GEOTHERMAL SYSTEMS and their Application in New York City

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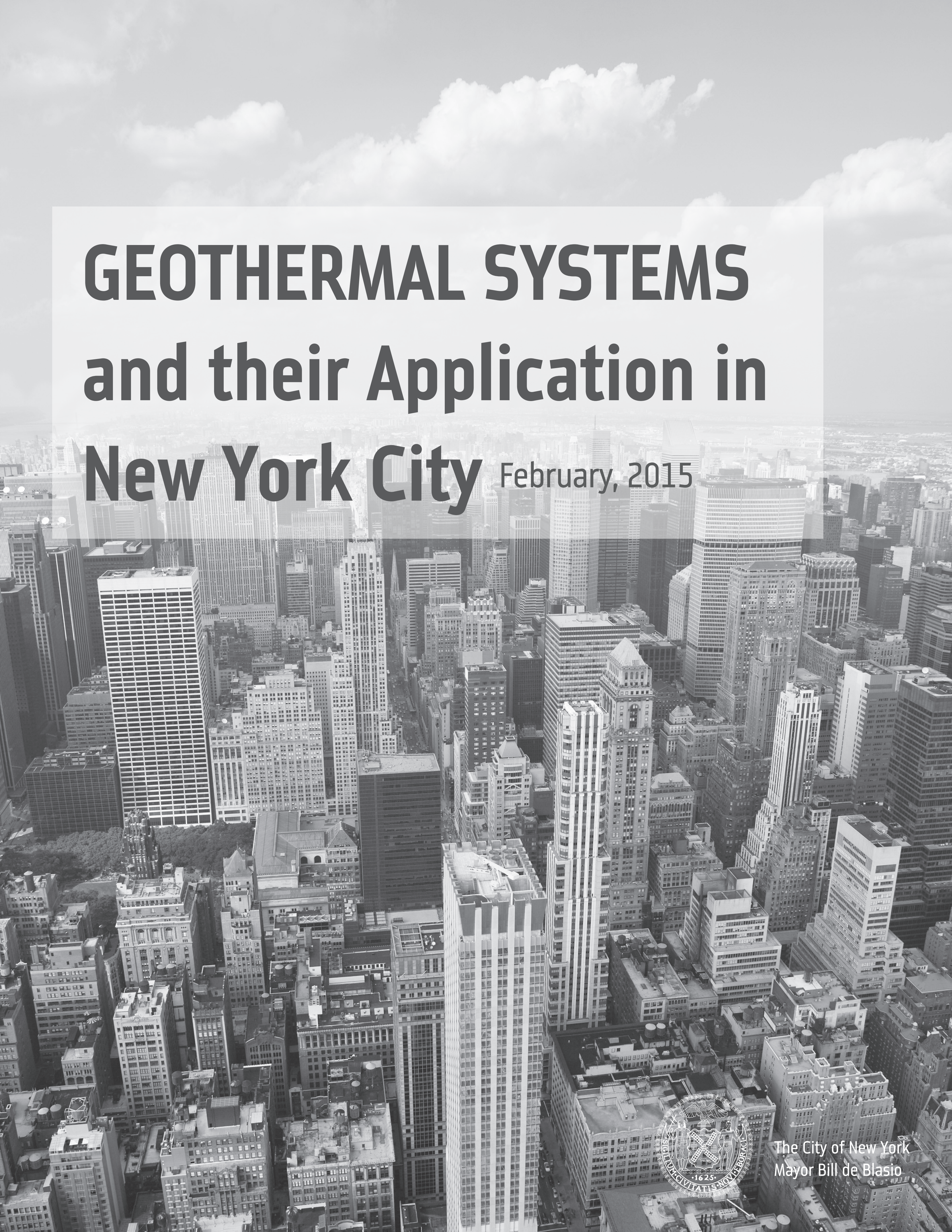

The City of New York
Mayor Bill de Blasio

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Executive Summary

This fall, Mayor de Blasio made a sweeping commitment to dramatically reduce our carbon footprint, with New York City becoming the largest city in the world to take on the goal of reducing greenhouse gas emissions by 80 percent over 2005 levels by 2050 ("80x50").

The increased reliance on renewable energy sources, such as geothermal, will play a critical role in achieving the city's goal to reduce greenhouse gas emissions by 80% over 2005 levels by 2050 ("80x50"). Nearly 75% of New York City's emissions come from the energy used in buildings. As described in the City's report One City, Built to Last: Transforming New York City's Buildings for a Low Carbon Future, New York City is well on its way to increasing the energy efficiency of buildings. The use of Geothermal Systems can improve the efficiency of how customers heat and cool buildings, thereby contributing to the City's 80x50 carbon emissions reduction goal.

Geothermal energy is clean and renewable heat from the Earth. In addition to reducing emissions, the use of geothermal can provide building owners with energy cost savings, increased reliability, and reduced exposure to market energy price fluctuations.

New York City can take advantage of this renewable energy through the use of heat pumps. The pumps extract the ground's thermal energy to heat buildings during winter months. During the summer, the pumps transfer excess heat to the ground to cool buildings.

This report serves as a tool to help determine if geothermal energy systems are a viable solution for meeting a building's energy requirements. The successful implementation of geothermal technology is dependent on a number of factors, many of which are site specific.

The land area available for geothermal wells, the specific load profile of a building or group of buildings for heating and cooling energy demand, and the underlying geology all play a key role in determining if a geothermal system is technically, and economically, feasible. In addition to these factors, for building retrofits, the existing heating and cooling equipment, as well as the current efficiency of the building envelope, are factors that must be evaluated.

Each project site will have its unique requirements, constraints, and opportunities. This Report describes how Geothermal Systems work, and examines the fundamental factors that must be assessed by a developer contemplating the implementation of such systems, the potential impact such factors have on a project's feasibility and economics, and the opportunities that are available for integrating geothermal into a building's energy management portfolio.

The Report also describes the types of Geothermal Systems already in place in New York City and provides a thorough analysis of New York City geology to indicate where geothermal applications are most likely to succeed, as well as the type of systems that best fit within each geological area.

The Report sets forth the challenges to installing Geothermal Systems in the City, including the significant up-front investment. Also reviewed are the countervailing benefits that such systems can provide, including energy cost savings, reduced greenhouse gas emissions (GHG) emissions, increased reliability and reduced exposure to market energy price fluctuations.

The Report demonstrates that the installation of a Geothermal System in New York City requires a site-specific analysis. As an aid, included are hypothetical feasibility studies of a geothermal system for two different types of buildings: (1) an approximately 100,000 square foot multi-family residential building; and (2) an approximately 100,000 square foot commercial building. The Report illustrates that geothermal systems for these two buildings can achieve significant overall energy savings (in the range of 25 to 30%) when compared to "business as usual" or conventional options (i.e., natural gas fueled boilers and furnaces).

The model results also show the Geothermal Systems consume only 30% of the energy consumed by natural gas fueled boilers and furnaces, and approximately 80% of the energy consumed by air and water cooled air conditioning systems. However, these savings must be measured against the incremental up-front capital costs associated with the systems.

Finally, the Report includes a life cycle cost analysis that compares energy savings with capital costs and operations and maintenance costs over the span of the project's life for both business case scenarios.

The life cycle cost analysis results show that over the lifetime of the project, for the two cases studied, the energy cost savings alone are not substantial enough to completely balance the initial capital costs associated with purchase and installation of the geothermal wells.

However, there are a myriad of tangible benefits realized from the application of geothermal heat pump technology that are not accounted for in the business case analysis, including peak load reduction to the grid (avoided costs of utility infrastructure investment through reduced electricity consumption), GHG emission reductions and the offset of fuel cost volatility. These benefits are not accounted for in the business case analysis, but may provide strategic long term incentives when considering geothermal technologies.

In addition, the Report describes opportunities to reduce the initial project costs of geothermal systems, and thereby make these systems more economical without valuation of the above described benefits. These options include developing hybrid and district scale solutions, as well as procuring renewable federal, state, and local incentives that may be available. Creative solutions that strive to reduce a portion of a building's load profile (i.e., base load) also can significantly reduce capital costs. Moreover, economies of scale and the diversification offered in district scale energy management may make the integration of renewables, such as geothermal, more feasible.

This Report is meant to serve as a tool to those interested in implementing geothermal technology throughout New York City and to assist in identifying and analyzing the relevant factors to determine if geothermal energy systems are a viable solution. This Report should be considered in conjunction with the New York City Department of Design and Construction's Geothermal Heat Pump Systems Manual for a comprehensive overview of the necessary processes for installing geothermal systems throughout the City.

Introduction

Climate change is one of the most urgent challenges the world faces. The United Nation's Framework Convention on Climate Change has called for limiting temperature increases this century to 2 degrees Celsius, requiring a 50% reduction in global emissions and an 80% emissions reduction in developed countries by 2050.

New York City Mayor Bill de Blasio has committed to reducing the city's greenhouse gas emissions by 80% over 2005 levels by 2050 ("80x50"). His report titled One City, Built to Last: Transforming New York City's Buildings for a Low Carbon Future puts the city on the path to achieving this goal, with City government operations leading the way with a target reduction of 35% over 2005 levels by 2025.

The 80x50 pledge makes New York City the largest city in the world to commit to such significant carbon reductions.

New York City tracks its progress in achieving this goal by taking an inventory of its greenhouse gas ("GHG") emissions annually. GHG emissions are already 19% lower than they were in 2005, which is the reference base year used in the Inventory of New York City Greenhouse Gas Emissions . The city has made great strides in reducing its carbon usage, but there is still much work to do. Renewable energy sources will play a critical role in achieving the 80x50 goal.

Renewable resources, including wind, hydro, solar, geothermal, solid waste, biomass and tidal, provide nearly 11% of the energy the New York State uses for transportation, space heating, industrial processes and electric power; and there is the potential to increase the amount of renewable resources used to satisfy up to 40% of the State's energy needs by 2030.

Geothermal energy is the heat stored in the Earth. From the use of hot springs for heat 10,000 years ago, to the development of the first ground-source heat pump ("GHP") used to heat a residence in Ohio State in 1948, geothermal energy has served as a valuable energy source.

The majority of geothermal power plants in the United States are located in the western states, where elevated subterranean temperatures make power generation feasible. Currently, nine states produce electricity from geothermal plants, with more than 80% of total geothermal generation capacity located in California.

In the city of New York, lower subterranean temperatures do not support power generation at this scale; however, the city can take advantage of geothermal energy provided by these stable lower subterranean temperatures through the use of GHPs. GHPs take advantage and thrive off of stable ground and aquifer temperatures - allowing GHPs to efficiently heat and cool buildings. The Earth's constant temperature provides an efficient alternative to ambient air temperature, resulting in less energy consumed.

Building new developments and retrofitting existing buildings to be more energy efficient is the first step towards achieving the city's GHG emissions reduction goal of 80x50. Buildings provide up to 75% of the city's GHG emissions. GHPs are a growing sector in the heating and cooling market, and have been successfully operated for decades in virtually every building type.

The use of GHPs for space conditioning became operational within the last 15 years. Despite such a limited application of geothermal, recent geothermal development in New York City includes the Brooklyn Children's Museum, the Queen's Botanical Garden, Weeksville Heritage Center, Lion House at the Bronx Zoo, Staten Island Museum at Snug Harbor and a comfort station at Washington Square Park. Two geothermal projects currently under construction are the Bronx River Boathouse and the Fire Department Rescue Company 2 in Brooklyn.

More recently, the design of New York City's first "net-zero" energy school, PS 62 on Staten Island (see Box 1), includes a plan to integrate a geothermal system for heating and cooling. As described in more detail below, by being net zero, the school will harvest as much energy as it uses on an annual basis. This project will produce energy through a combination of solar photovoltaic arrays and geo-exchange wells.

The purpose of this report is to look at the factors influencing the feasibility of geothermal systems in heating and cooling New York City buildings. For any given project site, be it a new development, a retrofit project, or a group of buildings within a district, it is necessary to assess how well different opportunities for energy management meet project objectives. Such an assessment may include an analysis that considers project economics, GHG emissions, work force development, and meeting the specific needs identified by the community

This Report demonstrates that when using geothermal technology to retrofit existing buildings in New York City, the main factors to consider in addition to building envelope efficiencies are land availability for geothermal wells, the energy demand profile of a building, and geological constraints. This Report investigates which types of geothermal projects will have the highest likelihood of success in New York City, and examines the various factors that should be assessed to determine if geothermal energy is a viable energy management solution.

This Report should be considered in conjunction with the New York City Department of Design and Construction's Geothermal Heat Pump Systems Manual for a comprehensive overview of the necessary processes for installing geothermal systems throughout the City.

Box 1. Net Zero Energy – PS 62, New York City's First Net Zero Public School

Net zero energy is a term used to describe a building, campus or community that relies on energy conservation and on-site renewable energy generation to meet all of its heating, cooling and electricity needs. There are a few different definitions and concepts of a net-zero building that take into consideration the boundary and the metric of a building. For the Staten Island PS 62 project, "Net Zero Site Energy", means the campus will produce at least as much energy as it uses in a year.

No single technology or group of technologies provides a guaranteed solution to reaching net-zero. The optimal solution will depend on climate, geology, building-specific heating and cooling demand profiles, existing policies, regulations, and mandates. First and foremost, overall energy demand must be reduced as much as possible. As part of its plan, PS 62 prioritized energy efficiency first. As a primary goal, the entire heating, ventilation, air conditioning ("HVAC") design was analyzed to reduce energy consumption in every practicable way. The orientation and massing of the building is optimized to take advantage of sunlight for both daylighting and photovoltaic arrays on the roof and south façade. Other sustainable and low-energy features incorporated in the design include a high performance building envelope, day lit offset corridors, energy recovery ventilators and demand-control ventilation. Overall, energy used at PS 62 will be reduced by 50% when compared to standard public schools.

After minimizing the initial energy demands, an integrated design process was used to determine how best to meet the remaining energy needs. The ultimate PS 62 design includes a combination of solar photovoltaic arrays and geo-exchange wells to meet the energy needs of this school. A total of 81 geothermal wells within a closed loop system are planned for installation to a depth of approximately 420 feet (this extends to the bedrock). Notably, the three acre site provided the land area needed to accommodate the 81 geothermal wells needed to meet the school's energy needs.1

Figure 1. PS 62, Staten Island, New York[10]

An Introduction to Geothermal Exchange Systems

A Geothermal Exchange System consists of a GHP installed within the building and the ground coupling ("GRCO") system installed outside the building. The GRCO consists of horizontal piping arrays, or vertical wells, to transfer heat to and from the earth. Together, the GHP and GRCO make up a Geothermal Exchange System.

GEOTHERMAL HEAT PUMPS

A GHP is an adaptation of the standard heat pump, where the ground or subterranean water serves as the heat sink or heat source. GHPs can work in conjunction with a number of resources, not just the ground. While this Report is limited to evaluating the feasibility of geothermal wells in the ground, Box 2 sets forth additional opportunities for a geothermal system beyond the ground.

Box 2. Heat Pump Resources – Beyond the Ground as a Source

This Report focuses on the use of wells in the ground as part of a geothermal system. There are, however, other resources that can work with heat pumps to provide the stable temperatures needed for energy efficiency gains. Below are some examples. The optimal geothermal resource will depend upon what resources are available at any particular site.

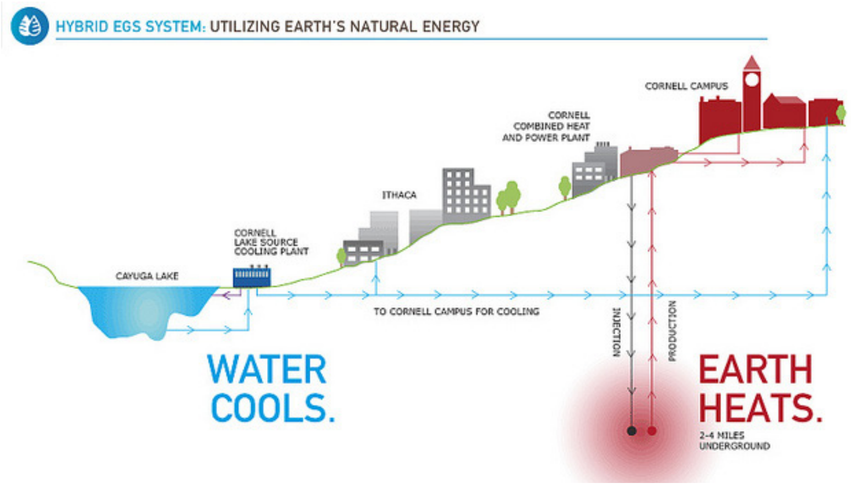
LAKES AND PONDS: Stationary surface water, such as a lake, pond, or even a constructed pond, can act as the geothermal resource in a geo-exchange system. Either closed-loop or open-loop systems can be used. A closed-loop surface water heat pump system transfers heat to and/or from the water body by circulating a heat transfer fluid in an enclosed pipe. An open-loop heat pump system withdraws water from a surface water supply, passes it through a heat exchanger, and discharges the water to a surface body of water or a storm sewer. Cornell University in Ithaca, New York, uses Cayuga Lake as a source for cooling its campus. The campus has reduced electricity consumption for central campus air-conditioning by 86% and reduced overall electricity use by 10%. [11]

OCEANS: Low temperature ocean water can be used to cool individual buildings or groups of buildings. An example of this is Purdy's Wharf in Halifax, Nova Scotia Canada, an office and commercial complex. Heat is transferred to the cold ocean water through a series of cooling loops and heat exchangers. The seawater provides all cooling for 10 ½ months per year. The project has provided a simple payback in two years. [11]

MOVING SURFACE WATER, I.E. RIVERS: A large river with reliable flow and modest current could be a heat exchange resource for nearby buildings. Issues that should be considered are historical high and low water conditions, debris flow, and commercial and recreational traffic would be serious considerations.

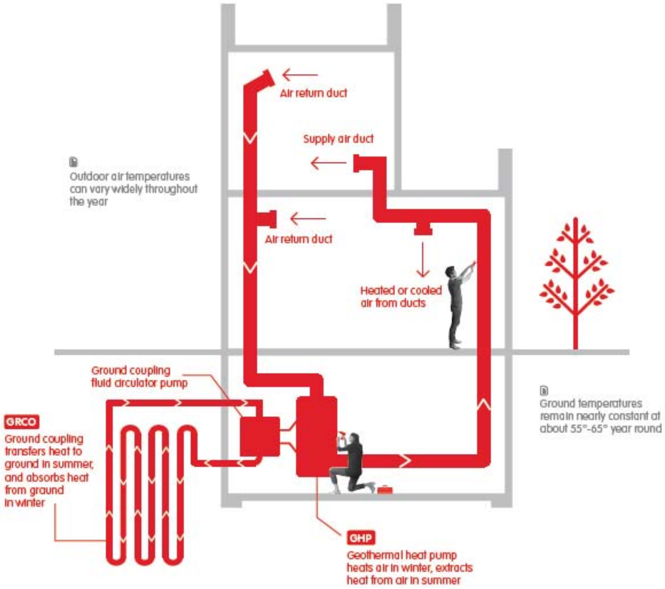
SEWAGE GEOTHERMAL: Large-volume, reliable, flowing wastewater streams can be used to condition a heat exchanger. The Philadelphia Water Department ("PWD")and Philadelphia-based Nova Thermal Energy partnered to be the first site in the United States to deploy a commercial scale geothermal system that provides buildings heat using domestic wastewater. The sewage geothermal installation operates at the Southeast Water Pollution Control Plant. Thermal energy is extracted from the sewage arriving at the plant and is used to heat the plant's compressor and gallery space, saving PWD $18,000 annually. The project was partially funded through a $150,000 Greenworks Pilot Energy Technology Program Grant. NovaThermal covered the balance of the $240,000 project cost. As a result, the system was installed at no cost to the PWD and its ratepayers. [12]

Figure 2. Cornell Campus - Heating and Cooling Energy System[11]



Since ground temperatures are cooler than air temperatures in the summer, GHPs can be more efficient than comparable cooling equipment because the equipment will work more efficiently and use less energy during these summer months. Similarly, GHPs extract heat from the ground during the winter that, when combined with heat recovered from the refrigerant cycle, can provide sufficient heating without additional space heating equipment. Figure 4 demonstrates how a GHP system works.

Figure 4. Simplified Ground Source Heat Pump Layout[5]



The refrigerant cycle allows heat pumps to provide either cooling or heating by transferring heat energy between the refrigerant and another medium. In cooling mode, the compressor compresses low pressure refrigerant vapor and discharges it at a higher pressure into the condenser. A cooler medium, such as water, travels through the condenser, absorbs heat from the vapor refrigerant and condenses it. The liquid refrigerant, at high pressure, then flows through the expansion device, which is designed to maintain a specific flow rate while reducing pressure to allow the refrigerant to boil in the evaporator. As the refrigerant evaporates, it extracts the heat from the warmer air passing through it.

The reverse process occurs in heating mode. "Water-to-air" units are typically used to directly heat and cool the building spaces they serve. "Water-to-water" units are typically used to indirectly heat and cool buildings spaces by producing chilled water for cooling or hot water for heating. The heating or cooling of building spaces is provided by auxiliary HVAC equipment serving individual locations such as radiators, fan coil units, or air handlers.

Because most GHPs are packaged HVAC units, on-site capacity can range from ½ ton up to 30 tons (which are commonly used on city and commercial projects). The heat pumps can be distributed throughout the building or centralized at one location.[6]

GROUND COUPLING

The GHP uses the GRCO to transfer heat energy to and from the ground. The units can be installed and connected to distribution systems in the same manner as water-to-water or water-to-air heat pumps. An additional device called a de-superheater can be integrated to heat domestic hot water with waste heat normally rejected back into the ground.

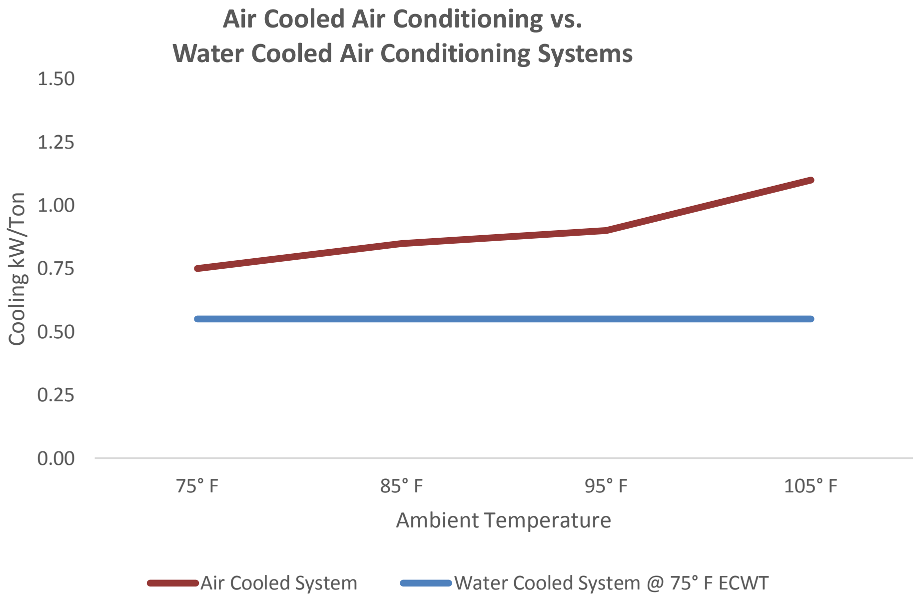
Ground temperatures for wells drilled throughout New York City range from 55-65 degrees Fahrenheit, which is already close to the design temperatures for space conditions. Coefficient of Performance ("COP") is a measure of the amount of energy transferred when compared to the amount of energy input. For example, if an electric baseboard is used to heat a home and it has a COP of 1, for every 1 kW of power transferred there is 1 kW of heat delivered. Or if an air conditioner is used to cool a home and has a COP of 3, 1 kW of power transferred results in 3 kW of heat removed. COP is dependent upon ambient temperature (see Box 3). In the heat pump systems, the COP improves as the temperature differential is minimized, indicating an increase in efficiency. GHPs in both heating and cooling mode are capable of delivering COP's greater than 3. Therefore, GHPs require less electrical energy to provide the same heating and cooling than conventional air and water based HVAC equipment.[7]

Box 3. The Benefit of Cooling with Constant Temperature Water

The Geothermal Exchange System that utilizes a heat pump for cooling can offer significant savings compared to air cooled refrigeration equipment. The geothermal heat pump in cooling mode is capable of delivering COP's greater than 3. The economic benefit is a function of the heat pump COP, cooling equipment efficiency, and the cost of electricity.

