Subsurface Object Delineation at the SCWA Dune Road Wellfield, Westhampton, Using GPR.

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Abstract

A subsurface foundation was encountered at a shallow depth during the drilling of a new public supply well in Westhampton Dunes, Westhampton. In order to delineate the extent of this object, a tight, high-frequency grid using ground-penetrating radar (GPR) was surveyed. After collection of data near the surface extent of the foundation, the lateral limits of the foundation were mapped. Additionally, in an adjacent area believed to be clear of subsurface hazards, a smaller grid showed the area to be relatively free of hazards, allowing the successful installation of a well.

Introduction

The barrier beach community known as the Village of Westhampton Dunes is mostly comprised of seasonal residences ranging from small cottages to multi-million dollar homes all situated along a five-mile portion of Dune Road (Fig. 1). The vicinity is currently serviced by only one well located at the Dune Road (South) well field. The area is frequently hampered by extremely low water pressure, which adversely affects available fire protection. Dune Road well no. 1 provides water for the entire barrier beach. A second well was proposed to be constructed that would greatly increase water reliability in the immediate area and improve pressure in the mains, which in the past has reached critically low levels. The need for an additional water source in this area is crucial and of the available solutions, the construction of a new well is much more cost effective when compared to other alternatives.

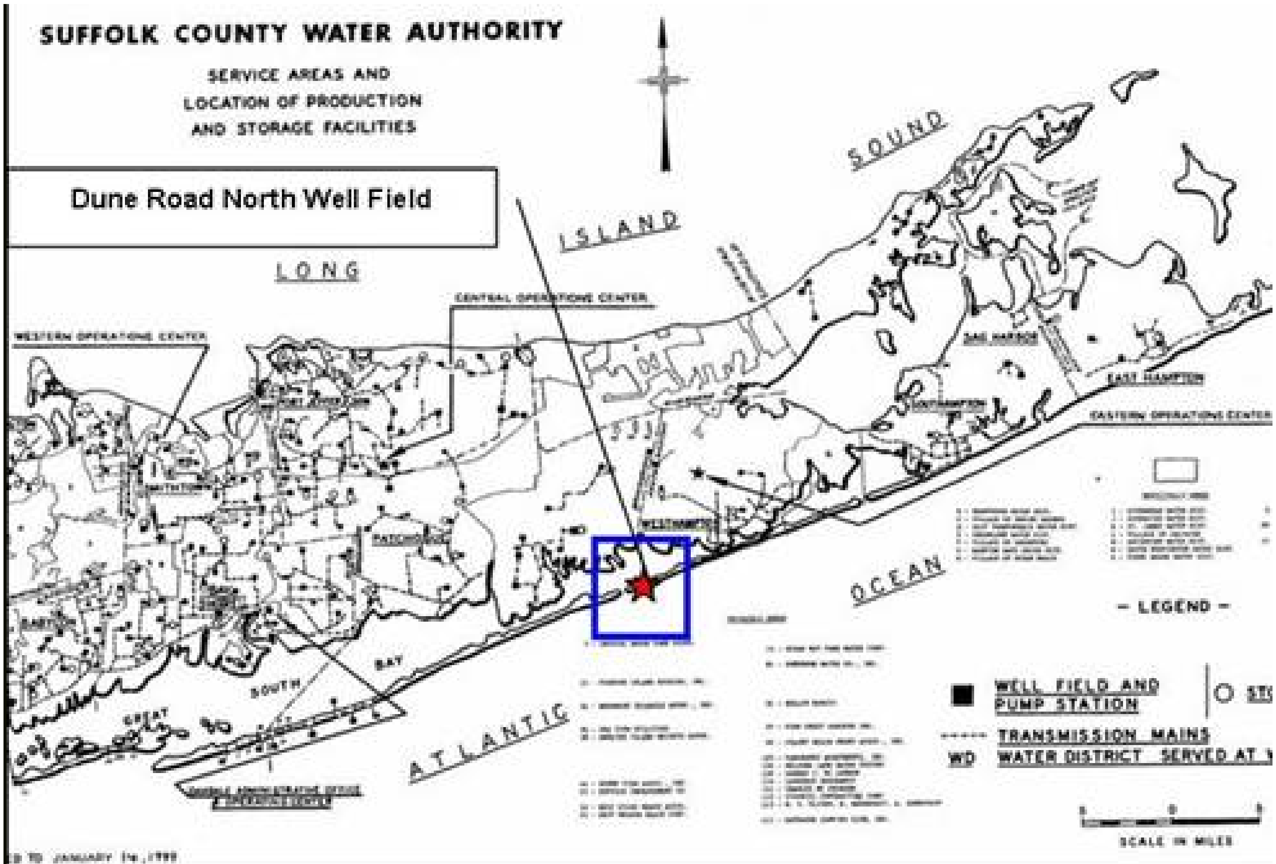

Figure 1: SCWA Service Areas and Location of Dune Road Wellfield

Study Site

A. Regional Hydrogeology

The Dune Road North well field is located on the barrier beach, in what is known as the Village of Westhampton Dunes. Ground surface elevation at the well site is approximately +9' (2.74 m) msl. The water table elevation is approximately +5' (1.52 m) msl. Typical of deep wells on barrier beaches, the Magothy potentiometric surface is above grade, at an elevation of approximately +11’ (3.35 m) msl. According to geophysical and lithologic logs of the subsurface taken during construction of the Dune Road North test boring in 2004, the Upper Glacial aquifer extends from the land surface to a depth of approximately 95 feet (28.96 m) below grade. The Monmouth Greensand unit is present beneath the upper Glacial aquifer and continues to a depth of approximately 230 feet (70.12 m) below grade. The remainder of the subsurface geology is characteristic of the Magothy aquifer consisting of fine to coarse sand strata, various clay and silty layers, and gravel to a depth of approximately 715' (218 m) below grade, at which point the test boring was terminated. For the purposes of this study, which is concerned with only the first 5-10’ (2 m) of subsurface, the sequence was represented as a medium gray sand.

B. Site Characteristics

