Appendix 5. Laboratory Comparison between StablCal and Polymer Turbidity Standards using natural sediment and water (from the Neosho River at Neosho Rapids, Kansas, U.S. Geological Survey [USGS] station number 07182390) at the Kansas Water Science Center Laboratory, Lawrence, Kansas

Comparison Description

Station name: Kansas Water Science laboratory, Lawrence, Kansas.

Equipment: A Yellow Springs Instrument (YSI) EXO water-quality monitor equipped with two YSI EXO turbidity sensors calibrated using two different standards were deployed in a laboratory turbidity testing apparatus for comparison between the two standards. (See "Performance Evaluation Tests," "Laboratory Tests," p. 7 of main report, for a full description of laboratory methods.) The Hach model 2100AN laboratory turbidimeter with a flow-through cell was used as a reference to measure the turbidity in the bucket apparatus every 15 minutes before adding more sediment. No datum corrections were applied to either dataset.

Testing material and water: Sediment and water from Neosho River at Neosho Rapids, Kansas (U.S. Geological Survey [USGS] station number 07182390).

Calibration standard used: One sensor was calibrated with Hach StablCal turbidity standard and one sensor was calibrated with YSI polymer standard.

Laboratory comparison date: March 28, 2017.

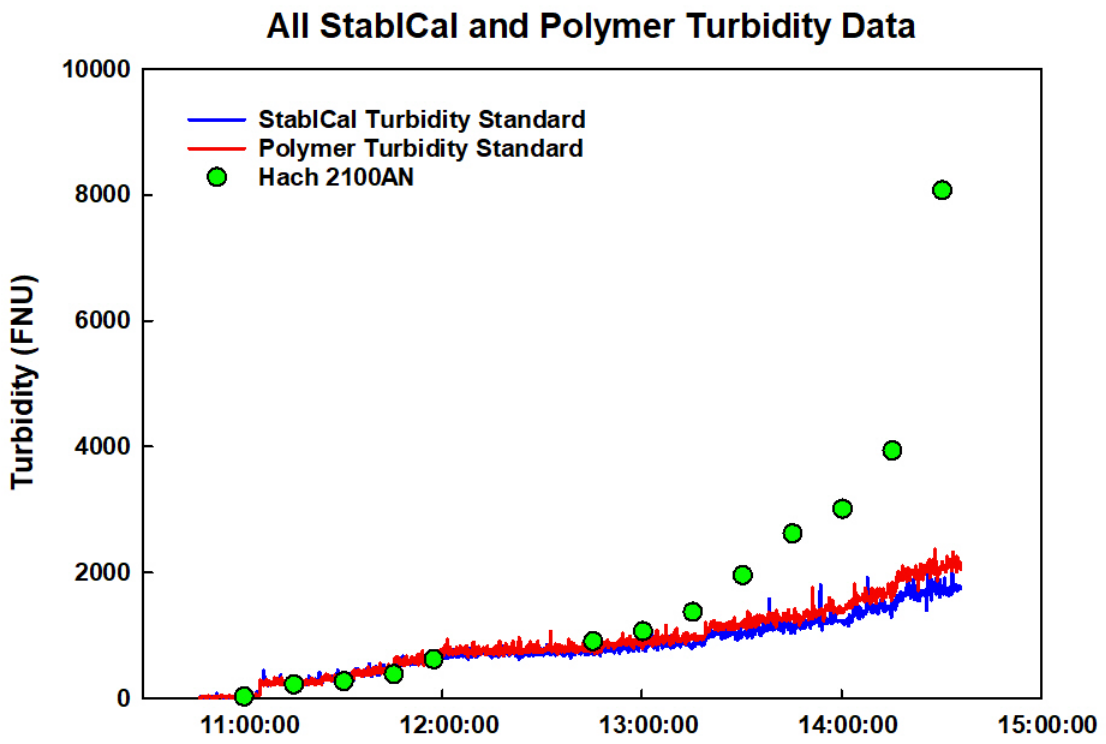
Datasets

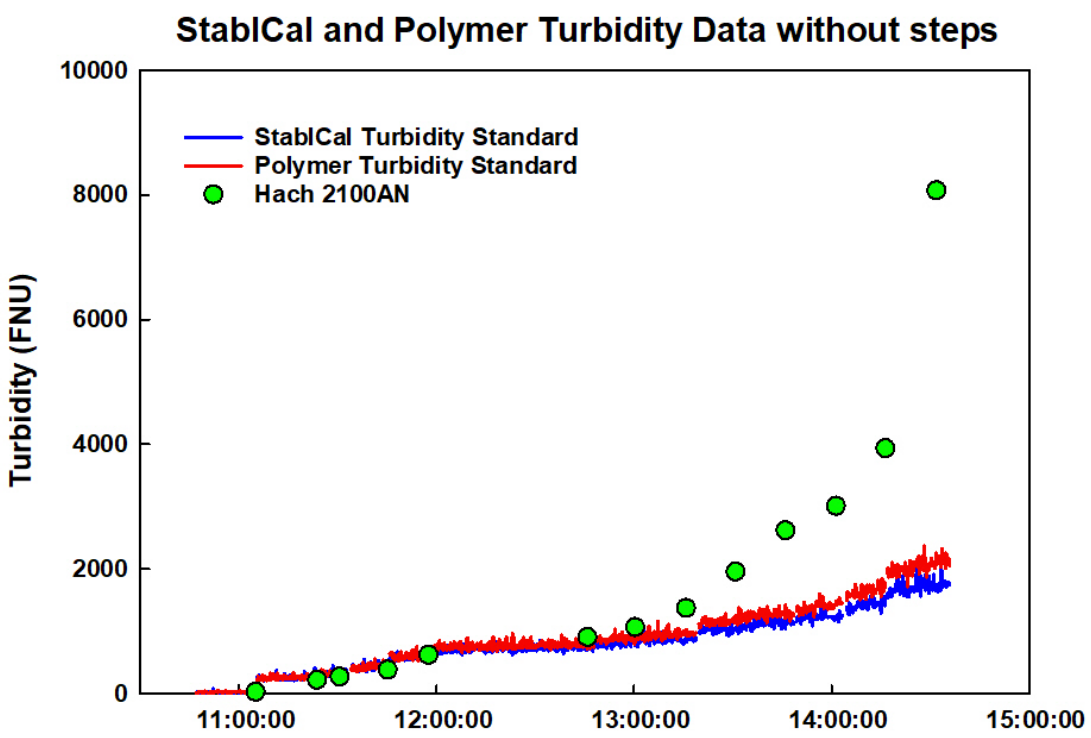
All data were collected using U.S. Geological Survey [USGS] protocols (U.S. Geological Survey, variously dated) and are published in King (2021). Data were edited to remove periods where material was added to the testing apparatus, leaving the steady-state data for analysis.

Polymer Standard Identification

	124 FNU Lot Number	1,010 FNU Lot Number
Polymer #1	17C795054	17B793997

Time Series


All StablCal and Polymer Turbidity Data
StablCal Turbidity Standard
Polymer Turbidity Standard
Hach 2100AN
Turbidity (FNU)
10000
8000
6000
4000
2000
0
11:00:00
12:00:00
13:00:00
14:00:00
15:00:00


StablCal and Polymer Turbidity Data without steps
StablCal Turbidity Standard
Polymer Turbidity Standard
Hach 2100AN
Turbidity (FNU)
10000
8000
6000
4000
2000
0
11:00:00
12:00:00
13:00:00
14:00:00
15:00:00

