REMEDIATION OF DEICER SALT CONTAMINATED SOILS USING NATIVE MONTANA PLANTS

Task 2 Report – Soil Sampling Results

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Disclaimer Statement

Alternative Format Statement

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Acronym List

DOT	Department of Transportation
EC	Electric conductivity
FHWA	Federal Highway Administration
MDT	Montana Department of Transportation
MSU	Montana State University
MT	Montana
NRCS	Natural Resource Conservation Service
PDF	Portable Document Format
PPE	Personal Protective Equipment
ROW	Right of Way
TDS	Total Dissolved Solids
USDA	United States Department of Agriculture
USU	Utah State University
WTI	Western Transportation Institute

avg.	average
C	Celsius
Cl	Chloride
dS/m	deci Siemens per meter
ft	feet
g	grams
in	inch
mm	millimeters
NaCl	Sodium Chloride
µS	micro Siemens
µS/cm	micro Siemens per centimeter
min.	minimum
mg	milligrams
mg/L	milligrams per liter
mL	milliliters
ppm	parts per million
Std Dev	Standard Deviation

Objective

In this task 2 report, salt/sand storage facilities and roadways with elevated concentration of winter salt in the adjacent environment were identified for soil sampling using the help of MDT staff, data from MDT, and other data sources. Following analysis of this information, a selection of MDT salt and salt/sand storage facilities and highway road segments were identified for soil sampling. Methods for soil sampling and analysis are provided. The goal of soil sampling is to get a representative view of chloride concentration in soils, identify a range of concentrations that are present, so that they can be used in the Greenhouse study (Task 3) of this research project. The goal of soil sampling is not to perform a detailed sampling of the DOT facilities but to guide future tests.

Soil Sampling Locations

Soil sampling occurred at MDT salt/sand storage facilities in Alberton, Deer Lodge (Figure 1), Three Forks, and Wilsall (Figure 2) and at highway locations in Billings, Laurel, and Missoula (Figure 3).

Figure 1. Deer Lodge MDT salt/sand storage facility sampling location.

Figure 2. Wilsall MDT salt/sand storage facility sampling location.

Figure 3. Missoula highway soil sampling location.

MDT Facility and Highway Sampling Plan

MDT salt/sand storage facilities sampled differently from the highway roadside samples for each site based on local maintenance crew knowledge and existing information from the reports provided by MDT. Sampling occurred in areas with supposedly high salt levels and based on slope or other significance (former salt storage area, snow storage location, etc.).

Soil samples collected from highway roadside were collected based on local maintenance crew knowledge, proximity to the sampling town, on and off ramps, and the safety of the sampling location. In the near-road environment, a systematic grid sampling approach was used, with samples collected parallel along either side of the highway, then extending out to the tree line, change in grade, or end of the right-of-way (Figure 4).

