The Complexities of High-Level Turbidity Measurement – How to Select the Technology to Meet Your Monitoring Needs

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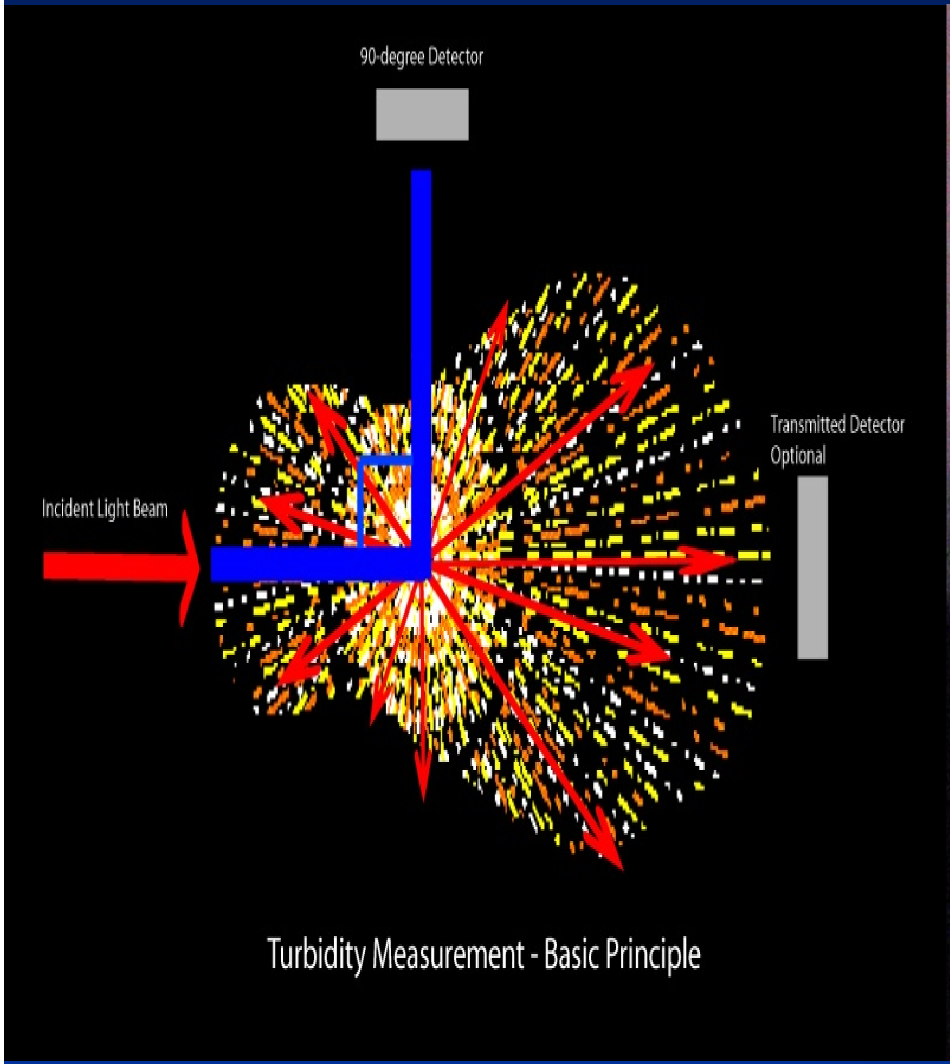
Overview

1. Basics of HL turbidity measurement
   - Interferences in turbidity
   - How many technologies attempt to compensate for them
2. Review the different available technologies for turbidity measurement
   - ASTM Round Robin Study Data Example
3. How to select the best technology to meet your monitoring needs
   - Simple tests on interference mitigation

What is Turbidity?