Statistical Analyses – Stablcal and Polymer Turbidity Standard Data

Slope comparison

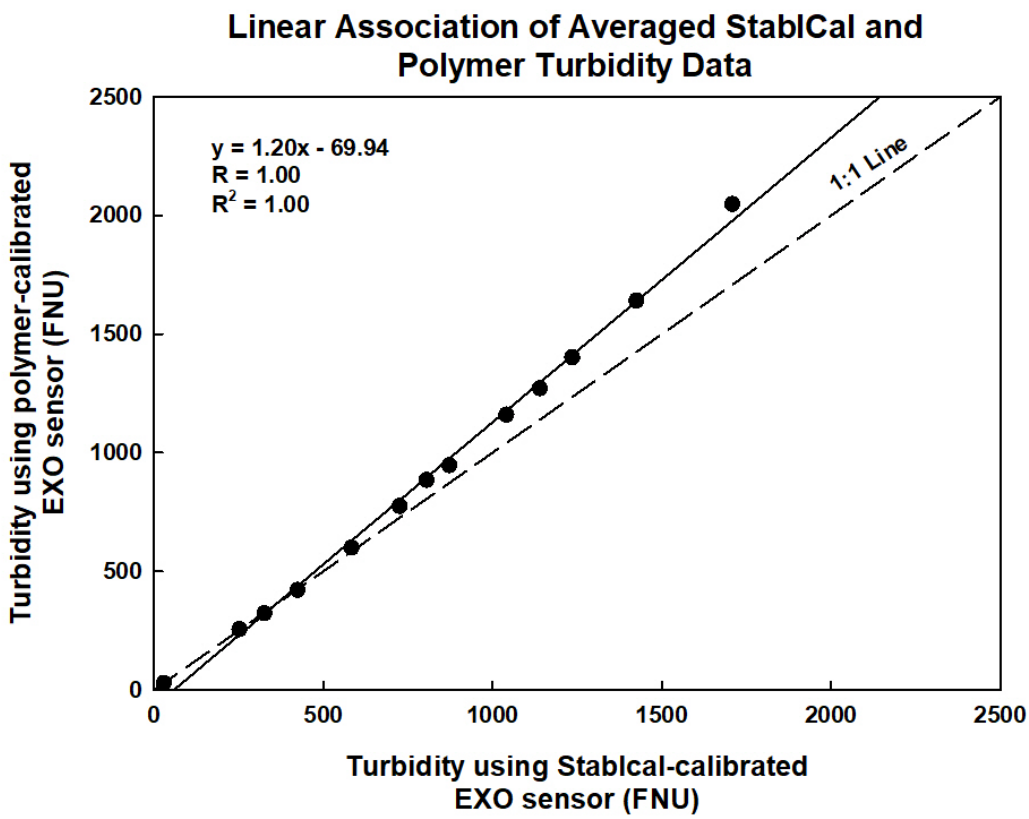
The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor calibrated by using two different calibration standards at the Kansas Water Science Center laboratory, Lawrence, Kansas, on March 28, 2017; the data used in the final regressions were averages of turbidity for each step, each of which had a duration of approximately 15 minutes once the sensor had stabilized:

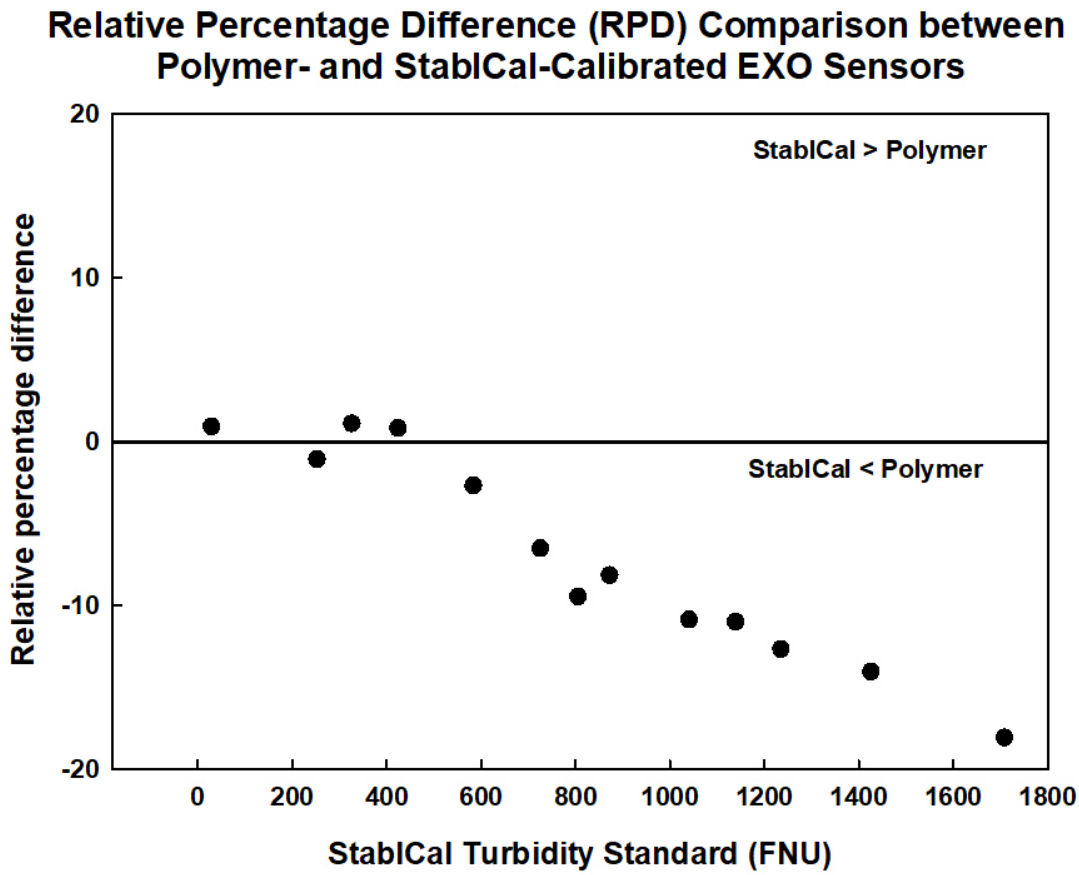
$$y = 1.20x - 69.94$$

where

y = turbidity measured with Polymer-calibrated EXO sensor (FNU)

x = turbidity measured with StablCal-calibrated EXO sensor (FNU).





Wilcoxon Signed-Rank Test for StablCal and Polymer Data

SigmaPlot Statistical Output:

Normality Test (Shapiro-Wilk): Failed (P < 0.050)

Group	N	Missing	Median	25%	75%
StablCal	13	0	804.913	375.214	1187.058
Polymer	13	0	884.899	371.704	1336.836

W= 75.000 T+ = 83.000 T-= -8.000

Z-Statistic (based on positive ranks) = 2.621

P(est.) = 0.010 P(exact)= 0.006

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = 0.006).

R Statistical Output:

```
Wilcoxon Signed-Rank test with continuity correction

data:  StablCal and Polymer
V = 8, p-value = 0.006104
alternative hypothesis: true location shift is not equal to 0
95 percent confidence interval:
 -167.03427  -24.30251
sample estimates:
(pseudo)median
     -79.98575
```

Summary of Results

There is a strong linear association between measurements made with the two sensors (R = 1.00). Relative percentage difference ranged from 1 to 18 percent (median: 8 percent; mean: 7 percent). The data did not pass the Shapiro-Wilk test for normality (P<0.05); therefore, a Wilcoxon signed-rank test was performed. The difference between median values for the StablCal- and polymer-calibrated EXO sensors was statistically significant (P<0.05).

