A. Problem and Research Objectives

The objective of this research was to determine whether ground penetrating radar (GPR) could be used to make nondestructive measurements of infiltration rates into the bed of Rillito Creek following natural flow events. GPR measures the two-way travel time of electromagnetic waves from the ground surface to a reflective target (e.g. a metal pipe) in the subsurface. This travel time increases with increasing saturation of the sediments above the target, potentially allowing for measurement of the amount of water stored in the subsurface. Measurements of the change in water storage with time can indicate the rate of drainage following a surface flow event. This can then be related to the hydraulic properties of the soil that control infiltration rates.

B. Methodology

The research was conducted in four steps. The first three steps were completed in an effort to optimize signal quality. The final step was completed to attempt to explain the observed results.

Step 1: Establishing GPR targets. An ideal GPR target consists of a metallic pipe of at least 30 cm in diameter buried between 1.5 and 3 meters below ground surface. A survey of buried utilities was conducted for the entire reach of Rillito Creek. Most buried utilities were found to be either too small in diameter or too shallow to act as GPR targets. However, preliminary surveys were conducted over a series of buried pipes located near Dodge Boulevard to preclude their use. Survey results showed that these pipes did not provide useful GPR targets. Based on historical records we also located a water conduit near Craycroft Boulevard that was installed and used by Mormon settlers. While this target could be identified at select locations in the creekbed, it was not continuous enough to allow for reliable infiltration measurements. Given the inability of GPR to reliably identify existing buried targets, two metal pipes were buried in the creekbed to improve our surveying efforts. Each pipe was 0.75 m in diameter. A trench was dug near Dodge Boulevard with a backhoe. One pipe was buried in the trench at a depth of 1.5 meters and the second pipe was buried at a depth of 2.5 meters. The trench was backfilled with streambed materials.

Step 2: Optimizing GPR collection parameters. The bed of Rillito Creek proved to be a difficult environment for collecting useful GPR data. Therefore, the majority of the efforts expended on this project were spent optimizing the GPR collection parameters to improve GPR signals. The buried pipes were used as targets during these optimization activities. The primary control on signal quality was the choice of an appropriate antenna frequency. We tested 25, 100, and 200 MHz antennae. The 200 MHz antennae were found to give sufficient depth of investigation while maximizing near-surface detail. In addition to antenna selection, the following system parameters were optimized: transmitter voltage, signal stacking, step size, and antenna separation.

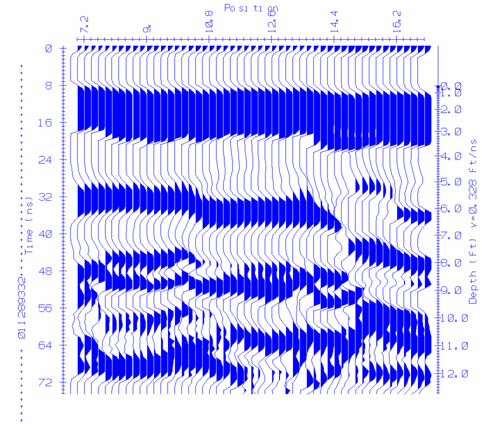

Figure 1: Data collected with a 100MHz Antenna.

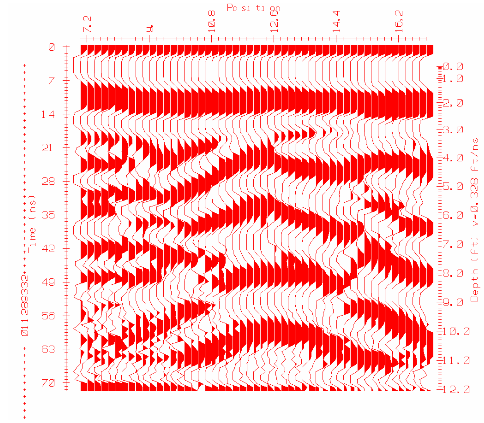

Figure 2: Data collected with a 200MHz Antenna.

Figure 1 and 2 show how each of these parameters can be optimized to improve signal quality. Notice the parabolic reflectors visible in the center of Figure 2 that are not evident in the traces collected with 100 MHz antennae. Our optimized system used a 1000V transmitter with 128 times stacking, a step size of 0.1 feet and 200 MHz antennae separated by a distance of 2 feet.

Step 3: Data Collection and Interpretation. GPR surveys conducted over the buried pipes did not show the parabolic reflections characteristic of these targets (Figure 3). It is hypothesized that the extreme variation in grain size, ranging from silt to very large boulders, led to excessive scattering of returning signals, obscuring any useable reflections. However, examination of the GPR records shows apparent flat lying reflectors, which may be associated with changes in subsurface geology or water content. Additional efforts focused on examining the change in travel time to these flat-lying reflectors. However, there was no consistent observed change in travel times to these targets following a flow event.

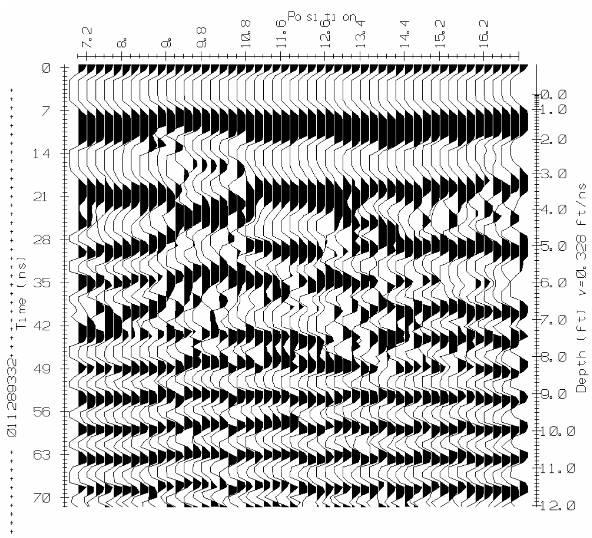

Figure 3: Inconclusive transect.

