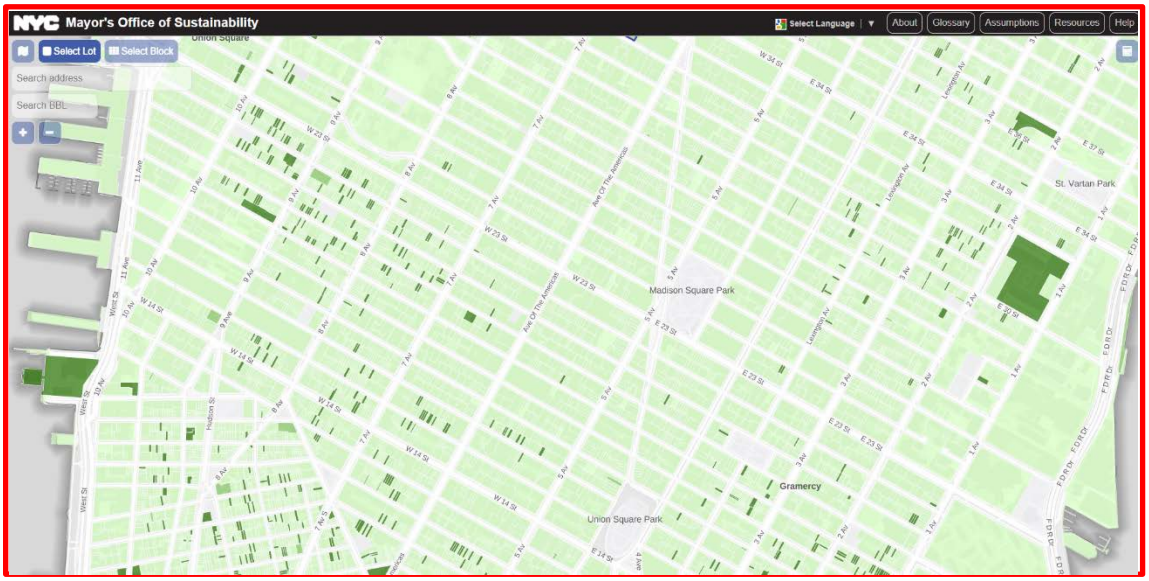
GEOTHERMAL SCREENING WEBTOOL
PRE-FEASIBILITY



NEW YORK CITY
MAYOR'S OFFICE OF SUSTAINABILITY
IN COLLABORATION WITH USGS

Prepared For:

NYC Mayor's Office of Sustainability

NYC DDC Department of Design and Construction

Prepared By:

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PWGC Strategic Environmental Engineering Solutions

Forward

New York City passed Local Law 6 of 2016 that required the City to develop, and make publicly available, a pre-feasibility screening tool to determine the viability of installing a geothermal system for a particular building. Under the guidance of the Mayor's Office of Sustainability (MOS) and Department of Design and Construction (DDC), Goldman Copeland, along with the help of PW Grosser and OverMorgen, created this tool based on professional experience, case studies, and the publicly available geology data from the United States Geological Survey (USGS) and building information. This report serves as a basis of understanding on how the tool was built, how it operates, and what exactly it is meant to accomplish.

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1.0 Executive Summary

The objective of this report is to provide the end user with a clear understanding of the how the tools development methodology and the summary of results found throughout New York City. Overall, three different geothermal systems (closed loop, standing column well, and open loop) were analyzed for potential implementation in comparison to installing a conventional HVAC system. Buildings were categorized into 25 different building types based on vintage, size, and occupancy to establish a baseline for thermal load and the conventional energy consumption. Potential ground thermal capacity was determined by calculating the amount of thermal capacity that could be accessed by wells or loops installed within the available outdoor area on each lot.

Positive results were limited in Manhattan and the Bronx where building loads often exceed the potential thermal capacity accessible using the available outdoor area. Staten Island, Queens, and Brooklyn demonstrate promising results as outdoor area for drilling is much more prevalent and building loads are generally less intense. The majority of commercial buildings were deemed not feasible due to the large cooling load that they require and the limited outdoor area available. Of the feasible lots in New York City the majority were small multifamily buildings or single-family homes where the outdoor space available is sufficient to meet the heating and cooling requirements for those buildings. While our generic installation costs suggested these locations may be feasible, a site-specific review may result in additional costs that negatively impact the payback period of the project. All decisions should be made only after completing an in-depth feasibility study for the site.

Borough	Payback Period	Closed Loop		Standing Column Well		Open Loop	
		# of Lots	% of Lots	# of Lots	% of Lots	# of Lots	% of Lots
Manhattan	< 12 Years	8402	20%	0	0%	73	0%
	< 25 Years	438	1%	10286	24%	6	0%
	≥ 25 Years	33846	79%	32400	76%	42607	100%
Bronx	< 12 Years	68908	77%	0	0%	365	0%
	< 25 Years	2103	2%	6227	7%	4	0%
	≥ 25 Years	18674	21%	83458	93%	89316	100%
Brooklyn	< 12 Years	203626	74%	0	0%	69788	25%
	< 25 Years	4322	2%	3106	1%	176	0%
	≥ 25 Years	68872	25%	273803	99%	206945	75%
Queens	< 12 Years	267253	82%	0	0%	200703	62%
	< 25 Years	11407	4%	3601	1%	43	0%
	≥ 25 Years	45508	14%	320567	99%	123422	38%
Staten Island	< 12 Years	111904	90%	11	0%	51708	42%
	< 25 Years	0	0%	51356	41%	0	0%
	≥ 25 Years	11885	10%	72422	59%	72081	58%

Table 1: *Results for All Five Boroughs in NYC*

The results are explained in more detail throughout this report.

2.0 Background

New York City has committed to reducing its total greenhouse gas (GHG) emissions by 80%, relative to 2005 levels, by 2050 (80 x 50). As described in *New York City's Roadmap to 80 x 50*, meeting heating needs in buildings through the use of heat pump technology is a necessary component in the reduction of our fossil fuel consumption and their associated GHG emissions. One method to efficiently utilize heat pump technology for both heating and cooling is through the use of geothermal systems.

As per Local Law 32 of 2013, the City published *Geothermal Systems and their Application in New York City*, which analyzed the application of geothermal heat pump systems in New York City. This report pointed to the many potential benefits of geothermal systems and their ability to reduce GHG emissions. However, the success of these systems is site-specific and dependent on many variables. Ground source heat pumps should be deployed in the city where they can meet a building's heating and cooling needs cost-effectively.

Following the results of the report, NYC Council passed Local Law 6 of 2016, requiring the City to produce a publicly-available online geothermal heat pump screening tool to provide a threshold assessment of the potential for the use of ground source heat pumps for buildings within New York City.

3.0 Project Overview

The overall purpose of the screening tool is to provide a threshold assessment of the potential for using ground source heat pumps for buildings within New York City. This assessment is based on key known variables, including but not limited to, building thermal demand, land area availability for drilling, and geology at the Borough-Block-Lot (BBL) level. The results provided by the tool are based on a feasibility analysis of three different ground coupling systems (closed loop, standing column well, and open loop) on every building lot. Building owners or other interested parties can choose the location of their building on a web based map which will provide them with a simple payback period to guide them in a decision to fully review project cost, savings, and feasibility.

It is important to note that the tool is limited by the wide variety of actual building stock in New York City and therefore cannot be taken as a guarantee that a geothermal system is feasible. In addition, subsurface geologic conditions beneath a BBL are uncertain without actual drilling and can vary from the inferred mapped conditions thereby affecting system feasibility. Detailed descriptions and information on the evaluation, design and operation of GHPs is provided in DDC's *Geothermal Heat Pump Manual: A Design and Installation Guide for New York City*, (Geothermal Heat Pump Manual) (2013).

4.0 Methodology Summary

The methodologies for the calculations are summarized below.

4.1 Geological and Technical Suitability

Each lot first underwent a "geologic suitability" test, whereby a determination was made of which geothermal systems are suitable based on the underlying geologic and hydrogeologic conditions available from the USGS. Then, for each

geothermal system that is geologically suitable, its "technical suitability" was determined. Technical suitability reviews the lot specific conditions that affect overall thermal capacity and project costs. If either of these criteria are not met the lot is deemed not suitable.

The assumptions for geologic and technical suitability are summarized in Table 2 below along with the default depths for wells and loops used in the tool.

	Closed Loop	Standing Column Well (SCW)	Open Loop
Default Depth	500 ft., deeper depths require obtaining NYSDEC mining permit	1,500 ft., standard SCW depth in NYC	Depths variable depending on geologic conditions
Geologic Suitability Assumptions	Suitable everywhere, can be installed in both bedrock and unconsolidated geologic deposits	Suitable where DTB is less than 150 ft. and DTW is less than 100 ft.	Suitable where lot overlies a sand and gravel aquifer (not bedrock) and DTW is less than 100 ft.
Technical Suitability Assumptions	Suitable but unit thermal capacity is lower where the Lloyd aquifer exists less than 500 ft. deep.	Suitable but potentially costly where DTB is between 100 and 150 ft.	Suitable where lot is large enough to space out supply and diffusion wells, and there is sufficient outdoor area to install wells

Table 2: *Geologic and Technical Suitability Assumptions*

4.2 Ground Thermal Capacities

If a lot passed the geologic and technical suitability tests, the tool calculated its ground thermal capacity and carried it through subsequent calculations. Ground thermal capacities were determined by:

1. Establishing the thermal capacity of a standard individual loop or well for each of the geothermal systems using standard industry values and local experience as referenced in the DDC *Geothermal Heat Pump Manual.*[1]
2. Calculating unit ground thermal capacities in Btus per square foot (sf) over the estimated area of influence of an individual loop or well.
3. Calculating the outdoor area available for the installation of the ground coupling of each type of geothermal systems for each building lot by using block and lot size, and building footprint and square footage data from Primary Land Use Tax Lot Output (PLUTO).
4. Multiplying the unit ground thermal capacities by the outdoor area.

4.3 Building Demand versus Available Ground Thermal Capacity

For each suitable system type on a lot, the first test for feasibility was to determine if the geothermal ground coupling could access ground thermal capacity in the available outdoor area that is close to or exceeds the building's peak and annual heating and cooling loads. This feasibility was determined by:

[1] Nominal capacities are 25 tons per 1,500 ft. deep standing column well, 2.86 tons of heating/cooling capacity per 500 ft. deep closed loop borehole (1 ton per 175 linear feet), and 1 ton of heating/cooling capacity per 2-3 gallons per minute of groundwater flow from an open loop supply well.

1. Determining the approximate building annual heating and cooling loads based on building size, type, and vintage.
2. Determining the dominant load (heating or cooling).
3. Comparing the ground thermal capacity with the building dominant load to determine if sufficient capacity is available, and if annual heating/cooling loads are sufficiently balanced.
4. Reviewing the potential to use a hybrid system to achieve balance if required.

4.4. Economic Feasibility

Where sites were deemed to be feasible as above for a geothermal system, further review was completed to determine economic feasibility of the system as follows:

1. All economic evaluations were completed based on the assumption that the building was planning a full heating/cooling system upgrade. As such, baseline evaluations were completed for each building type, size, and vintage based on current standard, code compliant systems.
2. Sample building baselines were developed to estimate energy consumption and installation costs for standard systems, and applied to all buildings.
3. Based on the ground thermal capacity calculations as described above, and typical geothermal systems, energy consumption, and installation costs were developed and applied to all buildings where these systems were feasible.
4. Annual tons of carbon dioxide equivalent (CO2e) was calculated based on baseline energy usage versus the geothermal systems. Site to source ratios for electricity and other utilities were used to assure the full scope of GHG emissions was accounted for.
5. Price comparisons were completed based on energy savings with the geothermal system, comparative maintenance costs, a carbon credit as determined by the MOS, and anticipated installation costs.
6. An incremental simple payback period was determined for replacement of the existing system with a geothermal system versus a typical system, and a general recommendation was provided based on these findings.

5.0 Screening Tool Functionality

All analysis completed as a part of this project were then exported to a web-based map for public access. The map enables the user to access the following information upon selection of any lot or building in New York City:

1. Basic lot/building information including lot size, building indoor area (SF), building footprint (SF), and building type for confirmation.
2. Geological/technical feasibility of each geothermal system types.
3. Depth to bedrock (all boroughs) and depth to groundwater (all boroughs, excluding Manhattan and Bronx).
4. Carbon footprint reduction and cost savings with installation of geothermal.

5. Simple payback period analysis based on energy savings and initial costs associated with installation of geothermal, with and without the carbon credit.
6. An option to override basic building information including building type, footprint, and square footage is also included; the tool re-runs the calculations and provides an output for the new building.
7. As is noted within the tool, all findings are preliminary and should not be taken as a guarantee that a full study will determine installation of a geothermal study to be feasible.

As mentioned above, in addition to enabling users to asses existing buildings for geothermal, an override function is available to enable users to investigate the possibility of installing geothermal systems with new construction for any lot or combination of lots in the city.

6.0 Assumptions and Conditions

A number of caveats must be attached to the results. First, all space not occupied by the building was assumed to be available and accessible for the installation of the geothermal system. This may not always be the case. Further evaluation is necessary to ensure that the land is not archeologically significant, protected marshland, or contaminated. The City's critical infrastructure, such as water tunnels, shafts, or appurtenant facilities are regulated by the New York City Department of Environmental Protection ("DEP"). DEP is in the process of promulgating rules to require that any boring, drilling or excavation to a depth of 50 feet in the borough of the Bronx or north of 135th Street in the borough of Manhattan or to a depth of 100 feet in any other location / borough in New York City first be reported to DEP. Please send written notification of intention to drill or excavate to: Chief of Site Connection and Plan Review, Bureau of Water and Sewer Operations, 9605 Horace Harding Expy, 3rd Floor, Flushing, NY 11368-4100.

Second, economic analysis was a comparison between the installation of a geothermal system and the installation of an energy code compliant high efficiency centralized system. However, both system types may be beyond the financial capacity of some building owners. With incentives in place to support the installation of geothermal systems, a full economic analysis should be completed in advance of any decision.

Other consideration in implementing a geothermal system might include preserving building aesthetics or making a statement for clean energy as a public relations initiative. As such, in addition to economic feasibility, the final tool presents the user with technical and geological feasibility. This provides the end user with the option of pursuing a geothermal solution where it may not be viable to install a cooling tower on the roof or a boiler in the basement. The geothermal systems perform all heat rejection and absorption within the ground and utilize minimal building square footage which is appealing to buildings that suffer from the constraints mentioned above.

Further details of the analysis process are described in the sections below.

6.1 Mechanical Systems

As mentioned previously in this report, the mechanical systems proposed for the conventional systems were assumed to be energy code compliant high efficiency centralized systems. Although the existing buildings may not currently have a centralized system (i.e. window units or no air conditioning at all), the only way to justify the economic cost of installing a geothermal system was to compare it with a full renovation of the HVAC system in

the building. For the 25 building types, as defined by the Technical Working Group, three conventional cooling systems and four conventional heating systems were analyzed and applied to the appropriate buildings.

For cooling, a cooling tower and heat pump system was the most comparable technology to a geothermal system and that is what was used for the large multifamily and NYCHA buildings. Similarly, for commercial buildings, the conventional system was assumed to be a cooling tower with packaged AC units. Although buildings normally have a chiller to perform cooling in the summer, packaged AC units were used for ease of comparison with geothermal heat pump systems as the refrigeration cycle is similar throughout and the relevant piece of equipment is the cooling tower which is performing the heat rejection. The smaller multifamily, K-12 schools, and single-family buildings were the only building types assumed to use air cooled packaged units. These units are less efficient than the water cooled packaged units and therefore an air-cooled kW/ton penalty was attributed to the energy consumption. Warehouses were assumed to not have any cooling equipment.

Heating was assumed to be heating hot water throughout with the only difference being the type of boiler being used. In Manhattan, commercial buildings that were greater than 7 stories and built before 1980 were assumed to utilize district steam and a heat exchanger to produce heating hot water. In the remaining boroughs, it was assumed that a condensing boiler would be used. Condensing boilers were used for the majority of the building types, minus K-12 schools and warehouses which used standard boilers. NYCHA buildings were assumed to utilize steam boilers as is common in most NYCHA buildings currently. It should be noted that because warehouses were considered heated but not cooled they were immediately disqualified from the feasibility study as their heating and cooling balance would not work.

See Table 3 below for full breakdown.

Building Type	Building Description	Cooling System	Heating System
C1	Commercial, Post-1980 > 7 Stories	Cooling Tower + Packaged AC Units	Condensing Boiler
C2	Commercial, Post-1980 up to 7 Stories	Cooling Tower + Packaged AC Units	Condensing Boiler
C3	Commercial, Post-war > 7 Stories	Cooling Tower + Packaged AC Units	Condensing Boiler (District Steam in MN)
C4	Commercial, Post-war up to 7 Stories	Cooling Tower + Packaged AC Units	Condensing Boiler
C5	Commercial, Pre-war > 7 Stories	Cooling Tower + Packaged AC Units	Condensing Boiler (District Steam in MN)
C6	Commercial, Pre-war up to 7 Stories	Cooling Tower + Packaged AC Units	Condensing Boiler
C7	Commercial, Very Large	Cooling Tower + Packaged AC Units	Condensing Boiler
IN1	Hospital and Health Facilities	Cooling Tower + Packaged AC Units	Condensing Boiler
IN2	Institutional General	Cooling Tower + Packaged AC Units	Condensing Boiler
IN3	K-12 Schools	Packaged Air Cooled AC Units	Standard Boiler
IN4	Religious	Cooling Tower + Packaged AC Units	Condensing Boiler
IN5	University	Cooling Tower + Packaged AC Units	Condensing Boiler
MF1	Multifamily, Post-1980 > 7 Stories	Cooling Tower + Heat Pumps	Condensing Boiler
MF2	Multifamily, Post-1980 up to 7 Stories	Split System AC Units	Condensing Boiler
MF3	Multifamily, Post-war > 7 Stories	Cooling Tower + Heat Pumps	Condensing Boiler
MF4	Multifamily, Post-war up to 7 Stories	Split System AC Units	Condensing Boiler
MF5	Multifamily, Pre-war > 7 Stories	Cooling Tower + Heat Pumps	Condensing Boiler
MF6	Multifamily, Pre-war up to 7 Stories	Split System AC Units	Condensing Boiler
MF7	Multifamily, Very Large	Cooling Tower + Heat Pumps	Condensing Boiler
NYCHA	New York City Housing Authority	Cooling Tower + Heat Pumps	Steam Boiler
SF1	1 - 4 Family, Free Standing Wood Frame	Split System AC Units	Condensing Boiler
SF2	1 - 4 Family, Row House, Masonry	Split System AC Units	Condensing Boiler
W1	Warehouse/Factory > 3 Stories	-	Standard Boiler
W2	Warehouse/Factory up to 3 Stories	-	Standard Boiler
W3	Transportation, Garages, and Utilities	-	Standard Boiler

Table 3: *Building Type Conventional System Breakdown*

7.0 Geothermal Heat Pumps (GHP) Systems Review

Geothermal Heat Pump (GHP) systems are a growing sector in the space conditioning market as energy efficiency has become a critical issue in building operations. GHPs have been successfully operated for decades in virtually every building type for both heating and cooling. However, within New York City, GHP use has been limited by a number of factors, including the geology of the city, the density of its buildings, and the high cost of construction.

While there are three types of systems considered in this study (closed loop, standing column well, and open loop), all three provide the same function within the building. Each system extracts heat from the ground in the winter to provide space heating, and rejects this heat back into the ground in the summer to provide cooling. This is typically accomplished with water as the medium of heat transfer. The water is delivered to heat pumps throughout the building where, with the use of a typical refrigeration loop, air is conditioned for delivery to the building. The main difference between the three systems is the ground coupling, or the arrangement of piping and fluid handling equipment depending on the geology of the earth. For more information on each type of system and their application in New York City, please refer to the *Geothermal Heat Pump Manual* and *Geothermal Systems and their Application in New York City*, respectively.

7.1 Hybrid Systems

All three of the systems can be used with supplemental heat rejection provided by cooling towers or supplemental heat supply by condensing boilers. Both can be used in conjunction when peak heating and cooling loads are not quite met by the geothermal capacity or where the heating/cooling balance is greater than acceptable. For the purposes of this tool it was assumed that if the heating/cooling balance is greater than 30% than a hybrid system was necessary. After a more precise site-specific feasibility study is completed, it may be necessary to utilize a hybrid system even with a closer balance. This increases system cost, but may still be economical in some cases.

8.0 Geology and Geothermal Capacities

The viability of geothermal systems on a lot and the type(s) of ground coupling that is suitable depends on the underlying geological conditions. Larger versions of the maps included in the section can be found in Appendix D.

8.1 Geologic Data and Mapping

As part of an ongoing mapping project, the USGS compiled geologic data from several City agencies into a preliminary GIS database that was used in the screening tool. The data provided by USGS were for depth to bedrock and depth to groundwater. Published USGS data for the Lloyd Aquifer in Brooklyn and Queens was also incorporated into this tool. Limitations associated with this aquifer are addressed below in this report.

Depth to Bedrock

Depth to bedrock (DTB) was one of two criteria used to delineate the geologic suitability of standing column wells (SCWs). Figure 1 indicates DTB throughout the city.

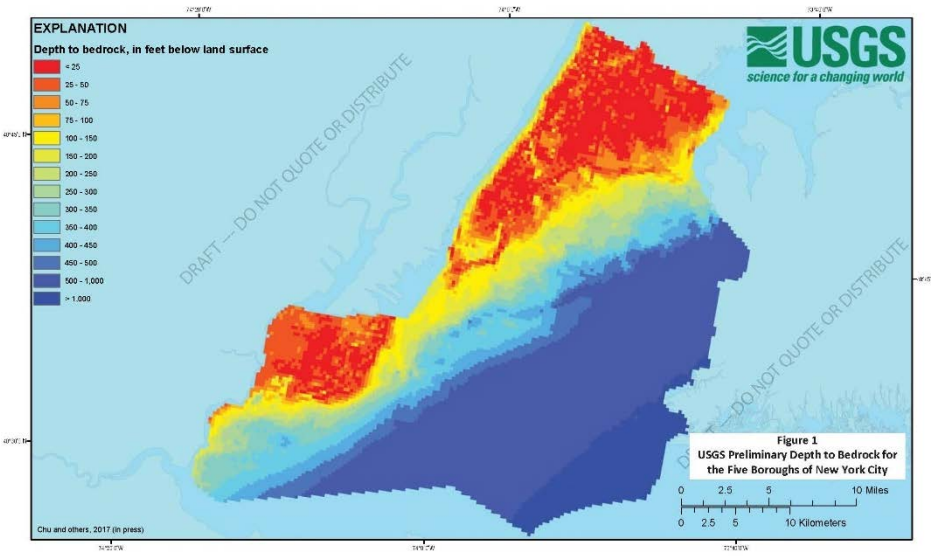


Figure 1: *USGS Preliminary Depth to Bedrock for the Five Boroughs of New York City*

Depth to Water

Depth to water (DTW) was the second criteria used to delineate the geologic suitability of SCWs, and one of two criteria used for the open loop system. At the time of publication, data was only available for Staten Island, Brooklyn, and Queens. Data for Manhattan and the Bronx is limited. Figure 2 is the DTW map provided by USGS.

