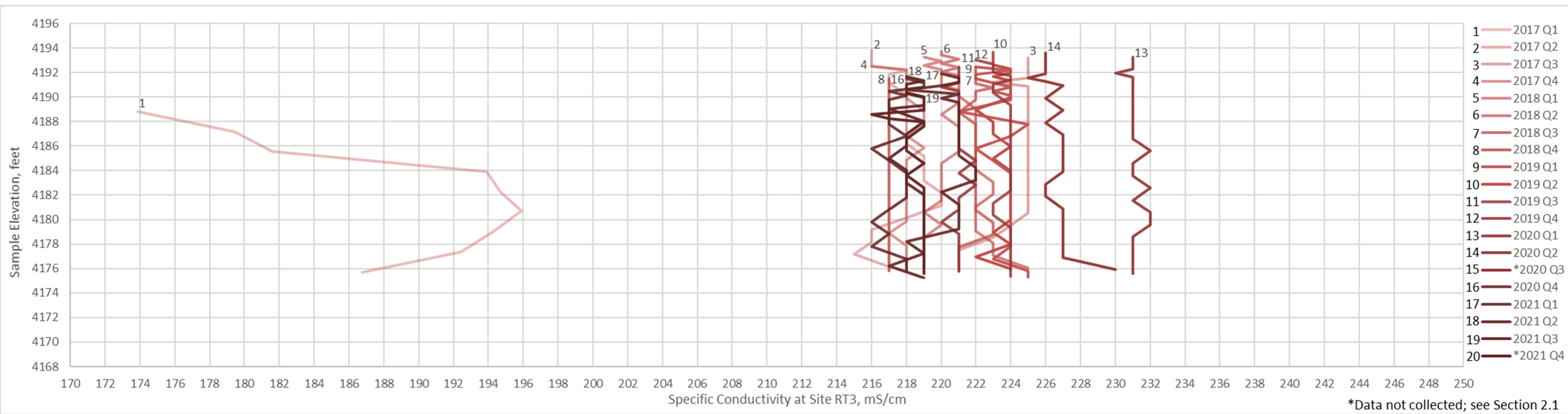


Figure 17. Lake Water Specific Conductivity Profiles at Site RT3



2.3 North and South Arm Salinity

UP computed and reported the salinity for each discrete water sample collected at each sampling site in the North and South Arms, based on density data. The salinity value was calculated using the USGS empirical formula as shown below and documented in Water-Resources Investigations Report 00-4221 (WRI 4221), *Water and Salt Balance of Great Salt Lake, Utah, and Simulation of Water and Salt Movement through the Causeway, 1987–98* (USGS 2000):

$$C = \frac{(\rho - 1)(1{,}000)}{0.63}$$

Where C = dissolved-solids concentration, in grams per liter (g/L)
ρ = density at 20 degrees Celsius, in g/mL

Then, using the measured density and calculated TDS, UP calculated the salinity using the following equation:

$$\text{Salinity, in percent} = \frac{C}{\rho(10)}$$

These data were used to compute the South Arm average salinity and showed that the salinity performance standard was met.

The calculated salinity data are shown in profiles for each of the open-water sampling sites (Figure 18 [site AS2], Figure 19 [site AC3], Figure 20 [site FB2], and Figure 21 [site RT3]). The following general observations are made:

- North and South Arm computed salinity varied with seasonal hydrologic influences. Over the 5-year monitoring period, the calculated South Arm salinity generally increased during the summer and fall months as WSEs decreased and generally decreased during the winter and spring months as WSEs increased.
- Calculated salinity at the South Arm sampling sites (AS2, AC3, and FB2) generally indicated the presence of a DBL when other data also indicated the presence of a DBL. This was shown with an increased calculated salinity at the deepest samples, which is one indicator reflecting the presence of the DBL.
- The average calculated salinity of the DBL at the sampling sites, in general, was about 60% of the salinity of the North Arm brine.
- Computed salinity values indicated that the thickness of the DBL detected at the South Arm sampling sites varied seasonally for most of the 5-year monitoring period. In 2021, salinity values indicated that the thickness of the DBL was reduced at sites AS2 and FB2, and, in the fourth quarter of 2021, the DBL was not present at site AC3.
- Salinity values in the North Arm (site RT3) varied seasonally and were generally constant with depth for all quarterly monitoring events.

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Figure 18. Lake Water Salinity Profiles at Site AS2

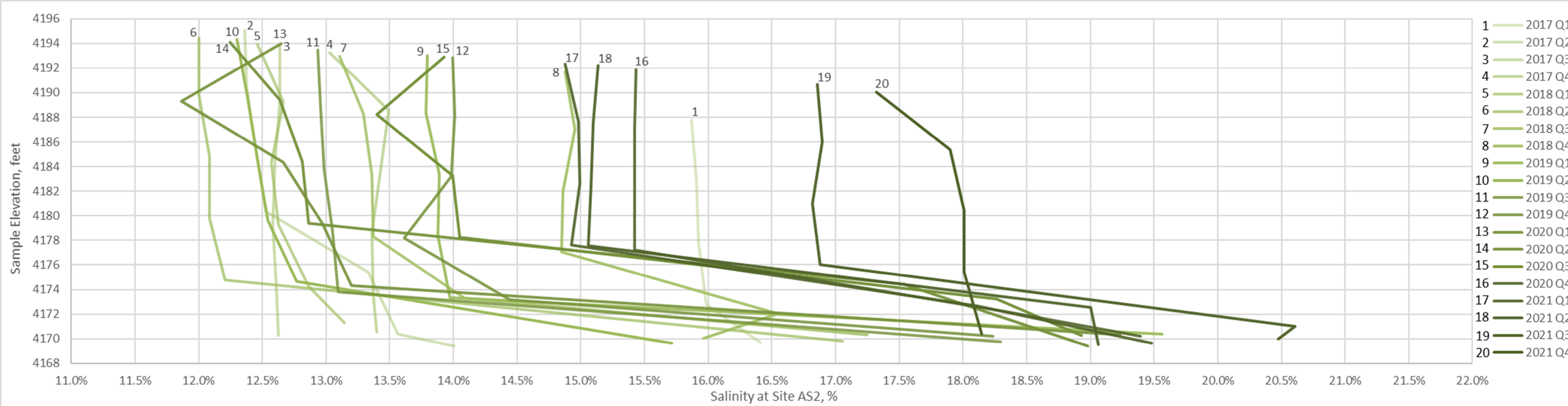


Figure 19. Lake Water Salinity Profiles at Site AC3

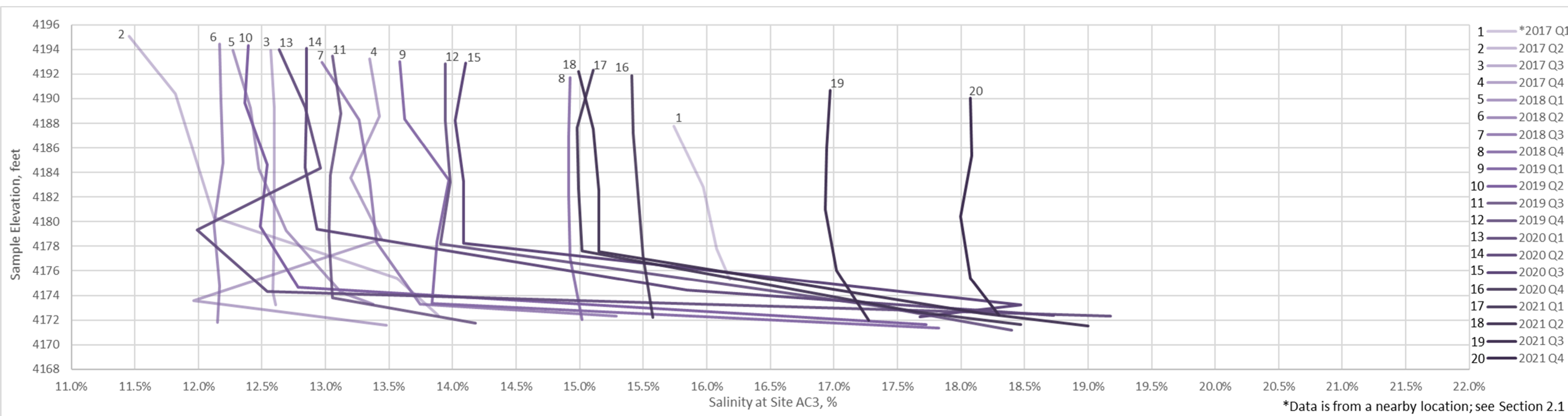


Figure 20. Lake Water Salinity Profiles at Site FB2

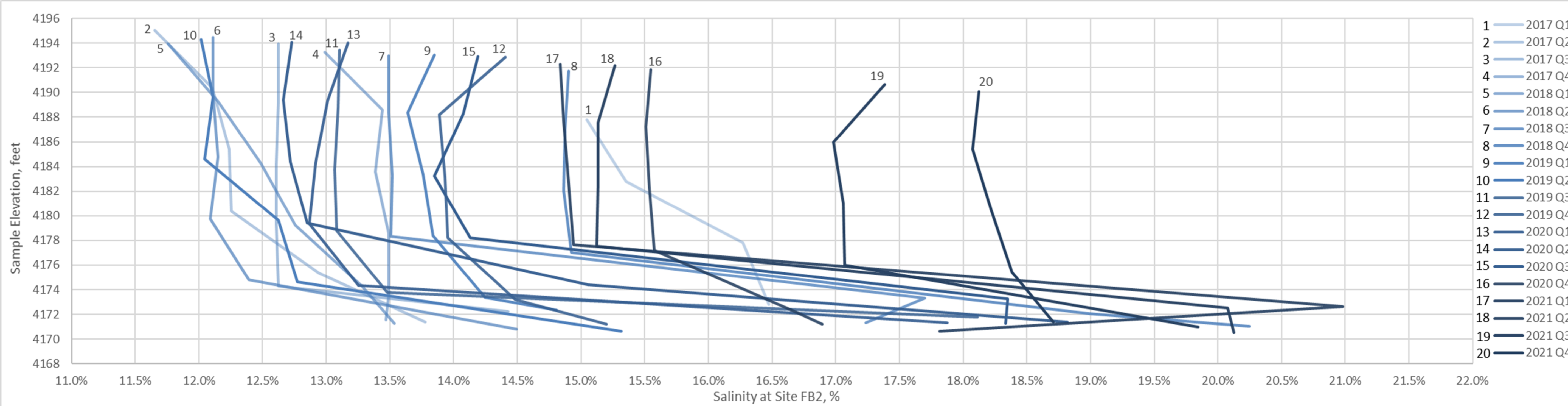
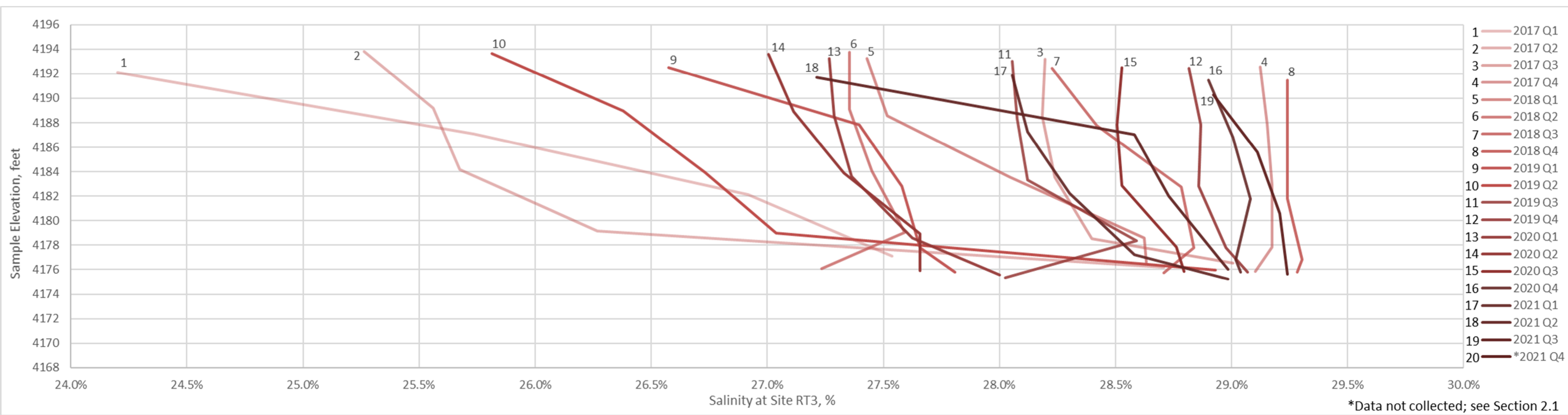


Figure 21. Lake Water Salinity Profiles at Site RT3



2.4 Causeway Opening Geometry

The Project, which constructed a new causeway opening consisting of a new 180-foot-long railroad bridge, earthen control berm, and south channel, was designed to allow the transfer of water and salt between the North and South Arms of the Great Salt Lake to duplicate, as closely as possible, the transfer of water and salt that was previously provided by the now-closed east and west culverts for average lake conditions (Figure 22). Bathymetric and topographic survey data collected during the 5-year monitoring period indicated that the Project remains stable and consistent with as-built conditions, meeting the geometry performance standards.

