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Making Silt Smart and other Outcome-Based Monitoring Systems "Smarter"




Dr. Paul Villard, Ph.D., P.Geo., CAN-CISEC

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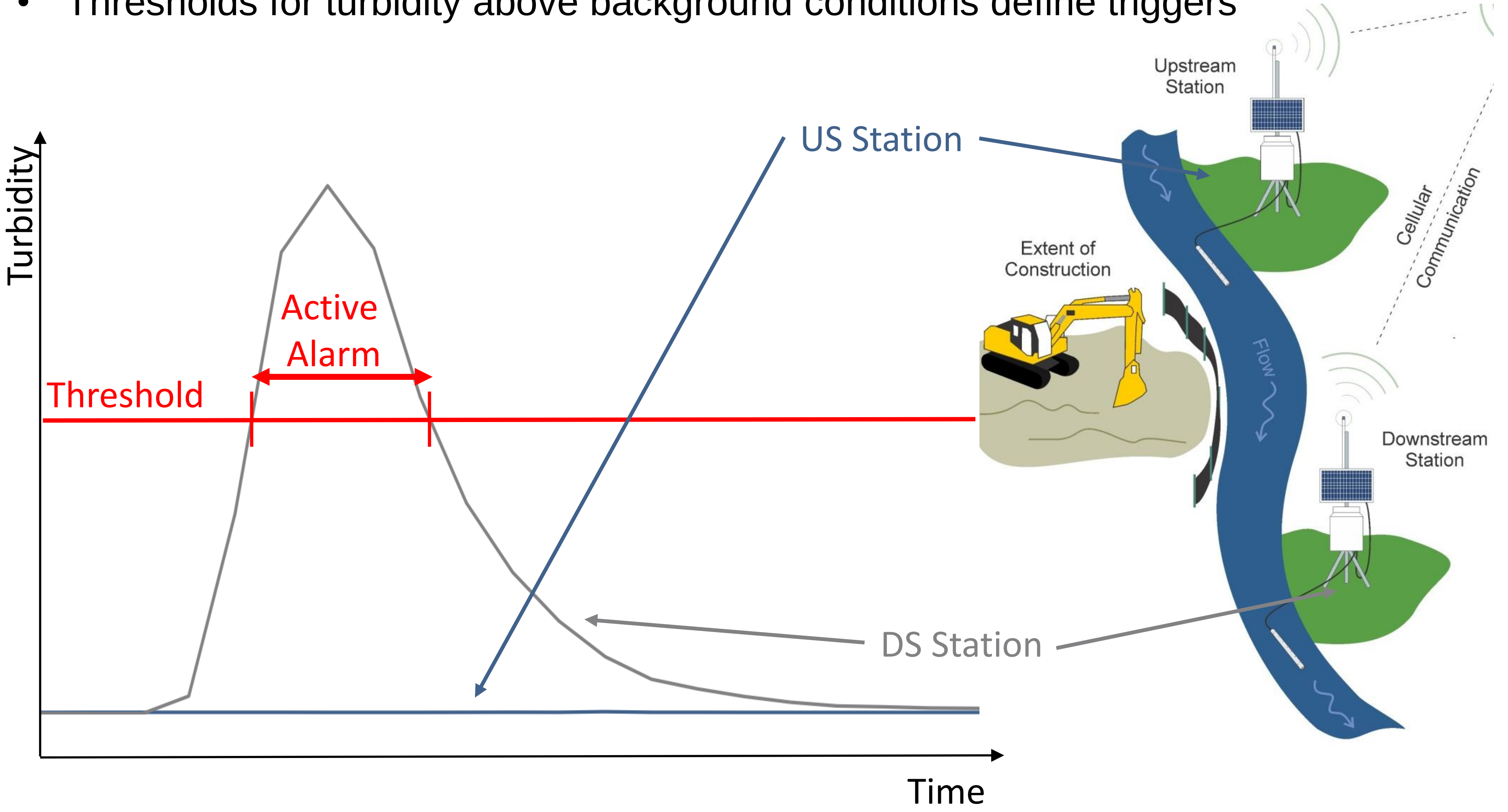
Spoilers

- Outcome-based ESC monitoring programs aim to limit construction-related sediment from entering waterbodies
- Silt Smart is one outcome-based approach to monitoring and managing sites that can reduce the **intensity** and **duration** of sediment-related events
  - Silt Smart dictates triggers based on an environmental threshold for turbidity above background conditions (i.e. triggers are a function of environmental sensitivity)
  - Assumes exceedance is associated with construction
- Although it is effective at decreasing intensity and duration of events, one valid criticism is the time and effort required to address false alarms
  - False alarms can be triggered by litter, upstream events, or other natural inputs not directly contributed from the monitored site
- To address this criticism, triggers need to "get smarter"
- We propose a more intelligent alarm system to reduce false alarm scenarios

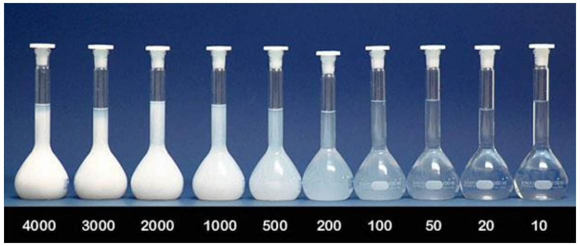
Environmental Thresholds

- Thresholds for turbidity above background conditions define triggers



How are Turbidity and TSS Different?

- The distinction between turbidity and TSS is apparent in the way each one is quantified.
- Turbidity is an optical property, measured by observing the ability of light to be transmitted through a sample of fluid, without being scattered or absorbed.
- The turbidity of a fluid varies with the volume of suspended particles, the size, colour, and shape of the particles, their refractive indices, light wavelengths, and the presence of other elements (e.g. air bubbles, organics, ice crystals) in the fluid.
- Total suspended solids (TSS) is a gravimetric or volumetric property, measured as the total mass or volume of material in a fluid sample.
- **You can measure turbidity faster, cheaper, and at higher sampling rates**



Typical series of turbidity standards (Optek, 2012)

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Potential Effects of Turbidity and TSS on Fish

Fish responses to suspended sediment can be categorized as follows:

- Behavioural effects (lowest degree of severity)
  - Alarm reaction, abandonment of cover, avoidance response
- Sublethal effects (intermediate degree of severity)
  - Reduction in feeding rates and success
  - Physiological stress such as increased respiration rate
  - Habitat degradation and impaired homing
- Lethal and paralethal effects (highest degree of severity)
  - Reduced growth rate and delayed hatching
  - Mortality