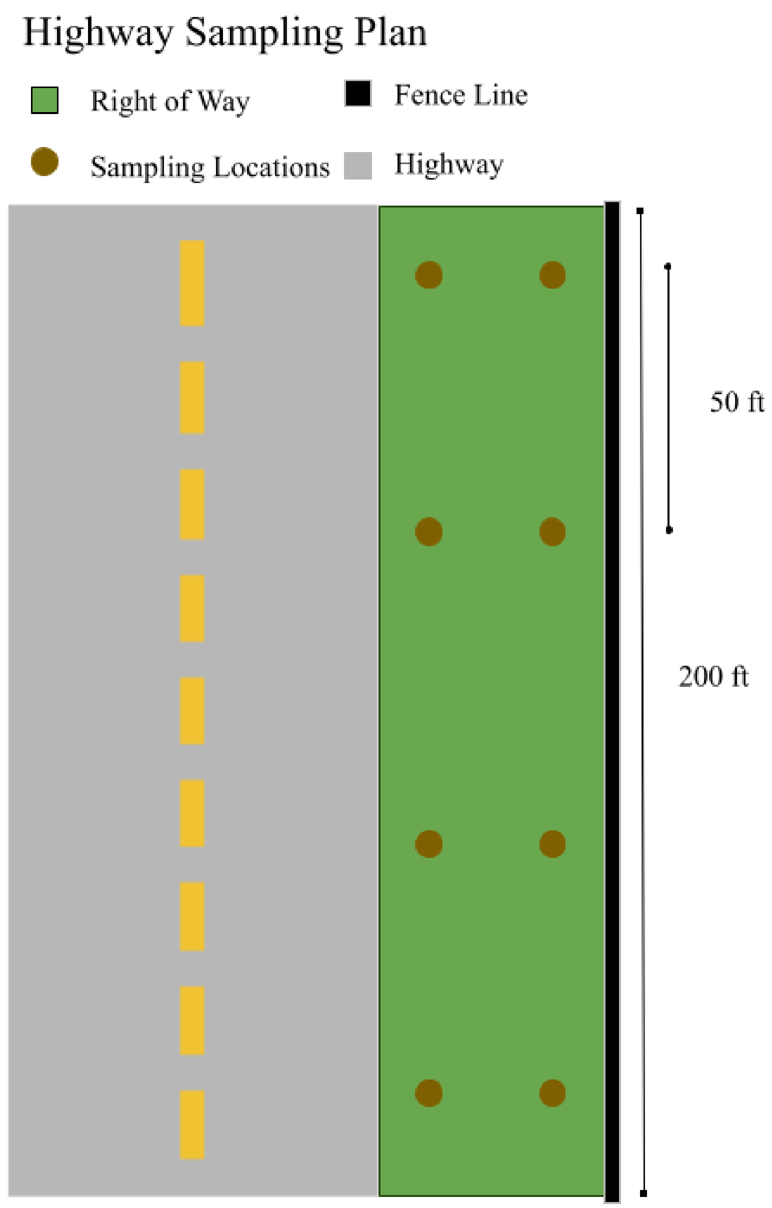

Figure 4. Highway Soil Sampling Plan

Soil Sampling Method

In an effort to quantify soil chloride concentrations at MDT salt/sand storage facilities and in the near road environment soil samples were collected in the Spring of 2025, between April 8 and May 1, 2025, from the seven locations identified. At each site 6 – 10 samples were collected from locations based on slope, drainage, or historical spill locations. At each site notes on plant life and soil texture were collected (Appendix A. Soil Sampling Notes).

Soil Sample Collection Method

A soil probe (PN003 JMC Backsaver N-2 Handle, Clements Associates) was used to collect soil samples at the identified locations. The 1-inch diameter probe was pushed down into the soil to an approximate depth of 1 foot (Figure 5). The soil samples were then placed in labeled 1-gallon sealing plastic bags (Figure 6).

Figure 5: Soil probe in the field.

Figure 6: Soil sample storage and labeling.

Soil Chloride Analysis

For each soil sample collected the following methods were used to determine the soil chloride concentration.

Soil Extract Processing Method

The Florida Department of Transportation State Materials Office's methods for soil drying and extract processing were used (FDOT State Materials Office, 2023).

Soil Drying

Materials

- 10-mesh / 2 mm sieve
- Oven trays
- Pulverizing device
- Bags

Steps

1. Set drying oven to no higher than140° (60 °C) (Figure 7)
2. Weigh 150 grams of soil from each sample and spread evenly on an oven tray for drying (Figure 8).
3. Dry soil samples in oven until evenly dry.
4. After drying, record the weight of each sample.
5. Break up large clods with a mallet or other pulverizing device and push dried soil through a 10-mesh sieve (Figure 9).
6. Weigh soil after sieving and record data.

Figure 7. Soil drying oven

Figure 8. Soil sample on a tray after being dried in the oven.

Figure 9. Sieved soil sample.

Sample Preparation

Materials

- 500 mL flasks
- Buchner funnel
- 41 Whatman filter paper
- Ferric Sulfate
- Labeling tape

Steps

1. Weigh out up to 100 grams of dried and sieved soil to a 500 mL flask. (Average dry soil sample weight 62.28g ± 19.96g used. See Appendix B. Soil Data Table for all dry soil sample weights.).
2. Add up to 3 mL distilled water to maintain a water to dry soil ratio of 3:1 (or 1mL of water for every gram of dry soil) and shake to mix for 20 seconds (Figure 9). (Average volume of water used 187mL ± 59mL. See Appendix B. Soil Data Table for all water volume used.)
3. Repeat shaking after 1 hour and leave for at least 12 hours.
4. If the water is has suspended particles after setting, dissolve 0.1 grams ferric sulfate into 1 mL of distilled water and add to the solution. Let the mixture sit for 3-4 hours.
5. Place a Whatman 41 filter paper into a Buchner funnel and pour water and soil into the reservoir. Let it filter until there is no standing water in the Buchner funnel (Figure 10).