As the ambient temperature increases and the Condenser Water Temperature decreases, GHP cooling advantages versus air cooled systems are realized. The electrical demand (kW) per 1,000 tons of cooling in this example will be reduced significantly (200 kW – 500 kW) depending on ambient air and groundwater temperatures during warm weather.

Figure 5. Air cooled air conditioning versus water cooled air conditioning systems



GRCO Applications in New York City

The three primary types of GRCO's employed in New York City are open loop, closed loop and standing column wells. Depending on the site's geology and other subsurface conditions, the GRCO can be a series of wells or plastic pipes grouted in boreholes. Despite construction differences, all GRCOs use a circulating liquid, either ground water or an anti-freeze solution in closed piping, to transfer heat energy between the buildings and the ground.Closed loop systems circulate water with an antifreeze solution in a network of closed piping installed in the ground. Open loop systems use groundwater pumped from a supply well to transfer heat, and return the water back to the ground through diffusion wells. Standing column wells also use groundwater, but rely on smaller amounts within a very deep well to exchange heat with the surrounding bedrock. Figures 6, 7 and 8 demonstrate each GRCO system. The optimal type of GRCO for a given project depends on the geology and hydrogeology of the site and land availability (See Section 3 on geothermal feasibility).

It should be noted that there are technologies for new construction, where a GHP can be coordinated with the foundations of a building. This is especially suitable where land is not available for the quantity of geothermal wells required in a loop system or standing column wells (See Bo for a description of Geothermal Energy Piles). [11]

Figure 6. Closed Looped System[8]

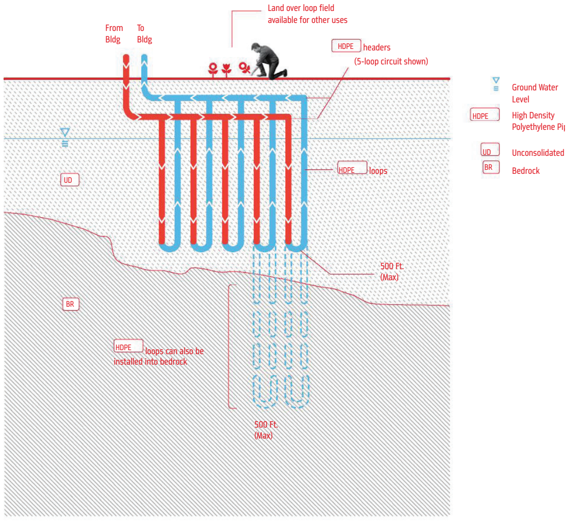


Figure 7. Open Loop System[9]

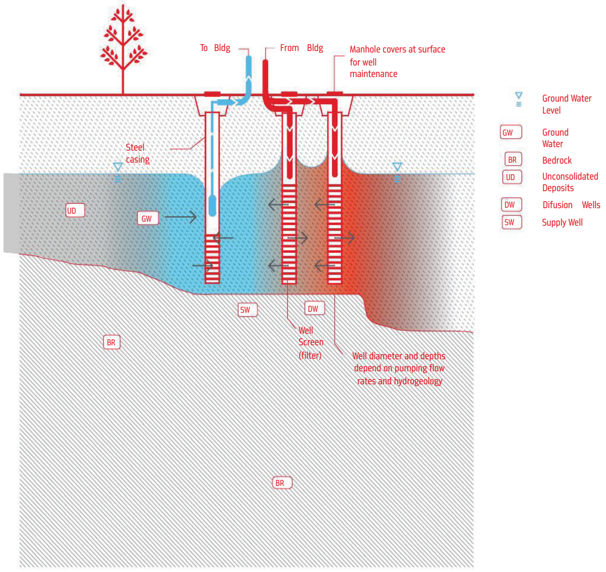
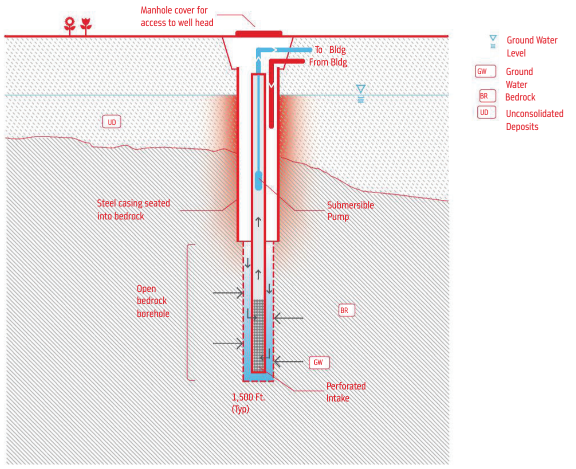


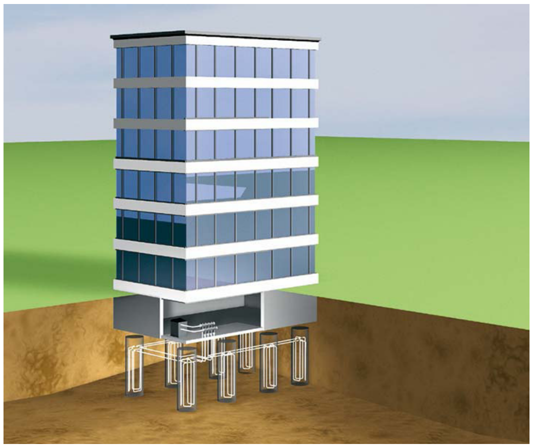
Figure 8. Standing Column Well System[10]



Box 4. Geothermal Energy Piles

Pile foundations are long, column elements in a foundation that are installed into the ground during a building's construction. A geothermal pile consists of pile foundations combined with closed-loop ground source heat pump systems. The geothermal pipe loops are laid vertically within the pile foundations. Geothermal piles are especially attractive in dense city centers with limited land availability. Geothermal Energy Piles cannot be integrated into existing buildings, but should be considered in new large scale construction.

Figure 9. Geothermal Piles[20]



2. Benefits of Geothermal

There are a number of factors to consider when choosing an energy solution for a given project. Prior to investing time and resources into a detailed engineering and economic analysis, a pre-feasibility study can identify the most viable options that warrant further exploration. Depending on the type of project, such as a building retrofit, a new build or district scale development, geothermal technology has the potential to provide a significant number of customer benefits. An accounting of the benefits, and the overall project costs, will help determine if geothermal is a viable component of a project's energy management solution.

2.1 General

GHPs provide the potential for integrated water heating. Most conventional HVAC systems rely on the use of separate mechanical equipment for heating and cooling, but a GHP can serve both functions. The units are designed and fabricated with fewer operating components that have an extended useful lifespan. GHP systems are also capable of providing independent climate control for many spaces by simultaneously providing heating and cooling to different zones.

In older cities like New York, GHP systems could be an option for historic buildings, which may have restrictions on rooftop unit placement because of preservation or zoning requirements. GHPs may also eliminate the noisy rooftop or pad-mounted exterior cooling equipment.

GHPs may require fewer annual inspections and operating permits from local authorities as compared to conventional HVAC systems, reducing building maintenance, staff time and operational costs. It has been found that buildings with GHP systems had average total maintenance costs ranging from 6 to 11 cents per square foot, or about one-third that of conventional HVAC systems.[12] Additionally, little maintenance is required for GHP systems because the primary parts of the system (i.e., piping) are located underground.

Durability is also another beneficial factor to consider. Since very little equipment is necessary for the operation of a GHP system, and such equipment is mostly protected from above-ground weather conditions, GHP systems are durable and highly reliable. The warranty for underground piping can range from 25 to 50 years, and GHP systems generally have a lifespan of approximately 20 years or more.[13]

When used for heating, GHPs also have the additional benefit of reducing emissions at the site by eliminating or reducing the size of fuel-fired boilers. Without cooling towers, there is a significant water reduction and cost savings as algaecides, or other microbiological control programs, are no longer needed. Moreover, because a geothermal system does not contain combustion flames, flues, or odors, operation of GHPs are considered safer and cleaner than other HVAC systems.

2.2 Greenhouse Gas Emissions Reductions

One of the most significant advantages of using GHPs are the sustainability benefits associated with this technology. Renewable energy sources, like solar, wind and geothermal, are considered to be carbon neutral, and therefore are preferred over the use of fossil fuels. Increased reliance on carbon neutral energy sources is a goal that the City of New York is committed to achieving. Through the Green Buildings Plan, Mayor de Blasio announced the City's plan to make more than 3,000 public buildings less carbon reliant, and simultaneously call upon the private sector to institute sweeping changes to reduce energy use and increase energy efficiency. The prudent use of GHPs will assist the City in reaching this target.

In a study performed by the United State Environmental Protection Agency ("EPA"), it was found that GHPs are the most energy efficient, environmentally clean, and cost-effective space-conditioning systems available, with the lowest carbon dioxide emissions.[14] The EPA has found that ground source heat pumps can reduce energy consumption, and corresponding emissions, by over 44% compared to air source heat pumps, and by over 72% compared to electric resistance heating with standard air-conditioning equipment.[15] To put this into perspective, for every 100,000 units of normally sized residential GHPs installed, more than 37.5 trillion Btu's of energy used for space conditioning and water heating can be saved, which is analogous to an emissions reduction of approximately 2.18 million metric tons of carbon equivalents, and customer savings of approximately $750 million over the 20-year-life of the equipment.[16]

2.3 Reduced Exposure to Price Risk

Wholesale natural gas and electricity prices are dependent upon a number of factors. The combination of tight supplies, high demand, and unpredictable factors, such as weather, results in widely varying price points for natural gas. Natural gas supply price volatility translates directly to increased electricity price volatility. For retail customers, the degree to which wholesale price volatility is reflected in electricity prices faced by retail customers is a fundamental factor influencing a customer's need for, or interest in, price hedging. In an open competitive wholesale electricity market like New York, retail customers are exposed to greater price volatility. The use of a geothermal energy system provides retail customers with a mechanism by which they can hedge against, and mitigate, the impacts of fossil fuel volatility. Limiting a customer's exposure to market volatility is a tremendous benefit associated with geothermal technology and can significantly reduce electric and gas price risks.

2.4 Increased Reliability of the Electric Grid

The use of GHPs has the potential to increase the reliability of the electric grid through peak load reduction and the implementation of utility demand response programs. Peak load reduction actions are taken to modify the level and pattern of electricity consumption of consumers during "peak hours" or periods of very high demand. Peak load reduction results in minimizing the operation of expensive peaking generation units, avoids transmission congestion costs and defers the building of new generation and transmission infrastructure. Demand response is the set of actions taken by consumers to reduce their consumption of electricity and/or increase their own production of electricity in response to economic signals or dispatch requests by the utility.

Presently there is potential for reduction of the electrical demand supplying geothermal retrofit air conditioning systems. The Consolidated Edison Summer Electric Peak load is approximately 14,000 MW. Consider that of the New York City building stock, 40% is Residential Multi-family, and 20% is Commercial Mixed Use space. Estimating, to an order of magnitude accuracy, it is possible that geothermal retrofits could reduce the summer electric peak reduction of these sectors by 1,000 MW and 350 MW, respectively. Accepting these estimates for the moment, geothermal retrofits could yield a summer peak load reduction of 10% (1,350 MW).

In the summer, incentives to reduce electricity use will reduce the first costs of a Geothermal System based on the demand reductions (kW). These savings will make installing a geothermal system more viable, shortening the economic payback period.

In the winter, a geothermal exchange system will reduce the natural gas peak load. The reduction will correlate, one to one, with the capacity of Geothermal Systems installed. The fuel switch, from gas to electricity, during the heating season has the potential to reshape both the electric and natural gas winter peak loads.[17]

3. Exploring Geothermal Applications in New York City

3.1 Geology

The thickness of continental crust in an area determines how readily deep-sourced heat flow can be used for power generation and direct use heating systems. In much of North America, the relatively thick continental crust inhibits the economic feasibility of exploiting these high-temperature resources because of drilling costs and inefficiencies associated with circulating fluids to extreme depths, as much as 10,000 feet or more. Here in New York City, however, there are a number of geographic areas that offer considerably more geothermal promise, and far more accessible drilling depths.

High temperature geothermal energy can be transferred from underground rocks and sediments, and the resulting heat flow can be harnessed by engineered systems to produce electricity, or alternatively to directly heat commercial buildings and homes. In areas of high geothermal energy density, such as the western United States, current technology allows for the generation of electrical power because of corresponding high temperatures. Generating electrical power from geothermal resources requires no fuel while providing true baseload energy at a high reliability rate, often in excess of 90%. In essence, geothermal energy is a carbon-free, renewable and sustainable form of energy that provides a continuous, uninterrupted supply of heat.

In order to extract geothermal energy, it is necessary to efficiently transfer heat from a geothermal reservoir to a power source, where electrical energy is converted from the heat, much as is done in conventional steam plants. The principal approach is to use stored thermal energy. As relatively shallow subterranean deposits tend to have very stable temperatures distributed within a narrow range as compared to widely variable surface air temperatures, a well-designed geothermal facility can operate to both warm surface facilities in the winter, and to cool them in the summer. In effect, the Earth acts as a thermal battery source.

In areas such as New York City, geothermal heat pumps can extract low temperature energy and transfer heat into buildings during winter months, and inject excess heat back into the ground during summer months, thus deriving a cooling effect. This dual capability offers a high capacity factor, permitting virtually year-round operations. And by exchanging heat with the Earth in this fashion, properly designed systems are typically more efficient than conventional heating and cooling systems. This temperature difference is exploited by ground source heat pumps that are used for heating and/or cooling of homes, commercial buildings, and other structures.

New York City's geology is quite complex, and varies across the five boroughs, presenting an interesting challenge for implementing GHP systems. Understanding how these systems interact with the ground is essential for proper design, and requires a brief overview of local geology and hydrogeology. Geologic formations identified in the City range from Precambrian bedrock that is some 1.2 billion years old to unconsolidated deposits that are less than 12,000 years old. In addition, the presence of ground water aquifers and their chemical characteristics fluctuate considerably, even between adjacent properties. Therefore, a given site's distinct hydrogeologic profile is a major factor in determining which systems are suitable and guide the ultimate selection.

UNITED STATES GEOLOGICAL SURVEY MAPS OF NEW YORK CITY

Appendix A includes GIS maps of the five boroughs developed by the United States Geological Survey (USGS) in conjunction with the NYC Department of Design and Construction (NYCDDC) to enhance the generalized maps provided in the NYCDDC publication--Geothermal Heat Pump Manual: A Design and Installation Guide for New York City, 2012. The GIS maps were constructed using data provided by numerous New York City agencies in addition to historical information from the NYCDDC and USGS archives. This mapping effort is unique considering numerous government agencies participated, providing crucial information which otherwise would not have been possible.

Because of security issues and the sensitivity to subsurface structures, names of the cooperating agencies have been omitted. Therefore, only the 'data point' and its associated 'value' have been listed on each map.

The current maps are the first phase of a continuing effort to update citywide geologic information providing extensive 'depth to bedrock' and 'overburden thickness' information for geothermal applications. Depth to bedrock can be used to determine the drilling conditions that may be encountered at a specific site, permanent or temporary casing that may be required to keep a borehole open, and to determine the selection of one system type over another. As an example, if a building owner decides to install a 'Standing Column Well' for geothermal heat pump applications, knowing the depth to bedrock is imperative in determining drilling costs and feasibility. 'Casing' a standing column well for bedrock that is greater than 200 ft. below the surface may be cost prohibitive, thereby requiring a re-evaluation of the system selection. In addition, selecting an Open Loop system requires one to locate the system in an area of New York City that has a very thick overburden or unconsolidated aquifer which would provide sustainable yields of ground water. Therefore, areas such as in northwestern Queens which has bedrock close to the surface, and thin to negligible overburden may not be a suitable place for this type of geothermal system. Final versions of the interactive map will be presented as separate GIS layers which will be available on both NYCDDC's and the USGS' website.

The bedrock elevation map is constructed using 'iso-contour' lines representing imaginary lines of equal bedrock elevation. Therefore, any data point found on a line, represents an equal value in bedrock elevation. A negative number would therefore represent bedrock which is below sea level at that point. Overburden thickness on the other map is represented by different colors. Each gradation of color in the 'Explanation' section of the map represents a specific range in overburden thickness at a particular location. Orange represents thinner overburden materials in an area, while blue tends to be thicker.

This information can be useful to a designer for geothermal selection and costing. Thicker aquifers (bluish colors) in general can represent larger, sustainable quantities of ground water, crucial for an open loop system. However, additional testing and analysis may also be required.

The second phase of DDC's upcoming mapping effort will be to update a water table map of the City to further delineate the overburden (unconsolidated) deposits providing detailed hydrogeologic information at each data point. Water level information is primarily critical for Open Loop and Standing Column well systems which use ground water as the heat transfer medium. However, it has less significance for Closed Loop designs. Detailed interactive, geologic information will also be available at specific data points which can also assist in evaluating one system over another.

GENERAL DESCRIPTION

Across most of its geographic area, the City is essentially characterized by a layer of unconsolidated glacial deposits overlying various types of crystalline bedrock. Wide variations exist in their origin, distribution, thickness, and hydraulic properties. Unconsolidated deposits are composed of sand, silt, clay, gravel, or mixtures thereof. They generally contain ground water and can readily yield large, sustainable amounts of ground water from properly constructed wells. In contrast, bedrock is a consolidated, crystalline material that typically provides low water yields unless highly fractured. Bedrock is present everywhere in the City; however, it varies widely in depth throughout the five boroughs. Notable areas where bedrock is found at the surface include Central Park in Manhattan, Astoria and Queens.

Bedrock surface elevations across New York City are shown in Figure 10. More detailed elevations for the five boroughs are also included in Appendix A. Bedrock is closest to the surface along the East River at a peak elevation of 4-15 feet above mean sea level and drops off steeply to -1,100 feet in the Rockaways, at an approximate slope of 80 feet per mile. As the bedrock depth increases, the overlying deposits thicken and form distinct hydrogeologic units.

In contrast, Manhattan and Bronx are characterized by bedrock at or close to the surface with thin layers of overlying deposits in most areas. The central and western areas of Staten Island show a similar distribution to that found in Manhattan and the Bronx, while the eastern and southern portions of the island are mostly unconsolidated deposits, similar to those found in Brooklyn and Queens.

Pleistocene materials were deposited during the last glacial period and generally contain large volumes of ground water. As glaciers advanced from the north, scouring and eroding the top of bedrock, they entrained sand, clay and rock fragments of various sizes into the ice mass. As the glaciers receded, the meltwater deposited this material at the surface, which presently makes up the upper Pleistocene. These surface deposits form the upper glacial aquifer and consist of glacial outwash and two types of glacial till: terminal and ground moraine.

The upper glacial aquifer is the thickest and most extensive formation in the City, providing as much as 1,500 gallons per minute (gpm) in yield. The U.S. Geological Survey ("USGS") reports that till generally has a lower hydraulic conductivity than the outwash, although hydraulic testing for some geothermal systems in Brooklyn has shown these deposits to be very productive.

The Gardiners Clay and Jameco aquifers are the two deep-lying Pleistocene deposits, with the Jameco being both deeper and older. Wells tapping this aquifer have yielded up to 1,600 gpm, and depending on the ground water quality, may be suitable for an open loop system that draws in groundwater. The overlying Gardiners Clay protects the underlying Jameco aquifer from surficial man-made pollutants, but also creates confined ground water conditions. Wells installed in this aquifer have a wider area of hydraulic influence, and accordingly must be spaced farther apart to avoid well interference.

Cretaceous deposits are the deepest and oldest, directly overlying the bedrock surface, and are present in Brooklyn, Queens and Staten Island. Two aquifers in Brooklyn and Queens, the Magothy and the Lloyd, have been used extensively as a source of ground water supply.

The Magothy aquifer can yield as much as 1,600 gpm, and reach a maximum thickness of 200 feet in southern Brooklyn, and 500 feet in southeastern Queens, according to the USGS. This aquifer can generally yield sufficient ground water for most open loop systems.

The Lloyd aquifer is the deepest in Brooklyn, Queens and eastern Long Island, and is characterized by the oldest and most pristine ground water. In the City, it underlies southeastern Brooklyn and central and southeastern Queens. However, the New York State Department of Environmental Conservation ("DEC") regulations prohibit drilling into the aquifer unless permitted for municipal ground water supply.

