

Appendix 18. Field Comparison between YSI EXO and YSI 6136 Turbidity Sensors at Difficult Run above Fox Lake near Fairfax, Virginia (U.S. Geological Survey [USGS] Station Number 01645704), May 6 to July 25, 2017

Comparison Description

Station name: Difficult Run above Fox Lake near Fairfax, Virginia (U.S. Geological Survey [USGS] station number 01645704).

Equipment: A Yellow Springs Instrument (YSI) EXO water-quality monitor equipped with a YSI EXO turbidity sensor and a YSI 6 series equipped with a YSI 6136 turbidity sensor were deployed at the site for comparison between the sensors. The monitors were set to log data every 15 minutes. The sensors were strapped together and side-by-side during the deployment. Fouling and calibration corrections were applied when necessary.

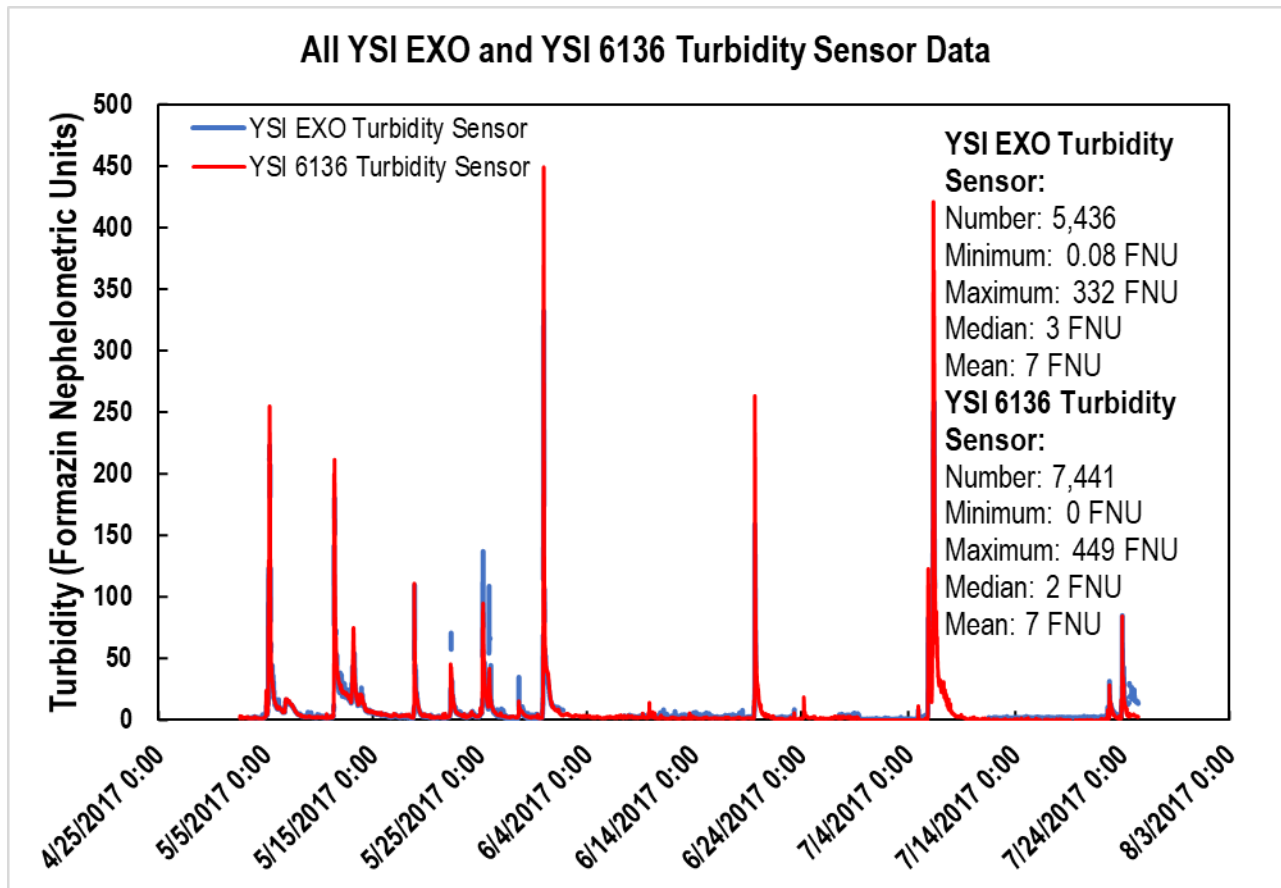
Calibration standard used: Hach StablCal standard.

