Geothermal Heat Pump Manual

City of New York

DDC

Department of Design and Construction

Prepared for
NYC Department of Design & Construction
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& Sergio Smiriglio

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Table of Contents

Chapter 5.

a. Hydrogeology of NYC

b. Choosing a geo-exchanger using hydrogeological analysis. Systems analyzed will include:

- remote and diffusion wells (an example will be included for such an application in Queens and/or Brooklyn)
- slinkies and buried pipe
- vertical pipe
- standing column well

Chapter 6.

Permitting requirements of geothermal heat exchangers in NYC:

- list of agencies involved
- water tests required by regulatory agencies

Chapter 7.

Heating and cooling loads, the effect of load dominance.

Chapter 8.

How to pick an appropriate ground source heat pump type once the ground coupled heat exchanger has been selected.

a. Building distribution
b. Installation Follow-up (Commissioning)
c. Training

Chapter 9.

Performance and Ratings

a. Capital Costs
b. Procurement requirements
c. Pay backs – Simple, Return on Investment, Present Value
d. Maintenance

- Case Studies

Chapter 10.

Summary of refrigerant types used in geothermal equipment:

Appendix A.
Sources for hydrogeological information.

Appendix B.
Specifications:

- well drilling
- well testing
- open loop systems
- slinky
- standing column well

Appendix C.
Evaluation of Heat Pump System Models

a. System Level
   I. DOE2
   II. BLAST
   III. ENERGY 10

b. Heat Pump Selection
   I. Manual-J
   II. Manual-N
   III. ASHRAE
   I. GLPRO 3.0

c. Engineering Considerations (Flags)

Appendix D.
Description of Three Existing Projects

a. Long Island Lighting
c. 360 Court Street Brooklyn
d. 9 East 64th Street

Appendix E.
Geothermal Heat Pump Manufacturers

Appendix F.
EPA Form 7520-6 and Instructions

Appendix G.

Open Systems in Brooklyn, Queens and Long Island.

Appendix H.

Kensington Library Geophysical Log.

Appendix I.

Contributor Directory.

Credits and Acknowledgements

The contributors are:

P. Andrew Collins, PE – principal of P.A. Collins, PE Consulting Engineers. Registered Professional Engineer in the States of New York, Massachusetts and New Jersey. Member ASHRAE and International Ground Source Heat Pump Association, currently pursuing LEED certification.
Bachelor of Science in Mechanical Engineering at Columbia University School of Engineering and Applied Science, in the City of New York, and a Masters of Science from the Domus Academy in Milan, Italy.
The company has pioneered the use of ground source heat pumps in New York City, and has five operating installations, with new buildings totaling 180,000 square feet currently in design or construction.
Sustainable, or “green” design forms a cornerstone for the practice.

Carl Orio - Chairman, Water Energy Distributors Inc.

Mr. Orio has one of the longest involvement’s with geothermal heat pumps in the United States today. He is a Certified GeoExchange Designer (AEE), an approved Design Assistant (GHPC) and a Certified Geothermal Instructor (IGSPHA). He has been a member of the International Ground Source Heat Pump Association’s (IGSPHA) Advisory Broad and the IGSPHA Marketing Committee Chairman.

Mr. Orio started his involvement with geothermal heat pumps in 1974 and between that time and 1981 manufactured approximately 2,000 geothermal heat pumps, distributing them throughout the northern US and Canada. Since that time he has been a geothermal heat pump distributor and systems designer, and has been involved in well over 8,000 geothermal heat pump installations, both residential and commercial.

Mr. Orio is a charter member of the Geothermal Heat Pump Consortium , he was contributing member of the National Earth Comfort Program and has been a member of the National Ground Water Association’s Geothermal Heat Pump Committee. He has been a speaker at Association of Energy Engineers, ASHRAE, IGSPHA, National Geothermal Resources Council and National Ground Water Association conferences. He has been an active member and incorporating founder of the Northeast ACCA Council.

Mr. Orio is presently or has been a geothermal consultant for over 70 Power Utilities, US Department of Energy, U S Park Service, Oklahoma State University, NY City Dept of Design & Construction and Engineering firms in the Northeastern United

States and Canada. His firm distributes geothermal heat pumps in the Northeast. His mechanical consulting activities include in-building heat pump design, earth loop design and standing column well design. His analysis activities include economic and energy analysis projects in the application of geothermal heat pumps to industrial, educational and commercial buildings. Mr. Orio has also been a contributor to several nationally recognized software programs for geothermal and mechanical systems.

Mr. Orio has an advanced degree in Engineering and a BS in Physical Chemistry. He has served as a Captain in the US Marine Corps, a senior missile system engineer for Raytheon, and an international systems analyst for BDM Crop in Washington DC.

Sergio Smiriglio graduated from Hofstra University with a Bachelor of Science degree in Geology in 1979. He first worked as a geophysical field operative on a natural gas exploration team in south Texas. In 1980, he was included on a team of hydrogeologists in the Syosset branch of the United States Geological Survey. Mr. Smiriglio, during this time, working under Julian Soren and Murrey Garber of the USGS, was responsible for collecting and mapping the hydrogeologic data for the Brooklyn/ Queens portion of Long Island, using a variety of techniques including test borings and well drilling, to be included in a series of Maps being produced by the USGS.

Mr. Smiriglio began working in 1981 for Geraghty and Miller, Inc., as a hydrogeologist, where he soon specialized in developing water supplies in bedrock aquifers, becoming the lead bedrock aquifer geologist in the firm. Mr. Smiriglio further developed remote sensing techniques for selecting suitable drilling locations for high yield wells. Using these techniques, Mr. Smiriglio has developed some of the highest yielding bedrock wells in the Tri-State metropolitan Area. Mr. Smiriglio further developed these techniques, as well as developing methodologies for the testing of bedrock aquifers, when he become a senior hydrogeologist at the Paramus office of Malcolm Pirnie, Inc.

For the past fourteen years, Mr. Smiriglio has been the president of SSEC Inc., a firm specializing in developing groundwater supplies for large-scale water users such as golf courses, municipalities and large housing and industrial developments. SSEC also conducts groundwater contamination investigations and groundwater remediation studies, as well as geothermal feasibility studies.

Foreword

This manual was written for Project Managers and Consulting Engineers working for the New York City Department of Design and Construction (DDC). As a part of the High Performance Design Initiative, it is meant to enable the introduction of geothermal heat pump technology into projects managed by the DDC.

This manual was prepared under DDC Contract Number DDC002000146

Executive Summary

Geothermal heat pumps use the earth as a heat source or sink by means of a circulating water loop. Mean earth temperatures are approximately 55 degrees Fahrenheit in New York City, resulting in excellent coefficients of performance. Since the heat pump supplies both heating and cooling, only one appliance is needed to satisfy both conditioning needs. No exterior equipment such as cooling towers or condensing units is needed, nor are heating plants. Each heat pump unit can heat or cool at any time, zoning is easy to accomplish and the part load performance is excellent. Maintenance is simple and less costly than conventional fossil fuel and cooling tower systems.

Where building loads can be matched with viable ground source heat exchangers such as a well system or buried loops, over all system performance will easily exceed fossil fuel heating systems and air cooled condensers or cooling tower air conditioning systems. The systems must be sized accurately, with over-sizing being avoided.

Geothermal heat pumps are available from all major manufacturers and are configured as water-to-air, water-to-water, and split equipment.

The design process must include a certified geothermal heat exchanger designer, and a hydrogeologist if ground water is to be used. These consultants should be integrated into the design process and design team in the same way the consulting engineers are.

Wells must be properly designed and developed, and periodic maintenance on the well and well pumps must be performed.

When used appropriately, geothermal heat pumps can form the cornerstone of a sustainable and high-performing building design with excellent life-cycle cost savings.

Operational & Benefit Analysis

1

The benefits offered by GeoExchange[1] systems can be summarized as follows:

- One appliance provides both heating and cooling, reducing maintenance compared to conventional fossil fuel and cooling tower systems;
- Flexible layout with a reduction in mechanical space;
- As the atmosphere is not used as a heat sink, bulky and noisy exterior equipment such as cooling towers and condensing units are not necessary;
- High coefficients of performance due to favorable ground temperatures leading to economical operating costs;
- Hot water for domestic or snow melting use can be scavenged any time the compressors are running;
- An all-electric service classification from the New York Power Authority at an average of $0.08 per kilowatt hour allows economical operating costs; this is approximately equivalent to $0.62/gallon fuel oil and $0.69 /therm gas for an average GeoExchange efficiency (COP=3.5)
- The fossil fuel used is burned at a large, industrial generating facility where air scrubbers and other anti-pollution equipment can be installed due to the economy of scale.
- Chilled water is available, which has superior latent cooling capabilities.
- Excellent zoning and part load performance

As with any mechanical system, all factors pertaining to the design must be evaluated carefully to ascertain whether or not the system is appropriate. Capital, operating and maintenance costs, physical criteria and quality of service are among the factors that are normally analyzed when performing systems comparison studies. When considering geoExchange systems, special attention must be given to the hydrogeology of the area, and the design of the geothermal heat exchanger.

Geothermal heat pump installations are the smallest portion of the Heating, Ventilation and Air Conditioning (HVAC) market today, but is growing at the rate of 20% per year[2]. Primary advantages of the GeoExchange systems are low operational cost. A 1993 study by the U.S. Environmental Protection Agency[3] showed today's geothermal heat pumps:

- Provide the lowest cost heating & cooling, even when higher first costs are factored into analysis
- Geothermal Heat Pumps had the lowest CO_2 (greenhouse gas) emissions and the lowest over all environmental cost
- Can be highly cost-effective for utility conservation programs
- Provide strategic partnerships to promote advance space conditioning equipment

Operating Costs

Operating costs and paybacks can be evaluated by:

a. Return on Investment
b. Simple Payback on Differential Cost, e.g. new construction
c. Simple Payback on Total Cost, e.g. retrofit

GeoExchange systems can be best evaluated on the basis of weather history bin-hour or hour-by-hour analysis. The use of degree-day based cost analysis is not considered sufficiently accurate. The importance of an accurate heating, cooling load profile, and where appropriate, domestic water heating requirements must be foremost in the design and decision process.

1. Unlike a fossil fuel heating system a GeoExchange system's cost is nearly linear with heat energy (Btu's) delivered. A non-condensing boiler can add approximately 25% to its cost as its size is doubled, however a heat pump based system, geo or other heat pump type system, can almost double its cost when its output is doubled.
2. GeoExchange is most often selected on the basis of energy savings. Over-sizing a geothermal heat pump, or even a fossil burner leads to short cycling and inefficiency.
3. With respect to environmental concerns, over-sizing and short cycling also promotes inefficient burning of fossil fuels and increased emissions.
4. Over-sizing of geothermal or conventional chillers, increased the requirement for electrical service and attendant installation costs.

Because of these factors, an accurate analysis of the heating and cooling loads is mandatory when designing a GeoExchange system. Sizing rules-of-thumb, e.g. "400 sqft/ton for cooling or 30 btu/sqft for heating" are not sufficiently accurate nor desirable. Accurate heating, cooling and domestic water heating loads and cost estimating are calculated using the following methods:

For Commercial applications:

	Sizing	Cost Analysis
1. ASHRAE Standards	X	
2. ACCA Manual-N (Wright-N®)[4]	X	
3. Wight-Dollar®		X
4. DOE 2	X	X
5. ENERGY-10		X
6. TRANE TRACE	X	X
7. CARRIER	X	X

Table 1c –2 – Software & Evaluation Methods of Operational Costs[5]

When working with retrofits or buildings that can provide an energy use history, it is appropriate to complete a theoretical analysis and then verify that analysis against the actual energy billing data. Accurate inputs and careful analysis can yield operational cost estimates within ten per cent. Below, paragraph 1 d. is a discussion and summary of the maintenance cost advantages associated with GeoExchange systems.

Factors often overlooked in cost and benefits analysis of the GeoExchange system are:

Measurable
Maintenance Cost Savings
Full System Cost Factors
Life Factors *(keep in mind well systems are usually twice as long-lived as heat pumps*
Adaptation to sites where external equipment cannot be installed)
General Construction cost savings in mechanical space reduction, elimination of structural support for equipment
Elimination of flue for fossil fuel systems

Other benefits
Aesthetics: *no rooftop equipment*
Comfort: *better control options*
Safety: *no fossil fuel fired equipment, no gas piping or on-site fuel storage;*
no cooling tower requiring microbiological organism control
Durability: *less exposure to weather and long Mean Time Between Failure*
Vandalism: *the equipment is indoors or underground*

Table 1c-3– Factors Other than Operation in Cost Analysis

Other Factors that are Measurable

Maintenance Cost Factors are discussed in section 9 and show savings in the 30% to 50% range. These savings have been measured and quantified and are not “simulated estimates”.

Full System Cost Factors often are difficult to compare. Note the Geothermal heat pump ratings both the old ARI and the recently adopted ISO efficiency rating all included the full system level operational costs. Coefficient of Performance (COP) represents these factors. COP being the ratio of the purchased energy to the energy delivered or removed by the heat pump system. These costs include the efficiency of the heat pump but also penalties for water or loop pumping rates and penalties for pressure head in various applications.

When comparing a geothermal heat pump against a chiller system other factors as water pumping, water purchase and chemical purchase must be added to the chiller costs. When comparing a geothermal heat pump against a fossil burning system, remember to include the cost electricity to operate that fossil system.

Geothermal heat pumps are a single source of heating or cooling and in some cases heaters of domestic water. The reduction in operational costs by have a single piece of equipment for these functions should be considered in the evaluation of operational costs.

Life Factors are discussed in section 9.5. Field quantified historical data has evaluated compressors on small heat pumps and have measured a Mean Time Between Failure (MTBF) of 46 years. This is further discussed below.

Adaptation to Restricted Sites –Landmarks Districts in New York City restrict the use of exterior and roof top equipment (no external air conditioning condensers on the building). Often first cost of rigging roof top condensers or cooling towers provide the GeoExchange system with a lower first cost.

Quality of Life Factors

The negative **Aesthetics** of a myriad window air conditioners or a noisy air conditioning condenser on a roof or in a garden is alleviated. Historic buildings or buildings in historic districts where external equipment is not allowed have been provided with air conditioning with no external condensers to mar a building outline.

The personal **Comfort** Geothermal Heat Pumps provided by a geothermal heat pump system can be tied to superior year around humidity control. Lower winter temperature delivery systems do not dry the air in a conditioned space. In the summer, the colder condensers permit substantially colder evaporators with more efficient dehumidification, when compared with conventional air or water-cooled equipment. With better dehumidification, occupants are often more comfortable at higher temperatures which are less costly to maintain.

Safety for buildings and occupants can be traced to the lack of flame heating and the on-site use and storage of flammable gas or fuel oil. Building owners should inquire whether their insurance carrier will offer a reduced fire insurance premium for “no flame heating”. In New York City annual boiler inspections and permit fees are saved. Without cooling towers and a condenser water loop, there is no need for algicides or other microbiological control programs, and possibility for the growth of Legionella bacteria.

Component and over all design **durability** is required from geothermal heat pumps. These heat pumps are designed for wide temperature variations and are fabricated with components that have wider dynamic controls ranges and of alloys and other components that are not found in normal range heat pumps used with circulating loops having a boiler and cooling tower controlling the loop temperature. The additional costs of these enhancements are accounted for above in the geothermal heat pump quantitative cost evaluations. Equipment located indoors is not subject to deterioration caused by the extremes of weather.

Vandalism has no opportunity when there is no component above ground that can be accessed to damage or remove. The vandalism factor is often quantified when considering GeoExchange systems in schools and other public venues.

(Footnotes)

[1] Term for a complete geothermal heat pump system including, earth coupling method, the geothermal heat pump(s) and the terminals in the conditioned space.

[2] See www.ghpc.org, the Geothermal Heat Pump Consortium, Washing DC. A consortium of Federal and industrial agencies speaking for the GeoExchange market.

[3] M. L'Ecuyer et al, *Space Conditioning the Next Frontier*, EPA 430-R-93-004, April 1993

[4] "Wright Suite" is an integrated software package with components that are the property of ACCA . The package has cost estimating and heat loss and gain and domestic water heating analysis. The package also has integrated earth coupling and radiant floor design software (Wright Soft, Lexington MA). Primarily used for residential and light commercial. The ACCA manual-N (Wright-N), is a literal interpretation of ASHRAE standard xxx.

[5] These must be considered only a summary of some of the more popular New York area evaluation programs, is list is not exhaustive.

Definitions and Descriptions of Ground Source Heat Pump Equipment

Ground source heat pumps are space conditioning units that use the refrigeration cycle to heat or cool a medium (air or water), using the earth as a heat source or sink. The refrigeration cycle is reversible, so these units can be used to heat or cool.

The configurations manufactured are:

Water-to-air: water from a ground source is circulated through the unit, and air ducted to and from the space to be conditioned is either heated or cooled.

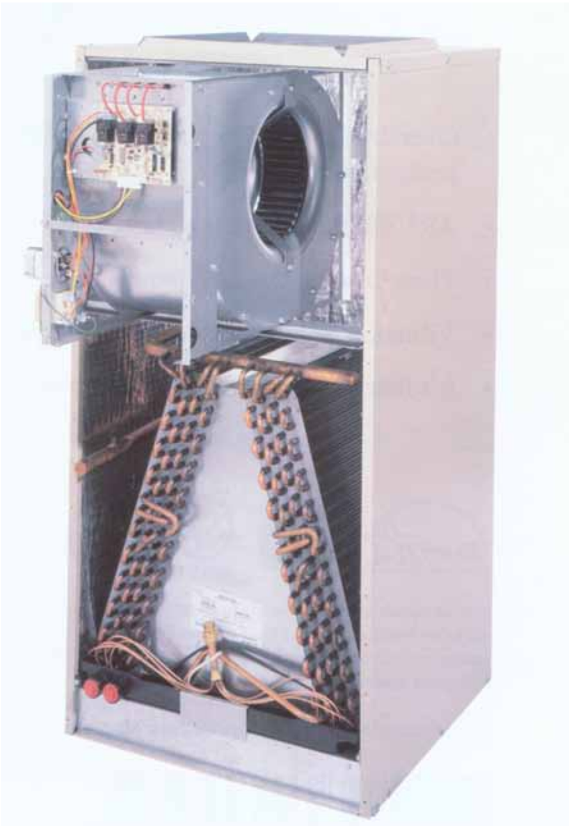
Courtesy Climatemaster

Water-to-water: water from a ground source is circulated through the unit, and chilled or hot water is circulated to fan coil units for cooling, and to heating elements, radiant floor systems, or fan coils for heating.

Courtesy Climatemaster

Water to air split type:
Water from a ground source is circulated through the unit containing the compressor and condenser/evaporator section. Refrigerant piping connects this part with a remote direct expansion type air handler that heats or cools air ducted to and from the space to be conditioned.

Compressor section of split type ground source heat pump
Courtesy Climatemaster



Blower section of split type ground source heat pump
Courtesy Climatemaster

Description of Geothermal Heat Exchangers

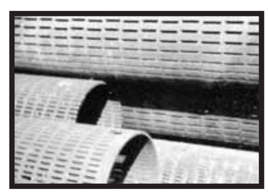
3

Open System with Supply and Diffusion Wells

The open type of geothermal heat exchanger consists of one or more supply wells which supply water to the heat pump loop, and return or diffusion wells into which the same water is re-injected into the aquifer from which it was drawn. These wells are relatively shallow (several hundred feet in depth), and are generally cased to the depth where the water is available for pumping, or in the case of a diffusion well, can be accepted by the geologic formation. Aquifers that can furnish water at high flow rates are generally of coarse material such as gravel, but not clay, sand or bedrock.

3

The water must be drawn into the supply well and re-injected into the diffusion well through a screen. **Screens** consist of perforated pipe wrapped at a calculated interval with wire having a V-shaped cross section. This permits the well to remain clear of sediment and maintain the required flow rates. Screens for diffusion wells must be twice the size of screens for supply wells which compensate for screens not being optimized for diffusion (return) and the need to overcome the earth's natural resistance to return water to an aquifer (hydrologic tension).



Examples of Well Screens,
Courtesy Johnson Screens

An open well earth coupling can be the lowest cost and the highest efficiency method. A hydrogeological study is required to determine if the required water flow rate of three gallons per minute per ton of air conditioning will be available for the life of the well. A sustainable method of returning the water must also be determined. Disposing of the water into the sewer system is never an option. This type system is most economical in large portions of Brooklyn, Queens and parts of Staten Island. As the availability of water from a given well unknown, test wells and monitoring wells must be drilled in these areas. Monitoring wells are called 'piezometers', and are generally one, two or four inches in diameter which allows a monitoring device called a 'troll' to be installed. The piezometers are placed at specific intervals from the source well as determined by the hydrogeologist, and allow the draw-down of the water table to be measured. Diffused water at the re-injection point may also need to be measured.

There are limited areas of Manhattan, Bronx and Staten Island with intersecting bedrock fractures that allow open well systems. Staten Island has geologic formations similar to Brooklyn and Queens in the eastern part.The ideal design spacing between a supply and a diffusion (return) well can be in the 100 – 500 foot range and is generally defined as:

Separation in feet = $(\text{btu/hr design X } 0.2)^{1/2}$.

Environmental permitting for open wells in NYC is defined by the diffusion flow rate. Any system 50 tons or over will probably need a permit. The EPA considers geothermal re-injection well water as a beneficial use (formally called a Class V use). Permitting or notice maybe required dependent upon average daily water flow rates. Open wells may be serviced by any qualified well contractor.

Open wells may require servicing due to:

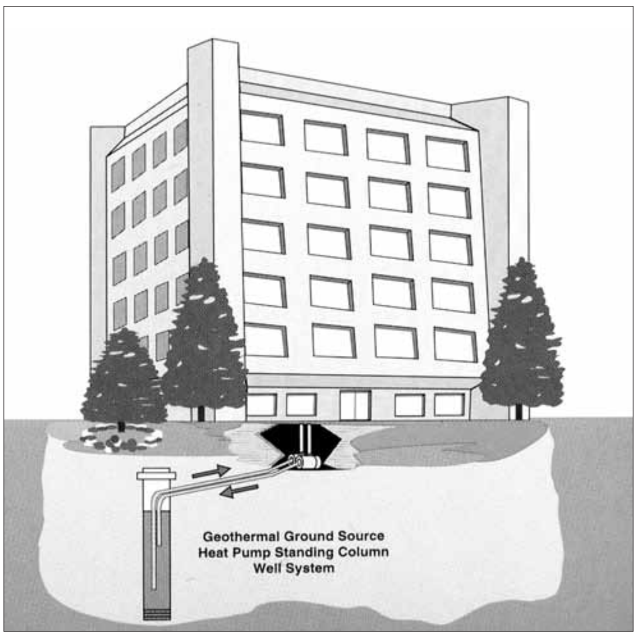
-Reduced yield caused by incrustation or biofouling
-Changes in the water table due to natural or man-made phenomena
-Plugging of the formation around the screen by fine par ticles
-Sand pumping caused by changes in the screen
-Structural failure of the well screen or casing
-Pump damage or failure

With proper maintenance such as the replacement of screens and pumps, wells routinely last 50+ years.

For more information see:
Groundwater and Wells, Driscoll F.G., 1986 Johnson Screens, St Paul. MI.

Standing Column Wells (SCW)

Standing column wells consist of a borehole that is cased until competent bedrock is reached. The New York State Department of Mineral Resources DMR requires that the well casing be driven 75 feet into competent bedrock. Upon indication of solid and unfractured rock the DMR has agreed upon a reduction of that depth to as low as 35 feet. The remaining depth of the well is then self-supporting through bedrock. A central pipe is dropped to form a core through which the water is pumped up, and an annulus into which the water is returned. The length of the central pipe at the bottom is perforated to form a diffuser. Water is drawn into the diffuser and up the central riser pipe. The well pump is usually located at some depth below the water table in-line with the central riser

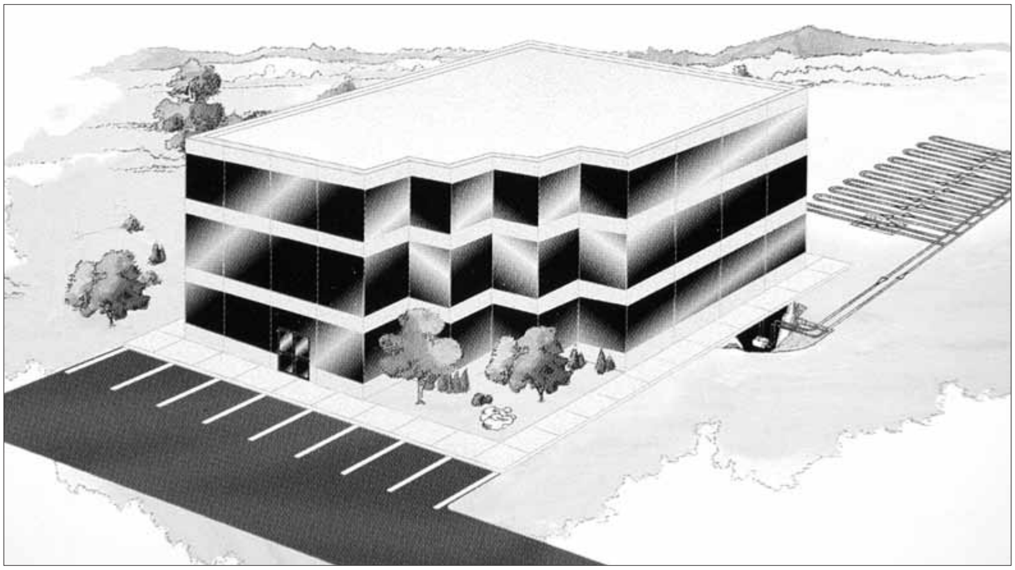


pipe. The standing column well combines the supply and diffusion wells into one, and is not dependent upon the presence or flow of ground water, although fractures in the bedrock that allow flow across the well can enhance performance, and reduce the required depth.

In practice, standing column wells are a trade-off between the open well systems and the closed loop earth coupling discussed below. The standing column well is advantageous during the design phase because the performance can be predicted without an extensive hydrogeological study. The savings in design fees and time are attractive. Given that standing column wells are predictable in projected performance, the use of this type of geothermal heat exchanger in most of Manhattan, the Bronx, northern Queens and western Staten Island, where bedrock is close to the surface is recommended. The standing column well can be designed and expected to perform to specification without the need for a test well. A heating or cooling capacity of 420 to 480 MBH (thousands of Btu/hr, equivalent to 35 - 40 tons of cooling) can be reliably expected from a 1,500 foot deep standing column well. Ideal spacing between SCW is at 50-75 feet. Closer spacing will affect the performance of the well field and can be projected with available design software (typically GLPRO, see below). Geothermal re-injection well water is considered a Class V water use and is regarded by the EPA as a 'beneficial' use. Permitting or notice may be required dependent upon average daily water flow rates. SCW's are serviced by qualified well contractors with minimal training.

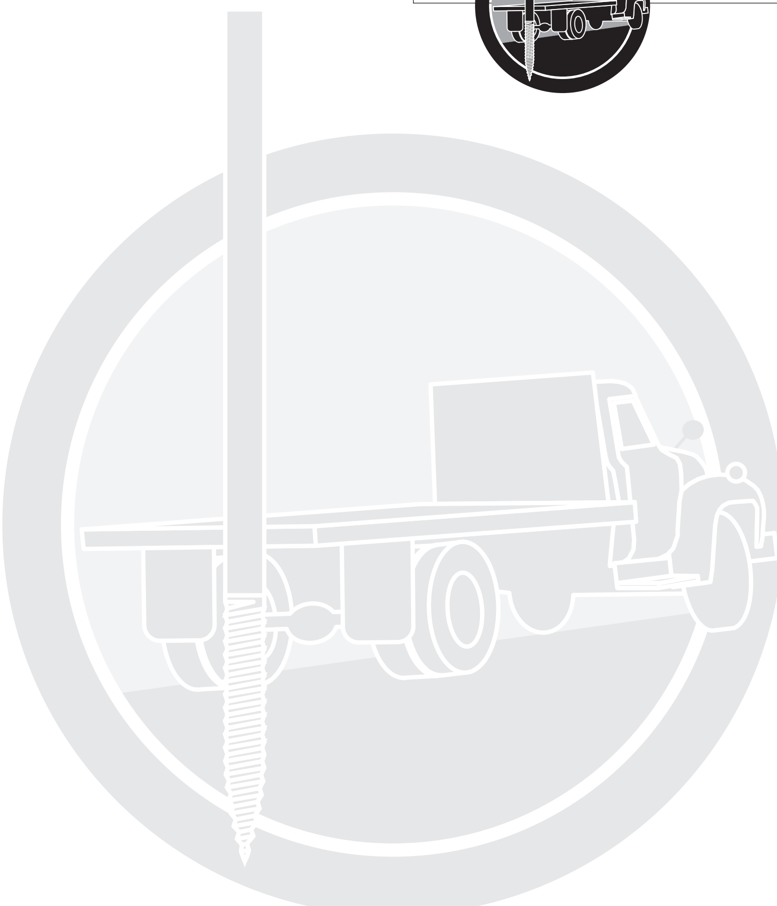
Closed Loop Geothermal Heat Exchangers

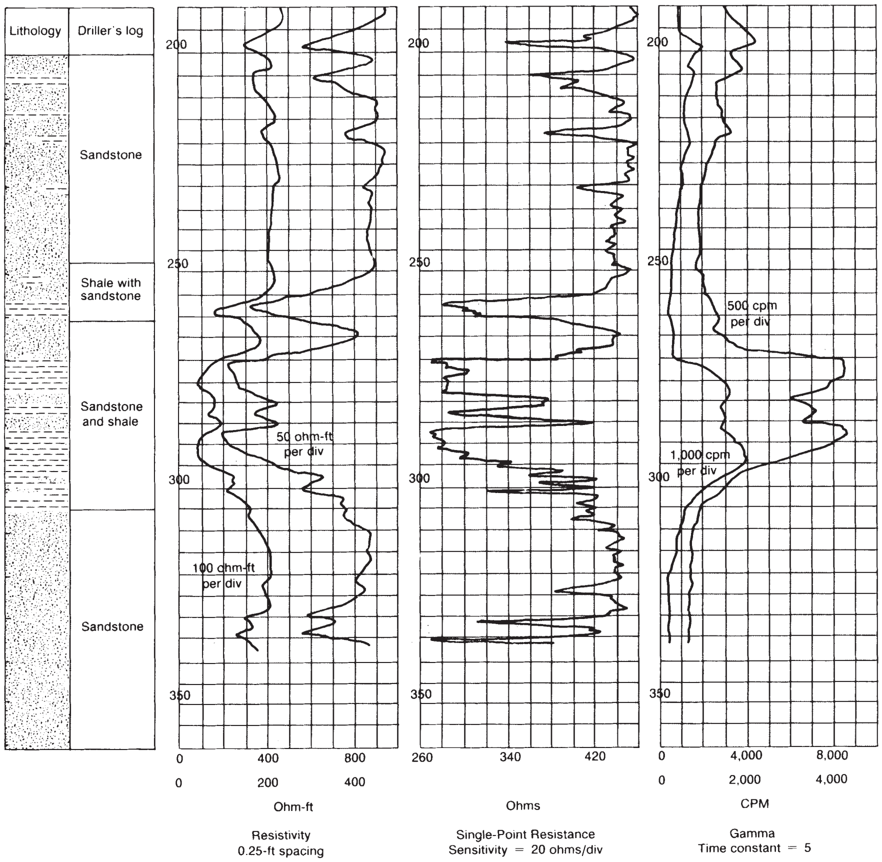
Close loop earth coupling is used in areas where the installation is simple or there are issues with the permitted use of ground water (aquifers reserved by governing bodies), lack of water or with the water quality. This type of geothermal heat exchanger consists of closed loops of plastic piping.



As closed loop piping and the required grouting material add another layer of heat transfer resistance, the closed loop system is designed for lower winter entering water temperatures and higher summer entering temperature. These wider temperature ranges reduce the effective capacity and efficiency of the heat pump system. Closed loop piping costs are typically in the same range as the cost of the heat pumps and thus add to the overall cost of the installation. Generally, these closed loop systems are more first cost than the above systems. A compensating increase in the overall system efficiency can be anticipated by the reduction in loop pumping costs. However, the requirement for slightly larger equipment remains a disadvantage. Closed loops with environmentally friendly propylene glycol may not realize as much pumping advantage in the winter period as the typical propylene glycol concentrations tend to greatly increase solution viscosity. Typical closed loop spacing is 15-20 feet and are 300-400 feet deep. In the areas of NYC (Brooklyn, Queens, parts of Staten Island and limited areas of Manhattan and the Bronx) that allow the installation of vertical closed loops, the typical closed loop bore will provide 2 tons of heat transfer. Closed loop systems are installed and serviced by contractors certified by the International Ground Source Heat Pump Association (IGSPHA).

Site Evaluation and Test Wells





Three plots are shown here that depict different logging functions made in an open sandstone hole. The single-point resistance log shows a sharp deflection to the left, beginning at 254 ft (77.4 m) and ending at 260 ft (79.3 m). This indicates a low-resistance material (shale). The 0.25 normal resistivity also shows the beginning of low-resistance material at about 253 ft (77.1 m). In addition, the gamma-ray log shows a slightly higher gamma-ray count beginning at 254 ft, indicating an abundance of clay minerals contained in the shale. Notice the excellent correlation of the sandstone layer between 260 ft (79.3 m) and 270 ft (82.3 m) on the single-point and resistivity logs. This layer also shows up slightly as a small deflection to the left in the gamma-ray log. This indicates that the readings were influenced by actual changes in formation, and not simply by changes in borehole diameter (which can affect the single-point resistance log and the 0.25 normal resistivity log). Below 320 ft (97.6 m), single-point and resistivity logs show changes in material that are not shown in the gamma-ray log. In this case, the two resistance logs appear to be influenced by changes in the borehole diameter or the chemical quality of interstitial fluid, and not by actual changes in lithology. This theory could easily be checked by running a resistivity log with greater electrode spacing or a caliper log. *(Howe, 1979)*

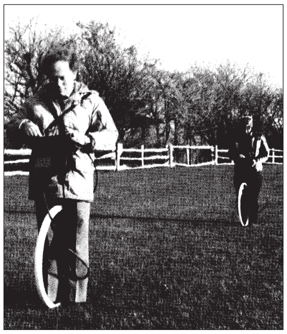
Courtesy:
Groundwater and Wells, Driscoll F.G., 1986 Johnson Screens, St Paul. MI.

4

Introduction

This chapter is an overview what needs to be known about the hydrogeology of a site before committing to the implementation of a ground sourced heating and cooling system. The various system options, such as closed loop, standing column or extraction/ injection systems are described in more detail in other chapters of this manual. The purpose of this chapter is to assist the engineer in determining what type of system is most suitable for the given geologic conditions for the particular location selected, building configuration and load.

The primary determining factor for the system type that is most suitable for a given location is the geology, or more specifically the hydrogeology. For example, if a system is to be designed using extraction and injection wells, it will be necessary to develop wells that have sufficient capacity to provide the required quantity of water for the system needs (based on the tonnage of the system). Conversely, it will be necessary to develop wells that can accept the quantity of water that is extracted. If, as an example, the geothermal system requires a flow rate of 100 gallons per minute [gpm], wells capable of providing an excess of 100 gpm and wells capable of receiving an excess of 100 gpm will need to be completed. Such wells are possible in Queens, Brooklyn, eastern Staten Island and limited areas of Manhattan and the Bronx. Specifically areas that do not have highly productive granular aquifers below the surface. Areas that are underlain by glacially scoured bedrock, as is most of Manhattan and the Bronx, are typically only suitable for the development of "bedrock" wells.



Hand-carried terrain conductivity devices use electromagnetic waves to measure the canductivity of earth materials. Direct contact with the ground is not required during data gathering. Thus, subsurface information can be obtained quickly in both highly urbanized and rural environments.

Courtesy:
Groundwater and Wells, Driscoll F.G., 1986 Johnson Screens, St Paul. MI.

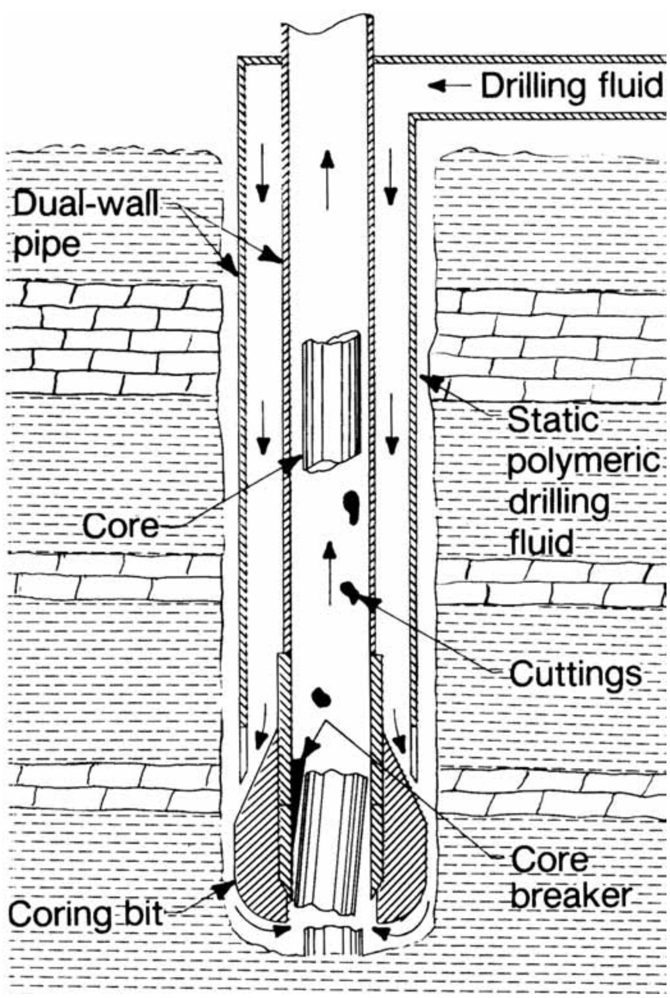
Bedrock wells which are either standing column wells or boreholes into which vertical loops have been installed, are typically open borings six inches, or larger, in diameter and are drilled deep into the bedrock, as much as 1600 feet or more. Steel pipe is used to isolate the upper portion of the well, that penetrates the soil that overlies the bedrock. Therefore, a bedrock well, from the surface, appears to be a six inch, or larger, steel pipe in the ground. The water that is developed from bedrock wells comes from fractures in the bedrock. The fractures form part of an interconnected system that eventually reaches the top of the bedrock surface where surface water or precipitation recharges the bedrock aquifer. The size and extent of the system of fractures encountered by the well dictates the productivity of the well. Bedrock wells drilled at random locations produce an average yield of water typical for the area, generally less than 10 gpm. Occasionally a well will intercept a large fracture system that will produce sizable quantities of water. Such wells are relatively rare, but the chances of drilling such wells can be improved if the location of high yield fracture systems are known and are reachable from the project location.

In areas that are underlain by unconsolidated aquifer materials composed of sand and or gravel, shallower wells that are more productive can be completed. These areas include portions of Kings, Queens and Richmond counties, and isolated areas in the Bronx and Manhattan. Such wells are generally constructed of six inch, or larger, steel casing or well screen to hold back the soil and slotted steel casing in the most productive portion of the aquifer, to allow the entrance of water into the well. The productivity of such wells depends on various factors including the transmissivity of the aquifer, the thickness of the aquifer and the well design. A poorly designed well will not allow the efficient withdrawal of water from the aquifer, regardless of the productivity of the

4

Undisturbed samples are obtained with a split spoon by driving the hollow sampler into the ground. After retrieval, the sampler is split open for visual observation.

Courtesy: *Groundwater and Wells, Driscoll F.G., 1986 Johnson Screens, St Paul. MI.*



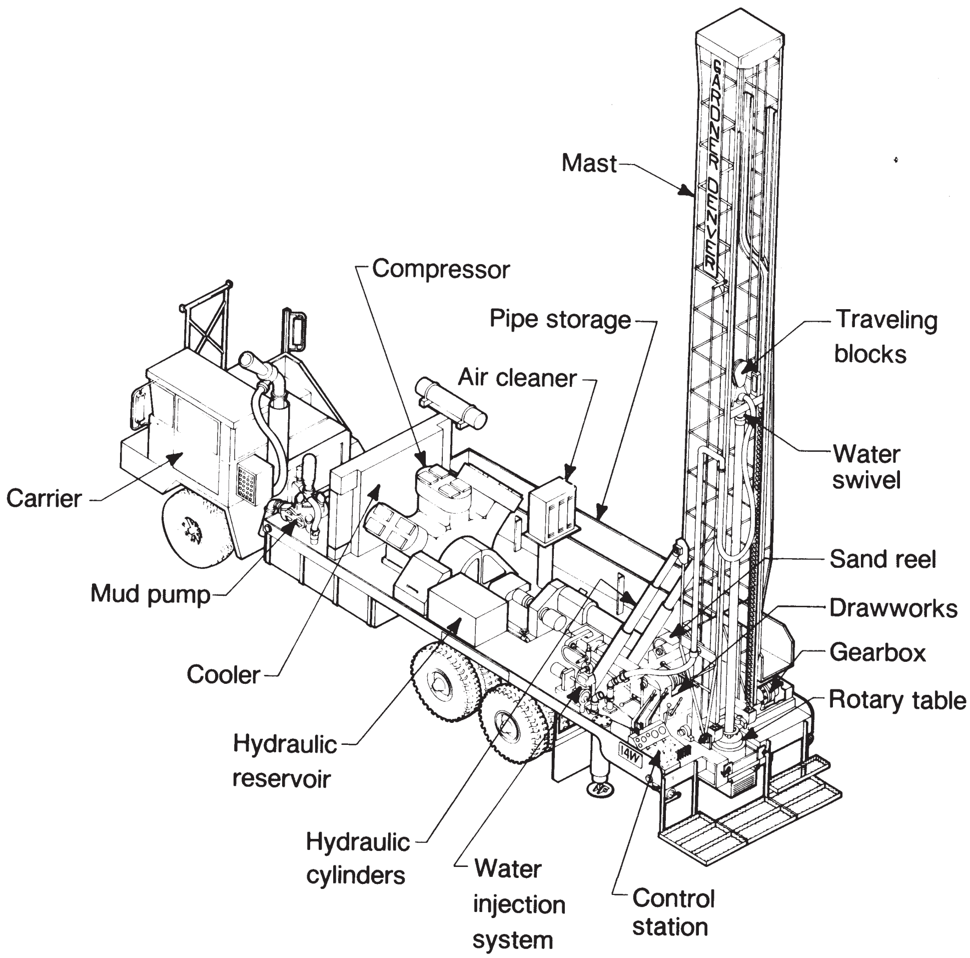
In this sampling procedure, a 4 1/2" (114 mm) OD drill pipe equipped with a diamond or carbide coring bit drills a 4 7/8" (124 mm) diameter hole while cutting a 2" (51 mm) diameter core.

Courtesy: *Groundwater and Wells, Driscoll F.G., 1986 Johnson Screens, St Paul. MI.*

aquifer. Conversely, a well with a screen slot size with too wide spacing for the given formation will not prevent the aquifer material from entering the well and damaging the pumps and or geothermal systems.

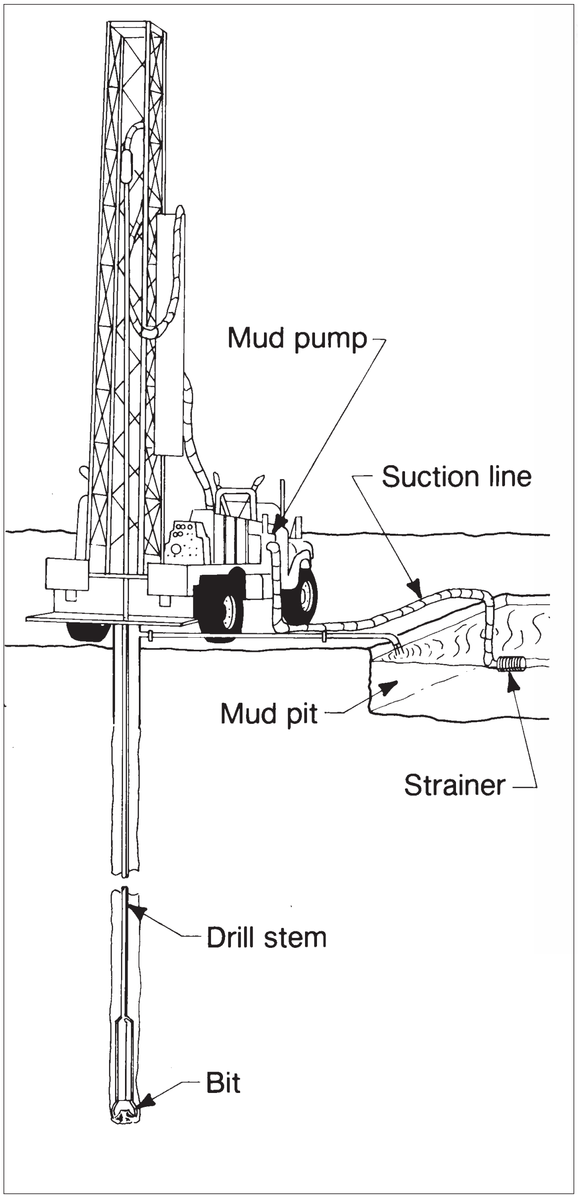
Clearly, the construction of geothermal systems requires some advanced planning to optimize the system's efficiency. Knowledge of the site-specific geology is as critical to the design of the geothermal system as is knowledge of the heating and cooling demands of the project. This chapter will not impart the reader with the site specific geologic information required to design a geothermal system. However, the reader will gain a general understanding of the use of geologic resources available for a particular area of concern so that preliminary design decisions may be made. The designing engineer will be able to assess the likelihood of the type of geo-exchange system that may be employed (most suitable) at a given location. However, since the manual does not deal with site-specific geology, conditions may be encountered at any given location that will give the designer more options to choose from. A part of this discussion will be a suggested procedure for drilling wells that will take advantage of the site-specific geology that may be encountered.