CONSOLIDATED BEDROCK

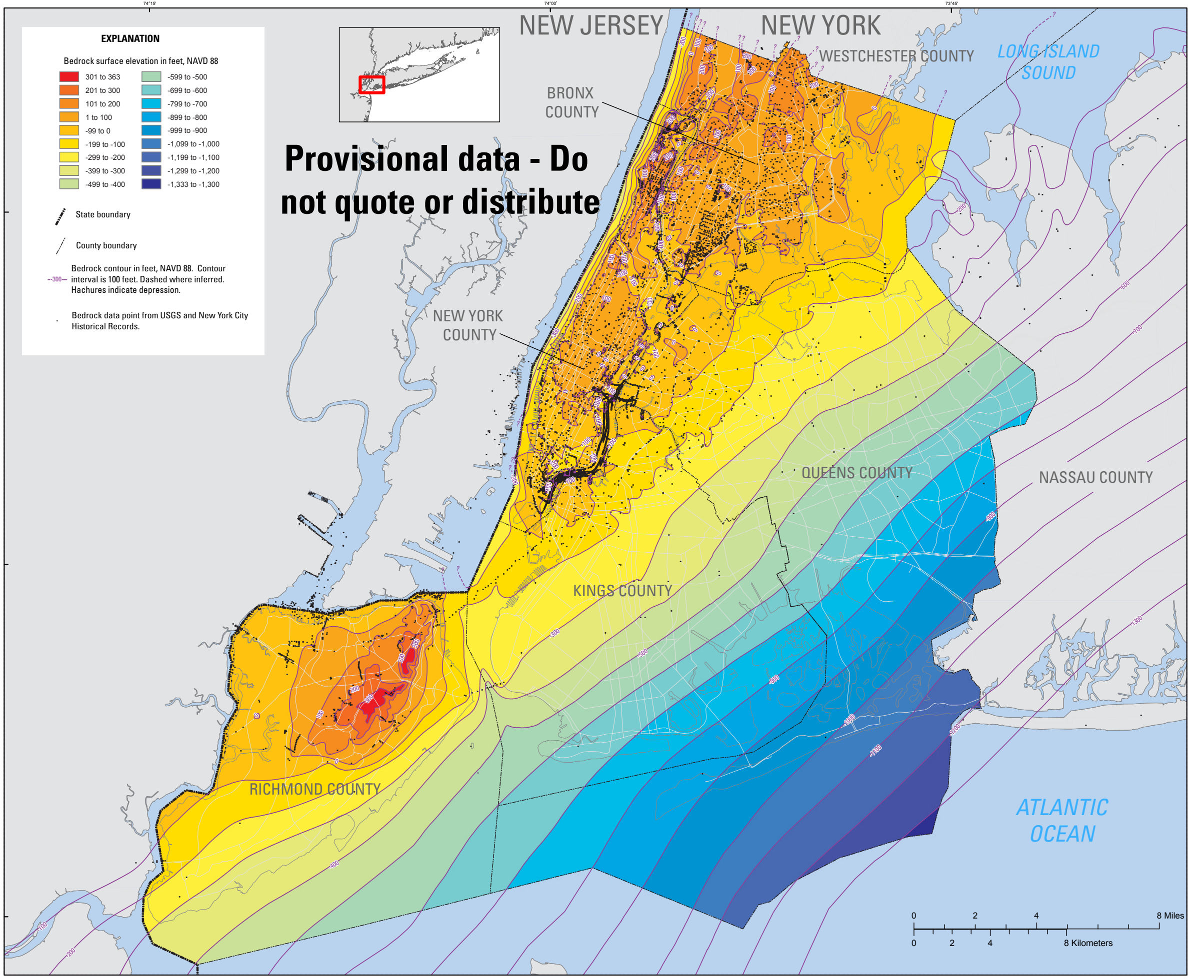
Bedrock in the City is represented by several geologic formations. Reports and maps published by the USGS are significant sources of information for bedrock in the area. USGS engineering geology maps, which are based on numerous tunneling projects, are also available for Manhattan and Bronx. Appendix A illustrates approximate depth to bedrock, and the general distribution of geologic formations.

Figure 10 Bedrock Surface Elevation of the Five Boroughs of New '

Prepared in cooperat
NEW YORK CITY DEPARTMENT OF DESIGN AND CONSTRUCTION

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

SCIENTIFIC INVESTIGATIONS MAP XXXX
Bedrock Surface Elevation of Five Boroughs—SHEET 1 of 7
Stumm, Frederick, Noll, Michael, Como, Michael, Chu, Anthony, and Finkelstein, Jason, 2015,
Bedrock Surface Elevation of the Five Boroughs of New York City, New York



Base digital data NOAA's Medium Resolution 1:70,000 scale Digital Vector Shoreline
Lambert Conformal Conic Projection
North American Datum of 1983

For additional information write to:
Director, U.S. Geological Survey, 2045 Route 112, Coram, NY 11727

Copies of this report are available on-line at http://ny.water.usgs.gov

Bedrock Surface Elevation of the Five Boroughs of New York City, New York
By
Frederick Stumm, Michael Noll, Michael Como, Anthony Chu, and Jason Finkelstein
2015

These formations are the result of geologic processes that include sedimentation and metamorphism of upto a billion years. Each rock type is physically distinct, and represents its own unique set of drilling conditions and requirements. For example, Manhattan Schist will require longer drilling times and may wear down standard drilling bits sooner because of its relative hardness, while Inwood Marble is softer and will require less time on average.

It should be noted that bedrock is not always homogeneous, and may be solid, fractured, extensively weathered or a combination thereof. Deeper formations tend to be less fractured because of overlying pressures and consolidation of materials. In contrast, shallow bedrock within 100 feet of the surface is generally more fractured. Also, fractures and faults may occur at boundaries between different geologic formations. The upper surface of bedrock in contact with overlying unconsolidated deposits is typically weathered and decomposed.

Unlike unconsolidated deposits, bedrock is generally not permeable. However, ground water can collect in fractures and faults to create a bedrock aquifer. The size and degree of interconnection between the fractures will determine the relative permeability and sustainable yield. While major faults have been mapped, faults and fractures at a specific location can only be verified through drilling and seismic surveys. Typically, bedrock wells do not have great sustainable yields, although there can be rare exceptions.

GROUND WATER OCCURRENCE

Ground water originates from precipitation, which infiltrates and recharges the ground, moving through soil, unconsolidated deposits and bedrock aquifers via capillary action and gravity. In New York City, leaking water mains and sewers can also be a significant source for ground water recharge. The surface of ground water at atmospheric pressure is known as the water table, and separates the unsaturated deposits from water-bearing aquifers. Ground water continues to move naturally from higher to lower elevations, and overtime, may discharge to surface water in the form of streams, rivers, lakes or the ocean.

Because ground water is principally held in the pore spaces of unconsolidated deposits, aquifers with the most abundant yield are usually found in Brooklyn and Queens. Areas with bedrock close to the surface, such as Manhattan and Bronx, typically provide minimal ground water yield. Exceptions occur where bedrock wells intercept a large network of fractures and are able to provide sufficient ground water. However, bedrock fractures can be difficult to locate and determining yield requires drilling or other diagnostic instruments.

Ground water presence can be an important factor in determining the suitability of a GHP system. Open loop systems will only be applicable for sites with sustainable yield of ground water. Other systems can also benefit from the additional thermal capacity gained from surrounding ground water. Because ground water continues to move, the direction of flow should also be investigated and incorporated into any design. Other ground water issues, such as quality, will also affect system design and maintenance procedures.

CRITERIA AND SYSTEMS FOR HEAT PUMPS

Various geological factors have to be considered when selecting and designing any ground source heat pump system. As discussed in Section 1, GHPs are broadly grouped into three principal types: open-loop, closed-loop systems and standing column wells.

Open-loop systems, for example, exchange heat with subsurface water (groundwater) and require the presence of water-bearing formations (aquifers) within a suitable distance from the surface. In general, however, open-loop systems are of limited application in most areas of the City other than portions of Brooklyn, Queens and Staten Island where aquifers are accessible. However, there are limited areas of Manhattan, Bronx and Staten Island with intersecting bedrock fractures that allow open well systems. (GHPM2002)[19]

Closed-loop systems, as the name implies, are not directly exposed to groundwater. Rather, they rely on a continuous enclosed loop of circulating water (or solution), and rely on conductivity to extract the heat from the ground via heat exchangers (vertical systems) or in shallow horizontal trenches (horizontal systems). Typical closed loop spacing is

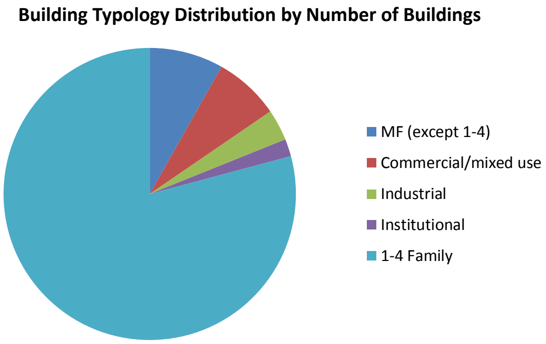
15-20 feet and are up to 500 ft in depth. In the areas of NYC (Brooklyn, Queens, parts of Staten Island and limited areas of Manhattan and the Bronx) that allow the installation of vertical closed loops, the typical closed loop bore will provide 2 tons of heat transfer.

The standing column well can be implemented in most of Manhattan, the Bronx, northern Queens and western Staten Island where bedrock is reasonably close to the surface.

3.2 Load Profile

New York City has a diverse buildings stock encompassing approximately 1 million structures of almost every imaginable type and combination of uses. These buildings include New York City's homes, workplaces, hospitals, museums, historic landmarks, community centers, and places of worship. The distribution of New York City Buildings is shown below and is classified by 1-4 Family Residential (low rise), Multi-family Residential (high rise), Commercial/Mixed Use and Industrial and Institutional.

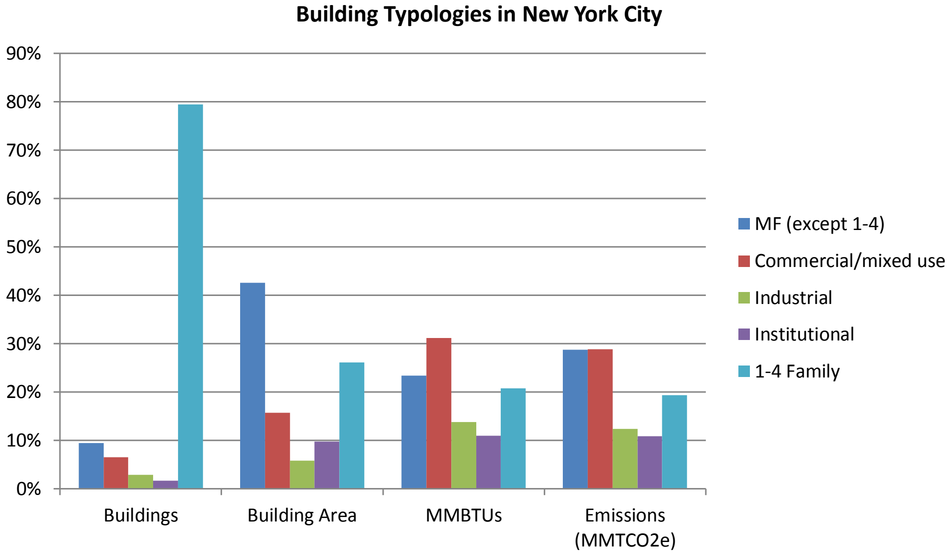
Figures 11 and 12: Building Typology Distribution



New York City is well known for its high density buildings, i.e., high rises with a large total square footage for a given building footprint. In fact, the City's square footage is highly concentrated in less than two percent of its properties; two percent translates into 15,000 properties over 50,000 square feet, which account for almost half of New York City's square footage, and as much as 48% of New York City's total energy use.[20]

As you can see from Figures 11 and 12,[21] the majority of City lots are occupied by 1 to 4 family buildings. However, in terms of total square footage, we see that higher density multifamily residential accounts for the most significant proportion of overall square footage. Moreover, the multifamily residential and commercial/mixed use buildings are the largest overall contributors to GHG emissions.

The load profile of a building, or set of buildings in the case of a district, plays a significant role in determining the potential efficiency and design of a geothermal system. To effectively meet the heating and cooling needs of a given project, the geothermal system must supply the necessary number of geothermal wells that can meet heating and cooling requirements. In general, as load increases, the number of wells needed increases. There is, therefore, a direct relationship between the size of load demand and the land area available to supply that building's load.



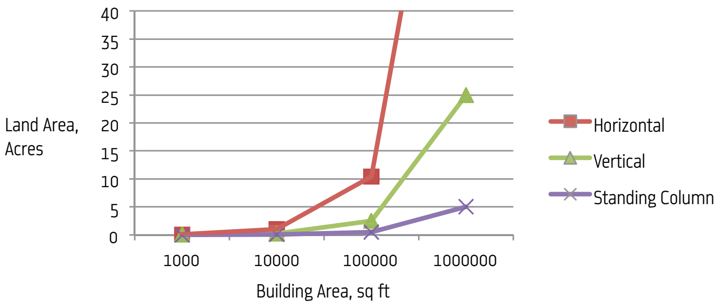
3.3 Land Availability

The Geothermal Exchange System applications sited in New York City utilize heat exchange piping deployed horizontally and vertically in three basic configurations. The horizontal configuration consists of shallow trenches encapsulating the heat exchange piping. The vertical configurations consist of bored wells encapsulating the heat exchange piping. The standing vertical open well consists of a deep well that directly pumps groundwater to the heat exchange equipment. As noted in Section 2, Geothermal Piles can also supply the heating and cooling needs of a building. However, this can only be integrated into new construction and is not a retrofit solution.

The heating and cooling capacity of geothermal wells is determined by the thermal characteristics of the soil and geohydrology as it relates to the specific type of heat exchange piping arrangement. The choice of heat exchange piping arrangement, horizontal or vertical, is dependent on the characteristics of the site.

Each GRCO type requires adequate spacing of wells or boreholes to maintain thermal and hydraulic gradients and properties. If sufficient distance is not provided, interference between wells or loops will occur during operation and may cause additional problems. Land availability therefore plays a key role in determining if geothermal systems are feasible, and what type of system is most suitable for a given site. In many areas of the high density Borough of Manhattan, land availability will be a hurdle to geothermal well advancement. However, in the lower density outer boroughs, fewer wells and more land may make a geothermal viable option to meet a project's overall load requirements. As shown in Figure 13, horizontal heat exchange loops are appropriate for sites that have ample open space available. The vertical well systems and standing column wells are more appropriate for sites that have limited amount of area.[22]

Figure 13. Land Area Requirements by Geothermal Exchange System Well Configuration



Horizontal closed loop systems rely upon a spiral of piping at the bottom of a trench or open excavation backfilled to a depth up to 8 feet. Trench systems require 300 feet of two-foot-wide trench for two tons of load with four foot spacing between trenches, yielding approximately 24 tons of load capacity per acre. An alternative horizontal design requires an open excavation with a piping coil "slinky" that yields approximately 90 tons of load capacity per acre. Figure 13 demonstrates that the horizontal loop application requires the greatest area of the three exchanger configurations. The best opportunity is one where the building site offers open areas for the trenches.

Vertical Closed Loop systems rely upon bore holes that are typically 150 ft. to 450 ft. deep. Systems require between 150 ft. to 200 ft. of borehole depth per ton of load. At 20 ft. bore spacing, a shallow field of 150 ft. bores requires approximately 1 acre per 100 tons of load capacity. The best opportunity for the vertical closed loop application is one where the building site offers accessible locations for the well heads. The vertical loop application requires 25% of the area required by the horizontal exchanger configuration.

The Standing Column Well system relies upon wells approximately 1,500 feet deep and spaced about 75 feet apart. The water is pumped from the bottom of the well and re-injected at the top. As water moves along the length of the well, it exchanges heat with the surrounding earth and often circulates with ground water. A 1,500 foot deep Standing Column Well will supply approximately 40 tons of load capacity. This type of system is well suited to urban projects with limited space. At 75 feet bore spacing, a well field bores array requires approximately 1 acre per 500 tons of load capacity. The best opportunity for the standing column well application is one where the building site offers accessible locations for the well heads. The vertical loop application requires 20% of the vertical exchanger configuration.

As shown in Figure 14, well costs differ depending on the system that is selected. This figure shows the approximate land area required to support a 100,000 square foot building with a geothermal system. The approximate cost per ton of cooling delivered is also shown. Figure 14 illustrates that the installation cost of a standing column well is the highest of all three systems on a per well basis, but is the lowest cost for total cooling delivered.

Figure 14. Well Cost Per Ton of Heat Exchange

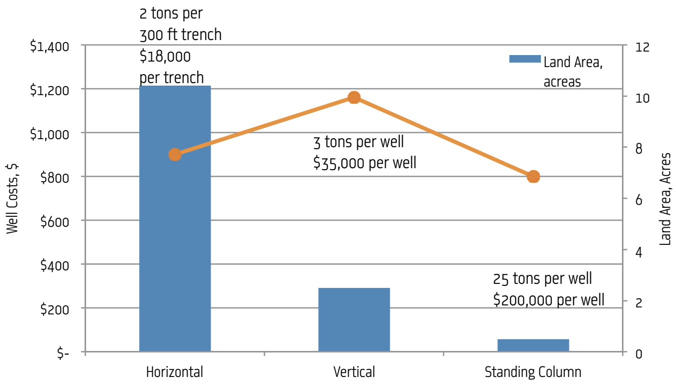
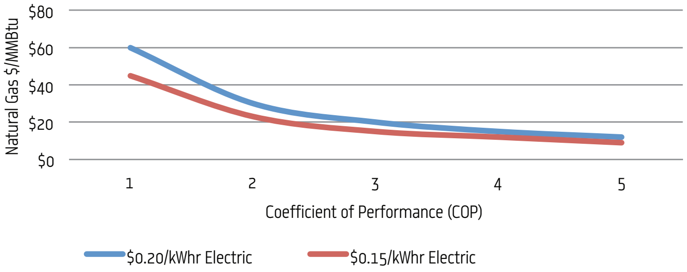


Figure 15: Natural Gas “Break Even” Costs



3.4 Fuel Costs

The HVAC System that utilizes a heat pump for heating can offer a competitive alternative to natural gas fueled heating equipment - the heat pump in heating mode is capable of delivering heat at a COP greater than 3. As discussed earlier, this means that the energy output is three times greater than the energy input. This can result in significant fuel savings. A GHP uses electricity as its input, replacing the use of natural gas as the heating fuel.

Figure 15 shows the relationship between the cost of natural gas per MMBTU and the “break even” cost when compared to the cost of electricity at $0.20/ kWh and $0.15/ kWh. The” break even” cost refers to the minimum cost at which natural gas must be for a given cost of electricity so that a geothermal exchange heat pump system, of a specific COP, becomes cost competitive.

For comparative purposes, currently, natural gas and electric unit costs are typically between $10 to $20 per MMBtu, and $0.15 to $0.20 per kWh, respectively.[23] A one MMBtu natural gas heating load is equivalent to approximately 300 kWh of electric heating load. Given the current price of natural gas, coupled with an electricity price of $0.15 per kWh, a COP between 2 and 4 is needed to “break even”. Applying an electricity cost of $0.20 per kWh, a COP between 3 and 5 is needed.

Accordingly, the business case for a geothermal system is dependent upon fuel costs. Given the approximate costs provided in Figure 15, because a geothermal heat pump can achieve a COP of 3, it does have the potential to be a cost competitive alternative to a natural gas powered heating system. A full life cycle analysis which considers changing fuel and electricity prices with time is needed to more accurately determine geothermal viability (see Section 4).

3.5 Underground Infrastructure

New York City's infrastructure is one of the oldest in the country. As such, restrictions and regulations related to drilling should be investigated and confirmed early in the development stages for GHP systems. Structures for the City's water supply, such as water tunnels, shafts, or appurtenant facilities are regulated by the New York City Department of Environmental Protection ("NYCDEP"). Project teams should contact NYCDEP to verify if a site is within 500 feet or less of a water supply facility or structure. Approval for drilling is required and requirements on controls and documentation during drilling will vary.

Regulations also exist for transportation tunnels such as subways. The relevant agency, such as the Metropolitan Transit Authority, should be contacted to confirm any requirements. Local utilities must also be notified of any drilling activities.

4. The Geothermal Business Case

4.1 Preliminary Cost Estimate

There are a number of potential benefits to using geothermal as part of a project's energy management approach, as discussed in in prior Sections. Economic viability is assessed through a cost benefit analysis which compares different energy management approaches to the BAU scenario. The BAU is defined as the most common way of doing business, or in this case, the most common way to provide heating and cooling to a given building.

A business case analysis is one that diligently examines many aspects of a decision to demonstrate a project's value in the strongest manner. The costs accounted for in the Report's business case analysis include capital costs and operation and maintenance lifecycle costs. The operation costs also include the cost of fuel through the lifetime of the project. As a geothermal system will require less fuel throughout its lifetime as compared to the BAU scenario, there will be fuel cost savings over time.

The purpose of this Section is to show the typical economic factors that are considered when a developer is analyzing if geothermal is a worthwhile investment for their project. This Report analyzes the economic feasibility for geothermal for two building typologies: (1) a multi-family residential building (approximately 100,000 square feet); and (2) a commercial building (approximately 100,000 square feet) which, as noted earlier, are large contributors to GHG emissions. As well, based on the geology characteristics of New York City across the five boroughs, Brooklyn, Queens or Staten Island are most conducive to geothermal retrofits. Both the 100,000 sqft residential and 100,000 sqft commercial building reflect a common building density found in these boroughs and a load profile that could be supported by an acceptable number of wells for a typical lot size.

The business case assessment was made using a building simulation model within Trane Tracer 700 Software. The simulation assumes building construction details and building orientation typical to New York City. Local hourly weather data was taken at the John F. Kennedy (JFK) airport weather station.

4.2 Business Case Example #1:

COMMERCIAL OFFICE BUILDING (100,000 SQ. FT.)

Within this analysis the preliminary costs for retrofitting a 102,400 square foot commercial office building with a geothermal system was assessed. The costs were compared to a BAU scenario. The two alternatives are as follows:

BAU Alternative: Office Building Direct Expansion-Air Cooled Condenser/Natural Gas Furnace Rooftop Package HVAC Units

Geothermal Alternative: Office Building with Geothermal Water Source Heat Pumps and Standing Column Wells

Table 2 sets forth the equipment used to analyze each Alternative:

Table 2. System Characteristics Used for Business Case Example #1

BAU Alternative: Packaged VAV Rooftop Units	Geothermal Alternative: Geothermal Water Source Heat Pumps
· Direct Expansion Cooling Technology delivering 193.2 Tons of Cooling at Design Conditions	· Total rated capacity 218.5 Tons of Cooling and 1,225 MBH Heating Plant at Design Conditions
· Four (4) Air Handlers with Variable Frequency Drive Fan Motors and Make-up Air Filtration	· Individual water source electric heat pumps (70) serving individually controlled zones
· Gas Fired Heat Exchangers delivering 950.8 MMBTU of Heating at Design conditions	· Fresh Air Filtration System
· Morning warmup utilizes gas heating	· Geothermal Exchange System: Standing Column Vertical wells operating with a 10 °F temperature difference
· Economizer controls for free cooling during the winter months	· Standing Column Well capacity: 25 Tons per Well
· Air flow distribution: Ductwork with thermostat controlled Variable Air Volume Terminal Units with Electric Re-Heat	· Geothermal Loop Pump Energy included.
· Supplemental Heating: Perimeter Electric Resistance Baseboard delivering 649.2 MMBTU of Heating at Design conditions	· Back-up Heat Source: Electric Hot Water Boiler (Not included in energy consumption)

4.2.1 Energy Savings Analysis – Business Case Example #1

Energy consumption for the two alternatives is shown in Figure 16. The consumption is broken into natural gas used for heating equipment for the Packaged VAV rooftop units, electricity used for HVAC equipment, and electricity used for lights and other equipment needs. We see that the monthly energy usage is greater under the BAU Alternative.

Figure 16 Geothermal Water Source Heat Pumps and Packaged VAV Rooftop Units – Monthly Energy Use Comparison

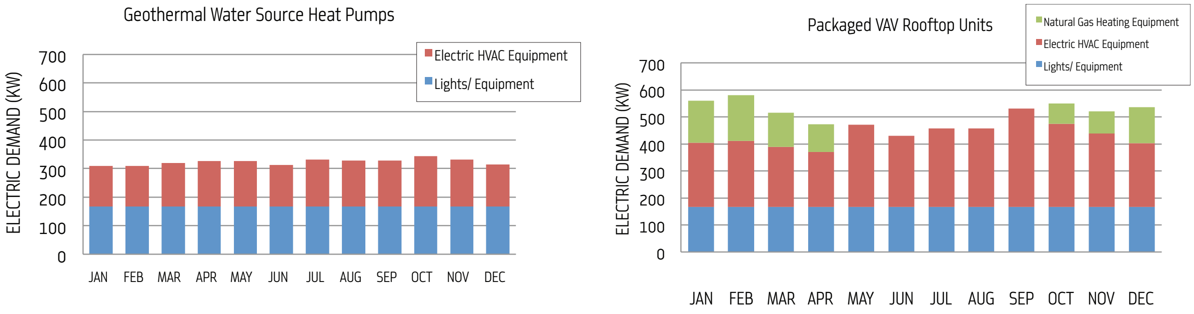


Figure 17 demonstrates that the Geothermal Alternative offers a significant reduction in both monthly total energy and peak electricity demand from reduction in electricity use for HVAC systems.