6. Store the final solution in a closed container with a label until measurement (Figure 11).

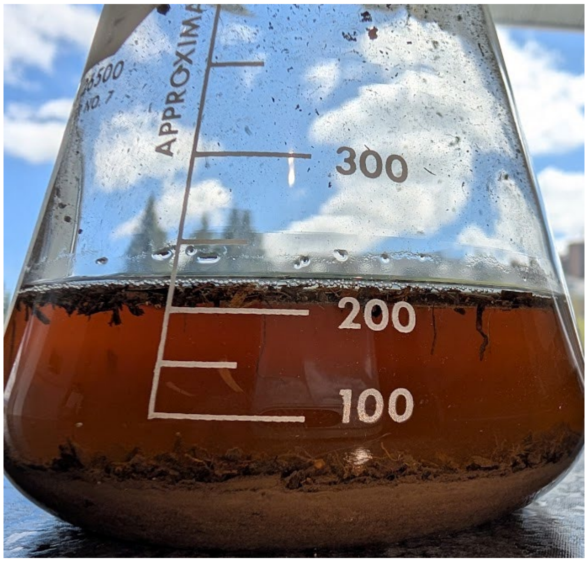

Figure 10. Soil water mixture.

Figure 11. Soil water mixture after treatment with ferric sulfate and filtration.

Figure 12. Deer Lodge soil water extracts ready for testing.

Standard Solution and Titration

Standard solutions had their electrical conductivity (EC) determined through titration and the use of the handheld EC meter to ensure that the calibration of the EC meter was accurate for use in soil extracts. The soil EC concentration levels were too low for titration, so validating the handheld sensor was necessary to ensure accurate data. The University of Canterbury's public document on chloride determination by titration using Mohr's method was used for our titrations (University of Canterbury).

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Materials

- Burette
- Hanna Instruments 98130 pH/Conductivity/TDS tester
- Clamp stand
- 250 mL flasks
- 3 - 250 mL beakers
- NaCl Salt brine
- Silver Nitrate (titrant)
- Potassium Chromate (indicator)
- Prepared soil/water solution

Steps

1. Calibrate the handheld EC meter using the given 1288 µs standard calibration solution (Hanna Instruments).
2. Prepare the standard solutions using NaCl.
   - Measure out 125 mg, 250 mg, and 500 mg into three beakers with labels.
   - Mix in 100 mL distilled water until NaCl is fully dissolved.
3. Mix 1 gram of Potassium chromate in 20 mL of distilled water to create the indicator solution.

4. In a 250 mL flask, add 1 mL indicator solution and 50 mL distilled water. Measure 10 mL of the known standards solution, record the EC with a handheld meter, and then add it to the flask.
5. Titrate in silver nitrate until the solution is a light rust color, indicating that the endpoint has been reached. Titrate each standard solution in triplicate.
6. Measure the amount of silver nitrate used and record.
7. Repeat steps 4, 5, and 6 for all standard solutions.
8. Calculate the error between the standard solution conversion to electrical conductivity and the handheld meter's reading of electrical conductivity.
    - If the difference is lower than 5% proceed with measurement of soil extracts.

Soil Extract Measurements

Materials

- Handheld EC Meter
- 150 mL beaker
- Cleaning station
- Towels
- Soil extract

Steps

1. Record relevant sample data, the date, and if ferric sulfate was used for the extract.
2. Pour out about 1/3rd of the extract in the beaker and measure the EC with the handheld meter, waiting until the result is stable, and record results.
3. Repeat the last step 2 more times.
4. Clean the beaker and meter using distilled water.
5. Repeat to all samples.

Soil Extract Chloride Data

The EC of soil extracts was collected in triplicate. Averages of the three recordings were found and converted from EC (dS/m) to parts per million (ppm). Average and Standard deviation (Std Dev) were calculated for each location (Table 1). The minimum, median, and maximum values from the entire data set are also reported to show the range of soil chloride EC values.

The average soil chloride concentration was 593 ppm for all sampling locations, with minimum and maximum values being 125 ppm to 3093 ppm (Table 2). Deer Lodge had the highest soil chloride concentration, followed by Three Forks (Figure 12 and Figure 13).