The geometry of the causeway opening was measured and reported during the 5-year monitoring period in accordance with Section 3.10.1 of the CMMP (UP 2016a), which required bathymetric and topographic survey measurements to be taken semiannually for the first 2 years of the 5-year monitoring period, then annually until the 5-year monitoring period is complete. UP conducted and reported the semiannual surveys for 2017 and 2018 (the first 2 years of the monitoring period) and the annual surveys for 2019, 2020, and 2021 (the third, fourth, and fifth years of the monitoring period) and determined that the geometry performance standards were met.

No adaptive management measures or maintenance activities were required or conducted during the 5-year monitoring event, so the as-built survey measurements of the physical elements (bridge, control berm, and channel) were used to compare against survey measurements collected during the 5-year monitoring period.

Cross-sections were developed from the bathymetric and topographic survey data collected and were overlaid on the as-built survey data at designated cross-sections. These comparisons were used to determine that the flow channel at the bridge (station 0+00), the flow channel at the control berm (station 0+75), the water depth at the bridge (station 0+00), and the average control berm grading contours (station 0+75) remain stable and that there was no excessive erosion or accumulation of debris. These measurements correlate to geometry performance standards 1, 2, 3, and 4, respectively, defined in the CMMP (UP 2016a). Figure 22 shows the locations of the Project components and survey cross-sections.

The results of the previously reported bathymetric and topographic surveys and the comparison to the as-built survey measurements are shown in Figure 23 and Figure 24. The following observations are made:

- The 180-foot-long railroad bridge and opening (centered on station 0+00) remain consistent with the original design and construction. There were no significant areas of material accumulation or degradation that would result in obstructions to the conveyance of water and salt through the flow channel.
- The control berm, consisting of east and west side berms and an invert berm, acts as a restriction by collapsing the 180-foot-long bridge opening to the model-defined flow opening of 150 feet wide, which was determined to best duplicate, as closely as possible, the transfer of water and salt that was previously provided by the now-closed east and west culverts at average lake conditions (UP 2016a). The control berm is also a key component of the adaptive management element of the Project since the area can be modified if required. The average control berm contours and average flow area remained stable with no significant areas of material accumulation or degradation that would result in decreasing or increasing the amount of water and salt transferred between the North and South Arms of the Great Salt Lake (centered on station 0+75N).
- Generally, the survey data for the causeway opening consisting of the bridge, flow channel, and control berm that convey bidirectional flows between the North and South Arms of the Great Salt

Lake was consistent with the range specified by the modeling, original design, and constructed structure, thereby meeting the geometry performance standards. There were no significant areas of material accumulation or degradation documented during the 5-year monitoring period that would result in obstructions to the conveyance of water and salt through the flow channel.

Figure 22. Project Components and Locations of Geometric Cross-Sections

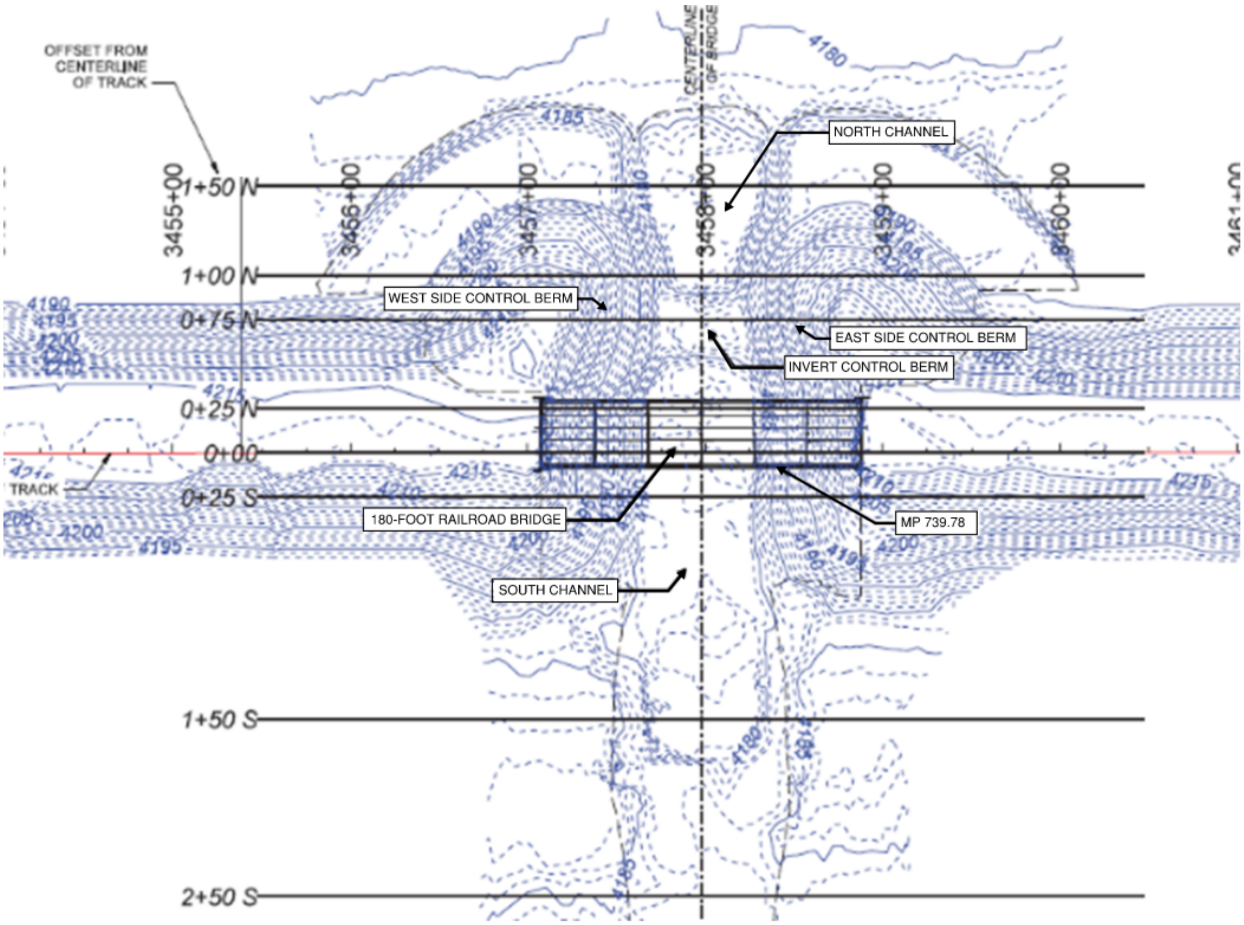


Figure 23. Cross-Section Geometry Comparison (1 of 2)

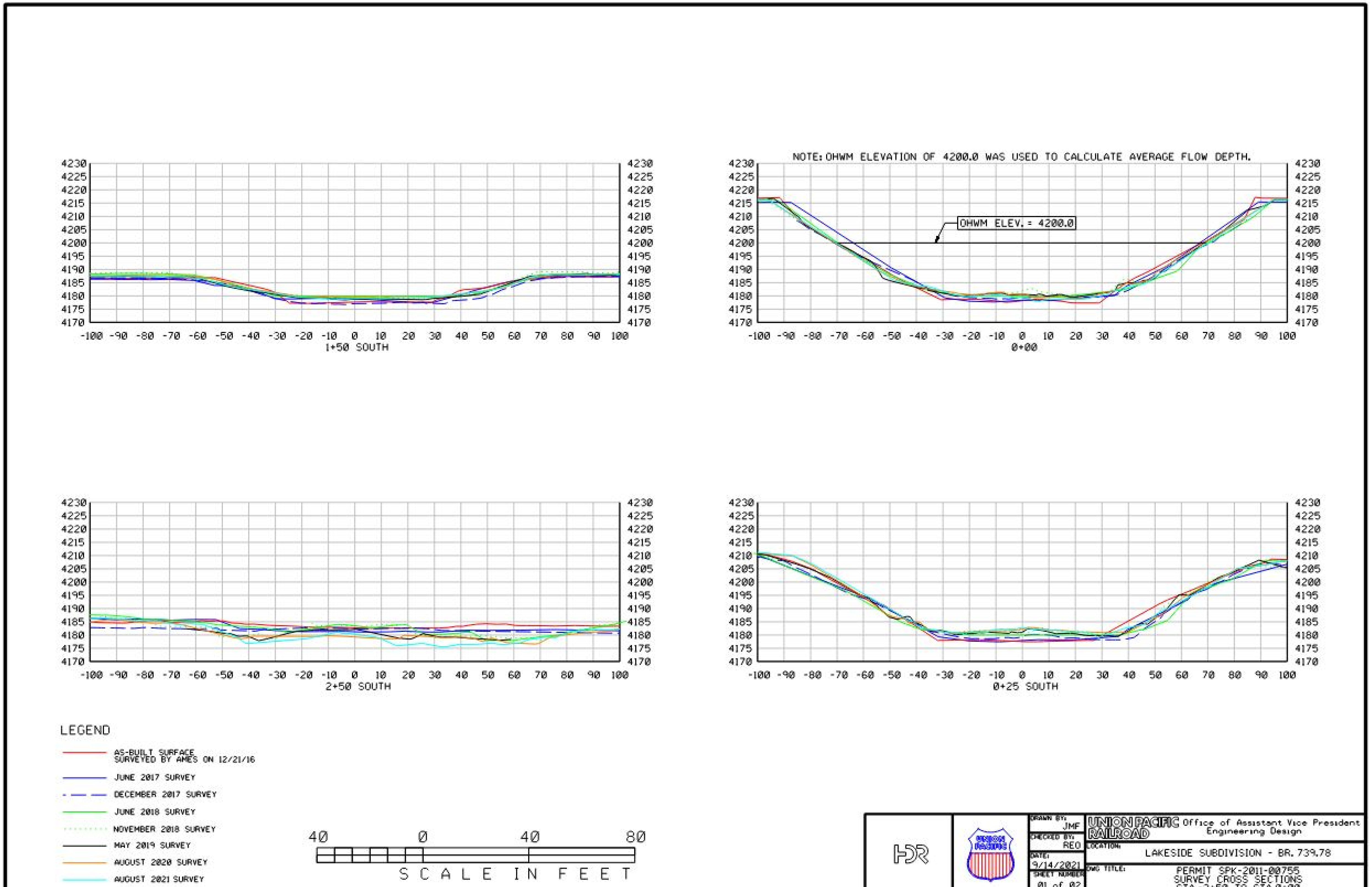
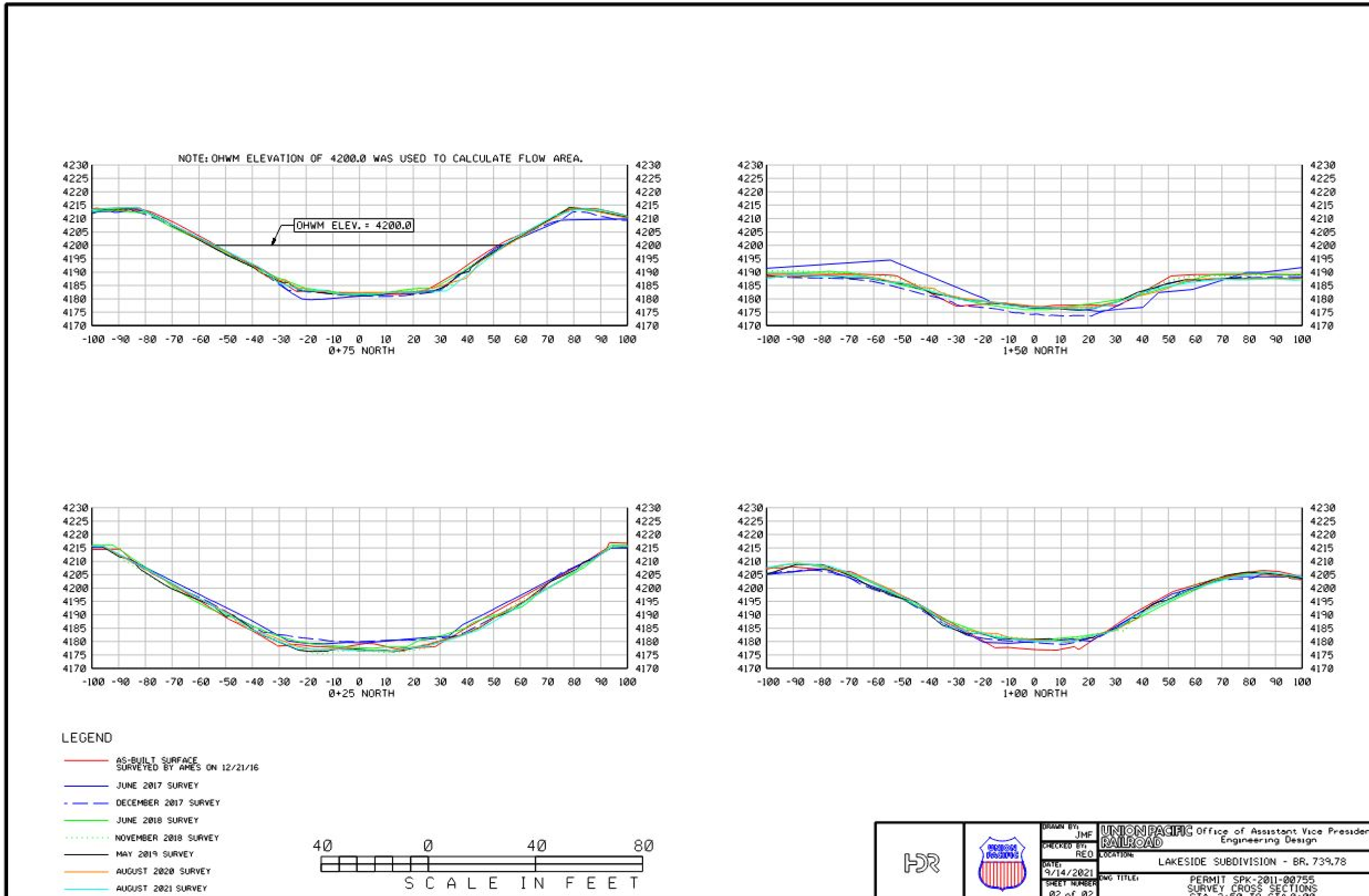


