APPENDIX A. DATA QUALITY OBJECTIVES AND ASSESSMENT

This appendix describes the methods by which the Data Quality Objectives (DQOs) specified in Table A.1 were established and provides methods for determining whether laboratories are meeting DQOs, a process referred to as *Data Quality Assessment*. GAW precipitation chemistry laboratories should meet or exceed the DQOs in this table. This may require some laboratories to improve their analytical and quality control procedures. Each of the following sections refers specifically to the DQOs specified in Table A.1.

A.1   Detection Limits

The DQOs for *Detection Limits* presented in column 2 of Table A.1 were established from a review of the 2001 detection limits provided by all laboratories participating in the European Monitoring and Evaluation Programme (EMEP). Listed are the median detection limits of all participating EMEP laboratories.

The preferred method of determining *Detection Limits* in the GAW Precipitation Chemistry Programme requires making 30 (or preferably more) repetitive chemical analyses of a low-concentration solution. This solution must be stable with a concentration at or near the detection limit of the analytical method. Ideally, the concentration would be between deionized water, referred to as a blank level, and the expected detection limit. In practice, the concentration can be as high as five times the anticipated detection limit but not higher. For example, if the anticipated detection limit of a sulfate analysis is 0.04 mg L^{-1}, then the solution from which the actual detection limit is established should have a stable sulfate concentration less than 0.20 mg L^{-1}. Ideally, the concentration would be between 0.01 and 0.04 mg L^{-1}. The 30 or more repetitive analyses can be done either in a single analytical batch or, preferably, in several batches analyzed over time. The *Detection Limit* for each analyte is set equal to 3 times the standard deviation of the 30 or more repetitive analyses. Compare *Detection Limits* determined this way with the DQOs listed in the column 2 of Table A.1. *Detection Limits* equal to or lower than the values in column 2 meet the DQOs.

A.2   Overall Precision

Overall Precision is the precision of the complete precipitation chemistry measurement system, which includes both field and laboratory components. The DQOs for *Overall Precision* listed in column 3 of Table A.1 were set at 1.5 times the precision values measured by one specific GAW network, the Canadian Air and Precipitation Monitoring Network (CAPMoN). The precision values for this network are published in Table I of Sirois and Vet (1999). Here and in Sirois and Vet (1999) *Overall Precision* is expressed as the Modified Median Absolute Difference (M.MAD), described below. The factor of 1.5 was chosen to account for the wide variation in measurement methods and capabilities across the GAW member countries. It is worth noting that Sirois and Vet (1999) found the M.MAD values for Mg^{2+}, Na$^+$ and K$^+$ were less than the CAPMoN analytical detection limits for these ions, so the *Overall Precision* DQOs for these ions were set to the detection limits times a factor of 1.5. The DQO for pH >5.0 was set arbitrarily since no precision estimates were available.

To estimate *Overall Precision* a GAW participant should operate two identical precipitation chemistry collectors and standard gauges simultaneously at the same location for a year or more. The paired concentration and depth data from the individual samples are used to calculate the M.MAD. The M.MAD is a non-parametric estimator of the spread of the frequency distribution that is relatively insensitive to the presence of outliers and a consistent estimator of the standard deviation when the underlying frequency distribution is normal. The mathematical expression of the M.MAD is as follows:

$$M.MAD = \frac{1}{0.6745} \, Median(\, | \, x_i - Median(x_i) \, | \,)$$

Eq. A-1

where x_i = variable of interest.

A description and sample calculation of the M.MAD are given below. Readers are referred to Sirois and Vet (1999) for complete details.

A.2.1 Calculation of the Modified Median Absolute Difference (M.MAD)

1) For each set of paired concentration data, *i*, from Sampler 1 and Sampler 2, calculate the between-sampler error, e_i, using equation A-2

$$e_i = \frac{1}{\sqrt{2}} (C_{1i} - C_{2i})$$
Eq. A-2

where C_{1i} and C_{2i} are the concentrations from Samplers 1 and 2 for the ith sample and $1/\sqrt{2}$ accounts for the fact that the errors in the two measurements are assumed to be drawn from the same distribution.

