#1443

Tracking Large Particle Movement with Passive Radio Transponders in Ephemeral, Alluvial Channels

M.H. Nichols[1]

[1] USDA-ARS, Southwest Watershed Research Center, 2000 E. Allen Rd., Tucson, AZ 85719; email: mnichols@tucson.ars.ag.gov

Abstract

In the semi-arid southwest, channel runoff associated with intense summer thunderstorms reaches high velocities with sufficient energy to move large gravel and cobbles. Thunderstorm generated runoff hydrographs are characterized by short durations and rapidly rising peaks. Highly variable flow conditions and alluvial channel beds make tracking and relocating individual particles difficult. Previously reported methods for tracking particles include painted rocks, magnetic tracers, and active radio methods. The use of these methods can be limited by difficulty in relocating and identifying individual particles, as well as by expense. This paper presents a description of the use of a commercially available radio frequency identification system for tracking the movement of individual particles. The tracking system consists of transponders, an antenna, a reader, and software. The passive transponder system offers the advantages of low cost, consistent results under harsh environmental conditions, and no need for a power supply in the particle. The radio frequency identification system offers the potential to efficiently collect data for developing sediment transport equations and improving mathematical models for simulating sediment transport under natural runoff conditions.

Introduction

Sound land use and management decisions require information regarding the effects of erosion and subsequent sediment transport. Within a channel system, transported sediment can move as part of the suspended load or as part of the bedload. The bedload contribution to the total load of sediment transported varies as water discharge varies. In the semi-arid southwest, runoff hydrographs generated by thunderstorm rainfall are characterized by short durations and rapidly rising peaks. Under these conditions, sliding, rolling, or saltating transports coarse-grained particles. Understanding how individual particles move and quantifying the total amount of material transported during a flow event are first steps toward developing mathematical expressions that can be used to predict the consequences of runoff.

Although samples collected during flows can be used to quantify suspended load (Edwards and Glysson, 1999, Renard et al., 1976), quantifying bedload transport is more difficult. A range of methods and equipment are available for sampling the coarse sediments that make up a channel bed. These include hand held samplers and cable and reel samplers (Edwards and Glysson,

Proc. ASCE Hydraulic Measurements & Experimental Methods Conf., 2002, T.L. Wahl, C.A. Pugh, K.A. Oberg and T.B. Bermeyen (eds.), 6 p.

1999). Bedload material sampling with a Helley-Smith Bedload Sampler offers a method for capturing material that moves in a flow (Emmett, 1980). Although several methods of monitoring and measuring bedload are reported in the literature, empirical data are relatively rare, and the accuracy is limited. Samples provide a basis for quantifying total bedload, but provide less information on the transport characteristics of bedload particles. The ability to track individual particles offers great potential for field experiments and hypothesis testing.

Tracers, traditionally in the form of painted rocks (Leopold et al., 1966, Wilcock, 1997), and more recently magnetic (Custer et al., 1987, Gintz, et al., 1996) and "radio" rocks (Ergenzinger at al., 1989, Emmett et al., 1990, Rosenfeld et al., 1996), offer an opportunity to characterize the movement of individual particles. Recent advances in technology provide the opportunity to monitor individual particles efficiently at a greatly reduced cost.

This paper describes a passive tracking system for monitoring individual coarse-grained particles. The system was implemented under laboratory conditions in early 2002 and will be tested in the field in July, August, and September during the 2002 "monsoon" season in southeastern Arizona.

Methods

Radio frequency identification system. Radio frequency identification (RFID) is a wireless, automatic identification system. RFID systems are employed in a diverse array of applications from supply chain operations and inventory tracking in industrial settings, to toll road access and automatic gasoline payments in the consumer setting. RFID technology and applications are evolving rapidly. Because of their efficiency for identifying individual items, research was undertaken to evaluate the utility of RFID systems for monitoring bedload particle movement in alluvial channel systems.

RFID systems consist of 3 parts, a transponder (derived from transmitter/responder), a reader, and an antenna. RFID transponders may be active or passive. Active transponders rely on an internal battery for power. Passive transponders rely on an external power source, usually delivered by the reader through an antenna. Passive transponders have a shorter read range, but are less expensive. Components purchased from Texas Instruments were used to develop the system for monitoring particles. Texas Instruments has been developing RFID systems since 1991 under the business name TIRIS[2] (Texas Instruments Registration and Identification System, http://www.ti.com/tiris).