Figure 24. Cross-Section Geometry Comparison (2 of 2)



2.5 Additional Data Collected

UP, through agreements with USGS, collected and reported additional data in compliance with the USACE Permit, UDWQ Certification, CMMP Section 3.11 (UP 2016a), and the SAP (UP 2016b). The additional data provide supplementary information for salinity modeling and lake management as needed (UP 2016a). These additional data include:

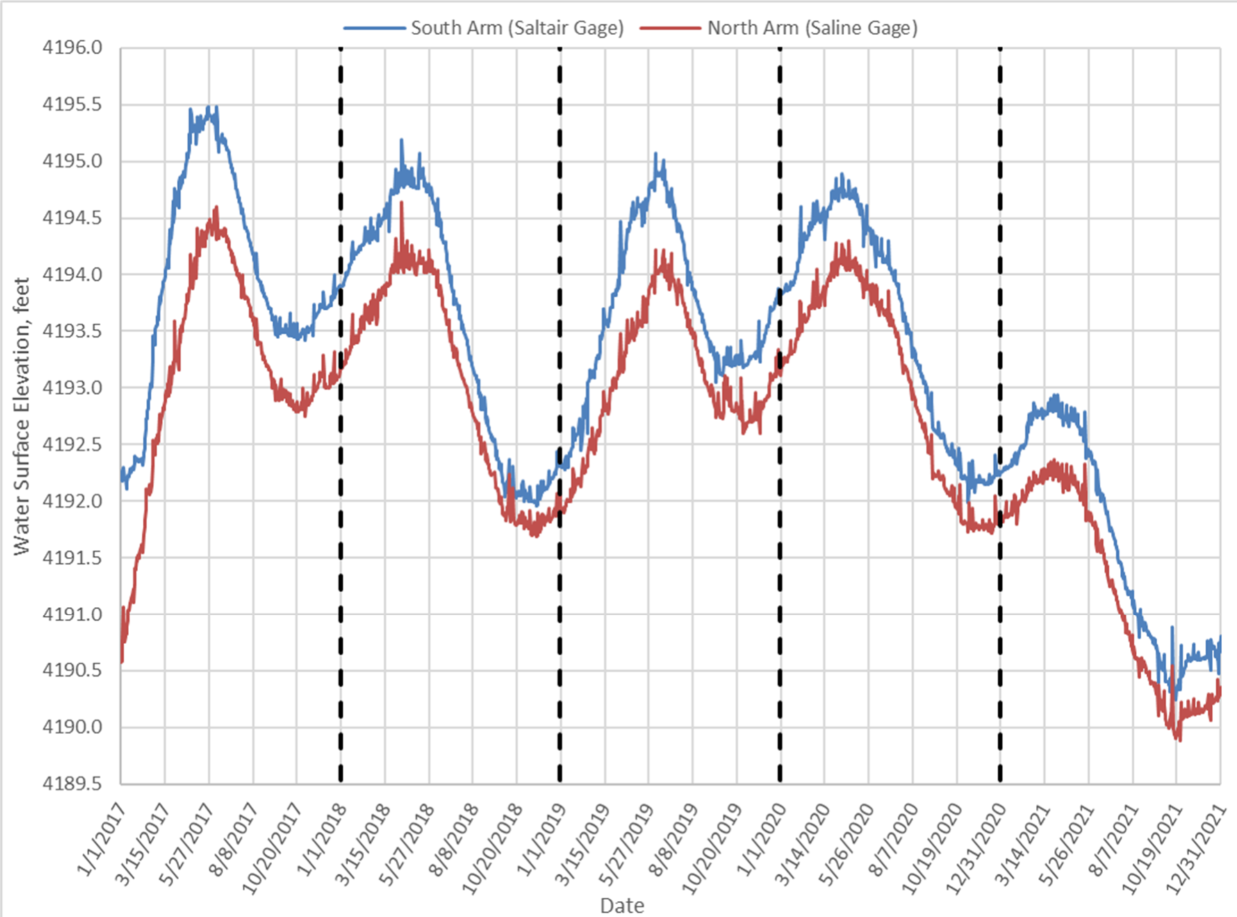
- USGS daily North and South Arm WSEs
- USGS monthly flow measurements through the causeway
- USGS monthly North and South Arm WSEs at the causeway opening
- UP monthly water quality monitoring at the causeway opening
- UP quarterly measurements of the South Arm DBL
- UP monthly water quality parameters of the south-to-north flow and north-to-south flow

These additional data are summarized in this section. To characterize flow through the opening during normal weather conditions, data collection events were generally conducted by USGS and UP when the wind was calm. High wind conditions have been documented to shift the bi-directional flows through the causeway to flow in one direction, with all the flow either north-to-south or south-to-north, depending on the strength, duration, and direction of the wind. These high wind conditions are not specifically documented but are reflected in the average data (flow measurements and water quality monitoring) presented below.

2.5.1 Lake Water Surface Elevations and Flow Measurements through Causeway Opening

UP acquired WSE data in 15-minute increments for the North and South Arms from the USGS website (USGS 2022). South Arm WSEs were obtained for USGS Station 10010000 (Great Salt Lake at Saltair Boat Harbor, UT), and North Arm WSEs were obtained for USGS Station 10010100 (Great Salt Lake near Saline, UT). The USGS data presented in this Completion Report are reported as provisional and are subject to review by USGS during their quality control process before they become final. Figure 25 shows the North Arm and South Arm WSEs during the 5-year monitoring period.

Figure 25. USGS Daily North Arm and South Arm Water Surface Elevations



Monthly bidirectional WSEs, flow measurements, and ratings at the Project site were collected by USGS.

USGS reported the data collected on the website https://waterdata.usgs.gov/nwis for the following sites, which are near the Project site:

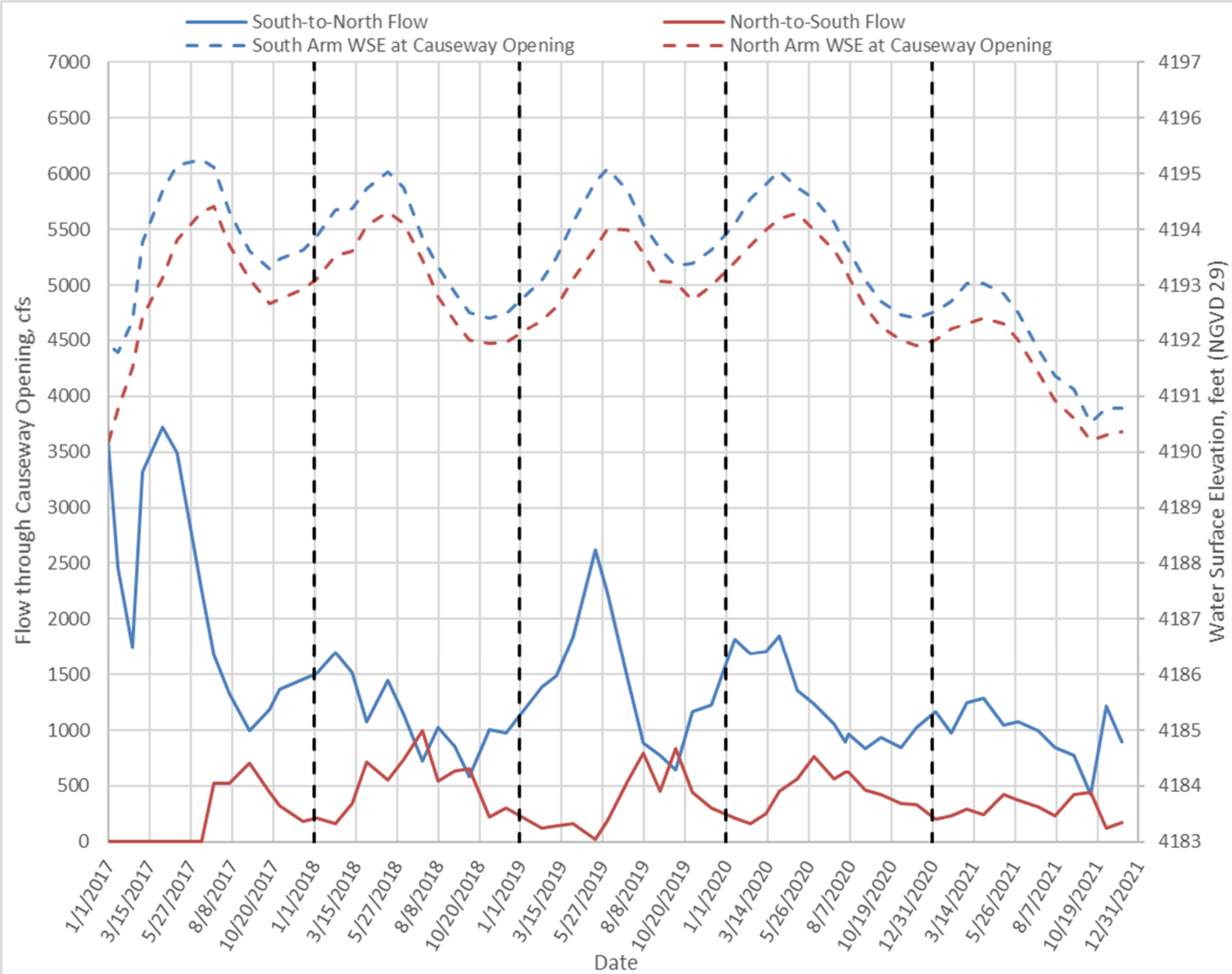
- Site 10010025 (Great Salt Lake breach 6 miles east of Lakeside, Utah) for south-to-north flow
- Site 10010026 (Great Salt Lake breach 6 miles east of Lakeside, Utah) for north-to-south flow

Great Salt Lake South Arm and North Arm WSE data were collected and reported by USGS at the following sites for the South and North Arm WSEs, respectively:

- Site 10010000 (Great Salt Lake at Saltair Boat Harbor, UT)
- Site 10010100 (Great Salt Lake near Saline, UT)
- Site 10010024 (Great Salt Lake south side of causeway, 6 miles east of Lakeside, Utah)
- Site 10010027 (Great Salt Lake north side of causeway, 6 miles east of Lakeside, Utah)

The WSE and bidirectional flow data, as collected and reported by USGS, are graphically represented in Figure 26. The USGS data presented in this Completion Report are reported as provisional and are subject to review by USGS during their quality control process before they become final.

Figure 26. USGS Water Surface Elevation at and Flow through the Causeway Opening



Sources: USGS sites for WSE: 10010024 (South Arm); 10010027 (North Arm); 10010025 (south-to-north flow); 10010026 (north-to-south flow). USGS data are reported as provisional and subject to review by USGS during their quality control process before they become final.

