

APPLICATION OF ADVANCED SURFACE AND BOREHOLE GEOPHYSICAL METHODS TO ENVIRONMENTAL AND ENGINEERING PROBLEMS ON LONG ISLAND AND MANHATTAN, NEW YORK

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Abstract

Advanced surface and borehole-geophysical methods were used in studies relating to environmental and geotechnical engineering problems on Long Island and Manhattan. Surface geophysical techniques, such as continuous marine seismic-reflection, research-grade fathometer, and two dimensional (2D) land-resistivity surveys, have been used to map hydrogeologic units offshore, bridge scour, and roadsalt plumes. Advanced borehole geophysical methods such as gamma, single-point resistance, resistivity, fluid temperature and resistivity, electromagnetic induction (EM), caliper, magnetic susceptibility, P- and S- wave velocity, flowmeter, acoustic televiewer, optical televiewer, borehole video, spectral gamma, borehole radar, and crosshole seismic tomography have been used to characterize fractured-rock ground-water flow, delineate bedrock foliation and fracture orientation, map unconsolidated hydrogeologic units, and delineate saltwater intrusion.

Introduction

Surface and borehole geophysical techniques can provide information on the physical and chemical properties of bedrock, unconsolidated sediments, and groundwater. Surface and borehole geophysical techniques have been applied to several studies in New York (Manhattan), Kings, Queens, Nassau, and Suffolk Counties on Long Island, New York (figure 1). Fractured-rock studies utilizing continuous marine seismic-reflection and advanced borehole geophysical methods have been completed in Manhattan.

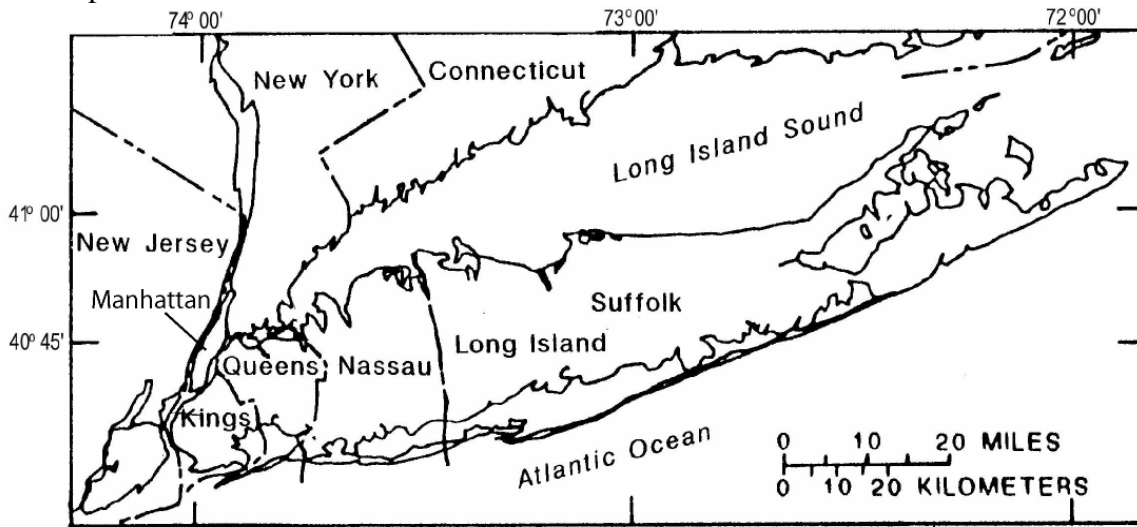


Figure 1.: Location of Manhattan and Long Island, New York (Nassau and Suffolk Counties).

Borehole geophysical logging (gamma and EM) and marine seismic-reflection surveys have been used in both Nassau and Suffolk Counties on Long Island where unconsolidated hydrogeologic framework mapping and delineation of saltwater intrusion issues are paramount.

Surface Geophysical Methods

Continuous marine seismic-reflection surveys transmit acoustic (300 Hz-1.5 kHz) signals generated by a sound source which travel through the water column and penetrate the sea floor sediments. When a contrast in the acoustic impedance is encountered by the seismic signal, part of the signal is reflected back toward the surface, and part is transmitted to the deeper material (Haeni, 1986). Continuous marine low-frequency seismic-reflection surveys have been used in the East River to map discontinuities and the surface elevation of bedrock, and in the coastal areas of Long Island to map the hydrogeologic framework in Nassau and Suffolk Counties (Stumm, 2001). Several clay-filled buried valleys that extend hundreds of feet below sea level have been delineated cross-cutting the regional hydrogeologic framework (figure 2).