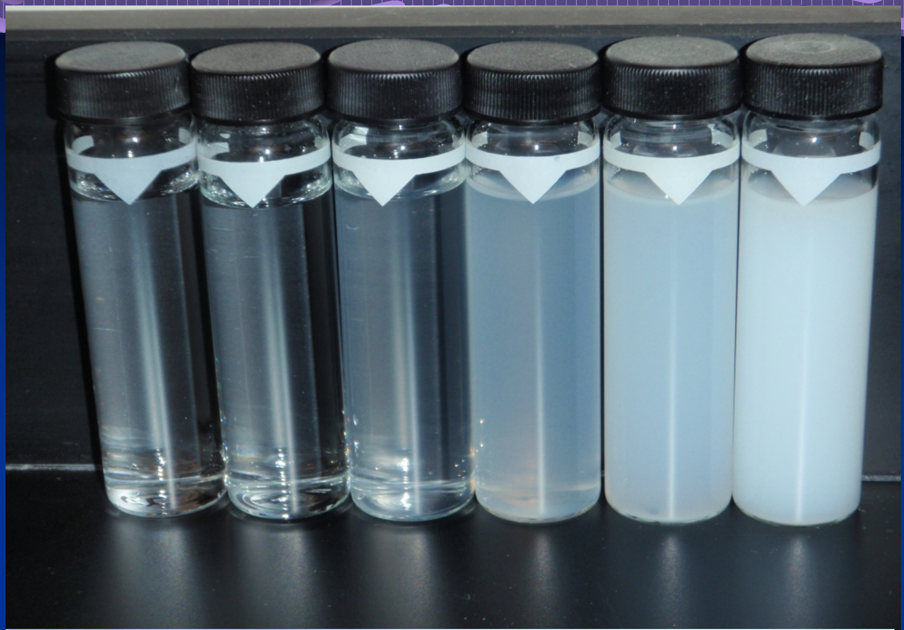


Hi Level Turbidity

ASTM – Any level above about 1 NTU

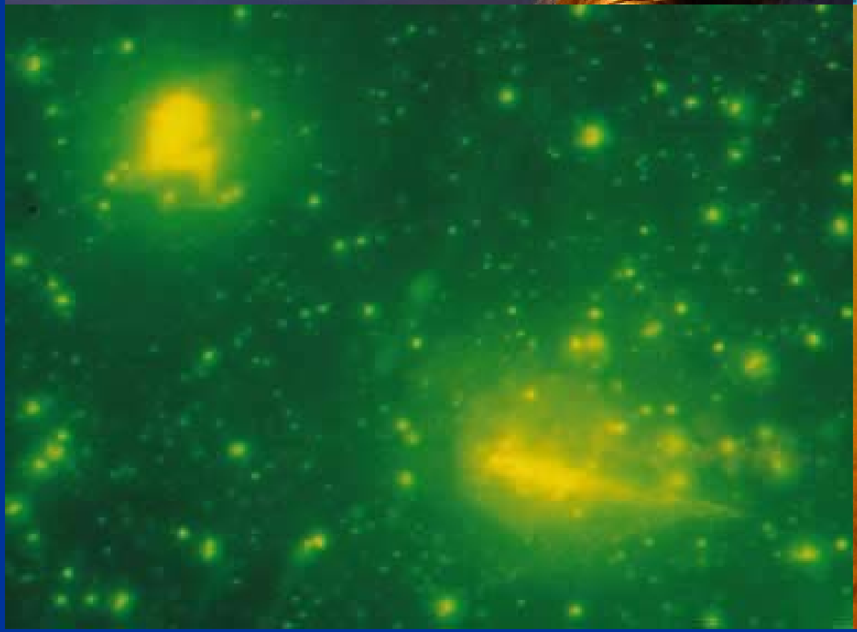
Host of Common Interferences:

- Particle size, shape, morphology
- Particle Size Distributions (natural) vs non-natural
- **Particle density**
- **Sample preparation variations**
- **Color (absorption)**
- **Matrix color**
- **Bubbles**
- **Environmental (ambient light)**



Calibration standards are colorless, samples are not!

Any Sample Will Have a Combination of Inherent Interferences!



Measurement Technologies

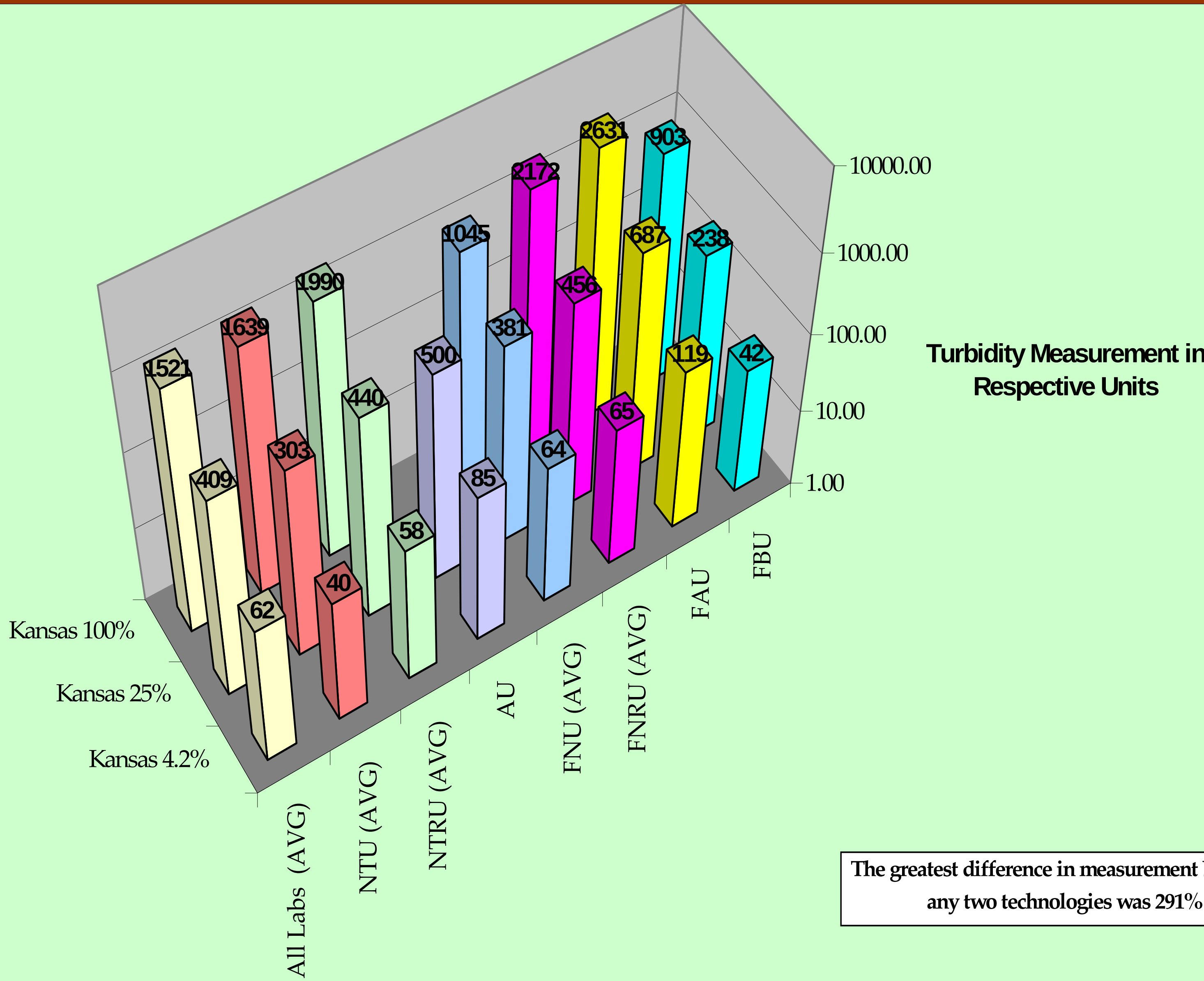
The Technical Features of a Turbidimeter

- Different technological features within turbidimeters include
  - Light source type
  - Detector type
  - Number of detectors
  - Detector orientation angle(s)
  - Path length

Changing any or a combination of these features can deliver a different result on the same sample!

