Ground Heat Exchanger
Science & Diagnostics

Moderator: Aeowyn Kendall / *Aztech Geothermal*

Panel: José Acuña / *KTH (Sweden)*
John Williams / *USGS*
Isabel Varela / *HEET*
Connor Dacquay / *GeoFease*

KTH ROYAL INSTITUTE
OF TECHNOLOGY

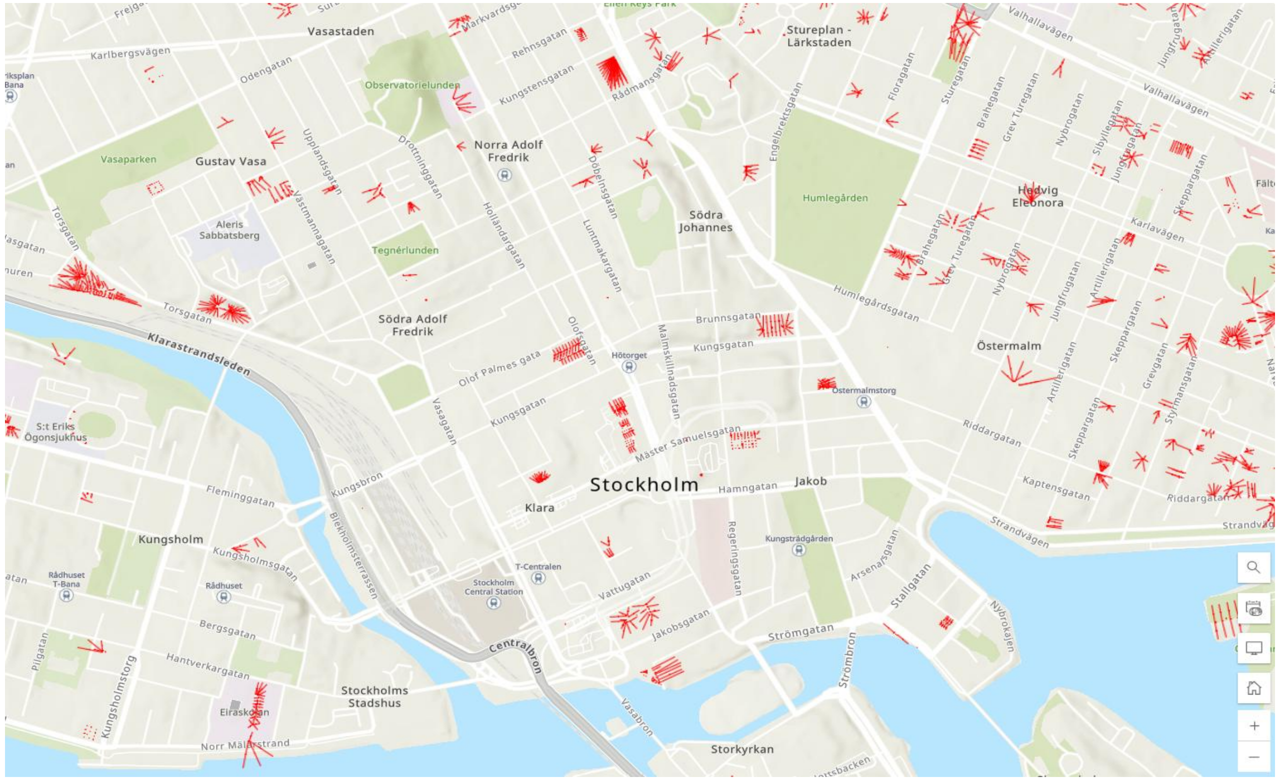
Temperature and XYZ-coordinate measurements along Ground Heat Exchangers

Dr. José Acuña

Swedish context

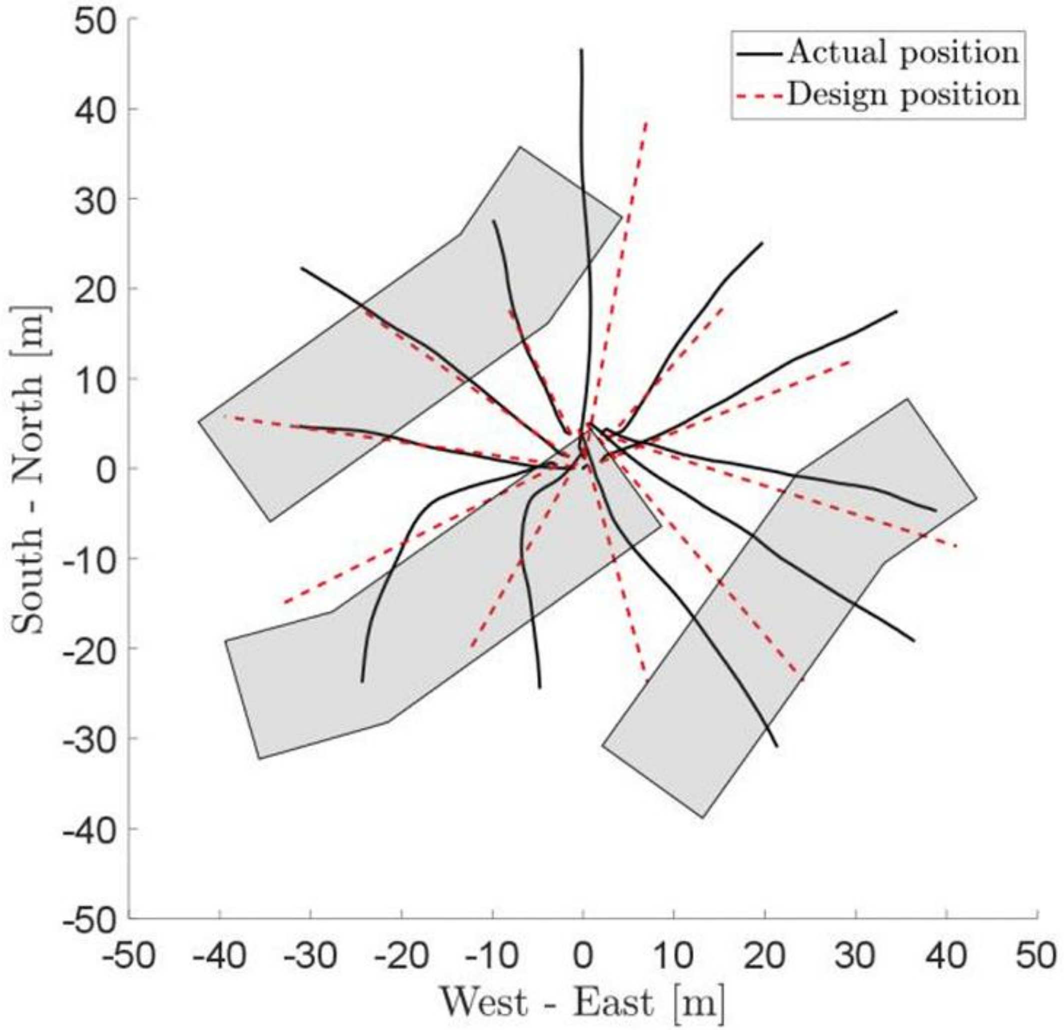
- Most GSHP installations per capita
- Saturated Villa GSHP market & Growing market in large residential and commercial.
- Drilling depth increases year after year

