Geothermal Systems on Long Island

A Final Report Presented

By

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Master of Science in Geosciences with concentration in Hydrogeology

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2009

This paper examines geothermal systems and their potential effect on groundwater. Low temperature geothermal systems and their interaction with groundwater aquifers is an area that has been little researched and raises many complex questions and issues for both individuals and regulators. On Long Island, these issues are particularly critical, as its aquifers constitute a "sole source" of potable water. In addition, there has been much effort to preserve coastal ecosystems, where groundwater discharges. These questions are considered through a literature search combined with reports on personal experience with geothermal systems on Long Island. This review provides insight into how little is known about the effects of these systems, how important additional research is, and the need for review and regulation of geothermal installations.
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Introduction

With the rising cost of fuel, coupled with heightened awareness of America's dependency on foreign-fuel supply and the current economic crisis, individuals as well as companies are looking for alternative sources of energy. In places such as the Northeast, where Americans rely heavily on fuel oil to heat their homes during the winter months, alternative energy solutions such as solar power and geothermal heat transfer are coming under consideration and gaining in popularity.

High-temperature geothermal heat utilizes heat from the interior of the earth to produce energy. This type of geothermal heat can be found in the western United States, and countries which border on the Pacific Ocean near volcanically active areas. Low-temperature geothermal heat utilizes the heat that is absorbed from the sun by the upper most layers of the earth. This moderate heat can be reclaimed by a heat pump is and is available almost everywhere (Pahl, 2007).

This report will primarily focus on geothermal systems on Long Island and its unique circumstances. The principal concept behind low-temperature geothermal systems is that the earth can be utilized as both a source and sink for heating and cooling. On Long Island, the temperature of the groundwater remains consistently at the average annual (air) temperature of approximately between 50 and 55°F. Water at this temperature can be utilized as the initial temperature for heating and cooling a commercial or residential structure, reducing the energy needed for heat in the winter or for cooling in the summer.
In operation, a geothermal system will heat the groundwater around the installation in the winter and cool it in the summer. To be efficient, any excess, or deficit, of heat in the aquifer in the vicinity of the system must be removed so that the initial temperature remains at the average annual temperature. This occurs either by dispersion of heat around the wells or by the advection of groundwater past the system. The latter process can be aided by density-driven advection caused by the change in groundwater temperature itself.

The change in groundwater temperature caused by a geothermal system may have three types of impacts: groundwater density changes will alter the flow patterns; changes in the groundwater temperature can alter the solubility of contaminants; and, via seepage, may alter the temperature in open, receiving waters like ponds and streams.

**Basic description of geothermal systems**

Small scale geothermal systems are those for individual homeowners or commercial applications, not for entire communities. These operate as either open-loop systems or closed-loop systems.

Open-loop systems require the installation of both a supply well and an injection well. Groundwater is extracted directly from the aquifer through the supply well, and is passed through the heat pump. The heat pump is often a copper, or cupro-nickel, heat-exchanger in conjunction with heating or cooling elements and a blower system to distribute heated (or cooled) air through the building. Circulated groundwater is then returned to the aquifer via the injection well. The water returned to the aquifer will be of a different temperature than the
water withdrawn from the aquifer. During the heating cycle, the water returned to the aquifer will be cooler than what was withdrawn from the aquifer. During the cooling cycle, the water returning to the aquifer will be warmer than what was withdrawn from the aquifer. The amount of water required to pass through the heat pump is determined by the heating and cooling load of the building.

Closed-loop systems include the installation of high density polyethylene (HDPE) pipe through which water is circulated. The water may be mixed with an environmentally friendly antifreeze solution, such as food grade propylene glycol. This system can either be installed vertically (Figure 1) or horizontally (Figure 2) in configuration and the amount of piping which is required is determined by the heating and cooling load of the building. The water or water-and-antifreeze mixture in the HDPE piping is then circulated through a heat exchanger in the same way as in the open-loop application. However, there is no exchange of water with the aquifer in closed-loop systems; water is not withdrawn or added to the aquifer. Rather, the temperature of the groundwater around the system is utilized to heat or cool the fluid as it circulates through the HDPE pipe.

In the case of closed-loop systems, transfer of heat through the earth, or thermal conductivity, is dependent upon subsurface conditions, including soil type and soil saturation. Saturated, sandy soils are best, as indicated in Table 2 (STS Consultants, 1989).

Geothermal heat pumps and heat exchangers operate on the concept of heat transfer. In the heating mode, thermal energy from the earth is carried to the heat pump. Fluids pass through the heat exchanger where heat is
transferred from the fluid to the refrigerant solution in the unit. The refrigerant solution is passed through a compressor where the solution is compressed causing a rise in temperature and pressure and vaporize. The vapor is passed through a condenser where the pressure drops and the released heat is blown through the ductwork of the home/structure. This cycle is reversed when utilized for the cooling or air conditioning mode.

Geothermal heat pumps can last for 20 years or more, with geothermal HDPE piping warrantied for approximately 50 years (US Department of Energy, 2009).

Figure 1: Basic vertical closed-loop system configuration (Pahl, 2007).
Many factors are taken into consideration prior to the design of the loop field. These include the geology, local codes/regulations, and the available space in which the loop field is to be installed.

Open-loop and closed-loop geothermal systems both have pros and cons. Open-loop systems, require less space, and while less expensive to install will likely require maintenance of the pump and well screens. Therefore, well locations will need to be known and accessible at a later date. Closed-loop systems, require more space, and while more expensive to install have very little to no maintenance costs. Following the installation of a closed-loop system, no evidence of the system is visible on the property. However, the location of pipe runs should be known in the event of any future landscape work.

