A Department of Ecology Report

Replicate Precision for 12 TMDL Studies and Recommendations for Precision Measurement Quality Objectives for Water Quality Parameters

Abstract

The Washington State Department of Ecology (Ecology) Environmental Assessment Program collects water quality samples for developing Total Maximum Daily Loads (TMDLs) and other studies. During these studies, field replicate samples are often collected to analyze the overall precision of both the field sampling and laboratory analysis process.

This report summarizes replicate data from 12 TMDL studies and recommends precision measurement quality objectives for conventional water quality parameters collected by the Environmental Assessment Program and analyzed by Manchester Environmental Laboratory.

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List of Acronyms and Abbreviations

BOD	biochemical oxygen demand
CV	coefficient of variation
DO	dissolved oxygen
DOC	dissolved organic carbon
EA Program	Environmental Assessment Program
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
FC	fecal coliform
MQO	measurement quality objective
P	phosphorus
RPD	relative percent difference
RSD	relative standard deviation
SM	standard method
TDS	total dissolved solids
TMDL	Total Maximum Daily Load (water cleanup plan)
TNVSS	total non-volatile suspended solids
TPN	total persulfate nitrogen
TSS	total suspended solids

Introduction

Measurement quality objectives (MQOs*)* refer to the performance or acceptance criteria for individual data quality indicators such as precision, bias, and lower reporting limit. Precision is defined as a measure of variability in the results of replicate measurements due to random error (Lombard and Kirchmer, 2004).

This report reviews precision results for water quality data from 12 Total Maximum Daily Load (TMDL) studies conducted by the Washington State Department of Ecology (Ecology).

In addition, the report contains recommendations for Watershed Ecology Section standard MQOs for precision of replicate samples. The Watershed Ecology Section is part of Ecology's Environmental Assessment (EA) Program.

All data were exported from Ecology's Environmental Information Management (EIM) web database. Statistics were generated using Microsoft® Excel 2002.

Historical Data Precision

Scope

The 12 TMDL studies discussed in this report were selected based on sampling dates and parameters of interest. The primary selection criteria were projects with conventional water quality data from 1997-2005. Conventional parameters, as opposed to toxics, can be present even in non-polluted surface water. Conventional parameters become a problem when their concentrations increase or decrease to a level that negatively impacts water quality.

The TMDL studies are listed in the References section of this document. Below are the studies, titled as they appear in EIM:

1. Colville River Bacterial TMDL
2. Dungeness/Matriotti Creek TMDL
3. Grays Harbor Fecal Coliform TMDL
4. Henderson TMDL
5. Nisqually TMDL
6. Skokomish River Fecal Coliform TMDL
7. South Prairie Creek TMDL
8. Stillaguamish River Watershed Fecal Coliform, Dissolved Oxygen TMDL
9. Upper Yakima TMDL
10. Walla Walla Bacteria and pH TMDL
11. Wenatchee River TMDL
12. Willapa River TMDL for Fecals and Dissolved Oxygen

Statistical Measures

Common statistics used to measure precision between replicate pairs include the coefficient of variation (CV), relative standard deviation (RSD), and the relative percent difference (RPD). The CV is calculated by dividing the standard deviation of two or more values by their mean. When multiplied by 100 and expressed as a percent, the CV is known as the RSD. RPD is calculated by taking the difference of the two samples and dividing by their mean, multiplying by 100, and expressing the result as a percent.

Results of the Data Review and Data Summary

Table 1 compares the results by parameter and method for all 12 projects. Bacteria replicates accounted for the highest RSD percentages; however, only three of these data sets were above an RSD of 30%, and each of these sets had fewer than 10 replicate pairs.

Table 2 compares the cumulative results by parameter and method for the 12 projects. For bacteria parameters, the RSD of the most probable number methods, which ranged from 37 to 41%, was significantly higher than the membrane filter methods, which ranged from 19 to 24%.

Current Practices for Setting Measurement Quality Objectives

Precision objectives for TMDLs vary between studies. These objectives are written by the author of the *Measurement/Data Quality Objectives* section of the Quality Assurance Project Plan, usually the project manager or the field lead. Most Quality Assurance Project Plans use either RSD, RPD, or log transformed RSD or RPD, as the statistical measure of precision.

General Considerations

The higher percentages of variability in lower results limit the effectiveness of the RSD and RPD statistics for evaluating precision of water quality data, especially with bacteria parameters. For example, replicate results of 2 and 5 cfu/100mL yield a RSD of 61% and a RPD of 86%, whereas results of 22 and 25 yield a RSD of 9% and a RPD of 13%. Each replicate pair is only 3 cfu apart; however, the RSD and RPD between the two pairs are dramatically different. For this reason, projects where the mean of replicate pairs is relatively low may have difficulty meeting precision standards.

