Round Up Method, Binomial Method and Statistical Confidence

ADEQ has historically employed a "rounding up method" during the data evaluation process to avoid listing a water body as non-attainment when it actually is attaining (Type I error). This method allowed ADEQ to assess the data in the same way as the samples are collected, as whole samples. Not using the rounding method would result in the assessment of partial samples, which does not reflect actual field sampling procedures. Even though this method has been historically accepted by EPA, other more statically based methods (Binomial Method) are becoming more readily used during the assessment process.

The EPA July 2002 Consolidated Assessment and Listing Methodology, First Edition, states, "EPA does not recommend making decisions based on small data sets of water column chemistry for attainment" because of the "large degree of uncertainty associated with basing impairment decisions on small datasets (Iowa, 2012)". EPA goes on to state that states should determine the acceptable level of decision error they are willing to accept during the decision making process. In addition, EPA suggests employing statistical methods to help achieve the decided upon acceptable level of error. EPA also lists and discusses several different statistical methods that may be employed by the states.

The Nebraska Department of Environmental Quality, Methodologies for Water Assessments and Development of the 2016 Integrated Report for Nebraska, June 2015, Section 2.5.3 - Estimating the Uncertainty Associated with Criteria Violations in Determining Beneficial Use Impairment (Note: Much of the following discussion is from: *"A Nonparametric Procedure for Listing and Delisting Impaired Waters Based on Criterion Exceedances"* Lin et.al., 2000; *"Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data, 2002"* TNRCC, 2001; and *"A Modern Approach to Statistics"* Iman and Conover, 1983) stated:

> For a given water quality parameter measured in a waterbody, the sample of water quality violations are an estimator of the *true exceedance probability – " p"* for the parameter. Since the estimator varies in a random manner from sample to sample, inferences about the true exceedance probability based on the estimator will be subject to uncertainty. The degree of uncertainty depends on the exceedances and the sample size – the smaller the sample size is, the greater the uncertainty will be. Therefore, the number of water quality violations should not be used for the determination of waterbody impairment without considering the sample size. The reliability of the estimated exceedance probability relating to sample size should be addressed. The *binomial method* is a useful tool for estimating the probability of committing a *Type I* or *Type II error* for situations when the analysis is based on a single variable that falls into one of two categories; the measurement is either equal to or less than a criterion, or greater than the criterion.

Likewise, the Iowa Department of Natural Resources has developed an alternate approach for assessing water quality data that "(1) avoid the need to compare raw percentage values to state criteria to identify impairments and (2) incorporate estimates of the numbers of samples and the corresponding number of violations that represent a significant exceedance of the 10 percent rule. The state of Nebraska (NDEQ 2006), drawing on information from Lin et al. (2000), adopted an assessment approach where the sample sizes and the corresponding number of violations needed to identify a significant exceedance of the 10%-rule with greater than 90 percent confidence are specified. This approach is based on the binomial method for estimating the probability of committing Type I and Type II errors".

In order to determine the level of decision error occurring during the assessment process and reduce the probability of committing Type I and Type II errors, ADEQ proposes to use the binomial method in lieu of the "rounding up method". Table 1 compares the two methods and notes the number of samples, the number of exceedances needed for an impairment listing, and the confidence level that corresponds to that listing. The table has the requirements for the 10%, 20%, and 25% exceedance rates.

Methodology for Iowa's 2012 Water Quality Assessment, Listing, and Reporting Pursuant to Sections 305(b) and 303(d) of the Federal Clean Water Act. March 25, 2013.

Table 1. Comparison of Confdence Levels using the Binomail Method versus the Round Up Method.

