UNDERSTANDING 1993 GROUNDWATER CONDITIONS AT THE TOWN OF BROOKHAVEN LANDFILL THROUGH SLIDING STIFF DIAGRAMS

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Contamination of groundwater by landfills has been the subject of many groundwater studies, particularly on Long Island because of its sole source aquifer. The prevalent analytical technique for these studies has been uni-variate maps and models of contaminant constituents. A new multi-variate analytical technique, sliding-scale Stiff diagrams, was applied to monitoring results at the Town of Brookhaven landfill in 1993. This methodology is shown to provide a more sensitive and precise means of determining groundwater conditions and in delineating the source(s) of contaminants.

Introduction

The Town of Brookhaven Landfill Facility in the hamlet of Brookhaven, Long Island, NY, is a 534-acre site, south of the deep-recharge zone, in an area of southeastern groundwater flow in the Upper Glacial and Magothy Aquifers (Dvirka & Bartilucci, 1993a). Four contiguous landfill cells occupy approximately 90 acres of the site, which opened in 1974. Cells 1-3 were used for the disposal of municipal solid waste (MSW) from 1974-1991. Final closure of these cells occurred in 1992-1993. Cell 4 was opened in 1991, and is used for the disposal of incinerator ash and MSW in discrete sections of the cell. All four cells are lined and have leachate collection systems (Tonjes and Black, 1994).

Despite the presence of the containment systems, contamination of the Upper Glacial Aquifer has been measured and studied (Pearsall and Wexler, 1986; EA Science and Technology, 1987; Wexler, 1988a; Wexler and Maus, 1988; Wexler, 1988b; Dellaria, et al., 1990; Dvirka & Bartilucci, 1990a; Dvirka & Bartilucci, 1990b; Black and Dellaria, 1992; Dvirka & Bartilucci, 1992; Tonjes and Black, 1993; Dvirka & Bartilucci, 1993a; Dvirka & Bartilucci, 1993b; Tonjes and Black, 1994).

Problem Definition

Traditional analytical techniques for determining the extent and scope of groundwater contamination at this site have been to create uni-variate mappings of plumes based on the results of groundwater monitoring. Constituents so mapped have included specific conductance, total dissolved solids (TDS), chloride, ammonia, iron, and volatile organic compounds (VOCs) (Pearsall and Wexler, 1986; Wexler, 1988a; Wexler and Maus, 1988; Wexler, 1988b; EA Science and Technology, 1987; Dvirka & Bartilucci, 1990a; Dvirka & Bartilucci, 1990b; Dvirka & Bartilucci, 1992), with chloride being identified as the best measure because of its presumed conservative nature in groundwater (Wexler, 1988a). Figure 1 (Dvirka & Bartilucci, 1992) is an example of such maps.

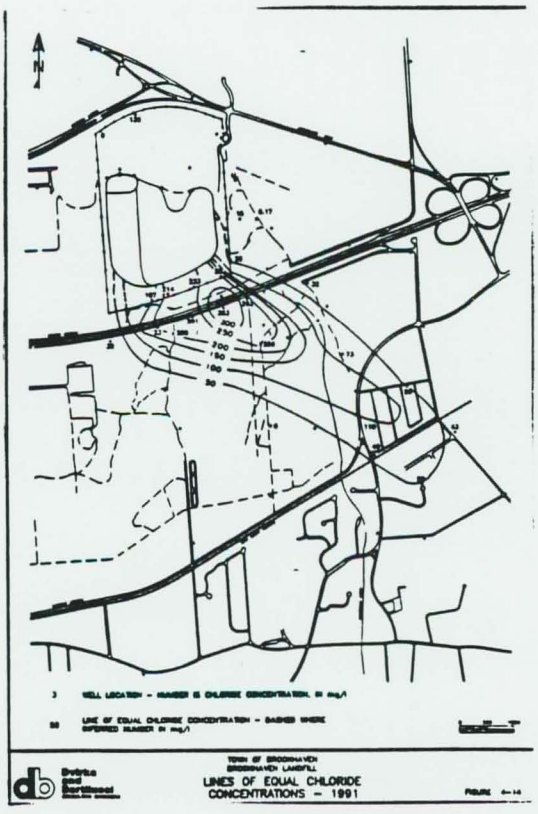

Fig. 1. Leachate plume based on chloride levels, 1991.

Two of the difficulties with such an approach are: 1) plume definitions can change radically depending on the choice of constituent; and 2) concentrations of a constituent in the downgradient "plume" may be lower than concentrations found well upgradient (consistently with chloride, TDS, and specific conductance, for example, and less regularly with VOCs), or be greater than the presumed leachate system source term (iron).