The greater the number of replicates, the more accurately the RSD and RPD statistics can chacterize variability. For example, supppose only two fecal coliform replicates are taken during a project, and one replicate pair has a RSD of 20% while the other pair has a RSD of 80%. There is no way of determining which is the *wrong*, or uncharacteristic, value. Both pairs are within the range of RSD% for individual replicate pairs observed by EA Program staff; however, the range of *mean* RSD% from Table 1 is between 14 and 25%. Given this expanded data set, the replicate pair with a RSD of 80% appears to be a statistical outlier, possibly caused by a rare sampling error or a temporary high variability in water quality. The greater the number of replicates taken, the more accurately the frequency of this error or variability can be characterized and the more representative the mean RSD statistic becomes.

To ensure statistical significance, the EA Program requires a minimum of 10 results for calculating bias and confidence intervals (Lombard and Kirchimer, 2004). This same principle applies to precision results; therefore, a minimum of 10 replicate pairs is needed to represent precision for a given set of samples.

Recommendations

Recommendations for All Parameters Except Bacteria

Table 3 contains proposed precision MQOs for conventional parameters, except bacteria parameters which are discussed in the next section. All MQOs are intended to evaluate precision between replicate samples taken in the field, not duplicate aliquots analyzed at Manchester Environmental Laboratory. The laboratory reviews lab duplicates for precision using their own lab control specifications. Manchester Laboratory will not be required to reanalyze field replicate samples that do not meet a given MQO.

These objectives represent the target mean RSD for each project, when the sample set of replicate pairs is 10 or more. Given that the mean RSD may not accurately characterize variability for small sample sets, a minimum of 10 replicate pairs is needed for the samples to be evaluated for precision as a group. For sample sets with less than 10 pairs, precision will be reviewed by the project manager to determine the usability of the data.

Figure 1 illustrates how data would be separated and analyzed:

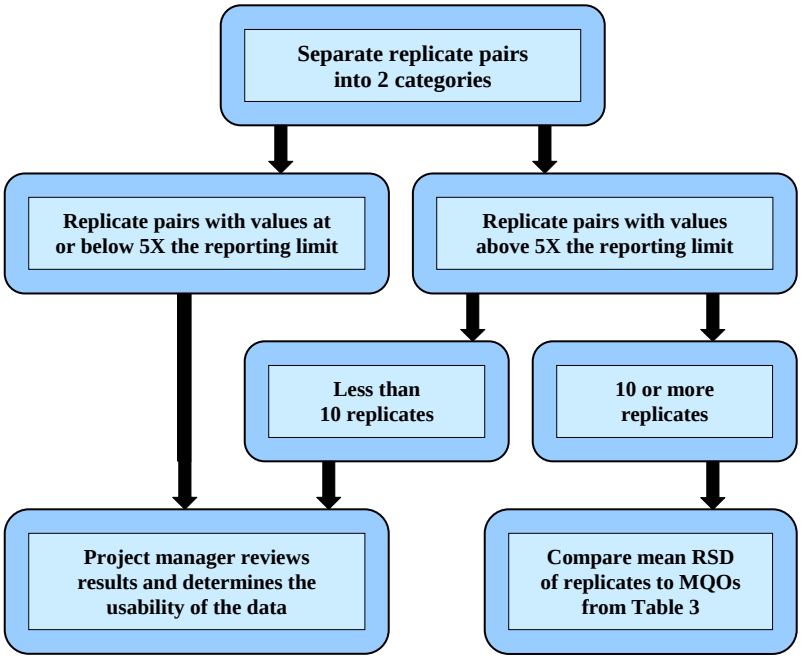

Figure 1. MQO analysis process for replicate precision of all parameters, excluding bacteria.

Recommendations for Bacteria Parameters

Higher variability with low results is especially noticeable for bacteria. Therefore, the precision MQO for bacteria parameters requires that replicate pairs be divided initially into two categories: (1) those pairs with a mean less than or equal to 20 colonies/100 mL and (2) those pairs with a mean greater than 20 colonies. For the second category, the mean RSD of replicate pairs will be evaluated by a cumulative frequency distribution. The project manager will review replicate pairs in the first category, as well as sample sets with less than 10 replicate pairs, to determine the usability of the data.

