Testimony of Anthony Fiore
New York City Mayor's Office of Sustainability
and
Alex Posner
Department of Design and Construction

Before the
New York City Council Committee on Environmental Protection

Hearing on Introduction 609
Regarding Geothermal Energy Systems

September 22, 2015

Introduction

Good morning Chairman Constantinides and members of the Committee on Environmental Protection. I am Anthony Fiore, Director of Energy Regulatory Affairs from the Mayor's Office of Sustainability, and I am joined by my colleagues Cathy Pasion, Senior Policy Advisor in the Mayor's Office of Sustainability, and Alex Posner, a Professional Geologist and Project Director with the Department of Design and Construction.

Thank you for inviting us to testify regarding Introduction 609 ("Intro 609"), which would further the City's understanding of where opportunities for geothermal systems lie in New York City and foster their application where it makes sense both technically and economically.

Intro 609 is an expansion of Local Law 32 for the year 2013, which sought to explore the feasibility of developing geothermal energy resources in the City. On February 28, 2015, the Mayor's Office of Sustainability, in coordination with the Department of Design and Construction (DDC), published online a report entitled "Geothermal Systems and their Application in New York City, February 2015" ("GSA Study"). This, in conjunction with the "Geothermal Heat Pump Manual, 2012" developed by DDC, meet many of the reporting requirements in Intro 609. These reports also provide valuable lessons that can inform Intro 609 and focus the City's efforts on the greatest opportunities for geothermal systems in New York City.

I would like to turn it over to Alex who will provide a brief overview of geothermal systems, their benefits, and what conditions are necessary for their success. I will then speak to some ideas on how to strengthen the bill.

I am Alex Posner and I have been working for the Department of Design and Construction since 1999. For the past 15 years, I and others at DDC have been designing and installing geothermal systems for DDC public building projects throughout the five boroughs.

Geothermal systems have been used extensively for heating and cooling buildings throughout the world for over 70 years. These systems, if designed properly, can reduce or eliminate a building's dependency on fossil fuels, eliminate rooftop mechanical equipment, and reduce energy costs. Because of DDC's proactive position in advancing the concept of "high performance" (i.e., green or sustainable) buildings since the 1990s, geothermal systems have been one of many options for improving a building's energy efficiency and overall design.

Just to be clear, these systems, as many may believe, do not generate electricity but instead utilize low temperature energy, generally between 50 and 60 degrees Fahrenheit and found at depths between 300 and 2,000 feet below the earth's surface, to precondition indoor air temperatures. This constant, stable temperature available year round is the beauty of these systems. Compared to solar, which does not operate when the sun does not shine, geothermal is always available, 24 hours a day.

By constructing boreholes or wells to the depths mentioned above, we create a pathway to retrieve the earth's stored energy from the surrounding bedrock or groundwater. The energy is transferred either by pumping natural groundwater or circulating a groundwater-antifreeze solution in and out of grouted boreholes or wells, thereby transferring this energy to the building.

A heat pump, which incorporates a compressor, similar to those found in your home air conditioner or refrigerator is used to bring temperatures into the range designed for human comfort. The advantage here is that the heat pumps are reversible to accommodate changing needs throughout the four seasons, providing both heating and cooling in one unit. Again, this is all accomplished by utilizing the year round, steady temperature of the earth.

The three basic types of geothermal systems utilized by DDC and others within the City are: Open Loop, Closed Loop, and Standing Column. An Open Loop system essentially utilizes groundwater from an aquifer, such as those found in great quantities in Brooklyn and Queens. Energy transfer is directly from the constant water temperature in the aquifer to the heat pumps. The second system, known as a Closed Loop, utilizes drilled boreholes down to approximately 500 feet. Energy transfer here occurs by pumping an antifreeze solution in and out of each borehole via polyethylene tubing and into the building's heat pumps which then precondition indoor air, resulting in the need for less fossil-based energy to bring indoor air to the desired comfort level. The third type of system, called a Standing Column, is a free standing, open borehole down to 2,000 feet that brings in small amounts of available groundwater up through the center of the borehole and into the heat pumps. The heat pumps reject the water and send it back down into the borehole. As the water flows down the inner walls of the borehole, it rejects the higher or lower temperatures back to the earth for later use, similar to a rechargeable battery.

For projects that do not have enough horizontal space for stand-alone geothermal systems, hybrid designs may be available. Hybrid designs that combine geothermal systems with traditional systems can still reduce energy usage and increase the overall efficiency of a building.

The geology of the City is very complex compared to other parts of the country where the subsurface geology may be more homogeneous in nature, which is why understanding the subsurface is key to any project's success. A system that may work in one part of the City may not be the most appropriate or cost-effective for another. For example, Open Loop systems use groundwater for heat exchange by extracting and returning groundwater through supply and diffusion wells installed in permeable aquifers such as sand and gravel deposits. While these are generally the least expensive systems to install, water quality is a critical factor as dissolved metals, bacteria, and high salinity can severely impact system design, maintenance, and overall life expectancy. Open Loop systems are most appropriately used in areas of Queens and Brooklyn where highly productive aquifers are very common.

By contrast, a Standing Column system is a variation of the Open Loop system that combines the supply and diffusion well into one unit. This results in a slower transfer of heat requiring much greater depths for boreholes (1,500 feet is common) to achieve sufficient surface area for heat transfer. These systems are applicable where bedrock is close to the surface, which mitigates drilling costs, as is the case in sections of Manhattan and the Bronx. Finally, a Closed Loop system is sealed and completely separated from the surrounding environment. Heat exchange occurs through conduction between a closed antifreeze loop and the ground. System costs are similar to a Standing Column system. They also require the least amount of maintenance but are also the least efficient and so require the greatest amount of land area.

Because of the above described complexities, it is imperative that not only qualified engineers but geologists who are well-versed in subsurface conditions of the City facilitate the design and construction of geothermal systems.

Since beginning the geothermal program at DDC around the year 2000, the agency has installed approximately six systems with a few more currently in construction and several new ones in design. (The number of installations reflects the majority of DDC's work, which involves building renovations, and the difficulty of installing geothermal systems in existing buildings.) To educate and assist DDC project managers and their consultants, DDC published the first edition of our Geothermal Heat Pump Manual ("Manual") in 2002, the only one of its kind at the time. Subsequently, because of changes in the industry and technological advances in materials, the book was updated in 2012. Since this time, the Manual has become the How-to-Guide for doing geothermal in the City.

I will now turn it back to Anthony to discuss recommended modifications to the bill for consideration.

The Office of Sustainability appreciates the attention the City Council is paying to geothermal energy systems. We believe that these systems hold the potential to help us reach the goal of cutting citywide greenhouse gas emissions 80 percent from 2005 levels by 2050. As Alex described, geothermal systems have the potential to provide many benefits for any building energy management project. Given DDC's breadth of experience with these systems, and what we learned in our research, as described in the February 2015 GSA Study, we would like to provide some suggestions to strengthen this bill so that it results in the implementation of geothermal systems in a judicious and cost-effective manner. Our suggestions fall into three main categories: 1) amending the reporting requirements to make the information as useful as possible, 2) determining ways to ensure that standards are set for quality geothermal systems, and 3) designing an efficient and easier way to assess geothermal feasibility on a site-specific basis.

Intro 609 asks the City to play a leadership role in scaling up the application of geothermal systems within City buildings and on private properties. It looks to do this in a number of ways. The bill calls for a report on a range of issues relating to geothermal systems in the City. These issues have in large part been addressed by MOS and DDC's February 2015 GSA Study.

Where the bill requires additional or new information, such information would be very difficult to obtain and in some instances impossible, and in our opinion would not be necessary to advance geothermal systems. For example, the bill requires making publicly available "the locations of buildings currently using geothermal systems and, for each such building, the type of geothermal system used." While this is possible for City buildings, it would be would be impossible for private buildings because permits are not required for closed loop geothermal systems with wells less than 500 feet in depth. Therefore, there are no readily available records of private buildings that have installed these types of geothermal systems. We would like to see this gap filled by requiring notification of such installations.

In addition, the bill requires making publicly available the "potential benefits of replacing all fossil fueled heat systems with geothermal systems," including the "expected health benefits" like "premature mortality, morbidity, emergency room admissions and lost work days." First, it should be noted that the complete replacement of fossil fuels by geothermal systems is in fact not possible. Geologically, there is not enough thermal capacity to supply geothermal energy to a city as dense as New York City. Second, it would be tremendously resource intensive to demonstrate something that we already know to be true: there is no arguing that avoiding the use of fossil fuels through the increased efficiency of a geothermal system would result in health benefits. In fact, the Department of Health and Mental Hygiene ("DOHMH") recently published a paper looking at the public health benefits of reducing fine particulate matter through the clean heat program, which helped building owners comply with clean fuel regulations promulgated by the Department of Environmental Protection ("DEP"). While DOHMH's work can potentially be leveraged to assess the impact of geothermal systems on public health indicators, this would require significant additional resources to conclude what is already demonstrably true.

Beyond the reporting requirements, the bill would also call for rulemaking to set standards for the installation and maintenance of geothermal systems and registration as well as other requirements for designers and installers. To the extent such standards can be developed on a broad basis, they can be found in DDC's Manual, which provides general guidance related to the criteria for selecting a specific geothermal system, construction of those systems, and operation and maintenance. Anything more than this would require a detailed, site-specific engineering study. The bill also directs rulemaking related to requirements for persons who design and install geothermal systems. The Administration agrees that required qualifications should be made clear. We look forward to further discussions with industry stakeholders and the Council to determine the most appropriate method to determine such standards. Other important considerations include: how these standards would be enforced, what the workload and costs involved with enforcement and registration might be, would these justify a registration fee, what penalties might come from violations of these standards, and would any of these standards require amendments to the plumbing or construction codes.

Finally, the bill calls for a determination of the number of City-owned buildings in each community district for which installation of geothermal system would be cost-effective. The City manages roughly 4,000 buildings. To determine the cost-effectiveness of a geothermal system for each City building would be very costly and time-consuming because a site-specific engineering analysis would need to be completed.

Rather than performing a full assessment of each City building, we recommend that the Council authorize the development of a geothermal system screening tool to address new construction or a retrofit to an existing building's heating and cooling system, then, where and when applicable, a detailed engineering and benefits analysis. This would allow the City to cost-effectively assess where geothermal systems make sense and then provide a definitive mechanism for valuing the climate benefits associated with geothermal systems as compared to more traditional solutions.

By using the screening tool, we will be able to zero in on those projects that present viable opportunities for successful geothermal implementation without undergoing a costly engineering study for buildings where a geothermal system does not make sense. As Alex mentioned, the successful implementation of geothermal systems depends on site-specific conditions. DDC has completed Phase I of mapping work that describes the underlying hydrogeology of New York City and its applications for siting geothermal systems. In Phase II this map will be layered with thermal conductivity, building energy use, and lot area to further define where conditions are suitable for geothermal systems. This tool will also consider neighboring lots coupled with the space requirements for a given building. It is our belief that this approach would make the process of determining feasibility of geothermal in City buildings much quicker and less costly, as well as providing the public with a tool to help determine feasibility.

Where a given public project meets the key criteria included in the screening tool, then a detailed engineering and benefits analysis should be required to compare geothermal systems, with one coupled with a photovoltaic system and other options as determined by the building owner or developer. This benefits analysis should include the federal Environmental Protection Agency's (EPA's) Social Cost of Carbon (SCC) to factor in the cost-effectiveness calculation greenhouse gas emissions associated with each of the alternative systems. The EPA and other federal agencies use the SCC to estimate the climate impacts of rulemaking. The SCC is an estimate of the economic damages associated with an increase in carbon dioxide (CO_2) emissions, conventionally one metric ton, in a given year. This dollar figure also represents the value of damages avoided for a one ton emission reduction in CO_2 emissions. The SCC is meant to be a comprehensive estimate of climate change impacts and includes changes in net agricultural productivity, human health, property damages from increased flood risk, and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning. However, given current modeling and data limitations, it does not include all important damages. The International Panel on Climate Change's Fifth Assessment report observed that SCC estimates omit various impacts that would likely increase damages from CO_2 emissions. Therefore, we recommend using the highest of the SCC numbers reported by EPA – the 95th percentile SCC estimate at a 3 percent discount rate, which is currently valued at $117 per metric ton, as the minimum dollar value to factor into the benefits analysis. Alternatively, site and project specific data can be developed. The higher of the two values should be used in the benefits analysis. In addition, if in the future other monetary benefit programs come into existence (e.g., payments for peak load reductions), they should also be factored into the benefits analysis. Once these elements have been factored in to the analysis, the option with the lowest Net Present Value should be selected.

The proposed legislation is aligned with the sustainability goals outlined in OneNYC and the Office of Sustainability agrees with its intent. We hope these suggestions help to strengthen the bill and foster the implementation of this low carbon energy solution in New York City. The Administration looks forward to working with the Council to further refine the proposed legislation in a way that allows the City to meet the energy efficiency, resiliency, affordability, and sustainability goals laid out in OneNYC in a cost-effective manner.

FOR THE RECORD

AIA New York Chapter

The American Institute of Architects New York Chapter
Testimony before the New York City Council Committee on Environmental Protection on
Intro. 609
September 22, 2015

The American Institute of Architects New York Chapter (AIANY) represents over 5,200 registered architects and associated design and construction professionals. The AIANY Committee on the Environment (COTE) aims to lead, inspire, and educate our members on design and sustainability. AIANY COTE organizes engaging programs and events that focus on outstanding green buildings, current technologies and product research, and sustainable design practices by leading architects. Our efforts are based on the belief that sustainability should be an essential part of the design process and be fully integrated with all aspects of a building, including form, function, site, structure, systems, and construction.

AIANY is partaking in a sustained push for systems that reduce carbon emissions in the built environment and create healthy spaces for New Yorkers to live and work. In order to achieve the Mayor's 80x50 goals, both public and private sectors must undergo large-scale changes. AIANY supports Intro. 609 in its effort to encourage the use of ground source heat pumps, a readily available and realistic option, by seeking to determine how NYC can better utilize this technology to help reach sustainability objectives. We applaud the bill for its understanding of the unavoidable complexities related to the context, design, and construction of ground source heat pumps, and the provision for an essential professional approval process. A series of NYC-specific requirements for those who design or install systems and a corresponding registration database will help to ensure that ground source heat pumps are used properly and efficiently, while protecting the health, safety, and welfare of all New Yorkers.

Intro. 609 successfully emphasizes the urgency of reducing carbon emissions in NYC's building stock and a solution. Ground source heat pump technology, however, is only one carbon reduction intervention that architects currently employ. Instead of favoring a particular technology, AIANY urges the city to set goals and allow the industry to determine the best processes and strategies for achieving those goals. In an effort to make this legislation as widely applicable as possible, we have the following suggestions:

- Replace "geothermal" with "ground source heat pump," a term that more accurately represents the technology for use in NYC.
- The City should encourage extensive deep energy retrofits in existing buildings before enacting policy partial to new technologies. Ground source heat pumps are most viable when combined with other sustained efforts to significantly reduce energy loads. Without validated high performance building envelopes, capital and operational energy costs as well as the desired carbon reductions cannot be optimally met.
- Establish performance expectations. A ground source heat pump system will inevitably experience a performance inefficiency curve if annual heating and cooling loads are not balanced.
- Legislation regarding ground source heat pumps should also consider intended scales. Physical specifications differ depending on whether pumps serve individual homes or entire communities, and regulation should properly reflect that.
- As it stands, Intro. 609 does not distinguish between open and closed loop systems. Open loop systems present a number of challenges in NYC, including requiring quality source of groundwater, and are not suitable in every case.

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- Much of the research and resources outlined in the bill have already been accomplished by other City bodies. In an effort to prevent duplication, the legislation can consider the Mayor's Office of Sustainability's 2015 *Geothermal Systems and their Application in New York City* and the NYC Department of Design and Construction's *Geothermal Heat Pump Manual* and related 2012 update. Applicable research on the financing and science of this technology as it pertains to NYC's landscape can be found in these thorough documents. They also include case studies and definitions.

AIANY is a proponent of ground source heat pumps, and supports the progressive work of this Committee. We installed a pump at the Center for Architecture in 2003 and continue to reap the rewards. With entities such as ConEd and other large stakeholders experimenting with a wide range of energy saving solutions, the time is ripe to think holistically about our next steps. We look forward to working with you on this.

Submitted on behalf of the AIANY Committee on the Environment

AIANY
COTE

The New York City Council - Hearing on Int.0609-2015 - Geothermal City Hall, September 22, 2015, 10:00 AM

Comments/Testimony by Catherine Skopic

Greetings, and thank you to members of the New York City Council and to the Environmental Protection Committee, Costa Constantinides, Chair for introducing this local law to enable the installation of geothermal renewable energy in New York City; particularly as our buildings account for about 75% of our emissions. I applaud you for the timeline of beginning reporting by July 1st of 2016, as the issue is so urgent.

As I've taken several courses at General Theological Seminary,175 Ninth Avenue @ 20th Street, Chelsea, I am aware that in August 2006, having received approval from Community Board 4 on July 26th, they began work on their long-planned for geothermal heating/cooling system. At that time, they created the single largest geothermal well field in the New York City area consisting of 22 standing column wells installed beneath the sidewalks surrounding the campus. They had to drill down into the bedrock to a depth of 1,500 feet; and the Empire State Building, to the top of its lightening rod is 1,453 feet - so they had to drill down further than the Empire State building is high.

As they were interested in preserving the integrity of their buildings, the hot water system fit perfectly with the hot water system the buildings already had. There was little construction needed for the buildings. They expected to recoup their costs within 9 years so that year 10 would be clear, with low maintenance for this geothermal system that has been estimated to reduce GTS's carbon dioxide emissions by more than 1,400 tons a year.

I thank the council and Samara Swanston for the outstanding Site-sourced & Stored Renewable Energy Conference held February 27, 2015 at the CUNY Advanced Science Research Center, Steinman Hall that presented several types of closed and open, vertical and horizontal loop geothermal systems. It was a most educational conference, especially on this renewable energy source and served as good preparation.

I have two questions. 1.This bill calls for reporting of the number of city-owned buildings in each district for which installation of a geothermal system would be cost-effective. This implies the need for more trained professionals able to make these assessments. Will there be funding from the city for training the people needed for these jobs?
2. In the case of GTS, it took quite a while to get community support for the project as drilling was required. Will there be coordination with the related city agencies to ease any potential difficulties and help the geothermal installation projects go smoothly?

Again, I applaud and thank you for taking this step to move us closer to reducing our greenhouse gas emissions. I hope that if there is anything you can do to help the City obtain power purchase agreements for offshore wind that could also help us reduce greenhouse gases in a big way, you will. Thank you for this opportunity for comment.

Multi-source Heat Pumps and Underground Thermal Storage

Gaylord Olson

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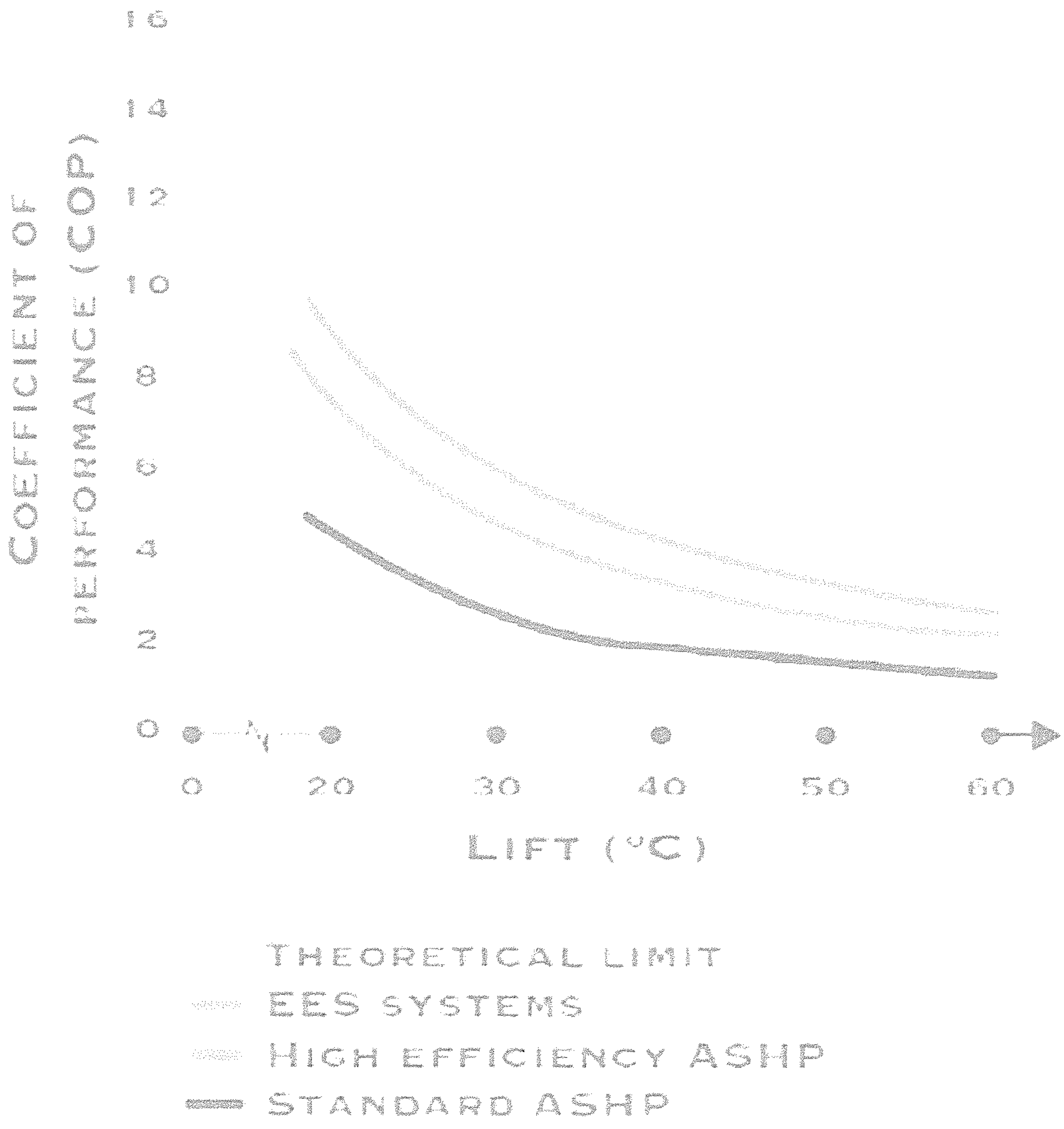
September 21, 2015

gg_olson@yahoo.com

HEAT PUMP PERFORMANCE



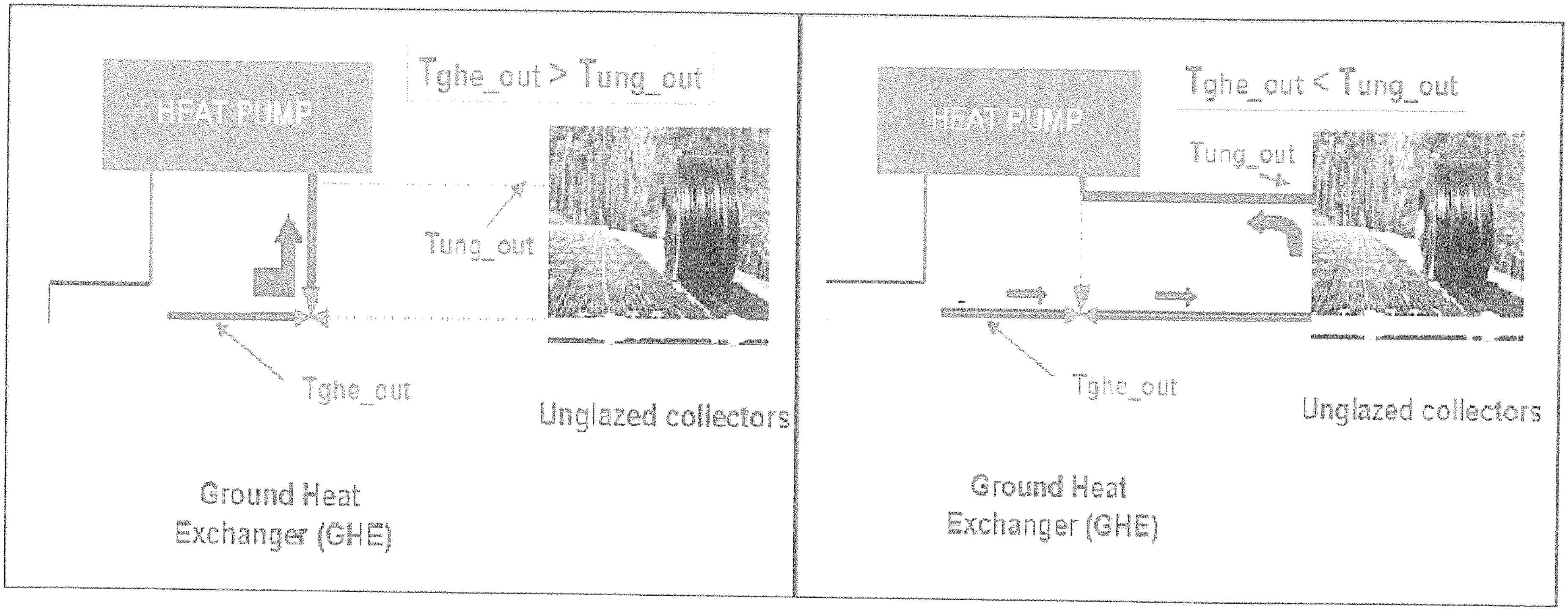


Figure 1. Hybrid heat source principle (photo: HELIOPAC)