Number of Exceedance Needed for Non Attainment 20% Exceedance Rate					Number of Exceedance Needed for Non Attainment 25% Exceedance Rate					Number of Exceedance Needed for Non Attainment 10% Exceedance Rate				
Number of Samples	Binomial Method	Confidence Level	Round Up Method	Confidence Level	Number of Samples	Binomial Method	Confidence Level	Round Up Method	Confidence Level	Number of Samples	Binomial Method	Confidence Level	Round Up Method	Confidence Level
10	4	0.9672	3	0.8791	10	4	0.9219	4	0.9219	10	2	0.9298	2	0.9298
11	4	0.9496	4	0.9496	11	5	0.9657	4	0.8854	11	2	0.9104	3	0.9815
12	4	0.9274	4	0.9274	12	5	0.9456	4	0.8424	12	3	0.9744	3	0.9744
13	4	0.9009	4	0.9009	13	5	0.9198	5	0.9198	13	3	0.9658	3	0.9658
14	5	0.9561	4	0.8702	14	6	0.9617	5	0.8883	14	3	0.9559	3	0.9559
15	5	0.9389	4	0.8358	15	6	0.9434	5	0.8516	15	3	0.9444	3	0.9444
16	5	0.9183	5	0.9183	16	6	0.9204	5	0.8103	16	3	0.9316	3	0.9316
17	6	0.9623	5	0.8943	17	7	0.9598	6	0.8929	17	3	0.9174	3	0.9174
18	6	0.9487	5	0.8671	18	7	0.9431	6	0.8610	18	3	0.9018	3	0.9018
19	6	0.9324	5	0.8369	19	7	0.9225	6	0.8251	19	4	0.9648	3	0.8850
20	6	0.9133	5	0.8042	20	8	0.9591	6	0.7858	20	4	0.9568	3	0.8670
21	7	0.9569	6	0.8915	21	8	0.9439	7	0.8701	21	4	0.9478	4	0.9478
22	7	0.9439	6	0.8670	22	8	0.9254	7	0.8385	22	4	0.9379	4	0.9379
23	7	0.9285	6	0.8402	23	8	0.9037	7	0.8037	23	4	0.9269	4	0.9269
24	7	0.9108	6	0.8111	24	9	0.9453	7	0.7662	24	4	0.9149	4	0.9149
25	8	0.9532	6	0.7800	25	9	0.9287	8	0.8506	25	4	0.9020	4	0.9020
26	8	0.9408	7	0.8687	26	9	0.9091	8	0.8195	26	5	0.9601	4	0.8882
27	8	0.9263	7	0.8444	27	10	0.9472	8	0.7859	27	5	0.9529	4	0.8734
28	8	0.9100	7	0.8182	28	10	0.9321	8	0.7501	28	5	0.9450	4	0.8579
29	9	0.9507	7	0.7903	29	10	0.9145	9	0.8337	29	5	0.9363	4	0.8416
30	9	0.9389	7	0.7608	30	11	0.9493	9	0.8034	30	5	0.9268	4	0.8245
31	9	0.9254	8	0.8492	31	11	0.9356	9	0.7710	31	5	0.9166	5	0.9166
32	9	0.9102	8	0.8254	32	11	0.9196	9	0.7367	32	5	0.9056	5	0.9056
33	10	0.9492	8	0.8000	33	11	0.9013	10	0.8190	33	6	0.9583	5	0.8939
34	10	0.9380	8	0.7731	34	12	0.9390	10	0.7894	34	6	0.9519	5	0.8815
35	10	0.9253	8	0.7450	35	12	0.9244	10	0.7581	35	6	0.9448	5	0.8684
36	10	0.9111	9	0.8324	36	12	0.9078	10	0.7251	36	6	0.9372	5	0.8546
37	11	0.9483	9	0.8091	37	13	0.9423	11	0.8060	37	6	0.9289	5	0.8402
38	11	0.9377	9	0.7845	38	13	0.9290	11	0.7772	38	6	0.9200	5	0.8253
39	11	0.9258	9	0.7586	39	13	0.9138	11	0.7469	39	6	0.9106	5	0.8097
40	11	0.9125	9	0.7318	40	14	0.9456	11	0.7151	40	6	0.9005	5	0.7937
41	12	0.9479	10	0.8177	41	14	0.9334	12	0.7944	41	7	0.9523	6	0.8898
42	12	0.9379	10	0.7950	42	14	0.9195	12	0.7664	42	7	0.9461	6	0.8786
43	12	0.9267	10	0.7711	43	14	0.9038	12	0.7370	43	7	0.9393	6	0.8667
44	12	0.9142	10	0.7462	44	15	0.9374	12	0.7064	44	7	0.9321	6	0.8544