Figure 2 illustrates how bacteria replicate pairs would be separated and analyzed:

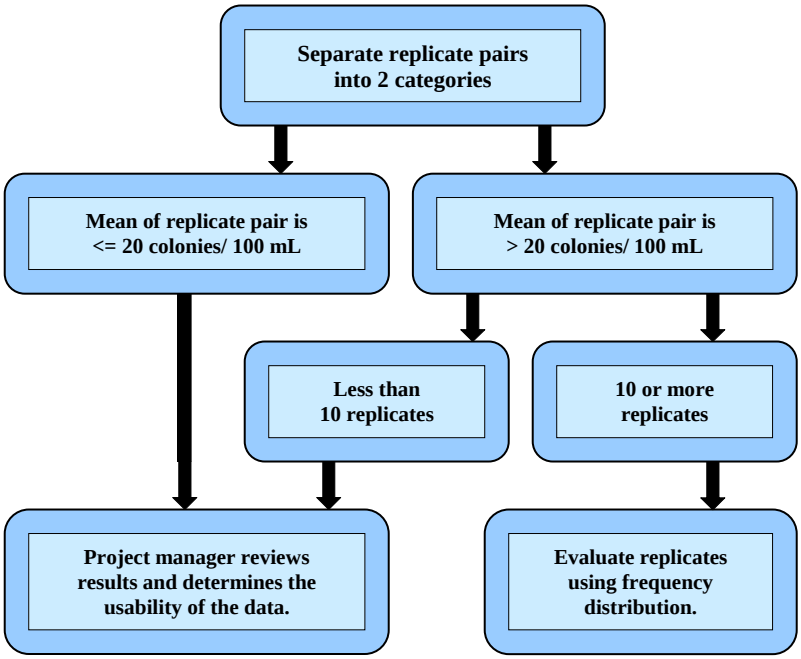

Figure 2. MQO analysis process for replicate precision of bacteria.

A frequency distribution will be used to evaluate precision results based on the percentage of those results that fall at or below a certain %RSD. Under this MQO, 50% of the replicate pairs must be at or below 20% RSD, and 90% of the pairs must be at or below 50% RSD.

Under this MQO, all projects with sample sets of 10 or more for fecal coliform bacteria would fall below the 20% RSD and 50% RSD objectives, respectfully. Table 4 and Figure 3 illustrate how each project would compare to this MQO.

References

Lombard S. and C. Kirchmer, 2004. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-030. www.ecy.wa.gov/biblio/0403030.html

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11b. Carroll, J., S. O'Neal, and S. Golding, 2006. Wenatchee River Basin Dissolved Oxygen, pH, and Phosphorus Total Maximum Daily Load Study. Publication No. 06-03-018. www.ecy.wa.gov/biblio/0603018.html

12. Water Quality Program, 2006. Willapa River Dissolved Oxygen Total Maximum Daily Load: Water Quality Improvement Report and Implementation Plan. Publication No. 06-10-017. www.ecy.wa.gov/biblio/0610017.html

Tables

Table 1. Precision comparison between the 12 projects for all parameters and methods.