2.5.2 Additional Water Quality Parameters

UP collected additional water quality parameters in compliance with the CMMP (UP 2016a). These data include:

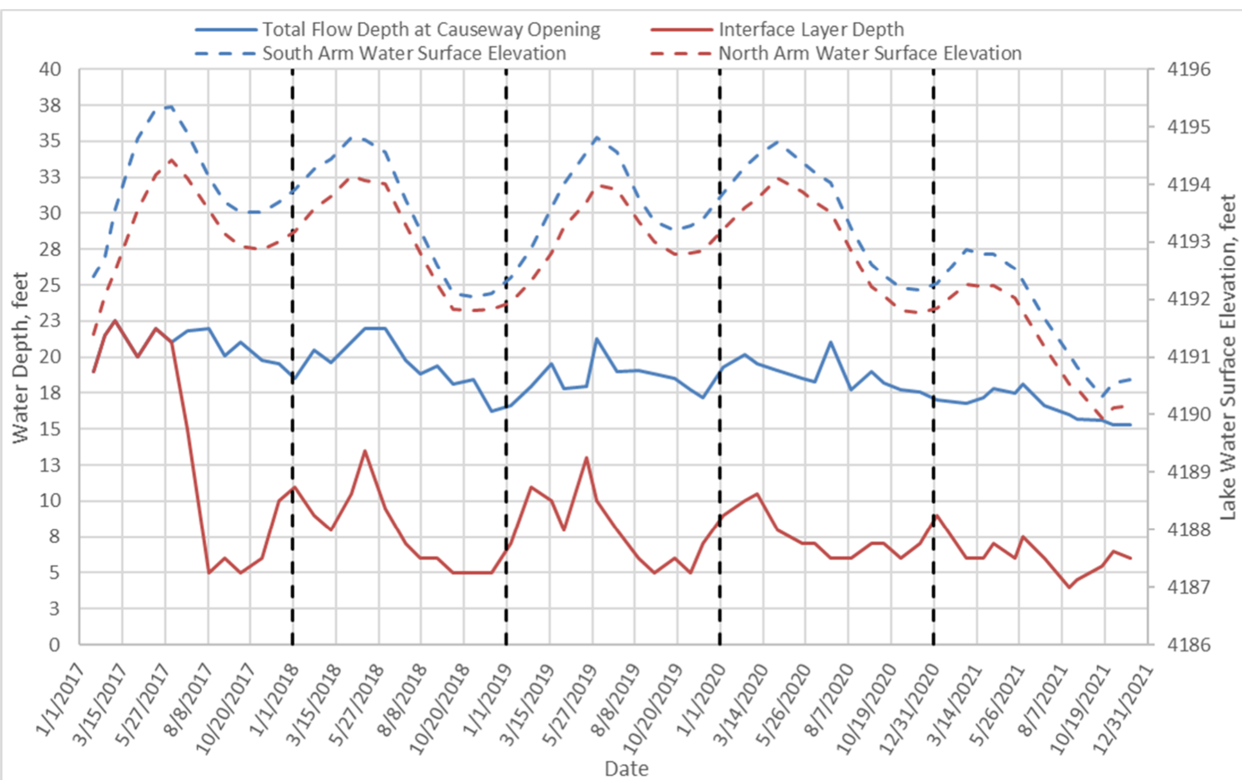
- Monthly water depth at the causeway opening and depth of bidirectional flows
- Monthly density of the South Arm brine flowing north and North Arm brine flowing south
- Quarterly evaluation of the presence of a DBL at the South Arm sampling sites
- Monthly water quality parameters of the south-to-north flow and north-to-south flow

Bi-Directional Flow Depth

UP collected monthly instantaneous measurements of total water depth of the bi-directional flow through the causeway opening at the center of the 180-foot-long railroad bridge, as well as the depth of the interface layer (the zone that separates north-to-south flow and south-to-north flow). These data are shown in Figure 27. Measurements were conducted during calm weather conditions to characterize normal flow characteristics through the causeway opening. In general, the following observations are made:

- Bi-directional flow was first observed and measured approximately 7 months after the causeway opening was constructed.
- Under normal weather conditions, the causeway opening conveyed bi-directional flow, south-to-north flow and north-to-south flow, during the 5-year monitoring period. At times, during high wind events, one-directional flow was observed, with all the flow either north-to-south or south-to-north depending on the strength, duration, and direction of the high wind event.
- The water depth for each direction of the bi-directional flows through the causeway opening varied seasonally, generally with south-to-north flows higher in the spring and lower in the fall, corresponding to seasonal hydrologic influences on the Great Salt Lake.
- The depth from the WSE to the interface layer (the boundary between the south-to-north flow and the north-to-south flow) also varied seasonally and was generally greater in the spring and lesser in the fall. The depth of the interface layer is interrelated to other factors, such as the lake WSE, South and North Arm densities, and the difference in WSEs between the South (usually higher) and North Arms (USGS 2000).

Figure 27. Interface Depth and Total Depth of Flow at Causeway Opening

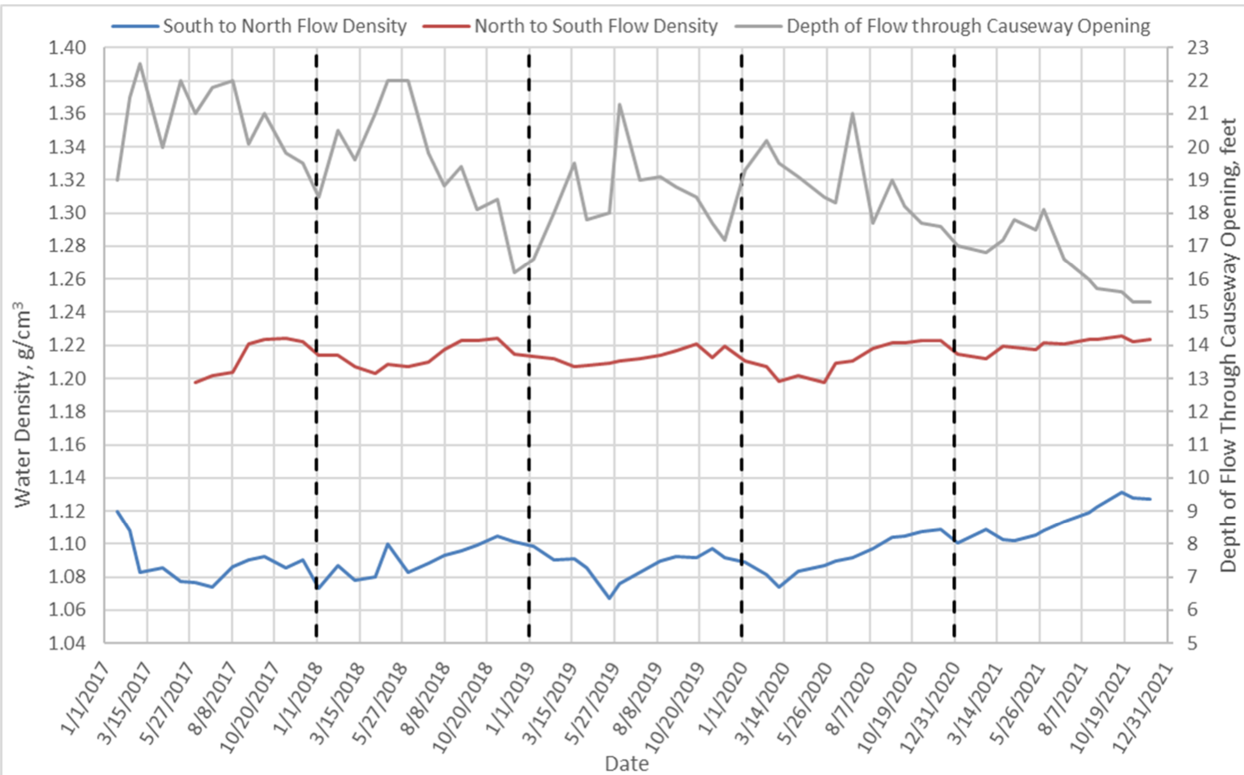


Sources: USGS sites for WSE: 10010000 (South Arm); 10010100 (North Arm). USGS data are reported as provisional and subject to review by USGS during their quality control process before they become final.

Bi-Directional Flow Density

UP collected discreet water samples of the bi-directional flow on a monthly basis from the center of the 180-foot-long railroad bridge. Generally, a water sample was collected near the surface to represent the south-to-north flow, and a second sample was collected near the Project invert to represent the north-to-south flow. The density of each discreet sample was analyzed using an Anton-Paar meter. These densities, as well as the depth of water through the causeway opening, are shown in Figure 28. The density of both the south-to-north flow and north-to-south flow generally increased as the lake WSE decreased and generally decreased as the lake WSE increased.

Figure 28. Density of South-to-North and North-to-South Flow Through the Causeway Opening



Deep Brine Layer Presence at South Arm Sampling Sites

UP generally used the specific conductivity data that were presented in Section 2.2.4 to determine whether a DBL was present at the South Arm sampling sites (FB2, AC3, and AS2), as well as the nature (concentration) and extent (thickness) of the DBL at each site. The extent of the DBL compared to the total water depth for each of the quarterly monitoring events is shown in Figure 29 for site FB2, in Figure 30 for site AC3, and in Figure 31 for site AS2. In general, the following observations are made:

- When monitoring began in January 2017, no DBL was measured at the three South Arm sampling sites.
- Specific conductivity data indicate that the DBL was first measured at sites FB2 and AS2 in November 2017 (about 5 months after the causeway opening began to convey bi-directional flow) and was measured throughout the 5-year monitoring period.
- Specific conductivity data indicate that the DBL was first measured at site AC3 in May 2018. The AC3 sampling site is located in a shallower part of the South Arm than sites FB2 and AS2 and was measured throughout the 5-year monitoring period until the fourth quarter of 2021, when specific conductivity measures were no longer increasing with depth.