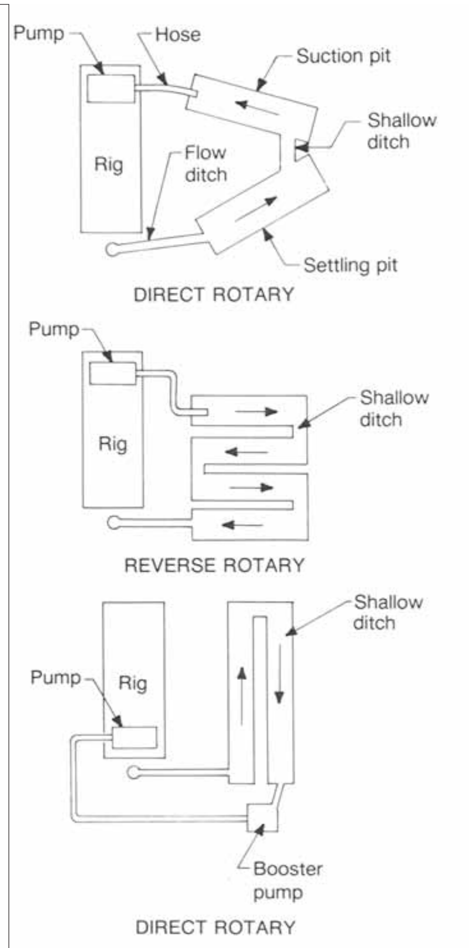
All projects will require a hydrogeologist to recommend test well, and production well design for specific sites. There is coordination required between the hydrogeologist, site engineering, consulting engineer and architect in order to bring the project to fruition.



Schematic diagram of a direct rotary rig illustrates the important operational components of this truck-mounted drilling machine. This machine, operating with either an air-based or water-based drilling fluid, can drill more rapidly than a cable tool rig.

Courtesy: *Groundwater and Wells, Driscoll F.G., 1986 Johnson Screens, St Paul. MI.*





Components of a complete drilling fluid circulating system for a direct rotary rig.

Courtesy: *Groundwater and Wells, Driscoll F.G., 1986 Johnson Screens, St Paul. MI.*

Example Photograph of a mud pit.

Courtesy: *Groundwater and Wells, Driscoll F.G., 1986 Johnson Screens, St Paul. MI.*

4

a. Hydrogeology of NYC
b. Choosing a Geo-exchanger using Hydrogeological Analysis

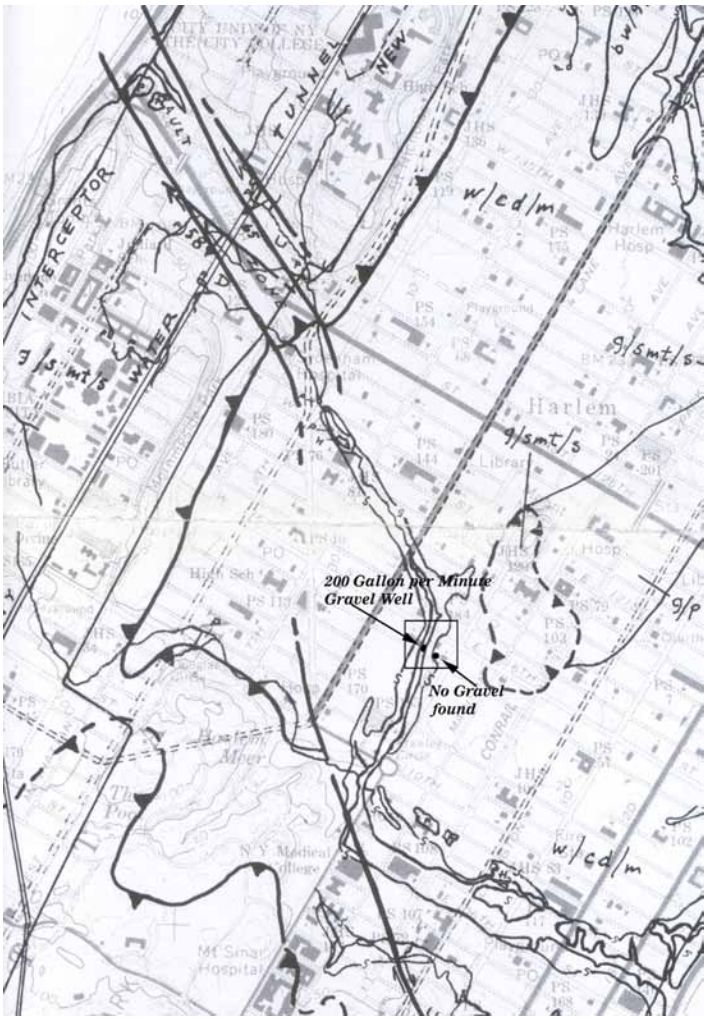
5.a The Hydrogeology of New York City

The geology of the New York City counties is complex and varied. Geologic formations range from Precambrian bedrock the age of which can be measured in billions of years to glacial deposits that are less than twelve thousand years old to land filled areas that were created in the recent past. The stratigraphy of geologic units tends to be ordered with the younger formations resting on top of older formations. The oldest formations, the crystalline bedrock, such as granites and gneisses, form the "basement" rocks, with younger, softer rocks and unconsolidated deposits, such as sand, gravel and clay, resting on top of the basement. In New York City, the basement-rocks are generally inclined so that they are close to the land surface, or are the land surface, in the Bronx and Manhattan and parts of Queens and Richmond and slope downward towards the southeast. Southeastern portions of Queens and eastern portions of Kings counties are covered with sedimentary deposits with the bedrock as much as 1000 feet below the land surface in south Brooklyn and Queens.

If the "project site" is located in Manhattan or the Bronx, it is expected that the geo-exchange wells will be drilled into the bedrock since the likelihood of encountering usable quantities of granular aquifer materials in these counties is unlikely. Conversely, if the project site is located in southern Brooklyn or Queens, several productive unconsolidated aquifers exist in these locations. Therefore, either the project designer has the option of using extraction/diffusion wells or standing column wells.

Site C as shown on the map below is located adjacent to a mapped thrust fault, a fault in which one block (referring to the section of rock on one side of a fault and not to city blocks) is pushed over the top of another block. The symbol for a thrust fault used in the map above is a heavy line with a saw tooth pattern. The points of the saw tooth refer to the downward movement of the fault plane. Since these fault types generally produce shallow fault angles, a well drilled on the downward side of the fault line will encounter the fault plane further down as the location of the well is moved further away (in the direction of the saw tooth pattern, from the fault line. If the well is located on the upward side of the fault, the main (mapped) fault plane will be missed. However, since thrust fault systems tend to have multiple planes (like a stack of papers pushed from the side), it may be possible to develop a productive well on the "wrong" side of the fracture line. Again, just because the fault is mapped does not guarantee a productive well.

The section of the Baskerville Manhattan map, "Bedrock and Engineering Geology Maps of New York County and Parts of Kings and Queens Counties, New York, and Parts of Bergen and Hudson Counties, New Jersey", shown below is for an area north of Central Park. The box on the map indicates an area that is currently being investigated for geothermal potential. An 8 story apartment building with 130 dwelling units is planned for the site. The map indicates that the project site lies over a former swamp or marsh associated with a drainage channel or stream. During drilling of test wells, a productive gravel zone was discovered at the western end of the project site. The gravel was found to be absent less than 75 feet to the east. The presence and absence of the unconsolidated aquifer corresponds very well with the mapping. The mapping also shows a fault zone that crosses Manhattan starting at the Hudson River at 125th street and trends towards the southeast. The mapping indicates that the fault zone does not cross the project site, but turns south, away from the mapped drainage area, avoiding the project site. Several deep wells were drilled as test wells, for this project. The wells ranged from 600 feet to 900 feet deep and had yields ranging from 150 to 30 gallons per minute. It is clear from these results that these wells are tapping significant fractures, even though none are mapped in the immediate area of the project site. This illustrates the need for a thorough and careful analysis of any given site.



Working in bedrock areas, the Bronx and Manhattan and portions of Staten Island, requires design flexibility since the actual outcome of the drilling program cannot be predicted in advance. The system designer should assume that the wells to be drilled will not produce sufficient water for the project requirements and, therefore, the wells should be designed as standing column wells with minimal extraction. If, as described above, high yielding wells are developed, the depth of the wells can be limited in proportion to the yield of the wells.

Brooklyn/Queens

The geology of Brooklyn and Queens is very different from the geology of the other boroughs. Where The Bronx, Manhattan and parts of Richmond are predominantly underlain by bedrock with little if any soil covering the rock surface, most of Queens and Brooklyn have very thick surficial deposits of unconsolidated material overlying the bedrock basement. These deposits range from clay to gravel and are from zero to over 1,000 feet deep. The sand and gravel aquifers include the Upper Glacial, Jameco, Magothy and the Lloyd. These aquifers are all extensively used as sources of ground water for eastern Long Island. The most widely used aquifer for municipal water supplies is the Magothy Aquifer. The Lloyd aquifer is the deepest aquifer, directly in contact with the underlying bedrock. The Lloyd is a restricted use, protected, aquifer only available for use by communities that have no other option for a water supply, such as barrier island communities that find their shallow wells become brackish. The New York State Department of Environmental Conservation will not allow the use of the Lloyd for extraction/diffusion type geothermal wells. The Jameco and Upper Glacial aquifers are shallower lower productivity aquifers that may be available for use depending on the project location.

Table 1. Major hydrogeologic units of the Long Island groundwater reservoir.

Hydrogeologic Unit	Approximate Maximum Thickness	Water-Bearing Character
Upper glacial aquifer	400’	Mainly sand and gravel of moderate to high permeability; also includes clayey deposits of low permeability.
Gardiners Clay	150’	Clay, silty clay, and a little fine sand of low to very low permeability.
Jameco aquifer	200’	Mainly medium to coarse sand of moderate to high permeability.
Magothy aquifer	1000’	Coarse to fine sand of moderate permeability; locally contains highly permeable gravel, and abundant silt and clay of low to very low permeability.
Raritan Clay	300’	Clay of very low permeability; some silt and fine sand of low permeability.
Lloyd aquifer	300’	Sand and gravel of moderate permeability; some clayey material of low permeability.

Table from "pbisotopes.ess.sunysb.edu/geo101_f00/articles/exam 2/liqr/ table1.htm - 4k

All Long Island aquifers receive their fresh water from precipitation. Long Island receives, on average, about 44 inches of precipitation a year. Of this, about half of the precipitation, or approximately 22 inches of rain, percolates into the ground and is recharged into the groundwater system. The remaining precipitation is either evaporated, taken up by plants, or runs off into creeks, bays and estuaries. In areas where the water table and the ground surface meet, streams, ponds and wetlands are formed. In an undisturbed natural setting, (e.g., before human activities) all of Long Island’s groundwater would ultimately reach the coast where the ground water would mix with and the ocean. This process is called underflow - due to human activity, this process has been significantly changed so that not all water in the ground water system is returned to the ocean.

Today, ground water is withdrawn from the system constantly. Over 138 billion gallons of water is taken each year from beneath Nassau and Suffolk Counties. In coastal areas, as water is drawn up for use, less groundwater is available to be discharged into the estuaries. The resulting loss of water and pressure allows saltwater from the ocean to flow into the aquifer, causing the ground water to become saline, resulting in a condition called “saltwater intrusion”. New water from precipitation is constantly recharging, or replenishing, the aquifers. Unfortunately, as water recharges the system, it can easily carry contaminants with it into the ground water. Since it is the shallowest and closest to most sources of contamination, the Upper Glacial aquifer is the most heavily contaminated of the three. The next most seriously contaminated aquifer is the Magothy, which is the layer below the Upper Glacial. The Magothy aquifer supplies over 90% of the water used in Nassau County and about 50% of all water used in Suffolk County.

The heat exchangers which transfer heat in or out of the heat pump refrigerant should be of an alloy such as copper-nickel that experiences no ill effects from salinity or variation in pH. The contaminants in the ground water will have an effect on the maintenance requirements for the well and well pump. See Chapter 3, Description of Geothermal Heat Exchangers for a discussion of potential problems with open wells due to water quality and other factors.

Principal Hydrologic Units

The three principal aquifers of Long Island are (top to bottom) the Upper Glacial Aquifer, the Jameco, the Magothy Aquifer, and the Lloyd Aquifer.

Continental glaciers of Wisconsinan age (20 to 86 thousand years ago) brought to Long Island the materials that now comprise nearly all of its surficial sediments. Glacial material was deposited in two terminal moraines: the Ronkonkoma moraine, which forms Suffolk’s “spine” and South Fork, and the Harbor Hill moraine, which runs along the North Shore and forms the North Fork. Some of the original glacial material (till) can still be seen along the north shore of the South Fork, at Montauk, and on Shelter Island, where it acts to retard the downward movement of recharge.

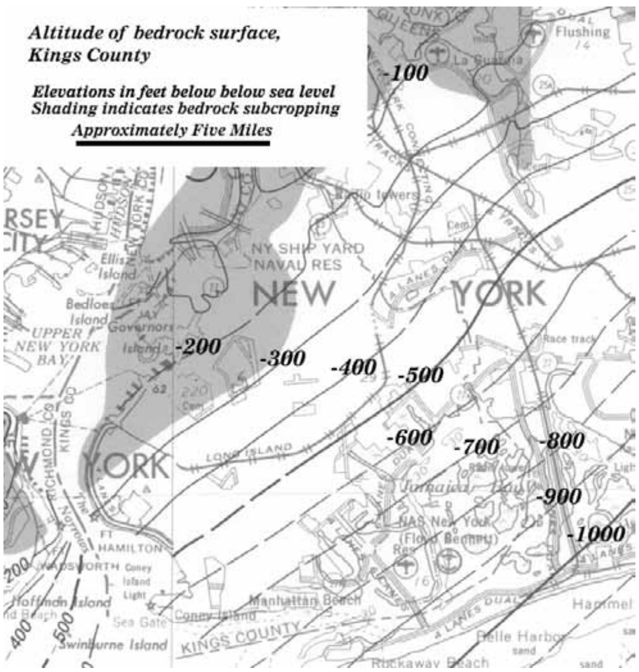
Most of the glacial material was reworked by meltwater to form large, sandy outwash plain deposits south of, and between, the two moraines. These highly permeable, stratified sand and unconsolidated deposits filled in the valleys eroded on the surface of the Magothy (although some filling may have occurred prior to the ice sheet’s advance to Long Island).

The glacial deposits can reach thicknesses of up to 700 feet (e.g., in the “Ronkonkoma Basin”). They generally overlie Magothy deposits, except in areas of the North Shore where the Magothy was scoured away by glaciers, and in areas of the South Shore where the Gardiners Clay or Monmouth Group intervene.

Bedrock

Bedrock below Queens and Kings Counties is comprised of crystalline metamorphic rocks (gneisses and schists) that are similar to those found in Connecticut. The original basement rocks are believed to have been early Paleozoic (Cambro-Ordovician) to Precambrian granite or sandstone more than 400 million years old. These rocks were crystallized by heat and pressure during folding and faulting caused by tectonic forces during early Paleozoic time (200-300 million years ago).

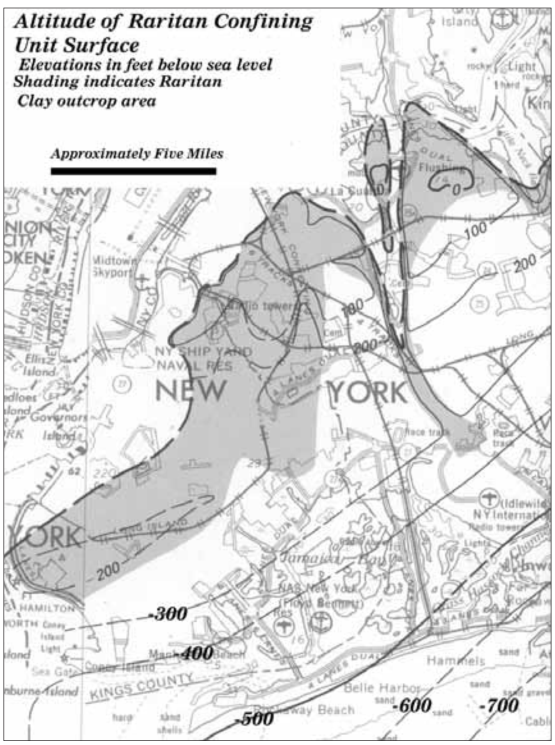
The bedrock surface below Suffolk County is tilted southeast to south at a slope of approximately 50 to 70 feet per mile. It is, therefore, closest to land surface (subcropping) in northwest Queens and Brooklyn, and deepest along the South Shore (over 700 feet deep at the western part of Fire Island). In many places, the upper surface of the bedrock is weathered to a residual clay. Since the water bearing capacity of the unit is extremely low, the bedrock surface is considered to be the bottom of the groundwater reservoir.

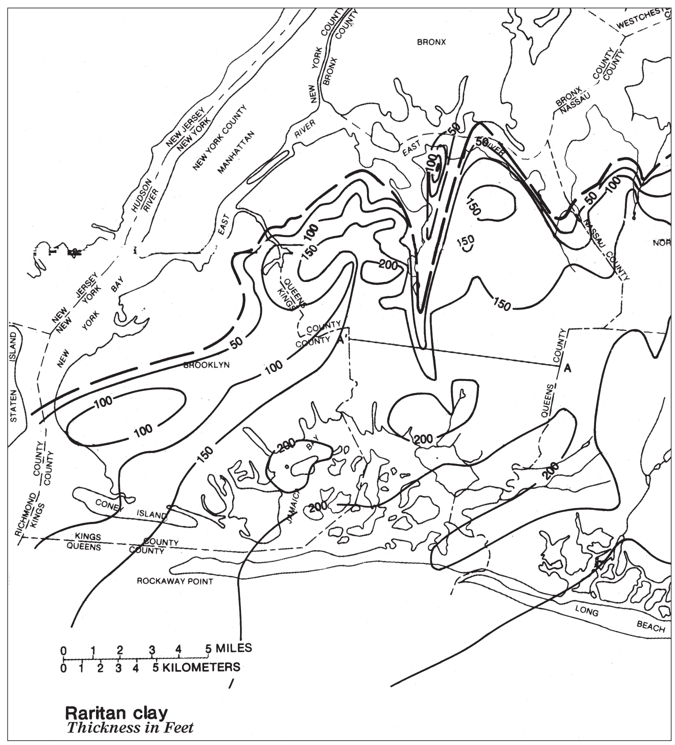


Raritan/Lloyd

The sediments comprising the Raritan Formation lie on the bedrock surface and are believed to have been derived from stream erosion of areas to the north and west during late Cretaceous time (60-100 million years ago). The formation is made up of a lower sand and gravel member (Lloyd Sand) and upper clay member (Raritan clay).

The Lloyd Sand Member has a moderate overall hydraulic conductivity and consists of sand and gravel interbeds, with occasional lenses of clay and silt. The Lloyd's beds are about parallel to the bedrock surface below. Its upper surface lies about 200 feet below sea level in northwest Queens, and over 900 feet below sea level at Rockaway. The unit is believed to terminate somewhere close to the North Shore beneath Long Island Sound, and is not found in Connecticut. The thickness of the Lloyd increases from north to south; it is about 100 feet thick in central Queens, and over 350 feet thick at Rockaway.

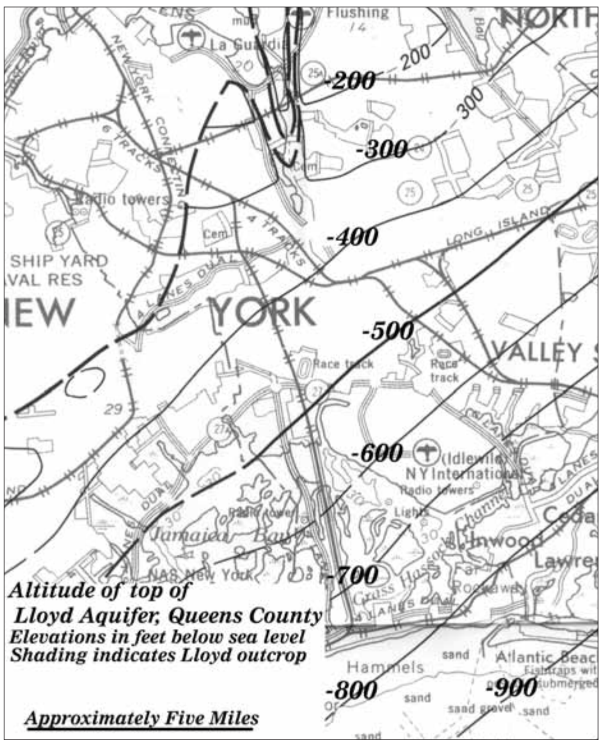




Clay Member of the Raritan Formation

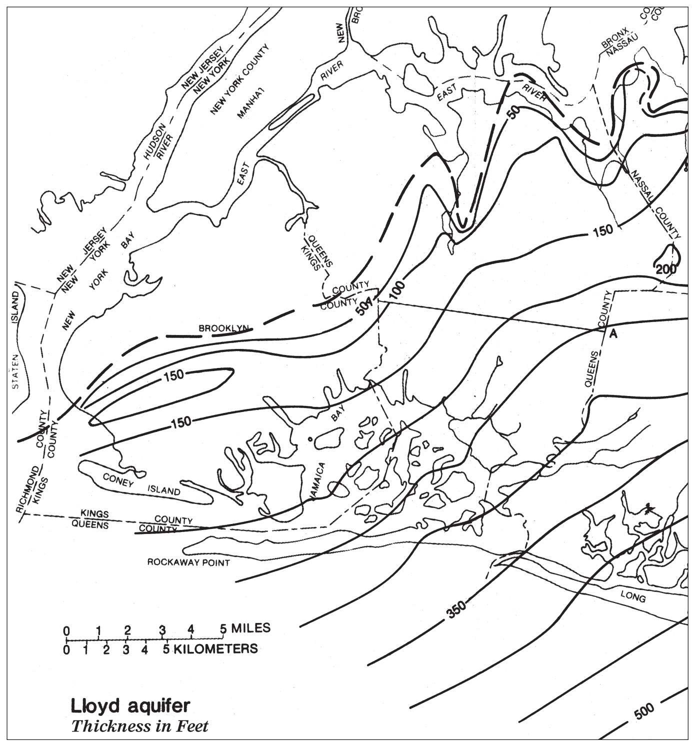
The clay member of the Raritan Formation (Raritan clay) overlies the Lloyd Sand Member throughout Suffolk County. In some locations, however, the clay has been eroded, and glacial deposits overlie the Lloyd, thus providing good hydraulic conductivity between the glacial deposits and the Lloyd aquifer. The Raritan clay, although composed mainly of clay and silt, does contain some sand and gravel beds and lenses; overall, however, the hydraulic conductivity of the clay member is low, and it confines the water in the Lloyd aquifer.

The Raritan clay parallels the Lloyd Sand Member and terminates just offshore in Long Island Sound. The surface of the clay member lies between 0 and 100 feet below sea level in northwest Queens, and about 700 feet below sea level at Rockaway. Clay member thicknesses range between 50 and 100 feet in the northern areas, and reach nearly 300 feet in the western part of Fire Island.



Altitude of top of Lloyd Aquifer, Queens County
Elevations in feet below sea level
Shading indicates Lloyd outcrop

Approximately Five Miles



Lloyd aquifer
Thickness in Feet

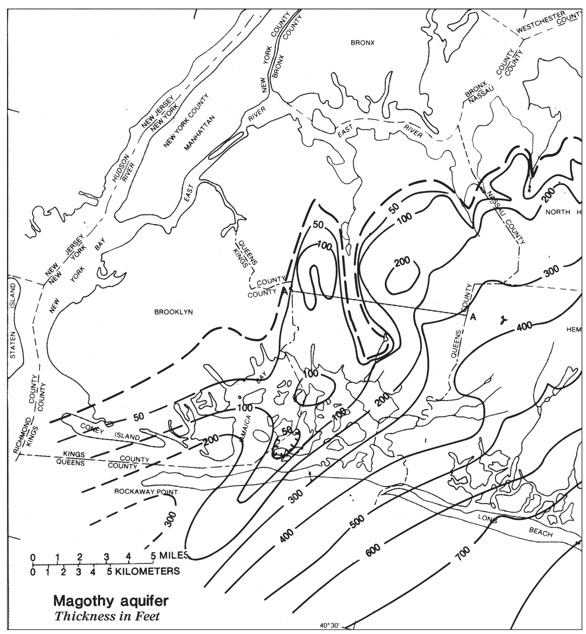
a
5

Magothy

The Magothy Formation - Matawan Group undifferentiated (informally “Magothy”) is composed of river delta sediments that were deposited on top of the Raritan Formation during the late Cretaceous after a period of erosion. It consists of highly permeable quartzose sand and gravel deposits with interbeds and lenses of clay and silt that may have local hydrologic significance.

The Magothy was eroded during the time period between the end of Cretaceous and the Pleistocene. The surface was scoured by glaciers meltwaters that also shaped the Magothy’s surface, creating north-south valleys. Unlike the upper surfaces of bedrock and the members of the Raritan Formation, the highly eroded upper surface of the Magothy does not exhibit any distinctive tilt to the southeast, although bedding planes within the formation have this orientation. Because the upper surface is so irregular, the thickness of the Magothy varies; however, the thickness generally increases from north to south, with the greatest thickness (around 1,000 feet) found along the South Shore.

Altitude of Magothy Aquifer
Elevations in feet below sea level
Shading indicates extent of Magothy Aquifer

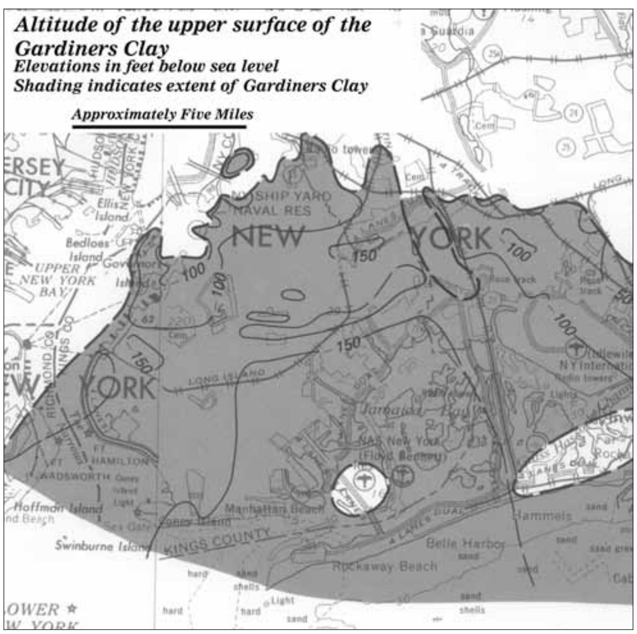


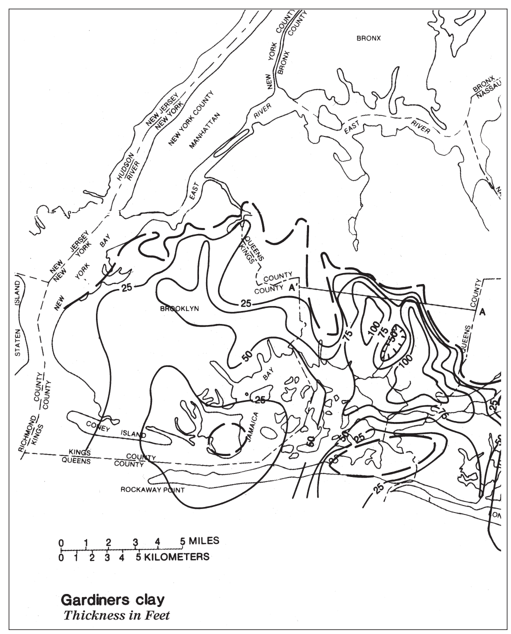
Magothy aquifer
Thickness in Feet

Gardiners Clay

The Gardiners Clay is a shallow marine or brackish-water deposit of late Pleistocene age. It is typically grayish-green to gray; the variation in color is due to the content of minerals such as glauconite. The unit contains some beds and lenses of sand and silt, but its overall hydraulic conductivity is low, making it a confining layer for underlying aquifer formations, particularly the Magothy.

The Gardiners Clay is found along most of the south shore. Its northern extent varies from 3 to 5 miles inland and is indented by long, narrow north-south channels, which indicate the effects of erosion by glacial meltwater streams and areas of nondeposition. The upper surface of the unit ranges in altitude from 40 to 120 feet below sea level. The thickness of the unit increases southward toward the barrier island, reaching thicknesses of over 100 feet.

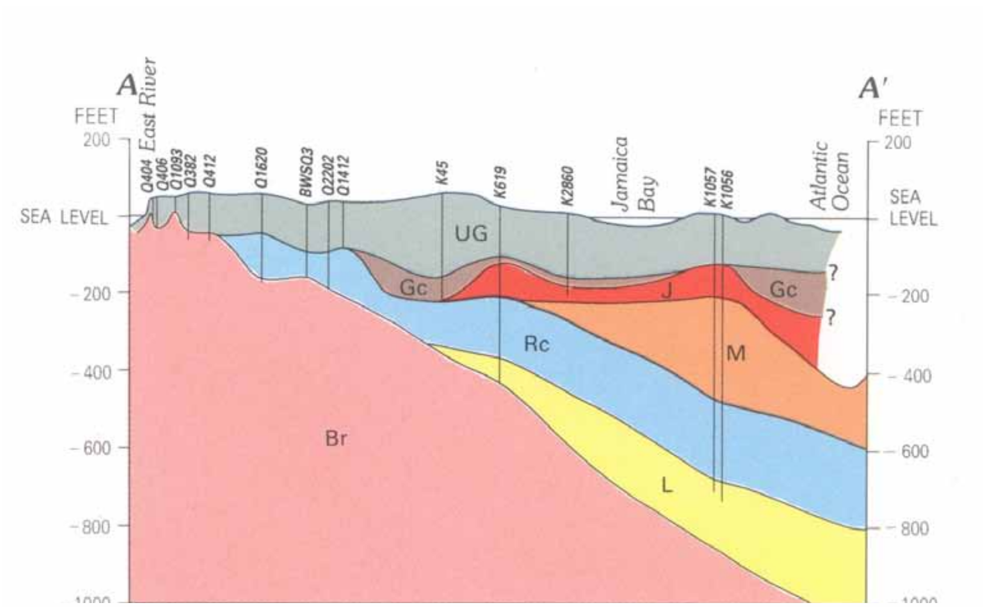


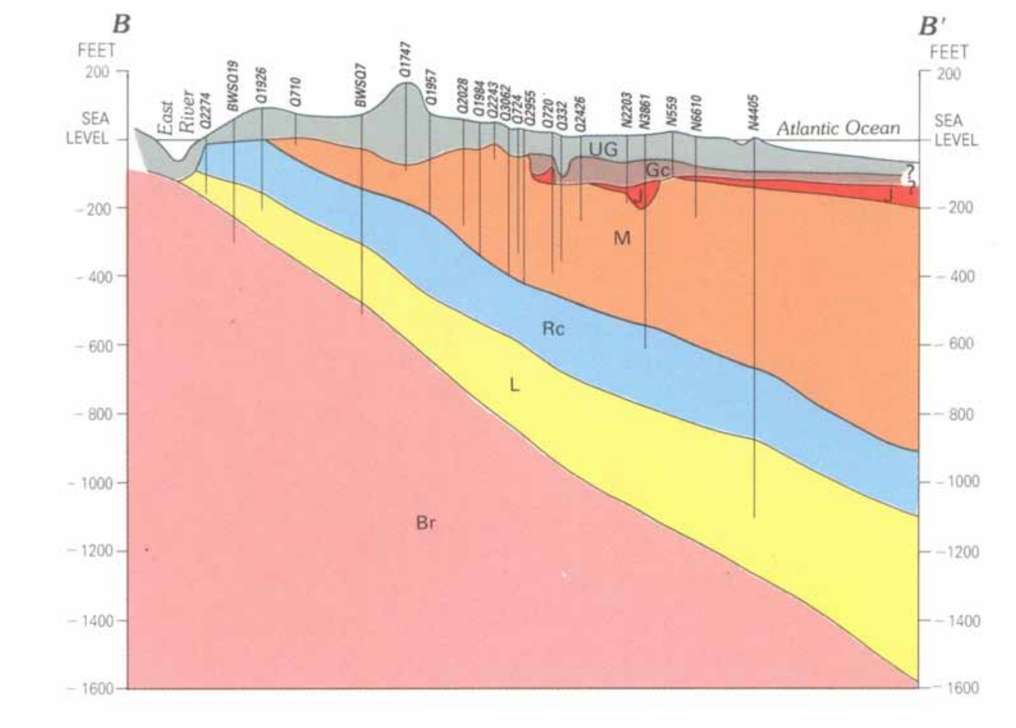


Jameco

The Pleistocene Jameco Gravel unconformably overlies the Monmouth Group and is only present in western Long Island; its eastward extent just barely enters Nassau County. The Jameco Gravel attains thicknesses of 200 feet and is comprised of brown, fine to coarse

grained sand and gravel. The Jameco Gravel may represent fluvioglacial deposits of Illinoian age associated with deposition in an ancestral Hudson River valley (Soren, 1978). The Jameco Gravel makes up the Jameco aquifer which is confined below the Gardiners Clay and displays a average horizontal hydraulic conductivity between 200 to 300 feet per day (Smolensky et al., 1989).





Upper Glacial

Except for a small portion of recent sediments deposited on Long Island, the upper section of sediments on the island consist of Pleistocene glacial deposits which were a result of Wisconsin age glaciation. The upper glacial deposits lie unconformably atop the subcropping Matawan/Magothy, Jameco Gravel and Gardiners Clay.

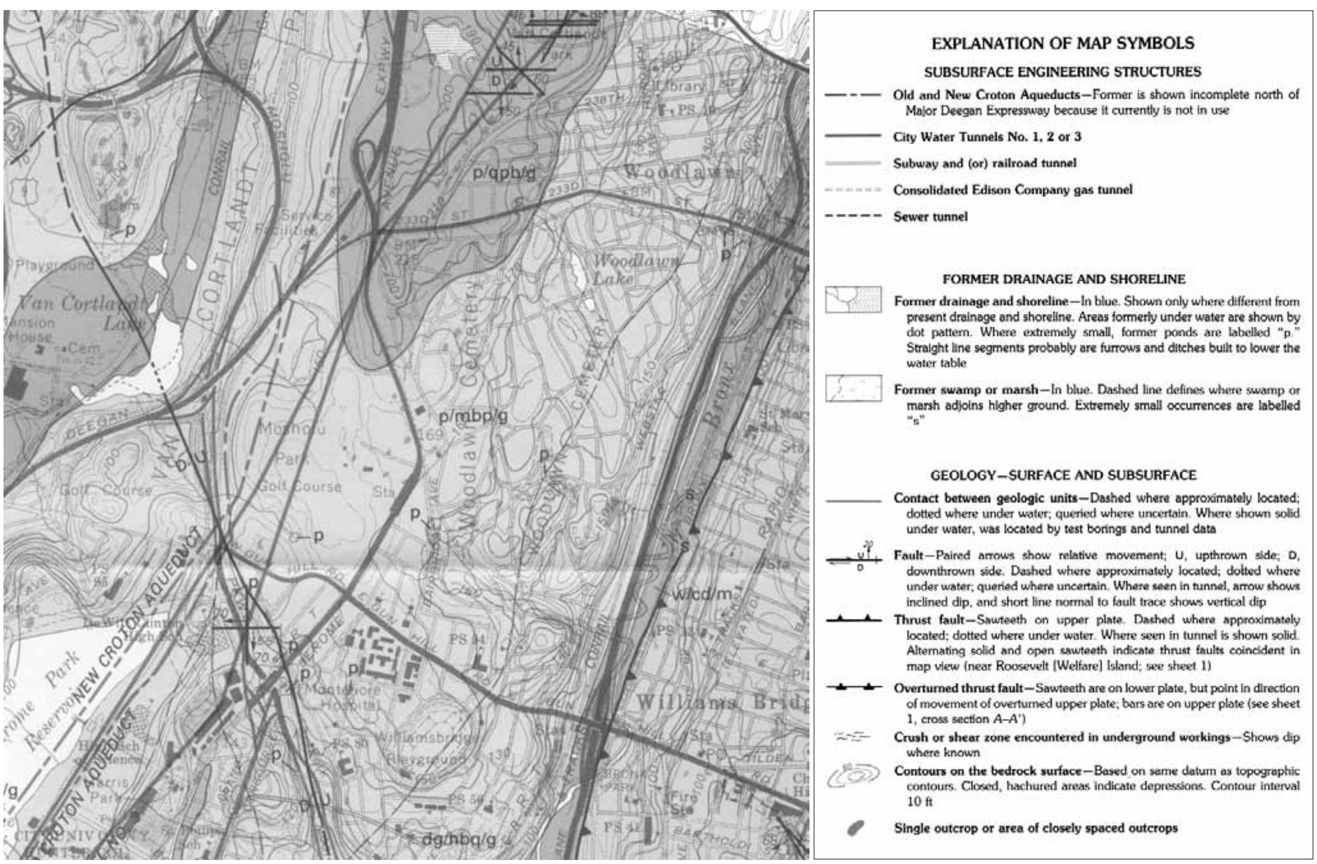
Glacial scour has cut deeply into subcropping formations, particularly into the Matawan/Magothy section. The upper glacial deposits outcrop at the surface and represent a full range of glacial depositional environments from moraine to outwash plain to lacustrine. Upper glacial deposits can reach a thickness of 700 feet. The geomorphology of Long Island is marked by the resultant hills of the Ronkonkoma and Harbor Hill moraines and gently sloping plains associated with glacial outwash deposits. The upper glacial deposits make up the Upper Glacial aquifer, which is the predominant source of private water supply wells. The moraines consist of till composed of sand, clay and gravel and display an average horizontal hydraulic conductivity of 135 feet per day (Smolensky et al., 1989). The highly permeable stratified drift of the outwash plains that lie south of the moraines consists of fine to very coarse grained quartzose sand and pebble to boulder sized gravel. The average horizontal hydraulic conductivity of the glacial outwash deposits is 270 feet per day (Smolensky et al., 1989).

Holocene deposits, which are as much as 50 feet thick and consist of salt-marsh deposits, stream alluvium, and beach sands, occur locally throughout the island. Holocene deposits consist of sand, clay, silt, organic muck, and shells. They are at land surface and generally overlie Pleistocene deposits. They are either unsaturated or too thin and discontinuous to form aquifers. In some areas, they form local confining units.

Geologic Unit	Function	Age
Upper Glacial Aquifer	aquifer	Pleistocene
Gardiners Clay (Kings & Queens Cnty)	confining unit	
Jameco (Kings & Queens Cnty)	aquifer	
Monmouth Group (south shore)	confining unit	Upper Cretaceous
Magothy Formation	aquifer	
Raritan Fm - Clay Member	confining unit	

The Bronx and Manhattan

The Bronx has been the subject of limited geologic explorations and, as a result, few geologic reports (Bulletin GW-32, 1953, Geology in the Bronx and Richmond Counties … by N.M. Perlmutter and T. Arnow) exist that cover the geology of that borough. Similarly with Manhattan, the existence of a “city” in these boroughs has limited the amount of classic geologic studies that can be made. Charles Baskerville has produced a set of engineering geology maps that cover both the Bronx and Manhattan. Mr. Baskerville has used engineering data including data developed from the numerous tunneling projects, such as water tunnels, subway tunnels and power lines. Data from foundation borings for numerous projects such as building and bridge construction were also used. The mapping is intended to assist engineers in foundation design and is not intended to be a definitive geologic investigation. Mr. Baskerville does not devote much space to the identification and in depth description of geologic units (lithology). Instead, he does provide generalized descriptors for the various rock types that exist in the Bronx and Manhattan. More importantly, however, Mr. Baskerville has mapped the existence of bedrock features that bear more relevance to geothermal system. The locations of bedrock faults, bedding contacts and strata folds have been mapped. These features can improve the chances of developing higher than average yielding wells, which will, in turn, reduce the amount of drilling necessary to develop the necessary thermal exchange for the project. Please note that for “closed loop” systems the existence of highly productive fracture zones is irrelevant.



The above map is a section of the Baskerville Bronx map centered on the Mosholu Park in north central Bronx. The map symbols are explained to the right of the map. As can be seen, this map contains a wealth of information usable to the designer of geothermal systems. The blue letters (A,B and C) indicate hypothetical locations considered for a geothermal system. Location “A” is in an area that indicates significant fracturing, shown by the black line that runs from the upper left corner of the map to the lower center of the map. The line is labeled with U/D at several locations. The U infers that that side of the fault is displaced upwards with respect to the other side of the fault, labeled D. In addition to the main line discussed above is a shorter east west fracture that is partially obscured by the letter A. Wells at the intersection of two, or more, fracture systems typically produce more ground water than wells that are located in areas free of fractures or adjacent to single fractures.

Site A is located over the mapped path of one of the City’s water tunnels. Before attempting to drill a well in any location in New York, it is imperative that the possible existence of any underground utilities be discovered. Utilities can include currently active water tunnels, sewers, telephone and power lines, subway lines and steam pipes. In addition to active utilities, “old “unused or abandoned utilities may be found that may include any of the above listed. Therefore, before the drilling starts, the One Call Center for New York and Long Island should be called. Their number is 1-800-272-4480. For additional information and to setup safety seminars call 1-718-631-6700. They also have a WEB page with the address: **WWW.OCUC.net**. The One Call Center will mark the project site with the location of “member” utilities. A list of their members is provided on the WEB page. The New York City agencies, such as sewer and water, are not members and need to be contacted separately.
Site B on the above map is not directly on any mapped faults or fracture systems. The results of drilling at this location should produce a well with an average yield of 20 gallons per minute, or less. However, the key term above is “mapped” fracture system. Just because a fracture system is not mapped it does not mean that a fracture system does not exist at that location. Generally a fracture is mapped when there is evidence of its existence, such as a linear valley, bedrock outcrops, or data developed from subsurface work. When such evidence is not available, the geologist may not know of the existence of a fracture system and, therefore, cannot map it. Therefore, the preliminary design should be for a standing column well, assuming that a low yield well will be drilled, but sufficient flexibility should be built into the design to allow for an alternate design if a high yield well system is drilled. Similarly, in location A, the existence of mapped fractures does not guarantee the production of high yield wells and the system design should be sufficiently flexible to allow for alternate configurations.

Richmond County

The geology of Staten Island is varied and complex, ranging from artificial fill, various glacial deposits including glacial till and glacial outwash, as well as exposed bedrock including ancient serpentines. The geothermal designer, with respect to particular locations in Richmond County, has the option of completing wells in the outwash deposits in eastern Staten Island or the completion of bedrock wells throughout most of the remainder of the borough. Portions of Staten Island are artificially filled wetlands and coastal areas that may contain transmissive deposits. However, it is more likely that the fill materials used are not sufficiently transmissive for water production.

The outwash deposits located in eastern Staten Island are similar to the outwash deposits found in southern Brooklyn and Queens. Both units are capable of ground water yields in the hundreds of gallons per minute to thousands of gallons per minute. However, unlike the Long Island outwash deposits, the outwash on Staten Island are limited to a maximum of 125 feet. The proximity of the outwash deposits to New York Bay places this aquifer in danger of salt water intrusion from over pumping. Therefore, a system of five New York City drinking water wells was limited to pumping less than 5 million gallons of water per day, although the wells were capable of significantly higher yields. These wells have not been operated since the early 1970's. Geothermal systems return the water pumped out to the aquifer, so they should not increase the risk of saltwater intrusion. Salty or contaminated water will increase the maintenance required for wells and well pumps.

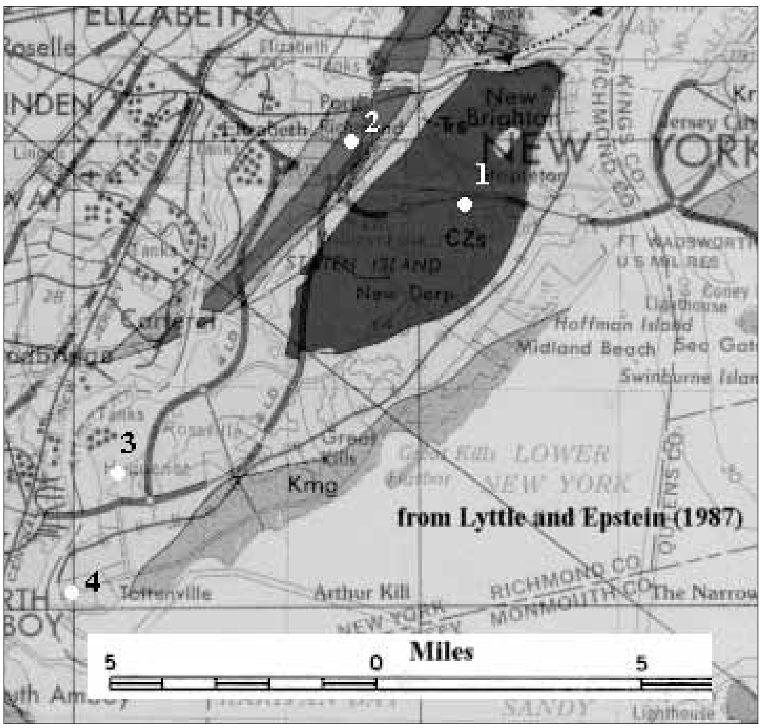
The terminal and ground Moraines of Staten Island are generally composed of glacial till, a material that results from the grinding of rocks by the advancing glacial ice. The material, till, appears to be a hard clay with various amounts of sand and gravel mixed in. Till has poor hydraulic conductivity and should not be considered as a source of ground water. Occasionally sandy till is encountered. These deposits, although more productive than the clay tills discussed above, are still limited to about ten gallons per minute, on average (Soren 87-4048, 1988).