Number of Exceedance Needed for Non Attainment 20% Exceedance Rate				
Number of Samples	Binomial Method	Confidence Level	Round Up Method	Confidence Level
45	12	0.9005	10	0.7205
46	13	0.9385	11	0.8048
47	13	0.9279	11	0.7826
48	13	0.9162	11	0.7595
49	13	0.9034	11	0.7355
50	14	0.9393	11	0.7107
51	14	0.9293	12	0.7933
52	14	0.9183	12	0.7717
53	14	0.9063	12	0.7492
54	15	0.9403	12	0.7260
55	15	0.9309	12	0.7021
56	15	0.9205	13	0.7830
57	15	0.9092	13	0.7619
58	16	0.9415	13	0.7401
59	16	0.9325	13	0.7175
60	16	0.9228	13	0.6944
61	16	0.9121	14	0.7737
62	16	0.9005	14	0.7531
63	17	0.9343	14	0.7318
64	17	0.9250	14	0.7100
65	17	0.9150	14	0.6876
66	17	0.9040	15	0.7652
67	18	0.9361	15	0.7451
68	18	0.9273	15	0.7244
69	18	0.9178	15	0.7032
70	18	0.9075	15	0.6814
71	19	0.9379	16	0.7575
72	19	0.9296	16	0.7378
73	19	0.9205	16	0.7176
74	19	0.9108	16	0.6970
75	19	0.9003	16	0.6759
76	20	0.9318	17	0.7504
77	20	0.9232	17	0.7312
78	20	0.9140	17	0.7115
79	20	0.9040	17	0.6913
80	21	0.9340	17	0.6708

Number of Exceedance Needed for Non Attainment 25% Exceedance Rate				
Number of Samples	Binomial Method	Confidence Level	Round Up Method	Confidence Level
45	15	0.9247	13	0.7841
46	15	0.9104	13	0.7568
47	16	0.9413	13	0.7282
48	16	0.9296	13	0.6986
49	16	0.9164	14	0.7747
50	16	0.9017	14	0.7481
51	17	0.9341	14	0.7203
52	17	0.9219	14	0.6916
53	17	0.9084	15	0.7662
54	18	0.9383	15	0.7402
55	18	0.9271	15	0.7132
56	18	0.9146	15	0.6853
57	18	0.9008	16	0.7585
58	19	0.9318	16	0.7331
59	19	0.9203	16	0.7067
60	19	0.9075	16	0.6796
61	20	0.9363	17	0.7514
62	20	0.9256	17	0.7265
63	20	0.9137	17	0.7008
64	20	0.9007	17	0.6744
65	21	0.9305	18	0.7448
66	21	0.9195	18	0.7205
67	21	0.9074	18	0.6954
68	22	0.9350	18	0.6696
69	22	0.9248	19	0.7387
70	22	0.9136	19	0.7149
71	22	0.9013	19	0.6904
72	23	0.9297	19	0.6652
73	23	0.9193	20	0.7330
74	23	0.9078	20	0.7097
75	24	0.9343	20	0.6857
76	24	0.9246	20	0.6612
77	24	0.9139	21	0.7278
78	24	0.9023	21	0.7049
79	25	0.9295	21	0.6814
80	25	0.9195	21	0.6574

