# IN-SITU MONITORING OF SUSPENDED SEDIMENTS: DEVELOPMENT OF A DENSIMETRIC MONITORING INSTRUMENT

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**Abstract**. We present a new technique for continuously monitoring total suspended solids concentrations. Our approach is to use a differential pressure sensor to measure the fluid density within the water column. The fluid density is directly affected by the concentration of suspended solids, thus allowing us to infer the sediment concentration. Ten demonstration sites on the Broad River in northeast Georgia have been selected for comparing the densimetric technique with turbidity, grab samples, and integrated samples. Variations in sediment concentrations with stage, velocity, and temperature will be evaluated.

## INTRODUCTION

Sediment in streams have been identified as both a source and agent of pollution in surface waters. Sediments deposited after relatively short periods of suspension may have long term effects on aquatic communities and continue to cause adverse effects after land disturbances have ceased (Golladay, et. al., 1987). Sediment deposition appears to cause declines in biomass and species diversity as well as shifts in the species composition of the benthos through drift (Waters, 1995; Campbell and Doeg, 1989). Suspended sediments transported by a stream are also of biological concern because they interrupt the respiration and feeding ability of stream biota (Campbell and Doeg, 1989). Suspended sediments adversely affect filter-feeding invertebrates (Haefner and Wallace, 1981). Fish communities are disturbed in the short term by suspended sediments as evidenced by an alteration in behavioral patterns (Gibbons and Salo, 1974). These adverse effects have prompted an increased focus within the U.S. on the monitoring and elimination of sediment pollution.

While several technologies are presently available for monitoring sediment concentrations in water, each of these have significant shortcomings.

Grab samples are obtained by physically collecting a sample of water in the stream. The samples are filtered, dried, and then the filtrate is weighed. The sediment concentration is then determined based on the volume of the original water sample. This technique can be time-consuming and costly and the sampling must be timed to coincide with the hydrologic events during which sediment entrainment is to be expected. Errors in the technique can also easily occur. Automated grab sampling is routinely conducted, but samples must also be returned to a laboratory for analysis, thus limiting the number and frequency of samples that can be collected.

The turbidity meter utilizes the scattering of light by sediment across a water sample to estimate suspended sediment and can be used in situ or in the lab. It is widely relied upon as an accurate estimate of suspended sediment due to its positive correlation with filtered water measurements taken either by hand or through the automated sampler (Riley, 1998). However, both physically obtaining water samples and using turbidity measurements assume that a spatial homogeneity exists in the concentration and density of sediment in a given sample across the water body of interest. Research has shown that this assumption is not valid as different concentrations of sediment can move through a stream in regions very close to each other (Riley, 1998). Furthermore, organic particles of a given size can show the same optical scatter as grains of sand and clay when measured by a turbidity meter. As a result, an over-estimation of suspended sediment in the water body can occur.

Turbidity meters are also limited by the fact that their range of measurement is often well below the actual sediment concentrations commonly found in streams during high flow conditions. High values will be missed entirely when these sensors are used in situ. When used in the lab, turbidity meters can quantify the high values through dilution of the original sample and subsequent measurement, however this process is commonly not done. Turbidity values of surface waters are also used to correlate with satellite imagery to estimate the sediment loads in water bodies remotely (Harrington, 1992). Planning and regulatory decisions are increasingly based on these findings and it is essential that valid data be used during this process.

Another method employed to measure suspended sediment is the acoustic velocity meter. Acoustic techniques utilizing Doppler sound velocities to determine fluid velocity are being adopted for the continuous monitoring of sediments. Acoustic techniques require extensive calibration and can be prohibitively expensive. For reasons of overall accuracy and reliability, some authors state that application of this method is almost wholly inappropriate for the determination of sediment concentrations but can be used effectively for the analysis of stream bed elevations (Reichel and Nachtnebel, 1994).

New monitoring methodologies that have a relatively low cost, an ability to operate continuously at remote locations, and an ability to differentiate moving inorganic sediment from organic sediments must be created. These methodologies must also take into account as much of the spatial variability of the water body as is possible to be more fully representative of that water body. The urgent need for a device that can accomplish these goals will become apparent when regulations begin to be more diligently enforced upon municipalities, industries, and individuals.