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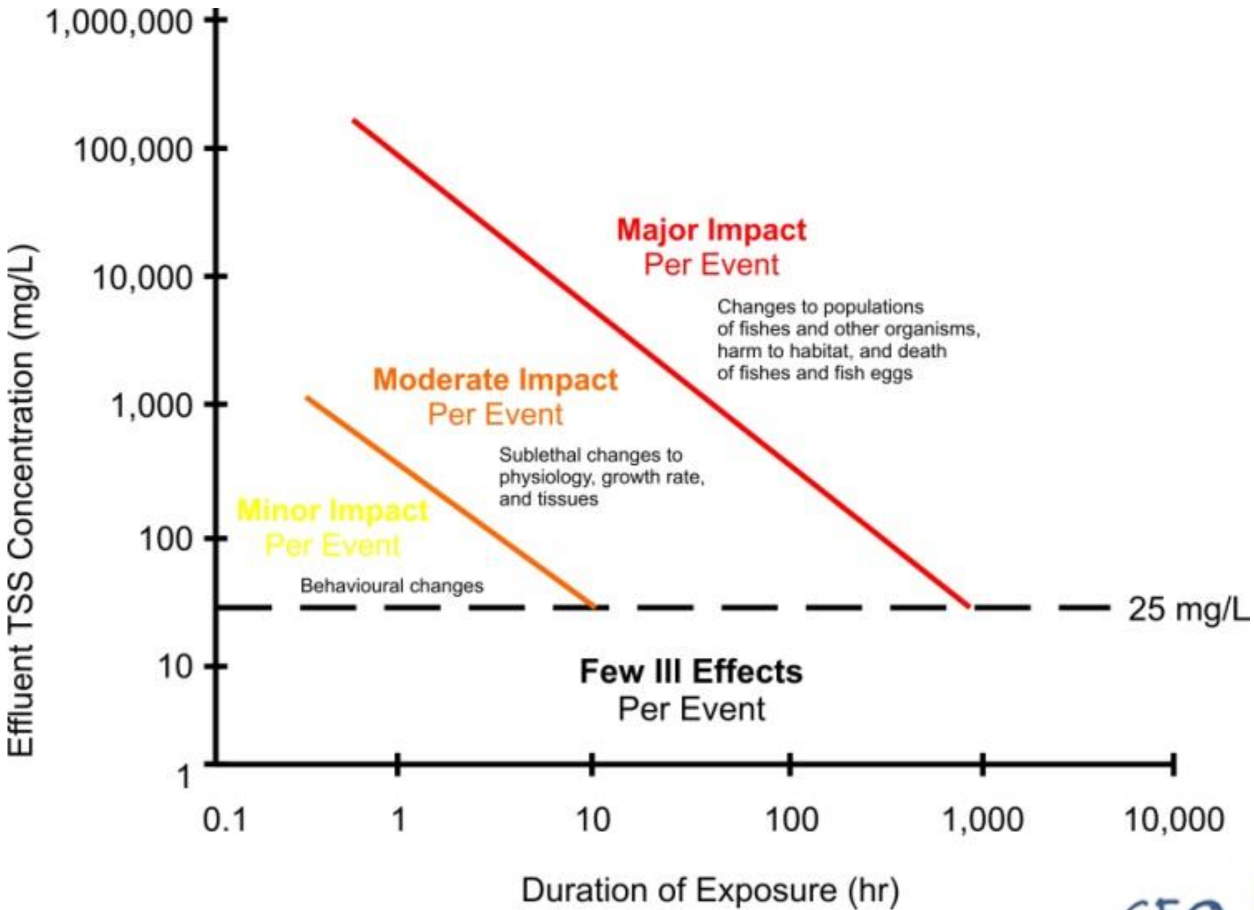
Newcombe & Jensen (1996)

Fish Responses to Turbidity and TSS



Newcombe (1986)

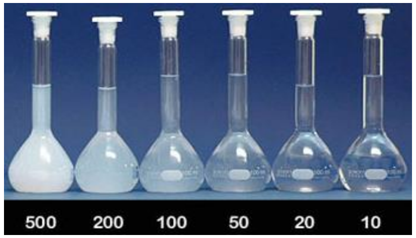
Measuring Turbidity

Turbidity is quantified using a nephelometer, which measures the amount of light that is scattered from a light source by suspended particles in the water. The greater the scattering, the higher the turbidity.

Unlike TSS, which is described as a concentration, turbidity is described using NTU values.