Project Name (in EIM)	Parameter	Method	Number of Pairs	Average Mean of Replicate Pairs	Units	Average RPD% of Field Replicate Pairs	Average RSD% of Field Replicate Pairs
Colville River Bacterial TMDL	Alkalinity	EPA310.2	8	169.5	mg/L	7.9	5.6
Stillaguamish River Watershed TMDL	Alkalinity	SM2320	1	37.7	mg/L	1.6	1.1
Walla Walla Bacteria and pH TMDL	Alkalinity	SM2320	18	101.9	mg/L	0.8	0.5
Wenatchee River TMDL	Alkalinity	SM2320	47	47.9	mg/L	1.0	0.7
Walla Walla Bacteria and pH TMDL	Alkalinity	SM2320B	4	41.4	mg/L	4.0	2.8
Wenatchee River TMDL	Alkalinity	SM2320B	3	11.8	mg/L	2.0	1.4
Colville River Bacterial TMDL	Ammonia	EPA350.1	2	0.03	mg/L	5.0	3.5
Dungeness/ Matriotti Creek TMDL	Ammonia	EPA350.1	6	0.10	mg/L	30.1	21.3
South Prairie Creek TMDL	Ammonia	EPA350.1	3	0.01	mg/L	0.0	0.0
Stillaguamish River Watershed TMDL	Ammonia	EPA350.1	7	0.0626	mg/L	9.0	6.4
Henderson TMDL	Ammonia	SM4500NH3H	12	0.05	mg/L	11.8	8.3
Nisqually TMDL	Ammonia	SM4500NH3H	22	0.14	mg/L	5.4	3.8
Stillaguamish River Watershed TMDL	Ammonia	SM4500NH3H	19	0.1153	mg/L	9.4	6.7
Walla Walla Bacteria and pH TMDL	Ammonia	SM4500NH3H	22	0.0773	mg/L	7.7	5.5
Wenatchee River TMDL	Ammonia	SM4500NH3H	10	0.8172	mg/L	18.1	12.8
Stillaguamish River Watershed TMDL	BOD5	EPA405.1	9	3.11	mg/L	7.4	5.2
Walla Walla Bacteria and pH TMDL	BOD5	EPA405.1	1	8.50	mg/L	11.8	8.3
Willapa River TMDL	BOD5	EPA405.1	18	3.42	mg/L	15.7	11.1
Nisqually TMDL	BOD5	SM5210B	1	2.00	mg/L	0.0	0.0
Walla Walla Bacteria and pH TMDL	BOD5	SM5210B	3	4.83	mg/L	9.5	6.7
Stillaguamish River Watershed TMDL	Chloride	EPA300.0	14	2.77	mg/L	2.6	1.8
Upper Yakima TMDL	Chloride	EPA300.0	21	3.14	mg/L	2.0	1.4
Walla Walla Bacteria and pH TMDL	Chloride	EPA300.0	62	11.97	mg/L	3.4	2.4
Wenatchee River TMDL	Chloride	EPA300.0	81	3.61	mg/L	6.4	4.5
Colville River Bacterial TMDL	Chlorophyll	SM10200H3M	8	5.89	µg/L	10.1	7.2
Henderson TMDL	Chlorophyll	SM10200H3M	1	3.07	µg/L	51.5	36.4
Stillaguamish River Watershed TMDL	Chlorophyll	SM10200H3M	7	755.85	µg/L	23.4	17.5
Walla Walla Bacteria and pH TMDL	Chlorophyll	SM10200H3M	34	3.19	µg/L	5.8	4.1
Wenatchee River TMDL	Chlorophyll	SM10200H3M	19	0.71	µg/L	14.1	10.0
Colville River Bacterial TMDL	Conductivity	EPA120.1	12	340.7	µS/cm	0.5	0.5
Skokomish TMDL	Conductivity	EPA120.1	14	65.6	µS/cm	1.5	1.1
Stillaguamish River Watershed TMDL	Conductivity	EPA120.1	7	2252.7	µS/cm	0.3	0.2
Dungeness/ Matriotti Creek TMDL	DO	Meter vs. Winkler	15	10.06	mg/L	1.4	1.0
Henderson TMDL	DO	Meter vs. Winkler	88	8.88	mg/L	5.1	3.6
Nisqually TMDL	DO	Meter vs. Winkler	7	7.38	mg/L	2.6	1.8
Stillaguamish River Watershed TMDL	DO	Meter vs. Winkler	49	10.14	mg/L	6.6	4.7