Geothermal systems are also good for the environment. When compared to conventional heating or cooling systems, geothermal systems utilize 25% to 50% less electricity. This reduction in energy consumption translates into an emission reduction of between 44% and 72% (US Department of Energy, 2009).
Relevant conditions on Long Island

Long Island is surrounded by the Long Island Sound to the north and the Atlantic Ocean to the east and south. Drinking water is obtained from a sole source aquifer, with some areas experiencing salt water intrusion from excessive water withdrawals from the aquifer. This has created debates about various geothermal systems and their impact to the aquifer and environment. Open-loop systems have come under primary scrutiny in various communities on Long Island and, in some circumstances, they have been banned. Impacts of concern to Long Island’s aquifers include the increased potential for salt water intrusion in open-loop systems, changes in chemistry to the groundwater when returned to the aquifer via the injection well, changes in groundwater flow patterns, changes in the temperature of receiving waters such as streams or ponds, and possible contamination of the aquifer due to the disruption of confining units, the direct introduction of contaminants in open-loop systems, or leakage in closed-loop systems.

The primary water-bearing units of Long Island’s aquifer system are comprised of unconsolidated sand, gravel, and clay deposits. They dip downward toward the south shore of Long Island. The aquifers are comprised of the Upper Glacial, Magothy, and Lloyd aquifers. The Lloyd Aquifer is confined by the Raritan Clay and is the oldest of the aquifers. The Upper Glacial and Magothy aquifers are younger, and are generally under water-table conditions. Some portions of the Magothy aquifer are confined by the Gardiners Clay,
typically in the south (Nemickas, 1989). A typical cross-section of Long Island’s aquifer system can be found in **Figure 3**.

![Figure 3: Long Island aquifer cross-section depicting major hydrogeologic units (New York State Department of Environmental Conservation, 2009).](image)

The Upper Glacial Aquifer consists of minor till, outwash sands and gravels, and glaciolacustrine clays, while the Magothy Aquifer is comprised of sand, partially clayey, interbedded with lenses and layers of coarse sand and sandy and solid clay (Smolensky, et al., 1989). More detailed characteristics of these hydrogeologic units can be found in **Table 1** (Nemickas, 1989).
<table>
<thead>
<tr>
<th>Hydrogeologic unit</th>
<th>Maximum Thickness (feet)</th>
<th>Depth from land surface to top (feet)</th>
<th>Character of deposits</th>
<th>Water-bearing properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent deposits</td>
<td>50</td>
<td>0</td>
<td>Sand, gravel, clay, silt, organic mud, peat, loam, and shells. Colors are gray, brown,</td>
<td>Permeable sandy beds beneath barrier beaches yield freshwater at shallow depths, brackish</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>green, black, and yellow. Recent artificial fill deposits of gravel, sand, clay, and</td>
<td>to salty water at greater depths. Clay and silt beneath bays retard saltwater encroachment</td>
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<td></td>
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<td></td>
<td>rubbish.</td>
<td>and confine underlying aquifers. Stream flood plain and marsh deposits may yield small</td>
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<td>quantities of water but are generally clayey or silty and much less permeable than the</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>underlying upper glacial aquifer.</td>
</tr>
<tr>
<td>Upper Glacial aquifer</td>
<td>600</td>
<td>0 - 50</td>
<td>Till (mostly along north shore and in moraines) composed of clay, sand, gravel, and</td>
<td>Till is poorly permeable; impedes downward percolation of water to underlying beds. Outwash</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>boulders from Harbor Hill and Ronkonkoma terminal moraines. Outwash deposits (mostly</td>
<td>deposits are moderately to highly permeable; good to excellent infiltration characteristics.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>between and south of terminal moraines, but also interlayered with till) consist of</td>
<td>Glaciolacustrine and marine clay deposits are mostly poorly permeable and generally retard</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>sand, fine to very coarse, and gravel, pebble to boulder sized. Glaciolacustrine deposits</td>
<td>downward percolation of groundwater. contains fresh water except near shores. Till and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(mostly in central and eastern Long Island) and marine clay (locally along south shore)</td>
<td>marine deposits locally retard saltwater encroachment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>consists of silt, clay, and some sand and gravel layers; includes the “20-foot clay” in</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>southern Nassau and Queens Counties. Colors are mainly gray, brown, and yellow; silty</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>and clay locally are grayish green. Contains shells and plant remains, generally in finer</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>grained beds; also contains Foraminifera.</td>
<td></td>
</tr>
</tbody>
</table>
### Table 1 Continued:

<table>
<thead>
<tr>
<th>Hydrogeologic unit</th>
<th>Maximum Thickness (feet)</th>
<th>Depth from land surface to top (feet)</th>
<th>Character of deposits</th>
<th>Water-bearing properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gardiners Clay</td>
<td>300</td>
<td>50 - 400</td>
<td>Clay, silt, and few layers of sand and gravel. Colors are grayish-green and brown. Contains marine shells, Foraminifera, and lignite; also locally contains glauconite. Occurs in Kings, Queens, and southern Nassau and Suffolk Counties; similar clay occurs in buried valleys near north shore.</td>
<td>Poorly permeable; constitutes confining layer for underlying Jameco aquifer. Locally, sand layers yield small quantities of water.</td>
</tr>
<tr>
<td>Jameco aquifer</td>
<td>300</td>
<td>50 - 550</td>
<td>Sand, fine to very coarse, and gravel to large pebble size; few layers of clay and silt. Gravel is composed of crystalline and sedimentary rocks. Color is mostly dark brown. Occurs in Kings, Queens, and southern Nassau Counties; similar deposits occur in buried valleys near north shore.</td>
<td>Moderately to highly permeable; contains mostly fresh water, but brackish water and water with high iron content occurs locally in southeastern Nassau and southern Queens Counties.</td>
</tr>
<tr>
<td>Mannetto Gravel</td>
<td>300</td>
<td>0 - 120</td>
<td>Gravel, fine to coarse, and lenses of sand; scattered clay lenses. Colors are white, yellow, and brown. Occurs only near Nassau-Suffolk County border near center of island.</td>
<td>Highly permeable but occurs mostly above water table. Excellent infiltration characteristics.</td>
</tr>
<tr>
<td>Magothy Aquifer</td>
<td>1,100</td>
<td>0 - 600</td>
<td>Sand, fine to medium, clayey in part; interbedded with lenses and layers of coarse sand and solid clay. Gravel is common in basal 50-200 feet. Colors are gray, white, red, brown, and yellow.</td>
<td>Most layers are poorly to moderately permeable, some are highly permeable locally. Water is unconfined in uppermost parts, elsewhere is confined. Water is generally of excellent quality but has high iron content locally along north and south shores. Constitutes principal aquifer for public-supply wells in western Long Island, except Kings County, where it is mostly absent. Has been invaded by salty groundwater locally in southwestern Nassau and southern Queens Counties and in small areas along north shore.</td>
</tr>
</tbody>
</table>
Table 1 Continued:

<table>
<thead>
<tr>
<th>Hydrogeologic unit</th>
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<th>Character of deposits</th>
<th>Water-bearing properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raritan confining unit</td>
<td>300</td>
<td>70 - 1,500</td>
<td>Clay, solid and silty, few lenses and layers of sand; little gravel. Colors are gray, red, and white, commonly variegated.</td>
<td>Poorly to very poorly permeable; constitutes confining layer for underlying Lloyd aquifer. Very few wells produce appreciable water from these deposits.</td>
</tr>
<tr>
<td>Lloyd Aquifer</td>
<td>500</td>
<td>200 - 1,800</td>
<td>Sand, fine to coarse, and gravel, commonly with clayey matrix; locally contains thin lignite layers. Locally has gradational contact with overlying Raritan Clay. Colors are yellow, gray, and white, clay is red locally.</td>
<td>Poorly to moderately permeable. Water is confined under artesian pressure by overlying Raritan clay; generally of excellent quality but locally has high iron content. Has been invaded by salty groundwater locally in necks near north shore, where aquifer is mostly shallow and overlying clay is discontinuous. Called “deep confined aquifer” in some earlier reports.</td>
</tr>
<tr>
<td>Bedrock</td>
<td>0 - 2,700</td>
<td></td>
<td>Crystalline metamorphic and igneous rocks; a soft, clayey zone of weathered bedrock locally is more than 100 feet thick.</td>
<td>Poorly permeable to virtually impermeable; constitutes virtually the lower boundary of groundwater reservoir. Some hard, fresh water is contained in joints and fractures but is impractical to develop at most places; however, a few wells near the western edges of Queens and Kings Counties obtain water from the bedrock.</td>
</tr>
</tbody>
</table>
The ability of Long Island’s hydrogeologic units to advect and conduct heat is critical to the effectiveness of geothermal systems and dependent upon the subsurface geologic conditions. Open-loop geothermal systems are also dependent upon the formation’s ability to provide the quantity of groundwater required for the system to meet the structure’s heating and cooling load. On average, two to three gallons per minute (gpm) of aquifer water are required to circulate per 3.5 kilowatts of heating or cooling capacity. The amount of heating and cooling required by a home is case specific and is dependent upon a multitude of variable, including but not limited to: square footage, window type, and insulation. Exact heating and cooling requirements can be determined by HVAC contractors. Prior to the installation of an open-loop geothermal system, a pump test can be conducted to determine whether or not adequate water yield will be obtained from the formation. In addition, groundwater temperature can be confirmed.

Vertical closed-loop geothermal wells typically range in depths of 200 to 400 feet below ground surface. These depths are dependent upon the thermal properties of the subsurface soils. Based on experience, on Long Island, based on soil conditions, 150 feet to 250 feet of bore are required per 3.5 kilowatts of heating or cooling capacity (Remund, et al., 2008). Closed loop geothermal wells on Long Island penetrate the Upper Glacial and Magothy aquifers. Prior to the installation of such wells, hydrogeologic framework maps of Long Island need to be consulted to determine whether or not confining layers are penetrated. Penetration of confining layers is not recommended to protect water quality; if the
confining unit is perforated, the potential may exist for contaminated water in the upper aquifer to seep into the lower. Should a system require 1,600 feet of geothermal loop, i.e. four 400-foot bores, but confining units might be penetrated, eight 200-foot bores can be installed instead provided adequate space on the property is available.

Typical deposits found in Long Island’s aquifers have effective thermal properties as indicated in Table 2.