2) Calculate the *Overall Precision* (which is defined as the spread of the e_i values) equal to the M.MAD as follows:
   a) For all values of e_i from the paired measurements, calculate the median e_i, or Median(e_i).
   b) For each e_i, subtract the Median(e_i) and take its absolute value, $|e_i - \text{Median}(e_i)|$.
   c) Determine the median $|e_i - \text{Median}(e_i)|$, i.e., Median $|e_i - \text{Median}(e_i)|$.
   d) Multiply the Median $|(e_i - \text{Median } e_i)|$ by (1/0.6745), a factor that sets the M.MAD as a consistent estimator of the standard deviation, when the underlying distribution of $|e_i - \text{Median}(e_i)|$ is normal.

3) Compare the M.MAD (i.e., the *Overall Precision*) with the DQO in column 3 of Table A.1.

A.2.2 Example Calculation of the M.MAD

Below is a list of sulfate concentrations from two identical CAPMoN precipitation chemistry collectors operated at the same location. The measurements offer an example for calculating the M.MAD for sulfate, which is used as an estimate of the *Overall Precision* for sulfate.

Applying equation A-1, the M.MAD in this example equals (1/0.6745) x 0.018 mg L^{-1}= 0.027 mg L^{-1}. The DQO for the *Overall Precision* of GAW precipitation chemistry measurements of sulfate in column 3 of Table A.1 is 0.06 mg L^{-1}. Since 0.027 mg L^{-1}< 0.06 mg L^{-1}, CAPMoN sulfate measurements meet the GAW DQO.

Sampler 1	Sampler 2	e_i	Median(e_i)	$|e_i$ -Median(e_i)$|$	Median $|e_i$-Median(e_i)$|$
5.234	5.453	-0.155	0.003	0.158	0.018
2.343	2.328	0.011		0.008	
2.359	2.335	0.017		0.014	
4.778	4.167	0.432		0.429	
0.736	0.733	0.002		0.001	
0.737	0.767	-0.021		0.024	
3.772	3.793	-0.015		0.018	
1.345	1.329	0.011		0.008	
11.787	11.426	0.255		0.252	
2.987	2.995	-0.006		0.009	
3.080	3.050	0.021		0.018	
1.095	1.098	-0.002		0.005	
1.636	1.631	0.004		0.001	
1.086	1.082	0.003		0.000	
3.207	3.314	-0.076		0.079	
1.756	1.788	-0.023		0.026	
1.772	1.778	-0.004		0.007	
3.118	3.102	0.011		0.008	
1.842	1.765	0.054		0.051	
2.719	2.677	0.030		0.027	
3.231	3.185	0.033		0.030	
1.239	1.289	-0.035		0.038	
4.392	4.354	0.027		0.024	
4.108	4.145	-0.026		0.029	
3.766	3.798	-0.023		0.026	
3.668	3.699	-0.022		0.025	
1.056	0.917	0.098		0.095	
2.560	3.580	-0.721		0.724	
0.863	0.870	-0.005		0.008	
1.202	1.207	-0.004		0.007	
2.812	2.809	0.002		0.001	
0.448	0.441	0.005		0.002	
15.412	14.285	0.797		0.794	
2.224	2.207	0.012		0.015	
2.621	2.631	-0.007		0.010	
0.920	0.928	-0.006		0.009	
1.642	1.601	0.023		0.020	
3.338	3.317	0.015		0.012	
5.910	5.839	0.050		0.047	

A.3   Laboratory Precision

Laboratory Precision is the precision of the analytical measurements made by GAW precipitation chemistry laboratories. The DQOs for *Laboratory Precision* listed in column 4 of Table A.1 were set equal to 1.5 times the analytical precision of the CAPMoN laboratory, as published in Table II of Sirois and Vet (1999). The metric used for the analytical precision of the CAPMoN laboratory was the M.MAD calculated from a large number of between-run replicate analyses. The factor of 1.5 was chosen to expand the tolerance of the DQOs beyond that of a single laboratory to account for the wide variety of analytical methods and measurement capabilities within the GAW Programme.