Step 4: Explanation of GPR Results. Given the inability of GPR to detect changes in near surface water content, we designed a monitoring network to measure the water content at discrete depths using buried TDR probes. Whereas GPR measurements require that an operator walk in the streambed, buried TDR probes can measure the water content continuously without an operator. Therefore, while TDR can capture the water content drainage immediately following cessation of flow, GPR measurements typically began 6 to 18 hours following cessation. This delay was due to the time lag between notification of cessation and mobilization of the field crew. In addition, safety considerations limit the minimum time following flow when the creekbed can be accessed. Figure 4 shows the water content as a function of time immediately following a flow event. The results indicate that the upper 1.5 meters of sediment had dried completely within 0.5 days. This extremely rapid drainage adequately explains the inability of GPR to identify water content changes; drainage was likely nearly complete before the surveys began.

C.

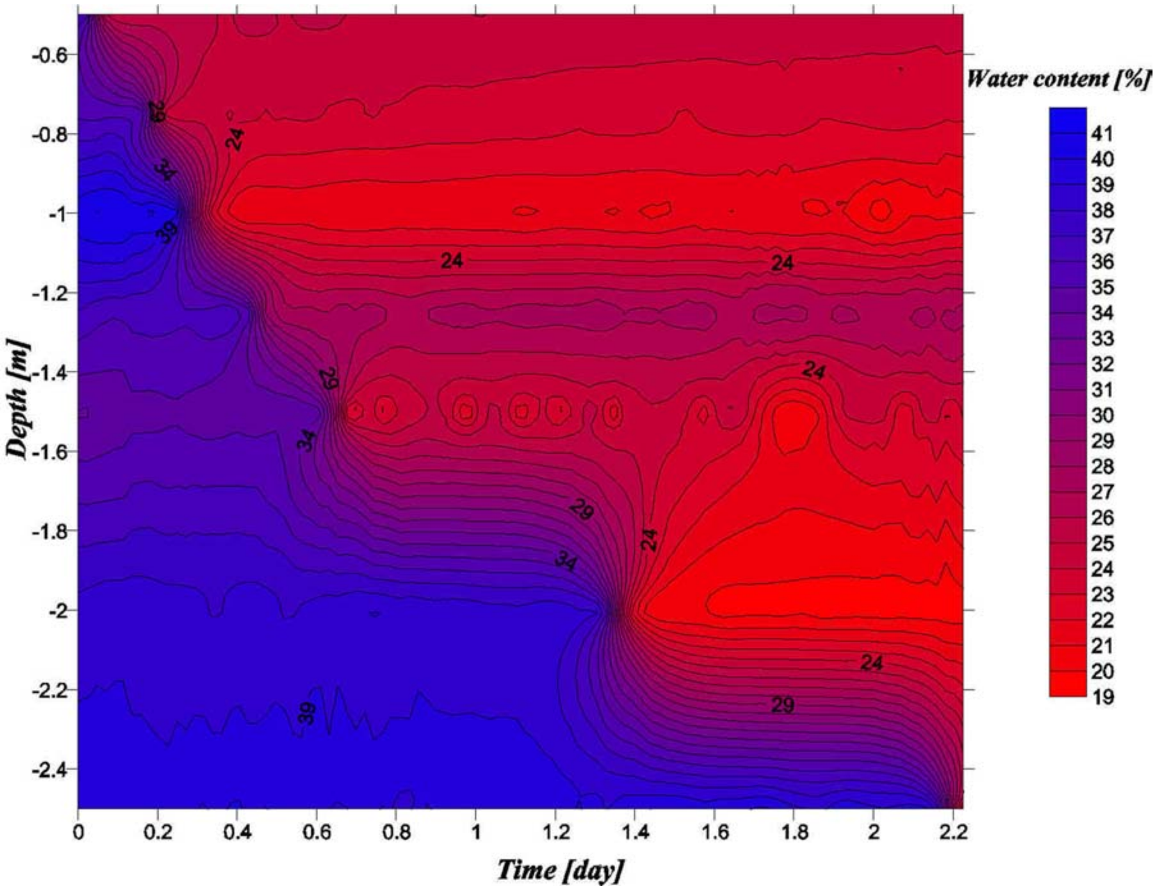

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Figure 4: TDR data collected after a surface flow event.

Findings and Significance

Although we were unable to monitor drainage in Rillito Creek using GPR, the study did produce several useful results. The rapid rate of drainage of the subsurface sediments measured with TDR was unexpected. This finding suggests that evaporative loss following flow events is minimal, facilitating the direct use of infiltration measurements to estimate recharge beneath the streambed. The limitations to using GPR in ephemeral streambeds posed by the presence of large boulders were also unexpected. Given that these materials are not identifiable from standard drilling and boring activities, it is recommended that shallow trenching be conducted at sites of potential GPR monitoring to allow for visual inspection of the particle size distribution. Finally, the ability of GPR to locate the buried water conduit demonstrates the promise of this technology for archaeological investigations. However, the same cautions listed above should be applied to identify which environments will be amenable to GPR surveying.