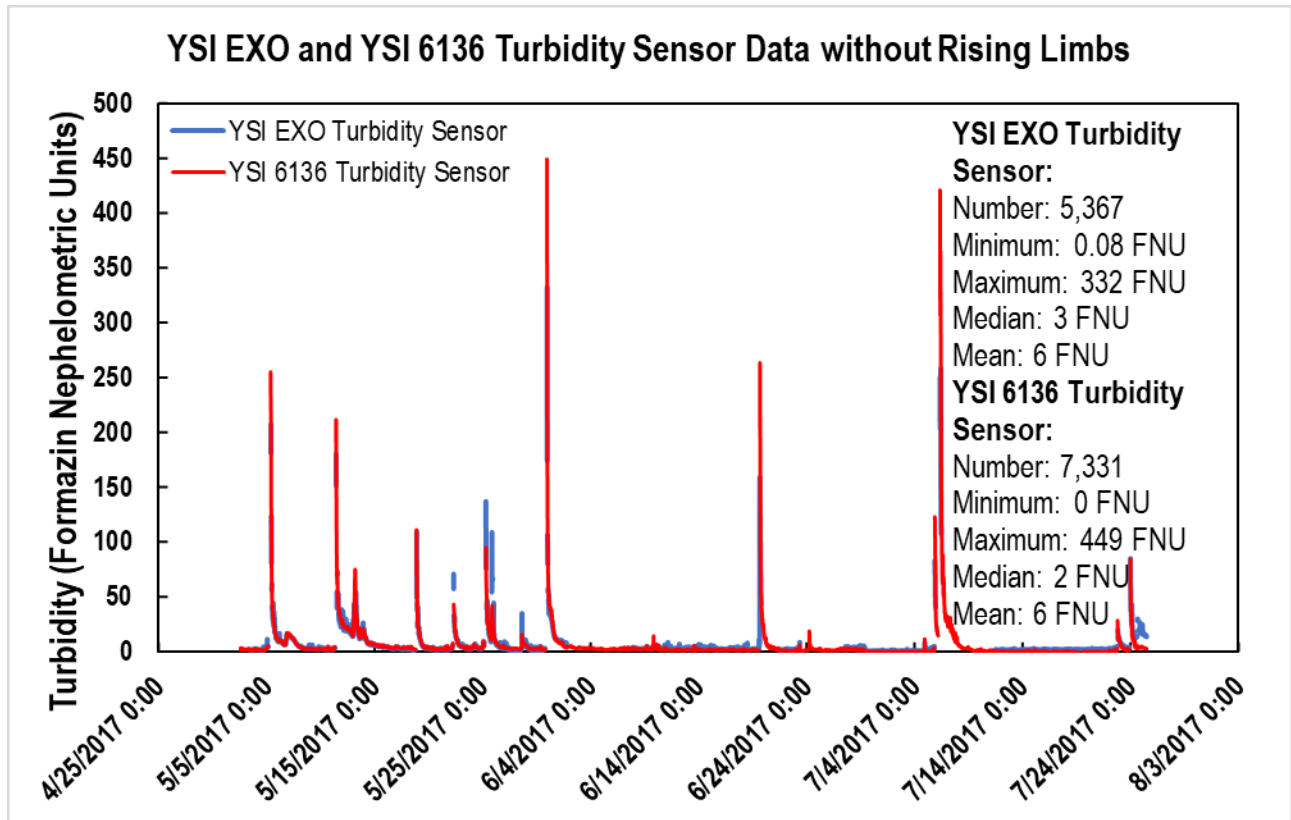
Side-by-side comparison data period: May 6 to July 25, 2017.