Soil chloride data from previous studies reported values for Ashland, MT ranging from 15.2 – 17,257 ppm (2022) and for Plains, MT ranging from 9 – 67,800 ppm (2023).

Table 1. Soil chloride data for each Montana sampling location (deciSiemen per meter, electrical conductivity)

Locations	Average (dS/m)	Std Dev	Min (dS/m)	Med (dS/m)	Max (dS/m)	n
Alberton	0.78	0.36	0.25	0.68	1.39	6
Billings (h)	0.93	0.12	0.71	0.87	1.10	7
Deer Lodge	2.18	1.94	0.50	1.14	6.19	8
Laurel (h)	1.37	0.41	0.79	1.42	1.87	8
Missoula (h)	0.83	0.24	0.50	0.97	1.22	8
Three Forks	1.86	0.97	1.17	1.33	3.44	8
Wilsall	0.85	0.36	0.39	0.87	1.44	11
Totals	**1.19**	**0.88**	**0.25**	**1.03**	**6.19**	**56**

Table 2. Soil chloride data for each Montana sampling location (parts per million (ppm) NaCl = milligrams per liter (mg/L))

Locations	Average (ppm)	Std Dev	Min (ppm)	Med (ppm)	Max (ppm)	n
Alberton	391	182	125	340	695	6
Billings (h)	467	59	355	437	548	7
Deer Lodge	1088	968	252	570	3093	8
Laurel (h)	687	204	395	708	935	8
Missoula (h)	414	122	252	487	612	8
Three Forks	928	484	587	667	1720	8
Wilsall	423	181	195	433	720	11
Totals	**593**	**439**	**125**	**515**	**3093**	**56**

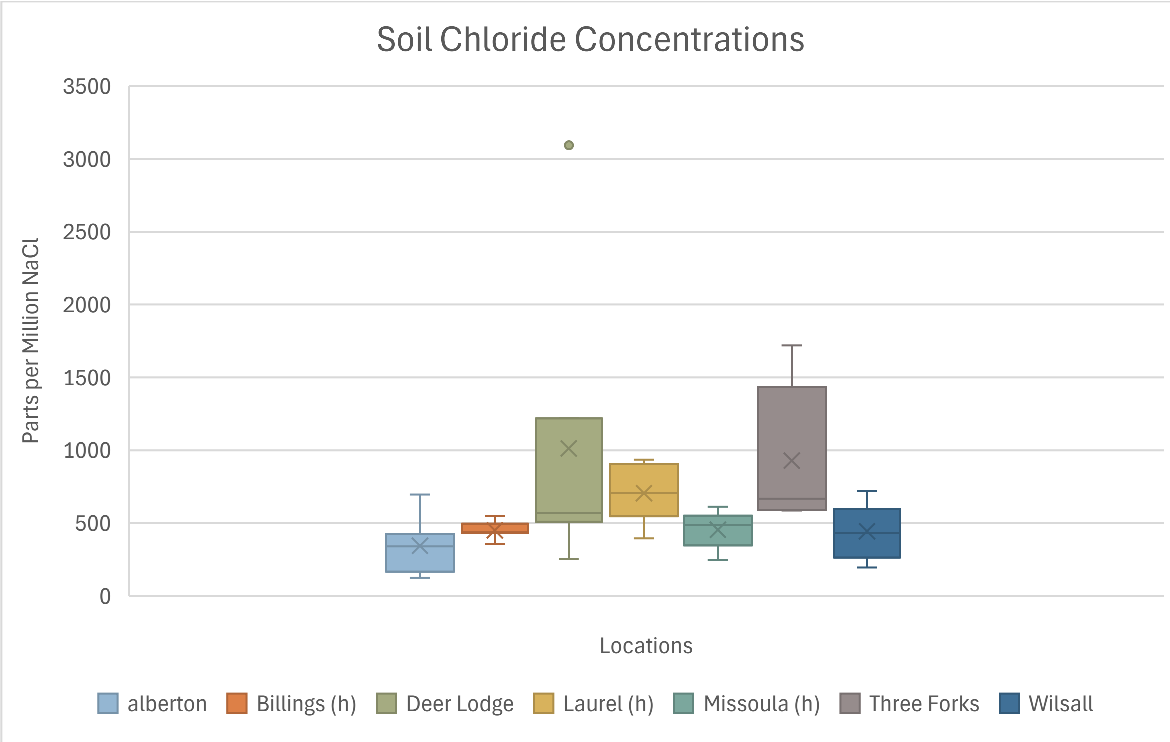

Figure 13. Soil chloride concentrations of all sites. (h) notes sampling along the highway in the near road environment.