Stiff Diagrams

Stiff diagrams are two-dimensional graphs on a milli-equivalent scale, balancing selected anions and cations (Stiff, 1951). They have been used at the Brookhaven site to describe groundwater conditions (Wexler, 1988a; Dellaria, et al., 1990; Dvirka & Bartilucci, 1990a; Dvirka & Bartilucci, 1990b; Black and Dellaria, 1992; Dvirka & Bartilucci, 1992; Tonjes and Black, 1993; Dvirka & Bartilucci, 1993a; Dvirka & Bartilucci, 1993b). Although a distinct MSW-leachate signature has been discovered (Dellaria, et al., 1990), and even traced in the downgradient aquifer (Black and Dellaria, 1992), the use of traditional Stiff diagrams to describe the landfill region groundwater conditions may lead to inaccurate results. This is because the traditional presentation of these

diagrams loses definition as the degree of contamination decreases (Figure 2) (Tonjes and Black, 1993). The utility of the diagram is lost as the groundwater conditions described in the diagram shrink in size.

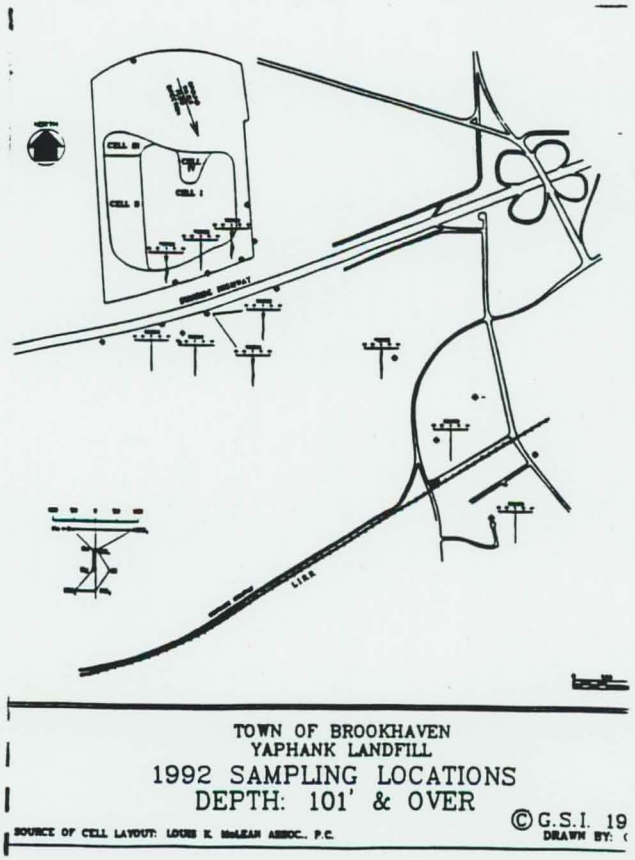

Fig. 2 Map of Stiff diagrams, demonstrating information loss due to downgradient attenuation (1992).

Sliding-scale Stiff Diagrams

A simple adaption of the traditional Stiff diagram resolves this difficulty, and immeasurably strengthens its utility as an analytical tool. The adaption is to scale each diagram on the basis of the greatest value of the constituents of the individual diagram. We call this adaption a "sliding-scale Stiff diagram."

Analysis of 1993 Sampling Results

This approach was used to analyze the 1992 and 1993 monitoring programs at the Landfill Facility (Tonjes and Black, 1993; Tonjes and Black, 1994). We will report here on the results from 1993 (Figure 3 shows the monitoring sites).

The distinct MSW-leachate source signature was replicated, and was traced as far south as Montauk Highway. South of Montauk Highway, however, there was no occurrence of the MSW-leachate