Datasets

All data were collected using USGS protocols (U.S. Geological Survey, variously dated) and are published in King (2021). Data were analyzed in three ways: (1) the entire dataset (0–1,000 formazin nephelometric units [FNU]) with only clearly erroneous data edited out, (2) 0–99 FNU with the rising limbs removed, and (3) 100–1,000 FNU with the rising limbs removed. Rising limbs were removed (on the basis of visual inspection, when the hydrograph became vertical to near vertical) to eliminate the effect of the highly variable turbidity readings commonly observed during this part of the hydrograph.

Time Series





Statistical Analyses – All Data

Slope comparison

The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor and a YSI 6136 turbidity sensor at Difficult Run above Fox Lake near Fairfax, Virginia, May 6, 2016 to July 25, 2017.

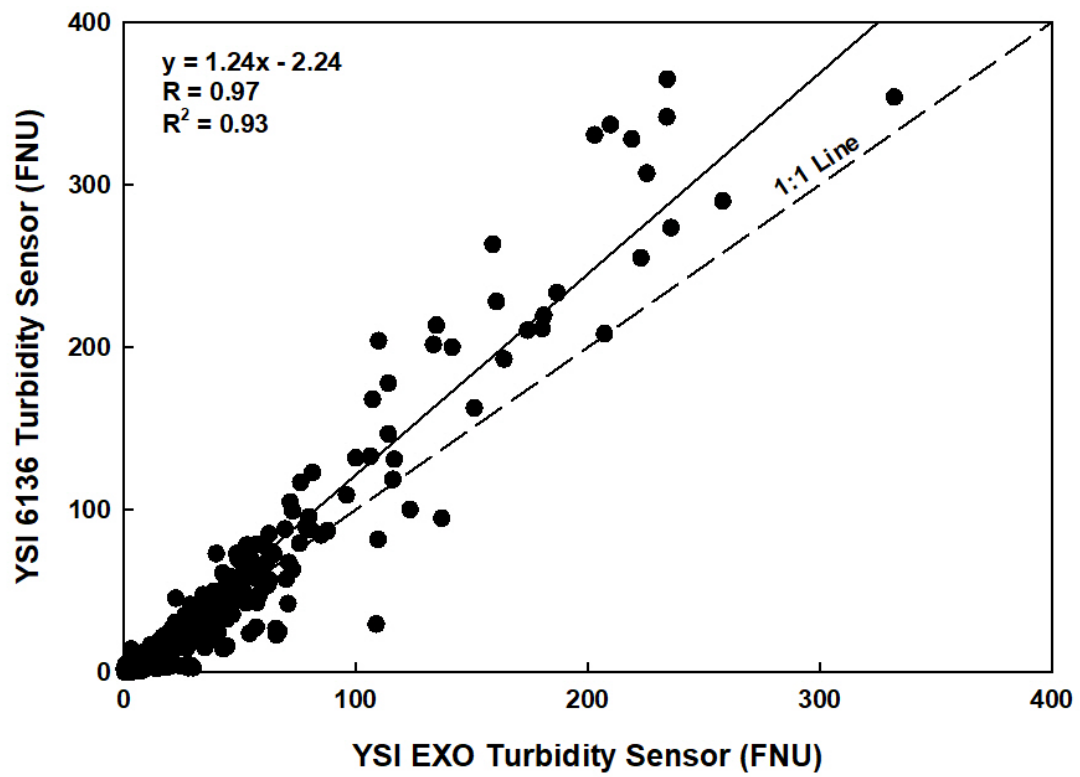
$$y = 1.24x - 2.24$$

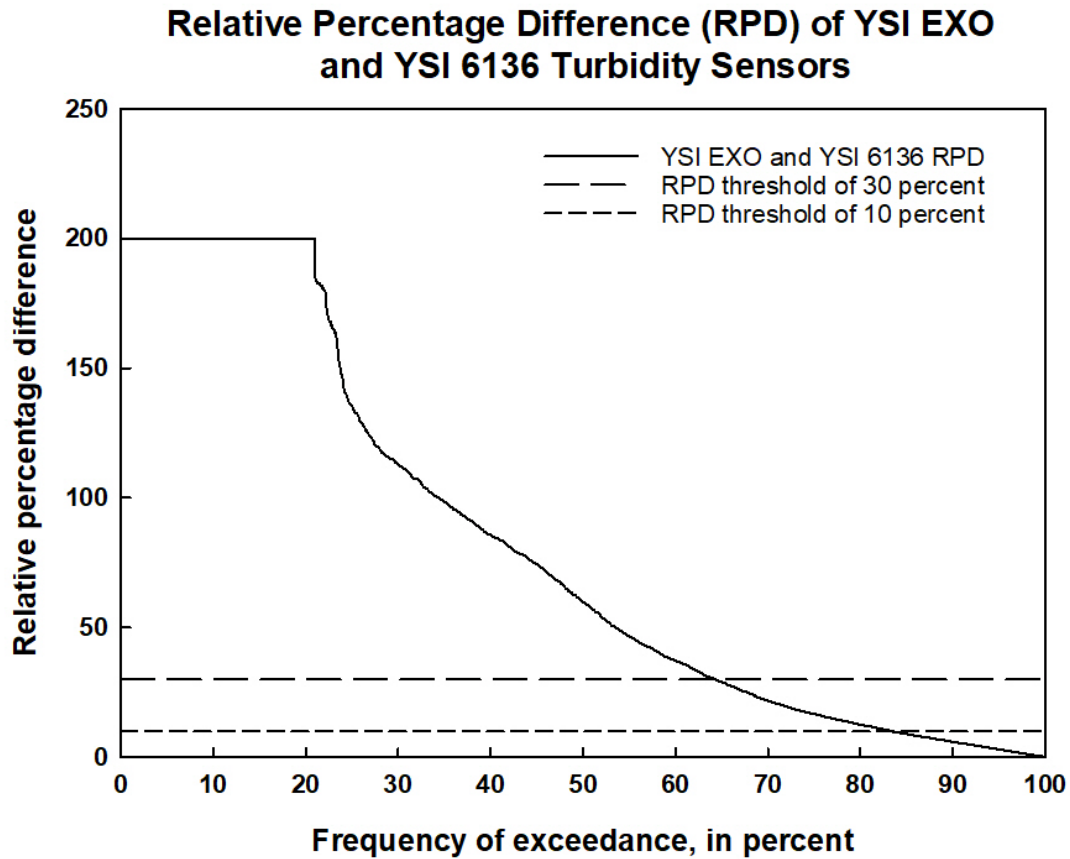
where

y = turbidity measured with YSI 6136 turbidity sensor (FNU)

x = turbidity measured with YSI EXO turbidity sensor (FNU).

Linear Association of All YSI EXO and YSI 6136 Turbidity Data





Wilcoxon Signed-Rank Test for All Data

SigmaPlot Statistical Output:

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

Group	N	Missing	Median	25%	75%
YSI EXO	4957	1	2.800	2.000	4.576
YSI 6136	4957	1	1.700	0.500	3.600

W= -7211525.000 T+ = 2528528.000 T- = -9740053.000

Z-Statistic (based on positive ranks) = -35.828

($P = < 0.001$)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference ($P = < 0.001$).