Transponders are available in a variety of physical shapes, as well as options for programming, read ranges, and costs. The TIRIS RI-TRP-WR2B is a 32 mm Transponder encased in a glass capsule. The transponders are 100% waterproof and operate reliably under harsh environmental conditions. Each transponder consists of a resonant circuit that is energized by the

[2] The use of the TIRIS system does not imply an endorsement by USDA

electromagnetic field generated with an antenna. The circuit further charges a capacitor, which provides energy for the return signal. The operating frequency of the transponder is 134.2 kHz. The transponders can be programmed by the user to impart an individual identification tag.

The reader consists of digital electronics that send data to the transponder and interpret the returned signal. Each transponder can be tagged with an alphanumeric string up to 128 bits long. The reader is used to interpret the bits. The small form factor (approximately 10 cm x 10 cm x 8 cm) of the reader makes it suitable for field application. Under ideal conditions with a powerful antenna, the typical read range of the transponders used in this application can reach 100 cm. The read range is determined by the power of the reader, the power available for response within the transponder, and environmental conditions. Read range is also affected by the antenna.

The strength of the antenna signal decreases inversely in proportion to the square of the distance. In addition to distance, antenna shape, size, and power, as well as spatial orientation of the antenna to the transponder affect the power of the signal. Although metal obstacles and surrounding interference are a serious concern in industrial settings, they are of minor concern for this application. A stick antenna was tested in the lab and the read range of 8 cm was found to be insufficient for field application. The antenna was replaced with a gate antenna and read range was improved to 30 cm. Read range and antenna configuration were considered with respect to practicality of use in the field.

The system that will be deployed in the field consists of a laptop computer running signal interpretation software and a pole with the antenna mounted on one end and the reader mounted on the other end. A cable attaches the antenna to the reader, and a serial cable attaches the reader to the laptop. Power is supplied by a battery pack. Particles are found by walking the channel and sweeping the antenna over the bed. The returned signal indicates which particle was found.

Field experiment. The USDA-ARS Walnut Gulch Experimental Watershed (Renard et al., 1993) is located in southeastern Arizona (http://www.tucson.ars.ag.gov). The watershed is located in the semiarid transition zone between the Sonoran and Chihuahuan deserts. Walnut Gulch is the main channel on the watershed and is a tributary to the San Pedro River. The main channel and its tributaries are dry most of the time. Flow events in response to thunderstorm rainfall dominate the surface runoff regime.

Runoff is monitored at several locations within the watershed. The Lucky Hills Intensive Monitoring Site is made up of 6 small subwatersheds. Santa Rita Critical Depth Flumes (Smith et al., 1982) at the outlets of 3 of the subwatersheds provide event runoff discharge data. Depth integrated traversing slot sediment samplers collect data representing sediment that travels in suspension through the Santa Rita Flumes. Additionally, one of the subwatersheds is instrumented with an H flume at the subwatershed outlet. Mean annual runoff at the 6 subwatersheds ranges from 16.99 mm to 27.29 mm (standard deviation = 14.18 mm and 19.45 mm, respectively). Two-year runoff volume ranges from 6.93 mm to 9.08 mm and two-year peak runoff rates range from 30.60mm to 51.63 mm.

Synthetic coarse sediment particles were cast based on the size and density of natural rock particles (Figure 1). Natural particles weresampled from a channel on the USDA-ARS Walnut Gulch Experimental Watershed. The sampled particles ranged in size from 32 to 130 cubic centimeters with an average density of 2.3 g/cm^3 (standard deviation = 0.2 g/cm^3). A total of 150 transponders were cast into 5.72 cm (2.25 in) diameter concrete spheres with aggregate added to adjust the bulk density. The average density of cast spheres was 2.2 g/cm^3 (standard deviation = 0.1 g/cm^3), which was in close agreement with natural particles.