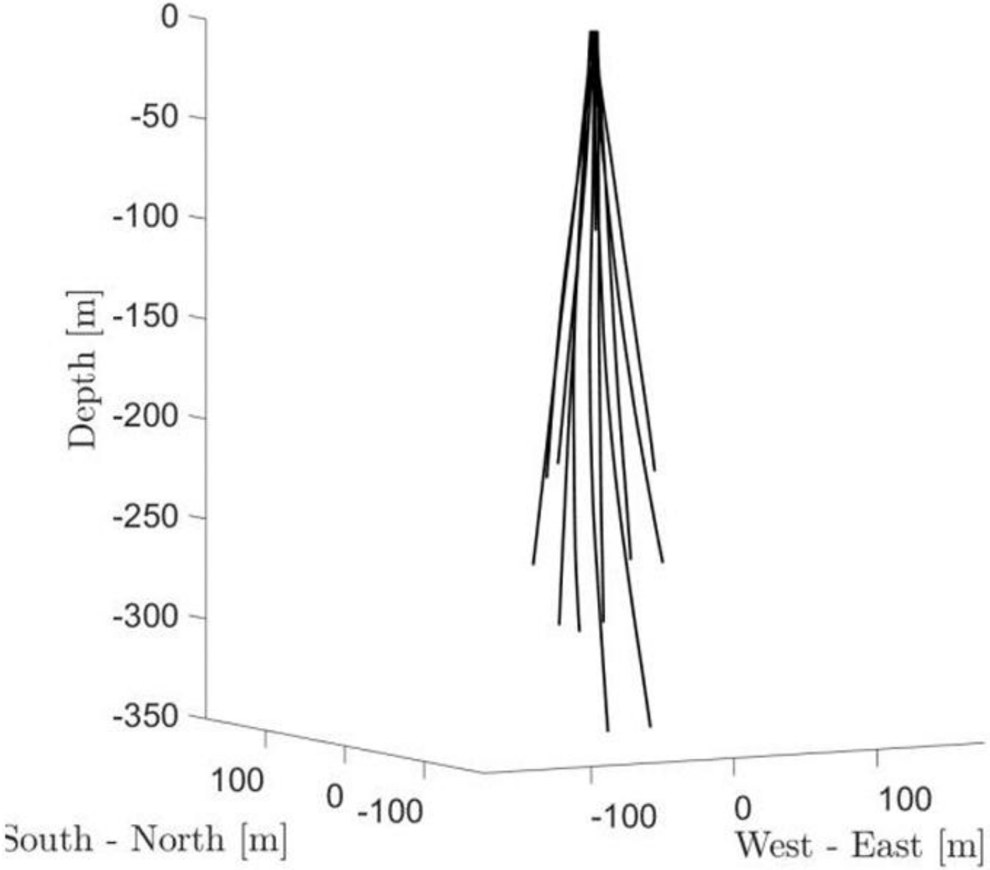
Example: villa area in Stockholm



Example: Down town Stockholm

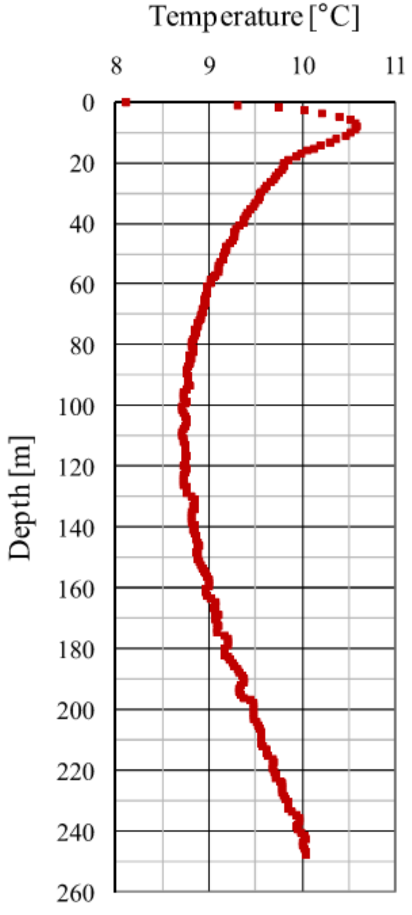
Documentation XYZ coordinates



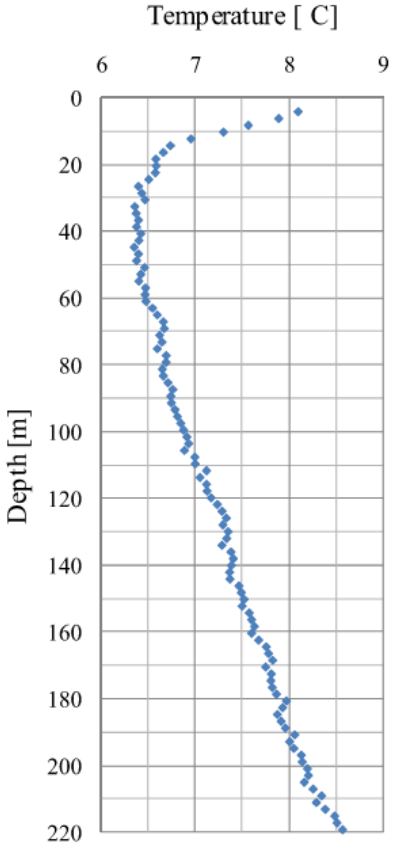


mazzotti-pallard2021forskningenswedencase-study-report-annex-52final_v2.pdf