Laboratories in the GAW Precipitation Chemistry Programme should estimate their *Laboratory Precision* by making between-run replicate analyses of 30 or (preferably) more precipitation chemistry samples covering a broad range of ion concentrations. As with *Overall Precision*, the *Laboratory Precision* is calculated as the M.MAD of these replicate data pairs, as described in Section A.2.

A.4   Overall Inter-Network Bias

Overall Inter-network Bias is a measure of relative accuracy or comparability between different networks making measurements at the same time and place, and hence under the same environmental conditions.

Overall Inter-Network Bias is quantified by making simultaneous side-by-side measurements of two or more networks at the same location. Each network uses its own (a) instrumentation, (b) standard operating procedures, (c) analytical laboratory, and (d) data management methods. This collocated sampling must take place for at least one year to capture the full range of concentrations and environmental conditions that affect the measurements. The multiple networks' data sets are then inter-compared to determine the *Overall Inter-Network Bias.*

The DQOs for *Overall Inter-Network Bias* shown in column 5 of Table A.1 were based on a number of assumptions about collocated sampling, namely:

- Collocated collectors from different networks sample the same population of precipitation events.
- Each network's measurement system produces a unique distribution of sampling data that reflects that network's field and laboratory measurement methods.
- Perfectly comparable networks theoretically can produce identical data distributions but, in practice, are unlikely to do so. Even collocated samplers from the same network typically produce different data distributions.
- Highly comparable networks will typically produce data distributions that differ by at least as much as collocated collectors from a single network. In other words, two different networks will generally differ by more than the *Overall Precision* of an individual network.
- Networks that are significantly different from each other (to a given probability level) will typically have data distributions that differ from each other by as much as or more than the precision of the individual networks.

Based on these assumptions, the DQOs for *Overall Inter-Network Bias* in Table A.1 were set at 1.5 times the inter-network biases measured in a network inter-comparison study that involved two GAW networks, CAPMoN and the United States National Atmospheric Deposition Programme/National Trends Network. The *Overall Inter-Network Biases* measured in this study were published as the M.MAD in Table I of Sirois et al. (2000). The multiplicative factor of 1.5 was chosen arbitrarily as a way of expanding the tolerance in the GAW Programme to account for the wide variation of measurement methods and capabilities across GAW member countries. For Mg^{++} and K^+, the *Overall Inter-Network Bias,* as quantified by the M.MAD in Sirois et al. (2000), was less than the analytical detection limit, so the DQO values in Table A.1 were set equal to the detection limit times 1.5. The DQO for pH> 5.0 was set arbitrarily at twice the DQO for pH< 5.0, because quantitative estimates were not available above pH 5.0.

The *Overall Inter-Network Bias* DQOs for sample depth and standard gauge precipitation depth were set arbitrarily at ±5% for rain, ±15% for snow, and ±10% for mixed rain/snow relative to the total annual precipitation depth for each type of precipitation. The DQOs were expressed in relative terms (i.e., percentages) because of the difficulty in establishing absolute values for the 50 or more national standard gauges (Sevruk and Klemm, 1989) and the more than 14 types of precipitation chemistry samplers in use, each having its own wind speed, exposure, wetting and evaporation errors (see Sevruk 1989 and Goodison et al., 1998 for a discussion of these errors).

GAW members can calculate *Overall Inter-Network Bias* from collocated sampler data by following the method described, below. In this description only two networks are involved though this study could be expanded to multiple networks. Sirois et al. (2000) provide a detailed description of the statistical model and methodology for determining *Overall Inter-Network Bias*.

Calculation of *Overall Inter-Network Bias* is done by collocating a precipitation chemistry sampler and

standard precipitation gauge from each network at the same site. After a minimum of one year of collocated operation, tabulate the paired ion concentrations from the two samplers for all precipitation sampling periods. In cases where the sampling periods of the two networks are the same (e.g., daily-versus-daily, weekly-versus-weekly), this tabulation is straightforward. For cases where the sampling periods are different (e.g., daily-versus-weekly sampling periods), the concentration values of the shorter sampling periods must be converted to precipitation-weighted mean concentrations of the longer sampling periods. For example, if a daily sampler is collocated with a weekly sampler, the daily concentrations must be converted into weekly precipitation-weighted mean concentrations for the same weekly periods as the weekly sampler. To do this, the standard gauge depth must be used as the weighting factor, not the sample depth. Weekly sample depths and standard precipitation gauge depths also must be calculated and tabulated.