Walla Walla Bacteria and pH TMDL	DO	Meter vs. Winkler	242	10.26	mg/L	4.9	3.5
Wenatchee River TMDL	DO	Meter vs. Winkler	68	10.70	mg/L	7.6	5.4
Stillaguamish River Watershed TMDL	DOC	EPA415.1	3	3.20	mg/L	4.1	2.9
Upper Yakima TMDL	DOC	EPA415.1	8	3.48	mg/L	10.0	7.1
Walla Walla Bacteria and pH TMDL	DOC	EPA415.1	34	2.46	mg/L	5.5	3.9
Wenatchee River TMDL	DOC	EPA415.1	10	3.91	mg/L	8.9	6.3
Walla Walla Bacteria and pH TMDL	E.coli	EPA0000	21	268.62	cfu/100mL	29.8	21.1
Colville River Bacterial TMDL	E.coli	EPA1103.1	24	274.00	cfu/100mL	29.6	20.9
Stillaguamish River Watershed TMDL	E.coli	EPA1103.1	15	216.23	cfu/100mL	31.0	21.9
Walla Walla Bacteria and pH TMDL	E.coli	EPA1103.1	11	189.41	cfu/100mL	24.0	17.0
Dungeness/ Matriotti Creek TMDL	E.coli	EPA1105	32	214.48	cfu/100mL	27.7	19.6
Henderson TMDL	E.coli	EPA1105	38	209.38	cfu/100mL	30.6	21.7
Nisqually TMDL Study	E.coli	EPA1105	47	77.31	cfu/100mL	27.0	19.1
South Prairie Creek TMDL	E.coli	EPA1105	3	500.67	cfu/100mL	55.5	39.2
Upper Yakima TMDL	E.coli	EPA1105	6	396.00	cfu/100mL	46.2	32.7
Colville River Bacterial TMDL	Enterococci	EPA1600	41	284.89	cfu/100mL	39.0	27.6
South Prairie Creek TMDL	Enterococci	EPA1600	20	765.95	cfu/100mL	25.4	18.0
Stillaguamish River Watershed TMDL	Enterococci	EPA1600	30	810.27	cfu/100mL	28.3	20.0
Colville River Bacterial TMDL	Enterococci	SM17-9230C	18	230.61	cfu/100mL	26.3	18.6
Willapa River TMDL	Enterococci	SM17-9230C	27	54.56	cfu/100mL	20.7	14.7
South Prairie Creek TMDL	Enterococci	SM17-9230C	2	51.25	cfu/100mL	22.5	15.9
Stillaguamish River Watershed TMDL	Enterococci	SM17-9230C	8	56.38	cfu/100mL	45.9	32.4
Colville River Bacterial TMDL	Fecal Coliform	SM16-909C	51	219.94	cfu/100mL	25.6	18.1
Dungeness/ Matriotti Creek TMDL	Fecal Coliform	SM16-909C	45	195.32	cfu/100mL	23.3	16.5
Henderson TMDL	Fecal Coliform	SM16-909C	23	217.83	cfu/100mL	21.4	15.2
Nisqually TMDL Study	Fecal Coliform	SM16-909C	22	70.17	cfu/100mL	20.2	14.3
South Prairie Creek TMDL	Fecal Coliform	SM16-909C	17	229.19	cfu/100mL	35.1	24.8
Stillaguamish River Watershed TMDL	Fecal Coliform	SM16-909C	33	624.10	cfu/100mL	26.5	18.7
Upper Yakima TMDL	Fecal Coliform	SM16-909C	13	434.57	cfu/100mL	27.2	19.3
Walla Walla Bacteria and pH TMDL	Fecal Coliform	SM16-909C	28	219.25	cfu/100mL	25.6	18.1
Wenatchee River TMDL	Fecal Coliform	SM16-909C	35	473.71	cfu/100mL	25.4	18.0
Henderson TMDL	Fecal Coliform	SM9222D	19	145.09	cfu/100mL	22.1	15.6
Wenatchee River TMDL	Fecal Coliform	SM9222D	84	329.85	cfu/100mL	32.4	22.9
Willapa River TMDL	Fecal Coliform	SM9222D	80	733.63	cfu/100mL	24.1	17.0
Nisqually TMDL Study	Fecal Coliform	SM9222D	7	149.79	cfu/100mL	32.4	22.9