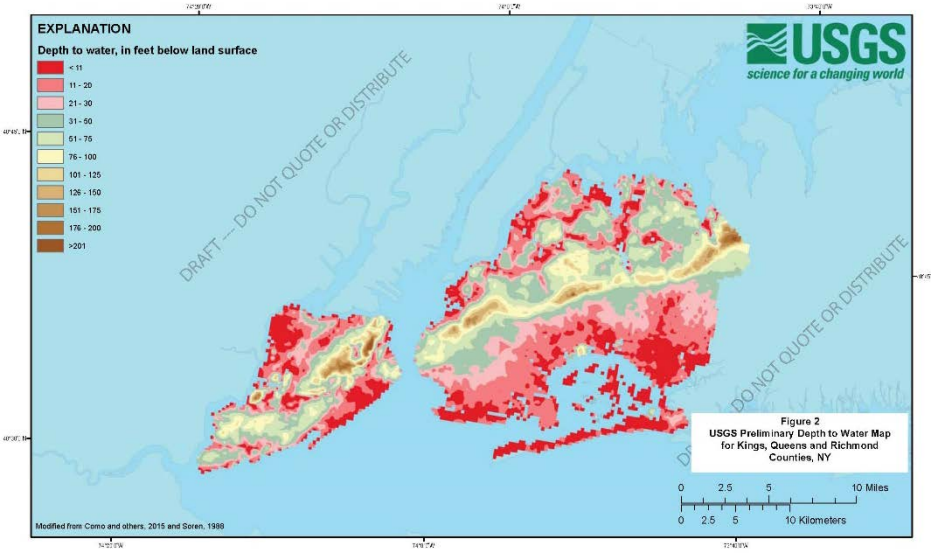


Figure 2: *USGS Preliminary Depth to Water Map for Kings, Queens, and Richmond Counties, NY*

Depth to Lloyd Aquifer

The Lloyd is a protected aquifer that is reserved for usage only by coastal communities in Nassau and Suffolk Counties. Depth of the top of this aquifer varies, and in some areas, falls within the typical depth for open loop and closed loop systems. The New York State Department of Environmental Conservation (NYSDEC) has imposed a moratorium on any new wells being installed in this aquifer. In addition, drilling into this protected aquifer is not permitted. All references in this study to the top of the Lloyd aquifer are for estimation of the maximum depth available for geothermal applications and is not an endorsement to drill into the Lloyd aquifer by NYC. It is highly recommended that project managers research the hydrogeology carefully in the area of their projects and review any planned drilling to insure a safety factor of at least 50 feet above the estimated depth to the top of Lloyd aquifer. The estimated depths presented in this report are estimates since the hydrogeology in parts of NYC can be highly variable and complex. Figure 3 indicates the extent of the Lloyd Aquifer and the depth to the top of the Lloyd. This figure also presents the areas where the Lloyd Aquifer exists with estimated iso-contour lines. Due to the limitations on the mapping data, care should be taken that these are estimates of the depth to the top of the Lloyd aquifer

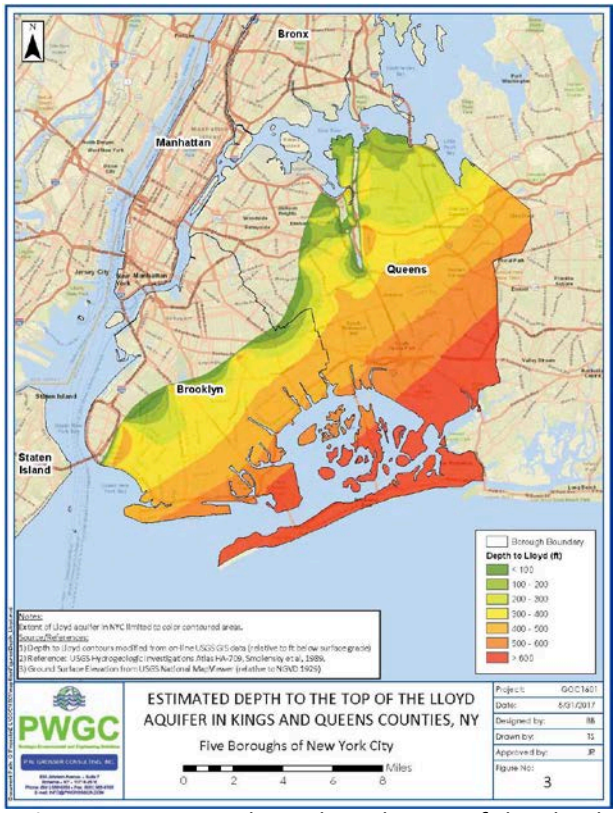


Figure 3: *Estimated Depth to the top of the Lloyd Aquifer in Kings and Queens Counties, NY*

Using the updated USGS data and information developed in the *Geothermal Heat Pump Manual*, criteria was established where the "geologic suitability" and "technical suitability" of a geothermal system on a lot can be determined. If a site passes the geological suitability test, it proceeds to the technical suitability test. If a site also passes that test, it proceeds to the ground thermal capacities calculation and calculations developed related to the feasibility to meet the building demand or not, etc.

The approach and assumptions for determining geologic suitability, technical suitability, and ground thermal capacity are discussed below for each system type.

8.2 Geologic Suitability

Geologic suitability is described below by GHP type and is illustrated in Figures 4, 5, and 6. These maps are updated versions found in the *Geothermal Heat Pump Manual*. More detailed information on geothermal systems and their suitability to geology is presented in the *Geothermal Heat Pump Manual*.

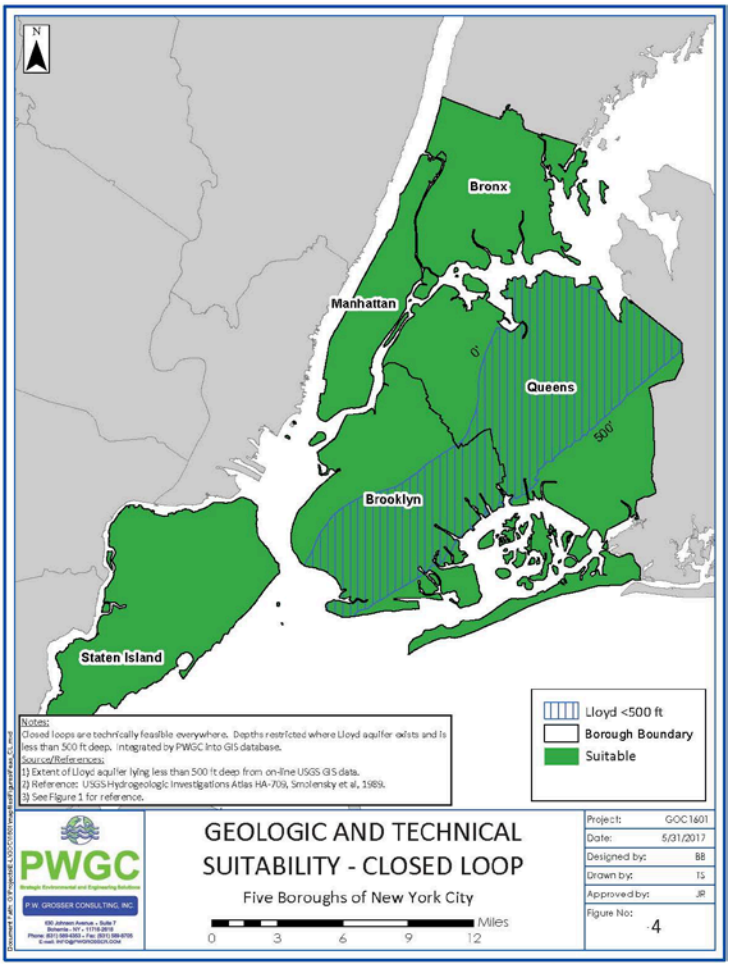


Figure 4: *Closed Loop Suitability*

Closed Loop

Only vertical, closed loop systems were evaluated for the screening tool, per Local Law 6 of 2016 requirements. Closed loop systems are not dependent on the presence of groundwater and can be installed in both unconsolidated geologic deposits as well as bedrock. Therefore, closed loop systems are geologically suitable throughout the city (Figure 4).

Standing Column Wells

A SCW is designed to be installed predominantly in bedrock rather than unconsolidated deposits. A steel, 'surface casing' for a SCW is required to extend a minimum of 75 ft. into competent bedrock as per NYSDEC regulations and as cited in the *Geothermal Heat Pump Manual.* [2] Below this depth, the well is a self-supporting, uncased open borehole. If the DTB is greater than 150 ft., the high cost for additional steel casing becomes cost prohibitive.[3]

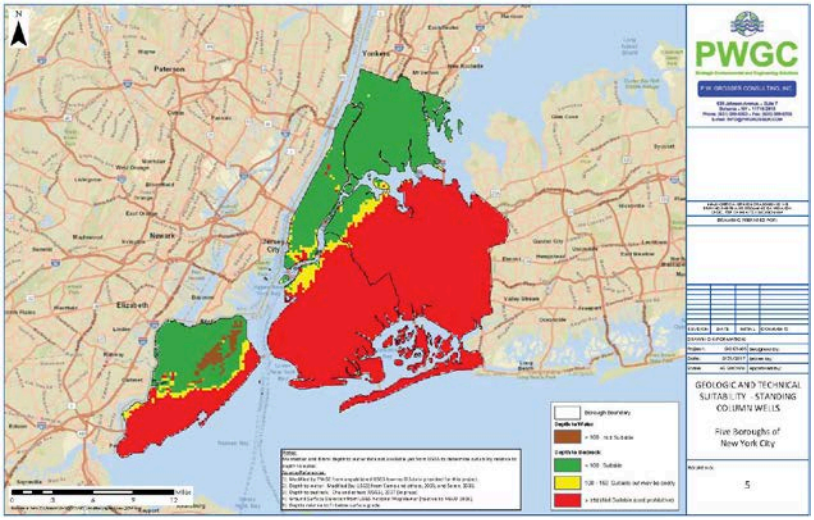


Figure 5: *Standing Column Well Suitability*

Therefore, for the tool, SCWs are geologically suitable where the DTB is less than 150 feet (see Figure 5 developed by PWGC from the preliminary GIS DTB data provided by the USGS). A second test of geologic suitability for SCWs was applied if

[2] NYSDEC routinely accepts waivers of 50 ft. into bedrock.

[3] The *Geothermal Heat Pump Manual* states that the installation costs for SCWs increases as DTB increases above 100 ft. and is cost-prohibitive above 150 ft.

the lot passed the DTB test. Where DTW is greater than 100 ft., SCWs are not geologically suitable due to the high cost of pumping groundwater to the building.

Open Loop

Open loop systems are geologically suitable where permeable unconsolidated deposits exist, e.g., sand and gravel aquifers. These aquifers have been extensively mapped by USGS. Figure 6 shows the areas where these aquifers exist throughout the city and open loop systems may be suitable. The thickness, depth, yield, and water quality of these aquifers vary significantly from one area to another.

An open loop system also requires DTW to be less than 100 ft., consistent with the *Geothermal Heat Pump Manual,* before proceeding to the technical suitability test and beyond.

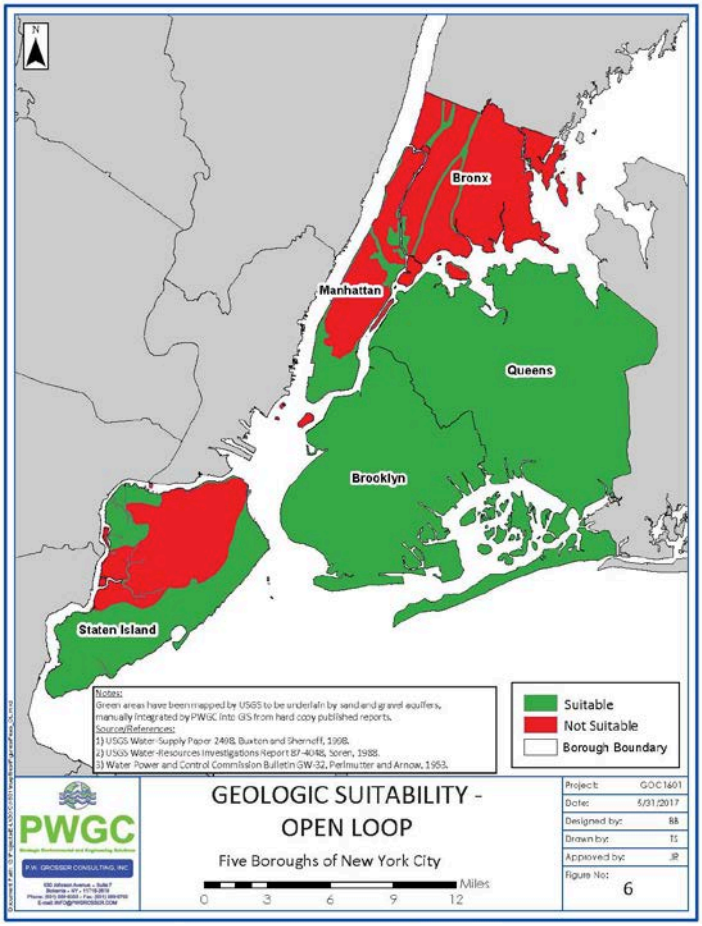


Figure 6: *Open Loop Suitability*

8.3 Technical Suitability

If a geothermal system is geologically suitable for a lot, a second test is run to determine if it is "technically suitable."

These criteria are explained below by system type and technical suitability is illustrated in Figures 4, 5, and 7. System technical suitability is discussed in more detail in the *Geothermal Heat Pump Manual*.

Closed Loop

The thermal capacity of a closed loop borehole is primarily dependent on the depth of each loop. At depths greater than 500 feet a NYSDEC mining permit is required. Obtaining this permit is potentially time-consuming and costly. Therefore, virtually all closed loop projects terminate at 500 ft. or less, and 500 ft. is the default depth in the tool.

Some closed loops may be less than 500 feet in areas where the Lloyd Aquifer exists; therefore, shallower borehole (loop) depths will result in a lower unit thermal capacity per loop. The unit thermal capacity of a 500-foot-deep closed loop is 2.8 tons/loop, or 33.6 kBtu/loop. Where the Lloyd aquifer is absent, or deeper than 500 feet beneath a lot, the unit thermal capacity per loop was applied. Where the top of the Lloyd is shallower than 500 feet, the thermal capacity of the loops on the lot were reduced proportionally.

Figure 4 indicates the extent of the Lloyd aquifer and where it is shallower than 500 feet deep; boreholes on lots that fall within the cross-hatched area will have a lower thermal capacity than the standard borehole because shallower boreholes will provide less thermal capacity.

Standing Column Wells

The SCW depth in the tool was set at 1,500 ft., which is the typical depth of wells installed in the city and as cited in the *Geothermal Heat Pump Manual*. Unlike closed loop boreholes, permits and approvals are required to drill SCWs, including the NYSDEC mining permit noted above under closed loop.

The *Geothermal Heat Pump Manual* states that SCWs are feasible where DTB is less than 100 ft. deep, and both cost-prohibitive and technically infeasible (i.e., cannot physically be constructed) where DTB exceeds 200 ft. Between 100 and 200 ft. the cost of SCWs increases as depth increases. In the tool, SCWs are technically suitable where DTB is less than 150 ft. deep, however, the end user should be aware that installation costs may be higher than the tool presents where the DTB exceeds 100 ft.

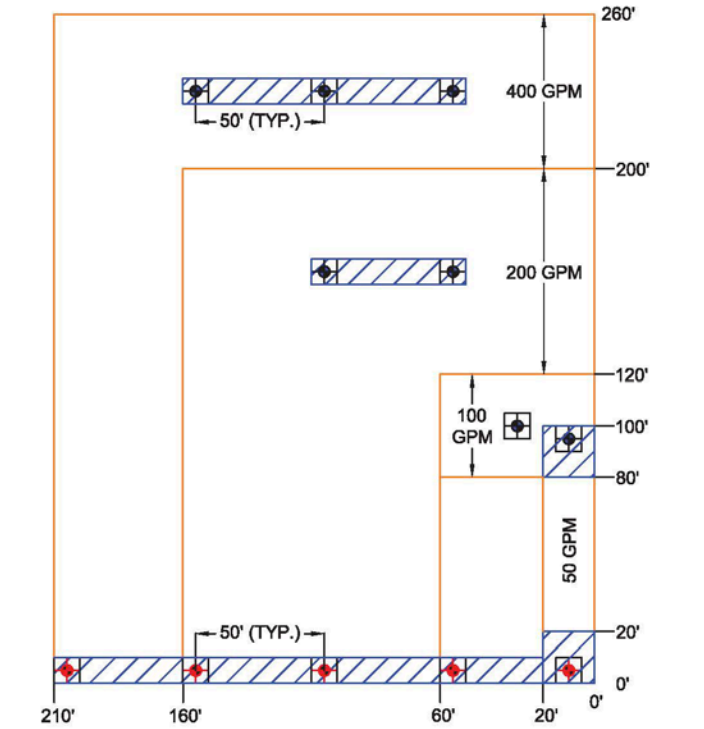
Figure 5 on page 13 delineates three areas, where DTB is less than 100 feet (green), between 100 feet and 150 feet (yellow), and greater than 150 feet (red).

Open Loop

Proper spacing is required between the supply and diffusion wells of an open loop system to avoid thermal interference, a condition by which the thermally-altered water is drawn back into the supply wells. Additionally, sufficient spacing is required between individual supply wells, and individual return wells, to avoid hydraulic interference between the wells creating an excessive "drawdown" or "mounding" effect near each well.

These criteria are lot-specific, in contrast to geology-specific for closed loop and SCW systems. Therefore, there is no map of technical suitability. Instead, Figure 7 illustrates the minimum outdoor area and lot size thresholds for systems of various demand ranges. Calculations using these requirements were completed through ArcGIS to determine technical suitability for individual lots.

FIGURE 7
OPEN LOOP TECHNICAL SUITABILITY



MINIMUM LOT SIZE AND OUTDOOR AREA REQUIRED FOR OPEN LOOP WELL SYSTEMS

LEGEND

SUPPLY WELL

RETURN WELL

MINIMUM OPEN OUTDOOR AREA REQUIRED FOR DRILL RIG ACCESS (AND FUTURE WELL MAINTENANCE)

0 50 100

SCALE: 1" = 50'

Open Loop - Technical Suitability

Dominant Demand (tons)	Dominant Demand (kBTU)	Flow (gpm)	No. of Wells (@50-135 gpm cap.)		Outdoor Area Minimum (sf)	Lot Area Minimum (sf)
			SW	RW		
0-25	0-300	Up to 50	1	1 [1]	800	1,900 [1]
25-50	300-600	50 - 100	1	2	800	4,800
50-100	600-1,200	100-200	2	4	2,500	7,200
100-200	1,200-2,400	200 - 400	3	5	3,200	32,000
>200	>2,400	> 400	>3	>5	4,000	54,600

NOTES:
(1) 0-300 kBTU Dominant Demand Lot Area Minimum is 1,900 sf to capture 20' x 100' lots, which constitute a high percentage of lot sizes throughout the city.

8.4 Potential Ground Thermal Capacity Calculations

After determining geological and technical suitability, potential ground thermal capacity (GTC) was calculated for each lot and geothermal system type to compare to the building demand and determine geothermal feasibility as presented in Section 8. Every effort was made to provide accurate analysis of potential ground thermal capacity for each site; however, all calculations are generalized and do not take the place of a detailed site-specific study. The procedures used to calculate GTC are presented separately below for closed loop, SCWs, and open loop systems

Closed Loop

The GTC for a closed loop system was determined by first calculating the maximum number of loops that could "fit" in the available open area of each lot using the "Point Grid Method" (Zhang and Soga, 2015). Using ArcGIS software, 25 iterations of point-grids were spaced across the city, where each point represented a closed loop. The points/loops were spaced 20-ft. apart, which is the minimum spacing cited in the *Geothermal Heat Pump Manual*, and after each iteration the grid was shifted over then down four feet. For each iteration, the number of points that fell within the open area was recorded. The maximum number over all iterations was finally multiplied by 2.8 tons, or 33.6 kBtu, per 500-ft. loop to arrive at the GTC.[4]

Where the Lloyd aquifer exists and restricts the allowable drilling depth to less than 500 ft., the per loop capacity was reduced proportionally (depth of the aquifer/500 ft.). Figure illustrates the Point Grid Method results for a portion of Bronx following six iterations.

When the open area or building footprint is overwritten by the user, a new potential GTC needs to be calculated. The Point Grid Method could not be integrated into the tool functionality. Instead, the results of the Point Grid Method were back-calculated to develop unit thermal capacities (tons or Btus per square foot) that are multiplied by the new open area.

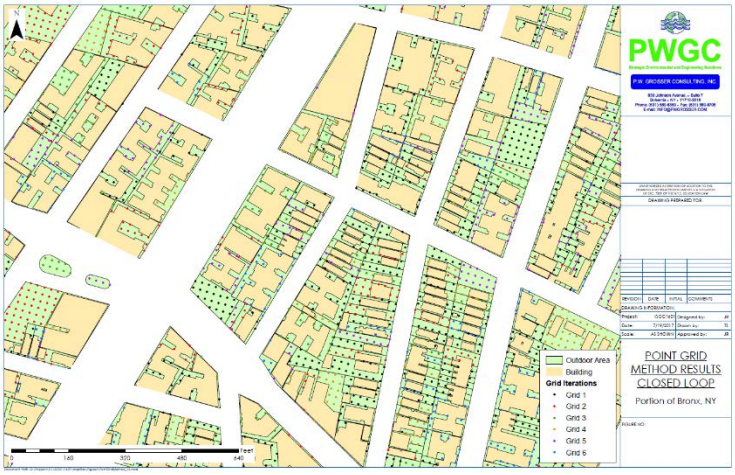


Figure 8: *Closed Loop Point Grid Map*

[4] 2.8 tons equals the industry-standard rule of thumb thermal capacity of 175 linear ft./ton of drilled borehole, multiplied by 500 ft.; this is an average value consistent with ASHRAE estimates for the geologic deposits that exist beneath the city, and is in the middle of the range value cited in the *Geothermal Heat Pump Manual* of 2.5-3.3 tons per 500-ft. borehole

Standing Column Wells

The GTC for SCWs was calculated using the same techniques as the closed loop system. The Point Grid Method was used initially to determine the maximum number of wells that could fit in the available open area of each lot within a subarea of Staten Island where SCWs are geologically and technically suitable.[5] The points/wells were spaced 50-ft. apart, which is the minimum spacing cited in the Geothermal Heat Pump Manual, and after each iteration the grid was shifted over then down five feet, for a total of 100 iterations. The maximum number of wells over all iterations was multiplied by 25 tons, or 300 kBtu, per 1,500-ft. well to arrive at the GTCs for the lots in this subarea. [6]

Like the closed loop system, unit thermal capacities were back-calculated from the Point Grid Method results and were applied for both the baseline and override tool options for SCWs. Figure 9 illustrates the Point Grid Method results for the portion of Staten Island analyzed.

Figure 9: *SCW Point Grid Map*

Open Loop

Based on the well system flow/capacity versus lot areas shown on Figure 7, there is a direct linear relationship between peak capacity/flow and total lot size, equal to 0.048 kBTU/SF. Potential GTC was calculated for each lot by multiplying the lot outdoor area by this factor. The same factor is applicable when the outdoor area is overwritten; the new potential GTC is calculated by multiplying the new outdoor area by 0.048 kBTU/SF.

[5] The entire area where SCWs are suitable, i.e., remaining area of Staten Island, and all of Manhattan and the Bronx, could not be used this analysis due to computational constraints.

[6] 25 tons is in the middle of the range value cited in the *Geothermal Heat Pump Manual* of 15-42 tons per 1,500-ft. well

9.0 Building Load and Feasibility

A previous analysis completed by the Mayor's Office of Sustainability divided building types into a number of categories based on findings by the Buildings Technical Working Group (TWG), as summarized below.

9.1 Building Type Parameters

Building Type	Building Description	Building Type	Building Description
C1	Commercial, Post-1980 > 7 Stories	MF1	Multifamily, Post-1980 > 7 Stories
C2	Commercial, Post-1980 up to 7 Stories	MF2	Multifamily, Post-1980 up to 7 Stories
C3	Commercial, Post-war > 7 Stories	MF3	Multifamily, Post-war > 7 Stories
C4	Commercial, Post-war up to 7 Stories	MF4	Multifamily, Post-war up to 7 Stories
C5	Commercial, Pre-war > 7 Stories	MF5	Multifamily, Pre-war > 7 Stories
C6	Commercial, Pre-war up to 7 Stories	MF6	Multifamily, Pre-war up to 7 Stories
C7	Commercial, Very Large, > 500,000 SF	MF7	Multifamily, Very Large
IN1	Hospital and Health Facilities	NYCHA	New York City Housing Authority
IN2	Institutional General	SF1	1 - 4 Family, Free Standing Wood Frame
IN3	K-12 Schools	SF2	1 - 4 Family, Row House, Masonry
IN4	Religious	W1	Warehouse/Factory > 3 Stories
IN5	University	W2	Warehouse/Factory up to 3 Stories
		W3	Transportation, Garages, and Utilities

Table 4: *Building Type Breakdown*

As part of the TWG report, for each of these building types, data was analyzed to determine the energy consumption of the buildings, and the portion of this energy that was used for heating and cooling. We analyzed a spreadsheet of all buildings in New York City which included all buildings listed by block and lot number, building type, building square footage, and building lot size, along with additional information.

Based on these findings, we developed a spreadsheet model for each building type based on typical parameters to size building peak heating and cooling requirements. Cooling load was estimated based on typical tons/SF, and heating load was based on approximate building surface area, volume, and ventilation rates. Factors were added to account for window to wall ratio, building envelope, and building usage. Bin weather analysis was then used to estimate approximate annual heating and cooling loads. This information was tabulated into peak and annual heating and cooling loads per 1000 SF for the various building types.

The feasibility calculation imported the load data to determine geological feasibility for the three geothermal systems. After confirming the feasibility of each system for the site, the thermal capacity of the site for the given system was compared with the required capacity. If this requirement was met, the annual heating and cooling loads were compared to confirm that an appropriate balance was achieved. A factor of 1.2 was applied to the total cooling load in this phase to account for compressor heat rejection into the heat transfer fluid. If the heating and cooling systems were found to be appropriately balanced, the system was deemed feasible. If they were found to be nearly appropriately balanced, a hybrid system was deemed feasible. It should be noted that, as this

tool is intended only to determine potential, somewhat optimistic figures were selected in terms of heating/cooling balance. A detailed study specific to the site would be necessary to confirm that the system will not be saturated over time.