Figure 17 Monthly Energy Use and Peak Demand Comparison

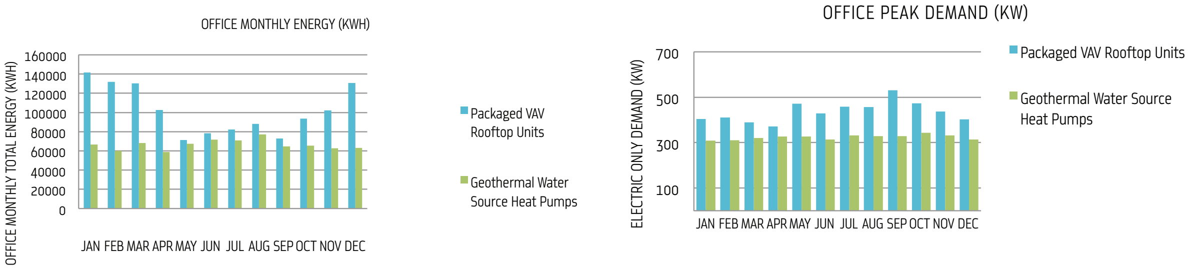


Table 3 summarizes the substantial, annual reductions in energy consumption, peak demand, and GHG emissions associated with the Geothermal Alternative.

	Packaged VAV Rooftop Units	Geothermal Water Source Heat Pumps	
Annual Electrical Energy Consumption, kWh	814,942	797,101	2% Reduction in Consumption
Peak Electrical Power Summer Demand, kW	530	332	37% Reduction
Peak Electrical Power Summer Demand , kW (without Electric Heat -Packaged VAV scenario only)	426	332	22% Reduction in Demand (With Electric Heat Included)
Annual Natural Gas Consumption, Therms	14, 025	NA	100% Reduction (Geothermal does not use natural gas)
Annual Energy Consumption (Electric and Natural Gas), GJ	4,415	2,870	35% less energy consumed
Annual Greenhouse Emissions, kg CO2e	324.2	244.2	25% reduction

As described in Table 3, the Geothermal System will result in significant energy savings. This can be quantified throughout the lifetime of the project in a life cycle analysis.

A significant factor which drives the overall cost-effectiveness of an energy efficiency project is the discount rate assumed to calculate the net present value ("NPV") of annual costs and benefits. Since costs typically occur upfront and savings occur over time, the lower the discount rate the more likely the cost effectiveness result is to be positive. For a household, the consumer lending rate is used since this is the debt cost that a private individual would pay to finance an energy efficiency investment. For a business firm, the discount rate is the firm's weighted average cost of capital, typically in the 10 to 12 percent range. When commercial and industrial partners demand payback periods in two years or less, this implies a discount rate in excess of 20%. The social discount rate refers to the benefits to society over the long term. This is typically the lowest discount rate.

As per guidance from the EPA in the document National Action Plan for Energy Efficiency, this Report uses the recommended social discount rate of 5%.[24]

As used herein, levelized cost is a constant value or payment that, if applied in each year of the analysis, would result in a net present value equivalent to the actual values or payments which change each year.

Using an annual escalation of 2% for electricity costs with time and a discount rate of 5%, this Report tests a determined range of levelized electricity costs as high, medium and low for $0.25, $0.20 and $0.15 respectively. The resulting levelized costs are $0.30/kWh, $0.24/kWh and $0.18/kWh. We applied the same escalation and discount rate to the natural gas costs. The assumed high, medium and low costs of $0.85/therm, $0.9775/therm and $1.1241/therm resulted in the levelized costs of $1.01/therm, $1.16/therm and $1.33/therm respectively.

Using these levelized electricity costs, the Geothermal Exchange System results in considerable cost savings over the BAU option. Figure 18 shows the impact of an increasing electricity cost ranging from $0.18/kWh to $0.30/kWh. This shows a savings from electricity over the BAU range from $3,172 to $5,287 annually.

With regard to natural gas, the Geothermal System does not use natural gas. Any natural gas accounted for in the BAU is an avoided cost for the Geothermal System. As the natural gas cost increases for the BAU scenario, the savings for the business case increases. By varying the levelized natural gas cost from $1.01 to $1.33, this resulted in an avoided cost ranging from $14,132 to $18,690 per year. It is important to note that these annual costs are nominal and do not account for the volatility of fuel costs over time. As discussed in Section 2 supra, one major benefit of geothermal systems and renewable energy sources is the ability to hedge against fuel cost volatility.

Figure 18. Annual Levelized Electricity Costs- Low, Medium and High

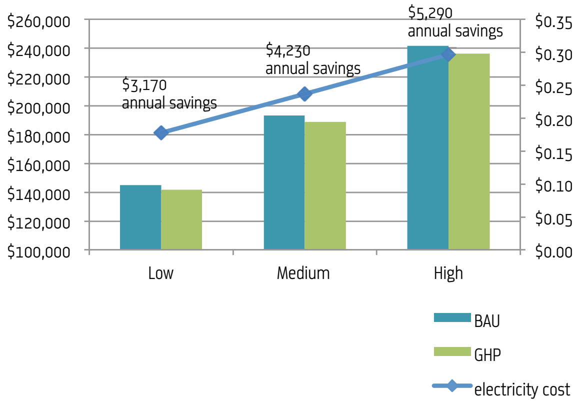
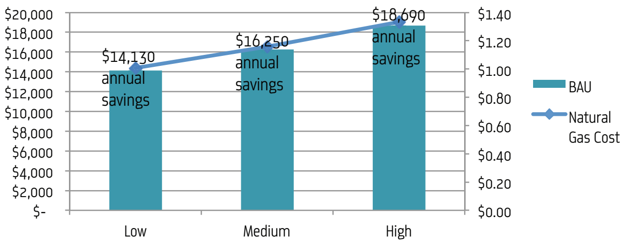


Figure 19. Annual Levelized Natural Gas Costs – Low, Medium, and High



Figures 18 and 19 illustrate that as both the levelized cost of natural gas and the levelized cost of electricity increase, the overall energy savings increases when using geothermal technology over the BAU Alternative.

4.2.2 Capital Cost Analysis for Business Case Example #1

We see that the Geothermal Alternative for the modeled office building offers substantial benefits in terms of efficiency gains. We now look at a comparison of the costs. The costs accounted for in this simple business case analysis include capital expenditures and operation and maintenance lifecycle costs. The table below is a summary of system costs.[25] As noted in Appendix B, for retrofits, the total costs will depend upon existing building characteristics.

Table 4. Capital Costs

	Packaged VAV Rooftop Units		Geothermal Water Source Heat Pump	
System Equipment Technology	Four 60 ton packaged units with gas fired heat exchanger	$600,000	70 3.5 ton water source heat pumps	$1,050,000
	(70) 2000 CFM VAV Terminal boxes with ductwork connections	$450,000	10 standing column vertical wells	$2,000,000
	750 W Perimeter Electric Heat with Electrical Connections	$70,000	1 300 kw back-up electric water boiler	$35,000
Retrofit Installation Requirements	Building with existing air distribution ductwork requires minimum modification	$0	Building with existing air distribution ductwork must be modified with extensive water distribution piping	No Allowance
New Construction Requirements	Complete Air Distribution Ductwork system	No Allowance	Complete Water Distribution Piping system	No Allowance
		$1,120,000		$3,085,000

4.2.3 Life Cycle Analysis for Business Case Example #1

A life cycle analysis evaluates and accounts for the costs over the lifetime of the project including capital costs and Operation and Maintenance costs. The fuel savings alone over the lifetime of the project may be great enough to recover the initial project costs. To compare projects with different lifetimes, the Equivalent Uniform Annual Cost ("EUAC") can be used. The EUAC is the annual cost of owning and operating an asset over its entire lifespan.

The EUAC allows for the use of differing study periods by expressing costs as an annualized estimate of cash flow instead of a lump-sum estimate of percent value. EUAC = (A/P, I,n) where A/P = annualized cash flow or payment ($/sq.ft.), i=annual interest rate(%), and n=service life(years).

The following elements were assumed within the EUAC analysis:

- operation and maintenance costs are 3% of equipment costs
- operation and maintenance costs increase at 2% per year over the lifetime of the project
- electricity and gas costs are assumed to be midrange, increasing at 2% per year
- real discount rate of 5%
- BAU scenario has a project life of 20 years
- Geothermal Alternative has a project life of 25 years

The results from the EUAC analysis for each system based on the assumptions above are $371,360 for the BAU case and $482,620 for the geothermal system. The EUAC analysis shows that there is a cost hurdle to overcome in order to make the business case. However, this analysis does not consider other tangible benefits derived from the Geothermal Alternative such as peak load reduction to the grid (avoided costs of utility infrastructure investment), GHG emission reductions and reduced exposure to market energy price fluctuations. It also does not consider existing cost incentives for implementing geothermal technology.

The potential to achieve even greater cost savings exists through the use of various state and federal incentives. Federal incentives for installation of a Geothermal System exist in the form of a tax credit. For residential geothermal systems, taxpayers are granted a personal tax credit of 30% of the total expenses of project costs and installation.[26] There is no cap on this credit. New York State provides several property tax incentives for geothermal improvements: (1) qualifying energy-conservation improvements to homes, such as GHPs, are exempt from real property taxation to the extent that the addition would increase the value of the home;[27] and (2) New York enacted legislation allowing municipal corporations to exempt green buildings from real property taxes – the new construction or improvement must commence on or after January 1, 201, be valued in excess of $10,000, and meet the LEED, Green Globes, American National Standards Institute, or equivalent green building certification standards.[28] Furthermore, the New York State Energy Research and Development Authority ("NYSERDA") periodically releases incentives for renewable resources. The particular incentives that are available for geothermal at any given time can change. However, NYSERDA incentives can offer a project develop additional relief for initial costs.

4.3 Business Case Example #2: Residential Office Building (100,000 sq. ft.)

Within this analysis, the preliminary costs for retrofitting a 100,000 square foot residential building with a geothermal system was assessed. The costs were compared to a BAU scenario. The two alternatives are as follows:

BAU Alternative: Apartment Building Direct Expansion-Air Cooled Condenser/Natural Gas Furnace Central Cooling and Heating Plant serving individual split systems in each apartment.

Geothermal Alternative: Apartment Building with Geothermal Water Source Heat Pumps

Table 6. System Characteristics Used for Business Case Example #2

BAU Alternative: Packaged VAV Rooftop Units	Geothermal Alternative: Geothermal Water Source Heat Pumps
· Direct Expansion Cooling Technology (DX) delivering 157.5 Tons of Cooling at Design conditions	· Total rated capacity (156.9 Tons of Cooling and 1,166 MBH Heating Plant) consisting of 68 individual water source electric heat pumps
· Sixty Eight (68) Split System (DX) with Constant Volume Drive Fan Motors and Make-up Air Filtration	· One thermostat per heat pump zone
· Gas Fired Heat Exchangers delivering 1157 MMBTU of Heating at Design conditions	· Fresh Air Filtration System
· Morning warmup utilizes gas heating	· Geothermal Exchange System
· Economizer controls for free cooling during the winter months	· Vertical Column wells operating with a 10 °F temperature difference
· Air Flow Distribution: System type is a single zone system with a heating and cooling coil.	· Geothermal Loop Pump Energy included.
· Supplemental Heating: None	· Back-up Heat Source: Electric Hot Water Boiler (Not included in energy consumption)

4.3.1 Energy Savings Analysis for Business Case Example #2

Energy consumption for the two alternatives is shown in Figure 20. The consumption is broken into natural gas used for heating equipment for the split systems, electricity used for HVAC equipment, and electricity used for lights and other equipment needs. Figure 20 shows that the monthly energy usage is greater under the BAU Alternative.

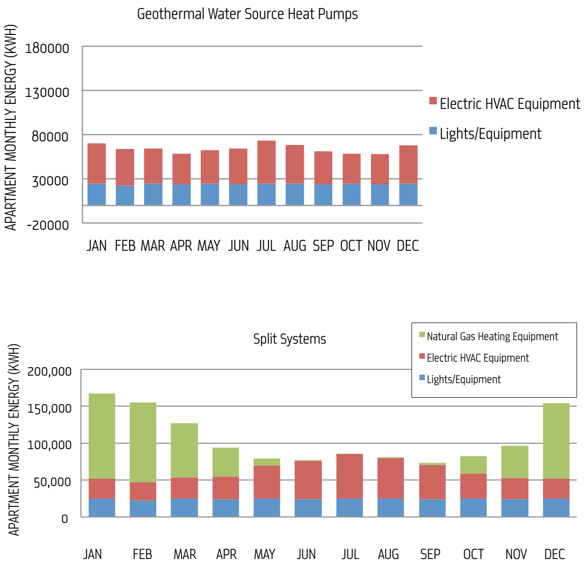


Figure 20 Annual Monthly Energy Comparison of Geothermal Water Source Heat Pumps to Split Systems

Figure 21 illustrates that the Geothermal Alternative offers a significant reduction in monthly total energy. In contrast, the split system efficiency is comparable to geothermal when looking at electric peak demand.

Figure 21: Monthly Energy Use and Peak Demand Comparison

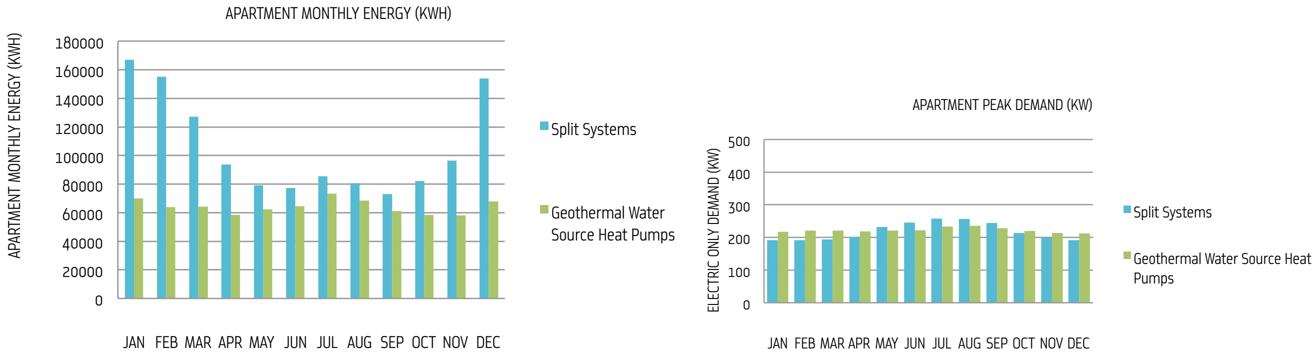


Table 7 summarizes the substantial, annual reductions in energy consumption, peak demand, and GHG emissions associated with the Geothermal Alternative.

Table 7. Summary Comparison

	Split Systems	Geothermal Water Source Heat Pumps	
Annual Electrical Energy Consumption, kWh	750,743	771,487	3% Increase in Consumption
Peak Electrical Power Summer Demand, kW	257.7	236	8% Reduction in Demand (With Electric Heat Included)
Annual Natural Gas Consumption, Therms	17,771	NA	100% Reduction (Geothermal does not use natural gas)
Annual Energy Consumption (Electric and Natural Gas),	4579	2777	39% less energy consumed
Annual Greenhouse Emissions, kg CO2e	324.5	236.3	27% reduction

The Geothermal Alternative results in overall fuel cost savings over the BAU Alternative.

Using an annual escalation of 2% for electricity costs and a discount rate of 5%, the analysis tested a determined range of levelized electricity costs as high, medium and low for $0.25, $0.20 and $0.15 respectively. The resulting levelized costs were $0.30/kWh, $0.24/kWh and $0.18/kWh. The same escalation and discount rate was then applied to the natural gas costs. The assumed high, medium and low costs of $0.85/therm, $0.9775/therm and $1.1241/therm resulted in the levelized costs of $1.01/therm, $1.16/therm and $1.33/therm, respectively.

Using these levelized electricity costs, the Geothermal Alternative resulted in increased costs as compared to the BAU Alternative. Figure 22 shows the impact of increasing the levelized electricity cost from $0.18 to $0.30. The analysis shows added costs over the BAU Alternative range from $3,690 to $6,150 annually. In terms of natural gas, the Geothermal Alternative does not use natural gas. Any natural gas accounted for in the BAU Alternative is automatically an avoided cost for the Geothermal Alternative. As the natural gas costs increase, the savings associated with the Geothermal Alternative increase. By varying the levelized natural gas cost from $1.01 to $1.33, this resulted in an avoided cost ranging from $17,910 to $23,680 annually.

Taking into consideration both the energy savings from electricity and cost avoided as a result of not using natural gas, the analysis shows that there are net savings associated with the Geothermal Alternative when compared to the BAU Alternative. The costs do not account for the cost of fuel volatility over time. As discussed in Section 2, one major benefit of geothermal systems and renewable energy sources is the ability to hedge against the cost of fuel volatility.

Figure 22. Annual Levelized Electricity Costs – Low, Medium and High

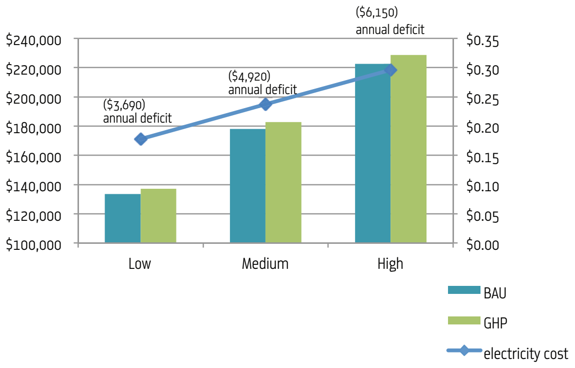
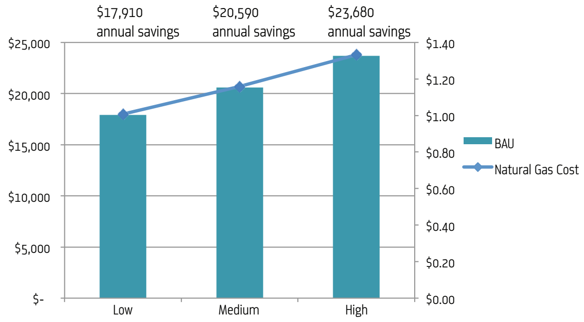


Figure 23. Annual Levelized Natural Gas Costs – Low, Medium and High



Figures 22 and 23 illustrate that as both the levelized cost of natural gas and the levelized cost of electricity increase, the overall energy savings increases when using the Geothermal Alternative over the BAU Alternative.

Box 6. District Energy Examples

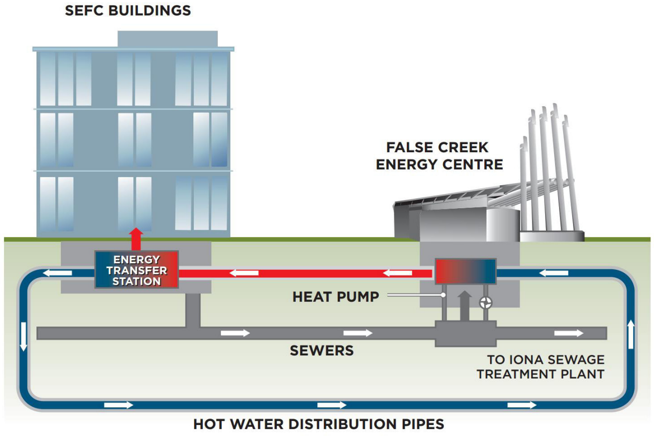
CHICAGO – DISTRICT COOLING

Owned and operated by Thermal Chicago, the City of Chicago benefits from a district cooling system that moves grid stress off-peak where electricity is cheaper. By leveling out the electrical grid, there is less need for infrastructure or for energy production. About half of a building's use on peak is air conditioning; district cooling abates that need. By integrating diverse buildings (with varying load profiles) such as condos, apartment complexes and office buildings, the electricity demand curve becomes less variable thereby optimizing the efficiency of the system. Thermal Chicago employs three different technologies to cool the city: ice tanks, ammonia chillers and river water chillers. The system serves around 100 buildings and upwards of 45 million square feet of space.

VANCOUVER - DISTRICT SCALE WASTEWATER HEAT RECOVERY

In Vancouver, Canada the Southeast False Creek Neighborhood Energy Utility ("NEU") recovers heat from wastewater to heat six million square feet of development at a district scale. An energy center, integrated with a sewage pumping station, recovers heat from urban wastewater, a renewable source. Heat pumps transfer the energy to a hot water distribution system. A system of insulated pipes circulates hot water around the neighborhood. Energy transfer stations in each building exchange energy with the circulating hot water. The NEU reduces GHG emissions by over 50% as compared to conventional energy sources, and the sewage heat recovery supplies approximately 70% of the annual energy demand. The NEU is a self-funded utility that provides a return on investment to taxpayers.

Figure 26. Neighborhood Sewer Heat Recovery System in Vancouver, British Columbia, Canada



4.3.2 Capital Cost Analysis for Business Case Example #2

The Geothermal Alternative for the modeled apartment building offers substantial benefits in terms of efficiency gains. A comparison of the costs Shows that the costs accounted for in this simple business case analysis include capital expenditures and operation and maintenance lifecycle costs. The table below is a summary of system costs.[29]
As noted in Appendix B regarding the heating and cooling building retrofit assessment, the total costs will depend upon existing building characteristics.

4.3.3 Life Cycle Analysis for Business Case Example #2

Applying the same assumptions used in the life cycle analysis for Business Case Example #1, the final EUAC analysis results for each system were $347,260 for the BAU Alternative and $443,810 for the Geothermal Alternative. The EUAC analysis illustrates that there is a cost hurdle to overcome to make the business case for a geothermal system. However, this analysis does not consider other tangible benefits derived from the Geothermal Alternative such as peak load reduction to the grid (avoided costs of utility infrastructure investment), GHG emission reductions and reduced exposure to market energy price fluctuations.

The same state and federal incentives discussed in Business Case #1 also apply here and can offer additional cost savings for a customer or project developer.

Table 8. Capital Costs

	Packaged VAV Rooftop Units		Geothermal Water Source Heat Pump	
System Equipment Technology	68 Split Systems with Gas-Fired Heat Exchanger	$1,020,000	(68) 3.5 ton water source heat pumps	$1,020,000
			(8) standing column vertical wells	$1,600,000
			(1) 300 kw back-up electric hot water boiler	$35,000
Retrofit Installation Requirements	Building with existing split systems require minimum modification	$0	Building with existing air distribution ductwork must be modified with extensive water distribution piping	No Allowance
New Construction Requirements	Complete split system	No Allowance	Complete Water Distribution Piping system	No Allowance
		$1,020,000		$2,655,000

4.4 Business Case Summary

When compared to conventional heating and cooling technologies, a Geothermal presents measureable benefits in the form of energy savings with reductions in GHG emissions. For example, Geothermal Systems consume only 30% of the energy consumed by natural gas fueled boilers and furnaces, and approximately 80% of the energy consumed by air and water cooled air conditioning systems. In fact, the GHG emissions associated with the Geothermal alternative are only 73% of the emissions associated with the standard BAU alternative. Another significant benefit of a Geothermal alternative is its potential to reduce summer electric demand, increase winter electric demand, and reduce winter natural gas demand. While the effect geothermal has on demand is not an easily quantifiable benefit, it none the less is an attribute that adds tremendous value to using geothermal technology.