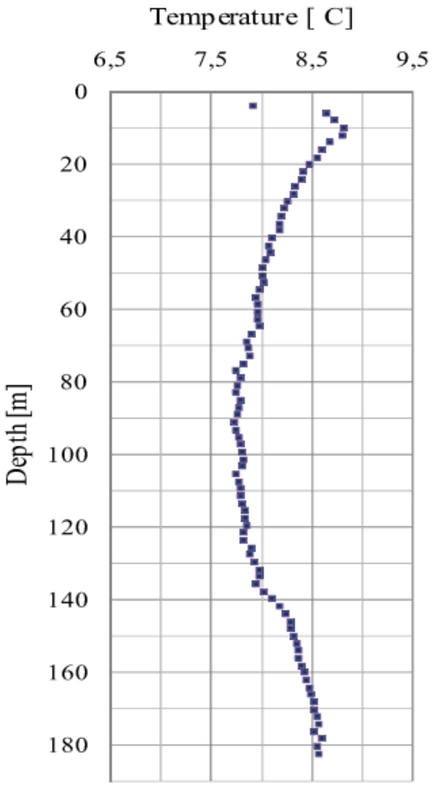
Distributed Temperatures in BHEs



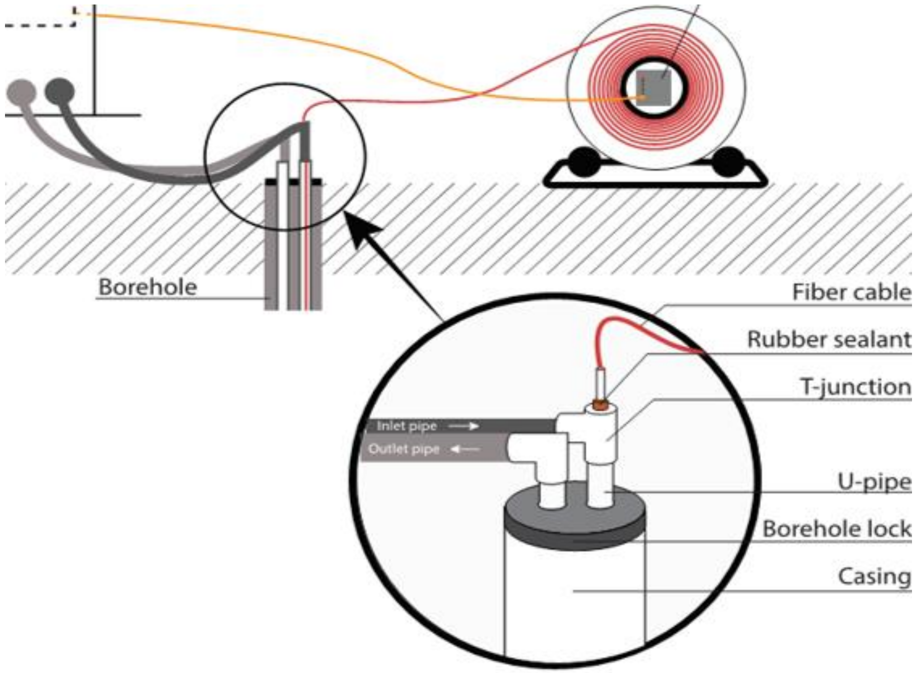
(a)

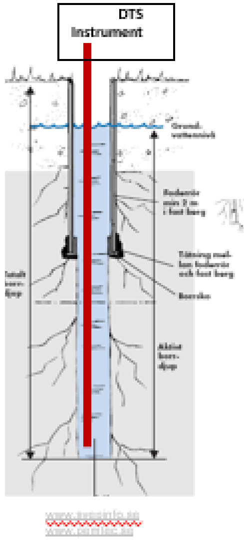


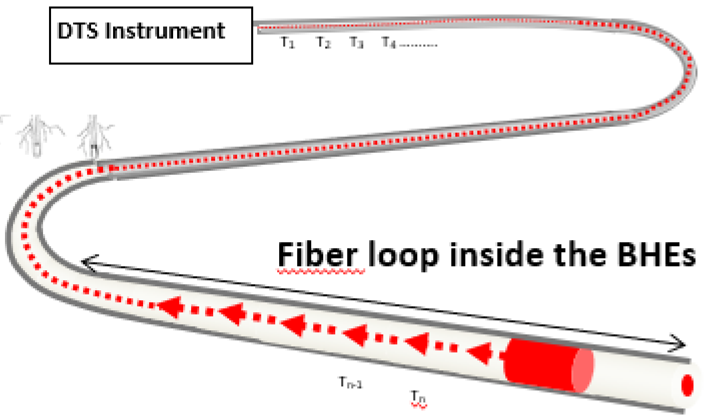
(b)



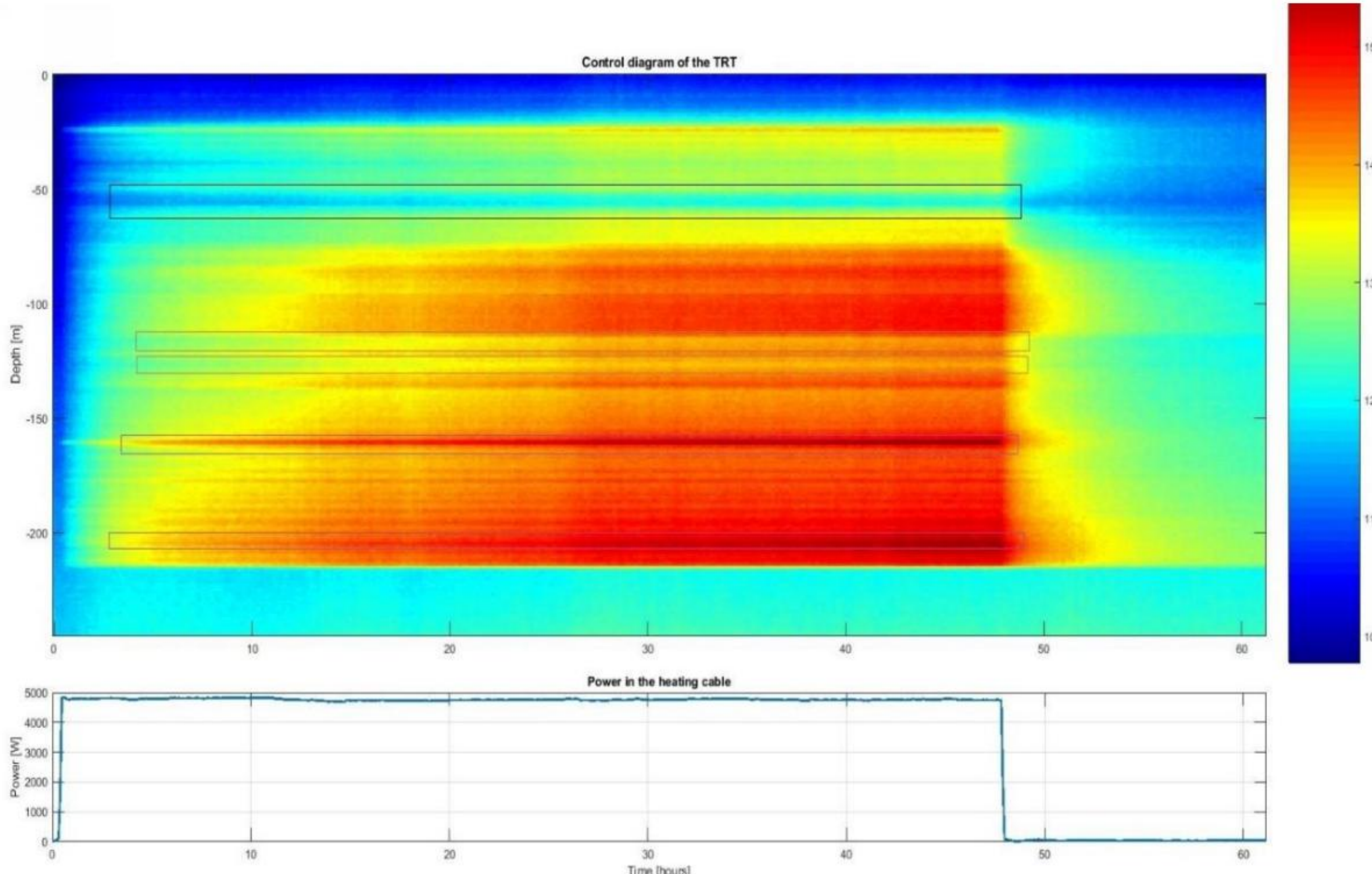
(c)