<table>
<thead>
<tr>
<th>Thermal Texture Class</th>
<th>Thermal Conductivity</th>
<th>Thermal Diffusivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W/m °K</td>
<td>Btu/ft hr °F</td>
</tr>
<tr>
<td>Sand or gravel</td>
<td>0.77</td>
<td>0.44</td>
</tr>
<tr>
<td>Silt</td>
<td>1.67</td>
<td>0.96</td>
</tr>
<tr>
<td>Clay</td>
<td>1.11</td>
<td>0.64</td>
</tr>
<tr>
<td>Loam</td>
<td>0.91</td>
<td>0.52</td>
</tr>
<tr>
<td>Saturated Sand</td>
<td>2.50</td>
<td>1.44</td>
</tr>
<tr>
<td>Saturated Silt or clay</td>
<td>1.67</td>
<td>0.96</td>
</tr>
<tr>
<td>Long Island formation**</td>
<td>2.65</td>
<td>1.53</td>
</tr>
</tbody>
</table>

Table 2: Soil thermal properties (STS Consultants, 1989). **Long Island formation values are based on personal experience and are an average of results taken from actual geothermal conductivity tests conducted across Suffolk County.

**LI Experience**

A geothermal conductivity test is recommended prior to the design and installation of a closed-loop field. Pertinent information obtained from geothermal conductivity tests are site specific. These consist of measured formation thermal conductivity, the estimated thermal diffusivity, and the undisturbed earth temperature. This information is needed in order for engineers to accurately size
and design a loop field to meet the required heating and cooling loads of the structure it is to serve.

A geothermal conductivity test includes the installation of a pilot geothermal closed-loop, which can later be incorporated into the final loop field design. The pilot geothermal closed-loop is given five to seven days to remain undisturbed prior to the commencement of the geothermal thermal conductivity test. This resting period allows the formation to return to undisturbed, equilibrium conditions and for any drilling fluid to exit the bore hole via groundwater transport. The pilot geothermal closed-loop is then connected to a unit which will circulate water at a known temperature through the loop. The differences in water temperature entering and exiting the loop are recorded continuously for the duration of the test. Circulation of water through the geothermal closed-loop and data collection will continue for 48-hours. The geothermal conductivity test is intended to measure the thermal conductivity, estimated thermal diffusivity, and undisturbed deep earth temperature. Thermal conductivity tests conducted across Suffolk County have resulted in an estimated average heat capacity of 37.02 Btu/ft$^3$ °F, average thermal conductivity of 1.53 Btu/hr-ft-°F, and an estimated thermal diffusivity of 0.994 ft$^2$/day.

While numerous systems have been installed on Long Island, reporting of system performance has only occurred once problems are encountered. Poor system performance can be attributed to poor system design, poor loop field design, and/or mismatching of heat pumps to required heating and cooling loads. In only a few instances, consumers of geothermal systems have been willing to
provide detailed accounts of system performance. Outlined below are some examples of existing geothermal systems which have been installed. Detailed discussion is based on willingness of individuals to provide additional information as well as permission to use such information for the purposes of this report.

**Example of some existing systems**

**Port Jefferson/Belle Terre**

In December of 2008 a vertical closed-loop geothermal system was installed in a two-story, 4,000-square foot home. The system included the installation of five HDPE geothermal loops one inch in diameter and between 200 and 250 feet deep. Water alone, not antifreeze solution is presently circulating through the loops. On the first floor, the loops are connected to a two-stage WaterFurnace Envision Self Contained model heat-exchanger. The second floor of the home is connected to a two-stage WaterFurnace Envision Split model heat-exchanger, with a matching air handler. Both systems are equipped with a copper heat-exchanger, a variable speed blower motor, and a de-superheater hot water accessory. A Fantech Heat Recovery Ventilator is also installed in the basement which exhausts air from the attic while taking in fresh air from a window well and supplies it to the return duct for the first floor. With outside temperatures as low as 23°F the air supplied to the return was about 58°F and the attic temperature was about 69°F.

A Whirlpool 80-gallon and Whirlpool 50-gallon Energy Smart Electric Water Heater are piped in series, with cold water entering the 50-gallon water heater and hot water exiting the 80-gallon water heater. The 50-gallon water
heater is used only for preheating water with the de-superheater hot water accessory from the heat pumps. Electric service is only supplied to the 80-gallon water heater. The water temperature entering the heat pump from the geothermal loops ranges from 43°F to 47°F and the return temperature to the ground via the geothermal loops is never more than 5°F less than the supply temperature.

Calverton

A commercial building of approximately 25,500 square feet had a closed loop-geothermal system installed in 2008. Of the 25,500 square feet, 10,068 square feet consist of office space, with the remaining 15,432 square feet being shop/warehouse space. The loop field was comprised of twenty-nine, 200-foot closed loops, servicing the office space of the building only. The shop/warehouse space is not serviced by the geothermal system. Ten loops service the north side of the building, while nineteen loops service the south side of the building.

Six of the closed loops in the loop field on the north side of the building were placed in service on March 20, 2009. These loops are connected to a common flow center with separate circulator pumps which divert circulating fluid to two Hydron Module heat pumps. One of the heat pumps is a two-ton capacity unit and the other is a four-ton capacity unit. Both Hydron Module units are capable of heating and cooling modes. The circulator pumps are thermostatically
controlled, Grundfos 2699, 1/12 horsepower units, which operate on 60 watts each.

The two-ton Hydron Module maintains the temperature in the room containing temperature sensitive computer equipment and is operating in the cooling mode. This unit went into service on March 3, 2009. Currently, the entering water temperature to this unit is 54°F and the exiting water temperature from this unit is 62°F.