R Statistical Output:

wilcoxon Signed-Rank test with continuity correction

```
data: YSI 6136 and YSI EXO
v = 2528528, p-value < 2.2e-16
alternative hypothesis: true location shift is not equal to 0
95 percent confidence interval:
 -0.9868205 -0.8956972
sample estimates:
(pseudo)median
 -0.940699
```

Summary of Results

There is a strong linear association between measurements made with the two sensors ($R = 0.97$). Sixty-four percent of the time, the relative percentage difference in turbidity values measured with the two sensors was greater than 30 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 YSI EXO and YSI 6136 turbidity sensors was statistically significant ($P < 0.05$).

Statistical Analyses - Low-Turbidity Conditions (0 to 99 FNU)

The data from the side-by-side comparison were separated into low- and high-turbidity conditions. These statistical analyses are for low-turbidity conditions between 0 and 99 FNU.

Slope comparison

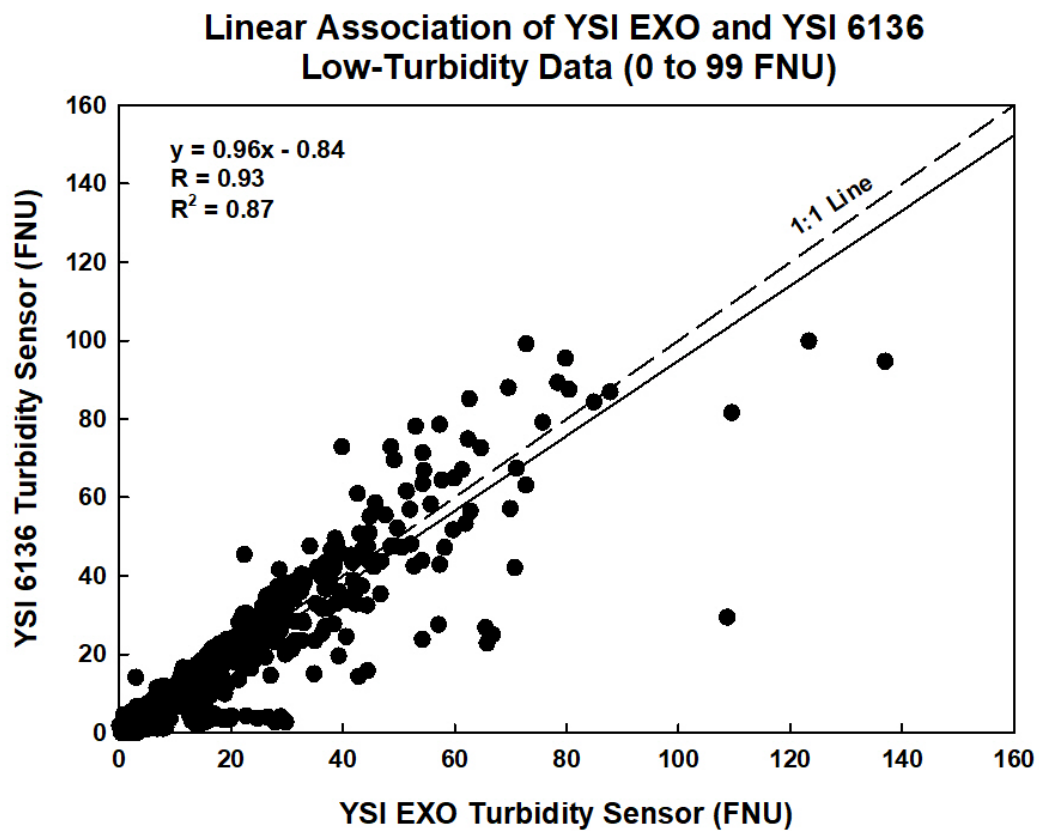
The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor and a YSI 6136 turbidity sensor at low-turbidity conditions (0 to 99 FNU) at Difficult Run above Fox Lake near Fairfax, Virginia, May 6 to July 25, 2017.