Low NTU values → high water clarity

High NTU values → low water clarity



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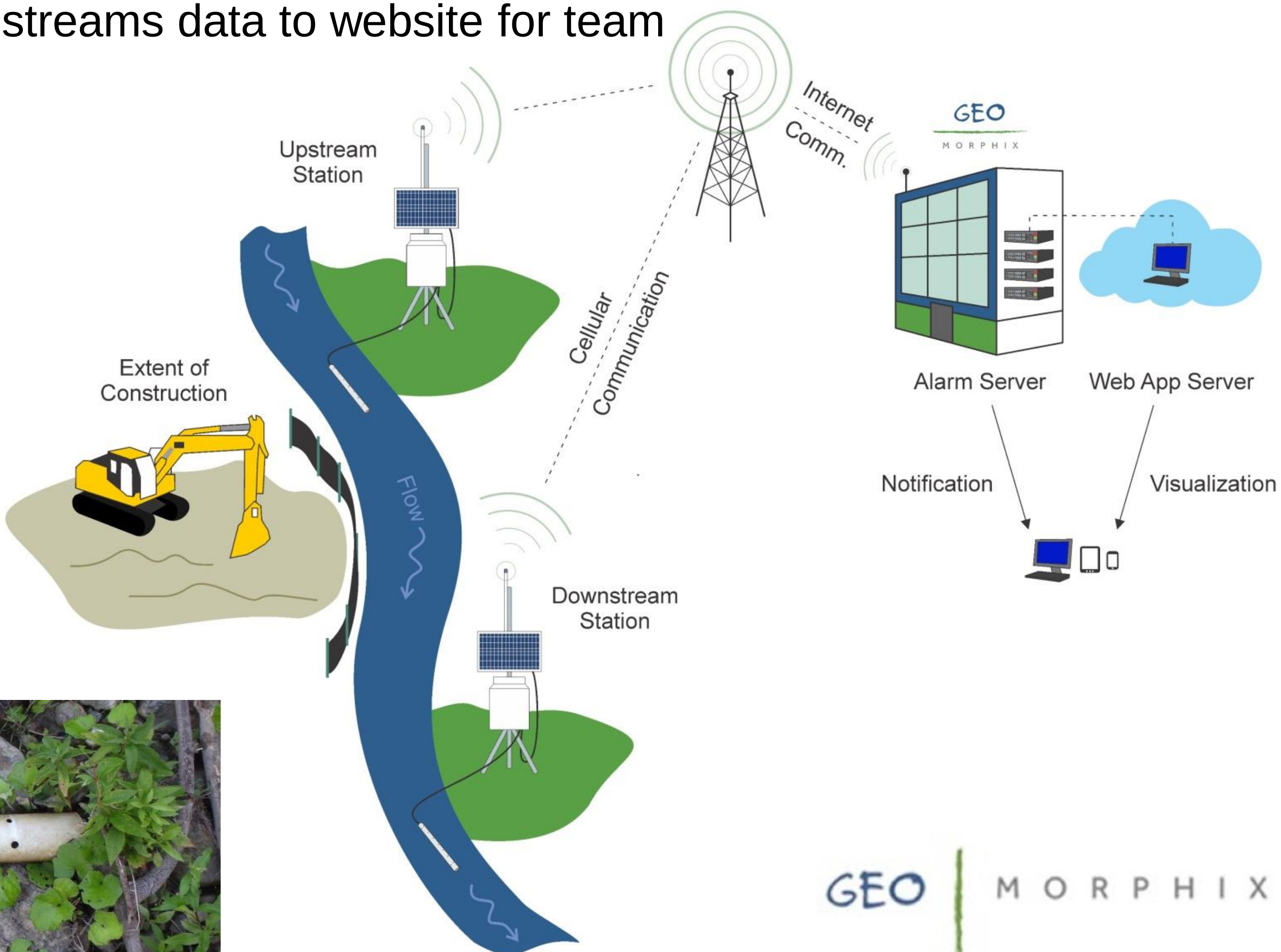
Telemetry-based Turbidity Monitoring System

- Telemetry-based stations communicate with in-house server
- In-house server checks for triggers and sends out notifications to team
- External server live-streams data to website for team



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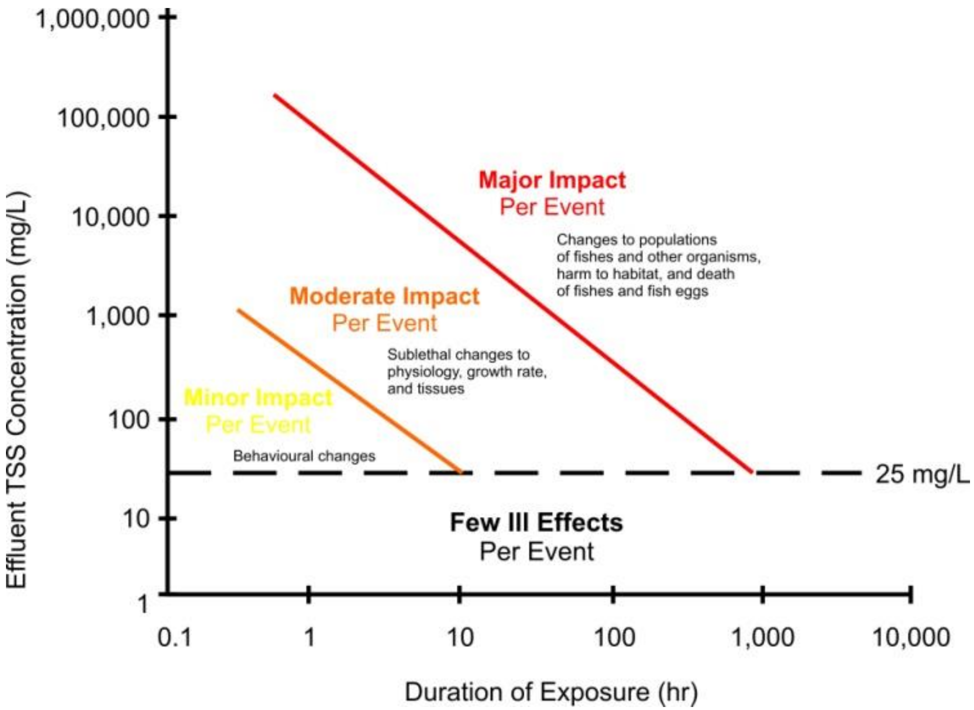
Reactive Monitoring Protocols

- Silt Smart
- Monitoring through telemetry-based instruments
- Notification of issues as they arise
- Notification of project team, client, and agencies
- Response to issues documented
- Quantification with regards to concentration and duration
- Used to improve response, not for enforcement



Newcombe (1986)

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Effectiveness Monitoring Communication Protocol (Example)

	Occurrence Scenario 1	Occurrence Scenario 2	Occurrence Scenario 3
Occurrence	Two consecutive turbidity measurements of 8 NTUs above background *	Turbidity is 8 NTUs above background for 10 hours or more	Two consecutive turbidity measurements greater than 330 NTUs above background
Alert	Alert is sent to Contact Group 1 & repeated every 2 hours until turbidity decreases below target	Alert is sent to Contact Group 2 and repeated every 2 hours until turbidity decreases to below target	Alert is sent to Contact Group 3 and repeated every 2 hours until turbidity decreases to below target
Contact Group Members	Landowners Group Contractor Inspector	Landowners Group Contractor Inspector Conservation Authority MOECC MNRF	Landowners Group Contractor Inspector Conservation Authority MOECC MNRF DFO

* Target value can be adjusted to better match natural background levels

Telemetry-Based Optical Sensors

Advantages

- Outcome oriented, identifies issues immediately reducing durations, accounts for natural inputs
- Monitors during high risk periods
- Good educational and communication tool

Disadvantages

- Requires regular maintenance
- Expensive
- Does not replace regular review of ESC measures reactive

Overall

- Due to expense and maintenance only appropriate for large complicated projects with high value/ sensitive watercourses
- Outcome oriented

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Sediment Input

- Silt smart dictates triggers based on an environmental threshold for turbidity above background conditions
- This approach assumes exceedance is associated with construction
- However, false alarms can be triggered by:
  - Litter/debris/fouling
  - Upstream events
  - Natural inputs

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Making Silt Smart "Smarter": A Case Study

- Developed several filter approaches that scan turbidity data for signatures of false alarms and applied filters to 7 months of field data
  - Smoothing
  - Peak Tracking
  - Noise Detection

- Evaluated performance by comparing number of false alarms, active alarm time, and alarm days

- Advantages:
  - Considers natural sediment sources between monitoring stations that can result in false alarms
  - Provides methods to identify the signatures associated with natural debris (e.g. leaf litter or woody debris)
  - Recognizes events from upstream of the construction and alarms associated with transit time between stations.