The Suffolk County Water Authority (SCWA) proposed to construct a new production well (no. 2) at its Dune Road North well field, located on the north side of Dune Road, approximately

110.38' (33.65 m) east of Dune Lane, Village of Westhampton Dunes. The new well was designed be constructed to a depth of approximately 430 feet (131.1 m) below land surface with 375 feet of casing, 40 feet of 14" well screen and a capacity of 700 gpm. The well will be part of the Moriches-Westhampton Low water supply system which serves the area south of Sunrise Highway extending from Mastic to East Quogue. Of the 32 wells that currently make up the system, 18 wells have been in service for more than 20 years (of which 13 wells have been in service for over 25 years). The SCWA realized that the complications associated with an aging infrastructure may eventually comprise service to the Moriches-Westhampton Low water supply system, specifically water pressure in the mains. Construction of well no. 2 is part of the effort to revitalize and stabilize the water supply system in an area currently experiencing rapid growth and development.

During the initial well construction phase that took place in September 2004, an anomaly was encountered at approximately 3 feet (1 m) below grade. The remnant of a concrete foundation was discovered around the wellfield construction site. Because of the high costs of excavating the entire site, the extent of the foundation was not initially determined. A steel pick was first used to estimate the perimeter of the underground foundation. The endpoints were flagged and eventually plotted onto Arcview GIS, in order the get a spatial representation of the foundation, GPR was considered to be an ideal option to further delineate the foundation, because of the low costs and accuracy in determining anomalies at shallow depths.

Basics of GPR

Ground-penetrating radar is a geophysical investigation tool which involves the subsurface emission of electromagnetic radiation in the radio spectrum. The system generally consists of a pair of antennae which operate on a central frequency (Fig. 2), in this case moved in tandem in a cart along the area to be surveyed. The transmitting antenna puts forth a short pulse of radiation, which travels outward in a hemispheric path into the ground. A portion of this radiation is reflected off of subsurface areas (whether individual objects, layers, or general regions) of differing electromagnetic characteristics, and can return upward to the receiving antenna. Computer software is able to record this information and display it as a 2-dimensional figure called a radargram (Fig. 3): depth is calculated as half the time it takes for the wave to travel to the reflective area and back to the surface (provided the subsurface velocity can be constrained: the present study was found to have a velocity of 15-16 cm/ns [5 ft/ns], typical for dune sand) while the horizontal distance covered in the course of the survey is recorded by moving the antennae a prescribed distance between measurements or, in the present study, via odometer (*Knight*, 2001; Fig. 2).