The four-ton Hydron Module is currently being utilized to control the temperature of 1,300 square feet of office space located at the northeast corner of the building. It is operating in the heating mode. This unit went into service on April 4, 2009. The entering water temperature to this unit is 54°F; with the exiting water temperature from this unit is 50°F. Approximately 2.5 gallons of fluid per minute are being circulated through the six loops. The circulating fluid being utilized at this time is water only; no propylene glycol is circulating through the loops.

While the loops which will service the south side of the building have been installed, the heat pumps had not yet been installed to date. The south side of the building will be serviced by two 2-ton Hydron Module units and four 3-ton Hydron Modules. These units will be utilized to control the temperature of approximately 8,768 square feet of office space.
Laurel

In November of 2008 a vertical, closed-loop geothermal system was installed to meet the heating and cooling loads of a 2,500-square foot home. The loop field consisted of five 200-foot deep geothermal loops, which are connected to a five-ton Waterfurnace heat pump unit. While no further specifics are available from the client, the client has reported being satisfied with the system.

Lawrence

In June and July of 2008 fifty-six 100-foot vertical closed-loop geothermal loops were installed to meet the heating and cooling loads of a 16,000 square foot newly constructed home. Review of geological cross sections indicated the presence of the Gardiners Clay layer at approximately 120 feet below grade. To avoid penetration of this layer, the loop field was designed shallower, however, to accommodate the total length of bore which were required to meet the heating and cooling demand of the home, more loops were needed.

Regulations

Regulations for open-loop geothermal wells fall under the New York State Environmental Conservation Law 15-1527. This law requires permits from the New York State Department of Environmental Conservation (NYSDEC) for wells when the total capacity of a well on a property is in excess of 45-gallons per minute (gpm). Permits are also required for wells which are 500 feet deep or deeper (New York State Department of Environmental Conservation, 1995).
The Suffolk County Department of Health Services has additional, more stringent requirements for private water systems, under which open-loop geothermal wells would be considered. Requirements include separation from foundations, leaching pools, property lines, septic tanks, sewer lines, storm drains, and washing machine dry wells, as well as requirements on minimum depth of wells and well construction guidelines (Harper & Minei, 1985).

As of the date of this report, the NYSDEC and the Suffolk County Department of Health Services do not have any requirements on the design, construction, or installation of closed-loop geothermal systems. However, discussions are on-going for setback requirements.

Local town or village agencies and officials should be contacted prior to the installation of open-loop systems, as local communities, such as Great Neck, Sands Point, and Bayville have banned them. In August 2008, Shelter Island issued a moratorium on all geothermal wells, and subsequently banned all new geothermal systems at the April 17, 2009 Town Board meeting.

**Issues and previous work concerning the issues**

*Changing temperature in the aquifer*

Observations of the entering and exiting water temperatures indicate the potential for changes in the temperature of the aquifer. Depending on how great
the temperatures changes to aquifer waters are, the potential also exists for modifications to the chemistry of the aquifer waters.

In the case of open-loop systems, groundwater is directly pumped or extracted from the aquifer with heat either extracted from or returned to the water and then discharged back to the aquifer, resulting in a change in aquifer temperatures. While fluid circulated through closed-loop geothermal systems is not withdrawn and returned from the aquifer, rather merely circulated through HDPE pipes, the concern for changes in the aquifer temperature still apply. A need for greater understanding of subsurface heat flow, as well as geothermal regulations has recently been expressed (Ferguson, 2009). These sentiments are also echoed by researchers in Germany studying temperature anomalies, specifically cold plumes, resulting from geothermal usage (Haehnlein, et al., 2008). The velocity of groundwater flow, and energy output appeared to have the largest impact on the length of the thermal plumes. Minimum spacing requirements in Germany vary between 3 meters (approximately 10 feet) to 10 meters (approximately 33 feet) and in Austria the spacing requirement is 0.5 meter per 10 meters drilling depth, but spacing requirements between geothermal wells in Germany were not adequate for all conditions encountered at depth. They therefore, stress the necessity for the assessment of local conditions (Haehnlein, et al., 2008). Local subsurface conditions can be identified through the geothermal thermal conductivity test and pumping tests. The need for the assessment of local conditions is clearly important, however, when performed outside the realm of research (i.e. for the home- or business-
owner), can be a difficult issue to pursue due to the additional costs involved. These additional costs may threaten the project budget.

Other important considerations are impacts of temperature changes in the aquifer in coastal areas, and legal issues. For example, aquifer temperature changes potentially could affect biota when groundwater discharges to coastal environments. Researchers in Germany have identified the need to define limits on heating and cooling of groundwater and to define minimum distances between geothermal systems to avoid negative impacts on ecosystems. They concluded additional research is required and indicated a need for national and international legal frameworks to address such issues (Haehnlein, et al., 2009). A general national and international legal framework, however, may be difficult to establish, because subsurface conditions vary vastly from location to location. It may be better for local governmental agencies to establish regulations which best suit the specific conditions of an area or region. What may be valid for the sandy aquifers of Long Island may not be valid for Germany, or even for that matter, other areas of New York State.

Research conducted in Canada addressed thermal pollution resulting from low temperature geothermal systems (Ferguson & Woodbury, 2006). The study was done on four open-loop systems which are utilized for cooling purposes in an area that is underlain by a carbonate rock aquifer. A numerical model was used to evaluate the effect of spacing between systems and to determine the importance of advective heat transport. Geothermal systems in this area of Canada were found to be unsustainable and inefficient due to the breakthrough
of warm water from the injection well to the pumping well; the spacing between these systems is too small. The spacing requirements would limit the number of systems which can be installed in a particular aquifer. The systems were only being utilized in a cooling mode. Perhaps the spacing may have been based on the assumption for both heating and cooling modes. If the systems were to be reversed, that is, alternately placed in the heating mode, the increased aquifer temperature might be extracted for heating purposes, perhaps rendering the system both efficient and sustainable.