A more effective measuring process would not only add to the accurate estimation of environmental pollutants in streams, but also to the effectiveness of present and future management strategies. A focus on individual aspects of hydraulics is required for this approach.

## THEORETICAL FOUNDATION

Variations in fluid density result from changes in temperature along with changes in dissolved and suspended solids concentrations. Differential fluid velocities can alter the apparent height of water (Lewis and Rasmussen, 1996). Because methods are available that account for thermal variations, water velocity, and dissolved solids concentrations in water, the residual effects of total suspended solids (TSS) in a column of water can be ascertained. Extensions to sediment load estimation require additional discharge information and the TSS - discharge relationship, allowing integration over the flow-duration curve (Miller, 1951).

Lewis and Rasmussen (1996) demonstrated the utility of a fluid density method and set the stage for field applications of the theory to measure TSS. This work focused on the temporal variations in measured pressures that are attributable to factors that alter fluid density and total measured head. Particle sizes were determined with a ninety-five percent accuracy and sediment concentrations were determined to ninety-nine percent accuracy in the study.

Lewis and Rasmussen identified the challenges likely to be faced under field conditions including temperature, velocity, and particle density variability. Also provided by the authors were suggestions that have aided in the selection of pressure transducers for the present study based upon the transducers method of pressure analysis. Lewis and Rasmussen spent great deal of time to calibrate the responses of two separate transducers. Usage of a single, differential pressure transducer reduces a large portion of the error that can be otherwise encountered.

## OBJECTIVES

It is our intent to evaluate a device that has been designed and constructed to continuously measure depth-integrated suspended sediment concentrations in situ and in real time. A single transducer utilizing differential pressure analysis has been selected for this study based upon the published recommendations, its high accuracy, the simplicity it adds to the design, and its durability in the field. After completion of the design and evaluation of various equipment options, we will test the device in the laboratory to ensure its functionality and calibration. Field placement will take place where security can be controlled and damage from environmental variables such as flooding minimized.

The field trials will be coupled with various physical and automated grab sampling techniques, the samples from which will be brought to a laboratory and analyzed by filtration and weighing to assess the accuracy of the pressure-derived suspended sediment readings.

Our primary goal is to determine the effectiveness of this densimetric technology in the field setting. In order for this instrument to be considered for future implementation within the regulatory regime, we will attempt to meet the 10-milligram per liter accuracy of suspended sediment determination realized by the earlier laboratory trials (Lewis and Rasmussen, 1996). This research will be conducted in partnership with the Environmental Protection Agency and will be subjected to its scrutiny regarding the study's methodology and results. The EPA will use the results of this study to calibrate a hydrodynamic computer model presently under construction. The intention of this modeling effort is to provide the ability to predict the non-point source pollution resulting from land use in a particular watershed.

A secondary goal of this research is to explore alternative designs for additional applications that are deemed feasible. Stream sampling for suspended sediment will be the initial application, with applications to wastewater treatment a secondary consideration. Analyses of sediment particle sizes and of water levels deep in groundwater wells where density based errors are commonly made, have also been envisioned. Various possible uses of a densimetric instrument are summarized in Table 1. Variations of densimetric monitoring for these additional applications will likely require alterations in the instrument design and may be outside of the bounds of this study from other than a theoretical level. Time and resources permitting, consideration of alternative designs will be conducted. A final goal is to evaluate the cost-performance relationship of the methodology. A cost comparison will be conducted to determine if the technology tested in this study will be financially justifiable and available to a sufficient range of potential users.