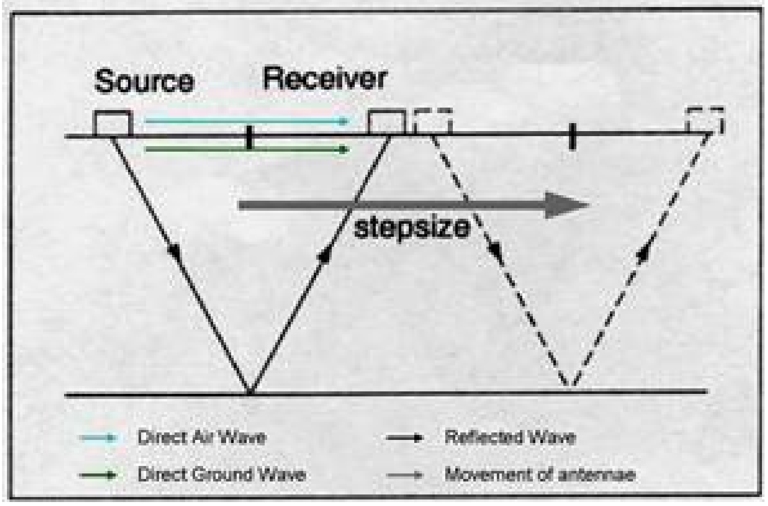

Fig. 2: GPR Basics: A short electro-magnetic wavelet is emitted by the transmitter. Portions of this wavelet travel directly through the air and along the surface (air and ground waves). The subsurface portion may be reflected and recorded by the receiving antenna, and the resulting signal is displayed graphically on a computer. After Hubbard et al., *2002.*

Survey Methodology

A series of short radar surveys were conducted on October 13, 2004. Two preliminary GPR lines were gathered in the vicinity of the foundations, the first towards the east, the second diagonally towards the SE, using 500 MHz (fairly high frequency and resolution; shallow penetration) antennae to discern whether the foundations were visible on GPR. In addition, a south-running line was gathered in an area immediately to the west, where no remnants of the foundation were visible above ground. The results of these tests were good, leading to a second pair of test lines which repeated the first two with 800 MHz antennae (higher frequency and better resolution, but less penetration). However, these lines appeared noisy and difficult to interpret; thus it was decided to carry out the main survey in the vicinity of the foundation using only the 500 MHz antennae.

The main grid around the area of the foundation was constructed to make the maximum amount of use out of the limited area of the potential well field site. It consisted of a 10 m by 15 m (32.8' x 49.2') rectangular grid oriented parallel to Dune Road. A total of 20 east-trending lines were run, evenly spaced every half meter (the final line was deemed too close to a surface hazard to run) (Fig. 4B). Samples were taken automatically every 5 cm (2"), as registered by the odometer attached to the cart. To avoid aliasing (incorrectly interpreting the signal frequency due to inadequate sampling), the sampling rate was set to 6408 MHz, and the signal was repeated (stacked) 16 times at each location to improve the strength of the signal with respect to random noise.

