Investigating Groundwater: Surface Water Interaction Using Distributed Temperature Sensing (DTS) Technology

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Background/Objectives. At an approximate 350-acre railyard, a long history of diesel use and subsurface releases have resulted in a 30-acre area impacted with light non-aqueous phase liquid (LNAPL). Studies showed this LNAPL body was present in a shallow and deeper aquifer and discharging to a stream that flows across the site through a 1750-foot long and 25-foot wide culvert with an open bottom. Previous investigation efforts examining the extent and quantity of groundwater discharge into the stream were limited to using conventional approaches collecting surface water elevations and hydraulic head data from piezometers within the culvert and nearby monitoring wells. As a means to gather higher resolution groundwater discharge data, a distributed temperature sensing (DTS) survey was conducted.

Approach/Activities. DTS surveys utilize a buried fiber optic cable to send and receive laser pulses and record the frequencies of backscattered light. A known relationship between temperature and the frequency of backscattered light is used to calculate temperature adjacent to the cable, and precise timing of the returned light reveals locations of the measured temperature in sediment porewater. The absolute temperature accuracy is ~ 0.05 °C to 0.1 °C, and precision (comparing adjacent locations on the same cable, which is key to identifying seeps) is ~ 0.03 °C to 0.06 °C. The temperature in the sediment porewater is compared to surface water temperature as an indicator of where groundwater discharge is occurring.

A steel encased, fiber optic cable was buried 8 inches below the stream bed surface for the DTS survey. Pressure transducers were deployed in monitoring wells outside the culvert and at the stream inlet and outlet to monitor the changes in surface water levels within the culvert. Surface water level data were reviewed to select a range of stream stage elevation periods representative of transient, stable and baseflow conditions. DTS data were collected through four seasons with select periods evaluated using a heat transfer model to estimate the rate of groundwater discharge where occurring.

Results/Lessons Learned. The DTS data were successfully used to locate and quantify groundwater discharge to the culverted stream. Groundwater discharge was observed in approximately the same areas in both winter and summer but with a larger footprint in winter (6% more) versus summer. The discharge area in winter was 17% of monitored locations while the discharge area in summer totaled 11% of the monitored area. This observation may be due to the greater temperature differential between surface water and groundwater within the culvert in winter than in summer

During the winter DTS collection period when four different surface water level conditions were observed, the groundwater discharge rate was highest at near base flow water level conditions. In contrast, lower discharge rates were estimated during most elevated stage levels.

The total groundwater discharge rate was estimated to vary in the range of 1.7 to 6.8 gallons per minute (gpm).