Number of Exceedance Needed for Non Attainment 10% Exceedance Rate				
Number of Samples	Binomial Method	Confidence Level	Round Up Method	Confidence Level
45	7	0.9243	6	0.8415
46	7	0.9160	6	0.8281
47	7	0.9072	6	0.8143
48	8	0.9537	6	0.8000
49	8	0.9481	6	0.7853
50	8	0.9421	6	0.7702
51	8	0.9357	7	0.8671
52	8	0.9288	7	0.8559
53	8	0.9215	7	0.8442
54	8	0.9138	7	0.8321
55	8	0.9056	7	0.8196
56	9	0.9506	7	0.8066
57	9	0.9452	7	0.7934
58	9	0.9395	7	0.7797
59	9	0.9334	7	0.7658
60	9	0.9269	7	0.7516
61	9	0.9201	8	0.8477
62	9	0.9128	8	0.8366
63	9	0.9052	8	0.8252
64	10	0.9484	8	0.8134
65	10	0.9433	8	0.8013
66	10	0.9379	8	0.7888
67	10	0.9321	8	0.7761
68	10	0.9260	8	0.7631
69	10	0.9195	8	0.7498
70	10	0.9127	8	0.7363
71	10	0.9056	9	0.8309
72	11	0.9470	9	0.8201
73	11	0.9421	9	0.8089
74	11	0.9369	9	0.7975
75	11	0.9315	9	0.7858
76	11	0.9257	9	0.7738
77	11	0.9196	9	0.7615
78	11	0.9132	9	0.7490
79	11	0.9066	9	0.7363
80	12	0.9462	9	0.7234

Number of Exceedance Needed for Non Attainment 20% Exceedance Rate				
Number of Samples	Binomial Method	Confidence Level	Round Up Method	Confidence Level
81	21	0.9259	18	0.7438
82	21	0.9171	18	0.7250
83	21	0.9077	18	0.7058
84	22	0.9361	18	0.6861
85	22	0.9284	18	0.6661
86	22	0.9201	19	0.7378
87	22	0.9111	19	0.7193
88	22	0.9016	19	0.7005
89	23	0.9309	19	0.6813
90	23	0.9230	19	0.6617
91	23	0.9145	20	0.7321
92	23	0.9054	20	0.7141
93	24	0.9333	20	0.6956
94	24	0.9258	20	0.6768
95	24	0.9177	20	0.6577
96	24	0.9090	21	0.7269
97	25	0.9356	21	0.7092
98	25	0.9284	21	0.6911
99	25	0.9208	21	0.6727
100	25	0.9125	21	0.6540

Number of Exceedance Needed for Non Attainment 25% Exceedance Rate				
Number of Samples	Binomial Method	Confidence Level	Round Up Method	Confidence Level
81	25	0.9087	22	0.7228
82	26	0.9340	22	0.7004
83	26	0.9247	22	0.6773
84	26	0.9146	22	0.6538
85	26	0.9036	23	0.7182
86	27	0.9296	23	0.6961
87	27	0.9201	23	0.6736
88	27	0.9098	23	0.6505
89	28	0.9341	24	0.7139
90	28	0.9252	24	0.6922
91	28	0.9156	24	0.6700
92	28	0.9052	24	0.6474
93	29	0.9300	25	0.7098
94	29	0.9210	25	0.6884
95	29	0.9112	25	0.6667
96	30	0.9344	25	0.6445
97	30	0.9260	26	0.7059
98	30	0.9168	26	0.6849
99	30	0.9069	26	0.6635
100	31	0.9307	26	0.6417

Number of Exceedance Needed for Non Attainment 10% Exceedance Rate				
Number of Samples	Binomial Method	Confidence Level	Round Up Method	Confidence Level
81	12	0.9415	10	0.8163
82	12	0.9366	10	0.8057
83	12	0.9314	10	0.7948
84	12	0.9259	10	0.7837
85	12	0.9202	10	0.7724
86	12	0.9142	10	0.7608
87	12	0.9079	10	0.7490
88	12	0.9013	10	0.7370
89	13	0.9413	10	0.7249
90	13	0.9366	10	0.7125
91	13	0.9317	11	0.8034
92	13	0.9265	11	0.7931
93	13	0.9211	11	0.7825
94	13	0.9154	11	0.7717
95	13	0.9095	11	0.7607
96	13	0.9033	11	0.7495
97	14	0.9415	11	0.7381
98	14	0.9370	11	0.7266
99	14	0.9323	11	0.7149
100	14	0.9274	11	0.7030