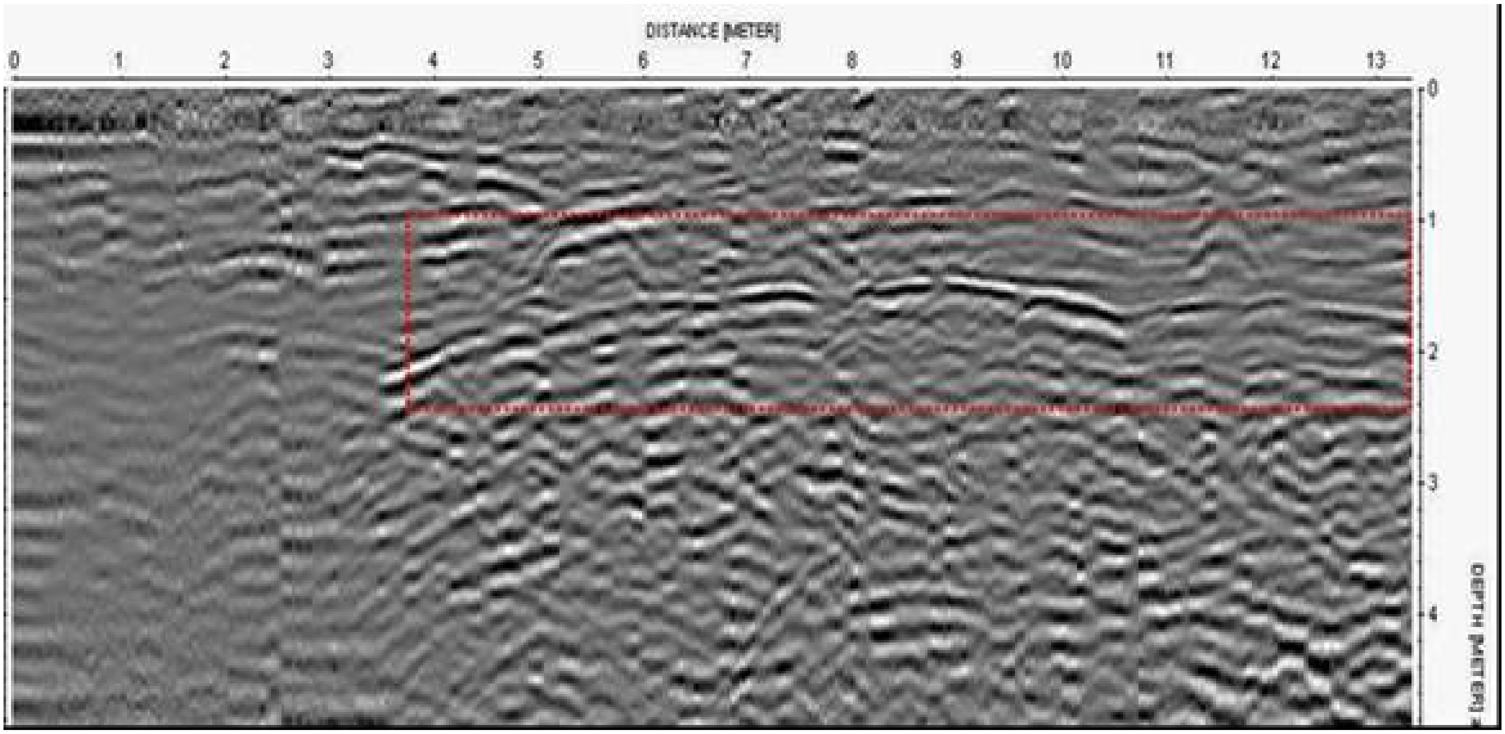

Fig. 3: 500 MHz radargram of the foundation at the Dune Road well field with vertical exaggeration removed. The foundation measures about 7 m (23') long and is about 2 m (6.5') deep in this radargram. The vertical scale is radar wave travel time (which has been converted to depth), and the horizontal is west-east (left-right) distance.

Following the completion of the first grid, it was decided to explore the adjacent area to the west, which appeared free of surface obstacles other than the clean fill which had been laid down for the drill rigs. This portion of the site could potentially be employed as an alternative location for the wells. Due to the importance of locating subsurface hazards in this area, the higher-resolution 800 MHz system was utilized. A 3 m by 10 m grid (9.84' x 32.8') of north-trending lines was established, once again using half-meter spacing between each of seven lines (Fig. 4B). The first line was run along the western edge of the previous grid, and the survey continued westward. The sampling rate was set to 10282 MHz, samples were collected every 4.1 cm (1.6"), and samples were stacked 32 times to further limit the amount of noise influencing the sensitive antennae. Finally, a single 18 m (59')-long 800 MHz line was run along the western edge of the well field property for purely exploratory purposes using the same settings as the 800 MHz grid.

Subsequently the GPR data were processed at Stony Brook University using RAMAC GroundVision and Sandmeier Software's REFLEX processing software. Steps were taken to remove consistent background and system noise, limit the frequencies recorded by the receiver to those similar to the transmitter frequency, and restore the loss of energy due to natural attenuation of signal with depth (gaining).

Results

The 500 MHz survey in the area near the concrete blocks clearly delineated a subsurface object within two meters of the surface (Fig. 3, 4A). The foundation was easily visible even without the application of a gain, and the approximate location of the boundaries of this object matched well with the estimated boundaries discovered during the initial drilling process, as demarcated by flags. It appeared to extend from about the 4.5 m line (northern boundary) to the 9 m line, and from about 8.5 m (western boundary) to the end of each line (Fig. 3, 4A). A three-dimensional cube was constructed by plotting several radargrams in a grid-like format, from which the extent of the foundation could be recognized. This illustrates the powerful mapping capabilities of GPR when used in concert with other geological techniques.

The 800 MHz survey had slight difficulties penetrating through the clean fill which covered the majority of the area, but was still able to locate buried objects outside of the study area which are thought to represent pipes beneath Dune Road and other features not of interest to the current project. However, no significant objects within the system's resolution (about 5 cm [2"]) were observed, allowing the drilling to be undertaken in this alternate area (Fig. 4A).