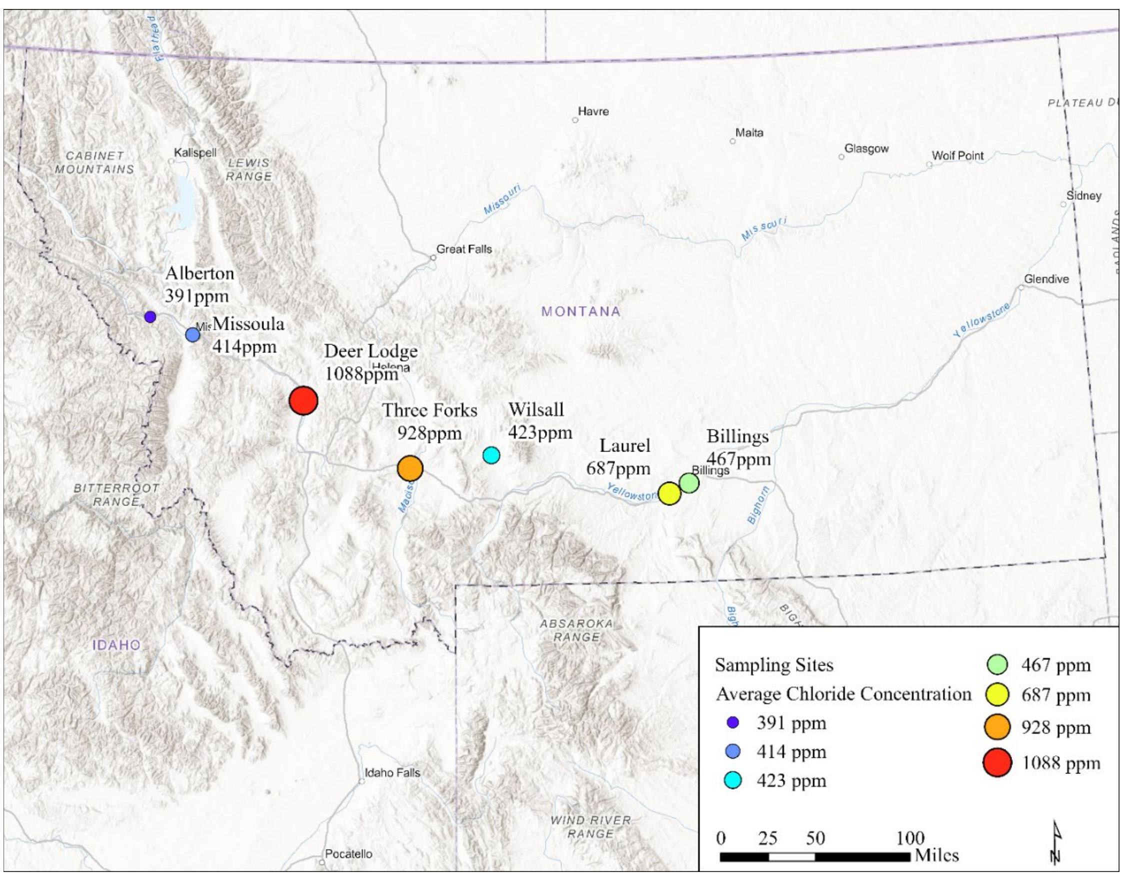

Figure 14. Map of Montana showing soil sampling locations with the soil chloride concentration shown for each location, with the larger circle equating higher soil chloride concentrations.

For the purposes of this research effort, the soil chloride concentration data will be used to guide the Greenhouse study. Soil chloride concentrations of 125 ppm to 3093 ppm will be targeted in the Greenhouse study to ensure that the plants being used can survive and potentially remediate soils when exposed to chloride concentration in the observed range. Given that other efforts have identified soil chloride concentrations as high at 67,800 ppm, evaluating some plant species at this excessively high soil chloride concentration may be warranted.