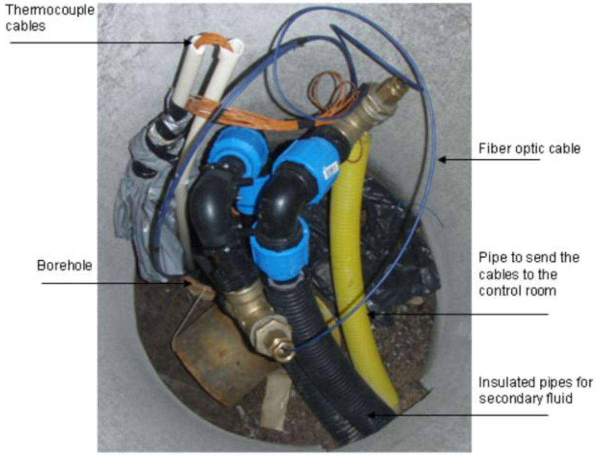


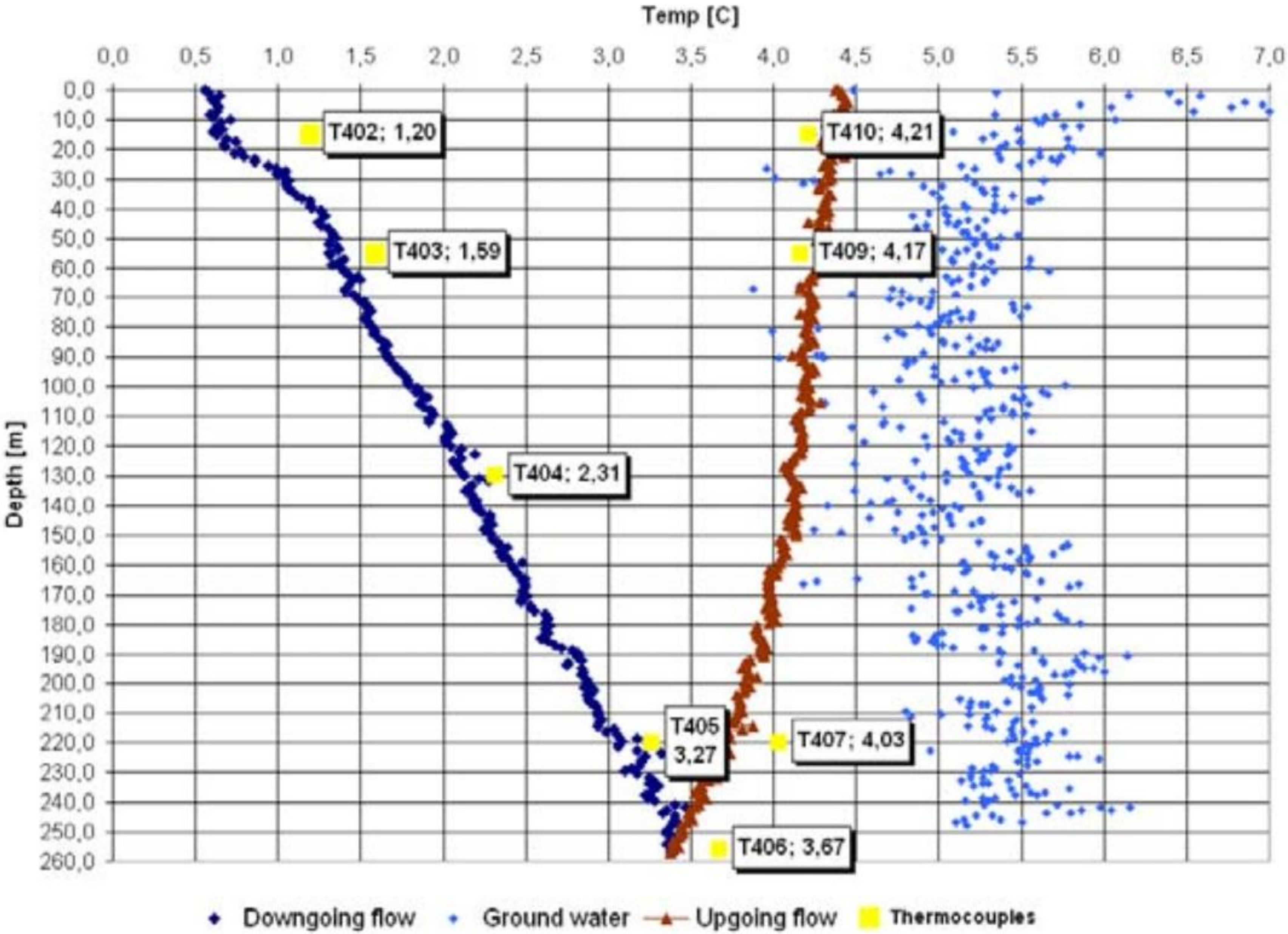
Design phase (TCT)