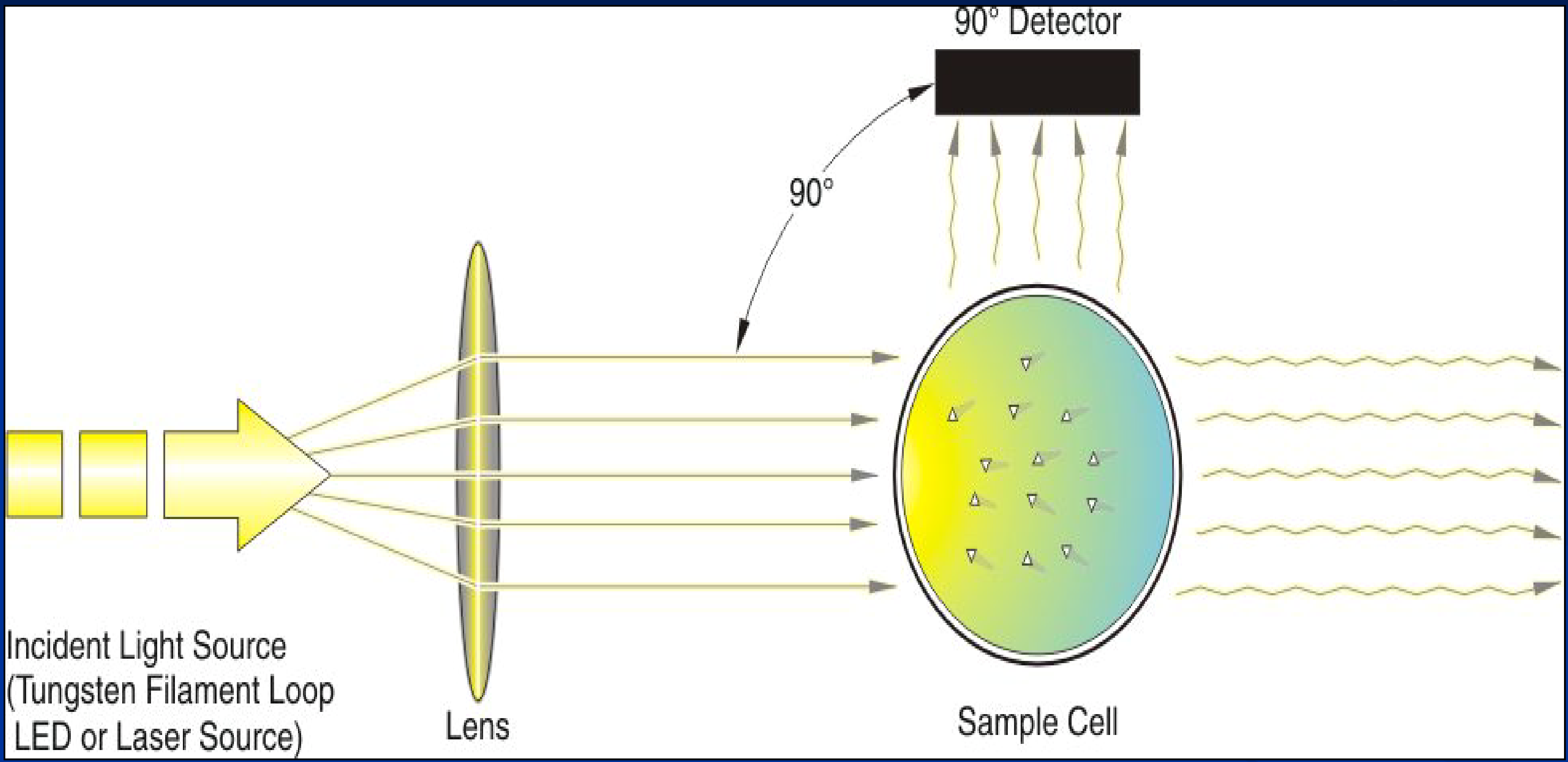
Field Sample from Kansas

Original sample plus a 25% and 4.2% dilutions measured across seven different technologies