1) For each pair of samples for each sampling period, calculate the between-network difference in concentration as $\Delta C_i = C_{1i} - C_{2i}$ where C_1 and C_2 represent the concentrations measured by networks 1 and 2 for sampling periods, $i = 1$ to n. Do this calculation for sample depth and for standard precipitation gauge depth, as well.

2) Test the distribution of the between-network differences, ΔC_i, for normality. A test such as the Kolmogorov-Smirnov test can be used (see, for example, Gibbons, 1985).

3) Determine whether there are statistically significant between-network differences (i.e., statistically significant *Overall Inter-Network Biases*).
   (a) If the between-network differences are normally distributed, use the *student-t test* to determine whether the mean value is significantly different from zero.
   (b) If the distribution of ΔC_i is not normally distributed, use the *sign test* to determine whether the median value of the between-network differences is significantly different from zero. Note that special tests must be used if more than two networks are compared. One such test is the Friedman Rank Sum Test described in Hollander and Wolfe (1973) and used in Vet et al. (1988).

4) For normally distributed ΔC_i, the mean ΔC is an estimate of *Inter-Network Bias.* Otherwise, the median ΔC is an estimate of *Overall Inter-Network Bias.* In either the normal or non-normal case, compare the *Overall Inter-Network Bias* with the DQO in column 5 of Table A.1. If the value is less than or equal to the DQO, the two networks are considered to have met the DQO.

5) For the sample depth and standard precipitation gauge depth, separately calculate the total annual rain, snow, and mixed rain/snow depths for each instrument. Compute the difference of the total depth of rain from instrument 1 with the total depth of rain from instrument 2. Combine the depths of rain from both instruments and calculate the average total depth of rain. Divide the difference of the total rain depth by the average total rain depth. Compare this number with the DQO in Table A.1. Repeat these calculations for snow and for mixed rain/snow.

A.5   Laboratory Inter-Network Bias

Laboratory Inter-Network Bias is a measure of laboratory comparability. The DQOs for *Laboratory Inter-Network Bias* in column 6 of Table A.1 were determined using data from WMO/GAW Inter-laboratory Comparison Studies 36 through 55. These 20 studies were conducted between 2007 and 2016 and the number of participants in each study ranged from 69 to 81 laboratories. Laboratories were challenged with 3 samples, each of different ionic concentrations. These 20 Inter-laboratory Comparison Studies of 3 samples each generated 60 sets of analytical measurements. The frequency distribution of measurements in each set was determined from which an *Acceptable Range* of measurements was calculated, as defined in equation A-3.

$$\textit{Acceptable Range (in percent)} = \pm [0.5 \bullet \frac{IQR}{Median} \bullet 100] \qquad \text{Eq. A-3}$$

IQR designates the interquartile range of the frequency distribution, i.e., the middle 50% of the reported values. The *Acceptable Range* of a set of measurements, then, is half of the IQR expressed in relative terms by dividing by the median of the set.

GAW Guidelines for Precipitation Chemistry Measurements – Appendix A (Updated – 10 July 2020; Previous Versions - 30 June 2018, and Original Version – November 2004)

The *Acceptable Ranges* of the 60 sets of measurements from the Inter-laboratory Comparison Studies were ranked from lowest to highest and the DQO for *Laboratory Inter-Network Bias* for each analyte was set at or close to the 90th percentile. This value was chosen to avoid the influence of outliers and was considered to represent a reasonable and attainable DQO for all GAW laboratories.