The Business Case Analysis estimated that the Geothermal alternative installation costs for the multi-family residential and commercial building types selected are greater than the standard, BAU, heating and cooling technology. Although energy code efficiency improvements to standard heating and cooling systems and refrigerant technologies benefit the BAU Alternative, the Geothermal Alternative can offer 30% more in energy savings when compared to the BAU Alternative.

4.5 Geothermal Building Retrofits

New York City has a dense building stock that will remain in place for decades to come. The City has devised a plan to increase the efficiency of existing buildings through its Green Buildings Plan. Coupling energy efficient GHP systems with high performance building envelope designs, could provide a viable path to energy sustainability.

Retrofitting existing buildings with geothermal technology is one potential option for meeting efficiency goals. The potential efficiency gains that geothermal can deliver and its associated costs, should be compared to other energy management solutions available.

The business case analyses set forth above demonstrate that geothermal has the potential to provide a number of benefits; however, there are technical difficulties in its application. Drilling and installing the GRCO, with its related piping, requires considerable property area and must be physically accessible for drill rigs. Vertical clearance must also be available to accommodate the drill rig mast, which ranges from 30 to 35 feet in height. As a result, GHP systems are not well suited for retrofitting existing structures that occupy the entire surface area of the property, particularly if the heating and cooling load is high.

Although these constraints exist, there are opportunities to integrate geothermal where the conditions are more optimal. A major objective of this Report is to investigate and identify where viable retrofitting opportunities exist. In previous sections, land availability, geology, load profile, the cost of fuel switching and the influence of these factors on feasibility were all addressed.

As addressed in the business case section, the major portion of the initial capital expenditures for a geothermal exchange system are the well costs. When considering a building retrofit, the feasibility of integrating a Geothermal System is largely dependent upon the type and condition of heating and cooling system already installed in the building. Beyond technical feasibility, the costs associated with new GHP equipment, and changes to existing infrastructure within the building, will present additional capital expenditures.

Each potential geothermal project is site specific. For example, Landmark Districts in New York City restrict the use of exterior and roof top equipment (i.e., no external air conditioning condensers on the building). Moreover, the negative aesthetic of a window air conditioner, or a noisy air conditioning condenser on a roof or in a garden, is eliminated by the implementation of a geothermal system. Historic buildings, where external equipment is prohibited, have been provided with air conditioning that contains no external condensers to mar a building outline.[30] While these are only a few of the issues that can exist, factors such as these play a critical role in determining viable retrofit opportunities.

4.5.1 Assessment of Geothermal Retrofits by Building Type

In addition to the factors already discussed, such as geology, land availability, load profile, and costs, there are a few other initial key factors to consider:

* The capital cost of the geothermal retrofit is reduced if portions of the existing system (i.e., ductwork, piping, space heating equipment) can be used in the GHP system.

* The potential for long term energy savings must be compared to the initial capital expenditures and operations and maintenance costs with time, when assessing feasibility.

* It is not economically feasible to replace highly efficient, recently purchased equipment. There is more potential for savings when GHPs replace older, less efficient equipment that is approximately 10 -20 years old.

* The effectiveness of the building envelope's insulation will drive the feasibility and cost of retrofitting buildings with geothermal technology.

* In general, the most promising applications for GHP retrofits are buildings that are maintained at reasonably comfortable temperature set points (68-78 degrees Fahrenheit) for at least 40 hours per week.[31]

* In buildings with high domestic water heating loads (i.e., residences, hotels, laundry facilities), GHPs can provide hot water during the cooling season.

Appendix B provides an assessment of the likely efficiency gains versus costs for retrofitting different building types with a Geothermal System. Looking at a typically well maintained and properly sized heating and cooling system within existing buildings, an assessment of "high", "medium" or "low" was given with respect to the potential for energy efficiency gains (or fuel cost savings) and costs associated with equipment replacement. Note, the assessment does not attempt to consider the efficiency of the building's envelope or the specific load profile of the building and its impact on the efficiency of the Geothermal System.

The table located in Appendix B yields the following conclusions:

* The most favorable retrofit sites have water based heating and cooling air handling systems distributed throughout the building.

* The least favorable retrofit sites are buildings with window style air conditioners and steam perimeter radiator systems. In a building with window air conditioners and a steam radiator system, new water piping must be installed to serve heat pumps delivering both heating and cooling. This type of modification in multi-family buildings is complicated when the building is occupied and space for the new piping and equipment is limited. When updated for efficiency, the envelope insulation and windows of the building will reduce the heating and cooling capacity required. The cost associated with replacing the window air conditioners with GHP terminal units is prohibitive due to costs, despite the fact that the potential efficiency gains are high.

* The retrofits that will realize high efficiency gains have associated high costs.

* The most promising energy efficiency opportunities are those that convert all electric, heat and cooling with GHPs.

4.6 Opportunities for Reducing Capital Investment

The increased energy efficiency, fuel cost savings and GHG emissions reductions when compared to BAU heating and cooling solutions are compelling. There are, however, initial cost hurdles to overcome. This section discusses the potential for reducing the capital cost outlay, and thereby improving project economics, by developing a hybrid, joint energy management system for a single building, or district scale solutions, which are centralized systems that provide energy for a series of buildings. When geothermal technology is integrated into a hybrid and/or district scale solution, this can yield cost effective opportunities.

4.6.1 Hybrid

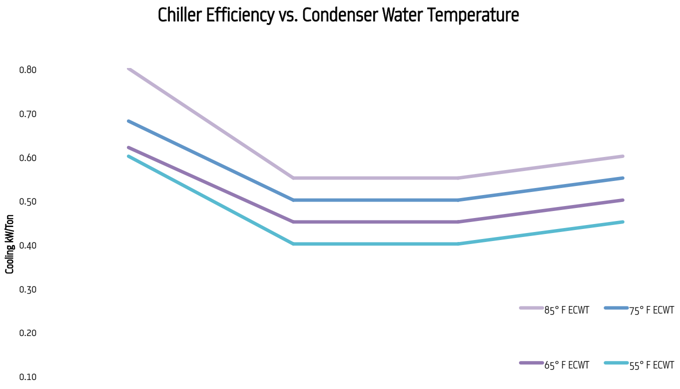
A hybrid geothermal system is a way to balance the high cost of bore-field construction with the efficiency gains of geothermal technology. Coupling geothermal with a conventional central system can significantly reduce upfront costs (savings on borehole wells).[32] Heat exchange with supplemental equipment, such as a small boiler or cooling tower, reduces the GRCO energy load while continuing to utilize the energy available from the Earth. A hybrid system may also be used to better address seasonal imbalances, depending on the actual space conditioning design and equipment. If a significant difference in heating and cooling load requirements exist, the developer may consider a hybrid system instead of increasing the GRCO size to meet the larger energy load.

Hybrid geothermal applications can also be well suited for facilities with substantial domestic hot water requirements. Large scale residential and institutional facilities that have common domestic hot water distribution systems can integrate a geothermal heat exchange economizer that captures the heat pumps' waste heat. The energy recovered from the GHP system maintains storage tank temperature and pre-heats the cold supply water in the heating process cycle.

A hybrid geothermal cooling tower is one example where the geothermal investment specifically targets the high value load reduction of electric cooling load during the summer electric grid peak periods. The energy advantage of the hybrid geothermal system is realized when the ambient air temperature rises above the geothermal system water temperature (see Box 5). The water cooled air conditioning operates more efficiently as the cooling water temperature is controlled to maximum system efficiency.

Management of the City's Electric Summer Peak Demand is a critical consideration in the balance of economy, reliability, and resiliency of electrical supply. The efficiency of cooling equipment is reduced during summer temperatures. The hybrid geothermal cooling tower has the potential to reduce peak demand by 25% and yield reductions of 25 MW per 100 MW of cooling system summer peak load (see Box 5). A hybrid geothermal system sized to support the cooling peak load reduction will require a smaller geothermal system of wells and/or trench arrays. The target value per kW of Capacity to support capital requirements for a hybrid geothermal system will be near $200 per kW per year as a capacity payment or credit.

Figure 24. Hybrid Geothermal System[33]



4.6.2 District Scale

Much of the City's existing infrastructure (e.g.., the electricity and water systems), are centralized and considered a single purpose system. When initially built and expanded, these systems were seen as an efficient way to distribute energy and resources throughout the City. Today, many cities are grappling with aging, less efficient infrastructure, while simultaneously being faced with fiscal constraints, new technologies, changing societal values and densification and expansion. Today, cities are again looking at district scale systems as a means to meeting energy needs and optimizing energy efficiency at a neighborhood level.

District scale systems can provide a number of advantages. By generating energy locally, distribution losses and costs incurred by a centralized system are lessened. The district scale can also offer economies of diversification. By combining the loads of a series of buildings with varying load profiles, the overall load is more consistent and less variable, thereby increasing the efficiency of the centralized equipment.

Cities around the globe are looking to modern district energy systems and their ability to integrate renewable energy sources as a way to meet GHG reduction goals. For example, the City of Copenhagen has achieved a 57% reduction in its CO2 emissions largely through district energy systems fueled by combined heat and power and all available fuels, including waste and biomass. Washington D.C. has set the target of reducing its emissions by 57% through the replacement of 80% of small fossil fuel boilers and electric heating with district heating, and the replacement of 50% of central and small unit air conditioning systems with district cooling.[34]

Geothermal Systems can be considered as a potential technology to be integrated into a district energy system. If the land is available, for example in the form of a public park, the ground can be considered as an energy resource to be harnessed. Existing district systems served by an energy plant can even be retrofitted without overly invasive modifications. Access to volumes of wastewater and effluent flows offers increased energy exchange opportunities. A centralized energy district located in proximity to wastewater treatment plant outfalls may be able to use the energy expended from such wastewater outfalls as part of the Geothermal Exchange System.

Similar to the hybrid solution discussed above, at the district scale, the Geothermal System can target a portion of the energy requirement, such as the base load, while other conventional technologies (such as boilers) can be used to meet peak load. The optimal balance of technologies for any given project should be determined through a feasibility study.

5. Regulatory Requirements

5.1 U.S. Environmental Protection Agency

Pursuant to the Underground Injection Control ("UIC") program administered by the United States Environmental Protection Agency ("USEPA"), standing column wells and open loop diffusion wells are considered beneficial use, Class V, injection wells. The USEPA can, therefore, authorize operation of a geothermal well "by rule" pursuant to the regulations, so long as operation of the well does not return well fluids to the ground level. If the return fluid is discharged to a surface water body, the USEPA will then determine if additional permitting is necessary.

Upon application, specific inventory information on the well and the site's hydrogeologic condition must be submitted to USEPA prior to construction. The well owner will also need to submit operating data for each well (i.e., source of fluids to be injected, average and maximum daily rates and volume of fluids to be injected, etc.). However, construction may proceed before final approval. Vertical closed loop and open loop system supply wells are exempt from the USEPA's requirements.

During the application process, injection procedures will also have to be disclosed, as will construction procedures and construction details (i.e., schematic drawings of surface and subsurface construction details of the well). Following well installation, a ground water sample must be analyzed for pH, chlorides, total dissolved solids, specific gravity and be submitted to USEPA for approval. As part of the USEPA filing under the UIC program, a well Plugging and Abandonment Plan must also be submitted in the event that a well will be taken out of service in the future. Without proper abandonment, the well casing can act as a potential conduit for surficial contamination into deeper aquifers. The USEPA review and approval period for permitting a Class V injection well is approximately four to six weeks.

5.2 New York State Department of Environmental Conservation

DIVISION OF MINERAL RESOURCES

The New York State Department of Environmental Conservation ("NYSDEC") Division of Mineral Resources requires a "mining" permit for any drilling activity below a depth of 500 feet. These permits have historically been issued for standing column wells. Well locations, depth, use, casing material, cementing procedures, drilling fluid and cuttings disposal methods must be submitted with a permit application (Form 85-12-5). A well owner must also submit a completed Division of Mineral Resources well permitting Environmental Assessment Form ("EAF"), which provides information that enables the NYSDEC to evaluate the environmental impacts and decide whether special permit conditions, a Supplemental Environmental Impact Statement, or any additional NYSDEC permits are required. Before a well owner, operator, driller, and/or plugger commences any regulated activity, including preparatory work, a notarized copy of the Oil and Gas Organizational Form must be filed with the Division of Mineral Resources, along with proof of financial security using the Financial Security Worksheet.

With respect to well construction, the well surface casing must extend a minimum of 75 feet beyond the deepest fresh water zone encountered or into competent bedrock, whichever is deeper. The Division of Mineral Resources also requires that the wells do not drift beneath adjacent properties for which the applicant has not received permission from the property owner. To demonstrate compliance, angular deviation and directional surveys must be performed at 100 foot intervals during drilling using a gyroscope or other approved method. If the borehole drifts near the property boundary of an adjoining site for which the building owner has not received approval, drilling must stop, and the well must be completed at that depth. Any borehole intersecting such a property boundary must be abandoned and sealed.

The Division of Mineral Resources will consult with the New York State Office of Parks, Recreation and Historic Preservation ("NYS Parks") on whether the location of a well is within a state-listed historic area in which case permission is required. NYS Parks will review the project to ensure that the installation of a well will not have a negative impact upon cultural resources. If approval from New York City agencies is required, the Division of Mineral Resources will require documentation of approvals as part of the permit application.

During the well permitting process, the owner must present a certified site plan, a casing and cementing plan, and report to the NYS Department of Mineral Resources specific milestones and activities, including, but not limited to the start of drilling, date of casing cementing, date when drilling reaches total depth, and date of pump installation. Within 30 days after the completion of the well, a Well Drilling and Completion Report (Form 85-15-7) must be filed by the owner summarizing the drilling and completion details. An interim Well Drilling and Completion Report must be filed if there is a delay in completing the well for its intended use. An annual report must also be filed, which describes the current status and use of the well.

The Division of Mineral Resources' review and approval process takes approximately six to eight weeks. If separate approval by NYS Parks or other City agency is required, approval may take longer. Filing fees vary depending on the depth of the well, however, a filing fee for a 1,500 foot standing column well is approximately $670, and a $2,500 security must be paid and put into escrow by the Division of Mineral Resources in case a building owner defaults, and the well must be abandoned. Financial assurance and application fees apply to non-governmental agencies, otherwise, only application fees apply to governmental agencies.

DIVISION OF WATER

The NYSDEC Division of Water regulates wells that are less than 500 feet deep. Drillers and pump installers are required to be registered and certified for open loop or standing column well systems. The Division of Water also requires pre-notification and well completion reports to be filed for open loop or standing column well systems. Closed loop systems are not required to follow these regulations.

A Long Island Well Permit is required from the Division of Water to install and operate an open loop or standing column well system in Brooklyn and Queens with a total pumping capacity greater than 45 gallons per minute ("gpm"). The permit application is filed with the Division of Water Region 2 office in Long Island City, and includes a joint application for permitting with the Army Corps of Engineers, a Short EAF, and a Long Island Well Permit form.

If well return water is discharged to a surface water body, a State Pollutant Discharge Elimination System ("SPDES") permit is required. The Division of Water review and approval period takes approximately six to eight weeks to complete.

Project sites near areas considered by the NYCDEC to be environmentally sensitive such as regulated wetlands, may require an environmental assessment form ("EAF") that outlines potential impacts and plans for mitigation.

5.3 New York City Department of Environmental Protection

WATER TUNNEL CLEARANCE

The NYCDEP will issue riders to address geothermal wells located between 200 and 500 feet of any City water supply facility, specifically aqueducts, water tunnels, shafts or appurtenant facilities. Drilling is prohibited within 200 feet of the centerline of a water tunnel or an aqueduct, and proposed drilling locations located within 500 feet from water tunnels are to be identified. This clearance is required by proposed projects in all the boroughs.

Rider A covers drilling locations 201 feet to 300 feet from the centerline of a water tunnel. The angular deviation and directional survey requirements are as follows: (i) a survey is required every 50 feet of depth from land surface to a depth of 150 feet above the crown of a tunnel or aqueduct; (ii) a survey is required for every 25 feet of depth from a depth of 150 feet above the crown of a tunnel or aqueduct to a depth of 100 feet below the invert; and (iii) surveys are not required from a depth of 100 feet below the invert of the water tunnel.

Rider B covers drilling locations 301 feet to 500 feet away from the centerline of a water tunnel. The angular deviation and directional survey requirements are as follows: (i) a survey is required every 100 feet of depth from land surface to a depth of 150 feet above the crown of the tunnel or aqueduct, (ii) a survey is required for every 50 feet of depth from a depth of 150 feet above the crown of a tunnel or aqueduct to a depth of 100 feet below the invert and (iii) surveys are not required from a depth of 100 feet below the invert of the tunnel or aqueduct. For drilling locations over 500 feet from the centerline, NYCDEP approval is required but angular deviation surveys are not required.

If the drilling company utilizes directional drilling techniques, with continuous deviation measurements, and steering control capable of corrections, any deviation from the vertical, then owner shall not be required to obtain a deviation survey for a well that is drilled while maintaining a distance of at least 200 feet from the tunnel or aqueduct center line.

The NYCDEP will review a site plan with plotted well locations and make a determination of the actual distance of the well(s) to a City water tunnel. As noted above, submissions of angular deviation and directional surveys will be required with depth intervals, depending on the distance from a tunnel. The NYCDEP will usually respond to a request for determination regarding a proposed wells' proximity to a water supply within a month.

SEWER DISCHARGE PERMIT

The NYCDEP issues a Dewatering Permit for temporary disposal of drilling fluids and ground water to the City sewers generated during construction. Approval may be necessary from two separate NYCDEP bureaus depending on the daily discharge amount, one for quality analysis of water from the Bureau of Wastewater Treatment (BWT), and the other from the permitting and compliance section of the bureau of water and sewer operations (BWSO) for daily discharge volume.

If the estimated daily water discharge is less than 10,000 gallons per day ("GPD"), only approval from the BWT is required. This bureau reviews water quality of the proposed discharge water and determines if pre-treatment is necessary. BWT requires a completed Wastewater Quality Control Application (Form DEP WQ-D-001), water quality data, and a site plan showing the type and size of public sewers, existing and proposed sewer connections, temporary pumps and piping to be used, and the proposed points of discharge to the sewer system. All documents and drawings must be stamped by a New York State professional engineer ("PE") or registered architect ("RA"). A sample of the proposed wastewater must be analyzed by a New York State Department of Health certified wastewater laboratory and the results must be submitted with the application. BWT will specify the parameters, analytical methods, and detection limits. Treatment of the water before disposal into the sewer may be necessary if any of the compounds exceed regulatory limits. If so, a treatment system must be proposed in the application, including specifications, engineering calculations and other details.

If the estimated daily construction water discharge is greater than 10,000 GPD, then in addition to the BWT approval, approval is also required from the BWSO. This division reviews the proposed water quantity discharge to ensure that the local sewer mains have the capacity to handle the discharge.

BWSO's Application for Permit for Temporary Discharge of Groundwater into City Sewer System requires an indemnification agreement, site plan, number and capacity of pumps to be utilized, the quantity, maximum flow rate, average daily flow, and duration of the proposed discharge. In addition, data on the City sewer main and the connection piping to the site must be provided, including pipe locations and diameters, invert elevations at the property line and at the point of connection to sewer main, total capacity of the connection and the percent capacity to be used for dewatering (must be less than 10%), distance from City sewer to the property line, and the slope of connection. Backup computations must be provided and all documents and drawings must be stamped by a New York State PE.

As-Built Sewer records and connection records can be obtained through the borough sewer office. If connection records are not available, the Owner must arrange with the NYCDEP to perform a dye test with the results provided to BWSO. However, NYCDEP does not allow direct connections to the sewers through catch basins or manholes in the City sidewalks or streets. Rather, connection must be via an on-site discharge point e.g., existing house connections. If a new temporary sewer connection is required for dewatering, a licensed plumber must submit a sewer connection permit application.

There is no filing fee, but a discharge fee based on the estimated volume will apply. Normal turnaround time for approval from the BWT is two to four weeks, although approval from the BWSO may take longer. Upon approval from BWT and BWSO, the fee is paid to the Borough Office of the Bureau of Customer Services, which then issues a discharge permit.

5.4 New York City Department of Health

Under Article 141 of the New York City Health Code, the New York City Department of Health and Mental Hygiene ("NYCDOH") permit Type 33 is required if well water is used for purposes other than potable supply, such as an open loop supply well. A standing column well that recycles bleed water for other uses, such as irrigation, water fountains or grey water also requires a permit. Bacteriological testing is required, and recommended for volatile organic compounds ("VOC"). Recycled standing column well bleed water must be rendered bacteriologically safe. An initial disinfection of the well is required using guidelines of the American Water Works Association. Specifically, a solution containing one quart of ordinary laundry bleach (approximately 5% available chlorine) and 10 gallons of water must be poured down the well shaft. The solution should remain in the well for at least 24 hours, followed by straight pumping of the well to waste for at least 3 hours.

Form 314C, Application for Permit, and Form PHE 98, Well Water Questionnaire, must be submitted by the well owner. A site plan indicating possible pollution sources up to 200 feet of the well and a completed well log from the contractor are also required. The Bureau of Public Health Engineering will perform an inspection and collect a water sample for its analysis. A well may not be used until a permit has been issued by the NYCDOH. The initial fee for this permit is $300 and must be renewed each year. An annual renewal fee is $15 after the first year and an annual bacteriological sample from a New York State Health Department certified laboratory is also required for renewal. It takes approximately one month from filing to approval to receive a Type 33 permit from the NYCDOH. This permit is applicable to geothermal projects constructed in all boroughs.

5.5 New York City Department of Transportation

REVOCABLE CONSENT

A building owner that plans to install any type of ground coupling system in New York City that requires the owner to construct permanent wells or loops through City sidewalks must enter into a Revocable Consent Agreement ("RCA") with the New York City Department of Transportation ("NYCDOT") Bureau of Franchises. The agreement allows the City to reclaim use of the land at some future time in which case the wells may have to be taken out of service and abandoned. Building owners should submit a Petition for a New Revocable Consent (Form RC-1) to initiate this process. Usually, a petition must be accompanied by a certified site plan drawn by a PE or RA licensed by the State of New York (Plan requirements can be found in the Rules Relating to Revocable Consents). The building owner should meet with NYCDOT regarding the application procedure and any special requirements that may be required prior to submitting the application.

NYCDOT requires angular deviation and directional surveys per NYCDEP requirements if drilling within 500 feet of a water tunnel. Wells located greater than 500 feet of a water tunnel, and not under NYCDEP jurisdiction, requires deviation surveys to 850 feet at 100 feet intervals as part of the RCA.

There is no initial filing fee, however annual fees apply for wells and possibly for buried connector piping installed beneath City sidewalks. The fee is $3,000 per well, unless the building is a City-designated landmark or non-landmark building located in a historic district. The annual fee is $25 per well for historic buildings. A minimum time frame of four months is required from initial NYCDOT submission to receive the RCA. However, it is recommended that the project team allow five to six months in their schedule.