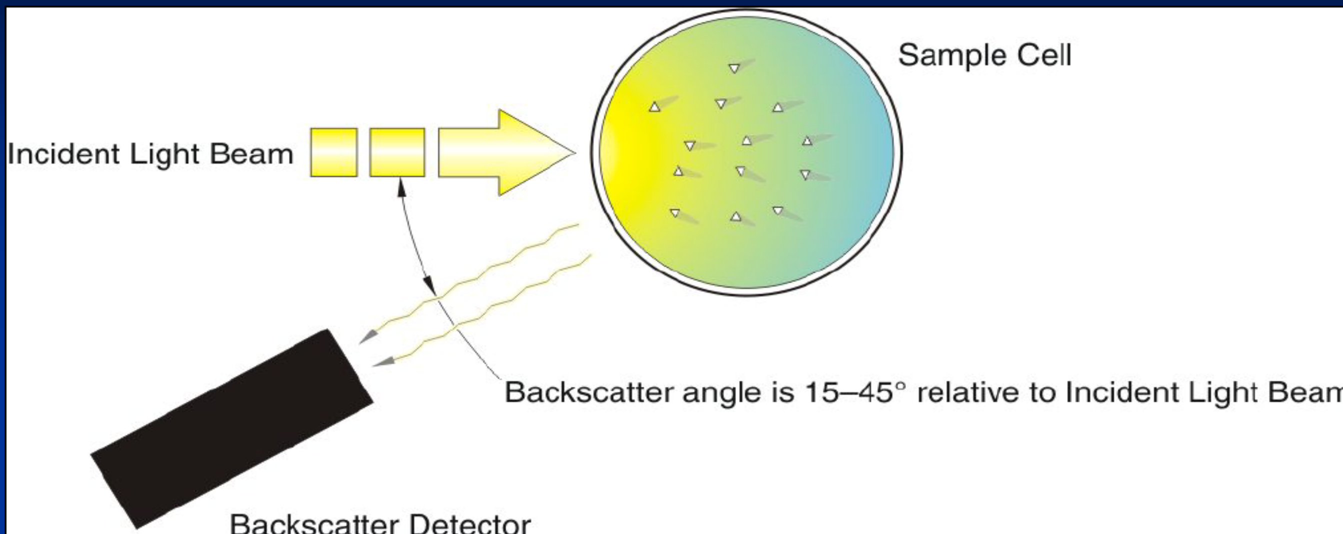
The greatest difference in measurement between any two technologies was 291%

Nephelometric Turbidimeter Design

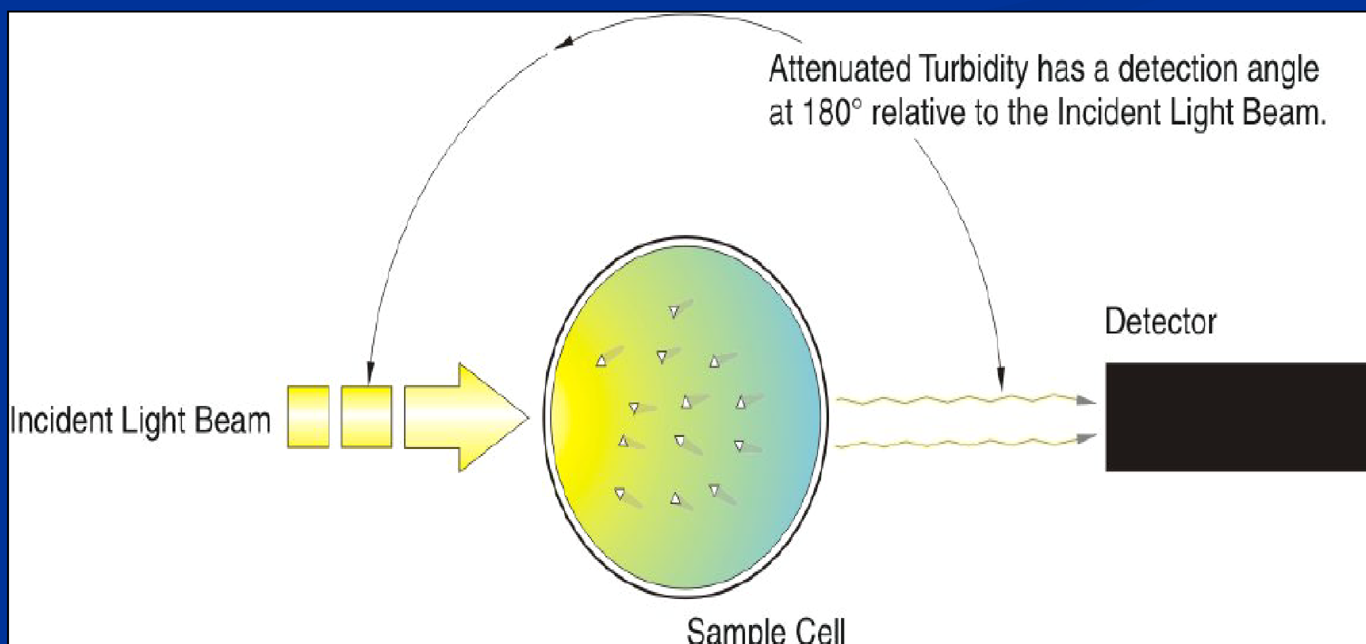


- Very susceptible to color interference
- Best used on highly reflecting samples (i.e. white)
- Default technology for most regulatory applications