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Making Silt Smart “Smarter”: A Case Study

- 5 Silt Smart stations that monitor turbidity on 2 tributaries in the GTA
- Data collected between 3 upstream and downstream station pairs over 231 days (5,544 hours) from April 20 – December 7, 2017
- Data collected during ice-free conditions and through period of active construction
- Construction sites used due-diligence and Best Management Practices (BMP)
- Even with BMPs, Silt Smart turbidity alarms did occur
- A portion of the alarms were a result of other factors aside from construction-related activities

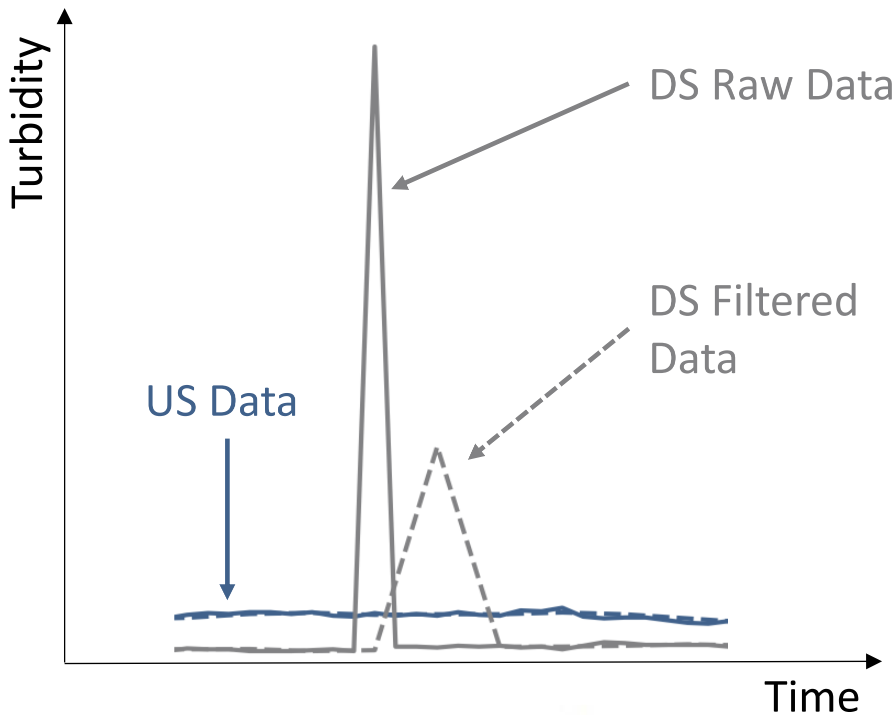
Making Silt Smart "Smarter": A Case Study

	Stations A-B	Stations B-C	Stations D-E
Level 1 Alarms	46	32	30
Level 2 Alarms	2	0	4
Level 3 Alarms	9	4	1
Total Time of Active Alarms	114 hr	49 hr	40 hr
Number of Alarm Days	27	26	22

Smoothing

- Common practice: Trigger alarm when 2 consecutive exceedances
- Smoothing of random spikes: Measure every 5 min, and average over 15 min
- Results:
  - Active alarm time: -10 %
  - No. of days with alarms: -25%

	Alarm Time	Alarm Days
2 Consecutive Exceedances	- 8 %	- 22 %
2 Consecutive Exceedances + 15 min Average	- 10 %	- 25 %