STREET CONSTRUCTION PERMITS

Since drilling can occupy large areas needed for a rig and other necessary equipment, projects with limited outdoor space may need to use the adjoining sidewalk and street lane as a work area or for equipment and material storage. There also may be instances where a geothermal project may disturb the street and/or sidewalk due to construction. There are four categories of construction-related permits for work on a street: Street Opening, Building Operations/Construction Activity, Sidewalk Construction, and Canopy Permits. A well owner may need to obtain one, or multiple, permits from the NYCDOT Bureau of Permit Management and Construction Control regarding construction-related permitting. Applicant requirements vary depending on the size and complexity of the project and the borough in which it is being undertaken. A filing is typically made in the form of a Permittee Registration Application and supporting documentation by the General Contractor, who must be registered with the NYCDOT. There is one permit application form that covers Street Opening, Building Operations/Construction Activity, and Sidewalk Construction Permits for non-governmental work. There are separate permit applications for governmental work, Canopy Permits, and permit renewals and re-issuance. All permits that are required by other state and federal agencies must be in place before the NYCDOT issues a street construction permit. The filing fee varies depending on the type of permit requested, and the permitting process takes approximately one month.

5.6 Department of Parks and Recreation

Trimming, removal, or replacement of City-owned trees in the sidewalk may at times be necessary, and will require coordination with and approval from NYC Department of Parks and Recreation. Any work within a park requires a Parks work permit and may require consideration of alienation issues.

5.7 Public Transportation Agencies

The Metropolitan Transit Authority ("MTA") which includes the New York City Transit Authority ("NYCTA"), the Long Island Rail Road ("LIRR") and Metro North, and the Port Authority of New York and New Jersey ("PANYNJ") must be informed of planned geothermal drilling located within a distance of 200 feet from their transportation structures, including tunnels, substations, ventilation buildings, and stations. If MTA review and approval is required, the New York City Department of Buildings ("NYCDOB") requires that MTA approval be noted in the drawings for building permit applications. The owner and drilling firm may have to procure additional insurance coverage. Moreover, vibration monitoring may be required in tunnels that are in close proximity to the site.

5.8 Resources for Identifying Permitted Ground Water Wells

There are federal and state requirements for maintaining records for identifying ground water wells. The NYSDEC, Division of Mineral Resources, maintains records for wells that are deeper than 500 feet (mainly standing column wells) – wells that are shallower than 500 feet do not require a permit from the Division of Mineral Resources. The NYSDEC, Division of Water, Region 1, Stony Brook, New York, maintains records for existing well permits under the Long Island Well Permit program, which can be accessed through the Freedom of Information Law ("FOIL"). The USEPA UIC Program maintains records for wells that are regulated as Class V injection wells. These include standing column wells and open loop diffusion wells, and records for such wells can be accessed through a FOIL request with the USEPA.

5.9 Technical Standards

The American Society of Heating, Refrigerating and Air-Conditioning Engineers ("ASHRAE") is the HVAC industry's technical organization. Among many activities, ASHRAE develops and promulgates standards, guidelines, and other important information relating to this technology. Although ASHRAE is not a regulator, its guidelines are used industry-wide and should be known to potential geothermal developers. The ASHRAE standards that effect geothermal heat pump systems are included in Appendix C.

6. SUMMARY

This Report demonstrates that the use of Geothermal Systems can improve the efficiency of how customers heat and cool buildings, thereby furthering the City's 80x50 energy efficiency goal. Combatting the effects of climate change is a challenge faced worldwide, and the City has committed to mitigating such effects through its reduction of GHG emissions. The Report concludes that there are potential opportunities to increase the use of renewable resources throughout the City, specifically through the increased implementation of Geothermal Systems, but there are geological, cost and other hurdles that may limit widespread geothermal development in the City.

The successful implementation of geothermal is dependent on a number of factors, many of which are site specific. The land available for geothermal wells, the specific load profile of a building or group of buildings for energy demand, and the underlying geology all play a key role in determining if a geothermal system is technically, and economically, feasible. For example, the load profile of a building is a significant factor in determine the viability of a geothermal solutions and therefore, there is a direct relationship between the size of load demand and the land area available to supply that building's load.

As demonstrated by the business case analyses presented earlier in the Report, one of the most significant challenges to installing a Geothermal Exchange System in the City is the significant up-front investment that is required.

The results of the life cycle cost analyses conducted in the Report for two hypothetical business case scenarios revealed that, on their own, the energy cost savings over the lifetime of the project are not substantial enough to completely balance the initial capital costs associated with purchase and installation of the geothermal wells.

The Report, also reveals the multiple benefits that a geothermal system can provide, including energy cost savings, reduced greenhouse gas emissions, reduced operations and maintenance costs, increased overall electric reliability and reduced exposure to market energy price fluctuations.

However, the life cycle analyses did not consider a myriad of benefits associated with a geothermal system, including the potential for demand response and peak load demand, GHG reductions, and hedging against the volatility of fossil fuels. These additional market and environmental-based benefits, which extend beyond sheer cost savings, are attractive and should be considered by potential developers and customers.

Lastly, in response to the results of the life cycle analyses, the Report explores potential opportunities to reduce the initial project costs of geothermal systems. These include hybrid and district scale solutions, in addition to procuring renewable incentives. Using creative solutions such as these may positively impact the financial analysis and tip the scale in favor of a geothermal project.

This Report is meant to serve as a tool to those interested in implementing geothermal technology throughout New York City and to assist in identifying and analyzing the relevant factors to determine if geothermal energy systems are a viable solution. This Report should be considered in conjunction with the New York City Department of Design and Construction's Geothermal Heat Pump Systems Manual for a comprehensive overview of the necessary processes for installing geothermal systems throughout the City.

(Endnotes)

[1] Architecture team Skidmore, Owings & Merrill

[2] See Cornell University Sustainable Campus. www.sustainablecampus.cornell.edu/energy

[3] See Centre for the Analysis and Dissemination of Demonstrated Energy Technologies. "Seawater cooling system for buildings" http://file.seekpart.com/keywordpdf/2011/5/23/2011523124132667.pdf

[4] See Philadelphia Water Department. Sewage Geothermal Installation. http://www.phila.gov/water/PDF/SewageGeothermal.pdf]

[5] The New York City Department of Design and Construction, Geothermal Heat Pump Systems Manual: A Design and Installation Guide for New York City Projects (2013).

[6] The New York City Department of Design and Construction, Geothermal Heat Pump Systems Manual: A Design and Installation Guide for New York City Projects (2013).

[7] Id.

[8] Id.

[9] Id.

[10] Id.

[11] Rehau AG+CO, Geothermal Piles, http://www.tectonica-online.com/products/2564/piles_geothermal_pe-xa_raugeo/# (26 Jan. 2015).

[12] U.S. Department of Energy, Energy Efficiency and Renewable Energy: Geothermal Heat Pumps (Sep. 1998) http://www.nrel.gov/docs/legosti/fy98/24782.pdf.

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[15] Id.

[16] Geothermal Heat Pump Consortium, Inc., GeoExchange Heating and Cooling Systems: Fascinating Facts (Jan. 2006).

[17] In addition, carbon pricing may be imposed at some point to address global climate change. Geothermal system installations would provide an excellent hedge against the price impacts of such legislation or regulation.

[18] United States Geological Survey (USGS) prepared in cooperation with the New York City Department of Design and Construction

[19] City of New York Department of Design and Construction, Geothermal Heat Pump Manual (August 2002) http://www.nyc.gov/html/ddc/downloads/pdf/geotherm.pdf.

[20] City of New York, PlaNYC: Green Buildings & Energy Efficiency http://www.nyc.gov/html/gbee/html/plan/plan.shtml.

[21] New York City Department of City Planning. BYTES of the BIG APPLE, http://www.nyc.gov/html/dcp/html/bytes/applbyte.shtml.

[22] The New York City Department of Design and Construction, Geothermal Heat Pump Systems Manual: A Design and Installation Guide for New York City Projects (2013).

[23] New York State Department of Public Service, Monthly Residential Bills Including State GRT http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/c56a606db183531f852576a50069a75d/$FILE/Typical%20Bill-%20Elecric-Residential-%20Winter%202013-%208-21-13.pdf.

[24] U.S. Environmental Protection Agency, Understanding Cost-Effectiveness of Energy Efficiency Programs: Best Practices, Technical Methods, and Emerging Issues for Policy-Makers (Nov. 2008) http://www.epa.gov/cleanenergy/documents/suca/cost-effectiveness.pdf.

[25] Note, that the calculations do not consider the costs for retrofit installations or the cost for different construction requirements in new construction.

[26] Energy Star, Federal Tax Credits for Consumer Energy

Efficiency (28 Jan. 2015) http://www.energystar.gov/about/federal_tax_credits.

[27] The New York State Department of Taxation and Finance, Assessor's Manual, Volume 4, Exemption Administration (28 Jan. 2015) http://www.tax.ny.gov/research/property/assess/manuals/vol4/pt1/sec4_01/sec487_a.htm.

[28] U.S. Department of Energy, Database of State Incentives for Renewables & Efficiency (28 Jan. 2015) http://www.dsireusa.org/incentives/index.cfm?state=NY.

[29] Note, that the calculations do not consider the costs for retrofit installations or the cost for different construction requirements in new construction.

[30] DDC Geothermal Heat Pump Manual 2002 http://www.nyc.gov/html/ddc/downloads/pdf/geotherm.pdf.

[31] National Renewable Energy Laboratory – Super ESPC Best Practices. Preliminary Screening for Project Feasibility and Applications for Geothermal Heat Pump Retrofit Projects. http://www.nrel.gov/tech_deployment/climate_neutral/pdfs/ghp_screening_21oct03.pdf

[32] Geothermal Central System. Thomas H. Durkin, Keith Cecil. ASHRAE Journal, August 2007. file:///C:/Users/cpasion/Downloads/20070727_durkin.pdf.

[33] "Assessment of Hybrid Geothermal Heat Pump Systems." U.S. Department of Energy. DOE/EE-0258. Federal Energy Management Program. December 2001.

[34] District Energy Partnership, http://www.districtenergypartnership.com/.

APPENDIX A

United States Geological Survey Maps

Prepared in cooperation with the

NEW YORK CITY DEPARTMENT OF DESIGN AND CONSTRUCTION

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

SCIENTIFIC INVESTIGATIONS MAP XXXX
Bedrock Surface Elevation of Five Boroughs—SHEET 1 of 7
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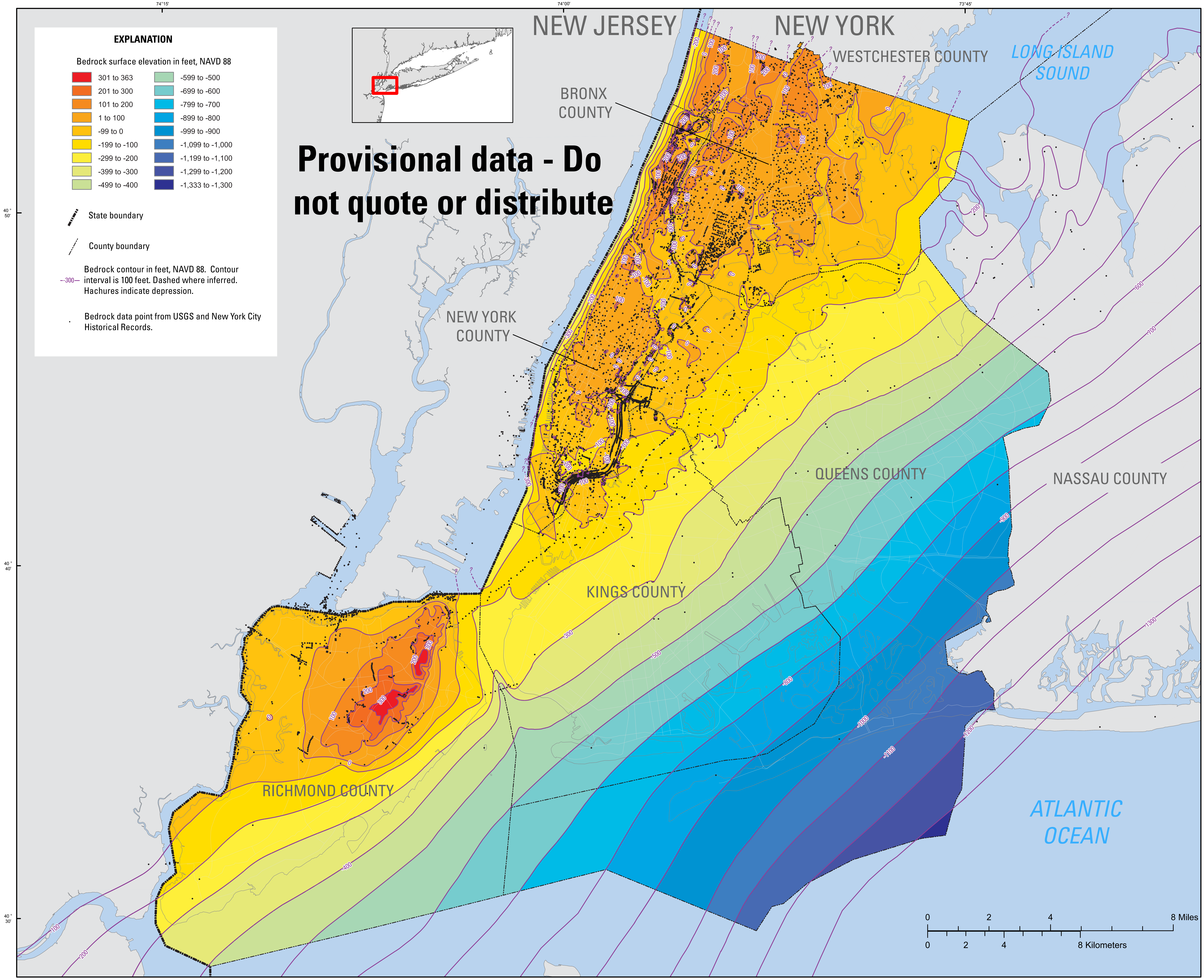
Bedrock Surface Elevation of the Five Boroughs of New York City, New York



Base digital data NOAA's Medium Resolution 1:70,000 scale Digital Vector Shoreline
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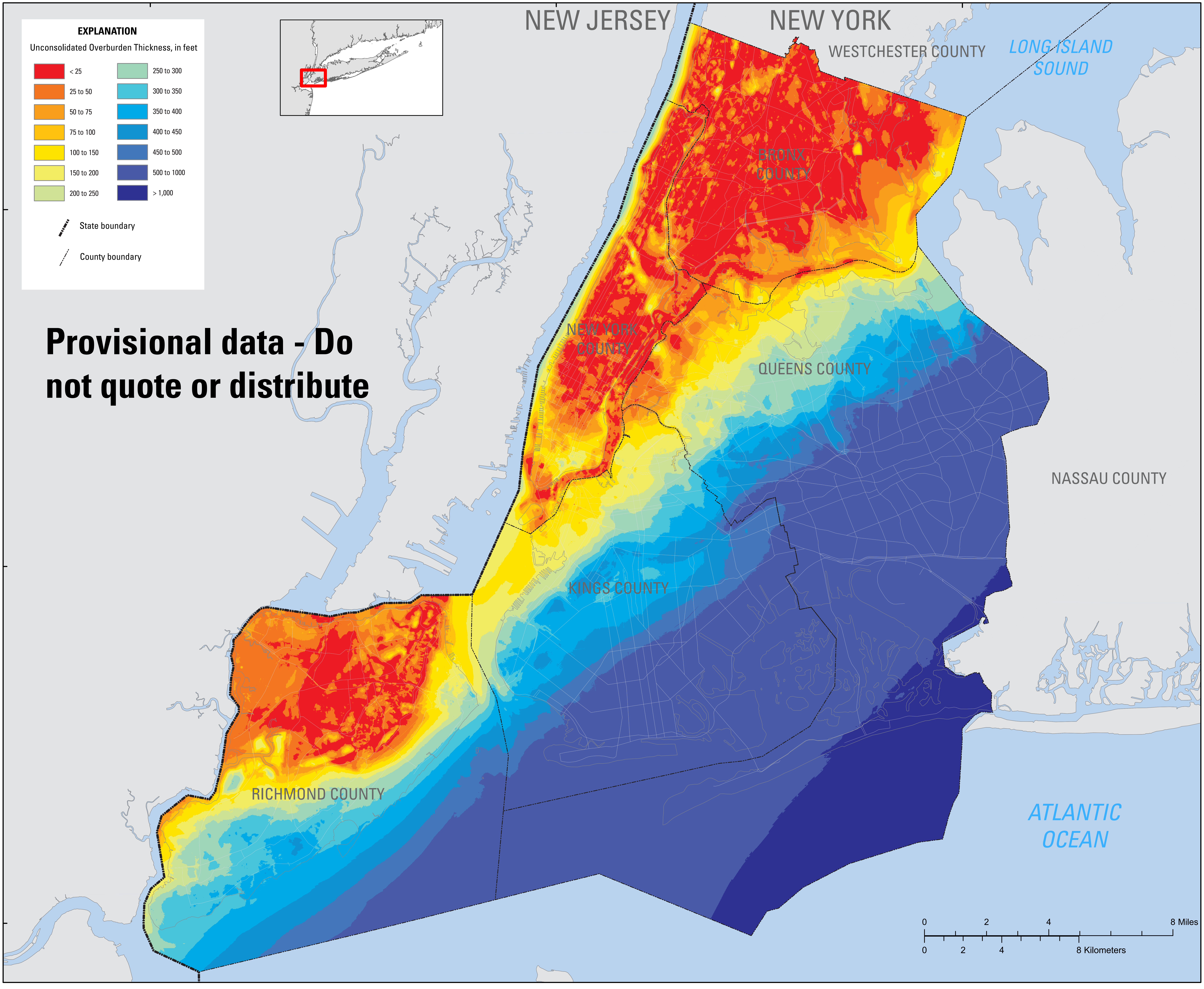

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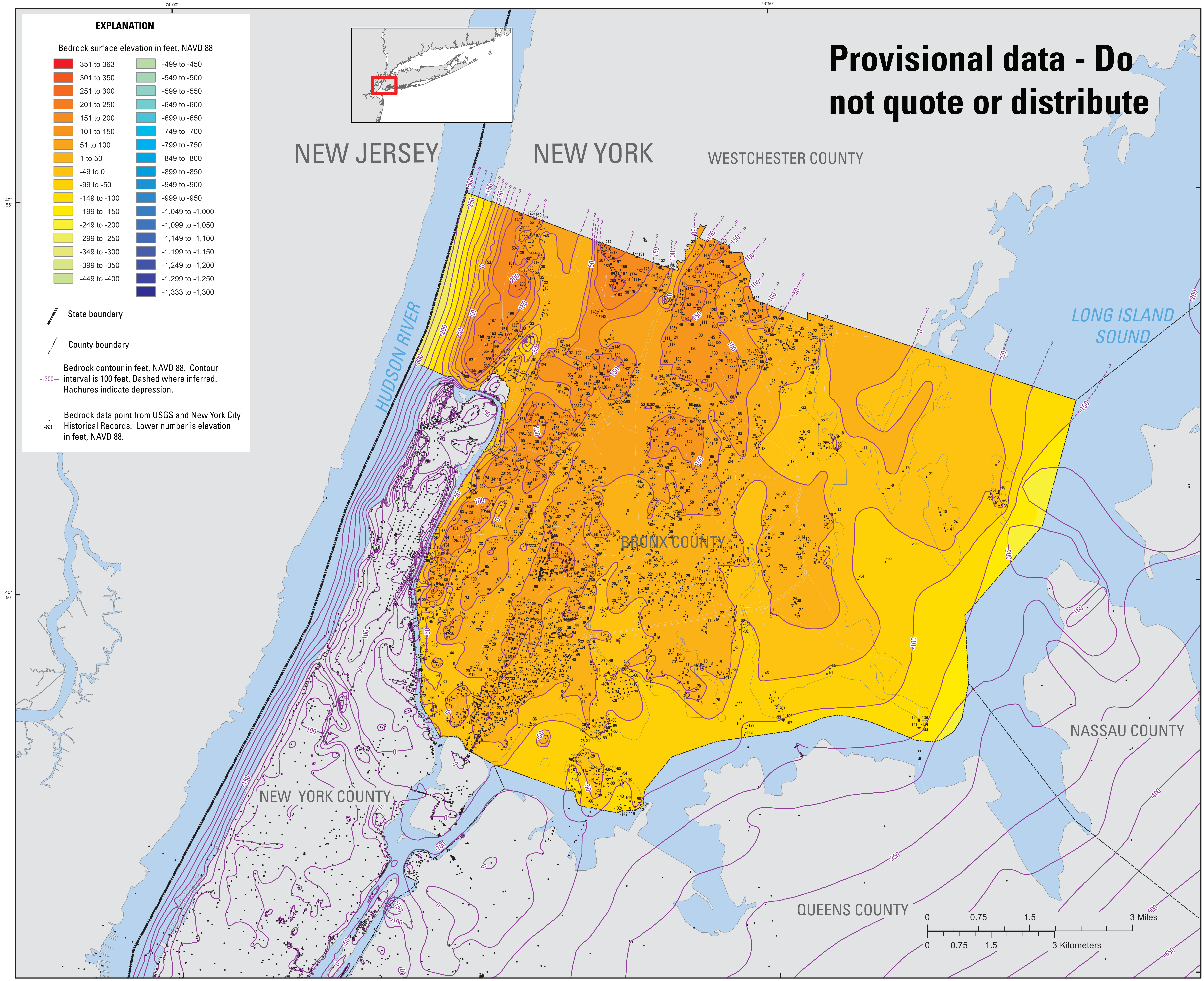

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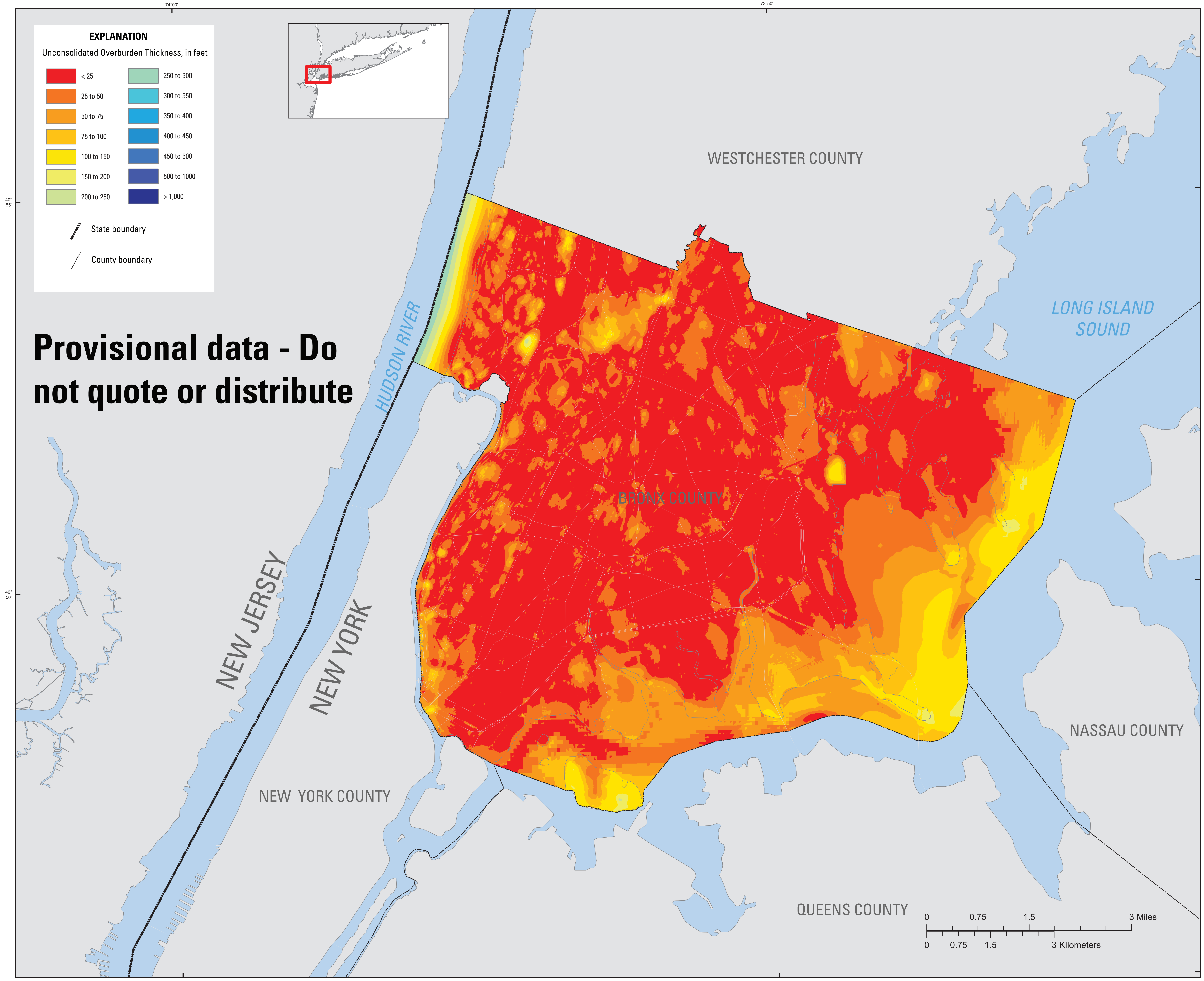