Common Turbidimeter Designs



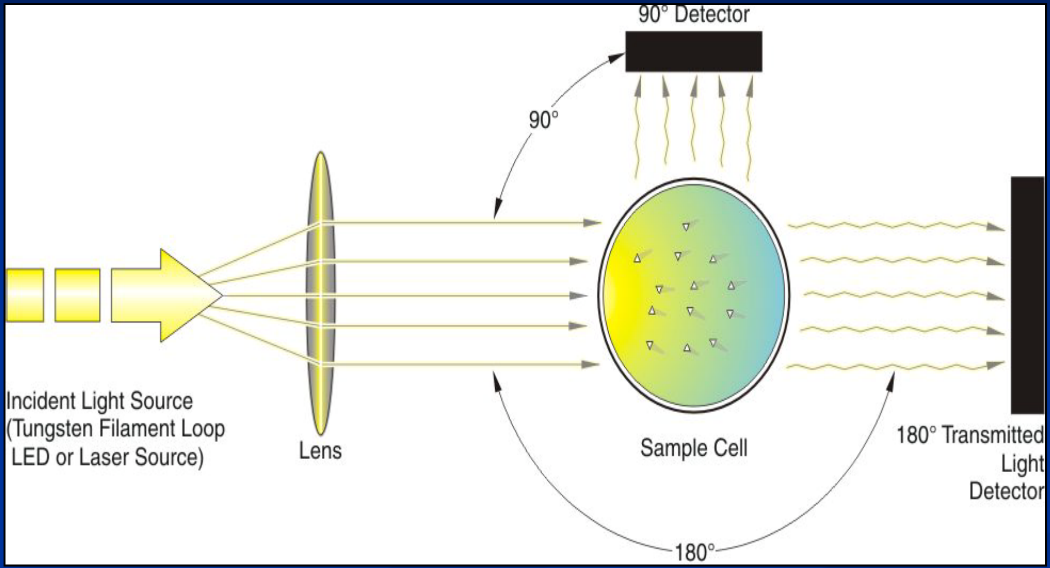
Backscatter Turbidity

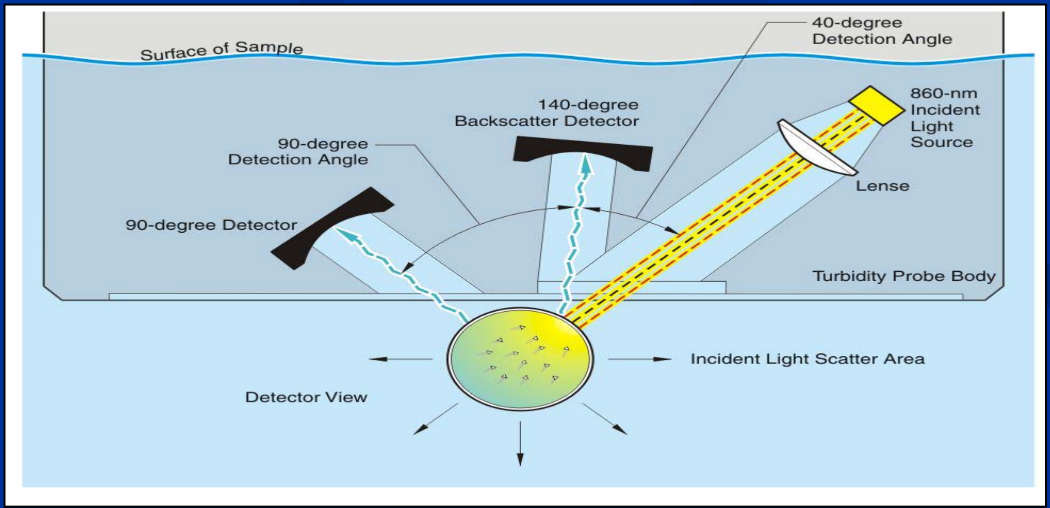


Attenuated Turbidity

Ratio Turbidimeter Design – Two Detector System

- One detector is always at 90
- Design corrects for variations in the incident light source
- Partially corrects for color and absorption
- Provides an extension of the measurement range





Summary of Common Turbidity Technologies

Design and Proposed Reporting Unit ()	Key Design Features
Nephelometric non-ratio turbidimeters (NTU)	The incident light source is a tungsten filament lamp operated at a color temperature between 2200 and 3000 K. The detector is centered at 90° degrees relative to the incident light beam.
Ratio white light turbidimeters (NTRU)*	This technology uses the same light source as the NTU design but uses several detectors in the measurement. A primary detector centered at 90° relative to the incident light beam plus other detectors at other angles.
Nephelometric near-IR non-ratiometric turbidimeters (FNU)	The technology uses a light source in the near IR range (830-890 nm). The detector is centered at 90° relative to the incident light beam.
Nephelometric near-IR turbidimeters, ratiometric (FNRU)*	This technology uses the same light source as a FNU measurement, but uses several detectors in the measurement. A primary detector centered at 90° relative to the incident light beam plus other detectors at other angles.
Formazin back scatter (FBU)	This design applies a near-IR monochromatic light source in the 780-900 nm range as the incident light source. The scattered light detector is positioned at <90° relative to the incident light beam.
Backscatter unit (BU)	The design applies spectral light source similar to that uses for the NTU measurement. The detector geometry is >90° relative to the incident light beam.
Formazin attenuation unit (FAU)	The incident light beam is at a wavelength of 860±30 nm. The detector is geometrically centered at 0° relative to the incident light beam.
White light attenuation unit (AU)	The wavelength(s) of the incident light is in the 400-680 nm range. The detector is geometrically centered at 0° relative to the incident light beam.

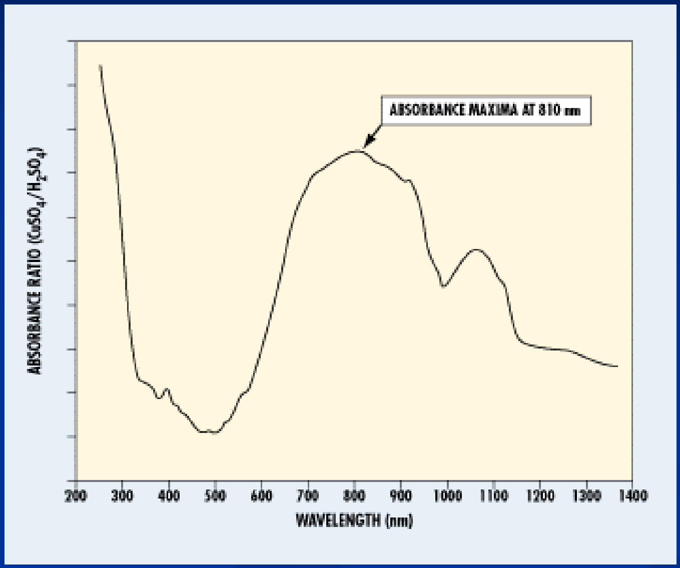
***Address color and absorbance interferences the best and have the widest ranges!**