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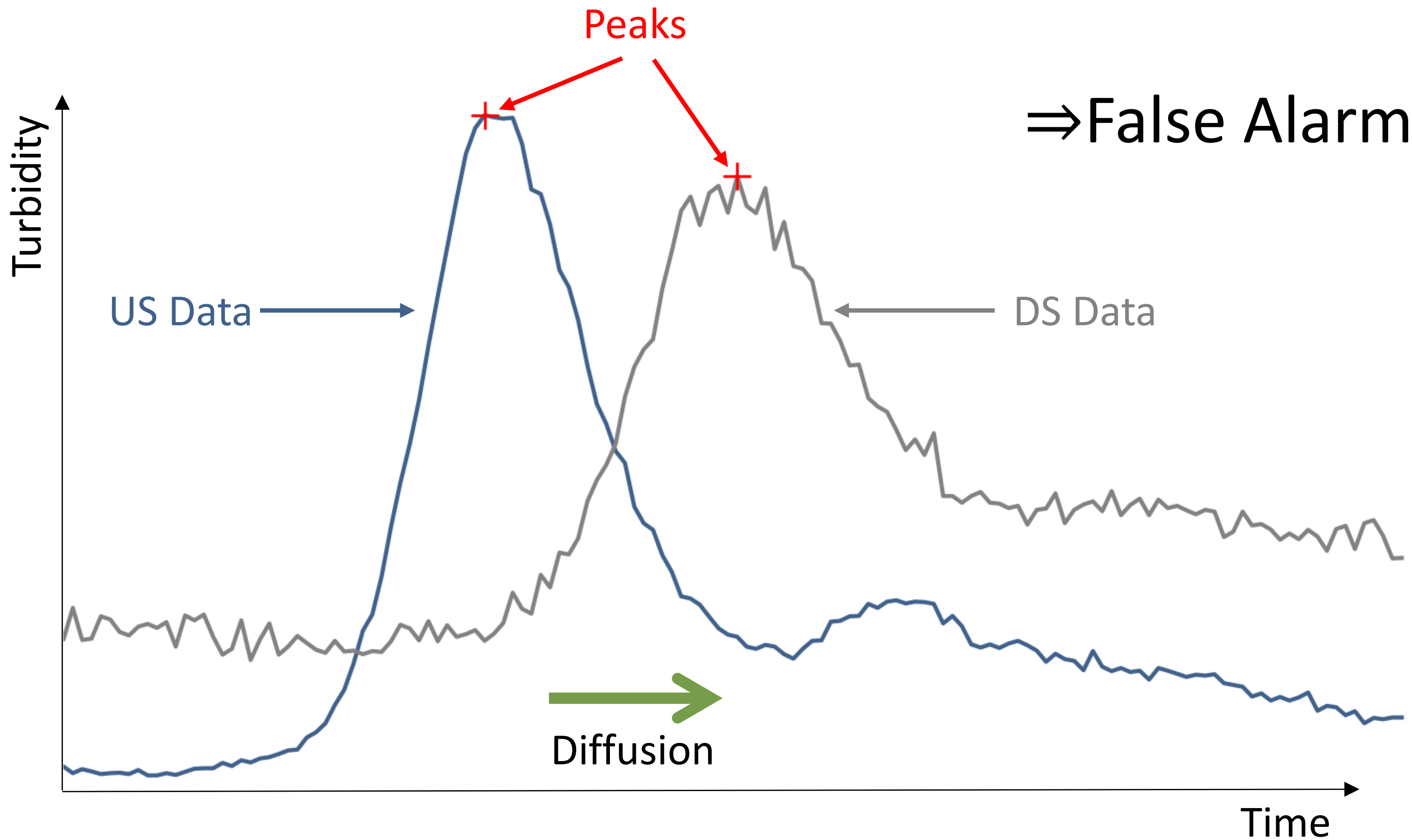
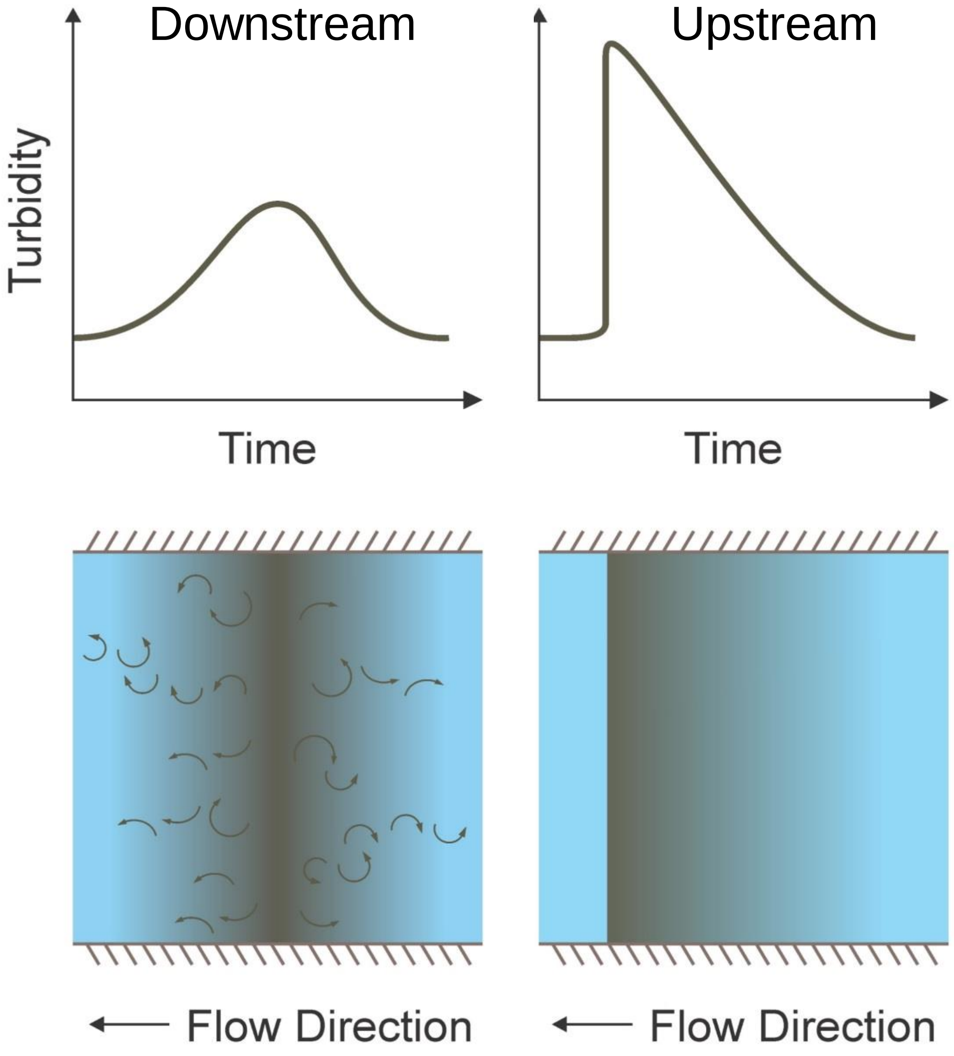
Peak Tracking

- False alarm, if DS peak is later and smaller than US peak



Diffusion of Sediment and its Signature



An initial impulse of sediment enters the watercourse at the upstream location

Through Brownian motion and turbulent mixing the sediment diffuses and turbidity events starts to resemble a Gaussian distribution