$$y = 0.96x - 0.84$$

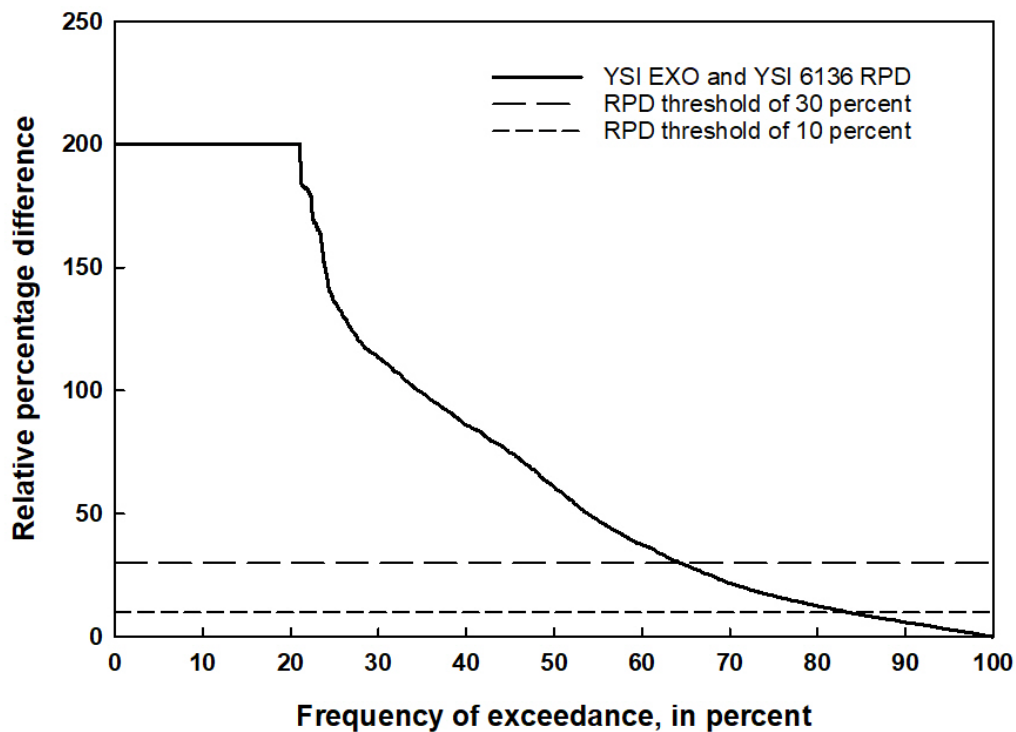
where

y = turbidity measured with YSI 6136 turbidity sensor (FNU)

x = turbidity measured with YSI EXO turbidity sensor (FNU).



Relative Percentage Difference (RPD) of YSI EXO and YSI 6136 Turbidity Sensors During Low-Turbidity Conditions (0 to 99 FNU)



Wilcoxon Signed-Rank Test for Low-Turbidity Data

SigmaPlot Statistical Output:

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

Group	N	Missing	Median	25%	75%
YSI EXO	4920	0	2.800	2.000	4.500
YSI 6136	4920	0	1.687	0.449	3.600

$W = -7377999.000$ $T+ = 2358911.000$ $T- = -9736910.000$

Z-Statistic (based on positive ranks) = -37.047

($P = < 0.001$)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference ($P = < 0.001$).

R Statistical Output:

wilcoxon Signed-Rank test with continuity correction

```
data: YSI 6136 and YSI EXO
v = 2358911, p-value < 2.2e-16
alternative hypothesis: true location shift is not equal to 0
95 percent confidence interval:
 -1.0048967 -0.9155347
sample estimates:
(pseudo)median
 -0.9598338
```

Summary of Results

There is a strong linear association between measurements made with the two sensors ($R = 0.93$). Sixty-four percent of the time, the relative percentage difference in turbidity values measured with the two sensors was greater than 30 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 YSI EXO and YSI 6136 turbidity sensors was statistically significant ($P < 0.05$).