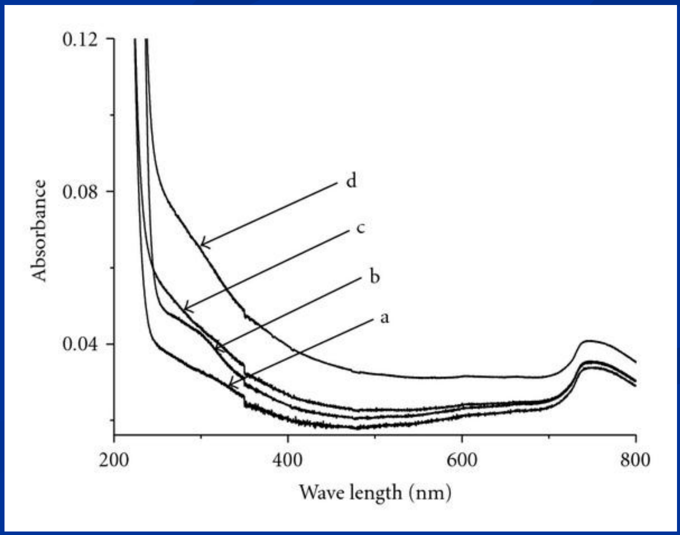
Selecting a Technology

- Key Questions in Technology Selection:
  - Selection of an appropriate light source
  - Sensitivity – does the technology respond to changes in turbidity and its interferences
  - Impact of ambient light?
  - Impact of Bubbles?

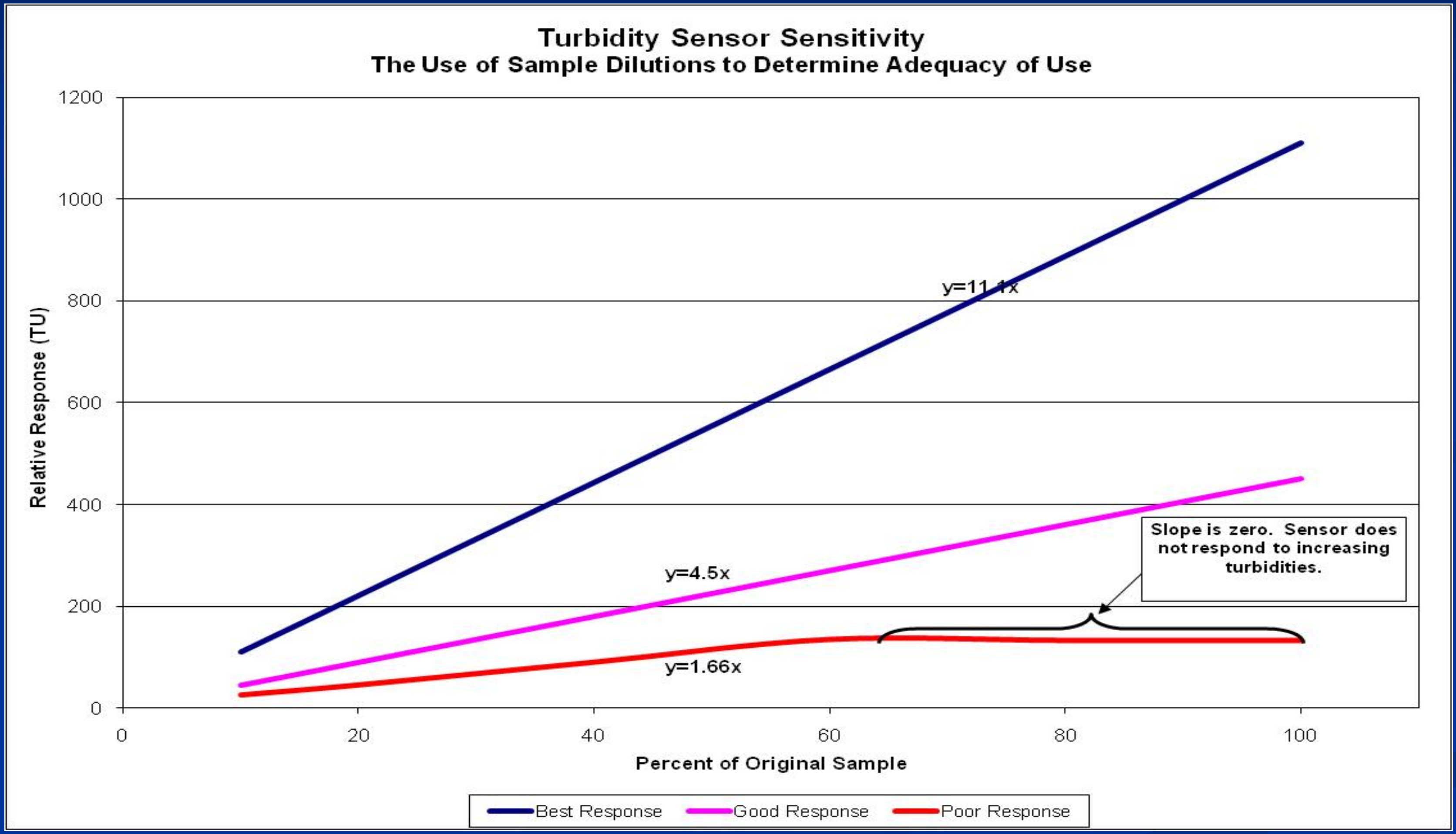
Light Source Selection

- Choose a source that is not absorbed by the sample:
  - Run a spectral scan of the sample over the wavelengths of interest (400-900-nm)
  - Select the source wavelength where the absorbance of light is minimal