Table 1 (continued).

Project Name (in EIM)	Parameter	Method	Number of Pairs	Average Mean of Replicate Pairs	Units	Average RPD% of Field Replicate Pairs	Average RSD% of Field Replicate Pairs
Colville River Bacterial TMDL	NO2/NO3	EPA353.2	8	0.18	mg/L	0.4	0.4
Dungeness/ Matriotti Creek TMDL	NO2/NO3	EPA353.2	17	0.13	mg/L	3.2	2.3
Colville River Bacterial TMDL	NO2/NO3	SM4500NO3I	4	0.26	mg/L	2.1	1.5
Dungeness/ Matriotti Creek TMDL	NO2/NO3	SM4500NO3I	3	0.24	mg/L	0.5	0.4
Henderson TMDL	NO2/NO3	SM4500NO3I	19	1.44	mg/L	3.5	2.5
Nisqually TMDL	NO2/NO3	SM4500NO3I	18	0.89	mg/L	11.5	8.1
South Prairie Creek TMDL	NO2/NO3	SM4500NO3I	3	0.43	mg/L	0.5	0.3
Stillaguamish River Watershed TMDL	NO2/NO3	SM4500NO3I	25	0.35	mg/L	2.4	1.7
Walla Walla Bacteria and pH TMDL	NO2/NO3	SM4500NO3I	37	1.392	mg/L	0.9	0.7
Wenatchee River TMDL	NO2/NO3	SM4500NO3I	29	0.722	mg/L	2.3	1.6
Colville River Bacterial TMDL	Ortho P	EPA365.3M	12	0.02	mg/L	3.6	2.6
Dungeness/ Matriotti Creek TMDL	Ortho P	EPA365.3M	9	0.02	mg/L	10.7	7.5
South Prairie Creek TMDL	Ortho P	EPA365.3M	3	0.01	mg/L	8.4	5.9
Stillaguamish River Watershed TMDL	Ortho P	EPA365.3M	6	0.024	mg/L	4.3	3.0
Henderson TMDL	Ortho P	SM4500PG	16	0.06	mg/L	14.5	10.3
Nisqually TMDL	Ortho P	SM4500PG	22	0.20	mg/L	1.6	1.2
Stillaguamish River Watershed TMDL	Ortho P	SM4500PG	19	0.041	mg/L	7.7	5.4
Walla Walla Bacteria and pH TMDL	Ortho P	SM4500PG	36	0.249	mg/L	1.1	0.8
Wenatchee River TMDL	Ortho P	SM4500PG	33	0.155	mg/L	11.1	7.8
Wenatchee River TMDL	TDS	EPA160.1	27	48.907	mg/L	7.3	5.1
Wenatchee River TMDL	TDS	SM2540C	2	408.00	mg/L	1.5	1.0
Stillaguamish River Watershed TMDL	TNVSS	EPA160.4	3	47.833	mg/L	10.8	7.6
Walla Walla Bacteria and pH TMDL	TNVSS	EPA160.4	9	6.722	mg/L	8.0	5.6
Wenatchee River TMDL	TNVSS	EPA160.4	9	5.556	mg/L	15.2	10.8
Walla Walla Bacteria and pH TMDL	TNVSS	SM2540E	6	112.833	mg/L	10.6	7.5
Colville River Bacterial TMDL	TOC	EPA415.1	12	2.25	mg/L	4.8	3.4
Stillaguamish River Watershed TMDL	TOC	EPA415.1	13	4.431	mg/L	2.7	1.9
Upper Yakima TMDL	TOC	EPA415.1	8	4.200	mg/L	12.8	9.0
Walla Walla Bacteria and pH TMDL	TOC	EPA415.1	35	2.662	mg/L	5.8	4.1
Wenatchee River TMDL	TOC	EPA415.1	23	2.411	mg/L	10.6	7.5
Walla Walla Bacteria and pH TMDL	Total P	EPA200.8	9	0.417	mg/L	11.3	8.0
Henderson TMDL	Total P	EPA200.8M	9	0.06	mg/L	3.9	2.8
Nisqually TMDL	Total P	EPA200.8M	3	0.36	mg/L	12.1	8.5
Colville River Bacterial TMDL	Total P	EPA365.1	12	0.06	mg/L	7.4	5.2
Dungeness/ Matriotti Creek TMDL	Total P	EPA365.1	14	0.03	mg/L	9.6	6.8
South Prairie Creek TMDL	Total P	EPA365.1	3	0.02	mg/L	10.2	7.2
Stillaguamish River Watershed TMDL	Total P	EPA365.1	7	0.059	mg/L	3.0	2.1
Stillaguamish River Watershed TMDL	Total P	SM4500PH	8	0.459	mg/L	5.7	4.0
Wenatchee River TMDL	Total P	SM4500PH	18	0.486	mg/L	11.6	8.2
Henderson TMDL	Total P	SM4500PI	7	0.06	mg/L	9.8	6.9
Nisqually TMDL	Total P	SM4500PI	14	0.27	mg/L	2.4	1.7
Stillaguamish River Watershed TMDL	Total P	SM4500PI	11	0.511	mg/L	7.4	5.3
Walla Walla Bacteria and pH TMDL	Total P	SM4500PI	37	0.234	mg/L	2.5	1.8
Wenatchee River TMDL	Total P	SM4500PI	5	0.932	mg/L	8.7	6.2
Dungeness/ Matriotti Creek TMDL	TPN	SM4500NB	14	0.18	mg/L	5.8	4.1
Henderson TMDL	TPN	SM4500NB	19	1.84	mg/L	10.2	7.2
Nisqually TMDL	TPN	SM4500NB	21	1.01	mg/L	3.3	2.3
South Prairie Creek TMDL	TPN	SM4500NB	3	0.49	mg/L	7.2	5.1
Stillaguamish River Watershed TMDL	TPN	SM4500NB	26	0.661	mg/L	5.8	4.1
Walla Walla Bacteria and pH TMDL	TPN	SM4500NB	37	1.410	mg/L	7.2	5.1
Wenatchee River TMDL	TPN	SM4500NB	34	0.979	mg/L	12.0	8.5
Skokomish TMDL	TSS	EPA160.2	16	6.69	mg/L	11.1	7.8
South Prairie Creek TMDL	TSS	EPA160.2	1	1.00	mg/L	0.0	0.0
Stillaguamish River Watershed TMDL	TSS	EPA160.2	37	205.189	mg/L	21.7	15.4
Upper Yakima TMDL	TSS	EPA160.2	71	21.697	mg/L	11.7	8.1
Walla Walla Bacteria and pH TMDL	TSS	EPA160.2	29	5.569	mg/L	13.3	9.4
Wenatchee River TMDL	TSS	EPA160.2	16	5.813	mg/L	13.0	9.2
Walla Walla Bacteria and pH TMDL	TSS	SM2540D	26	72.308	mg/L	13.6	9.6
Wenatchee River TMDL	TSS	SM2540D	69	14.15	mg/L	20.3	14.3
Dungeness/ Matriotti Creek TMDL	Turbidity	SM2130	17	7.26	NTU	13.5	9.6
Upper Yakima TMDL	Turbidity	SM2130	67	8.829	NTU	15.0	10.6
Wenatchee River TMDL	Turbidity	SM2130	29	3.583	NTU	9.0	6.4

Table 2. Replicate precision data summary for all results combined.