Peak Tracking

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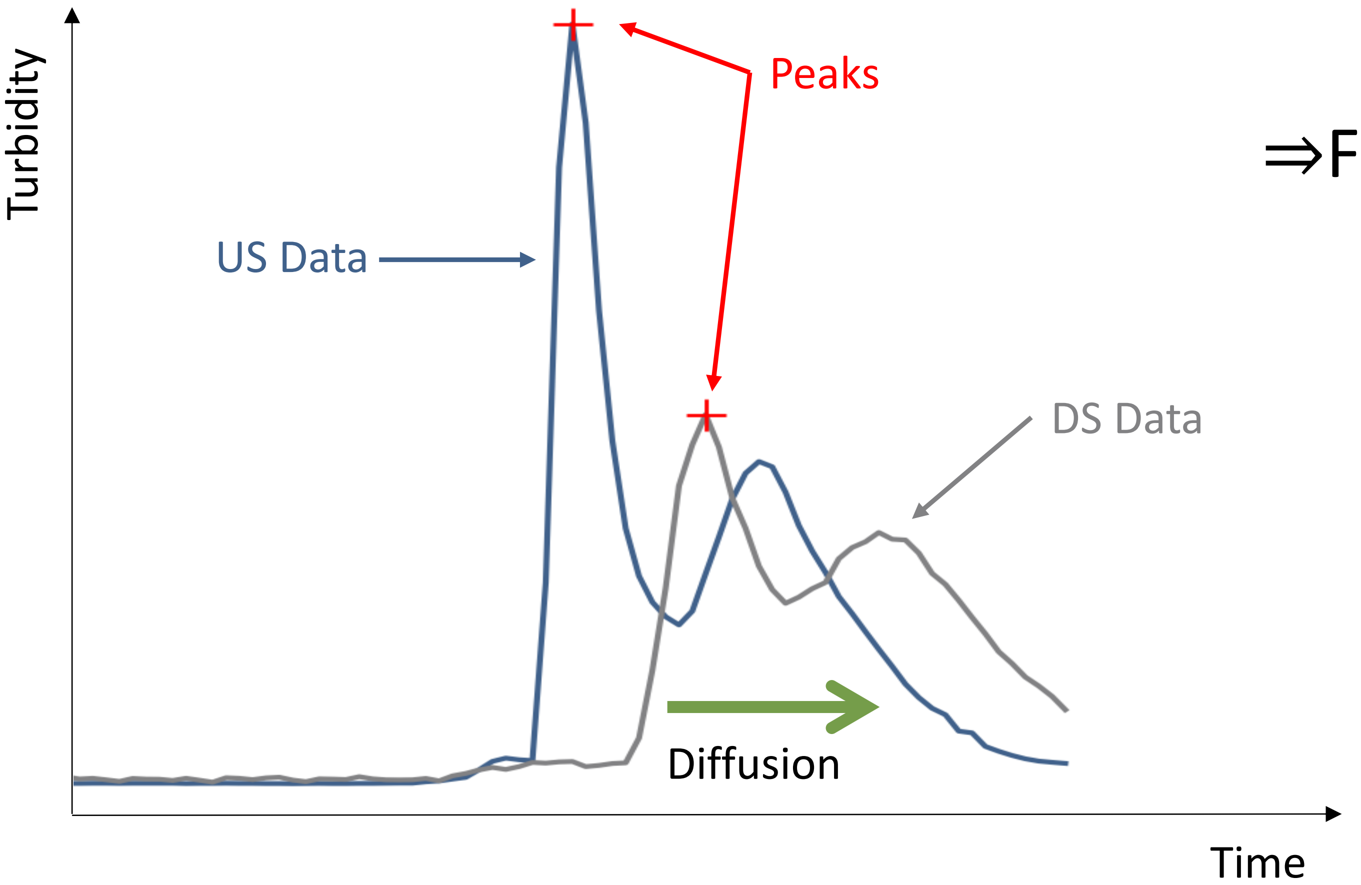

⇒False Alarm

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Peak Tracking

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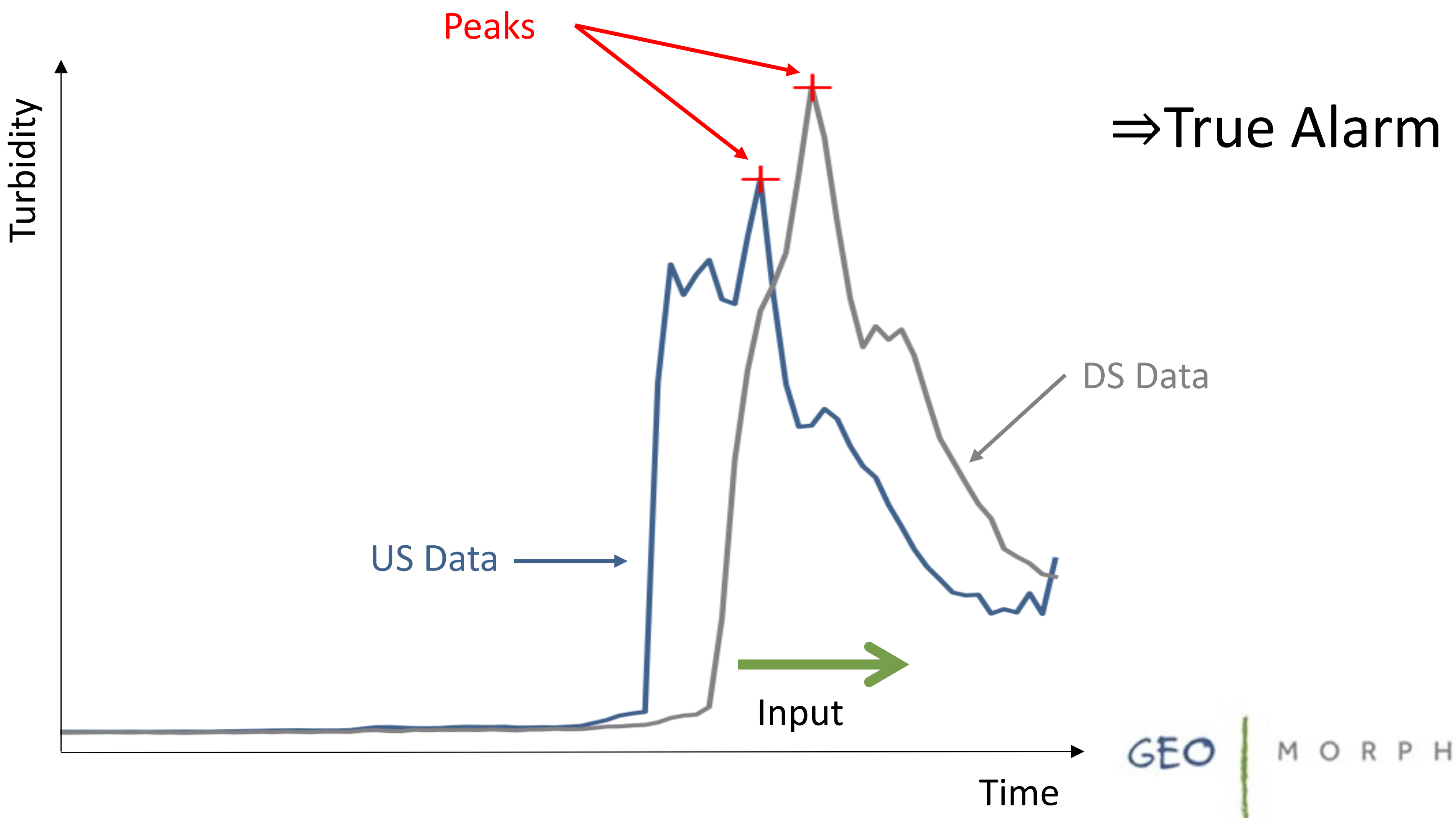