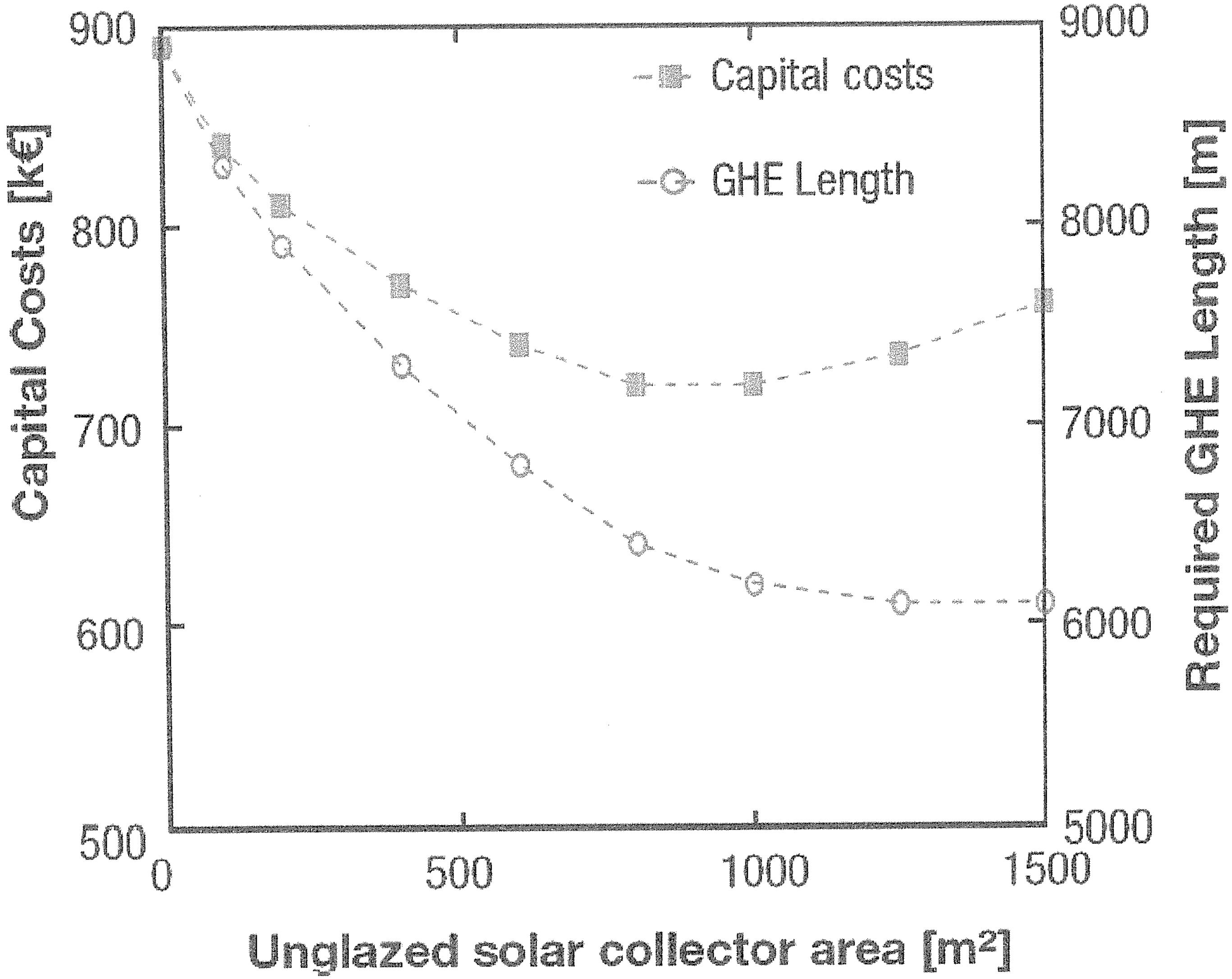


Figure 5. Impact of unglazed collectors on the required GHE sizing and the capital costs.

http://rehvajournal.com/magazine/default.asp?sayi=24

Volume 24 August 2011

pages 16 - 20

Authors: M. Kummert and O. Cauret

Also, with more detail:

Proceedings of Building Simulation 2011:
12th Conference of International Building Performance Simulation Association, Sydney, 14-16 November

EXPERIMENTAL AND SIMULATION STUDY OF HYBRID GROUND-SOURCE HEAT PUMP SYSTEMS WITH UNGLAZED SOLAR COLLECTORS FOR FRENCH OFFICE BUILDINGS

Vincent Helpin[1], Michaël Kummert[1], and Odile Cauret[2]

[1]Department of Mechanical Engineering, École Polytechnique de Montréal, QC, Canada

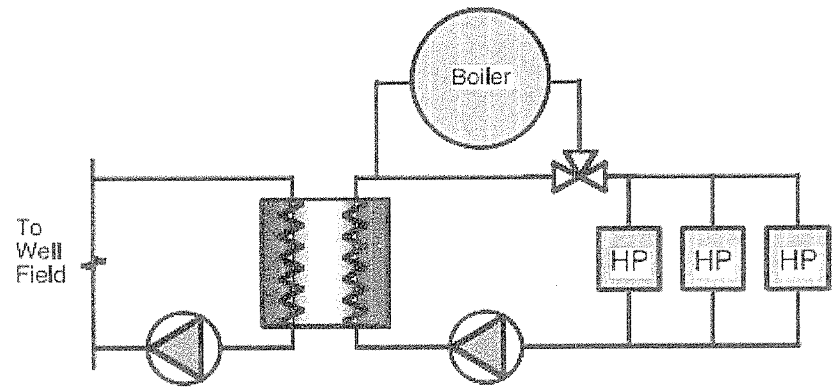
[2]Department "Energy in buildings and territories", EDF R&D, France

www.globalengineeringconference.com/GEC2012Presentations/Workshops/2012_GEC_ALDERSON_3_23_12.pdf

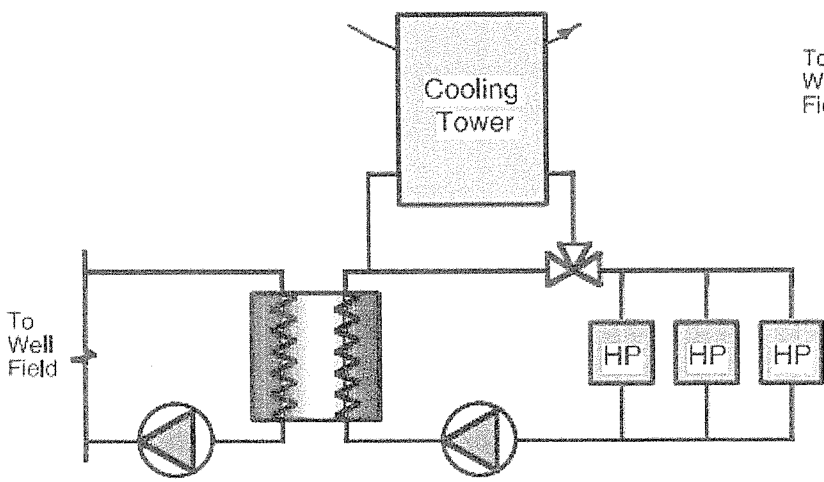
Hybrid Systems

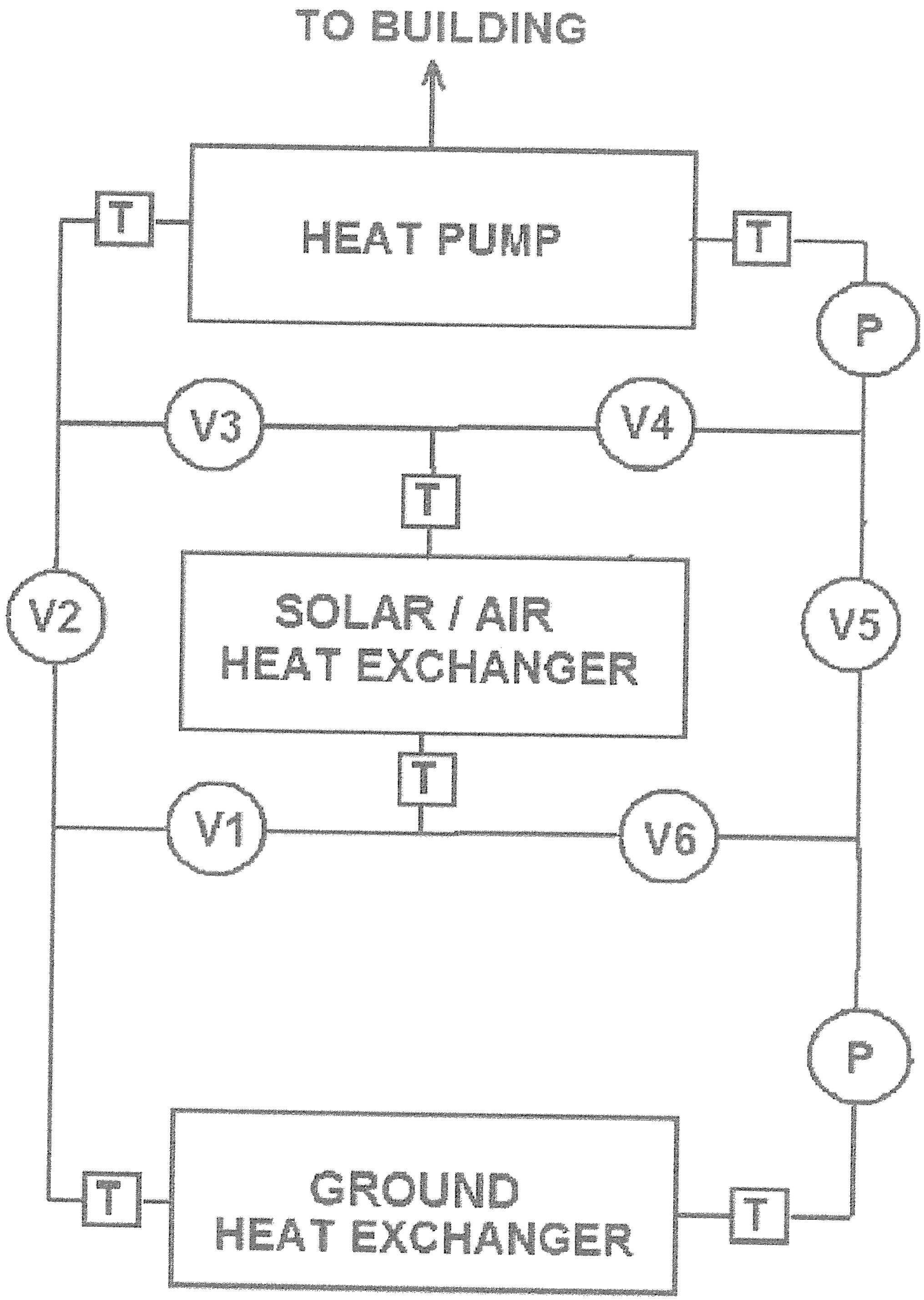
2012 GLOBAL ENGINEERING CONFERENCE

Hybrid System with Boiler



Hybrid System with Cooling Tower




TO BUILDING
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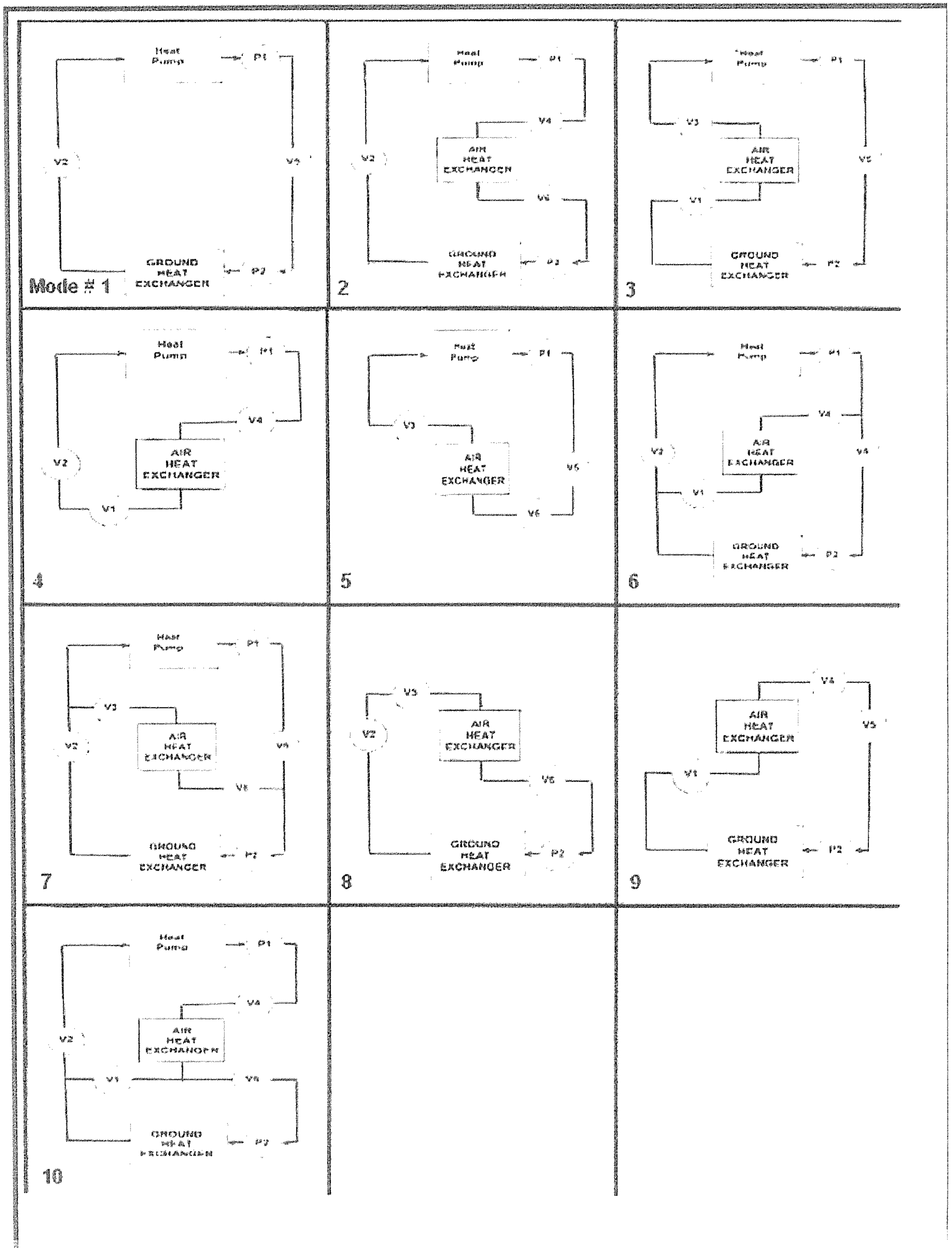
Mode # 1
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GROUND HEAT EXCHANGER
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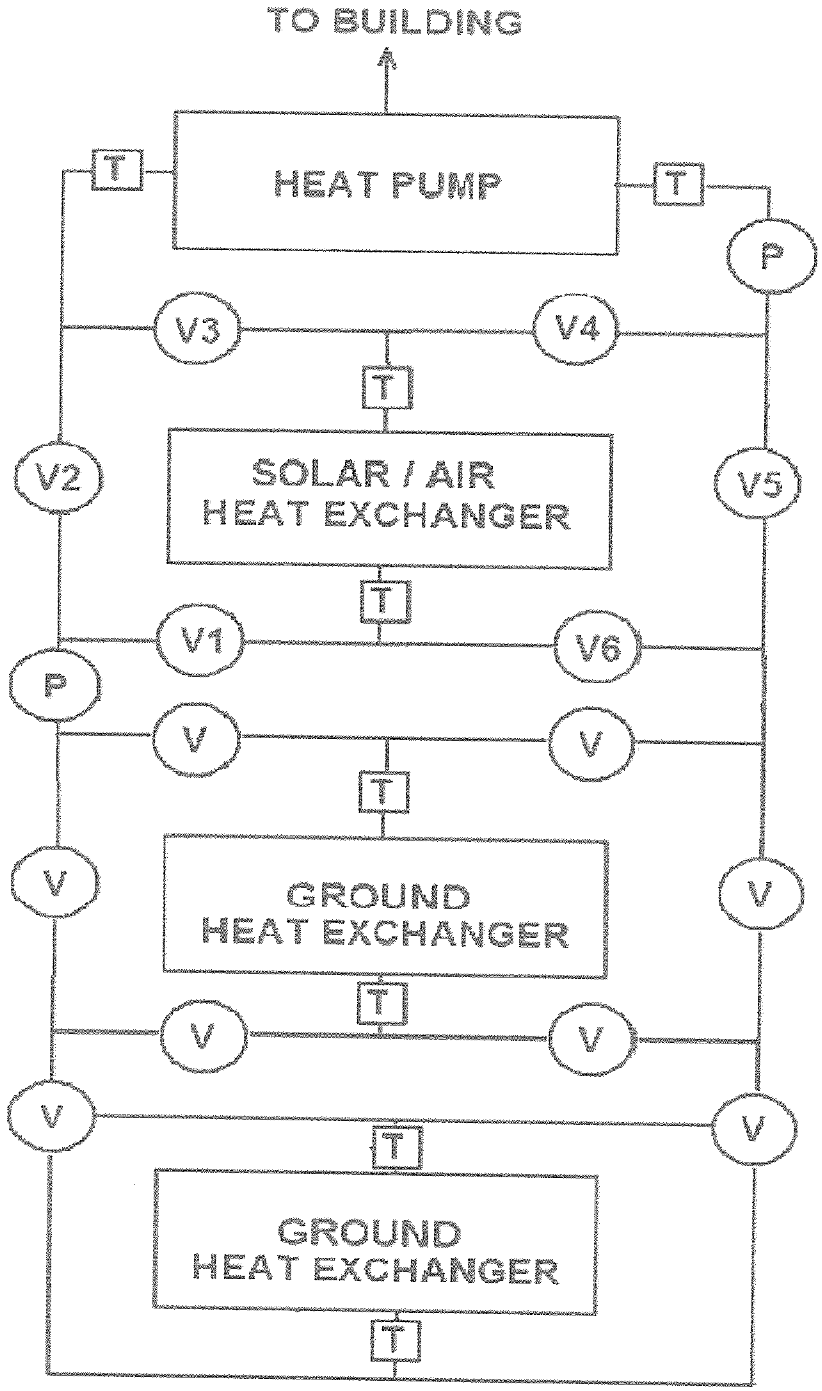
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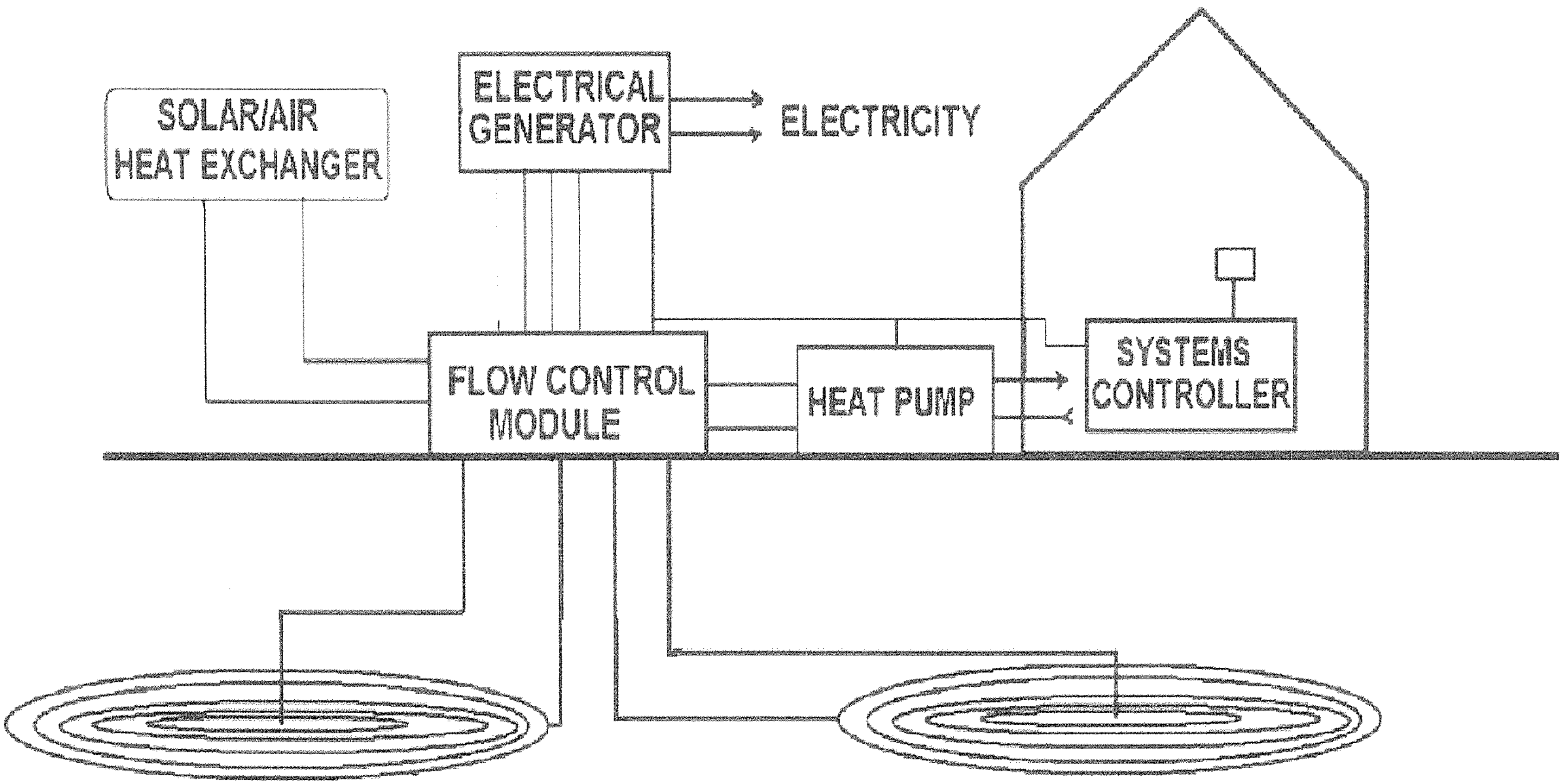
SOLAR/AIR
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SYSTEMS
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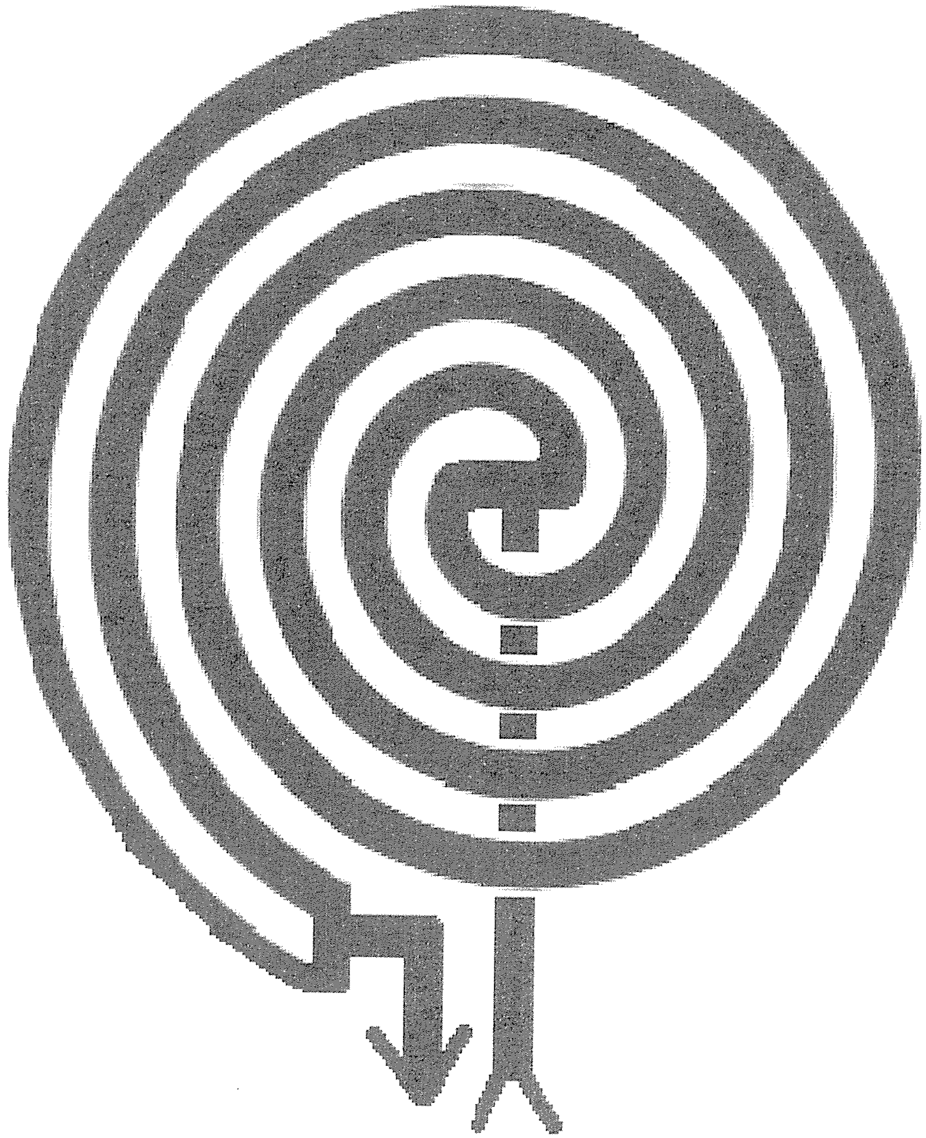
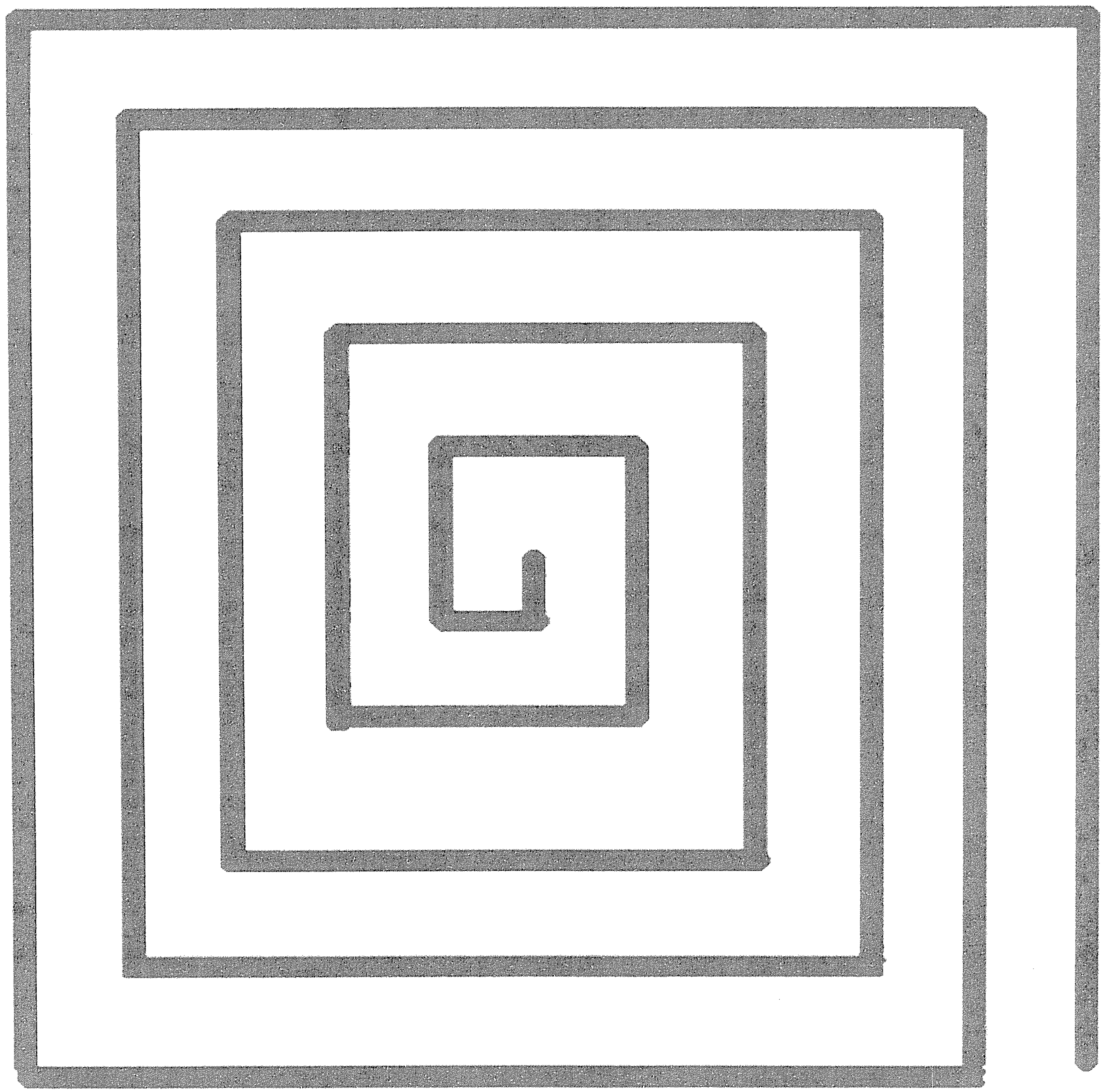
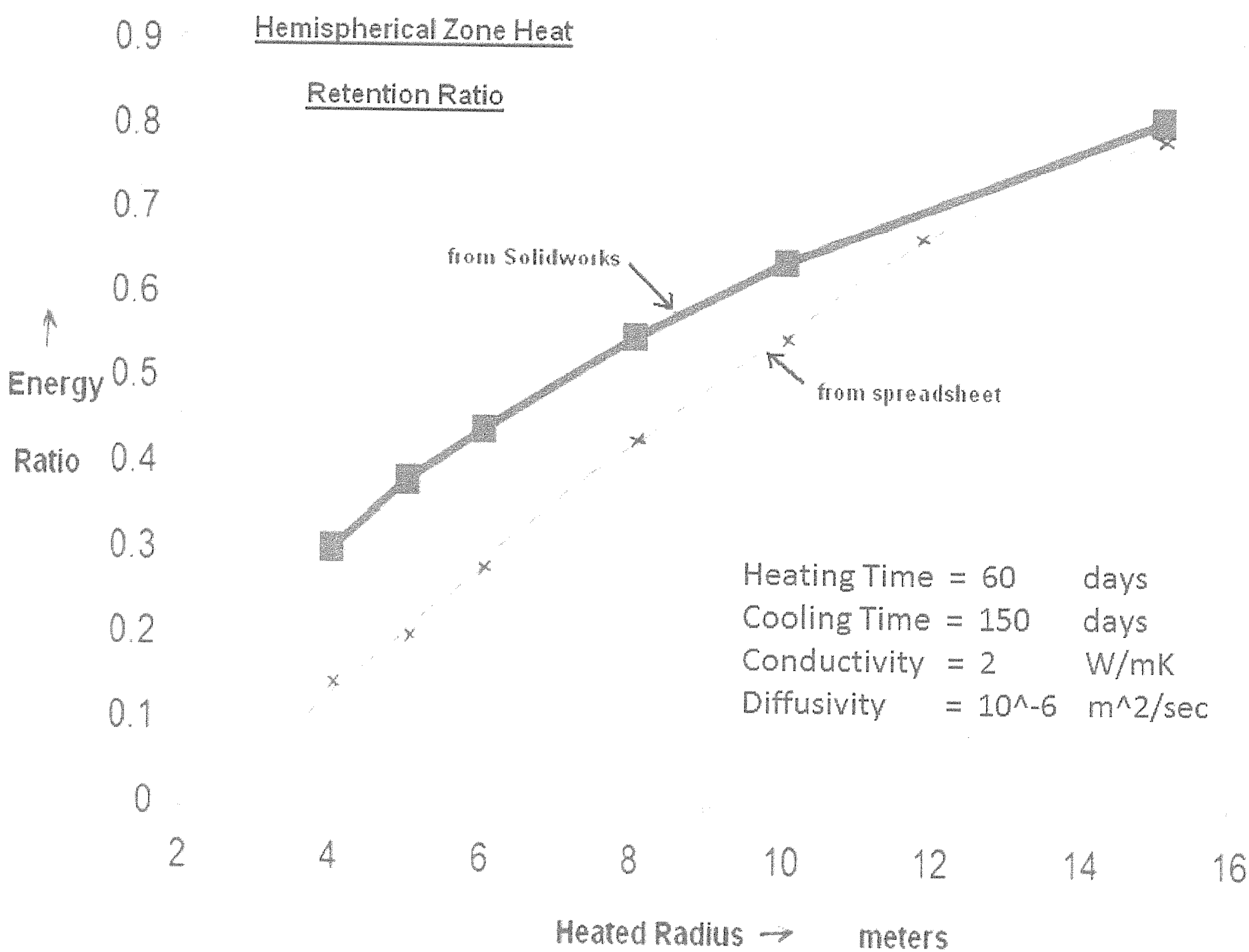