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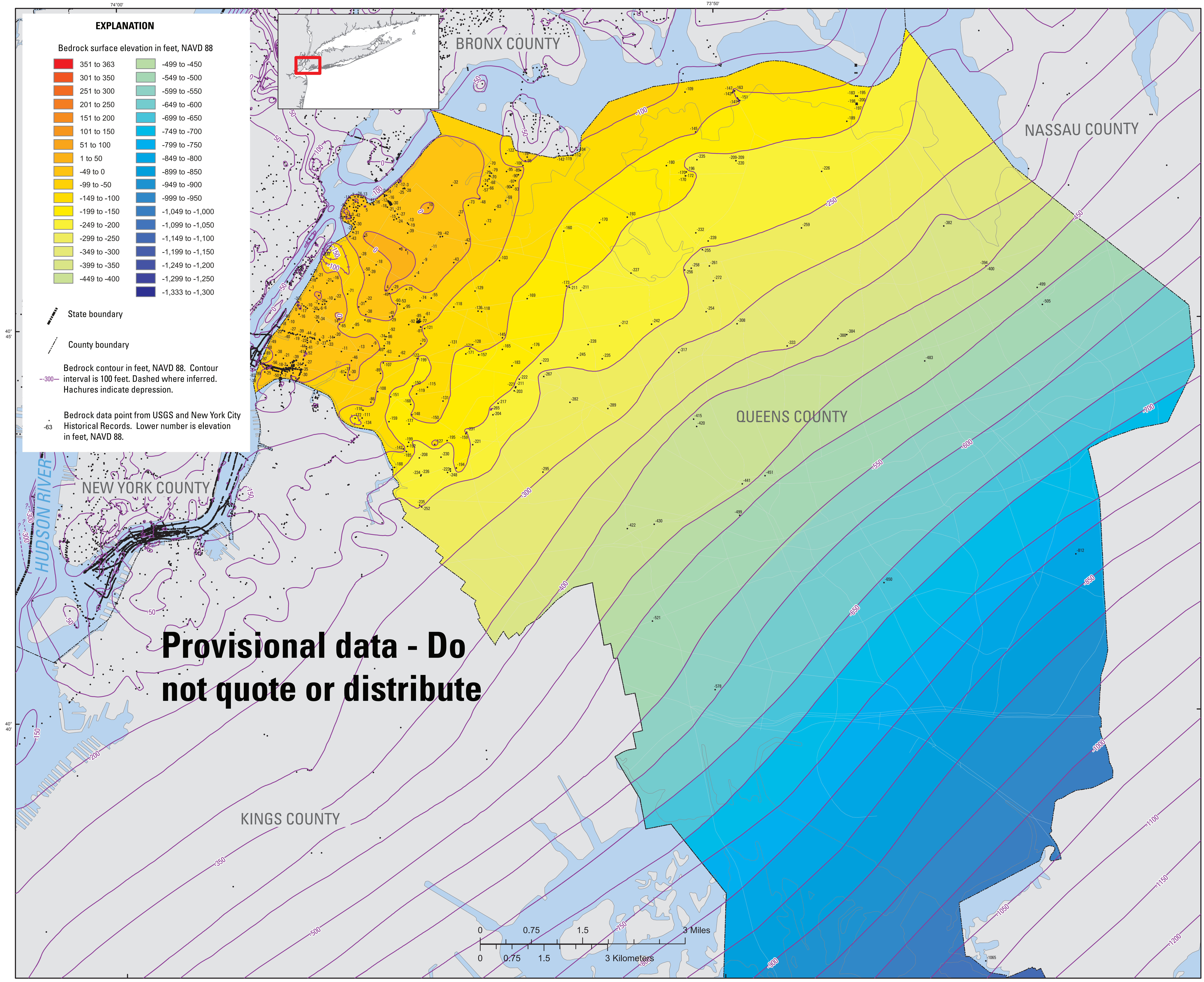

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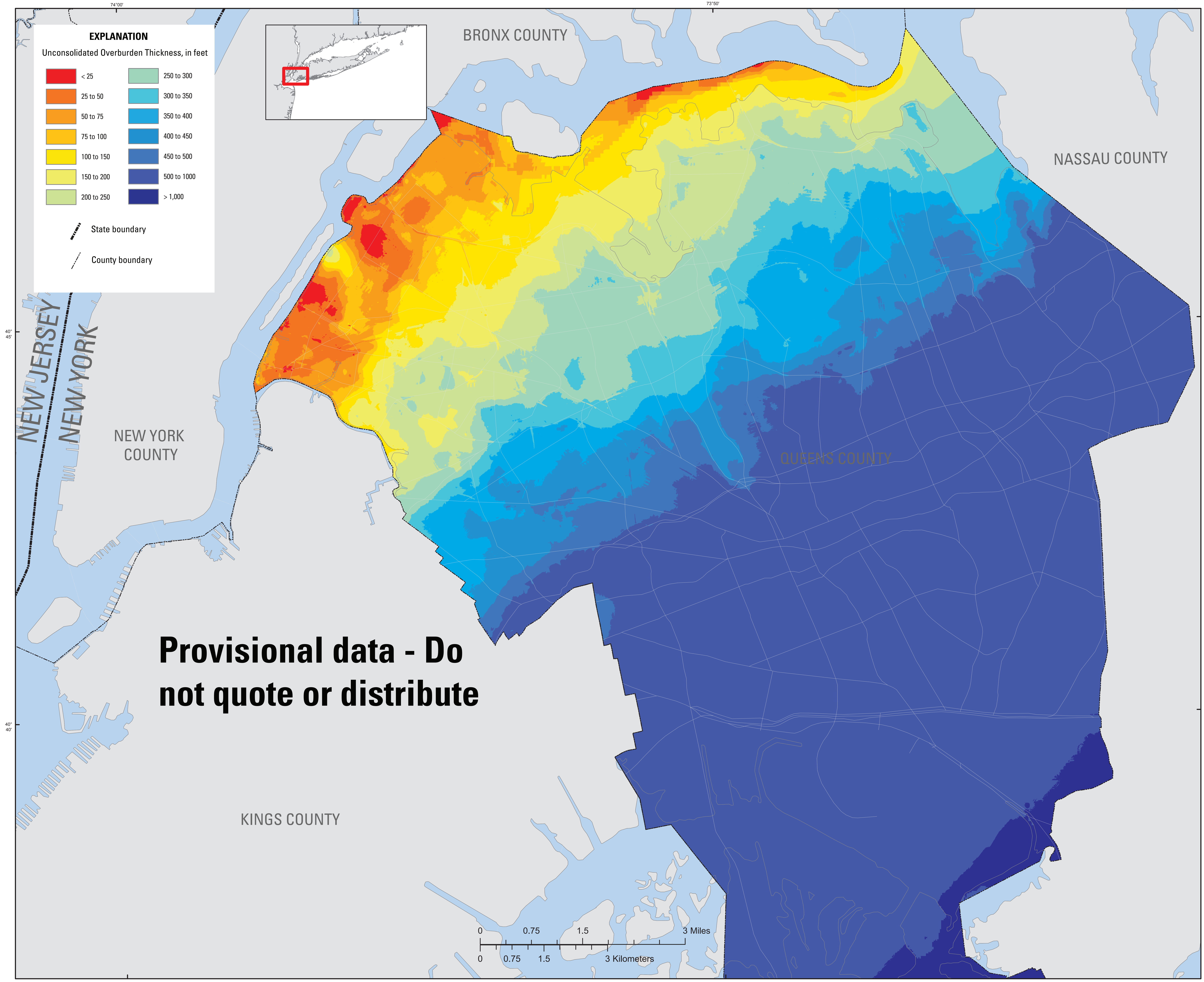

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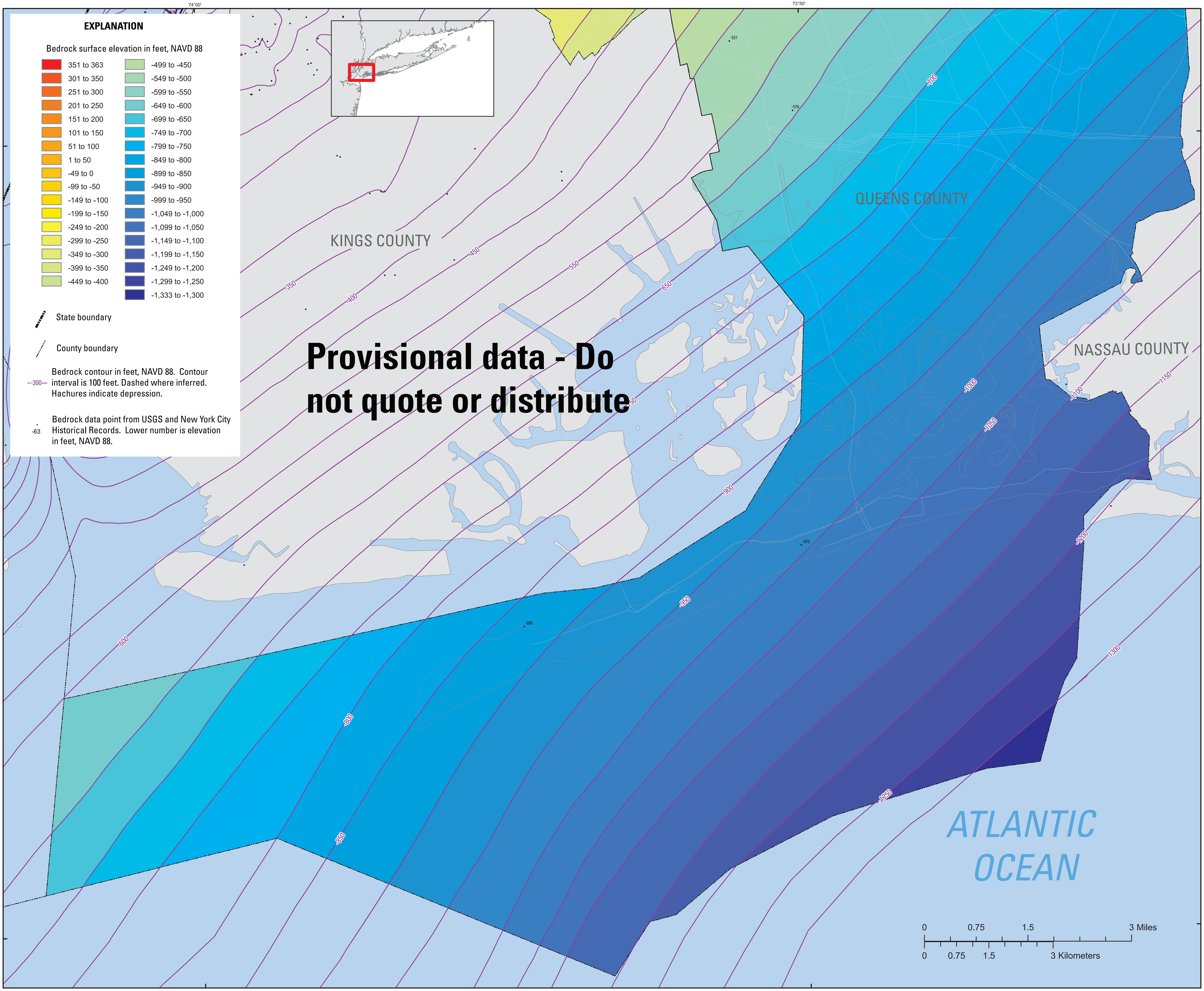

EXPLANATION

Bedrock surface elevation in feet, NAVD 88

🟥	351 to 363	🟩	-499 to -450
🟥	301 to 350	🟩	-549 to -500
🟧	251 to 300	🟦	-599 to -550
🟧	201 to 250	🟦	-649 to -600
🟧	151 to 200	🟦	-699 to -650
🟧	101 to 150	🟦	-749 to -700
🟧	51 to 100	🟦	-799 to -750
🟧	1 to 50	🟦	-849 to -800
🟨	-49 to 0	🟦	-899 to -850
🟨	-99 to -50	🟦	-949 to -900
🟨	-149 to -100	🟦	-999 to -950
🟨	-199 to -150	🟦	-1,049 to -1,000
🟨	-249 to -200	🟦	-1,099 to -1,050
🟨	-299 to -250	🟦	-1,149 to -1,100
🟨	-349 to -300	🟪	-1,199 to -1,150
🟩	-399 to -350	🟪	-1,249 to -1,200
🟩	-449 to -400	🟪	-1,299 to -1,250
		🟪	-1,333 to -1,300

State boundary

County boundary

-300— Bedrock contour in feet, NAVD 88. Contour interval is 100 feet. Dashed where inferred. Hachures indicate depression.

-63 Bedrock data point from USGS and New York City Historical Records. Lower number is elevation in feet, NAVD 88.

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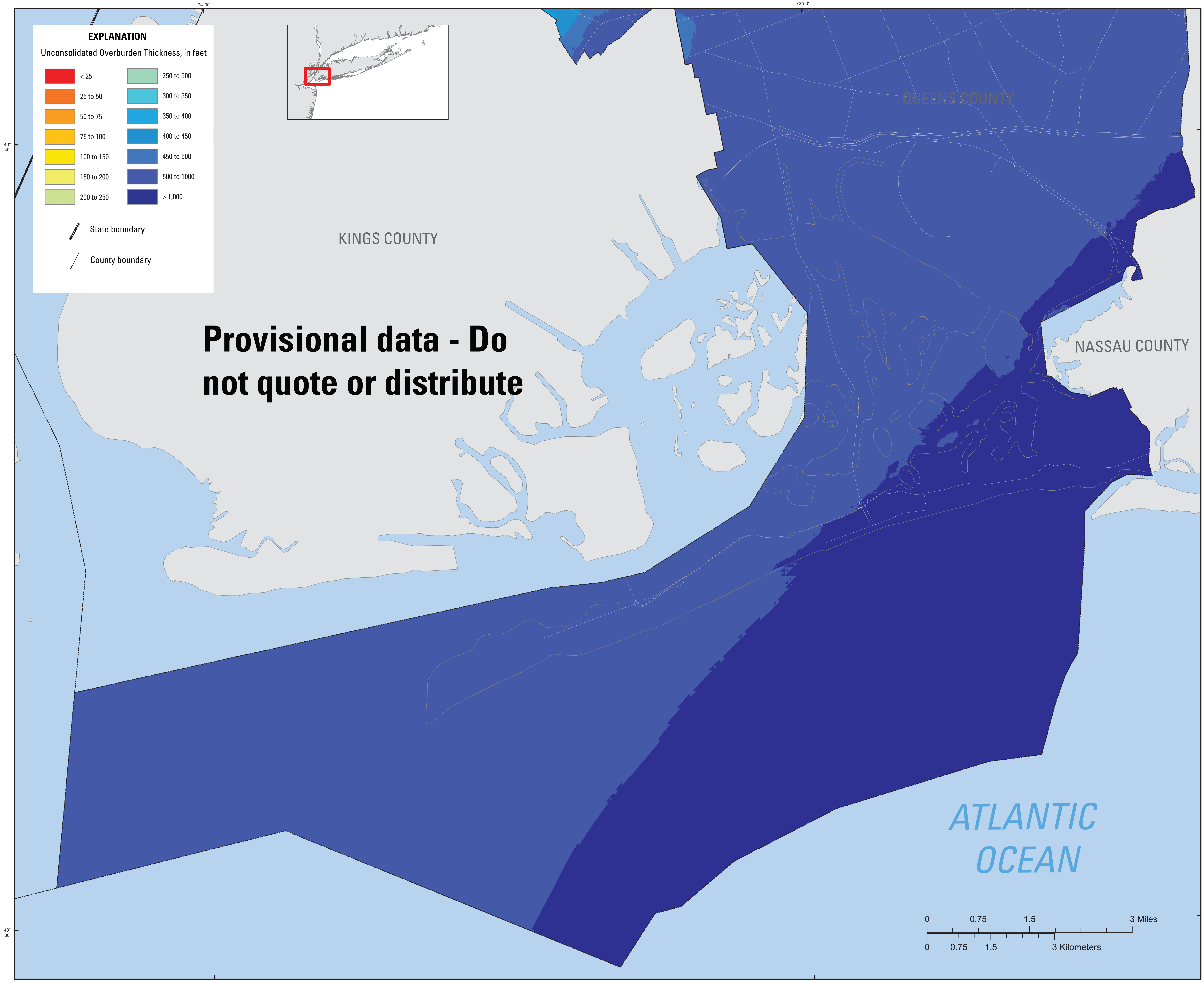

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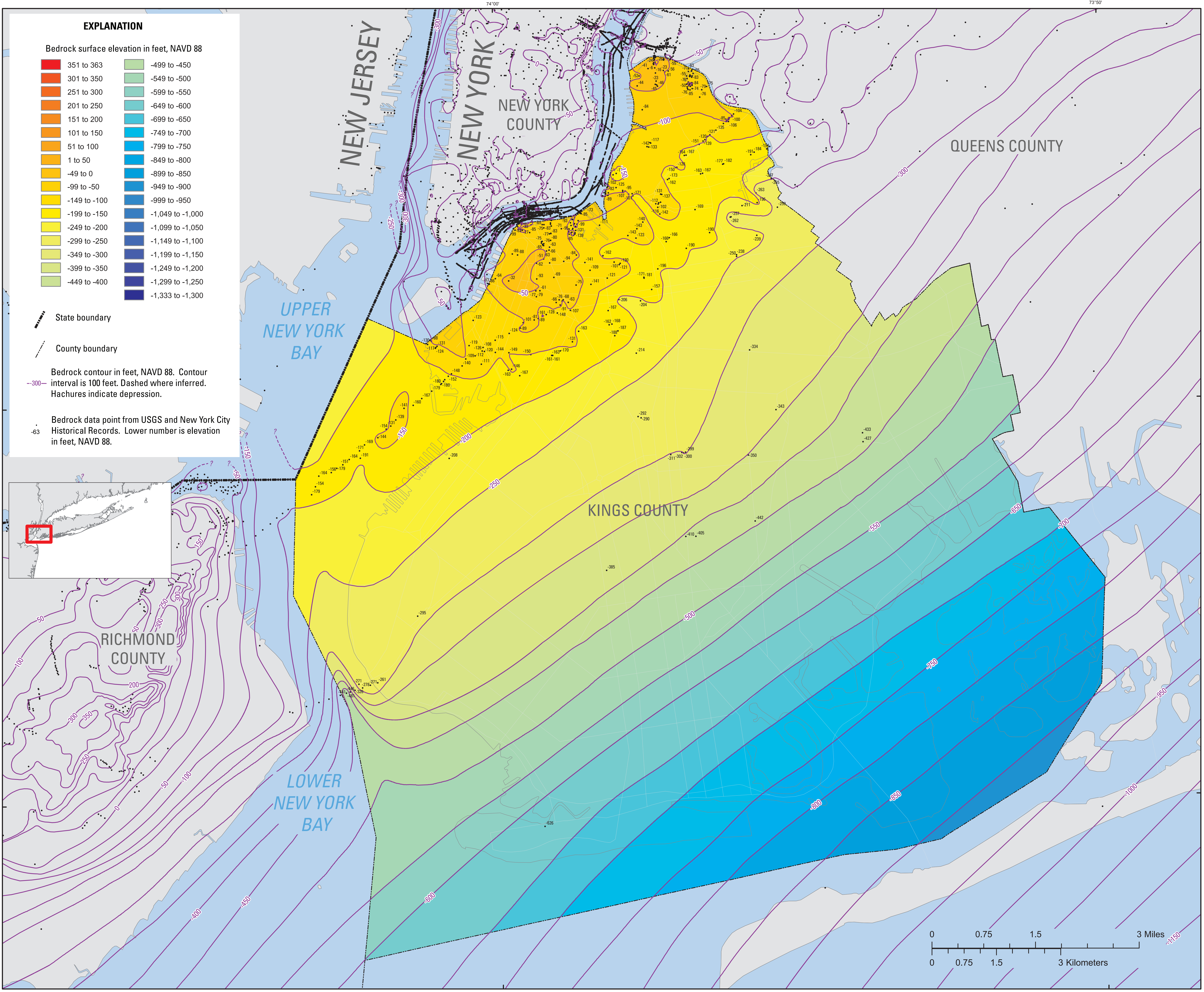