Individual GAW laboratories can use the DQO for *Laboratory Inter-Network Bias* in Table A.1 to evaluate their WMO/GAW Inter-laboratory Comparison results by following these steps:

1) For each measurement, calculate your laboratory bias as:

$$Bias = 100 \bullet \frac{(C_{lab} - Median\ C)}{Median\ C}$$

   Eq. A-4

   C_{lab} = laboratory's reported measurement
   Median C = median measurement of all laboratories

2) Compare your laboratory bias to the DQO for *Laboratory Inter-Network Bias* in column 6 of Table A.1. The DQO is met if the laboratory bias is within the range of the tabulated value.

3) Follow the same procedure for each measurement in every sample.

Example: Laboratory reported a sulfate concentration of 2.31 mg L^{-1}. The median sulfate concentration of the 70 participants in the study was 2.54 mg L^{-1}.
Laboratory Bias = 100 • (2.31 – 2.54) / 2.54 = -9.1%.
Laboratory Bias (-9.1%) is outside of the DQO range for sulfate ($\pm 5\%$).
Conclusion - Laboratory did not meet the DQO for sulfate for that sample.

A.6 Calibration Levels

Multi-point calibration curves are mandatory for all analytical measurements in GAW laboratories. As a general rule, at least 5 calibration solutions should be used to formulate each calibration curve. Even more solutions should be used when the analytical range is large, when the calibration curves are not linear, or when many of the concentrations in an analytical run are at or near the analytical detection limit. The concentrations of the calibration solutions should vary at regular intervals between the 2nd and 98th percentile concentrations of the precipitation chemistry samples routinely analyzed by the laboratory. The exception is pH, for which two low-conductivity calibration standards (pH 4.0 and pH 7.0) are recommended. To compensate for using only two calibration standards, several pH check solutions (i.e., stable low-conductivity solutions with a certified pH) should be included in each batch of samples to ensure that the pH meter is in control. Instrument calibration for each analytical measurement is described in detail in the Laboratory Operations section.

A.7 Data Completeness

Data Completeness is an important data quality indicator when measurement data are summarized statistically over monthly, seasonal, quarterly, or annual periods. This is because summary statistics such as the mean, median, and standard deviation can be highly misleading when large amounts of data are missing or deemed invalid for the summary period. It is incumbent upon all reporting agencies to ensure that they have sufficient data before reporting their summary statistics. A detailed analysis of the effects of missing data on precipitation chemistry statistics can be found in Sirois (1990).

Two DQOs for *Data Completeness* were selected for the GAW Precipitation Chemistry Programme:

The *Percent Precipitation Coverage Length (%PCL).* %PCL is the percentage of a summary period (e.g., month, season, year) for which there are valid precipitation measurements. It is important to note

that zero is a valid measurement when no precipitation occurred. In practice, %PCL is the percentage of the summary period that a standard precipitation gauge was operating properly and reporting precipitation depths. When precipitation occurred but there is no measurement of the depth, the depth measurement is missing and there was no knowledge of precipitation occurrence. Example: if a standard precipitation gauge reported data properly for 300 of 365 days in a year (including both precipitation and non-precipitation days), then the %PCL = 300/365 = 82.2%.

The *Percent Total Precipitation* (%TP). %TP for a given summary period (e.g., month, season, year) is the percentage of the total precipitation depth measured by a standard precipitation gauge *that was associated with valid precipitation chemistry measurements*. It is important to note that %TP must be calculated for each analyte, since for any given precipitation sample, one or more of the analyte measurements may be invalid. Example: if a standard precipitation gauge measures a total of 1000 mm in a year but the total standard precipitation gauge depth associated with the valid precipitation chemistry samples was 782 mm, then the %TP = 78.2%.

The DQOs for *Data Completeness* in Table A.1 were taken from Olsen et al. (1990):

GAW DQO for Annual Data Completeness

%PCL:	%TP
Annual $\geq$90%	Annual $\geq$70%
Every quarter $\geq$60%	Every quarter $\geq$60%

GAW DQO for Seasonal Data Completeness

%PCL $\geq$90%
%TP $\geq$70%

Each GAW site should calculate its data completeness values for seasonal, annual, and quarterly periods as follows:

$$\%PCL = 100 \bullet \frac{M}{N} \qquad \text{Eq.A-5}$$

where
  M = number of days in the year, season, or quarter for which data from a properly functioning standard precipitation gauge are available. A standard gauge that detects no precipitation on a dry day is operating properly and is included in M.
  N = total number of days in the year, season, or quarter.

$$\%TP = 100 \bullet \frac{M}{N} \qquad \text{Eq.A-6}$$

Where
  M = total precipitation depth during the summary period having valid analytical chemistry measurements.
  N = total precipitation depth during the summary period.