Next Steps

A Greenhouse testing plan will be developed and submitted for review by the project panel.

References

FDOT State Materials Office. *Florida Method of Test for Chloride in Soil and Water*. No. FM5-552, 24 Aug. 2023. *Florida Sampling and Testing Methods*, www.fdot.gov/docs/default-source/materials/administration/resources/library/publications/fstm/methods/fm5-552.pdf. Accessed 7 Aug. 2025.

University of Canterbury. *Determination of Chloride Ion Concentration by Titration (Mohr's Method)*. Accessed May 2025, https://www.canterbury.ac.nz/content/dam/uoc-main-site/documents/pdfs/d-other/Determination-of-Chloride-Ion-Concentration-by-Titration-Mohr.pdf

Appendix A. Soil Sampling Notes

Location and Date	Notes
Three Forks 4/8	• Notable plants were primarily grasses and salsify. • Samples were taken around the salt storage structure on the north side of the storage facility, with some samples taken near the middle.
Deer Lodge 4/9	• Cattails, cheatgrass, and wild mustards were the primary identifiable plants. • Covered and uncovered salt piles were present at this facility. • Runoff goes into the nearby field and the side of the road waterway. • Sampling was done based on where piles were stored previously and where runoff would collect and drain. • Soil was wet from rain hours prior. • One sample has visible salt chunks present.
Wilsall 4/10	• Cheatgrass was the only identifiable plant at this location. • Sandy soil downslope, facility on a hill. • Wet soil but not fully saturated.
Laurel 4/10	• Very compacted clay soil. • One grass species dominates. • Samples on slope and at the bottom of the side of the road ditch. • 8 samples spread over ~200 feet on the right side of the highway where snow is plowed.
Billings 4/10	• Very compacted clay soil. • One grass species dominates. • Samples on slope and at the bottom of the side of the road ditch. • 8 samples spread over ~200 feet on the right side of the highway where snow is plowed.
Alberton 4/17	• Sandy soil surrounds the location. • Stores salt brine. • Clover, reed canary grass, and other grasses dominate the location. • A couple of samples sat between the highway (I-90) and the salt storage structure. • Lower clay horizons.
Missoula 5/1	• Cheatgrass, euphorbia, dandelion, prickly lettuce, tumble mustard, and other wild mustards were the primary plants at this location. • Visible salt bits in the soil. • Silty rocky dirt.

Location and Date	Notes
	• Still moist after 2 days of no rain. • Dirt was red in parts. • 10 samples spread over ~200 feet on the right side of the highway where snow is plowed. • 1 sample was collected up slope on the opposite side of the ditch.
Overall Notes	• Many facilities were fenced off from true soil horizons, resulting in gravely dirt sitting on an impermeable layer. • Where lower horizons were available, most locations were clay to silt types with gravel from the facility ground.

