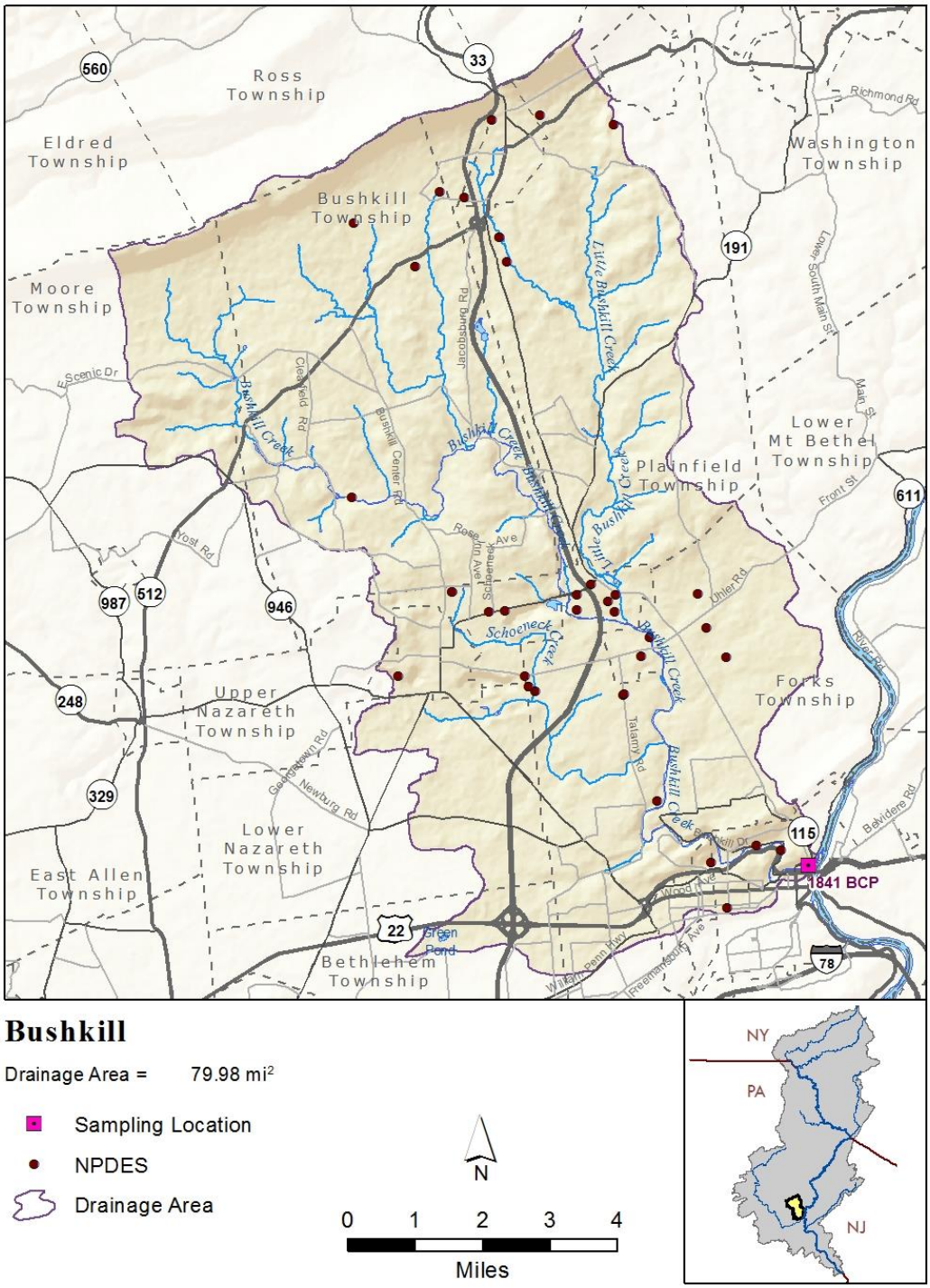
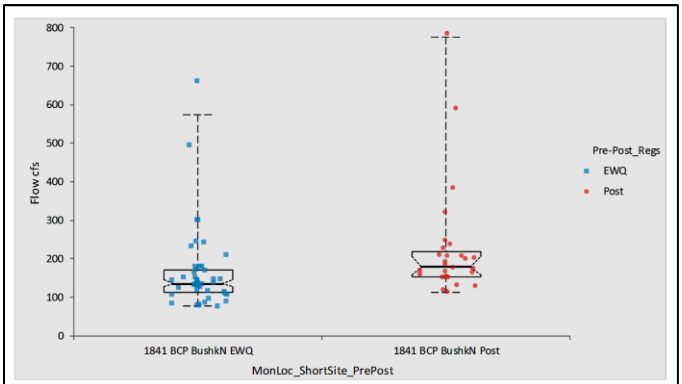
Chapter 19: 1841 BCP Bushkill Creek, Northampton County, PA



Analysis of flow differences between the EWQ and post-EWQ periods:



N	75					
Flow cfs by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	76.0	112.8	135.7	171.3	659.9	58.5
1841 BCP BushkN Post	112.0	153.0	179.6	218.8	784.4	65.8

Post-EWQ flow was higher than baseline EWQ flow by about 45 cfs. Fewer samples were collected in the post-EWQ period. The range of flow conditions sampled was roughly equal, so water quality analyses should not be affected except for comparisons of water quality at very low flow conditions (<112 cfs).

Kruskal-Wallis test

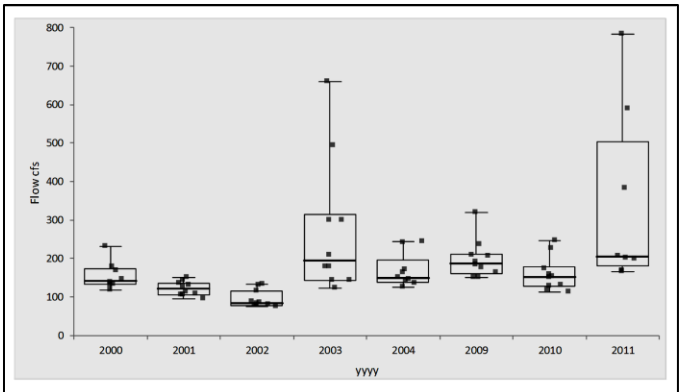
Flow cfs by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	47	2165.1	46.07
1841 BCP BushkN Post	28	3634.3	129.80

H statistic	12.21
X^2 approximation	12.21
DF	1
p-value	0.0005[1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Reject the null hypothesis in favour of the alternative hypothesis at the 5% significance level.

The 80 square mile Bushkill Creek watershed is about 31% forested and about 15% urban land cover (USGS StreamStats, accessed Feb. 2014). About 38% of the watershed is underlain by carbonate bedrock, and this limestone naturally affects water quality. The watershed was not affected by glacial activity. The upper part of the watershed is an excellent trout fishery of good water quality. The creek is captured and then pumped back to the stream by a large quarry (Goodwin Pumps 2003*), which changes stream water quality and largely controls the downstream flow regime. In the summers of 2000-2002, many samples taken consisted almost exclusively of quarry discharge. Bushkill Creek would have been nearly dry those summers but for the constant 65 cfs pumped to the stream from the quarry bottom. Below the quarry are some large dischargers that further affect the stream, until by the time the Bushkill enters the Delaware River, overall water quality is poor.

*Goodwin Pumps. 2003. Case History: Hercules Cement Plant Case Study: Between a Rock and a Fluid Place. Case History Vol. 4, No. 2, Goodwin Pumps of America, Inc., Bridgeport, NJ.



N	75					
Flow cfs by yyyy	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
2000	117.0	132.1	141.7	174.6	230.4	42.6
2001	94.7	104.3	120.7	136.3	150.0	32.0
2002	76.0	77.4	83.8	116.4	133.1	39.0
2003	124.2	142.9	194.6	314.6	659.9	171.7
2004	126.4	138.7	149.8	195.3	243.4	56.6
2009	151.9	161.9	186.8	211.4	319.8	49.5
2010	112.0	127.8	153.3	178.6	245.4	50.8
2011	167.2	181.5	204.5	503.4	784.4	321.9

There are no independent data available to compare with DRBC results at this site. There is a USGS gage in the watershed, but it is located in the upper portion of the watershed, above the quarry. The gage is located too far from the Rt. 611 monitoring site to be of use for flow estimation. Lafayette College maintains a useful stream gage at Cemetery Road just upstream of Easton, PA (David Brandes, Lafayette College, personal communication). Under backwater conditions at Rt. 611, DRBC samples water at the Cemetery Road location.

Annual May to September flow statistics associated with water quality measurements are plotted above. These are measurements or estimates associated with the time of each water quality sample. Mean annual flow is about 121 cfs; and harmonic mean flow is about 73 cfs (USGS Stream Stats retrieval, Feb. 2014). Stream Stats flow statistics must be adjusted to include the constant quarry discharge – when the quarry pumps are in operation, which is most of the time, there are no true low-flow conditions. Though a wide range of flows were sampled by DRBC, these data appear to be most representative of slightly above-normal flow conditions. Flows corresponding to each water quality sample were estimated using the USGS BaSE model with an adjustment for quarry discharge. DRBC intends to use the Lafayette College data when available, and the BaSE program otherwise for future flow estimates.

*Stuckey, M.H., Koerkle, E.H., and Ulrich, J.E., 2012, Estimation of baseline daily mean streamflows for ungaged locations on Pennsylvania streams, water years 1960–2008: U.S. Geological Survey Scientific Investigations Report 2012–5142, 61 p.)

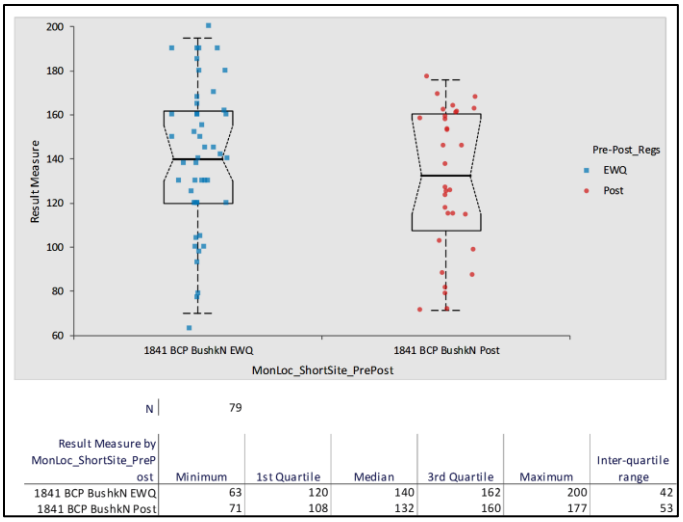
Upstream ICP: Delaware River at Belvidere 1978 ICP
Downstream ICP: Delaware River at Easton 1838 ICP

Chapter 19: 1841 BCP Bushkill Creek, PA

Alkalinity as CaCO3, Total mg/l

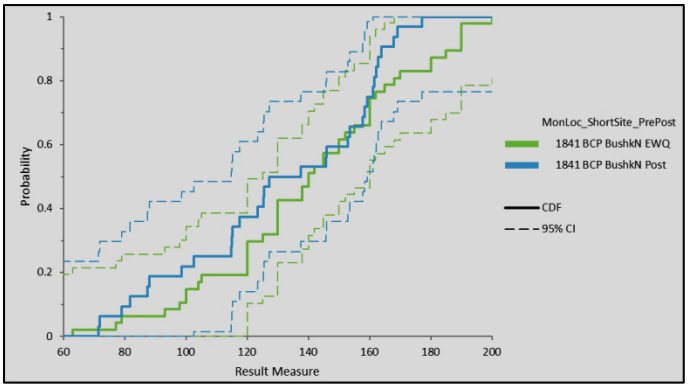
Existing Water Quality (Table 2H):

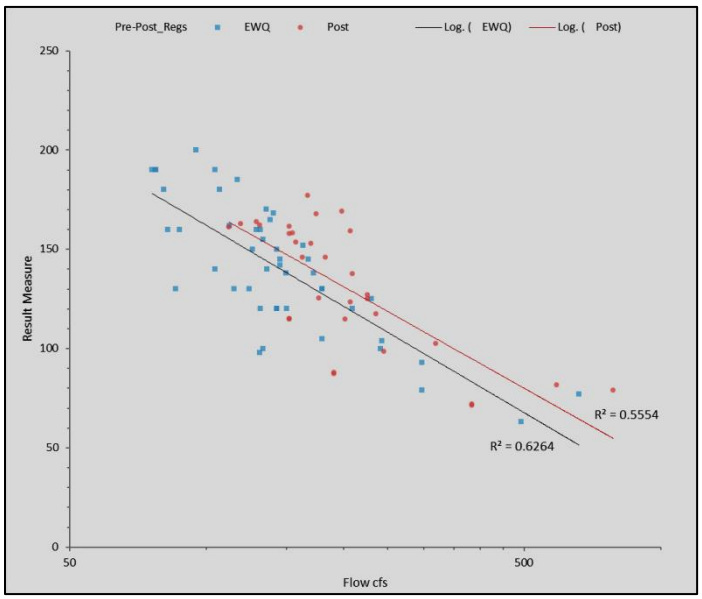
Median 140 mg/l
Lower 95% Confidence Interval 130 mg/l
Upper 95% Confidence Interval 155 mg/l
Defined in regulations as a flow-related parameter

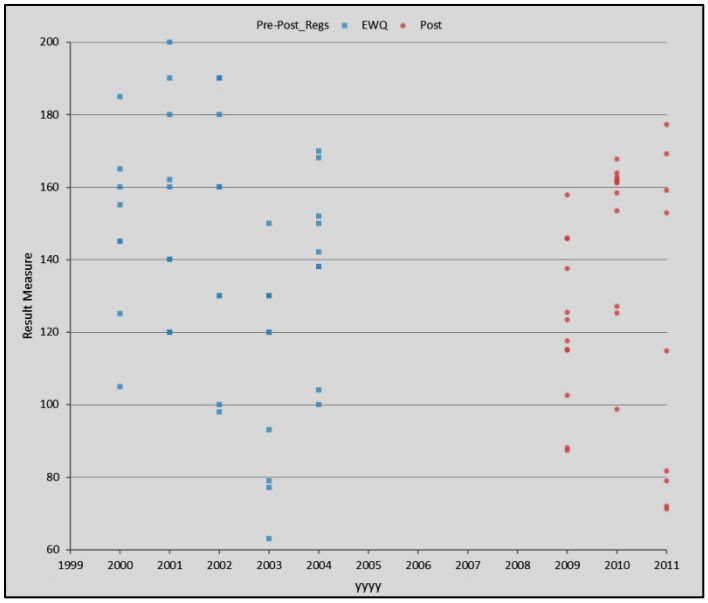


N	79

Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	63	120	140	162	200	42
1841 BCP BushkN Post	71	108	132	160	177	53







Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	47	271.7	5.78
1841 BCP BushkN Post	32	399.0	12.47

H statistic	1.27
X^2 approximation	1.27
DF	1
p-value	0.2589[1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Do not reject the null hypothesis at the 5% significance level.

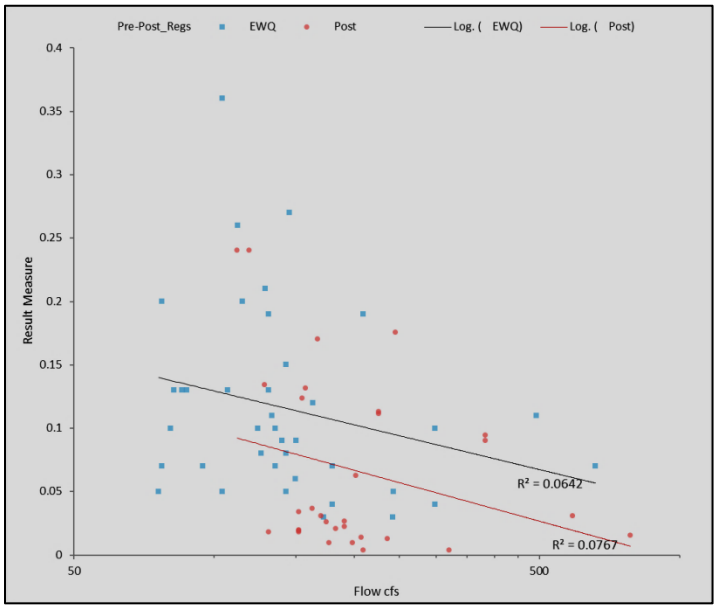
No water quality degradation is evident here. Alkalinity apparently did not measurably change between the EWQ and post-EWQ periods. However, analytical uncertainty was introduced by potential laboratory artifacts and insufficient post-EWQ samples taken under very low flow conditions. Alkalinity is inversely related to flow in both data sets. Post-EWQ median alkalinity was within the EWQ 95% confidence intervals. Flow is plotted on a logarithmic scale. These alkalinities are typical of limestone streams.