The calculated values of *%PCL* and *%TP* should be compared against the DQOs in column 8 of Table A.1. Note that networks must satisfy both annual and quarterly *Data Completeness* when reporting summary statistics for annual periods. This prevents biases from occurring in the annual statistics caused by large amounts of missing data within one or more seasons of the year.

The *Data Completeness* DQO for the standard gauge precipitation depth has been set at %PCL = 95% for a given annual period and %PCL = 90% for each of the calendar quarters within the annual period. This means that a standard gauge measurement must be made for every sampling period, with little to no tolerance for lost or missing data. The stricter requirement imposed for the standard gauge measurements is because missing and lost data result in a negative bias in the chemical deposition and loading estimates discussed elsewhere in this manual.

References

Gibbons, J. D. (1985). *Nonparametric Statistical Inference*, Second Edition. Marcel Dekker, Inc, Statistics Textbooks and Monographs: Volume 65, New York, NY.

Goodison, B. E., Louie, P. Y. T. and Yang, D. (1998) WMO Solid Precipitation Measurement Intercomparison Final Report, World Meteorological Organization Report WMO/TD No. 872, Geneva, Switzerland.

Hollander, M. and Wolfe D.A. (1973). *Nonparametric Statistical Methods*. John Wiley & Sons, Inc., New York, NY, 503 p.

Olsen, A. R., Voldner E. C., Bigelow D. S., Chan W. H., Clark T. L., Lusis M. A., Misra P. K. and Vet R. J. (1990) Unified wet deposition data summaries for North America: data summary procedures and results for 1980-1986. *Atmos. Environ.* **24A**(3), 661-672.

Sevruk, B. (1989) Reliability of Precipitation Measurement. International Workshop on Precipitation Measurements, St. Moritz, Switzerland, 3-7 December 1989, Report WMO/TD No. 328, World Meteorological Organization, Geneva, Switzerland.

Sevruk, B. and Klemm, S. (1989) Catalogue of National Standard Precipitation Gauges, World Meteorological Organization Report WMO/TD No. 313, Geneva, Switzerland.

Sirois, A. and Vet, R. (1999) The precision of precipitation chemistry measurements in the Canadian Air and Precipitation Monitoring Network (CAPMoN). *Environ. Monitor. and Assess.* **57**, 301-329.

Sirois, A., Vet, R. J. and Lamb, D. (2000) A comparison of the precipitation chemistry measurements obtained by the CAPMoN and NADP/NTN networks. *Environ. Monitor. and Assess.* **62**, 273-303.

Sirois, A. (1990) The effects of missing data on the calculation of precipitation-weighted mean concentrations in wet deposition. *Atmos. Environ.* **24A**: 9, 2277-2288.

Vet, R. J., Sirois A., Jeffries, D. S., Semkin, R. G., Foster, N. W., Hazlett, P. and Chan, C. H. (1988) Comparison of bulk, wet-only, and wet-plus-dry deposition measurements at the Turkey Lakes Watershed. *Canadian J. of Fish. and Aquat. Sci.* **45**, 26-37.