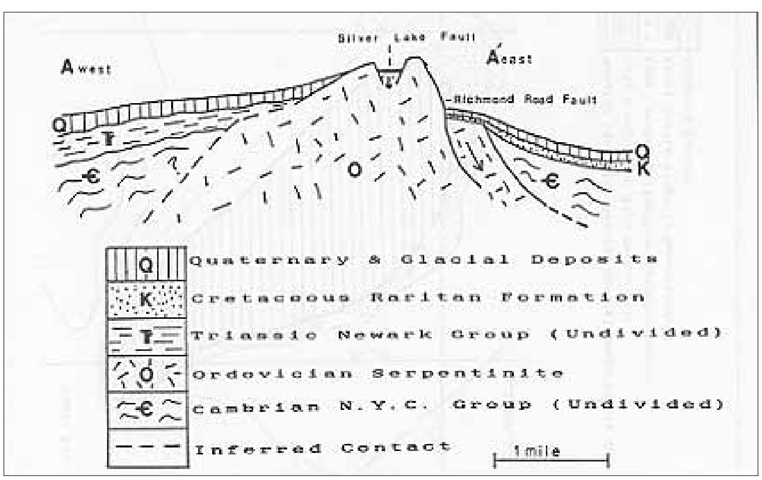
The Raritan Formation underlies the outwash deposits of eastern Richmond. Wells tapping this formation, which includes the Lloyd, or Farrington as it is referred to in New Jersey, have yields as high as 200 gallons per minute. This formation appears to be confined, separated from the water table aquifer, but insufficient data exists to fully make that determination.

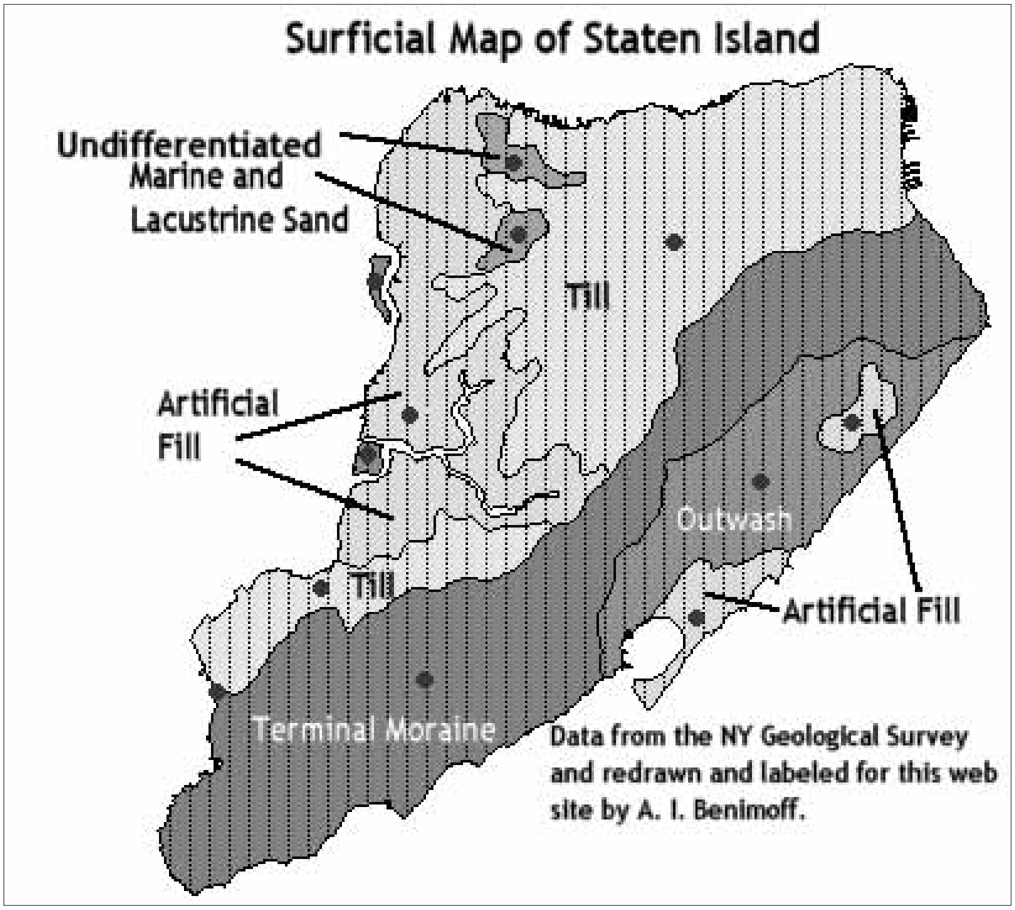
The bedrock units underlying Richmond include the Newark Supergroup (shales, sandstones and limestones), the Palisades Diabase, the Manhattan Schist and the Staten Island Serpentine. Ground water data from the Staten Island portion of the Newark Supergroup is not generally available and, therefore, the yield of this formation within Richmond is not known. However the Newark formations is tapped extensively in Rockland County New York and is found to have an average yield of 83 gallons per minute (Permutter, 101-120, 1959). This average yield is based on a list of wells, which include mostly municple wells, including a well yielding a reported

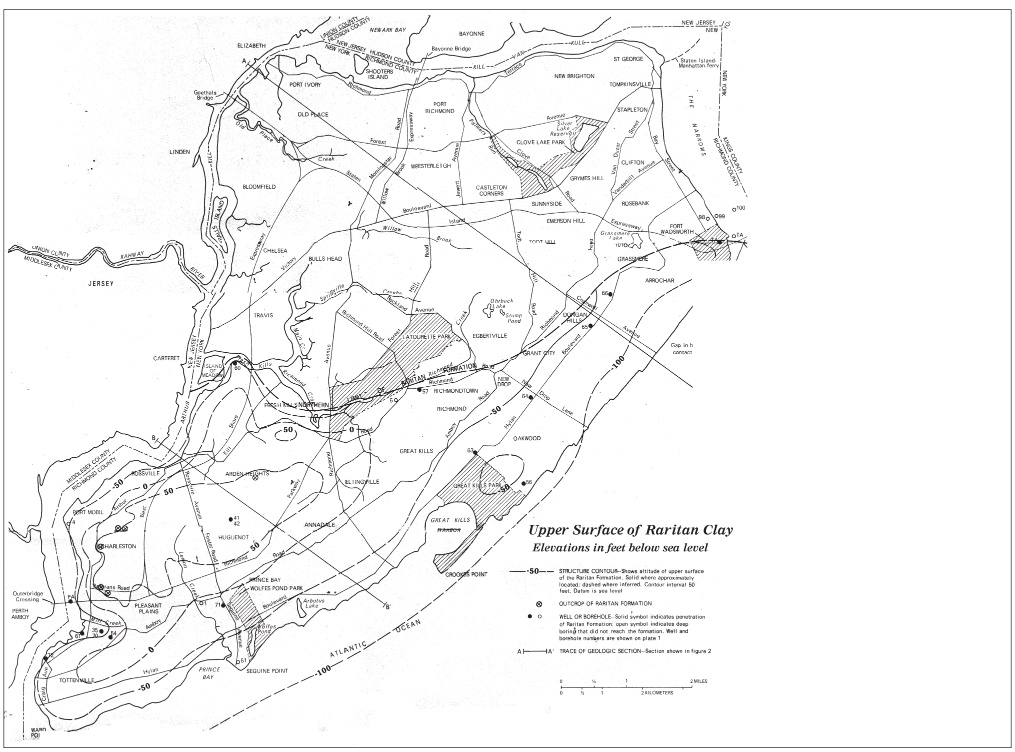
1,515 gallons per minute. If all wells, including domestic wells, tapping this formation were included in the average, the average yield for the formation will be found to be considerably lower, more in the range of 10's of gallons per minute.

The Palisades Diabase is considered a poor water producing formation with yields limited to less than 10 gallons per minute. The Manhattan Schist unit in Richmond is not generally used for water supply due to the existence of more productive unconsolidated deposits. However, wells drilled in the Manhattan Schist in Manhattan and Westchester generally produce yields of between 5 and 50 gallons per minutes, with some wells yielding as high as 150 gallons per minutes. The productivity of this unit is completely dependant on the existence of faults and fractures that may be tapped by the well.






Surficial Map of Staten Island
Undifferentiated
Marine and
Lacustrine Sand
Till
Artificial
Fill
Outwash
Till
Artificial Fill
Terminal Moraine
Data from the NY Geological Survey
and redrawn and labeled for this web
site by A. I. Benimoff.


Upper Surface of Raritan Clay
Elevations in feet below sea level
STRUCTURE CONTOUR--Shows altitude of upper surface of the Raritan Formation. Solid where approximately located; dashed where inferred. Contour interval 50 feet. Datum is sea level
OUTCROP OF RARITAN FORMATION
WELL OR BOREHOLE--Solid symbol indicates penetration of Raritan Formation; open symbol indicates deep boring that did not reach the formation. Well and borehole numbers are shown on plate 1
TRACE OF GEOLOGIC SECTION--Section shown in figure 2
2 MILES
2 KILOMETERS
ATLANTIC OCEAN

Conclusion

The hydrogeology of the City of New York is complex and varied presenting an interesting challenge for the design and implementation of geothermal systems. Since the location of the intended system is critical in determining the nature of the geology and, consequently, the type of well that will be used for the system, the designer must consult the mapping that is in this chapter or additional mapping listed at the end of the chapter. It is important that a hydrogeologist is consulted at the initiation of the design process so that the nature and extent of the drilling can be assessed early.

The cost of well drilling is affected by many variables including non-geotechnical factors such as site access and noise restrictions. Various geologic environments present difficulties to the driller that will extend the amount of time necessary to complete a well. A well drilled in an area that has bedrock close to the land surface is considerably easier to drill than a well that has to first penetrate many feet of unconsolidated deposits. The boring through the unconsolidated deposits must be kept open so that the formation does not fall into the boring, locking the drill tools into the earth. This is done by either using high density drilling fluids to drill through the earth or by installing steel casing as the boring is drilled. If the objective is to tap an unconsolidated aquifer, the well must be finished with a well screen to hold back the aquifer material while letting in the ground water. Bedrock wells, in most cases, do not require well screens. However, bedrock wells generally do not produce as much water as wells screening unconsolidated deposits. Therefore, bedrock wells will be significantly deeper than gravel wells.

Certain sections of New York are underlain by highly productive unconsolidated aquifer materials. Wells tapping these aquifers can produces prodigious quantities of water, limiting the amount of drilling necessary for the project. However, if the underlying aquifer is the Lloyd, as it is in parts of north/central Queens, the New York State Department of Environmental Conservation will not issue a permit for use of the Lloyd, since it is a highly protected aquifer. In that case, it is necessary to utilize any overlying aquifer material, if available, or to drill through the Lloyd, isolating the aquifer with steel casing, and continue into the underlying bedrock.

The following reports were referenced in this chapter:
Buxton, H.T., Shernoff, P.K., 1999,Ground-Water Resources of Kings and Queens Counties, Long Island, New York, U.S. Geological Survey Water Supply Paper 24978, 113p, 7 plates

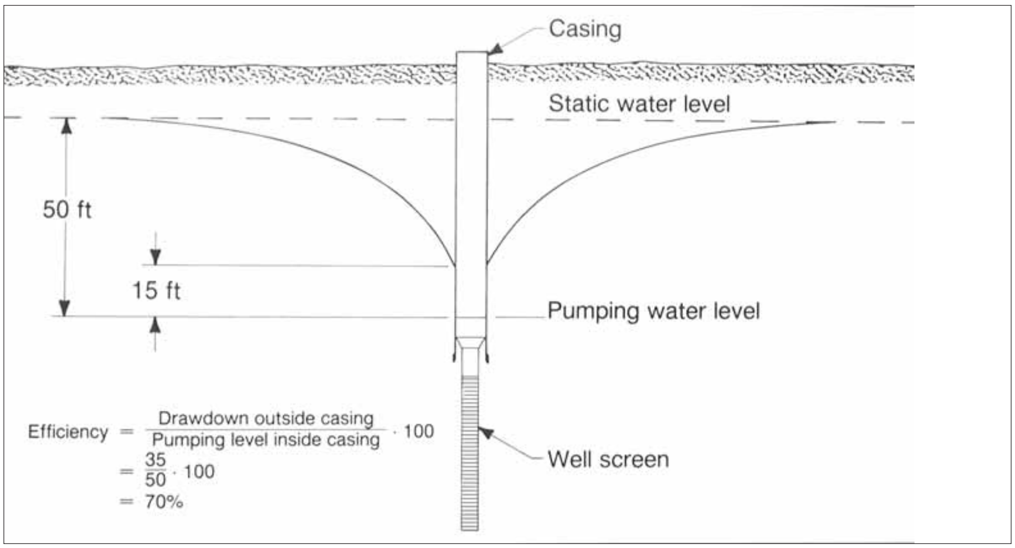
Buxton, H.T., Soren, J., Posner, A., Shernoff, P.K., 1981, Reconnaissance of the Ground-Water Resources of Kings Queens Counties, New York, U.S. Geological Survey Open Report 81-1186, 59 p.

Bedrock and Engineering Geologic Maps of Bronx County and Parts of New York and Queens Counties, New York, Charles Baskerville, Miscellaneous Investigation Series, Published by the U.S. Geological Survey, 1992.

5. b Choosing a geoexchanger

OPEN EARTH COUPLING

Brooklyn and Queens, and any site with a similar geology, are well suited to the geothermal earth coupling formed by a supply and a diffusion well. A requirement of 3 gpm per dominant ton is required from the supply well and a responsible diffusion well must be capable of receiving this flow rate. It should be noted the typical diffusion well is “double the size” of the supply well. This increase in size is attributed to the relative hydrologic potential between a well with a *depressed* source cone around the well head as compared to the *impressed* diffusion cone around the return well.

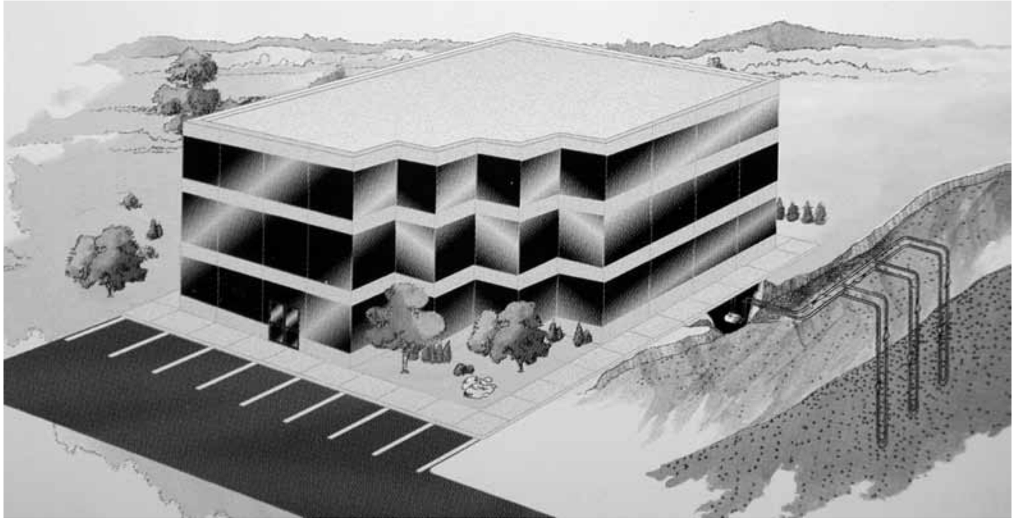


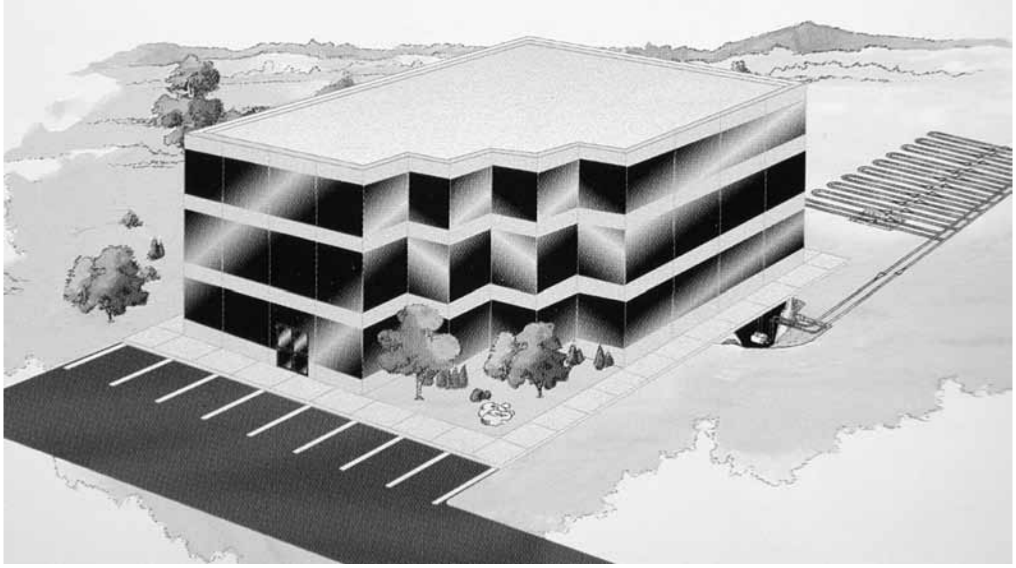
The diameter of the impressive and depressive cones are a function of the permeability of the surrounding geological strata. The only limiting factors to these type systems is the availability of 3 gallons per minute per connected heat pump ton of flow and a responsible method of returning the water to the environment. Aquifer testing and modeling may be necessary if large, multiple well systems are to be installed. This will allow a proper design which avoids overlapping cones and provides sufficient water flow. Typical design temperatures for the New York City area are 50°F well water the year around, heating and cooling season (ARI standards rate at 50°F all year around; new ISO standards rate cooling at 59°F and heating at 50°F entering water).

Attention must be paid to the source of the water being returned to any given aquifer. Earth recharge via septic or sewers is not permitted. The Upper Glacial Aquifer which lies closest to the surface in Brooklyn and Queens may carry both natural and industrial contaminants. The Lloyd aquifer which is the next aquifer down is considered to be pure and uncontaminated cannot be used as a diffusion well if the source water is not also the Lloyd Aquifer. See also the section on permitting. Existing installations east of the East River favor this two-well system. See the description below of the four Long Island Power Authority buildings.

CLOSED EARTH COUPLING

Sites where a concern for surface or ground water quality exists typically utilize closed loop systems. These vertical or horizontal closed loop earth coupling systems are designed to move an antifreeze solution through a series of loops arranged either vertically or horizontally. The material used for this piping is high density plastic pipe with a low friction loss and consequent low pumping effort[1]. This method is employed in areas with polluted water, e.g. do not meet primary drinking quality standards are encountered. Closed loop systems are somewhat less efficient and more costly. There is a trade off between loop pipe length and minimum design temperature. Existing ARI (ARI-330) and ISO (ISO-13256) standards specify design temperatures at 32°F for the heating season and 77°F for the cooling season.





b
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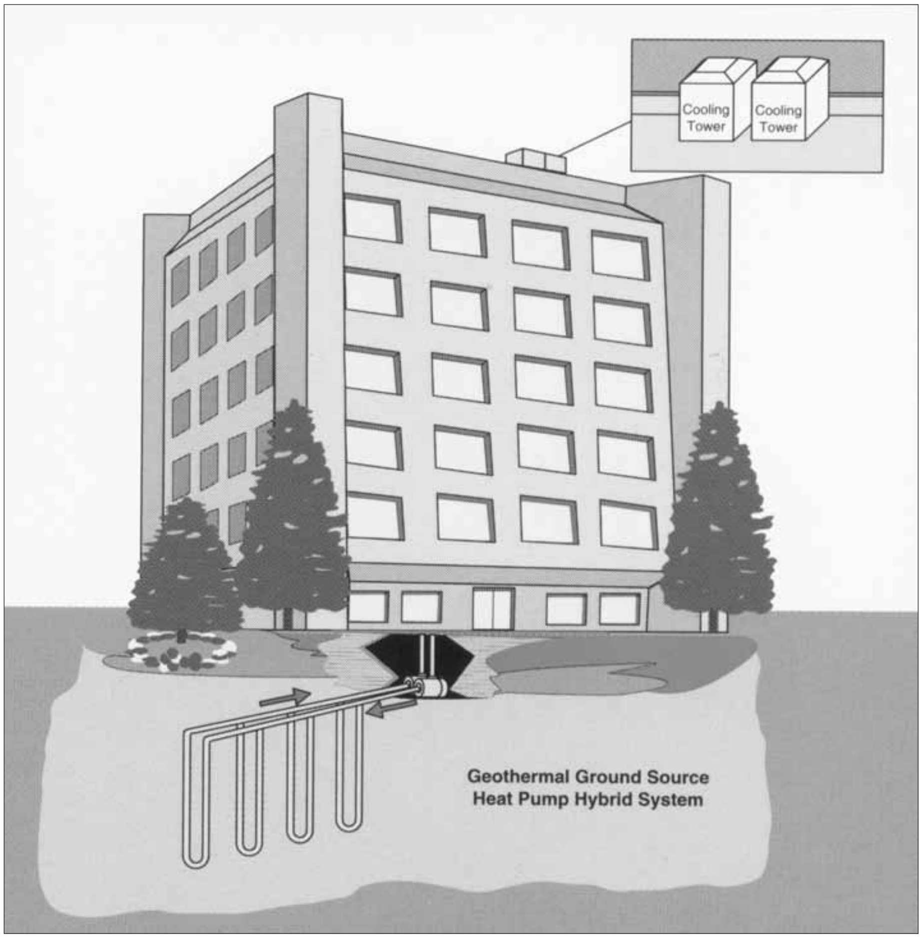
Horizontal closed loops take one of two forms either a straight pipe of approximately 1,000 linear feet per ton, out and returned to the heat pump in a 4-6 foot deep 500 foot trench or a more recent and popular method call the Slinky®. The Slinky® also employs approximately 1,000 linear feet of high density polyethylene pipe but it is coiled and the extended as a flat map similar to child's slinky toy. In this manner an 80-100 foot trench can be loaded with 1,000 feet of pipe providing a one ton capacity. Generally, if trenching is easily achieved and no sharp rocks exist, a horizontal earth coupling system can be less costly than other systems, with the exception of the two well system described above. Typical Slinky®. Installation is shown in figure 2b-4

Vertical Closed Loop earth coupling utilizes the same design specifications and piping methods and material. Antifreeze solutions in the loops are also required. As the earth is warmer at depth, the heating dominated vertical closed loops typically require only 300-400 linear feet of pipe per ton, see figure 5. The average practical heating dominated borehole is 300-400 feet deep, this implies approximately two tons capacity per bore hole.

A cooling dominated vertical closed loop may require nearly twice that length. (keeping in mind a cooling load not only must remove the sensible and latent loads of the building, but also must remove the inductive heat generated by the heat pump's motors.)

See appendix C for the software modeling available for closed loop systems.
Loop length and commensurate **cost** are reduced as the design temperature limits are further away from the average earth temperature, 51°F in this example.



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Performance and efficiency of a typical heat pump in the heating mode at 30°F versus operation at 20°F can be reduced by 15%[2]. In the cooling mode at 70°F vs. 90°F the reduction in performance is approximately 9%, with a reduction in efficiency of approximately 25%! In this example, these penalties are offset by a reduction on total closed loop length by approximately 80 feet per ton for heating and 90 feet per ton for cooling requirements.

While reducing the cost of the loop field is an important design factor, it also can severely impinge upon a design **safety margin**. Designing at the heat pump's minimum or maximum entering temperature limits provide no design. An unusually cold winter or hot/moist summer can place a higher demand on the closed loop than published design conditions, leaving no capacity in the ground loop and driving the loop temperatures beyond the heat pump's design capabilities.

Closed loop systems, are designed for heat pump evaporators operating at or below 32°F, e.g. entering water temperatures below approximately 38°-39°F. Because of the probability of creating ice in a heat pump's evaporator heat exchanger, good closed loop design practices require an antifreeze be added to the closed loop. While the antifreeze will somewhat decrease efficiency it permits the heat pump to operate at these lower temperatures. Antifreeze solutions are typically designed for temperatures 10°F lower than the minimum entering water solution. A common solution of 20% food grade propylene glycol, this solutions provides an 18°F freezing point. This implies a minimum of 28°F (i.e. +10°F) minimum entering water temperature from the ground loop.

We recommend the use of propylene glycol as it is not a pathenogenic poison and is environmentally friendly. However, propylene glycol solution tends to become increasingly viscous as temperatures go below 35°F. The designer must consider this increase in viscosity when designing ground loop pumping.

Other antifreezes without the increased viscosity effect, as methyl alcohol (methanol) are equally effective as antifreeze agents, however, its designation as a poison and flammability do not recommend this compound. Several ethyl alcohol (ethanol) based compounds are also available to the designer. Use of these antifreeze solutions should be tempered with a review of the denaturants used in the ethanol solution. Some of ethanol's denaturants are equally poisonous as methanol.

STANDING COLUMN WELLS (SCW)

Standing column wells consist of a borehole that is cased until competent bedrock is reached. The remaining depth of the well is then self-supporting through bedrock for the remainder of its depth. A central pipe smaller than the well diameter is dropped to form a core through which the water is pumped up, and an annulus into which the water is returned. The length of the central pipe at the bottom is coarsely perforated to form a diffuser. Water is drawn into diffuser and up this central riser pipe. The well pump is usually located at some depth below the water table in-line with central riser pipe. The standing column well combines the supply and diffusion wells into one, and is not dependent upon the presence or flow of ground water, although fractures in the bedrock that allow flow across the well can enhance performance, and reduce the length of the water column.

In practice, standing column wells are a trade-off between the open well systems and the below discussed closed loop earth coupling. The standing column well has the an advantage during the design phase in that the performance can be predicted without an extensive hydro-geological study. The savings in design fees and the elimination of the time period required for the hydro-geological analysis are attractive.

Given that standing column wells are unambiguous in projected performance, the use of this type of geothermal heat exchanger in most of Manhattan, the Bronx and northern Queens, where near surface bedrock can be anticipated is recommended. The standing column well can be designed and expected to perform to specification without the need for a test well. A heating or cooling capacity of 480 to 600 MBH (thousands of Btu/hr, equivalent to 40-50 tons of cooling) can be reliably expected from a 1,500 foot deep standing column well.

Should multiple wells be required, the spacing should be at least 50-75 feet. Closer spacing will affect the performance of the well field as the earth has a limited capacity to accept and reject heat. The diminished performance can be projected with available design software (typically GLPRO, see below).

Geothermal re-injection well water is considered a Class V water use and is regarded by the EPA as a 'beneficial' use. Permitting or notice may be required dependent upon average daily water flow rates. SCW wells shall be installed and serviced by qualified and experienced geothermal well contractors.

EXISTING GEOTHERMAL INSTALLATIONS ON LONG ISLAND

Long Island Power Authority (LIPA, formerly Long Island Lighting Company) has installed open loop geothermal heat pumps in four of its buildings over the past six years, see table 2a – 1 – LIPA facilities.

Facility	Design Load	Completed	
Brentwood	180 tons	1994	retrofit of 1958 geo system
Riverhead	80 tons	1997	
Garden City	80 tons	1998	
Hewett	100 tons	2000	

Table 2a – 1 Long Island Power Authority Two Well (Open) Geothermal Heat Pump Installations

Of particular note is the Brentwood facility[3], designed with an R-12 ground source heat pump installation in 1958. The facility has two wells, one a supply and one a diffusion well, both operational since 1958. The facility is a 6,500 square feet, two story building, providing office accommodations for 300 operating staff, and hosts a large cafeteria. Some offices, lockers and workshops are located in the basement, which also houses eighteen geothermal heat pump modules. The water to water geothermal heat pump modules replaced two 350 kW and one 900 kW gas fired boiler. The original wells and pumps were retained, but with a new variable frequency drive (VFD) which provides additional operational cost savings. A conceptual schematic of the system is shown in figure 2a – 7.

Note the modules are not centralized as in most other commercial applications. Each of the existing air handlers was left unmodified and was provided with matching capacity of heat pump modules. A comprehensive Honeywell system is employed to control each of the modules, air handler pumps and other related controls.

The Brentwood facility has been available to qualified engineering and design professionals for review and is well documented.

Based upon the success of the Brentwood operation, subsequent installations were made at the Riverhead operations facility, the Garden City Office and the Hewett Office. The Hewett Office has tied the geothermal heat pumps into a hybrid cooling tower system.

(Footnotes)

[1] High density polyethylene pipe is specified as 3408 resin with a cell classification of 345434C or 345534C; pipe should be marked along its length with these specifications. Suppliers in the New York area are Driscopipe, Charter Pipe, Vanguard Plastics and others.

[2] Typical GSV 048 heat pump for HEATING at 35°F, 36.9 mbtuh (3.56 COP) vs. at 20°F, 31.4 mbtuh (3.12 COP). For COOLING at 70°F, 50.9 mbtuh (17.9 EER) vs. at 90°F 47.1 mbtuh (13.7 EER)

[3] *Long Island Lighting Co., Brentwood Facility*, ClimateMaster 97-BB101-9410-0, July 30, 1994

a. Hydrogeology of NYC
b. Choosing a Geo-exchanger using Hydrogeological Analysis

5

a
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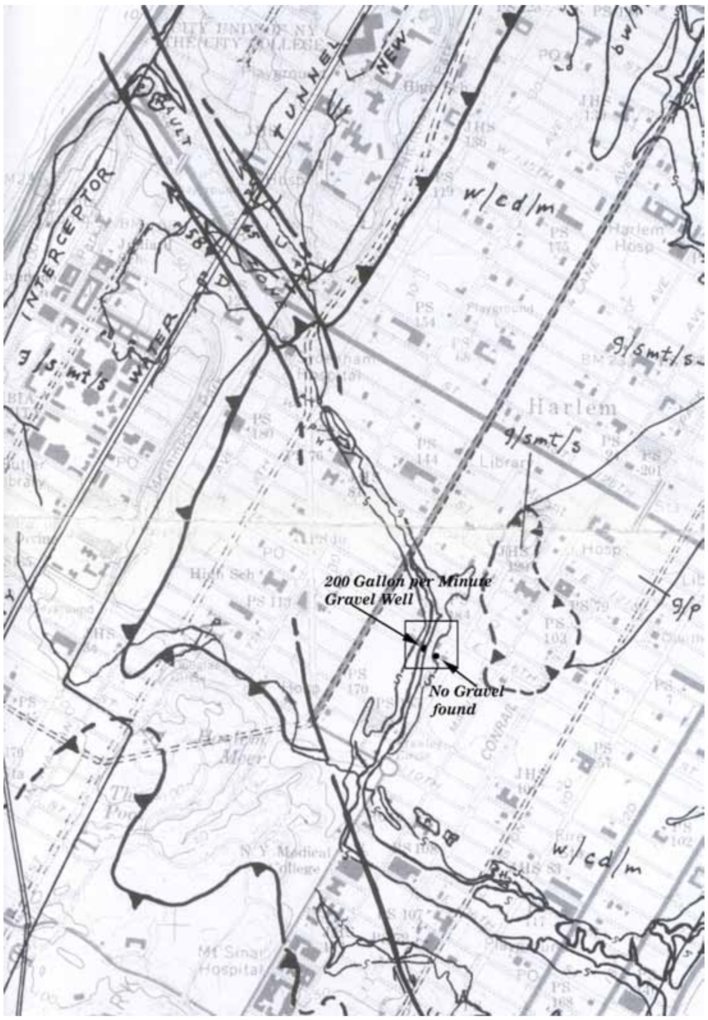
5.a The Hydrogeology of New York City

The geology of the New York City counties is complex and varied. Geologic formations range from Precambrian bedrock the age of which can be measured in billions of years to glacial deposits that are less than twelve thousand years old to land filled areas that were created in the recent past. The stratigraphy of geologic units tends to be ordered with the younger formations resting on top of older formations. The oldest formations, the crystalline bedrock, such as granites and gneisses, form the "basement" rocks, with younger, softer rocks and unconsolidated deposits, such as sand, gravel and clay, resting on top of the basement. In New York City, the basement-rocks are generally inclined so that they are close to the land surface, or are the land surface, in the Bronx and Manhattan and parts of Queens and Richmond and slope downward towards the southeast. Southeastern portions of Queens and eastern portions of Kings counties are covered with sedimentary deposits with the bedrock as much as 1000 feet below the land surface in south Brooklyn and Queens.

If the "project site" is located in Manhattan or the Bronx, it is expected that the geo-exchange wells will be drilled into the bedrock since the likelihood of encountering usable quantities of granular aquifer materials in these counties is unlikely. Conversely, if the project site is located in southern Brooklyn or Queens, several productive unconsolidated aquifers exist in these locations. Therefore, either the project designer has the option of using extraction/diffusion wells or standing column wells.

Site C as shown on the map below is located adjacent to a mapped thrust fault, a fault in which one block (referring to the section of rock on one side of a fault and not to city blocks) is pushed over the top of another block. The symbol for a thrust fault used in the map above is a heavy line with a saw tooth pattern. The points of the saw tooth refer to the downward movement of the fault plane. Since these fault types generally produce shallow fault angles, a well drilled on the downward side of the fault line will encounter the fault plane further down as the location of the well is moved further away (in the direction of the saw tooth pattern, from the fault line. If the well is located on the upward side of the fault, the main (mapped) fault plane will be missed. However, since thrust fault systems tend to have multiple planes (like a stack of papers pushed from the side), it may be possible to develop a productive well on the "wrong" side of the fracture line. Again, just because the fault is mapped does not guarantee a productive well.

The section of the Baskerville Manhattan map, "Bedrock and Engineering Geology Maps of New York County and Parts of Kings and Queens Counties, New York, and Parts of Bergen and Hudson Counties, New Jersey", shown below is for an area north of Central Park. The box on the map indicates an area that is currently being investigated for geothermal potential. An 8 story apartment building with 130 dwelling units is planned for the site. The map indicates that the project site lies over a former swamp or marsh associated with a drainage channel or stream. During drilling of test wells, a productive gravel zone was discovered at the western end of the project site. The gravel was found to be absent less than 75 feet to the east. The presence and absence of the unconsolidated aquifer corresponds very well with the mapping. The mapping also shows a fault zone that crosses Manhattan starting at the Hudson River at 125th street and trends towards the southeast. The mapping indicates that the fault zone does not cross the project site, but turns south, away from the mapped drainage area, avoiding the project site. Several deep wells were drilled as test wells, for this project. The wells ranged from 600 feet to 900 feet deep and had yields ranging from 150 to 30 gallons per minute. It is clear from these results that these wells are tapping significant fractures, even though none are mapped in the immediate area of the project site. This illustrates the need for a thorough and careful analysis of any given site.



Working in bedrock areas, the Bronx and Manhattan and portions of Staten Island, requires design flexibility since the actual outcome of the drilling program cannot be predicted in advance. The system designer should assume that the wells to be drilled will not produce sufficient water for the project requirements and, therefore, the wells should be designed as standing column wells with minimal extraction. If, as described above, high yielding wells are developed, the depth of the wells can be limited in proportion to the yield of the wells.

Brooklyn/Queens

The geology of Brooklyn and Queens is very different from the geology of the other boroughs. Where The Bronx, Manhattan and parts of Richmond are predominantly underlain by bedrock with little if any soil covering the rock surface, most of Queens and Brooklyn have very thick surficial deposits of unconsolidated material overlying the bedrock basement. These deposits range from clay to gravel and are from zero to over 1,000 feet deep. The sand and gravel aquifers include the Upper Glacial, Jameco, Magothy and the Lloyd. These aquifers are all extensively used as sources of ground water for eastern Long Island. The most widely used aquifer for municipal water supplies is the Magothy Aquifer. The Lloyd aquifer is the deepest aquifer, directly in contact with the underlying bedrock. The Lloyd is a restricted use, protected, aquifer only available for use by communities that have no other option for a water supply, such as barrier island communities that find their shallow wells become brackish. The New York State Department of Environmental Conservation will not allow the use of the Lloyd for extraction/diffusion type geothermal wells. The Jameco and Upper Glacial aquifers are shallower lower productivity aquifers that may be available for use depending on the project location.

Table 1. Major hydrogeologic units of the Long Island groundwater reservoir.

Hydrogeologic Unit	Approximate Maximum Thickness	Water-Bearing Character
Upper glacial aquifer	400’	Mainly sand and gravel of moderate to high permeability; also includes clayey deposits of low permeability.
Gardiners Clay	150’	Clay, silty clay, and a little fine sand of low to very low permeability.
Jameco aquifer	200’	Mainly medium to coarse sand of moderate to high permeability.
Magothy aquifer	1000’	Coarse to fine sand of moderate permeability; locally contains highly permeable gravel, and abundant silt and clay of low to very low permeability.
Raritan Clay	300’	Clay of very low permeability; some silt and fine sand of low permeability.
Lloyd aquifer	300’	Sand and gravel of moderate permeability; some clayey material of low permeability.

Table from "pbisotopes.ess.sunysb.edu/geo101_f00/articles/exam_2/liqr/ table1.htm - 4k

All Long Island aquifers receive their fresh water from precipitation. Long Island receives, on average, about 44 inches of precipitation a year. Of this, about half of the precipitation, or approximately 22 inches of rain, percolates into the ground and is recharged into the groundwater system. The remaining precipitation is either evaporated, taken up by plants, or runs off into creeks, bays and estuaries. In areas where the water table and the ground surface meet, streams, ponds and wetlands are formed. In an undisturbed natural setting, (e.g., before human activities) all of Long Island’s groundwater would ultimately reach the coast where the ground water would mix with and the ocean. This process is called underflow - due to human activity, this process has been significantly changed so that not all water in the ground water system is returned to the ocean.

Today, ground water is withdrawn from the system constantly. Over 138 billion gallons of water is taken each year from beneath Nassau and Suffolk Counties. In coastal areas, as water is drawn up for use, less groundwater is available to be discharged into the estuaries. The resulting loss of water and pressure allows saltwater from the ocean to flow into the aquifer, causing the ground water to become saline, resulting in a condition called "saltwater intrusion". New water from precipitation is constantly recharging, or replenishing, the aquifers. Unfortunately, as water recharges the system, it can easily carry contaminants with it into the ground water. Since it is the shallowest and closest to most sources of contamination, the Upper Glacial aquifer is the most heavily contaminated of the three. The next most seriously contaminated aquifer is the Magothy, which is the layer below the Upper Glacial. The Magothy aquifer supplies over 90% of the water used in Nassau County and about 50% of all water used in Suffolk County.

The heat exchangers which transfer heat in or out of the heat pump refrigerant should be of an alloy such as copper-nickel that experiences no ill effects from salinity or variation in pH. The contaminants in the ground water will have an effect on the maintenance requirements for the well and well pump. See Chapter 3, Description of Geothermal Heat Exchangers for a discussion of potential problems with open wells due to water quality and other factors.

Principal Hydrologic Units

The three principal aquifers of Long Island are (top to bottom) the Upper Glacial Aquifer, the Jameco, the Magothy Aquifer, and the Lloyd Aquifer.

Continental glaciers of Wisconsinan age (20 to 86 thousand years ago) brought to Long Island the materials that now comprise nearly all of its surficial sediments. Glacial material was deposited in two terminal moraines: the Ronkonkoma moraine, which forms Suffolk's "spine" and South Fork, and the Harbor Hill moraine, which runs along the North Shore and forms the North Fork. Some of the original glacial material (till) can still be seen along the north shore of the South Fork, at Montauk, and on Shelter Island, where it acts to retard the downward movement of recharge.

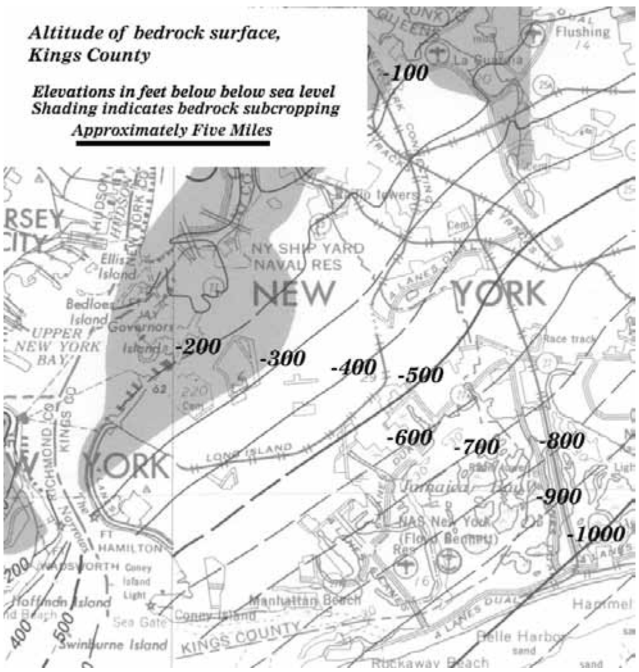
Most of the glacial material was reworked by meltwater to form large, sandy outwash plain deposits south of, and between, the two moraines. These highly permeable, stratified sand and unconsolidated deposits filled in the valleys eroded on the surface of the Magothy (although some filling may have occurred prior to the ice sheet's advance to Long Island).

The glacial deposits can reach thicknesses of up to 700 feet (e.g., in the "Ronkonkoma Basin"). They generally overlie Magothy deposits, except in areas of the North Shore where the Magothy was scoured away by glaciers, and in areas of the South Shore where the Gardiners Clay or Monmouth Group intervene.

Bedrock

Bedrock below Queens and Kings Counties is comprised of crystalline metamorphic rocks (gneisses and schists) that are similar to those found in Connecticut. The original basement rocks are believed to have been early Paleozoic (Cambro-Ordovician) to Precambrian granite or sandstone more than 400 million years old. These rocks were crystallized by heat and pressure during folding and faulting caused by tectonic forces during early Paleozoic time (200-300 million years ago).

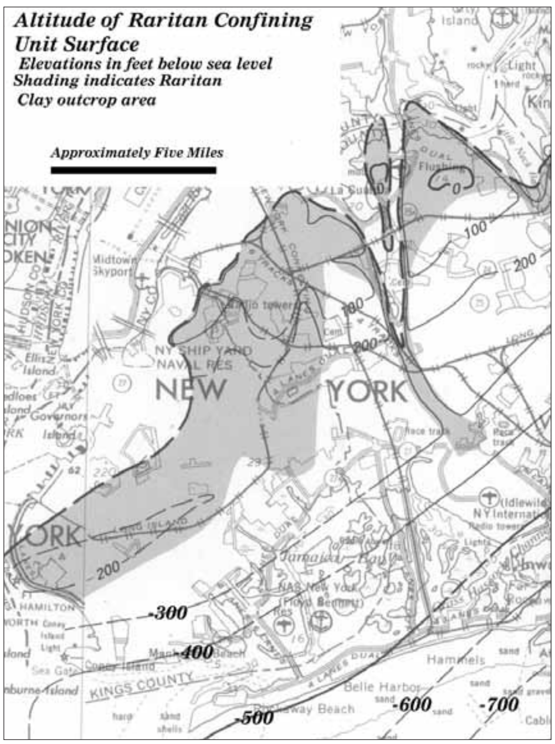
The bedrock surface below Suffolk County is tilted southeast to south at a slope of approximately 50 to 70 feet per mile. It is, therefore, closest to land surface (subcropping) in northwest Queens and Brooklyn, and deepest along the South Shore (over 700 feet deep at the western part of Fire Island). In many places, the upper surface of the bedrock is weathered to a residual clay. Since the water bearing capacity of the unit is extremely low, the bedrock surface is considered to be the bottom of the groundwater reservoir.

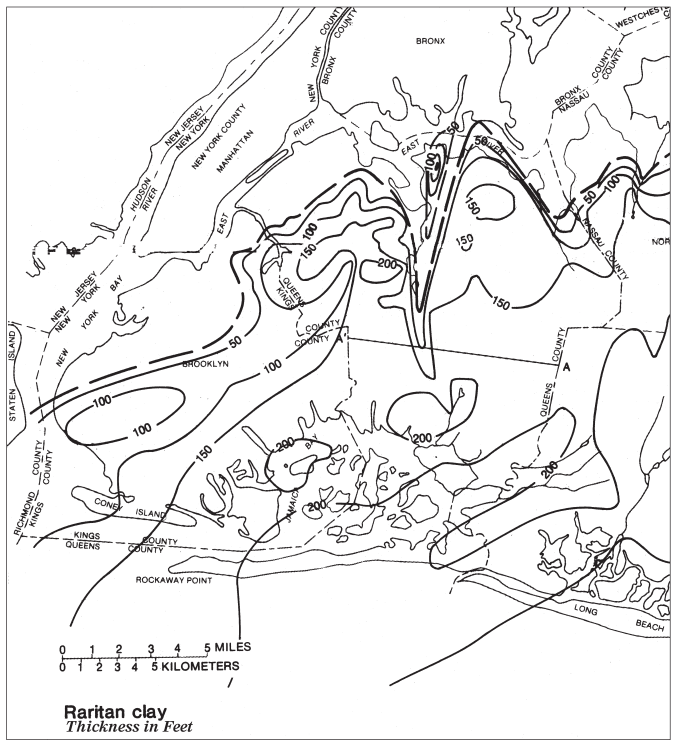


Raritan/Lloyd

The sediments comprising the Raritan Formation lie on the bedrock surface and are believed to have been derived from stream erosion of areas to the north and west during late Cretaceous time (60-100 million years ago). The formation is made up of a lower sand and gravel member (Lloyd Sand) and upper clay member (Raritan clay).