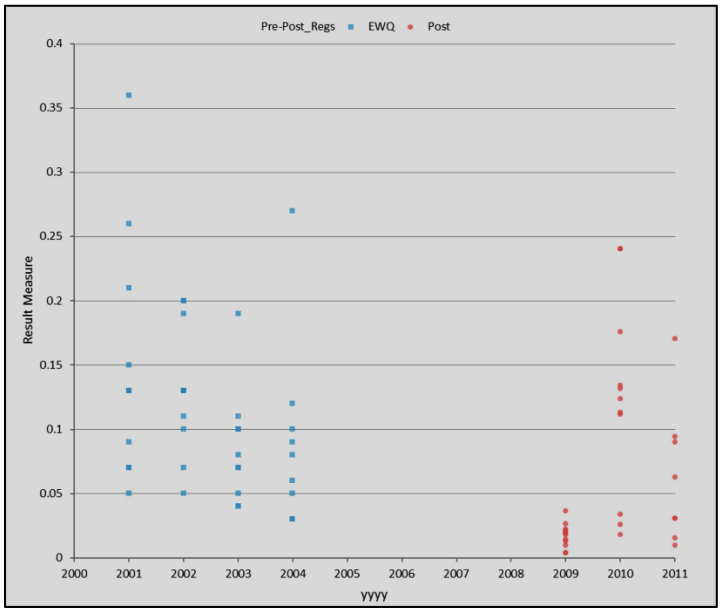
Chapter 19: 1841 BCP Bushkill Creek, PA

Ammonia Nitrogen as N, Total mg/l

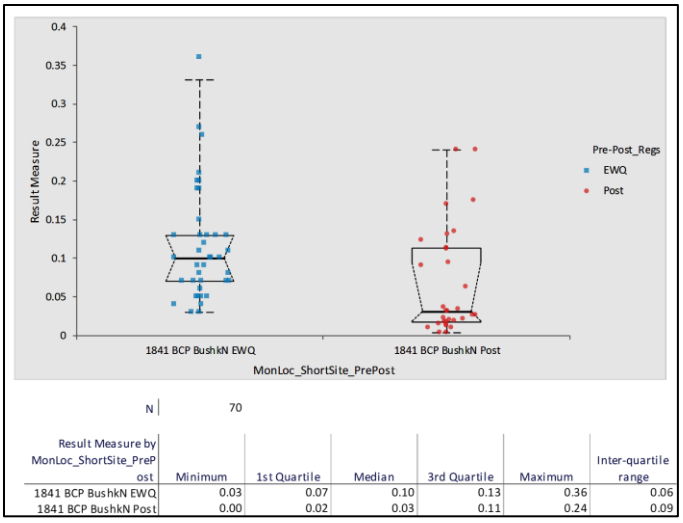
Existing Water Quality (Table 2H):

Median 0.10 mg/l
Lower 95% Confidence Interval 0.07 mg/l
Upper 95% Confidence Interval 0.13 mg/l



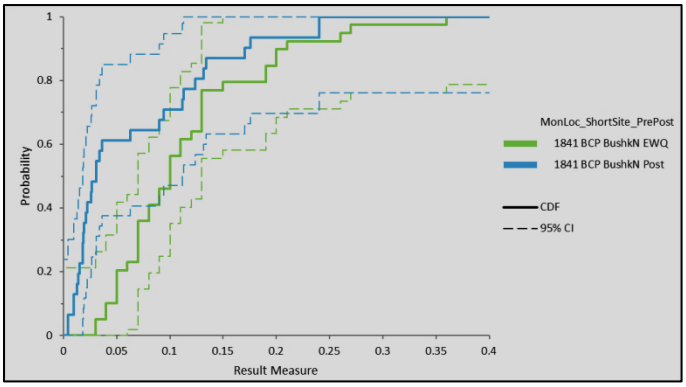


No water quality degradation is evident here. Ammonia concentrations apparently declined. However, analytical uncertainty was introduced by potential laboratory artifacts, detection limit differences, and insufficient post-EWQ low-flow samples.



N	70

Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	0.03	0.07	0.10	0.13	0.36	0.06
1841 BCP BushkN Post	0.00	0.02	0.03	0.11	0.24	0.09



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	39	2090.0	53.59
1841 BCP BushkN Post	31	2629.4	84.82

H statistic	11.41
X^2 approximation	11.41
DF	1
p-value	0.0007 [1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Reject the null hypothesis in favour of the alternative hypothesis at the 5% significance level.

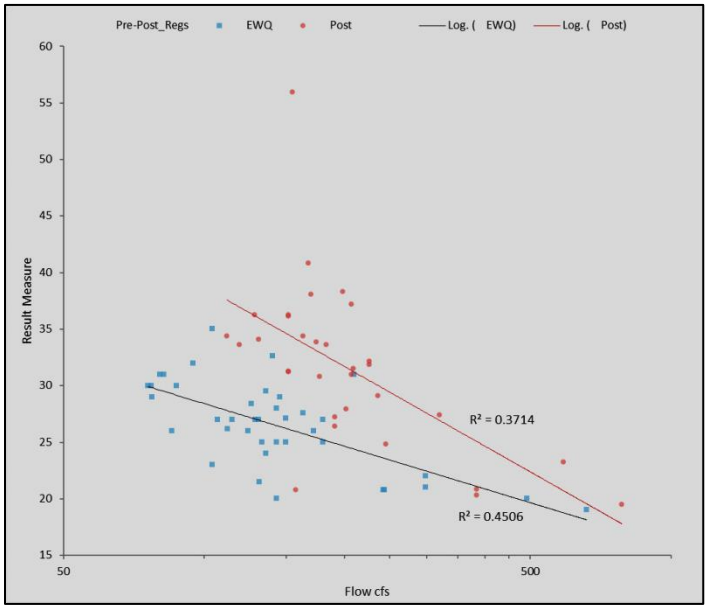
Post-EWQ median ammonia concentration was below the EWQ lower 95% confidence interval. No independent data were available for comparison with DRBC results. Ammonia is unrelated to flow in both data sets. DRBC's post-EWQ detection limit was much lower than during the EWQ period, but concentrations in the Bushkill typically are high enough that there is no interference in the results. EWQ data had 2/39 undetected results. Under post-EWQ very low detection levels there were 2/31 undetected results. Ambient concentrations apparently improved, at least in 2009, unless this is simply a laboratory artifact. There are still numerous high-concentration sample results.

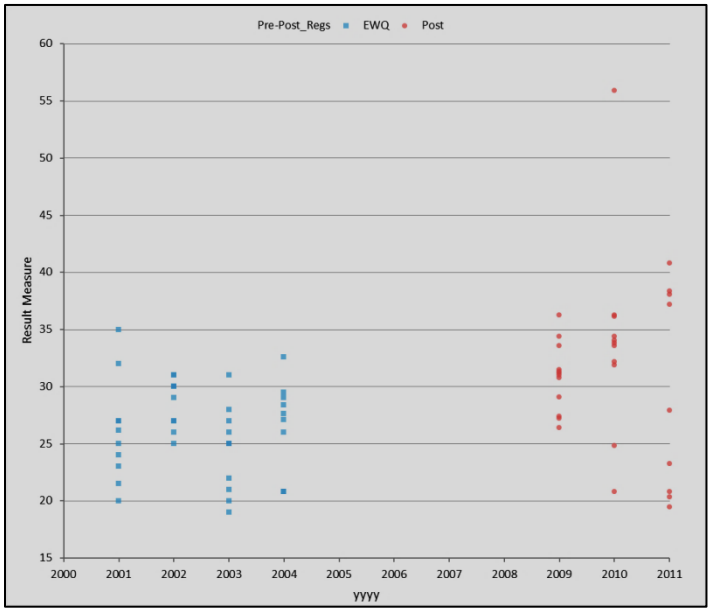
Chapter 19: 1841 BCP Bushkill Creek, PA

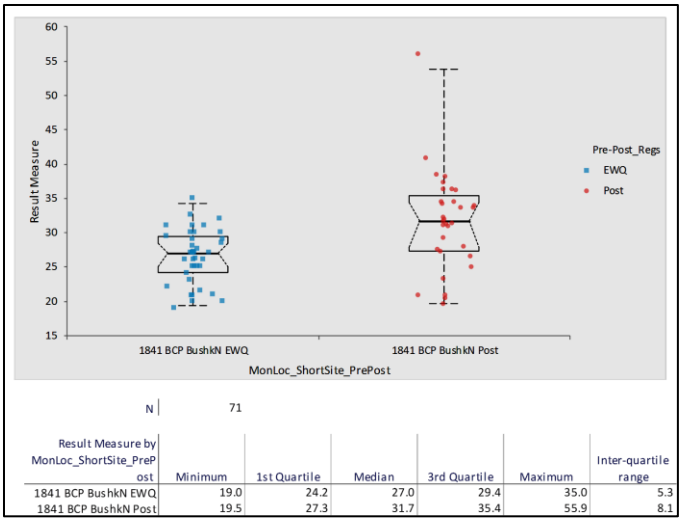
Chloride, Total mg/l

Existing Water Quality (Table 2H):

Median 27.0 mg/l
Lower 95% Confidence Interval 25.0 mg/l
Upper 95% Confidence Interval 28.4 mg/l
Defined in regulations as a flow-related parameter

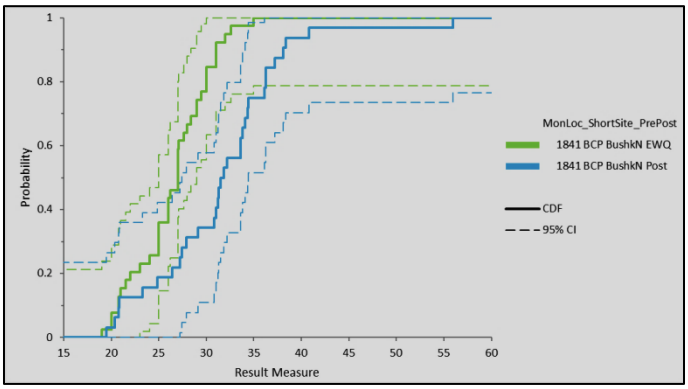






N	71

Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	19.0	24.2	27.0	29.4	35.0	5.3
1841 BCP BushkN Post	19.5	27.3	31.7	35.4	55.9	8.1



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	39	2568.5	65.86
1841 BCP BushkN Post	32	3130.4	97.82

H statistic	13.39
X^2 approximation	13.39
DF	1
p-value	0.0003 [1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Reject the null hypothesis in favour of the alternative hypothesis at the 5% significance level.

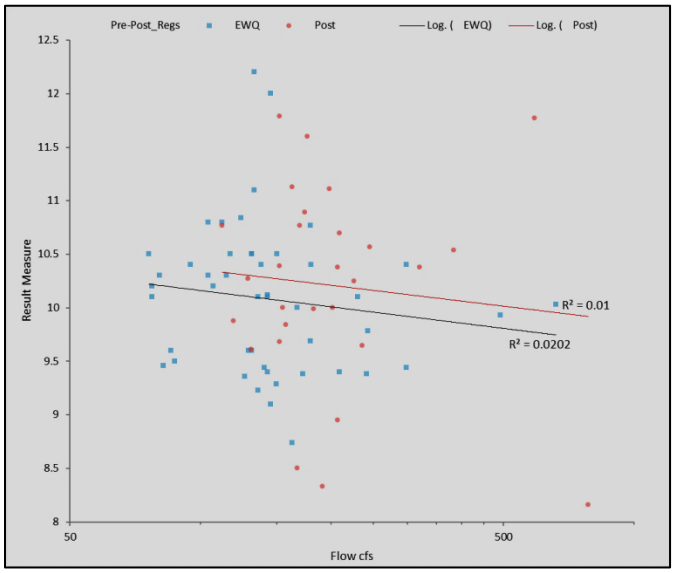
Water quality degradation is evident here. Chloride concentrations apparently rose between the two periods. However, analytical uncertainty was introduced by potential laboratory artifacts and insufficient post-EWQ low-flow samples. Post-EWQ median concentration rose above the EWQ upper 95% confidence interval. Chloride concentration is inversely related to flow in both data sets. No independent data were available for comparison with DRBC results.

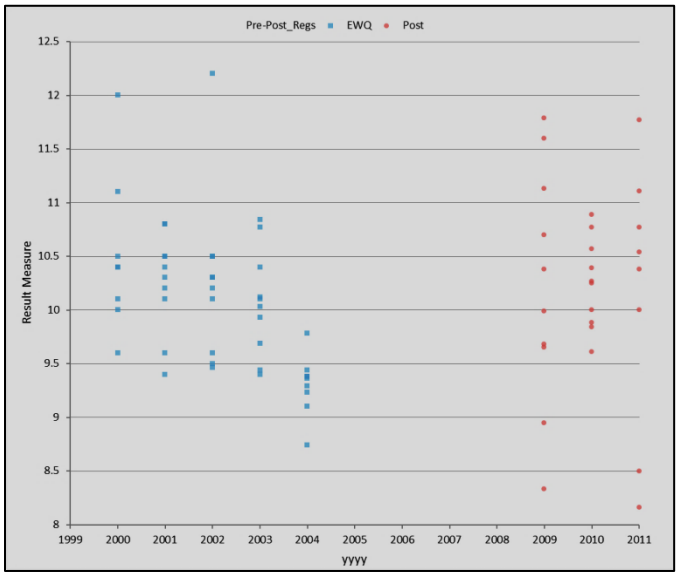
Chapter 19: 1841 BCP Bushkill Creek, PA

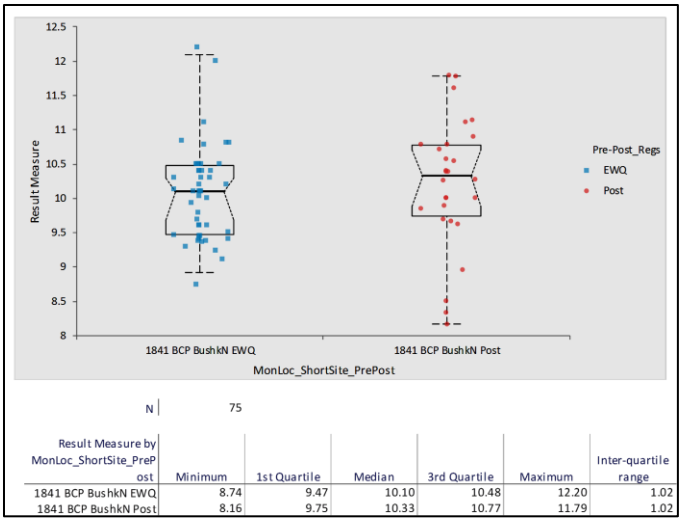
Dissolved Oxygen (DO) mg/l

Existing Water Quality (Table 2H):

Median 10.10 mg/l
Lower 95% Confidence Interval 9.69 mg/l
Upper 95% Confidence Interval 10.30 mg/l

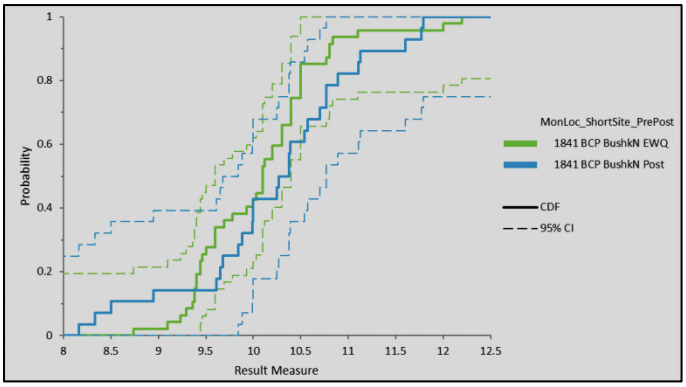






N 75

Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	8.74	9.47	10.10	10.48	12.20	1.02
1841 BCP BushkN Post	8.16	9.75	10.33	10.77	11.79	1.02



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	47	230.1	4.90
1841 BCP BushkN Post	28	386.3	13.80

H statistic	1.30
X^2 approximation	1.30
DF	1
p-value	0.2544 [1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Do not reject the null hypothesis at the 5% significance level.