Statistical Analyses - StablCal and Hach 2100AN Data

Slope comparison

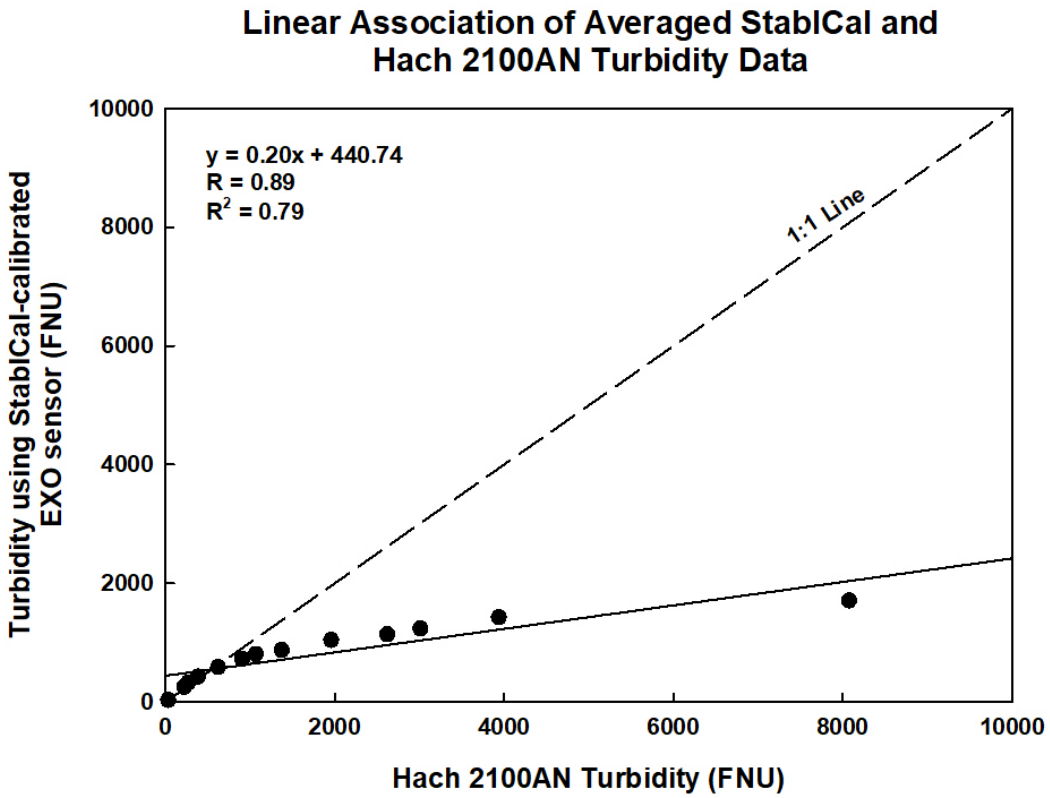
The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor calibrated by using StablCal turbidity standard and compared to turbidity measured with a Hach 2100AN laboratory turbidimeter at the Kansas Water Science Center laboratory, Lawrence, Kansas, on March 28, 2017; the data used in the final regressions were averages of turbidity for each step, each of which had a duration of approximately 15 minutes once the sensor had stabilized:

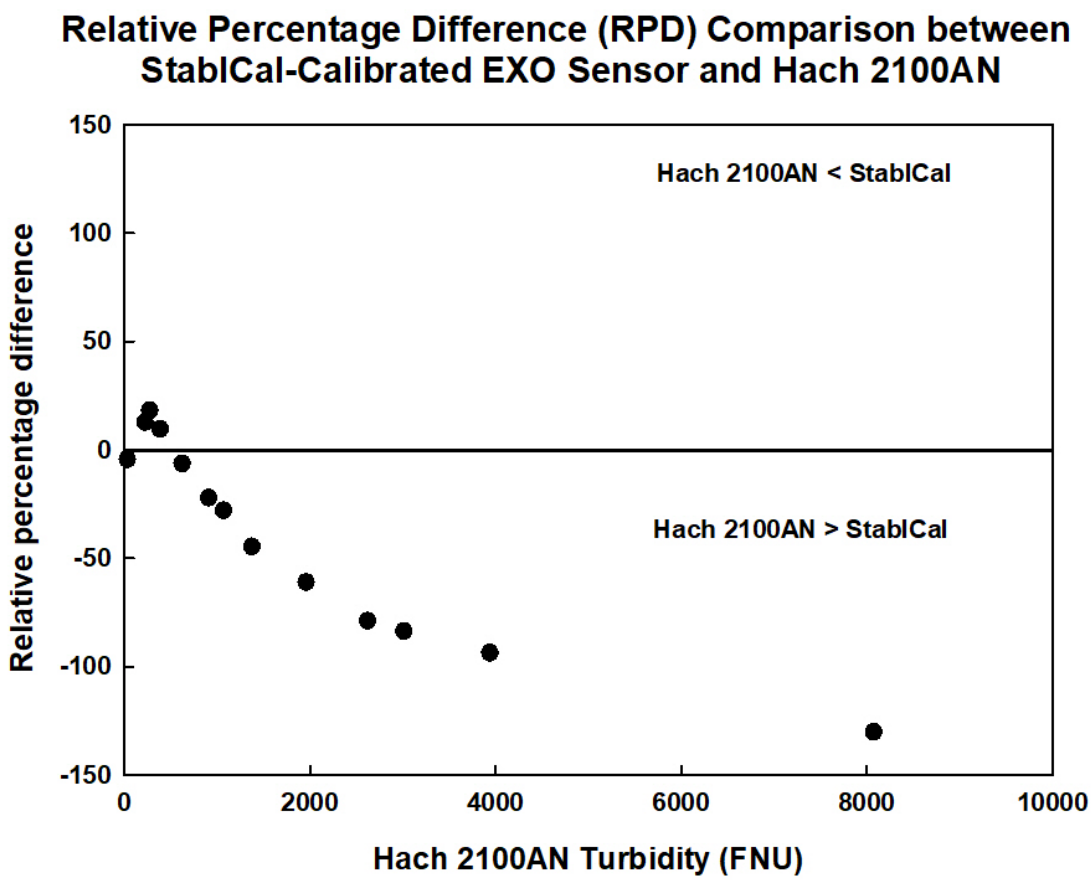
$$y = 0.20x + 440.74$$

where

y = turbidity measured with tStablCal-calibrated EXO sensor (FNU)

x = turbidity measured with Hach 2100AN turbidimeter (FNU).


Linear Association of Averaged StablCal and
Hach 2100AN Turbidity Data
y = 0.20x + 440.74
R = 0.89
R2 = 0.79
1:1 Line
Turbidity using StablCal-calibrated
EXO sensor (FNU)
Hach 2100AN Turbidity (FNU)
0
2000
4000
6000
8000
10000



Wilcoxon Signed-Rank Test for StablCal and Hach 2100AN

SigmaPlot Statistical Output:

Normality Test (Shapiro-Wilk): Failed (P < 0.050)

Group	N	Missing	Median	25%	75%
Hach 2100AN	13	0	1067.000	328.250	2815.250
StablCal	13	0	804.913	375.214	1187.058

W= -69.000 T+ = 11.000 T-= -80.000

Z-Statistic (based on positive ranks) = -2.411

P(est.) = 0.017 P(exact)= 0.013

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = 0.013).

R Statistical Output:

```
Wilcoxon Signed-Rank test with continuity correction

data:  Hach 2100AN and StablCal
V = 80, p-value = 0.01343
alternative hypothesis: true location shift is not equal to 0
95 percent confidence interval:
   75.20981 1713.40939
sample estimates:
(pseudo)median
      720.6608
```

Summary of Results

There is a strong linear association between measurements made with the two sensors (R = 0.89). Relative percentage difference ranged from 4 to 130 percent (median: 28 percent; mean: 46 percent). The data did not pass the Shapiro-Wilk test for normality ($P<0.05$); therefore, a Wilcoxon signed-rank test was performed. The difference between median values for the StablCal-calibrated EXO sensor and Hach 2100AN was statistically significant ($P<0.05$).