2D-resistivity surveys were completed in eastern Suffolk County at a public-supply pumping center (figure 3). A recharge basin adjacent to the public-supply wells was suspected of being a source for elevated chloride concentrations in the local ground water. High amperage current was injected into the earth and the resulting potentials were measured using a computerized data acquisition system. The resulting data were processed using a computer program which produced a 100 ft. deep resistivity cross-section that mapped the depth to water and the location of the plume of conductive roadsalt.

Borehole Geophysical Techniques

Gamma and electric logging have been used for stratigraphic correlation of all the major hydrogeologic units on Long Island. EM logging was pioneered by the USGS on Long Island as a tool to delineate and monitor changes in the extent of saltwater intrusion in New York, Kings, Queens, Nassau, and Suffolk Counties in New York (figure 4). The logging methods have been described by Keys, 1990; Serra, 1984; Stumm, 1993; and Stumm and others, 2001, and 2003.

The U.S. Geological Survey (USGS), in cooperation with the New York City Department of Environmental Protection (NYCDEP), began a project to apply advanced borehole-geophysics to assess the geohydrology of the crystalline bedrock in southeastern New York. These techniques are applied to test boreholes along proposed tunnel- excavation routes to provide data on the bedrock lithology and major contacts, the location and orientation (true strike and dip) of fractures and foliation, and the hydraulic characteristics of fractures that transmit ground water (figure 5).

Borehole geophysical data collected from six boreholes in southwestern Manhattan, New York indicate the depth to bedrock ranges from 8 to 108 ft below land surface. Fracture indexes range from 0.25 to 0.44 fractures per foot of bedrock. Overall, the foliation of the bedrock generally ranges from a southwest to northwest dip azimuth with a 60° dip plunge angle. Water levels in the fractured bedrock ranged from 29.1 ft elevation in the northern part of the study area (W55th Street and 10th Avenue) to 0 ft elevation in the southern part (Hudson and Houston Streets). Ground water appears to flow within an interconnected fracture network toward the south and west. Each of the six