Figure 29. Deep Brine Layer Compared to Total Water Depth at Site FB2

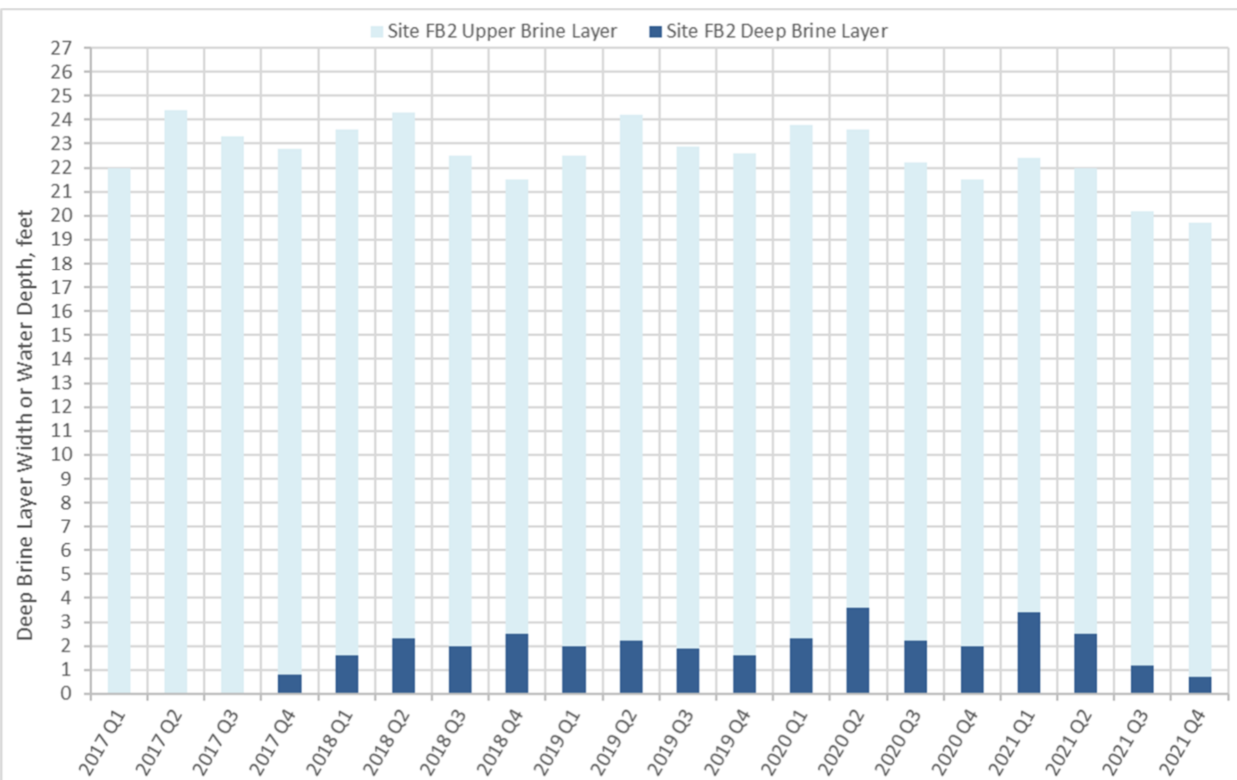


Figure 30. Deep Brine Layer Compared to Total Water Depth at Site AC3

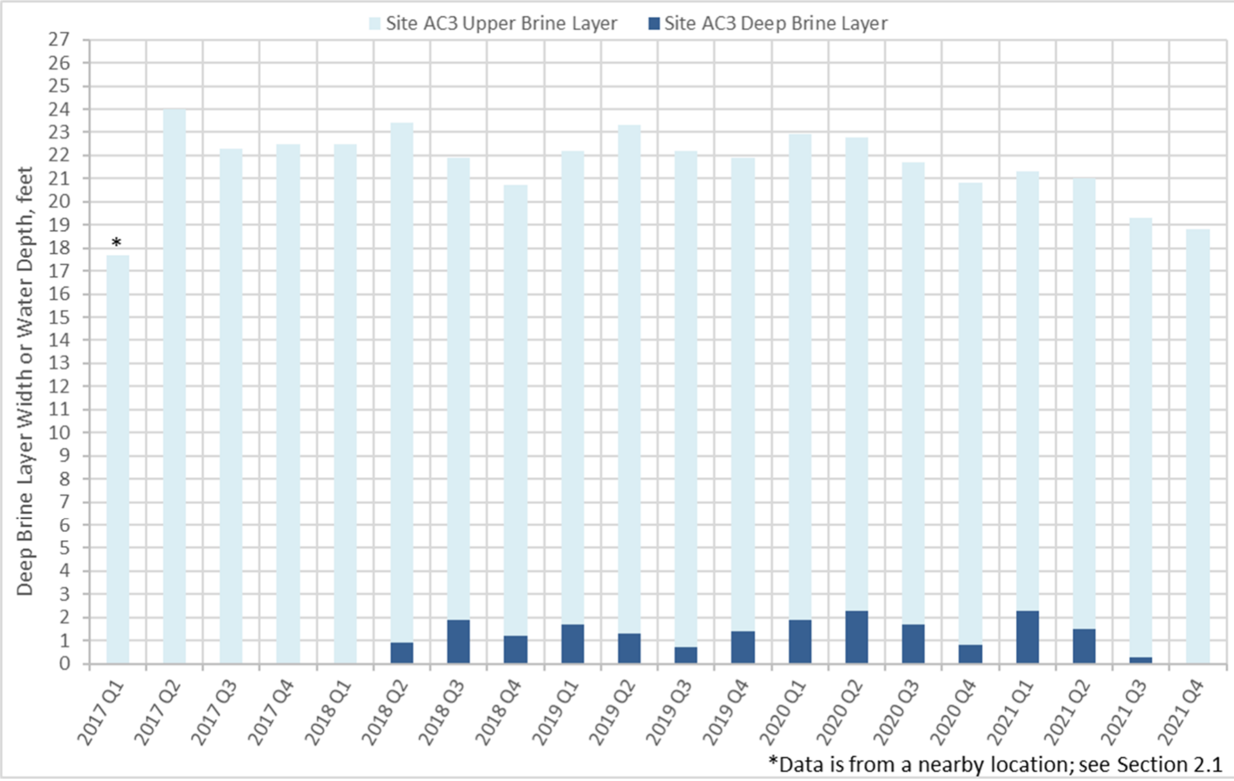
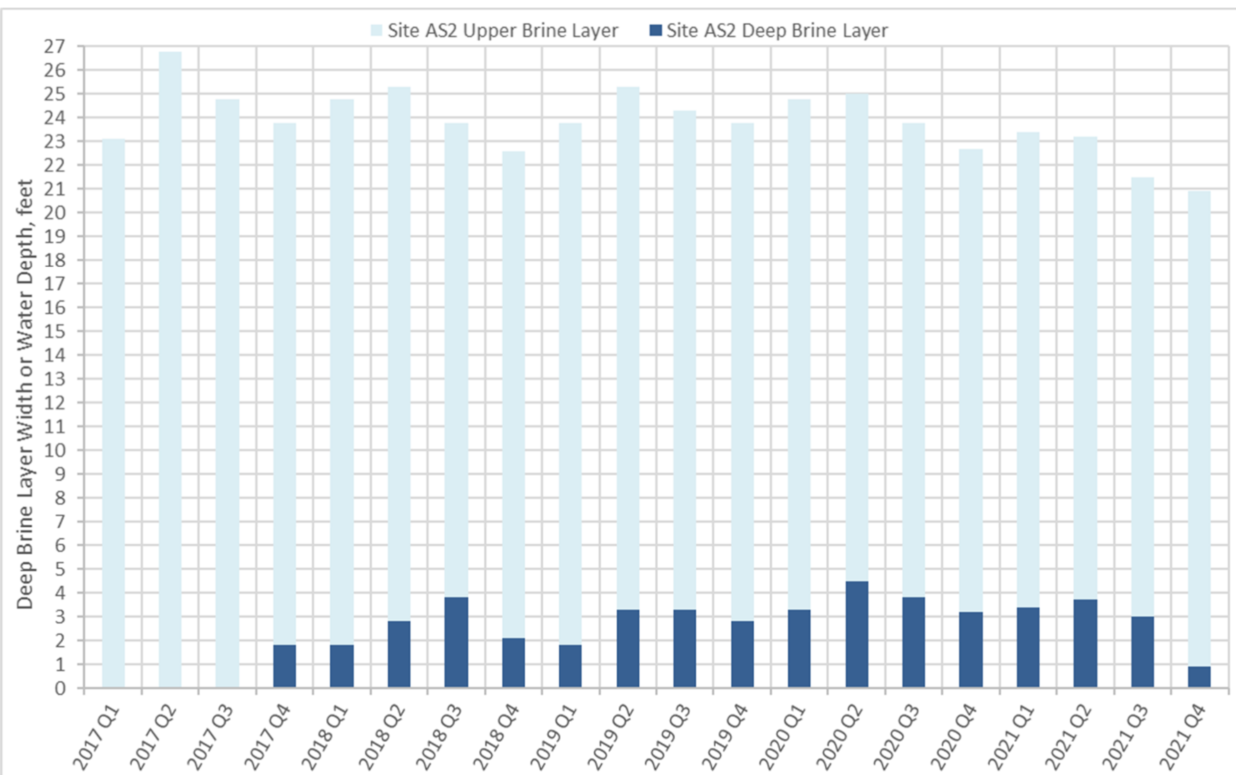


Figure 31. Deep Brine Layer Compared to Total Water Depth at Site AS2



Water Quality Parameters of the South-to-North and North-to-South Flows

Water quality data, including water temperature, density, TDS, specific conductivity, and cations and anions, were collected on a monthly basis at the causeway opening to characterize the south-to-north and north-to-south flows. These data were included in Appendix C of each quarterly data monitoring report (Appendix C; UP 2017a, 2017b, 2017c, 2018a, 2018c, 2018d, 2018e, 2019a, 2019c, 2019d, 2019e, 2020a, 2020c, 2020d, 2020e, 2021a, 2021c, 2021d, 2021e, 2022a).

3.0 Attainment of Mitigation Objectives and Project Performance Standards

The mitigation goal of the Project was to construct a new Great Salt Lake causeway opening that would duplicate, as closely as possible, the aquatic function (water and salt transfer) at average lake conditions, lost due to closing the east and west culverts. In the previously submitted reports, UP documented successfully meeting the Project geometry and salinity performance standards. This information is summarized below.

As stated in the CMMP (UP 2016a) and SAP (UP 2016b), the goals of mitigation monitoring were to (1) facilitate determination of whether the geometry and salinity performance standards are being met and (2) provide additional information for salinity modeling and lake management as needed.

Monitoring data were used to determine whether the mitigation was meeting the following geometry and salinity performance standards:

1. Determine whether the average bridge site is stable without excessive erosion or accumulation of debris. Average bridge site contours remain within 10% of as-built or agreed-upon altered geometry (UP 2016a, Performance Standard 1, Table 3-5).
2. Determine whether the causeway opening area conveys water between the North and South Arms at varying lake levels. Average cross-sectional area of the causeway opening is within 10% of the as-built or agreed-upon area (UP 2016a, Performance Standard 2, Table 3-5).
3. Determine whether the causeway opening is accessible to inundation of waters with no obvious restriction present. Average water depth of the causeway opening is within 10% of as-built or agreed-upon altered depths at specific lake levels (UP 2016a, Performance Standard 3, Table 35).
4. Determine whether the average grading contours of the control berm are stable. Average control berm contours remain within 10% of as-built or agreed-upon altered geometry (UP 2016a, Performance Standard 4, Table 3-5).
5. Determine whether the causeway with mitigation provides water and salt transfer similar to that of the free-flowing culverts at average lake conditions before closure. Average salinity in Gilbert Bay is within the UP/USGS 2012 model salinity range. (UP 2016a, Performance Standard 5, Table 3-6).

UP evaluated the bathymetric and topographic survey data collected over the 5-year monitoring period, reported the data, and demonstrated success in meeting geometry performance standards 1, 2, 3, and 4 as discussed above. UP also collected, evaluated, and reported the lake water quality data and demonstrated success in meeting salinity performance standard 5 as discussed above. These evaluations were presented in the five annual data monitoring reports (Appendix D; UP 2018b, 2019b, 2020b, 2021b, 2022b). The following sections summarize the attainment of the Project geometry and salinity performance standards and the supporting data.

3.1 Causeway Opening Geometry Performance Standards

Four geometry performance standards focused on the stability of the mitigation site and determining whether there was excessive erosion or accumulation of debris, including at the bridge and bidirectional flow conveyance areas, control berm, and channel area. Topographic (above the water surface) and bathymetric (under the water surface) surveys were conducted and demonstrated compliance with the geometry performance standards. All survey data were reported in the National Geodetic Vertical Datum of 1929 (NGVD 1929).

Survey data were collected semiannually for the first 2 years of the 5-year monitoring period, then annually for the last 3 years. The seven survey events were conducted and compared to the as-built survey data. Each performance standard evaluation compared the survey data against the as-built survey and reported on whether the difference between the two surveys was within 10%.

UP did not conduct any adaptive management of the causeway opening, so the survey data are compared to as-built data since there was no other agreed-upon geometry.

Each of the geometry performance standards (1 through 4) is summarized below since the attainment of the geometry performance standards was previously reported in the annual data monitoring reports (Appendix D).

3.1.1 Geometry Performance Standard 1 – Average Bridge Side-Slope Contour

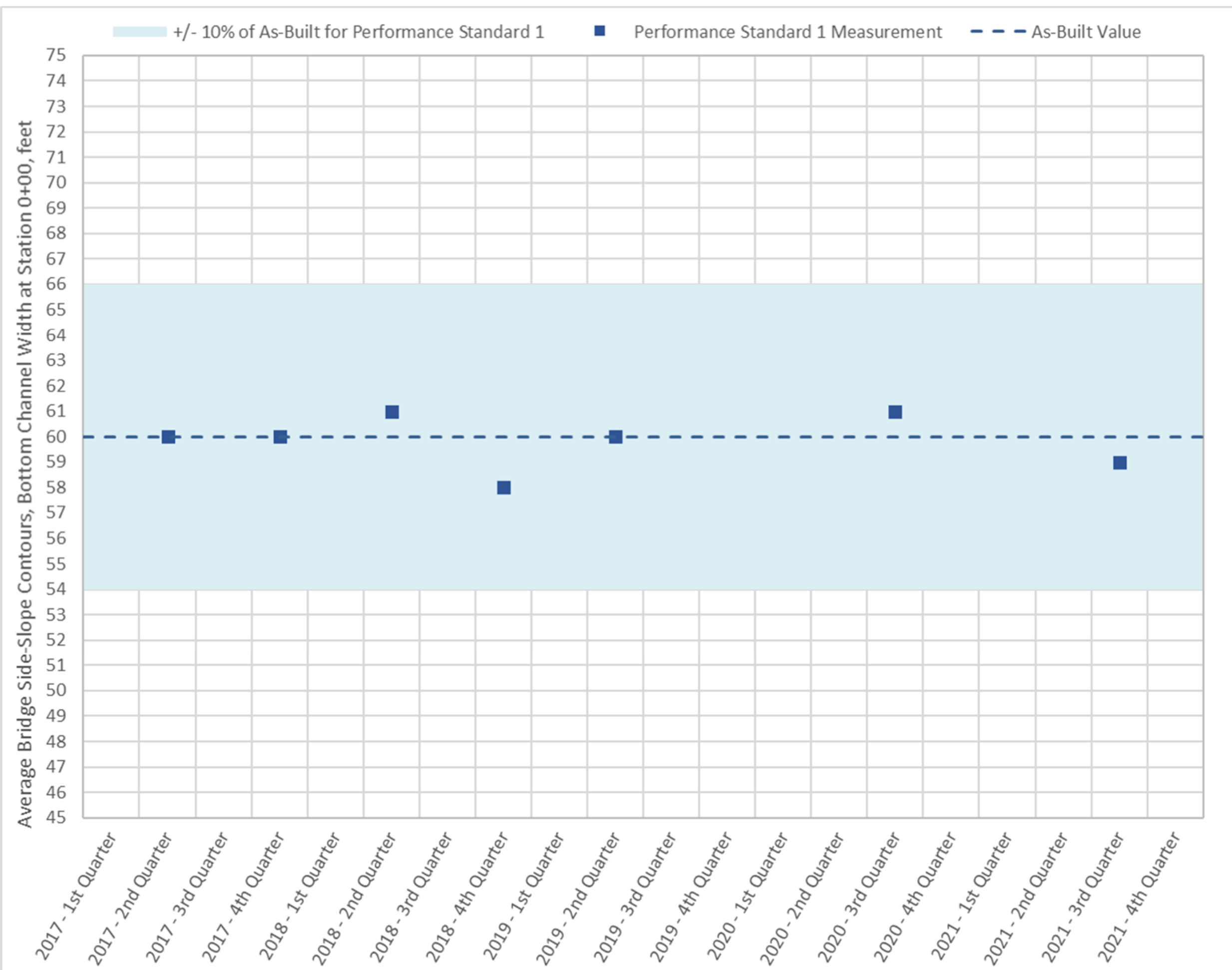
To assess whether the mitigation bridge site was stable without excessive erosion or accumulation of debris, UP measured the bidirectional flow channel bottom width from the eastern side slope to the western side slope under the bridge at the rail centerline (elevation 4,178 feet above mean sea level AMSL, station 0+00; see Figure 22). The monitoring period survey data were compared to the as-built survey data channel bottom width for the evaluation of performance standard 1. The channel bottom width as surveyed during the monitoring period varied between 58 feet and 61 feet compared to the as-built channel bottom width of 60 feet (Table 2 and Figure 32). The slight variability in the data can be attributed to the spatially variable locations of the bathymetric survey shots and survey accuracy tolerances.

