

## MONITORING COARSE SEDIMENT PARTICLE DISPLACEMENT USING A RADIO FREQUENCY IDENTIFICATION SYSTEM

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**Abstract:** Coarse particles make up a relatively high contribution to overall sediment yield in ephemeral alluvial channels. A radio frequency identification system was developed and implemented to monitor the displacement of coarse particles following runoff in two upland, ephemeral channels on the USDA-ARS Walnut Gulch Experimental Watershed in southeastern Arizona. Sediment transporting flows are typically of short duration with rapidly rising and falling hydrographs. Commercially available radio frequency identification components including transponders, an antenna, a reader, and software were used to develop a system for locating particles under field conditions. During the 2003 field season 124 particles were located following four runoff events in two ephemeral channels. A total of 340 particle positions were measured with a differential geopositioning system after each particle was located with the radio frequency identification system. The overall recovery rate was 96%. 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. Buried particles can be located and identified without disturbing channel bed material. The radio frequency identification system can be used to efficiently collect data for developing sediment transport equations and improving mathematical models for simulating sediment transport under natural runoff conditions.

### INTRODUCTION

Sediment transport processes in normally dry channels in semiarid regions are generally poorly understood and difficult to quantify. In the southwestern US, channel runoff associated with intense summer thunderstorm rainfall is highly variable, turbulent, and often short lived, making measurement and data collection difficult. Because of the difficulties associated with collecting data, there are more data describing the relatively fine sediment that travels in suspension (Edwards and Glysson, 1999, Renard et al., 1976) as opposed to the coarse fraction that generally travels as bedload. Tracking individual particles is especially difficult

There is a need for field data coupling runoff measurements and sediment measurements to improve sediment transport prediction equations. Tracers have been used in sediment research to study the sediment movement for at least a century (Foster, 2000), with varying degrees of success. 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 et al., 1989, Emmett et al., 1990, Rosenfeld et al., 1996), have been used to study the movement of individual particles.

A radio frequency identification (RFID) system was developed to monitor the displacement of individual coarse, synthetic, sediment particles on the USDA-ARS Walnut Gulch Experimental Watershed as part of a long-term sediment transport experiment (Nichols, 2004). This paper describes the RFID system for monitoring individual coarse-grained particles and summarizes particle recovery rates for the 2003 measurement season. Additional detail can be found in Nichols 2004.

## METHODS

Radio frequency identification (RFID) is a wireless, automatic identification system. RFID systems are employed in diverse applications from supply chain operations and inventory tracking in industrial settings, to toll road access and automatic gasoline payments in consumer settings. RFID systems consist of three parts, a transponder (derived from transmitter/responder), a reader, and an antenna. Each transponder can be coded with a unique alphanumeric string.

The particle tracking system (reader and antenna) is implemented in a manner similar to that of a metal detector. Particles are found by walking the channel and sweeping the antenna over the channel bed. The sweeper is powered by a battery pack made up of three 6V rechargeable batteries and consists of a gate antenna attached to one end of a pole and the reader mounted on the other end. A cable attaches the antenna to the reader, and a serial cable attaches the reader to a portable computer. When a transponder is detected, a buzzer sounds, and the computer displays the alphanumeric string stored within the transponder that indicates which particle was found.

Concrete spheres with a 5.72 cm diameter ( $95 \text{ cm}^3$ ), representing very coarse gravel, were cast from concrete with aggregate added to adjust the density. Transponders were placed into wet concrete during casting. The average density of cast spheres was  $2.2 \text{ g/cm}^3$  (standard deviation =  $0.1 \text{ g/cm}^3$ ), which was in close agreement with the natural rocks. In addition, synthetic cubes ( $98 \text{ cm}^3$ ) were cast. This analysis summarizes measurement of 124 transponder laden concrete particles that were set on channels 102-104 and 106-104 within the Lucky Hills Subwatersheds (Figure 1). A natural particle was removed from the channel for each particle added and the location of each particle was measured using a surveyor's total station. Particles were located by sweeping the channel with the antenna and locations were surveyed.