The Lloyd Sand Member has a moderate overall hydraulic conductivity and consists of sand and gravel interbeds, with occasional lenses of clay and silt. The Lloyd's beds are about parallel to the bedrock surface below. Its upper surface lies about 200 feet below sea level in northwest Queens, and over 900 feet below sea level at Rockaway. The unit is believed to terminate somewhere close to the North Shore beneath Long Island Sound, and is not found in Connecticut. The thickness of the Lloyd increases from north to south; it is about 100 feet thick in central Queens, and over 350 feet thick at Rockaway.

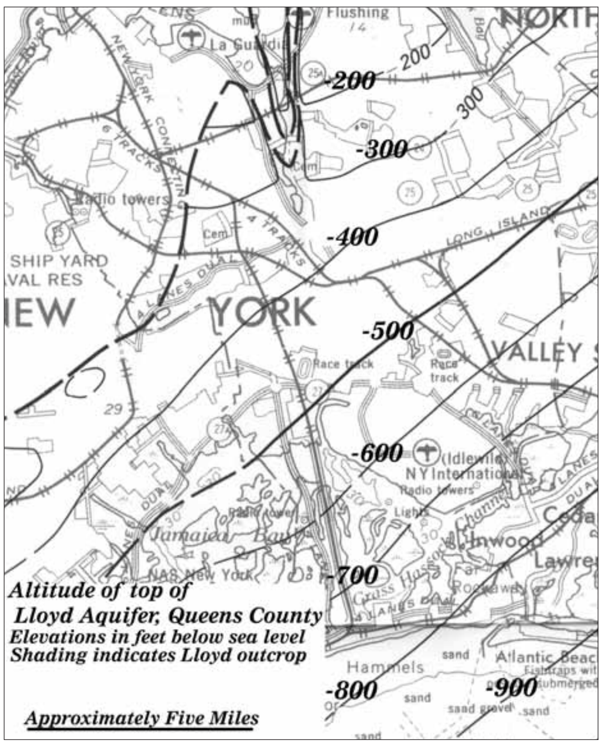




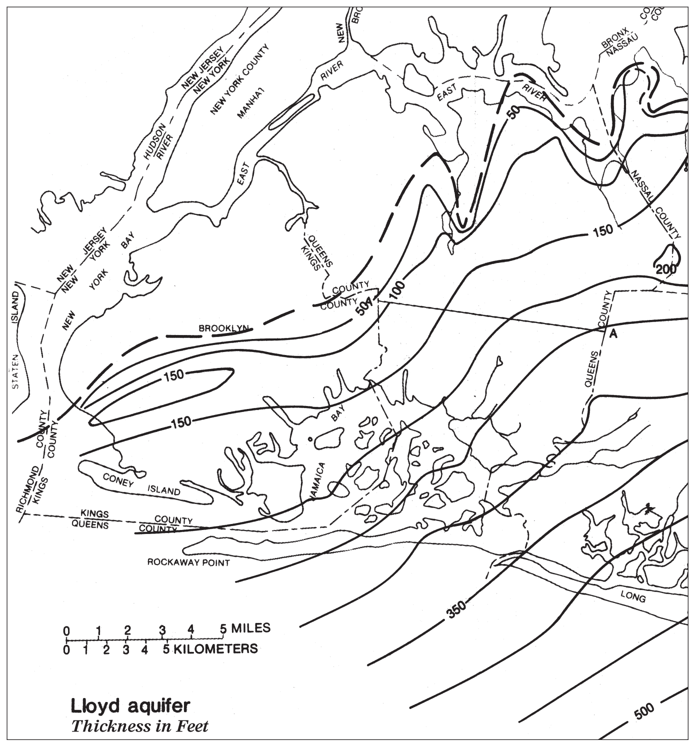
Clay Member of the Raritan Formation

The clay member of the Raritan Formation (Raritan clay) overlies the Lloyd Sand Member throughout Suffolk County. In some locations, however, the clay has been eroded, and glacial deposits overlie the Lloyd, thus providing good hydraulic conductivity between the glacial deposits and the Lloyd aquifer. The Raritan clay, although composed mainly of clay and silt, does contain some sand and gravel beds and lenses; overall, however, the hydraulic conductivity of the clay member is low, and it confines the water in the Lloyd aquifer.

The Raritan clay parallels the Lloyd Sand Member and terminates just offshore in Long Island Sound. The surface of the clay member lies between 0 and 100 feet below sea level in northwest Queens, and about 700 feet below sea level at Rockaway. Clay member thicknesses range between 50 and 100 feet in the northern areas, and reach nearly 300 feet in the western part of Fire Island.



Altitude of top of Lloyd Aquifer, Queens County
Elevations in feet below sea level
Shading indicates Lloyd outcrop

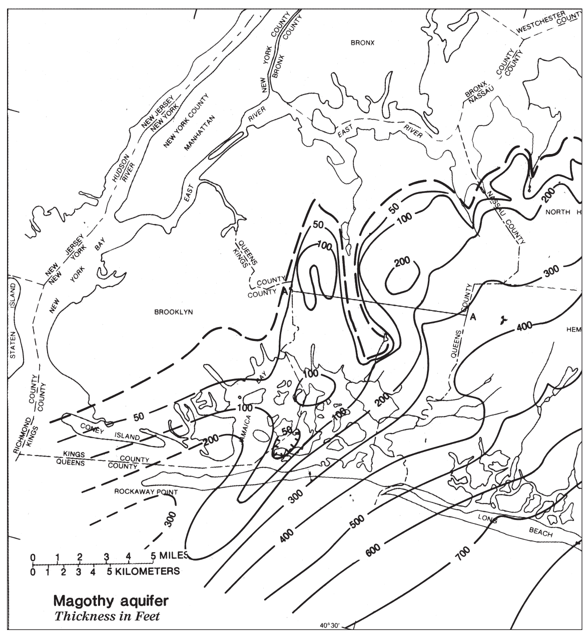


Lloyd aquifer
Thickness in Feet

Magothy

The Magothy Formation - Matawan Group undifferentiated (informally “Magothy”) is composed of river delta sediments that were deposited on top of the Raritan Formation during the late Cretaceous after a period of erosion. It consists of highly permeable quartzose sand and gravel deposits with interbeds and lenses of clay and silt that may have local hydrologic significance.

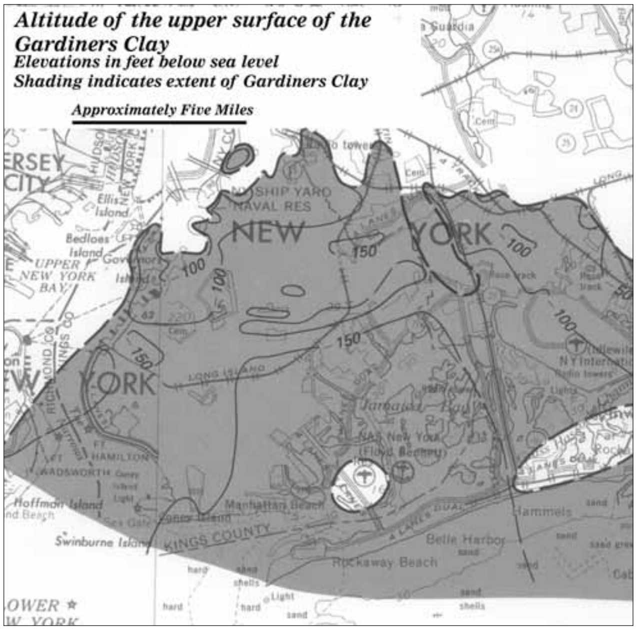
The Magothy was eroded during the time period between the end of Cretaceous and the Pleistocene. The surface was scoured by glaciers meltwaters that also shaped the Magothy’s surface, creating north-south valleys. Unlike the upper surfaces of bedrock and the members of the Raritan Formation, the highly eroded upper surface of the Magothy does not exhibit any distinctive tilt to the southeast, although bedding planes within the formation have this orientation. Because the upper surface is so irregular, the thickness of the Magothy varies; however, the thickness generally increases from north to south, with the greatest thickness (around 1,000 feet) found along the South Shore.

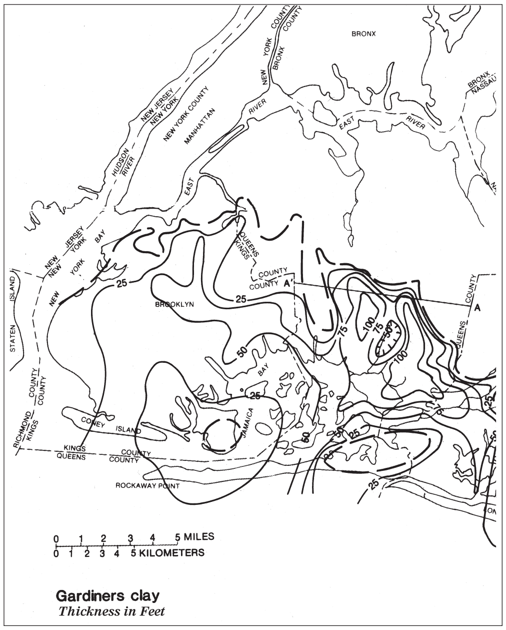


Gardiners Clay

The Gardiners Clay is a shallow marine or brackish-water deposit of late Pleistocene age. It is typically grayish-green to gray; the variation in color is due to the content of minerals such as glauconite. The unit contains some beds and lenses of sand and silt, but its overall hydraulic conductivity is low, making it a confining layer for underlying aquifer formations, particularly the Magothy.

The Gardiners Clay is found along most of the south shore. Its northern extent varies from 3 to 5 miles inland and is indented by long, narrow north-south channels, which indicate the effects of erosion by glacial meltwater streams and areas of nondeposition. The upper surface of the unit ranges in altitude from 40 to 120 feet below sea level. The thickness of the unit increases southward toward the barrier island, reaching thicknesses of over 100 feet.

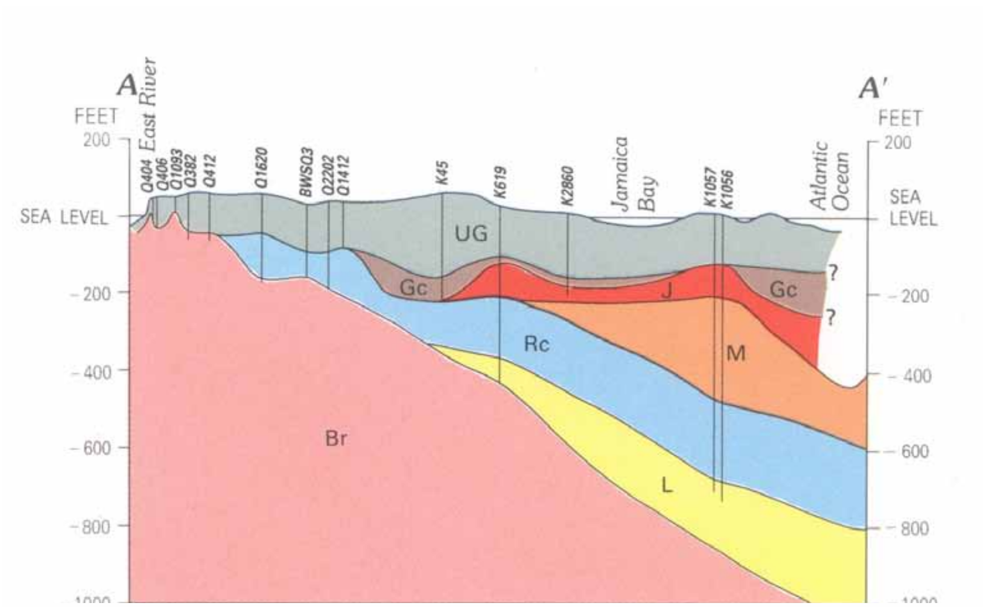


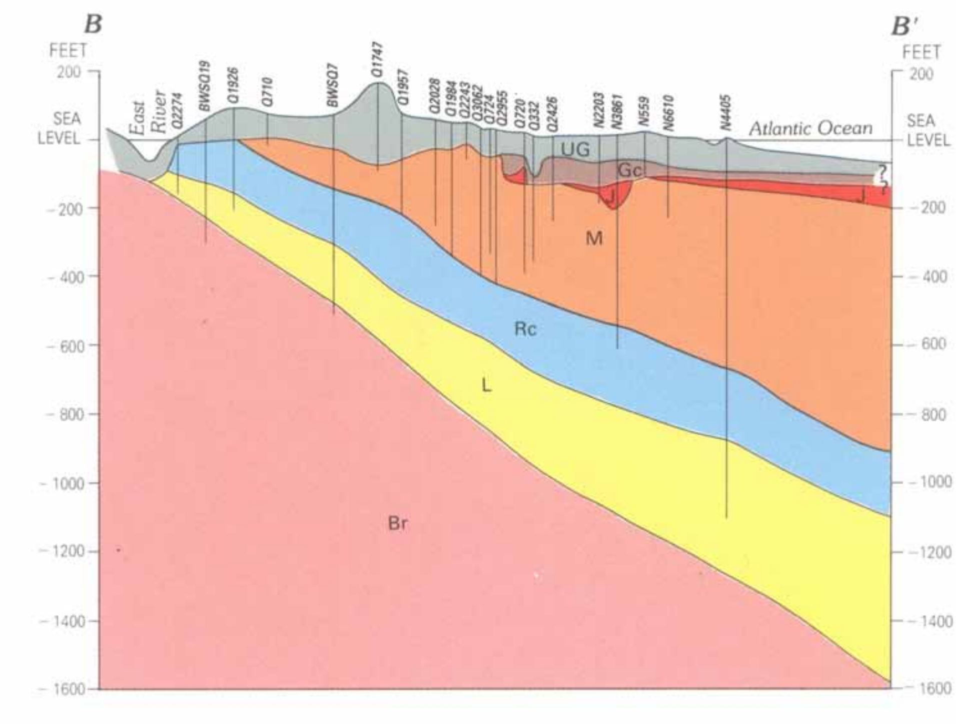


Jameco

The Pleistocene Jameco Gravel unconformably overlies the Monmouth Group and is only present in western Long Island; its eastward extent just barely enters Nassau County. The Jameco Gravel attains thicknesses of 200 feet and is comprised of brown, fine to coarse

grained sand and gravel. The Jameco Gravel may represent fluvioglacial deposits of Illinoian age associated with deposition in an ancestral Hudson River valley (Soren, 1978). The Jameco Gravel makes up the Jameco aquifer which is confined below the Gardiners Clay and displays a average horizontal hydraulic conductivity between 200 to 300 feet per day (Smolensky et al., 1989).





Upper Glacial

Except for a small portion of recent sediments deposited on Long Island, the upper section of sediments on the island consist of Pleistocene glacial deposits which were a result of Wisconsin age glaciation. The upper glacial deposits lie unconformably atop the subcropping Matawan/Magothy, Jameco Gravel and Gardiners Clay.

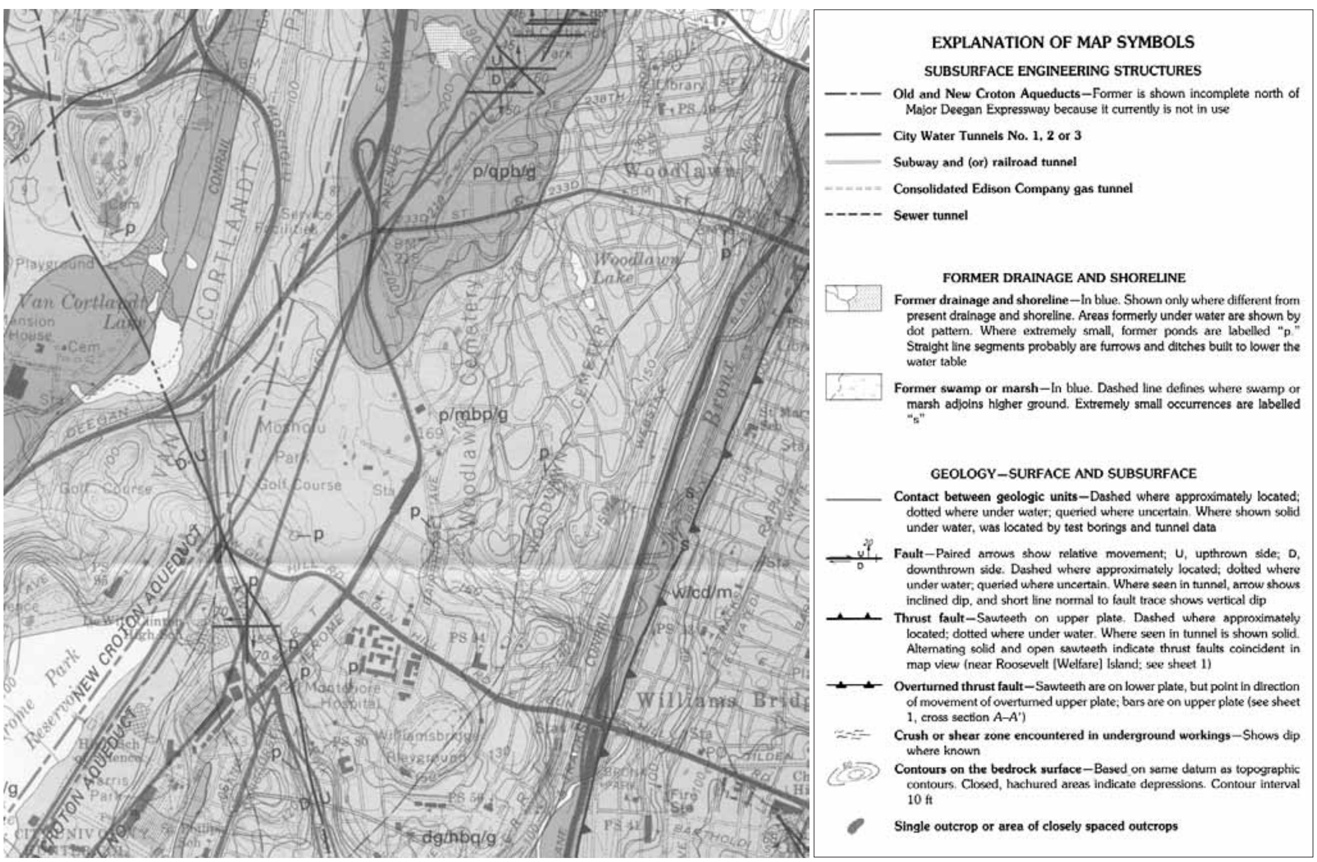
Glacial scour has cut deeply into subcropping formations, particularly into the Matawan/Magothy section. The upper glacial deposits outcrop at the surface and represent a full range of glacial depositional environments from moraine to outwash plain to lacustrine. Upper glacial deposits can reach a thickness of 700 feet. The geomorphology of Long Island is marked by the resultant hills of the Ronkonkoma and Harbor Hill moraines and gently sloping plains associated with glacial outwash deposits. The upper glacial deposits make up the Upper Glacial aquifer, which is the predominant source of private water supply wells. The moraines consist of till composed of sand, clay and gravel and display an average horizontal hydraulic conductivity of 135 feet per day (Smolensky et al., 1989). The highly permeable stratified drift of the outwash plains that lie south of the moraines consists of fine to very coarse grained quartzose sand and pebble to boulder sized gravel. The average horizontal hydraulic conductivity of the glacial outwash deposits is 270 feet per day (Smolensky et al., 1989).

Holocene deposits, which are as much as 50 feet thick and consist of salt-marsh deposits, stream alluvium, and beach sands, occur locally throughout the island. Holocene deposits consist of sand, clay, silt, organic muck, and shells. They are at land surface and generally overlie Pleistocene deposits. They are either unsaturated or too thin and discontinuous to form aquifers. In some areas, they form local confining units.

Geologic Unit	Function	Age
Upper Glacial Aquifer	aquifer	Pleistocene
Gardiners Clay (Kings & Queens Cnty)	confining unit	
Jameco (Kings & Queens Cnty)	aquifer	
Monmouth Group (south shore)	confining unit	Upper Cretaceous
Magothy Formation	aquifer	
Raritan Fm - Clay Member	confining unit	

The Bronx and Manhattan

The Bronx has been the subject of limited geologic explorations and, as a result, few geologic reports (Bulletin GW-32, 1953, Geology in the Bronx and Richmond Counties … by N.M. Perlmutter and T. Arnow) exist that cover the geology of that borough. Similarly with Manhattan, the existence of a “city” in these boroughs has limited the amount of classic geologic studies that can be made. Charles Baskerville has produced a set of engineering geology maps that cover both the Bronx and Manhattan. Mr. Baskerville has used engineering data including data developed from the numerous tunneling projects, such as water tunnels, subway tunnels and power lines. Data from foundation borings for numerous projects such as building and bridge construction were also used. The mapping is intended to assist engineers in foundation design and is not intended to be a definitive geologic investigation. Mr. Baskerville does not devote much space to the identification and in depth description of geologic units (lithology). Instead, he does provide generalized descriptors for the various rock types that exist in the Bronx and Manhattan. More importantly, however, Mr. Baskerville has mapped the existence of bedrock features that bear more relevance to geothermal system. The locations of bedrock faults, bedding contacts and strata folds have been mapped. These features can improve the chances of developing higher than average yielding wells, which will, in turn, reduce the amount of drilling necessary to develop the necessary thermal exchange for the project. Please note that for “closed loop” systems the existence of highly productive fracture zones is irrelevant.



The above map is a section of the Baskerville Bronx map centered on the Mosholu Park in north central Bronx. The map symbols are explained to the right of the map. As can be seen, this map contains a wealth of information usable to the designer of geothermal systems. The blue letters (A,B and C) indicate hypothetical locations considered for a geothermal system. Location “A” is in an area that indicates significant fracturing, shown by the black line that runs from the upper left corner of the map to the lower center of the map. The line is labeled with U/D at several locations. The U infers that that side of the fault is displaced upwards with respect to the other side of the fault, labeled D. In addition to the main line discussed above is a shorter east west fracture that is partially obscured by the letter A. Wells at the intersection of two, or more, fracture systems typically produce more ground water than wells that are located in areas free of fractures or adjacent to single fractures.

Site A is located over the mapped path of one of the City’s water tunnels.
Before attempting to drill a well in any location in New York, it is imperative that the possible existence of any underground utilities be discovered. Utilities can include currently active water tunnels, sewers, telephone and power lines, subway lines and steam pipes. In addition to active utilities, “old “unused or abandoned utilities may be found that may include any of the above listed. Therefore, before the drilling starts, the One Call Center for New York and Long Island should be called. Their number is 1-800-272-4480. For additional information and to setup safety seminars call 1-718-631-6700. They also have a WEB page with the address: **WWW.OCUC.net**. The One Call Center will mark the project site with the location of “member” utilities. A list of their members is provided on the WEB page. The New York City agencies, such as sewer and water, are not members and need to be contacted separately.
Site B on the above map is not directly on any mapped faults or fracture systems. The results of drilling at this location should produce a well with an average yield of 20 gallons per minute, or less. However, the key term above is “mapped” fracture system. Just because a fracture system is not mapped it does not mean that a fracture system does not exist at that location. Generally a fracture is mapped when there is evidence of its existence, such as a linear valley, bedrock outcrops, or data developed from subsurface work. When such evidence is not available, the geologist may not know of the existence of a fracture system and, therefore, cannot map it. Therefore, the preliminary design should be for a standing column well, assuming that a low yield well will be drilled, but sufficient flexibility should be built into the design to allow for an alternate design if a high yield well system is drilled. Similarly, in location A, the existence of mapped fractures does not guarantee the production of high yield wells and the system design should be sufficiently flexible to allow for alternate configurations.

Richmond County

The geology of Staten Island is varied and complex, ranging from artificial fill, various glacial deposits including glacial till and glacial outwash, as well as exposed bedrock including ancient serpentines. The geothermal designer, with respect to particular locations in Richmond County, has the option of completing wells in the outwash deposits in eastern Staten Island or the completion of bedrock wells throughout most of the remainder of the borough. Portions of Staten Island are artificially filled wetlands and coastal areas that may contain transmissive deposits. However, it is more likely that the fill materials used are not sufficiently transmissive for water production.

The outwash deposits located in eastern Staten Island are similar to the outwash deposits found in southern Brooklyn and Queens. Both units are capable of ground water yields in the hundreds of gallons per minute to thousands of gallons per minute. However, unlike the Long Island outwash deposits, the outwash on Staten Island are limited to a maximum of 125 feet. The proximity of the outwash deposits to New York Bay places this aquifer in danger of salt water intrusion from over pumping. Therefore, a system of five New York City drinking water wells was limited to pumping less than 5 million gallons of water per day, although the wells were capable of significantly higher yields. These wells have not been operated since the early 1970's. Geothermal systems return the water pumped out to the aquifer, so they should not increase the risk of saltwater intrusion. Salty or contaminated water will increase the maintenance required for wells and well pumps.

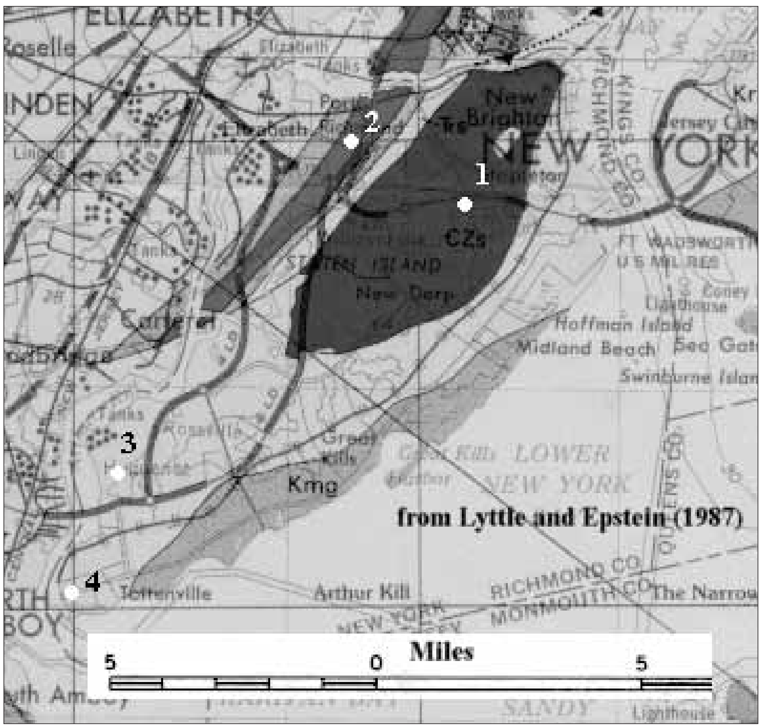
The terminal and ground Moraines of Staten Island are generally composed of glacial till, a material that results from the grinding of rocks by the advancing glacial ice. The material, till, appears to be a hard clay with various amounts of sand and gravel mixed in. Till has poor hydraulic conductivity and should not be considered as a source of ground water. Occasionally sandy till is encountered. These deposits, although more productive than the clay tills discussed above, are still limited to about ten gallons per minute, on average (Soren 87-4048, 1988).

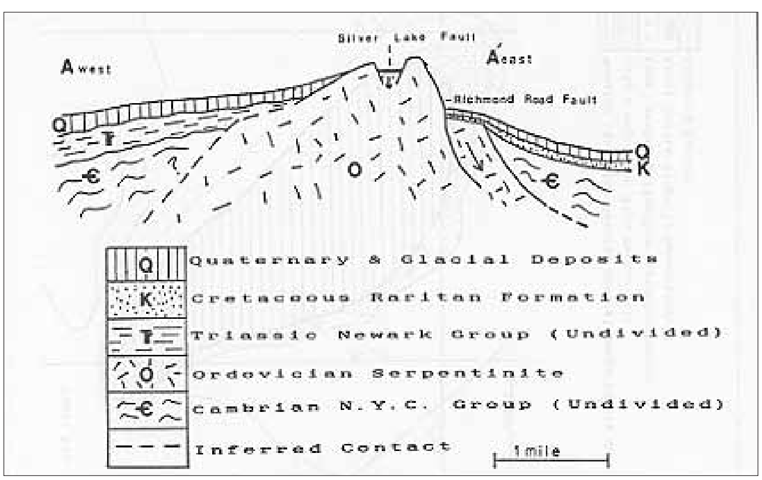
The Raritan Formation underlies the outwash deposits of eastern Richmond. Wells tapping this formation, which includes the Lloyd, or Farrington as it is referred to in New Jersey, have yields as high as 200 gallons per minute. This formation appears to be confined, separated from the water table aquifer, but insufficient data exists to fully make that determination.

The bedrock units underlying Richmond include the Newark Supergroup (shales, sandstones and limestones), the Palisades Diabase, the Manhattan Schist and the Staten Island Serpentine. Ground water data from the Staten Island portion of the Newark Supergroup is not generally available and, therefore, the yield of this formation within Richmond is not known. However the Newark formations is tapped extensively in Rockland County New York and is found to have an average yield of 83 gallons per minute (Permutter, 101-120, 1959). This average yield is based on a list of wells, which include mostly municple wells, including a well yielding a reported

1,515 gallons per minute. If all wells, including domestic wells, tapping this formation were included in the average, the average yield for the formation will be found to be considerably lower, more in the range of 10’s of gallons per minute.

The Palisades Diabase is considered a poor water producing formation with yields limited to less than 10 gallons per minute. The Manhattan Schist unit in Richmond is not generally used for water supply due to the existence of more productive unconsolidated deposits. However, wells drilled in the Manhattan Schist in Manhattan and Westchester generally produce yields of between 5 and 50 gallons per minutes, with some wells yielding as high as 150 gallons per minutes. The productivity of this unit is completely dependant on the existence of faults and fractures that may be tapped by the well.





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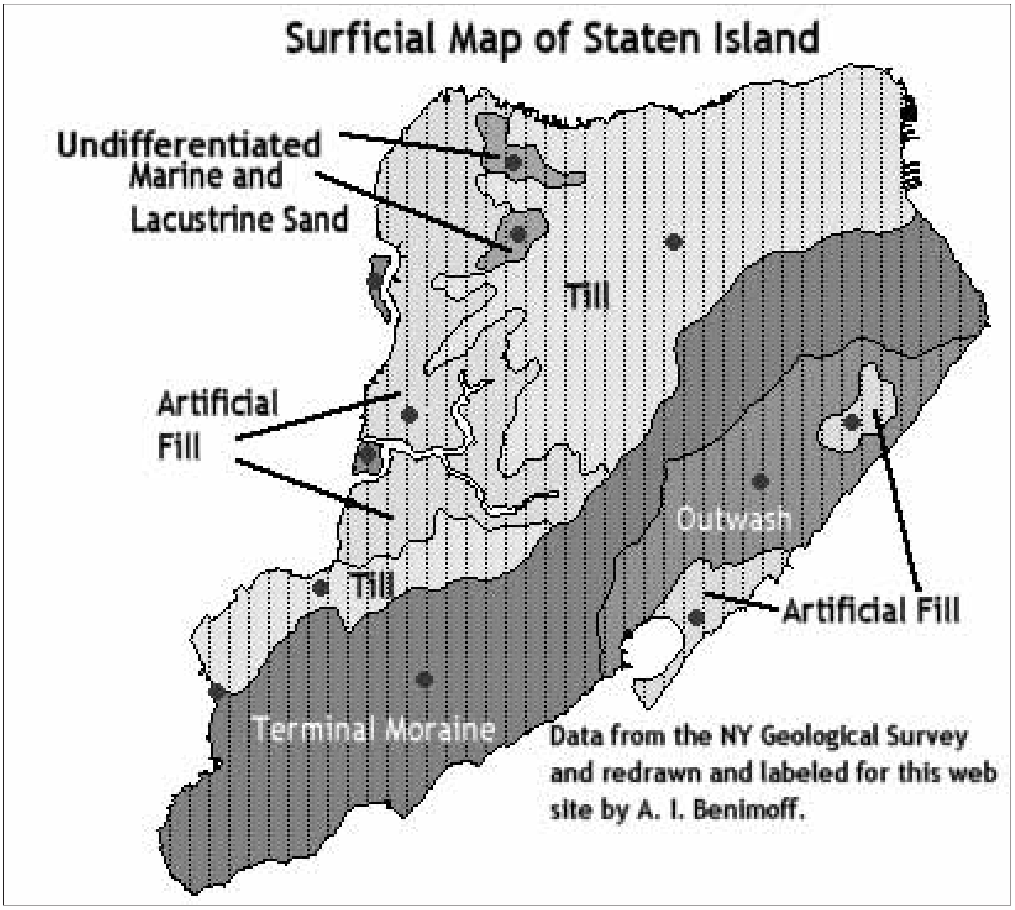
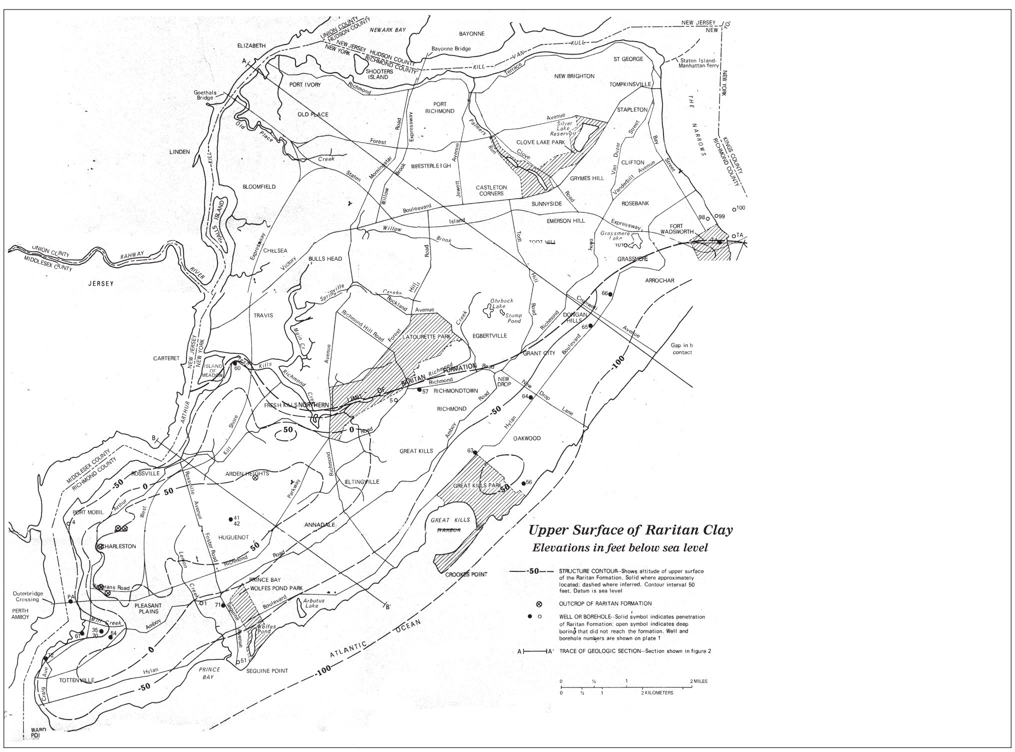

Surficial Map of Staten Island
Undifferentiated
Marine and
Lacustrine Sand
Till
Artificial
Fill
Till
Outwash
Artificial Fill
Terminal Moraine
Data from the NY Geological Survey
and redrawn and labeled for this web
site by A. I. Benimoff.


Upper Surface of Raritan Clay
Elevations in feet below sea level
ATLANTIC OCEAN
GREAT KILLS
TOTTENVILLE
RICHMONDTOWN

Conclusion

The hydrogeology of the City of New York is complex and varied presenting an interesting challenge for the design and implementation of geothermal systems. Since the location of the intended system is critical in determining the nature of the geology and, consequently, the type of well that will be used for the system, the designer must consult the mapping that is in this chapter or additional mapping listed at the end of the chapter. It is important that a hydrogeologist is consulted at the initiation of the design process so that the nature and extent of the drilling can be assessed early.

The cost of well drilling is affected by many variables including non-geotechnical factors such as site access and noise restrictions. Various geologic environments present difficulties to the driller that will extend the amount of time necessary to complete a well. A well drilled in an area that has bedrock close to the land surface is considerably easier to drill than a well that has to first penetrate many feet of unconsolidated deposits. The boring through the unconsolidated deposits must be kept open so that the formation does not fall into the boring, locking the drill tools into the earth. This is done by either using high density drilling fluids to drill through the earth or by installing steel casing as the boring is drilled. If the objective is to tap an unconsolidated aquifer, the well must be finished with a well screen to hold back the aquifer material while letting in the ground water. Bedrock wells, in most cases, do not require well screens. However, bedrock wells generally do not produce as much water as wells screening unconsolidated deposits. Therefore, bedrock wells will be significantly deeper than gravel wells.

Certain sections of New York are underlain by highly productive unconsolidated aquifer materials. Wells tapping these aquifers can produces prodigious quantities of water, limiting the amount of drilling necessary for the project. However, if the underlying aquifer is the Lloyd, as it is in parts of north/central Queens, the New York State Department of Environmental Conservation will not issue a permit for use of the Lloyd, since it is a highly protected aquifer. In that case, it is necessary to utilize any overlying aquifer material, if available, or to drill through the Lloyd, isolating the aquifer with steel casing, and continue into the underlying bedrock.

The following reports were referenced in this chapter:

Buxton, H.T., Shernoff, P.K., 1999,Ground-Water Resources of Kings and Queens Counties, Long Island, New York, U.S. Geological Survey Water Supply Paper 24978, 113p, 7 plates

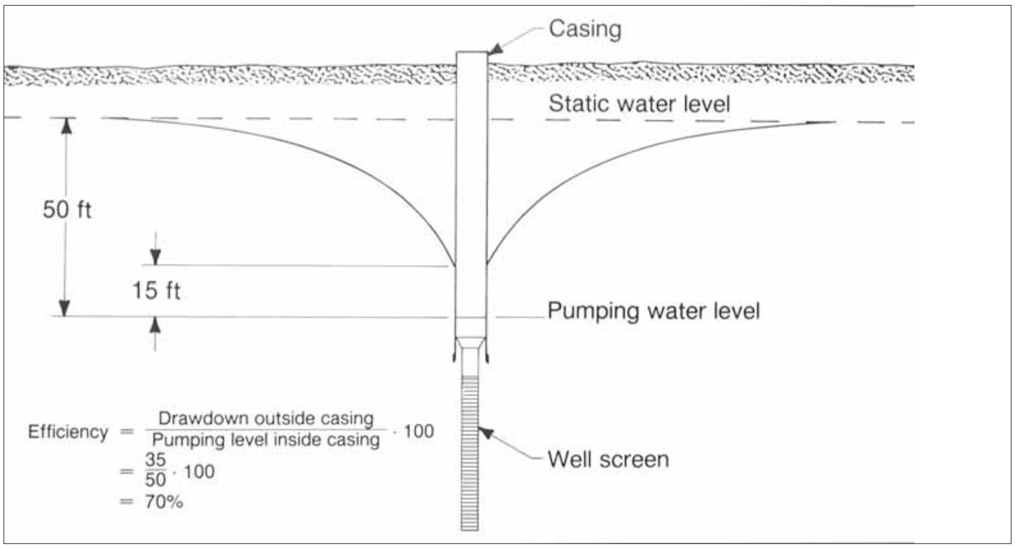
Buxton, H.T., Soren, J., Posner, A., Shernoff, P.K., 1981, Reconnaissance of the Ground-Water Resources of Kings Queens Counties, New York, U.S. Geological Survey Open Report 81-1186, 59 p.

Bedrock and Engineering Geologic Maps of Bronx County and Parts of New York and Queens Counties, New York, Charles Baskerville, Miscellaneous Investigation Series, Published by the U.S. Geological Survey, 1992.

5. b Choosing a geoexchanger

OPEN EARTH COUPLING

Brooklyn and Queens, and any site with a similar geology, are well suited to the geothermal earth coupling formed by a supply and a diffusion well. A requirement of 3 gpm per dominant ton is required from the supply well and a responsible diffusion well must be capable of receiving this flow rate. It should be noted the typical diffusion well is “double the size” of the supply well. This increase in size is attributed to the relative hydrologic potential between a well with a *depressed* source cone around the well head as compared to the *impressed* diffusion cone around the return well.

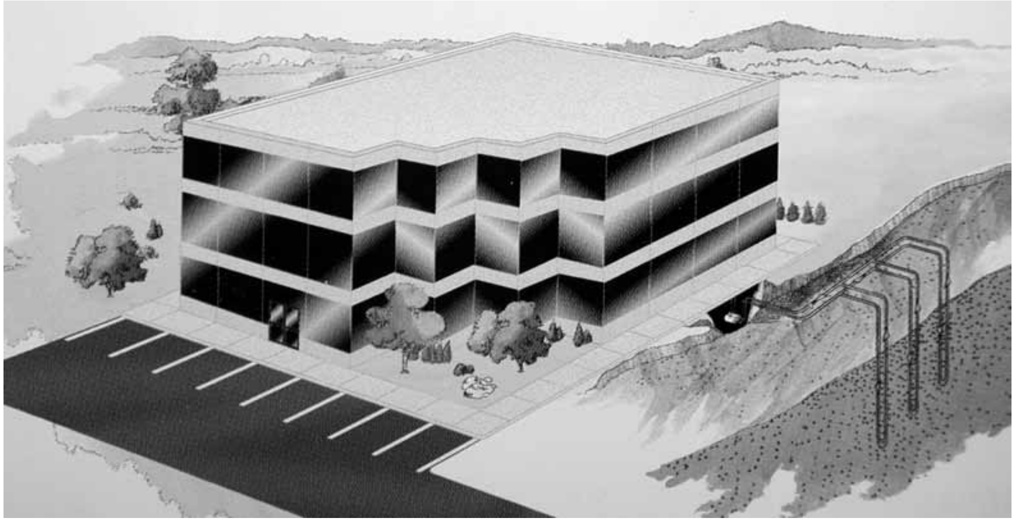


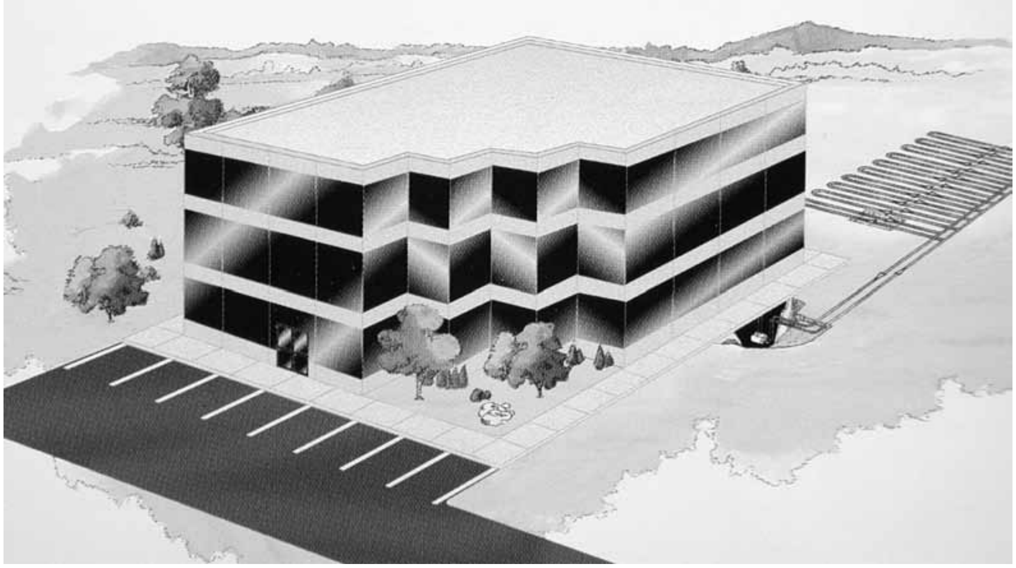
The diameter of the impressive and depressive cones are a function of the permeability of the surrounding geological strata. The only limiting factors to these type systems is the availability of 3 gallons per minute per connected heat pump ton of flow and a responsible method of returning the water to the environment. Aquifer testing and modeling may be necessary if large, multiple well systems are to be installed. This will allow a proper design which avoids overlapping cones and provides sufficient water flow. Typical design temperatures for the New York City area are 50°F well water the year around, heating and cooling season (ARI standards rate at 50°F all year around; new ISO standards rate cooling at 59°F and heating at 50°F entering water).

Attention must be paid to the source of the water being returned to any given aquifer. Earth recharge via septic or sewers is not permitted. The Upper Glacial Aquifer which lies closest to the surface in Brooklyn and Queens may carry both natural and industrial contaminants. The Lloyd aquifer which is the next aquifer down is considered to be pure and uncontaminated cannot be used as a diffusion well if the source water is not also the Lloyd Aquifer. See also the section on permitting. Existing installations east of the East River favor this two-well system. See the description below of the four Long Island Power Authority buildings.

CLOSED EARTH COUPLING

Sites where a concern for surface or ground water quality exists typically utilize closed loop systems. These vertical or horizontal closed loop earth coupling systems are designed to move an antifreeze solution through a series of loops arranged either vertically or horizontally. The material used for this piping is high density plastic pipe with a low friction loss and consequent low pumping effort[1]. This method is employed in areas with polluted water, e.g. do not meet primary drinking quality standards are encountered. Closed loop systems are somewhat less efficient and more costly. There is a trade off between loop pipe length and minimum design temperature. Existing ARI (ARI-330) and ISO (ISO-13256) standards specify design temperatures at 32°F for the heating season and 77°F for the cooling season.