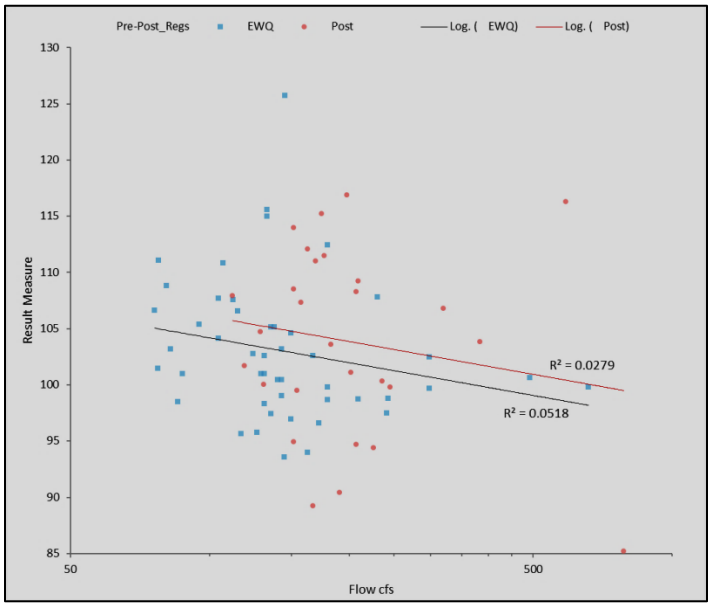
No water quality degradation is evident here. No measurable change took place between the EWQ and Post-EWQ periods. However, analytical uncertainty was introduced by insufficient post-EWQ low-flow samples. Post-EWQ median DO concentration was above the upper EWQ 95% confidence interval but the difference was not statistically significant. Such an increase would constitute a water quality improvement anyway. DO concentration is unrelated to flow in both data sets. No independent data were available for comparison with DRBC results.

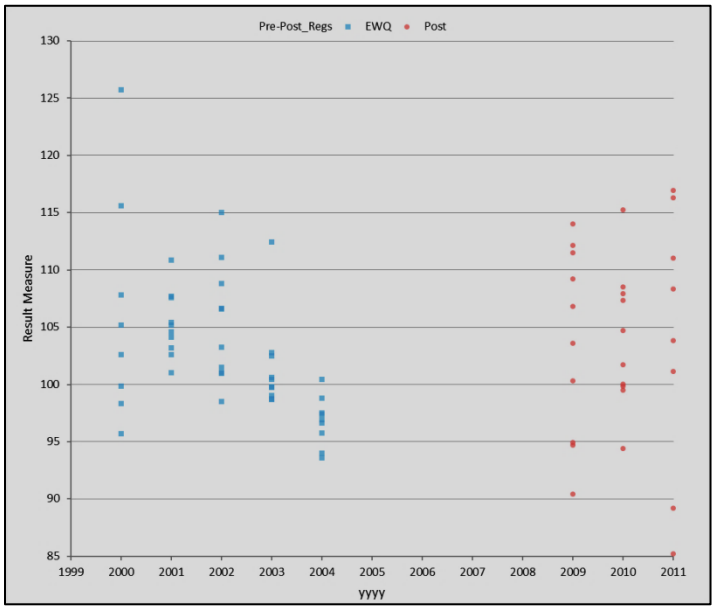
Chapter 19: 1841 BCP Bushkill Creek, PA

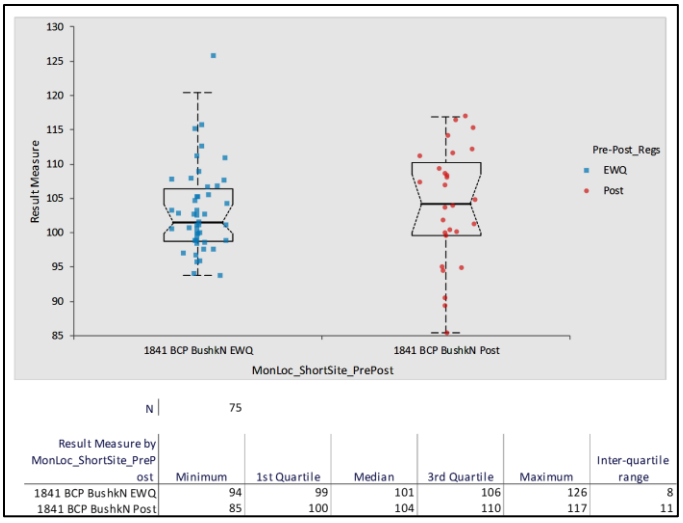
Dissolved Oxygen Saturation %

Existing Water Quality (Table 2H):

Median 102%
Lower 95% Confidence Interval 100%
Upper 95% Confidence Interval 104%

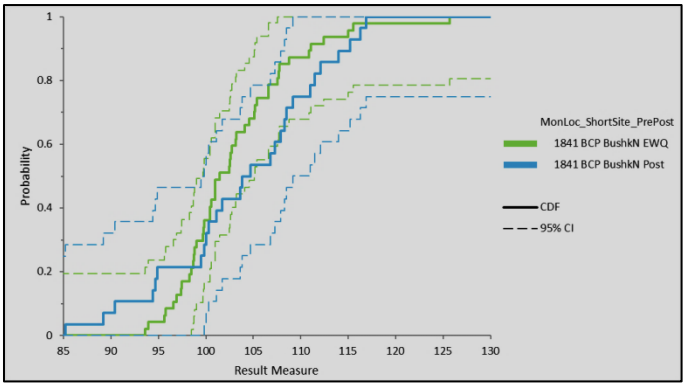






N 75

Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	94	99	101	106	126	8
1841 BCP BushkN Post	85	100	104	110	117	11



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	47	192.0	4.09
1841 BCP BushkN Post	28	322.3	11.51

H statistic	1.08
X^2 approximation	1.08
DF	1
p-value	0.2981 [1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Do not reject the null hypothesis at the 5% significance level.

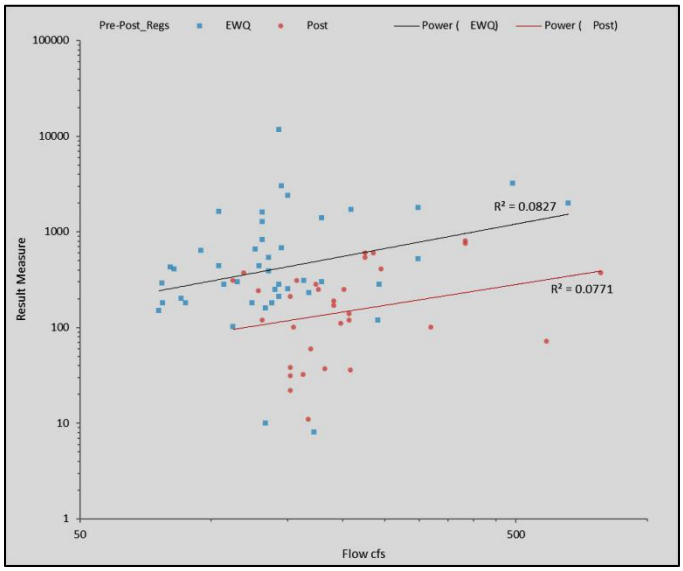
No water quality degradation is evident here. Dissolved Oxygen Saturation is unrelated to flow, and did not measurably change between the EWQ and post-EWQ periods. However, analytical uncertainty was introduced by insufficient post-EWQ low-flow samples. Post-EWQ median DO saturation matched the upper EWQ 95% confidence interval. There were no measurements that caused concern about an excess of oxygen-reducing material. As a rule of thumb, 80-120% is considered "normal"; in that range a balance exists between oxygen demand and supply. No independent data were available to corroborate DRBC results.

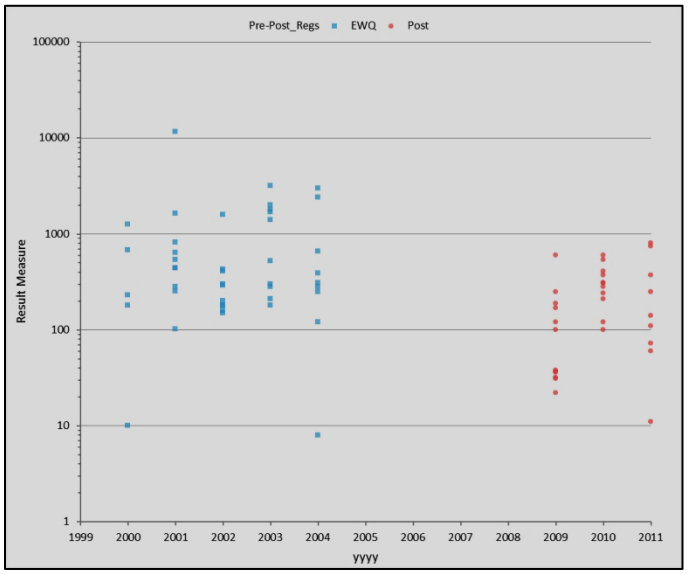
Chapter 19: 1841 BCP Bushkill Creek, PA

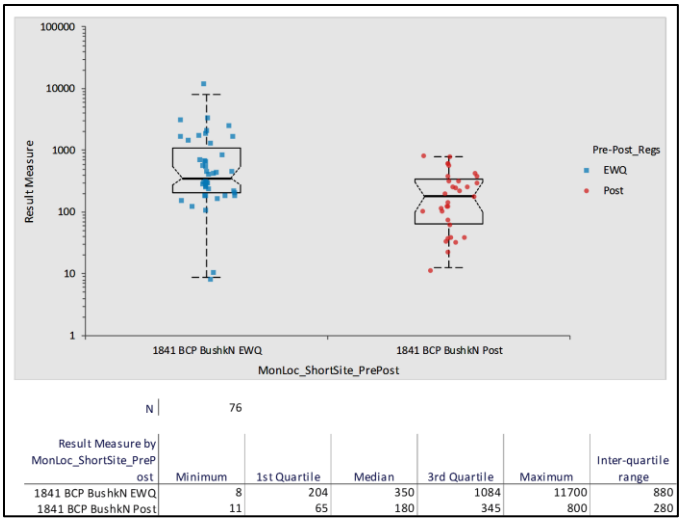
Enterococcus colonies/100 ml

Existing Water Quality (Table 2H):

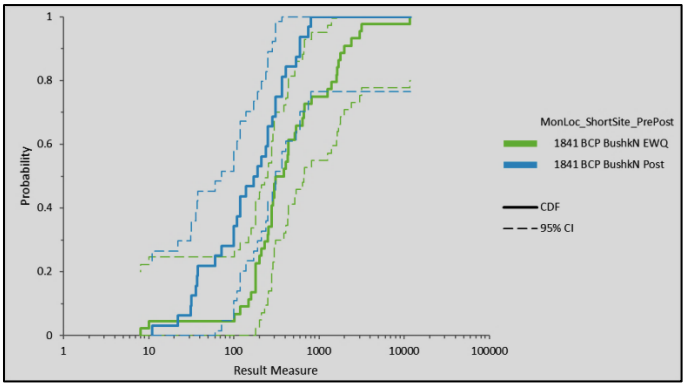
Median 350/100 ml
Lower 95% Confidence Interval 280/100 ml
Upper 95% Confidence Interval 540/100 ml







N	76					
Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	8	204	350	1084	11700	880
1841 BCP BushkN Post	11	65	180	345	800	280



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	44	2349.1	53.39
1841 BCP BushkN Post	32	3230.1	100.94

H statistic	11.45
X^2 approximation	11.45
DF	1
p-value	0.0007 [1]

H0: $\theta_i = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Reject the null hypothesis in favour of the alternative hypothesis at the 5% significance level.

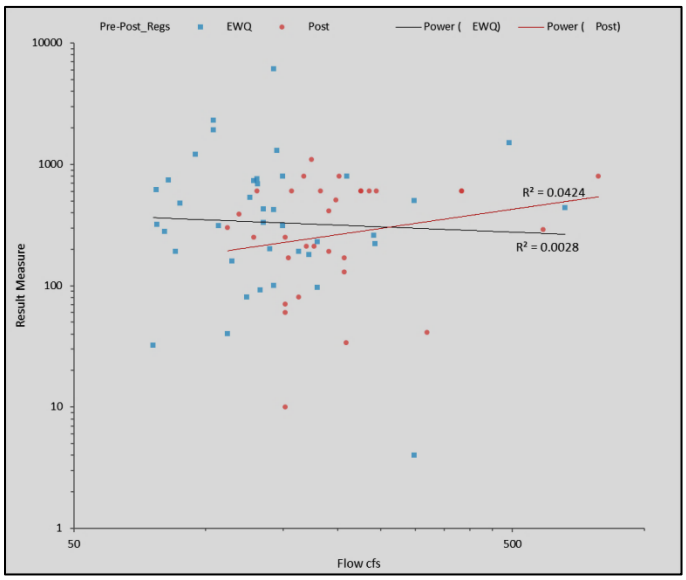
No water quality degradation is evident here. Enterococci apparently declined between the EWQ and Post-EWQ periods. However, analytical uncertainty was introduced by laboratory artifacts and insufficient post-EWQ low-flow samples. Enterococcus concentrations are unrelated to flow in both data sets. Concentrations and flows are plotted on logarithmic scale, and regressions are power relationships. Post-EWQ median enterococcus concentrations fell below the lower EWQ 95% confidence interval.

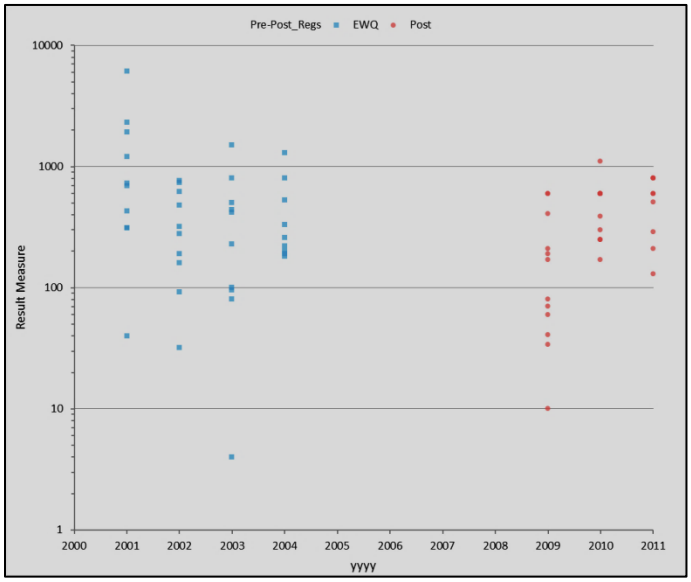
Chapter 19: 1841 BCP Bushkill Creek, PA

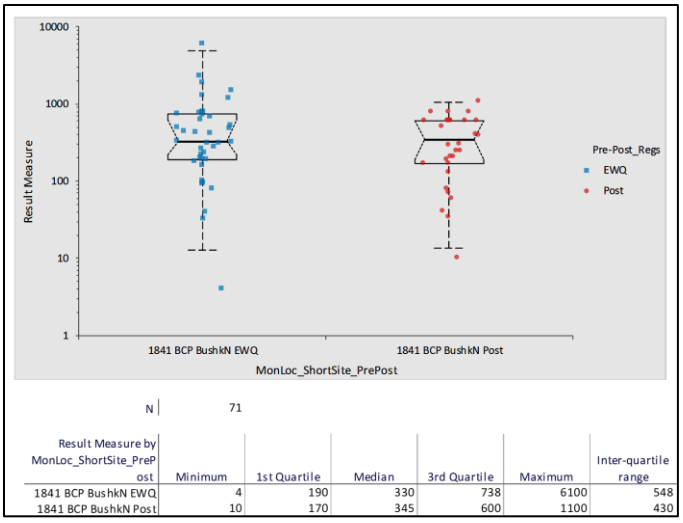
Escherichia coli colonies/100 ml

Existing Water Quality (Table 2H):

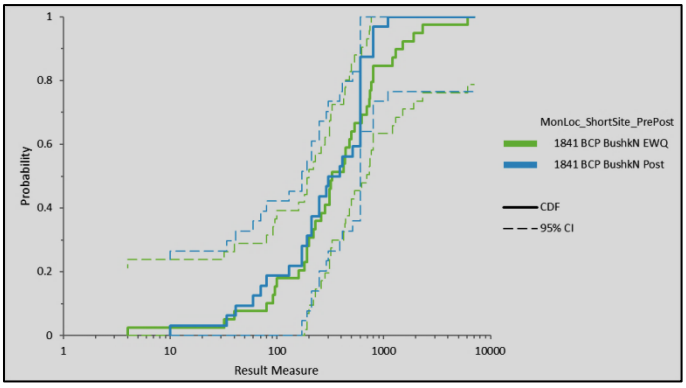
Median 330/100 ml
Lower 95% Confidence Interval 220/100 ml
Upper 95% Confidence Interval 620/100 ml
EWQ exceeds federally recommended criteria







N	71					
Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	4	190	330	738	6100	548
1841 BCP BushkN Post	10	170	345	600	1100	430



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	39	103.4	2.65
1841 BCP BushkN Post	32	126.0	3.94

H statistic	0.54
X^2 approximation	0.54
DF	1
p-value	0.4625 [1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Do not reject the null hypothesis at the 5% significance level.