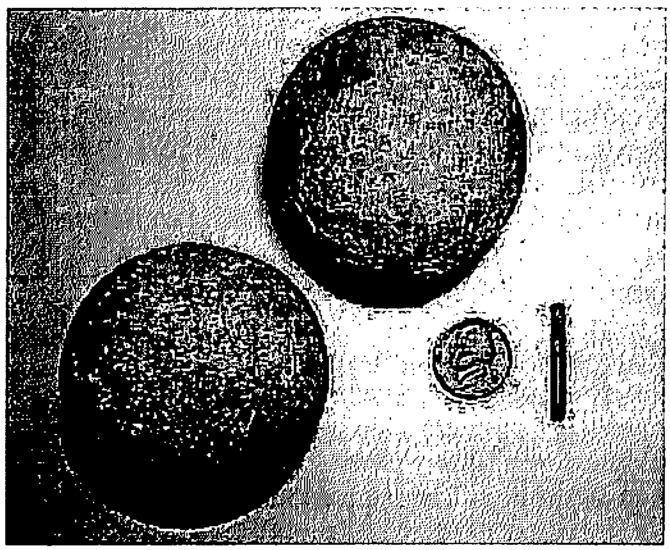

Figure 1. Cast concrete spheres and a 32 mm transponder

In early July of 2002, transponder laden concrete spheres were set on the channels within the Lucky Hills Monitoring Site (Figure 2). A natural particle was removed from the channel for each particle added. The location of each particle was measured using a surveyor's total station. Locations were tied to permanent benchmarks on the watershed. Particles will be relocated after each flow event by sweeping the channel with the antenna. New locations will be measured with the total station. Runoff event characteristics during the 2002 "monsoon" season will be coupled with particle displacement information to describe the transport of bedload particles in small alluvial channels.

Figure 2. Synthetic particles on channel bed

Summary

The radio frequency identification system provides reliable identification of tagged particles in a laboratory setting. The tracking system consists of transponders, an antenna, a reader, and software. The passive transponder system offers the advantages of low cost, consistent results under harsh environmental conditions, and no need for a power supply in the particle. In addition, no line of site is required for locating particles.

A field experiment has been designed and implemented to further test the system under natural runoff conditions. Future improvements to the field implementation include installation of an antenna at the outlet of the runoff measuring flumes and developing a more efficient positioning system. As RFID technology evolves, longer read ranges and lower costs will advance the feasibility of conducting field experiments based on radio frequency tracking. However, in it's current implementation, the radio frequency identification system offers the potential to efficiently collect data for developing sediment transport equations and improving mathematical models for simulating sediment transport under natural runoff conditions.

References

Custer, S. G., Bugosh, N., Ergenzinger, P. J., and Anderson, B. C. (1987). Electromagnetic detection of pebble transport in streams: a method for measurement of sediment transport

waves. In: Etheridge, Flores (Eds) *Recent Developments in Fluvial Sedimentology.* Society of Paleontologists and Minerologists, pp. 21-26.
Edwards, T. K. and Glysson, G. D. (1999). "Book3, Chapter 2: Field Methods for Measurement of Fluvial Sediment." *Techniques of Water-Resources Investigations of the U.S. Geological Survey.* 89 p.
Emmett, W. W. (1980). *A field calibration of the sediment-trapping characteristics of the Helley-Smith bed-load sampler.* USGS Professional Paper 1139. 44 p.
Emmett, W. W., Burrows, R. L., and Chacho, E. F., Jr. (1990). "Coarse-particle transport in a gravel-bed river." *International Journal of Sediment Research*, 11(2), 8-21.
Ergenzinger, P. J., Schmidt, K. H. and Busskamp, R. (1989). "The pebble trasmitter system (PETS) – 1st results of a technique for studying coarse material erosion, transport, and deposition." *Zeitschrift fur Geomorphologie,* 33(4), 503-508.
Gintz, D., Hassan, M. A., and Schmidt, K. H. (1996). "Frequency and magnitude of bedload transport in a mountain river." *Earth Surface Processes and Landforms*, 21(5), 433-445.
Leopold, L. B., Emmett, W. W., and Myrick, R. M. (1966). "Channel & Hillslope Processes in Semi-arid Areas, New Mexico." *USGS Professional Paper 352-G.*
Renard, K. G., Simanton, J. R., Donica, L. D. (1976). "A Time-Based Total-Load Automatic Sediment Sampler." *Proc. 3rd Federal Interagency Sedimentation Conference,* 7.17-7.29.
Renard, K. G., Lane, L. J., Simanton, J. R., Emmerich, W. E., Stone, J. J., Weltz, M. A., Goodrich, D. C., Yakowitz, D. S. (1993). "Agricultural impacts in an arid environment." *Hydrologic Science and Technology*, 9, 145-190.
Rosenfeld, C. L., Castro, J. M., and Childers, E. S. (1996). "Individual Gravel Tracking Using a Passive Radio Transponder System " *Proc. 6th Federal Interagency Sedimentation Conference,* 5.47 – 5.51.
Smith, R. E., Chery, D. L. Jr., Renard, K. G., and Gwinn, W. R. (1982). "Supercritical flumes for measuring sediment-laden flow." *USDA Tech. Bull. 1655*, 70 pp.
Wilcock, P. R. (1997). "Entrainment, Displacement and Transport of Tracer Gravels." *Water Resources Research*, 37(3), 813.