ELECTROMAGNETIC METHODS TO DELINEATE HIGH CONDUCTIVITY IN SHALLOW AQUIFERS, EAST POPLAR OIL FIELD AREA, NORTHEASTERN MONTANA

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Abstract

Airborne, ground, and borehole geophysical studies by the U.S. Geological Survey (USGS), in cooperation with the Fort Peck Assiniboine and Sioux Tribes, have been used to delineate areas of saline groundwater in shallow (<40 meters) unconfined aquifers underlying the East Poplar oil field in northeastern Montana. In the 20 years since the first delineation of saline groundwater, the quality of water from wells completed in the shallow aquifers has changed markedly. The current estimated extent of saline-water plumes based on integrated geophysical and hydrologic studies differs from that delineated in the early 1990s.

Ground electromagnetic surveys began in the mid-1990s using an EM-34 (10, 20, and 40 meter vertical and horizontal loops) to measure subsurface electrical conductivity. Results from the EM surves indicated broad areas of high conductivity, which when integrated with results from groundwater quality samples, led to estimates of more than 12 square miles of saline groundwater. In 2004; an airborne electromagnetic survey funded by the Ft. Peck tribes was conducted over a 106 square-mile area that included most of the southeast East Poplar oil field. These surveys provided a foundation for developing a hydrogeologic framework and saline plume mapping over a large area. These surveys, in conjunction with water quality analyses, led to the determination that handling and disposal of brine produced with oil in the East Poplar oil field area resulted in contamination of not only the deeper aquifers, but also shallower areas some of which are near the Poplar River. The integrated interpretation of hydrogeological and geophysical studies has increased the understanding of the subsurface glacial hydrostratigraphy which controls groundwater flow and migration of saline waters.

In one area (termed the Biere area near Biere well #1-22), Pioneer Natural Resource (PNR) voluntarily designed and built a plume capture and remediation system consisting of fifteen saline, groundwater removal wells, five crude oil recovery wells and a deep, 7,800 foot, USEPA Class V, injection well. The brine remediation system became fully operational in August 2008 and is operating at an average daily rate of 5,100 barrels per day (214,200 gallons/day). As of January 2015 the system has removed 8,798,390 barrels (369,532,380

gallons) of brine contaminated water with an average chloride concentration >10,000 mg/L. PNR personnel have conducted EM-34 surveys beginning in 2008 to monitor changes in groundwater salinity in the Biere area. These surveys were used in conjunction with water well sampling to develop an estimate of the extent of the brine and crude oil plumes in the Biere area. The survey consists of 237 stations over a 1.03 square mile grid. The repeated EM-34 surveys show decreases of high subsurface conductivity in the area that correlates with a decrease in the plume extent determined by monitoring wells and geophysical induction logs. These EM surveys are relatively inexpensive and easy to conduct and can give useful and more detailed information about saline water extent in much more detail than possible with well-based measurements.

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