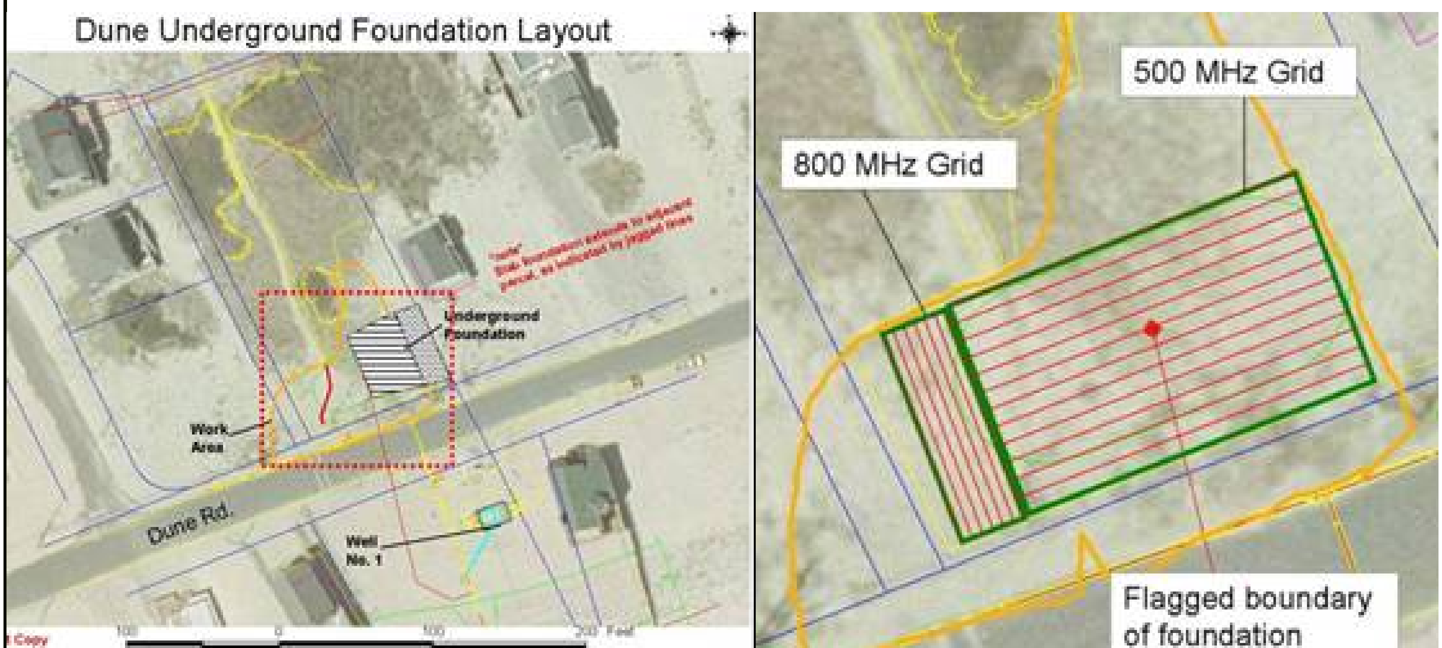

Fig. 4: Results and details of GPR survey near Westhampton. A (left): Aerial photo of survey area, near the intersection of Dune Road and Dune Lane, Westhampton Dunes. The SCWA property line (study area) is the orange boundary line. Superimposed is the outline of the foundation (as imaged by GPR) which continues into the adjacent parcel (as marked by jagged lines to the right). Figure links to larger version. B (right): Close-up of highlighted area in A showing area of GPR grids, including orientation of lines (red). Also shown is the location of a flagged section of the foundation for ground-truthing.

Conclusion

The use of GPR, in conjunction with field observations, provided a quick, inexpensive, and fairly accurate means of delineating a subsurface hazard to hydrologic well drilling. It also revealed the lack of such hazards beneath an alternate adjacent site, allowing drilling to continue. Such surveys can also be undertaken as an exploratory tool prior to the initiation of drilling at prospective sites, possibly saving thousands of dollars and significant amounts of lost man-hours and delay time in creating vital access to groundwater resources.

Acknowledgments

KTG would like to thank DMD for technical assistance in planning the survey and a review of the manuscript.

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