TABLE A.1. DATA QUALITY OBJECTIVES (DQOS) FOR GAW PRECIPITATION CHEMISTRY MEASUREMENTS (effective 1 January 2018)

Measurement Parameter	Detection Limits	Precision		Inter-Network Bias		Calibration Levels	Data Completeness (See footnotes for PCL & TP)
		Overall	Laboratory	Overall	Laboratory		
pH (pH units)	Not Applicable	pH > 5: ± 0.1 pH < 5: ± 0.03	pH > 5: ± 0.04 pH < 5: ± 0.02	pH > 5: ± 0.24 pH < 5: ± 0.12	pH < 4: ±0.05 pH 4.00–4.99: ±0.07 pH $\geq$ 5.00: ±0.10	4.0 & 7.0 low ionic strength reference solution	90% PCL 70% TP
Conductivity ($\mu S\ cm^{-1}$)	± 2	Not Available	Not Available	Not Available	± 7%	Between 2nd & 98th percentile concentrations	90% PCL 70% TP
Acidity/Alkalinity ($\mu mole\ L^{-1}$)	Not Applicable	Not Available	Not Available	Not Available	± 25%	Between 2nd & 98th percentile concentrations	90% PCL 70% TP
SO_4^{2-} ($mg\ L^{-1}$)	0.06	0.06	0.03	± 0.42	± 5%	Between 2nd & 98th percentile concentrations	90% PCL 70% TP
NO_3^- ($mg\ L^{-1}$)	0.09	0.06	0.03	± 0.36	± 5%	Between 2nd & 98th percentile concentrations	90% PCL 70% TP
Cl^- ($mg\ L^{-1}$)	0.04	0.02	0.02	± 0.05	± 10%	Between 2nd & 98th percentile concentrations	90% PCL 70% TP
F^- ($mg\ L^{-1}$)	Not Available	Not Available	Not Available	Not Available	± 20%	Between 2nd & 98th percentile concentrations	90% PCL 70% TP
NH_4^+ ($mg\ L^{-1}$)	0.02	0.02	0.01	± 0.08	± 7%	Between 2nd & 98th percentile concentrations	90% PCL 70% TP
Ca^{2+} ($mg\ L^{-1}$)	0.02	0.02	0.01	± 0.05	± 15%	Between 2nd & 98th percentile concentrations	90% PCL 70% TP
Mg^{2+} ($mg\ L^{-1}$)	0.01	0.01	0.01	± 0.02	± 10%	Between 2nd & 98th percentile concentrations	90% PCL 70% TP
Na^+ ($mg\ L^{-1}$)	0.02	0.01	0.01	± 0.03	± 10%	Between 2nd & 98th percentile concentrations	90% PCL 70% TP
K^+ ($mg\ L^{-1}$)	0.02	0.01	0.01	± 0.02	± 20%	Between 2nd & 98th percentile concentrations	90% PCL 70% TP
$HCOO^-$ Formate ($mg\ L^{-1}$)	Not Available	Not Available	Not Available	Not Available	Not Available	Between 2nd & 98th percentile concentrations	90% PCL 70% TP
CH_3COO^- Acetate ($mg\ L^{-1}$)	Not Available	Not Available	Not Available	Not Available	Not Available	Between 2nd & 98th percentile concentrations	90% PCL 70% TP
Standard Gauge Precipitation Depth (mm)	0.2	0.2 daily 0.3 weekly	Not Applicable	± 5% for rain ± 15% for snow ± 10%rain/snow	Not Applicable	Between 2nd & 98th percentile depths	95% PCL- annual 90% PCL-quarter
Sample Depth (mm)	0.2	0.1 daily 0.3 weekly	Not Applicable	± 5% for rain ± 15% for snow ± 10%rain/snow	Not Applicable	Between 2nd & 98th percentile depths	90% PCL 70%TP

1)   % Precipitation Coverage Length (% PCL) is a data completeness criterion. It sets the DQO for the percentage of a sampling period (e.g., year, quarter, month) that valid precipitation measurements must be available.
Example: To meet a DQO of 90% PCL for an annual period, there must be valid precipitation measurements for 329 days (or 90%) of the year. In this calculation, zero is a valid measurement when no precipitation occurred. A missing measurement is not valid, whether or not precipitation occurred. For an annual period, each quarter also must meet a 60% PCL.
2)   % Total Precipitation (% TP) is a data completeness criterion. It sets a DQO for the percentage of total precipitation that must have valid measurements. Example: To meet the 70% TP DQO for a sampling period during which 100 mm of precipitation occurred, there must be valid precipitation chemistry measurements for at least 70 mm of precipitation. For an annual period, each quarter also must meet a 60% TP.