Dual Path Spiral Heat Exchange Pattern



Rectangular Quasi-spiral


Hemispherical Zone Heat
Retention Ratio
0.9
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0.7
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0.5
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0.3
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Energy
Ratio
from Solidworks
from spreadsheet
Heating Time = 60 days
Cooling Time = 150 days
Conductivity = 2 W/mK
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4
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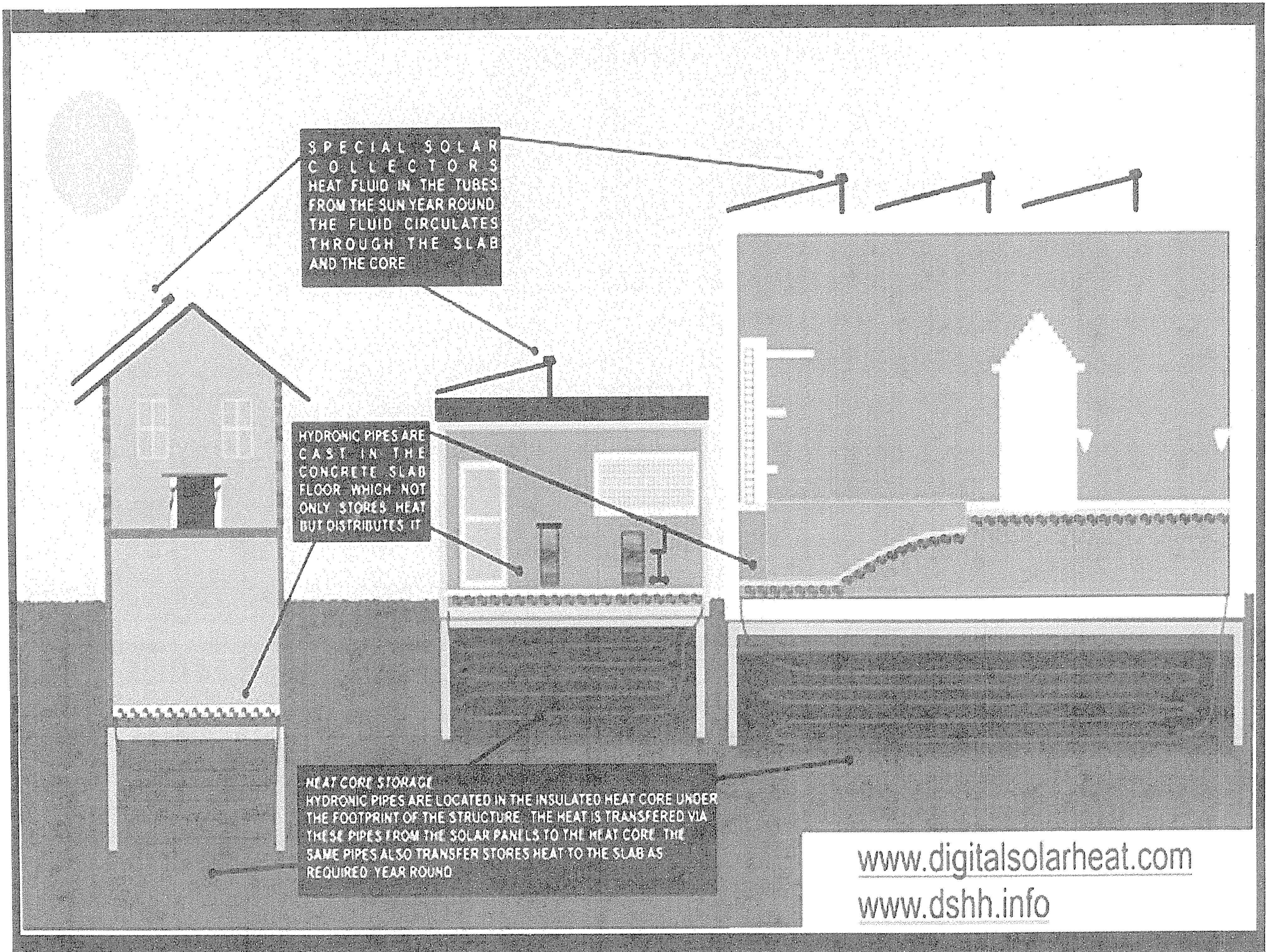
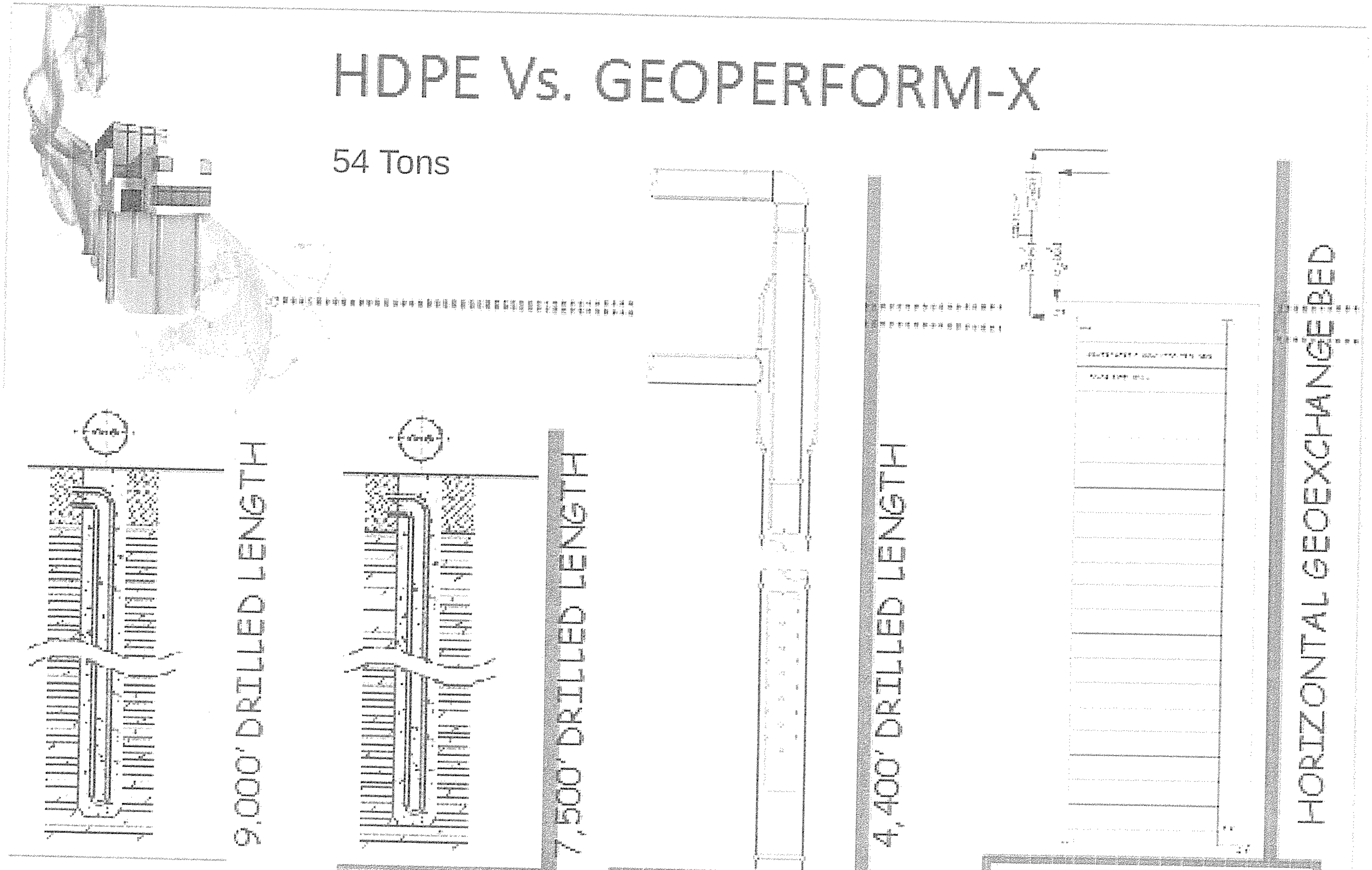

SPECIAL SOLAR COLLECTORS HEAT FLUID IN THE TUBES FROM THE SUN YEAR ROUND THE FLUID CIRCULATES THROUGH THE SLAB AND THE CORE
HYDRONIC PIPES ARE CAST IN THE CONCRETE SLAB FLOOR WHICH NOT ONLY STORES HEAT BUT DISTRIBUTES IT
HEAT CORE STORAGE
HYDRONIC PIPES ARE LOCATED IN THE INSULATED HEAT CORE UNDER THE FOOTPRINT OF THE STRUCTURE. THE HEAT IS TRANSFERED VIA THESE PIPES FROM THE SOLAR PANELS TO THE HEAT CORE. THE SAME PIPES ALSO TRANSFER STORES HEAT TO THE SLAB AS REQUIRED YEAR ROUND
www.digitalsolarheat.com
www.dshh.info

HDPE Vs. GEOPERFORM-X

54 Tons



18
500' 1-1/4"Ø
HDPE U-TUBE
BOREHOLES

=

15
500' 1-1/4"Ø
GPX® U-TUBE
BOREHOLES

=

4
1,100' 4"Ø
CONCENTRIC
GEOPERFORMX

=

1 bed
300' x 115'
46,000 LF
GEOPERFORMX
TUBE

Graphic Courtesy of Jeffrey. J. Harrison, PE. The Bicks Group

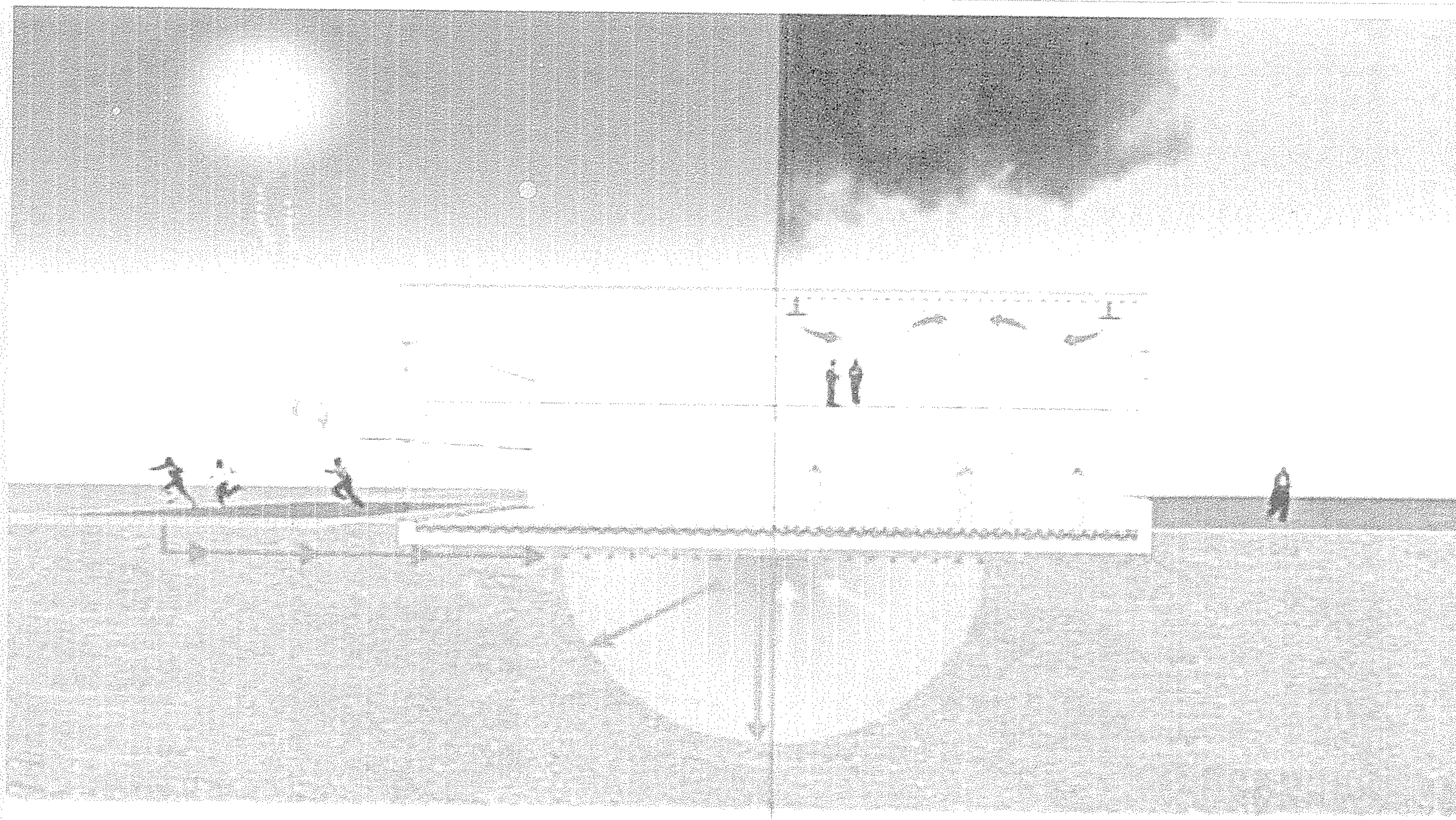
http://www.bts-hvac.com/residential/GEOEXCHANGE.html

Geo-Exchange Configuration Economics

	FT/Ton	Cost / Ton
U-Bend 500 FT	175	3,400
GeoperformX U-Bend 500 FT	150	3,100
Twister four ¾" U's -440 FT	125	2,800
Concentric 4" GeoperformX - 1100 FT	110	2,900
Horizontal grid/header Bed Under slab	640	1,100
Horizontal grid/header Bed exposed	900	1,600

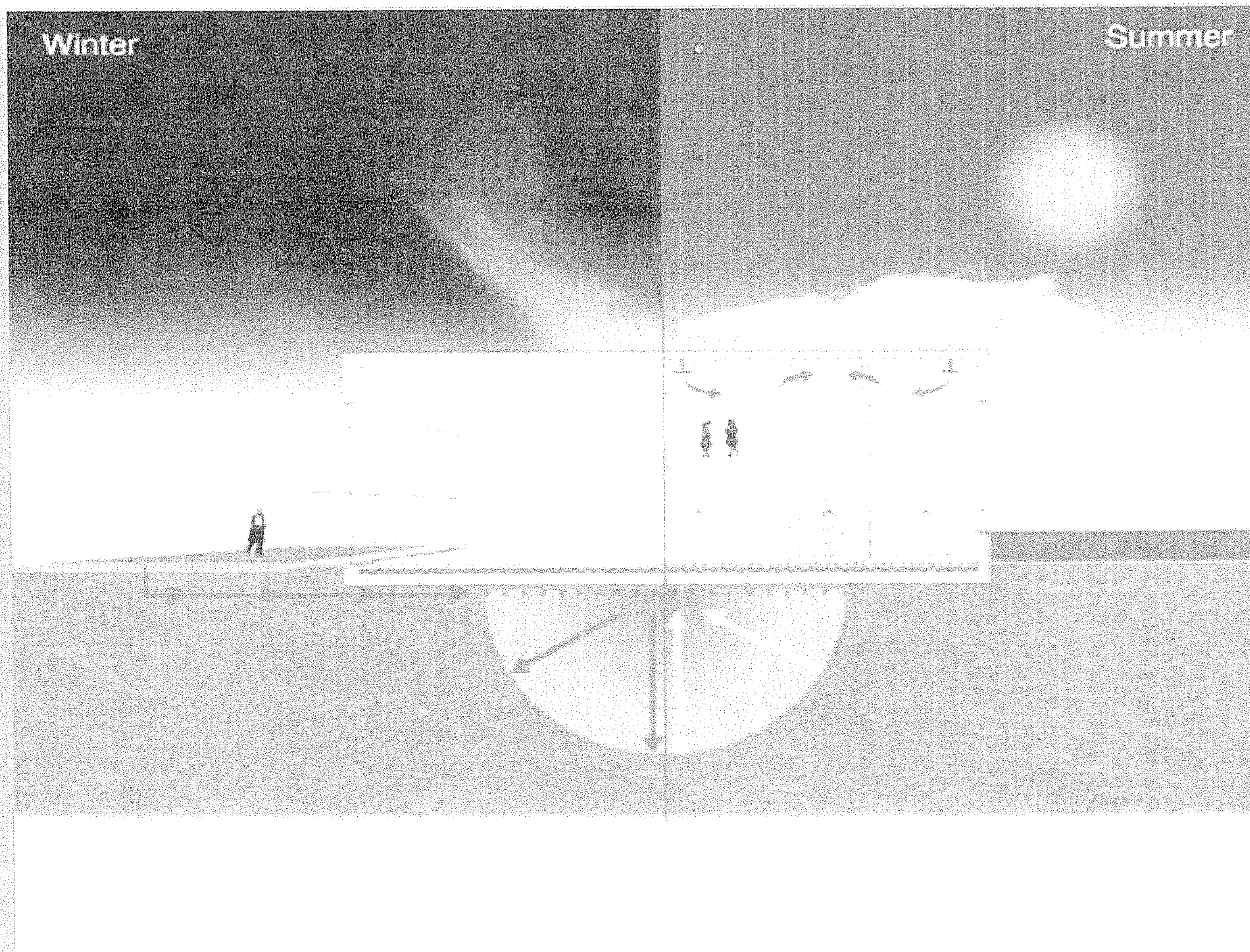
In addition to lower cost per ton of deep bores, lower costs for horizontal run-outs can make an even larger cost impact on the project as well as reducing the need to use a vault .

[illegible]



from: www.icax.co.uk

Interseasonal Heat Transfer (IHT) recycles heat from an Asphalt Solar Collector down to a ThermalBank in summer.
IHT uses a heat pump to recycle heating in winter without burning fossil fuels.
IHT doubles the Coefficient of Performance of the heat pump by starting from a warm ThermalBank.

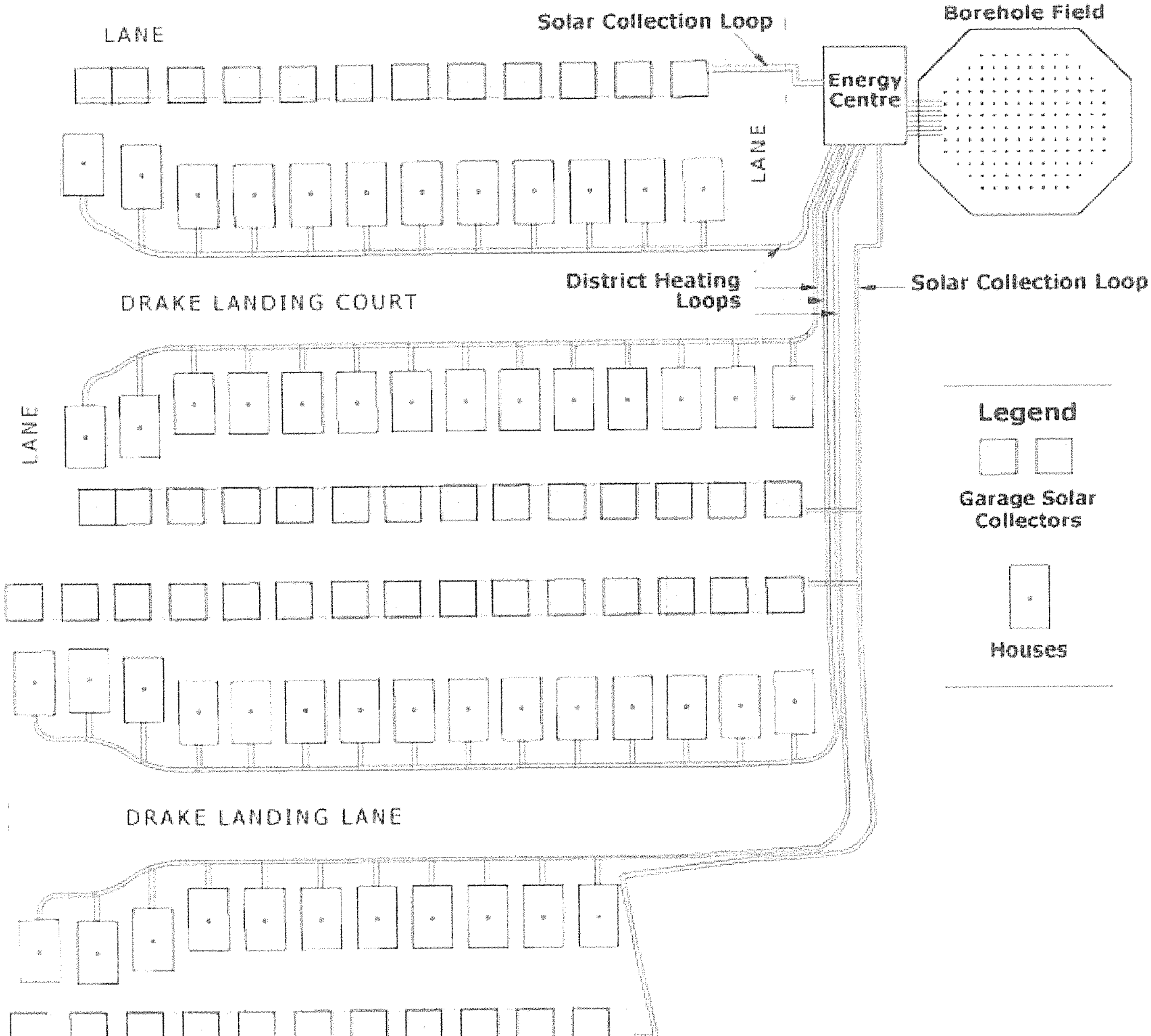


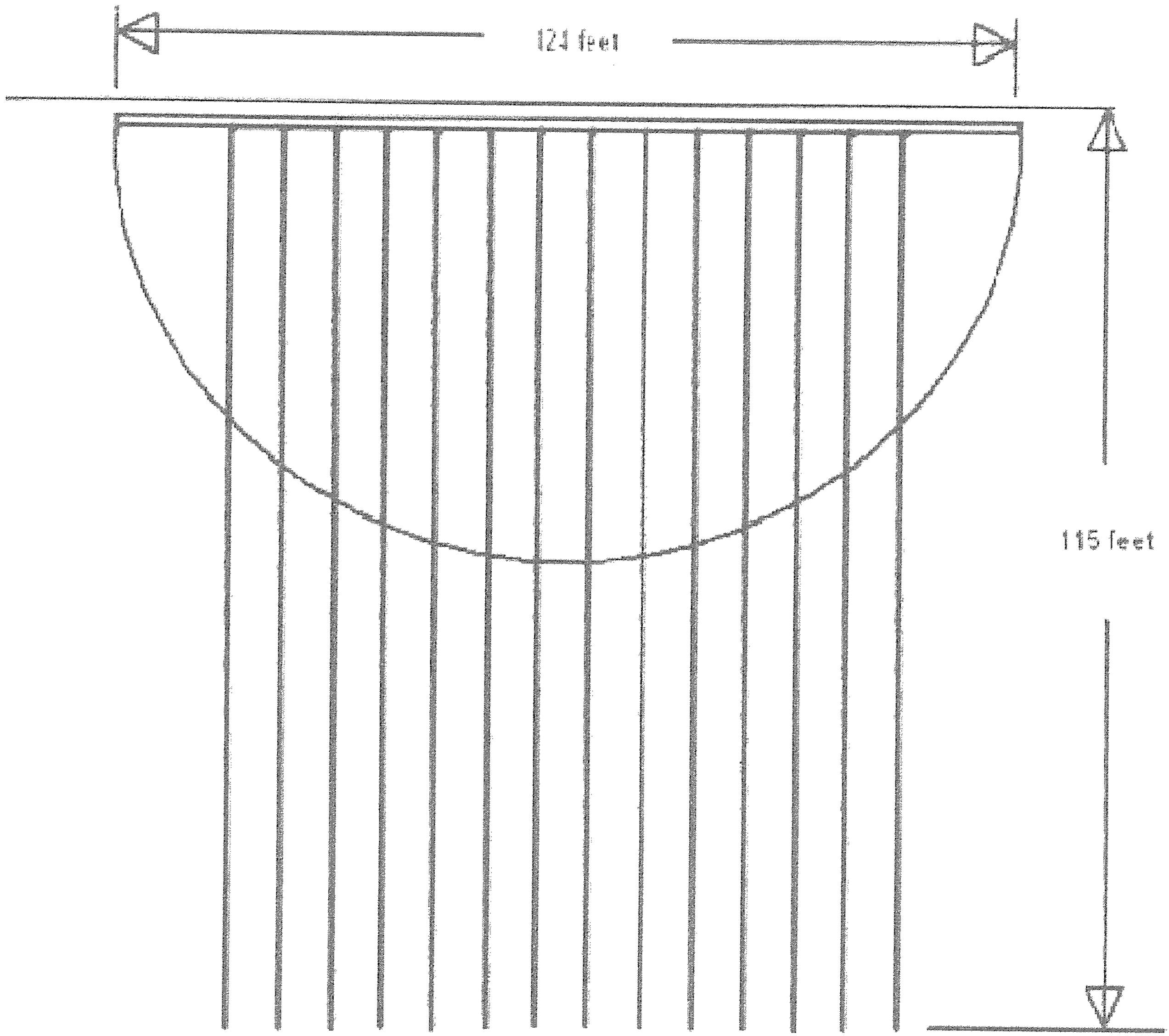
IHT allows the playground collector to reject heat from a ThermalBank in winter.
IHT allows the building to reject heat to a cold ThermalBank in summer.
IHT provides "critical period cooling" by allowing Natural Cooling to take place.