The channel bottom width as surveyed during the monitoring period was within 10% of the as-built survey data. This result indicated that no significant aggregation (accumulation) of debris or degradation (erosion of armor rock) occurred. The data indicate that the channel bottom width beneath the railway bridge was stable and allowed the transfer of water and salt between the North and South Arms, as designed and constructed, which documents successful attainment of performance standard 1.

Table 2. Geometry Performance Standard 1 – Average Bridge Side-Slope Contour

Survey Date	As-Built Value (feet)	Measured Value (feet)	Percent of As-Built
As- built value	60	—	—
June 2017	—	60	100%
December 2017	—	60	100%
June 2018	—	61	102%
November 2018	—	58	97%
May 2019	—	60	100%
August 2020	—	61	102%
August 2021	—	59	98%

Figure 32. Geometry Performance Standard 1 – Average Bridge Side-Slope Contour



3.1.2 Geometry Performance Standard 2 – Average Flow Cross-Sectional Area at Invert Berm

To assess that the causeway opening was stable and conveyed water and salt between the North and South Arms at varying lake levels without excessive erosion or accumulation of debris, UP measured the bidirectional flow area across the invert berm, which is the most constricted portion of the opening (UP 2016a). This flow area represents the cross-section area from the east-side control berm to the west-side control berm and from the WSE of 4,200 feet AMSL (the Great Salt Lake ordinary high water mark, or OHWM) (USACE 2015b) down to the top of the invert berm (elevation 4,183 feet AMSL, station 0+75; see Figure 22). Survey data collected during the 5-year monitoring period were compared to as-built survey data for the evaluation of performance standard 2.

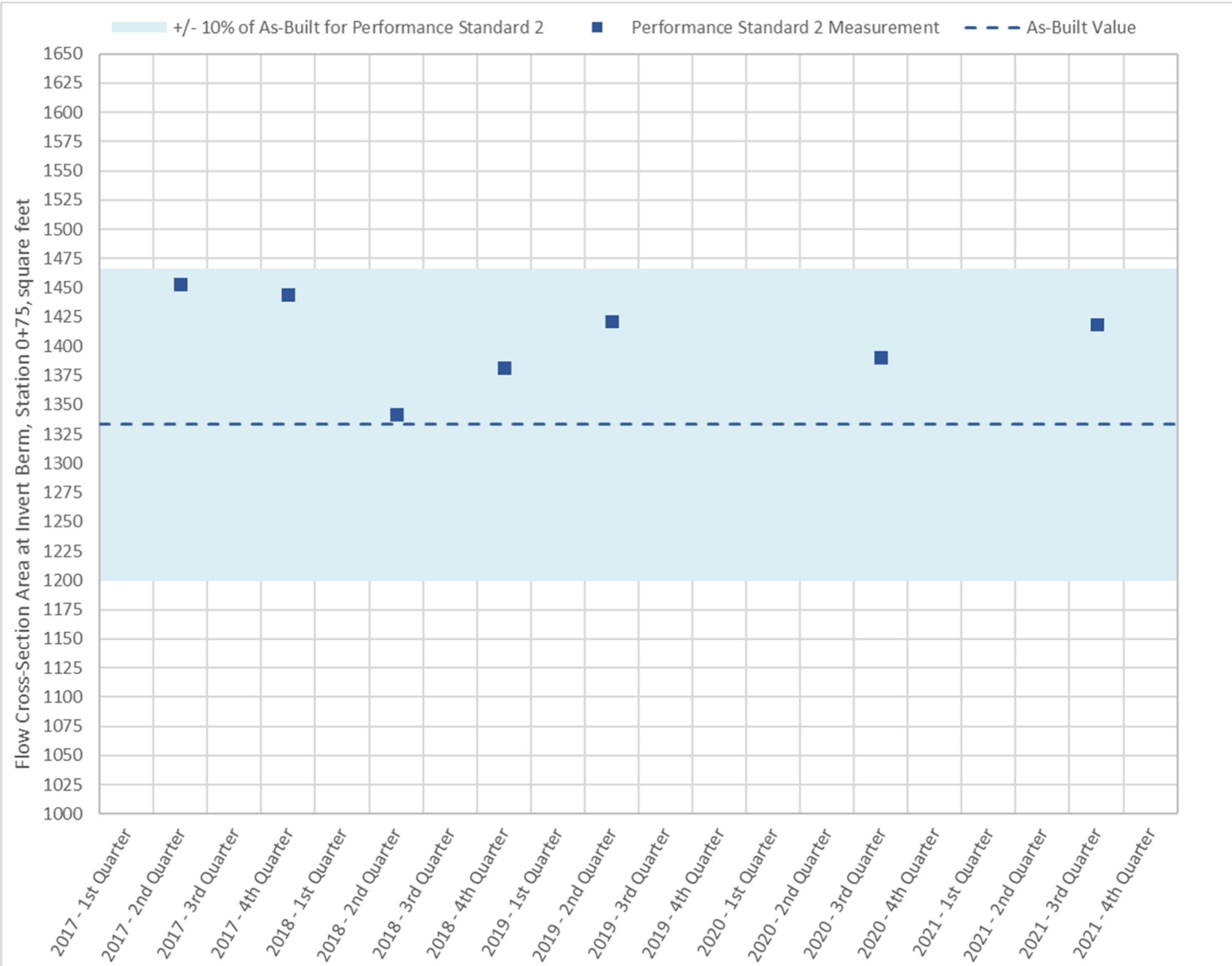
The flow area at the invert berm as surveyed during the monitoring period ranged from 1,382 square feet to 1,453 square feet, compared to the as-built flow area at the invert berm which was measured to be 1,333 square feet (Table 3 and Figure 33). The flow area at the invert berm was reported to be within 10% of the as-built survey data, and no significant change (either enlargement or constriction) in cross-section area at the invert berm was documented. The slight variability in the data can be attributed to the spatially variable locations of the bathymetric survey shots along the top of the invert berm, east control berm, and west control berm and the survey accuracy tolerances.

The survey data indicate that the bidirectional flow area through the causeway opening at the invert berm was stable and allowed the transfer of water and salt between the North and South Arms, as designed and constructed, which documents the successful attainment of performance standard 2.

Table 3. Geometry Performance Standard 2 – Flow Cross-Section Area at Invert Berm

Survey Date	As-Built Value (square feet)	Survey Value (square feet)	Percent of As-Built
As- built value	1,333	—	—
June 2017	—	1,453	109%
December 2017	—	1,444	108%
June 2018	—	1,342	101%
November 2018	—	1,382	104%
May 2019	—	1,421	107%
August 2020	—	1,390	104%
August 2021	—	1,419	106%

Figure 33. Geometry Performance Standard 2 – Average Flow Cross-Sectional Area at Invert Berm



3.1.3 Geometry Performance Standard 3 – Average Water Depth at Bridge

To assess whether the causeway opening was accessible to inundation of lake waters with no obvious restrictions, the average water depth at the bridge was measured at the rail centerline (station 0+00; see Figure 22) between a WSE of 4,200 feet (Great Salt Lake OHWM) and the channel bottom (elevation 4,178 feet AMSL). Survey data collected during the 5-year monitoring period were compared to as-built survey data for the evaluation of performance standard 3.

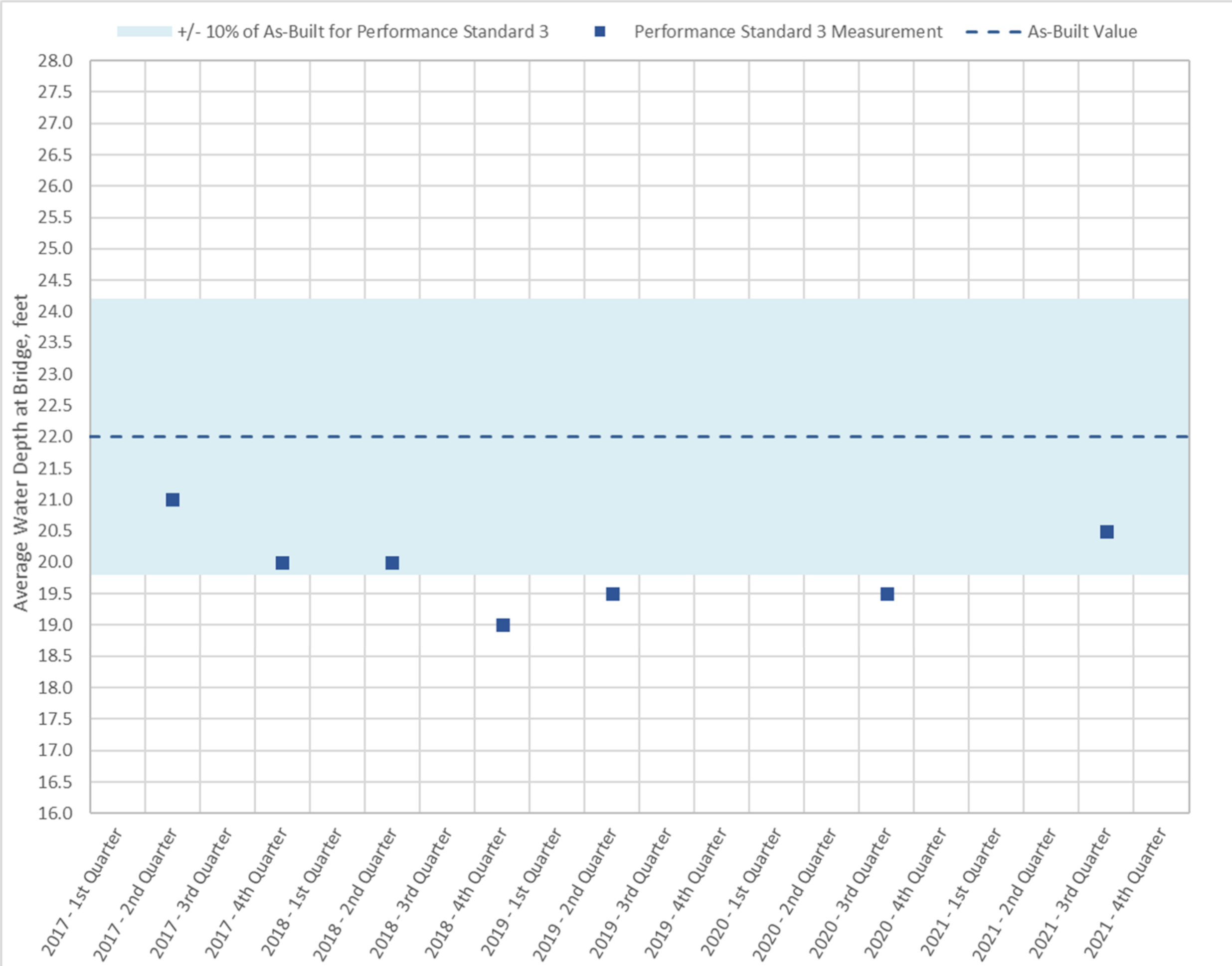
The as-built water depth was measured to be at 22 feet, compared to the calculated average water depth at the bridge over the 5-year monitoring period which ranged from 19 feet to 21 feet (Table 4 and Figure 34). The 2018, 2019, and 2020 data indicated that the depth was slightly below the 10% tolerance and was additionally evaluated and described in more detail in the 2020 annual data monitoring report (UP 2021b). In summary, the additional survey evaluation indicated that there was a limited area of accumulation of material in the channel invert at station 0+00, centered around a bridge pier, and that this limited area was not restricting the bidirectional flow or transfer of water and salt through the causeway opening. The additional evaluation concluded that the accumulated material would continue to be evaluated for maintenance purposes and did not require any adaptive management measures. The 2021 survey results indicated that the average water depth was within the 10% threshold. This variability (between 19 and 20 feet) can be attributed to the inconsistent locations of the underwater bathymetric survey shots along the bottom of the channel under the bridge and survey accuracy tolerances.

The data indicated that the average water depth under the railroad bridge was stable and allowed the transfer of water and salt between the North and South Arms, as designed and constructed, which documents successful attainment of performance standard 3.