Parameter	Reporting Limit	Method (Technique)	Number of Pairs	Average Mean of Replicate Pairs	Average RPD% of Field Replicate Pairs	Average RSD% of Field Replicate Pairs
Alkalinity	5 mg/L	SM2320	65	0.64	4.41	0.00
	5 mg/L	SM2320B	7	2.24	17.04	0.53
Ammonia	0.01 mg/L	SM4500NH3H	82	6.46	43.68	2.70
	0.01 mg/L	EPA350.1	12	14.94	6.25	6.98
BOD5	2 mg/L	EPA405.1	1	8.32	0.00	8.32
	2 mg/L	SM5210B	2	10.10	0.76	10.10
Chloride	0.1 mg/L	EPA300.0	178	3.20	19.50	0.96
Chlorophyll	0.05 µg/L	SM10200H3M	69	7.90	70.73	4.66
Conductivity	1 µS/cm	EPA120.1	33	0.62	12.58	0.21
DO	1 mg/L	Probe v. Winkler	469	3.80	1.65	2.26
DOC	1 mg/L	EPA415.1	55	4.73	4.81	3.01
E.coli	1 cfu/100mL	EPA1103.1(MF)	74	21.10	9.61	17.62
	1.8 mpn/100ml	EPA1104(MPN)	83	37.38	76.55	35.36
	1 cfu/100mL	EPA1105(MF)	175	22.90	15.91	17.09
	1 cfu/100mL	EPA0000(MF)	39	22.88	9.05	15.71
Enterococci	1 cfu/100mL	EPA1600(MF)	106	24.07	26.43	17.72
	1 cfu/100mL	SM17-9230C(MF)	72	21.24	5.79	15.06
Fecal Coliform	1 cfu/100mL	SM16-909C(MF)	512	19.94	34.23	15.37
	1.8 mpn/100ml	SM16-908C(MPN)	23	39.43	6.46	35.36
	1 cfu/100 mL	SM9222D(MF)	232	23.19	15.83	15.91
	1.8 mpn/100ml	SM9221E2(MPN)	65	41.32	51.40	37.94
NO2/NO3	0.01 mg/L	SM4500NO3I	137	2.31	0.00	0.27
	0.05 mg/L	EPA353.2	25	1.63	0.00	0.55
Ortho P	0.01 mg/L	EPA365.3M	30	4.49	0.00	1.82
	0.003 mg/L	SM4500PG	139	4.59	0.00	0.84
TNVSS	1 mg/L	EPA160.4	21	8.12	0.00	0.00
	1 mg/L	SM2540E	6	7.47	0.00	8.24
TOC	1 mg/L	EPA415.1	91	5.00	0.00	3.63
Total P	0.01 mg/L	SM4500PH	26	6.90	0.00	4.70
	0.01 mg/L	SM4500PI	74	3.06	0.00	1.88
	0.01 mg/L	EPA200.8	21	5.83	0.00	3.83
	0.01 mg/L	EPA365.1	36	5.40	0.00	3.54
TPN	0.025 mg/L	SM4500NB	199	5.20	0.00	1.91
TDS	1 mg/L	EPA160.1	27	5.15	0.00	2.24
	1 mg/L	SM2540C	2	1.03	0.00	1.03
TSS	1 mg/L	EPA160.2	169	10.58	0.00	2.77
	1 mg/L	SM2540D	95	11.98	0.00	4.29
Turbidity	0.5 NTU	SM2130	110	9.19	0.00	4.56

Table 3. Measurement quality objectives for conventional water quality parameters.

Parameter	Preferred Method	Unit	Precision MQO
Alkalinity	SM2320	mg/L	10% RSD
Ammonia	SM4500NH3H	mg/L	10% RSD
Biochemical Oxygen Demand	SM5210B	mg/L	25% RSD
Chloride	EPA300.0	mg/L	5% RSD
Chlorophyll a	SM10200H3M	µg/L	20% RSD
Conductivity, Specific	EPA120.1	umhos/cm	5% RSD
Dissolved Organic Carbon	EPA415.1	mg/L	10% RSD
Dissolved Oxygen	Winkler	mg/L	5% RSD
Nitrite/Nitrate	SM4500NO3I	mg/L	10% RSD
Ortho-Phosphate	SM4500PG	mg/L	10% RSD
Total Dissolved Solids	EPA160.1	mg/L	15% RSD
Total Non-Volatile Suspended Solids	EPA160.4	mg/L	15% RSD
Total Organic Carbon	EPA415.1	mg/L	10% RSD
Total Persulfate Nitrogen	SM4500NB	mg/L	10% RSD
Total Phosphorus	ICP-MS (200.8)	mg/L	10% RSD
Total Suspended Solids	SM2540D	mg/L	15% RSD
Turbidity	SM2130	NTU	15% RSD

MQOs listed above are used to evaluate precision based on the average %RSD for a set of replicate pairs from a given project.