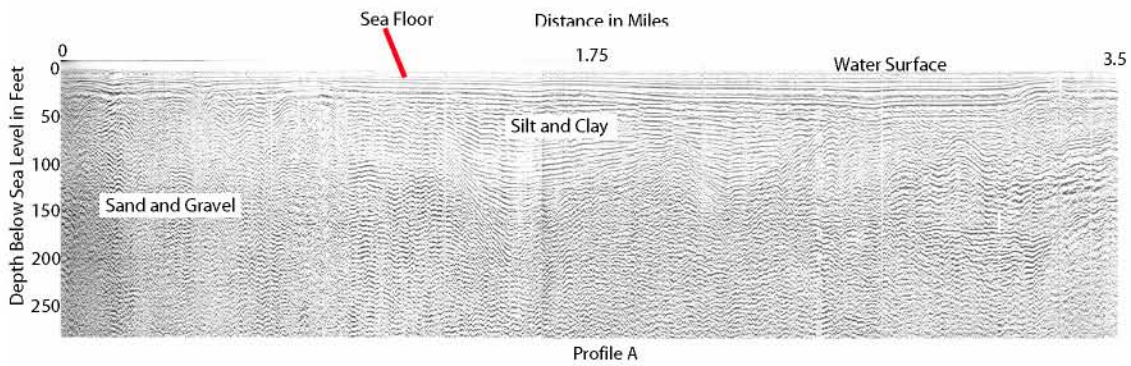
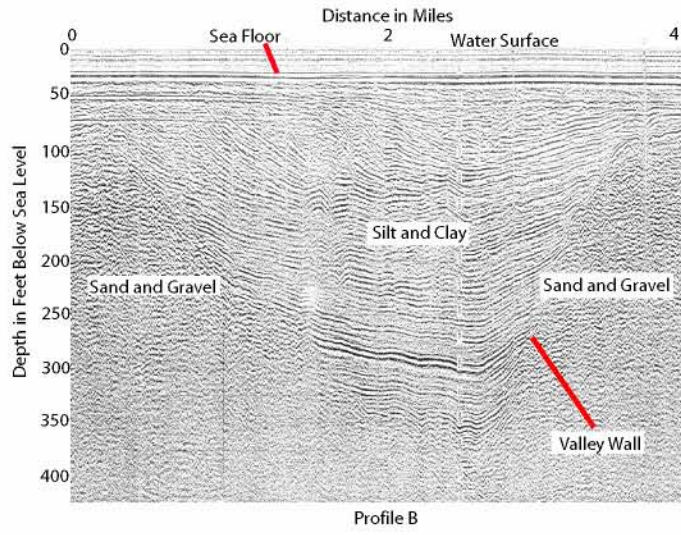
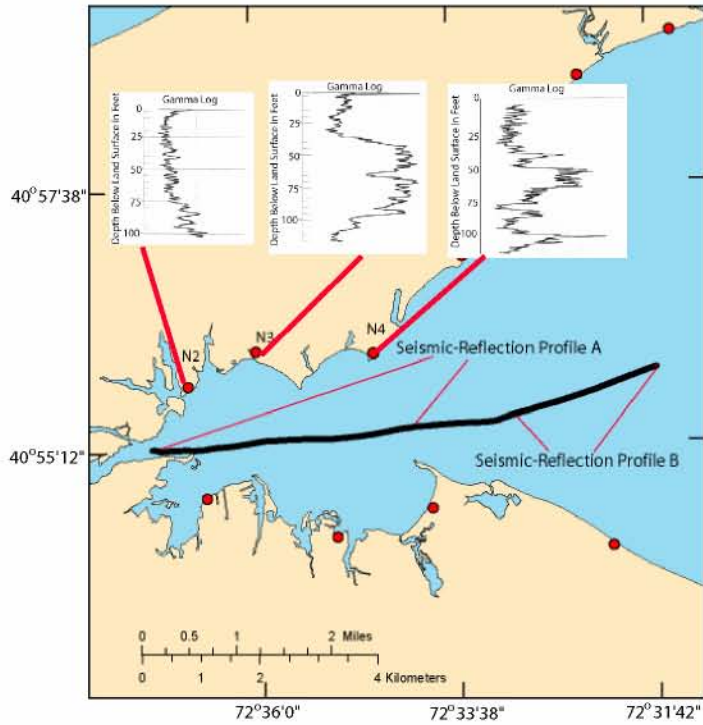


Figure 2.: Continuous marine seismic-reflection profiles of buried valleys correlated with gamma logs in eastern Suffolk County, New York.