Table 4. Geometry Performance Standard 3 – Average Water Depth at Bridge

Survey Date	As-Built Water Depth (feet)	Calculated Water Depth (feet)	percent of As-Built
As- built value (compared to 4,200 feet AMSL)	22	—	—
June 2017	—	21	95%
December 2017	—	20	91%
June 2018	—	20	91%
November 2018	—	19	86%
May 2019	—	19.5	89%
August 2020	—	19.5	89%
August 2021	—	20.5	93%

Figure 34. Geometry Performance Standard 3 – Average Water Depth at Bridge



3.1.4 Geometry Performance Standard 4 – Average Control Berm Contours

To assess that the geometry and the average grading contours of the control berm were stable, UP compared the width of the invert berm to the as-built survey data at the control berm cross-section (station 0+75 North; see Figure 22). This measurement reflected the stability of the width of the invert berm from the west-side control berm to the east-side control berm. Survey data collected during the 5-year monitoring period were compared to as-built survey data for the evaluation of performance standard 4.

The bathymetric and topographic survey data indicated that the invert berm width ranged from 45 feet to 53 feet, compared to the as-built invert berm width of 48 feet (Table 5 and Figure 35). The invert berm width survey results were generally within 10% of the as-built survey data, with the 2021 survey measurement of 53 feet at the 10% threshold.

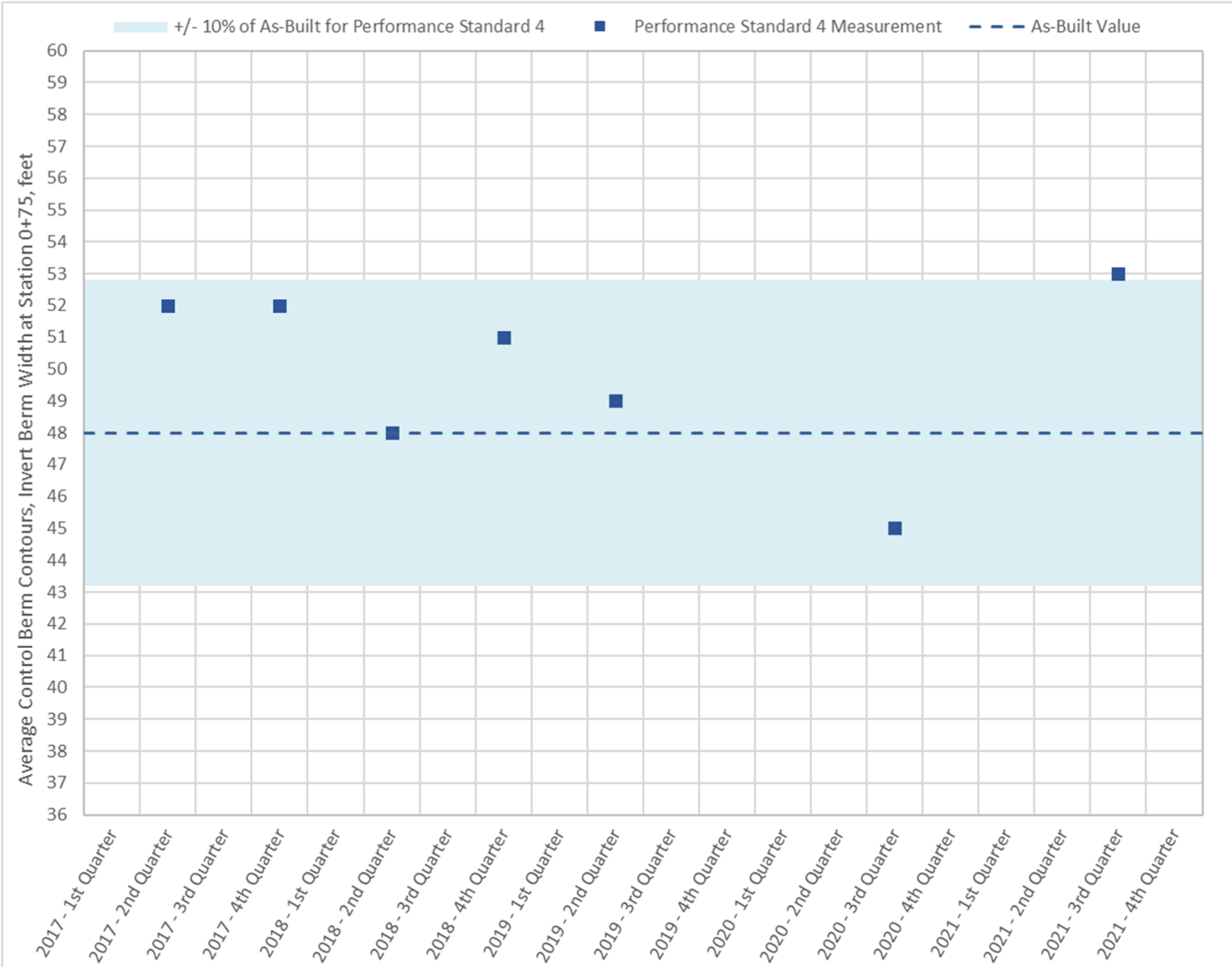
The August 2021 bathymetric and topographic survey was reviewed and further analyzed by UP, to determine whether any adaptive management measures were required, and this additional evaluation was reported in the third-quarter 2021 quarterly data monitoring report and the 2021 annual data monitoring report (UP 2021e, 2022b). The evaluation found that the 2021 survey measurements showed about a 2-foot decrease in the eastern side control berm slope, which increased the width of the invert berm to 52.5 feet (rounded to 53 feet for consistent reporting). UP and others observed that some of the protective armor rock on the east-side control berm had shifted, which might have changed the berm contours in isolated places. Also, the evaluation confirmed that the survey results reflected the natural variability of the control berm contours due to the jaggedness of the large armor rock protecting the invert and side control berms. The additional evaluation concluded that the east-side control berm would continue to be evaluated for maintenance purposes and did not require any adaptive management measures. The survey data variances for all measurements were attributed to the spatially variable locations of the bathymetric survey shots along the invert berm and survey accuracy tolerances.

These data, along with the data for performance standard 2, indicated that the average invert control berm as measured from the west-side control berm to the east-side control berm was stable and allowed the transfer of water and salt between the North and South Arms, as designed and constructed, which documents successful attainment of performance standard 4.

Table 5. Geometry Performance Standard 4 – Average Control Berm Contours

Survey Date	As-Built Invert Berm Average Width (feet)	Surveyed Invert Berm Average Width (feet)	Percent of As-Built
As- built value	48	—	—
June 2017	—	52	108%
December 2017	—	52	108%
June 2018	—	48	100%
November 2018	—	51	106%
May 2019	—	49	102%
August 2020	—	45	94%
August 2021	—	53	110%

Figure 35. Geometry Performance Standard 4 – Average Control Berm Contours



3.2 South Arm Salinity Performance Standard

To assess the attainment of the salinity performance standard—that the causeway with the constructed mitigation provided water and salt transfer similar to that of the free-flowing culverts at average lake conditions before they were closed—UP compared the bathymetric average salinity of the South Arm for each open-water monitoring event to the 2012 UP/USGS Model historic salinity range, consistent with Section 3.9.2, Table 3-7, and Appendix F of the CMMP (UP 2016a). This comparison is shown graphically in Figure 36 and shows attainment of the salinity performance standard.

The discrete density samples from the water column (see Section 2.2.2) at each of the South Arm sampling sites (AS2, AC3, and FB2) were used to bathymetrically calculate an average South Arm salinity using the USGS salt load calculation process developed for the 1998 USGS Model and documented in WRI 4221 (USGS 2000) for each quarterly monitoring event.

The South Arm quarterly average salinity calculations were consistent with the UP/USGS model range for average historic South Arm salinities.

As previously reported in the 2021 quarterly and annual data monitoring reports, the last five quarterly monitoring events occurred when the South Arm WSE was below the lower model WSE threshold of 4,193.0 feet AMSL. In accordance with Section 3.10.3 of the CMMP (UP 2016a),

> … if the South Arm water surface elevation falls outside the salinity range for two consecutive monitoring events, additional steps are required to evaluate whether the project caused the variation and, if so, whether that variation is having significant adverse effects on aquatic resources protected by the lake's beneficial uses.

UP conducted additional evaluations to determine whether the low lake WSE was caused by the Project. These evaluations included reviewing the monthly average South Arm WSEs and precipitation records in the 2021 quarterly and annual data monitoring reports (UP 2021c, 2021d, 2021e, 2022a, 2022b). UP reviewed the data for trends and concluded that the WSE data reflected seasonal and annual fluctuations in response to the hydrologic cycle, which is currently trending drier than average. UP's review of the precipitation data reflects generally lower-than-normal precipitation levels from June 2019 through the fall months of 2021. Because the Great Salt Lake is a terminal lake, multi-year, regional precipitation patterns are a major determinant of the lake's WSE. UP concluded that the low South Arm WSEs were not caused by the Project but rather were a result of generally lower-than-normal precipitation levels consistent with the current drought cycle in Utah. In accordance with Section 3.10.3, subsection 1, of the CMMP (UP 2016a), UP consulted with UDWQ to extend, through extrapolation, the salinity range to a lower WSE range (UDWQ 2021b).

Therefore, the model range was extrapolated to a lower WSE threshold of 4,189 feet AMSL (Figure 36, area in dashed lines). The South Arm average salinity data was within the extrapolated range for the lower lake WSEs.

Based on this analysis, UP determined that the Project met the salinity performance standard.

Figure 36. Monitoring Results Compared to UP/USGS Historic Model South Arm Salinity Range

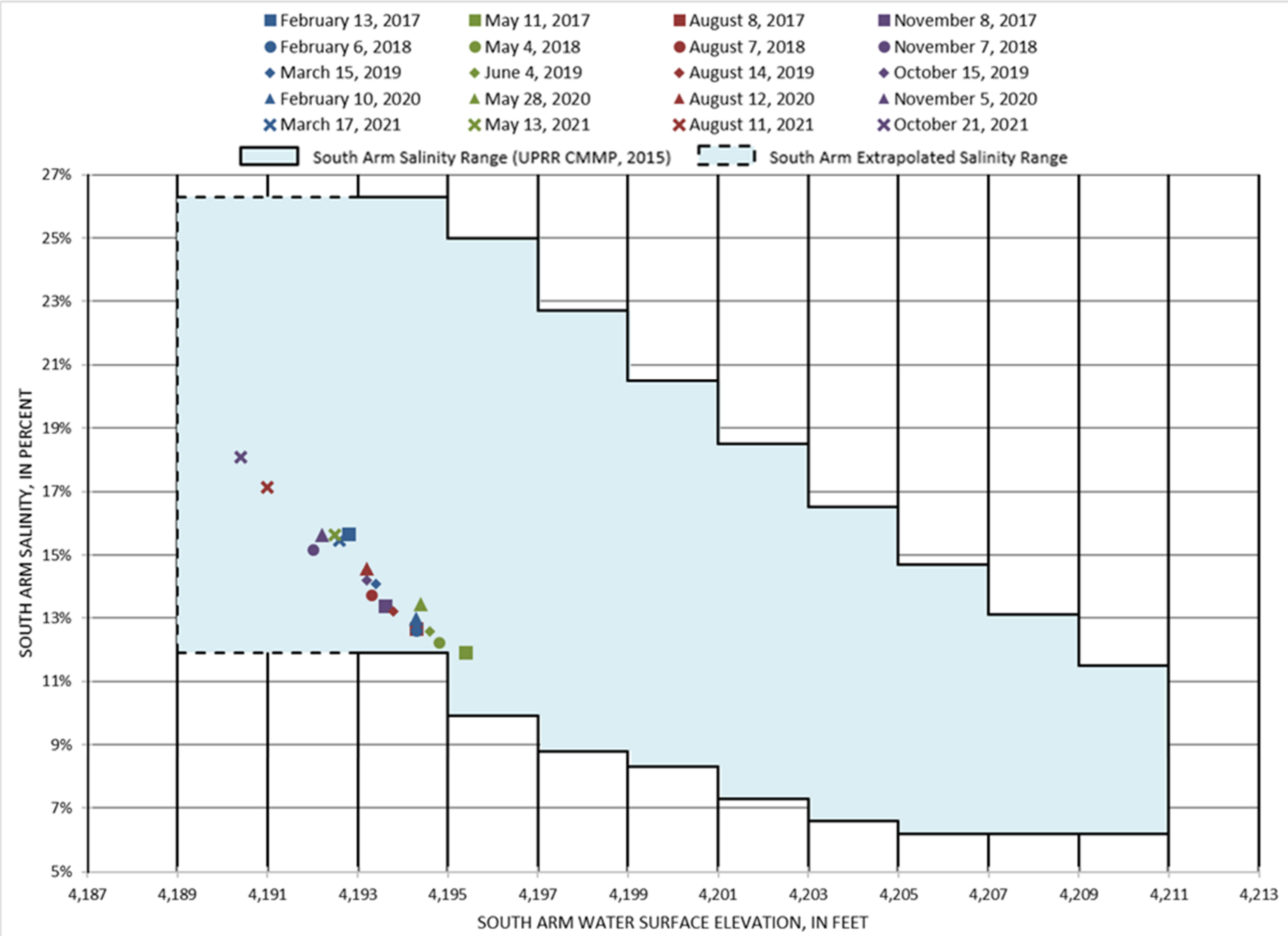


Table 6. Comparison of Monitored South Arm Salinity to Performance Standard Salinity Range by Water Surface Elevation