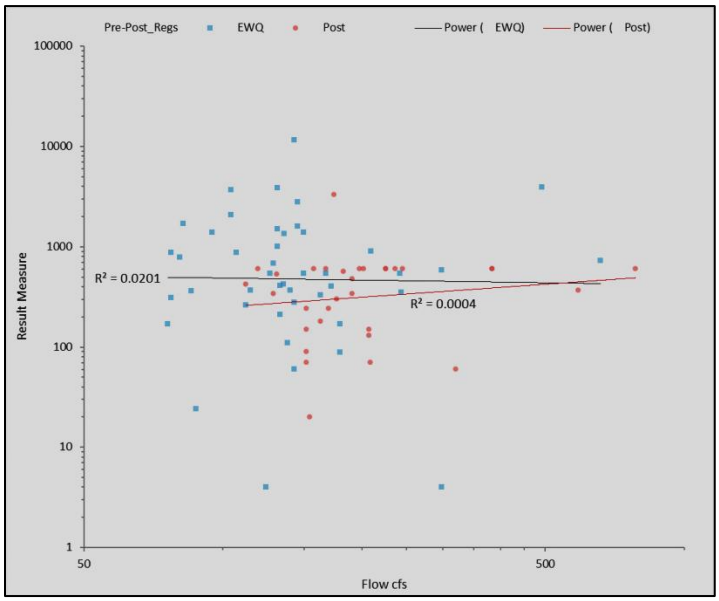
No water quality degradation is evident here. E. coli apparently did not measurably change between the EWQ and Post-EWQ periods. Analytical uncertainty was introduced by potential laboratory artifacts and insufficient post-EWQ low-flow samples. High values (9) were laboratory truncated to upper quantification limits, which affected the comparison above the 75th percentile. Post-EWQ median E. coli fell within the EWQ 95% confidence intervals. Concentrations and flows are plotted on logarithmic scale, and regressions are power relationships. E. coli concentrations are unrelated to flow in both data sets. No independent data were available to validate DRBC results.

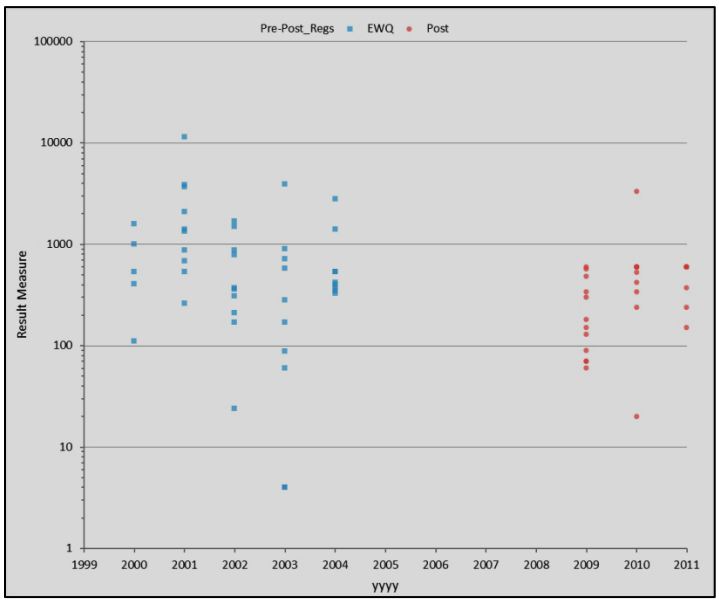
Chapter 19: 1841 BCP Bushkill Creek, PA

Fecal coliform colonies/100 ml

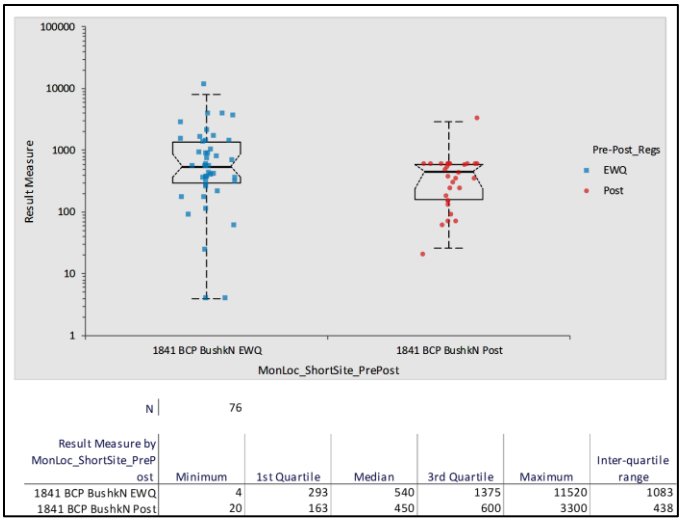
Existing Water Quality (Table 2H):

Median 540/100 ml
Lower 95% Confidence Interval 370/100 ml
Upper 95% Confidence Interval 880/100 ml

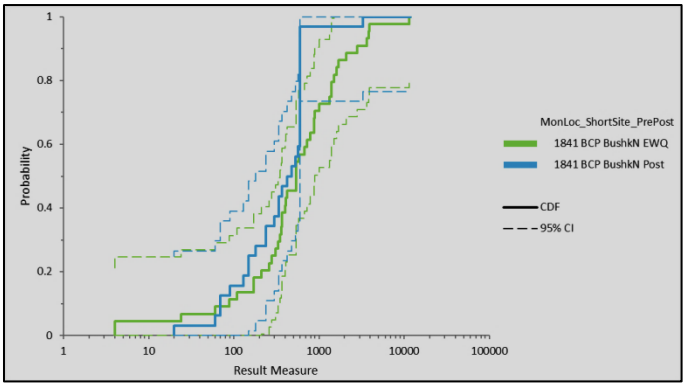




No water quality degradation is evident here. Fecal coliform apparently did not measurably change between the EWQ and post-EWQ periods, though lack of post-EWQ results over 1000 colonies/100ml were due to the laboratory truncating high results (n=10) to upper quantification limits.



N	76					
Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	4	293	540	1375	11520	1083
1841 BCP BushkN Post	20	163	450	600	3300	438



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	44	618.8	14.06
1841 BCP BushkN Post	32	850.8	26.59

H statistic	3.03
X² approximation	3.03
DF	1
p-value	0.0819 [1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Do not reject the null hypothesis at the 5% significance level.

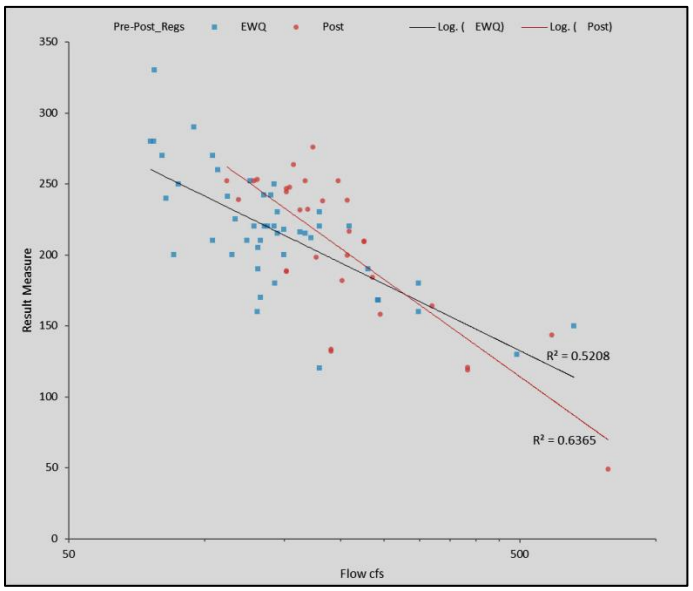
Truncation of results to UQL's affected the comparison above the 70th percentile. Analytical uncertainty was introduced by laboratory artifacts and insufficient post-EWQ low-flow samples. Fecal coliform concentrations are unrelated to flow in both data sets. Post-EWQ median concentrations were within the EWQ 95% confidence intervals. Concentrations and flows are plotted on logarithmic scale, and regressions are power relationships. There were no independent data for comparison with DRBC results.

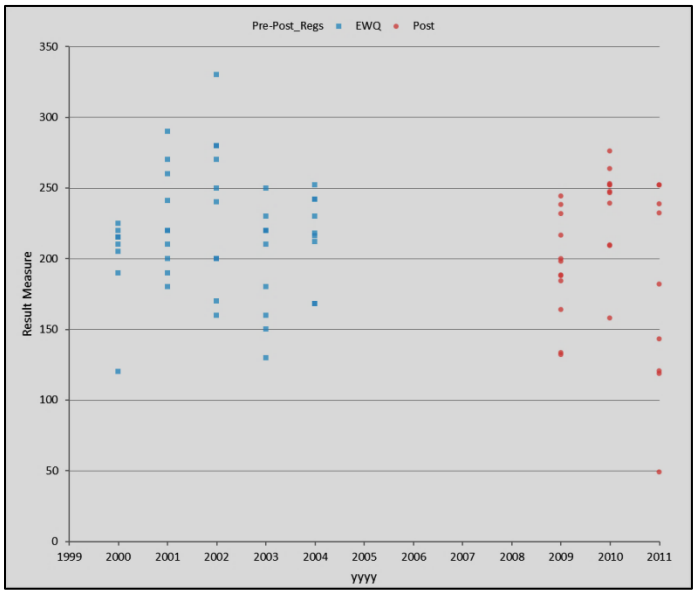
Chapter 19: 1841 BCP Bushkill Creek, PA

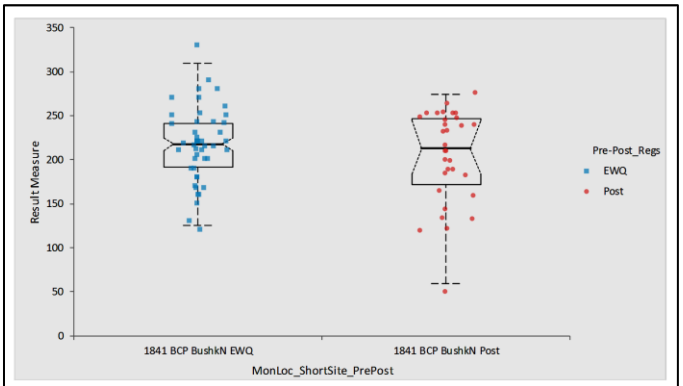
Hardness as CaCO3, Total mg/l

Existing Water Quality (Table 2H):

Median 218 mg/l
Lower 95% Confidence Interval 210 mg/l
Upper 95% Confidence Interval 225 mg/l
Defined in regulations as a flow-related parameter

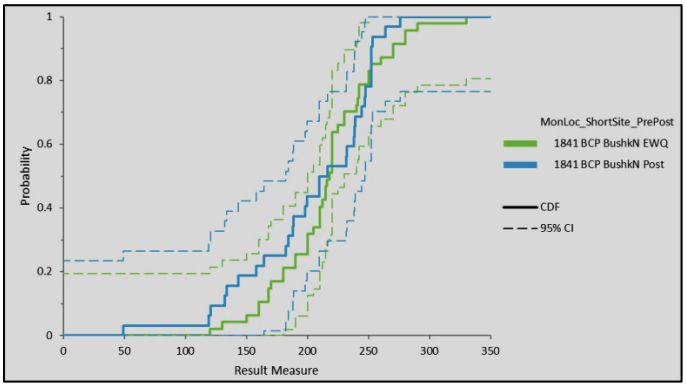






N	79

Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	120	192	218	242	330	50
1841 BCP BushkN Post	49	172	213	247	276	76



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	47	72.8	1.55
1841 BCP BushkN Post	32	106.9	3.34

H statistic	0.34
X^2 approximation	0.34
DF	1
p-value	0.5589 [1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Do not reject the null hypothesis at the 5% significance level.

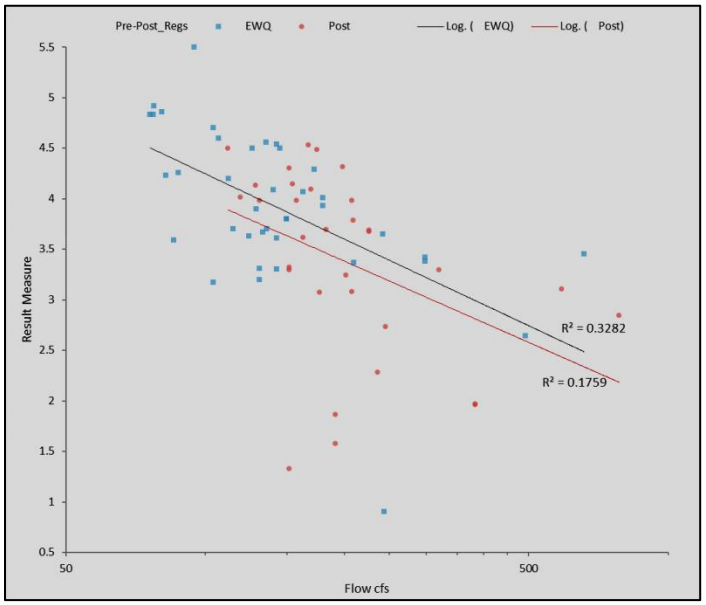
No water quality degradation is evident here. Hardness apparently did not measurably change between the EWQ and post-EWQ periods. However, analytical uncertainty was introduced by potential laboratory artifacts and insufficient post-EWQ low-flow samples. Hardness is inversely related to flow in both data sets. Post-EWQ median hardness was within the EWQ 95% confidence intervals. Flow is plotted on a logarithmic scale. No independent data were available for comparison with DRBC results.