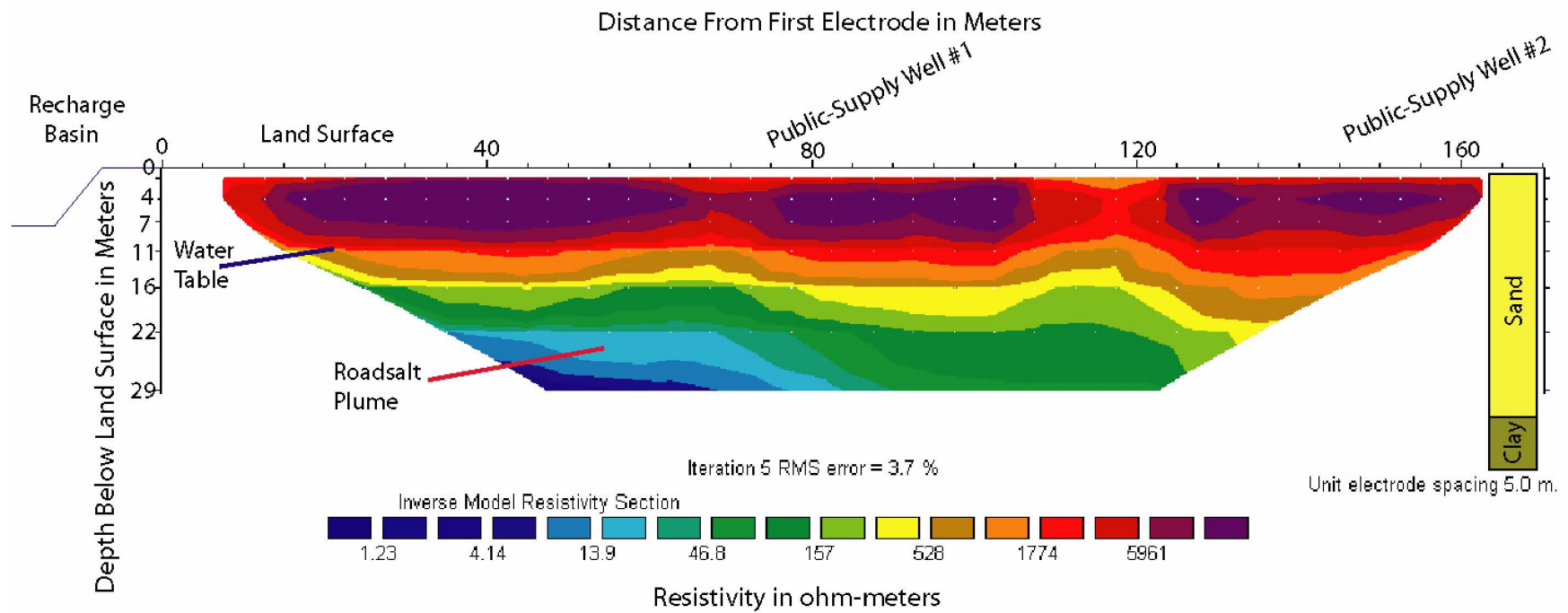


Figure 3.:2D resistivity profile of a roadsalt plume in eastern Suffolk County, New York.