South Arm WSE Range (feet)	South Arm Bathymetric Average Salinity				
	Performance Standard Salinity Range (%)	Year - Average South Arm Salinity from Sampling Data (%)			
		First Quarter	Second Quarter	Third Quarter	Fourth Quarter
Below 4,189	Not established				
4,189 up to 4,191	11.9 – 26.3 (extrapolated)				**2021** – 18.1
4,191 up to 4,193	11.9 – 26.3 (extrapolated)	**2017** – 15.7 **2021** – 15.5	**2021** – 15.6	**2021** – 17.2	**2018** – 15.2
4,193 up to 4,195	11.9 – 26.3	**2018** – 12.6 **2019** – 14.1 **2020** – 13.0	**2018** – 12.2 **2019** – 12.6 **2020** – 13.5	**2017** – 12.7 **2018** – 13.7 **2019** – 13.2 **2020** – 14.6	**2017** – 13.4 **2019** – 14.2 **2020** – 15.6
4,195 up to 4,197	9.9 – 25.0		**2017** – 11.9		
4,197 up to 4,199	8.8 – 22.7				
4,199 up to 4,201	8.3 – 20.5				
4,201 up to 4,203	7.3 – 18.5				
4,203 up to 4,205	6.6 – 16.5				
4,205 up to 4,207	6.2 – 14.7				
4,207 up to 4,209	6.2 – 13.1				
4,209 up to 4,211	6.2 – 11.5				

3.3 Performance Standards Discussion

The survey and monitoring data collected and reported during the 5-year monitoring period demonstrate successful attainment of the monitoring objectives and the Project geometry and salinity performance standards were met.

The Project geometry performance standards focused on ensuring that the bridge structure and control berm were constructed and maintained as designed and that the causeway opening remained unobstructed, free-flowing, and protected against erosion. The geometry performance standards have been successfully met, since the bathymetric and topographic survey data collected and analyzed over the 5-year monitoring period prove that average bridge side-slope contours, flow area, water depth, and control berm contours remain within 10% of as-built conditions. UP attributed slight and occasional variations of the data to the spatially variable locations of the bathymetric survey points. Also, the survey data had some natural variability due to the jaggedness of the large armor rock protecting the invert and side control berms. As concluded in the annual data monitoring reports, UP's survey data did not show significant variation in water depth below the bridge and showed that the transfer of water and salt through the opening was neither constricted nor increased, thereby meeting the mitigation objectives of the causeway opening as designed and constructed to convey bidirectional flows to replace the function of the closed culverts.

The Project salinity performance standard was based on water and salt balance modeling, resulting in the determination, with USACE's and UDWQ's concurrence, that the water and salt transfer function of the causeway culverts at average lake conditions would be best duplicated by constructing a 150-foot-wide causeway opening with an invert elevation of 4,183 feet (UP 2016a). This target opening width and invert was created by the adjustable features of the control and invert berms, located adjacent to the 180-foot-long railroad bridge with an invert elevation of 4,179 feet. Based on the water and salt balance modeling and a review of the historic South Arm salinity range, UP developed the salinity performance standard range. UP has demonstrated that the salinity performance standard was successfully met, since lake monitoring data collected and analyzed over the 5-year monitoring period show that the South Arm salinity falls within the 2012 UP/USGS model salinity range.

4.0 Summary of Adaptive Management Measures

No adaptive management measures were conducted during the 5-year monitoring and adaptive management period.

5.0 Project-Related Flow and Salt Transfer in Relation to Lake Salinity, Beneficial Uses, Mitigation Objectives, State Antidegradation Policy, and State Water Quality Standards

In accordance with paragraph 4 of the Amended Utah 401 Water Quality Certification, this section describes any long-term changes in flow and salt transfer associated with the Project in relation to:

- Mitigation objectives
- Lake salinity
- Beneficial uses of the Great Salt Lake
- Antidegradation policy
- Water quality standards (numeric and narrative)

Mitigation objectives were discussed in Section 3.0. The remaining items are discussed below.

As part of the USACE Permit and UDWQ Certification for the Project, UP prepared a resource evaluation report (UP 2014). This report evaluated lake salinity and the Project's impacts to the beneficial uses of the Great Salt Lake. UP also prepared an Antidegradation Review and provided supplemental information, which discussed the effects of the Project on salinity (UP 2015). The discussion below is based on these previous reports.

5.1 Lake Salinity

The Great Salt Lake's salinity has varied greatly over time. The Project was designed to duplicate, as closely as possible, the transfer of water and salt between the North and South Arms that was previously provided by the now-closed east and west culverts at average lake conditions (UP 2016a).

Lake salinity data (associated with the salinity performance standard) were calculated by UP from density measurements in compliance with USGS methodology (USGS 2000) and were reported previously for the 5-year monitoring period. The salinity data (Figure 18, Figure 19, Figure 20, and Figure 21) indicate that the North and South Arm salinity values vary seasonally at the sampling sites, in response to hydrologic inflows and outflows, as lake salinity seasonally varied prior to the Project. UP notes that the average South Arm salinity value (Figure 36), based on the three South Arm sampling sites, also varies seasonally. Therefore, the construction and operation of the causeway opening did not obstruct or impede the seasonal fluctuation of North or South Arm salinity. There is no evidence that the Project will interfere with the ability of water and salt to transfer between the North and South Arms or will prevent future seasonal variations in lake salinity.

5.2 Beneficial Uses of the Great Salt Lake

The Great Salt Lake is managed to provide beneficial uses for Gunnison Bay (North Arm), Gilbert Bay (South Arm), Bear River Bay (South Arm), and Farmington Bay (South Arm). The causeway opening is located in the railroad causeway between Gunnison Bay and Gilbert Bay and allows the transfer of water and salt between the two bays. The lake's beneficial uses for these water bodies are:

- Gilbert Bay waters below 4,208 feet – protected for frequent primary and secondary contact recreation, waterfowl, shore birds, and other water-oriented wildlife including their necessary food chain
- Gunnison Bay waters below 4,208 feet – protected for infrequent primary and secondary contact recreation, waterfowl, shore birds, and other water-oriented wildlife including their necessary food chain (Utah Administrative Code Rule R317-2-6, Use Designations, accessed December 2021)

UP conducted evaluations on brine shrimp and brine flies that support the food chain for wildlife. These evaluations, which were coordinated with USACE and UDWQ, found that these aquatic resources (brine shrimp and brine flies) depend on South Arm hydrologic, water quality (salinity), and ecologic (predator) conditions. UP conducted water and salt balance modeling to support the design and ultimate construction of the Project, so that water and salt would be transferred between the North and South Arms similar to the function of the now-closed east and west culverts at average lake conditions. With the transfer of water and salt between the North and South Arms, lake hydrology, salinity, and ecologic conditions would continue to be provided as they would have been by the east and west culverts at average lake conditions if they were in operation (UP 2014).

Over time, the salinity of the lake (all bays) has varied, and the beneficial uses of the lake have not been documented as impaired by high or low salinity (UDWQ 2021c). The causeway opening was designed, supported by water and salt balance models, and constructed to provide the transfer of water and salt, thereby allowing the natural variability of the lake's salinity to continue. Water quality monitoring data and opening geometry data collected over the 5-year monitoring period indicate that the causeway opening does allow for the natural variability of the lake's salinity to continue by providing the transfer of water and salt between the North (Gunnison Bay) and South (Gilbert Bay) Arms of the lake.

5.3 State Antidegradation Policy

In parallel with state protections for beneficial uses, UDWQ has set a statewide antidegradation policy that protects water bodies from activities that could lower or degrade water quality.

The Project is not associated with any effluent discharges that contain chemical, physical, or biological constituents that are normally considered parameters of concern (POCs). In its review comments of UP's Antidegradation Review, UDWQ stated that salinity and salt load may be used as a surrogate for the typical water quality POCs for this analysis, such that the Project-related effects are focused on salinity and the lake's beneficial uses. Through water and salt transfer modeling, the simulations indicated that lake salinity and salt loads resulting from the construction of the causeway opening would most closely match the salinity and salt load lake conditions previously provided by the east and west culverts at average lake conditions (UP 2016a). Because the causeway opening supports the natural variability of lake salinity values within the historical salinity range of the South Arm, the Project would continue to support the lake's beneficial uses, thereby meeting the state antidegradation policy of being nondegrading.

5.4 Water Quality Standards

UDWQ applies numeric and narrative water quality standards to protect designated beneficial uses. The State of Utah has not established numeric water quality standards to protect the beneficial uses of Gilbert and Gunnison Bays (except for the tissue-based selenium standard for Gilbert Bay). Therefore, the state's narrative water quality standards apply for protecting the Great Salt Lake's beneficial uses.

Narrative standards include general statements that prohibit the discharge of waste or other substances that result in unacceptable water quality conditions, visible pollution, or undesirable aquatic life. The Project does not discharge wastewater or other substances or cause visible pollution that might violate state narrative standards and degrade the lake's water quality.

UDWQ accepted lake salinity and salt load as surrogates for evaluating water quality impacts. The water and salt transfer modeling conducted by UP to support the design and construction of the causeway opening resulted in simulations that closely matched lake salinity and salt load conditions with the Project as compared to lake salinity and salt load conditions provided by the former east and west culverts at average lake conditions. This modeling indicated that the water quality narrative standards would be met, and the subsequent analysis supported by the 5-year monitoring data indicates that the standards have been met.

6.0 Conclusion

UP submits this completion report in compliance with Special Condition 1.d of the USACE Individual 404 Permit (No. SPK 2011-00755) issued September 9, 2015 (USACE 2015a), and modifications, and Condition 4 of the Amended Utah 401 Water Quality Certification with Conditions (No. SPK 2011-00755), which was issued to UP by UDWQ on September 13, 2017 (UDWQ 2017), for the Great Salt Lake Permanent East Culvert Closure and Bridge Construction Project, Great Salt Lake, UT.

The mitigation Project consisted of the construction, maintenance, and monitoring of a new Great Salt Lake causeway opening located at milepost 739.78. The new causeway opening, made up of a new 180-foot-long railroad bridge, earthen control berm, and south channel, was designed to allow the transfer of water and salt between the North and South Arms of the Great Salt Lake to duplicate, as closely as possible, the function of the now-closed east and west culverts.

Construction of the causeway opening began in October 2015 and was completed in December 2016. Mitigation monitoring began in January 2017, after construction was completed, and 5 years of monitoring and reporting were completed in December 2021.

Project monitoring data and reporting for the 5-year post-construction monitoring and adaptive management period have documented successful attainment of the geometry and salinity performance standards through the 5-year period and indicate that the causeway opening will continue to transfer water and salt between the North and South Arms in the future. The required MOU for long-term management and maintenance between UP and UDWQ has been executed.

No adaptive management measures have been required during the past 5 years.

This Completion Report requests the cessation of monitoring and adaptive management per the USACE Permit and the UDWQ Certification.

7.0 References

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2021a Annual Report UDWQ Approval. Letter from E. Brown Gaddis of UDWQ to Stephan L. Cheney of UP. February 18.

2021b Email between K. Nichols (HDR) and J. Harris (DWQ). March 25.

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2017c Quarterly Data Monitoring Report – Third-Quarter 2017 Monitoring Results. November 7.

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2018c Quarterly Data Monitoring Report – First-Quarter 2018 Monitoring Results. May 15.

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2019b 2018 Annual Data Monitoring Report. February 1.

2019c Quarterly Data Monitoring Report – First-Quarter 2019 Monitoring Results. May 15.

2019d Quarterly Data Monitoring Report – Second-Quarter 2019 Monitoring Results. August 15.

2019e Quarterly Data Monitoring Report – Third-Quarter 2019 Monitoring Results. November 15.

[UP] Union Pacific Railroad (*continued*)

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2020b 2019 Annual Data Monitoring Report. February 1.

2020c Quarterly Data Monitoring Report – First-Quarter 2020 Monitoring Results. May 15.

2020d Quarterly Data Monitoring Report – Second-Quarter 2020 Monitoring Results. August 15.

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2021c Quarterly Data Monitoring Report – First-Quarter 2021 Monitoring Results. May 15.

2021d Quarterly Data Monitoring Report – Second-Quarter 2021 Monitoring Results. August 15.

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2022a Quarterly Data Monitoring Report – Fourth-Quarter 2021 Monitoring Results. January 5.

2022b 2021 Annual Data Monitoring Report. January 5.

[USACE] United States Army Corps of Engineers

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