Statistical Analyses - High-Turbidity Conditions (100 to 1,000 FNU)

The data from the side-by-side comparison were separated into low- and high-turbidity conditions. These statistical analyses are for high-turbidity conditions between 100 and 1,000 FNU.

Slope comparison

The following is a summary of final regression analysis for sensor-measured turbidity from a YSI EXO turbidity sensor and a YSI 6136 turbidity sensor at high-turbidity conditions (100 to 1,000 FNU) at Difficult Run above Fox Lake near Fairfax, Virginia, May 6 to July 25, 2017.

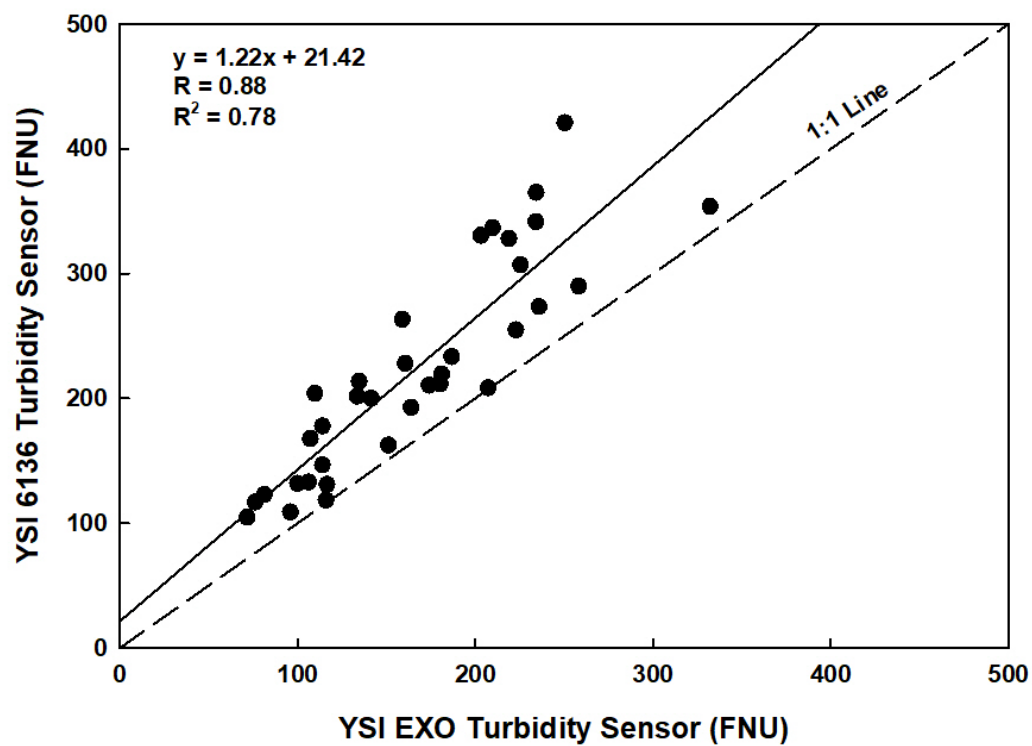
$$y = 1.22x + 21.42$$

where

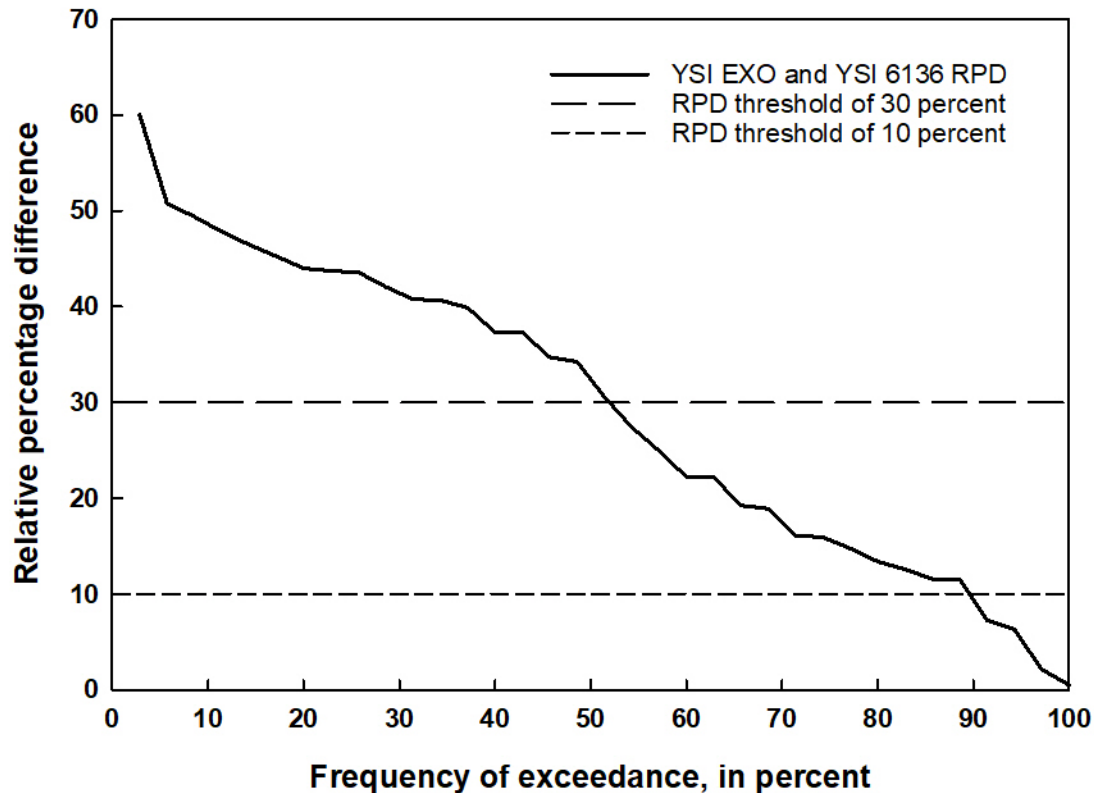
y = turbidity measured with YSI 6136 turbidity sensor (FNU)

x = turbidity measured with YSI EXO turbidity sensor (FNU).

**Linear Association of YSI EXO and YSI 6136
High-Turbidity Data (100 to 1,000 FNU)**



Relative Percentage Difference (RPD) of YSI EXO and YSI 6136 Turbidity Sensors During High-Turbidity Conditions (100 to 1,000 FNU)



Wilcoxon Signed-Rank Test for High-Turbidity Data

SigmaPlot Statistical Output:

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

Group	N	Missing	Median	25%	75%
YSI EXO	35	0	160.600	114.000	219.000
YSI 6136	35	0	210.319	146.500	289.900

W= 630.000 T+ = 630.000 T- = -0.000

Z-Statistic (based on positive ranks) = 5.159
($P = < 0.001$)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference ($P = < 0.001$).

R Statistical Output:

wilcoxon Signed-Rank test with continuity correction

```
data: YSI 6136 and YSI EXO
V = 630, p-value = 5.821e-11
alternative hypothesis: true location shift is not equal to 0
95 percent confidence interval:
 36.75231 70.31466
sample estimates:
(pseudo)median
 52.7371
```

Summary of Results

There is a strong linear association between measurements made with the two sensors ($R = 0.88$). Fifty-one percent of the time, the relative percentage difference in turbidity values measured with the two sensors was greater than 30 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 YSI EXO and YSI 6136 turbidity sensors 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/>.]