## METHODS

The experimental design for this study will primarily involve attempts to control the factors that can alter the fluid density and the measured head of water. Laboratory trials will be initially conducted in which these factors are not present. This will be done to enable a verification of

**Table 1. Potential applications**

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| Laboratory Applications |
| Particle Size Distributions |
| Fluid Density |
| Environmental Applications |
| Total Suspended Solids Concentration |
| Storm-water Runoff Characterization |
| Industrial/Municipal Wastewater Monitoring |
| Density Effects In Groundwater Wells |

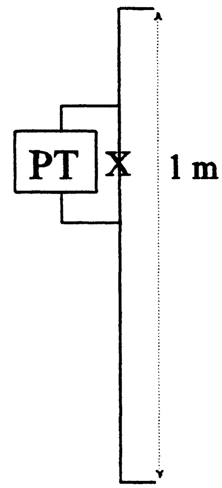


**Figure 1: Sensor design.**

the theoretical foundations of this study and the effectiveness of the particular instruments utilized. A Druck LPM 9381 high accuracy differential pressure transducer will be the main component (other less expensive and slightly less accurate models will also be tested). Swagelok stainless steel tubing and pipe fittings will be attached to the transducer to create measuring points in the water column at least 1 meter apart. A reference column will be established along the 1 meter length with 0.5 micron filters at each measurement point. A basic schematic of the instrument is included in Figure 1 (PT denotes the placement of the pressure transducer). The sediment passing through this distance is expected to create an increased pressure that will be read by the instrument and translated into an analog signal that is passed to a Campbell Scientific Datalogger for storage. The instrument will not require modification for the field application, however the previously mentioned variables must be accounted for. Meters attached to the platform supporting the densimeter will monitor and record water temperature, water velocity, and total dissolved solids. Two turbidity meters will also be installed at the pressure measuring points to provide for continuous readings of an accepted standard of TSS content. The study will be conducted in the winter of 1999 and into the spring until a sufficient number of storm events have been analyzed. The number of events necessary to determine if this methodology is appropriate is difficult to estimate based on the low probability that all facets of the experimental design will perform, as needed, all of the time. One storm event would likely be sufficient if all parameters were measured in concert. The use of a simulated stream (flume) that is present in the Hydraulics laboratory at the Georgia Institute of Technology will be sought in the event that a sufficient number of storm events does not occur. Through the partnership with the EPA, a comparison to automated grab samples of water taken alongside of the densimeter will be conducted. These will occur at preset intervals during storm events, which last approximately a day within the study area, and composite samples will be taken during normal flow periods.

The study site for the field trials is the South Fork of the Broad River in Northeastern Georgia. Three sites at different locations within the watershed have been chosen to test three model densimeters. Continuous readings will provide high data densities, resulting in potentially strong statistical comparisons. The scanning rate can be set to take as many readings as desired. Direct comparisons of the pressure-derived readings will be made to both the simultaneously collected and filtered samples and to the turbidity readings. These comparisons should provide a clear answer as to the instrument's effectiveness. Analysis of variance tests should allow for the effects of the confounding variables of temperature, water velocity, and TDS to be determined.

There will be challenges in the process of design, installation, and monitoring of this experiment. High flows from winter flooding are of concern because of the cost of the equipment involved. The platform should be set into the streambed as deep as possible to prevent outright loss of the equipment, however all of the equipment will be secured to an immovable object on the stream bank. Vandalism is also of concern and contingency plans will be developed to secure the most publicly accessible sites. Frequent visits to the site are planned to make certain that the equipment is functioning correctly and to ensure that the sites chosen are suitable for continued use.

## RECOMMENDATIONS

This study will be completed in 1999. The instrument is currently being assembled in the laboratory. Calibrations of the prototype equipment will be conducted prior to assembly of the remaining sensors. Field placement at the three selected sites is expected in partnership with the EPA in March.

The field experiments will be conducted during the spring and summer until a determination of effectiveness and applicability of use has occurred. The summer will be spent analyzing data, performing additional tests as needed, and presenting findings of the research at scientific meetings. A final report to the EPA will be completed in September and the research will be concluded as a Master's Thesis in December 1999. Should the instrument perform as predicted, a positive contribution to the monitoring of suspended sediments will have been accomplished. This should aid in the process of controlling the present influx of sediments into surface waters and provide cost effective methods for assessing the current conditions of a given stream.

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