This unanswered question has been raised locally. On Long Island, particularly on the east end, many homes are only used seasonally (in summer). These homes utilize their systems primarily for cooling. Given the sandy nature, thermal conductivity, thermal diffusivity, porosity, and permeability of the Long Island aquifer, and the seasonal nature of the cooling mode, it is surmised there is ample groundwater movement and time for the dissipation of heat in order to avoid thermal impacts on neighboring systems. However, this has not been verified. There currently is no permitting requirement or regulation with regard to geothermal systems on Long Island, which set forth where neighboring systems may be located to ensure proper spacing between them.

*Loss of integrity of confining layers*

Impacts of temperature change are one set of concerns. Other issues are more generic regarding well installation and use, and include loss of integrity of confining layers (potentially causing cross contamination of aquifers), and fouling of the geothermal systems.
Penetration through confining aquifer layers provides pathways for contamination between aquifers. Specific guidelines are provided by local and state municipalities for sealing both water wells and monitoring wells, often utilizing a bentonite grout. These sanitary seals provide measures for reducing contamination pathways, especially to prevent potentially contaminated surface waters from entering into the aquifer(s).

Geothermal wells, however, if sealed, require special thermally-enhanced grout in order to provide adequate heat transfer for an efficient system. A typical thermally-enhanced grout slurry can have a ratio of 50 pounds bentonite to 400 pounds of silica sand to 20 gallons of water. This mixture will vary dependent upon the desired thermal conductivity (Electric Power Research Institute, et al., 2000). While this mixture contains some bentonite, due to the addition of silica sand, it does not seal the well as thoroughly as a bentonite grout would seal a water or monitoring well. Additionally, given the subsurface conditions of Long Island’s aquifer, grouting geothermal wells with thermally enhanced grout actually lowers the thermal conductivity around the well as seepage velocity and groundwater flow around the well walls are reduced. Unlike like water and monitoring wells, there is no requirement in New York State to provide a sanitary seal on geothermal wells.

Long Island’s aquifer is our sole source of drinking water and care should be taken to determine subsurface conditions prior to the installation and design of geothermal systems. Utilization of hydrogeologic cross section maps published by the United States Geological Survey can help professionals determine the
location of potential confining layers. Design of the system can be done in such
a fashion as to avoid penetration of confining layers.

**Fouling**

Fouling of closed-loop geothermal systems is not a concern, as the
solution is simply circulated throughout the loops. However, depending on the
quality of groundwater, where open-loop systems are concerned, particularly on
Long Island, fouling can occur. Iron is of particular concern on Long Island, and
can lead to failure of the submersible pump located in the supply well. Should
this occur, pump maintenance, and, well redevelopment will be required. Of
greater concern is the fouling of the injection well. Water returned to the aquifer
has been oxygenated, and is gravity driven (i.e. no pump is installed in the return
well); deposition of iron oxides and biofouling (bacterial growth) can occur more
rapidly on well screens since flow velocity is reduced. Maintenance of the pump
and flushing and cleaning of well screens will result in additional costs to the
homeowner or business, and decrease the cost effectiveness of the system.

**Others**

Additional complications can occur with the use of geothermal systems.
The Roosevelt Field Mall, located in Garden City, New York, had seven open-
loop geothermal wells, which were utilized for the air conditioning system of the
mall building and office buildings. The system was in operation from
approximately 1960 until 1985 when volatile organic compounds (VOCs) were
identified in the groundwater (USEPA, 2009). Given the historical use of the
property for aviation purposes, as well as documented chlorinated solvent utilization in the aviation industry, it would not appear that the presence of contaminants in the groundwater was from the use of the open-loop geothermal system. However, the geothermal system altered the distribution of contaminants in the area.

The use of the geothermal wells as cooling water wells indicates that the aquifer was being utilized as a heat sink. The implications of this are an increase in aquifer temperature. A rise in temperature could increase the mobility of VOCs and other contaminants, but a quantitative assessment of such a risk has not been done.

Observations at the Calverton Site

Prior to the installation of the closed geothermal loop field at the Calverton site, a test geothermal bore hole was drilled via hollow stem auger. A closed geothermal loop was installed to a terminal depth of 200 feet. Installation of the geothermal test loop took place on March 19, 2008, and was backfilled with native material only. No thermally enhanced grout or other grouting materials were utilized. During the drilling of the bore hole, a boring log was generated based on the drilling cuttings from the augers. Subsurface conditions consisted of medium-grained sand throughout, with the exception of a hard-pan, compact glacial till layer located at the 92-foot to 98-foot depth interval. Depth to water was 37 feet below grade.

Subsequent to the installation of the closed geothermal loop, a geothermal conductivity test was conducted beginning on May 2, 2008, for 50 hours. The
thermal conductivity test revealed formation properties consisting of: an estimated average heat capacity of 36.7 Btu/ft$^3$ °F; thermal conductivity of 1.46 Btu/hr-ft-°F; and an estimated thermal diffusivity of 0.96 ft$^2$/day. These findings are consistent with the estimated soil thermal properties for saturated sand and the Long Island averages listed indicated in Table 2. A complete copy of the generated geothermal conductivity test results and interpretation for the Calverton site can be found in Appendix A at the end of this report.