Appendix B. Soil Data Table

Date Processed	Sample Name	Date Sampled	Date Dried	Wet Weight	Dried Weight	Sieved Weight	Soil	Water	Water/Soil Ratio	Ferric Sulfate	EC
14-Jul	Three Forks 1	8-Apr	9-Jun	125.41 g	104.44 g	93.89 g	94.10 g	282 mL	3.00	☐	1.18 dS/m
14-Jul	Three Forks 2	8-Apr	9-Jun	76.91 g	66.44 g	48.82 g	83.30 g	250 mL	3.00	☐	2.68 dS/m
14-Jul	Three Forks 3	8-Apr	9-Jun	125.63 g	101.05 g	82.97 g	49.00 g	147 mL	3.00	☐	1.46 dS/m
14-Jul	Three Forks 2	8-Apr	9-Jun	76.91 g	66.44 g	48.82 g	66.40 g	199 mL	3.00	☐	1.17 dS/m
14-Jul	Three Forks 3	8-Apr	9-Jun	125.63 g	101.05 g	82.97 g	89.90 g	269 mL	2.99	☐	1.21 dS/m
15-Jul	Three Forks 6	8-Apr	9-Jun	129.97 g	113.75 g	72.64 g	72.70 g	218 mL	3.00	☐	3.44 dS/m
16-Jul	Deer Lodge 1	9-Apr	8-Jun	120.12 g	104.02 g	57.47 g	57.47 g	172 mL	2.99	☐	1.13 dS/m
16-Jul	Deer Lodge 2	9-Apr	8-Jun	144.19 g	137.14 g	63.82 g	63.26 g	190 mL	3.00	☐	1.14 dS/m
16-Jul	Deer Lodge 3	9-Apr	8-Jun	109.23 g	102.06 g	51.87 g	51.55 g	154 mL	2.99	☐	1.76 dS/m
17-Jul	Deer Lodge 4	9-Apr	8-Jun	123.65 g	95.27 g	39.66 g	39.88 g	120 mL	3.01	☐	6.19 dS/m
17-Jul	Deer Lodge 5	9-Apr	8-Jun	102.62 g	89.92 g	50.04 g	50.08 g	150 mL	3.00	☐	0.50 dS/m
17-Jul	Deer Lodge 6	9-Apr	8-Jun	150.03 g	122.84 g	54.72 g	54.89 g	165 mL	3.01	☐	1.02 dS/m
18-Jul	Deer Lodge 7	9-Apr	9-Jun	132.88 g	118.56 g	72.95 g	72.64 g	218 mL	3.00	☐	2.44 dS/m
18-Jul	Billings 1	10-Apr	2-Jun	149.67 g	132.36 g	100.25 g	100.00 g	300 mL	3.00	☐	0.71 dS/m
18-Jul	Billings 2	10-Apr	2-Jun	149.97 g	128.55 g	84.10 g	84.65 g	253 mL	2.99	☐	0.87 dS/m
19-Jul	Billings 3	10-Apr	2-Jun	150.01 g	137.06 g	98.81 g	92.29 g	277 mL	3.00	☐	1.03 dS/m
19-Jul	Billings 4	10-Apr	3-Jun	149.97 g	127.48 g	60.38 g	60.84 g	182 mL	2.99	☐	0.86 dS/m
19-Jul	Billings 5	10-Apr	3-Jun	149.93 g	135.84 g	71.08 g	71.60 g	215 mL	3.00	☐	0.87 dS/m
20-Jul	Billings 6	10-Apr	3-Jun	149.96 g	129.65 g	65.99 g	66.44 g	199 mL	3.00	☐	1.10 dS/m
20-Jul	Billings 7	10-Apr	4-Jun	149.99 g	137.40 g	90.00 g	90.62 g	272 mL	3.00	☐	0.86 dS/m
20-Jul	Billings 8	10-Apr	4-Jun	149.94 g	126.49 g	72.44 g	73.04 g	219 mL	3.00	☐	0.88 dS/m
21-Jul	Laurel 1	10-Apr	5-Jun	149.93 g	124.22 g	54.48 g	54.81 g	164 mL	2.99	☐	1.16 dS/m
21-Jul	Laurel 2	10-Apr	5-Jun	150.09 g	120.98 g	22.82 g	22.88 g	69 mL	3.02	☐	1.86 dS/m
21-Jul	Laurel 3	10-Apr	5-Jun	107.11 g	91.93 g	68.22 g	68.33 g	205 mL	3.00	☐	0.79 dS/m
22-Jul	Laurel 4	10-Apr	5-Jun	150.01 g	122.08 g	27.07 g	27.10 g	81 mL	2.99	☐	1.66 dS/m
22-Jul	Laurel 5	10-Apr	5-Jun	104.16 g	86.83 g	61.56 g	62.00 g	186 mL	3.00	☐	1.17 dS/m
22-Jul	Laurel 6	10-Apr	5-Jun	150.02 g	120.27 g	19.22 g	19.28 g	58 mL	3.01	☐	1.87 dS/m