Peak Tracking

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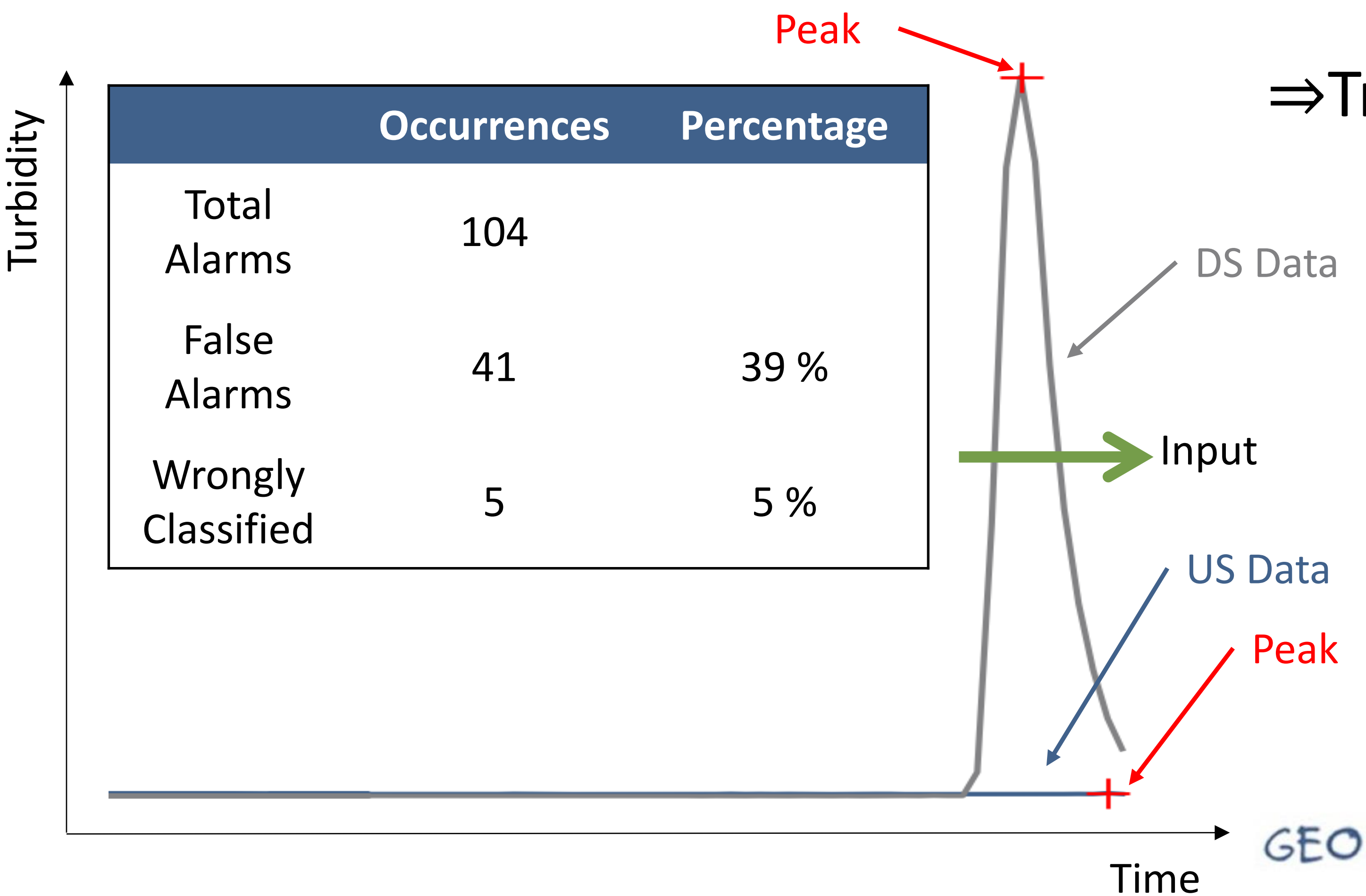

	Occurrences	Percentage
Total Alarms	104	
False Alarms	41	39 %
Wrongly Classified	5	5 %

⇒True Alarm

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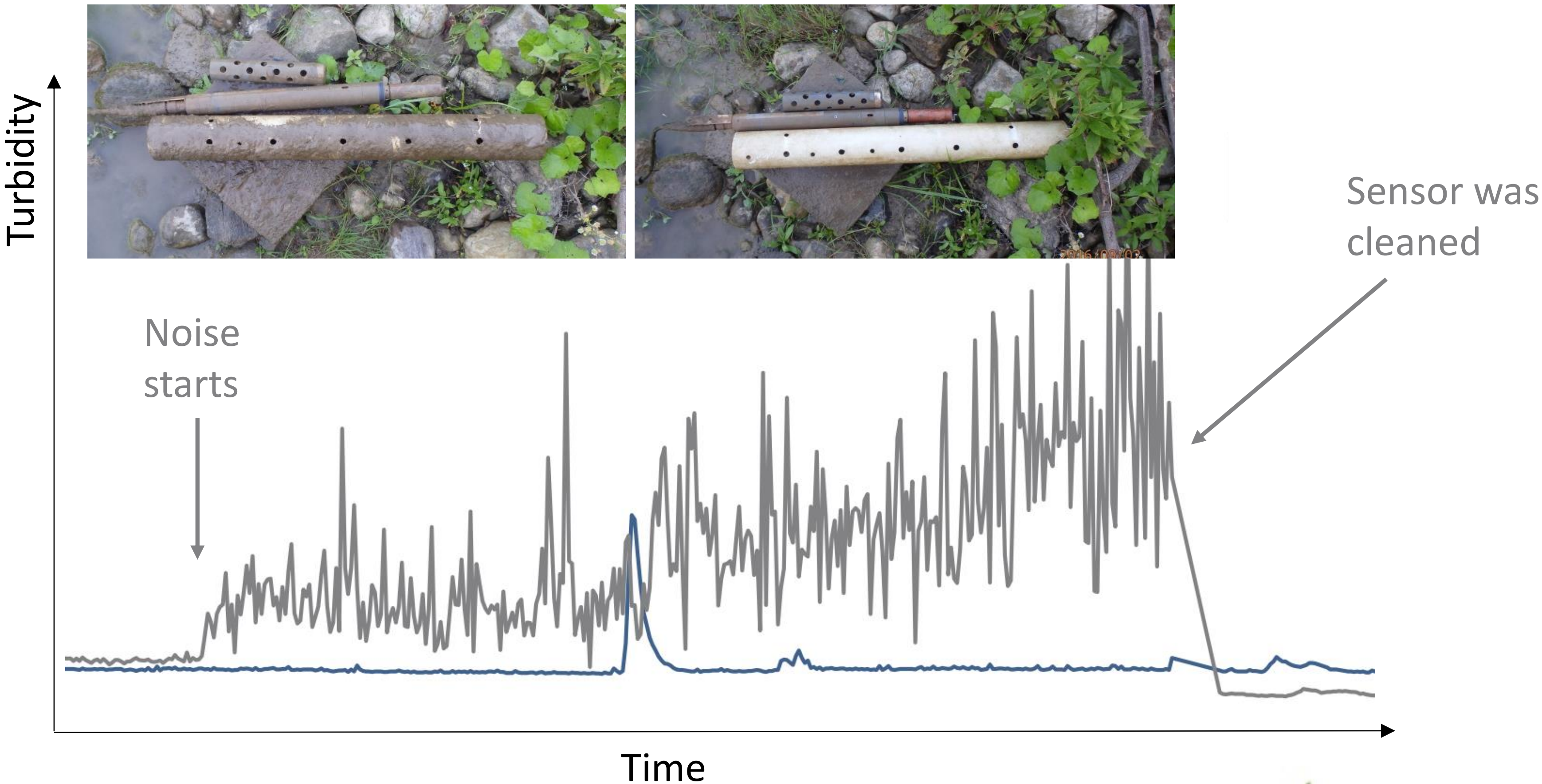
Noise Detection