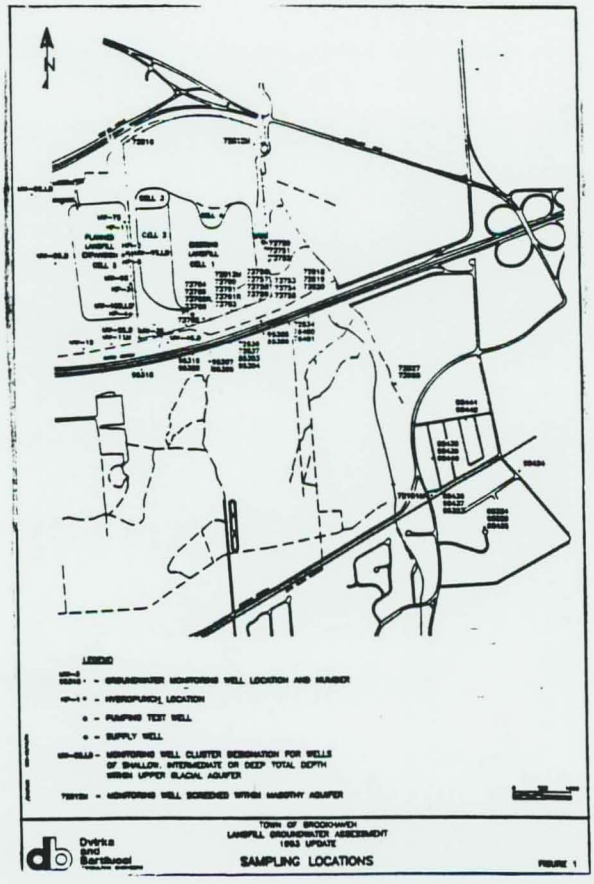

Fig. 3 1993 Monitoring locations

shape; rather, a different sliding-scale Stiff diagram predominated. It is apparent that a change in the chemical characteristics of the contaminated groundwater has occurred. Figure 4 describes the hypothesized progression of this chemical change, which appears to result from oxidation of ammonia and the replacement of calcium and magnesium on aquifer particles by sodium.

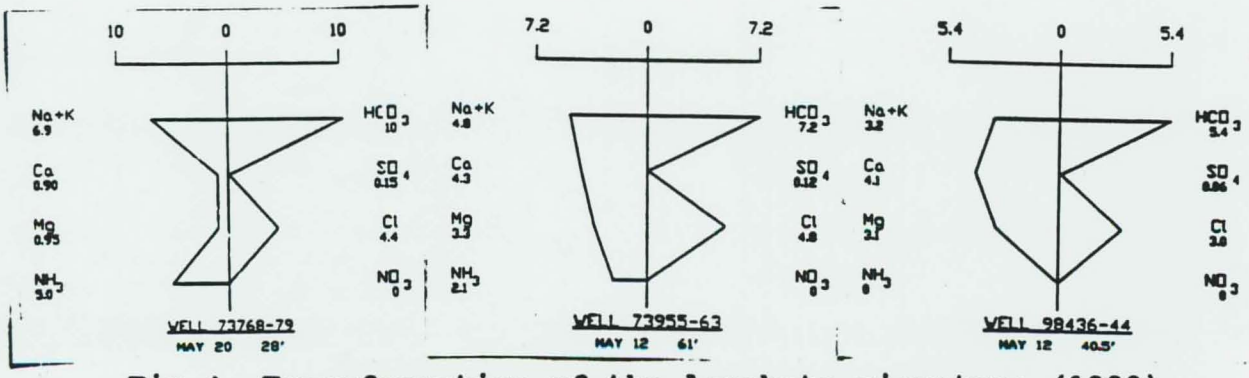

Fig 4. Transformation of the leachate signature (1993)

Sliding-scale Stiff diagrams describe another widespread "signature." This signature, found in wells upgradient of the landfill, is dominated by sodium and chloride (Figure 5). We ascribe it to road-salt contamination.

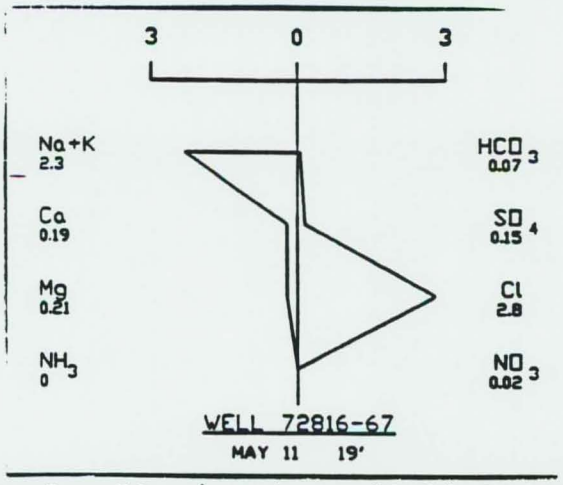

Fig. 5 Road salt signature (Well 72816) (1993)

A cluster of wells which has troubled earlier analyses has been the cluster 73750/73751/73752 (Dvirka and Bartilucci, 1990a). Sliding-scale Stiff diagram analysis (Figure 6) easily distinguishes the shallow MSW-leachate contamination from a slightly deeper road-salt contamination. The shape seen in well 73752 is also found in wells north-east and east of the landfill 80-110 feet deep in the aquifer; this seems indicative of "pristine" deep Upper Glacial Aquifer groundwater in this region.