Example
R&D application
Heat extraction profile

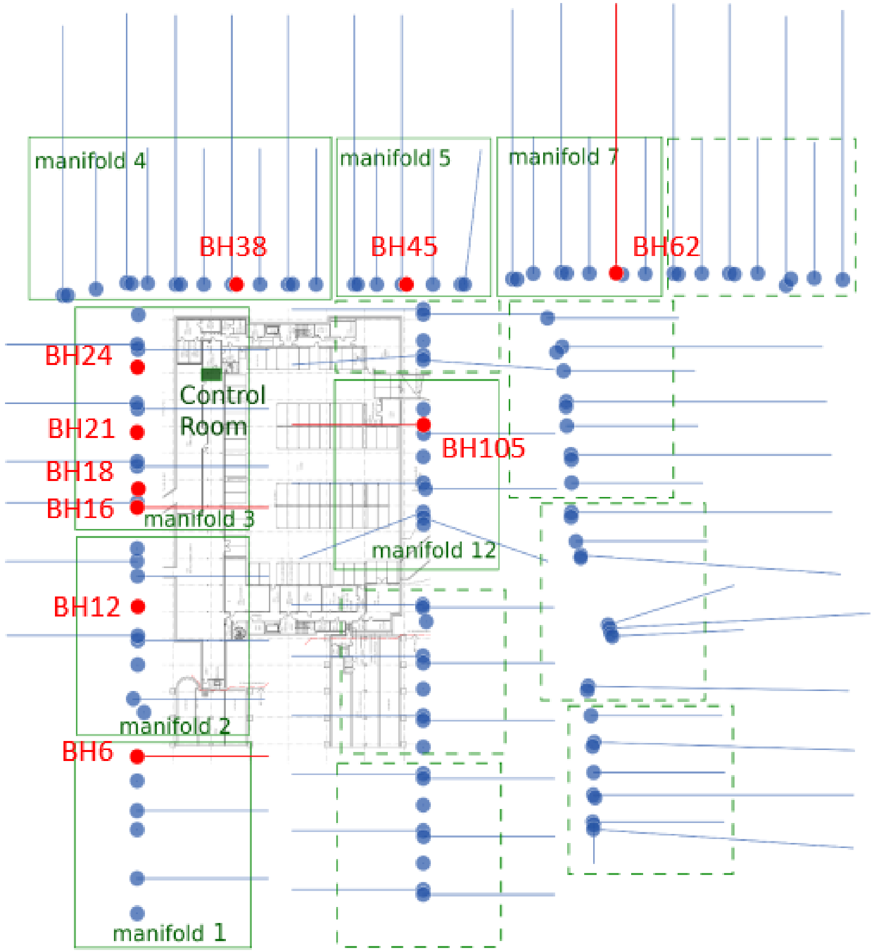
KTH | publications



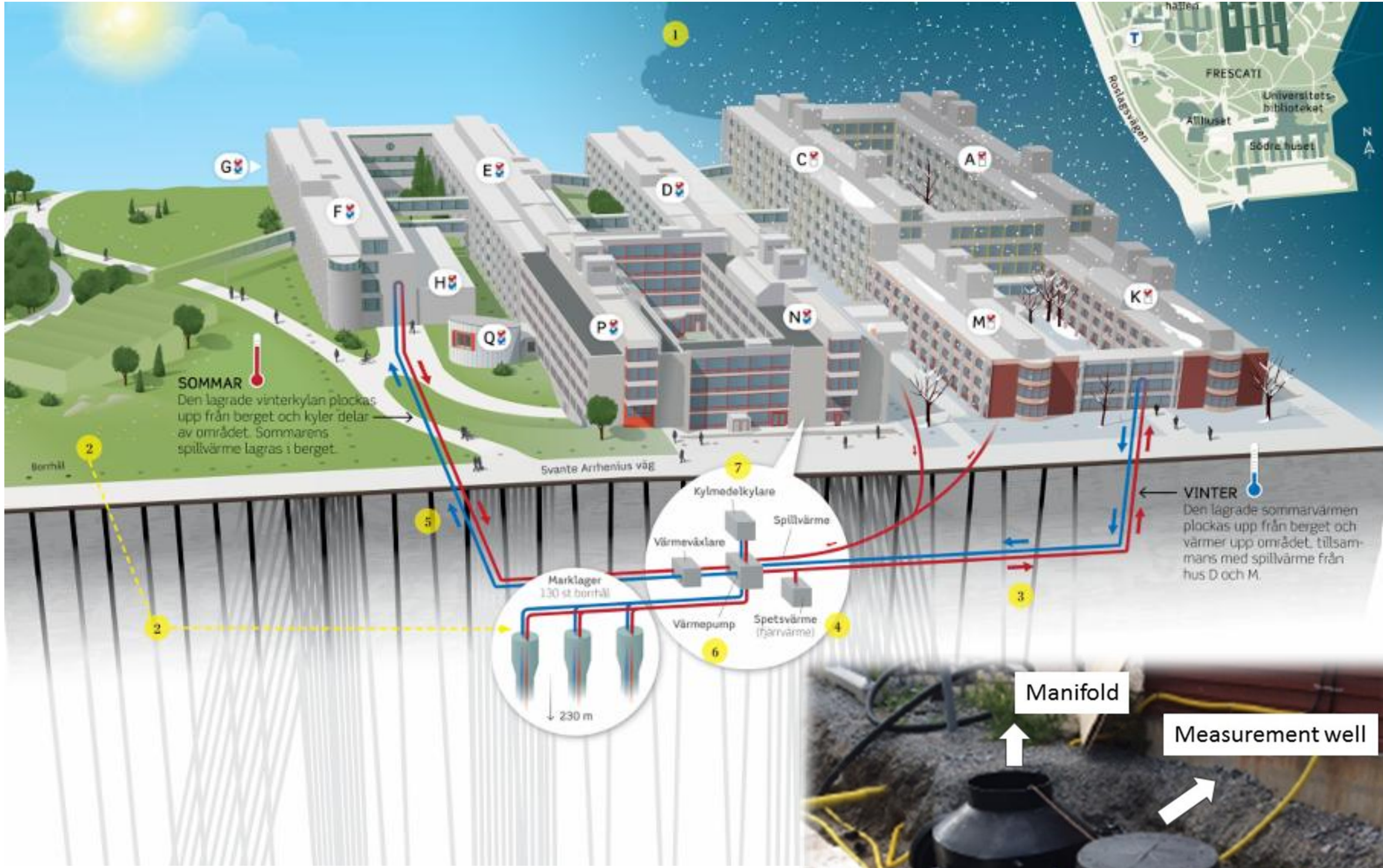


4D Monitoring of Multiple BHEs

- Total area: ~ 26,000 m^2
- 130 boreholes (9 monitoring)