- Woody debris, leaf litter and sediment can contaminate the sensor
- Warning when SNR is too low



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Summary

- Outcome-based ESC monitoring programs aim to limit construction-related sediment from entering waterbodies
- Silt Smart is one outcome-based approach to monitoring and managing sites that can reduce the **intensity** and **duration** of sediment-related events
- Outcome-based ESC monitoring programs limit construction-related sediment from entering waterbodies
- One criticism of the Silt Smart approach is the time and effort requirement to address false alarms (i.e. triggers need to get smarter)
- Filter approaches allow us to create more intelligent monitoring protocols to reduce the number of false alarms making the monitoring system more robust
- It should be noted that outcome-based alarm systems are important, but they are not the only potential measure of the success of mitigation approaches on site

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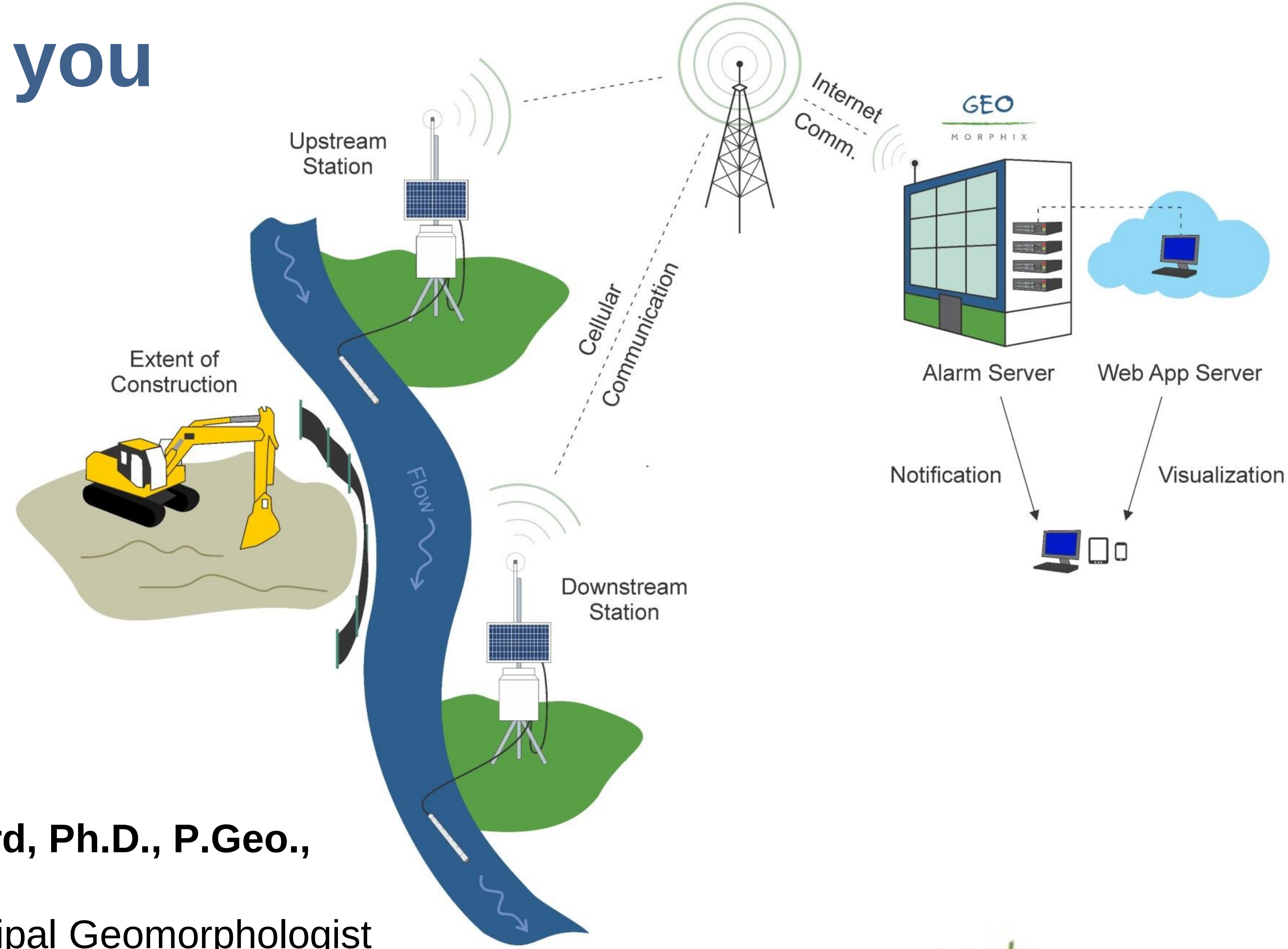
Thank you



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