SIMULATION OF ELECTRICAL POTENTIAL DIFFERENCES NEAR A CONTAMINANT PLUME EXCITED BY A POINT SOURCE OF CURRENT

James L. Osiensky¹, Roy E. Williams¹, Dale R. Ralston¹, Gary S. Johnson¹ and Leland L. Mink²

ABSTRACT

Finite-difference simulations of electrical excitation of conductive contaminant plumes indicated that approximate dimensions of a plume and the approximate location of its center of mass can be derived, under specified circumstances, from the resulting electrical potential fields. Direct electrical excitation of a contaminant plume by a point current source was simulated for homogenous and isotropic conditions as well as in the presence of conductive clay layers and lenses. When a very shallow water table was assumed, changes in the electrical potential field between baseline (preplume) and conditions that included a developing plume graphically formed a difference dipole. Simulations suggested that electrical flow is channeled preferentially through the negative difference pole at the approximate location of the center of mass in a dispersive contaminant plume. Electrical flow was channeled directly through the negative difference pole at the terminal end of a conductive clay lens. Simulations showed that even in the presence of conductive clays, the approximate location of the center of mass of an evolving contaminant plume could be delineated. This illustrates the potential future value of this approach, assuming continued technological advances in the field.

INTRODUCTION

Ground water monitoring programs generally are designed to show that contamination does not exist, is contained within specific boundaries, or will be detected immediately if it occurs. The literature is replete with case histories that used surface electrical resistivity methods to help detect contaminated ground water.

A single current electrode method known as the mise-a-la-masse method was first described by Schlumberger (1920). To date, most published applications of the mise-a-la-masse method involve mining applications that provided qualitative information on the extent and continuity of metallic ore bodies. With this method, an electrical current is

¹ Hydrology Program, Department of Geology and Geological Engineering, University of Idaho, Moscow, Idaho 83844-3022

² Director, Idaho Water Resources Research Institute, University of Idaho, Moscow, Idaho 83844-3011

passed directly into an ore body while steady state electrical potentials are measured at the land surface or in boreholes (Parasnis, 1967). Ketola (1972) described measurements
to map several ore bodies in Finland. Mansinha and Mwenifumbo (1983) delineated two vein-type mineralized zones in Canada. Eloranta (1985) compared measurements obtained with different electrode arrangements. Eloranta (1986) described the electrical potential field from a single current electrode near a vertical contact. Bowker (1987) described electrical potential field measurements to evaluate the size of slab-like ore bodies. Dey and Morrison (1979) simulated the three-dimensional potential distribution from an electrical point source for an arbitrary three-dimensional distribution of conductivity. Newkirk (1982) used a three-dimensional model to interpret apparent resistivity responses for three-dimensional bodies near a buried electrode. Beasley and Ward (1986) used a three-dimensional model to simulate the electrical potential field from a single current electrode near fracture zones. They modeled thin conductive bodies with orientations of vertical, horizontal, 30 degrees, and 60 degrees. Beasley and Ward (1986) found that the maximum depth at which a body can be detected at the land surface depends on the position of the current electrode and the contrast in conductivity. Wilt and Tsang (1985) used the three-dimensional model of Dey and Morrison (1979) to simulate changes in apparent resistivity due to the presence of a buried prism of contaminated ground water within an aquifer. Wilt and Tsang (1985) concluded that the mise-a-la-masse method may be used to roughly characterize the contaminant mass and its boundaries. Bevc and Morrison (1989, 1991) showed that a strong asymmetric anomaly (difference dipole as referred to later) developed during a salt water injection experiment when baseline electrical potential data were subtracted from post-injection data. Osiensky and Donaldson (1994, 1995) and Osiensky (1995) showed that the mise-a-la-masse method can be useful for the delineation of tracer plumes. However, the degree of success depends on the conductivity contrast between the plume and its surroundings.

The mise-a-la-masse method allows the direct measurement of the electrical potential field for existing (often unidentified) boundary conditions. The resulting electrical potential field incorporates all factors that contribute to its development at the particular time of measurement. Subsequent changes that occur over time can be evaluated where the baseline electrical potential field can be measured. The effects of an evolving contaminant plume can be delineated if subsequent data sets are collected under the same conditions as baseline data (e.g., similar moisture content and temperature of surface soils, same depth to the water table, etc.).

MODEL DEVELOPMENT

Jansen and Taylor (1995) showed that the ground water flow code MODFLOW (McDonald and Harbaugh, 1988) could be used to simulate electrical geophysical methods. Osiensky and Williams (1996) and Osiensky (1997) presented mathematical justification for use of the MODFLOW (McDonald and Harbaugh, 1988) code to simulate electrical flow through conductive contaminant plumes. Osiensky (1997) showed by the simulation of electrical flow through six different plumes that the center of mass of an evolving, conductive plume can be tracked by measurement of the resulting electrical potential fields over time.