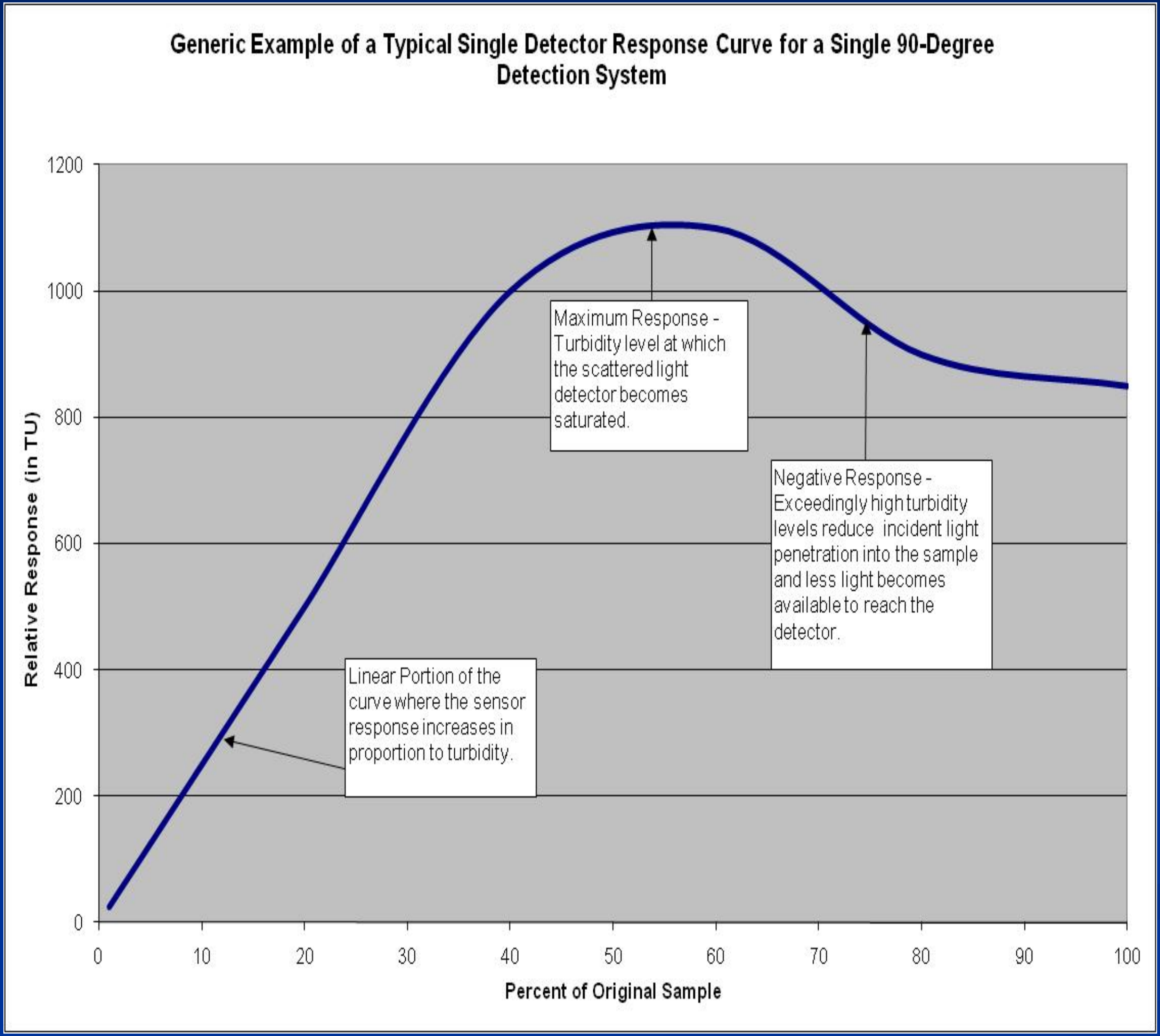


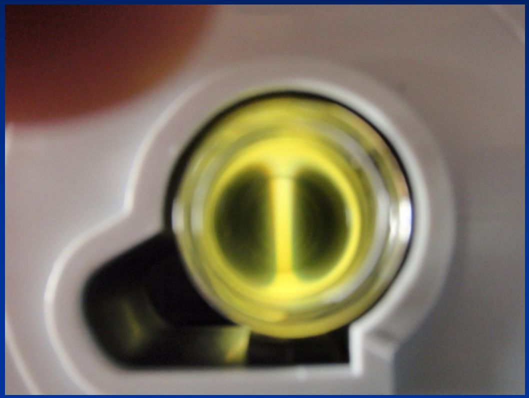
Does the Technology Respond to Changes in Turbidity?



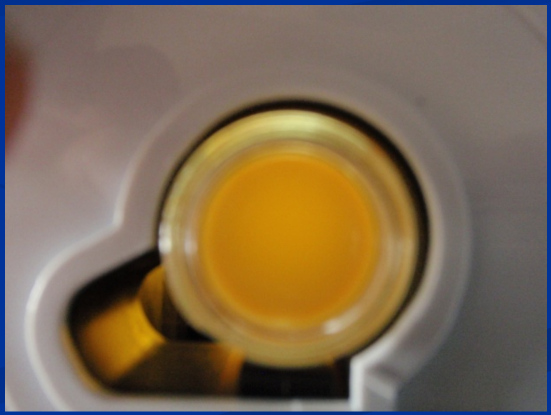
Perform dilutions of the sample and measure using an instrument with the same light source.

Typical Response Curve





Left Side of Curve



Right Side of Curve

What is the impact of Ambient Light?