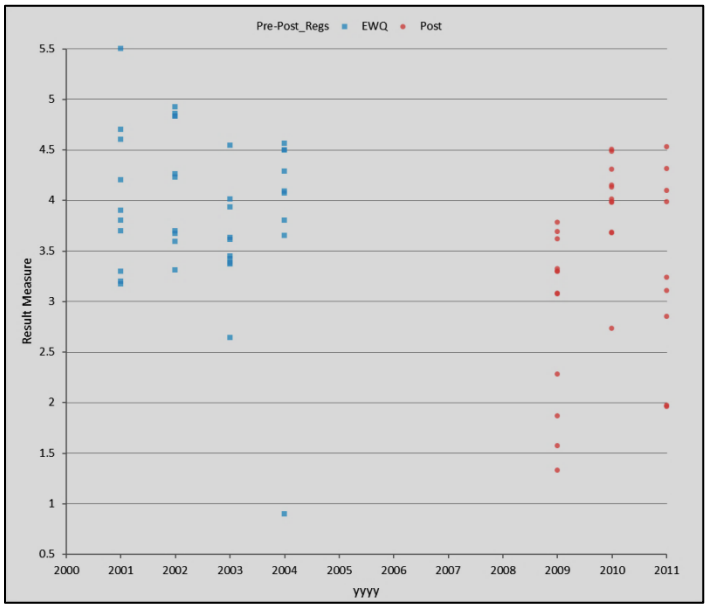
Chapter 19: 1841 BCP Bushkill Creek, PA

Nitrate + Nitrite as N, Total mg/l

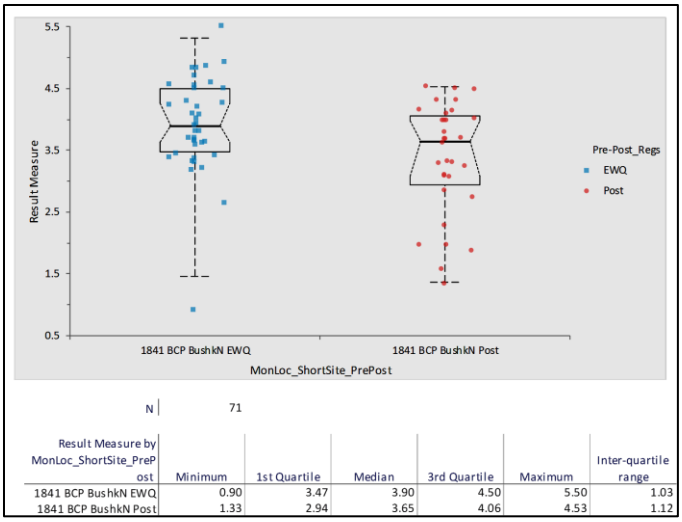
Existing Water Quality (Table 2H, as Nitrate only):

Median 3.90 mg/l
Lower 95% Confidence Interval 3.63 mg/l
Upper 95% Confidence Interval 4.26 mg/l



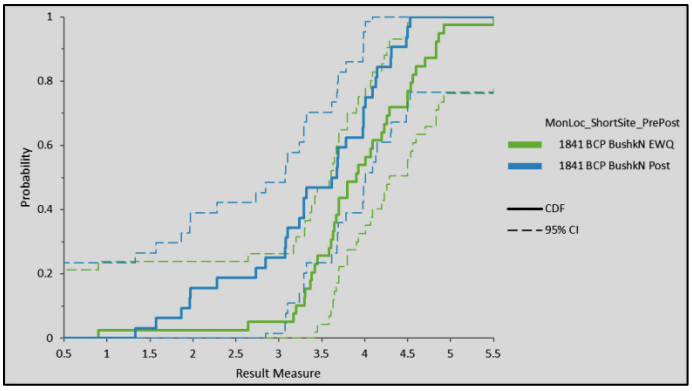


No water quality degradation is evident here. Nitrate concentrations apparently declined between the EWQ and post-EWQ periods. However, analytical uncertainty was introduced by potential laboratory artifacts and insufficient post-EWQ low-flow samples.



N	71

Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	0.90	3.47	3.90	4.50	5.50	1.03
1841 BCP BushkN Post	1.33	2.94	3.65	4.06	4.53	1.12



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	39	1185.3	30.39
1841 BCP BushkN Post	32	1444.5	45.14

H statistic	6.17
X^2 approximation	6.17
DF	1
p-value	0.0130[1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Reject the null hypothesis in favour of the alternative hypothesis at the 5% significance level.

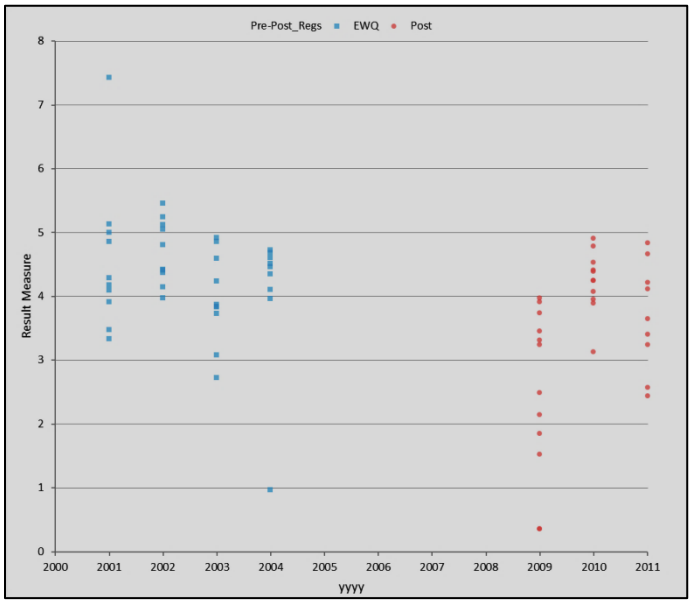
Nitrate is weakly related to flow in both data sets. Post-EWQ median concentrations fell near to the lower EWQ 95% confidence interval. Post-EWQ nitrate + nitrite concentrations were assumed equivalent for comparison with EWQ nitrate concentrations since EWQ nitrite concentrations were never detected. No independent data were available to compare with DRBC results. At other sites where concentrations are lower, there was a problem interpreting the data due to changing detection limits. Concentrations are sufficiently high in Bushkill Creek that problems with interpretation did not arise. This stream contains the highest nitrate concentrations in the Lower Delaware.

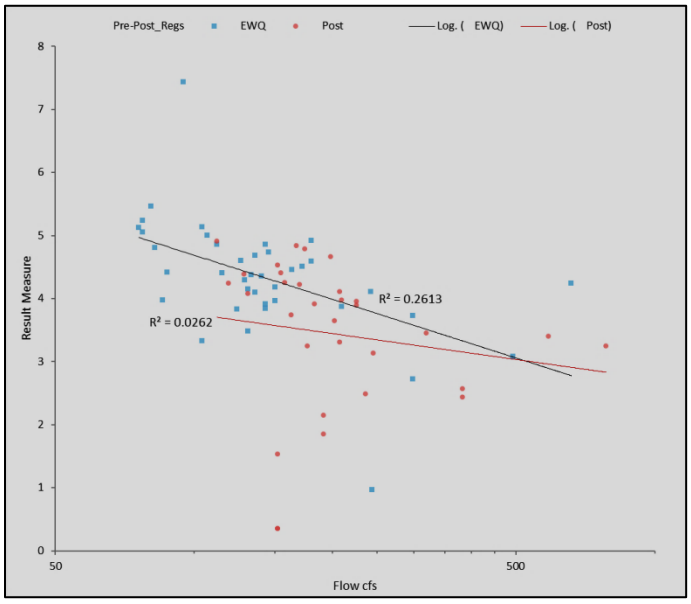
Chapter 19: 1841 BCP Bushkill Creek, PA

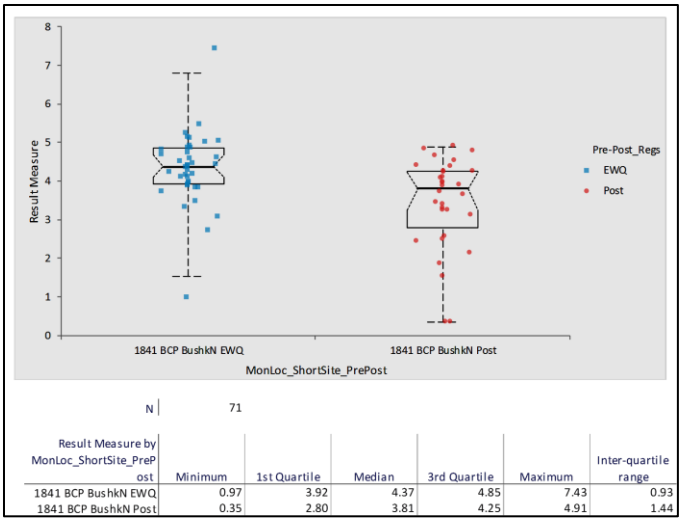
Nitrogen as N, Total (TN) mg/l

Existing Water Quality (Table 2H):

Median 4.41 mg/l (should read 4.37)
Lower 95% Confidence Interval 4.11 mg/l
Upper 95% Confidence Interval 4.73 mg/l

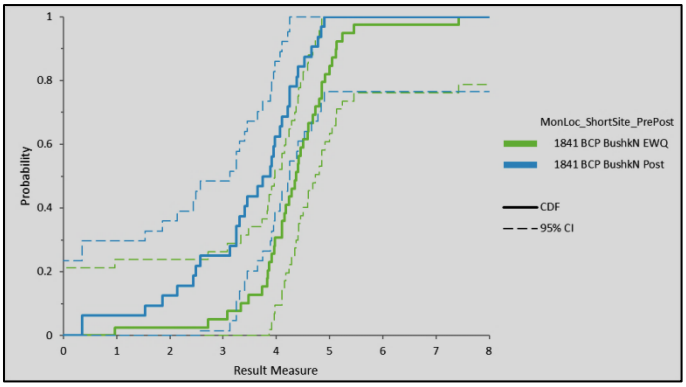






N	71

Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	0.97	3.92	4.37	4.85	7.43	0.93
1841 BCP BushkN Post	0.35	2.80	3.81	4.25	4.91	1.44



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	39	2178.8	55.87
1841 BCP BushkN Post	32	2655.4	82.98

H statistic	11.35
X^2 approximation	11.35
DF	1
p-value	0.0008 [1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Reject the null hypothesis in favour of the alternative hypothesis at the 5% significance level.

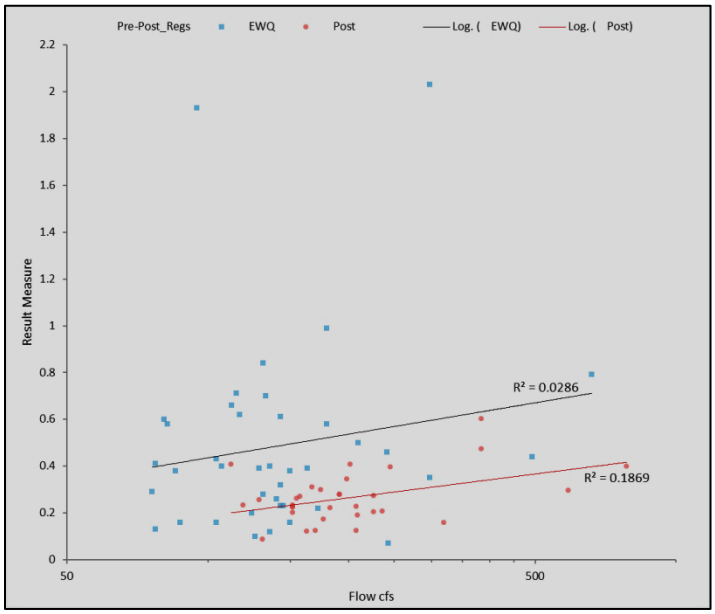
No water quality degradation is evident here. Total Nitrogen concentrations apparently declined between the EWQ and post-EWQ periods. However, analytical uncertainty was introduced by potential laboratory artifacts and insufficient post-EWQ low-flow samples. TN is unrelated to flow in both data sets. No independent data were available to compare with DRBC results. Post-EWQ median TN concentration fell below the lower EWQ 95% confidence interval. Even though TN apparently declined, concentrations in Bushkill Creek are still the highest in all the Lower Delaware.

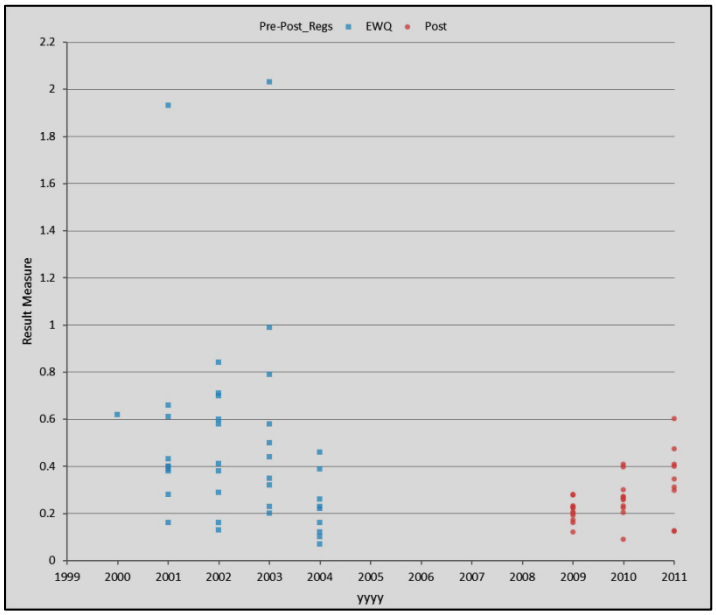
Chapter 19: 1841 BCP Bushkill Creek, PA

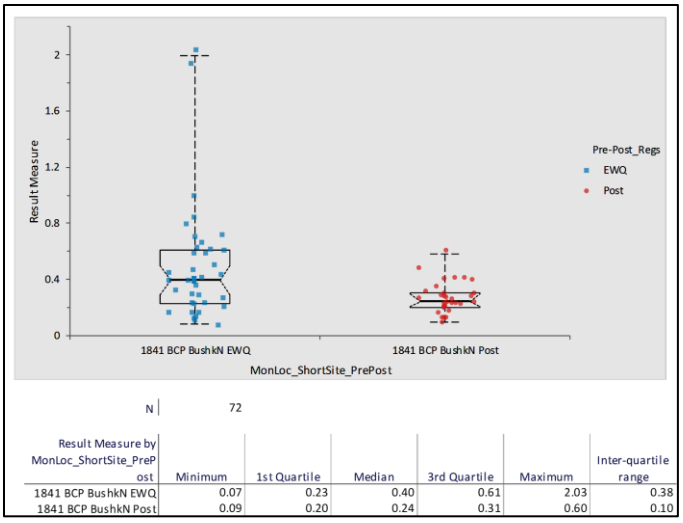
Nitrogen, Kjeldahl as N, Total (TKN) mg/l

Existing Water Quality (Table 2H):

Median 0.40 mg/l
Lower 95% Confidence Interval 0.29 mg/l
Upper 95% Confidence Interval 0.50 mg/l

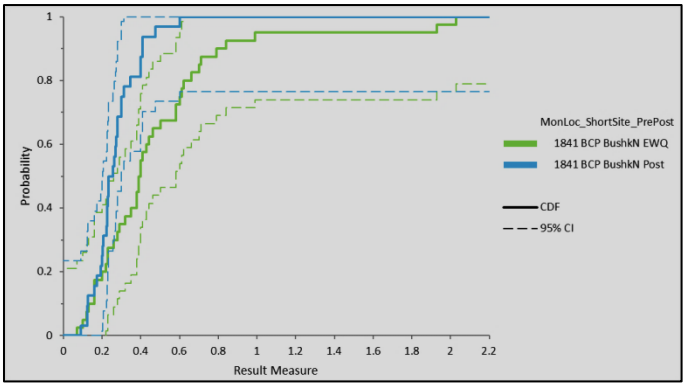






N	72

Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	0.07	0.23	0.40	0.61	2.03	0.38
1841 BCP BushkN Post	0.09	0.20	0.24	0.31	0.60	0.10



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	40	1716.1	42.90
1841 BCP BushkN Post	32	2145.1	67.04

H statistic	8.82
X^2 approximation	8.82
DF	1
p-value	0.0030[1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Reject the null hypothesis in favour of the alternative hypothesis at the 5% significance level.