To date, the geothermal system is maintaining comfortable office temperatures. Additionally monitoring of entering and exiting water temperatures reveal no significant fluctuations.

**Conclusions**

Since the impacts of geothermal systems on aquifers are poorly understood and Long Island’s aquifer is its sole potable water supply, additional monitoring and research are required. The Calverton site is providing a unique opportunity for additional studies as the loops on the south side of the building are not yet in operation. Baseline temperature and chemical makeup of the aquifer waters should be determined prior to system start up and monitoring continued the system is operational.

Geothermal systems are a viable sustainable alternative energy solution, however, proper understanding of their effects on water supply sources, the environment and ecosystems are essential. Additional research into the changes in the subsurface is required to provide an adequate understanding of these systems. Following an adequate understanding of the subsurface effects,
appropriate regulations and legislation can be developed to protect drinking water supplies, and prevent impacts to ecosystems from altered water quality. Local town and village officials should require the submittal of plans, both preliminary and final, and establish a permitting process for the installation of geothermal systems. A database of geothermal system layouts should be maintained to ensure systems do not interfere with one another, resulting in magnified thermal plumes. These steps appear to be essential in effective managing our natural resources and ensuring the success of geothermal energy as a sustainable and renewable energy source.
Bibliography


APPENDIX A
Geothermal Conductivity Test
Calverton, NY Site
FORMATION THERMAL CONDUCTIVITY TEST AND DATA ANALYSIS

Analysis for:

Calverton, NY 11933
Phone:
Fax:

Test location:

Calverton, NY

Report Date:

July 28, 2008

Test Performed by:

Miller Environmental Group
Executive Summary

A formation thermal conductivity test was performed at the site in Calverton, New York. The vertical bore was completed on March 19, 2008 by Miller Environmental Group. GRTI’s test unit was attached to the vertical bore on the afternoon of May 2, 2008. Geothermal Resource Technologies, Inc. analyzed the collected data using the “line source” method.

This report provides a general overview of the test and procedures that were used to perform the thermal conductivity test along with a plot of the data in real time and in a form used to calculate the formation thermal conductivity. The following average formation thermal conductivity was found from the data analysis.

\[ \text{Formation Thermal Conductivity} = 1.46 \text{ Btu/hr-ft-\textdegree F} \]

Due to the necessity of a thermal diffusivity value in the design calculation process, an estimate of the average thermal diffusivity was made for the encountered formation.

\[ \text{Formation Thermal Diffusivity} \approx 0.96 \text{ ft}^2/\text{day} \]

An estimate of the undisturbed formation temperature was determined from the initial temperature data at startup.

\[ \text{Undisturbed Formation Temperature} \approx 53-54\text{°F} \]

A copy of the original collected data is available either in a hard copy or an electronic format upon request.

July 28, 2008
Test Procedures

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) has published a set of recommended procedures for performing formation thermal conductivity tests for geothermal applications. GRTI is committed to adhering to ASHRAE recommendations. Some of these recommended procedures are listed below:

(1) Required Test Duration – A minimum test duration of 36 hours is recommended, with a preference toward 48 hours.

(2) Power Quality – The standard deviation of the power should be less than or equal to 1.5% of the average power, with maximum power variation of less than or equal to 10% of the average power. The heat flux rate should be 51 Btu/hr (15 W) to 85 Btu/hr (25 W) per foot of borehole depth to best simulate the expected peak loads on the u-bend.

(3) Undisturbed Formation Temperature Measurement – The undisturbed formation temperature should be determined by recording the minimum loop temperature as the water returns from the u-bend at test startup.

(4) Installation Procedures for Test Loops – The bore diameter is to be no larger than 6 inches, with 4.5 inches being the target diameter. To ensure against bridging and voids, the bore annulus is to be uniformly grouted from the bottom to the top using a tremie pipe.

(5) Time Between Loop Installation and Testing – A minimum delay of five days between loop installation and test startup is recommended if the formation is expected to have a low thermal conductivity or if low conductivity grouts (< 0.75 Btu/hr-ft-°F) are used. A minimum delay of three days is recommended for all other conditions.

GRTI’s testing procedures deviate slightly from those above with regard to item (5). While item (5) bases the delay between installation and testing on the expected formation conductivity, GRTI bases its delay on the type of drilling used in the installation. When air drilling is required, a five-day delay is recommended to allow the bore to return to its undisturbed temperature. For mud rotary drilling, a minimum waiting period of two days is sufficient.

For a complete list of recommended procedures, refer to the ASHRAE 2007 HVAC Applications handbook, pages 32.12-32.13.
Data Analysis

Geothermal Resource Technologies, Inc. uses the "line source" method of data analysis. The line source equation used is not valid for early test times. Also, the line source method assumes an infinitely thin line source of heat in a continuous medium. If a u-bend grouted in a borehole is used to inject heat into the ground at a constant rate in order to determine the average formation thermal conductivity, the test must be run long enough to allow the finite dimensions of the u-bend pipes and the grout to become insignificant. Experience has shown that the amount of time required to allow early test time error and finite borehole dimension effects to become insignificant is approximately ten hours.

In order to analyze real data from a formation thermal conductivity test, the average temperature of the water entering and exiting the u-bend heat exchanger is plotted versus the natural log of time. Using the Method of Least Squares, the linear equation coefficients are then calculated that produce a line that fits the data. This procedure is normally repeated for various time intervals to ensure that variations in the power or other effects are not producing erroneous results.