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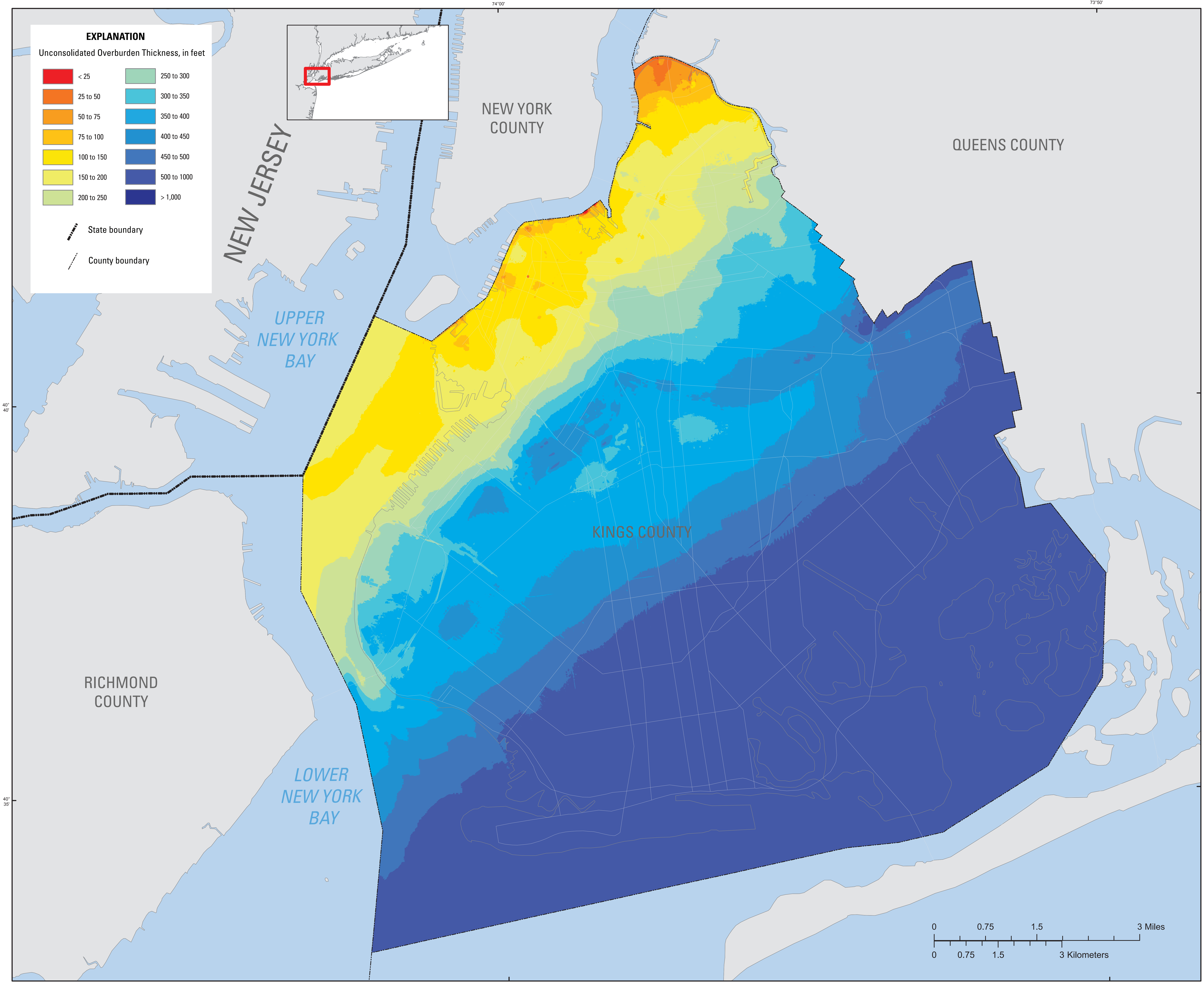

Base digital data NOAA's Medium Resolution 1:70,000 scale Digital Vector Shoreline
Lambert Conformal Conic Projection
North American Datum of 1983

For additional information write to:
Director, U.S. Geological Survey, 2045 Route 112, Coram, NY 11727

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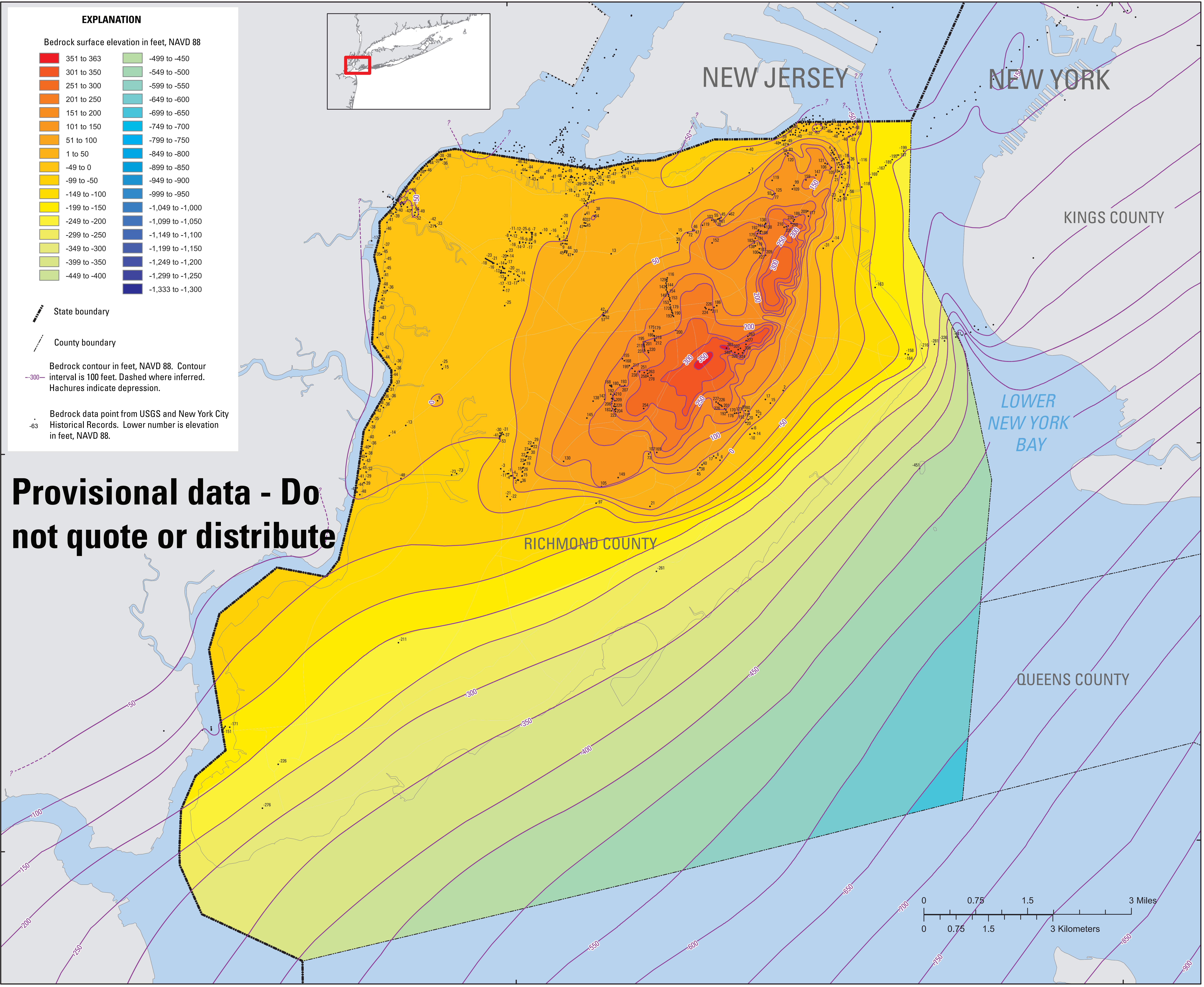

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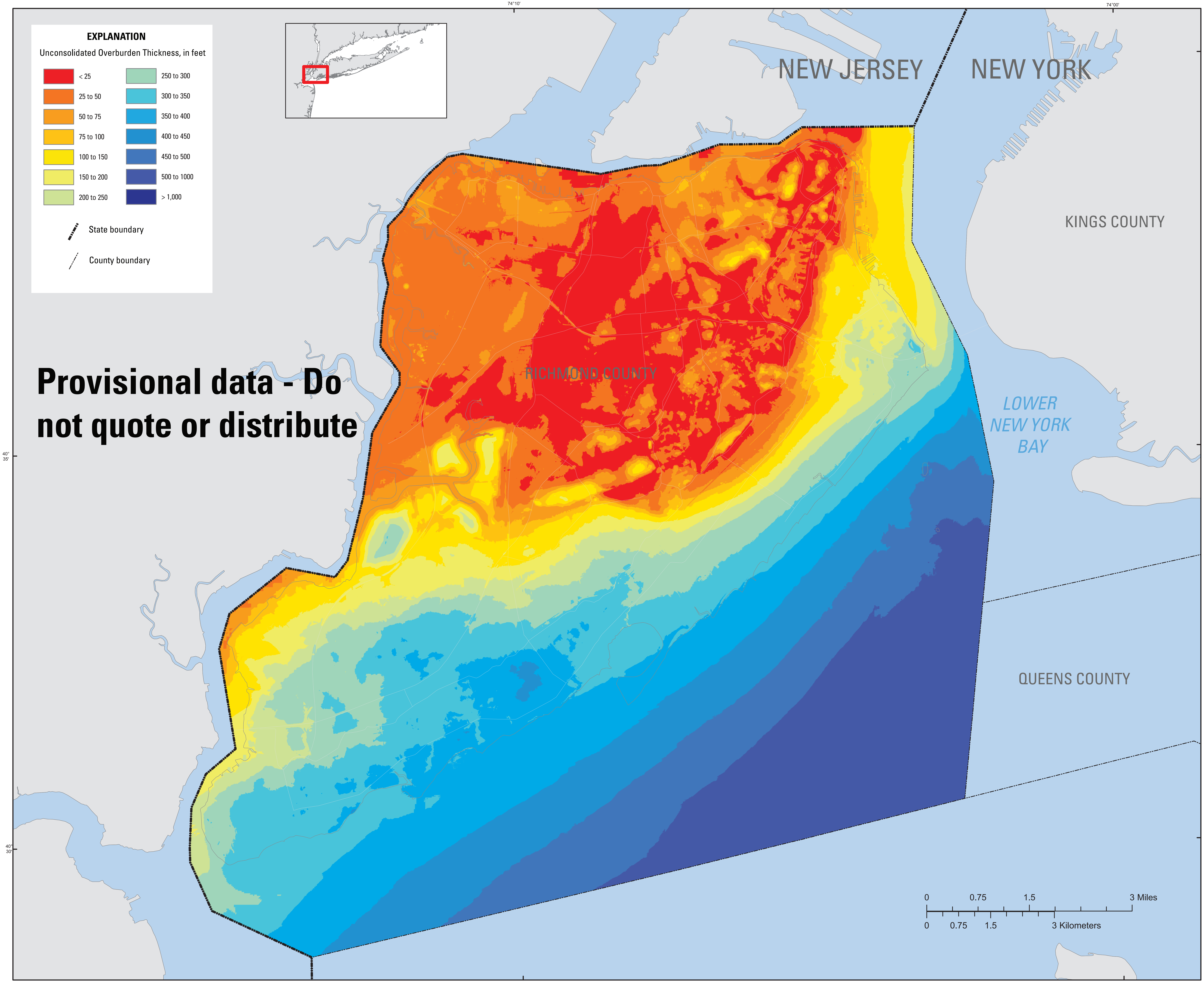

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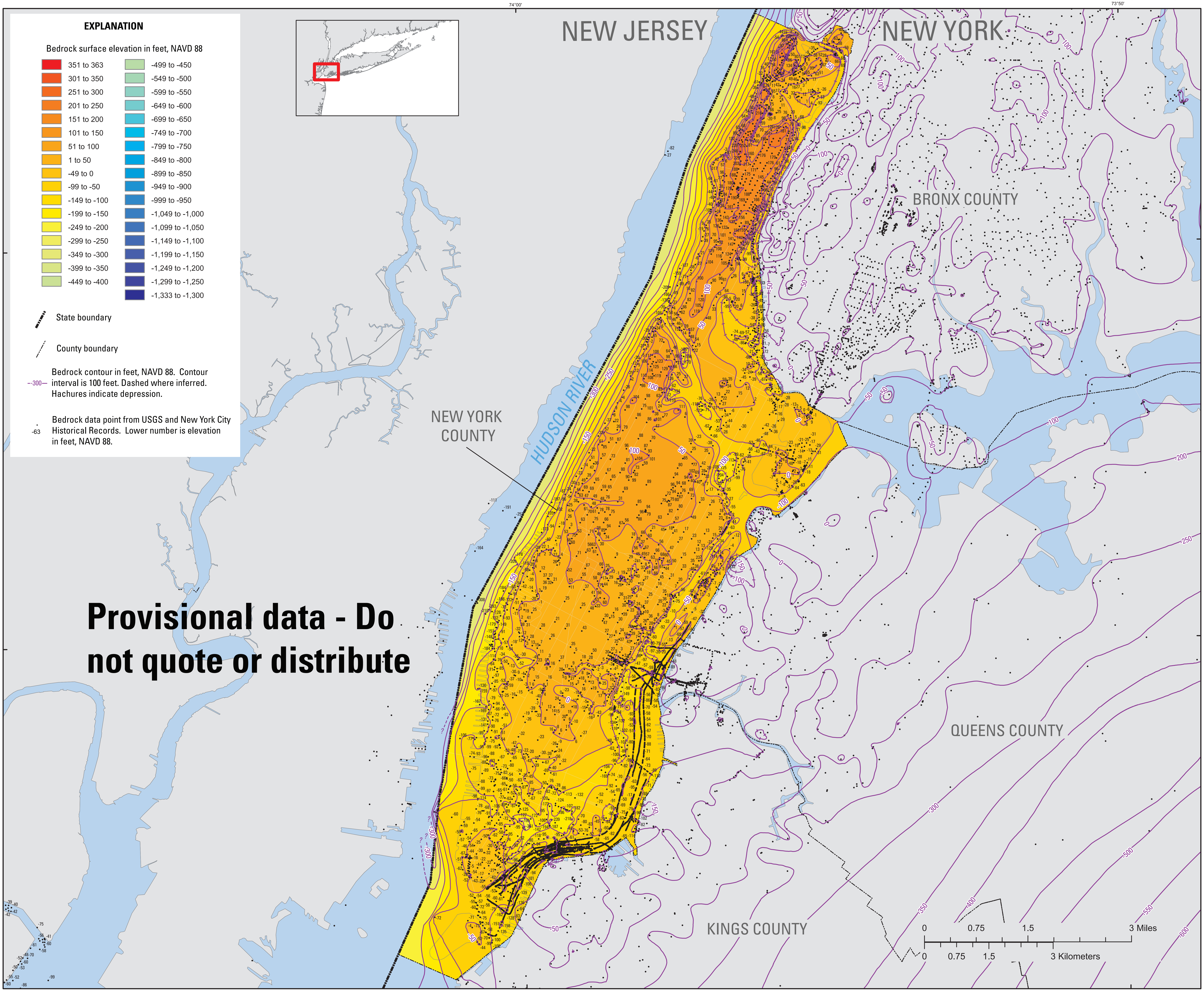

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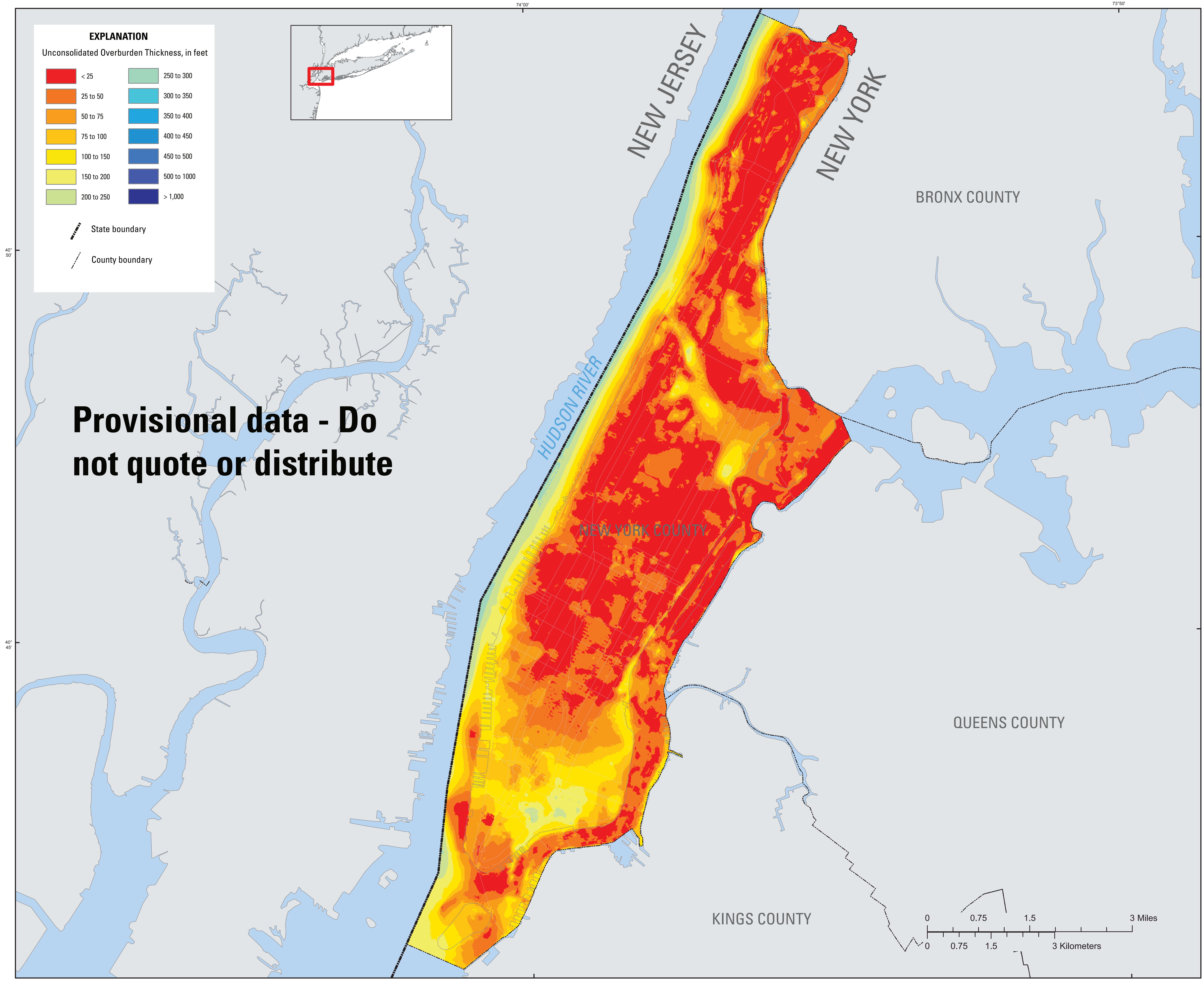

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APPENDIX B

Heating and Cooling Geothermal Retrofit Assessment

Heating and Cooling Geothermal Retrofit Assessment

HVAC System Type	Heating		Retrofit Concept	Heating Efficiency Improvement Opportunity	Heating Implementation Cost		Cooling		Retrofit Concept	Cooling Efficiency Improvement Opportunity	Cooling Implementation Cost
Terminal Units	Terminal Radiators	Hot Water	Geothermal Heat Exchanger coupled with Hot Water / Steam System	N/A (Gas-Fired Heat to Remain)	N/A		Window Unit	Electric Direct Expansion	None - Complete Replacement	High	High
		Steam									
Packaged Terminal Air Conditioner (PTAC)	PTAC	Electric	None - Complete Replacement	High	High		PTAC	Electric Direct Expansion	None - Complete Replacement	High	High
	PTAC	Air Source Heat Pump / Electric	None - Complete Replacement				PTAC	Air Source Heat Pump / Electric	None - Complete Replacement		
	PTAC	Water Source Heat Pump / Electric / Cooling Tower	Geothermal Heat Exchanger coupled with Hot Water / Steam System	Low	Low		PTAC	Water Source Heat Pump / Electric / Cooling Tower	Geothermal Heat Exchanger coupled with Condenser Water System	Low	Low
Packaged HVAC Units	Air Handler	Hot Water	Geothermal Heat Exchanger coupled with Hot Water / Steam System	N/A (Gas-Fired Heat to Remain)	N/A		Air Handler	Air Cooled Electric Direct Expansion	None - Complete Replacement	High	High
		Steam									
		Electric	None - Complete Replacement	High	High						
Central Plant to Distributed Air Handler Units	Boiler	Steam	Geothermal Heat Exchanger coupled with Hot Water / Steam System	N/A (Gas-Fired Heat to Remain)	N/A		Electric Chiller	Air Cooled Condenser	Geothermal Heat Exchanger coupled with Condenser System	Moderate	Moderate
		Hot Water						Water Cooling Tower	Geothermal Heat Exchanger coupled with Condenser Water System	Low	Low
		Steam	Geothermal Heat Exchanger coupled with Hot Water / Steam System	N/A (Gas-Fired Heat to Remain)	N/A		Hot Water Absorber	Air Cooled Condenser	Install a Geothermal Heat Exchanger Condenser System	High	High
		Hot Water						Water Cooling Tower	Geothermal Heat Exchanger coupled with Condenser Water System	Low	Low
		Steam	Geothermal Heat Exchanger coupled with Hot Water / Steam System	N/A (Gas-Fired Heat to Remain)	N/A		Steam Driven Chiller	Air Cooled Condenser	Geothermal Heat Exchanger coupled with Condenser System	High	High
		Hot Water						Water Cooling Tower	Geothermal Heat Exchanger coupled with Condenser Water System	Low	Low
		Steam	Geothermal Heat Exchanger coupled with Hot Water / Steam System	N/A (Gas-Fired Heat to Remain)	N/A		Steam Absorber	Air Cooled Condenser	Install a Geothermal Heat Exchanger Condenser System	High	High
		Hot Water						Water Cooling Tower	Geothermal Heat Exchanger coupled with Condenser Water System	Low	Low

APPENDIX C

ASHRAE Technical Standards and Guidelines

ASHRAE Technical Standards and Guidelines

The American Society of Refrigerating and Air-Conditioning Engineers ("ASHRAE") is the HVAC industry's technical organization. Among many activities, ASHRAE develops and promulgates standards, guidelines, and other important information relating to this technology. The standards that effect geothermal heat pump systems include the following sections:

- ASHRAE 15: Safety Code for Mechanical Refrigerants
- ASHRAE 34: Designation and Safety Classification of Refrigerants
- ASHRAE 62: Ventilation for Acceptable Air Quality
- ASHRAE 90.1: Energy Efficient Design of New Buildings, except Low-Rise Residential Buildings

Geothermal system designers should be familiar with the pertinent sections of these standards for developing geothermal heat pump system projects. With respect to ASHRAE 90.1, this section includes important climatic data in its Appendix C, as well as prescriptive data on energy efficient design.

APPENDIX D

Regulatory Agency Contact Information

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Agency Name	Agency Contact Information
USEPA Region 2	Water Compliance Branch, Groundwater Compliance Section Telephone: 212-637-3766 http://water.epa.gov/type/groundwater/uic/reportingforms.cfm#operators
NYSEDC	Division of Mineral Resources Bureau of Oil & Gas Permitting and Management Telephone: 518-402-8056 http://www.dec.ny.gov/energy/1772.html Division of Water, Region 2 Telephone: 718-482-4947 http://www.dec.ny.gov/docs/permits_ej_operations_pdf/jointapp.pdf
NYCDOT	Division of Franchises, Concessions & Consents Telephone: 212-839-6550 http://nyc.gov/html/dot/downloads/pdf/petitionform.pdf Bureau of Permit Management and Construction Control (Filing Office) Telephone: 212-839-9647 or 9648 Office of Construction Mitigation and Coordination (Technical, MPT Plans) Telephone: 212-839-8968 http://www.nyc.gov/html/dot/html/permits/franinfo.shtml
NYCDEP	Division of Pollution Control and Monitoring (water quality) Telephone: 718-595-4715 Division of Permitting and Connections (water quantity) Telephone: 718-595-5223 http://www.nyc.gov/html/dep/pdf/water_sewer/dewatering_application.pdf
	Bureau of Water and Sewer Operations Telephone: 718-595-5205
NYCDOH	Bureau of Public Health Engineering Telephone: 212-676-1531 http://home2.nyc.gov/html/doh/html/pheng/php33.shtml
NYCT LIRR Metro North PANYNJ	NYCT, Capital Program Management Telephone: 646-252-3673