9.2 Energy Consumption

Where geothermal systems were found to be geologically feasible, we completed follow up calculations to determine economic feasibility. To enable a generalization of all of the buildings in NYC into the very few categories listed above, it was necessary to make a number of assumptions in the development of this tool. The first assumption was that any building considering an upgrade to a geothermal system was already committed to an upgrade of heating and cooling equipment to a centralized system meeting current code requirements. The cost of the installation would never be justified by payback period alone unless considered incrementally against the installation of an alternative conventional centralized system. As actual buildings often have more antiquated systems, this means that our baseline energy projections are somewhat lower than actual findings as reported by the TWG.

Based on this assumption, we developed a baseline for each building type based on the conventional system most likely to be installed for that building type. Commercial buildings were assumed to operate with cooling towers and packaged water cooled AC Units, and natural gas fired condensing boilers or district steam for heating. Institutional sites were assumed to primarily have cooling towers and packaged water cooled AC units for cooling, and condensing boilers for heating, with the exception of schools which were assumed to have packaged air-cooled units and standard boilers. High rise residential buildings were assumed to have cooling towers and heat pumps, while low-rise residential buildings were assumed to have split system AC units and condensing boilers. Single family homes were assumed to have split system AC units and condensing boilers. Warehouses are typically heating only facilities, and were disqualified in all cases based on heating/cooling balance issues.

Once the system types were determined, a comparison between energy costs for the geothermal and the conventional systems were developed. Only the portions of the heating and cooling load that were impacted by the system type were considered in this portion of the study. Pump and fan peak energy consumption was determined based on ASHRAE standards for all cases, and weather bin data analysis was applied to determine annual consumption. For compressor energy consumption, factors were applied to the conventional case to reflect efficiency penalties in the summer for the relatively hot heat transfer fluid. In building types where heat pumps were utilized as a baseline, these factors were partially offset by efficiency gains from the hot heat transfer fluid in the winter. Boiler consumption was based on an assumed average condensing boiler efficiency of 90%. While this relatively high efficiency may not be consistently achieved in practice, it was deemed logical to assume that a building considering conversion to a geothermal system would be optimally run with either upgrade. Boiler consumption was also calculated based on weather bin data.

Once energy consumption data had been developed for each building type on a per SF basis, our results were compared to the findings of the TWG. As expected, our results were comparable but somewhat more efficient than those findings. A major exception, also as expected, was for older residential buildings. As these buildings are currently cooled primarily by window AC units, cooling is primarily logged as a basic plug load and does not

show up in the TWG data. As our calculation assumes conversion to a centralized system, cooling is more in line with other building types.

9.3 Economic Feasibility

After development of the energy consumption analysis for the various building types, this data was applied to the actual buildings to determine economic feasibility of the geothermal systems. Tables based on the weather bin data analysis summarized the energy consumption per 1000 SF for the various building types for both conventional and geothermal systems. This information was then imported into the master building table and individualized for the buildings based on type and square footage. Where the Master building table called for a hybrid system, energy consumption was pro-rated between the conventional and geothermal system types per the requirements of the hybrid system. Energy savings from the geothermal system was thus determined for each system in terms of both energy (Btus) and cost ($). A further cost savings was then attributed to the geothermal system based on the Carbon Credit as outline by LL6 of 2013. Output includes payback period with and without the Carbon Credit.

Installation costs were estimated based on tons for cooling equipment (including geothermal systems), horsepower for pumps, and kBtu for boilers. These assumptions are all based on prior work and rules of thumb. Actual costs vary considerably for each site, so it should be extensively reviewed during an individualized feasibility study before any decisions are implemented.

An incremental payback period is then determined by comparing the cost of the conventional system to the cost of the geothermal system, and then dividing by the energy savings. If the incremental payback is less than 12 years, a recommendation is made to move forward with the feasibility study, if it is less than 25 years, a recommendation is made to consider the study. Otherwise, it is not recommended to take the next step.

Appendices

A. Glossary
B. Building Type Calculations
C. Master Building Sheet Sample
D. Sample Maps

Appendix A: Glossary

1. Glossary

Definitions were drawn from Department of Design and Construction's Geothermal Heat Pump Manual [*link to document if possible*].

Closed loop system - Type of geothermal heat pump system that circulates water with an antifreeze solution in a network of closed piping installed in the group.

Coefficient of performance - Ratio of the heat extracted to the energy consumed in the process.

Ground coupling - Arrangement of piping and fluid handling equipment designed to exchange heat with the earth's interior.

Geothermal (ground source) heat pumps - Heating and cooling devices that take advantage of the relatively constant temperature of the earth's interior, using it as a source or sink for heat. When cooling, heat is extracted from the building and dissipated into the earth; when heating, heat is extracted from the earth and pumped into the space.

Geothermal potential capacity- Based on geological conditions, the thermal energy available from the lot. The capacity varies depending on the system utilized (open loop, closed loop, or standing column well).

Ground couple - Arrangement of piping and fluid handling equipment designed to exchange heat with the earth's interior.

Ground thermal capacity - See Geothermal potential capacity

Heat Exchangers - Device for transferring thermal energy from one fluid to another.

Heat pump - Device used for heating and cooling, which operates by moving heat from a cooler to a warmer location and vice versa, by extracting heat from the air, water, or earth.

Heating, ventilation and air conditioning (HVAC)

Hybrid systems – A system which uses a condensing boiler and/or a cooling tower to supplement the geothermal system

Open loop system - Type of geothermal heat pump system that uses ground water pumped from a supply well to transfer heat and returns the water to the ground through diffusion wells.

Simple payback period – The period of time required to recoup the funds expended in an investment. The calculation is determined by the initial cost divided by the annual savings, and is not a full life cycle cost analysis.

Standing column well system - Type of geothermal heat pump system that also uses ground water, but relies on smaller amounts inside a very deep well to exchange heat with the surrounding bedrock.

Appendix B: Building Type Calculations

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Heating and Cooling Load Calculations

Weather data			Hours				Operating Hours	Building Load			Conventional Operation															Geothermal Operation		Geothermal Operation		Geothermal Operation	
DB (+-2)	MCWB	h	1-8	9-16	17-0	Total	Occupied Space	Load Factor	Cooling Load	Heating Load	Condensing Boiler Load	Primary HW Pump Speed	Primary CW Pump Speed	Secondary CW Pump Speed	CT Fan Speed	Condensing Boiler Usage	HW Pump Demand	CW Pump Demand	CT Fan Demand	Cooling Penalty and Heating Benefit	Pump Energy Usage	CT Fan Energy Usage	Energy Usage	Demand Cost	Energy Cost	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs
		[btu/lb]							(Tons)	(Btu)	(%)	(%)	(%)	(%)	(%)	(Therms)	(kW)	(kW)	(kW)	(kW)	(kWh)	(kWh)	(kWh)	($)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)
102	79.9	43.2	0	0	0	0	0	1.00	300	0	0%	0%	0%	0%	70%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
97	75.7	39.6	0	8	1	9	7	0.92	276	0	0%	0%	96%	96%	62%	0	0.0	34.7	5.3	82.8	244	38	864	$ 1,041	$ 157	164.6	$ 30	192.0	$ 35	428.0	$ 78
92	73.0	37.7	0	51	9	60	45	0.84	252	0	0%	0%	92%	92%	55%	0	0.0	31.2	4.0	75.6	1,414	180	5,020	$ 914	$ 912	953.3	$ 173	1112.2	$ 202	2478.6	$ 450
87	69.7	35.7	5	184	68	257	170	0.76	228	0	0%	0%	88%	88%	47%	0	0.0	27.9	2.7	68.4	4,755	461	16,865	$ 796	$ 3,063	3205.5	$ 582	3739.7	$ 679	8334.2	$ 1,513
82	67.5	33.6	45	257	178	480	256	0.68	204	0	0%	0%	84%	84%	40%	0	0.0	24.9	1.8	61.2	6,366	468	22,506	$ 694	$ 4,087	4290.9	$ 779	5006.1	$ 909	11156.4	$ 2,026
77	65.4	32.1	206	263	265	734	291	0.60	180	0	0%	0%	80%	80%	33%	0	0.0	22.0	1.1	54.0	6,406	329	22,456	$ 601	$ 4,078	4318.1	$ 784	5037.8	$ 915	11227.1	$ 2,039
72	62.0	29.7	275	276	294	845	314	0.52	156	0	0%	0%	76%	76%	25%	0	0.0	19.4	0.6	46.8	6,070	177	20,925	$ 518	$ 3,800	4091.7	$ 743	4773.7	$ 867	10638.5	$ 1,932
67	58.2	26.4	385	267	325	977	321	0.44	132	0	0%	0%	72%	72%	50%	0	0.0	17.1	3.1	39.6	5,489	1,003	19,215	$ 525	$ 3,489	3700.0	$ 672	4316.7	$ 784	9620.1	$ 1,747
62	55.2	23.6	246	175	235	656	214	0.36	108	0	0%	0%	68%	68%	42%	0	0.0	14.8	2.0	32.4	3,168	437	10,536	$ 438	$ 1,913	2135.7	$ 388	2491.7	$ 452	5552.9	$ 1,008
57	51.3	20.8	280	212	220	712	246	0.28	84	0	0%	0%	64%	64%	35%	0	0.0	12.7	1.3	25.2	3,131	322	9,652	$ 365	$ 1,753	2110.5	$ 383	2462.3	$ 447	5487.4	$ 997
52	47.0	18.3	192	181	198	571	208	0.20	60	0	0%	0%	60%	60%	28%	0	0.0	10.8	0.7	18.0	2,249	155	6,142	$ 301	$ 1,115	1516.0	$ 275	1768.7	$ 321	3941.6	$ 716
47	41.9	15.9	229	271	251	751	298	0.36	0	1,604,383	29%	68%	0%	68%	0%	5,304	7.9	6.9	0.0	-13.4	4,407	0	429	$ 385	$ 4,838	2970.6	$ 539	3465.7	$ 629	7723.6	$ 1,403
42	37.4	13.9	309	265	289	863	306	0.44	0	1,941,410	35%	72%	0%	72%	0%	6,608	9.2	7.9	0.0	-16.2	5,234	0	278	$ 444	$ 5,981	3528.1	$ 641	4116.1	$ 747	9173.1	$ 1,666
37	32.8	12.0	294	237	268	799	277	0.52	0	2,278,436	42%	76%	0%	76%	0%	7,019	10.4	9.0	0.0	-19.0	5,366	0	102	$ 503	$ 6,317	3617.2	$ 657	4220.0	$ 766	9404.6	$ 1,708
32	28.0	10.1	187	124	185	496	156	0.60	0	2,615,463	48%	80%	0%	80%	0%	4,534	11.8	10.2	0.0	-21.8	3,433	0	32	$ 572	$ 4,075	2314.0	$ 420	2699.6	$ 490	6016.4	$ 1,093
27	23.2	8.3	124	92	89	305	106	0.68	0	2,952,490	54%	84%	0%	84%	0%	3,472	13.3	11.5	0.0	-24.6	2,630	0	27	$ 646	$ 3,120	1773.1	$ 322	2068.6	$ 376	4610.1	$ 837
22	18.9	6.7	109	50	37	196	59	0.76	0	3,289,516	60%	88%	0%	88%	0%	2,164	15.0	12.9	0.0	-27.4	1,653	0	30	$ 726	$ 1,947	1114.2	$ 202	1299.9	$ 236	2896.9	$ 526
17	14.7	5.2	22	4	6	32	6	0.84	0	3,626,543	66%	92%	0%	92%	0%	260	16.7	14.5	0.0	-30.2	202	0	6	$ 811	$ 235	136.0	$ 25	158.6	$ 29	353.5	$ 64
12	10.1	3.8	12	3	2	17	4	0.92	0	3,963,569	72%	96%	0%	96%	0%	176	18.6	16.1	0.0	-33.0	139	0	7	$ 902	$ 159	93.6	$ 17	109.2	$ 20	243.3	$ 44
7	11.4	2.4	0	0	0	0	0	1.00	0	4,300,596	79%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
2	1.2	1.2	0	0	0	0	0	1.08	0	4,637,623	85%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
-3	(2.6)	0.0	0	0	0	0	0	1.16	0	4,974,649	91%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
TOTALS:			2,920	2,920	2,920	8,760	3,285		304,400	2,658,337,032						29,537	19	35	5		62,357	3,569	135,093	$ 12,498	$ 63,537	4,318	$ 7,633	5,038	$ 8,905	11,227	$ 19,846

Assumptions	
Building Type	C1
Building Interior Square Footage	100,000
Building Footprint Square Footage	10,000
Number of Floors	10.0
Perimeter Surface Area	48,000
Wall to Window Ratio	70%
Outside Air CFM	14,775
Cooling Design Load (Tons)	300
Heating Design Load (Btu)	3,215,520
Demand Cost ($/kW)	$ 26.00
Electricity Energy Cost ($/kWh)	$ 0.18
Natural Gas Cost ($/Therm)	$ 0.90
#2 Fuel Oil Cost ($/gal)	$ 1.55
#4 Fuel Oil Cost ($/gal)	$ 1.37
District Steam Cost ($/Mlb)	$ 24.03
Cooling Penalty for EWT (kW/ton)	0.3
Heating Benefit for EWT (kW/Ton)	0.1
Load Factor Decrease per 5 F	0.08

Auxiliary Equipment	
Condensing Boiler (MBH)	5,472
Condensing Boiler Efficiency	90%
Cooling Tower Peak kW	16.8
Primary CW Pump Peak kW	19.8
Primary HW Pump Peak kW	19.8
Secondary CW Pump Peak kW	17.1
Closed Loop Pump Peak kW	24.9
Open Loop Pump Peak kW	29.0
Standing Column Well Pump Peak kW	64.7
Minimum Fan Speed	20%
Minimum Pump Speed	20%

VFD Efficiency	
2%	0.47
13%	0.86
25%	0.93
42%	0.94
50%	0.95
75%	0.96
100%	0.97

Installation Costs	
Condensing Boiler	$ 360,000
Cooling Tower	$ 300,000
Primary CW Pump	$ 3,000
Primary HW Pump	$ 2,600
Secondary CW Pump	$ 2,600
Maintenance Costs	
Condensing Boiler	$ 27,361
Cooling Tower	$ 4,200

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Heating and Cooling Load Calculations

Weather data			Hours				Operating Hours	Building Load			Conventional Operation															Geothermal Operation		Geothermal Operation		Geothermal Operation	
DB (+-2)	MCWB	h	1-8	9-16	17-0	Total	Occupied Space	Load Factor	Cooling Load	Heating Load	District Steam Load	Primary HW Pump Speed	Primary CW Pump Speed	Secondary CW Pump Speed	CT Fan Speed	District Steam Usage	HW Pump Demand	CW Pump Demand	CT Fan Demand	Cooling Penalty and Heating Benefit	Pump Energy Usage	CT Fan Energy Usage	Energy Usage	Demand Cost	Energy Cost	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs
		[btu/lb]							(Tons)	(Btu)	Mlbs	(%)	(%)	(%)	(%)	(Mlbs)	(kW)	(kW)	(kW)	(kW)	(kWh)	(kWh)	(kWh)	($)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)
102	79.9	43.2	0	0	0	0	0	1.00	300	0	0	0%	0%	0%	70%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
97	75.7	39.6	0	8	1	9	7	0.92	276	0	0	0%	96%	96%	62%	0	0.0	34.7	5.3	82.8	244	38	864	$ 1,041	$ 157	151.1	$ 27	176.2	$ 32	392.8	$ 71
92	73.0	37.7	0	51	9	60	45	0.84	252	0	0	0%	92%	92%	55%	0	0.0	31.2	4.0	75.6	1,414	180	5,020	$ 914	$ 912	874.9	$ 159	1020.7	$ 185	2274.7	$ 413
87	69.7	35.7	5	184	68	257	170	0.76	228	0	0	0%	88%	88%	47%	0	0.0	27.9	2.7	68.4	4,755	461	16,865	$ 796	$ 3,063	2941.8	$ 534	3432.1	$ 623	7648.6	$ 1,389
82	67.5	33.6	45	257	178	480	256	0.68	204	0	0	0%	84%	84%	40%	0	0.0	24.9	1.8	61.2	6,366	468	22,506	$ 694	$ 4,087	3937.9	$ 715	4594.2	$ 834	10238.6	$ 1,859
77	65.4	32.1	206	263	265	734	291	0.60	180	0	0	0%	80%	80%	33%	0	0.0	22.0	1.1	54.0	6,406	329	22,456	$ 601	$ 4,078	3962.9	$ 720	4623.3	$ 840	10303.4	$ 1,871
72	62.0	29.7	275	276	294	845	314	0.52	156	0	0	0%	76%	76%	25%	0	0.0	19.4	0.6	46.8	6,070	177	20,925	$ 518	$ 3,800	3755.1	$ 682	4381.0	$ 796	9763.3	$ 1,773
67	58.2	26.4	385	267	325	977	321	0.44	132	0	0	0%	72%	72%	50%	0	0.0	17.1	3.1	39.6	5,489	1,003	19,215	$ 525	$ 3,489	3395.7	$ 617	3961.6	$ 719	8828.7	$ 1,603
62	55.2	23.6	246	175	235	656	214	0.36	108	0	0	0%	68%	68%	42%	0	0.0	14.8	2.0	32.4	3,168	437	10,536	$ 438	$ 1,913	1960.0	$ 356	2286.7	$ 415	5096.1	$ 925
57	51.3	20.8	280	212	220	712	246	0.28	84	0	0	0%	64%	64%	35%	0	0.0	12.7	1.3	25.2	3,131	322	9,652	$ 365	$ 1,753	1936.9	$ 352	2259.7	$ 410	5036.0	$ 915
52	47.0	18.3	192	181	198	571	208	0.20	60	0	0	0%	60%	60%	28%	0	0.0	10.8	0.7	18.0	2,249	155	6,142	$ 301	$ 1,115	1391.3	$ 253	1623.2	$ 295	3617.4	$ 657
47	41.9	15.9	229	271	251	751	298	0.36	0	1,477,375	1.55	68%	0%	68%	0%	462	7.9	6.9	0.0	-12.3	4,407	0	744	$ 385	$ 11,247	2726.2	$ 495	3180.6	$ 578	7088.2	$ 1,287
42	37.4	13.9	309	265	289	863	306	0.44	0	1,786,178	1.88	72%	0%	72%	0%	576	9.2	7.9	0.0	-14.9	5,234	0	674	$ 444	$ 13,953	3237.9	$ 588	3777.5	$ 686	8418.5	$ 1,529
37	32.8	12.0	294	237	268	799	277	0.52	0	2,094,980	2.20	76%	0%	76%	0%	611	10.4	9.0	0.0	-17.5	5,366	0	526	$ 503	$ 14,777	3319.6	$ 603	3872.8	$ 703	8630.9	$ 1,567
32	28.0	10.1	187	124	185	496	156	0.60	0	2,403,783	2.53	80%	0%	80%	0%	395	11.8	10.2	0.0	-20.0	3,433	0	308	$ 572	$ 9,535	2123.6	$ 386	2477.6	$ 450	5521.4	$ 1,003
27	23.2	8.3	124	92	89	305	106	0.68	0	2,712,586	2.85	84%	0%	84%	0%	302	13.3	11.5	0.0	-22.6	2,630	0	238	$ 646	$ 7,299	1627.2	$ 296	1898.4	$ 345	4230.8	$ 768
22	18.9	6.7	109	50	37	196	59	0.76	0	3,021,388	3.18	88%	0%	88%	0%	188	15.0	12.9	0.0	-25.2	1,653	0	162	$ 726	$ 4,550	1022.5	$ 186	1193.0	$ 217	2658.6	$ 483
17	14.7	5.2	22	4	6	32	6	0.84	0	3,330,191	3.50	92%	0%	92%	0%	23	16.7	14.5	0.0	-27.8	202	0	22	$ 811	$ 548	124.8	$ 23	145.6	$ 26	324.4	$ 59
12	10.1	3.8	12	3	2	17	4	0.92	0	3,638,993	3.83	96%	0%	96%	0%	15	18.6	16.1	0.0	-30.3	139	0	18	$ 902	$ 371	85.9	$ 16	100.2	$ 18	223.3	$ 41
7	11.4	2.4	0	0	0	0	0	1.00	0	3,947,796	4.15	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
2	1.2	1.2	0	0	0	0	0	1.08	0	4,256,599	4.48	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
-3	(2.6)	0.0	0	0	0	0	0	1.16	0	4,565,401	4.80	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
TOTALS:			2,920	2,920	2,920	8,760	3,285		304,400	2,444,629,440						2,572	19	35	5	333	62,357	3,569	136,874	$ 12,498	$ 99,145	3,963	$ 7,005	4,623	$ 8,173	10,303	$ 18,214

Assumptions	
Building Type	C3
Building Interior Square Footage	100,000
Building Footprint Square Footage	10,000
Number of Floors	10.0
Perimeter Surface Area	48,000
Wall to Window Ratio	70%
Outside Air CFM	14,775
Cooling Design Load (Tons)	300
Heating Design Load (Btu)	2,862,720
Demand Cost ($/kW)	$ 26.00
Electricity Energy Cost ($/kWh)	$ 0.18
Natural Gas Cost ($/Therm)	$ 0.90
#2 Fuel Oil Cost ($/gal)	$ 1.55
#4 Fuel Oil Cost ($/gal)	$ 1.37
District Steam Cost ($/Mlb)	$ 24.03
Cooling Penalty for EWT (kW/ton)	0.3
Heating Benefit for EWT (kW/Ton)	0.1
Load Factor Decrease per 5 F	0.08

Auxiliary Equipment	
Heat Content for District Steam (Btu)	970
Heat Exchanger Efficiency	98%
Cooling Tower Peak kW	16.8
Primary CW Pump Peak kW	19.8
Primary HW Pump Peak kW	19.8
Secondary CW Pump Peak kW	17.1
Closed Loop Pump Peak kW	22.8
Open Loop Pump Peak kW	26.6
Standing Column Well Pump Peak kW	59.4
Minimum Fan Speed	20%
Minimum Pump Speed	20%

VFD Efficiency	
2%	0.47
13%	0.86
25%	0.93
42%	0.94
50%	0.95
75%	0.96
100%	0.97

Installation Costs	
Steam Heat Exchanger	$ 10,000
Cooling Tower	$ 300,000
Primary CW Pump	$ 3,000
Primary HW Pump	$ 2,600
Secondary CW Pump	$ 2,600
Maintenance Costs	
Steam Trap Maintenance	$ 4,850
Cooling Tower	$ 4,200

GOLDMAN COPELAND
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Heating and Cooling Load Calculations