More importantly, IHT allows you to keep your cool from the previous winter and recycle it in summer.

Laying down a ThermalBank at Howe Dell School before the insulated foundations of the building are installed.
The ThermalBank stores Renewable Heat directly in the ground – this is retrieved in winter for heating.
ICAX doubles the performance of the heat pump by starting with a warm ThermalBank instead of cold ground.

Drake Landing Solar Community Site Plan





Drake Landing Borehole Array Side View

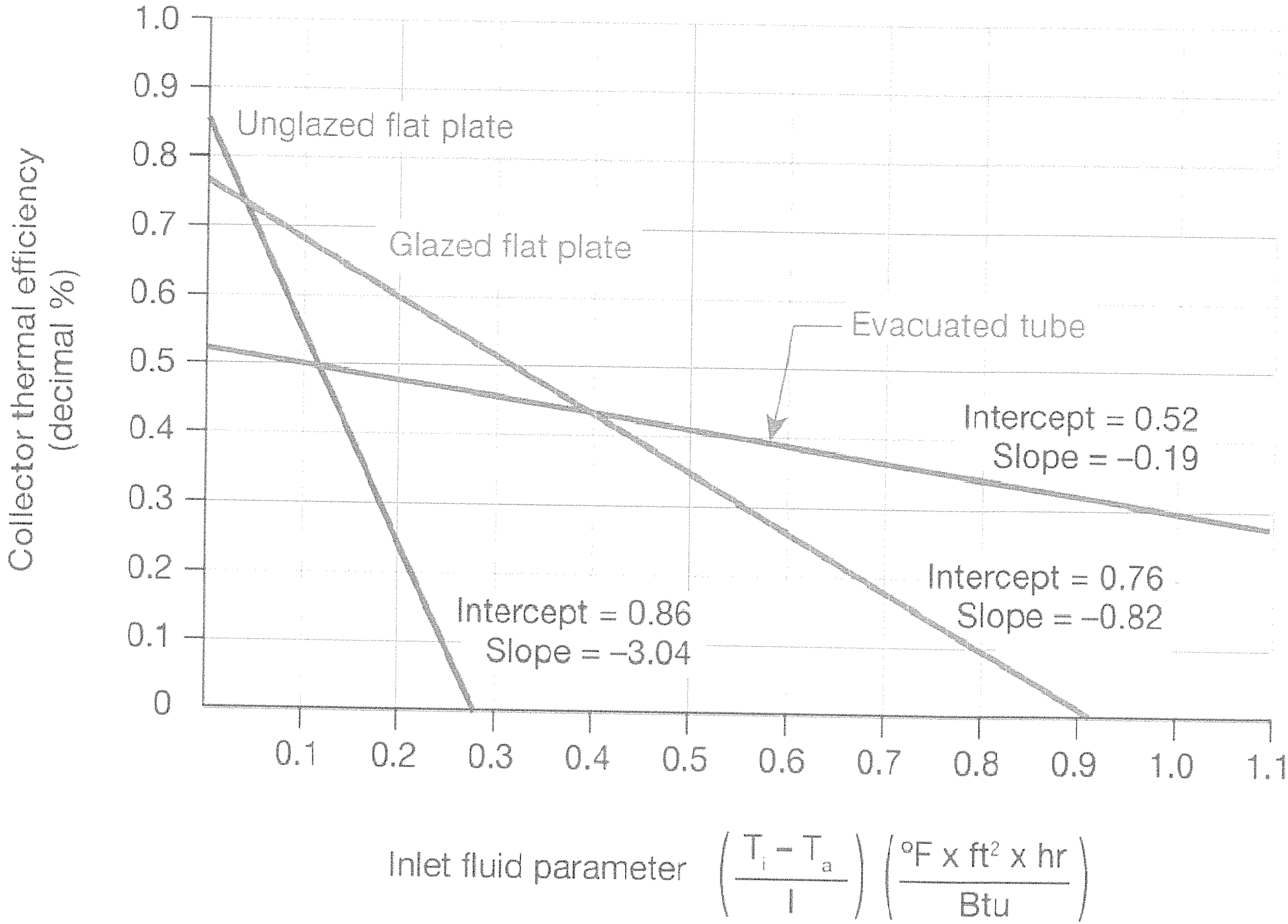
Drake Landing Solar Community

System Cost Summary

Item	Cost (CAD$ 2005-07)
Solar Collectors	710,000
Installation of Solar Collectors	430,000
Seasonal Storage Borehole Field	620,000
District Heating & Solar Collection Loops	1,025,000
Energy Centre including STTS Tanks	600,000
Total	3,385,000

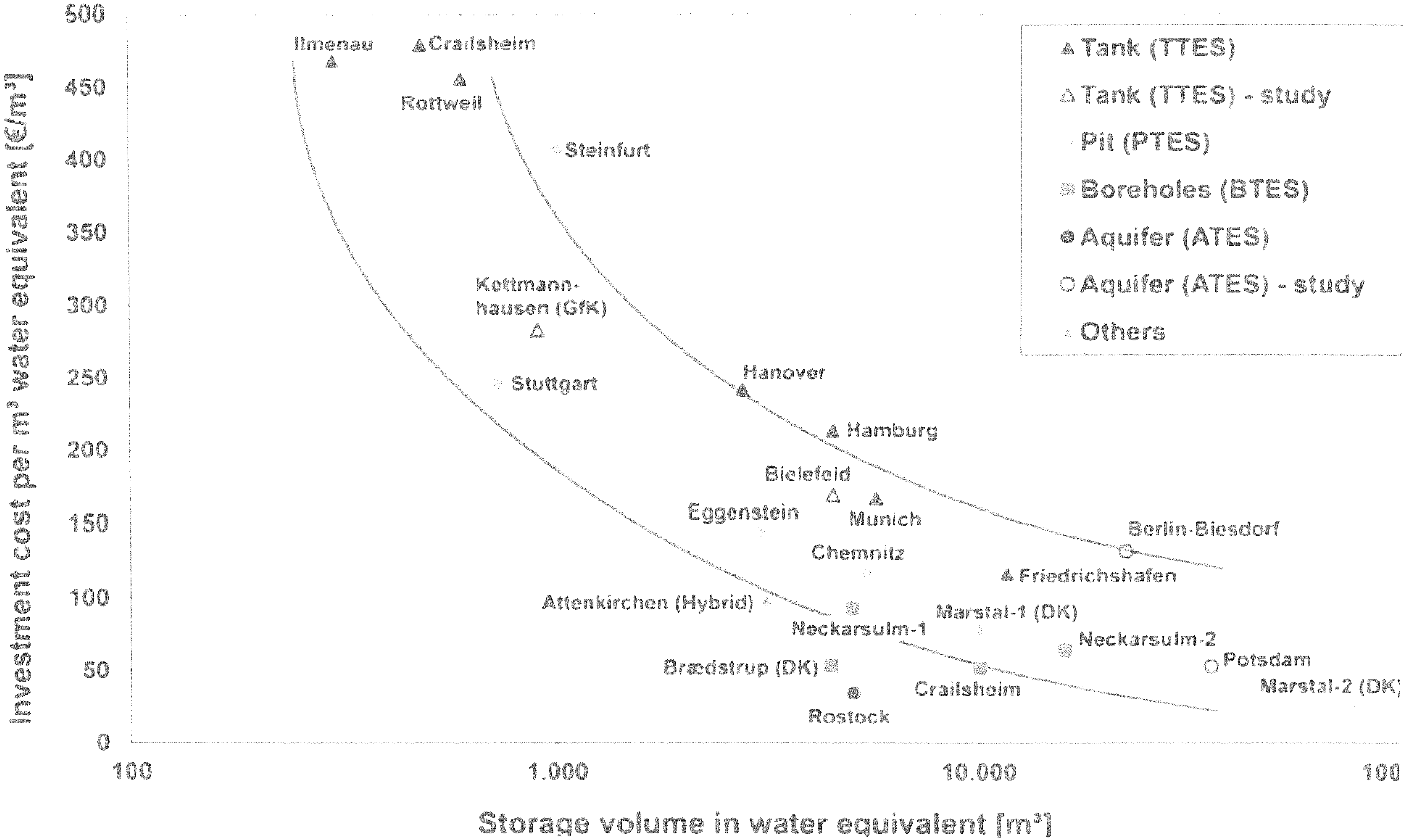
Borehole cost is $37 per foot

With 10,000 square feet of surface area, the borehole array cost is $62 per square foot

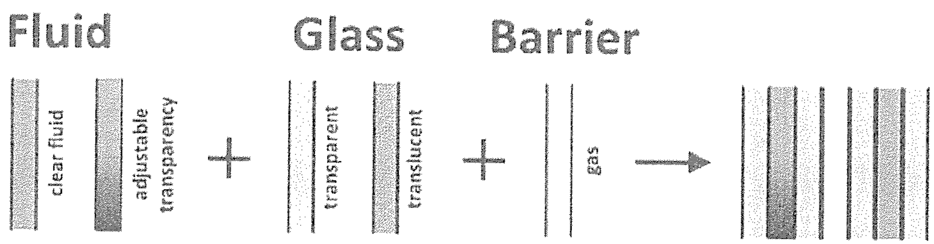


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Collector thermal efficiency (decimal %)
Unglazed flat plate
Glazed flat plate
Evacuated tube
Intercept = 0.52
Slope = –0.19
Intercept = 0.76
Slope = –0.82
Intercept = 0.86
Slope = –3.04
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Inlet fluid parameter $\left(\frac{T_i - T_a}{I}\right)\left(\frac{°F \times ft^2 \times hr}{Btu}\right)$

Investment cost of seasonal thermal energy storages



The collector panel is a combination of fluid and glass layers and a thermal barrier. In this way an optimized configuration of the layers can be assembled for different applications and different sections of the building envelope. The basic element of FLUIDGLASS remains the same, but the combination of the different layers allows wide applicability and simple production process. For example: Shading can be provided by tinted glass or fluid (fixed or adjustable). This modular approach has the advantage to offer customized panels depending on the user's need.



Modular layer approach

In the most advanced approach, two fluid filled layers are implemented in the glass façade. These two layers regulating all energy flow within the façade. The fluid layer to the interior space keeps the inside surface temperature just below or above room temperature for heating and cooling, while the liquid layer to the exterior controls the energy transmission by absorption of the solar irradiation.

Basic operating modes of advanced approach with two fluid layers

Consortium:

Universität Liechtenstein	LI
Mayer Glastechnik GmbH	AT
NTB Buchs	CH
Tech. Univ. München	DE
GlassX AG	CH
Hoval AG	LI
CEA-INES	FR
Universität Stuttgart	DE
Cyprus R&I Center	CY
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Steps toward a fossil fuel free NYC:

Develop large scale seasonal thermal storage

Build more and larger solar PV and wind farms

Use pumped hydro (without dams) along
the Hudson and Delaware rivers

Use multi-pane windows for collection
of both hot and cold fluid

Use ice storage tanks with heat pumps or
chillers for diurnal thermal storage

Testimony on September 22, 2015 by Frederick Stumm Ph.D., Research Hydrologist United States Geological Survey, New York Water Science Center Coram Office, 2045 Route 112, Coram, New York, 11727 (631) 736-0783 ext. 107.

USGS
science for a changing world

USGS Groundwater Investigations in New York City and their Application to Geothermal Projects

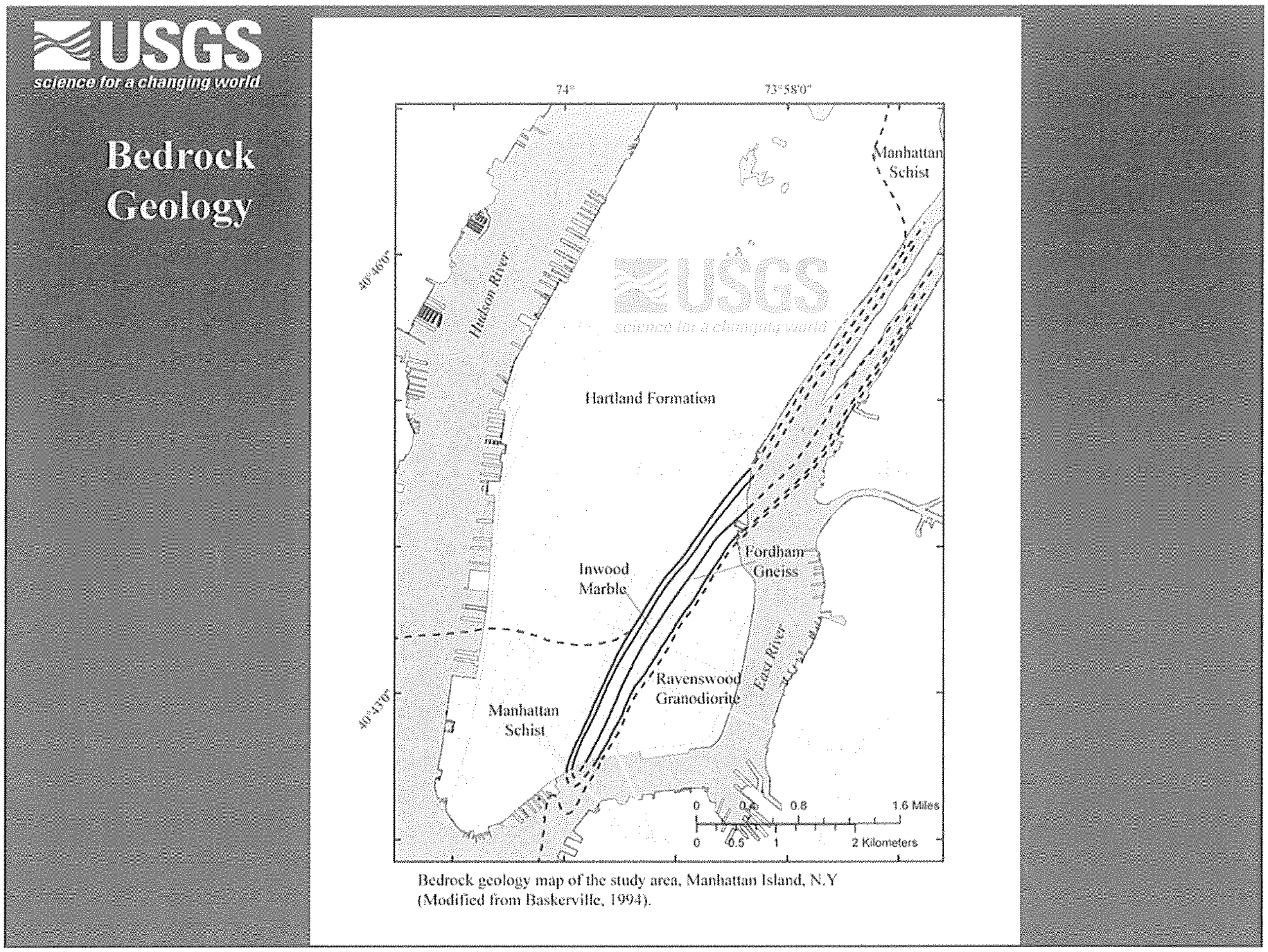
Frederick Stumm Ph.D.
U.S. Geological Survey, Coram, New York
fstumm@usgs.gov

In cooperation with
New York City Department of Design and Construction
New York City Department of Environmental Protection
Cornell University

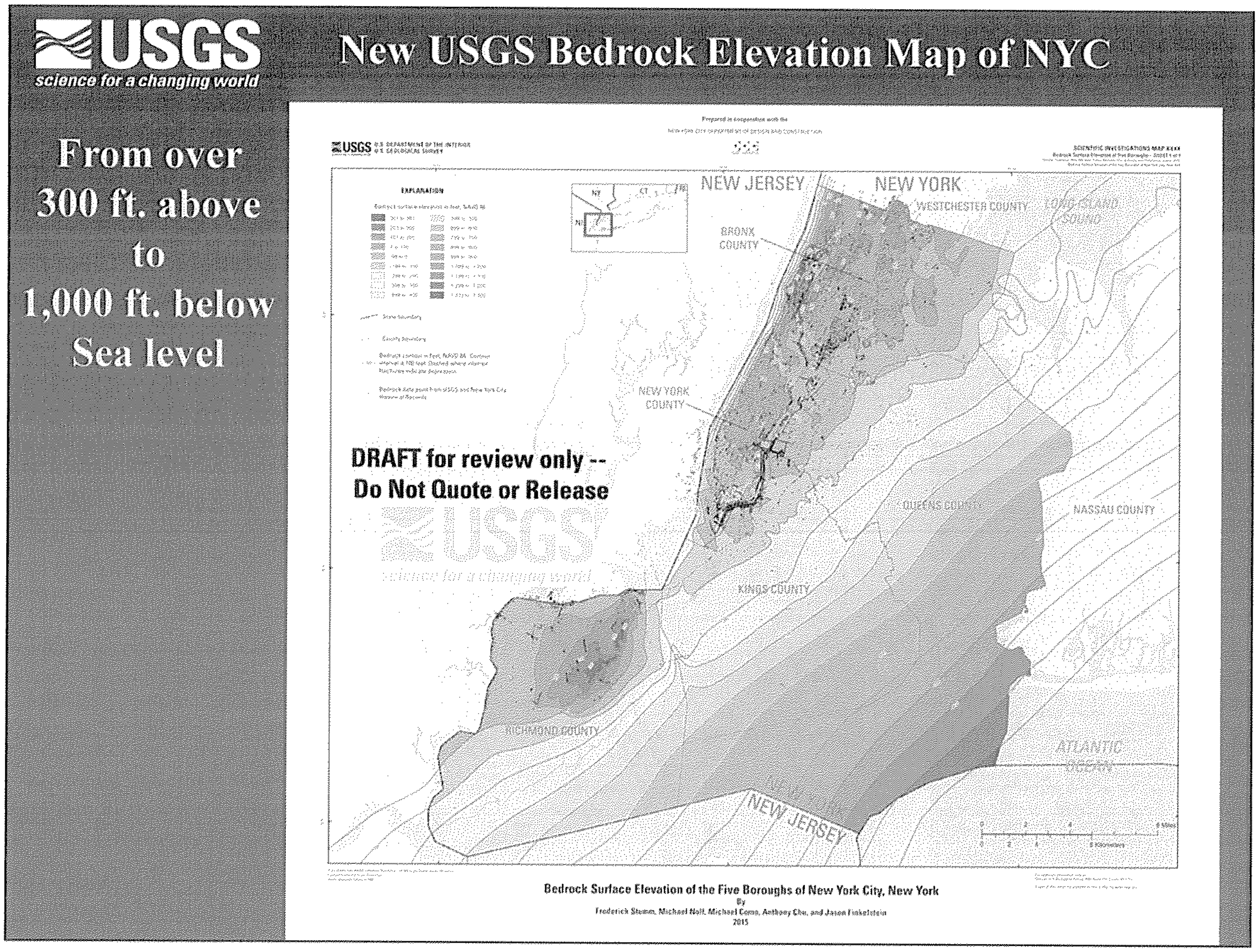
My name is Frederick Stumm Ph.D., I am a Research Hydrologist with the United States Geological Survey (USGS) in the New York Water Science Center Coram Office on Long Island. I wish to thank the Committee on Environmental Protection for inviting the USGS to present some of our work relating to geothermal energy. I have been applying advanced borehole and surface geophysical methods to environmental and engineering problems throughout New York City for almost 20 years. I have published over 20 scientific publications relating to groundwater, hydrogeology, and geophysical methods.

The USGS in cooperation with the NYCDEP has been collecting and analyzing NYC's hydrogeologic framework using over 50 test boreholes for the Third Water Tunnel beginning in 1998. Since 2014 the USGS in cooperation with the NYCDDC has been collecting, tabulating, and mapping the bedrock elevation and thickness of sediments in the five boroughs to produce the first comprehensive maps for geothermal application using Geographic Information Systems at high resolution.

Today I am going to provide the committee with a brief overview of some of this research and how it can be applied to help implement the use of geothermal energy in NYC.

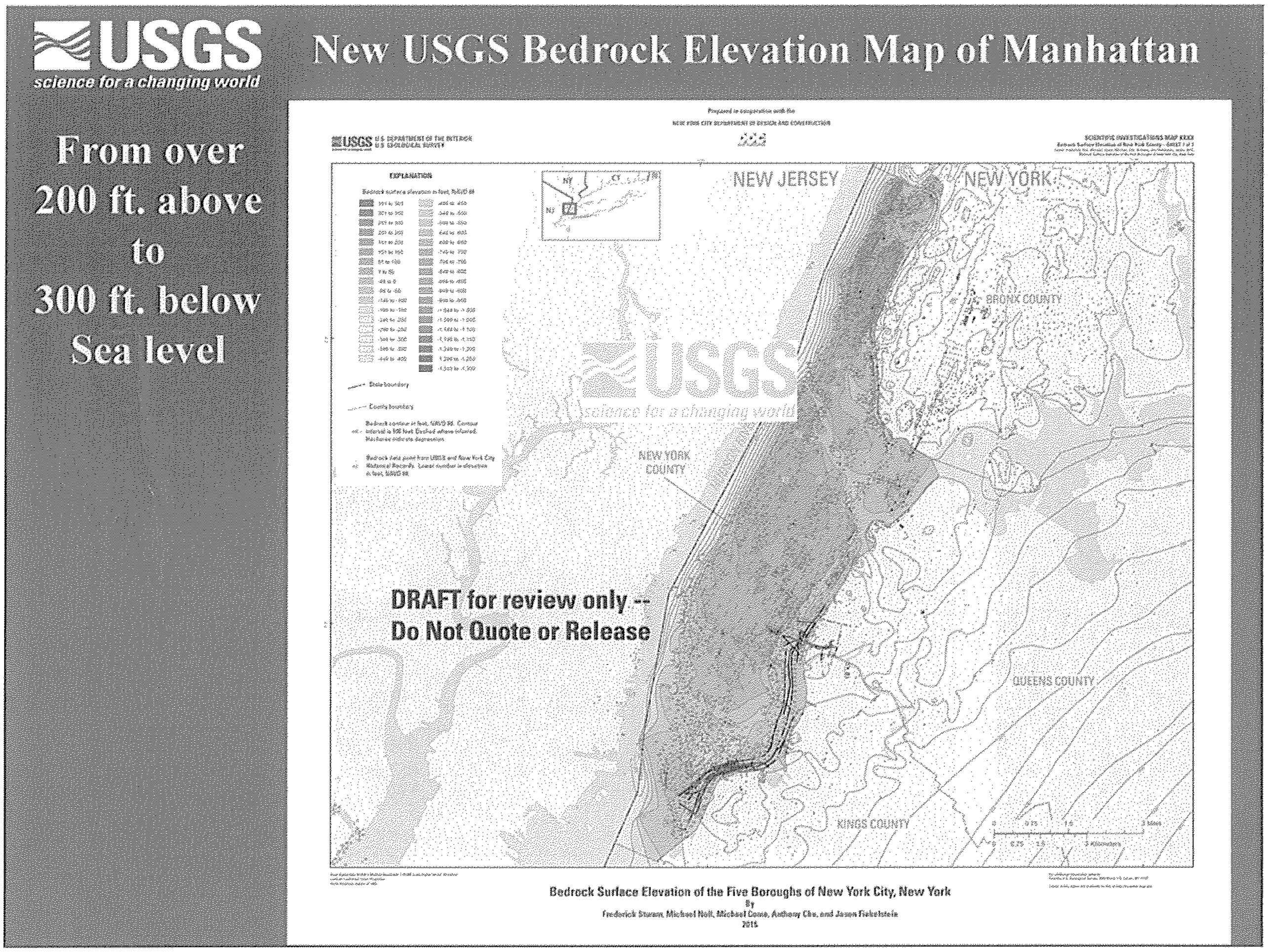


Most of NYC is underlain by high-grade metamorphic bedrock consisting of a sequence of gneiss and schist with isolated areas of marble. In Staten Island the westernmost part is underlain by sandstones and shales. These rocks were formed during the assembly and break up of continents. The bedrock varies in foliation or layering from sub-horizontal to over 70 degrees of dip. The bedrock is fractured with several known faults such as the 125th Street fault which cross-cuts northern Manhattan.. During the Cretaceous period sediments were deposited along the coastal plain included sands and clays underlying Queens, Brooklyn, and Staten Island. During the Pleistocene or Ice Age several advancing glaciers covered much of NYC and eroded and carved valleys into the bedrock and the Cretaceous sediments. The glaciers deposited sediment such as gravel, sand, silt , and clay throughout NYC. These sediments along with the coastal plain sediments comprise the aquifers and confining units overlying the bedrock.