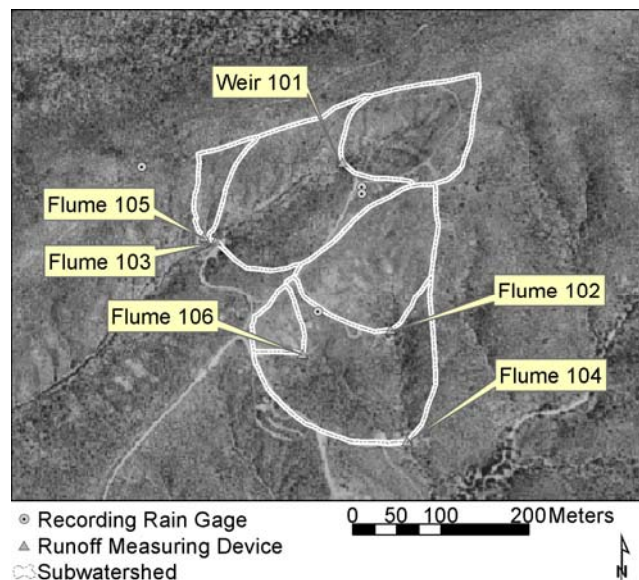


Figure1 Location of the Lucky Hills Subwatersheds and channels.

## RESULTS

The RFID system was used to locate 96% of the particles searched for following four runoff events during the 2003 “monsoon” season. Without the RFID system, recovery of uniquely identifiable particles would have been limited to 79% of the particles in the 102-104 channel and 63% of the particles in the 106-104 channel (Table 1).

Table 1 2003 particle recovery characteristics.

Channel Number	Particle Position	Number of Particles
102-104	buried	28
	half buried	24
	less than half buried	21
	more than half buried	25
	surface	44
	missing	3
	total number of positions	145
	recovery rate	0.98
	maximum recovery rate without RFID system	0.79
	106-104	buried
half buried		15
less than half buried		32
more than half buried		34
surface		42
missing		12
total number of positions		195
recovery rate		0.94
maximum recovery rate without RFID system		0.63

The field experiment is being conducted to monitor particle displacement following each flow event during three runoff seasons. Identifying buried particles is critical to maintaining continuity of particle travel data through successive flows. Given the high bed mobility and depth of alluvium in channels on the watershed, the state of burial of an individual particle is highly variable in response to runoff. Recovery of buried particles, and identifying the particles in situ has been a shortcoming of the use of painted rocks, or even magnetically tagged particles. The depth of alluvium in the 102-104 channels is variable ranging from zero (exposed hardpan) to approximately one meter in the fluvial deposit at the flume intake. During initial testing, several buried particles were dug up to verify their detection. With the RFID system, buried particles can be located and uniquely identified without disturbing the particle or the channel. However, a modified antenna configuration would be required if the system were used in a channel with deeper alluvium.

Although particles that were not classified as buried could be detected visually, particle detection was much more efficient with the RFID system. Often, particles were partially buried, obstructed by vegetation, or intermixed with particles of like color and size (Figure 2). Detecting the particles, particularly those particles under bank vegetation, was relatively easy by systematically sweeping the antenna below the vegetation. In addition, the synthetic particles employed in this experiment were intentionally of like shape and the RFID system was critical for uniquely identifying particles. When particles deposited in groups, additional care was taken when sweeping the antenna to ensure that the signal from any particular transponder did not dominate both the returned signal and the displayed identification string.



Figure 2 Typical channel segment with flag indicating a buried particle.

## CONCLUSION

The radio frequency identification system provides reliable identification of tagged particles in a field 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, line of site is not required for locating particles.

The system was implemented and tested under natural runoff conditions. The RFID system was successful in locating 96% of the particles searched for following four runoff events. As RFID technology evolves, longer read ranges and lower costs will advance the feasibility of conducting field experiments based on radio frequency tracking. The radio frequency identification system has been used to collect particle displacement data for 3 summer runoff season. Collected data are being analyzed to improve sediment transport equations and mathematical models for simulating sediment transport under natural runoff conditions.

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