Weather data			Hours				Operating Hours	Building Load			Conventional Operation															Geothermal Operation		Geothermal Operation		Geothermal Operation	
DB (+-2)	MCWB	h	1-8	9-16	17-0	Total	Occupied Space	Load Factor	Cooling Load	Heating Load	Condensing Boiler Load	Primary HW Pump Speed	Primary CW Pump Speed	Secondary CW Pump Speed	CT Fan Speed	Condensing Boiler Usage	HW Pump Demand	CW Pump Demand	CT Fan Demand	Cooling Penalty and Heating Benefit	Pump Energy Usage	CT Fan Energy Usage	Energy Usage	Demand Cost	Energy Cost	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs
		[btu/lb]							(Tons)	(Btu)	(%)	(%)	(%)	(%)	(%)	(Therms)	(kW)	(kW)	(kW)	(kW)	(kWh)	(kWh)	(kWh)	($)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)
102	79.9	43.2	0	0	0	0	0	1.00	400	0	0%	0%	0%	0%	70%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
97	75.7	39.6	0	8	1	9	9	0.92	368	0	0%	0%	96%	96%	62%	0	0.0	46.3	7.1	110.4	416	64	1,474	$ 1,389	$ 268	225.0	$ 41	262.4	$ 48	584.9	$ 106
92	73.0	37.7	0	51	9	60	60	0.84	336	0	0%	0%	92%	92%	55%	0	0.0	41.6	5.3	100.8	2,496	317	8,862	$ 1,219	$ 1,609	1348.3	$ 245	1573.0	$ 286	3505.6	$ 637
87	69.7	35.7	5	184	68	257	257	0.76	304	0	0%	0%	88%	88%	47%	0	0.0	37.2	3.6	91.2	9,568	927	33,933	$ 1,062	$ 6,162	5167.8	$ 938	6029.1	$ 1,095	13436.3	$ 2,440
82	67.5	33.6	45	257	178	480	480	0.68	272	0	0%	0%	84%	84%	40%	0	0.0	33.1	2.4	81.6	15,909	1,169	56,246	$ 925	$ 10,214	8592.2	$ 1,560	10024.3	$ 1,820	22339.8	$ 4,057
77	65.4	32.1	206	263	265	734	734	0.60	240	0	0%	0%	80%	80%	33%	0	0.0	29.3	1.5	72.0	21,534	1,105	75,487	$ 802	$ 13,708	11630.2	$ 2,112	13568.6	$ 2,464	30238.6	$ 5,491
72	62.0	29.7	275	276	294	845	845	0.52	208	0	0%	0%	76%	76%	25%	0	0.0	25.8	0.8	62.4	21,806	635	75,170	$ 691	$ 13,651	11777.6	$ 2,139	13740.5	$ 2,495	30621.8	$ 5,561
67	58.2	26.4	385	267	325	977	977	0.44	176	0	0%	0%	72%	72%	50%	0	0.0	22.8	4.2	52.8	22,257	4,069	77,911	$ 701	$ 14,149	12021.0	$ 2,183	14024.5	$ 2,547	31254.6	$ 5,676
62	55.2	23.6	246	175	235	656	656	0.36	144	0	0%	0%	68%	68%	42%	0	0.0	19.7	2.7	43.2	12,954	1,785	43,079	$ 584	$ 7,823	6996.7	$ 1,271	8162.8	$ 1,482	18191.3	$ 3,304
57	51.3	20.8	280	212	220	712	712	0.28	112	0	0%	0%	64%	64%	35%	0	0.0	17.0	1.7	33.6	12,083	1,242	37,248	$ 487	$ 6,764	6526.0	$ 1,185	7613.6	$ 1,383	16967.5	$ 3,081
52	47.0	18.3	192	181	198	571	571	0.20	80	0	0%	0%	60%	60%	28%	0	0.0	14.4	1.0	24.0	8,246	570	22,520	$ 401	$ 4,090	4453.8	$ 809	5196.1	$ 944	11579.8	$ 2,103
47	41.9	15.9	229	271	251	751	751	0.36	0	1,845,983	32%	68%	0%	68%	0%	15,404	10.6	9.2	0.0	-15.4	14,830	0	3,278	$ 513	$ 14,419	8009.9	$ 1,455	9344.9	$ 1,697	20825.7	$ 3,782
42	37.4	13.9	309	265	289	863	863	0.44	0	2,192,841	38%	72%	0%	72%	0%	21,027	12.2	10.6	0.0	-18.3	19,660	0	3,890	$ 592	$ 19,576	10618.3	$ 1,928	12388.1	$ 2,250	27607.7	$ 5,014
37	32.8	12.0	294	237	268	799	799	0.52	0	2,539,699	43%	76%	0%	76%	0%	22,547	13.8	12.0	0.0	-21.2	20,619	0	3,709	$ 671	$ 20,907	11136.5	$ 2,022	12992.5	$ 2,359	28954.8	$ 5,258
32	28.0	10.1	187	124	185	496	496	0.60	0	2,886,558	49%	80%	0%	80%	0%	15,908	15.7	13.6	0.0	-24.1	14,551	0	2,620	$ 763	$ 14,752	7859.1	$ 1,427	9169.0	$ 1,665	20433.7	$ 3,711
27	23.2	8.3	124	92	89	305	305	0.68	0	3,233,416	55%	84%	0%	84%	0%	10,958	17.8	15.4	0.0	-26.9	10,109	0	1,890	$ 862	$ 10,177	5459.6	$ 991	6369.6	$ 1,157	14195.1	$ 2,578
22	18.9	6.7	109	50	37	196	196	0.76	0	3,580,274	61%	88%	0%	88%	0%	7,797	20.0	17.3	0.0	-29.8	7,297	0	1,449	$ 968	$ 7,260	3941.2	$ 716	4598.1	$ 835	10247.1	$ 1,861
17	14.7	5.2	22	4	6	32	32	0.84	0	3,927,133	67%	92%	0%	92%	0%	1,396	22.3	19.3	0.0	-32.7	1,331	0	284	$ 1,082	$ 1,305	719.1	$ 131	838.9	$ 152	1869.6	$ 340
12	10.1	3.8	12	3	2	17	17	0.92	0	4,273,991	73%	96%	0%	96%	0%	807	24.8	21.4	0.0	-35.6	787	0	181	$ 1,203	$ 757	424.9	$ 77	495.7	$ 90	1104.8	$ 201
7	11.4	2.4	0	0	0	0	0	1.00	0	4,620,850	79%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
2	1.2	1.2	0	0	0	0	0	1.08	0	4,967,708	85%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
-3	(2.6)	0.0	0	0	0	0	0	1.16	0	5,314,566	91%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
TOTALS:			2,920	2,920	2,920	8,760	8,760		975,920	8,625,959,064						95,844	25	46	7	468	216,455	11,883	449,232	$ 16,663	$ 184,254	12,021	$ 21,230	14,024	$ 24,769	31,255	$ 55,199

Assumptions	
Building Type	IN1
Building Interior Square Footage	100,000
Building Footprint Square Footage	10,000
Number of Floors	10.0
Perimeter Surface Area	48,000
Wall to Window Ratio	39%
Outside Air CFM	48,000
Cooling Design Load (Tons)	400
Heating Design Load (Btu)	1,095,730
Demand Cost ($/kW)	$ 26.00
Electricity Energy Cost ($/kWh)	$ 0.18
Natural Gas Cost ($/Therm)	$ 0.90
#2 Fuel Oil Cost ($/gal)	$ 1.55
#4 Fuel Oil Cost ($/gal)	$ 1.37
District Steam Cost ($/Mlb)	$ 24.03
Cooling Penalty for EWT (kW/ton)	0.3
Heating Benefit for EWT (kW/Ton)	0.1
Load Factor Decrease per 5 F	0.08

Auxiliary Equipment	
Condensing Boiler (MBH)	5,846
Condensing Boiler Efficiency	90%
Cooling Tower Peak kW	22.4
Primary CW Pump Peak kW	26.4
Primary HW Pump Peak kW	26.4
Secondary CW Pump Peak kW	22.8
Closed Loop Pump Peak kW	26.6
Open Loop Pump Peak kW	31.0
Standing Column Well Pump Peak kW	69.1
Minimum Fan Speed	20%
Minimum Pump Speed	20%

VFD Efficiency	
2%	0.47
13%	0.86
25%	0.93
42%	0.94
50%	0.95
75%	0.96
100%	0.97

Installation Costs	
Condensing Boiler	$ 380,000
Cooling Tower	$ 400,000
Primary CW Pump	$ 3,500
Primary HW Pump	$ 3,500
Secondary CW Pump	$ 3,000
Maintenance Costs	
Condensing Boiler	$ 29,230
Cooling Tower	$ 5,600

GOLDMAN COPELAND
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Heating and Cooling Load Calculations

Weather data			Hours				Operating Hours	Building Load			Conventional Operation																Geothermal Operation		Geothermal Operation		Geothermal Operation	
DB (+-2)	MCWB	h	1-8	9-16	17-0	Total	Occupied Space	Load Factor	Cooling Load	Heating Load	Condensing Boiler Load	Primary HW Pump Speed	Primary CW Pump Speed	Secondary CW Pump Speed	CT Fan Speed	Condensing Boiler Usage	HW Pump Demand	CW Pump Demand	CT Fan Demand	Cooling Penalty and Heating Benefit	Pump Energy Usage	CT Fan Energy Usage	Energy Usage	Demand Cost	Energy Cost	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs
		[btu/lb]							(Tons)	(Btu)	(%)	(%)	(%)	(%)	(%)	(Therms)	(kW)	(kW)	(kW)	(kW)	(kWh)	(kWh)	(kWh)	($)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)
102	79.9	43.2	0	0	0	0	0	1.00	300	0	0%	0%	0%	0%	70%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
97	75.7	39.6	0	8	1	9	9	0.92	276	0	0%	0%	96%	96%	62%	0	0.0	34.7	5.3	82.8	312	48	1,106	$ 1,041	$ 201	159.5	$ 29	186.1	$ 34	414.7	$ 75
92	73.0	37.7	0	51	9	60	60	0.84	252	0	0%	0%	92%	92%	55%	0	0.0	31.2	4.0	75.6	1,872	238	6,646	$ 914	$ 1,207	955.9	$ 174	1115.2	$ 203	2485.3	$ 451
87	69.7	35.7	5	184	68	257	257	0.76	228	0	0%	0%	88%	88%	47%	0	0.0	27.9	2.7	68.4	7,176	695	25,450	$ 796	$ 4,622	3663.8	$ 665	4274.4	$ 776	9525.9	$ 1,730
82	67.5	33.6	45	257	178	480	480	0.68	204	0	0%	0%	84%	84%	40%	0	0.0	24.9	1.8	61.2	11,931	877	42,184	$ 694	$ 7,661	6091.6	$ 1,106	7106.8	$ 1,291	15838.1	$ 2,876
77	65.4	32.1	206	263	265	734	734	0.60	180	0	0%	0%	80%	80%	33%	0	0.0	22.0	1.1	54.0	16,150	829	56,615	$ 601	$ 10,281	8245.4	$ 1,497	9619.6	$ 1,747	21438.0	$ 3,893
72	62.0	29.7	275	276	294	845	845	0.52	156	0	0%	0%	76%	76%	25%	0	0.0	19.4	0.6	46.8	16,355	477	56,377	$ 518	$ 10,238	8349.9	$ 1,516	9741.6	$ 1,769	21709.7	$ 3,942
67	58.2	26.4	385	267	325	977	977	0.44	132	0	0%	0%	72%	72%	50%	0	0.0	17.1	3.1	39.6	16,693	3,052	58,434	$ 525	$ 10,612	8522.4	$ 1,548	9942.9	$ 1,806	22158.4	$ 4,024
62	55.2	23.6	246	175	235	656	656	0.36	108	0	0%	0%	68%	68%	42%	0	0.0	14.8	2.0	32.4	9,716	1,339	32,309	$ 438	$ 5,867	4960.4	$ 901	5787.1	$ 1,051	12897.0	$ 2,342
57	51.3	20.8	280	212	220	712	712	0.28	84	0	0%	0%	64%	64%	35%	0	0.0	12.7	1.3	25.2	9,062	931	27,936	$ 365	$ 5,073	4626.7	$ 840	5397.8	$ 980	12029.3	$ 2,185
52	47.0	18.3	192	181	198	571	571	0.20	60	0	0%	0%	60%	60%	28%	0	0.0	10.8	0.7	18.0	6,185	428	16,890	$ 301	$ 3,067	3157.6	$ 573	3683.8	$ 669	8209.7	$ 1,491
47	41.9	15.9	229	271	251	751	751	0.36	0	1,257,482	30%	68%	0%	68%	0%	10,493	7.9	6.9	0.0	-10.5	11,123	0	3,253	$ 385	$ 10,007	5678.7	$ 1,031	6625.2	$ 1,203	14764.7	$ 2,681
42	37.4	13.9	309	265	289	863	863	0.44	0	1,508,517	36%	72%	0%	72%	0%	14,465	9.2	7.9	0.0	-12.6	14,745	0	3,896	$ 444	$ 13,688	7528.0	$ 1,367	8782.7	$ 1,595	19572.8	$ 3,554
37	32.8	12.0	294	237	268	799	799	0.52	0	1,759,553	42%	76%	0%	76%	0%	15,621	10.4	9.0	0.0	-14.7	15,465	0	3,749	$ 503	$ 14,699	7895.4	$ 1,434	9211.2	$ 1,673	20527.9	$ 3,728
32	28.0	10.1	187	124	185	496	496	0.60	0	2,010,588	49%	80%	0%	80%	0%	11,081	11.8	10.2	0.0	-16.8	10,913	0	2,603	$ 572	$ 10,416	5571.8	$ 1,012	6500.5	$ 1,180	14486.7	$ 2,631
27	23.2	8.3	124	92	89	305	305	0.68	0	2,261,623	55%	84%	0%	84%	0%	7,664	13.3	11.5	0.0	-18.8	7,581	0	1,833	$ 646	$ 7,211	3870.7	$ 703	4515.8	$ 820	10063.8	$ 1,828
22	18.9	6.7	109	50	37	196	196	0.76	0	2,512,659	61%	88%	0%	88%	0%	5,472	15.0	12.9	0.0	-20.9	5,473	0	1,369	$ 726	$ 5,159	2794.2	$ 507	3259.9	$ 592	7264.9	$ 1,319
17	14.7	5.2	22	4	6	32	32	0.84	0	2,763,694	67%	92%	0%	92%	0%	983	16.7	14.5	0.0	-23.0	999	0	262	$ 811	$ 929	509.8	$ 93	594.8	$ 108	1325.5	$ 241
12	10.1	3.8	12	3	2	17	17	0.92	0	3,014,730	73%	96%	0%	96%	0%	569	18.6	16.1	0.0	-25.1	590	0	163	$ 902	$ 541	301.2	$ 55	351.5	$ 64	783.2	$ 142
7	11.4	2.4	0	0	0	0	0	1.00	0	3,265,765	79%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
2	1.2	1.2	0	0	0	0	0	1.08	0	3,516,800	85%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
-3	(2.6)	0.0	0	0	0	0	0	1.16	0	3,767,836	91%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
TOTALS:			2,920	2,920	2,920	8,760	8,760		731,940	5,971,318,771						66,348	19	35	5	362	162,342	8,912	341,075	$ 12,498	$ 133,977	8,522	$ 15,052	9,943	$ 17,560	22,158	$ 39,134

Assumptions	
Building Type	IN2
Building Interior Square Footage	100,000
Building Footprint Square Footage	10,000
Number of Floors	10.0
Perimeter Surface Area	48,000
Wall to Window Ratio	39%
Outside Air CFM	21,519
Cooling Design Load (Tons)	300
Heating Design Load (Btu)	1,685,410
Demand Cost ($/kW)	$ 26.00
Electricity Energy Cost ($/kWh)	$ 0.18
Natural Gas Cost ($/Therm)	$ 0.90
#2 Fuel Oil Cost ($/gal)	$ 1.55
#4 Fuel Oil Cost ($/gal)	$ 1.37
District Steam Cost ($/Mlb)	$ 24.03
Cooling Penalty for EWT (kW/ton)	0.3
Heating Benefit for EWT (kW/Ton)	0.1
Load Factor Decrease per 5 F	0.08

Auxiliary Equipment	
Condensing Boiler (MBH)	4,145
Condensing Boiler Efficiency	90%
Cooling Tower Peak kW	16.8
Primary CW Pump Peak kW	19.8
Primary HW Pump Peak kW	19.8
Secondary CW Pump Peak kW	17.1
Closed Loop Pump Peak kW	18.8
Open Loop Pump Peak kW	22.0
Standing Column Well Pump Peak kW	49.0
Minimum Fan Speed	20%
Minimum Pump Speed	20%

VFD Efficiency	
2%	0.47
13%	0.86
25%	0.93
42%	0.94
50%	0.95
75%	0.96
100%	0.97

Installation Costs	
Condensing Boiler	$ 320,000
Cooling Tower	$ 300,000
Primary CW Pump	$ 3,000
Primary HW Pump	$ 2,600
Secondary CW Pump	$ 2,600
Maintenance Costs	
Condensing Boiler	$ 20,723
Cooling Tower	$ 4,200

GOLDMAN COPELAND
CONSULTING ENGINEERS

Heating and Cooling Load Calculations

Weather data			Hours				Operating Hours	Building Load			Conventional Operation											Geothermal Operation		Geothermal Operation		Geothermal Operation	
DB (+-2)	MCWB	h	1-8	9-16	17-0	Total	Occupied Space	Load Factor	Cooling Load	Heating Load	Condensing Boiler Load	Primary HW Pump Speed	Split System Load	Extra kW/Ton for Air Cooled System	Condensing Boiler Usage	HW Pump Demand	Split System Demand	Pump Energy Usage	Split System Energy Usage	Energy Usage	Demand Cost	Energy Cost	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs
		[btu/lb]							(Tons)	(Btu)	(%)	(%)	(%)	(kW)	(Therms)	(kW)	(kW)	(kWh)	(kWh)	(kWh)	($)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)
102	79.9	43.2	0	0	0	0	0	1.00	250	0	0%	0%	70%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
97	75.7	39.6	0	8	1	9	4	0.92	230	0	0%	0%	62%	69	0	0.0	87.2	0	307	307	$ 2,267	$ 56	61.1	$ 11	88.8	$ 16	197.8	$ 36
92	73.0	37.7	0	51	9	60	23	0.84	210	0	0%	0%	55%	63	0	0.0	79.1	0	1,793	1,793	$ 2,058	$ 326	354.0	$ 64	514.1	$ 93	1145.6	$ 208
87	69.7	35.7	5	184	68	257	85	0.76	190	0	0%	0%	47%	57	0	0.0	70.8	0	6,028	6,028	$ 1,841	$ 1,095	1190.2	$ 216	1728.6	$ 314	3852.2	$ 700
82	67.5	33.6	45	257	178	480	128	0.68	170	0	0%	0%	40%	51	0	0.0	62.7	0	8,033	8,033	$ 1,631	$ 1,459	1593.3	$ 289	2313.9	$ 420	5156.7	$ 936
77	65.4	32.1	206	263	265	734	146	0.60	150	0	0%	0%	33%	45	0	0.0	54.7	0	7,960	7,960	$ 1,422	$ 1,446	1603.4	$ 291	2328.5	$ 423	5189.3	$ 942
72	62.0	29.7	275	276	294	845	314	0.52	130	0	0%	0%	25%	39	0	0.0	46.3	0	14,532	14,532	$ 1,205	$ 2,639	3038.7	$ 552	4412.9	$ 801	9834.5	$ 1,786
67	58.2	26.4	385	267	325	977	321	0.44	110	0	0%	0%	50%	33	0	0.0	47.7	0	15,315	15,315	$ 1,239	$ 2,781	2747.8	$ 499	3990.5	$ 725	8893.1	$ 1,615
62	55.2	23.6	246	175	235	656	214	0.36	90	0	0%	0%	42%	27	0	0.0	39.3	0	8,412	8,412	$ 1,022	$ 1,528	1586.1	$ 288	2303.4	$ 418	5133.3	$ 932
57	51.3	20.8	280	212	220	712	246	0.28	70	0	0%	0%	35%	21	0	0.0	31.3	0	7,692	7,692	$ 813	$ 1,397	1567.4	$ 285	2276.2	$ 413	5072.7	$ 921
52	47.0	18.3	192	181	198	571	208	0.20	50	0	0%	0%	28%	15	0	0.0	23.2	0	4,821	4,821	$ 604	$ 875	1539.5	$ 280	2235.7	$ 406	4982.5	$ 905
47	41.9	15.9	229	271	251	751	298	0.36	0	1,584,187	31%	68%	0%	0	5,238	6.6	0.0	1,971	0	1,971	$ 172	$ 5,058	2206.1	$ 401	3203.8	$ 582	7139.9	$ 1,297
42	37.4	13.9	309	265	289	863	306	0.44	0	1,885,639	37%	72%	0%	0	6,418	7.6	0.0	2,340	0	2,340	$ 199	$ 6,185	2620.1	$ 476	3805.1	$ 691	8479.9	$ 1,540
37	32.8	12.0	294	237	268	799	277	0.52	0	2,187,092	43%	76%	0%	0	6,737	8.7	0.0	2,399	0	2,399	$ 225	$ 6,482	2686.2	$ 488	3901.1	$ 708	8693.9	$ 1,579
32	28.0	10.1	187	124	185	496	156	0.60	0	2,488,545	49%	80%	0%	0	4,314	9.8	0.0	1,535	0	1,535	$ 256	$ 4,150	1718.4	$ 312	2495.6	$ 453	5561.7	$ 1,010
27	23.2	8.3	124	92	89	305	106	0.68	0	2,789,997	55%	84%	0%	0	3,280	11.1	0.0	1,176	0	1,176	$ 289	$ 3,157	1316.8	$ 239	1912.3	$ 347	4261.7	$ 774
22	18.9	6.7	109	50	37	196	59	0.76	0	3,091,450	61%	88%	0%	0	2,033	12.5	0.0	739	0	739	$ 325	$ 1,959	827.4	$ 150	1201.7	$ 218	2678.0	$ 486
17	14.7	5.2	22	4	6	32	6	0.84	0	3,392,902	67%	92%	0%	0	244	14.0	0.0	90	0	90	$ 363	$ 235	101.0	$ 18	146.6	$ 27	326.8	$ 59
12	10.1	3.8	12	3	2	17	4	0.92	0	3,694,355	73%	96%	0%	0	164	15.5	0.0	62	0	62	$ 404	$ 159	69.5	$ 13	100.9	$ 18	224.9	$ 41
7	11.4	2.4	0	0	0	0	0	1.00	0	3,995,807	79%	0%	0%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
2	1.2	1.2	0	0	0	0	0	1.08	0	4,297,260	85%	0%	0%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
-3	(2.6)	0.0	0	0	0	0	0	1.16	0	4,598,712	91%	0%	0%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
TOTALS:			2,920	2,920	2,920	8,760	2,900		188,316	2,558,608,908					28,429	16	87	10,313	74,894	85,207	$ 27,204	$ 68,190	3,039	$ 4,872	4,413	$ 7,075	9,835	$ 15,767

Assumptions	
Building Type	IN3
Building Interior Square Footage	100,000
Building Footprint Square Footage	10,000
Number of Floors	10.0
Perimeter Surface Area	48,000
Wall to Window Ratio	45%
Outside Air CFM	38,325
Cooling Design Load (Tons)	250
Heating Design Load (Btu)	1,181,219
Demand Cost ($/kW)	$ 26.00
Electricity Energy Cost ($/kWh)	$ 0.18
Natural Gas Cost ($/Therm)	$ 0.90
#2 Fuel Oil Cost ($/gal)	$ 1.55
#4 Fuel Oil Cost ($/gal)	$ 1.37
District Steam Cost ($/Mlb)	$ 24.03
Air Cooled kW/Ton Penalty	0.3
Load Factor Decrease per 5 F	0.08

Auxiliary Equipment	
Condensing Boiler (MBH)	5,059
Condensing Boiler Efficiency	90%
Split System Condenser Fan Peak kW	29.3
Primary HW Pump Peak kW	16.5
Closed Loop Pump Peak kW	18.5
Open Loop Pump Peak kW	26.8
Standing Column Well Pump Peak kW	59.8
Minimum Fan Speed	20%
Minimum Pump Speed	20%

VFD Efficiency	
2%	0.47
13%	0.86
25%	0.93
42%	0.94
50%	0.95
75%	0.96
100%	0.97

Installation Costs	
Condensing Boiler	$ 330,000
Split System AC Units	$ 250,000
Primary HW Pump	$ 2,200
Maintenance Costs	
Condensing Boiler	$ 25,293

GOLDMAN COPELAND
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Heating and Cooling Load Calculations