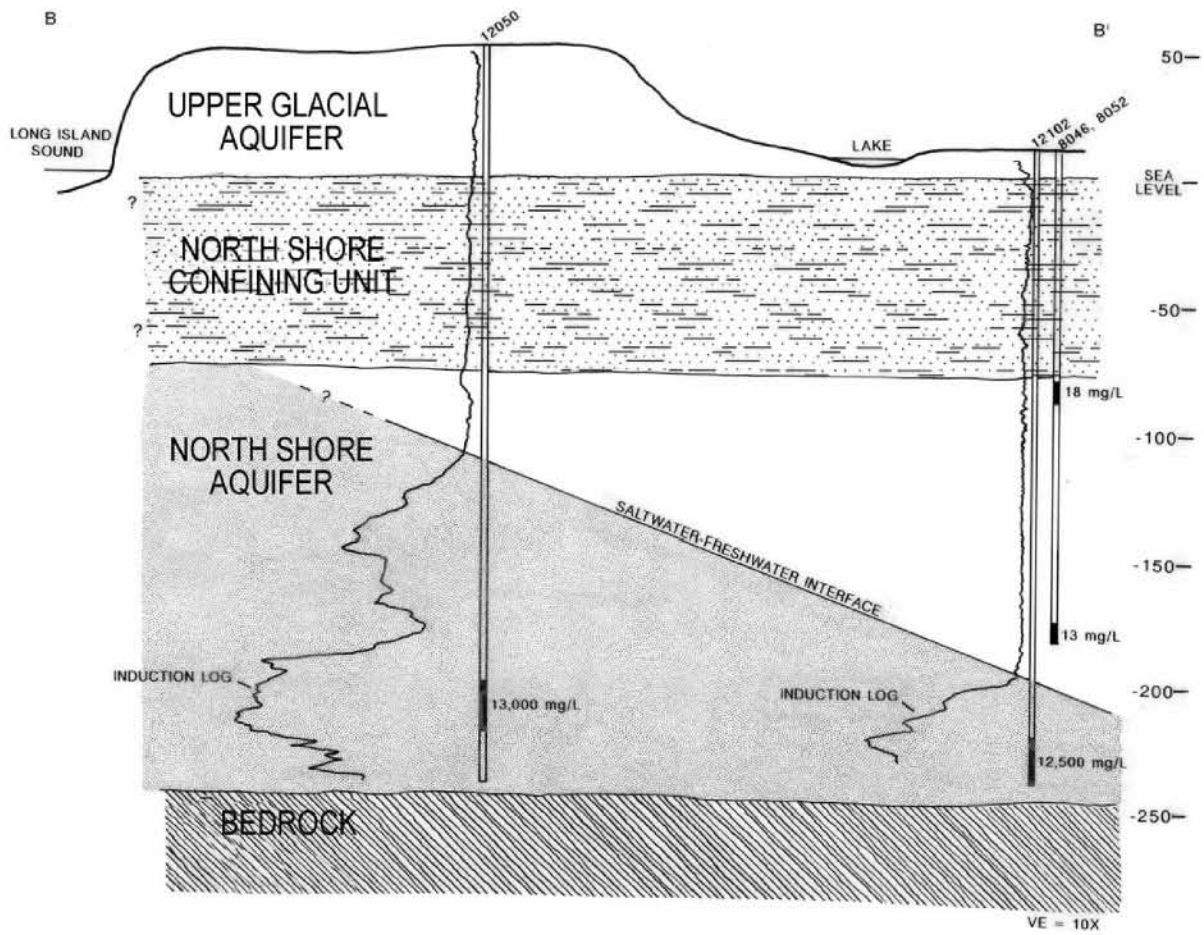


Figure 4.: Wedge of intruded saltwater delineated by electromagnetic induction logs in western Nassau County, New York (modified from Stumm, 2001).