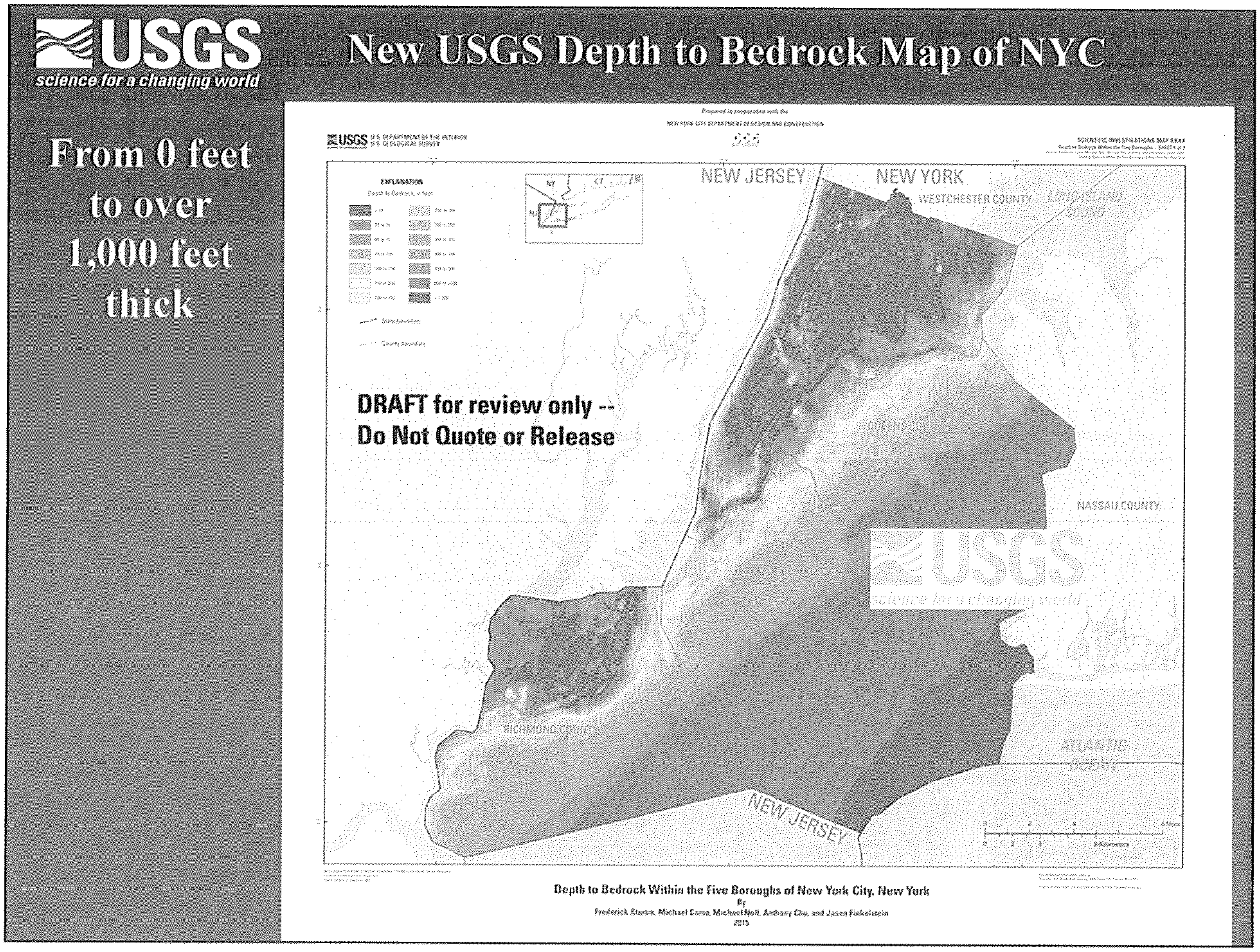


The USGS in cooperation with the NYCDDC compiled 80 years of test borings from various agencies including the NYCDDC to produce a database of over 14,000 data points of depth to bedrock throughout NYC. All of these points were georeferenced, plotted, contoured, and integrated into a GIS to produce the first comprehensive high-resolution depth to bedrock map of NYC. This depth to bedrock map will provide critical information for locating geothermal wells in NYC. The depth to bedrock will determine if either standing column or open/closed loop systems are appropriate in each of the five boroughs. It will also serve as a cost estimator for drilling geothermal wells in NYC.

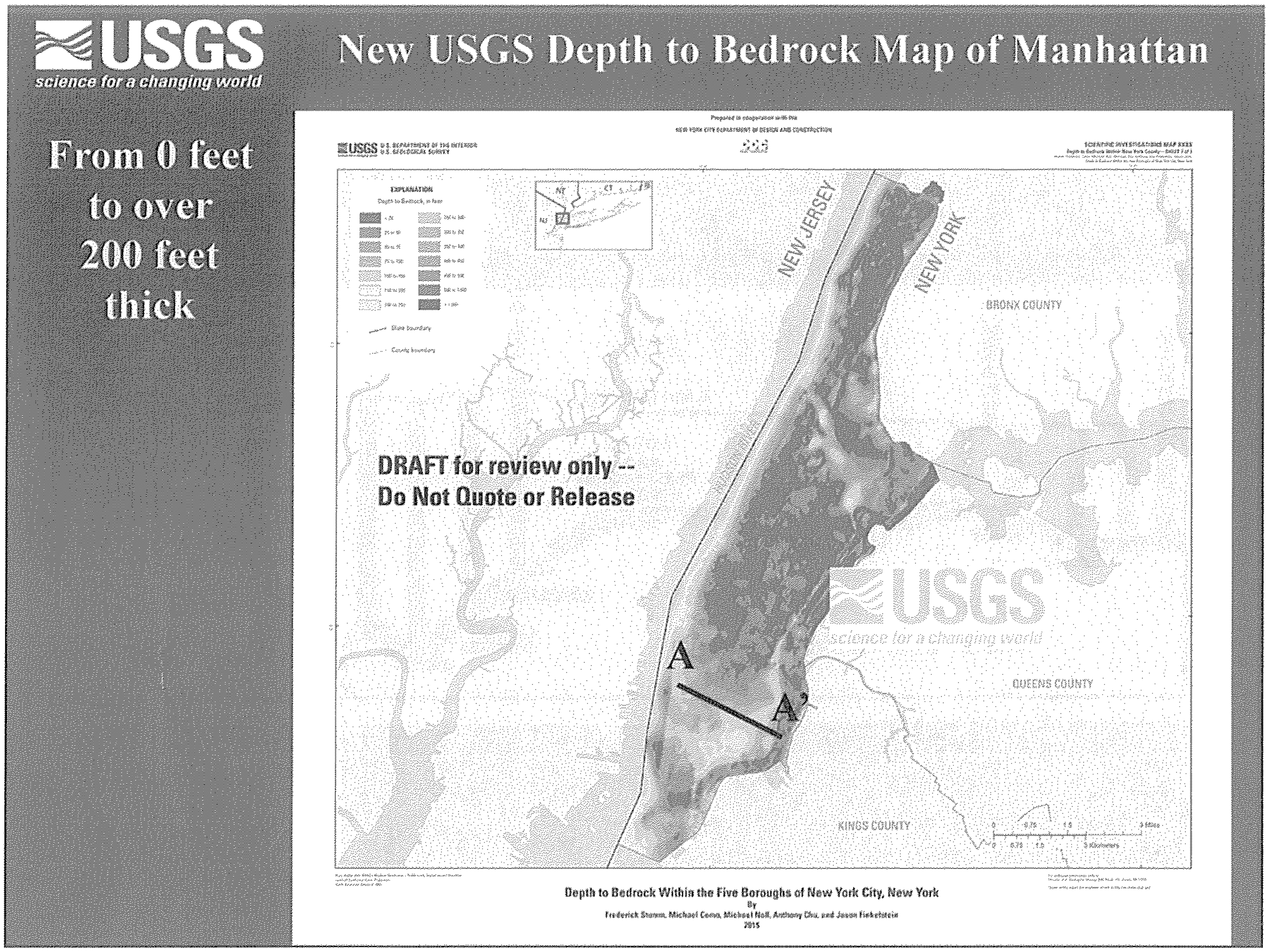
Overall, the elevation of the bedrock surface is highly variable and ranges from 300 feet above to 1,000 feet below sea level in the five boroughs.



This is a close up of Manhattan with the elevation of bedrock contoured and color coded. The bedrock ranges from over 200 feet above sea level in the northernmost part to 300 feet below sea level along the coastline areas. Two valleys can be seen, the northernmost is the 125th Street fault cross-cutting the island diagonally. The second valley in the southernmost part was eroded by the glaciers. The resolution is high enough to zoom into specific blocks for information.

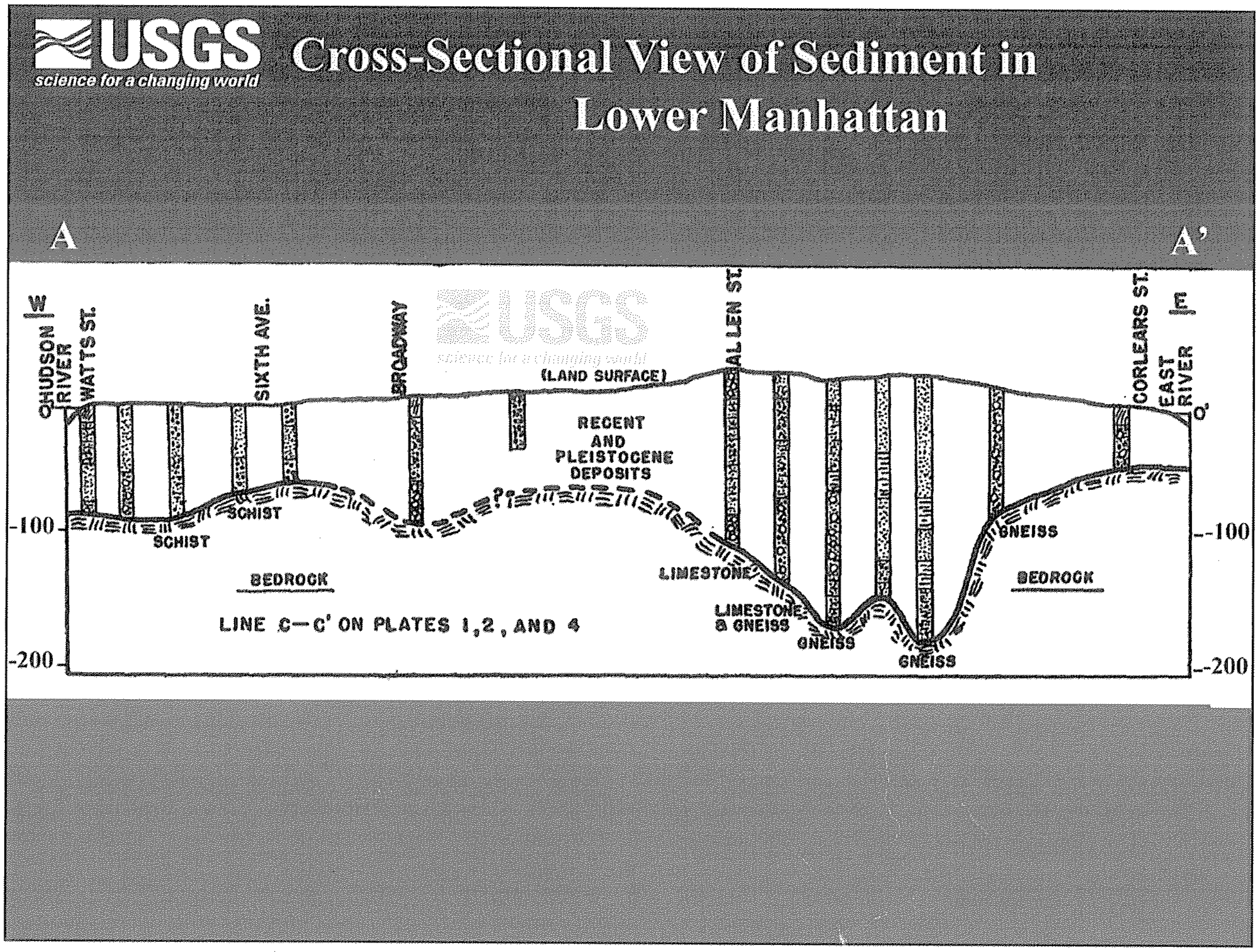


This USGS map is a depth to bedrock or sediment thickness map. It is the first of it's kind every made of the five boroughs. We used the elevation of bedrock map shown before and digitally subtracted a high resolution map of the land surface and surrounding bathymetry. The resulting depth to bedrock map or sediment thickness map is a very useful tool to rapidly determine the amount of sediment overlying the bedrock anywhere in NYC. This will aid in the selection of specific geothermal systems to be used and help determine the amount and type of drilling required.

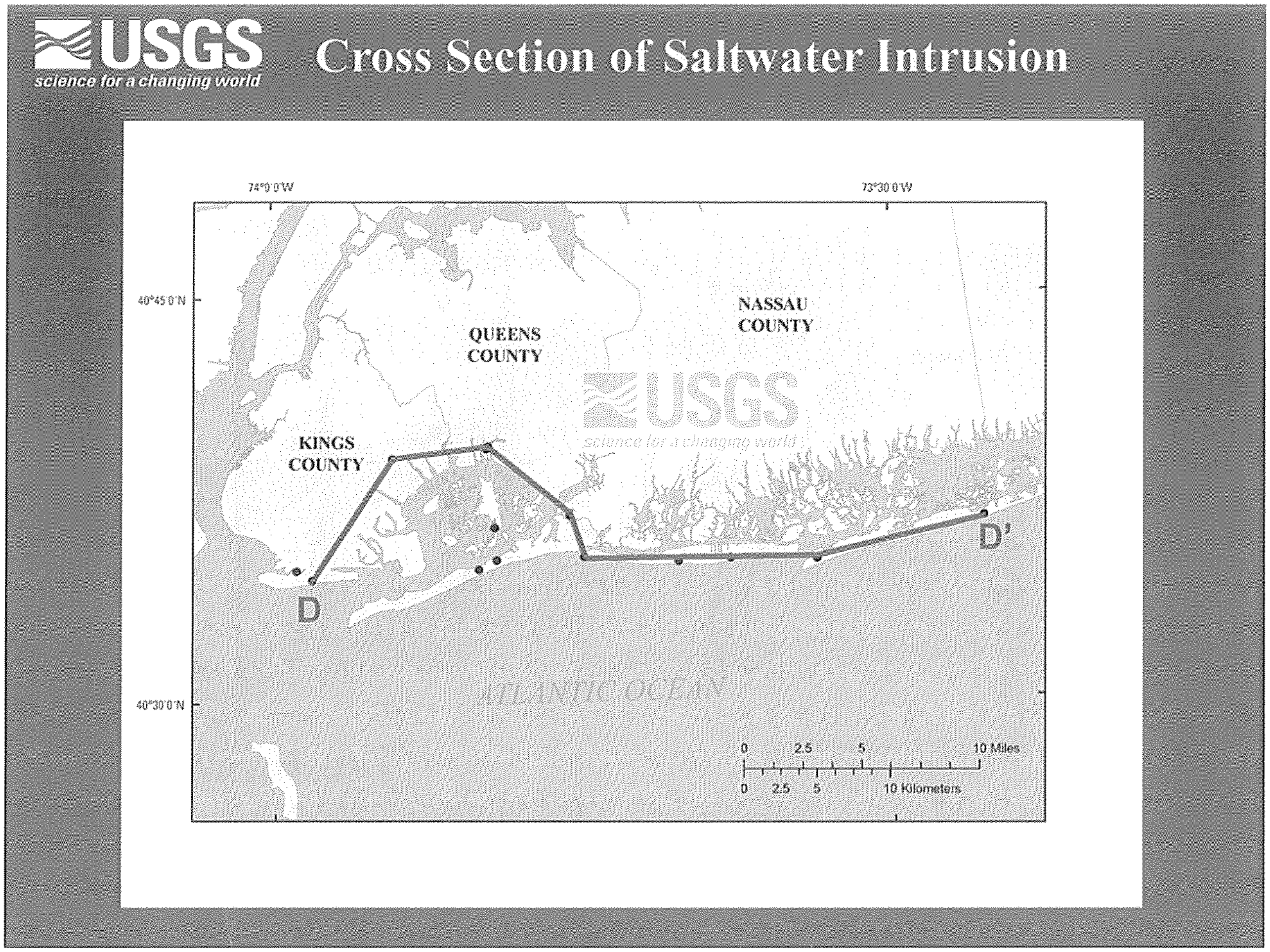


This is a close up depth to bedrock map of Manhattan. It quite clear even to the non-scientist that the thickest sediment is found within the 125th Street fault and the southernmost glacial valley. With each borough mapped at high resolution the NYCDDC now has a very useful tool to determine the feasibility of a geothermal project early on. The next question we need to ask is what are the hydraulic or groundwater properties of this sediment and bedrock. Such properties include sediment type either sand, silt, or clay. It can also include depth to the water-table, and how well the materials can transmit water or their transmissivity. Another important parameter is where saltwater is located in the groundwater to prevent costly corrosion of a geothermal system. These types of issues are currently being addressed in a Phase 2 study in cooperation with NYCDDC using the USGS's vast well log database, water-level well network and water-level measurement database, water-quality of groundwater database, and well core databases.

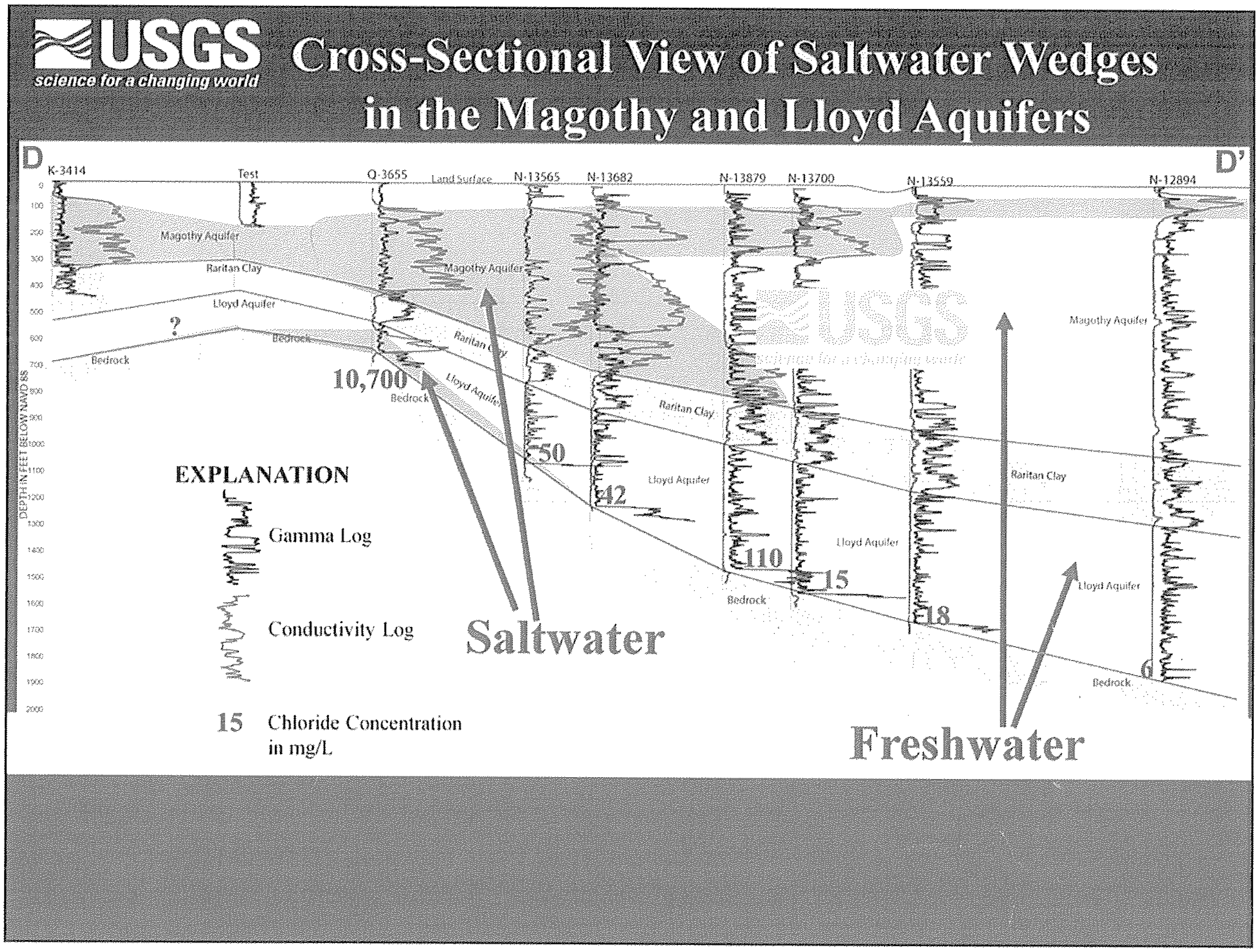
In section A to A' we can see what some of this data can produce.



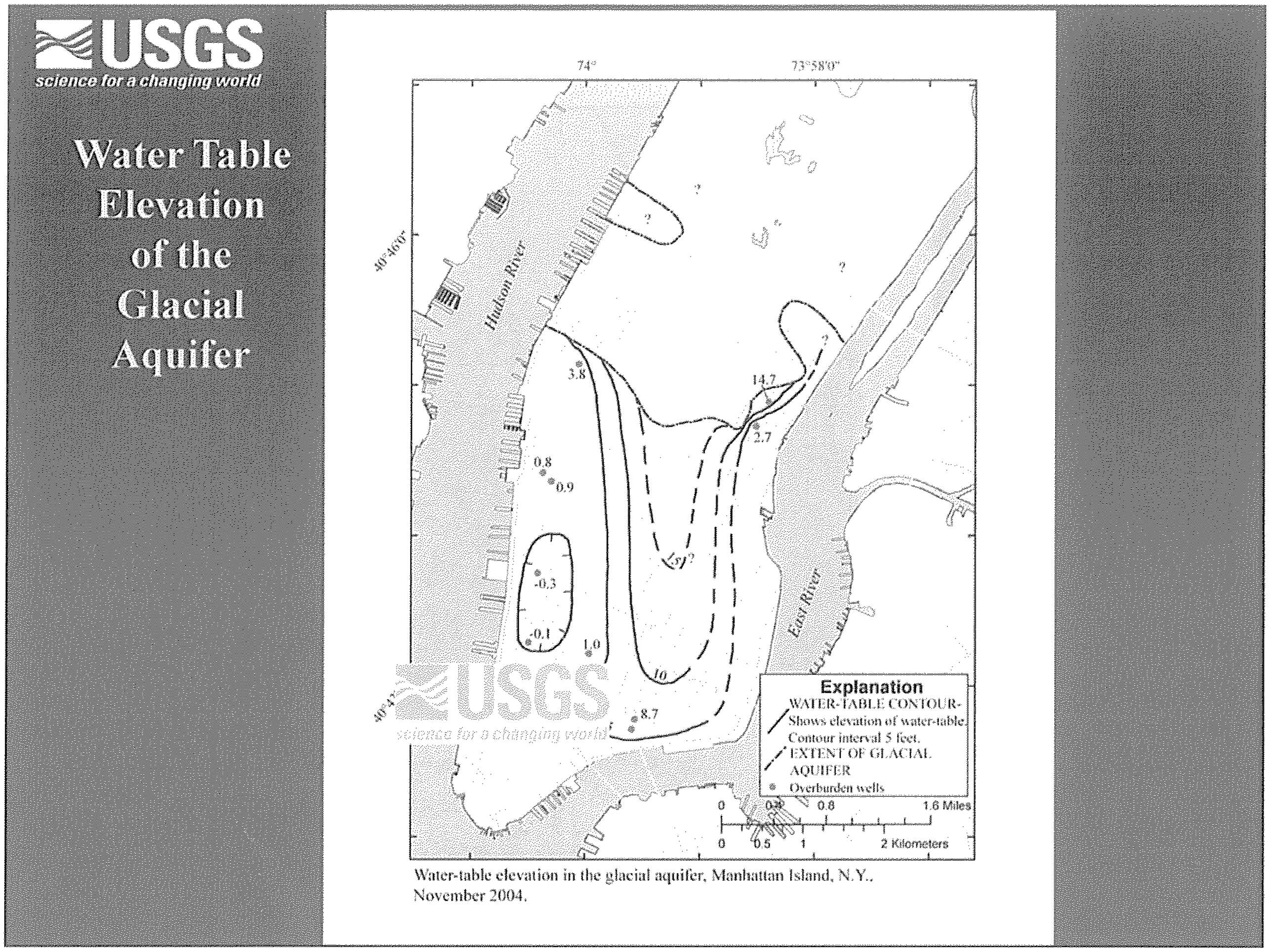
This is a cross-section of the southernmost buried valley in Manhattan. It was published in 1953 by the USGS using our well log database. Since that time the USGS has installed several dozens of new wells, collected many borehole geophysical logs, water quality samples and recorded water-levels from hundreds of wells in the five boroughs and surrounding areas.



Using older wells and newer wells drilled to bedrock a cross-section of the southernmost part of Brooklyn and Queens can be created. Borehole geophysical logs are collected by lowering probes down the wells to collect geologic data and determine the presence and concentration of saltwater in the groundwater aquifers.