Weather data			Hours				Operating Hours	Building Load			Conventional Operation																Geothermal Operation		Geothermal Operation		Geothermal Operation	
DB (+-2)	MCWB	h	1-8	9-16	17-0	Total	Occupied Space	Load Factor	Cooling Load	Heating Load	Condensing Boiler Load	Primary HW Pump Speed	Primary CW Pump Speed	Secondary CW Pump Speed	CT Fan Speed	Condensing Boiler Usage	HW Pump Demand	CW Pump Demand	CT Fan Demand	Cooling Penalty and Heating Benefit	Pump Energy Usage	CT Fan Energy Usage	Energy Usage	Demand Cost	Energy Cost	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs
		[btu/lb]							(Tons)	(Btu)	(%)	(%)	(%)	(%)	(%)	(Therms)	(kW)	(kW)	(kW)	(kW)	(kWh)	(kWh)	(kWh)	($)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)
102	79.9	43.2	0	0	0	0	0	1.00	200	0	0%	0%	0%	0%	70%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
97	75.7	39.6	0	8	1	9	6	0.92	184	0	0%	0%	96%	96%	62%	0	0.0	23.1	3.6	55.2	137	21	486	$ 694	$ 88	148.3	$ 27	173.1	$ 31	385.7	$ 70
92	73.0	37.7	0	51	9	60	38	0.84	168	0	0%	0%	92%	92%	55%	0	0.0	20.8	2.6	50.4	790	100	2,805	$ 610	$ 509	854.4	$ 155	996.8	$ 181	2221.5	$ 403
87	69.7	35.7	5	184	68	257	140	0.76	152	0	0%	0%	88%	88%	47%	0	0.0	18.6	1.8	45.6	2,598	252	9,214	$ 531	$ 1,673	2809.5	$ 510	3277.7	$ 595	7304.6	$ 1,327
82	67.5	33.6	45	257	178	480	201	0.68	136	0	0%	0%	84%	84%	40%	0	0.0	16.6	1.2	40.8	3,329	245	11,769	$ 463	$ 2,137	3599.5	$ 654	4199.4	$ 763	9358.7	$ 1,700
77	65.4	32.1	206	263	265	734	211	0.60	120	0	0%	0%	80%	80%	33%	0	0.0	14.7	0.8	36.0	3,102	159	10,875	$ 401	$ 1,975	3354.4	$ 609	3913.5	$ 711	8721.5	$ 1,584
72	62.0	29.7	275	276	294	845	223	0.52	104	0	0%	0%	76%	76%	25%	0	0.0	12.9	0.4	31.2	2,878	84	9,922	$ 345	$ 1,802	3112.4	$ 565	3631.1	$ 659	8092.3	$ 1,470
67	58.2	26.4	385	267	325	977	219	0.44	88	0	0%	0%	72%	72%	50%	0	0.0	11.4	2.1	26.4	2,491	455	8,720	$ 350	$ 1,584	2693.6	$ 489	3142.6	$ 571	7003.5	$ 1,272
62	55.2	23.6	246	175	235	656	145	0.36	72	0	0%	0%	68%	68%	42%	0	0.0	9.9	1.4	21.6	1,431	197	4,758	$ 292	$ 864	1547.2	$ 281	1805.0	$ 328	4022.6	$ 731
57	51.3	20.8	280	212	220	712	171	0.28	56	0	0%	0%	64%	64%	35%	0	0.0	8.5	0.9	16.8	1,450	149	4,471	$ 243	$ 812	1568.3	$ 285	1829.7	$ 332	4077.6	$ 740
52	47.0	18.3	192	181	198	571	147	0.20	40	0	0%	0%	60%	60%	28%	0	0.0	7.2	0.5	12.0	1,059	73	2,892	$ 201	$ 525	1145.1	$ 208	1336.0	$ 243	2977.4	$ 541
47	41.9	15.9	229	271	251	751	216	0.36	0	1,863,286	32%	68%	0%	68%	0%	4,479	5.3	4.6	0.0	-15.5	2,136	0	-1,223	$ 257	$ 3,797	2309.8	$ 419	2694.8	$ 489	6005.5	$ 1,091
42	37.4	13.9	309	265	289	863	215	0.44	0	2,208,967	38%	72%	0%	72%	0%	5,269	6.1	5.3	0.0	-18.4	2,445	0	-1,506	$ 296	$ 4,455	2643.9	$ 480	3084.6	$ 560	6874.2	$ 1,248
37	32.8	12.0	294	237	268	799	193	0.52	0	2,554,648	44%	76%	0%	76%	0%	5,469	6.9	6.0	0.0	-21.3	2,486	0	-1,616	$ 335	$ 4,614	2688.1	$ 488	3136.1	$ 570	6989.1	$ 1,269
32	28.0	10.1	187	124	185	496	104	0.60	0	2,900,329	50%	80%	0%	80%	0%	3,351	7.9	6.8	0.0	-24.2	1,526	0	-988	$ 381	$ 2,828	1649.6	$ 300	1924.5	$ 349	4288.9	$ 779
27	23.2	8.3	124	92	89	305	74	0.68	0	3,246,010	55%	84%	0%	84%	0%	2,659	8.9	7.7	0.0	-27.1	1,222	0	-772	$ 431	$ 2,246	1320.9	$ 240	1541.0	$ 280	3434.3	$ 624
22	18.9	6.7	109	50	37	196	39	0.76	0	3,591,691	61%	88%	0%	88%	0%	1,566	10.0	8.6	0.0	-29.9	731	0	-444	$ 484	$ 1,325	790.1	$ 143	921.7	$ 167	2054.2	$ 373
17	14.7	5.2	22	4	6	32	3	0.84	0	3,937,372	67%	92%	0%	92%	0%	147	11.2	9.6	0.0	-32.8	70	0	-40	$ 541	$ 124	75.5	$ 14	88.1	$ 16	196.4	$ 36
12	10.1	3.8	12	3	2	17	2	0.92	0	4,283,053	73%	96%	0%	96%	0%	111	12.4	10.7	0.0	-35.7	54	0	-29	$ 602	$ 95	58.5	$ 11	68.3	$ 12	152.2	$ 28
7	11.4	2.4	0	0	0	0	0	1.00	0	4,628,734	79%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
2	1.2	1.2	0	0	0	0	0	1.08	0	4,974,415	85%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
-3	(2.6)	0.0	0	0	0	0	0	1.16	0	5,320,096	91%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
TOTALS:			2,920	2,920	2,920	8,760	2,346		149,700	2,074,583,623						23,051	12	23	4	131	29,935	1,736	59,292	$ 8,332	$ 39,785	3,600	$ 5,878	4,199	$ 6,858	9,359	$ 15,283

Assumptions	
Building Type	IN4
Building Interior Square Footage	100,000
Building Footprint Square Footage	10,000
Number of Floors	10.0
Perimeter Surface Area	48,000
Wall to Window Ratio	21%
Outside Air CFM	51,805
Cooling Design Load (Tons)	200
Heating Design Load (Btu)	824,174
Demand Cost ($/kW)	$ 26.00
Electricity Energy Cost ($/kWh)	$ 0.18
Natural Gas Cost ($/Therm)	$ 0.90
#2 Fuel Oil Cost ($/gal)	$ 1.55
#4 Fuel Oil Cost ($/gal)	$ 1.37
District Steam Cost ($/Mlb)	$ 24.03
Cooling Penalty for EWT (kW/ton)	0.3
Heating Benefit for EWT (kW/Ton)	0.1
Load Factor Decrease per 5 F	0.08

Auxiliary Equipment	
Condensing Boiler (MBH)	5,852
Condensing Boiler Efficiency	90%
Cooling Tower Peak kW	11.2
Primary CW Pump Peak kW	13.2
Primary HW Pump Peak kW	13.2
Secondary CW Pump Peak kW	11.4
Closed Loop Pump Peak kW	26.6
Open Loop Pump Peak kW	31.0
Standing Column Well Pump Peak kW	69.2
Minimum Fan Speed	20%
Minimum Pump Speed	20%

VFD Efficiency	
2%	0.47
13%	0.86
25%	0.93
42%	0.94
50%	0.95
75%	0.96
100%	0.97

Installation Costs	
Condensing Boiler	$ 390,000
Cooling Tower	$ 200,000
Primary CW Pump	$ 2,000
Primary HW Pump	$ 2,000
Secondary CW Pump	$ 1,800
Maintenance Costs	
Condensing Boiler	$ 29,261
Cooling Tower	$ 2,800

GOLDMAN COPELAND
CONSULTING ENGINEERS

Heating and Cooling Load Calculations

Weather data			Hours				Operating Hours	Building Load			Conventional Operation														Geothermal Operation		Geothermal Operation		Geothermal Operation	
DB (+-2)	MCWB	h	1-8	9-16	17-0	Total	Occupied Space	Load Factor	Cooling Load	Heating Load	Condensing Boiler Load	Primary HW Pump Speed	Primary CW Pump Speed	Secondary CW Pump Speed	CT Fan Speed	Condensing Boiler Usage	HW Pump Demand	CW Pump Demand	CT Fan Demand	Cooling Penalty and Heating Benefit	Pump Energy Usage	CT Fan Energy Usage	Energy Usage	Demand Cost	Energy Cost	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs
		[btu/lb]							(Tons)	(Btu)	(%)	(%)	(%)	(%)	(%)	(Therms)	(kW)	(kW)	(kW)	(kW)	(kWh)	(kWh)	(kWh)	($)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)
102	79.9	43.2	0	0	0	0	0	1.00	230	0	0%	0%	0%	0%	70%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
97	75.7	39.6	0	8	1	9	4	0.92	212	0	0%	0%	96%	96%	62%	0	0.0	26.6	4.1	63.5	94	14	331	$ 798	$ 60	71.8	$ 13	83.8	$ 15	186.7	$ 34
92	73.0	37.7	0	51	9	60	23	0.84	193	0	0%	0%	92%	92%	55%	0	0.0	23.9	3.0	58.0	542	69	1,924	$ 701	$ 349	415.9	$ 76	485.2	$ 88	1081.2	$ 196
87	69.7	35.7	5	184	68	257	85	0.76	175	0	0%	0%	88%	88%	47%	0	0.0	21.4	2.1	52.4	1,823	177	6,465	$ 611	$ 1,174	1398.3	$ 254	1631.4	$ 296	3635.7	$ 660
82	67.5	33.6	45	257	178	480	128	0.68	156	0	0%	0%	84%	84%	40%	0	0.0	19.1	1.4	46.9	2,440	179	8,627	$ 532	$ 1,567	1871.8	$ 340	2183.8	$ 397	4866.8	$ 884
77	65.4	32.1	206	263	265	734	146	0.60	138	0	0%	0%	80%	80%	33%	0	0.0	16.9	0.9	41.4	2,456	126	8,608	$ 461	$ 1,563	1883.7	$ 342	2197.6	$ 399	4897.6	$ 889
72	62.0	29.7	275	276	294	845	314	0.52	120	0	0%	0%	76%	76%	25%	0	0.0	14.8	0.4	35.9	4,654	136	16,042	$ 397	$ 2,913	3569.9	$ 648	4164.9	$ 756	9281.7	$ 1,686
67	58.2	26.4	385	267	325	977	321	0.44	101	0	0%	0%	72%	72%	50%	0	0.0	13.1	2.4	30.4	4,208	769	14,731	$ 403	$ 2,675	3228.2	$ 586	3766.2	$ 684	8393.2	$ 1,524
62	55.2	23.6	246	175	235	656	214	0.36	83	0	0%	0%	68%	68%	42%	0	0.0	11.4	1.6	24.8	2,429	335	8,078	$ 336	$ 1,467	1863.4	$ 338	2173.9	$ 395	4844.7	$ 880
57	51.3	20.8	280	212	220	712	246	0.28	64	0	0%	0%	64%	64%	35%	0	0.0	9.8	1.0	19.3	2,400	247	7,400	$ 280	$ 1,344	1841.4	$ 334	2148.3	$ 390	4787.6	$ 869
52	47.0	18.3	192	181	198	571	208	0.20	46	0	0%	0%	60%	60%	28%	0	0.0	8.3	0.6	13.8	1,724	119	4,709	$ 231	$ 855	1322.7	$ 240	1543.1	$ 280	3438.9	$ 625
47	41.9	15.9	229	271	251	751	298	0.36	0	1,494,509	31%	68%	0%	68%	0%	4,941	6.1	5.3	0.0	-12.5	3,379	0	-327	$ 295	$ 4,375	2591.8	$ 471	3023.7	$ 549	6738.6	$ 1,224
42	37.4	13.9	309	265	289	863	306	0.44	0	1,779,079	37%	72%	0%	72%	0%	6,056	7.0	6.1	0.0	-14.8	4,013	0	-529	$ 341	$ 5,338	3078.2	$ 559	3591.2	$ 652	8003.2	$ 1,453
37	32.8	12.0	294	237	268	799	277	0.52	0	2,063,648	43%	76%	0%	76%	0%	6,357	8.0	6.9	0.0	-17.2	4,114	0	-654	$ 386	$ 5,586	3155.8	$ 573	3681.8	$ 669	8205.2	$ 1,490
32	28.0	10.1	187	124	185	496	156	0.60	0	2,348,217	49%	80%	0%	80%	0%	4,071	9.1	7.8	0.0	-19.6	2,632	0	-421	$ 439	$ 3,577	2018.9	$ 367	2355.3	$ 428	5249.1	$ 953
27	23.2	8.3	124	92	89	305	106	0.68	0	2,632,787	55%	84%	0%	84%	0%	3,096	10.2	8.8	0.0	-21.9	2,017	0	-305	$ 495	$ 2,723	1547.0	$ 281	1804.8	$ 328	4022.1	$ 730
22	18.9	6.7	109	50	37	196	59	0.76	0	2,917,356	61%	88%	0%	88%	0%	1,919	11.5	9.9	0.0	-24.3	1,267	0	-172	$ 557	$ 1,691	972.1	$ 177	1134.1	$ 206	2527.5	$ 459
17	14.7	5.2	22	4	6	32	6	0.84	0	3,201,926	67%	92%	0%	92%	0%	230	12.8	11.1	0.0	-26.7	155	0	-18	$ 622	$ 203	118.6	$ 22	138.4	$ 25	308.4	$ 56
12	10.1	3.8	12	3	2	17	4	0.92	0	3,486,495	73%	96%	0%	96%	0%	155	14.3	12.3	0.0	-29.1	106	0	-10	$ 692	$ 137	81.6	$ 15	95.3	$ 17	212.3	$ 39
7	11.4	2.4	0	0	0	0	0	1.00	0	3,771,064	79%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
2	1.2	1.2	0	0	0	0	0	1.08	0	4,055,634	85%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
-3	(2.6)	0.0	0	0	0	0	0	1.16	0	4,340,203	91%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
TOTALS:			2,920	2,920	2,920	8,760	2,900		173,251	2,414,154,906						26,824	14	27	4	220	40,453	2,171	74,481	$ 9,581	$ 47,179	3,570	$ 5,635	4,165	$ 6,574	9,282	$ 14,652

Assumptions	
Building Type	IN5
Building Interior Square Footage	100,000
Building Footprint Square Footage	10,000
Number of Floors	10.0
Perimeter Surface Area	48,000
Wall to Window Ratio	41%
Outside Air CFM	36,018
Cooling Design Load (Tons)	230
Heating Design Load (Btu)	1,125,902
Demand Cost ($/kW)	$ 26.00
Electricity Energy Cost ($/kWh)	$ 0.18
Natural Gas Cost ($/Therm)	$ 0.90
#2 Fuel Oil Cost ($/gal)	$ 1.55
#4 Fuel Oil Cost ($/gal)	$ 1.37
District Steam Cost ($/Mlb)	$ 24.03
Cooling Penalty for EWT (kW/ton)	0.3
Heating Benefit for EWT (kW/Ton)	0.1
Load Factor Decrease per 5 F	0.08

Auxiliary Equipment	
Condensing Boiler (MBH)	4,774
Condensing Boiler Efficiency	90%
Cooling Tower Peak kW	12.9
Primary CW Pump Peak kW	15.2
Primary HW Pump Peak kW	15.2
Secondary CW Pump Peak kW	13.1
Closed Loop Pump Peak kW	21.7
Open Loop Pump Peak kW	25.3
Standing Column Well Pump Peak kW	56.4
Minimum Fan Speed	20%
Minimum Pump Speed	20%

VFD Efficiency	
2%	0.47
13%	0.86
25%	0.93
42%	0.94
50%	0.95
75%	0.96
100%	0.97

Installation Costs	
Condensing Boiler	$ 360,000
Cooling Tower	$ 230,000
Primary CW Pump	$ 2,300
Primary HW Pump	$ 2,000
Secondary CW Pump	$ 2,000
Maintenance Costs	
Condensing Boiler	$ 23,871
Cooling Tower	$ 3,220

GOLDMAN COPELAND
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Heating and Cooling Load Calculations

Weather data			Hours				Operating Hours	Building Load			Conventional Operation																Geothermal Operation		Geothermal Operation		Geothermal Operation	
DB (+-2)	MCWB	h	1-8	9-16	17-0	Total	Fully Occupied Hours with Load Factor*	Load Factor	Cooling Load	Heating Load	Condensing Boiler Load	Primary HW Pump Speed	Primary CW Pump Speed	Secondary CW Pump Speed	CT Fan Speed	Condensing Boiler Usage	HW Pump Demand	CW Pump Demand	CT Fan Demand	Cooling Penalty and Heating Benefit	Pump Energy Usage	CT Fan Energy Usage	Energy Usage	Demand Cost	Energy Cost	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs
		[btu/lb]							(Tons)	(Btu)	(%)	(%)	(%)	(%)	(%)	(Therms)	(kW)	(kW)	(kW)	(kW)	(kWh)	(kWh)	(kWh)	($)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)
102	79.9	43.2	0	0	0	0	0	1.00	200	0	0%	0%	0%	0%	70%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
97	75.7	39.6	0	8	1	9	4	0.92	184	0	0%	0%	96%	96%	62%	0	0.0	23.1	3.6	55.2	101	16	357	$ 694	$ 65	57.9	$ 11	67.5	$ 12	150.5	$ 27
92	73.0	37.7	0	51	9	60	30	0.84	168	0	0%	0%	92%	92%	55%	0	0.0	20.8	2.6	50.4	625	79	2,220	$ 610	$ 403	359.2	$ 65	419.0	$ 76	933.9	$ 170
87	69.7	35.7	5	184	68	257	144	0.76	152	0	0%	0%	88%	88%	47%	0	0.0	18.6	1.8	45.6	2,675	259	9,488	$ 531	$ 1,723	1536.4	$ 279	1792.4	$ 326	3994.5	$ 725
82	67.5	33.6	45	257	178	480	306	0.68	136	0	0%	0%	84%	84%	40%	0	0.0	16.6	1.2	40.8	5,065	372	17,909	$ 463	$ 3,252	2908.9	$ 528	3393.7	$ 616	7563.1	$ 1,373
77	65.4	32.1	206	263	265	734	522	0.60	120	0	0%	0%	80%	80%	33%	0	0.0	14.7	0.8	36.0	7,658	393	26,847	$ 401	$ 4,875	4398.0	$ 799	5131.0	$ 932	11434.9	$ 2,077
72	62.0	29.7	275	276	294	845	612	0.52	104	0	0%	0%	76%	76%	25%	0	0.0	12.9	0.4	31.2	7,899	230	27,229	$ 345	$ 4,945	4536.2	$ 824	5292.2	$ 961	11794.1	$ 2,142
67	58.2	26.4	385	267	325	977	730	0.44	0	0	0%	0%	0%	72%	50%	0	0.0	5.3	0.0	0.0	3,851	0	3,851	$ 137	$ 699	4772.2	$ 867	5567.6	$ 1,011	12407.8	$ 2,253
62	55.2	23.6	246	175	235	656	492	0.36	0	0	0%	0%	0%	68%	42%	0	0.0	4.6	0.0	0.0	2,251	0	2,251	$ 119	$ 409	2789.2	$ 507	3254.0	$ 591	7251.9	$ 1,317
57	51.3	20.8	280	212	220	712	524	0.28	0	0	0%	0%	0%	64%	35%	0	0.0	3.9	0.0	0.0	2,061	0	2,061	$ 102	$ 374	2553.8	$ 464	2979.4	$ 541	6639.9	$ 1,206
52	47.0	18.3	192	181	198	571	416	0.36	0	865,132	28%	68%	0%	68%	28%	3,999	5.3	4.6	0.0	-7.2	4,107	0	1,108	$ 257	$ 3,790	2358.7	$ 428	2751.8	$ 500	6132.7	$ 1,114
47	41.9	15.9	229	271	251	751	533	0.36	0	913,732	29%	68%	0%	68%	0%	5,412	5.3	4.6	0.0	-7.6	5,264	0	1,204	$ 257	$ 5,076	3022.8	$ 549	3526.6	$ 640	7859.3	$ 1,427
42	37.4	13.9	309	265	289	863	632	0.44	0	1,104,903	36%	72%	0%	72%	0%	7,761	6.1	5.3	0.0	-9.2	7,201	0	1,380	$ 296	$ 7,215	4135.2	$ 751	4824.4	$ 876	10751.5	$ 1,952
37	32.8	12.0	294	237	268	799	589	0.52	0	1,296,075	42%	76%	0%	76%	0%	8,479	6.9	6.0	0.0	-10.8	7,598	0	1,238	$ 335	$ 7,834	4363.1	$ 792	5090.3	$ 924	11344.0	$ 2,060
32	28.0	10.1	187	124	185	496	376	0.60	0	1,487,246	48%	80%	0%	80%	0%	6,206	7.9	6.8	0.0	-12.4	5,508	0	854	$ 381	$ 5,724	3163.4	$ 574	3690.6	$ 670	8224.8	$ 1,494
27	23.2	8.3	124	92	89	305	224	0.68	0	1,678,418	54%	84%	0%	84%	0%	4,176	8.9	7.7	0.0	-14.0	3,711	0	579	$ 431	$ 3,853	2131.1	$ 387	2486.2	$ 451	5540.7	$ 1,006
22	18.9	6.7	109	50	37	196	147	0.76	0	1,869,589	60%	88%	0%	88%	0%	3,063	10.0	8.6	0.0	-15.6	2,745	0	448	$ 484	$ 2,830	1576.4	$ 286	1839.1	$ 334	4098.6	$ 744
17	14.7	5.2	22	4	6	32	26	0.84	0	2,060,761	66%	92%	0%	92%	0%	591	11.2	9.6	0.0	-17.2	537	0	94	$ 541	$ 548	308.6	$ 56	360.0	$ 65	802.3	$ 146
12	10.1	3.8	12	3	2	17	13	0.92	0	2,251,932	72%	96%	0%	96%	0%	334	12.4	10.7	0.0	-18.8	309	0	58	$ 602	$ 310	177.2	$ 32	206.7	$ 38	460.7	$ 84
7	11.4	2.4	0	0	0	0	0	1.00	0	2,443,104	79%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
2	1.2	1.2	0	0	0	0	0	1.08	0	2,634,276	85%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
-3	(2.6)	0.0	0	0	0	0	0	1.16	0	2,825,447	91%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
TOTALS:			2,920	2,920	2,920	8,760	6,320		195,584	3,601,890,015						40,021	12	23	4		69,166	1,349	99,175	$ 8,332	$ 62,257	4,772	$ 8,199	5,568	$ 9,565	12,408	$ 21,317

*These occupany hours factor in the actual % of occupancy for the multifamily buildings at each time period.

Assumptions	
Building Type	MF1
Building Interior Square Footage	100,000
Building Footprint Square Footage	10,000
Number of Floors	10.0
Perimeter Surface Area	48,000
Wall to Window Ratio	30%
Outside Air CFM	9,000
Cooling Design Load (Tons)	200
Heating Design Load (Btu)	1,782,144
Demand Cost ($/kW)	$ 26.00
Electricity Energy Cost ($/kWh)	$ 0.18
Natural Gas Cost ($/Therm)	$ 0.90
#2 Fuel Oil Cost ($/gal)	$ 1.55
#4 Fuel Oil Cost ($/gal)	$ 1.37
District Steam Cost ($/Mlb)	$ 24.03
Cooling Penalty for EWT (kW/ton)	0.3
Heating Benefit for EWT (kW/Ton)	0.1
Load Factor Decrease per 5 F	0.08

Auxiliary Equipment	
Condensing Boiler (MBH)	3,108
Condensing Boiler Efficiency	90%
Cooling Tower Peak kW	11.2
Primary CW Pump Peak kW	13.2
Primary HW Pump Peak kW	13.2
Secondary CW Pump Peak kW	11.4
Closed Loop Pump Peak kW	14.1
Open Loop Pump Peak kW	16.5
Standing Column Well Pump Peak kW	36.7
Minimum Fan Speed	20%
Minimum Pump Speed	20%

VFD Efficiency	
2%	0.47
13%	0.86
25%	0.93
42%	0.94
50%	0.95
75%	0.96
100%	0.97

Installation Costs	
Condensing Boiler	$ 240,000
Cooling Tower	$ 20,000
Primary CW Pump	$ 2,000
Primary HW Pump	$ 2,000
Secondary CW Pump	$ 1,800
Maintenance Costs	
Condensing Boiler	$ 15,540
Cooling Tower	$ 2,800

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Heating and Cooling Load Calculations