Statistical Analyses - Polymer and Hach 2100AN Data

Slope comparison

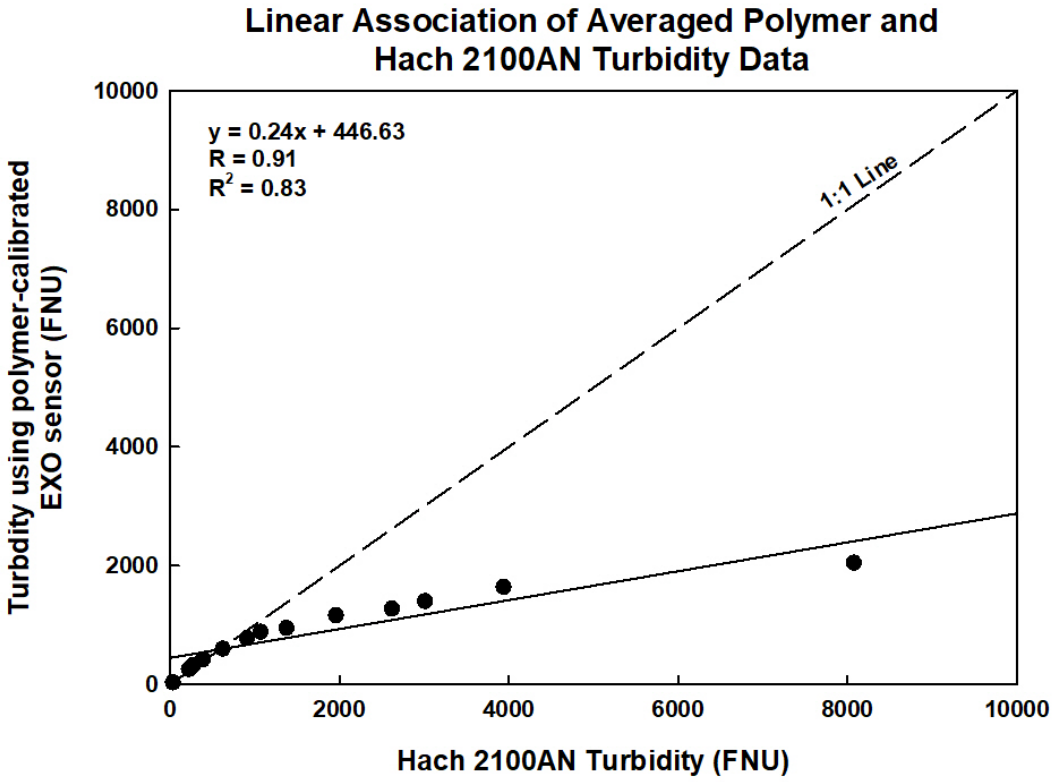
The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor calibrated by using polymer turbidity standard and compared to turbidity measured with a Hach 2100AN laboratory turbidimeter at Kansas Water Science Center laboratory, Lawrence, Kansas, on March 21, 2017; the data used in the final regressions were averages of turbidity for each step, each of which had a duration of approximately 15 minutes once the sensor had stabilized:

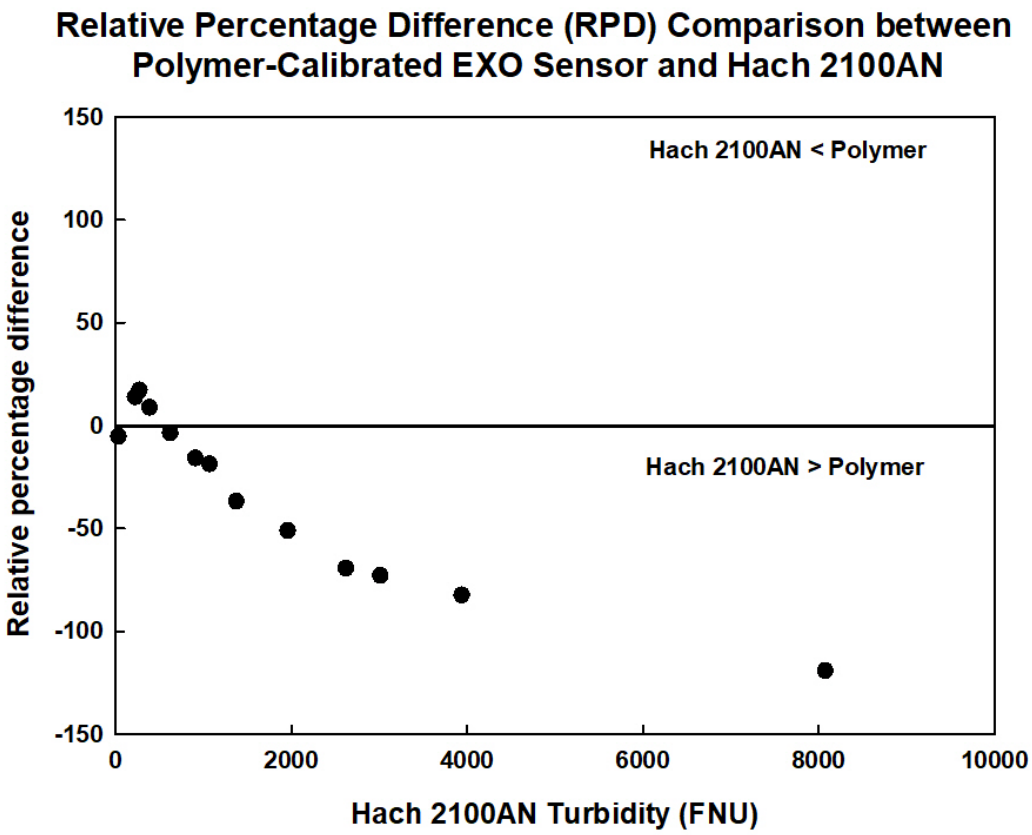
$$y = 0.24x + 446.63$$

where

y = turbidity measured with Polymer-calibrated EXO sensor (FNU)

x = turbidity measured with Hach 2100AN turbidimeter (FNU).


Linear Association of Averaged Polymer and
Hach 2100AN Turbidity Data
y = 0.24x + 446.63
R = 0.91
R2 = 0.83
1:1 Line
Turbdity using polymer-calibrated
EXO sensor (FNU)
Hach 2100AN Turbidity (FNU)
0
2000
4000
6000
8000
10000



Wilcoxon Signed-Rank Test for Polymer and Hach 2100AN

SigmaPlot Statistical Output:

Normality Test (Shapiro-Wilk): Failed (P < 0.050)

Group	N	Missing	Median	25%	75%
Hach 2100AN	13	0	1067.000	328.250	2815.250
Polymer	13	0	884.899	371.704	1336.836

W= -67.000 T+ = 12.000 T-= -79.000

Z-Statistic (based on positive ranks) = -2.341

P(est.) = 0.021 P(exact)= 0.017

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = 0.017).

R Statistical Output:

```
Wilcoxon Signed-Rank test with continuity correction

data:  Hach and Polymer
V = 79, p-value = 0.01709
alternative hypothesis: true location shift is not equal to 0
95 percent confidence interval:
   49.42509 1545.92453
sample estimates:
(pseudo)median
      656.1193
```

Summary of Results

There is a strong linear association between measurements made with the two sensors (R = 0.91). Relative percentage difference ranged from 4 to 119 percent (median: 19 percent; mean: 40 percent). The data did not pass the Shapiro-Wilk test for normality (P<0.05); therefore, a Wilcoxon signed-rank test was performed. The difference between median values for the polymer-calibrated EXO sensor and Hach 2100AN was statistically significant (P<0.05).

Selected References

Cleveland, W.S., 1979, Robust locally weighted regression and smoothing scatterplots: Journal of the American Statistical Association, v. 74, no. 368, p. 829–836.

Helsel, D.R., and Hirsch, R.M., 2002, Statistical methods in water resources—Hydrologic analysis and interpretation: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. A3, 522 p. [Also available at https://doi.org/10.3133/twri04A3.]

King, L.R., 2021, Laboratory and field data for selected turbidity standard and sensor comparisons, October 2014 to September 2017: U.S. Geological Survey Data Release, https://doi.org/10.5066/P9EVSDHH.

U.S. Geological Survey, variously dated, The national field manual for the collection of water-quality data: U.S. Geological Survey Techniques and Methods, book 9, chaps A1–A10. [Also available at https://water.usgs.gov/owq/FieldManual/.]