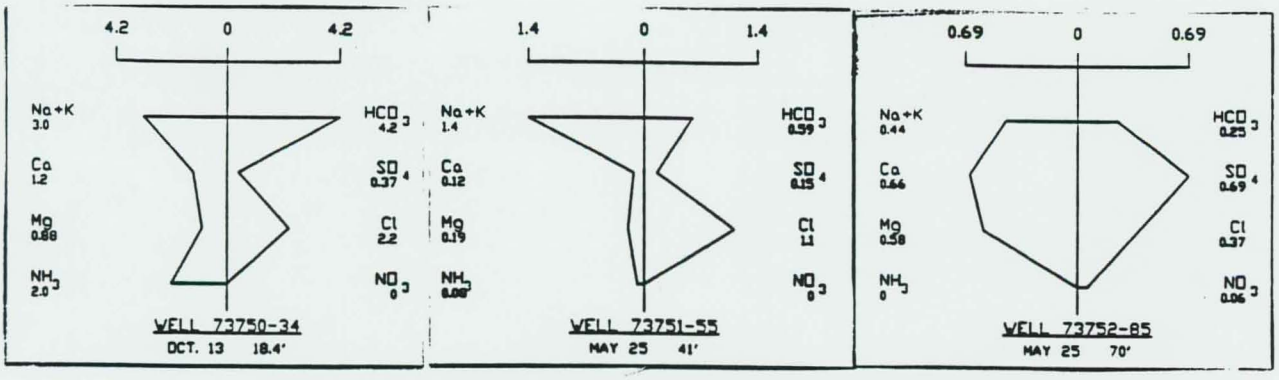

Fig 6. Cluster 73750/73751/73752 (1993)

Wells along the western edge of the Landfill have also presented analytical difficulties to traditional uni-variate explanations (Dvirka and Bartilucci, 1993a and 1993b). They have elevated levels of bicarbonate, iron, manganese, and VOCs, but no (or minor) elevation of chloride and ammonia. A representative

sliding-scale Stiff diagram (Figure 7) demonstrably shows there is no MSW-leachate contamination. We hypothesize that landfill gasses (approximately 50% carbon dioxide, 50% methane, together with a substantial presence of VOCs) have created this contamination, with the resultant pH changes releasing sediment-bound metals.

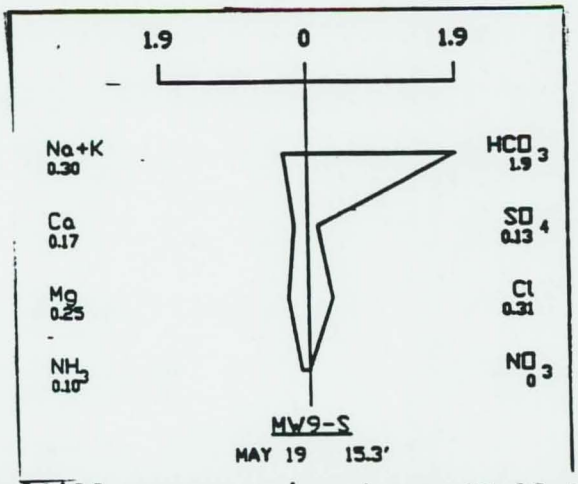

Fig. 7 Landfill gasses signature (Well MW9-S) (1993)

Thus the sliding-scale Stiff diagrams create much more sophisticated, dynamic descriptions of groundwater conditions than is possible by simplistic mappings of uni-variate results. We have been able to distinguish the MSW-leachate plume from chemically-distinct landfill-affected groundwater, delineate effects due to winter road-salting, describe unaffected deeper Upper Glacial Aquifer groundwater, and explain landfill contamination of groundwater unrelated to leachate releases.

Conclusion

Sliding-scale Stiff diagrams are a robust, yet sensitive, tool for groundwater analysis. The diagrams can depict heavily contaminated and unaffected groundwater conditions with no loss in clarity or cogency. An analysis built upon sliding-scale Stiff diagrams does not require the assumption of a singular contamination source. If signature diagrams can be discovered, sliding-scale Stiff diagrams could be utilized to trace groundwater movement, whether contaminated or not. This suggests a broader range of applications beyond contamination in the vicinity of landfills.

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