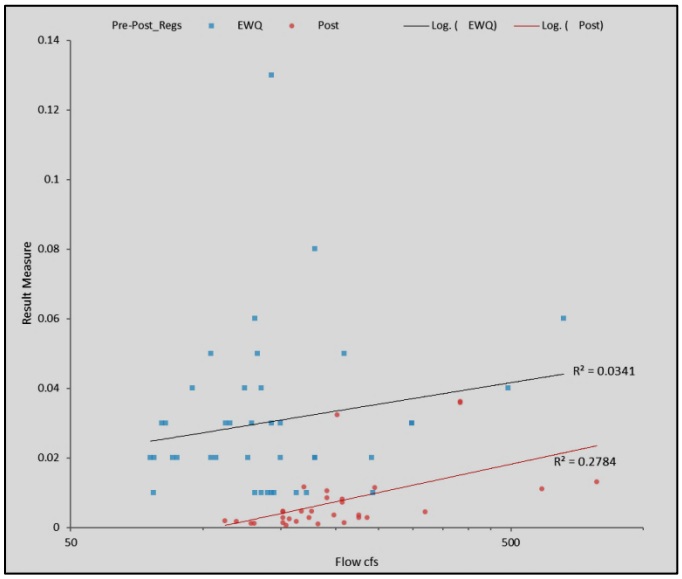
No water quality degradation is evident here. TKN concentrations apparently declined between the EWQ and post-EWQ periods. However, analytical uncertainty was introduced by potential laboratory artifacts and insufficient post-EWQ low-flow samples. The post-EWQ range was far narrower and all concentrations were less than 0.6 mg/l. TKN concentration is unrelated to flow in both data sets. Post-EWQ median TKN fell below the lower EWQ 95% confidence interval, unless the decline is merely a laboratory artifact. The TKN decline contributed to the improvement in total nitrogen concentrations. There were no additional data to confirm DRBC results.

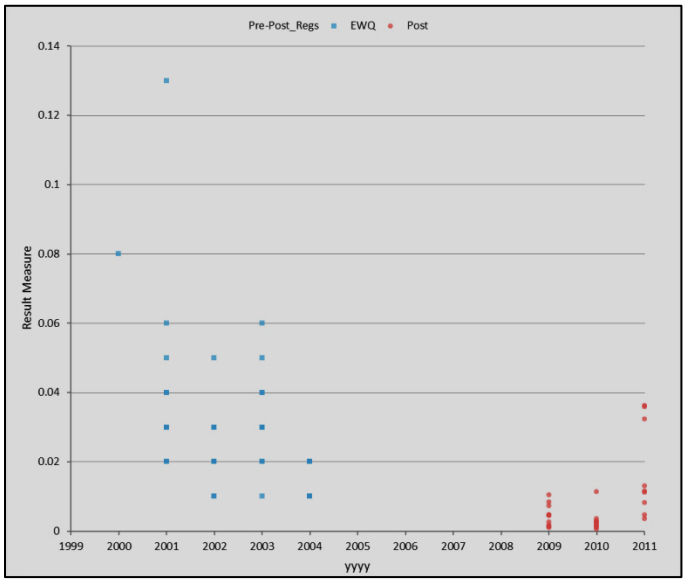
Chapter 19: 1841 BCP Bushkill Creek, PA

Orthophosphate as P, Total mg/l (OP)

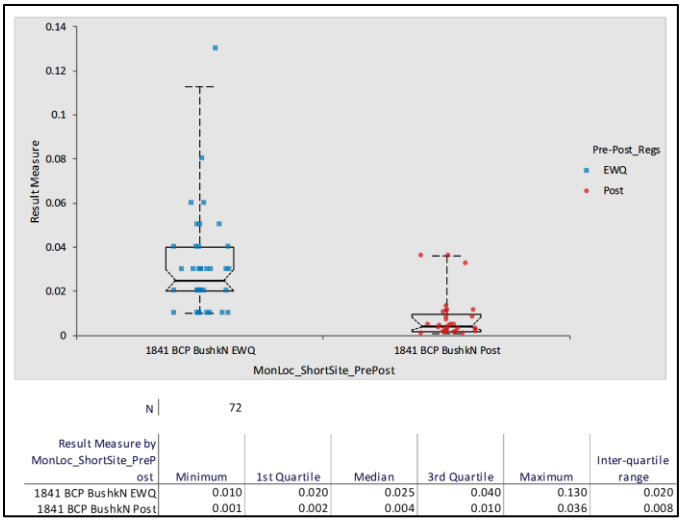
Existing Water Quality (Table 2H):

Median 0.02 mg/l
Lower 95% Confidence Interval 0.02 mg/l
Upper 95% Confidence Interval 0.03 mg/l



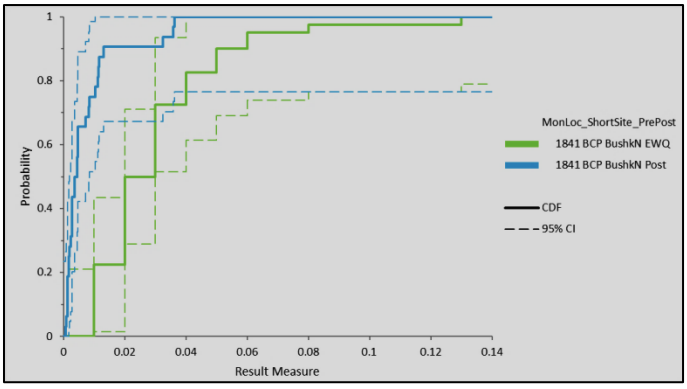


No water quality degradation is evident here. OP concentrations apparently declined between the EWQ and post-EWQ periods. However, analytical uncertainty was introduced by potential laboratory artifacts, detection limit differences and insufficient post-EWQ low-flow samples.



N	72

Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	0.010	0.020	0.025	0.040	0.130	0.020
1841 BCP BushkN Post	0.001	0.002	0.004	0.010	0.036	0.008



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	40	6451.6	161.29
1841 BCP BushkN Post	32	8064.5	252.02

H statistic	33.40
X^2 approximation	33.40
DF	1
p-value	<0.0001 [1]

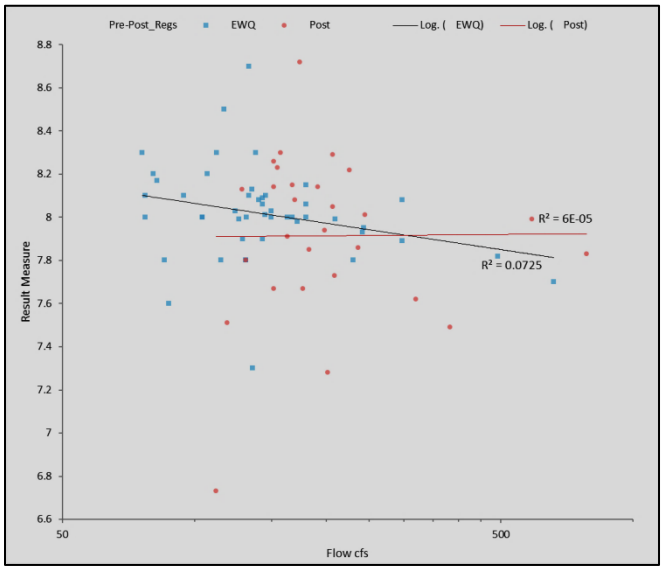
H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Reject the null hypothesis in favour of the alternative hypothesis at the 5% significance level.

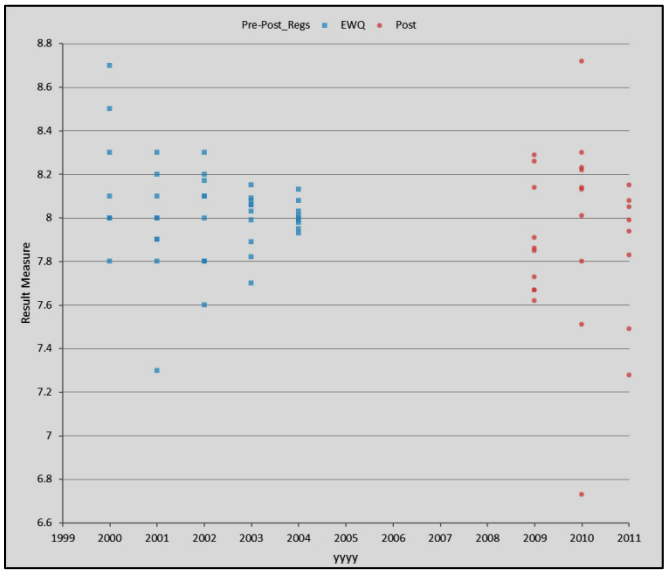
OP is unrelated to flow in both data sets, though there is a weakly positive relationship in the post-EWQ data. Post-EWQ median orthophosphate fell below the lower EWQ 95% confidence interval. Post-EWQ data were far less variable than EWQ data, and there were no post-EWQ measurements higher than 0.04 mg/l. EWQ data were highly variable and contained interference by detection limits, with 9 non-detect results out of 40 tests. There were no undetected results in the post-EWQ data, allowing a clearer picture of actual orthophosphate concentrations contributed by the Bushkill watershed. There were no independent data available for comparison with DRBC results.

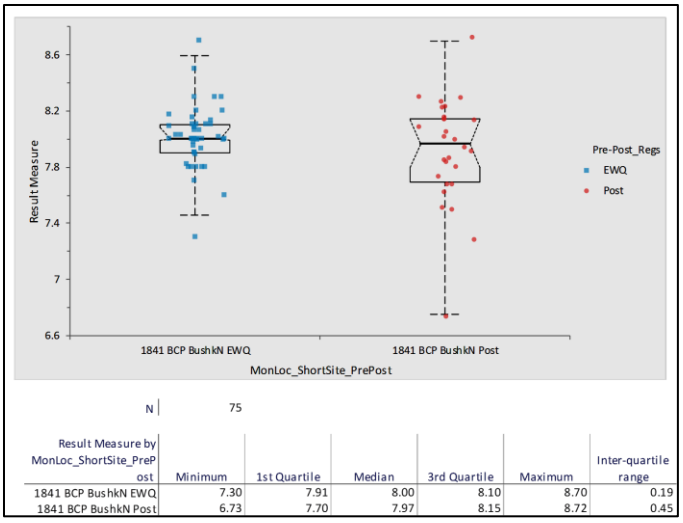
pH

Existing Water Quality (Table 2H):

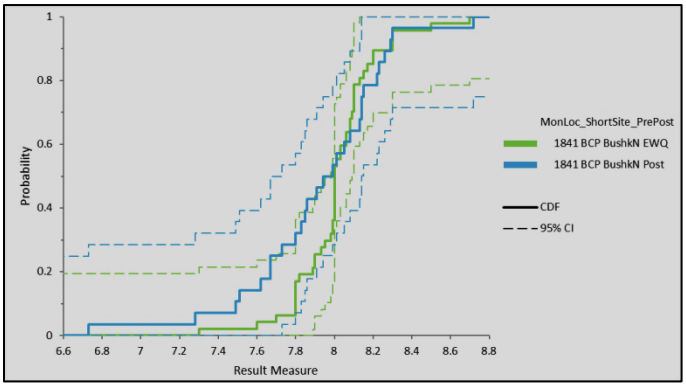
Median 8.00 standard units
Lower 95% Confidence Interval 7.99 standard units
Upper 95% Confidence Interval 8.08 standard units







Result Measure by MonLoc_ShortSite_PrePost	N	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
	75						
1841 BCP BushkN EWQ		7.30	7.91	8.00	8.10	8.70	0.19
1841 BCP BushkN Post		6.73	7.70	7.97	8.15	8.72	0.45



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	47	131.1	2.79
1841 BCP BushkN Post	28	220.1	7.86

H statistic	0.74
X^2 approximation	0.74
DF	1
p-value	0.3893 [1]

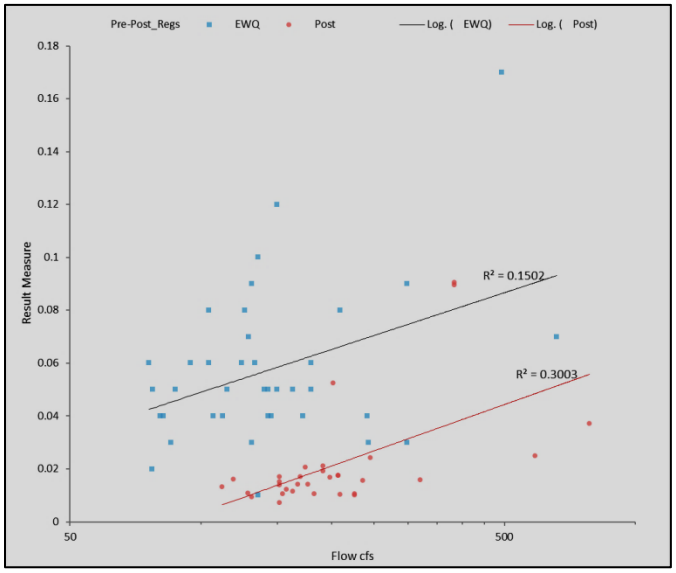
H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Do not reject the null hypothesis at the 5% significance level.

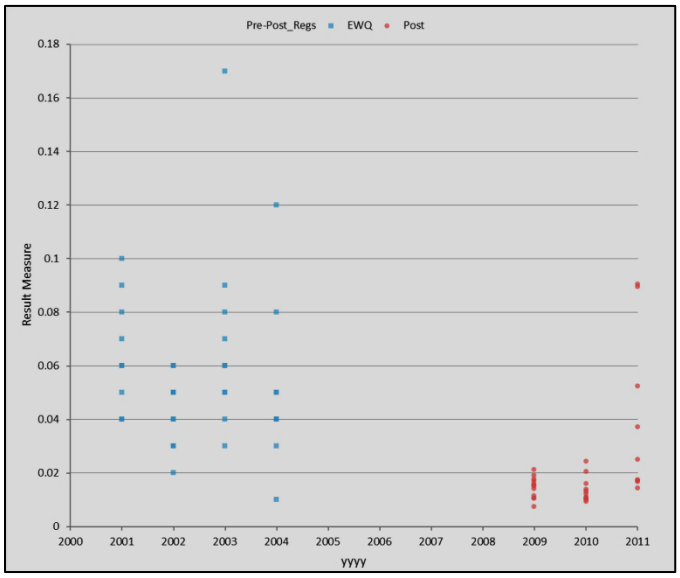
No water quality degradation is evident here. pH apparently did not measurably change between the EWQ and post-EWQ periods. However, analytical uncertainty was introduced by insufficient post-EWQ low-flow samples. pH is unrelated to flow in both data sets. Post-EWQ median pH was within the EWQ 95% confidence intervals. Bushkill Creek median pH is a bit higher than most streams but not unusually so. Median values of 8.0 (EWQ) and 7.95 (post-EWQ) reflect the natural limestone influence and groundwater content pumped from the quarry. The low value of 6.7 observed in 2010 was probably a probe malfunction.

Phosphorus as P, Total (TP) mg/l

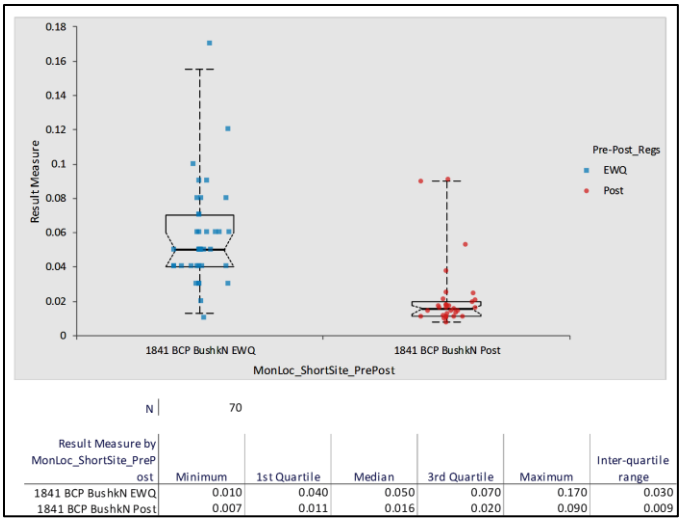
Existing Water Quality (Table 2H):

Median 0.05 mg/l
Lower 95% Confidence Interval 0.04 mg/l
Upper 95% Confidence Interval 0.06 mg/l (0.07 recalc*)

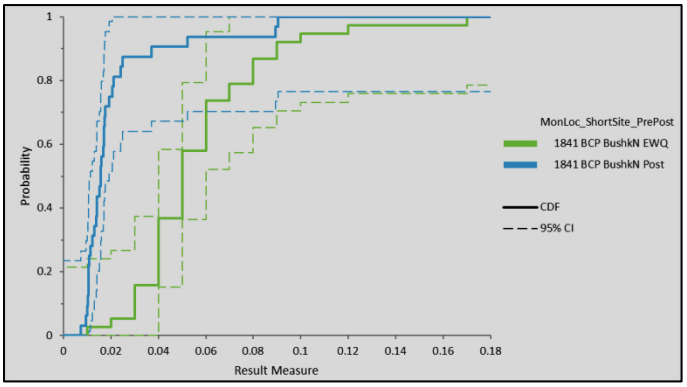




*The data set was recalculated upon removal of a single high outlier value of 0.61 mg/l from July 2001, a suspected data entry error. Inclusion of that data point distorted the view of remaining data. Its exclusion has no influence upon the median or percentile values other than reducing the overall number of data by 1.