Weather data			Hours				Operating Hours	Building Load			Conventional Operation												Geothermal Operation		Geothermal Operation		Geothermal Operation		Geothermal Heat Pump Energy	
DB (+-2)	MCWB	h	1-8	9-16	17-0	Total	Fully Occupied Hours with Load Factor*	Load Factor	Cooling Load	Heating Load	Condensing Boiler Load	Primary HW Pump Speed	Split System Load	Extra kW/Ton for Air Cooled System	Condensing Boiler Usage	HW Pump Demand	Split System Demand	Pump Energy Usage	Split System Energy Usage	Energy Usage	Demand Cost	Energy Cost	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Heat Pump Demand	Geothermal Heat Pump Energy Costs
		[btu/lb]							(Tons)	(Btu)	(%)	(%)	(%)	(kW)	(Therms)	(kW)	(kW)	(kWh)	(kWh)	(kWh)	($)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)
102	79.9	43.2	0	0	0	0	0	1.00	100	0	0%	0%	70%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
97	75.7	39.6	0	8	1	9	4	0.92	92	0	0%	0%	62%	28	0	0.0	34.9	0	152	152	$ 907	$ 28	31.0	$ 6	36.2	$ 7	80.6	$ 15	0	$ -
92	73.0	37.7	0	51	9	60	30	0.84	84	0	0%	0%	55%	25	0	0.0	31.7	0	952	952	$ 823	$ 173	192.4	$ 35	224.5	$ 41	500.3	$ 91	0	$ -
87	69.7	35.7	5	184	68	257	144	0.76	76	0	0%	0%	47%	23	0	0.0	28.3	0	4,069	4,069	$ 736	$ 739	823.1	$ 149	960.2	$ 174	2140.0	$ 389	0	$ -
82	67.5	33.6	45	257	178	480	306	0.68	68	0	0%	0%	40%	20	0	0.0	25.1	0	7,671	7,671	$ 652	$ 1,393	1558.4	$ 283	1818.1	$ 330	4051.8	$ 736	0	$ -
77	65.4	32.1	206	263	265	734	522	0.60	60	0	0%	0%	33%	18	0	0.0	21.9	0	11,420	11,420	$ 569	$ 2,074	2356.2	$ 428	2748.8	$ 499	6126.0	$ 1,112	0	$ -
72	62.0	29.7	275	276	294	845	612	0.52	52	0	0%	0%	25%	16	0	0.0	18.5	0	11,346	11,346	$ 482	$ 2,060	2430.2	$ 441	2835.2	$ 515	6318.5	$ 1,147	0	$ -
67	58.2	26.4	385	267	325	977	730	0.44	0	0	0%	0%	50%	0	0	0.0	0.0	0	0	0	$ -	$ -	2556.6	$ 464	2982.7	$ 542	6647.2	$ 1,207	0	$ -
62	55.2	23.6	246	175	235	656	492	0.36	0	0	0%	0%	42%	0	0	0.0	0.0	0	0	0	$ -	$ -	1494.2	$ 271	1743.3	$ 317	3885.0	$ 706	0	$ -
57	51.3	20.8	280	212	220	712	524	0.28	0	0	0%	0%	35%	0	0	0.0	0.0	0	0	0	$ -	$ -	1368.1	$ 248	1596.2	$ 290	3557.2	$ 646	0	$ -
52	47.0	18.3	192	181	198	571	416	0.36	0	463,895	28%	68%	28%	0	2,144	2.6	0.0	1,102	0	1,102	$ 69	$ 2,124	1263.6	$ 229	1474.2	$ 268	3285.4	$ 597	9,775	$ 1,775
47	41.9	15.9	229	271	251	751	533	0.36	0	488,195	29%	68%	0%	0	2,892	2.6	0.0	1,412	0	1,412	$ 69	$ 2,851	1619.4	$ 294	1889.3	$ 343	4210.4	$ 765	13,183	$ 2,394
42	37.4	13.9	309	265	289	863	632	0.44	0	590,742	35%	72%	0%	0	4,149	3.1	0.0	1,932	0	1,932	$ 79	$ 4,075	2215.3	$ 402	2584.6	$ 469	5759.9	$ 1,046	18,917	$ 3,435
37	32.8	12.0	294	237	268	799	589	0.52	0	693,290	42%	76%	0%	0	4,536	3.5	0.0	2,038	0	2,038	$ 90	$ 4,441	2337.4	$ 424	2727.0	$ 495	6077.3	$ 1,104	20,679	$ 3,755
32	28.0	10.1	187	124	185	496	376	0.60	0	795,838	48%	80%	0%	0	3,321	3.9	0.0	1,478	0	1,478	$ 102	$ 3,248	1694.7	$ 308	1977.2	$ 359	4406.3	$ 800	15,139	$ 2,749
27	23.2	8.3	124	92	89	305	224	0.68	0	898,385	54%	84%	0%	0	2,235	4.4	0.0	996	0	996	$ 116	$ 2,187	1141.7	$ 207	1331.9	$ 242	2968.3	$ 539	10,191	$ 1,851
22	18.9	6.7	109	50	37	196	147	0.76	0	1,000,933	60%	88%	0%	0	1,640	5.0	0.0	736	0	736	$ 130	$ 1,605	844.5	$ 153	985.3	$ 179	2195.7	$ 399	7,477	$ 1,358
17	14.7	5.2	22	4	6	32	26	0.84	0	1,103,481	66%	92%	0%	0	317	5.6	0.0	144	0	144	$ 145	$ 310	165.3	$ 30	192.9	$ 35	429.8	$ 78	1,444	$ 262
12	10.1	3.8	12	3	2	17	13	0.92	0	1,206,028	72%	96%	0%	0	179	6.2	0.0	83	0	83	$ 161	$ 175	94.9	$ 17	110.8	$ 20	246.8	$ 45	815	$ 148
7	11.4	2.4	0	0	0	0	0	1.00	0	1,308,576	79%	0%	0%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
2	1.2	1.2	0	0	0	0	0	1.08	0	1,411,124	85%	0%	0%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
-3	(2.6)	0.0	0	0	0	0	0	1.16	0	1,513,671	91%	0%	0%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
TOTALS:			2,920	2,920	2,920	8,760	6,320		97,792	1,927,096,614					21,412	6	35	9,921	35,610	45,531	$ 10,882	$ 38,365	2,557	$ 4,392	2,983	$ 5,124	6,647	$ 11,420	97,620	$ 17,728

*These occupany hours factor in the actual % of occupancy for the multifamily buildings at each time period.

Assumptions	
Building Type	MF2
Building Interior Square Footage	50,000
Building Footprint Square Footage	10,000
Number of Floors	5.0
Perimeter Surface Area	24,000
Wall to Window Ratio	30%
Outside Air CFM	4,500
Cooling Design Load (Tons)	100
Heating Design Load (Btu)	978,096
Demand Cost ($/kW)	$ 26.00
Electricity Energy Cost ($/kWh)	$ 0.18
Natural Gas Cost ($/Therm)	$ 0.90
#2 Fuel Oil Cost ($/gal)	$ 1.55
#4 Fuel Oil Cost ($/gal)	$ 1.37
District Steam Cost ($/Mlb)	$ 24.03
Air Cooled kW/Ton Penalty	0.3
Load Factor Decrease per 5 F	0.08

Auxiliary Equipment	
Condensing Boiler (MBH)	1,665
Condensing Boiler Efficiency	90%
Split System Condenser Fan Peak kW	11.7
Primary HW Pump Peak kW	6.6
Closed Loop Pump Peak kW	7.6
Open Loop Pump Peak kW	8.8
Standing Column Well Pump Peak kW	19.7
Heat Pump Efficiency (COP)	4.5
Heat Cooling Coincidence factor	0.7
Minimum Fan Speed	20%
Minimum Pump Speed	20%

VFD Efficiency	
2%	0.47
13%	0.86
25%	0.93
42%	0.94
50%	0.95
75%	0.96
100%	0.97

Installation Costs	
Condensing Boiler	$ 130,000
Split System AC Units	$ 100,000
Primary HW Pump	$ 1,000
Maintenance Costs	
Condensing Boiler	$ 8,325
Cooling Tower	$ 1,400

GOLDMAN COPELAND
CONSULTING ENGINEERS

Heating and Cooling Load Calculations

Weather data			Hours				Operating Hours	Building Load			Conventional Operation															Geothermal Operation		Geothermal Operation		Geothermal Operation	
DB (+-2)	MCWB	h	1-8	9-16	17-0	Total	Fully Occupied Hours with Load Factor*	Load Factor	Cooling Load	Heating Load	Steam Boiler Load	Primary HW Pump Speed	Primary CW Pump Speed	Secondary CW Pump Speed	CT Fan Speed	Steam Boiler Usage	HW Pump Demand	CW Pump Demand	CT Fan Demand	Cooling Penalty and Heating Benefit	Pump Energy Usage	CT Fan Energy Usage	Energy Usage	Demand Cost	Energy Cost	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs
		[btu/lb]							(Tons)	(Btu)	(%)	(%)	(%)	(%)	(%)	(Therms)	(kW)	(kW)	(kW)	(kW)	(kWh)	(kWh)	(kWh)	($)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)
102	79.9	43.2	0	0	0	0	0	1.00	200	0	0%	0%	0%	0%	70%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
97	75.7	39.6	0	8	1	9	4	0.92	184	0	0%	0%	96%	96%	62%	0	0.0	23.1	3.6	55.2	101	16	357	$ 694	$ 65	49.2	$ 9	57.4	$ 10	100.1	$ 18
92	73.0	37.7	0	51	9	60	30	0.84	168	0	0%	0%	92%	92%	55%	0	0.0	20.8	2.6	50.4	625	79	2,220	$ 610	$ 403	305.1	$ 55	355.9	$ 65	620.9	$ 113
87	69.7	35.7	5	184	68	257	144	0.76	152	0	0%	0%	88%	88%	47%	0	0.0	18.6	1.8	45.6	2,675	259	9,488	$ 531	$ 1,723	1305.0	$ 237	1522.5	$ 276	2655.7	$ 482
82	67.5	33.6	45	257	178	480	306	0.68	136	0	0%	0%	84%	84%	40%	0	0.0	16.6	1.2	40.8	5,065	372	17,909	$ 463	$ 3,252	2470.9	$ 449	2882.7	$ 523	5028.3	$ 913
77	65.4	32.1	206	263	265	734	522	0.60	120	0	0%	0%	80%	80%	33%	0	0.0	14.7	0.8	36.0	7,658	393	26,847	$ 401	$ 4,875	3735.8	$ 678	4358.4	$ 791	7602.4	$ 1,381
72	62.0	29.7	275	276	294	845	612	0.52	104	0	0%	0%	76%	76%	25%	0	0.0	12.9	0.4	31.2	7,899	230	27,229	$ 345	$ 4,945	3853.2	$ 700	4495.4	$ 816	7841.3	$ 1,424
67	58.2	26.4	385	267	325	977	730	0.44	0	0	0%	0%	0%	72%	50%	0	0.0	5.3	0.0	0.0	3,851	0	3,851	$ 137	$ 699	4053.6	$ 736	4729.2	$ 859	8249.2	$ 1,498
62	55.2	23.6	246	175	235	656	492	0.36	0	0	0%	0%	0%	68%	42%	0	0.0	4.6	0.0	0.0	2,251	0	2,251	$ 119	$ 409	2369.2	$ 430	2764.1	$ 502	4821.4	$ 876
57	51.3	20.8	280	212	220	712	524	0.28	0	0	0%	0%	0%	64%	35%	0	0.0	3.9	0.0	0.0	2,061	0	2,061	$ 102	$ 374	2169.3	$ 394	2530.8	$ 460	4414.5	$ 802
52	47.0	18.3	192	181	198	571	416	0.36	0	567,337	27%	68%	0%	68%	28%	2,622	5.3	4.6	0.0	-4.7	4,107	0	2,141	$ 257	$ 2,742	2003.6	$ 364	2337.5	$ 424	4077.3	$ 740
47	41.9	15.9	229	271	251	751	533	0.36	0	632,137	31%	68%	0%	68%	0%	3,744	5.3	4.6	0.0	-5.3	5,264	0	2,455	$ 257	$ 3,806	2567.6	$ 466	2995.6	$ 544	5225.2	$ 949
42	37.4	13.9	309	265	289	863	632	0.44	0	756,772	37%	72%	0%	72%	0%	5,316	6.1	5.3	0.0	-6.3	7,201	0	3,214	$ 296	$ 5,354	3512.5	$ 638	4097.9	$ 744	7148.1	$ 1,298
37	32.8	12.0	294	237	268	799	589	0.52	0	881,407	43%	76%	0%	76%	0%	5,766	6.9	6.0	0.0	-7.3	7,598	0	3,273	$ 335	$ 5,769	3706.1	$ 673	4323.8	$ 785	7542.0	$ 1,370
32	28.0	10.1	187	124	185	496	376	0.60	0	1,006,042	49%	80%	0%	80%	0%	4,198	7.9	6.8	0.0	-8.4	5,508	0	2,360	$ 381	$ 4,196	2687.1	$ 488	3134.9	$ 569	5468.2	$ 993
27	23.2	8.3	124	92	89	305	224	0.68	0	1,130,676	55%	84%	0%	84%	0%	2,813	8.9	7.7	0.0	-9.4	3,711	0	1,601	$ 431	$ 2,815	1810.2	$ 329	2111.9	$ 384	3683.7	$ 669
22	18.9	6.7	109	50	37	196	147	0.76	0	1,255,311	61%	88%	0%	88%	0%	2,057	10.0	8.6	0.0	-10.5	2,745	0	1,202	$ 484	$ 2,064	1339.0	$ 243	1562.2	$ 284	2724.9	$ 495
17	14.7	5.2	22	4	6	32	26	0.84	0	1,379,946	67%	92%	0%	92%	0%	396	11.2	9.6	0.0	-11.5	537	0	240	$ 541	$ 399	262.1	$ 48	305.8	$ 56	533.4	$ 97
12	10.1	3.8	12	3	2	17	13	0.92	0	1,504,581	73%	96%	0%	96%	0%	223	12.4	10.7	0.0	-12.5	309	0	141	$ 602	$ 226	150.5	$ 27	175.6	$ 32	306.3	$ 56
7	11.4	2.4	0	0	0	0	0	1.00	0	1,629,216	79%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
2	1.2	1.2	0	0	0	0	0	1.08	0	1,753,851	85%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
-3	(2.6)	0.0	0	0	0	0	0	1.16	0	1,878,486	91%	0%	0%	0%	0%	0	0.0	0.0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -
TOTALS:			2,920	2,920	2,920	8,760	6,320		195,584	2,442,169,883						27,135	12	23	4	183	69,166	1,349	108,839	$ 8,332	$ 52,448	4,054	$ 6,964	4,729	$ 8,125	8,249	$ 14,173

*These occupany hours factor in the actual % of occupancy for the multifamily buildings at each time period.

Assumptions	
Building Type	NYCHA
Building Interior Square Footage	100,000
Building Footprint Square Footage	10,000
Number of Floors	10.0
Perimeter Surface Area	48,000
Wall to Window Ratio	21%
Infiltration CFM	12,000
Cooling Design Load (Tons)	200
Heating Design Load (Btu)	747,936
Demand Cost ($/kW)	$ 26.00
Electricity Energy Cost ($/kWh)	$ 0.18
Natural Gas Cost ($/Therm)	$ 0.90
#2 Fuel Oil Cost ($/gal)	$ 1.55
#4 Fuel Oil Cost ($/gal)	$ 1.37
District Steam Cost ($/Mlb)	$ 24.03
Cooling Penalty for EWT (kW/ton)	0.3
Heating Benefit for EWT (kW/Ton)	0.1
Load Factor Decrease per 5 F	0.08

Auxiliary Equipment	
Walls, Steel-Framed R-13	2,066
Condensing Boiler Efficiency	90%
Cooling Tower Peak kW	11.2
Primary CW Pump Peak kW	13.2
Primary HW Pump Peak kW	13.2
Secondary CW Pump Peak kW	11.4
Closed Loop Pump Peak kW	12.0
Open Loop Pump Peak kW	14.0
Standing Column Well Pump Peak kW	24.4
Minimum Fan Speed	20%
Minimum Pump Speed	20%

VFD Efficiency	
2%	0.47
13%	0.86
25%	0.93
42%	0.94
50%	0.95
75%	0.96
100%	0.97

Installation Costs	
Condensing Boiler	$ 160,000
Cooling Tower	$ 200,000
Primary CW Pump	$ 2,000
Primary HW Pump	$ 2,000
Secondary CW Pump	$ 1,800
Maintenance Costs	
Steam Boiler	$ 10,332
Cooling Tower	$ 2,800

GOLDMAN COPELAND
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Heating and Cooling Load Calculations

Weather data			Hours				Operating Hours	Building Load			Conventional Operation												Geothermal Operation		Geothermal Operation		Geothermal Operation		Geothermal Heat Pump Energy	
DB (+-2)	MCWB	h	1-8	9-16	17-0	Total	Occupied Space	Load Factor	Cooling Load	Heating Load	Condensing Boiler Load	Primary HW Pump Speed	Split System Load	Extra kW/Ton for Air Cooled System	Condensing Boiler Usage	HW Pump Demand	Split System Demand	Pump Energy Usage	Split System Energy Usage	Energy Usage	Demand Cost	Energy Cost	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Heat Pump Demand	Geothermal Heat Pump Energy Costs
		[btu/lb]							(Tons)	(Btu)	(%)	(%)	(%)	(kW)	(Therms)	(kW)	(kW)	(kWh)	(kWh)	(kWh)	($)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)
102	79.9	43.2	0	0	0	0	0	1.00	200	0	0%	0%	70%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
97	75.7	39.6	0	8	1	9	3	0.92	184	0	0%	0%	62%	55	0	0.0	69.8	0	239	239	$ 1,814	$ 43	40.6	$ 7	59.1	$ 11	131.7	$ 24	0	$ -
92	73.0	37.7	0	51	9	60	24	0.84	168	0	0%	0%	55%	50	0	0.0	63.3	0	1,526	1,526	$ 1,646	$ 277	256.4	$ 47	373.5	$ 68	832.5	$ 151	0	$ -
87	69.7	35.7	5	184	68	257	122	0.76	152	0	0%	0%	47%	46	0	0.0	56.6	0	6,933	6,933	$ 1,472	$ 1,259	1165.4	$ 212	1697.5	$ 308	3783.1	$ 687	0	$ -
82	67.5	33.6	45	257	178	480	280	0.68	136	0	0%	0%	40%	41	0	0.0	50.2	0	14,062	14,062	$ 1,305	$ 2,554	2374.2	$ 431	3458.3	$ 628	7707.1	$ 1,400	0	$ -
77	65.4	32.1	206	263	265	734	518	0.60	120	0	0%	0%	33%	36	0	0.0	43.7	0	22,647	22,647	$ 1,137	$ 4,113	3883.0	$ 705	5656.1	$ 1,027	12605.0	$ 2,289	0	$ -
72	62.0	29.7	275	276	294	845	616	0.52	104	0	0%	0%	25%	31	0	0.0	37.1	0	22,824	22,824	$ 964	$ 4,145	4062.5	$ 738	5917.6	$ 1,075	13187.8	$ 2,395	0	$ -
67	58.2	26.4	385	267	325	977	749	0.44	0	0	0%	0%	50%	0	0	0.0	0.0	0	0	0	$ -	$ -	4364.8	$ 793	6358.0	$ 1,155	14169.3	$ 2,573	0	$ -
62	55.2	23.6	246	175	235	656	504	0.36	0	0	0%	0%	42%	0	0	0.0	0.0	0	0	0	$ -	$ -	2543.0	$ 462	3704.3	$ 673	8255.3	$ 1,499	0	$ -
57	51.3	20.8	280	212	220	712	537	0.28	0	0	0%	0%	35%	0	0	0.0	0.0	0	0	0	$ -	$ -	2328.7	$ 423	3392.1	$ 616	7559.6	$ 1,373	0	$ -
52	47.0	18.3	192	181	198	571	420	0.20	0	0	0%	0%	28%	0	0	0.0	0.0	0	0	0	$ -	$ -	2120.0	$ 385	3088.1	$ 561	6882.0	$ 1,250	0	$ -
47	41.9	15.9	229	271	251	751	531	0.36	0	1,056,767	31%	68%	0%	0	6,238	5.3	0.0	2,815	0	2,815	$ 138	$ 6,109	2682.2	$ 487	3907.1	$ 710	8707.2	$ 1,581	28,439	$ 5,164
42	37.4	13.9	309	265	289	863	642	0.44	0	1,265,204	37%	72%	0%	0	9,024	6.1	0.0	3,923	0	3,923	$ 159	$ 8,810	3738.7	$ 679	5446.0	$ 989	12136.7	$ 2,204	41,139	$ 7,471
37	32.8	12.0	294	237	268	799	600	0.52	0	1,473,641	43%	76%	0%	0	9,823	6.9	0.0	4,153	0	4,153	$ 180	$ 9,569	3958.1	$ 719	5765.5	$ 1,047	12848.9	$ 2,333	44,782	$ 8,132
32	28.0	10.1	187	124	185	496	385	0.60	0	1,682,078	49%	80%	0%	0	7,204	7.9	0.0	3,034	0	3,034	$ 205	$ 7,015	2891.0	$ 525	4211.2	$ 765	9384.9	$ 1,704	32,842	$ 5,964
27	23.2	8.3	124	92	89	305	230	0.68	0	1,890,516	55%	84%	0%	0	4,828	8.9	0.0	2,044	0	2,044	$ 231	$ 4,704	1947.8	$ 354	2837.2	$ 515	6322.9	$ 1,148	22,013	$ 3,997
22	18.9	6.7	109	50	37	196	157	0.76	0	2,098,953	61%	88%	0%	0	3,657	10.0	0.0	1,566	0	1,566	$ 260	$ 3,566	1492.4	$ 271	2173.9	$ 395	4844.8	$ 880	16,670	$ 3,027
17	14.7	5.2	22	4	6	32	28	0.84	0	2,307,390	67%	92%	0%	0	729	11.2	0.0	317	0	317	$ 290	$ 712	302.4	$ 55	440.5	$ 80	981.7	$ 178	3,323	$ 603
12	10.1	3.8	12	3	2	17	15	0.92	0	2,515,827	73%	96%	0%	0	410	12.4	0.0	182	0	182	$ 323	$ 401	173.7	$ 32	253.0	$ 46	563.8	$ 102	1,871	$ 340
7	11.4	2.4	0	0	0	0	0	1.00	0	2,724,264	79%	0%	0%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
2	1.2	1.2	0	0	0	0	0	1.08	0	2,932,701	85%	0%	0%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
-3	(2.6)	0.0	0	0	0	0	0	1.16	0	3,141,138	91%	0%	0%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
TOTALS:			2,920	2,920	2,920	8,760	6,361		187,550	3,772,039,780					41,912	12	70	18,035	68,231	86,266	$ 21,763	$ 75,040	4,365	$ 7,323	6,358	$ 10,667	14,169	$ 23,772	191,078	$ 34,700

Assumptions	
Building Type	SF1
Building Interior Square Footage	100,000
Building Footprint Square Footage	10,000
Number of Floors	10.0
Perimeter Surface Area	48,000
Wall to Window Ratio	15%
Outside Air CFM	20,000
Cooling Design Load (Tons)	200
Heating Design Load (Btu)	1,255,464
Demand Cost ($/kW)	$ 26.00
Electricity Energy Cost ($/kWh)	$ 0.18
Natural Gas Cost ($/Therm)	$ 0.90
#2 Fuel Oil Cost ($/gal)	$ 1.55
#4 Fuel Oil Cost ($/gal)	$ 1.37
District Steam Cost ($/Mlb)	$ 24.03
Air Cooled kW/Ton Penalty	0.3
Load Factor Decrease per 5 F	0.08

Auxiliary Equipment	
Condensing Boiler (MBH)	3,455
Condensing Boiler Efficiency	90%
Split System Condenser Fan Peak kW	23.5
Primary HW Pump Peak kW	13.2
Closed Loop Pump Peak kW	12.6
Open Loop Pump Peak kW	18.3
Standing Column Well Pump Peak kW	40.8
Heat Pump Efficiency (COP)	4.5
Heat Cooling Coincidence factor	0.7
Minimum Fan Speed	20%
Minimum Pump Speed	20%

VFD Efficiency	
2%	0.47
13%	0.86
25%	0.93
42%	0.94
50%	0.95
75%	0.96
100%	0.97

Installation Costs	
Condensing Boiler	$ 260,000
Split System AC Units	$ 200,000
Primary HW Pump	$ 2,000
Maintenance Costs	
Condensing Boiler	$ 17,276