- Borehole
- Measurement borehole
- Measurement manifolds
- Other manifolds



Installation outside the U-pipe for double ended measurements

KTH | publications

Example: Permanent measurements outside U-pipes

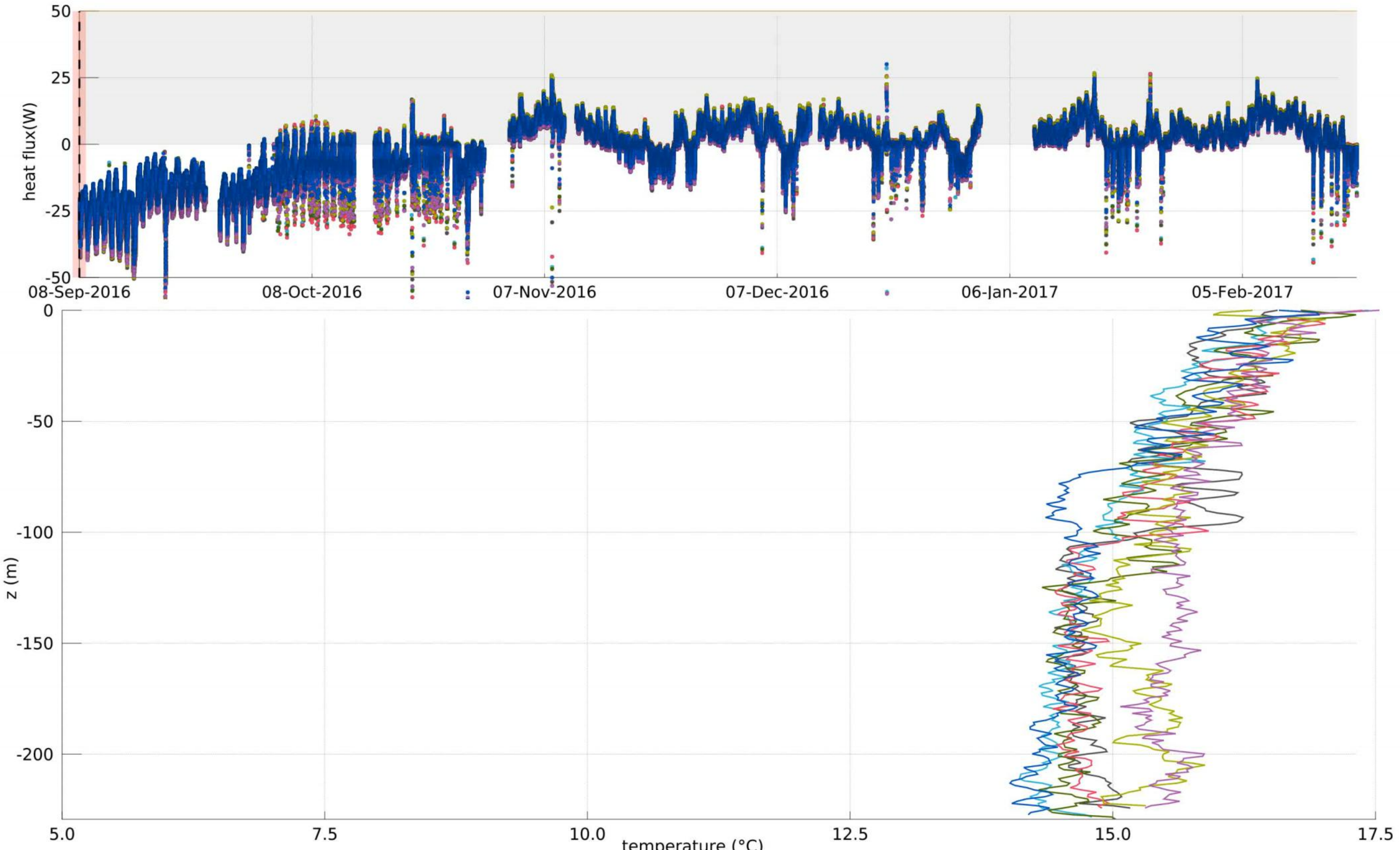
KTH | publications

TIME
day: 2016-09-08
hour: 12:08:00

BH12 open
BH16 open
BH18 open
BH21 open
BH47 open
BH62 open
BH106 open

play

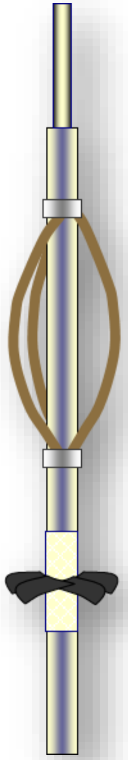
timesignal



Thank you!

jose.acuna@energy.kth.se

Hydrogeophysical Tools and Data for Geothermal Mapping and Site Characterization



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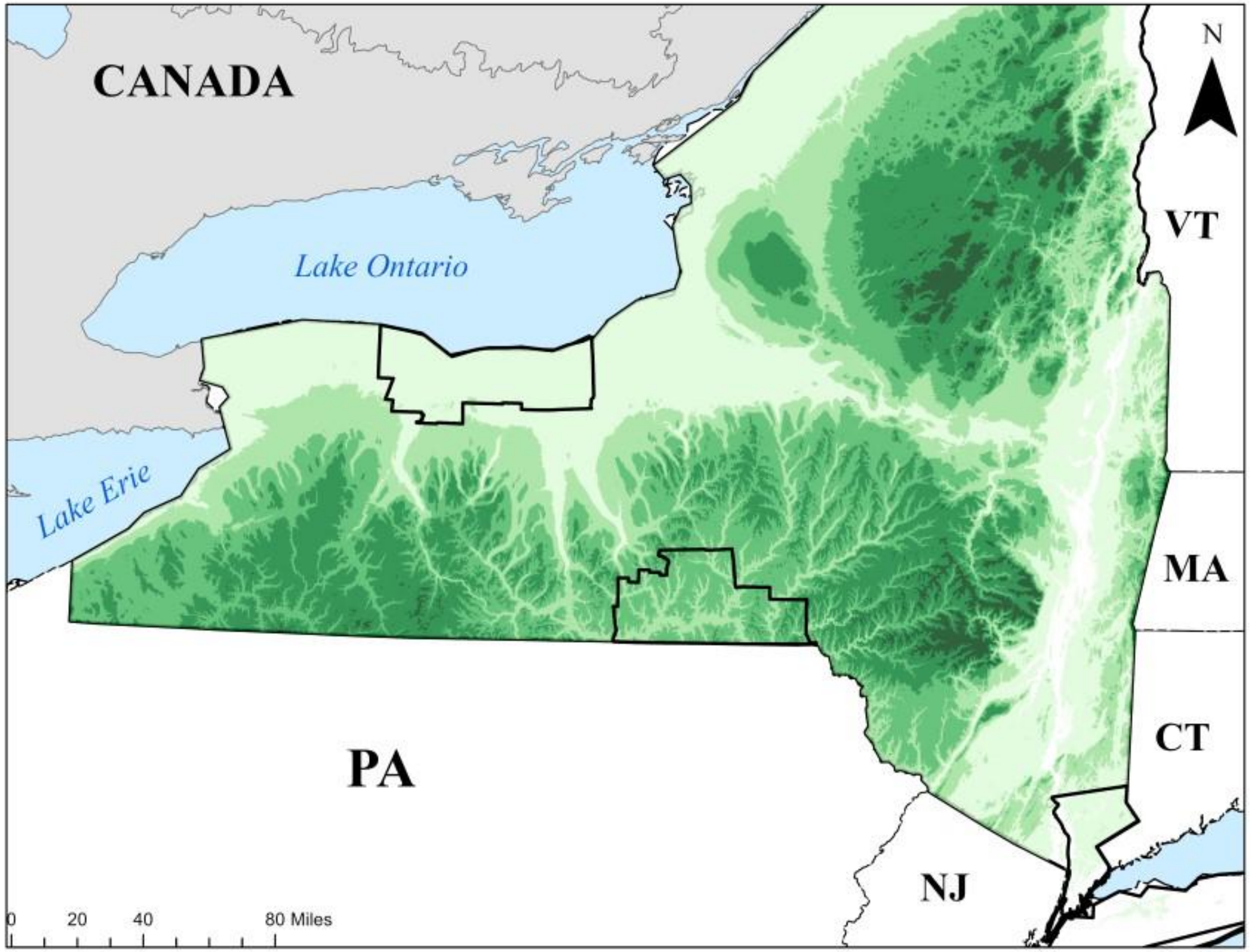
U.S. Geological Survey
New York Water Science Center