N	70					
Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	0.010	0.040	0.050	0.070	0.170	0.030
1841 BCP BushkN Post	0.007	0.011	0.016	0.020	0.090	0.009



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	38	6126.5	161.22
1841 BCP BushkN Post	32	7275.2	227.35

H statistic	32.48
X^2 approximation	32.48
DF	1
p-value	<0.0001 [1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Reject the null hypothesis in favour of the alternative hypothesis at the 5% significance level.

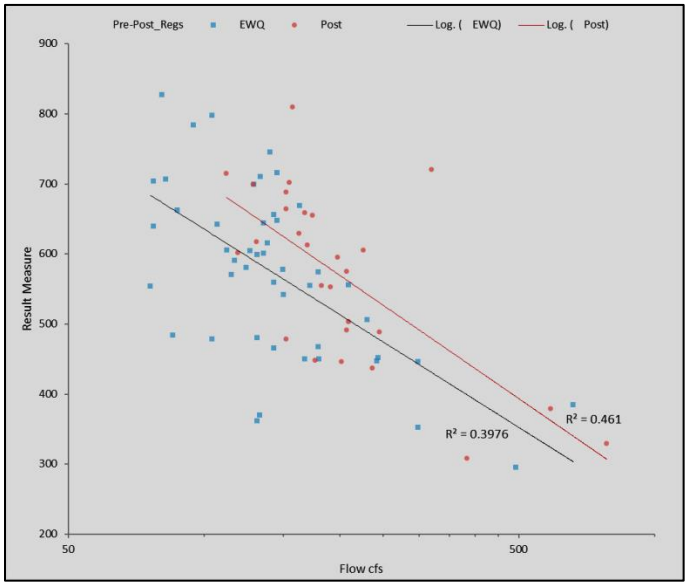
No water quality degradation is evident here. Total Phosphorus (TP) concentrations apparently declined between the EWQ and post-EWQ periods. However, analytical uncertainty was introduced by potential laboratory artifacts, detection limit differences and insufficient post-EWQ low-flow samples. Post-EWQ median total phosphorus fell below the EWQ lower 95% confidence interval. TP is weakly related to flow in both data sets. No additional data were available to confirm DRBC results. EWQ results were more variable than post-EWQ data, which contained no concentrations higher than 0.09 mg/l. This suggests either a water quality improvement or laboratory artifacts.

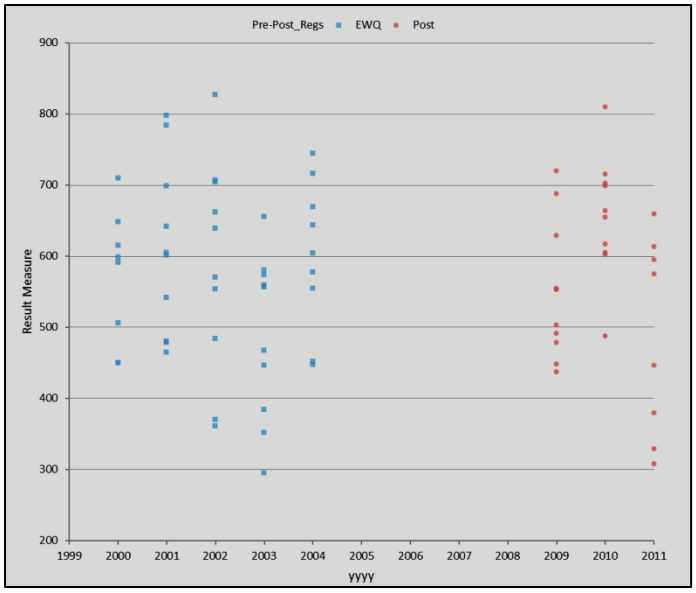
Chapter 19: 1841 BCP Bushkill Creek, PA

Specific Conductance µmho/cm

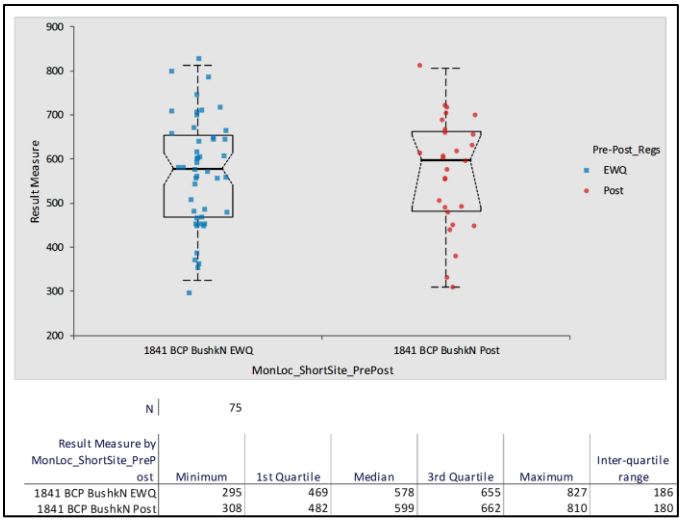
Existing Water Quality (Table 2H):

Median 578 µmho/cm
Lower 95% Confidence Interval 542 µmho/cm
Upper 95% Confidence Interval 615 µmho/cm
Defined in regulations as a flow-related parameter

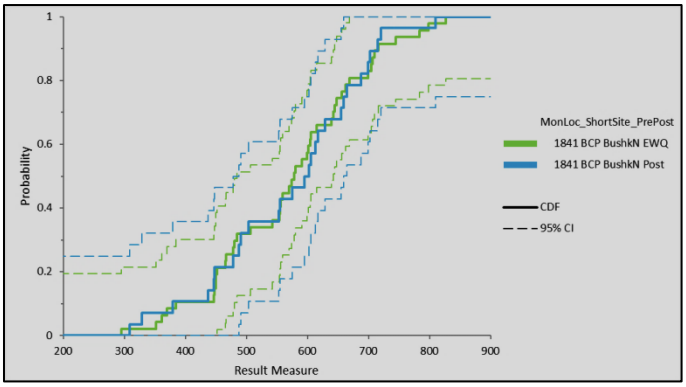




Water quality degradation may have occurred here. Specific conductance apparently increased but did not rise above the EWQ upper 95% confidence interval. However, analytical uncertainty was introduced by insufficient post-EWQ low-flow samples.



N	75					
Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	295	469	578	655	827	186
1841 BCP BushkN Post	308	482	599	662	810	180



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	47	2.8	0.06
1841 BCP BushkN Post	28	4.7	0.17

H statistic	0.02
X² approximation	0.02
DF	1
p-value	0.8998 [1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Do not reject the null hypothesis at the 5% significance level.

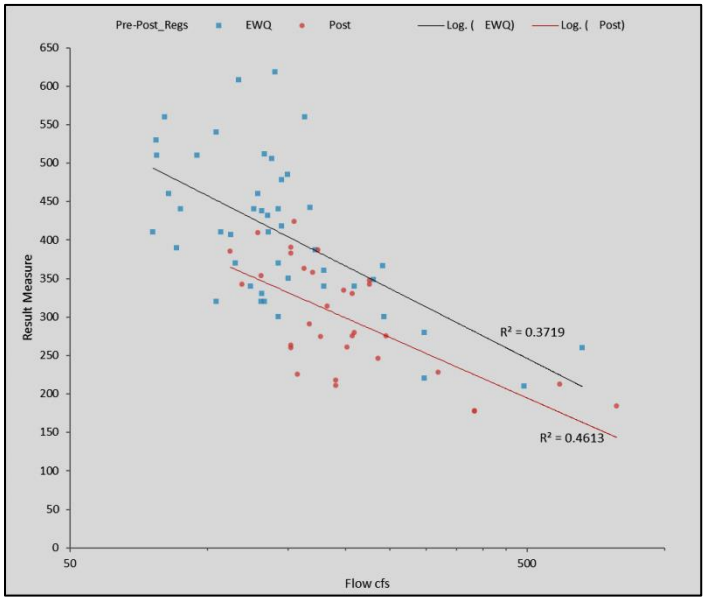
Specific conductance is inversely related to flow in both data sets. If median flow between the two data sets were equal, the increase would have been significant. Since post-EWQ median flow was 45 cfs greater than EWQ median flow, specific conductance did not measurably change. However, the difference is apparent on the plot of concentration vs. flow. The rise in specific conductance may be partially attributable to the concurrent rise in chloride concentrations. Median specific conductance has risen from 578 to 599 µmho/cm; a 10% increase in a few years' time. No data were available to confirm DRBC results.

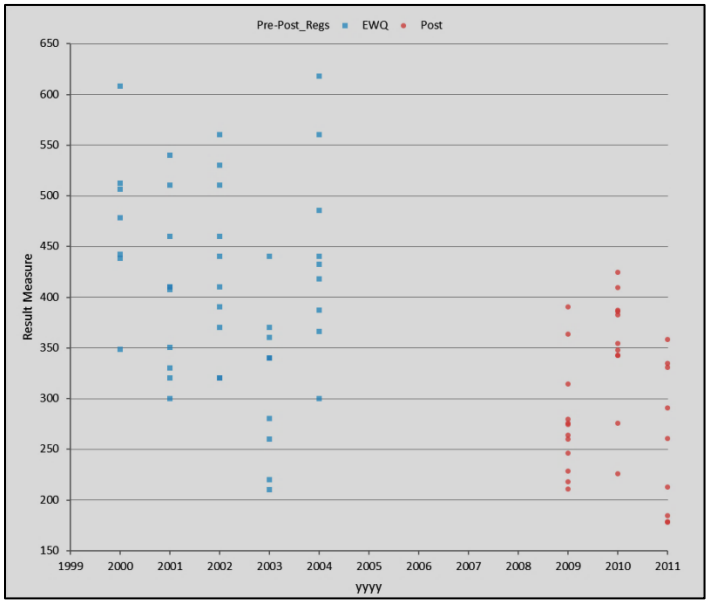
Chapter 19: 1841 BCP Bushkill Creek, PA

Total Dissolved Solids (TDS) mg/l

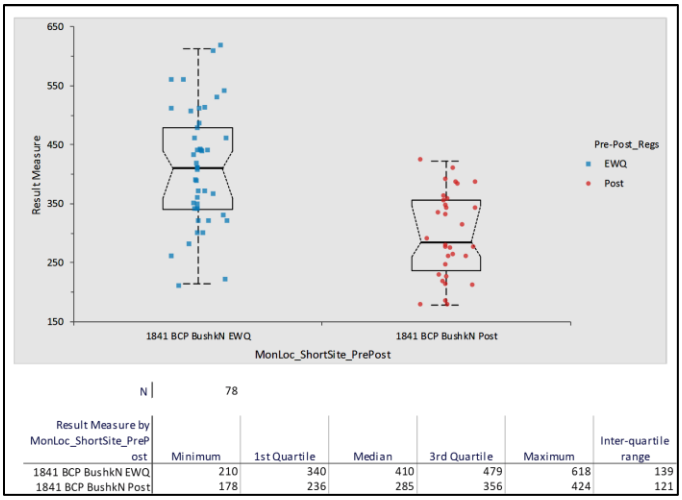
Existing Water Quality (Table 2H):

Median 410 mg/l
Lower 95% Confidence Interval 360 mg/l
Upper 95% Confidence Interval 440 mg/l
Defined in regulations as a flow-related parameter



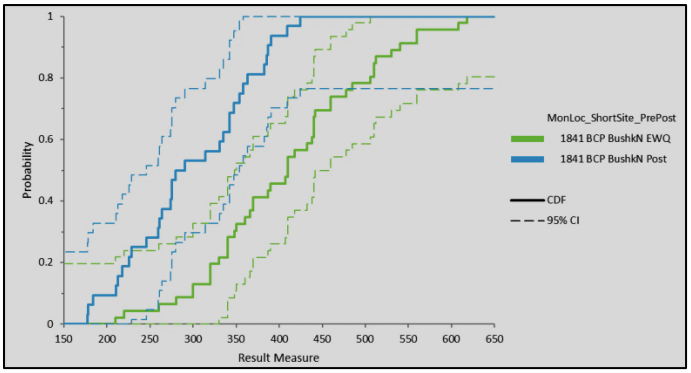


No water quality degradation is evident here. TDS apparently declined. However, analytical uncertainty was introduced by potential laboratory artifacts and insufficient post-EWQ low-flow samples.



N	78

Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	210	340	410	479	618	139
1841 BCP BushkN Post	178	236	285	356	424	121



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	46	4720.8	102.63
1841 BCP BushkN Post	32	6786.1	212.07

H statistic	22.41
X^2 approximation	22.41
DF	1
p-value	<0.0001[1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Reject the null hypothesis in favour of the alternative hypothesis at the 5% significance level.

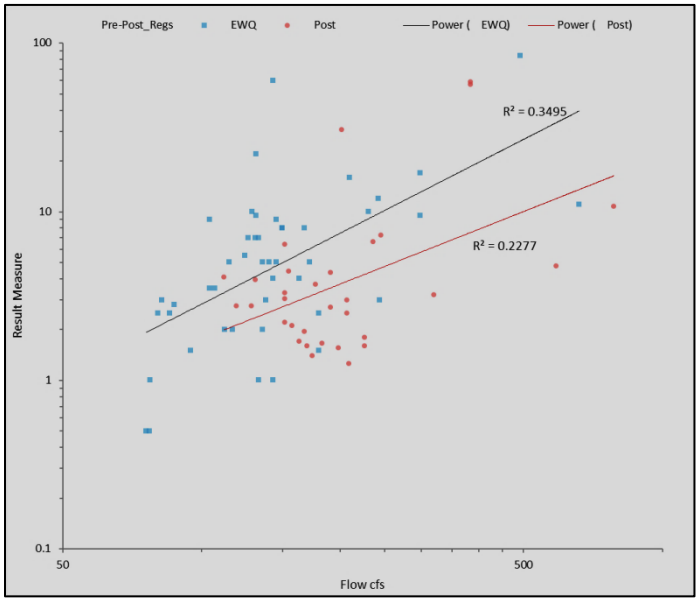
TDS is inversely related to flow in both data sets. Post-EWQ median TDS fell below the EWQ lower 95% lower confidence interval. Post-EWQ TDS was slightly less variable than the baseline samples as well. Post-EWQ detection limits were lower than EWQ detection limits, though there were no undetected results at any time.