24-Jul	Laurel 7	10-Apr	6-Jun	111.70 g	92.62 g	68.08 g	68.72 g	206 mL	3.00	☐	1.07 dS/m
24-Jul	Laurel 8	10-Apr	6-Jun	150.06 g	119.45 g	27.53 g	27.47 g	82 mL	2.99	☐	1.68 dS/m
24-Jul	Wilsall 1	10-Apr	6-Jun	149.96 g	126.88 g	37.43 g	37.69 g	113 mL	3.00	☐	1.23 dS/m
25-Jul	Wilsall 2	10-Apr	6-Jun	150.03 g	138.17 g	65.76 g	66.15 g	198 mL	2.99	☐	0.79 dS/m
25-Jul	Wilsall 3	10-Apr	6-Jun	149.98 g	134.44 g	43.58 g	43.74 g	131 mL	2.99	☐	0.44 dS/m
25-Jul	Wilsall 4	10-Apr	7-Jun	150.05 g	130.97 g	44.90 g	45.03 g	135 mL	3.00	☐	1.44 dS/m
26-Jul	Wilsall 5	10-Apr	7-Jun	150.03 g	131.92 g	50.84 g	51.03 g	153 mL	3.00	☐	1.07 dS/m
26-Jul	Wilsall 6	10-Apr	7-Jun	149.96 g	126.62 g	25.51 g	25.85 g	78 mL	3.02	☐	0.39 dS/m
26-Jul	Wilsall 7	10-Apr	7-Jun	149.95 g	136.21 g	69.29 g	69.61 g	209 mL	3.00	☐	0.82 dS/m
27-Jul	Wilsall 8	10-Apr	7-Jun	150.06 g	139.76 g	64.05 g	63.73 g	191 mL	3.00	☐	0.91 dS/m
27-Jul	Alberton 1	17-Apr	30-May	149.98 g	135.75 g	84.06 g	84.23 g	253 mL	3.00	☐	0.25 dS/m
27-Jul	Alberton 2	17-Apr	30-May	149.99 g	147.72 g	98.25 g	98.02 g	294 mL	3.00	☐	0.56 dS/m
28-Jul	Alberton 3	17-Apr	31-May	150.04 g	146.77 g	54.11 g	53.74 g	173 mL	3.22	☐	0.70 dS/m
28-Jul	Alberton 4	17-Apr	31-May	150.08g	144.66 g	69.76 g	69.57 g	209 mL	3.00	☐	0.66 dS/m
28-Jul	Alberton 5	17-Apr	31-May	149.98 g	135.70 g	33.72 g	33.56 g	101 mL	3.01	☐	1.39 dS/m
29-Jul	Alberton 6	17-Apr	1-Jun	149.83 g	142.29 g	32.29 g	32.00 g	96 mL	3.00	☐	0.83 dS/m
29-Jul	Alberton 7	17-Apr	1-Jun	149.98 g	137.61 g	56.27 g	56.17 g	169 mL	3.01	☐	0.26 dS/m
29-Jul	Alberton 8	17-Apr	1-Jun	150.08 g	132.89 g	63.71 g	63.53 g	191 mL	3.01	☐	0.85 dS/m
30-Jul	Missoula 1	1-May	27-May	149.90 g	142.62 g	97.48 g	97.53 g	293 mL	3.00	☐	0.85 dS/m
30-Jul	Missoula 2	1-May	27-May	150.01 g	130.11 g	76.96 g	77.27 g	233 mL	3.02	☐	0.97 dS/m
30-Jul	Missoula 3	1-May	27-May	150.00 g	132.64 g	56.25 g	56.22 g	169 mL	3.01	☐	1.10 dS/m
31-Jul	Missoula 4	1-May	28-May	149.91 g	130.26 g	67.41 g	67.52 g	203 mL	3.01	☐	1.03 dS/m
31-Jul	Missoula 5	1-May	28-May	149.96 g	137.07 g	61.09 g	61.23 g	184 mL	3.01	☐	1.10 dS/m
31-Jul	Missoula 6	1-May	28-May	150.03 g	126.13 g	58.60 g	58.72 g	176 mL	3.00	☐	1.18 dS/m
1-Aug	Missoula 7	1-May	29-May	150.02 g	137.47 g	78.10 g	78.38 g	235 mL	3.00	☐	0.69 dS/m
1-Aug	Missoula 8	1-May	29-May	150.01 g	129.07 g	67.69 g	68.03 g	205 mL	3.01	☐	0.60 dS/m
1-Aug	Missoula 9	1-May	29-May	150.03 g	130.88 g	62.26 g	62.32 g	187 mL	3.00	☐	0.50 dS/m
2-Aug	Missoula 10	1-May	30-May	150.08 g	131.90 g	83.57 g	60.77 g	182 mL	2.99	☐	1.22 dS/m
2-Aug	Missoula 11	1-May	4-Jun	150.03 g	143.83 g	71.80 g	72.26 g	217 mL	3.00	☐	0.78 dS/m