Through the analysis process, the collected raw data is converted to spreadsheet format (Microsoft Excel®) for final analysis. A copy of this data can be obtained either in a hard copy or electronic copy format at any time. If desired, please contact Geothermal Resource Technologies, Inc. and provide a ship-to address or e-mail address at one of the following:

Phone: (605) 692-9069
Fax: (605) 692-2604
E-mail: gstreich@brookings.net

July 28, 2008
Formation Thermal Conductivity Test Report

Date ....................................................... May 2-4, 2008
Location ................................................... Calverton, NY
Undisturbed Formation Temperature ....................... Approx. 53-54°F

Borehole Data – As Provided by Miller Environmental Group

<table>
<thead>
<tr>
<th>Borehole Diameter</th>
<th>7 inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drill Log</td>
<td>Brown silty loam</td>
</tr>
<tr>
<td></td>
<td>Yellow medium sand</td>
</tr>
<tr>
<td>U-bend Size</td>
<td>3/4 inch HDPE</td>
</tr>
<tr>
<td>U-Bend Length</td>
<td>200 ft</td>
</tr>
<tr>
<td>Grout Type</td>
<td>Native sand</td>
</tr>
<tr>
<td>Grout Solids</td>
<td>NA</td>
</tr>
<tr>
<td>Grouted Portion</td>
<td>NA</td>
</tr>
</tbody>
</table>

Test Data

<table>
<thead>
<tr>
<th>Test Duration</th>
<th>50.0 hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Voltage</td>
<td>240.2 V</td>
</tr>
<tr>
<td>Average Power</td>
<td>5,979 W</td>
</tr>
<tr>
<td>Total Heat Input Rate</td>
<td>20,405 Btu/hr</td>
</tr>
<tr>
<td>Calculated Circulator Flow Rate</td>
<td>3.9 gpm</td>
</tr>
</tbody>
</table>

May 2-4, 2008

![Temperature versus Time Data](image)

Figure 1: Temperature versus Time Data

July 28, 2008
May 2-4, 2008

Figure 2: Temperature versus Natural Log of Time

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Slope: $a_1$</th>
<th>Average Heat Input (Btu/hr-ft)</th>
<th>Thermal Conductivity (Btu/hr-ft°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 – 50.0 hrs</td>
<td>5.56</td>
<td>102.0</td>
<td>29.9</td>
</tr>
</tbody>
</table>

The temperature versus time data was analyzed using the line source analysis for the time period shown above. An average linear curve fit was applied to the data between 10 and 50.0 hours. The slope of the curve ($a_1$) was found to be 5.56. The resulting thermal conductivity was found to be 1.46 Btu/hr-ft°F.
Estimated Thermal Diffusivity

The reported drilling log for this test borehole indicated that the formation consisted of sand. An estimated diffusivity value was found using the calculated formation thermal conductivity and an estimated heat capacity. The thermal diffusivity for this formation was estimated to be 0.96 ft²/day.

<table>
<thead>
<tr>
<th>Est. Average Heat Capacity (Btu/ft² °F)</th>
<th>Thermal Conductivity (Btu/hr-ft-°F)</th>
<th>Est. Thermal Diffusivity (ft²/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>36.7</td>
<td>1.46</td>
<td>0.96</td>
</tr>
</tbody>
</table>
Frequently Asked Questions (FAQ's) Regarding FTC Testing

Q: Thermally-enhanced grout is specified for the final loop field design. The test bore was grouted with a low conductivity, 20% solids, bentonite grout. How do I adjust the thermal conductivity value to account for this?

A: While the conductivity of the grout is important for the loop field design, it is not important for determining formation thermal conductivity. We use the “line source” method to analyze data, which assumes an infinitely thin line rejecting heat at a constant rate into an infinite medium. The initial ten hours, which is influenced by the bore dimensions and grout conductivity, is ignored in the analysis. However, once the heat has penetrated into the formation, the temperature rise of the formation approaches steady-state. It is the slope of the temperature rise that is used in the analysis. Hence, no adjustment to the reported formation thermal conductivity is required.

Q: The software I use to design the loop field requires that I input a value for “soil conductivity”. Is this the same as formation thermal conductivity?

A: Absolutely. Formation, soil, and ground are all used interchangeably to describe the conditions in which the u-bends will be installed. The use of the word “formation” simply implies that the installation conditions may be soil, rock, or some combination of the two.

Q: I’ve just received your report. I have a formation conductivity of 1.54 Btu/hr-ft°-F. How do I translate that into a loop length requirement, in terms of bore depth (in feet) per ton?

A: The formation thermal conductivity test provides values for three key parameters required for the ground loop design. These are the “Undisturbed Formation Temperature, Formation Thermal Conductivity, and Formation Thermal Diffusivity.” These parameters, along with many others, are inputs to commercially available loop design software (e.g. GchpCalc, available at GeoKiss.com/software). The software uses all of the inputs to determine the required loop length in bore depth per ton.

Q: Is the “Undisturbed Formation Temperature” listed in the report the temperature that I enter into my loop design software where it calls for the “Deep-Earth Temperature”?

A: Generally, yes. The “Undisturbed Formation Temperature” is the constant temperature of the formation. We attempt to determine this value by measuring the temperature of the water entering the test unit at the beginning of the test. However, the value we measure and report may be inaccurate if the test is initiated too quickly after the installation of the test bore, or if the testing operator failed to activate the data acquisition unit prior to energizing the heating elements. If you suspect the temperature we are reporting to be too high or too low, we recommend that you investigate further through other sources.