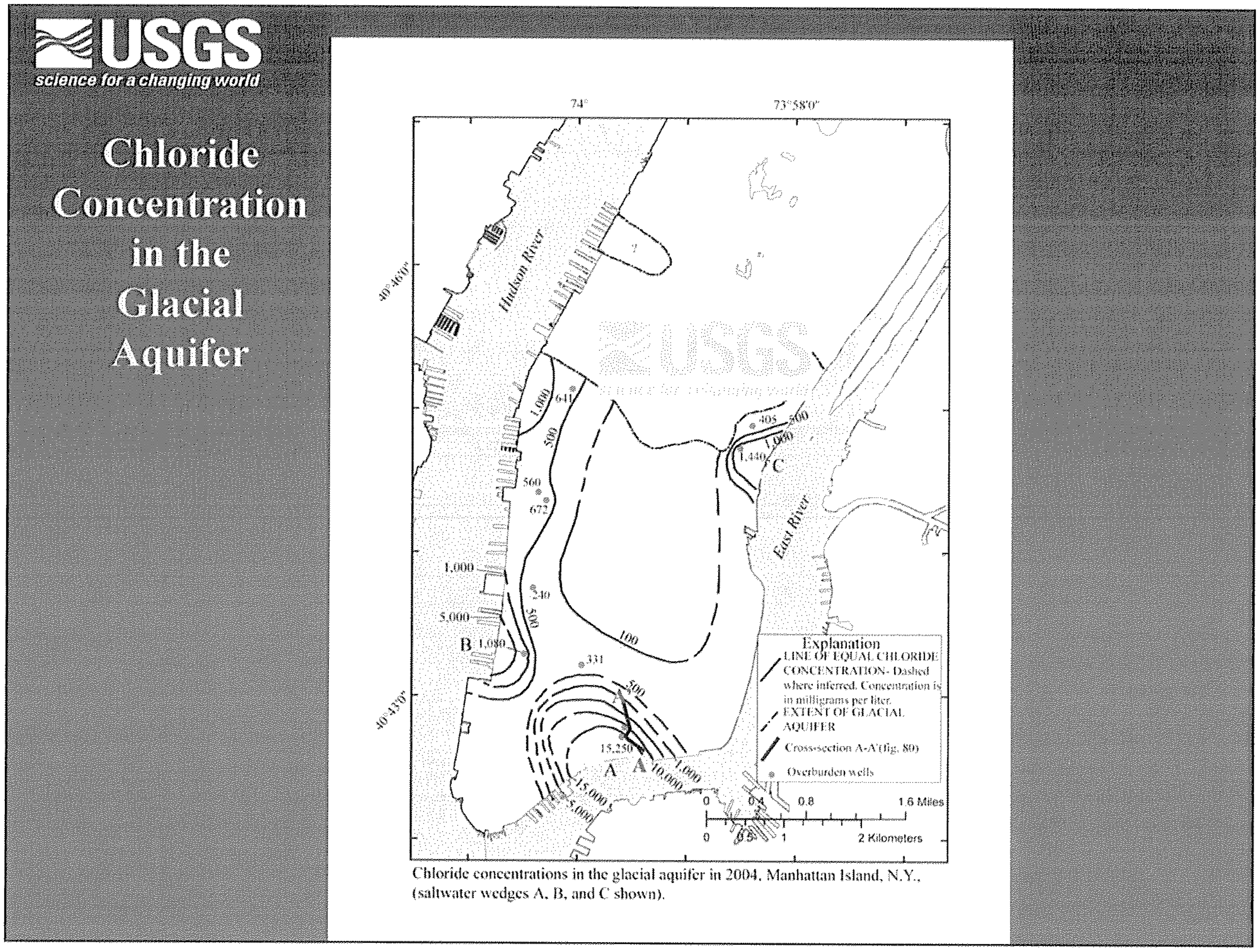


This is a cross-section I created using USGS borehole logs collected in wells that penetrated the sediment deposits overlying bedrock. The black graph-like lines are gamma logs which identify the thickness and depth of clay and sand deposits. Clay units which impede the flow of groundwater are filled in as gray units. The red graph-like lines are conductivity logs which indicate the concentration of saltwater or the presence of freshwater. The red shaded in areas are saltwater intrusion wedges created by over pumping the aquifers. Most of the aquifers in Queens and some in Brooklyn contain saltwater. Information like this is critical to determine if pumping aquifers for geothermal energy in some areas will induce further saltwater intrusion or if saltwater is already present. Some geothermal systems are very susceptible to the highly corrosive salty groundwater. In some areas future intrusion by saltwater could occur after a geothermal system is installed if proper research is not done. The USGS in cooperation with the NYCDDC is currently planning a Phase 2 approach to map such conditions for use in geothermal feasibility maps for NYC.

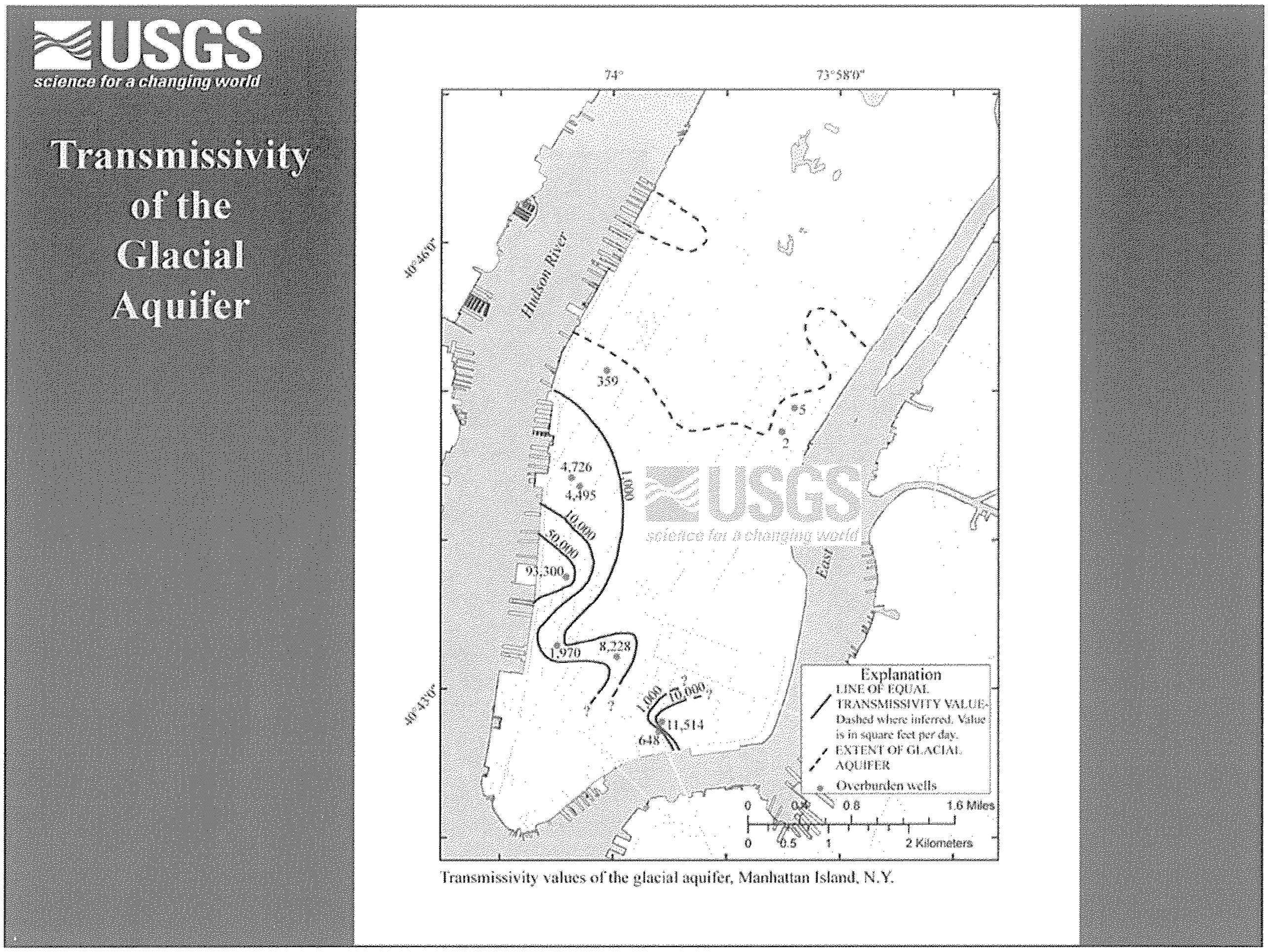


Water-table elevation in the glacial aquifer, Manhattan Island, N.Y., November 2004.

This is a map of the unconsolidated sediment water-table overlying the bedrock in southern Manhattan. The USGS measured several wells throughout the area during the pre-construction phase of the Third Water Tunnel for the NYCDEP. Such information will be integrated into a Phase 2 planned map of the depth to water for the five boroughs in cooperation with the NYCDDC. In general the water-table resides in the sediment found south of 30th Street. The highest elevations are in the recharge area in the center of the island and ground-water flows southward and toward the coastlines.

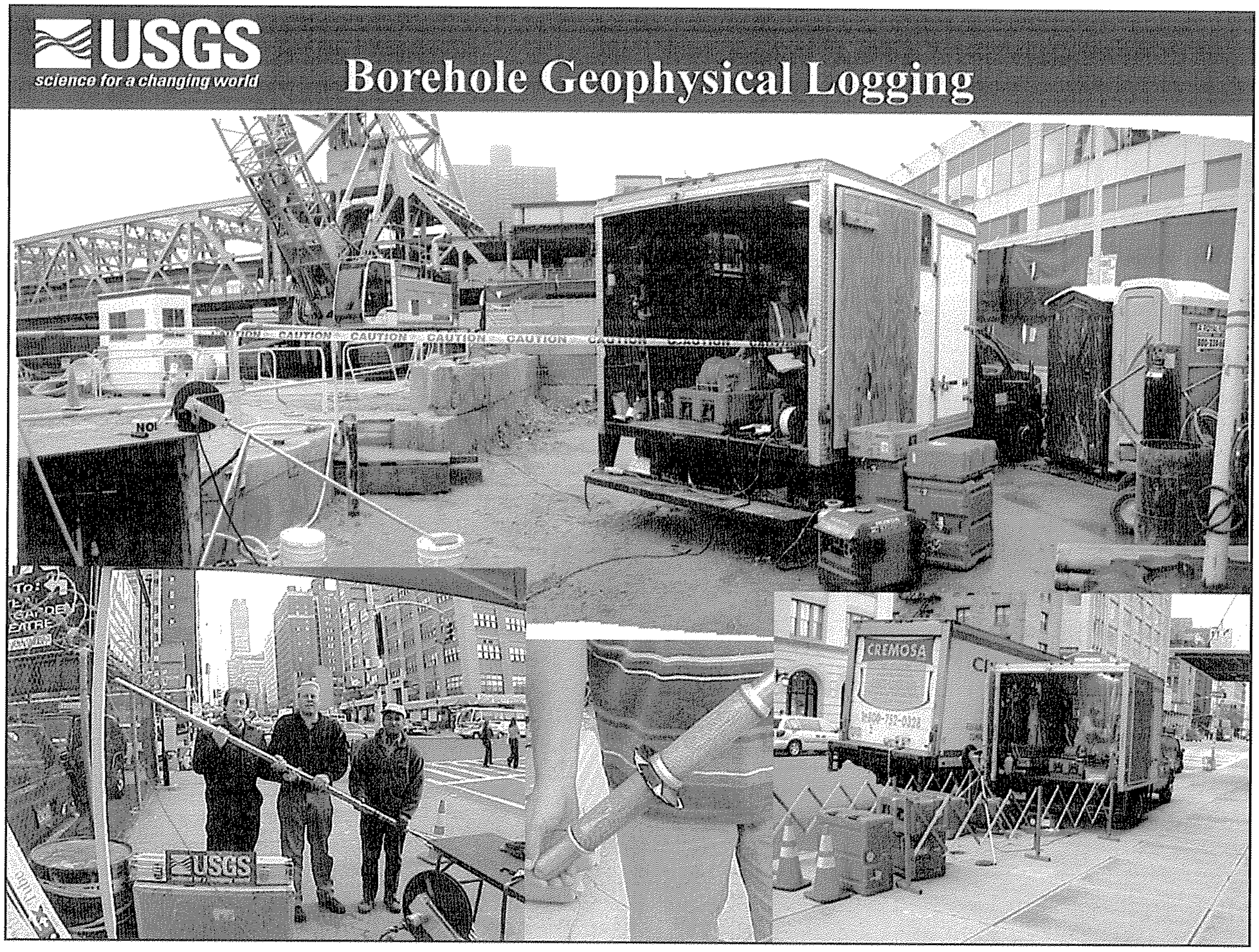


This is a USGS map of the extent of saltwater in the unconsolidated sediment in southern Manhattan. Extensive pumping of the water-table during the previous century caused large cones of depression which allowed the surrounding seawater to enter the aquifers. Several saltwater wedges were indicated with concentrations approaching pure seawater. This type of information will be compiled for other boroughs and a new map created in the next Phase of our cooperative program with the NYCDDC.

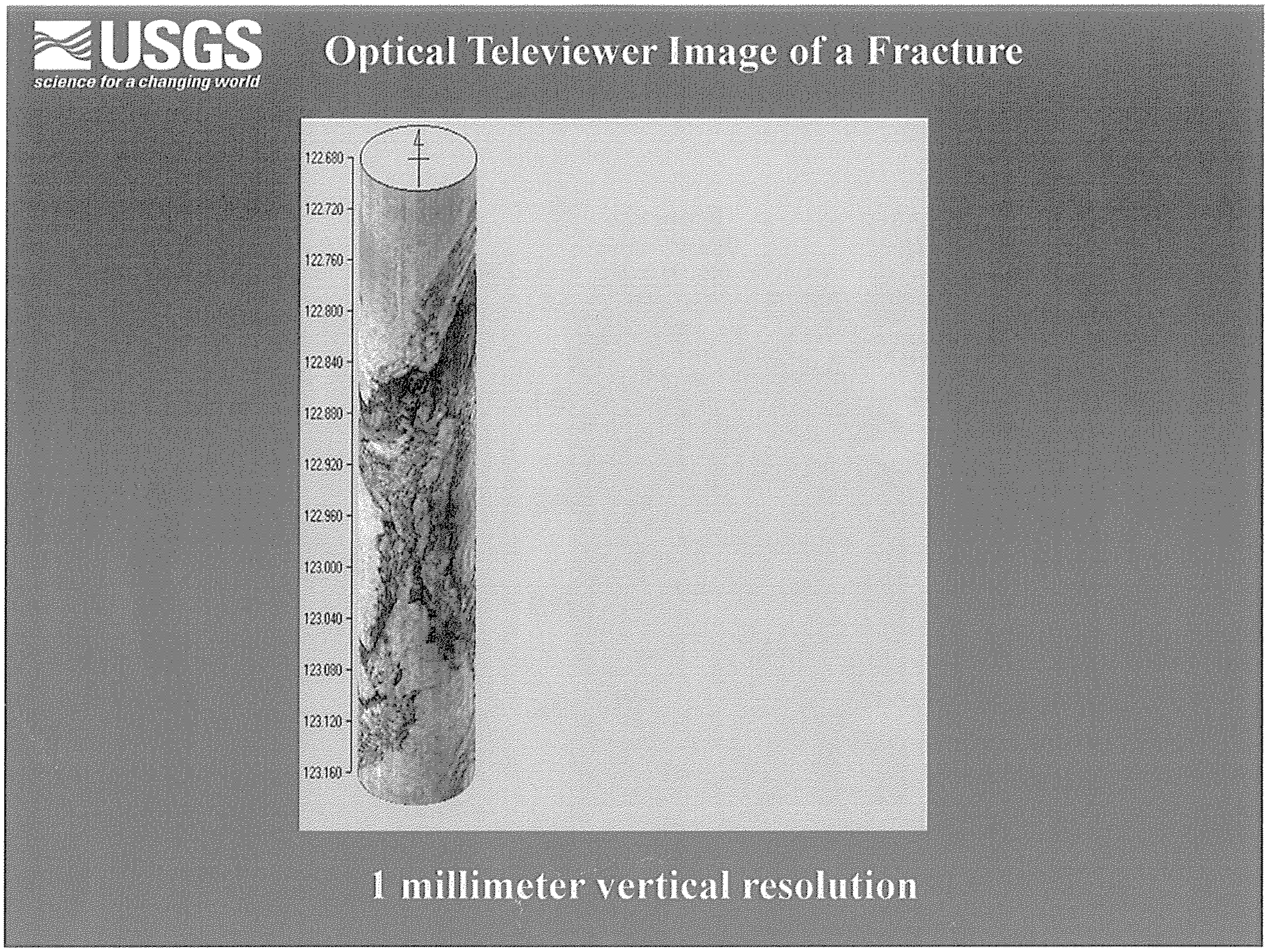


Transmissivity values of the glacial aquifer, Manhattan Island, N.Y.

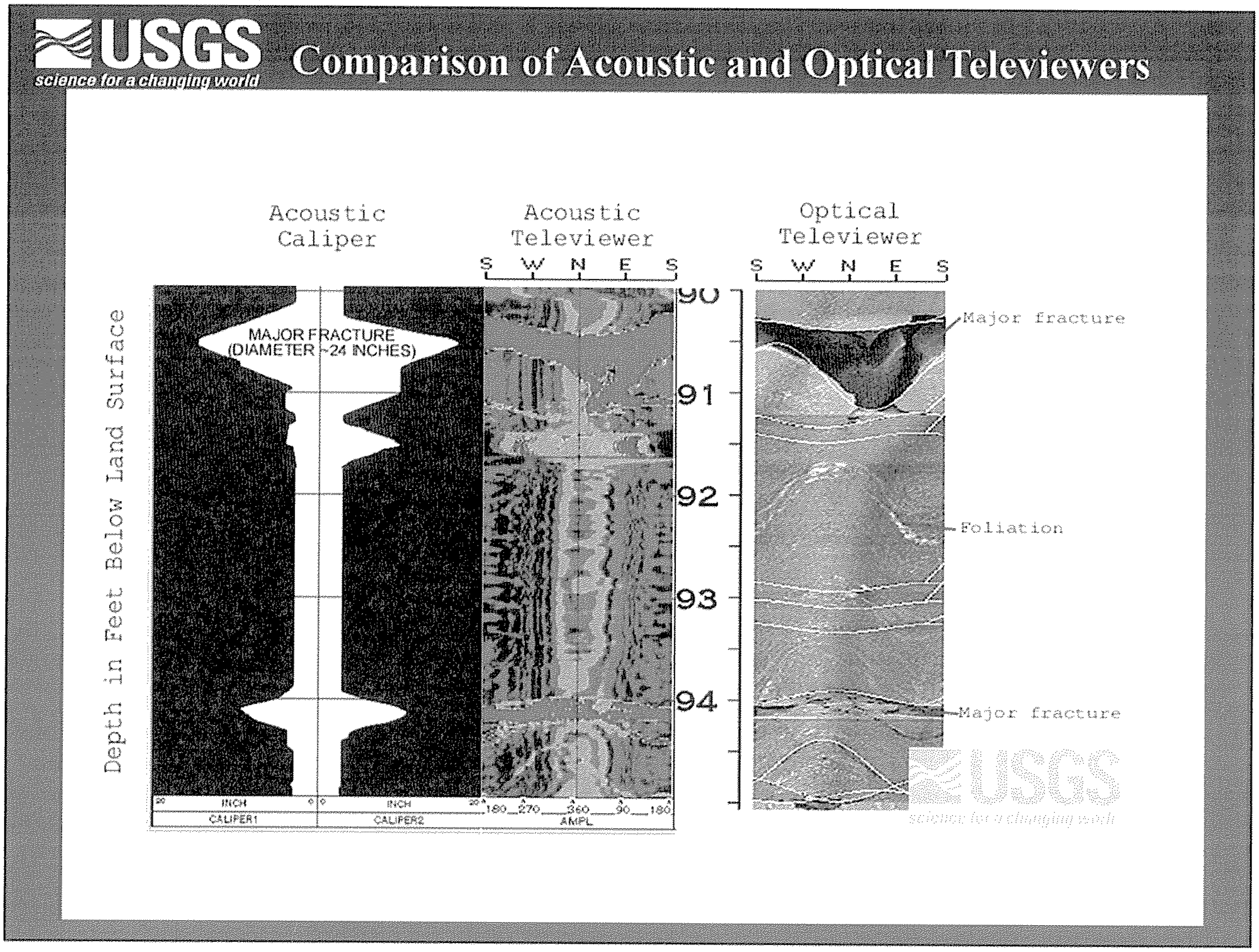
This is a USGS map of the estimated transmissivity or ability to transmit water of the glacial sediments in southern Manhattan. The estimates were calculated during aquifer pumping tests by the USGS. This type of information is very valuable in the planning of a geothermal well system. In some geothermal well designs the ability to produce groundwater is critical to a properly functioning system. The USGS plans to compile information like this during our future cooperative work with the NYCDDC for all five boroughs. In general, the highest values of transmissivity indicate the most transmissive parts of the aquifer are along the coastlines.



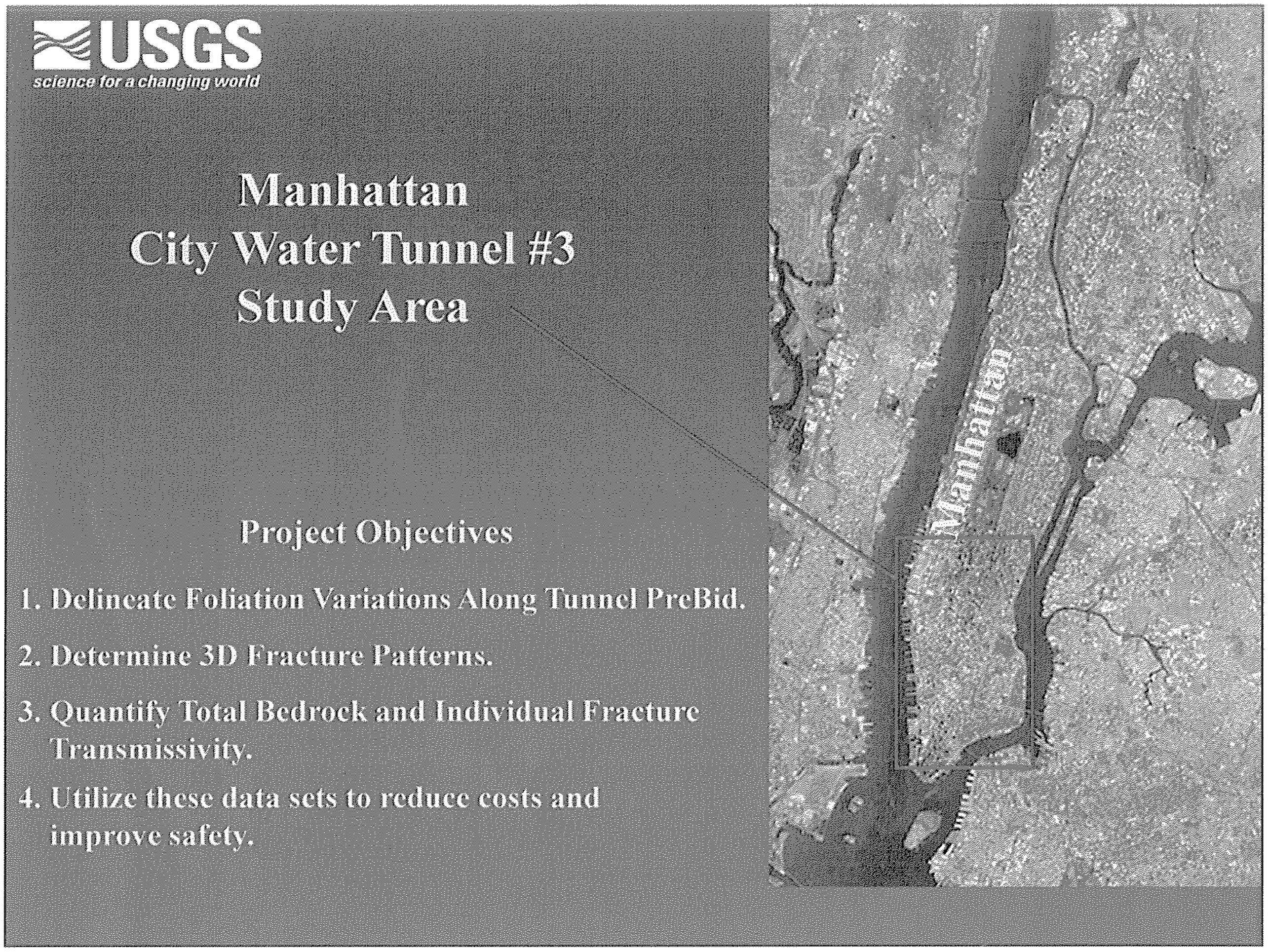
The USGS has been collecting borehole geophysical logs in NYC since the 1980's. The USGS in cooperation with the NYCDEP in support of the construction of the Third Water Tunnel began to collect advanced borehole geophysical logs. This project involved the collection of 3D information on the fractures, faults, and foliation of the bedrock along planned tunnel routes in southern Manhattan. Once the fractures were mapped in the test boreholes, accurate flowmeters were used to determine which fractures produced groundwater and how transmissive they were. With this information the NYCDEP was able to prepare and anticipate areas of significant groundwater inflows and locations of highly fractured bedrock or faults saving NYC millions in contractor change orders and increasing safety. This database will be used in the application of geothermal energy in NYC.



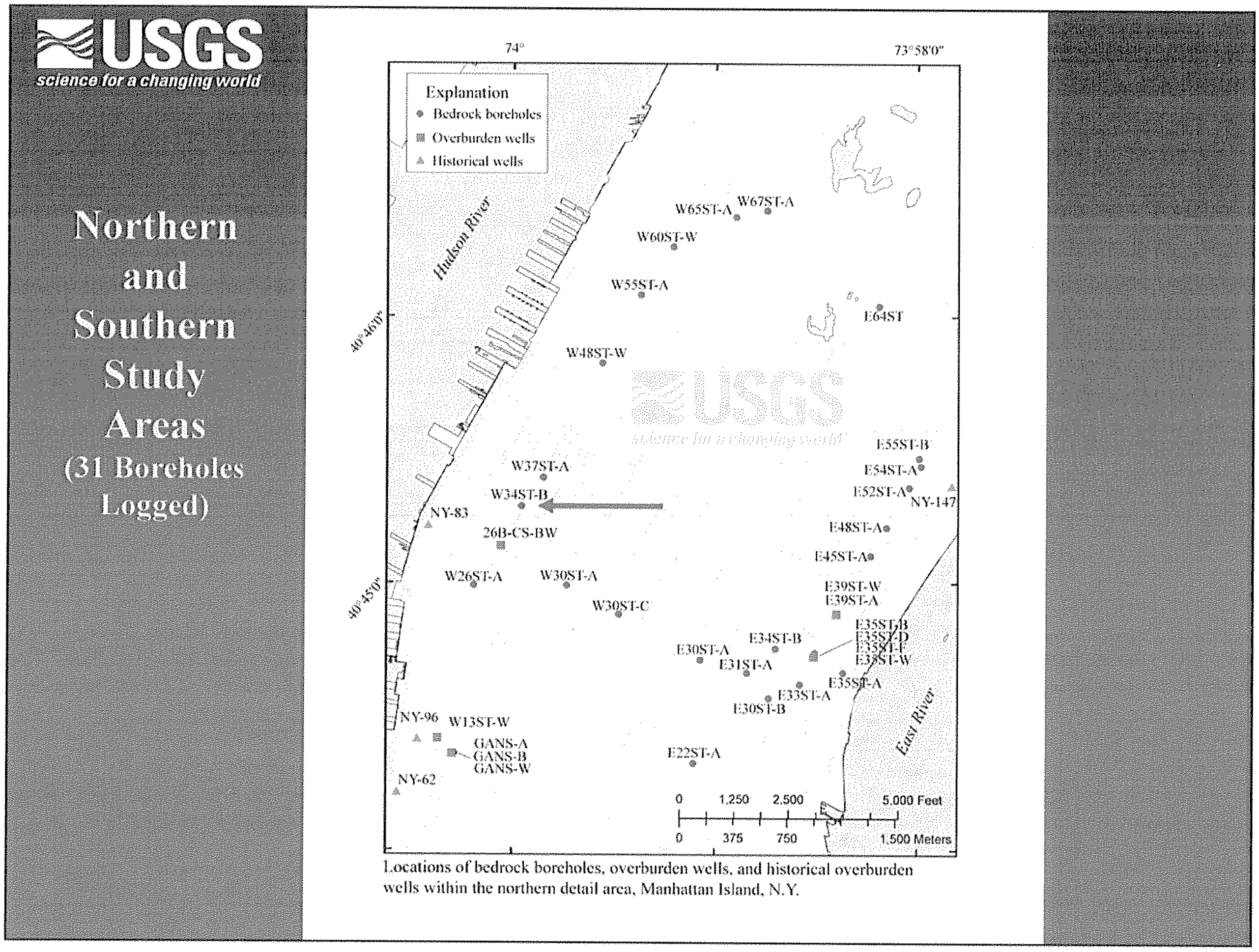
This is a virtual core of what a fracture in bedrock looks like 300 feet beneath Manhattan. The USGS utilizes advanced technology to measure fracture thicknesses, fracture 3D orientation, and fracture groundwater transmitting properties. A probe called an optical televiewer is lowered into a test boring and using a video camera and magnetometer scans the borehole wall at a 1 millimeter vertical resolution to map the depth and 3D orientation of fractures, faults, and rock type contacts.