GOLDMAN COPELAND
CONSULTING ENGINEERS

Heating and Cooling Load Calculations

Weather data			Hours				Operating Hours	Building Load			Conventional Operation												Geothermal Operation		Geothermal Operation		Geothermal Operation		Geothermal Heat Pump Energy	
DB (+-2)	MCWB	h	1-8	9-16	17-0	Total	Occupied Space	Load Factor	Cooling Load	Heating Load	Condensing Boiler Load	Primary HW Pump Speed	Split System Load	Extra kW/Ton for Air Cooled System	Condensing Boiler Usage	HW Pump Demand	Split System Demand	Pump Energy Usage	Split System Energy Usage	Energy Usage	Demand Cost	Energy Cost	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Pump Usage	Geothermal Energy Costs	Geothermal Heat Pump Demand	Geothermal Heat Pump Energy Costs
		[btu/lb]							(Tons)	(Btu)	(%)	(%)	(%)	(kW)	(Therms)	(kW)	(kW)	(kWh)	(kWh)	(kWh)	($)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)	(kWh)	($)
102	79.9	43.2	0	0	0	0	0	1.00	200	0	0%	0%	70%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
97	75.7	39.6	0	8	1	9	3	0.92	184	0	0%	0%	62%	55	0	0.0	69.8	0	239	239	$ 1,814	$ 43	39.1	$ 7	57.0	$ 10	127.0	$ 23	0	$ -
92	73.0	37.7	0	51	9	60	24	0.84	168	0	0%	0%	55%	50	0	0.0	63.3	0	1,526	1,526	$ 1,646	$ 277	247.3	$ 45	360.2	$ 65	802.6	$ 146	0	$ -
87	69.7	35.7	5	184	68	257	122	0.76	152	0	0%	0%	47%	46	0	0.0	56.6	0	6,933	6,933	$ 1,472	$ 1,259	1124.0	$ 204	1636.7	$ 297	3647.4	$ 662	0	$ -
82	67.5	33.6	45	257	178	480	280	0.68	136	0	0%	0%	40%	41	0	0.0	50.2	0	14,062	14,062	$ 1,305	$ 2,554	2289.9	$ 416	3334.3	$ 606	7430.7	$ 1,349	0	$ -
77	65.4	32.1	206	263	265	734	518	0.60	120	0	0%	0%	33%	36	0	0.0	43.7	0	22,647	22,647	$ 1,137	$ 4,113	3745.1	$ 680	5453.3	$ 990	12153.0	$ 2,207	0	$ -
72	62.0	29.7	275	276	294	845	616	0.52	104	0	0%	0%	25%	31	0	0.0	37.1	0	22,824	22,824	$ 964	$ 4,145	3918.2	$ 712	5705.4	$ 1,036	12714.9	$ 2,309	0	$ -
67	58.2	26.4	385	267	325	977	749	0.44	0	0	0%	0%	50%	0	0	0.0	0.0	0	0	0	$ -	$ -	4209.8	$ 765	6130.0	$ 1,113	13661.2	$ 2,481	0	$ -
62	55.2	23.6	246	175	235	656	504	0.36	0	0	0%	0%	42%	0	0	0.0	0.0	0	0	0	$ -	$ -	2452.7	$ 445	3571.5	$ 649	7959.3	$ 1,445	0	$ -
57	51.3	20.8	280	212	220	712	537	0.28	0	0	0%	0%	35%	0	0	0.0	0.0	0	0	0	$ -	$ -	2246.0	$ 408	3270.5	$ 594	7288.5	$ 1,324	0	$ -
52	47.0	18.3	192	181	198	571	420	0.20	0	0	0%	0%	28%	0	0	0.0	0.0	0	0	0	$ -	$ -	2044.7	$ 371	2977.4	$ 541	6635.3	$ 1,205	0	$ -
47	41.9	15.9	229	271	251	751	531	0.36	0	1,021,810	31%	68%	0%	0	6,032	5.3	0.0	2,815	0	2,815	$ 138	$ 5,924	2587.0	$ 470	3767.0	$ 684	8395.0	$ 1,525	27,498	$ 4,994
42	37.4	13.9	309	265	289	863	642	0.44	0	1,222,478	37%	72%	0%	0	8,719	6.1	0.0	3,923	0	3,923	$ 159	$ 8,537	3605.9	$ 655	5250.7	$ 954	11701.5	$ 2,125	39,750	$ 7,219
37	32.8	12.0	294	237	268	799	600	0.52	0	1,423,147	43%	76%	0%	0	9,486	6.9	0.0	4,153	0	4,153	$ 180	$ 9,267	3817.6	$ 693	5558.8	$ 1,009	12388.2	$ 2,250	43,247	$ 7,854
32	28.0	10.1	187	124	185	496	385	0.60	0	1,623,816	49%	80%	0%	0	6,954	7.9	0.0	3,034	0	3,034	$ 205	$ 6,791	2788.3	$ 506	4060.1	$ 737	9048.3	$ 1,643	31,704	$ 5,757
27	23.2	8.3	124	92	89	305	230	0.68	0	1,824,485	55%	84%	0%	0	4,660	8.9	0.0	2,044	0	2,044	$ 231	$ 4,553	1878.6	$ 341	2735.5	$ 497	6096.1	$ 1,107	21,244	$ 3,858
22	18.9	6.7	109	50	37	196	157	0.76	0	2,025,154	61%	88%	0%	0	3,528	10.0	0.0	1,566	0	1,566	$ 260	$ 3,450	1439.4	$ 261	2096.0	$ 381	4671.0	$ 848	16,084	$ 2,921
17	14.7	5.2	22	4	6	32	28	0.84	0	2,225,822	67%	92%	0%	0	703	11.2	0.0	317	0	317	$ 290	$ 689	291.7	$ 53	424.7	$ 77	946.5	$ 172	3,205	$ 582
12	10.1	3.8	12	3	2	17	15	0.92	0	2,426,491	73%	96%	0%	0	396	12.4	0.0	182	0	182	$ 323	$ 388	167.5	$ 30	243.9	$ 44	543.6	$ 99	1,804	$ 328
7	11.4	2.4	0	0	0	0	0	1.00	0	2,627,160	79%	0%	0%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
2	1.2	1.2	0	0	0	0	0	1.08	0	2,827,829	85%	0%	0%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
-3	(2.6)	0.0	0	0	0	0	0	1.16	0	3,028,498	91%	0%	0%	0	0	0.0	0.0	0	0	0	$ -	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
TOTALS:			2,920	2,920	2,920	8,760	6,361		187,550	3,642,917,817					40,477	12	70	18,035	68,231	86,266	$ 21,763	$ 73,753	4,210	$ 7,063	6,130	$ 10,285	13,661	$ 22,920	184,537	$ 33,512

Assumptions	
Building Type	SF2
Building Interior Square Footage	100,000
Building Footprint Square Footage	10,000
Number of Floors	10.0
Perimeter Surface Area	48,000
Wall to Window Ratio	15%
Outside Air CFM	20,000
Cooling Design Load (Tons)	200
Heating Design Load (Btu)	1,158,360
Demand Cost ($/kW)	$ 26.00
Electricity Energy Cost ($/kWh)	$ 0.18
Natural Gas Cost ($/Therm)	$ 0.90
#2 Fuel Oil Cost ($/gal)	$ 1.55
#4 Fuel Oil Cost ($/gal)	$ 1.37
District Steam Cost ($/Mlb)	$ 24.03
Air Cooled kW/Ton Penalty	0.3
Load Factor Decrease per 5 F	0.08

Auxiliary Equipment	
Condensing Boiler (MBH)	3,331
Condensing Boiler Efficiency	90%
Split System Condenser Fan Peak kW	23.5
Primary HW Pump Peak kW	13.2
Closed Loop Pump Peak kW	12.1
Open Loop Pump Peak kW	17.7
Standing Column Well Pump Peak kW	39.4
Heat Pump Efficiency (COP)	4.5
Heat Cooling Coincidence factor	0.7
Minimum Fan Speed	20%
Minimum Pump Speed	20%

VFD Efficiency	
2%	0.47
13%	0.86
25%	0.93
42%	0.94
50%	0.95
75%	0.96
100%	0.97

Installation Costs	
Condensing Boiler	$ 250,000
Split System AC Units	$ 200,000
Primary HW Pump	$ 2,000
Maintenance Costs	
Condensing Boiler	$ 16,657

Appendix C: Master Table Building Sheet Sample

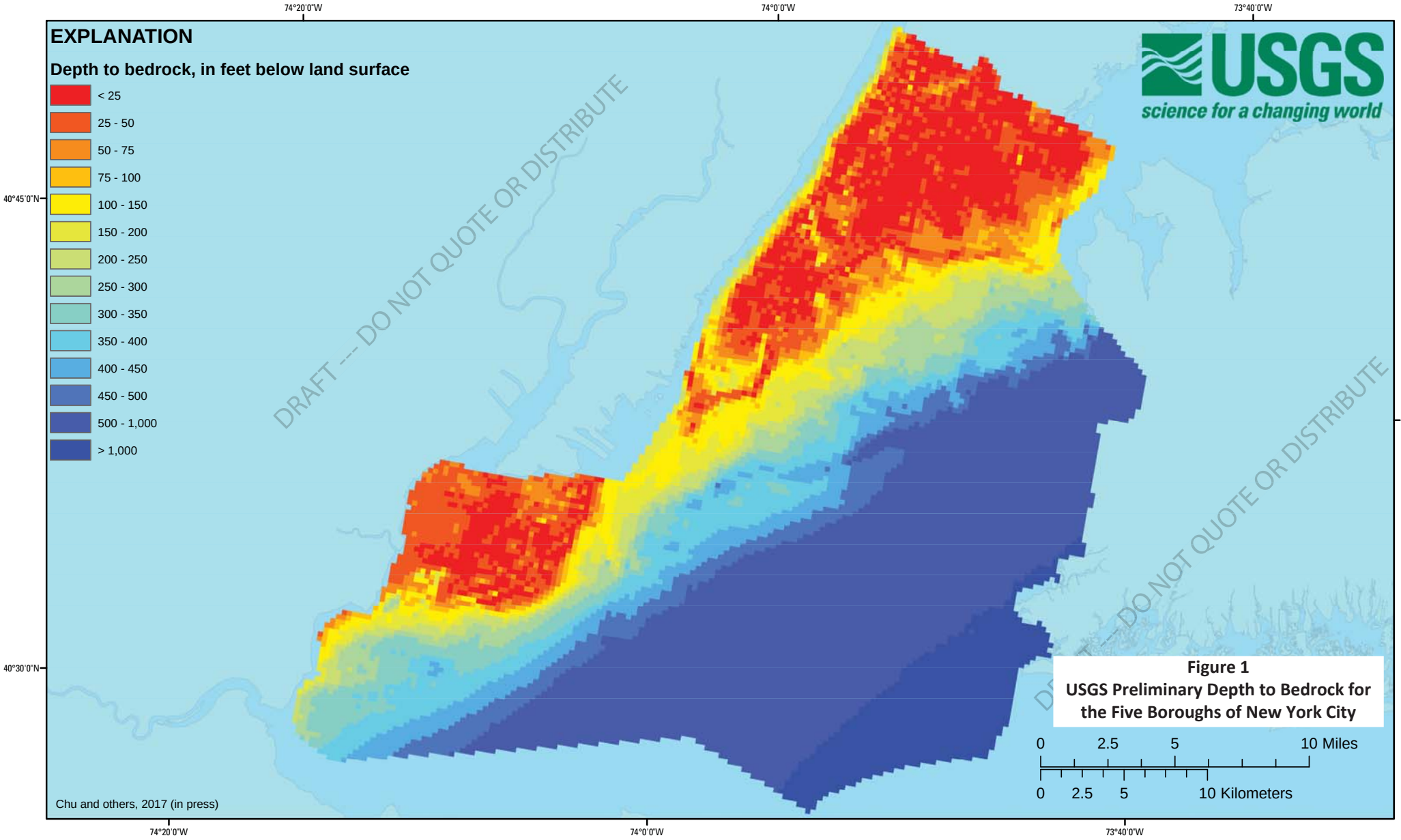
Lot Data									Building and Energy Data										Geological Data		
Borough	Block	Lot	Address	LotArea	BldgArea	BBL	LotAreaGIS	FootprSqFt	OutdArea	BldgType	Pk_Cooling	An_Cooling	Pk_Heating	An_Heating	Dom_Deman	HtCoBalanc	TotCoolCon	TotHeatCon	TotEnerCos	BasInstCos	DTR	DTW	DTL
QN	3825	32	78-56 76 STREET	2400	1284	4038250032	2350	1028	1322.729514	SF1	36.9792	34677.2448	40.332215	48432.99077	40.332215	-0.284016034	1107.650832	53814.43419	963.9529219	6153.907183	501	69	135
BK	6491	180	1730 SHORE PARKWAY	40958	20212	3064910180	38201	9044	29157	C2	873.1584	885963.8916	1005.476096	537303.0808	1005.476096	0.393538398	27304.95305	597003.4231	12853.15885	135056.584	491	13.5	363
SI	7590	11	74 ANDROVETTE STREET	7967	1160	5075900011	7259	1107	6152.61768	SF1	33.408	31328.352	36.43720358	43755.66145	33.408	-0.284016034	1000.681437	48617.40161	870.8608952	5559.60462	150	7	NA
BX	3457	4	1953 GILDERSLEEVE AVENUE	3025	2400	2034570004	2964	1683	1281.793822	MF6	69.12	67593.96864	72.65622528	92500.63746	72.65622528	-0.269259429	2185.484877	102778.4861	1842.379622	11088	30	NA	NP
MN	10	19	25 BRIDGE STREET	1583	7403	1000100019	1612	1307	304	C6	319.8096	324499.8362	368.2732803	196796.6904	368.2732803	0.393538398	10000.91863	218662.9894	4707.69518	49466.846	48	NA	NP
MN	2241	106	59 COOPER STREET	1808	3544	1022410106	1644	774	870	MF2	102.0672	99813.76036	107.289026	136592.608	107.289026	-0.269259429	3227.232669	151769.5644	2720.580576	16373.28	8	NA	NP
MN	962	50	500 EAST 30 STREET	63350	16000	1009620050	27549	7926	19623	C2	691.2	701336.9417	795.943872	425333.9251	795.943872	0.393538398	21614.84508	472593.2501	10174.67552	106912	52	NA	NP
BK	7020	7501	2818 WEST 17 STREET	0	9009	3070207501	4811	2331	2480	SF2	259.4592	243307.8648	272.8373488	328190.4661	272.8373488	-0.25863823	7771.671607	364656.0734	6647.446115	42221.28542	638	8.69	478
SI	1478	500	20 HOUSTON STREET	240550	226590	5014780500	217110	59296	157814.1626	IN3	8157.24	6144569.215	10420.22214	5797551.924	8157.24	0.056475447	193071.1047	6441724.36	154588.0635	1376518.202	7	21	NA
QN	651	32	30-35 36 STREET	2000	1800	4006510032	2202	970	1232.111994	SF2	51.84	48612.96	54.5129568	65572.5207	54.5129568	-0.25863823	1552.78154	72858.35633	1328.161062	8435.821262	66	38	NP

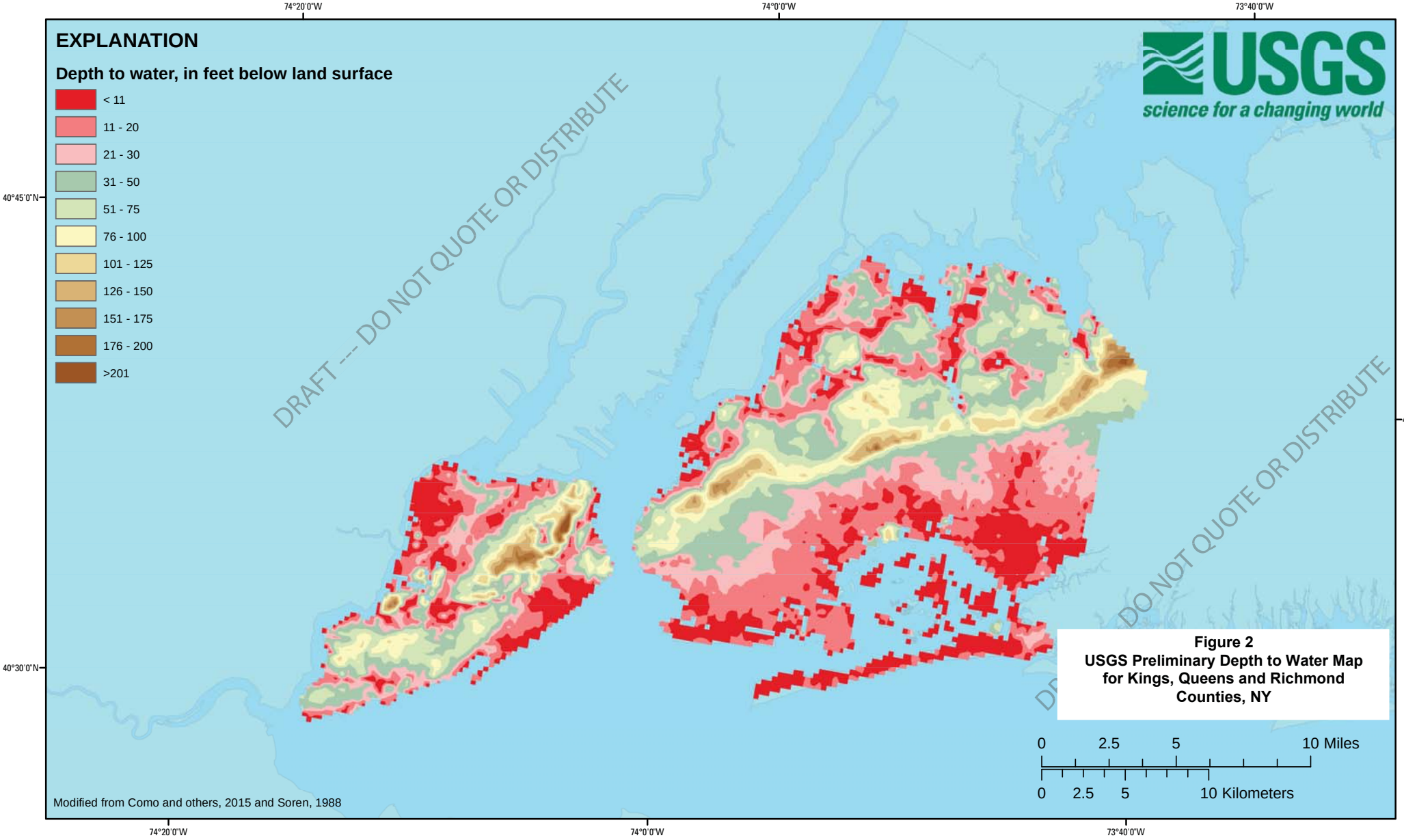
Lot Data									Closed Loop														
Borough	Block	Lot	Address	LotArea	BldgArea	BBL	LotAreaGIS	FootprSqFt	OutdArea	Feas_CL	NumWellCL	PotCapCL	FeasFulCL	FeasHybCL	HybTypeCL	HybConCL	HybInstCL	GeoConCL	EnerCosCL	SavGeoCL	CFtpRedCL	InstRedCL	InstCosCL	GeoPremC	AdjSavCL	IncrPayCL	RecomndCL	SimPayCL
QN	3825	32	78-56 76 STREET	2400	1284	4038250032	2350	1028	1322.729514	Y	6	55.54285714	Y	N/A	0	0	0	2503.895448	454.7074134	509.2455085	2.3330997	317.30156	12099.665	5945.76	826.547071	7.193489064	Y	11.6756205
BK	6491	180	1730 SHORE PARKWAY	40958	20212	3064910180	38201	9044	29157	Y	75	1866.857143	N	Y	Cooling Tower	10745.54749	42952.66977	775.672415	2092.253534	10760.90532	37.484386	5097.8765	344595.5	209539	15858.7818	13.21280015	M	19.4722385
SI	7590	11	74 ANDROVETTE STREET	7967	1160	5075900011	7259	1107	6152.61768	Y	18	617.1428571	Y	N/A	0	0	0	2262.08623	410.7948594	460.0660357	2.1077848	286.65873	10022.4	4462.8	746.724768	5.976493038	Y	9.70033655
BX	3457	4	1953 GILDERSLEEVE AVENUE	3025	2400	2034570004	2964	1683	1281.793822	Y	5	171.4285714	Y	N/A	0	0	0	4785.206227	868.9934509	973.3861714	4.4807397	609.3806	21796.868	10708.9	1582.76677	6.765916339	Y	11.001664
MN	10	19	25 BRIDGE STREET	1583	7403	1000100019	1612	1307	304	Y	3	102.8571429	N	N	0	0	0	293.3705915	0	0	-	0	0	0	0	-	N	-
MN	2241	106	59 COOPER STREET	1808	3544	1022410106	1644	774	870	Y	3	102.8571429	N	Y	Boiler	45405.98473	2166.643641	7100.496996	1696.923561	1023.657014	4.1982256	570.95868	34353.351	17980.1	1594.61569	11.27548883	Y	17.5645467
MN	962	50	500 EAST 30 STREET	63350	16000	1009620050	27549	7926	19623	Y	52	1782.857143	N	Y	Cooling Tower	8506.27151	34001.71761	690.895433	1670.205517	8504.470004	29.64446	4031.6465	272784.88	165873	12536.1165	13.23159996	M	19.5041995
BK	7020	7501	2818 WEST 17 STREET	0	9009	3070207501	4811	2331	2480	Y	8	262.2171429	N	Y	Boiler	104793.3349	5292.462675	17568.2197	4130.804085	2516.64203	10.133174	1378.1117	87143.667	44922.4	3894.75371	11.53407513	Y	17.8501278
SI	1478	500	20 HOUSTON STREET	240550	226590	5014780500	217110	59296	157814.1626	Y	401	13748.57143	Y	N/A	0	0	0	8168.773329	1483.449237	153104.6143	409.87425	55742.897	2447172	1070654	208847.512	5.126485776	Y	6.99295579
QN	651	32	30-35 36 STREET	2000	1800	4006510032	2202	970	1232.111994	Y	4	137.1428571	Y	N/A	0	0	0	3510.133806	637.4402991	690.7207628	3.1338838	426.2082	16353.887	7918.07	1116.92896	7.089139997	Y	11.4634831

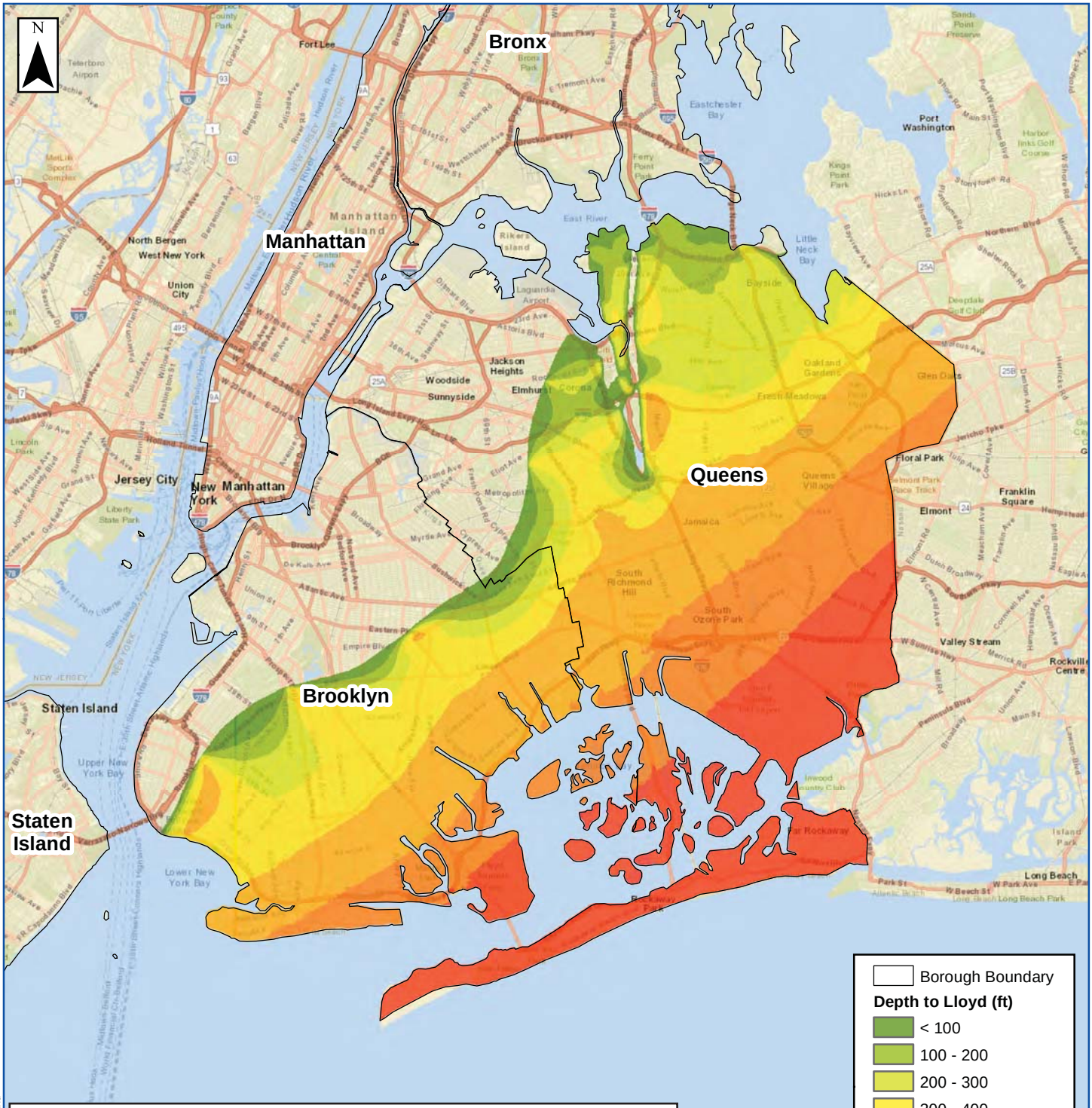
Lot Data									Standing Column Well														
Borough	Block	Lot	Address	LotArea	BldgArea	BBL	LotAreaGIS	FootprSqFt	OutdArea	Feas_DTR	Feas_DTW	PotCapSCW	FeasFulSCW	FeasHybSCW	HybTypeSCW	HybConSCW	HybInstSCW	GeoConSCW	EnerCosSCW	SavGeoSCW	CFtpRedSCW	InstRedSCW	InstCosSCW	GeoPremSC	AdjSavSCW	IncrPaySCW	RecomndSCW	SimPaySCW
QN	3825	32	78-56 76 STREET	2400	1284	4038250032	2350	1028	1322.729514	N	N	-	N	N	0	0	0	2635.372573	0	0	-	0	0	0	0	-	N	-
BK	6491	180	1730 SHORE PARKWAY	40958	20212	3064910180	38201	9044	29157	N	N	-	N	N	0	0	0	2269.211505	0	0	-	0	0	0	0	-	N	-
SI	7590	11	74 ANDROVETTE STREET	7967	1160	5075900011	7259	1107	6152.61768	P	F	984.4188288	Y	N/A	0	0	0	2380.866187	432.3652996	438.4955955	2.0637205	280.66599	22272	16712.4	719.161589	23.23872081	M	38.1130291
BX	3457	4	1953 GILDERSLEEVE AVENUE	3025	2400	2034570004	2964	1683	1281.793822	F	NA	400.7742016	Y	N/A	0	0	0	4944.342991	897.8926872	944.4869351	4.4217042	601.35176	48437.484	37349.5	1545.8387	24.16130708	M	39.5447328
MN	10	19	25 BRIDGE STREET	1583	7403	1000100019	1612	1307	304	F	NA	224.96	N	N	0	0	0	762.7635378	0	0	-	0	0	0	0	-	N	-
MN	2241	106	59 COOPER STREET	1808	3544	1022410106	1644	774	870	F	NA	307.4	Y	N/A	0	0	0	7390.436898	1342.103341	1378.477235	6.4962587	883.49119	71526.017	55152.7	2261.96842	24.38262923	M	40.0099007
MN	962	50	500 EAST 30 STREET	63350	16000	1009620050	27549	7926	19623	F	NA	3139.68	N	Y	Cooling Tower	8506.27151	18400201.11	1796.328126	1870.952094	8303.723427	29.234373	3975.8748	1893083O	1.9E+07	12279.5982	1532.942534	N	2266.92502
BK	7020	7501	2818 WEST 17 STREET	0	9009	3070207501	4811	2331	2480	N	N	-	N	N	0	0	0	18490.7099	0	0	-	0	0	0	0	-	N	-
SI	1478	500	20 HOUSTON STREET	240550	226590	5014780500	217110	59296	157814.1626	F	F	25250.26601	Y	N/A	0	0	0	22284.03088	4046.780008	150541.2835	404.63785	55030.748	5438160	4061642	205572.032	19.75775481	M	26.9802522
QN	651	32	30-35 36 STREET	2000	1800	4006510032	2202	970	1232.111994	F	F	385.2403503	Y	N/A	0	0	0	3694.447532	670.9116718	657.24939	3.0655082	416.90912	36341.971	27906.1	1074.15851	25.97954553	N	42.4589971

