An Investigation of Groundwater Flow in the Vicinity of Patoka Dam, Indiana: Research to Support United States Army Corps of Engineers Dam Safety Risk Assessment

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Several dams throughout the United States have been built on karst terrains, where especially soluble limestone bedrock has been dissolved to form features such as caves, sinkholes, and underground rivers. In such karst regions, subsurface hydrology can play an integral role in the condition, operation, and safety of dams and should be considered during risk assessment and subsequent dam safety management. Patoka Dam, near Jasper, Indiana, is situated on a well-developed karst landscape/aquifer system, faces significant potential challenges, and recently underwent risk assessment. A groundwater flow investigation using multiple fluorescent tracer tests, analysis of water table elevations, isopach mapping of the Glen Dean Limestone, and spring hydrograph analysis was performed to better understand local groundwater hydrology in the vicinity of the existing water control structures that include the dam, grout curtain, dike, and concrete cut-off wall (Figure 1). The previous 2008 risk analysis identified potential failure modes, one of which was abutment seepage and piping failure of the dike and therefore efforts were focused in this area. Results identified the general local flow direction as south to north and indicate that a limited amount of groundwater is bypassing the control structures in the vicinity of the cut-off wall (Figure 2). Groundwater travel times within the Glen Dean Lime-

Figure 1. Aerial view of study area

stone based on initial dye arrival were are 6 to 15 meters per hour; however, mean groundwater velocities based on quantitative sampling were 2 to 3 meters per hour. Tracer tests, potentiometric surface mapping, and interpretation of geologic mapping helped to delineate the recharge area for Robert Hall Cave Spring (RHCS), a significant groundwater discharge point downstream from Patoka Dam, and confirm the existence of a groundwater divide in the area of the dike. Since lake pool elevation is now at or above the elevation of the Glen Dean Limestone, Patoka Lake is now considered within the drainage basin for RHCS. However, based on spring hydrograph analysis and potentiometric surface variability with pool elevation, it appears that the lake, though it influences flow direction and hydraulic gradient, is a minor contributor to the amount of flow at RHCS. In this case, the lake should be considered a secondary region of the drainage basin in that it is hydrologically connected to RHCS but drainage appears to be largely restrained by subsurface hydraulic control structures. In delineating the RHCS basin, with an important groundwater divide, reviewing potentiometric surface variability, and spring discharge as it relates to pool elevation, it could be concluded that groundwater flow in the vicinity of the dike is diffuse and/or minimal, and therefore the likelihood and extent of groundwater pathways may be decreased. However, it should be noted that karst landscapes are dynamic and all results should be viewed as a 'snapshot in time' rather than a description of a static system. This groundwater investigation has offered a clearer characterization of the hydrogeology within the vicinity of Patoka Dam and provided some insight into the function and geometry of the local karst network that could potentially provide subsurface pathways for internal erosion of unconsolidated dam materials and affect the integrity of the dam and/or dike structures. The research as presented is intended to assist managers at Patoka Dam in additional intrusive and expensive geologic investigations, increase certainty in the risk assessment of potential failure modes related to the karst environment in which the dam operates, and inform dam management.

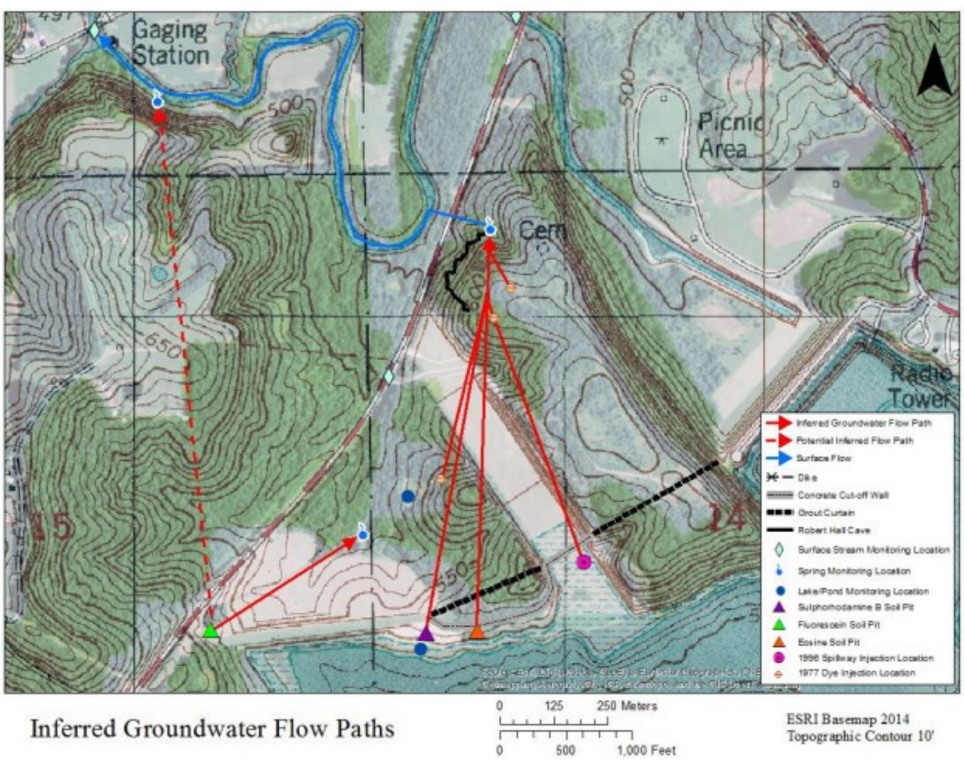

Figure 2. Inferred groundwater flowpaths from all traces