MAPPING COMPLEX GROUNDWATER FLOW PATHS: UNDERSTANDING PREFERENTIAL FLOW PATHS IN AQUIFER MATERIALS WITH DIFFERING POROSITIES

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Resumo

A utilização de métodos geofísicos na investigação de áreas contaminadas é uma ferramenta de grande valia, principalmente quando ocorrem substratos heterogêneos (com diferentes propriedades petrofisicas), o que acaba por gerar vias preferenciais de fluxo subterrâneo. O objetivo principal deste trabalho é apresentar um levantamento geofísico realizado em área de armazenamento subterrâneo de produtos químicos no oeste dos EUA. O método utilizado "Audio Frequency Domain Magnetics (AFDM)" permite identificar os caminhos preferenciais de fluxo subterrâneo, desde a superfície até a zona saturada do aqüífero, mediante análise em superfície do campo magnético, gerado como resposta a injeção de corrente elétrica no aqüífero. O levantamento geofísico realizado permitiu a identificação dos caminhos preferenciais de fluxo subterrâneo, melhorando em muito o modelo conceitual pré-existente, o qual caracterizava o substrato como homogêneo (principalmente em função das descrições litológicas pré-existentes).

Abstract

The use of geophysical methods in the investigation of contaminated areas is a valuable tool, especially when there are heterogeneous substrates (with different petrophysical properties), what generates preferential groundwater flow pathways. The objective of the geophysical survey discussed herein was to understand how meteoric water traveled preferentially from the ground surface to the water table (saturated zone) and if the saturated zone was homogeneous in nature as hypothesized due to the prevalence of sands and gravels as the principal geology. This procedure, which uses Audio Frequency Domain Magnetics (AFDM), begins by charging the groundwater site with a low voltage, low amperage, high frequency electrical current. A specially tuned receiver measures this field at the surface. Geophysical technology can play an important role in assisting operators to improve the knowledge of site characteristics. Drawing primarily from the above case study, this paper will examine the promise and the limitations of the aforementioned approach.

Keywords: Potential Flow Paths, Geophysical Survey, Audio Frequency Domain Magnetics (AFDM).

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1 - INTRODUCTION

In the Great Basin desert of the western United States is an airfield that has been in continuous operation for almost a century. The owners of the airfield had dumped fuel, oil, and other liquid waste into chemical disposal pits. When evidence recently emerged that one of these pits was linked to local groundwater contamination, the owners began an intensive remediation investigation.

The objective of the geophysical survey discussed herein was to understand how meteoric water traveled preferentially from the ground surface to the water table (saturated zone) and if the saturated zone was homogeneous in nature as hypothesized due to the prevalence of sands and gravels as the principal geology.

2 - METHODS

Detailing the method used in the above case study, this paper presents an alternative to traditional mapping methods, one much better suited to the demands of complex groundwater scenarios.

This procedure, which uses Audio Frequency Domain Magnetics (AFDM), begins by charging the groundwater site with a low voltage, low amperage, high frequency electrical current. As the current moves through the groundwater, it emits a magnetic field whose size, shape, magnitude and direction are characteristic of the surrounding aqueous system (Biot-Savart Law). A specially tuned receiver measures this field at the surface.

The data thus generated—after being run through a series of filters detailed in this paper—can be used to create both two-dimensional maps and three-dimensional models that indicate the attributes of the subsurface water network, including potential flow paths.

Because this method uses the broad diffusion of electrical current rather than targeted boreholes, it can capture the character of large and complicated groundwater systems much more effectively.

Figure 1 - The Willowstick instrument, which captures magnetic field strength data.

3 - RESULTS AND DISCUSSION

The results of the survey confirmed that the saturated zone was indeed homogeneous in nature with no preferential flow while the flow paths from the surface to the water table where mapped.

The investigation suggested that these paths of least resistance consisted of lenses of higher or lower porosity materials (silts, sands and/or gravels). As surface water seeped through and along these lenses of varying earthen materials, the groundwater flowed outward away from the pit in all directions before reaching the saturated zone.

The intricate flow pattern revealed in this investigation would have been extremely difficult to comprehend through traditional subsurface mapping methods. Such methods have typically relied on the drilling of investigative wells in the hope of a fortuitous intersection of the borehole with a contaminant flow path.

This sort of approach may have been suitable for relatively simple flow patterns, with one or two major channels, but a complex and counterintuitive pattern like the one in this study would require a prohibitively large amount of exploratory drilling, with all of the financial expense and ecological trauma entailed in such an invasive technique.

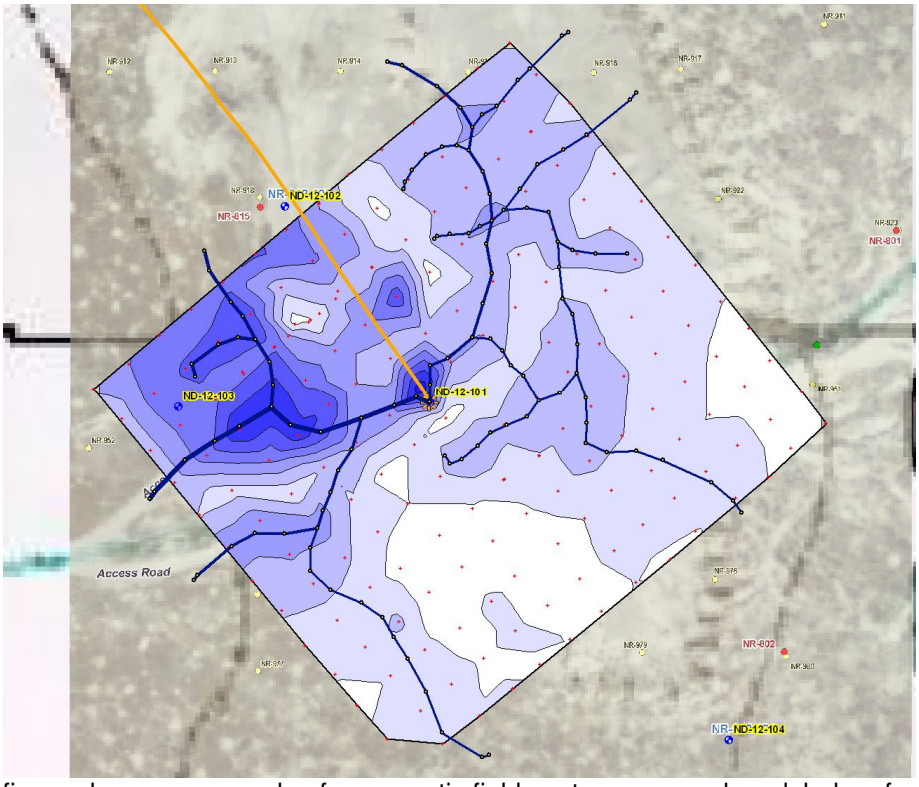

Figure 2 - This figure shows an example of a magnetic field contour map and modeled preferential flow paths of electrical current (dark blue lines). These maps pinpoint the location of groundwater preferential flow.

4 – CONCLUSION

Geophysical technology can play an important role in assisting operators to improve the knowledge of site characteristics. Drawing primarily from the above case study, this paper will examine the promise and the limitations of the aforementioned approach.