This is an example of what a fracture looks like using two types of probes. The colored image in the center is the cylinder wall of the borehole scanned using acoustic or sonar signals and was unwrapped. This is a very effective way of mapping fractures in cloudy groundwater wells. The second colored image to the right is an optical televiewer image of the same fracture using video to scan the walls and unwrapped. Notice how much more detailed the image is using video. These types of probes are used to collect important information on where fractures are located and to help predict where they might be encountered in a geothermal well field.

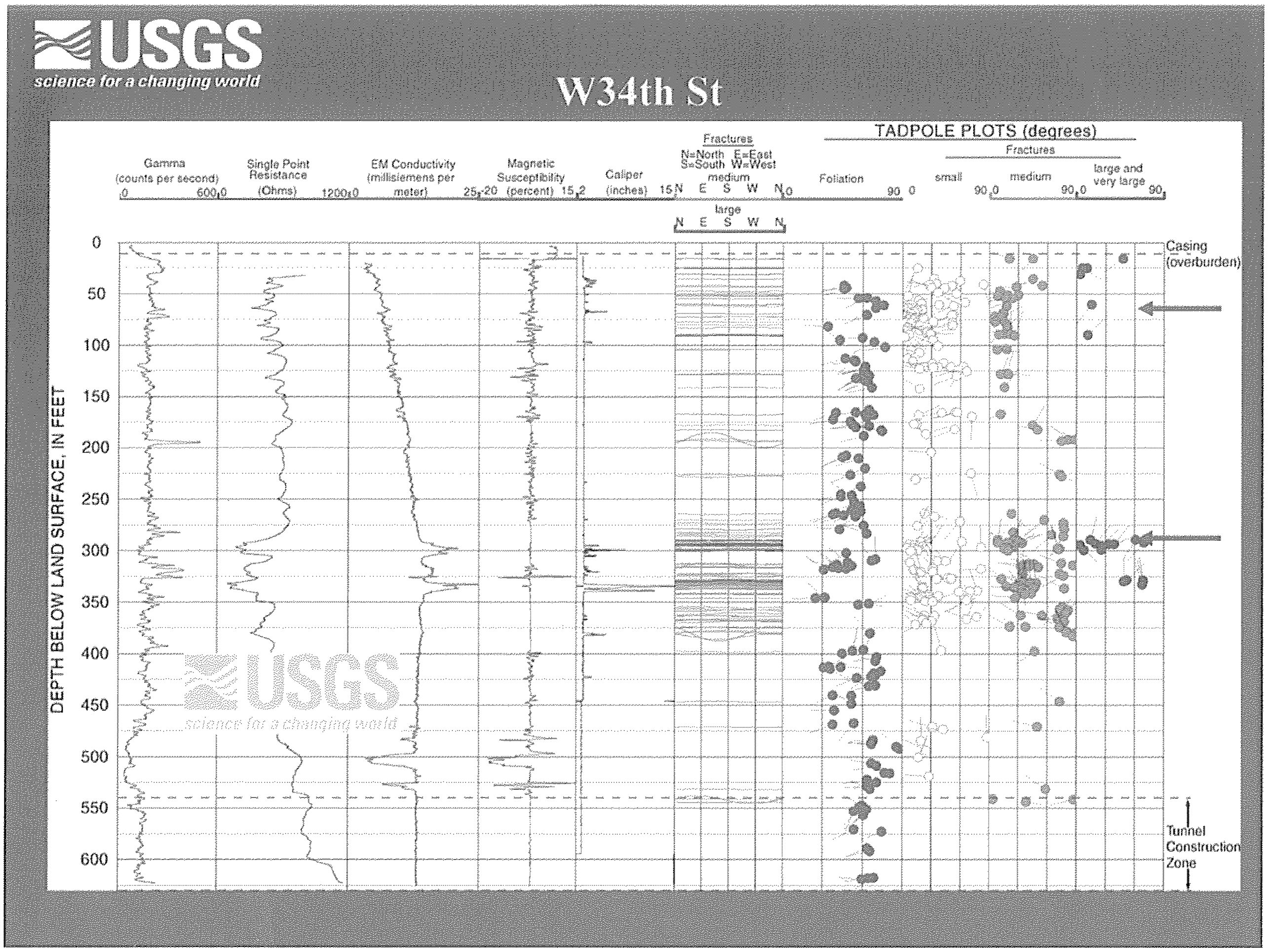


This is the general location of the USGS study area for the Third Water Tunnel project for the NYCDEP. Project objectives were met using the advanced techniques just outlined.

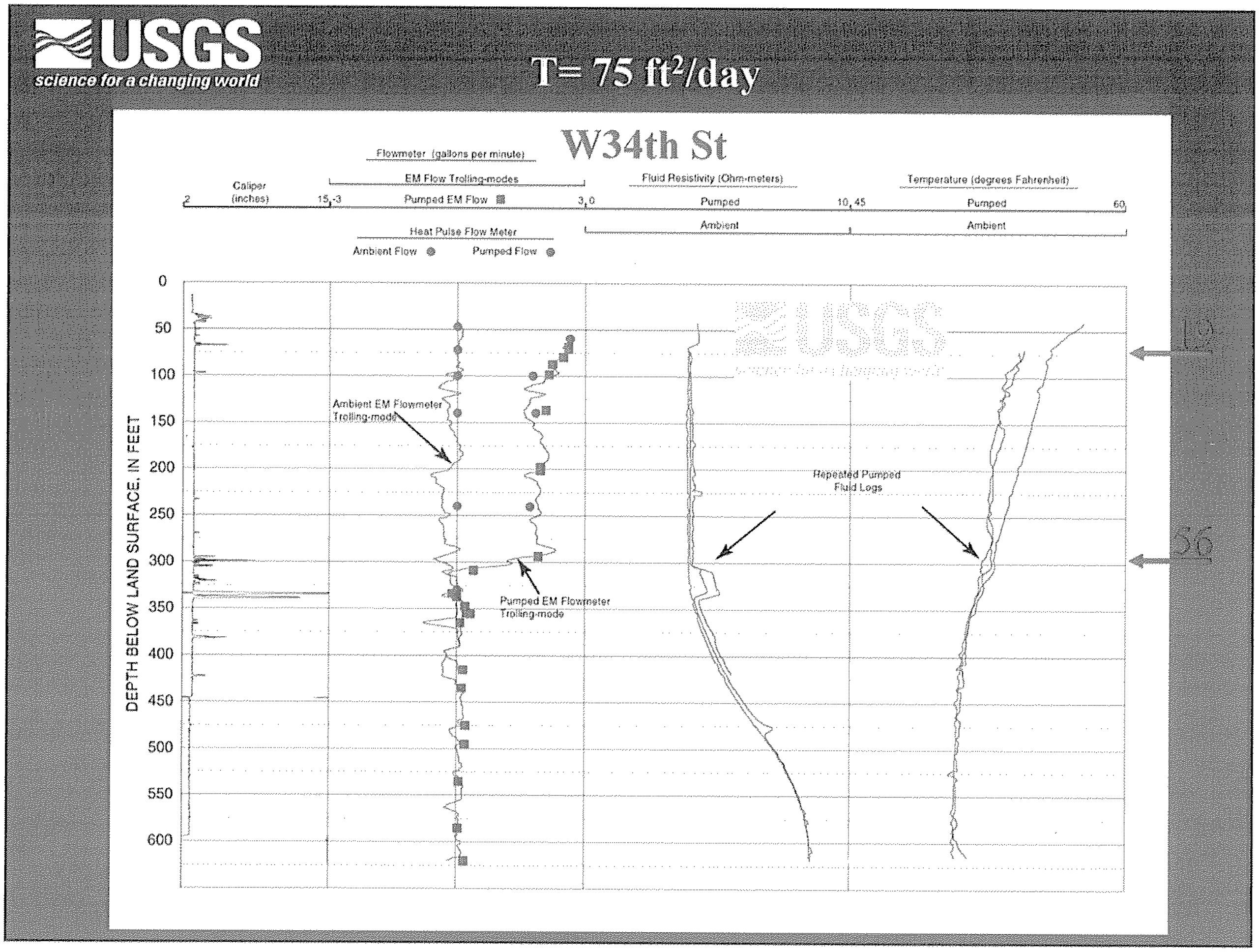


Locations of bedrock boreholes, overburden wells, and historical overburden wells within the northern detail area, Manhattan Island, N.Y.

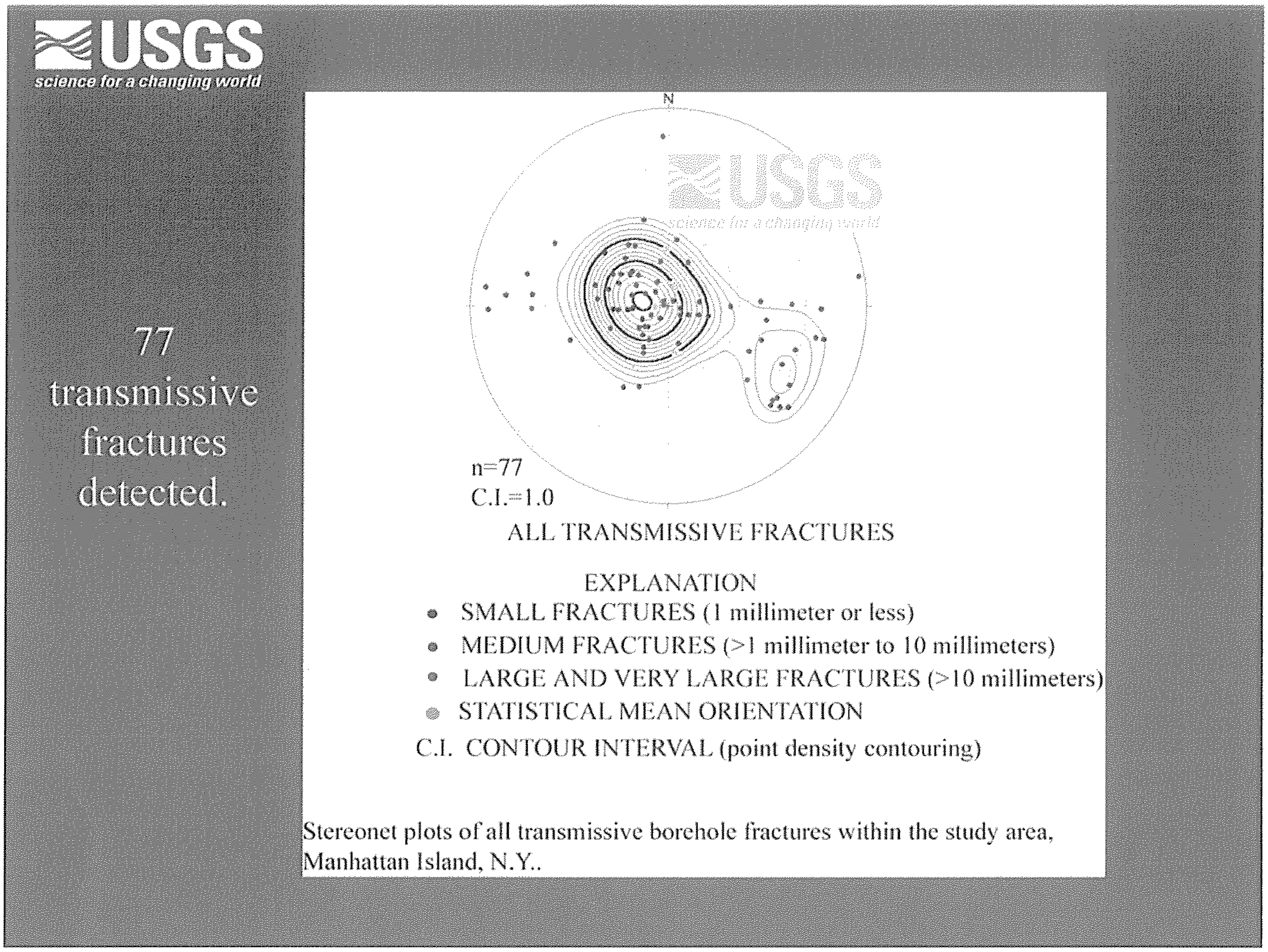
This is a partial map of the wells the USGS obtained groundwater flow information and 3D fracture data of the bedrock in southern Manhattan. We will look at one of these wells as an example of what was compiled. The well is located on W34th Street.



This is a suite of borehole geophysical logs collected by the USGS in one test borehole. The data indicates over 200 fractures were located throughout the 625 foot length of borehole. The yellow dots are small micro fractures, the green dots are medium sized fractures, and the blue dots are large fractures. The red arrows indicate the depths at which two sets of large and medium fractures were found.



This is another suite of groundwater related geophysical logs. Other probes measured the groundwater temperature, flow direction, and water quality to the bottom of the borehole. The temperature of the earth increases with depth below the surface called the geothermal gradient. In this well the temperature is unchanged until a depth of 350 feet due to the flow of groundwater between the two fracture zones shown in the red arrows. Using this type of information the USGS can determine the water transmitting properties of each fracture zone. In a geothermal application such information would be very helpful in designing a system to it's maximum efficiency.



Stereonet plots of all transmissive borehole fractures within the study area, Manhattan Island, N.Y..

Using the flowmeter data and 3D orientation data of transmissive or groundwater producing fractures in Manhattan collected by the USGS a pattern of flow can be determined. In general, the groundwater flow system in the fractured bedrock beneath Manhattan is dominated by sub-horizontal fractures (indicated by the points in the center of the bulls eye) and high angle northwest dipping fractures (indicated by the points plotted in the circle in the lower right part of the bulls eye). This type of analysis provides insight in how groundwater would flow through which types of fractures in geothermal wells in Manhattan. Similar analyses would be completed in wells drilled in the other boroughs in future phases of our work.

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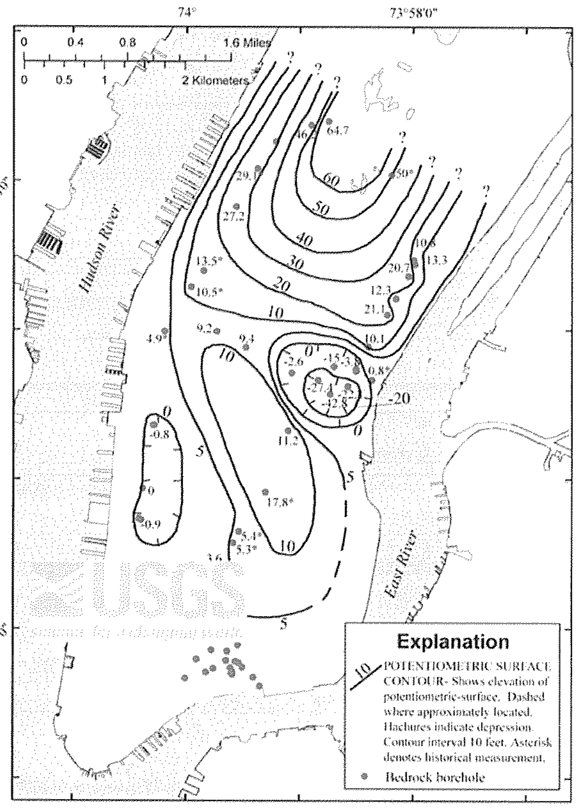
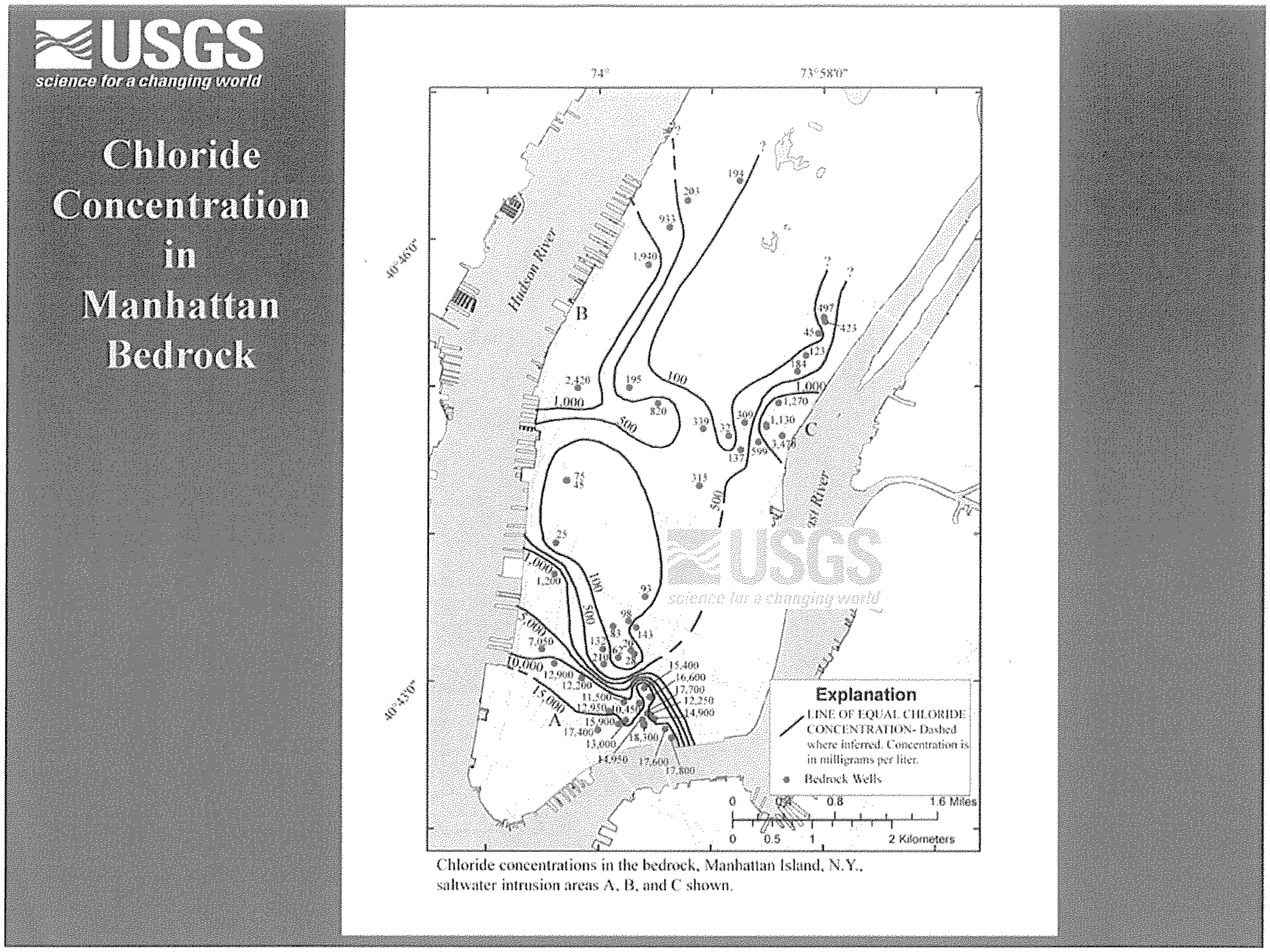
Bedrock Potentiometric-Surface

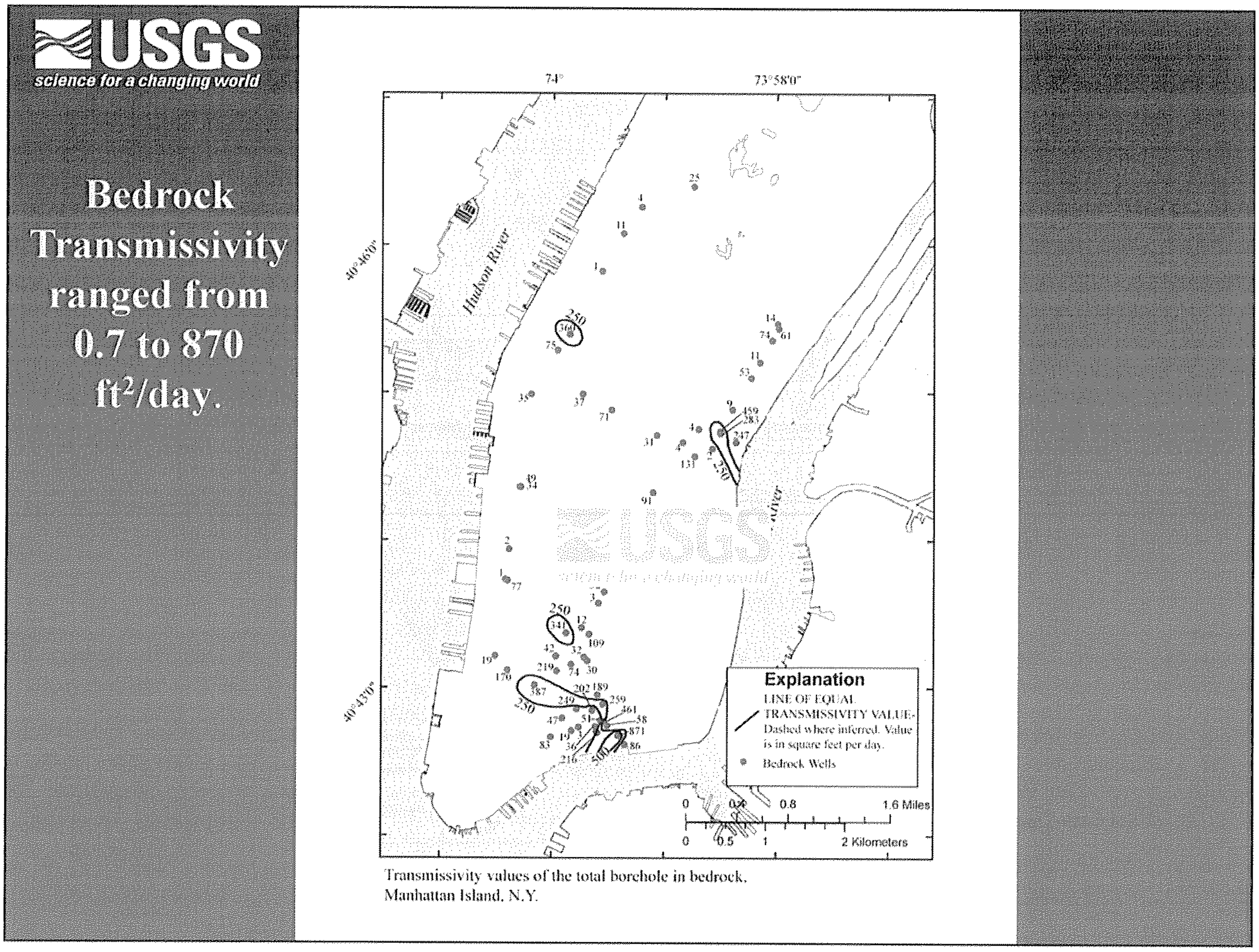


Potentiometric-surface elevation in the bedrock, Manhattan Island, N.Y., November 2004.

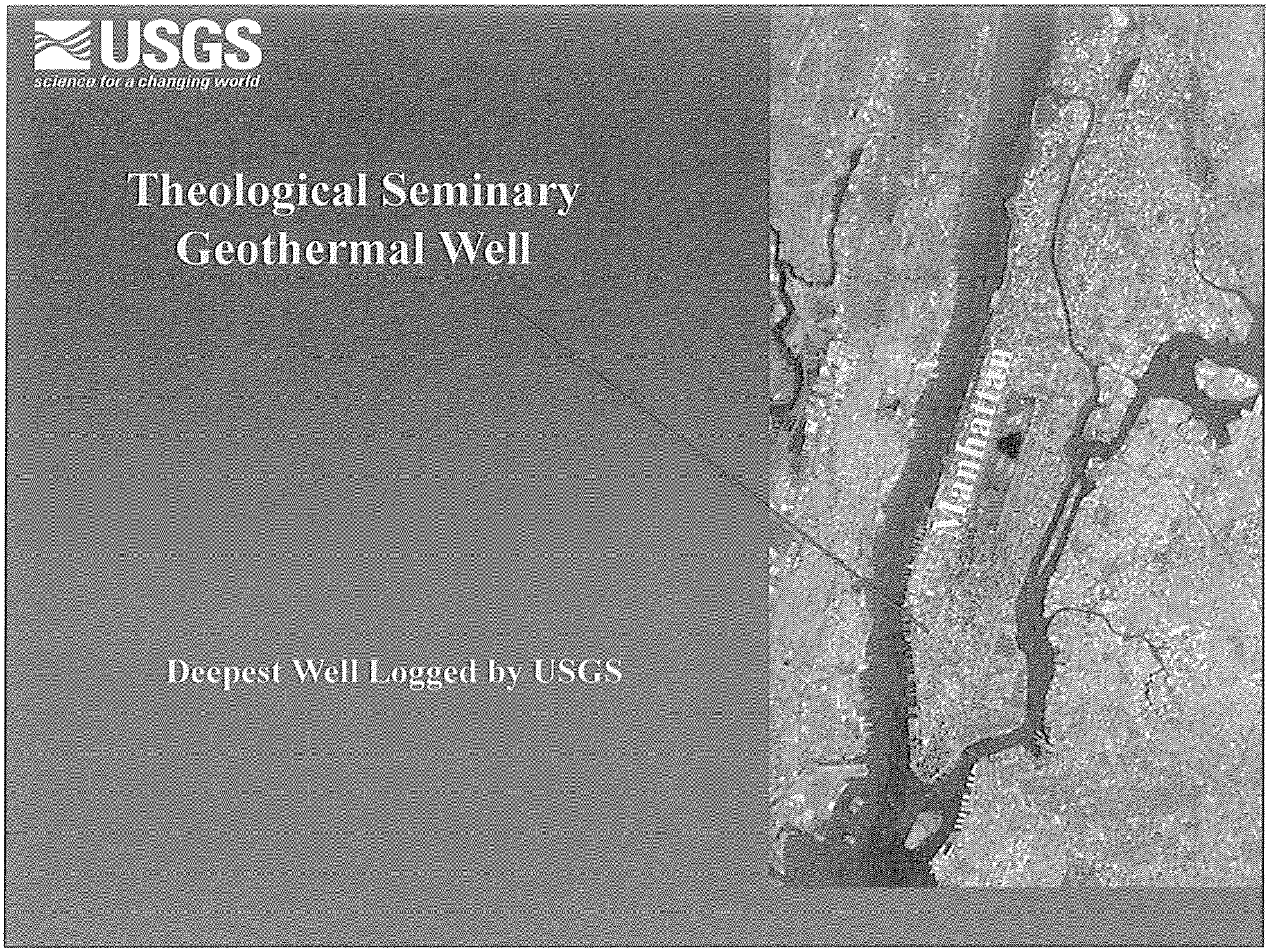
The USGS measured the elevation of groundwater in the test boreholes drilled throughout southern Manhattan to produce this map. In general, groundwater flows through fractures from a recharge area with the highest elevation in Central Park and it flows south and toward the coastline.