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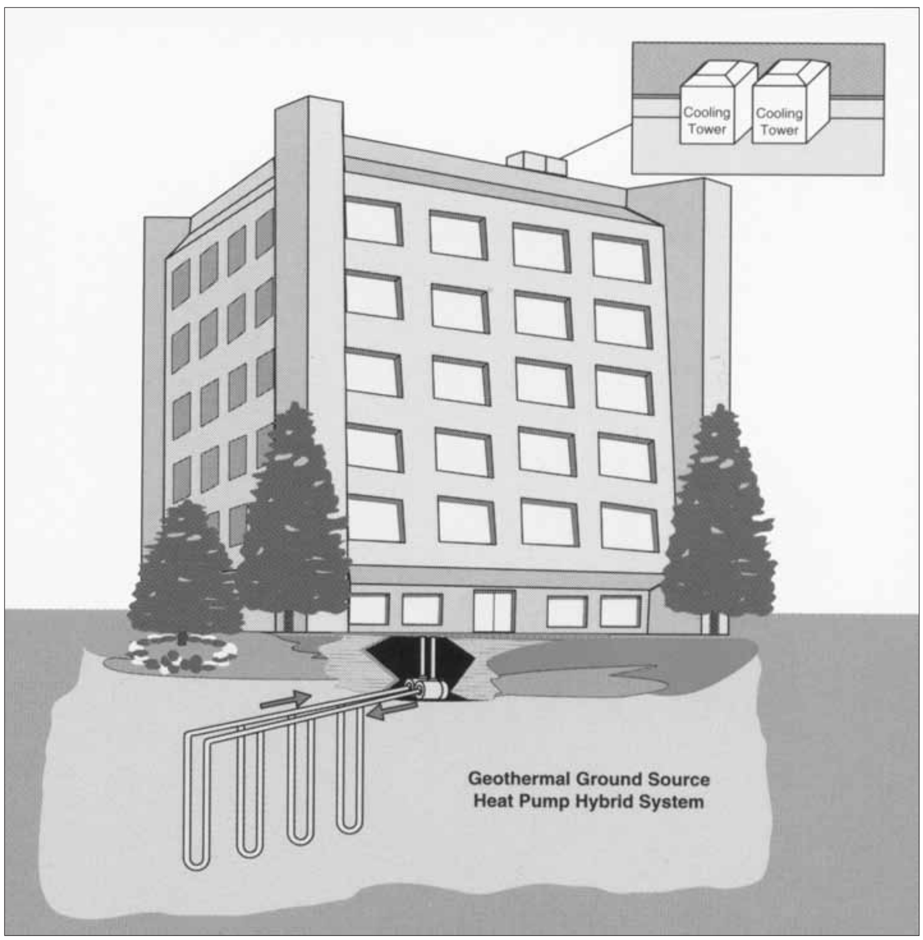
Horizontal closed loops take one of two forms either a straight pipe of approximately 1,000 linear feet per ton, out and returned to the heat pump in a 4-6 foot deep 500 foot trench or a more recent and popular method call the Slinky®. The Slinky® also employs approximately 1,000 linear feet of high density polyethylene pipe but it is coiled and the extended as a flat map similar to child's slinky toy. In this manner an 80-100 foot trench can be loaded with 1,000 feet of pipe providing a one ton capacity. Generally, if trenching is easily achieved and no sharp rocks exist, a horizontal earth coupling system can be less costly than other systems, with the exception of the two well system described above. Typical Slinky®. Installation is shown in figure 2b-4

Vertical Closed Loop earth coupling utilizes the same design specifications and piping methods and material. Antifreeze solutions in the loops are also required. As the earth is warmer at depth, the heating dominated vertical closed loops typically require only 300-400 linear feet of pipe per ton, see figure 5. The average practical heating dominated borehole is 300-400 feet deep, this implies approximately two tons capacity per bore hole.

A cooling dominated vertical closed loop may require nearly twice that length. (keeping in mind a cooling load not only must remove the sensible and latent loads of the building, but also must remove the inductive heat generated by the heat pump's motors.)

See appendix C for the software modeling available for closed loop systems.
Loop length and commensurate **cost** are reduced as the design temperature limits are further away from the average earth temperature, 51°F in this example.



Performance and efficiency of a typical heat pump in the heating mode at 30°F versus operation at 20°F can be reduced by 15%[2]. In the cooling mode at 70°F vs. 90°F the reduction in performance is approximately 9%, with a reduction in efficiency of approximately 25%! In this example, these penalties are offset by a reduction on total closed loop length by approximately 80 feet per ton for heating and 90 feet per ton for cooling requirements.

While reducing the cost of the loop field is an important design factor, it also can severely impinge upon a design **safety margin**. Designing at the heat pump's minimum or maximum entering temperature limits provide no design. An unusually cold winter or hot/moist summer can place a higher demand on the closed loop than published design conditions, leaving no capacity in the ground loop and driving the loop temperatures beyond the heat pump's design capabilities.

Closed loop systems, are designed for heat pump evaporators operating at or below 32°F, e.g. entering water temperatures below approximately 38°-39°F. Because of the probability of creating ice in a heat pump's evaporator heat exchanger, good closed loop design practices require an antifreeze be added to the closed loop. While the antifreeze will somewhat decrease efficiency it permits the heat pump to operate at these lower temperatures. Antifreeze solutions are typically designed for temperatures 10°F lower than the minimum entering water solution. A common solution of 20% food grade propylene glycol, this solutions provides an 18°F freezing point. This implies a minimum of 28°F (i.e. +10°F) minimum entering water temperature from the ground loop.

We recommend the use of propylene glycol as it is not a pathenogenic poison and is environmentally friendly. However, propylene glycol solution tends to become increasingly viscous as temperatures go below 35°F. The designer must consider this increase in viscosity when designing ground loop pumping.

Other antifreezes without the increased viscosity effect, as methyl alcohol (methanol) are equally effective as antifreeze agents, however, its designation as a poison and flammability do not recommend this compound. Several ethyl alcohol (ethanol) based compounds are also available to the designer. Use of these antifreeze solutions should be tempered with a review of the denaturants used in the ethanol solution. Some of ethanol's denaturants are equally poisonous as methanol.

STANDING COLUMN WELLS (SCW)

Standing column wells consist of a borehole that is cased until competent bedrock is reached. The remaining depth of the well is then self-supporting through bedrock for the remainder of its depth. A central pipe smaller than the well diameter is dropped to form a core through which the water is pumped up, and an annulus into which the water is returned. The length of the central pipe at the bottom is coarsely perforated to form a diffuser. Water is drawn into diffuser and up this central riser pipe. The well pump is usually located at some depth below the water table in-line with central riser pipe. The standing column well combines the supply and diffusion wells into one, and is not dependent upon the presence or flow of ground water, although fractures in the bedrock that allow flow across the well can enhance performance, and reduce the length of the water column.

In practice, standing column wells are a trade-off between the open well systems and the below discussed closed loop earth coupling. The standing column well has the an advantage during the design phase in that the performance can be predicted without an extensive hydro-geological study. The savings in design fees and the elimination of the time period required for the hydro-geological analysis are attractive.

Given that standing column wells are unambiguous in projected performance, the use of this type of geothermal heat exchanger in most of Manhattan, the Bronx and northern Queens, where near surface bedrock can be anticipated is recommended. The standing column well can be designed and expected to perform to specification without the need for a test well. A heating or cooling capacity of 480 to 600 MBH (thousands of Btu/hr, equivalent to 40-50 tons of cooling) can be reliably expected from a 1,500 foot deep standing column well.

Should multiple wells be required, the spacing should be at least 50-75 feet. Closer spacing will affect the performance of the well field as the earth has a limited capacity to accept and reject heat. The diminished performance can be projected with available design software (typically GLPRO, see below).

Geothermal re-injection well water is considered a Class V water use and is regarded by the EPA as a 'beneficial' use. Permitting or notice may be required dependent upon average daily water flow rates. SCW wells shall be installed and serviced by qualified and experienced geothermal well contractors.

EXISTING GEOTHERMAL INSTALLATIONS ON LONG ISLAND

Long Island Power Authority (LIPA, formerly Long Island Lighting Company) has installed open loop geothermal heat pumps in four of its buildings over the past six years, see table 2a – 1 – LIPA facilities.

Facility	Design Load	Completed	
Brentwood	180 tons	1994	retrofit of 1958 geo system
Riverhead	80 tons	1997	
Garden City	80 tons	1998	
Hewett	100 tons	2000	

Table 2a – 1 Long Island Power Authority Two Well (Open) Geothermal Heat Pump Installations

Of particular note is the Brentwood facility[3], designed with an R-12 ground source heat pump installation in 1958. The facility has two wells, one a supply and one a diffusion well, both operational since 1958. The facility is a 6,500 square feet, two story building, providing office accommodations for 300 operating staff, and hosts a large cafeteria. Some offices, lockers and workshops are located in the basement, which also houses eighteen geothermal heat pump modules. The water to water geothermal heat pump modules replaced two 350 kW and one 900 kW gas fired boiler. The original wells and pumps were retained, but with a new variable frequency drive (VFD) which provides additional operational cost savings. A conceptual schematic of the system is shown in figure 2a – 7.

Note the modules are not centralized as in most other commercial applications. Each of the existing air handlers was left unmodified and was provided with matching capacity of heat pump modules. A comprehensive Honeywell system is employed to control each of the modules, air handler pumps and other related controls.

The Brentwood facility has been available to qualified engineering and design professionals for review and is well documented.

Based upon the success of the Brentwood operation, subsequent installations were made at the Riverhead operations facility, the Garden City Office and the Hewett Office. The Hewett Office has tied the geothermal heat pumps into a hybrid cooling tower system.

(Footnotes)

[1] High density polyethylene pipe is specified as 3408 resin with a cell classification of 345434C or 345534C; pipe should be marked along its length with these specifications. Suppliers in the New York area are Driscopipe, Charter Pipe, Vanguard Plastics and others.

[2] Typical GSV 048 heat pump for HEATING at 35°F, 36.9 mbtuh (3.56 COP) vs. at 20°F, 31.4 mbtuh (3.12 COP). For COOLING at 70°F, 50.9 mbtuh (17.9 EER) vs. at 90°F 47.1 mbtuh (13.7 EER)

[3] *Long Island Lighting Co., Brentwood Facility*, ClimateMaster 97-BB101-9410-0, July 30, 1994

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Permitting Requirements of Geothermal Heat Exchangers in NYC

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6.0 PERMITTING REQUIREMENTS SUMMARY

6.1 BACKGROUND

Geothermal heat pump systems, GeoExchange, are most often employed with lowest cost and highest efficiency "open" earth coupling systems:

Region	Dominant Earth Coupling Method
Queens & Brooklyn Eastern Staten Island *Highly porous soils* *Highly water laden*	Supply Well(s) and RechargeWell(s)
Manhattan, Bronx N.W. Queens, Western Staten Island *Competent Bedrock*	Re-circulating Well(s)

MOST LIKELY GeoExchange EARTH COUPLING METHODS by AREA

A third, or closed loop, earth coupling method has been used in areas where there are regulatory or practical reasons that find the above two methods unpractical.

6.2 SUMMARY of REGULATIONS

At present there are no regulations affecting the "closed loop" earth coupling. Some close loop designs included pathogenic poisons as antifreezes and the design engineer and owner should carefully evaluate the chemical composition of closed loop antifreeze compounds before giving their approval for their use.

This section summarizes the New York State and local environmental requirements for the **above two** basic earth coupling methods.

The United States Federal Environmental Protection Agency has "primacy" in New York State. Having primacy the US EPA is the lead regulatory authority in these matters. This does not excuse any organization or agency from local regulations that may apply.

Additionally, if any of these **three types** of boreholes/wells exceed 500 feet in depth the well will require a permit from the Division of Mineral Resources (DMR). The DMR regulates drilling, construction, operation and plugging of geothermal wells drilled deeper than 500 feet. The DMR is at 50 Wolf Road in Albany NY 12233-6500. Submittals to the DMR include:

Organization of Drilling Company
Financial Stability of the Company
Drilling Permit see below
Environmental Assessment
Completion Report
Annual Report

Additonal Reports Required for Bore holes Greater than 500 feet in New York State

A section below also outlines environmental guide lines for the **closed loop** geothermal earth coupling methods.

6.3 REQUIREMENTS

Three levels of regulatory requirements will be generally applied. All are directed towards the preservation of the quality of ground (deeper than 50-60 feet) and surface waters in the earth. In all cases it is a requirement to maintain a segregation between the ground water (deep) and surface waters. Surface waters are considered polluted with road, agricultural and other surface run-offs. Protective regulations are from:

Local Health & Environmental Officials
State Environmental & Mineral Resource Agencies
Federal Environmental Protection Administration

It should be noted that all of these Agencies have cognizance over wells in the Long Island and Queens/Brooklyn areas. The below summary will related to the Federal EPA requirements.

Of the three methods described above (open, SCW and closed loop) require drilling bore holes, hence, all three require :

STEP #1 Permission to Drill - ALL BORE HOLES

1. **PRELIMINARY NOTICE of PROPOSED WATER WELL** (NY State form)

For Queens, Kings & Long Island
NY State Department of Environmental Conservation
Building 40, Room 1631
SUNY, Stony Brook, NY 11790 tel. 631 444 0405
For Manhattan and Richmond County (Staten Island)
NY Department of Environmental Conservation
50 Wolf Road, Room 392
Albany NY 12233 tel. 518 474 2121

Required for Open, Standing Columns and Closed Loops

NOTE - this form, when returned to the driller, will carry an IDENTIFICATION NUMBER and should be used in any further documents.

STEP #2 – For SMALL OPEN & STANDING COLUMN WELLS

2. **INVENTORY of INJECTION WELLS** (form 7520-16)
   this one page document is forwarded to the Offices mentioned above

Required for SMALL Open and Standing Columns –
Typically Residential and Commercial < 60 tons

As both the “Open” and Standing Column Well (SCW) have a requirement to return the water from the earth back to the earth they fall under both Health and Environmental regulations. The EPA considers a re-injection of clean geothermal waters as a beneficial, but regulated, use of natural waters and is governed by a “General Permit”. Under Ground Injection Control (UIC) regulations allow modest re-injection of drinking quality water back to the earth when the well is a Class V type 5A7 well.

For most residential and small commercial geothermal applications, this is the end of the regulatory paper work.

However, if in the eyes of the EPA, there is a questionable use of water, applications that could create damage to the re-injected water or other activities that could negatively effect the environment, the associated environmental regulatory agency may require submittal of a “Permit Application”.

6

STEP #2 – for LARGE COMMERCIAL OPEN & STANDING COLUMN

2A. INVENTORY of INJECTION WELLS (form 7520-16)
this one page document is forwarded to the Offices mentioned above

2B. UNDERGROUND INJECTION CONTROL PERMIT APPLICATION (form 7520-6)
a one page form with various descriptive attachments

Required for LARGE Open and Standing Columns
Typically Commercial >60 tons and all Industrial

TYPICAL REQUIREMENT for UIC PERMIT APPLICATIONS

Permit applications for a Class V Bore hole include:

A. Review within ¼ mile of the site
B. Topographic map within 1 mile radius of the site
C. Well data reasonably available from public records
D./E. Geologic maps of the immediate area – available from USGS & this document
F. Operating data for the heat pumps
G./H./I. Simulation of Heat pump operation including estimated injection
J./K. Description of Boring construction procedures and details
L. Description of proposed monitoring program
M. Description of Abandonment Plans
N./O.P. Description of Well drillers business and financial stability

Note- the above permit information is identical and similar to the DMR requirements (above), with concurrence of the DMR or EPA, the driller should request forwarding of copied information in lieu of submittal of actual additional forms.

6

6.4 NY STATE GUIDELINES for CLOSED LOOP INSTALLATIONS

While there are presently *no formal regulations* for the installation, type antifreeze or other attributes of the closed loop earth coupling method. The International Ground Source Heat Pump Association (IGSPHA) have complete installation specifications for the closed loop type of earth coupling.[1]

Additionally New York State has issued some guidelines for this type system[2]. These guidelines are:

1. Food grade propylene glycol (20%) is approved and recommended for use in a closed loop application.
2. Use of heat pumps with R-22 or other refrigerant with lesser ozone depletion potential, see section 7 of this manual
3. Unlimited automated heat exchange fluid makeup systems may not be used unless equipped with back flow devices and cumulative flow meters which shut down the closed loop system if more than five (5) per cent of the system's volume is exceeded.
4. Testing prior to loop burial:
   Pressure test for one hour at 100 psig
   After burial and prior to heat pump operation
   Anytime thereafter when system fluid is added, re-pressurized or other wise opened

5. Anytime the heat exchange fluid is added to an atmospheric reservoir system or a pre-pressurized system is re-pressurized – then entire buried system must be retested at 100 psi for a minimum of one hour. If the buried system fails this or other pressure test(s);, the complete system must be repaired and completely tested.
6. If the closed loop system is to be abandoned, it must be completely filled with a bacteria free bentonite grout slurry and heat fusion sealed at all openings.

U.S. Environmental Protection Agency Contacts for NY City

US EPA, Region 2
Division of Enforcement & Compliance Assistance
Water Compliance Branch
290 Broadway
New York, NY 10007-1866

Robert Ferri, Geologist tel 212 637 4227
ferri.robert@epamail.epa.gov

Charles J. Hillenbrand, Geologist tel 212 637 4232/fax 212 637 4211
hillenbrand.charles@epamail.epa.gov

(Footnotes)
[1] IGSPHA Closed Loop Specification
[2] NY State Dept of Environmental Conservation, *Paul Kolakowski,* January 29, 1993

Heating and Cooling Loads, the Effect of Load dominance

7

7

7.0 Rigid Heat Loss & Gain & Domestic Hot Water Estimates

The accurate sizing of GeoExchange systems is mandatory. The cost of a Geothermal heat pump system is approximately linear with performance. A geothermal heat pump installation that is oversized by a factor of two will nearly double the first cost. A fossil fuel heating system that has been oversized by a factor of two will add only about 25% to the cost. The oversized fossil system will fall short of achieving its published efficiencies because of short cycling.

The GeoExchange system is sized on the building loads for heating and cooling/ dehumidification. Although connected loads are an important consideration, the building itself places the loads on the earth. An oversized closed loop or well installation may become so expensive that the geothermal system would not be economically feasible. An under sized closed loop installation will fail at season extremes because of temperatures exceeding heat pump operational specifications. Well based or open systems may suffer the same fate, but are generally able to increase operational performance by pumping more water volume and increasing the bleed rate.

7.2 Requirements for Residential Facilities such as Prisons, Dormitories and Elderly Housing

Residential heating and cooling loads are universally estimated by a method known as Manual-J. Many states have recently adopted this estimating method as the sole source of heating and cooling loads for residences. Manual-J is a development of the Air Conditioning Contractors Association of America (ACCA) and derives its information from ASHRAE data. Hand derived Manual-J analysis tools are available through the ACCA headquarters.

Wright-Soft Corp publishes ACCA's version of Manual-J. Other organizations as Elite software and various manufacturers also have derived Manual-J analysis programs. Manual-J provides construction analysis, room-by-room analysis and overview reports for the GeoExchange installer.

Heat pump equipment selection for residential applications is based upon the dominant load, either heating or cooling. Unlike air-to-air heat pumps the geothermal heat pump does not suffer from reduced performance, as the weather gets colder in the winter or hotter in the summer. Additionally, the cooler condenser in the summer yields cooler and better dehumidification on the evaporator side of the geothermal heat pump – even with some level of over sizing good dehumidification can occur with oversized cooling heat pumps. Some manufacturers have dual stage or dual speed compressors that allow approximately one-half the capacity of the heat pump during lower demand summer operation.

Figure 7-1 is an example of the Manual-J summary report and 7-2 of a construction report. The importance of the construction report cannot be overemphasized as a building not meeting the analyst's construction assumptions will not have an accurate heating and cooling design.

RIGHT-J LOAD AND EQUIPMENT SUMMARY
Entire House
Water Energy Distributors, Inc.
100 Maple Ave, Atkinson, NH 03811 Phone: 603-362-4666 Fax: 603-362-4890

Project Information

For: Dirigo Pines
ME

Notes:

Design Information

Weather: Lewiston, ME, US

Winter Design Conditions

Outside db	-2	°F
Inside db	70	°F
Design TD	72	°F

Heating Summary

Building heat loss	38000	Btuh
Ventilation air	0	cfm
Ventilation air loss	0	Btuh
Design heat load	38000	Btuh

Infiltration

Method	Simplified
Construction quality	Average
Fireplaces	0

	Heating	Cooling
Area (ft²)	1173	1173
Volume (ft³)	9386	9386
Air changes/hour	1.0	0.5
Equiv. AVF (cfm)	157	78

Heating Equipment Summary

Make ClimateMaster
Trade Genesis PSC 042

Efficiency	4.37 COP	
Heating input	44500	Btuh
Heating output	44500	Btuh
Heating temp rise	35	°F
Actual heating fan	1150	cfm
Heating air flow factor	0.030	cfm/Btuh
Space thermostat		

Summer Design Conditions

Outside db	85	°F
Inside db	75	°F
Design TD	10	°F
Daily range	M	
Relative humidity	50	%
Moisture difference	22	gr/lb

Sensible Cooling Equipment Load Sizing

Structure	21046	Btuh
Ventilation	0	Btuh
Design temperature swing	3.0	°F
Use mfg. data	n	
Rate/swing multiplier	0.90	
Total sens. equip. load	18941	Btuh

Latent Cooling Equipment Load Sizing

Internal gains	2300	Btuh
Ventilation	0	Btuh
Infiltration	1147	Btuh
Total latent equip. load	3447	Btuh
Total equipment load	22388	Btuh

Cooling Equipment Summary

Make ClimateMaster
Trade Genesis PSC 042

Efficiency	18.2 EER	
Sensible cooling	31850	Btuh
Latent cooling	13650	Btuh
Total cooling	45500	Btuh
Actual cooling fan	1150	cfm
Cooling air flow factor	0.055	cfm/Btuh
Load sensible heat ratio	86	%

Printout certified by ACCA to meet all requirements of Manual J 7th Ed.

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Page 1

Figure7.1 Short Form Residential Report

RIGHT-J COMPONENT CONSTRUCTION REPORT
Entire House

Water Energy Distributors, Inc.
100 Maple Ave, Atkinson, NH 03811 Phone: 603-362-4666 Fax: 603-362-4890

Project Information

For: Dirigo Pines
ME

Design Information

	Htg	Clg
Outside db (°F)	-2	85
Inside db (°F)	70	75
Design TD (°F)	72	10
Daily range	-	M
Inside humidity (%)	-	50
Moisture difference (gr/lb)	-	22

Infiltration

Method	Simplified
Construction quality	Average
Fireplaces	0

CONSTRUCTION DESCRIPTIONS		AREA (ft²)	R-VAL (ft²-°F/Btuh)	A/R (Btuh/°F)	HTG HTM (Btuh/ft²)	LOSS (Btuh)	CLG HTM (Btuh/ft²)	GAIN (Btuh)
WALLS								
12F	Wood Fr,R-13,3/4" Bead Brd,R2.7 Sheath	988	14	69.2	5.0	4980	1.0	941
WINDOWS								
3A	Wood Frame,Dbl Pane, Clear Glass	180	1.8	99.2	40	7141	45	8082
8B	SGDoor,TIM Fr,Single Pane,Clear Glass	58	1.0	60.6	75	4364	30	1725
DOORS								
10A	Wood Hollow Core Door	42	1.8	23.5	40	1693	7.6	320
CEILINGS								
16G	Under Unconditioned room, R-30 insulation	1173	30	38.7	2.4	2788	1.1	1316
FLOORS								
22B	Slab Floor on Grade, R-5 1" Edge Insul	157	2.4	64.2	30	4620	0.0	0

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Page 1

Figure 7.2 Construction Assumption Report

Previous and most available ASHRAE and ACCA employed weather tables for New York City show winter design temperatures for two standard deviations (2_= 10F), it is recommended the new ASHRAE and ACCA table for 3 standard deviations, 0°F be employed in estimating all design requirements.

An unambiguous and agreed to construction report is a requirement for any residential installation.

7.3 Commercial Requirements

Several options are available to the designer for commercial heating and cooling load analysis. These are:

ASHRAE	Handbook of Fundamentals & other publications
ACCA Manual-N	One-to-one computerization of *ASHRAE Handbook of Fundamentals and ARI data*
DOE 2	Department of Energy Heat loss and gain analysis, with Cost estimating data
BLAST	DepartmentofEnergyHourbyHouranalysistool
Carrier & Trane	Manufacturer'ssoftwareforsizingandoperational costs. Carrier has easier to use and interpret tables. Both are proven to be accurate sizing and evaluation tools. Carrier appears to be easier to critique inputs for errors.

Other Manufacturer Software – not evaluated - however, it is assumed manufacturer sponsored software is traceable to the ASHRAE sources and other responsible sources. With the large amount of input data required for an accurate commercial load insure software employed will be easily critiqued.

Examples of Manual-N output is at figure 7-3. Note the cooling and heating load factors, per ASHRAE are included in the computation. As in the ACCA manual-J analysis, note the use of a construction report. The construction report must be evaluated and agreed to by the general contractor and architect.

Load Breakdowns
Auditorium
Contractor

Job: 123P January, 2002

NY

Project Information

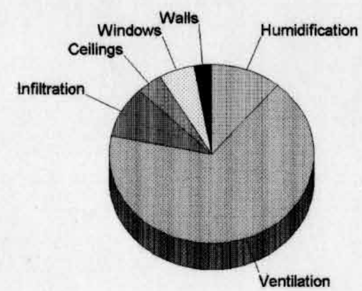
For: Example
Fifth Ave., New York, NY

Zone: Auditorium

Component	Btuh/ft²	Btuh	% of Btuh
Walls	3.1	37620	2.8
Windows	54.5	76230	5.6
Doors	60.5	7260	0.5
Ceilings	2.8	55000	4.0
Floors	0.4	8910	0.7
Partitions	0.0	0	0.0
Infiltration	6.2*	123420	9.0
Ducts	0.0*	0	0.0
Ventilation	45.4*	907500	66.4
Humidification	7.5*	149952	11.0
Totals	68.3*	1365892	100

* Calculated per ft² of floor area

Heating

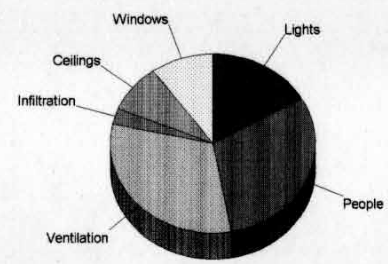


Jul 1500

Component	Btuh/ft²	Sens. Btuh	% of Btuh
Walls	1.0	12048	1.6
Windows	52.2	73060	9.7
Doors	13.8	1650	0.2
Ceilings	3.2	64403	8.6
Floors	0.0	0	0.0
Partitions	0.0	0	0.0
Infiltration	1.0*	20841	2.8
Ducts	0.0*	0	0.0
Ventilation	11.6*	231000	30.8
People	11.3*	225000	30.0
Lights	6.2*	123000	16.4
Appliances	0.0*	0	0.0
Motors	0.0*	0	0.0
Totals	37.6*	751002	100

* Calculated per ft² of floor area

Cooling (Jul 1500)



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Page 1

Figure 7.3 – Typical Manual-N Reports

Right-Suite Commercial Peak Loads
Ah1
Contractor

Job: 123P January, 2002

NY

Project Information

For: Example
Fifth Ave., New York, NY

		Htg	Clg
Outside db	(°F)	15	89
Outside RH	(%)	-	47
Outside wb	(°F)	-	73
Daily range	(°F)	-	17
Moisture diff.	(gr/lb)	-	32

		Htg	Clg
Inside db	(°F)	70	75
Inside RH	(%)	-	50
Inside wb	(°F)	-	63
Design TD	(°F)	55	14

Name	Sensible Gain(MBtuh)	Latent Gain(MBtuh)	Time of Day
Auditorium	751.00	466.05	Jul 1500
Ah1	751.00	466.05	Jul

Right-Suite Commercial Short Form
Ah1
Contractor

Job: 123P January, 2002

NY

Project Information

For: Example
Fifth Ave., New York, NY

		Htg	Clg
Outside db	(°F)	15	89
Outside RH	(%)	-	47
Outside wb	(°F)	-	73
Daily range	(°F)	-	17
Moisture diff.	(gr/lb)	-	32

		Htg	Clg
Inside db	(°F)	70	75
Inside RH	(%)	-	50
Inside wb	(°F)	-	63
Design TD	(°F)	55	14

Heating Equipment

Make		
Model		
Type		
Efficiency / HSPF	0.0	
Heating Input	0.0	MBtuh
Heating Output	0.0	MBtuh
Humidifier	0.0	gpd
Leaving Air Temp	70.0	°F
Actual Heating Fan	23636	cfm

Cooling Equipment

Make		
Model		
Type		
COP / EER / SEER	0.0	
Sensible Cooling	0.0	MBtuh
Latent Cooling	0.0	MBtuh
Total Cooling	0.0	MBtuh
Leaving Air Temp	55.0	°F
Actual Cooling Fan	23636	cfm

Equipment Location	Ah1	
System Type	PEAKCV	
Fan Motor Heat Type	PACKAGE	
Fan & Motor Combined Efficiency	0.0	%
Static Pressure Across Fan	0.0	in H2O

NAME	Area ft²	Heat Loss	Sensible Gain	Latent Gain	Htg cfm	Clg cfm	Time
Auditorium	20000	1365892	751001	466055	23636	23636	Jul 1500
Ah1	20000	1365892	751001	466055	23636	23636	Jul 1500

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Project1.rsc Page 1

7

7

Right-Suite Commercial Load Summary
Auditorium
Contractor

Job: 123P January, 2002

NY

Project Information

For: Example
Fifth Ave., New York, NY

Zone: Auditorium

COOLING LOAD

						Sensible	Latent
1.	**DESIGN CONDITIONS**		at Jul 1500		Peak load at Jul 1500		
	Inside:	75 °F	Outside:	89 °F	TD: 14 °F		
	RH:	50 %	Moisture:	31.9 gr/lb	Mult: 1.0	Ins.wb	63 °F
2.	**SOLAR RADIATION THROUGH GLASS**					56680	-
3.	**TRANSMISSION GAINS**			Sensible		94480	-
	Walls:			12048		-	-
	Glass:			16380		-	-
	Doors:			1650		-	-
	Partitions:			0		-	-
	Floors:			0		-	-
	Roofs/Ceilings:			64403		-	-
	Return Air Ceiling:			0		-	-
4.	**INTERNAL HEAT GAIN**			Sensible	Latent	348000	105000
	Occupants:			225000	105000	-	-
	Lights:			123000	-	-	-
	Motors:			0	-	-	-
	Appliances:			0	0	-	-
5.	**INFILTRATION:**		Outside air cfm:		1353	20841	29879
6.	**SUBTOTAL:**	Space load				520001	466055
7.	**SUPPLY DUCT**					0	-
8.	**SUBTOTAL:**	Bldg comp's and supply duct				520001	-
	Actual cfm:		23636	at Supply TD:	20	-	-
9.	**VENTILATION:**		Make-up air cfm:		15000	231000	331175
10.	**RETURN AIR LOAD:**		Lighting & roof (net)			0	-
11.	**RETURN DUCT**					0	-
12.	**TOTAL LOADS ON EQUIPMENT**					751001	466055

HEATING LOAD

13.	**DESIGN CONDITIONS**				Mult: 1.0	
	Inside:	70 °F	Outside:	15 °F	TD: 55 °F	
14.	**TRANSMISSION LOSSES**					185020
	Walls:			37620		-
	Glass:			76230		-
	Doors:			7260		-
	Partitions:			0		-
	Floors:			8910		-
	Roofs/Ceilings:			55000		-
	Return Air Roof:			0		-
15.	**INFILTRATION:**		Outside air cfm:		2040	123420
16.	**SUBTOTAL:**	Building components				308440
17.	**SUPPLY DUCT:**					0
18.	**VENTILATION:**		Make-up air cfm:		15000	907500
19.	**HUMIDIFICATION**					149952
20.	**RETURN DUCT**					0
21.	**TOTAL HEATING LOAD ON EQUIPMENT**					1366k

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Page 1

These two examples of the same building completed by two different sizing programs, amplify the requirement to utilize commercial sizing programs that allow the designer and software user to easily identify input factors and values. The difference in loads between the two are attributed to variations in the input assumptions. The sensitivity of the result to these inputs and the clear need for accuracy is well demonstrated.

As above, geothermal loads must be accurate. Rules of thumb and "industry accepted factors" must not be employed when sizing any space conditioning system and GeoExchange in particular.

An unambiguous and agreed to construction report is a requirement for any commercial installation.

How to pick an appropriate Ground Source Heat Pump Type

8

8

Section 8.0 Choosing a Geothermal Heat Pump System

The type of geothermal heat pump system that is suitable for a given building must be chosen carefully. The normal process is a collaborative effort involving the owner, the architect and the consulting engineer. Each different geothermal heat pump configuration will affect the architecture and the ability to define climate control zoning. At present the commercially available heat pump types and the major physical implications for the building layout and operation are described here. The consulting engineer and the architect will collaborate in generating a systems comparison study that details the advantages and disadvantages of each mechanical system being considered. This study should compare performance, architectural implications, capital costs, operating costs and maintenance.

Water to air geothermal heat pumps:

A Partially exploded view of a console style geothermal heat pump. The controld, air-side coil and compressor are visible.

Courtesy: *Climatemaster*

Each water to air type of geothermal heat pump is connected to the well water circulating loop. The conditioned air must be distributed through a ducted distribution system. Each unit that requires fresh (ventilation) air will need to have a ducted supply of outside air brought to it. This ducted outside air distribution system should be fan forced, filtered and possibly tempered. If perimeter tempering is required, this may be accomplished with console style units.

The mechanical space requirements are modest given that the heat pumps are distributed throughout the building. The units may be ceiling hung with limited duct runs, or grouped in mechanical rooms. Unit sizes range from one ton (12,000 Btu/hr, 400 cubic feet per minute) to 20 tons. The unit distribution dictates the well water loop configuration. Generally a piped distribution system is less expensive than a ducted one, and the piping is considerably less bulky.

Each heat pump is able to operate in the heating or cooling mode at any time. During the spring and fall when some spaces may require heating and others cooling, this operating mode will be used. Similarly, if large interior zones exist, these may require cooling and ventilation only, even during the heating season. Again, this operating mode will be used. The net load the wells and earth see will be reduced if there is simultaneous heating and cooling.

Water to water geothermal heat pumps:

Water-to-water geothermal heat pump. The water connection for well water and the chilled/ hot water supply and return for the load (building) side loop are visible.

Courtesy: *Climatemaster*

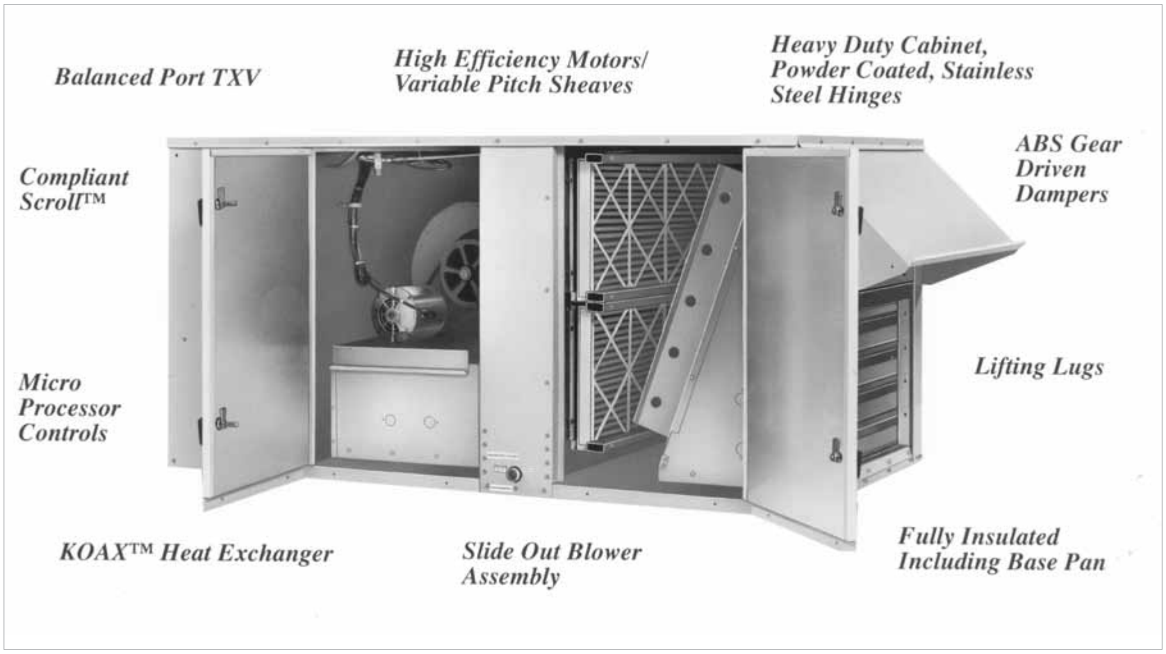
Each water to water type of geothermal heat pump is connected to the well water circulation loop. The chilled or hot water generated is then distributed as required to fan coil units, or heating only applications such as radiant floors or heating elements. The chilled water temperatures available are conventional (40-55 deg. F), while the heating water temperatures are approximately 115 to 125 deg. F. Given that most heating elements are rated at higher temperatures, the heat output at these temperatures must be checked with the heating element manufacturer, and overall heating element sizes will be larger than in installations using higher temperature heat sources. Fan coil units are available in all sizes, and can be ducted units or console style. The console style is available in smaller sizes ranging from approximately 8,000 to 24,000 Btu/hr.

Fan coil units and air handling units, as the larger sizes are called, distribute the conditioned air through ducted distribution systems. Each unit that requires ventilation air will need to be supplied by a ducted outside air distribution system, which should be filtered, but may not need to be conditioned.

The water to water geothermal heat pumps are usually grouped together in a mechanical space, and can be treated as a conventional heater/chiller plant insofar as the distribution systems are concerned. The unit sizes range from three tons to 30 tons, but the market is in flux, with many new variations on this product being developed.

Water to water heat pumps can be piped so that all units operate together which then allows the building to operate either in the cooling or the heating mode. Simultaneous heating and cooling are not possible. Multiple unit installations can be piped in groups to allow simultaneous heating and cooling, but this requires a costly pipe distribution system.

Rooftop Geothermal heat pumps:



Rooftop geothermal heat pump. These units are substantially similar in appearance to conventional rooftop units, but use geothermal wells as a heat source and sink. the fresh air intake/economizer cycle hood, filters, fan and the fan motor are visible.

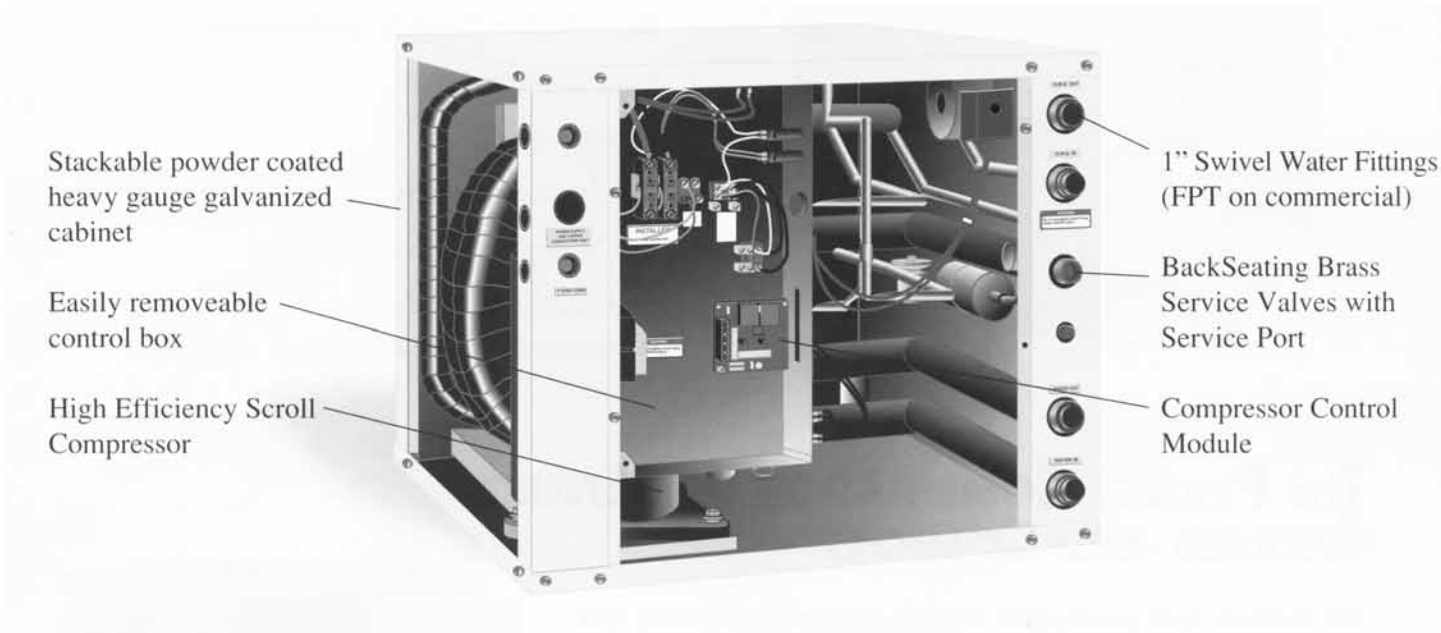
Courtesy: *Climatemaster*

Rooftop geothermal heat pumps are similar in all respects to conventional rooftop units, except that the circulating well water loop must be brought to each unit. The rooftop units are capable of taking in the required ventilation air and do not require a separate system. Commercially available rooftop geothermal heat pumps are available in the 15 to 30 ton sizes, but new models are currently being introduced.

Mechanical space requirements for the units themselves are restricted to the rooftop, and the ducted distribution system may be interior or exterior.

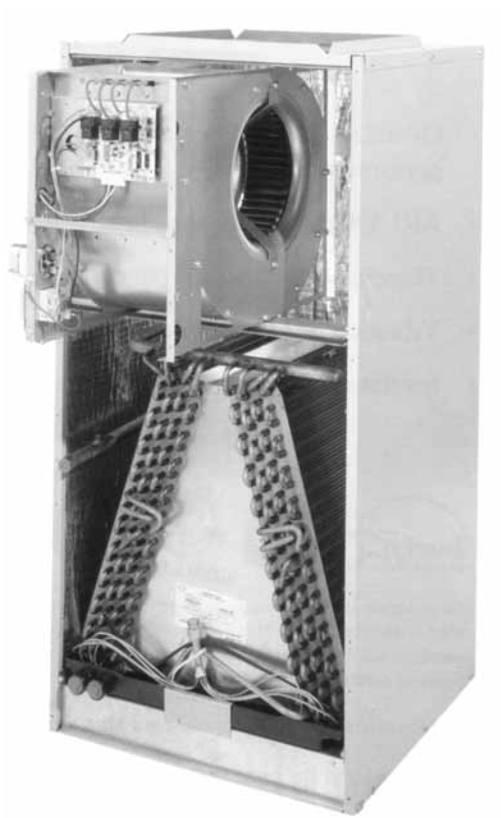
Simultaneous heating and cooling from the same rooftop unit are not possible. If multiple zones are required that have different heating and cooling needs, such as interior and perimeter areas, various rooftop units can be used to meet these needs.

Split type water to air geothermal heat pumps



The compressorized well-side module of the split type geothermal heat pump. Note the similarity to the water-to-water type, but with the refrigerant line connections at the bottom right. The reffrigerant lines can be run to a remote dirrect expansion/condensing section shown below.

Courtesy: *Climatemaster*



The air-side of a split-type geothermal heat pump. The fan section and the refrigerant coil are visible. The reversible refrigerant cycle allows the coil to heat or cool, as called for by the thermostat.

Courtesy: *Climatemaster*

8

The split type water to air geothermal heat pump is the water to air type ‘split’ into the condenser/compressor and coil/blower sections. The reason this configuration exists is that compressorized section which is the source of most of the noise generated by the unit can located remotely. The discussion of the packaged water to air unit above applies in all other respects.

Back up Heating Requirement

In geothermal systems having only one well pump the failure of this pump will leave the climate control system inoperable. Multiple well systems with multiple pumps do not run the same risk since the failure of one pump will not incapacitate the whole system. While the loss of air conditioning in summer is uncomfortable, it is less serious than the loss of heating during cold weather.
In projects where heating back up is warranted, the solutions can be various. The sizing of the back up heating system can be prudently set to provide adequate heat for the average winter temperature, which in New York City is approximately 36 deg. F.
The type of back up heating system used should be the one with the lowest first cost, as the use will be restricted times of pump failure, which are very infrequent.

a
5

8. b. Installation & Commissioning

1.0 A non-conventional diversity of trades is the constant demon of a GeoExchange system. Well drillers do not normally talk to heat pump trades, heat pump (refrigeration) trades do not normally talk to plumbers, and all too often duct installers are in their own world. In recent years the advent of the increasingly popular radiant floor heating adds another diverse trade. A strong general contractor or local "clerk of the works" is a key to a successful GeoExchange space conditioning system.

Manufacturers that provide startup supervision, commissioning services or first year service are an important and necessary addition to any GeoExchange installation. Commissioning provides the general contractor/owner with confidence that all parts of the diverse space conditioning system are properly integrated. A weakness in the chain from the earth coupling through and including the in-building distribution reflects on the entire system.

Including contractual responsibility for the entire HVAC system and verifying its integrity by a commissioning report is the mark of a wise designer and specification.

2.0 – Startup Sheets

The majority of manufactures and distributors all provide "startup sheets". These forms request information that any responsible HVAC installer notes, the requirement to "fill out the form" should not add any additional labor burden to the installer – these are numbers and values that should be recorded for any installation, Geothermal or otherwise.

3.0 – Commissioning

Some manufacturers and distributors, recognizing the need to insure the entire space conditioning system, the chain from the earth to the distribution, require a commissioning record to be completed. This level of recording will identify and allow early correction of potential future problems. Commissioning generally adds a planned cost to the overall job, but early identification of integration problems will inhibit a myriad of unplanned costs.