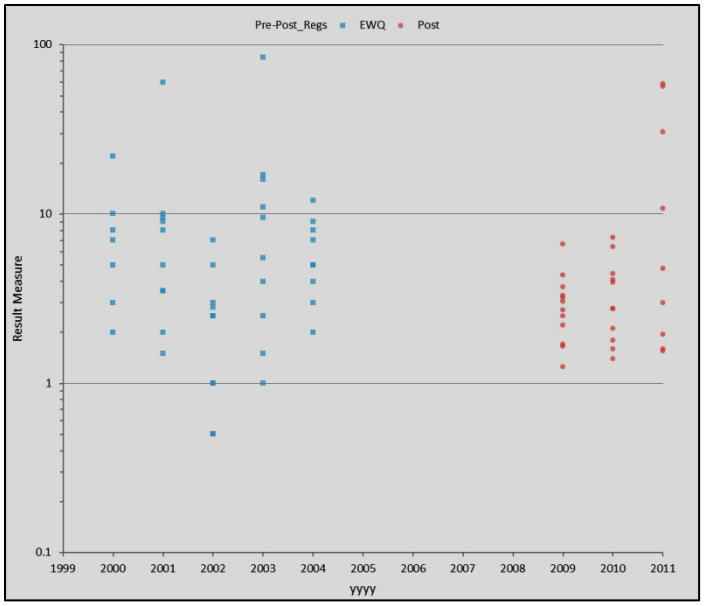
Chapter 19: 1841 BCP Bushkill Creek, PA

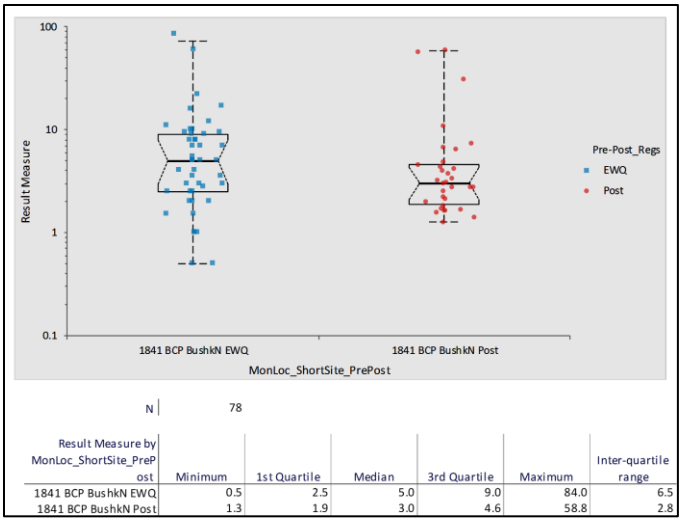
Total Suspended Solids (TSS) mg/l

Existing Water Quality (Table 2H):

Median 5.0 mg/l
Lower 95% Confidence Interval 3.0 mg/l
Upper 95% Confidence Interval 8.0 mg/l
Should have been designated in rules as flow-related

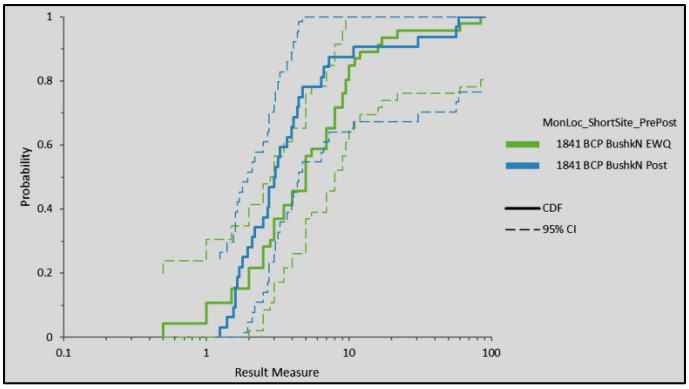






N	78

Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	0.5	2.5	5.0	9.0	84.0	6.5
1841 BCP BushkN Post	1.3	1.9	3.0	4.6	58.8	2.8



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	46	577.6	12.56
1841 BCP BushkN Post	32	830.3	25.95

H statistic	2.74
X^2 approximation	2.74
DF	1
p-value	0.0976 [1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Do not reject the null hypothesis at the 5% significance level.

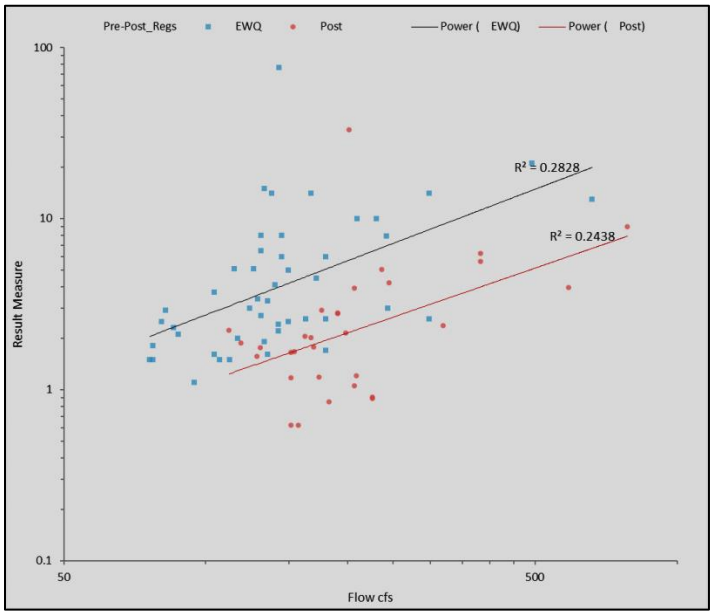
No water quality degradation is evident here. TSS apparently did not measurably change between the EWQ and post-EWQ periods. However, analytical uncertainty was introduced by potential laboratory artifacts and insufficient post-EWQ low-flow samples. TSS is positively but weakly related to flow in both data sets. Post-EWQ median TSS fell to the EWQ lower 95% confidence interval, which is expected given the higher flow conditions sampled in the post-EWQ data set. Flows and concentrations are plotted on logarithmic scale, and regressions are power relationships. There were no independent data available to confirm DRBC results.

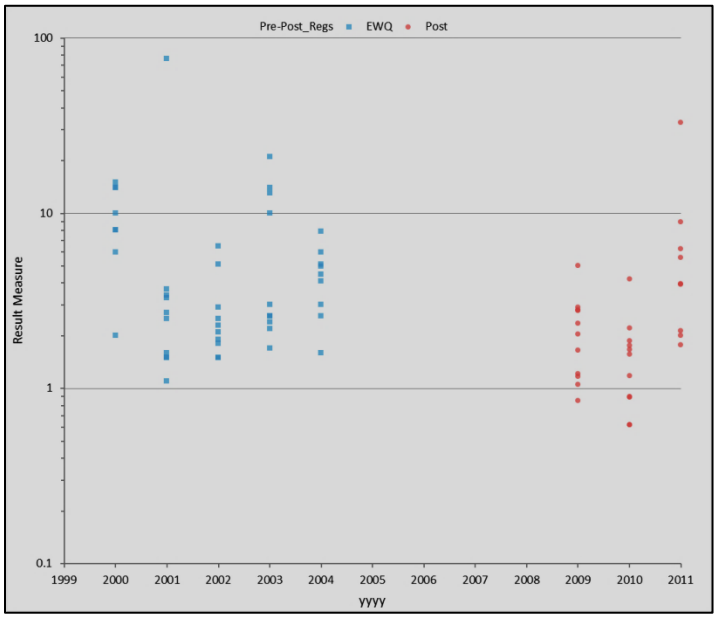
Chapter 19: 1841 BCP Bushkill Creek, PA

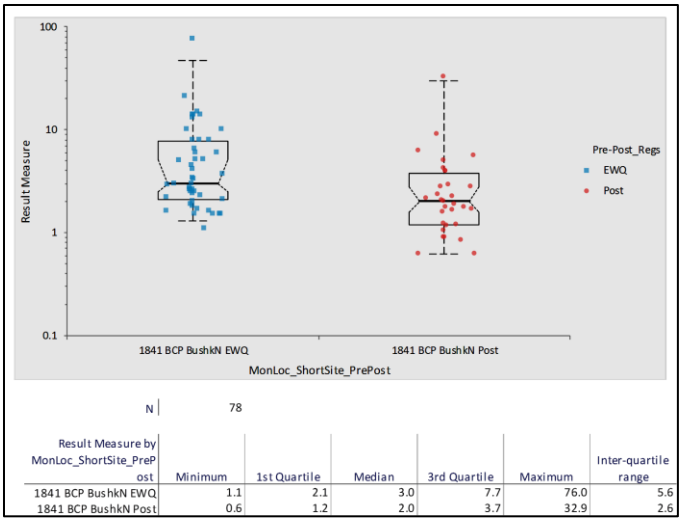
Turbidity NTU

Existing Water Quality (Table 2H):

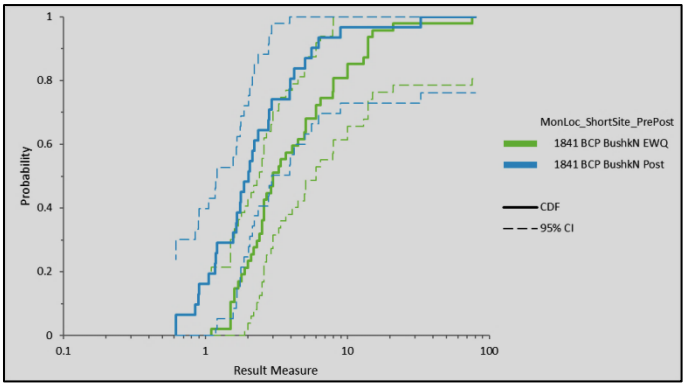
Median 3.0 NTU
Lower 95% Confidence Interval 2.5 NTU
Upper 95% Confidence Interval 5.1 NTU







N	78					
Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	1.1	2.1	3.0	7.7	76.0	5.6
1841 BCP BushkN Post	0.6	1.2	2.0	3.7	32.9	2.6



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	47	1845.3	39.26
1841 BCP BushkN Post	31	2797.8	90.25

H statistic	9.04
X^2 approximation	9.04
DF	1
p-value	0.0026 [1]

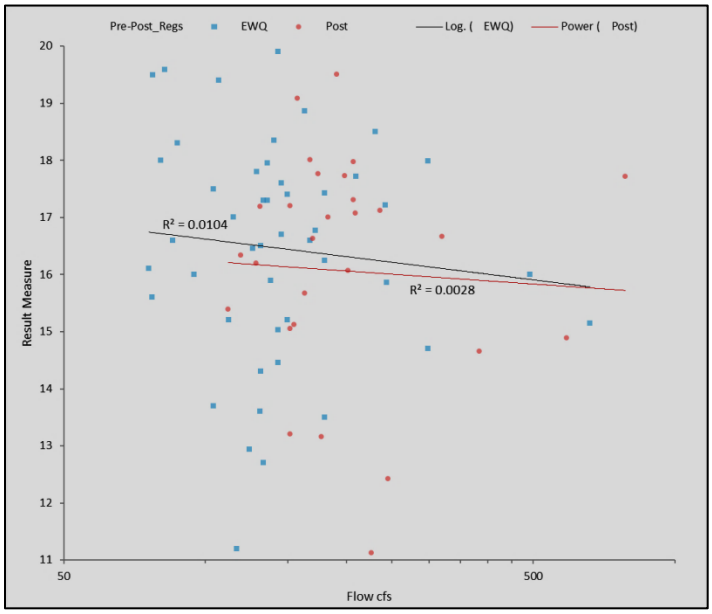
H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Reject the null hypothesis in favour of the alternative hypothesis at the 5% significance level.

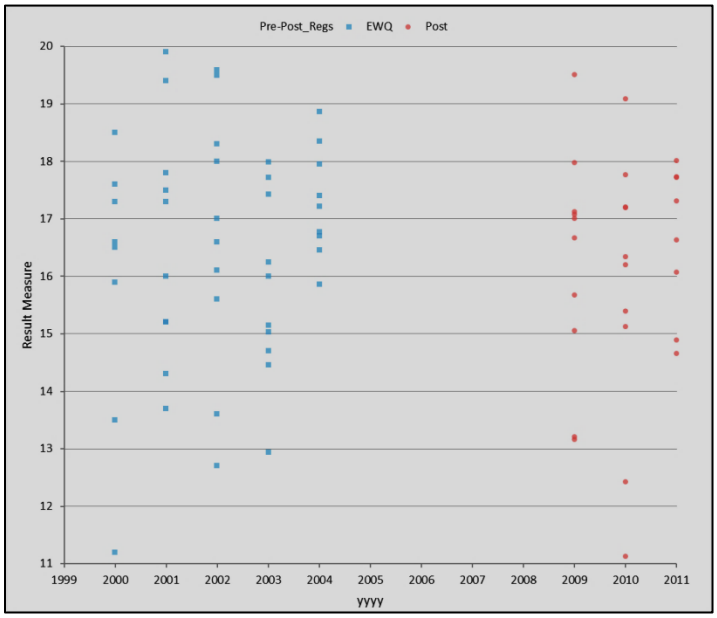
No water quality degradation is evident here. Turbidity apparently declined between the EWQ and post-EWQ periods. However, analytical uncertainty was introduced by insufficient post-EWQ low-flow samples. The post-EWQ median turbidity fell below the lower EWQ 95% confidence interval. Turbidity is positively but weakly related to flow in both data sets. Flows and concentrations are represented on logarithmic scale, and regressions are power relationships. There were no additional data available for comparison with DRBC results.

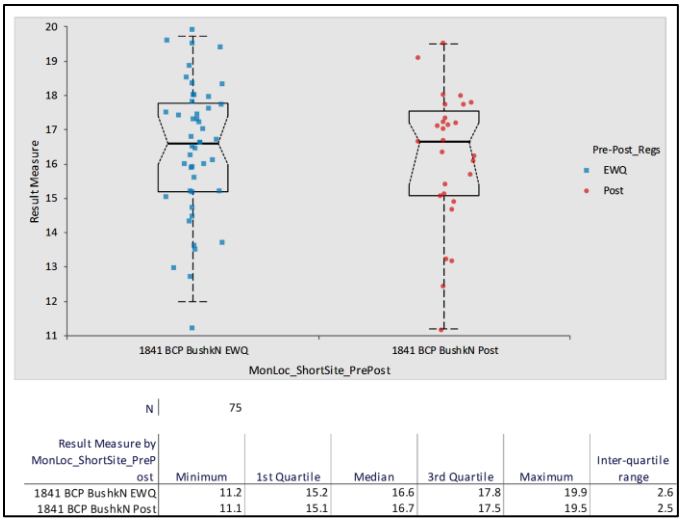
Chapter 19: 1841 BCP Bushkill Creek, PA

Water Temperature, degrees C

Not included in DRBC Existing Water Quality rules

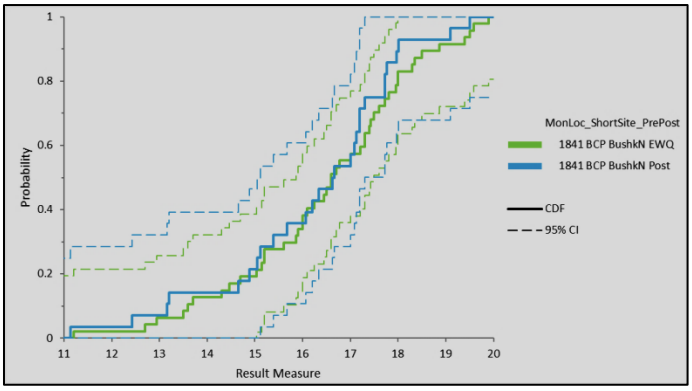






N	75

Result Measure by MonLoc_ShortSite_PrePost	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Inter-quartile range
1841 BCP BushkN EWQ	11.2	15.2	16.6	17.8	19.9	2.6
1841 BCP BushkN Post	11.1	15.1	16.7	17.5	19.5	2.5



Kruskal-Wallis test

Result Measure by MonLoc_ShortSite_PrePost	n	Rank sum	Mean rank
1841 BCP BushkN EWQ	47	50.0	1.06
1841 BCP BushkN Post	28	84.0	3.00

H statistic	0.28
X^2 approximation	0.28
DF	1
p-value	0.5952 [1]

H0: $\theta_1 = \theta_2 = \theta...$
The median of the populations are all equal.
H1: $\theta_i \neq \theta_j$ for at least one i,j
The median of the populations are not all equal.
[1] Do not reject the null hypothesis at the 5% significance level.

No water quality degradation is evident here. Water temperature appears identical between the EWQ and post-EWQ periods. However, analytical uncertainty was introduced by insufficient post-EWQ low-flow samples. Water temperature is unrelated to flow in both data sets. No independent data were available to confirm DRBC results.