- Critical on low-level measurements
- Simple Rule – white reflects, black absorbs
- Two bucket test
- If in a "white" environment, mask the view with black shielding

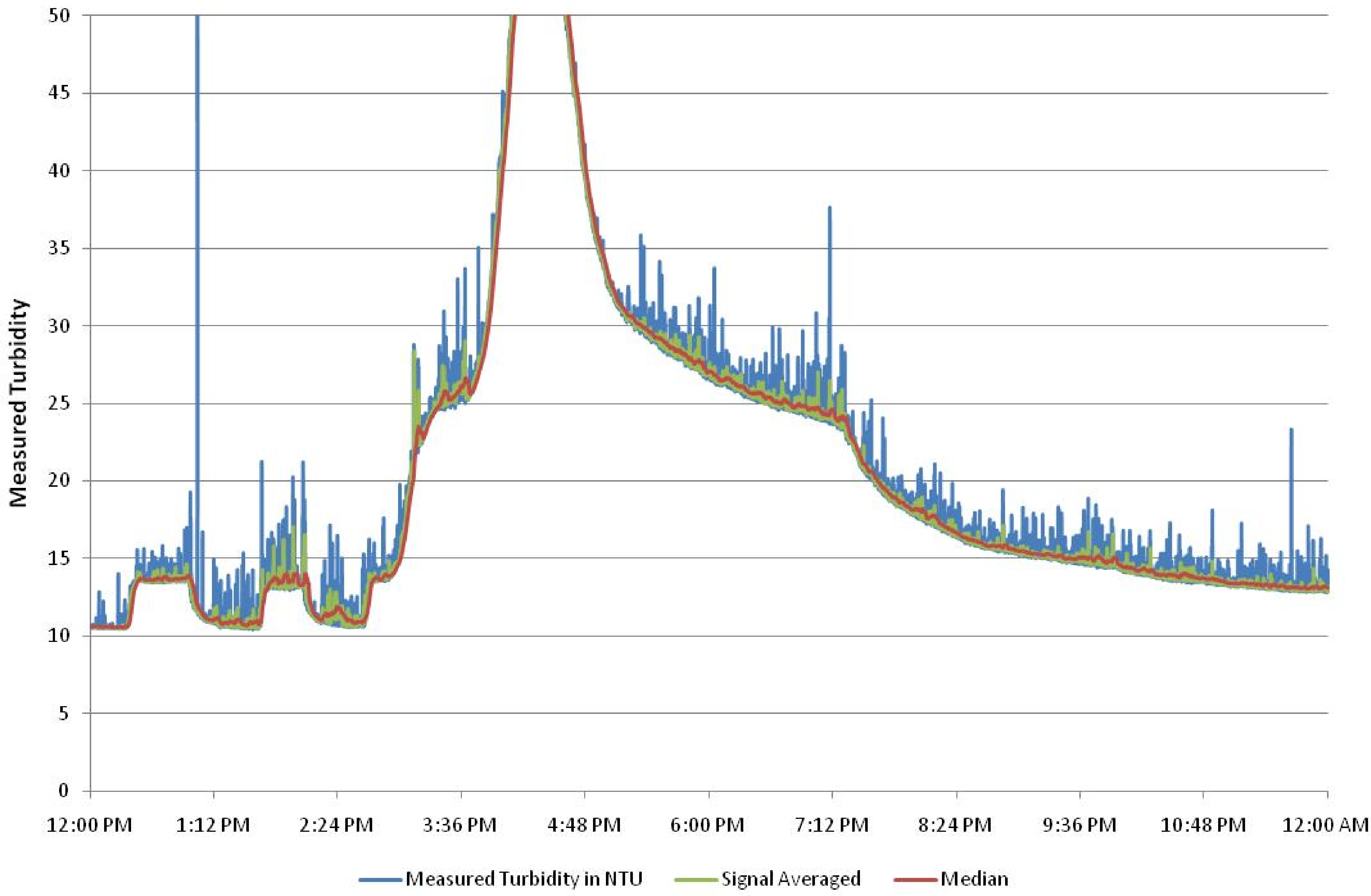

Bucket Test


Sensor Insertion

Bubbles?

- Very strong interference across all levels of measurement
- Most sensors have mathematical algorithms to exclude their interference
- Can post-process data to exclude raw turbidity data with simple algorithms

Addressing Bubbles - Implementation of Mathematical Exclusion Algorithms and Signal Averaging - Natural Water Sample with Excessive Bubbles



Conclusions:

- Today there are many types of available turbidity measurement technologies – and they are all different!
- **Samples measured by different technologies will likely produce different results!**
- ASTM Guidance Available – References
- Pre-installation Education on Sensitivity:
  - Color / Absorbance – Incident Light Source
  - Ambient Light and Light Reflection within the View Volume
  - Bubbles can be addressed

Pre-technology selection protocols can help mitigate these interferences!

Thank You!

Questions: email:
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2. ASTM 2007, "Standard Test Method for the Determination of Turbidity Above 1 TU in Static Mode", ASTM International, West Conshohocken, PA
3. United States Geological Survey, "National Field Manual for the Collection of Water Quality Data", Website: http://water.usgs.gov/owq/FieldManual/Chapter6/Section6.7_v2.1.pdf
4. Sadar, M. and Glyssen, G. (2006), "The Analysis of Turbidity Data: Establishing the Link Between Sample Characteristics and Measurement Technologies", 2006 National Water Quality Monitoring Conference, San Jose, CA.
5. Sadar, M. (2011), "The Influence of Turbidity Samples with Varying Particulate Characteristics on Different Measurement Technologies", International Erosion Control Association EC11 Conference Workshop, Orlando, FL

Approach for Sensor Monitoring in Shallow Channels