This is not "rocket science" it is prudence.

4.0 – Typical Commissioning Form

Attached below is a typical commissioning form. Note the form records all components of a GeoExchange system. While not an end all, it provides the engineer, designer and general with increased confidence that the GeoExchange system was properly installed and integrated.

Model #_______________ Serial __________________Job:______________

TIME DATE	HOUR/MINUTES				
ENTERING WATER psi					
temp					
LEAVING WATER psi					
temp					
Flow - GPM					
ENTERING AIR TEMPERATURE					
LEAVING AIR TEMPERATURE					
SUCTION PRESSURE					
HEAD PRESSURE					
SUCTION LINE TEMP & SUPERHEAT					
LIQUID LINE TEMP* & SUBCOOLING					
HOT GAS TEMP					
BLOWER AMPS					
COMPRESSOR AMPS					
LINE VOLTS					
CONTROL VOLTS					

TEST UNITS IN BOTH HEATING & COOLING MODES – ABOVE COLUMNS ALLOW YOU TO MAKE ADJUSTMENTS OR CHANGES. MARK ONE COLUMN EACH FOR HEATING & COOLING TO BE USED FOR EVALUATION. ALLOW 5 MINUTES RUN TIME BEFORE TAKING READINGS.

MAKE ALL MEASUREMENT WITH DESUPERHEATER PUMP DISCONNECTED

DUCTS SUPPLY STATIC					
RETURN STATIC Inches WC or Pacals *circle one*					
REMARKS (heat pump)					

TYPE EARTH COUPLING	STANDING COLUMN OPEN TWO WELL VERTICAL CLOSED LOOP HORIZONTAL CLOSED LOOP OPEN ONE WELL POND LOOP *Circle one*
GENERAL BORE DATA STANDING COLUMN **or** VERTICAL CLOSED LOOP WELL **or** OPEN SINGLE WELL **or** OPEN SUPPLY WELL	WELL DEPTH _________FT QUIET STATIC ________FT LENGTH of CASING _______FT SIZE_____IN. WT._____# DROP PIPE ________IN. PUMP ___________________ OFF-SET TO BUILDING ________FT PIPE SIZE _______IN.

COMPUTE COP

1. Gpm X 500 X Δ temp = Btu/hr heat from Water

2. Total Amps x Volts X 0.8 X 3.413 = Btu/hr heat from Electric

3. Add 1. + 2. = Total Heat Output Btu/hr

4. Total Heat Output Btu/hr (3.) / Btu/hr from Electric (2.) = COP

8

PLUS STANDING COLUMN ONLY INFORMATION	AT ________GPM STATIC LEVEL IS TO ________FT BLEED SYSTEM INSTALLED & OPERATING? NO YES (AQUASTAT, AUTO-VALVE, ISOLATION & POWER –) BLEED PIPE _______IN. & IS TO: (DESCRIBE) BLEED FLOW RATE is SET to ______________GPM
PLUS VERTICAL CLOSED LOOP ONLY INFORMATION	TOTAL LOOP LENGTH_________FT SIZE PIPE________IN. NUMBER OF WELLS_______# DEPTH of WELLS_______FT TYPE SOIL/ROCK: ANTIFREEZE & %_________________ GROUTED? NO YES WITH?:___________________
PLUS OPEN ONE WELL If RETURN (DIFFUSION) WELL IS USED	AT __________GPM DRAW DOWN IS TO _________FT. RECYCLED WATER PIPE _______IN. & IS TO: (DESCRIBE) WELL SCREENED NO YES SCREEN SIZE: LENGTH__________FT SLOT SIZE________ MAT'L______
PLUS DIFFUSION WELL (TWO WELL SYSTEM)	AT_________GPM IMPRESSION IS TO__________FT DIFFUSION WELL PIPE IS ____ IN & IS _________FT LONG WELL SCREENED NO YES SCREEN SIZE: LENGTH__________FT SLOT SIZE________ MAT'L______

8

OTHER EARTH COUPLING CONFIGURATIONS – describe with information as listed above

ClimateMaster COMMISSIONING SHEET FOR **Job:**
Model # **Serial #**

BUILDING
CONFIGURATION

Wall Insulation R =
Basement

Wall Insulation R =
First Floor

Wall Insulation R =
Upper Floors

Attic Insulation R =

Infiltration **Describe**
(leaky, tight, etc.)

Ducts in Attic?
Thickness of
Insulation

Ducts in Basement?
Thickness of
Insulation

IF YOU DO NOT KNOW THE "R" FACTORS OF THE INSULATION, WRITE-IN THE TYPE, EXAMPLE, "FIBER GLASS" AND ITS THICKNESS.

REPORT PREPARED by:

Name________________________________

COMPANY_____________________________Phone____________________

Submit completed COMMISSIONING FORM to:

Water Energy Distributors Inc., 100 Maple Ave, Atkinson NH 03811
Phone (603) 362-4666 – fax (603) 362-4890 - email carlo@tiac.net

ACCEPTED by WEDI : **date:**

8

8.c. CONTRACTOR TRAINING

OVERVIEW

The GeoExchange space conditioning system provides:

Heating Air or Heating Water
Cooling Air or Chilling Water
Heating Domestic or Process Water

Table 8c-1 – GeoExchange functions

A typical installation will provide 100% of the dominant heating or cooling load and approximately 50% - 65% of the domestic water heating. In all cases the successful installation will include a complete integration of all of the three major components of the GeoExchange installation.

Earth Coupling Portion
Heat Pumps
Building Distribution

Table 8c-2 – Major GeoExchange Components

Training programs and GeoExchange contractors that include *all of these three inter-related elements insure a successful installation.* A GeoExchange system lead by a organization with only a portion of the integrated knowledge is most likely to falter or fail to perform as intended.

8

While the present engineering, architectural and HVAC skills are familiar with Building Distribution and Water Source Heat pumps (Water-to-Air), there are interfaces that must be understood and addressed. Industry sponsored training programs for GeoExchange design and installation are discussed in this section.

ClimateMaster	www.climatemaster.com
Florida Heat Pump	www.fhp-mfg.com
Trane	www.trane.com
Water Furnace	www.waterfurnace.com

Table 8c-3 NYC Area Active Manufacturer Geothermal Training Programs:

International Ground Source Heat Pump Association (IGSPHA) – certified instructors , closed loop software
Geothermal Heat Pump Consortium (GHPC) –"Design Assistants", introductory videos, tools and instructors
Association of Energy Engineers (AEE) – Certified GeoExchange Designers[1],
Various tools and publications

Table 8c-4 NYC Available Agency Sources of GeoExchange Trainers

There are also approximately ten other manufacturers in the U.S. producing geothermal heat pumps. Their addresses and contacts can be obtained from the Air Conditioning and Refrigeration Institute (ARI), Roselyn, Virginia. Also see Appendix E, below.

Many manufacturers have segregated geothermal from conventional water source heat pump distributors/offices. ***Insure your inquiry and resultant manufacturing contacts are the Geothermal side of that organization.*** Boiler/Cooling Tower water source heat pumps (e.g. ARI 320) are not suitable for geothermal applications in New York

8c.2. EARTH COUPLING TRAINING

As discussed above earth coupling can take several forms either direct exchange with the earth or indirect through closed loop piping, the merit of each of these methods are discussed elsewhere in the Guide (see sections xxx). Each general method requires a trade skill. These skills are provided by two major segment of the trade structure:

1. Direct Coupling Well Water, either open or standing column wells – these are
typically experienced geothermal well drillers and installers. All are licensed well drillers and possess the equipment and skills to drill deep rock wells and appropriate casing. Qualified drillers are typically member of the National Ground Water Association (NGWA)[2] and have various levels of certification from that organization. Certification examinations are held at the NGWA annual meeting and at other sites throughout the year and are often jointly held with IGSPHA, see paragraph below. NGWA certifications are a trusted method to access the quality of a well drilling service. The well type earth coupling is either identical or very similar to conventional water well drilling.

2. Closed Loop Installers, vertical, horizontal or Slinky – these are a variety of
trades men. All are certified by the International Ground Spruce Heat Pump Association (IGSPHA)[3] and have pipe fusion certification from the primary high density pipe manufacturers. The certification program involves a three day training program, ending in a written examination. While this certification program has a dominant content of closed loop technology, the instruction outlines include well water methods and proper design techniques. IGSPHA has certified several hundred certification instructors. These instructors are from the manufacturing industry and academic resources.

Presently active well contractors in the New York City area with GeoExchange experience:

Contractor	Certifications	
Aquifer Drilling & Testing,Queens, NY	NGWA	
Boyd Wells, Carmel NY	NGWA	
Connecticut Wells, Bethlehem CT	NGWA	IGSPHA
Water Resources, Flushing NY	IGSPHA	
William Stothoff Co, Flemington NJ	NGWA IGSPHA	

Table 8.c-3 – GeoExchange Well Contractors, Presently Active NYC

While the majority of GeoExchange training has been directed towards the unfamiliar earth coupling methods, installation problems are most often traced to a lack of understanding on the integration of the three components of a GeoExchange system, earth, heat pump and distribution. An effective GeoExchange training program(s) must include all three elements.

7.a.3. HEAT PUMP & DISTRIBUTION TRAINING

Trade and manufacturer training programs for conventional water source heat pump systems are active and some have developed local New York GeoExchange training programs.

America Society of Refrigeration & Air Conditioning Engineers (ASHRAE)

Region 1-006 - Long Island
Region I-008 – Greater NYC

Commercial geo Information & Tools - www.ashrae.org

Air Conditioning Contractors Association (ACCA)

Region 1 – NYC
Residential geo information & Tools - www.acca.org
Software Tools - www.wrightsoft.com

Association of Energy Engineers (AEE)
www.aeecenter.org

Air Conditioning and Refrigeration Institute (ARI)
International Standards Product Efficiency Listings - www.ari.org

Table 8.c- 4 National Trade Organizations with GeoExchange Training Resources

These organizations have the structure and resources to integrate local professional training and informational seminars for GeoExchange. Integration of existing air and water design and distribution methods to the wider range geothermal heat pump technology and earth coupling technology is a formula for further success of GeoExchange in the New York City area.

8.c.3. SAMPLING of TYPICAL TRAINING AGENDAS

A. A TYPICAL MANUFACTURER'S Outline[4] - for Engineers and Contractors

Geothermal Installation & Service Technician Training Agenda
Introduction
Training Objectives & Overview

I. Equipment Installation Overview
Installation-Operation-Maintenance (IOM) Manuals
II. Refrigeration System Diagnosis (water source equipment)
III. Specification Catalog Data
Pressure Drop Calculations – Fluid Flow Verification

Heat of Extraction / Heat of Rejection
Water Side Diagnosis Procedure

IV. Troubleshooting Ground Loops & Pumps
Closed & Open Loop Diagnosis
Anti-Freeze Selection and Installation Flushing & Purging
Closed Loops

V. Hot Water Application- Installation-Diagnosis
Hot Water Generators (Desuperheaters)
Demand Hot Water Generation (Water to Water)

VI. Equipment Controls - Diagnosis and Troubleshooting
CXM – DXM – CCM

VII. Equipment Installation
Start Up & Troubleshooting Procedures

VIII. Review & Exam

B. Contractor/Installer Training[5]

GEOEXCHANGE TRAINING AGENDA – One Day

-Why are Geothermal Heat Pumps the Fastest Growing HVAC Market Today.
Federal Programs
State Programs
Your Utilities Programs

-Benefits
Economic
Environmental
Comfort
Low Maintenance & Durability

-How to Get Heat In & Out of the Earth
Closed Loops & Pipe Types
Domestic & Open Wells
Standing Column Wells

BREAK

-How to Properly Size a Building for Heating & Cooling
Insulation ECH & EPA Energy Star/Building Programs
Infiltration & Air Leakage
Fresh Air?

-What's on the Heat Pump Market Today?
Basic Single Stage w/EM Controls
Multi-stage/Speed w/ Digital Controls
Building Automation Controls

LUNCH

-Designing a GeoExchange System
- Earth Coupling Options
- Closed Loop Earth Coupling & Design
- Pumping & antifreeze
- Open Standing Column & Design
- Pumping & Options
  - Heat Pump Options
  - Selecting from Catalogue
- Distribution Options
  - Ducts
  - Radiant Floor
  - Fan Coils
  - Base Board.
- Recommended Design Packages

-Check, Test & Startup
- How to test for water flows
- Classic/Ultra/Genesis
- Commissioning Reports/How Well is it Working?

BREAK

-Take a Look at the Industrial Geothermal Heat Pump Market
-Questions & Answers

C. IGSPHA CERTIFICATION – Outline - (3 day)[6] – for Engineers &Contractors

CERTIFICATION OUTLINE

1- Introduction and Overview
2- Economics, marketing and Demand Reduction
3- Soils Identification
4- Selecting, sizing and Designing the Heat Pump system
5- Designing the Ground Heat Exchanger
6- Pipe Joining Methods
7- Installing the Ground Heat Exchanger
8- Grouting Procedures for Ground-Source Heat Pump systems
9- Flushing and Purging the System
10- Heat Pump Systems Start-up and Checkout
11- Accessories
12- Exam

D. Water-to-Water Geothermal Training for Engineers, Contractors & Utility Personnel[7]

DESIGN & INSTALLATION WORK SHOP for
WATER-to-WATER Geothermal- Heat Pumps

Water-to-Water HP's, Fan Coils & Components - Catalogue

Specifications
Fan Coil Selections
Schematics
Controls
Trim Items
DDC Interfaces

Geo-Coupling to the Earth

Closed Loops Horizontal
Pond Loops
Closed Loops Vertical
Open Well (s)
Slinkys
Standing Columns

Water Wells for Domestic & Heat Pump Use

Well Demonstrator & Components

Residential, Commercial & Industrial Markets
Component Block Diagram Level -

Retrofit to Base Board
Retrofit to AHUs
A/C Addition
Schools
Radiant Floor
Warehousing
Water Heating
Process
Pools
Water Heating

BREAK

Generating Requirements (Heat Gains & Losses) -

Manual "J" residential
Swimming Pools
Manual "N" commercial
Water Heating

Continue Residence - Component Selections

Hardware & Trim Items

LUNCH

Residential & Commercial Example Layouts & Components

Residential Retrofit
Expandable Retrofit
Multi-Zone New House
Sample New Residence
W-W HP Controls

Radiant Floors

Design Requirements
Installation Options
Component Selection/Piping
Interfacing w/Geo-HPs
Controls

Saving Well Pumping Costs

Schemes for Combined Domestic & Heat Pumps
Use of Power Factor Controllers
Electrical Trouble Shooting Well Pumps

Commercial Retrofit Example & Design - Layout

Library & Museum
School

BREAK

Continue Commercial Retrofit - Component Selections

Library
School
Museum
Office Building

Installation Checkout & Startup

Water Balancing
Heat of Absorption
Computing Efficiencies Heat of Extraction
Antifreeze Solutions

“Mixed” Systems

Replace Boiler/Cooling Tower
Water-to-Air & Water-to-Water Applications
Cold Space Applications

8

(Footnotes)

[1] A recently instituted certification program jointly administered by IGSPHA, GHPC and AEE

[2] National Ground Water Association – Dublin OH

[3] International Ground Source Heat Pump Association, Oklahoma State University, Stillwater OK

[4] Courtesy ClimateMaster Corp

[5] Courtesy of Water Energy Distributors Inc., Atkinson NH

[6] Courtesy of International Ground Source Heat Pump Association, OK State University, Stillwater OK

[7] Courtesy of Water & Energy Systems Corp, Atkinson NH

Performance and Ratings

9

9.0 Performance & Ratings

Appendix G provides a listing of commercially available geothermal heat pumps using open wells, standing columns and closed loops.

9.1 HOW ARE GEOTHERMAL HEAT PUMPS RATED

These heat pumps have been rated in the past by Air Conditioning and Refrigeration Institute (ARI). Since January 2000 the heat pumps have been rated by the International Standards Organization (ISO),

Past ARI ratings will still be used by many Manufacturers and will gradually transfer their ratings to ISO ratings. Past ARI Ratings are:

		Earth Coupled Entering Liquid	
	Commonly Called	Heating	Cooling
ARI 325[1]	"Well Water Rating"	50°F	50°F
ARI 330	"Closed Loop Rating"	32°F[2]	77°F

Entering Earth Water Temperatures for Various ARI Ratings

The ARI ratings only included procedures for rating Water-to-Air geothermal heat pumps and there were no rating methods for water-to-water heat pumps.

The ISO ratings include water-to-air geo heat pumps (ISO 13256-1) and water-to-water geo heat pumps (ISO 13256-2) rating methods.

Ratings are based upon similar, but somewhat different, entering water temperatures, they are:

		Earth Coupled (Outside) Entering Liquids	
	Commonly Called	Heating	Cooling
ISO 13256-1	"GWHP"	50°F	59°F
	"GLHP"	32°F[3]	77°F

Entering Earth (OUTSIDE) Water Temperatures for Various ISO 13256-1 Ratings

Dry bulb and wet bulb temperatures for building (Inside) air temperatures are approximately the same for the old ARI and ISO rating points.

It should be noted, ISO has adopted the terms "Outside" for the earth coupling water side and "Inside" for the building or load side of the heat pumps. Hopefully, to alleviate the continued confusion that exists between "ground", "well", "Condenser", "evaporator" and the myriad of terms used on both side of the geothermal heat pump.

9.2 CAPITAL COSTS

Geothermal heat pumps are priced very similar to their "Building Loop" heat pumps with several exceptions that add some pricing to the basic heat pump:

1. Additional controls, e.g. thermostatic expansion valves to provide efficient operation with wide entering water temperature ranges, typically 20°F to 110°F
2. Larger control transformers for built in or auxiliary water flow controls
3. Larger heat exchangers to allow the wide temperature range operation.
4. If using well water the requirement for a copper-nickel rather than copper heat exchangers for enhanced reliability

As with all heat pumps the smaller the unit the higher the "Cost per ton" – small units and large units both require cabinets, electronic controls, manufacturing overhead – all of these are relatively independent of the size of the heat pump.

Typical averaged list price costing for several manufacturers are:

Size Range	Typical Cost per Ton
½ to 1 ½ tons	$ 2,000 to $1,300
2 to 3 tons	$ 600 to $ 500
5 to 10 tons	$ 500 to $ 500
over 10 tons	$ 500 to $ 400

Typical Geothermal Heat Pump Commercial List Prices – 2001
Including Copper-Nickel Alloy HX on Geo-Side

Adds to these costs are typically various factory applied options:

- Direct Digital Control Interfaces, e.g. LON Work and Bac Net
- Two-way Communicating Controls
- Quieting/Muting Packages
- Dual Compressor Heat Pumps
- Dehumidification Modes
- Hot Gas Reheat Systems
- Desuperheaters (Hot Water Generators)

9.3 PROCUREMENT REQUIREMENTS

Matching building loads to the Geothermal heat pumps is a must. Using “rules-of-thumb” for equipment sizing is not acceptable. Section 7 discusses geothermal heat pumps and their earth coupling system. The entire system must be matched to an accurate building heating and cooling/dehumidification load.

Geothermal heat pump systems (GeoExchange) have a wide variety of configurations and many are discussed in the document. A successful procurement for geothermal recognizes the dependant relationship between the earth, the heat pumps and the delivery terminals. It is mandatory that the three elements be under the same technical and administrative organization. Breaking out each of the three or even two of the three elements will lead to errors and fault finding and damaging bickering.

Always procure a GeoExchange system as a sole entity, do not break out components. If an HVAC contractor cannot take the responsibility for the entire “package” - find one that will

If there are existing wells on the site; determine the earth coupling requirements first and then have the well(s) tested to see if they will meet these requirements. Do not accept old well information as correct, it must be field verified.

9.4 RETURNS ON INVESTMENT

9.4.1 Simple Payback

A simple pay back looks at the total price of an installation, the annualized savings and simply divides the two, with the result of so many years to payback the difference between a GeoExchange systems and a fossil based system. There are two ways to consider simple pay back for small systems of less than 350-400 tons;

Paying the first cost **difference** between the GeoExchange and an equivalent capacity fossil system – this difference is usually paid back in about 3 – 5 years.

Paying the cost of a **completely new** GeoExchange system installation as compared with keeping an existent fossil based heating and cooling system in place. – this difference is usually paid in 8 –12 years

9.4.2 Return on Investment (ROI)

A GeoExchange system can be a better investment than most conventional income investments. When considering the return on a down payment (e.g. 10% - 20%) for a building with a GeoExchange system the ROI for that amount of capital is often in the 20% - 30% range.

9.4.3 Present Value (PV)

PV is useful when comparing the GeoExchange investment with another investment. In a real sense this function will let the potential GeoExchange owner consider their investment in the Geo System as a source of an annuity.

9.4.4 CASH FLOW

In nearly all cases, there is almost always a positive cash flow when comparing a GeoExchange system to a competing fossil based system in the very first year.

9.5 MAINTENANCE

The reliability and maintenance cost for the GeoExchange heat pump has been the subject of several factual studies over the past decade. The overall life of a water source/ GeoExchange heat pump has been evaluated in an Electric Power Research Institute report[4] in 1988. Looking at a large population of actual heat pump installations, showed smaller water source heat pump had a mean time between failure (MTBF) of 46 years and large commercial water source heat pumps 19 years MTBF.

GeoExchange maintenance costs are more impressive with several site closely monitored in the past few years. GeoExchange installations have been recently evaluated by the U.S. Army[5] and Caneta Research Corp[6]. GeoExchange heat pumps are shown to be lower maintenance costs than comparable gas or oil based heating systems.

The Table below shows the results of these studies:

4,003 buildings, U.S. Army Study, Ft. Polk LA	30% reduction
25 Buildings (U.S. & Canada)	20% reduction

It should be noted that of the 25 building surveyed, 15 were schools. All of the schools were in Canada, New Jersey and Pennsylvania. School maintenance costs for GeoExchange heat pumps were evaluated for in-house and contractor maintenance:

GeoExchange Cost per Square Foot

	Mean Cost	Standard Deviation
In-House	\$0.0594	\$0.0509
Contractor	\$0.0697	\$0.0618

School Survey of Maintenance Costs – Actual Labor Costs Averaged Over System Life

In the above table the approximate labor rate was $26.00/hour plus 36% Overhead and Benefits allocation.

A comparison of total Maintenance Costs from a 1985 Caneta Research Survey compared against an ASHRAE[7] survey shows:

	Cost per Square Foot		
	Mean Cost	Standard Deviation	
Caneta Survey	$0.0732	$0.0692	Base Case, GeoExchange
ASHRAE Survey	$0.2180	$0.1640	Water Source Heat Pumps
	$0.5220	$0.3380	Gas Absorption Chiller

Results of Recent Maintenance Studies, Commercial Buildings
GeoExchange vs. Typical Fossil Based System

The ASHRAE survey included nearly 350 buildings and a variety of heating and cooling space-conditioning systems.

A recent study[8] (1999) of four types of space conditioning systems in the Lincoln Nebraska Public School District compared these different heating and cooling systems in the District's 20 school buildings. The results do not include preventative maintenance and capital renewal in the 20 school data base.

Type Space Conditioning System	Annual Cost/Square foot
Geothermal Systems	$ 0.0213
Air Cooled Chiller w/ Gas Hot Water Boiler	$ 0.0288
Water Cooled Chiller w/ Gas Hot Water Boiler	$ 0.0373
Water Cooled Chiller w/ Gas Steam Boiler	$ 0.0607

Operational Repair Maintenance 20 Schools – Lincoln Nebraska

These recent (1999) maintenance costs for geothermal are substantially lower than those report in previous studies, see above.

Reduced maintenance costs can be attributed to:

-Single machine provides heating and cooling, i.e. one piece of equipment replaces two or more items
-Geothermal heat pump systems are highly modular, i.e. multiple wells/ore and multiple heat pumps in a facility provide a high level of reliability
-Geothermal heat pumps and their well/bore components have no unique components requiring periodic maintenance –other than air filter cleanliness
Since the geothermal heat pump systems are highly modular many designers also

specify emergency electric backup elements in the supply airside. As a backup, these electric elements can utilize the power service designated for the heat pump, when that local heat pump is in a failure mode. This is not a common requirement, but critical areas can be maintained in a freeze-proof condition using the same electrical service as the temporarily disabled heat pump.

To backup a geothermal heat pump system with a fossil system is not recommended. If a fossil backup system is specified this essentially triples the maintenance costs. The geothermal pump has been shown to reduce maintenance costs by approximately 50% - keeping the fossil system in place then adds that maintenance cost – with the resultant 150% maintenance cost, viz. 50% geo and 100% fossil.

9.6 CASE STUDIES

Three different buildings representing three different building uses and types are evaluated for over all operational costs over a ten year period.

The above heating and cooling loads may not reflect the actual design and use characteristics of the buildings from which the loads and use profile data was taken. These buildings were selected as models to be used in the below analysis.

Each of these building types have been evaluated with a consistent set of economic assumptions. These and any other assumptions used in economic modeling must be verified <u>before</u> the results of any operational cost model are considered.

Summary results of these linear operational cost estimates are as shown in the table below. Payback periods are based upon simple payback of the differential costs of the geothermal over a natural gas fossil burning system.

Differential hardware costs must include added geothermal costs and avoided costs associated with a fossil based system, some typical added and avoided items are as listed below.

<u>Added First Cost</u>	<u>Avoided First Cost</u>
Wells/Bore holes	Boiler
Well/Bore Pumps	Chiller
Offset Piping & Installation	Cooling Tower (CT)
Well/Bore Controls	CT Pumps
Site Work/Trenching	CT/Boiler Controls
Geothermal Heat Pumps	Combustion Air Grills
Thermal Mass Tank (Water-Water HP)	Site Gas Service Piping or Oil Tank
2-Pipe Distribution System	4-Pipe Distribution System
Roof-top Curbs, Penetrations & Access	Roof-top Weight Bearing Structure
Roof-top Rigging	
Housekeeping pads	

9

Exterior Equipment Security
Reduced Mechanical Room Size

TYPICAL DIFFERENTIAL COST FACTORS GEOEXCHANGE vs. FOSSIL SYSTEMS

Other factors as aesthetics (no exterior equipment), no need for operating engineers, no combustion products (possible fire insurance reduction), lower site maintenance (no fuel spills, Cooling Tower scaling or carbon deposits) and no Cooling Tower chemicals are factors that are more difficult to quantify in the first cost analysis but are important continuing operational costs, and must be recognized.

COMPARISON OF GEOTHERMAL HEAT PUMPS TO NATURAL GAS BASED SYSTEM FOR PUBLIC LIBRARY

Differential Capital Cost (First Cost)	$ 75,000
First Year Operational Cost Savings	$ 7,900
Ten Year Total Cost Savings	$ 100,000
Simple Payback	8 years
Carbon Dioxide Inhibited[9]	41 tons each year

COMPARISON OF GEOTHERMAL HEAT PUMPS TO NATURAL GAS BASED SYSTEM FOR PUBLIC GARDENS BUILDING

Differential Capital Cost (First Cost)	$ 100,000
First Year Operational Cost Savings	$ 10,025
Ten Year Total Cost Savings	$ 138,549
Simple Payback	8 years
Carbon Dioxide Inhibited	92 tons each year

COMPARISON OF GEOTHERMAL HEAT PUMPS TO NATURAL GAS BASED SYSTEM FOR SINGLE FAMILY RESIDENCE
(an attached row house on Reade Street in Manhattan)

Differential Capital Cost (First Cost)	$ 13,000
First Year Operational Cost Savings	$ 1,553
Ten Year Total Cost Savings	$ 22,833
Simple Payback	6 ½ years
Carbon Dioxide Inhibited	22.4 tons each year

High first costs are estimated for the three examples. However, it must be noted that estimates by the Geo Heat Center, Klamath Falls, Oregon[10] have projected a cross over in installed geothermal costs at approximately 500± tons. Several larger geothermal heat pump projects have projected mcosts less than conventional fossil heating and cooling systems.

Energy Costs	Electric	$ 0.09 per kWh
	Natural Gas	$ 0.78 per CCF (Avg 100mbtu/CCF)
	Oil, #2	$ 1.10 per gallon (Avg 132 mbtu/gal)

		Library	Gardens	Residential
Operational Hours[11]	Heating	1,500	2,200	2,000
	Cooling	1,100	1,200	900

Equipment Efficiency

COP[12]	Electric Heat	1.0
	Air-to-Air Heat Pump Heating	2.0
	Geothermal Heat Pump Heating	3.6
Heating Efficiency[13]	Natural Gas Boiler/Furnace	80%
	Light Oil (# 2) Boiler/Furnace	75%
	Propane	80%
	Heavy Oil(# 4-6) – requires preheat	55%

EER[14] Cooling

	Window Air Conditioner	12.0
	Air-to-Air Heating Pump Cooling	14.0
	Geothermal Heat Pump Cooling	19.0
	Cooling Tower & Chiller & Pumps	15.0

TYPICAL EFFICIENCY VALUES USED IN BELOW COST EVALUATIONS
Actual Projects & Equipment Models will Vary Results

While these may not be the actual conditions for the actual building the economic model employed will have consistent and hence, comparative results.

9

(Footnotes)

[1] An alternative ARI-325 rating for Southern States applications uses 70°F geothermal water for heating and cooling

[2] At 32°F the rating includes a brine type antifreeze, brine is used as a standard antifreeze for evaluation purposes only. As it is not used in any actual applications it then becomes a universally accepted standard. Some antifreeze solutions may result in lower efficiencies than listed in the ARI or ISO standards.

[3] At 32°F the rating includes a brine type antifreeze

[4] Ross, Dr. David, PRA Inc. Pilot Study of Commercial Water-Loop Heat Pump Compressor Life, EPRI CU-6739, March 1990

[5] J.Shonder & P. Hughes, Results from the Geothermal Heat Pump Energy Savings Performance Contract at Fort Polk LA, Oak Ridge National Lab, IGSPHA Conference, 10-1997

[6] D.Cane et al, Survey and Analysis of Maintenance and Service Costs in commercial Building Geothermal Systems, Caneta Research Inc., RP-024 10-1997

[7] ADM Associates, Analysis of Survey Data on HVAC Maintenance Costs (RP-382), ASHRAE Technical Committee 1.8, 1985

[8] Martin, MA, Durfee and Hughes P.J, Comparing maintenance costs of geothermal heat pump systems with other HVAC systems in Lincoln (NB) public schools: Repair, service and corrective actions, ASHRAE Trans, 1999, Vol. 105, Part 2, #SE-99-20-04, 1208-1215

[9] Although Natural Gas is a cleaner burning fuel than fuel oil, it none-the-less has a CO_2 emission of 9-12 pounds of CO_2 per CCF about 50% less than fuel oil.

[10] Oregon Institute of Technology – Klamath Falls Oregon, geoheat@oit.edu

[11] ARI Standard 210 Lists New York City area as 2,400 hours heating and 700 hours cooling; these are modified by the typical use and urban building configurations, e.g. two of four walls are party walls, the effects of passive solar and estimated use profiles. From building to building these *key* numbers will vary. Hour-by-Hour simulations or a rigorous derivation from existing energy bills can provide relatively accurate values for these evaluations.

[12] Coefficient of Performance (COP) typically used for *Heating* efficiency evaluation worldwide. COP is the ratio of the purchased energy (electric) cost verses the output of the space heating equipment as measured by the same units, e.g. watts, calories, Btu etc.

[13] The efficiency of the fossil burning equipment also includes the cost of parasitic electricity, i.e. the cost of running the motors and controls in these devices. These costs are only a smaller portion of the overall equipment efficiency

[14] Energy Efficiency Ratio (EER) typically used in the United Sates for *Cooling* efficiency and is the ratio of Btu performance verses the amount of purchased energy in watts.

Summary of Refrigerant Types used in Geothermal Equipment

10

10. Summary fo refrigerant s used in Geothermal Heat Pumps

Hydrochlorofluorocarbons (HCFC's) are used in heat pumps and air conditioners worldwide and are now being regulated because of their impact on ozone depletion and will have to be replaced fairly soon. Hydroflourocarbons (HFC's) may be suitable as short to medium-term replacements, but may not be suitable for long term use due to their high global warming potential (GWP). Several issues will dictate the choice of long term replacements for HCFC's but in the long term only those technologies are sustainable that can address the dual challenge of protecting the ozone layer and containing adverse climate effects.

Air-conditioning and heat pump appliances must often satisfy national, regional and local requirements for energy efficiency, safety (operation, repair and disposal) and environmental acceptability. Designs that minimize the quantity of refrigerant for the same capacity will harm the environment proportionately less than those of greater volume. Currently, the main alternatives are HFC's and HFC blends, although there are potential non-HFC alternatives as well.

Alternative refrigerants for various applications:

Application	HFC's	Other than HFC's
Unitary air conditioners	R-410A, R407C	HCFC-22, HC's, CO_2
Centralized AC (chillers)	R-134a, R-410A, R-407C	HCFC-22, HCFC-123 NH_3, HCs, CO_2, H_2O
Heat Pumps (heating)	R-134a, R-152a, R-404A, R-407C, R410A	NH_3, HC's, CO_2

In certain applications it is currently technically feasible to phase out ozone depleting substances without resorting to HFC refrigerants. Hydrocarbons and ammonia are examples of possible replacements. However the use of such substances can result in a net negative impact on global warming. This is because in some applications replacing HFC-based substances by alternatives results in a lower energetic efficiency of the equipment. The 'energy penalty' resulting from this lower efficiency outweighs the gain achieved by the reduction in HFC emissions.

Environmental characteristics of some refrigerants:

Refrigerant	Atmospheric Lifetime (yrs)	ODP	GWP (100th yr ITH) (integrated time horizon)
HCFC's			
HCFC-22	12.1	.055	1500
HCFC-123	1.4	.02	90
HCFC-141b	9.4	.11	600
HFC's			
HFC-134a	14.6	0	1300
HFC-32	5.6	0	650
HFC-152a	1.5	0	140
HFC-245fa	7.3	0	820
HC's			
HC-290 (propane)	-	0	3
Zeotropes and Azeotropes			
R-404A	-	0	3260
R-407A	-	0	1770
R-407C	-	0	1530
R-410A	-	0	1730

HFC's are free from chlorine and have zero ozone depleting potential (ODP) However their GWP is much higher than the GWP of natural fluids such as hydrocarbons, carbon dioxide, ammonia and water. The latter are therefore the most likely long-term candidates for replacing HFC's. They may well become the future standard in their industry. A case in point is the use of supercritical carbon dioxide technology for mobile air-conditioning and other applications.

Appendix A

Sources for Hydrogeological Information

A
a

Sources for Hydrogeological Information

Agencies:

United States Department of the Interior
United States Geological Survey
Water Resources Division
2045 Route 112, Building 4
Coram, NY 11727-3085
tel 631 736 0783

NYC Department of Design and Construction
Mr. Michael Greenman – Subsurface Division
30-30 Thomson Avenue
Long Island City, NY 11101
tel 718 391 1700

Reports and Maps:

Busciolano, Ronald, Monti, Jack, Jr., and Chu, Anthony, 1998, **Water-table and potentiometric-surface altitudes of the upper glacial, Magothy, and Lloyd aquifers on Long Island, New York**, in March-April, 1997, with a summary of hydrogeologic conditions: U.S. Geological Survey Water-Resources Investigations Report WRI-98-4019, 17 p., 6 pls.

Baskerville, Charles, A. 1990, **Bedrock And Engineering Geologic Maps of New York County and Parts of Kings and Queens Counties**, New Jersey
Open File Report 89-462

Baskerville, Charles, A. 1990, **Bedrock And Engineering Geologic Maps of New York County and Parts of Kings and Queens Counties**, New Jersey
Open File Report 89-462

Donaldson, C.D., and Koszalka, E.J., 1983a, **Potentiometric surface of the Magothy aquifer, Long Island, New York**, in March 1979: U.S. Geological Survey Open-File Report 82-160, 2 sheets, scale 1:250,000.

Garber, M.S., 1986, **Geohydrology of the Lloyd aquifer, Long Island, New York**: U.S. Geological Survey Water-Resources Investigations Report 85-4159, 36 p.

Kimmel, G.E., 1971a, W**ater-level surfaces in the aquifers of western Long Island, N.Y.**, in 1959 and 1970, in Geological Survey Research 1971: U.S. Geological Survey Professional Paper 750-B, p. B224-B228.

Perlmutter, N.M., and Arnow, Theodore, 1953, **Ground water in Bronx, New York, and Richmond Counties with summary data on Kings and Queens Counties, New York City, New York**: New York State Water Power and Control Commission

Bulletin GW-32, 86 p.

Prince, K.R., 1976, **The potentiometric surface of the Magothy aquifer on Long Island, New York**, in March 1975: U.S. Geological Survey Open-File Report 76-536, 12 p.

Smolensky, D.A., 1984, **Potentiometric surfaces on Long Island, New York—a bibliography of maps**: U.S. Geological Survey Open-File Report 84-070, 31p.

Smolensky, D.A., Buxton, H.T., and Shernoff, P.K., 1989, **Hydrologic framework of Long Island, New York**: U.S. Geological Survey Hydrologic Investigations Atlas HA-709, 3 sheets, scale 1:250,000.

Soren, Julian, 1971a, **Ground-water and geohydrologic conditions in Queens County, Long Island, N.Y.**: U.S. Geological Survey Water-Supply Paper 2001-A, 39 p

Soren, Julian 1978b, **Subsurface geology and paleogeography of Queens County, Long Island, New York**: U.S. Geological Survey Water-Resources Investigation Open-File Report 77-34, 17 p.

Soren, Julian 1988, **Geologic and geohydrologic reconnaissance of Staten Island, New York**: U.S. Geological Survey Water-Resources Investigations Report 87-4048, 22 p.

Soren, Julian, and Simmons, D.L., 1987, **Thickness and hydrogeology of aquifers and confining units below the upper glacial aquifer on Long Island, New York**: U.S. Geological Survey Water-Resources Investigations Report 86-4175, 3 sheets, scale 1:125,000.

Other sources:

Local well drillers and water companies.

Appendix B

Sample Specifications

A
b

These specifications are samples only, and are not meant for use with any particular application. The use of professional consultants is required. No warranty is given, nor is any liability assumed.

Specifications for Standing Column Well – Typical for Near surface Bedrock, as Manhattan and NW Queens. Two slightly different specifications are included for residential and for commercial standing column wells.

The residential specification allows for the use of the standing column for domestic and/or irrigation purposes. This multiple use provides the standing column with convective temperature restabilization (returning the well column to the mean earth temperatures) every time domestic water is used; a desirable and practical design.

The two example specifications must be employed with care. Piping sizes are specified for that specific application and may change with offset distances, well depth or other well characteristics. These specifications are a guide template, not to be considered final and all encompassing specifications.

6 f .1 RESIDENTIAL STANDING COLUMN WELL RECOMMENDED SPECIFICATION
EARTH COUPLING/STANDING COLUMN WELLS

Reference Drawing ________________dated_________

PART 1. GENERAL
specwellNYRES.docc

1.1 DESCRIPTION

A. The work of this section describes the material associated with a GeoExchange Standing Column Well system. Sections included and managed by the SAME HVAC contractor are: Geothermal Heat Pumps specification section and other related mechanical material. This section governs items specified for work under this section and other integrated mechanical sections.

1.1 WORK INCLUDED

A. As specified and as shown, furnish, install, test and place in satisfactory and successful operation all equipment and one (1) bore holes, material, devices and necessary appurtenances to provide a complete and operable standing column well (SCW) system for the specified GeoExchange heating, cooling and domestic hot water systems. The standing column well system is defined as one (1): bore holes, casings, sanitary seal, pump wiring and exterior piping and submersible pump. As specified on prints exterior pump wiring, supply and return exterior piping, as defined interior piping, controls, wall penetrations and seals, pressure tanks, supply and return manifolds, pump and bleed controls and valves.
B. Work includes trenching, final back-fill, grading or reseeding.
C. Work includes water testing, rock sample collections and necessary permitting.

PART 2. PRODUCTS -

2.1 STANDING COLUMN WELLS –

A. The Contractor shall use water as the heat transfer medium.
The Contractor shall install one (1) SCW wells at 700 foot water column depth, the SCW with a minimum yield of 3-4 US gpm, without substantial reduction in the water column length. The design intent is to create a combined heat transfer capability each Standing Column Well of ten (10) tons.

2.2 WELL HEAD –

A. Two 1 ½ inch minimum bronze pitless adapters shall be used, either as two adapters or a single dual adapter at the SCW head. The pitless adapters shall allow for ease of setup and removal of the drop pipes and pump. Pitless adapter shall be a minimum of 1 ½ inch fittings.
B. The well shall be sealed with a standard sanitary well head
seal and shall be protected at all locations as indicated by general contractor's stake or as shown on prints.
The well head shall be protected with a sanitary seal as shown on drawings. Alternative well head protection as Carlson Industries model 1730-18 with polymer concrete cover and concealment maybe considered and must be submitted to General Contractor for approval.

2.3 PIPING –

A. Buried supply and return piping shall be 1 1/2 inch High Density Polyethylene (HDPE), PE3408 resin with ratings of ASTM D3035-93 for pipe and ASTM D3261 for fusion fittings. A pipe cell classification of 355444C, SDR-11 is required. Drisco 5300 series or equal is required to insure abrasion resistance.
B. Supply drop piping in each well shall be nominal 2 inch interior diameter (ID) or equivalent. Return drop pipe of identical nominal size and of HDPE, as specified above, shall discharge return water below the minimum static level by 10 -30 feet. Design of a free-fall water return is not permitted.
C. It is desired that all underground pipe shall be free of joints. Should joints be required they shall be butt or socket heat fuzed by a method approved by the pipe manufacturer and the International Ground Source Heat Pump Association (IGSHPA) or the pipe manufacturer.

2.4 CASING –

A. As shown on drawings the well shall be cased to bedrock and sealed by a drive shoe approximately 75 feet into the bedrock or in a manner specified by local code and the General Contractor.
B. The casings shall be OD 6 inches or by well contractor option, 8.625 inch, 19+ pounds/linear foot ASTM A-500 steel, made in U.S.A. The casing shall be an alloy approved by the National Ground Water Association (NGWA).
C. Bid should be based upon a 40 foot to bedrock and a casing length of 70 feet.

2.5 OTHER WORK –

A. The Well Contractor shall protect the area to prevent flooding while drilling the well and associated operations is the responsibility of the Well Contractor.
B. Excess and/or drilling water temporary containment pit is required. The Well Contractor prior to burial of piping and connection pit must perform testing of the well piping and coupling for leaks.
C. The Well Contract will nominally return the area to its earth grade condition. The Contractor will perform landscape work as specified. All trenching for the 1 1/2 inch HDPE pipe shall be provided. Trench shall be a nominal three foot wide. Back filling with 6 inches of sand above and below the HDPE pipe and the 3-4 inch moisture resistant extruded polystyrene foam board insulation separator shall be by the Well Contractor.
D. The Well Contractor shall provide temporary water pit and necessary dewatering pumps for drilling water.

2.6 SAFETY –

A. All material, equipment, labor and protection needed to safely complete this work shall be the responsibility of the Well Contractor.

2.7 HEALTH –

A. Disinfectant of the well, pumping and piping systems with a method approved by the National Ground Water Association is by the Well Contractor. In-process wells will be maintained in a disinfected state at all times.

2.8 WATER QUALITY-

A. Whether the Standing Column is used for domestic purposes or not, the well water must be tested for drinking quality standards by a test laboratory which is approved by the State and General Contractor.
B. Drinking quality standards of New York State must be met to re-inject the water back into the well column. A copy of the water test information must be maintained at the geothermal heat pump site and a copy forwarded to the General Contractor.

2.9 SUBMERSIBLE PUMP –

A. IF WELL IS FOR HEAT PUMP ONLY -Provide a submersible well pump with lift and flow capability as specified on well schematic drawing. The well pump shall be carefully sized to insure a flow of 30 US gpm at 20 psig to the building's heat pump manifold. Over sizing or under sizing shall not be tolerated.
B. IF WELL IS FOR HEAT PUMP AND DOMESTIC PURPOSES – **RECOMMENDED** Provide a submersible well pump with lift and flow capability as specified on well schematic drawing. The well pump shall be carefully sized to insure a flow of 30 US gpm plus domestic needs at 40 psig to the building's heat pump and domestic manifold. Over sizing or under sizing shall not be tolerated.
C. Pump selection shall be made only after the well is drilled and a probable mean static level is determined for the well at a flow rate of 3 gpm (The nominal bleed rate). The well pump shall not be installed until after submittal is approved by the General Contractor.

2.10 ELECTRICAL –

A. The well pump shall be provided to operated on 208230 ac volts *single phase*. The electric service to a Well Contractor provided disconnect shall be mounted on the sub-basement wall for the well pump nearby the pipe entrance through the basement wall.

B. The Well Contractor shall provide water blocked and waterproof pump cable suitable for submersible well pumps from the well disconnect to the submersible pump. All submersible wiring and connections shall be by the Well Contractor.

2.11 PRESSURE TANK & SAFETY VALVES –

A. Provide where shown on prints one (1) pressure tank.
An Amtrol WX-350 or approved equal shall be installed.

B. Pressure tanks shall be adjusted for operation between 20-
and 30 psig for sole heat pump applications and between 40 – 60 psig for dual heat pump and domestic applications.

C. Surface and well pump check valves shall be provided and a pressure relief set at 85 psig or as required by local code.

D. Well Contractor shall provide a ball valve as shown on drawings for connection to the heat pump manifold. Any other safety pressure controls and valves as required by New York State statutes are to be installed.

2.12 CONTROLS –

A. Provide Standard electric pressure actuated control device to control the well pump between the above specified pressure ranges.

B. Provide a Capacitor Run Control (CRC) device to control the well pump. This device will provide increased well pump efficiency at full load operating conditions.