Table 4. Variability (%RSD) that 50% and 90% of the replicate pairs are less than or equal to.

Project Name	50% of pairs <= to:	90% of pairs <= to:
1. Colville River Bacterial TMDL	14% RSD	35% RSD
2. Dungeness/Matriotti Creek TMDL	14% RSD	33% RSD
3. Grays Harbor FC TMDL*	--	--
4. Henderson TMDL	12% RSD	34% RSD
5. Nisqually TMDL	10% RSD	29% RSD
6. Skokomish River FC TMDL	9% RSD	41% RSD
7. South Prairie Creek TMDL	17% RSD	29% RSD
8. Stillaguamish River FC and DO TMDL	15% RSD	38% RSD
9. Upper Yakima TMDL	8% RSD	48% RSD
10. Walla Walla Bacteria and pH TMDL	12% RSD	44% RSD
11. Wenatchee River TMDL	16% RSD	48% RSD
12. Willapa River TMDL for FC and DO	10% RSD	36% RSD

* Grays Harbor is not included because the laboratory analysis method used was the fecal coliform most probable number (MPN) method, not the standard fecal coliform membrane filter (MF) method used by the Environmental Assessment Program.

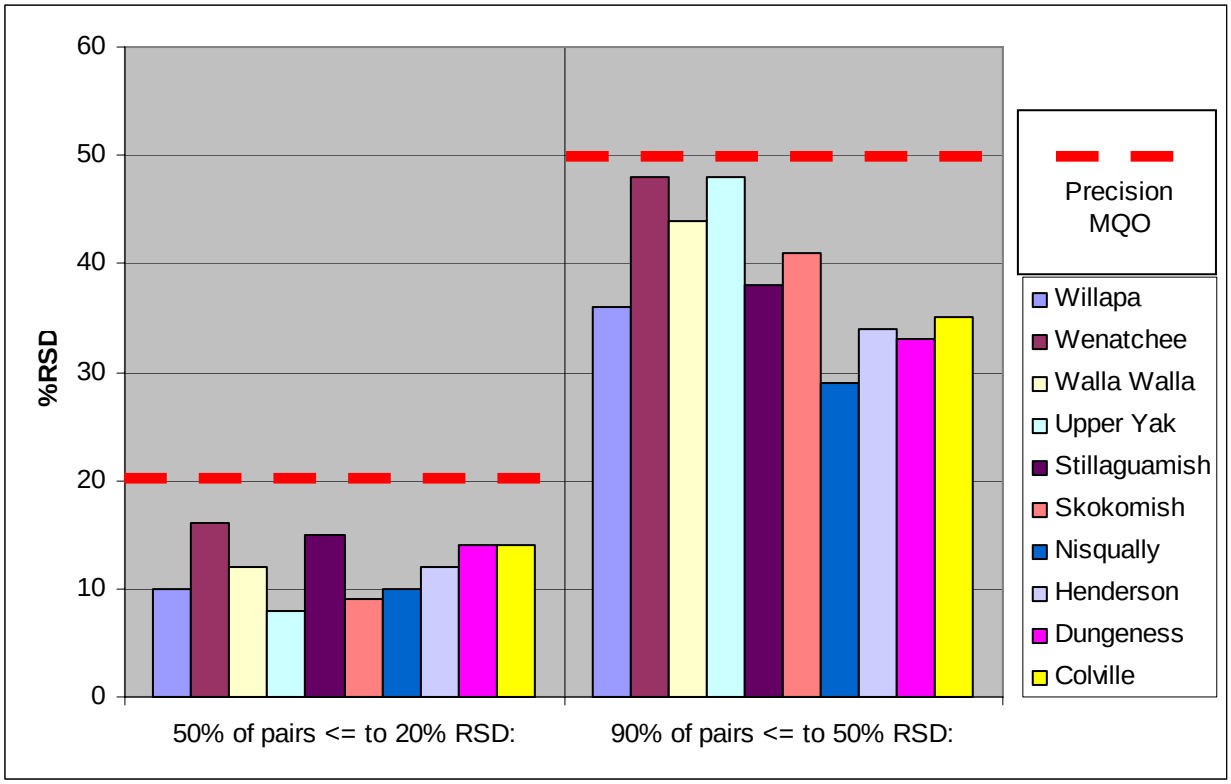

Figure 3. Data from Table 4 compared to the proposed measurement quality objective.