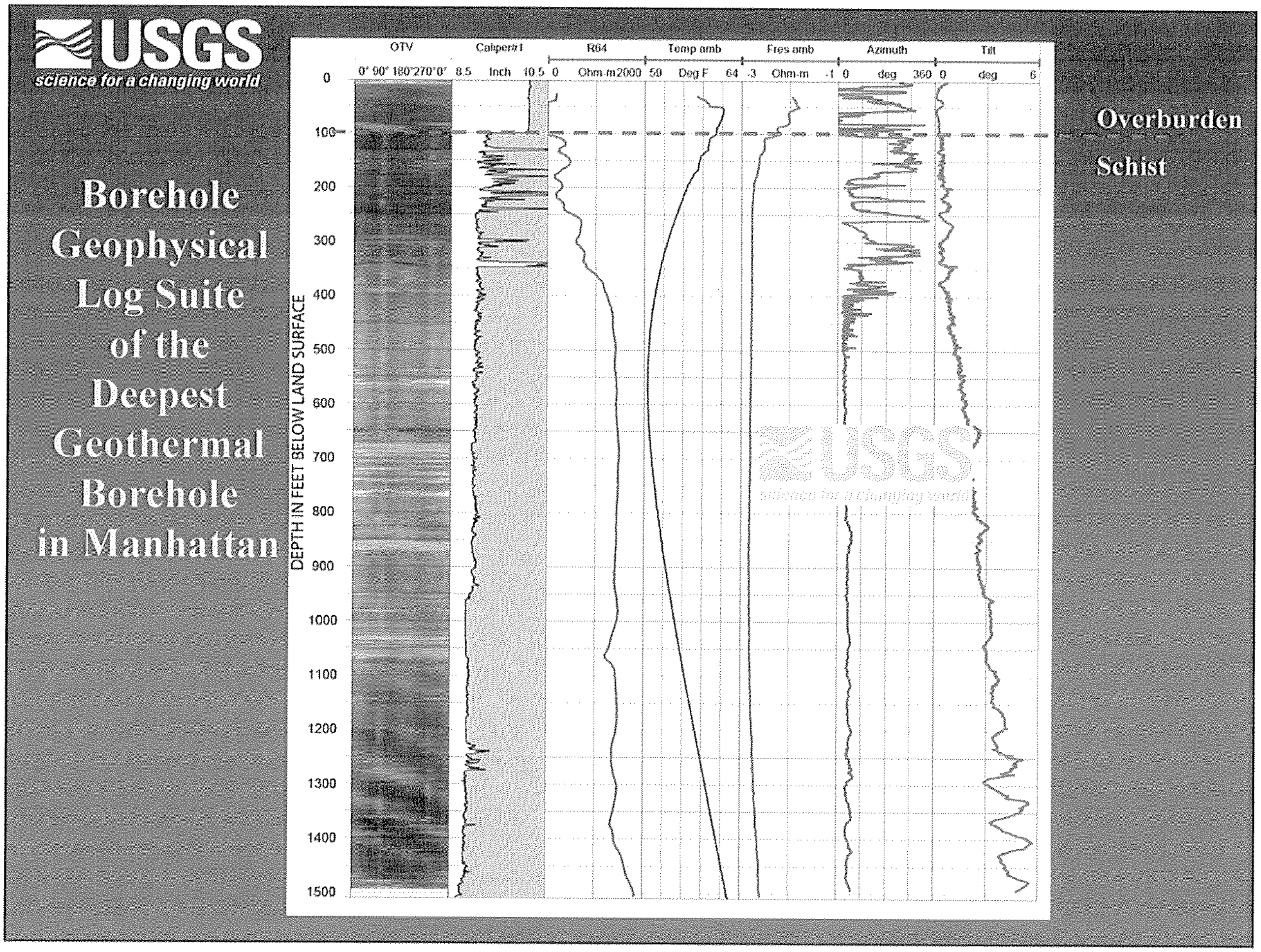
The USGS collected grab samples of groundwater during aquifer pump tests of the NYCDEP test boreholes. Chloride concentrations were measured, plotted, and contoured to produce this map. Over pumping of the bedrock has allowed saltwater from the surrounding embayments to intrude into the transmissive fractures in the bedrock. Several wedges of saltwater with concentrations approaching seawater along the coastal areas. Such information would be very useful in determining the type of geothermal system appropriate for some areas to avoid corrosion of the equipment.



The USGS completed aquifer pump tests of the NYCDEP bedrock well network. The data allowed estimates of the total bedrock transmissivity or ability to transmit groundwater. The range of transmissivity was very large with two orders of magnitude of values. The areas with the lowest groundwater transmitting capabilities were located in the northwest coastal part of Manhattan. Most areas were considered moderate. The areas with the highest capacity to produce groundwater were located in isolated areas such as the southeasternmost part of Manhattan and other isolated areas. These areas correlated with above average amounts of fractures and faults. These types of maps would be very useful in determining if geothermal systems would be appropriate in some areas. This same type of analyses are planned for future phases of our work with the NYCDDC.



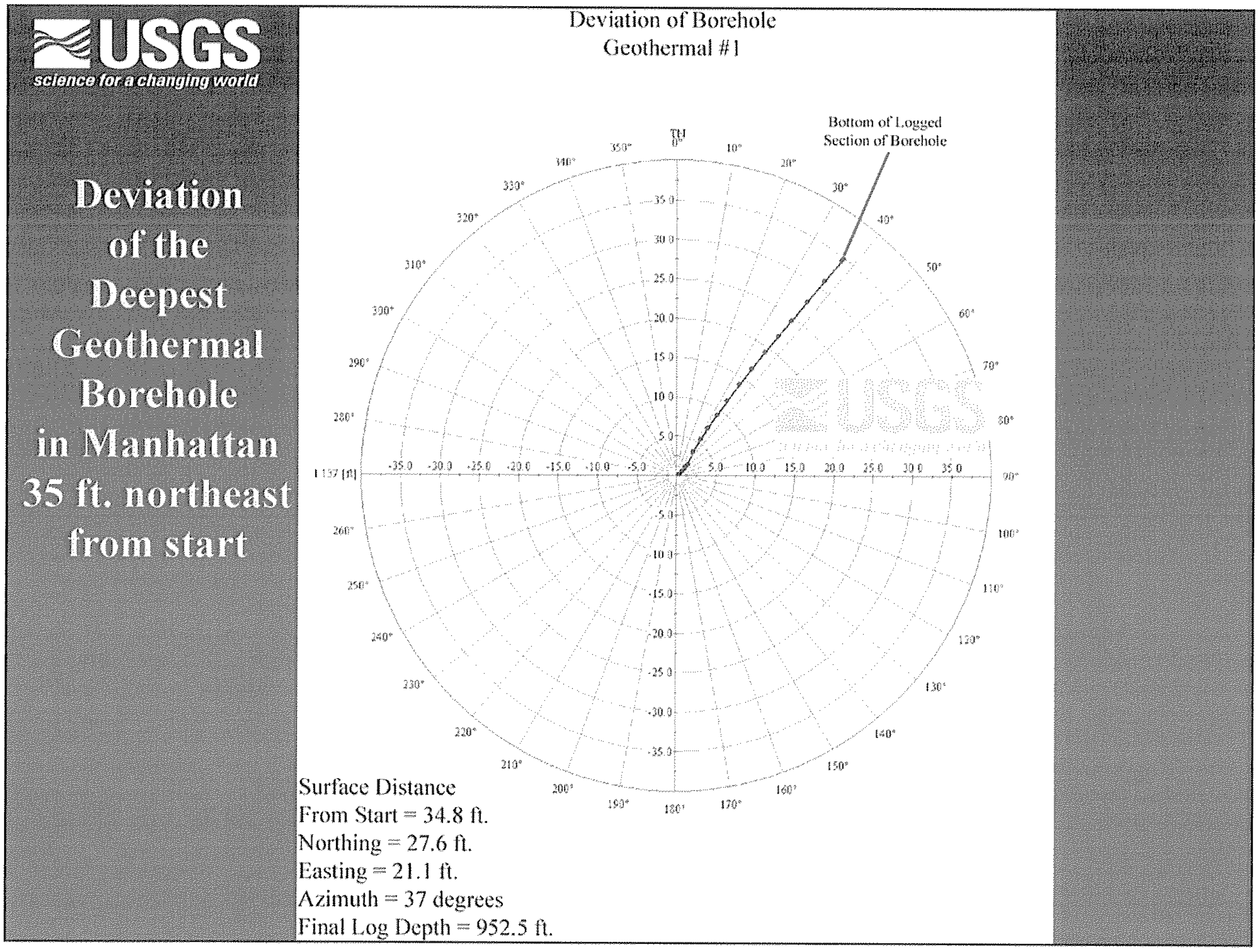
Location of the deepest geothermal well drilled in Manhattan.



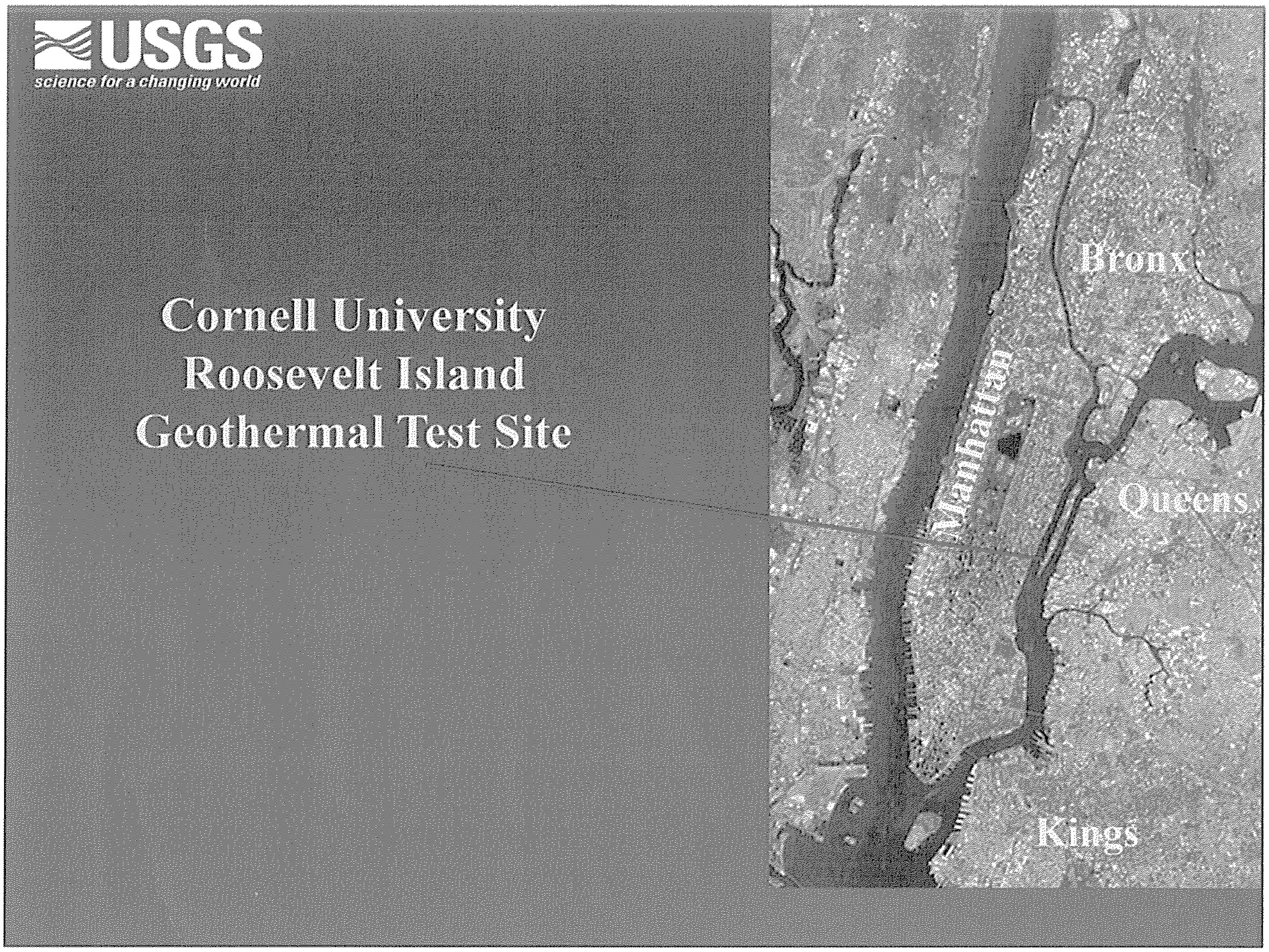
The USGS was requested to collected a full suite of geophysical logs to aid in the design of a geothermal system for the Theological Seminary. The figure above includes the optical televiewer of the bedrock, the caliper or width of the borehole, the resistivity, groundwater temperature, groundwater quality, borehole compass direction, and borehole tilt angle. In general the temperature log indicates increasing temperature near the surface followed by decreasing temperature and then a return to increasing temperatures below 600 feet. This is typical of what the USGS has found in NYC. The decades of heating buildings with basements and underground subways has produced an artificial heating of the bedrock seen within the first 100 feet. Groundwater effects the temperature curve by decreasing or stabilizing the temperature until about 500 feet where the nature geothermal gradient causes the temperature to increase with depth.

Of secondary interest is the direction the well seems to deviate from vertical. The magnetometer and tiltmeter in the optical televiewer indicates the well deviated toward the northeast with a maximum tilt of 6 degrees. The deviation of geothermal wells increases with depth and generally follows a path up-dip or in the opposite direction that the bedrock is dipping towards. In this well the bedrock is dipping toward the southwest and the action of drilling the well causes it to migrate or deviate toward the northeast. This type of information is critical if geothermal wells drilled in highly populated areas such as Manhattan are to remain within the property boundaries so as not to intersect Water

Tunnels or other persons property boundaries.



This is a plan view of the deviation of the same well. The bottom of the well deviated 35 feet from the starting point at the surface in the center of the bulls eye. This type of information collected by the USGS can be used to predict the potential for deviation of geothermal bedrock wells.



Location of the Cornell University Geothermal Test Site on Roosevelt Island. The USGS was requested to collect and analyze a suite of advanced borehole geophysical logs and collect aquifer pump test parameters.

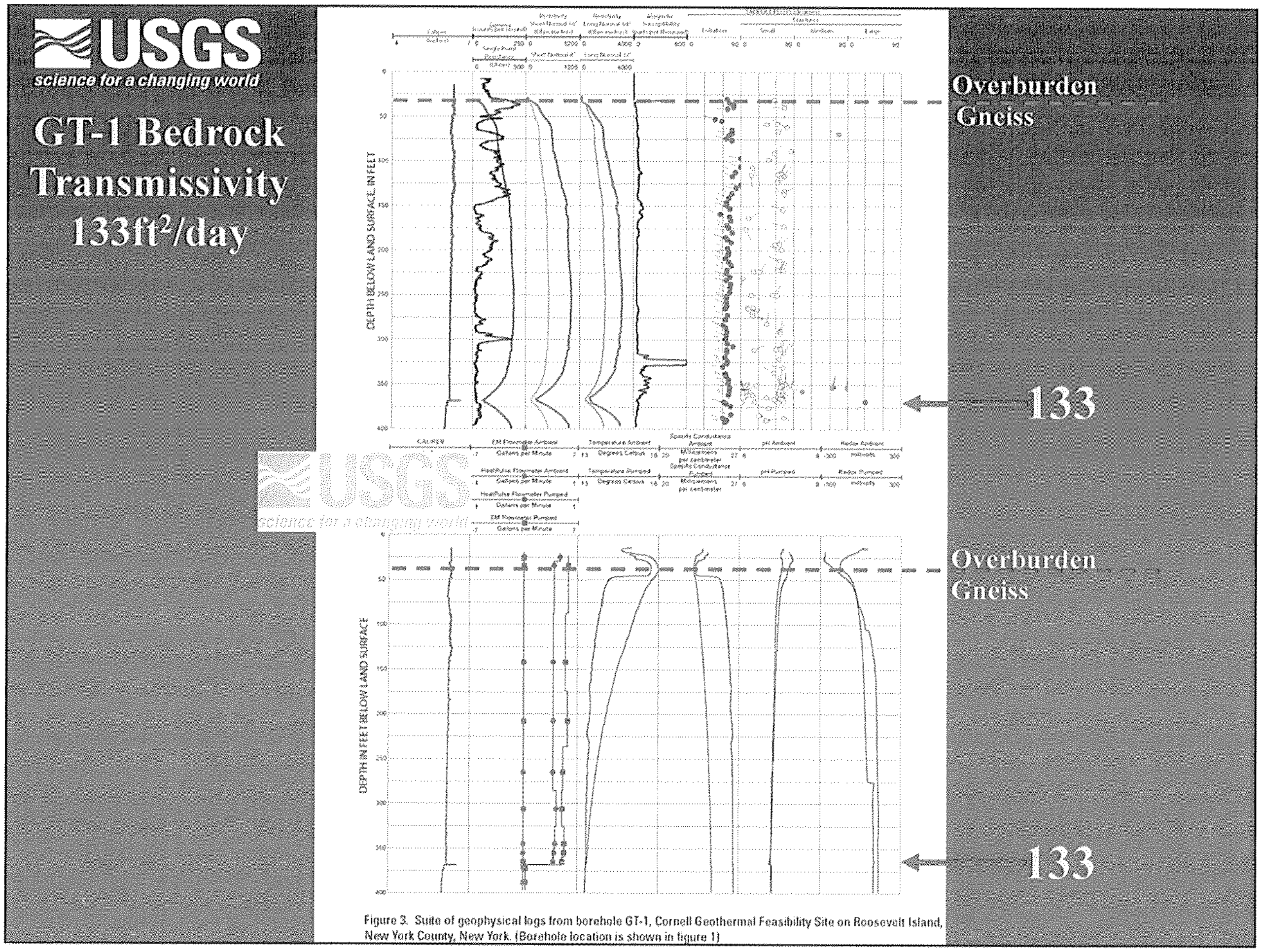
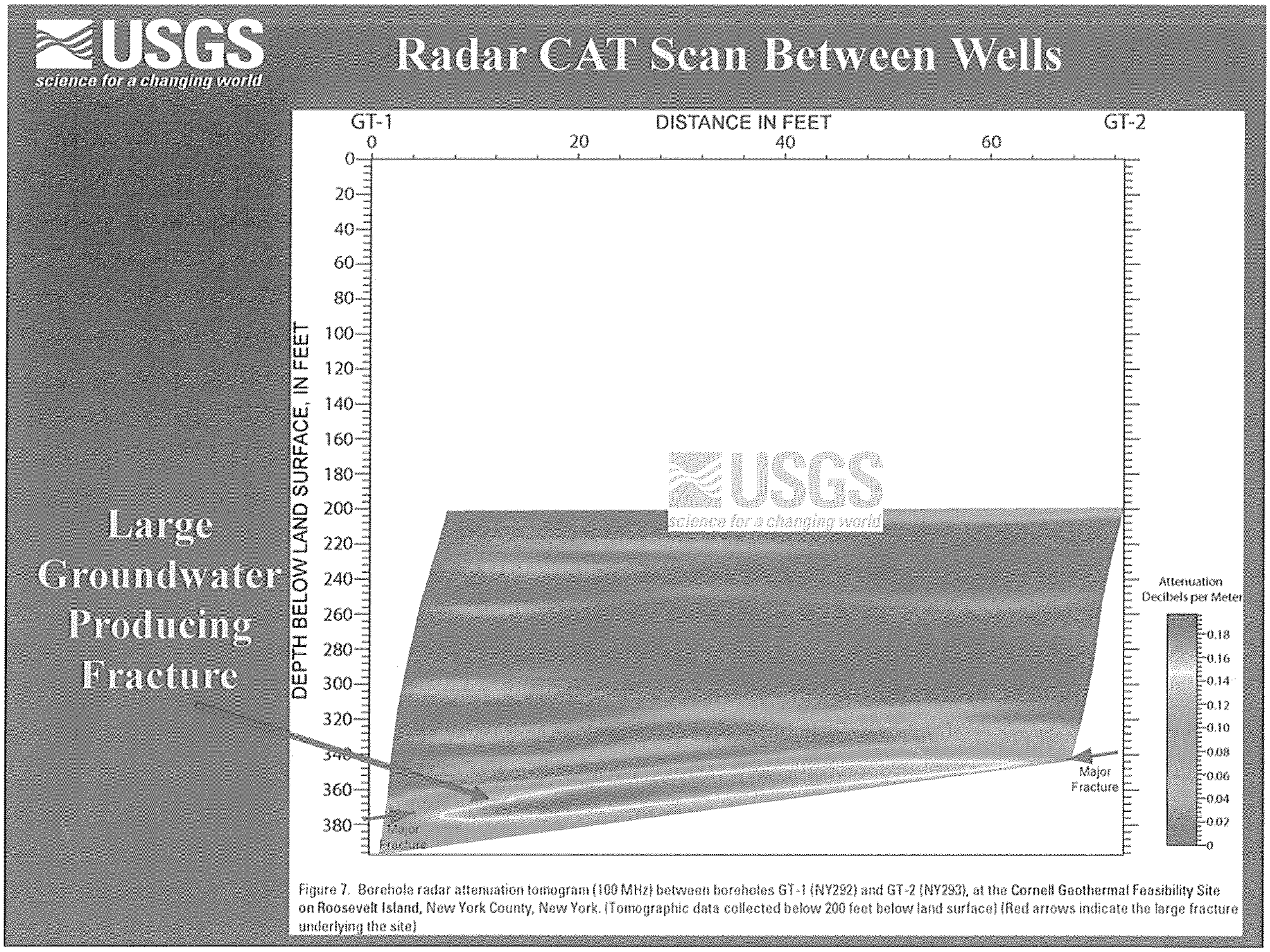
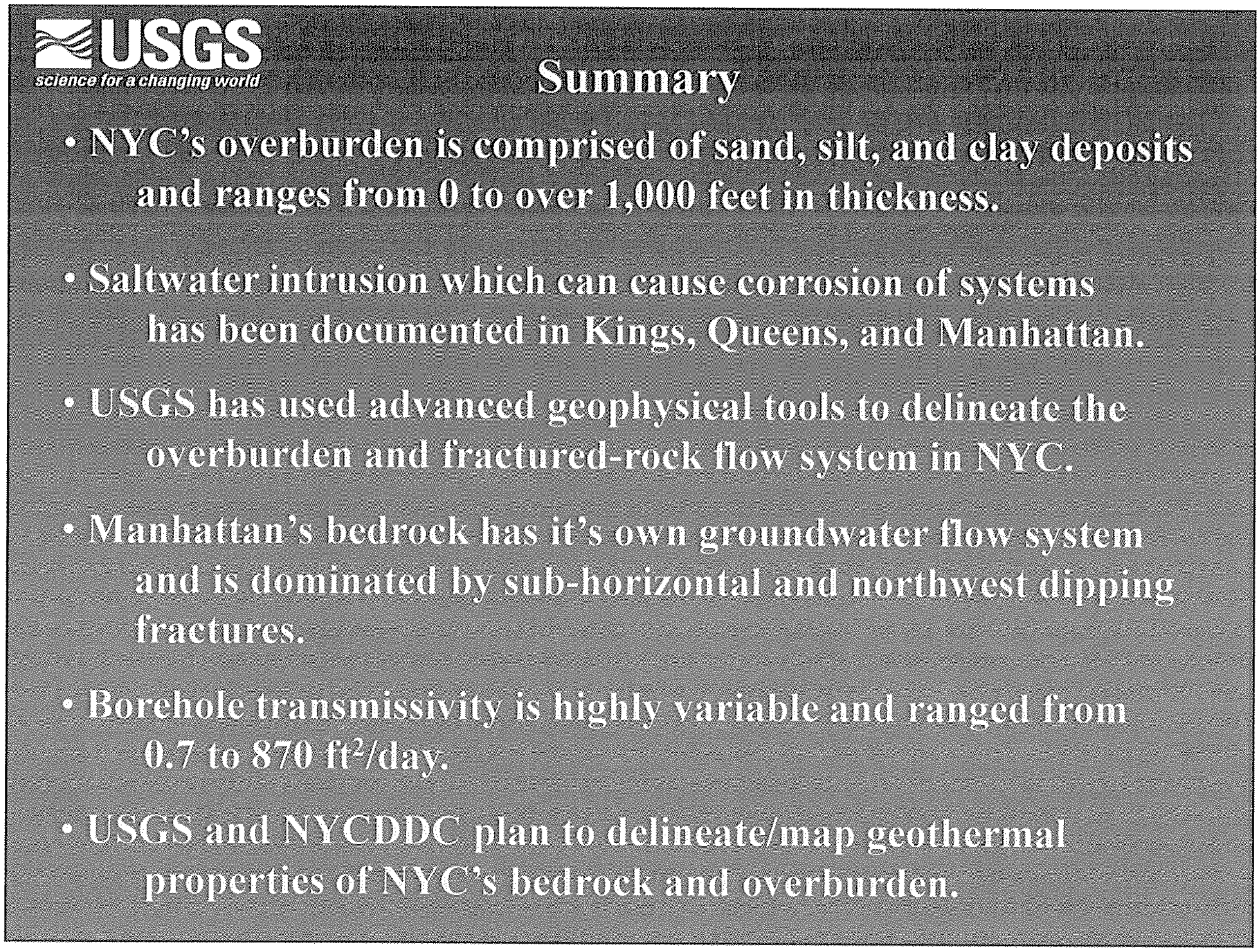


Figure 3. Suite of geophysical logs from borehole GT-1, Cornell Geothermal Feasibility Site on Roosevelt Island, New York County, New York. (Borehole location is shown in figure 1)

The USGS found one large fracture dipping about 30 degrees toward the southwest was the primary groundwater producing feature in the planned geothermal well field. Our analyses indicated the fracture had a very high transmissivity or water producing capacity. However, our water quality logging indicated significant saltwater intrusion from the nearby East River which needed to be considered in the final design.



In case anyone was curious what a large fracture looks like in 2D the USGS collected a tomogram or CAT scan of the bedrock between two test boreholes in the proposed geothermal well field. Radar waves were transmitted a total of 70 feet between both boreholes and processed to create this image of the large fracture 380 feet below the surface. In large geothermal projects where many wells are required in the design advanced borehole techniques such as this help define the properties and features of the bedrock to increase the efficiency of the system.



In order to promote the use of geothermal energy in an area with complex geology and highly variable thickness of sediment detailed hydrogeologic information is required. Through our cooperative program with the NYCDDC the USGS has begun the process of producing the data and maps required for proper application of geothermal energy in NYC.

I would like to thank the committee for allowing me this opportunity to present some of our research. I would welcome any questions you may have.

THE COUNCIL
THE CITY OF NEW YORK

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Name: Catherine Skopic

Address: 140 W. Broadway, N.Y., N.Y. 10013

I represent: Myself & SPNPN - Shut Down Indian Point Now

Address: People's Climate Movement - NY

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Address: ______

I represent: Mayor's Office of Sustainability

Address: ______

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Address: ______

I represent: Mayor's Office of Sustainability

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Date: 9/23/15

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Name: Alex Posner

Address: 161-18 59 Ave Fresh Meadows

I represent: NYC Dept of Design & Construction

Address: ________

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Name: Dr. Frederick Stumm

Address: 2045 Route 112 Coram NY

I represent: US Geological Survey

Address: ________

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Name: Bob Wyman

Address: 203 W 85 Apt PH2, New York, NY 10024

I represent: Self

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Name: Gaylord Olson

Address: 1273 Jefferson Rd. Princeton, NJ

I represent: self

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Name: Ling Tsou

Address: ______

I represent: United for Action

Address: ______

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