C. Minimum water pressure of 20 psig shall be maintained at all times to insure proper heat pump operation.

D. A suitable safety method must be included as part of the well control package to insure well pump can not over pressure the well/piping should the pressure sensors fail.

E. 208/230 vac/single phase disconnect to the well pump controls and disconnect are by others, refer to Electrical specifications and drawings.

-OR - alternative control using VFD

2.12 VARIABLE FREQUENCY DRIVE

A. Provide Electronic Variable Speed Drive (VFD) system for all well pumps. Well pump controls will insure activation of the well pumps when the pressure of the heat pump manifold is below 20 psig. Controls for heat pump operation maybe field adjusted between pressures of 15 and 30 psig or as maybe set by local requirements. A Domestic Pressure override shall be provided so that a check valve isolated water line trunk to the domestic appliances will maintain a pressure range of 40 to 60 psig.

B. VFD controls will include both line side Radio Frequency Interference (RFI) Filters and line reactors on the VFD to-submersible pump line. RFI filter must be designed to meet or exceed FCC electrical noise specification Part 15, Subpart J, Class A. Line reactor must meet submersible motor manufacturer's requirements.

C. Contractor shall adjust the VFD to permit operation of the wells under VFD analog control. Typical operating pressure is twenty (23) psig. Minimum water pressure of twenty (20) psig shall be maintained at all times at the heat pump(s)

D. A suitable safety method must be included as part of the VFD package to insure well pumps can not operate should the system pressure sensors fail and over pressure of 85 psig or higher develop.

E. Three phase disconnect to VFD and well pump controls are by Contractor, in accordance with the requirements of Division 16. VFD shall be field adjusted to insure control under all normal operating conditions. VFD controls are to be critically or slightly under damped.

2.13 CONTROLS –

F. Well pump controls will insure activation of the well pumps when the pressure of the heat pump manifold is below nominal 23 psig. Pressure controls maybe field adjusted between pressures of 15 and 45 psig or as maybe set by local requirements. The control shall provide two (2) stages of control as above described. The heat pump(s) shall operate in the 23 psig range and a domestic override will provide 40-60 psig to the domestic water trunk.

PART 3. EXECUTION

3.1 GENERAL

A. Install equipment as shown, in accordance with all recommendations and beneficial options suggested by the manufacturer. Report all discrepancies between specifications and local regulations to the General Contractor for resolution.

3.2 INTEGRITY –

A. The completed systems shall be pressure tested with water to a pressure of 90 psig for at least one (1) hour before back-filling. If during the pressure test there is a nominal loss of pressure, the cause shall be identified and corrected and the systems re-tested.

B. The General Contractor shall be notified one week prior to testing so that the exposed system can be inspected.

3.3 HIGH FLOW –

A. During the well drilling process, should the Well Contractor note a well yield in excess of 10-15 US gpm, the General Contractor should be immediately notified and the drilling stopped. The General Contractor will relay a decision on whether the well's high flow can be employed as a conventional over flow heat pump in lieu of the specified standing column well. This action may result in a *reduction* of well depth. General Contractor's decision time shall be within four (4) hours of clear verbal notification.

3.4 STANDING COLUMN WELL DESIGN –

A. Before the start of work the Well Contractor shall submit for General Contractor approval of full standing column well design.

B. The design shall be stamped and signed by a professional engineer currently registered in New York State. The design shall include but not be limited to, mathematical computation of the well design showing earth heat transfer, pipe sizing and losses, pump selections and controls. Additionally, the well field layout will be shown on a suitably scaled drawing, minimum sized "B" (11"x17") sheet.

3.5 DIG SAFE & CLEARANCES –

A. The Well Contractor shall arrange to have the site marked for underground utilities before digging, drilling or moving any heavy equipment on to the site.
B. Adequate earth loading and minimum clearance of 40 feet above, shall be the responsibility of the Well Contractor.
C. The Well Contractor will take particular care in not approaching any trees to within twenty-five (25) feet of the tree's drip line.

3.6 PERMITS -

A. The Well Contractor shall register, as required, the standing column well system with the Local Health officials, and shall obtain required well drilling permits for non-contact cooling water.
B. The Standing Column Well has been considered a class V Underground Injection Criteria (UIC) well by the Environmental Protection Administration (EPA) and as such is authorized by rule and does not require a permit. EPA must be notified and at their option may request submission of well information. Contractor will assist Owner in submission of well information. Any other State or Federal regulatory agencies claiming jurisdiction shall be identified and reported to the General Contractor.
C. Should a permit under Article 23 of the New York State Environmental Conservation law be required, the Well Contractor must provide technical assistance to the General contractor/Owner in the preparation of the permit. This may be required for wells greater than 500 feet.
D. The Well Contractor shall, if required, assist the Owner/General Contractor in the preparation of request for temporary EPA permit to allow discharge of drilling water to the existing storm drains. Discharge to sewer or sanitary systems is not anticipated nor allowed.

3.7 WATER TEST -

A. A standard "Drinking Quality" water test shall be performed at each well after the well has cleared and been sufficiently flushed.
B. Test results will be promptly forwarded to the General Contractor as soon as available and are a submittal item.

3.8 EXPERIENCE –

A. The Well Contractor shall be able to show that they have installed two or more Standing Column Wells within the past 12 months.
B. The Well Contractor's well driller must also be a five year or longer member in good standing and a certified well driller and pump installer with the National Ground Water Association (NGWA).
C. Preference will be given to Well Contractors with valid International Ground Source Heat Pump (IGSPHA) installer certification.

3.9 INSTALLATION SUBMITTAL

A. A complete set of detailed drawings or sketches of the exterior and building interior shall be submitted General Contractor for approval before any work is initiated.
B. The Well Contractor will submit a full well log to required regulatory agencies and a copy to the General contractor promptly upon completion of the well bore.

3.10 STARTUP

A. Well systems must be started by a qualified and licensed well/pump mechanic holding a National Ground Water Association (NGWA) certificate. The heat pump Factory's geothermal Representative or local authorized geothermal distributor must supervise the startup.
B. A field report summarizing well information, startup conditions and SCW related equipment performance must be submitted to the Contracting Officer for each SCW.
C. Provide the field report in a timely manner to the Contracting Officer and HVAC contractor.

3.11 COORDINATION

A. Coordinate control components and operation with the heat pump control contractor and heat pump installer. Ensure non-duplication of components and correct and safe operation of the SCW pumping and control systems described above.

3.12 TESTING

A. As specified in Testing Specifications.

DEMONSTRATION

A. As specified in Demonstration Specification.
B. Provide operating instructions and two operation manuals for the SCW system.

3.14 WARRANTY

A. One year warranty on all components. The term of the SCW warranty shall be determined by the submission of the above listed field report or 15 months after the completion of drilling the SCW bore holes.

PART 4. MEASUREMENT AND PAYMENT

4.1 EARTH COUPLING/STANDING COLUMN WELLS–

The work of this section payment will be included in the bid item into which this work relates.

6.f.2.COMMERCIAL STANDING COLUMN WELL RECOMMENDED SPECIFICATION
EARTH COUPLING/STANDING COLUMN WELLS

Reference Drawing ________________dated_________

PART 1. GENERAL
specwellNYCMCL.docc

1.1 DESCRIPTION

B. The work of this section describes the material associated with a GeoExchange Standing Column Well system. Sections included and managed by the SAME HVAC contractor are: Geothermal Heat Pumps specification section and other related mechanical material. This section governs items specified for work under this section and other integrated mechanical sections.

1.1 WORK INCLUDED

D. As specified and as shown, furnish, install, test and place in satisfactory and successful operation all equipment and two (2) bore holes, material, devices and necessary appurtenances to provide a complete and operable standing column well (SCW) system for the specified GeoExchange heating, cooling and domestic hot water systems. The standing column well system is defined as two (2): bore holes, casings, sanitary seal, pump wiring and exterior piping and submersible pump. As specified on prints exterior pump wiring, supply and return exterior piping, as defined interior piping, controls, wall penetrations and seals, pressure tanks, supply and return manifolds, pump and bleed controls and valves.
E. Work includes trenching, final back-fill, grading or reseeding.
F. Work includes water testing, rock sample collections and necessary permitting.

PART 2. PRODUCTS -

2.1 STANDING COLUMN WELLS –

B. The Contractor shall use water as the heat transfer medium.
The Contractor shall install two (2) SCW wells at 1,500 foot water column depth, each SCW with a minimum yield of 5-10 US gpm, without substantial reduction in the water column length. The design intent is to create a combined heat transfer capability each Standing Column Well of seventy (70) tons.

2.2 WELL HEAD –

C. Two 2 inch minimum bronze pitless adapters shall be used, either as two adapters or a single dual adapter at the SCW head. The pitless adapters shall allow for ease of setup and removal of the drop pipes and pump. Pitless adapter shall be a minimum of 2 inch fittings.
D. The well shall be sealed with a standard sanitary well head
seal and shall be protected at all locations as indicated by general contractor’s stake or as shown on prints.
E. The well head and sanitary seal shall be below grade and
protected with a shallow manhole as shown on drawings. Alternative well head

protection as Carlson Industries model 1730-18 with polymer concrete cover and concealment maybe considered and must be submitted to General Contractor for approval.

2.3 PIPING –

D. Buried supply and return piping shall be 3 inch High Density Polyethylene (HDPE), PE3408 resin with ratings of ASTM D3035-93 for pipe and ASTM D3261 for fusion fittings. A pipe cell classification of 355444C, SDR-11 is required. Drisco 5300 series or equal is required to insure abrasion resistance.
E. Supply drop piping in each well shall be nominal 2 inch interior diameter (ID) or equivalent. Return drop pipe of identical nominal size and of HDPE, as specified above, shall discharge return water below the minimum static level by 10 -30 feet. Design of a free-fall water return is not permitted.
F. It is desired that all underground pipe shall be free of joints. Should joints be required they shall be butt or socket heat fuzed by a method approved by the pipe manufacturer and the International Ground Source Heat Pump Association (IGSHPA) or the pipe manufacturer.

2.4 CASING –

D. As shown on drawings the well shall be cased to bedrock and sealed by a drive shoe approximately 75 feet into the bedrock or in a manner specified by local and New York State codes and the General Contractor.
E. The casings shall be OD 6 inches or by well contractor option, 8.625 inch, 19+ pounds/linear foot ASTM A-500 steel, made in U.S.A. The casing shall be an alloy approved by the National Ground Water Association (NGWA).
F. Bid should be based upon a 40 foot to bedrock and a casing length of 70 feet.

2.5 OTHER WORK –

E. The Well Contractor shall protect the area to prevent flooding while drilling the well and associated operations is the responsibility of the Well Contractor.
F. Excess and/or drilling water temporary containment pit is required. The Well Contractor prior to burial of piping and connection pit must perform testing of the well piping and coupling for leaks.
G. The Well Contract will nominally return the area to its earth grade condition. The Contractor will perform landscape work as specified. All trenching for the 3 inch HDPE pipe shall be provided. Trench shall be a nominal three foot wide. Back filling with 6 inches of sand above and below the HDPE pipe and the 3-4 inch moisture resistant extruded polystyrene foam board insulation separator shall be by the Well Contractor.
H. The Well Contractor shall provide temporary water pit and necessary dewatering pumps for drilling water.

2.6 SAFETY –

B. All material, equipment, labor and protection needed to safely complete this work shall be the responsibility of the Well Contractor.

2.7 HEALTH –

B. Disinfectant of the well, pumping and piping systems with a method approved by the National Ground Water Association is by the Well Contractor. In-process wells will be maintained in a disinfected state at all times.

2.8 WATER QUALITY-

C. Whether the Standing Column is used for domestic purposes or not, the well water must be tested for drinking quality standards by a test laboratory which is approved by the State and General Contractor.
D. Drinking quality standards of New York State must be met to re-inject the water back into the well column. A copy of the water test information must be maintained at the geothermal heat pump site and a copy forwarded to the General Contractor.

2.9 SUBMERSIBLE PUMP –

D. Provide a submersible well pump with lift and flow capability as specified on well schematic drawing. Each well pump shall be carefully sized to insure a flow of 75 US gpm at 20 psig to the building's heat pump manifold. Over sizing or under sizing shall not be tolerated.
E. Pump selection shall be made only after the first well is drilled and a probable mean static level is determined for all wells. Well pumps shall not be installed until after submittal is approved by the General Contractor.

2.10 ELECTRICAL –

C. The well pump shall be provided to operated on 208 ac volts *three phase*. The electric service to a Well Contractor provided disconnect shall be mounted on the sub-basement wall for each well pump nearby the pipe entrance through the basement wall.
D. The Well Contractor shall provide water blocked and waterproof pump cable suitable for submersible well pumps from the well disconnect to the submersible pump. All submersible wiring and connections shall be by the Well Contractor.

2.11 PRESSURE TANK & SAFETY VALVES –

E. Provide where shown on prints two (2) pressure tanks. An Amtrol WX-350 or approved equal shall be installed.
F. Pressure tanks shall be adjusted for operation between 20- and 30 psig.
G. Surface and well pump check valves shall be provided and a pressure relief set at 85 psig or as required by local code.
H. Well Contractor shall provide a ball valve as shown on drawings for connection to the heat pump manifold. Any other safety pressure controls and valves as required by New York State statutes are to be installed.

2.12 CONTROLS –

G. Provide Standard electric pressure actuated control device to control the well pump between the above specified pressure ranges.
H. Provide a Capacitor Run Control (CRC) device to control the well pump. This

device will provide increased well pump efficiency at full load operating conditions.

I. Minimum water pressure of 20 psig shall be maintained at all times to insure proper heat pump operation.

J. A suitable safety method must be included as part of the well control package to insure well pump can not over pressure the well/piping should the pressure sensors fail.

K. 208/230 vac/three phase disconnect to the well pump controls and disconnect are by others, refer to Electrical specifications and drawings.

-OR - alternative control using VFD

2.12 VARIABLE FREQUENCY DRIVE

F. Provide Electronic Variable Speed Drive (VFD) system for all well pumps. Well pump controls will insure activation of the well pumps when the pressure of the heat pump manifold is below 23 psig. Controls maybe field adjusted between pressures of 10 and 30 psig or as maybe set by local requirements.

G. VFD controls will include both line side Radio Frequency Interference (RFI) Filters and line reactors on the VFD to-submersible pump line. RFI filter must be designed to meet or exceed FCC electrical noise specification Part 15, Subpart J, Class A. Line reactor must meet submersible motor manufacturer's requirements.

H. Contractor shall adjust the VFD to permit operation of all the wells under VFD control. Typical operating pressure is twenty (23) psig. Minimum water pressure of twenty (20) psig shall be maintained at all times.

I. A suitable safety method must be included as part of the VFD package to insure well pumps can not operate should the system pressure sensors fail.

J. Three phase disconnect to VFD and well pump controls are by Contractor, in accordance with the requirements of Division 16. VFD shall be field adjusted to insure control under all normal operating conditions. VFD controls are to be critically or slightly under damped.

2.13 CONTROLS –

L. Well pump controls will insure activation of the well pumps when the pressure of the heat pump manifold is below 24 psig. Pressure controls maybe field adjusted between pressures of 15 and 45 psig or as maybe set by local requirements. The control shall provide two (2) stages of control.

PART 3. EXECUTION

3.1 GENERAL

B. Install equipment as shown, in accordance with all recommendations and beneficial options suggested by the manufacturer. Report all discrepancies between specifications and local regulations to the General Contractor for resolution.

3.2 INTEGRITY –

C. The completed systems shall be pressure tested with water to a pressure of 90 psig for at least one (1) hour before back-filling. If during the pressure test there is a nominal loss of pressure, the cause shall be identified and corrected and the systems re-tested.

D. The General Contractor shall be notified one week prior to testing so that the exposed system can be inspected.

3.3 HIGH FLOW –

C. During the well drilling process, should the Well Contractor note a well yield in excess of 25-30 US gpm, the General Contractor should be immediately notified and the drilling stopped. The General Contractor will relay a decision on whether the well's high flow can be employed as a conventional over flow heat pump in lieu of the specified standing column well. This action may result in a *reduction* of well depth. General Contractor's decision time shall be within two (2) hours of clear verbal notification.

3.4 STANDING COLUMN WELL DESIGN –

B. Before the start of work the Well Contractor shall submit for General Contractor approval of full standing column well design.

D. The design shall be stamped and signed by a professional engineer currently registered in New York State. The design shall include but not be limited to, mathematical computation of the well design showing earth heat transfer, pipe sizing and losses, pump selections and controls. Additionally, the well field layout will be shown on a suitably scaled drawing, minimum sized "B" (11"x17") sheet.

3.5 DIG SAFE & CLEARANCES –

D. The Well Contractor shall arrange to have the site marked for underground utilities before digging, drilling or moving any heavy equipment on to the site.

E. Adequate earth loading and minimum clearance of 40 feet above, shall be the responsibility of the Well Contractor.

F. The Well Contractor will take particular care in not approaching any trees to within twenty-five (25) feet of the tree's drip line.

3.6 PERMITS -

E. The Well Contractor shall register, as required, the standing column well system with the Local Health officials, and shall obtain required well drilling permits for non-contact cooling water.

F. The Standing Column Well has been considered a class V Underground Injection Criteria (UIC) well by the Environmental Protection Administration (EPA) and as such is authorized by rule and does not require a permit. EPA must be notified and at their option may request submission of well information. Contractor will assist Owner in submission of well information. Any other State or Federal regulatory agencies claiming jurisdiction shall be identified and reported to the General Contractor.

G. Should a permit under Article 23 of the New York State Environmental Conservation law be required, the Well Contractor must provide technical assistance to the General contractor/Owner in the preparation of the permit. This permit is required fro wells greater than 500 feet.

H. The Well Contractor shall, if required, assist the Owner/General Contractor in the preparation of request for temporary EPA permit to allow discharge of drilling water to the existing storm drains. Discharge to sewer or sanitary systems is not anticipated nor allowed.

3.7 WATER TEST -

C. A standard "Drinking Quality" water test shall be performed at each well after the well has cleared and been sufficiently flushed.

D. Test results will be promptly forwarded to the General Contractor as soon as available and are a submittal item.

3.8 EXPERIENCE –

D. The Well Contractor shall be able to show that they have installed two or more Standing Column Wells within the past 12 months.

E. The Well Contractor's well driller must also be a five year or longer member in good standing and a certified well driller and pump installer with the National Ground Water Association (NGWA).

F. Preference will be given to Well Contractors with valid International Ground Source Heat Pump (IGSPHA) installer certification.

3.9 INSTALLATION SUBMITTAL

C. A complete set of detailed drawings or sketches of the exterior and building interior shall be submitted General Contractor for approval before any work is initiated.

D. The Well Contractor will submit a full well log to required regulatory agencies and a copy to the General contractor promptly upon completion of the well bore.

3.10 STARTUP

D. Well systems must be started by a qualified and licensed well/pump mechanic holding a National Ground Water Association (NGWA) certificate. The heat pump Factory's geothermal Representative or local authorized geothermal distributor must supervise the startup.

E. A field report summarizing well information, startup conditions and SCW related equipment performance must be submitted to the Contracting Officer for each SCW.

F. Provide the field report in a timely manner to the Contracting Officer and HVAC contractor.

3.11 COORDINATION

B. Coordinate control components and operation with the heat pump control contractor and heat pump installer. Ensure non-duplication of components and correct and safe operation of the SCW pumping and control systems described above.

3.12 TESTING

C. As specified in Testing Specifications.

DEMONSTRATION

A. As specified in Demonstration Specification.
D. Provide operating instructions and two operation manuals for the SCW system.

3.14 WARRANTY

B. One year warranty on all components. The term of the SCW warranty shall be determined by the submission of the above listed field report or 15 months after the completion of drilling the SCW bore holes.

PART 4. MEASUREMENT AND PAYMENT

4.1 EARTH COUPLING/STANDING COLUMN WELLS–

The work of this section payment will be included in the bid item into which this work relates.

These specifications are samples only, and are not meant for use with any particular application. The use of professional consultants is required. No warranty is given, nor is any liability assumed.

Recommended Pump Test Specification for Test Well in Possible High Yield Overburden Well

PURPOSE:

1. To determine the yield of a test well for a static draw down of approximately fifty (50) to eighty (80) feet.
2. To determine the draw down depth of an existing well for a 24 hour pump test of 100 gpm and 200 gpm

METHOD:

1. The drilling contractor must quote, mobilize and be prepared to drill the first of (number) standing column wells per the attached preliminary specification 15600 03/02/99.
2. If a large water flow yield is encountered per section 3.3 of the referenced Preliminary specification, stop drilling at 400 foot or to bedrock which ever occurs sooner, a 6 inch well, cased and screened as necessary.
3. Screen shall be stainless steel 304 with slot size opening designed only after on-site seeve test is made. (Anticipate a slot opening of 0.007 to 0.025 inches for best application.)
4. SS well screen shall be designed for a flow rate of 300 gpm. (Anticipate a twenty foot six inch nominal diameter screen)
5. The Contracting Officer prior to insertion into the well shall approve screen design.
6. If drilling is terminated at or before bedrock, a well pump test will be performed following standard "Pump Test Procedures" as specified by the National Ground Water Association:
7. Drilling contractor will provide pump for well test and will provide power for the pump test. (A price deduct must be quoted if the Contracting Officer provides local power)
8. Drilling contractor will pump the well at two different initial pump rates; 100 gpm and 200 gpm. Recorded measurements of draw down will be at intervals of start, 15 minutes, 30 minutes, 60 minutes, 120 minutes and so on until 24 hours has elapsed or a three measurement period asymptote is reached.
9. Drilling contractor will pump the well at a variable rate recorded on an approximate hour by hour basis so as to hold the drawn down static to approximately fifty (50) feet for 24 hours.
10. Upon completion and acceptance of the pump test the contractor will temporarily seal the well casing 18 inches above ground level, with a welded cap.

REPORTS REQUIRED:

1. Technical information as required by various City, County, State and Federal
   permitting Agencies may require.
2. Drilling log
3. Three (3) to four (4) ounce samples of cuttings/sand/gravel in plastic bags with depth, estimated yield and other observations printed on bag(s) at each 100 feet of depth or whenever a change in drilling cuttings is observed.
4. Graph or table of time verses draw-down static's for various flow rates.
5. Graph or table of time verses flow rates for various draw-down static's.

Appendix C

Evaluation of Heat Pump Design Software

EVALUATION of HEAT PUMP DESIGN SOFTWARE

The available software for modeling building loads, operating costs and geothermal heat exchangers is ample. Consulting engineers and energy analysts are already using software that can model the building loads as required. The discussion below will outline the most common software load modeling programs and design tools employed in the GeoExchange industry.

a. SYSTEM LEVEL Software –

These models are typically employed in the evaluation of the merit of the GeoExchange system. Models develop energy use, some permit operational cost and societal benefit estimates.

Sizing geothermal heat pumps by "rules of thumb" is not acceptable. As geothermal system costs are nearly linear with dominant heat/cool loads, it is important that sizing be relatively accurate. Operational costs are a strong driving force in the selection of the geothermal heat pump system, over-sizing is equivalent to over-costing. The responsible designer will find it beneficial to utilize one or more of the well established evaluation and design tools discussed below.

Operating cost analysis evaluations should be performed by an hour-by-hour (commercial) analysis. Programs involving degree-day values are not considered an acceptable method of operational cost estimating.

All software contains climate information for the location being modeled. The source is the National Oceanographic and Atmospheric Administration (NOAA). Especially for analyses of annual energy consumption and thermal behaviour done hour by hour. These analyses are directed towards commercial applications.

DOE 2	Hour by Hour energy requirements and use estimates
BLAST	Building Load analysis, good for hour by hour analysis
ENERGY 10	An excellent method of building design trade offs. Geo can be simulated, but is cumbersome

Table – Appendix c –1 DOE Sponsored Programs with Geo Application

These programs are available from the U.S. Department of Energy (DOE) at effectively no cost. However, distributors of the programs may charge for training and support.

Carrier Energy Analysis
ClimateMaster Geo Designer
TRANE Trace
Water Furnace Geo
Wright Suite/Wright Dollar sub routine

Table – Appendix c – 2 Commercial Software for Systems Level Geo Evaluation

FLAGS – in all of these programs mere output does not guarantee a correct set of design requirements. Always check the design requirements – keep in mind the designer may have resorted to using “default” parameters, while defaults are most often acceptable, they sometimes do not represent the requirement of a given installation.

Always verify:

Seasonal Design Day Weather –
most default design temps offer the 2 standard deviation or 97 ½% occurrence. Keep in mind that statistically this could mean as much as 40 hours per year of inability of the heating system to maintain design temperatures – being exposed and near water may result in higher infiltration and moisture and latent loads.. Always check the weather/location assumptions carefully.

Equipment Parameters –
the above programs often have a universal use, they are for heat pumps and fossil systems. Did the designer enter the proper information for the geothermal systems? Keep in mind the geothermal system does not have as high a temperature rise as does a fossil system – an incorrect output temperature rise can mean incorrect duct requirements.

Earth Characteristics –
Incorrect earth moisture assumptions or rock characteristics can result in an earth coupling system that does not meet the requirement of the building. For large commercial applications the boring of a test well(s) is often prudent. While the open and standing column well systems can usually increase their capacity by pumping more water or bleeding morel often, the closed loop type system has little or no “fall back”. Closed Loop designs must carefully verify the earth and moisture assumptions, as this type system has no “fall back” margin unless overdesigned.

As Built Configurations –
The need for verification and commissioning of every GeoExchange component is a firm requirement. Installers of wells, loops, heat pumps, ducts, radiant floors, fan coils, air handlers and piping must report back to the designer and owner what was installed and its preliminary performance.

In these and all other input *assumptions* carefully review the designers assumptions in the software evaluations. Keep in mind that “average” weather may not be this years weather, or the building the designer though was being built was not the building that was built.

9.b. HEAT PUMP SELECTION

While Manual J methods were developed primarily for residential heat pump sizing, various commercially available and manufacturer’s programs using the Manual-J template are available. ACCA’s computerized version of manual-J, with pull down tables, is distributed by Wrightsoft Corp, www.wrightsoft.com. Manual-J is integrated into a Geothermal suite by this organization. See below. Manual-J was developed by ACCA from base line ASHRAE data and has been a residential industry standard for over 20 years.

There are several other commercial software organizations with versions of manual-J available in software packages. Elite Software is also commonly employed by the geothermal trade. Most manufacturers also offer their software versions of a Manual-J package.

Commercial sizing is best performed by ASHRAE method 92xx…. Several commercially available software package offer pull down tables and graphs, e.g. Wrightsoft (Manual-N) and Elite software have versions of this method of commercial building sizing. Many of the major manufacturers also provide commercial design packages. As above, Carrier and TRANE evaluation and sizing packages are popular.

9.c. GROUND COUPLING DESIGN

There is no substitute for a math model. The geology and hydrogeology must be analyzed in order to determine which type of geothermal heat exchanger can be used. The well design which includes aspects such as the depth of the wells, flow rate, screen design, and permitting among others must be determined by a certified ground source heat pump geothermal heat exchange designer in concert with a hydrogeologist. A well driller may be needed to drill test wells and perform monitoring and pumping tests to allow accurate mathematical modeling of any aquifers. If ground water is not present, a geothermal heat exchanger such as a standing column well or buried piping can be used. These consultants should work in concert with the rest of the design team, but especially the consulting engineer and the architect.

9. d. CLOSED LOOP SOFTWARE

Closed Loop Systems are designed around the same heat transfer mathematics as open and Standing Column Wells. Various design software is available to the designer for these closed loop applications. Design software employed in the New York area is:

C G L S – Close Ground State University – obtained through the International Ground Source Heat Pump Assn. (IGSPHA). This is the original version of the closed loop simulation programs and has been in existence for nearly 20 years. Use primarily for residential and light commercial

Wright Loop – The official version of the manual-J ACCA program. The program is a literal interpretation with pop-up the official tables version of CGLS , also has a library of most manufacturer's equipment and characteristics which are periodically updated
– obtained from Wright-Soft Corp, -, Lexington MA, as a stand alone program or part of their Geothermal Suite .

Elite Software – Similar to the ACCA Wright-Soft program and modeling.

GLPRO – A complex and comprehensive "English" version of Sweden's University of Lund, multi bore hole array software. This program has the ability to estimate future heating and cooling load effects on average earth temperatures and evaluate multiple bore hole array configurations – obtained through IGSPHA. The program has good pop-up window information and is used for large commercial applications. The program requires month by month peak and total loading information and can interface with DOE's BLAST and DOE2.

Manufacturer's Software - The major geothermal manufacturer's have varying levels of design and selection software and should be queried for availability, support and costs.

All of these closed loop programs will demand an accurate measure of the heat transfer characteristics of the soil or rock that is employed. The dryer the soils, the more closed loop pipe required, sometimes as much as 2 – 3 times more length on vertical applications. For residential applications, with a small number of bore holes, local inquiry and the drilling of the first bore hole or trench will usually provide adequate information to classify the soil/rock and permit a verification of the designers assumptions. On larger and more complex bore fields for commercial applications, it is recommended that series of heat transfer test bores be drilled and evaluated. To save several tens of feet of bore depth in a 2-3 bore residential installation would not justify these test bores. To save several tens of feet in a bore array of 300 bores (e.g. 600 tons) would do so.

Closed loop systems, are designed around a stringent trade off between minimum and maximum operating temperatures, as noted above, i.e. ARI-330 standards of 32°F and 77°F. Closed loops can be designed for any upper and lower limit within the average earth temperature band of a geographic area, e.g. 40°F to 60°F or even 20°F to 100°F for the New York City area.
However, there is a practical limit to expanding or contracting these designer selected ranges. Figure 6 is a typical residential requirements graph. Note the sharp "knee" of the loop length requirements as the design range becomes narrower. With an average area earth temperature of 51°F, the heating and cooling loop lengths approach an asymptote at the average earth temperature

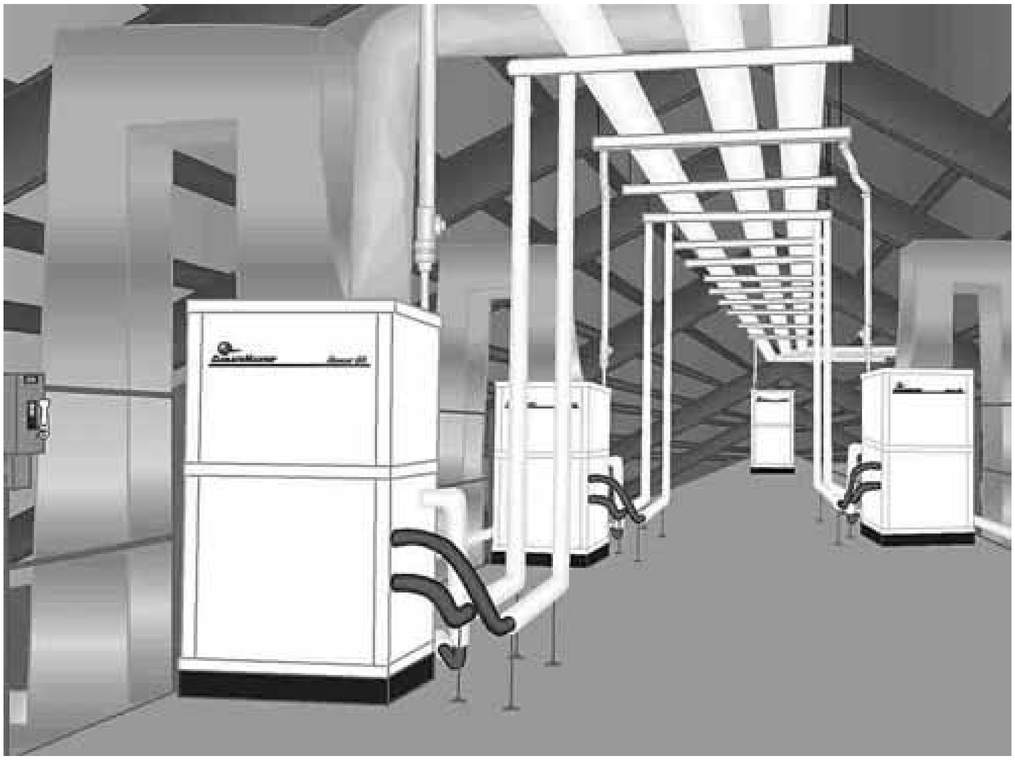
The designer's trade-off becomes the consideration of cost, performance, efficiency and safety margin.

The International Ground Source Heat Pump Association

Extensive information on ground source heat pumps and associated industries is available at www.igshpa.okstate.edu.

Appendix D

Description of Three Existing Projects



360 Court Street, Brooklyn

Description

This building was originally a church in the gothic style built in 1890. The 1980 conversion to residential use was accomplished by adding a floor in the nave and apse. A total of 34 apartments were fitted into the original volume. The lower floor (basement) of the Church is above grade on the south side, and this space was converted to professional and mechanical space. The first floor of the nave was converted to fourteen condos, with the new second floor containing 20 units. Apartments were approximately 800 square feet in space and included a high bay living area and a loft with ladder sleeping area.

The project was subsequently converted to condominium ownership in 1988.

Geothermal Configuration

This geothermal installation is one of the oldest in the New York City area. Geothermal heat pumps were selected by the developer as it was impossible to install exterior equipment on this historic building, and allowed one appliance to perfor both heating and cooling duties.

The geo-heat exchanger used is an open system taking advantage of the porous overburden geology as discussed above. The system has been operational since commissioning.

Heat Pumps and Distribution

Each apartment has its own vertical or horizontal geothermal water to air heat pump and its own thermostat control. Each dwelling unit is independent, and heating and cooling is available at all times. The only common portion of the geo-exchange system is the well water supply , its pump and controls.

Each heat pump is centrally located, allowing for short duct run to all areas requiring climate control. Most apartments have ducted returns, with some having a central return.

The heat pumps installed in the apartments is a mixture of ClimateMaster, Florida Heat Pump and TempMaster geothermal type in the 3 ½ to 5 tonrange. Each heat pump originally had, and today again has, a motorized shut off valve which automatically opens when the heat pump's thermostat alls for conditioning. An end-switch on the valve then energizes the compressor. Each apartment has its pressurized well water piping from a common pressurized supply manifold. The well water flows through the heat pumps and flows into a common return manifold to the diffusion well.

Geothermal Earth Coupling

The building site has narrow open earth corridors along the north and south (long) sides. The south side contains a small garden area and is approximately 25 feet wide and provides a site for a single 150 feet deep supply well. The well has a yield of 250 gpm and is typical of the shallow wells that would be found in the Brooklyn-Queen overburden, particularly in sites that are south of the Terminal Moraine area. The north side of the Building has a single diffusion well that is located behind a decorative iron fence bordering the side walk. The well originally had a single 25 hp submersible well pump that provided a constant 45 psig to a well manifold located on the mechanical room on the south side of the Building. This room contains pressure tanks originally installed to inhibit pump short cycling and the associated wear and tear. A piped distribution system brings well water to all heat pumps.

During the period after the formation of the condominium legal structure, the heat pump maintenance was abrogated to contractors retained by individual unit owners. This personnel had minimal geothermal experience and eventually removed all automatic shut off valves from the heat pumps. As these valves were removed, the submersible well pump was forced to run continuously, substantially increasing common costs. Additionally, the diffusion (return) well, which was designed for approximately 3,000 hours per year of equivalent full load, now was faced with absorbing 8,760 hours of continuous recharge to the earth. The return/diffusion well became saturated and started to overflow onto the street. High energy bills and water overflowing from the diffusion well prompted a reevaluation of the building geo controls.

In 1998, the automatic shut off valves were again installed on all of the heat pumps, and a small and properly sized 15 hp well pump was installed. A variable frequency drive (VFD) pump motor controller was included to reduce the work done by the pump. The VFD provided significant energy savings with the use of a single pump and 1 – 34 heat pumps calling at random times. Before the installation of the VFD a single heat pump calling for water would be required to absorb the full flow, creating a substantial energy penalty. A VFD is essential for economical operation with widely varying loads. Well pump short cycling has been proven to lead to well pump life reduction.

9 East 64th Street, Manhattan – Standing Column Wells

Description:

9 East 64th Street, NYC is a new building of approximately 14,000 square feet, with 5 aboveground floors and a cellar and sub-cellar. The location in the Upper East Side Historic District prevented the use of cooling towers or any other bulky equipment on the roof. Originally conceived as a sustainable design, it was to house the non-profit groups working on behalf of the environment, such as the Earth Pledge Foundation; Experiments for Art and Technology; and Theodore Keel's Foundation on Prevention and Early Resolution of Conflict. The building itself was to have been a model for environmentally friendly design, being energy efficient and using recycled and low environmental impact materials. Mr. Kheel sold the project due to high projected costs, and the structure is now residential.

Henry George Greene Architects, Leslie Gill, Architect, the energy consultant Steven Winter Associates and the project consulting engineer P. Andrew Collins, P.E. constituted the original design team. The geothermal consultant was Carl Orio of Water and Energy Systems. J and P Engineers, P.A. of Kendall Park, N.J. suggested to the Architects and Engineers for the project that geothermal heat pumps might be the best method for space conditioning this new building.

Subsequent analysis by Water & Energy Systems Corp., of Atkinson, NH, under contract to Consolidated Edison and The Electric Power Research Institute bore this out. A cost analysis and concept design of a geothermal heating and cooling system for the building was provided. A series of reports detailing New York City geology, earth coupling and geothermal heat pump approaches were issued to Con Ed during early 1997.

Two 1,500 foot deep Standing Column Wells were completed in April 1997. The wells are approximately 60 feet apart. The ground water level is just below the sub-cellar slab, and water crossing the site before construction appeared to be channeled by adjacent buildings, requiring a water resistant sub-cellar floor slab, below slab drainage, a sand trap weir and drains around the well heads to catch any water flowing out during maintenance that needs to be performed when the water table is high.

CONFIGURATION of GEOEXCHANGE SYSTEM

With the change in building use the heating and cooling loads were reduced, so the two Standing Column Wells were more than adequate.

Final well and pipe configuration was modified and a variable speed drive system was added. Note that early designs had a relatively small number of centralized geothermal heat pumps. Each heat pump is provided with the correct water flow and pressure at the motorized valve. This source side, well water valve automatically opens when the heat pump thermostat calls for heating or coling and the well water flows through the heat pump until the thermostat is satisfied.

The original well pumping scheme specified involved simple pressure logic, as the ratio of well pumps to the number of heat pumps was relatively high. The water flow requirement for any one heat pump is relatively large and the well water pumping energy used is then a relatively small portion of the total (heat pump + well pump) energy, i.e. the well water pumping penalty during partial flow is *relatively* small.

The new residential configuration of the building led to a marked increase in the number of zones, and the over-all number of heat pump units. The pump controls were then changed to variable speed driives. Well pumpng energy savings when only a small number of smaller heat pumps are active are then realized. As installed, a call from a single small heat pump, results on a well pump responding only with enough energy use to satisfy that low water flow. The ber of individual heat pump units increased due to the change in use from office to residential. Many of these heat pumps were of the split type, which allowed for the grouping of the compressorized sections in the sub-cellar, and the placement of the quieter blower section in the dwelling units.

Master (M) and slave (S) variable frequency drive (VFD) system is now installed. As there are now two occupants, with many more smaller heat pumps in the installation, any one call could result in a substantially lower well water flow rate. The VFD provides these small flow rates with commensurate power reductions in well pumping costs and prevents short cycling and the over pressurization of the well water manifold throughout the building.

Also note the use of the VFD has removed the requirement for the two relatively costly WX-350 pressure tanks. A small WX-104 pressure tank remains on-line to inhibit the effects of any possible small leak-back in the well pressured line due to check valve fouling or the like. Without this small accumulator the VFD could find itself in a rapid short-cycling if a small leak-back occurred in the well line.

GEOTHERMAL HEAT PUMPS & WELL WATER DISTRIBUTION

Heat pump configurations and distribution are essentially identical to conventional Boiler/Cooling Tower water source heat pump installations – a common multistory building configuration. The original design of the distribution system conformed to the commercial layout, with a large roof top unit and sepaate systems for each use. Large riser supply and return piping risers had already been installed when the decision to convert the system to residential was made.

The final building design, with more stringent noise reduction requirements, utilized a large portion of "split" geothermal heat pumps with the compressors and water heat exchangers in a basement mechanical room. The piping distribution system was then redesigned to accommodate the increase in heat pumps.

The building incorporates ClimateMaster brand geothermal heat pumps in vertical, horizontal and split configurations. The split heat pumps have the unit containing the compressor, controls and water side heat exchangers in a mechanical room in the basement. Refrigerant piping rises to the blower unit with a refrigerant coil in the various zones on upper floors. The building is commissioned and functional.

Long Island Power Authority Brentwood Facility
This article courtesy of the ClimateMaster Corporation

With R-12 refrigerant being rapidly phased out, many companies have had to evaluate the operating condition of their heating systems and many have taken the opportunity to review their expectations about their systems. The Long Island Lighting Co., a utility company in New York was just such a company.

The Brentwood facility, a 6000 square meter, two storey building, provides office accommodations for 300 operations staff and boasts a large cafeteria. Some offices are located in a basement which also contains the equipment room housing the HVAC system.

The old system was a hydronic, chiller system built in 1958 when energy was cheap and hydronic system technology was in its infancy. The system consisted of two 350 kW reciprocating chillers, a 900 kW gas fired boiler to heat make-up air in winter and a standby steam heat converter. Well water was continually circulated through the system by two alternating pumps with a total capacity of 50 HP.
In-duct air coils heated or cooled discharge air in core areas, while fan coils heated the perimeter. The hydronic system was equipped with well water preheating coils, hot water coils, chilled water coils and reheat coils. Since the system was built before automation, water flow had to be changed over manually in the early summer and the late fall. The maintenance supervisor personally had to nursemaid the system from season to season.

Although the basement was never designed to be a conditioned space, a makeshift system was in use. Humidity was high and comfort low most of the year

Maintenance on the system was constant, costly and environmentally unacceptable. R-12 to replenish the refrigeration circuits on the chillers had become cost prohibitive as well as environmentally unsound. Without water regulators, acidic well water running continuously through the system at 30 flow litres per second corroded and eroded the copper and steel piping. Over the 30 year life of the system, the piping was completely replaced five times, section by section.

In 1990, the company approached the ClimateMaster agent to design a ground source, hydronic system to replace the old system. The requirements laid down for a new system included low first cost, low operating cost, low maintenance and improved comfort. The company also requested that the new system be contained within the existing mechanical room and that the system change-out be transparent to employees.

Bids were also secured for direct expansion style air-cooled condensers (split systems), air cooled chillers and water cooled chillers.

When all the bids were in, the hydronic system designed using ClimateMaster equipment had the first cost advantage of 35% - 50% over the alternative systems and the system fit comfortably within the existing equipment room. In contrast, some of the alternative systems required that the equipment room be enlarged.

The preliminary study performed by ClimateMaster's agent identified that the old system had been altered over time by undocumented changes so air performance was unknown. The complexity of the duct system was a limiting design factor, as was the client's desire to contain cost by saving much of what was operational in the existing system.

The new system kept the existing air handlers and some fan coils in place. Sixty percent of the in-duct coils had to be discarded. Reheat coils were removed since they were no longer required. The two 350 kW chillers were replaced with eighteen 37 kW water-to-water heat pumps. The existing wells were found to be stable and were allowed to remain in place. The well loop was separated from the building loop and adjustable, variable drive pumps were installed to control the flow of well water.

The new system was substantially repiped. Reductions in the amount of piping required allowed the 2 existing circulating pumps (50 HP) to be replaced by 9 pumps with a total capacity of 10 HP. For the convenience of the maintenance staff, the new system was designed with reversing valves and a Honeywell Energy Management system was specified.

The final design of the system divided the building into 5 zones, each with an air handler and in-duct coils. Every zone was supplied with one or more ClimateMaster WE Series heat pumps based on the air delivery of the air handlers. The basement zone has 4 dedicated WE units; the perimeter zone has 3 WE units;the 24 hour service system has I WE unit; the core was divided into 3 sub-zones with 2 WE units dedicated to each; and the cafeteria was divided into 2 sub-zones with I WE unit each. The make-up air supply was split. Two WE units are dedicated to one side for cooling only. The other side has no air tempering. A full economiser cycle can be operated in mid-season periods.

Motorised dampers on the make-up air system are controlled by the Honeywell EMS system. Renovation of the facility began on December 1, 1993. According to the contractor on the job, the biggest challenge was to keep the building space conditioning system operational while the retrofit was taking place. The standby steam heat converter was temporarily piped into the well water coils and the hot water heat coils. Because hundreds of feet of old pipe were paper thin and could be perforated by a finger, extreme care was necessary to install and remove the temporary piping. The retrofit system was put into operation May 1, 1994. During the 5 month project, construction had been almost entirely transparent to the office staff.

Although outdoor ambient temperatures have been higher than normal this year, no complaints have been received from employees since the system was placed on-line. In fact, it was only when summer heat came without expected discomforts that employees realized something had changed. The basement offices are comfortable now, both in terms of relative humidity and temperature. The Honeywell EMS system monitors both temperature and humidity. To date, average temperature holds within 2° C of set-point. Estimated energy savings is expected to be 600,000 kwh per year and maintenance costs should be reduced by 90% over the next 5 years.

Appendix E

Geothermal Heat Pump Manufacturers

Appendix E Geothermal Heat Pump Manufacturers

The list shows the manufacturer, the web site address and the New York area dealer.