Lot Data									Open Loop															
Borough	Block	Lot	Address	LotArea	BldgArea	BBL	LotAreaGIS	FootprSqFt	OutdArea	Feas_OL	FeasGeoOL	FeasTechOL	PotCapOL	FeasFulOL	FeasHybOL	HybTypeOL	HybConOL	HybInstOL	GeoConOL	EnerCosOL	SavGeoOL	CFtpRedOL	InstRedOL	InstCosOL	GeoPremOL	AdjSavOL	IncrPayOL	RecomndOL	SimPayOL
QN	3825	32	78-56 76 STREET	2400	1284	4038250032	2350	1028	1322.729514	F	F	F	63.49101666	Y	N/A	0	0	0	2526.855669	458.8769895	505.07593	2.3245821	316.14316	10755.3	4601.35015	821.2190959	5.6030725	Y	9.110214635
BK	6491	180	1730 SHORE PARKWAY	40958	20212	3064910180	38201	9044	29157	F	F	F	1399.536	N	Y	Cooling Tower	10745.54749	23244054.05	904.9511509	2115.730552	10737.428	37.436427	5091.3541	2.3E+07	23326850.6	15828.78236	1473.6984	N	2172.480223
SI	7590	11	74 ANDROVETTE STREET	7967	1160	5075900011	7259	1107	6152.61768	F	F	F	295.3256486	Y	N/A	0	0	0	2282.829109	414.5617662	456.29913	2.1000897	285.6122	8908.8	3349.19538	741.9113327	4.5142799	Y	7.339911842
BX	3457	4	1953 GILDERSLEEVE AVENUE	3025	2400	2034570004	2964	1683	1281.793822	N	N	N	-	N	N	0	0	0	4801.782974	0	0	-	0	0	0	0	-	N	-
MN	10	19	25 BRIDGE STREET	1583	7403	1000100019	1612	1307	304	N	F	N	-	N	N	0	0	0	342.2656901	0	0	-	0	0	0	0	-	N	-
MN	2241	106	59 COOPER STREET	1808	3544	1022410106	1644	774	870	N	N	N	-	N	N	0	0	0	7130.699069	0	0	-	0	0	0	0	-	N	-
MN	962	50	500 EAST 30 STREET	63350	16000	1009620050	27549	7926	19623	F	F	F	941.904	N	Y	Cooling Tower	8506.27151	18400201.11	806.0446718	1691.116619	8483.5589	29.601743	4025.837	1.9E+07	18465743.6	12509.39589	1476.1499	N	2176.650605
BK	7020	7501	2818 WEST 17 STREET	0	9009	3070207501	4811	2331	2480	N	F	F	119.04	N	N	0	0	0	17729.31676	0	0	-	0	0	0	0	-	N	-
SI	1478	500	20 HOUSTON STREET	240550	226590	5014780500	217110	59296	157814.1626	N	N	N	-	N	N	0	0	0	11887.2552	0	0	-	0	0	0	0	-	N	-
QN	651	32	30-35 36 STREET	2000	1800	4006510032	2202	970	1232.111994	F	F	F	59.14137573	Y	N/A	0	0	0	3542.321031	643.2854993	684.87556	3.1219432	424.58427	14536.8	6100.96722	1109.459838	5.4990429	Y	8.908139742

Appendix D: Sample Maps


74°20'0"W
74°0'0"W
73°40'0"W
40°45'0"N
40°30'0"N
EXPLANATION
Depth to bedrock, in feet below land surface
< 25
25 - 50
50 - 75
75 - 100
100 - 150
150 - 200
200 - 250
250 - 300
300 - 350
350 - 400
400 - 450
450 - 500
500 - 1,000
> 1,000
USGS
science for a changing world
DRAFT --- DO NOT QUOTE OR DISTRIBUTE
Figure 1
USGS Preliminary Depth to Bedrock for the Five Boroughs of New York City
0 2.5 5 10 Miles
0 2.5 5 10 Kilometers
Chu and others, 2017 (in press)


74°20'0"W
74°0'0"W
73°40'0"W
40°45'0"N
40°30'0"N
EXPLANATION
Depth to water, in feet below land surface
< 11
11 - 20
21 - 30
31 - 50
51 - 75
76 - 100
101 - 125
126 - 150
151 - 175
176 - 200
>201
USGS
science for a changing world
DRAFT --- DO NOT QUOTE OR DISTRIBUTE
DO NOT QUOTE OR DISTRIBUTE
Figure 2
USGS Preliminary Depth to Water Map for Kings, Queens and Richmond Counties, NY
0 2.5 5 10 Miles
0 2.5 5 10 Kilometers
Modified from Como and others, 2015 and Soren, 1988



Notes:
Extent of Lloyd aquifer in NYC limited to color contoured areas.
Source/References:
1) Depth to Lloyd contours modified from on-line USGS GIS data (relative to ft below surface grade)
2) Reference: USGS Hydrogeologic Investigations Atlas HA-709, Smolensky et al, 1989.
3) Ground Surface Elevation from USGS National MapViewer (relative to NGVD 1929)

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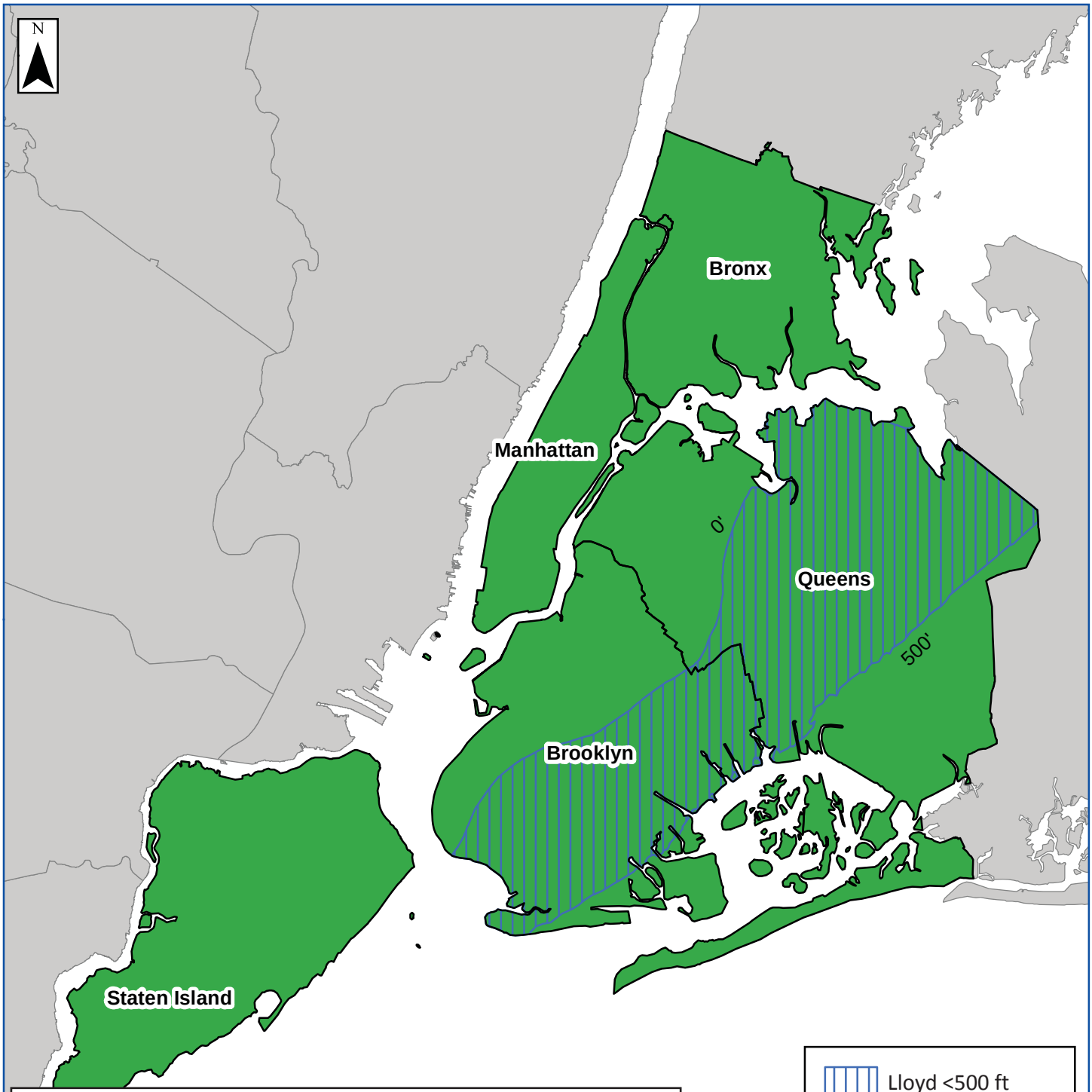
ESTIMATED DEPTH TO THE TOP OF THE LLOYD AQUIFER IN KINGS AND QUEENS COUNTIES, NY

Five Boroughs of New York City

0 2 4 6 8 Miles

Project:	GOC1601
Date:	5/31/2017
Designed by:	BB
Drawn by:	TS
Approved by:	JR
Figure No:	3

Document Path: G:\Projects\E-L\GOC\1601\mapfiles\Figures\Depth_Lloyd.mxd



Notes:
Closed loops are technically feasible everywhere. Depths restricted where Lloyd aquifer exists and is less than 500 ft deep. Integrated by PWGC into GIS database.
Source/References:
1) Extent of Lloyd aquifer lying less than 500 ft deep from on-line USGS GIS data.
2) Reference: USGS Hydrogeologic Investigations Atlas HA-709, Smolensky et al, 1989.
3) See Figure 1 for reference.

Lloyd <500 ft
Borough Boundary
Suitable

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GEOLOGIC AND TECHNICAL SUITABILITY - CLOSED LOOP

Five Boroughs of New York City

0 3 6 9 12 Miles

Project:	GOC1601
Date:	5/31/2017
Designed by:	BB
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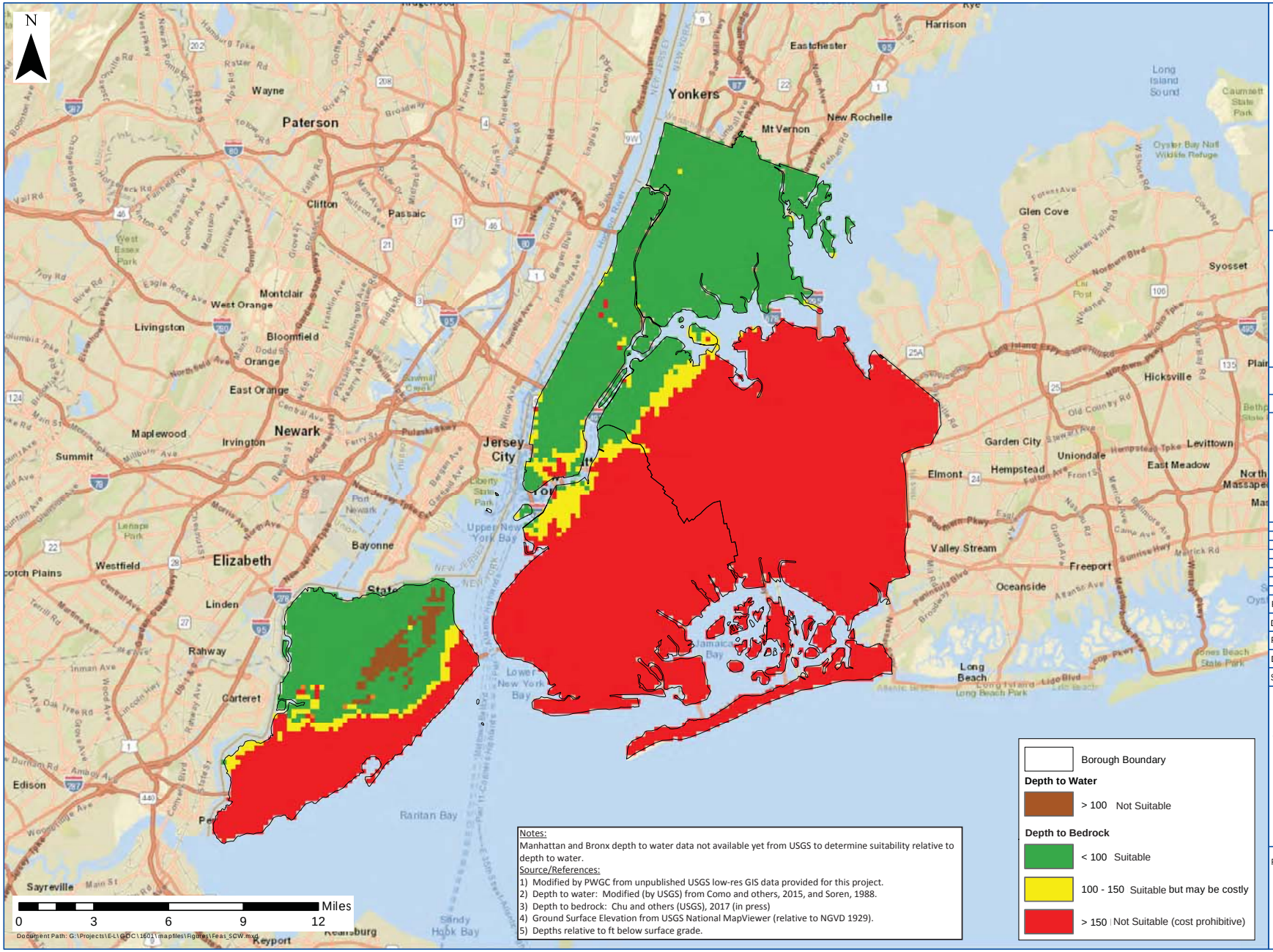
Figure No:	4

Document Path: G:\Projects\E-L\GOC\1601\mapfiles\Figures\Feas_CL.mxd



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REVISION	DATE	INITIAL	COMMENTS

DRAWING INFORMATION:

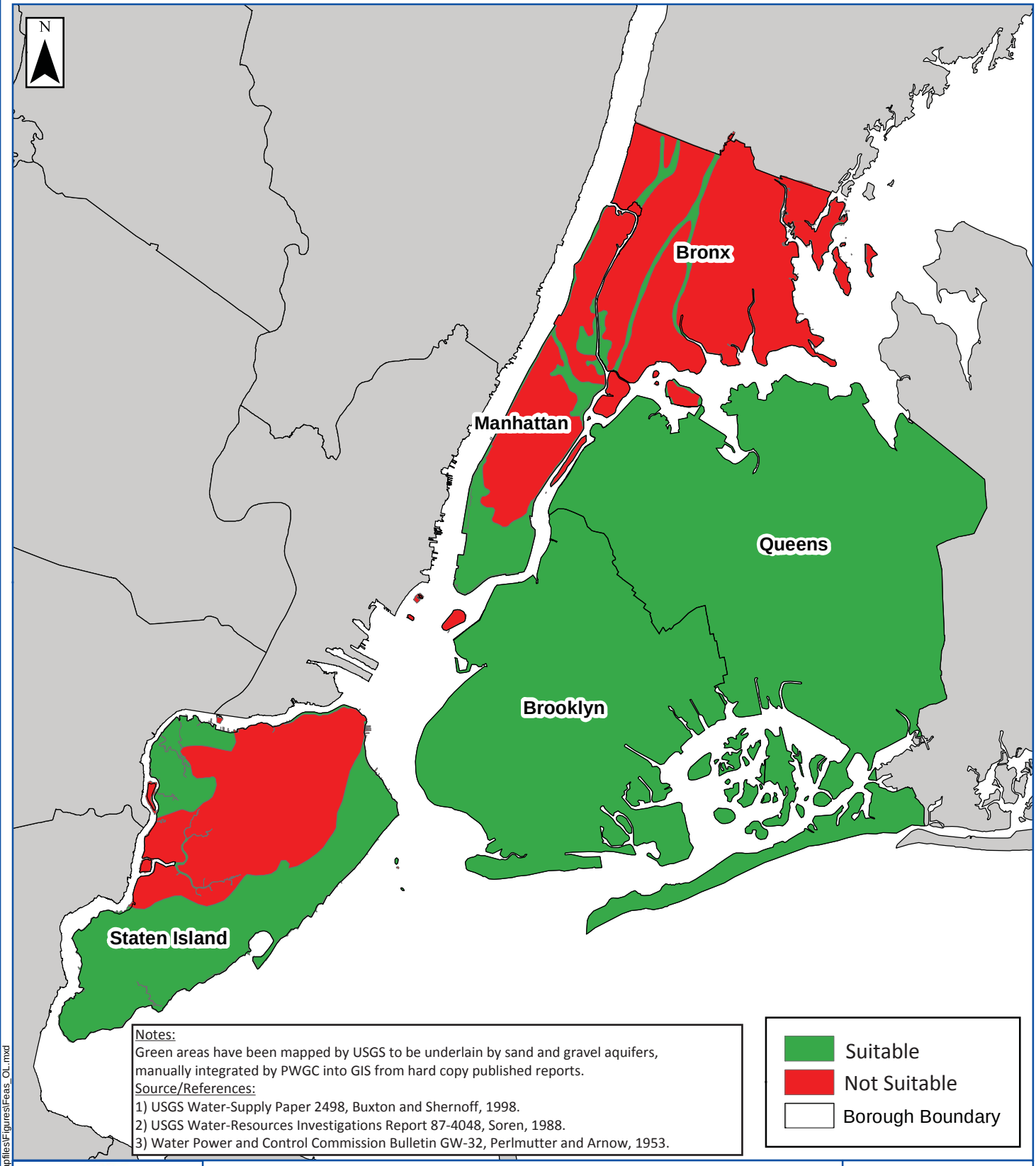
Project:	GOC1601	Designed by:	
Date:	5/31/2017	Drawn by:	
Scale:	AS SHOWN	Approved by:	

GEOLOGIC AND TECHNICAL SUITABILITY - STANDING COLUMN WELLS

Five Boroughs of New York City

FIGURE NO:

5



Notes:
Green areas have been mapped by USGS to be underlain by sand and gravel aquifers, manually integrated by PWGC into GIS from hard copy published reports.

Source/References:
1) USGS Water-Supply Paper 2498, Buxton and Shernoff, 1998.
2) USGS Water-Resources Investigations Report 87-4048, Soren, 1988.
3) Water Power and Control Commission Bulletin GW-32, Perlmutter and Arnow, 1953.

Suitable
Not Suitable
Borough Boundary

GEOLOGIC SUITABILITY - OPEN LOOP

Five Boroughs of New York City

0 3 6 9 12 Miles

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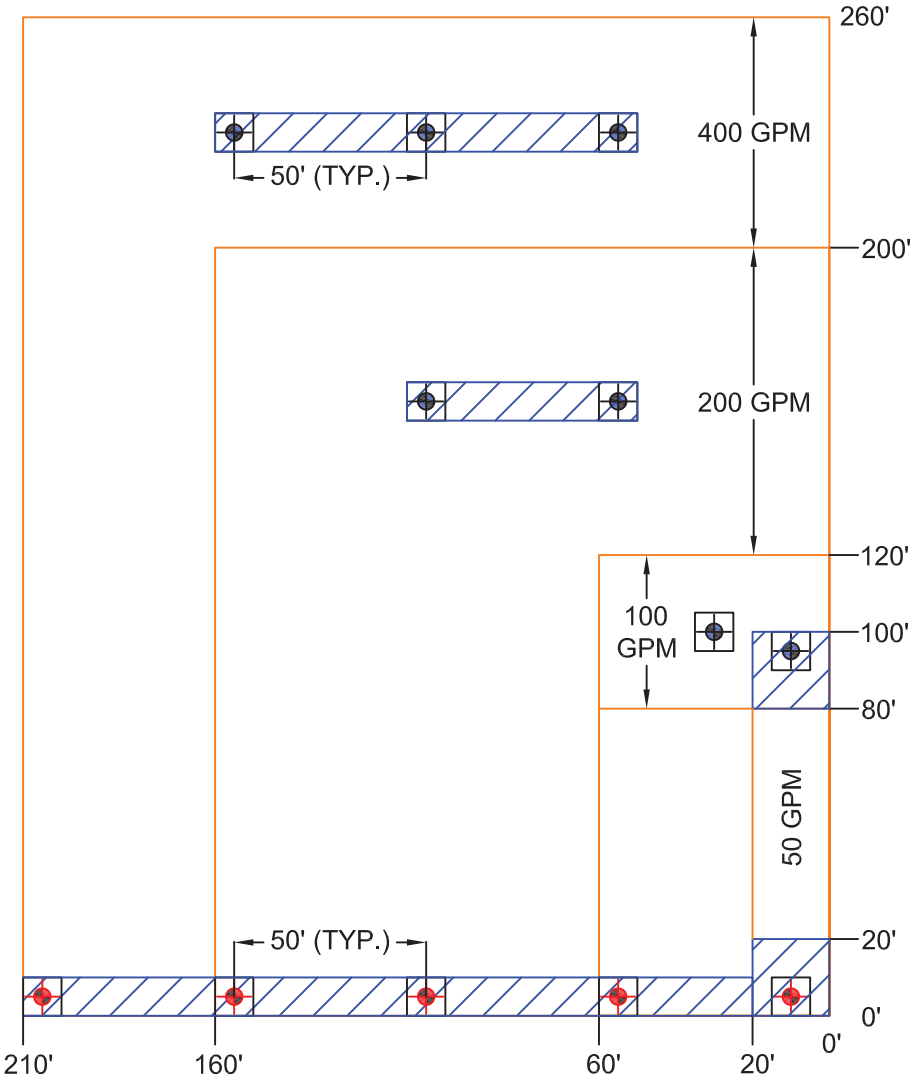
Document Path: G:\Projects\E-L\GOC\1601\mapfiles\Figures\Feas_OL.mxd

FIGURE 7
OPEN LOOP TECHNICAL SUITABILITY



MINIMUM LOT SIZE AND OUTDOOR AREA REQUIRED FOR OPEN LOOP WELL SYSTEMS

LEGEND

SUPPLY WELL

RETURN WELL

MINIMUM OPEN OUTDOOR AREA REQUIRED FOR DRILL RIG ACCESS (AND FUTURE WELL MAINTENANCE)

0 50 100

SCALE: 1" = 50'

Open Loop - Technical Suitability						
Dominant Demand (tons)	Dominant Demand (kBTU)	Flow (gpm)	No. of Wells (@50-135 gpm cap.)		Outdoor Area Minimum (sf)	Lot Area Minimum (sf)
			SW	RW		
0-25	0-300	Up to 50	1	1 (1)	800	1,900 (1)
25-50	300-600	50 - 100	1	2	800	4,800
50-100	600-1,200	100-200	2	4	2,500	7,200
100-200	1,200-2,400	200 - 400	3	5	3,200	32,000
>200	>2,400	> 400	>3	>5	4,000	54,600

NOTES:

(1) 0-300 kBTU Dominant Demand Lot Area Minimum is 1,900 sf to capture 20' x 100' lots, which constitute a high percentage of lot sizes throughout the city.