Project team: Laura DeMott,
Jason Finkelstein, Bill Kappel, Angela Rienzo,
Fred Stumm, Neil Terry, and Alton Anderson

U.S. Department of the Interior
U.S. Geological Survey

USGS-NYSERDA Geothermal Investigation



In cooperation with NYSERDA, the USGS is compiling, collecting, and analyzing *geologic maps, borehole logs, well yield, thermal conductivity tests, and associated data* to inform geothermal development in New York

Three multi-county areas representative of the **Ontario Lowlands, Allegheny Plateau, and Manhattan Prong-Hudson Highlands** were selected for the pilot investigation

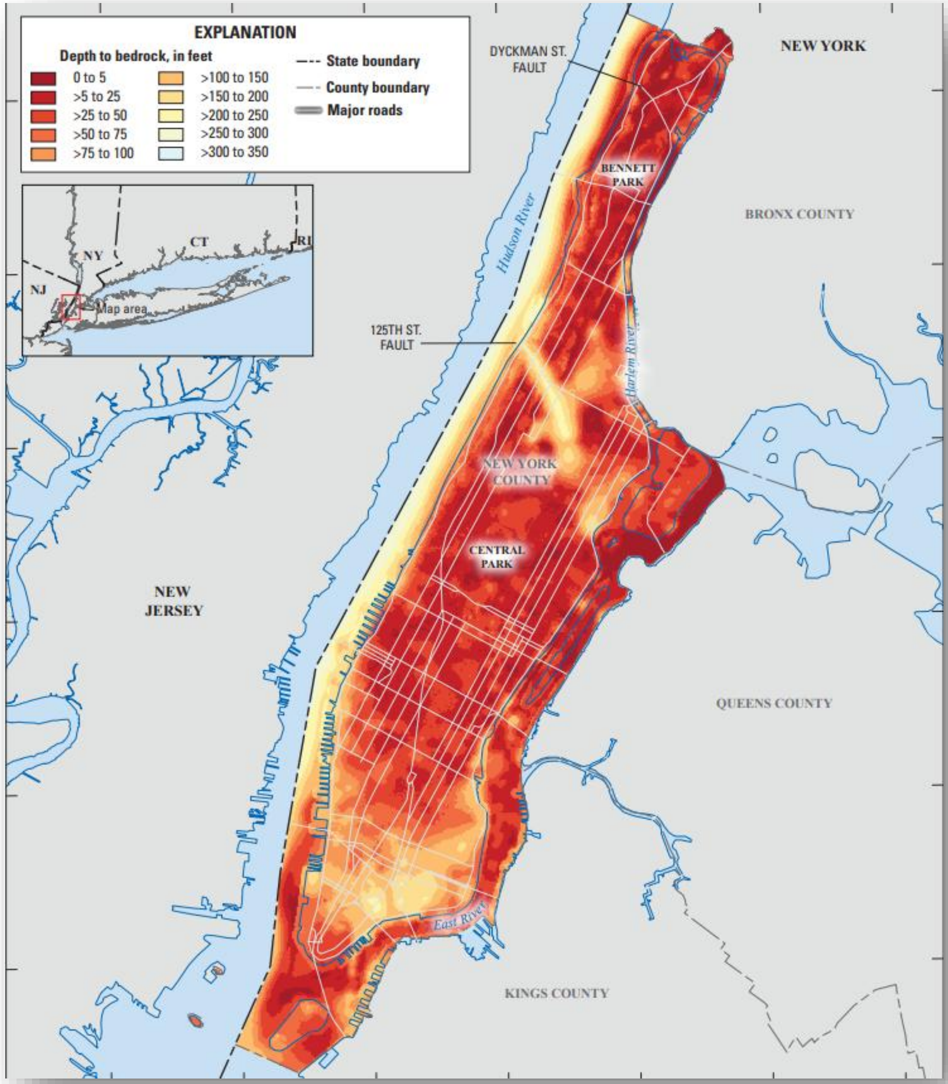
Sources of geologic maps, borehole, and well data include NYSM, NYSDEC, and USGS databases and published and unpublished reports

An ***interactive web-based mapper*** is in development that will present a wide range of hydrogeologic information important for safe and efficient geothermal development