ClimateMaster
www.climatemaster.com

Water and Energy Systems Co.
100 Maple Avenue
Atkinson, NH 03811
tel 603 362 4666 contact Carl Orio

Florida Heat Pump
www.fhp-mfg.com

DNT Enterprises Inc.
60 East 42nd Street
New York, NY 10165
tel 212 682 0797 contact Jim Temple

Trane
www.trane.com
Trane New York
45-18 Court Square
Long Island City, NY 11101
tel 718 269 3600contact Mike Tedesco

Water Furnace
www.waterfurnace.com
9000 Conservation Way
Fort Wayne, Indiana 46809
(800) 934-5667
tel 800 934 5160 x 8869 contact Garth Gibson

Airedale
info@airedaleusa.com
769 haunted Lane
POB 749
Bensalem, PA 19020
tel. 215 639 6030

Appendix F

EPA Form 7520-6 and Instructions

A f

Instructions for UIC Permit Application Attachments
Class V - Geothermal Wells

Attachments to be submitted with permit application for Class V - Geothermal Wells.

A. AREA OF REVIEW METHOD - The area of review shall be a fixed radius of 1/4 mile from the well bore.

B. MAPS OF WELLS/AREA AND AREA OF REVIEW - Submit a topographic map extending one mile beyond the property boundaries of the facility. The area of review shall be a fixed radius of 1/4 mile from the well bore depicting:

- The facility and each of its intake and discharge structures;
- Any hazardous waste treatment, storage, or disposal areas(s);
- Those wells, springs, and other surface water bodies and drinking water wells listed in public records or otherwise known to the applicant within one mile of the facility property boundary.
- If the well is located in a rural or sparsely populated area, a list of names and addresses of all land owners within 1/4 mile of the well must be attached to the map.

A reasonable scale, such as 1:4800, should be used for the map.

C. CORRECTIVE ACTION PLAN AND WELL DATA - Submit a tabulation of data reasonably available from public records or otherwise known to the applicant on all wells within the area of review, including those on the map required in B, which penetrate the proposed injection zone. Such data shall include the following:

- Description of well type
- Construction
- Date drilled
- Location
- Depth
- Records of completion and/or plugging

D. GEOLOGIC MAPS AND CROSS SECTIONS - Submit maps and cross sections within the area of review depicting the following:

- All Underground Sources of Drinking Water (USDWs);
- Direct of ground water flow in all USDWs that may be affected by the injection;
- Geologic faults and fracture orientation of the local area;
- Local stratigraphy (all aquifers and confining layers);
- The injection formation;
- Formations above and below the injection zone;

The cross section legend shall contain the formation and hydrologic names.

E. **GEOLOGICAL DATA ON INJECTION ZONES** - Submit the appropriate geological data on the injection zone including lithologic description, geologic name, thickness and depth.

F. **OPERATING DATA** - Submit the following operating data for each well (including those to be covered by area permits):

- A description of all wastes to be injected;
- Source(s) of fluids to be injected;
- Analysis of the physical and chemical characteristics of the injection fluid;
- Average and maximum daily rates and volume of fluids to be injected;
- Average and maximum injection pressure;
- Nature of the annulus fluid and,

In addition, if the well was in operation prior to applying for a permit, submit the type(s) of fluids discharged to each well and the length of time that the fluids have been discharged to that well.

G. **FORMATION TESTING PROGRAM** - Describe any formation testing programs to be utilized. Include data on porosity, permeability, physical and chemical characteristics of the injection zones.

H. **STIMULATION PROGRAM** - Outline any proposed stimulation program if applicable.

I. **INJECTION PROCEDURES** - Describe the proposed injection procedures including pump, surge, tank, etc.

J. **CONSTRUCTION PROCEDURES** - Discuss the construction procedures to be utilized. Include details of the casing and cementing program, drilling and logging procedures. Describe any testing and coring programs if applicable. Include proposed annulus fluid descriptions.

K. **CONSTRUCTION DETAILS** - Submit schematic or other appropriate drawings of the surface and subsurface construction details of the well.

L. **MONITORING PROGRAM** - A monitoring program must be developed to ensure that the facility meets the requirements of 40 Code Federal Regulations (CFR) 144.12(a). The monitoring program should include a baseline analysis of the injectate and groundwater prior to injecting, monitoring schedule (sampling frequency), parameters to be measured, location of sampling points(s) and a discussion of the technical basis for selecting the sampling point(s).

M. **PLUGGING AND ABANDONMENT PLAN -** Submit a plan to ensure that all USDWs are protected from unauthorized injection once the well is taken out of service or is converted. Plugging and abandonment plans shall include:

o Type and quantity of material to be used in plugging;
o Diagram(s) of plug placement (including the elevation of the top and bottom);
o Describe the type of plug to be used and the method used to place the plugs;
o Description of casing left in the well(s),

N. **NECESSARY RESOURCES** - Submit evidence of financial responsibility such as a surety bond or financial statement to verify that the resources necessary to close, plug or abandon the well(s) are available.

O. **EXISTING EPA PERMITS -** List the program (NPDES, PSD, PCS, RCRA, etc.) and permit number for any EPA permits which you currently have or have applied for.

P. **DESCRIPTION OF BUSINESS** - Give a brief description of the nature of the business and provide the Standard Industrial Classification (SIC) Code.

Form Approved. OMB No. 2040-0042. Expires 6-30-98

EPA

United States Environmental Protection Agency

Underground Injection Control Permit Application

(Collected under the authority of the Safe Drinking Water Act. Sections 1421, 1422, 40 CFR 144)

I. EPA ID Number		T/A	C
U			

Read Attached Instructions Before Starting

For Official Use Only

Application approved			Date received			Permit Number	Well ID	FINDS Number
mo	day	year	mo	day	year			

II. Owner Name and Address			III. Operator Name and Address		
Owner Name			Operator Name		
Street Address		Phone Number	Street Address		Phone Number
City	State	ZIP CODE	City	State	ZIP CODE

IV. Commercial Facility	V. Ownership	VI. Legal Contact	VII. SIC Codes
☐ Yes ☐ No	☐ Private ☐ Federal ☐ Other	☐ Owner ☐ Operator	

VIII. Well Status *(Mark "x")*

☐ A. Operating	Date Started			☐ B. Modification/Conversion	☐ C. Proposed
	mo	day	year		

IX. Type of Permit Requested *(Mark "x" and specify if required)*

☐ A. Individual	☐ B. Area	Number of Existing Wells	Number of Proposed Wells	Name(s) of field(s) or project(s)

X. Class and Type of Well *(see reverse)*

A. Classes(es) (enter codes(s)	B. Type(s) (enter codes(s)	C. If class is "other" or type is code 'x,' explain	D. Number of wells per type (if area permit)

XI. Location of Well(s) or Approximate Center of Field or Project														XII. Indian Lands (Mark 'x')
Latitude			Longitude			Township and Range								☐ Yes ☐ No
Deg	*Min*	*Sec*	*Deg*	*Min*	*Sec*	*Sec*	*Twp*	*Range*	*1/4 Sec*	Feet From	Line	Feet From	Line	

XIII. Attachments

(Complete the following questions on a separate sheet(s) and number accordingly; see instructions)
For Classes I, II, III, (and other classes) complete and submit on a separate sheet(s) Attachments A--U (pp 2-6) as appropriate. Attach maps where required. List attachments by letter which are applicable and are included with your application.

XIV. Certification

I certify under the penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. (Ref. 40 CFR 144.32)

A. Name and Title *(Type or Print)*	B. Phone No. *(Area Code and No.)*
C. Signature	D. Date Signed

EPA Form 7520-6 (Rev. 8-91)

Well Class and Type Codes

Class I	Wells used to inject waste below the deepest underground source of drinking water.
Type "I"	Nonhazardous industrial disposal well
"M"	Nonhazardous municipal disposal well
"W"	Hazardous waste disposal well injecting below USDWs
"X"	Other Class I wells (not included in Type "I,","M,"or "W")
Class II	Oil ans gas production storage related injection wells.
Type "D"	Produced fluid disposal well
"R"	Enhanced recovery well
"H"	Hydrocarbon storage well (excluding natural gas)
"X"	Other Class II wells (not included in Type "D,""R," or"H")
Class III	Special process injection wells.
Type "G"	Solution mining well
"S"	Sulfur mining well by Frasch process
"U"	Uranium mining well (excluding solution mining of conventional mines)
"X"	Other Class III wells (not included in Type "G,""S," or "U")
Other Classes	Wells not included in classes above.
	Class V wells which may be permitted under §144.12
	Wells not currently classified as Class I, II, III, or V.

Attachments to Permit Application

Class	**Attachments**
I new well	A, B, C, D, F, H - S, U
existing	A, B, C, D, F, H - U
II new well	A, B, C, E, G, H, M, Q, R; optional - I, J, K, O, P, U
existing	A, E, G, H, M, Q, R - U; optional - J, K, O, P, Q
III new well	A, B, C, D, F, H, I, J, K, M - S, U
existing	A, B, C, D, F, H, J, K, M - U
Other Classes	To be specified by the permitting authority

INSTRUCTIONS - Underground Injection Control (UIC) Permit Application

PAPERWORK REDUCTION ACT NOTICE

Public reporting burden for this collection of information is estimated at an average of 255 hours for Class I wells, 16 hours for Class II wells, and 200 hours for Class III wells per application, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collecting of information. Send comments regarding the burden estimate or any aspect of this collection of information, including suggestions for reducing this burden, to Chief, Information Policy Branch, PM-223, U.S. Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460, and to the Office of Management and Budget, Paperwork Reduction Project, Washington, DC 20503.

This form must be completed by all owners or operators of Class I, II, and III injection wells and others who may be directed to apply for permit by the Director.

I. EPA I.D. NUMBER - Fill in your EPA Identification Number. If you do not have a number, leave blank.

II. OWNER NAME AND ADDRESS - Name of well, well field or company and address.

III. OPERATOR NAME AND ADDRESS - Name and address of operator of well or well field.

IV. COMMERCIAL FACILITY - Mark the appropriate box to indicate the type of facility.

V. OWNERSHIP - Mark the appropriate box to indicate the type of ownership.

VI. LEGAL CONTACT - Mark the appropriate box.

VII. SIC CODES - List at least one and no more than four Standard Industrial Classification (SIC) Codes that best describe the nature of the business in order of priority.

VIII. WELL STATUS - Mark Box A if the well(s) were operating as injection wells on the effective date of the UIC Program for the State. Mark Box B if well(s) existed on the effective date of the UIC Program for the State but were not utilized for injection. Box C should be marked if the application is for an underground injection project not constructed or not completed by the effective date of the UIC Program for the State.

IX. TYPE OF PERMIT - Mark "Individual" or "Area" to indicate the type of permit desired. Note that area permits are at the discretion of the Director and that wells covered by an area permit must be at one site, under the control of one person and do not inject hazardous waste. If an area permit is requested the number of wells to be included in the permit must be specified and the wells described and identified by location. If the area has a commonly used name, such as the "Jay Field," submit the name in the space provided. In the case of a project or field which crosses State lines, it may be possible to consider an area permit if EPA has jurisdiction in both States. Each such case will be considered individually, if the owner/operator elects to seek an area permit.

X. CLASS AND TYPE OF WELL - Enter in these two positions the Class and type of injection well for which a permit is requested. Use the most pertinent code selected from the list on the reverse side of the application. When selecting type X please explain in the space provided.

XI. LOCATION OF WELL - Enter the latitude and longitude of the existing or proposed well expressed in degrees, minutes, and seconds or the location by township, and range, and section, as required by 40 CFR Part 146. If an area permit is being requested, give the latitude and longitude of the approximate center of the area.

XII. INDIAN LANDS - Place an "X" in the box if any part of the facility is located on Indian lands.

XIII. ATTACHMENTS - Note that information requirements vary depending on the injection well class and status. Attachments for Class I, II, III are described on pages 4 and 5 of this document and listed by Class on page 2. Place EPA ID number in the upper right hand corner of each page of the Attachments.

XIV. CERTIFICATION - All permit applications (except Class II) must be signed by a responsible corporate officer for a corporation, by a general partner for a partnership, by the proprietor of a sole proprietorship, and by a principal executive or ranking elected official for a public agency. For Class II, the person described above should sign, or a representative duly authorized in writing.

INSTRUCTIONS - Attachments

Attachments to be submitted with permit application for Class I, II, III and other wells.

A. AREA OF REVIEW METHODS - Give the methods and, if appropriate, the calculations used to determine the size of the area of review (fixed radius or equation). The area of review shall be a fixed radius of 1/4 mile from the well bore unless the use of an equation is approved in advance by the Director.

B. MAPS OF WELL/AREA AND AREA OF REVIEW - Submit a topographic map, extending one mile beyond the property boundaries, showing the injection well(s) or project area for which a permit is sought and the applicable area of review. The map must show all intake and discharge structures and all hazardous waste treatment, storage, or disposal facilities. If the application is for an area permit, the map should show the distribution manifold (if applicable) applying injection fluid to all wells in the area, including all system monitoring points. Within the area of review, the map must show the following:

Class I

The number, or name, and location of all producing wells, injection wells, abandoned wells, dry holes, surface bodies of water, springs, mines (surface and subsurface), quarries, and other pertinent surface features, including residences and roads, and faults, if known or suspected. In addition, the map must identify those wells, springs, other surface water bodies, and drinking water wells located within one quarter mile of the facility property boundary. Only information of public record is required to be included in this map;

Class II

In addition to requirements for Class I, include pertinent information known to the applicant. This requirement does not apply to existing Class II wells;

Class III

In addition to requirements for Class I, include public water systems and pertinent information known to the applicant.

C. CORRECTIVE ACTION PLAN AND WELL DATA - Submit a tabulation of data reasonably available from public records or otherwise known to the applicant on all wells within the area of review, including those on the map required in B, which penetrate the proposed injection zone. Such data shall include the following:

Class I

A description of each well's types, construction, date drilled, location, depth, record or plugging and/or completion, and any additional information the Director may require. In the case of new injection wells, include the corrective action proposed to be taken by the applicant under 40 CFR 144.55.

Class II

In addition to requirement for Class I, in the case of Class II wells operating over the fracture pressure of the injection formation, all known wells within the area of review which penetrate formations affected by the increase in pressure. This requirement does not apply to existing Class II wells.

Class III

In addition to requirements for Class I, the corrective action proposed under 40 CFR 144.55 for all Class III wells.

D. MAPS AND CROSS SECTION OF USDWs - Submit maps and cross sections indicating the vertical limits of all underground sources of drinking water within the area of review (both vertical and lateral limits for Class I), their position relative to the injection formation and the direction of water movement, where known, in every underground source of drinking water which may be affected by the proposed injection. (Does not apply to Class II wells.)

E. NAME AND DEPTH OF USDWs (CLASS II) - For Class II wells, submit geologic name, and depth to bottom of all underground sources of drinking water which may be affected by the injection.

F. MAPS AND CROSS SECTIONS OF GEOLOGIC STRUCTURE OF AREA - Submit maps and cross sections detailing the geologic structure of the local area (including the lithology of injection and confining intervals) and generalized maps and cross sections illustrating the regional geologic setting. (Does not apply to Class II wells.)

G. GEOLOGICAL DATA ON INJECTION AND CONFINING ZONES (CLASS II) - For Class II wells, submit appropriate geological data on the injection zone and confining zones including lithologic description, geological name, thickness, depth and fracture pressure.

H. OPERATING DATA - Submit the following proposed operating data for each well (including all those to be covered by area permits): (1) average and maximum daily rate and volume of the fluids to be injected; (2) average and maximum injection pressure; (3) nature of annulus fluid; (4) for Class I well, source and analysis of the chemical, physical, radiological and biological characteristics, including density and corrosiveness, of injection fluids; (5) for Class II wells, source and analysis of the physical and chemical characteristics of the injection fluid; (6) for Class III wells, a qualitative analysis and ranges in concentrations of all constituents of injected fluids. If the information is proprietary, maximum concentrations only may be submitted, but all records must be retained.

I. FORMATION TESTING PROGRAM - Describe the proposed formation testing program. For Class I wells the program must be designed to obtain data on fluid pressure, temperature, fracture pressure, other physical, chemical, and radiological characteristics of the injection matrix and physical and chemical characteristics of the formation fluids.

For Class II wells the testing program must be designed to obtain data on fluid pressure, estimated fracture pressure, physical and chemical characteristics of the injection zone. (Does not apply to existing Class II wells or projects.)

For Class III wells the testing must be designed to obtain data on fluid pressure, fracture pressure, and physical and chemical characteristics of the formation fluids if the formation is naturally water bearing. Only fracture pressure is required if the program formation is not water bearing. (Does not apply to existing Class III wells or projects.)

J. STIMULATION PROGRAM - Outline any proposed stimulation program

K. INJECTION PROCEDURES - Describe the proposed injection procedures including pump, surge, tank, etc.

L. CONSTRUCTION PROCEDURES - Discuss the construction procedures (according to §146.12 for Class I,

§146.22 for Class II, and §146.32 for Class III) to be utilized. This should include details of the casing and cementing program, logging procedures, deviation checks, and the drilling, testing and coring program, and proposed annulus fluid. (Request and submission of justifying data must be made to use an alternative to packer for Class I.)

M. CONSTRUCTION DETAILS - Submit schematic or other appropriate drawings of the surface and subsurface construction details of the well.

N. CHANGES IN INJECTION FLUID - Discuss expected changes in pressure, native fluid displacement, and direction of movement of injection fluid. (Class III wells only.)

O. PLANS FOR WELL FAILURES - Outline contingency plans (proposed plans, if any, for Class II) to cope with all shut-ins or well failures, so as to prevent migration of fluids into any USDW.

P. MONITORING PROGRAM - Discuss the planned monitoring program. This should be thorough, including maps showing the number and location of monitoring wells as appropriate and discussion of monitoring devices, sampling frequency, and parameters measured. If a manifold monitoring program is utilized, pursuant to §146.23(b)(5), describe the program and compare it to individual well monitoring.

Q. PLUGGING AND ABANDONMENT PLAN - Submit a plan for plugging and abandonment of the well including: (1) describe the type, number, and placement (including the elevation of the top and bottom) of plugs to be used; (2) describe the type, grade, quantity of cement to be used; and (3) describe the method to be used to place plugs, including the method used to place the well in a state of static equilibrium prior to placement of the plugs. Also for a Class III well that underlies or is in an exempted aquifer, demonstrate adequate protection of USDWs. Submit this information on EPA Form 7520-14, Plugging and Abandonment Plan.

R. NECESSARY RESOURCES - Submit evidence such as a surety bond or financial statement to verify that the resources necessary to close, plug or abandon the well are available.

S. AQUIFER EXEMPTIONS - If an aquifer exemption is requested, submit data necessary to demonstrate that the aquifer meets the following criteria: (1) does not serve as a source of drinking water; (2) cannot not and will not in the future serve as a source of drinking water; and (3) the TDS content of the ground water is more than 3,000 and less than 10,000 mg/l and is not reasonably expected to supply a public water system. Data to demonstrate that the aquifer is expected to be mineral or hydrocarbon production, such as general description of the mining zone, analysis of the amenability of the mining zone to the proposed method, and time table for proposed development must also be included. For additional information on aquifer exemptions, see 40 CFR Sections 144.7 and 146.04.

T. EXISTING EPA PERMITS - List program and permit number of any existing EPA permits, for example, NPDES, PSD, RCRA, etc.

U. DESCRIPTION OF BUSINESS - Give a brief description of the nature of the business.

Appendix G

Open Systems in Brooklyn, Queens and Long Island

Below is a discussion for the use of well water open systems in Brooklyn, Queens and Long Island. Long Island Lighting, now Long Island Power Authority, Marketing[1] has indicated there are approximately 1,000 open-type geothermal heat pump systems on LI today. Some open geothermal heat pumps systems have been active since the late 1950's.

Well water/Open Well Geothermal Heat Pump systems as compared to closed loop systems are generally:

- ✓ Most Efficient
- ✓ Lowest First Cost Heat Pumps
- ✓ Lowest First Cost Earth Side

Table 1 – What Well Water Systems Have to Offer

EFFICIENCY IS HIGHEST

Geothermal heat pump efficiency can be measured by the difference between the temperature of the hot side (condenser) and the cold side (evaporator) of the heat pump. The smaller the difference the less power is consumed in compressing the refrigerant gas – and consequently, the lower the electric costs and the higher the heat pumps output. Both are a measure of efficiency.

In its simplest terms:

- Long Island's 52°F well water is closer to 100°F heat pump output winter temperature than the 32°F design temperature for a closed loop GT system.

- In the summer the 52°F well water temperature is closer to the 58°F heat pump output temperature than the 77°F design temperature for a closed loop ST system.

Table 2 – Why More Stable Ground Water Temperatures are More Efficient

Open Wells Provide Highest Efficiency Equaling Lowest Operational Costs

LOWEST FIRST COST – Heat Pump

Rating a heat pump at 50°F[2] well water temperatures water for both heating and air conditioning results in a smaller less costly heat pump as the higher winter and lower summer temperatures are more stable. Rating an installation at the 32°F (heating) and 77°F (cooling)[3] often results in the next larger and consequently higher priced heat pump. Temperatures for the Closed Loop applications requires more power in the winter and in the summer, making the heat pumps less efficient and have lower output – requiring usually a one step larger model.

As an example, taking a four ton model geothermal heat pump, with a building load of 41,000 btuh heating and 32,000 btuh cooling. The required heat pump used for well water is smaller and less cost:

Type GTHP	Model	Well Water	Model	Closed Loop
Standard	VP048	$4,480	VP060	$4,870
High Efficiency	VT060	$6,440	VT072	$6,870

Table 3 – Difference in GTHP Sizing & List Cost for Well Water & Closed Loop

A Well Water Heat Pump Can be Smaller and Less Costly

LOWEST FIRST COST – Wells & Closed Loops

The above 41,000 btuh heat loss would result in a requirement for approximately:

1,200 feet of closed loop in 550 feet of **vertical**[4] bore hole, at $ 5,100
3,500 feet of closed loop pipe in 350 feet of **Slinky**[5] trench, at $ 4,800

Table 4 – Typical HDPE Pipe Required for Example Installation

Closed Loops Have Been Approximately $500 - $800 more Per Nominal Ton

DESCRIPTION OF OPEN SYSTEMS

The Well Water/Open system can have several configurations, some of the more popular configurations are:

- Open Well to Responsible Surface Discharge
- Open Well to Diffusion Well
- Open to Return to Same Well (Standing Column Well)

Open Well to Responsible Surface Discharge

This design requires two important facts:

1. That the well can produce 3 gpm per ton of load, with the dominant load being the design requirement.
2. There is a responsible place to recycle the water back into the aquifer.

Although there maybe some of these designs on LI, we are not aware of any surface discharge with any of the very old LI systems as Solalrgy, TempMaster, Friedrich or ClimateMaster geothermal heat pumps. A basic problem can be the lack of a stream, pond or other surface water entity for a responsible return to the environment. Assuming a sufficiently large well yield and a responsible recycle point the open well can be the lowest cost and highest efficiency GT System. There are preponderance of these systems in the Northeastern States.

We understand there are some old sites with commercial geothermal heat pumps that are recycling directly to LI Sound.

Recycle to a "navigable stream/body of water" will require a National Pollution Discharge Elimination System permit (NPDES). The NPDES for a geothermal system is not a difficult task and we have yet to have any problems with this type system.

Open Well to a Diffusion Well

A very popular method for geothermal heat pump earth coupling in LI. We have been involved in many installations over the years, since 1978. The water table in many areas on the Island are near the surface and the soil is exceptionally permeable.

Spacing two wells at a proper distance with one well providing the necessary 3 gpm/ton and the second well accepting this amount of water is a relatively low cost and unambiguous design. Providing the water from the well is drinking quality the EPA categorizes this type well as a "Class V" Underground Injection Criteria (UIC) well. The EPA considers this type well to be

Ag

environmentally beneficial and does not require permitting for small systems.

We would recommend this type system in any application on the Island. Long Island Lighting retrofitted its Riverhead Office to a geothermal heat pump system and drilled a second diffusions well. LILCO's Brentwood facility was installed as a geothermal heat pump with a single supply and diffusion well. The original 200 ton installation pumped over 500 gpm to their heat pump since 1955! The Brentwood system was retrofitted in 1995 and have integrated the new geothermal equipment to the old supply and diffusion well.

Supply and Diffusion Well(s) are Recommended for Queens, Brooklyn and Long Island Installations

STANDING COLUMN WELLS

Standing Column Wells (SCW) return the water to the same bore hole after passing through the heat pump. These wells are generally categorized as Class V wells and are regulated by "rule" – viz. a permit is not normally required.

The SCW usually employs about 50-60 Lft of bore hole per ton, or approximately 2½ times less bore depth than a vertical closed loop (150 Lft/ton). The SCW are normally employed in areas where there is near-surface bedrock and are often 1,500 Lft deep (supporting 30 - 40 tons). The SCW method is useful in areas where the bedrock is within approximately 60 -100 feet of the surface and commensurate casing lengths and costs are minimized.

There are no SCW on LI as the sand/gravel over-burden is 600-800 feet deep. Nearby Northeast portions of Queens and Manhattan are prime candidates for SCWs.

For the past 35 years the *open* geothermal heat pump systems on Long Island has been exemplary. There has been a history of lowest first cost, low maintenance, low operating costs and harmony with the environment.

(Footnotes)

[1] LILCO survey 1988, also in NYSERDA survey mid 1980's

[2] ARI 325 is the "Well Water" Air Conditioning & Refrigeration Institute's Standard, both heating & air conditioning are rated at 50°F water in the Northeast

[3] ARI 330 is the "Closed Loop" ARI spec for standard design at 32°F Heating and 77°F A/C

[4] Based upon the damp soil minimum depth of 150 Lft/ton. and has been $1,400 - $1,900/ton, $1,500 was used in this example

[5] As above, this is the low end of the Slinky type closed loop, a recent system on Martha's Vineyard cost $2,200/ton, $1,400 was used in this example. Although easier to dig, it requires about $1,000 more pipe.

Appendix H

Kensington Library Geophysical Log

AQUIFER DRILLING & TESTING, INC.
150 Nassau Terminal Road
New Hyde Park, New York 11040
(516) 616-6026 Phone • (516) 616-6194 Fax
www.aquiferdrilling.com

July 30, 1999

Mr. Ed Wegener
NYCDDC
30-30 Thompson Avenue
Long Island City, NY 11101

Re: RW-1 24-Hour Pump Test
Kensington Library
Brooklyn, NY

Dear Mr. Wegener:

As requested, I am providing construction details and results from the pump test, for the above referenced site.

Construction Detail

Well No:	RW-1		
Outside Casing Diameter:	10" BSC	Length: 0 – 200 feet	
Riser Diameter:	6" BSC	Length: 0 – 215 feet	
Screen Diameter:	6" 304 SS Channel Pack (Johnson)	Slot Size:	0.040
Screen Length:	215' to 235'		
Gravel Pack:	200' to 235'		
Drilling Fluid:	Johnson Revert		
Well Development:	Jetting, Surging, Pumping 8 hours.		

Pump Test Summary

Test Period: 12:00 p.m., July 27, 1999 through 12:00 p.m., July 28, 1999
PTW-41.2 Pump: 6" Grunfos 30 HP Submersible
Pump Setting: 210' Riser: 0 – 210' Diameter: 3" -?

Pumping Data (Abbreviated)

Specific Gravity: 1.29 gpm/ft

Date	Time	DTW	GPM
7/~~28~~/99 ~~28~~ 27	12:00 p.m.	41.2	0
	12:30	102.0	150
	1:00	152.0	200
	6:00	174.0	190
7/~~28~~/99 ~~29~~ 28	5:30 a.m.	190.6	190
	6:00	152.0	150
	10:15	157.83	150
	11:00	157.80	150
	12:00 p.m.	157.8	150

If you have any questions or would like additional information, please call me at 1-800-238-3745.

Sincerely,
Aquifer Drilling & Testing, Inc.

H.L. Rexrode, Jr.
President

cc: M. Greenman
J. Katz

DTW = DEPTH TO WATER

JIM SEIVEL 1-800 238-3745
OPERATIONS

AQUA TERRA GEOPHYSICS INC

16 STATION RD. #8
BELLPORT, NY 11713
(516) 286-7699

BOREHOLE: TESTHOLE
LOGS: NATURAL GAMMA
S. POINT RESISTANCE
SPONT. POTENTIAL

PROJECT: KENSINGTON LIBRARY
CLIENT: AQUIFER DRILLING AND TESTING
LOCATION: BROOKLYN

DATE: 6-25-99
COUNTY/COUNTRY:
STATE/PROVINCE: NY

BOREHOLE DATA

DRILLING CONTRACTOR: AQUIFER DRILLING AND TESTING
ELEV:
DEPTH REF: GRADE
CUSTOMER TD: 388 FT
LOGGER TD 387 FT

RUN	BIT RECORD			CASING RECORD		
NO.	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	10 IN	0 FT	35 FT	6 IN HSA	0 FT	35 FT
2	6 IN	35 FT	TD			
3						

DRILL METHOD: MUD ROTARY
HOLE MEDIUM: DRILLING FLUID
VISCOSITY:
DATE DRILLED: 6-25-99
FLUID LEVEL: 8 FT
WEIGHT:
TIME SINCE CIRC: 1 HR
MUD TYPE: BETONITE
Rm: at Deg

GENERAL DATA

LOGGED BY: B. RICE / T. TAYLOR-O'NEIL
WITNESS: DENNIS MAYER
OTHER SERVICES:
UNIT/TRUCK: MT. SOPRIS/ 2

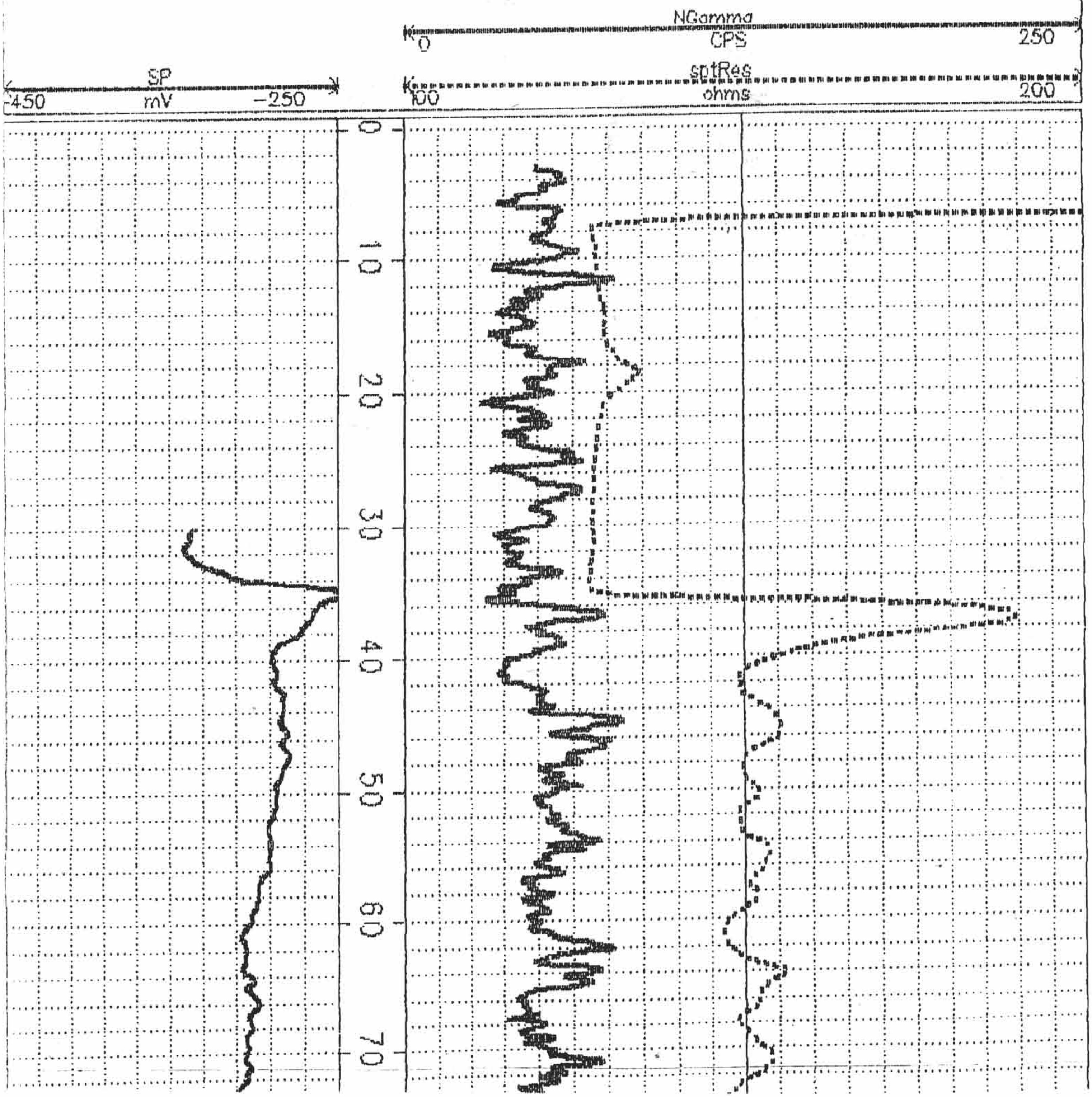
LOGGING DATA

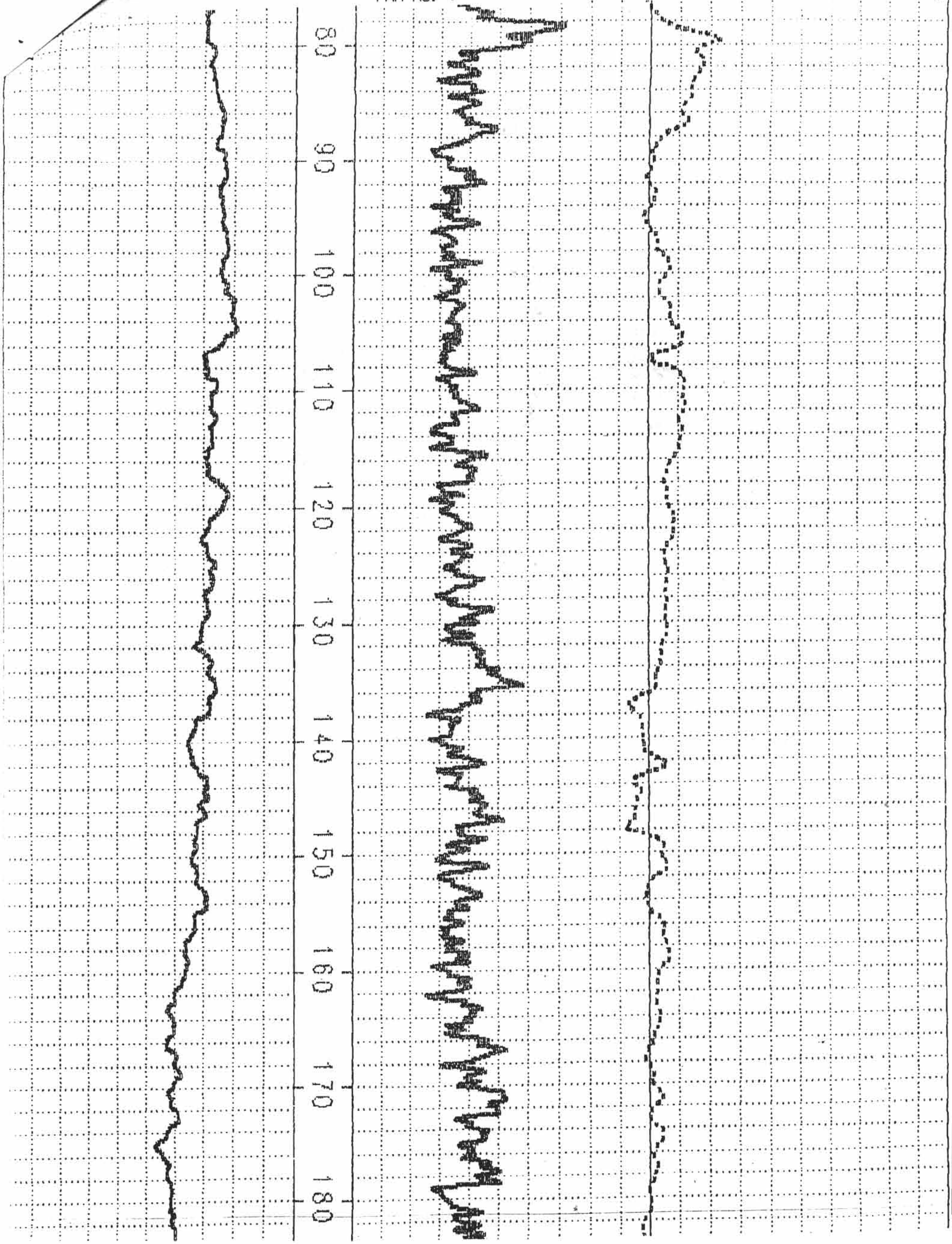
LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR	SOURCE		LOGGED INTERVAL			COMMENTS
		MODEL	PROBE S.N.	UPHOLE S.N.	DIG INT FEET	SPEED FT./MIN	TYPE	TYPE	SIZE GBq	FROM	TO	INT. FEET	
N. GAMMA	1	305	2201	0200		20	NaI			3	387	384	W.A -- 2
SP-R	2	308	2201	0200		26				35	387	382	

DIGITAL FILE NAME(S):
REMARKS:

SUB SURFACE JOB # 2990A
CAPITAL PROJECT L8--104 KEN

(C: BKLYN TESTHOLE.AA1) kensingtonlibrarytesthole

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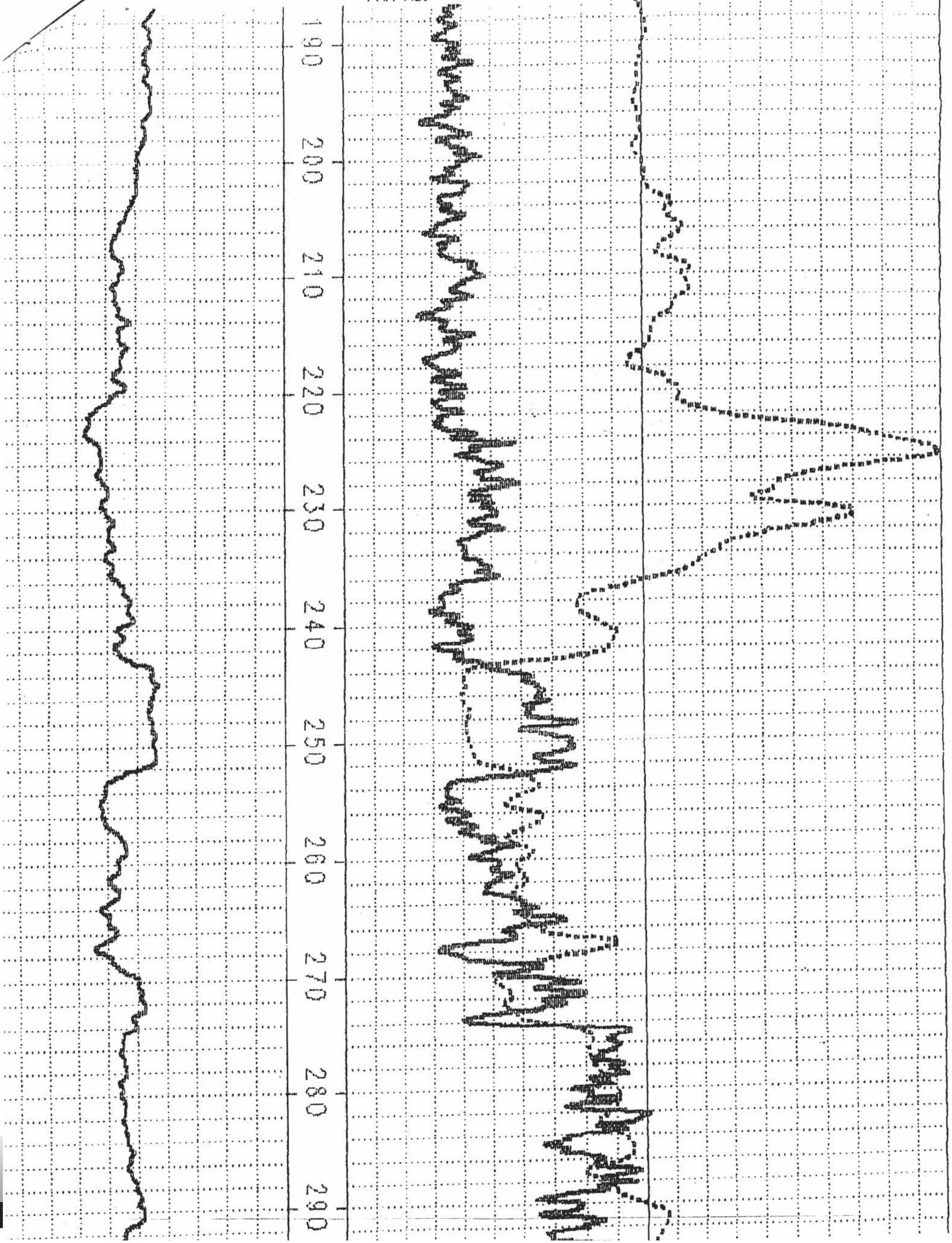
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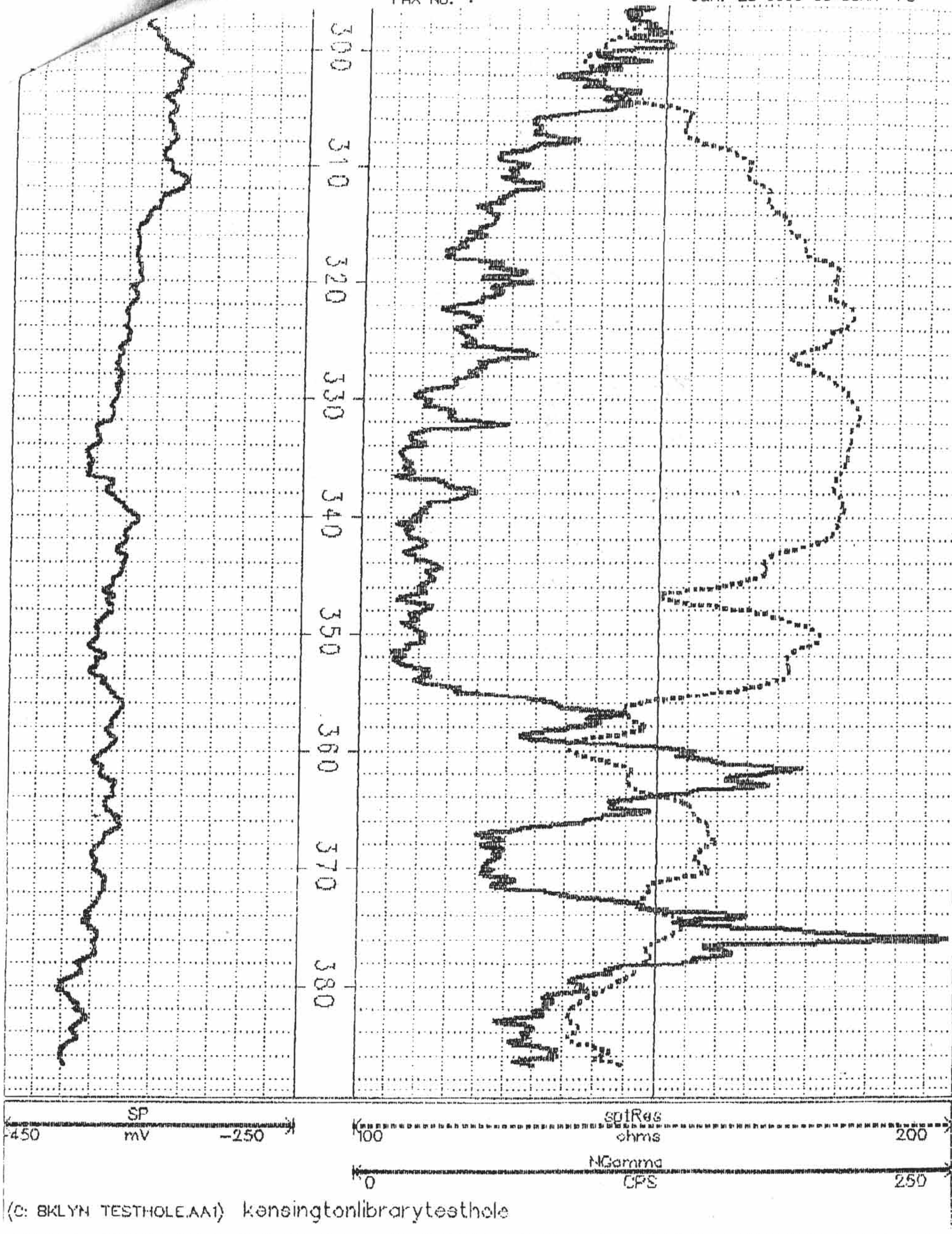
300
310
320
330
340
350
360
370
380
SP
-450 mV -250
sptRes
100 ohms 200
NGamma
0 CPS 250
(C: BKLYN TESTHOLE.AA1) kensingtonlibrarytesthole

Appendix I

Contributor Directory

Directory of Contributors:

P. Andrew Collins, PE is the principal of the homonymous consulting engineering firm. A large portion of the practice is devoted to sustainable projects. The principal is licensed in New York, New Jersey and Massachusetts, is a full time member of ASHRAE, a member of the International Ground Source Heat Pump Association, and is active in the federal LEED (Leadership in Energy Design) certification program.

P. A. Collins, P E
1140 Broadway suite 203
New York, NY 10001
telephone: 212 696 5294

Carl D. Orio is the chairman of Water Energy Distributors Inc. and is a certified Geo-Exchange Designer by the Association of Energy Engineers, and a Designated Design assistant by the Geothermal Heat Pump Consortium, and a certified Installation Trainer by the International Ground Source Heat Pump Association, and is a full member of ASHRAE.

Water Energy Distributors Inc.
100 Maple Ave
Atkinson, NH 03811
telephone: 603 362 4666

Sergio Smiriglio is a hydrologist and the principal of SSEC, Inc.

SSEC, Inc.
4 Deer Trail
Cornwall, NY 12518
telephone: 845 534 3816