SURROGATE TECHNIQUES FOR SUSPENDED-SEDIMENT MEASUREMENT

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ABSTRACT

Introduction: Physical, chemical and biological sediment damage in North America has been estimated to be up to \$16 x 10^9 annually (Osterkamp et al., 1998). Accepted methods of collecting sediment data are labor intensive, expensive and may be of unknown accuracy due to the large spatial and temporal variability associated with the transport of suspended sediment. To fill this data void, automatic, cost-effective techniques are needed to collect high quality data on suspended sediment load.

The following paragraphs describe, in no particular order, methods for measuring suspended-sediment concentration. The operating principle of each method is briefly described and, where the information was available, the particle size and concentration ranges are included. For more information and additional references, see Wren et al., 2000.

Optical backscatter (OBS): Infrared or visible light is directed into the sample volume where a portion of the light will be backscattered if particles are in suspension. A series of photodiodes positioned around the emitter detect the backscattered light. An empirical calibration is used to convert backscatter to concentration. The measurement volume varies according to turbidity but is on the order of several cubic centimeters. OBS devices are readily available and relatively inexpensive. The particle size range for best operation is 200-400 µm, and concentrations may range up to 100 g/L. (Black & Rosenberg, 1994)

Optical transmission: Light is directed into the sample volume where sediment will absorb and/or scatter a portion of the light. A sensor located opposite the light source measures the attenuation of the light beam. The sediment concentration is determined using empirical calibration information. The size of the measurement volume will vary according to the geometry of the device. Optical transmission devices are relatively inexpensive. (Clifford et al. 1995)

Focused beam reflectance: A laser beam focused to a very small spot (<2 μm^2) in the sample volume is rotated very quickly (many times per second). As it rotates, the beam encounters particles that reflect a portion of the beam. The time of this reflection event is used to determine the sizes of particles in the path of the laser. The particle size range is 1-1000 µm and the concentration range is 0.010-50 g/L. Few references to this type of device are found in the literature. (Phillips and Walling, 1995)

Laser diffraction: A laser beam is directed into the sample volume where particles in suspension will scatter, absorb, and reflect the beam. Scattered laser light is received by a detector or array of detectors that allow measurement of the scattering angle of the beam. Particle size can be calculated from knowledge of this angle. By basing concentration measurements on measured particle sizes, particle size dependency is eliminated. The optical path length is either 2.5 or 5 cm, the particle size range is 1.25-250 µm or 2.5-500 µm, and the concentration may range up to about 5 g/L. These devices are relatively expensive and are readily available. (Agrawal and Pottsmith, 1994)

Acoustic: Short bursts (≈10 µs) of high frequency sound (1-5 MHz) emitted from a transducer are directed towards the measurement volume. Sediment in suspension will direct a portion of this sound back to the transducer. The strength of the backscattered signal allows the calculation of sediment concentration. Backscatter amplitude depends on the concentration, particle size, and acoustic frequency. This can be exploited by using multiple frequencies to determine both particle size and concentration. Acoustic devices measure the concentration in a range-gated vertical profile of 1-2 m in depth. Using typical ultrasonic frequencies, the particle size range is approximately 62-2000 µm and concentrations may range up to 30 g/L, although the available sampling depth will be limited at high concentrations. Acoustic technology is still under development. Appropriate hardware is available, but there is no commercially available hardware/software system to acoustically measure suspended-sediment concentration profiles. (Thorne et al., 1991; Hay and Sheng, 1992)

Nuclear: This technique relies on the attenuation or backscatter of radiation, usually X or gamma rays, by sediment particles. An empirical calibration is used to convert backscatter to concentration. The concentration range is approximately 0.5-12 g/L. The measurement volume will depend on instrument geometry. Nuclear devices are not readily available, and there is little evidence that these devices are currently being used for fluvial sediment measurement. (McHenry et al., 1967)

Spectral reflectance: This technique is based on the relationship between the amount of radiation, generally in the visible or infrared range, reflected from a body of water and the properties of that water. The radiation is measured by a hand held, airborne, or satellite based spectrometer. The size of the measured area is much larger than the other devices discussed here and may range from m^2 to km^2 of the surface of the water body. This technique is better suited to marine environments where large areas are under observation or in other situations where concentration variations over large areas are of interest. (Novo et al., 1989)

Digital optical: A charge-coupled device (CCD) records the sediment/water mixture in-situ. This recording can be analyzed so that, among other things, the size and concentration of suspended-sediment particles can be determined. It can also be used to visually confirm the nature of the sediment. Recent improvements in computer and imaging technology should expand the usefulness of this technology. The device is under development in the laboratory with plans to expand into field application. The size of the measurement volume will be dependant on light penetration in the water. (Gooding, 2001)

Vibrating tube: Water is routed through a vibrating tube in a stationary housing located either on the stream bank or in the stream. The frequency of the vibration will be affected by the density of the water in the tube and can be used to determine the sediment concentration. However, several other factors such as temperature, debris on the tube walls, and dissolved solids concentration also affect the vibration frequency. All of these must be accounted for to obtain an accurate measurement. The device works best in concentrations over 1 g/L. (Skinner, 1989)

Differential pressure: A differential pressure transducer may be used to determine differences in the specific weight of sediment bearing water versus water nearer the surface with lower concentrations. This difference in pressure can be used to determine the average suspended sediment concentration between the two inlets of the differential pressure transducer. The size of the measurement volume will depend on the separation of the pressure inlets of the differential transducer. The concentration range is dependant on the sensitivity of the transducer. The hardware for this device is readily available and relatively inexpensive. Changes in temperature gradient, turbulence, and dissolved solids concentration will affect measurements. (Lewis and Rasmussen, 1996)

Impact sampler: The sampler works on the principle of momentum transfer. The impact rate of sediment particles hitting a sensor is measured. The detected impact rate is dependent on the mass, velocity, and angle of particle impact. Few references to this type of device are found in the literature. There are many technical problems with the use of this device in a fluvial environment. (Salkield et al., 1981, as referenced by Van Rijn and Schaafsma, 1986)

Conclusion: At the present time many options exist for the measurement of sediments suspended in water. All of the techniques reviewed above, however, suffer from limitations that render the techniques inadequate in some environments. Perhaps the best option for suspended sediment measurement remains a hybrid approach that relies on more than one technique and maintains a manual component. Continued improvements in technology will undoubtedly translate into improved methods to collect suspended sediment data in the future.

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