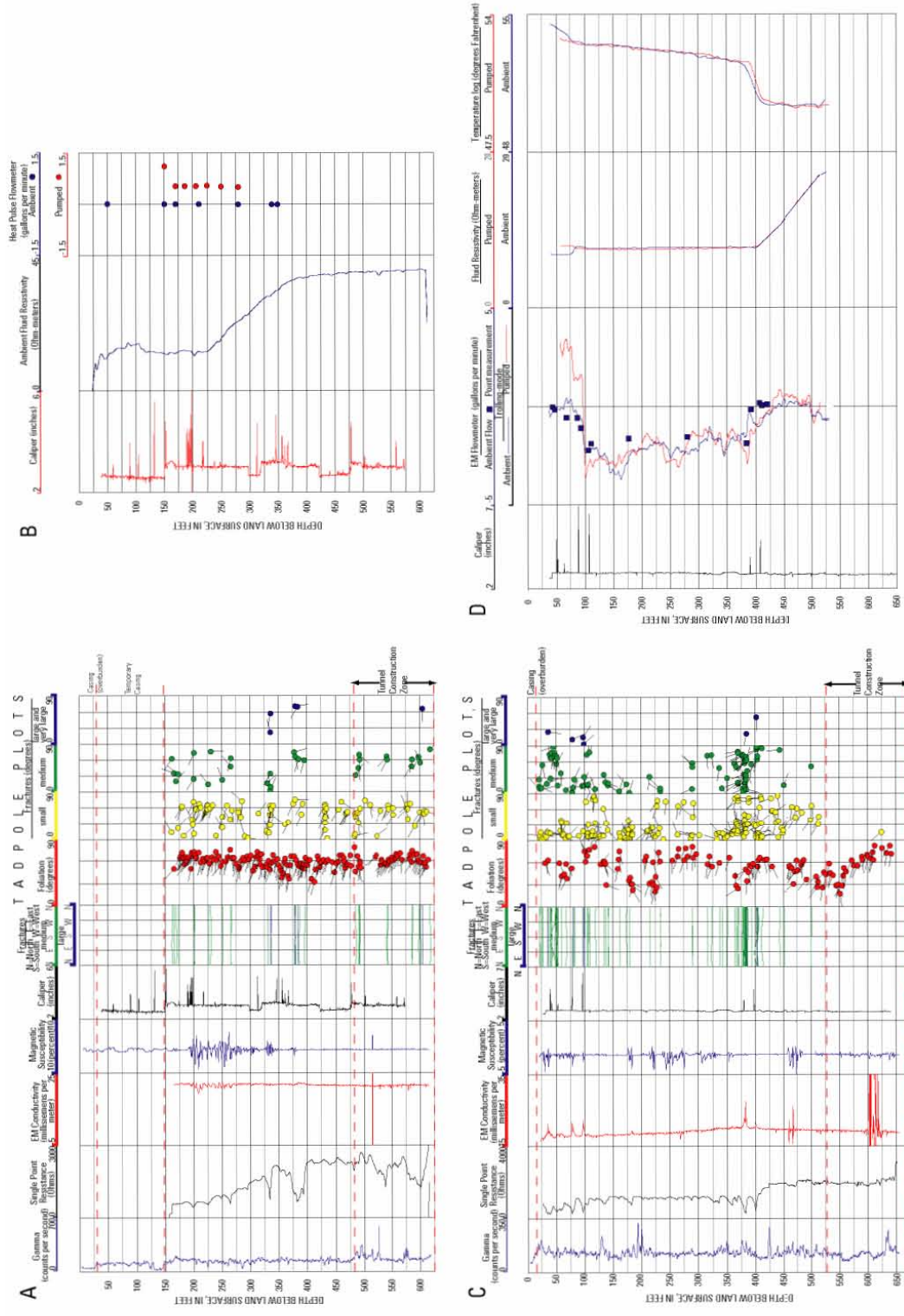


Figure 5.: Suite of geophysical logs from boreholes in southwestern Manhattan, N. Y.

boreholes tested had several transmissive fracture zones, some with moderate transmissivity. Borehole transmissivities ranged from less than 1 to 360 feet squared per day (ft²/d). No correlation is indicated between borehole fracture index and total transmissivity (Stumm and others, 2003). Recent experiments in bedrock test boreholes in Queens County using crosshole seismic tomography indicate that fracture discontinuities can be detected between boreholes over 300 feet apart.

Conclusions

Surface and borehole geophysical techniques provided information on the physical and chemical properties of bedrock, unconsolidated sediments, and groundwater. Continuous marine seismic-reflection surveys were used in the East River to map bedrock surface discontinuities, and in coastal areas of Long Island to map the hydrogeologic framework. Several clay filled buried valleys extending hundreds of feet below sea level were delineated on Long Island. 2D resistivity surveys were used in eastern Suffolk County to delineate the unsaturated zone, depth to the water-table, and determine the extent of a roadsalt plume.

Borehole geophysical techniques such as gamma and EM have been used to map the hydrogeologic units and extent of saltwater intrusion on Long Island. Fractured-rock applications in Manhattan included the use of advanced methods. Borehole logging of six boreholes in southwestern Manhattan indicate fracture indexes range from 0.25 to 0.44 fractures per foot of bedrock, a southwest to northwest dip azimuth with a 60° dip, and borehole transmissivities of 1 to 360 ft²/d.

References

- Haeni, F.P., 1986, Application of continuous seismic-reflection methods to hydrologic studies: *Groundwater*, v. 24, no. 1, p. 23-31.
- Keys, W.S., 1990, Borehole geophysics applied to water-resources investigations: U.S. Geological Survey Techniques of Water Resources Investigations, book 2, chap. E2, 150 p.
- Paillet, F. L., 2000, A field technique for estimating aquifer parameters using flow log data: *Ground Water*, v. 38, no. 4, p. 510-521.
- Serra, Oberto, 1984, *Fundamentals of well-log interpretation*: New York, Elsevier, 423 p.
- Stumm, F., 1993, Use of focused electromagnetic induction borehole geophysics to delineate the saltwater-freshwater interface in Great Neck, Long Island, New York, in Bell, R.S., and Lepper, C.M. (eds.), *Proceedings of the symposium on the application of geophysics to engineering and environmental problems*, v. 2, April 18-22, 1993, San Diego, CA., p. 513-525.
- Stumm, F., 2001, Hydrogeology and extent of saltwater intrusion of the Great Neck Peninsula, Great Neck, New York: U.S. Geological Survey Water-Resources Investigations Report 99-4280, p. 41.
- Stumm, F., Chu, Anthony, Lange, A.D., Paillet, F., Williams, J.H., and Lane, J.W., 2001, Use of advanced borehole geophysical techniques to delineate fractured-rock ground-water flow and fractures along water-tunnel facilities in northern Queens County, New York: U.S. Geological Survey Water Resources Investigations Report 00-4276, 12p.
- Stumm, F., Chu, Anthony, Lange, A.D., 2003, Delineation of ground-water flow in fractured rock in the southwestern part of Manhattan, New York, through use of advanced borehole geophysical methods, *Proceedings of the symposium on the application of geophysics to engineering and environmental problems*, April 6-10, 2003, San Antonio, TX., p. 758-771.