USGS

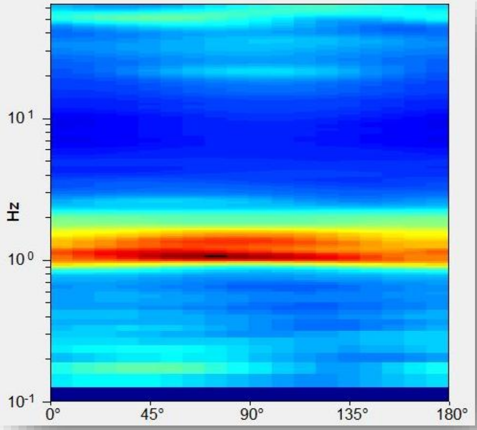
Depth to Bedrock Mapping

Manhattan

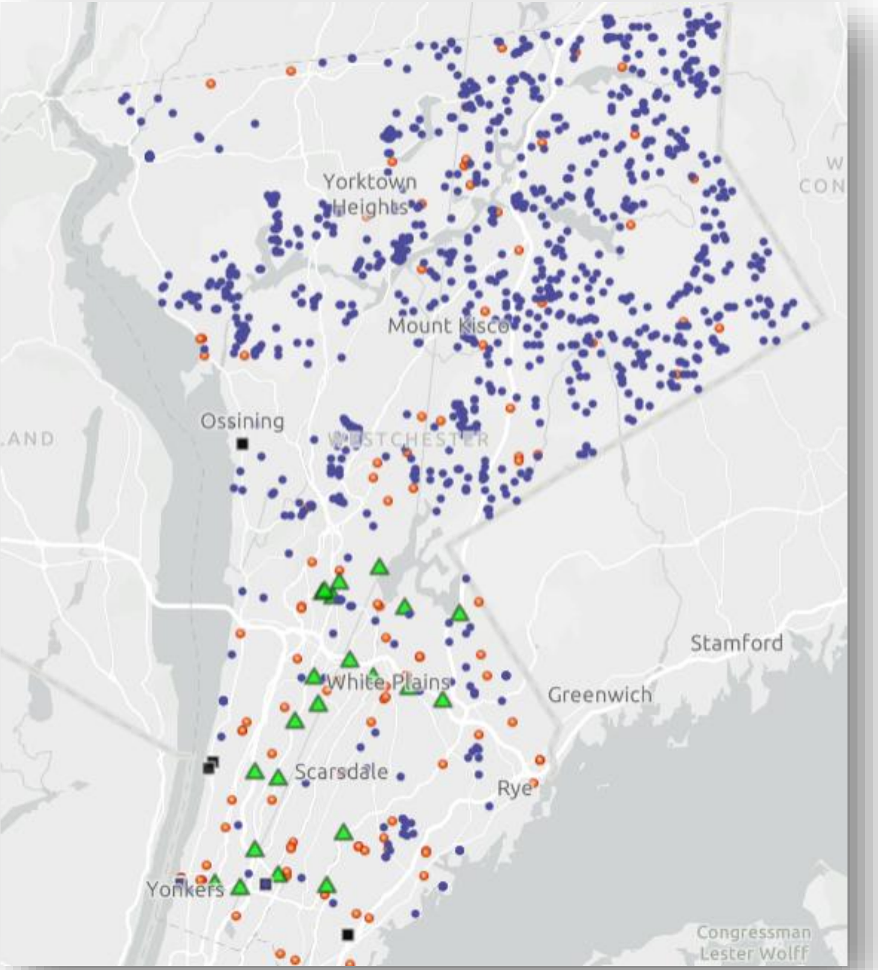


DeMott and others (2023)

Passive Seismic



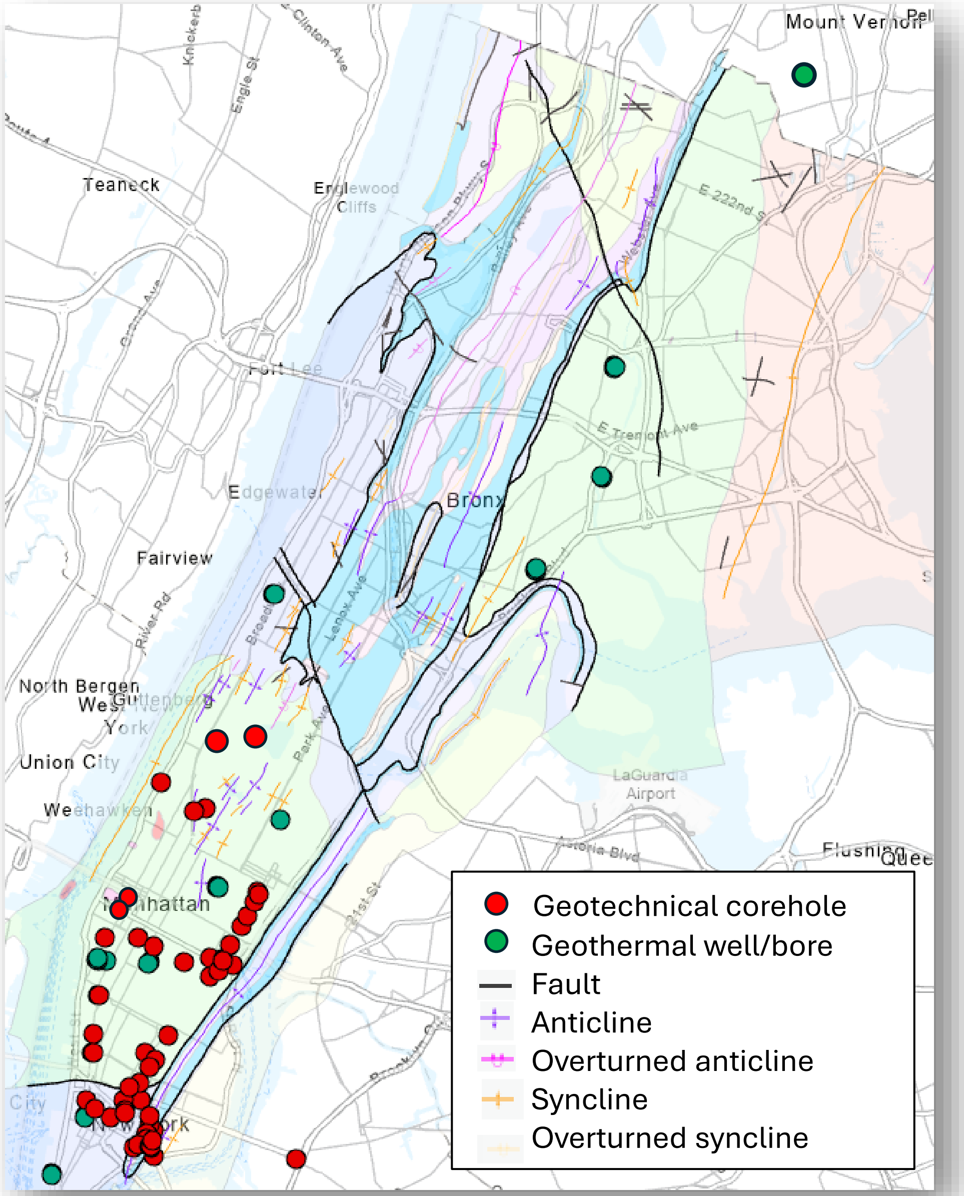
Westchester County



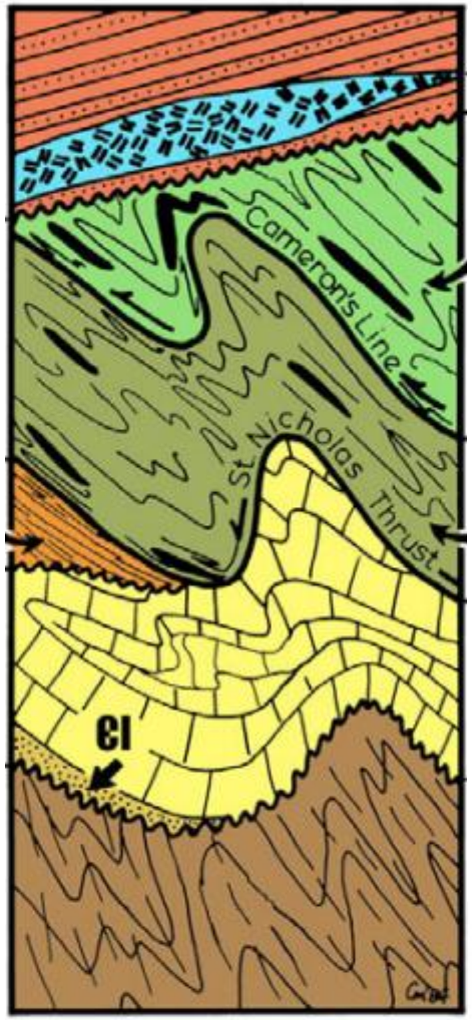
- Water well (USGS database)
- Water well (NYSDEC database)
- Geothermal well (NYSM database)
- Geotechnical corehole (NYSM database)

USGS

Bedrock Geologic Mapping



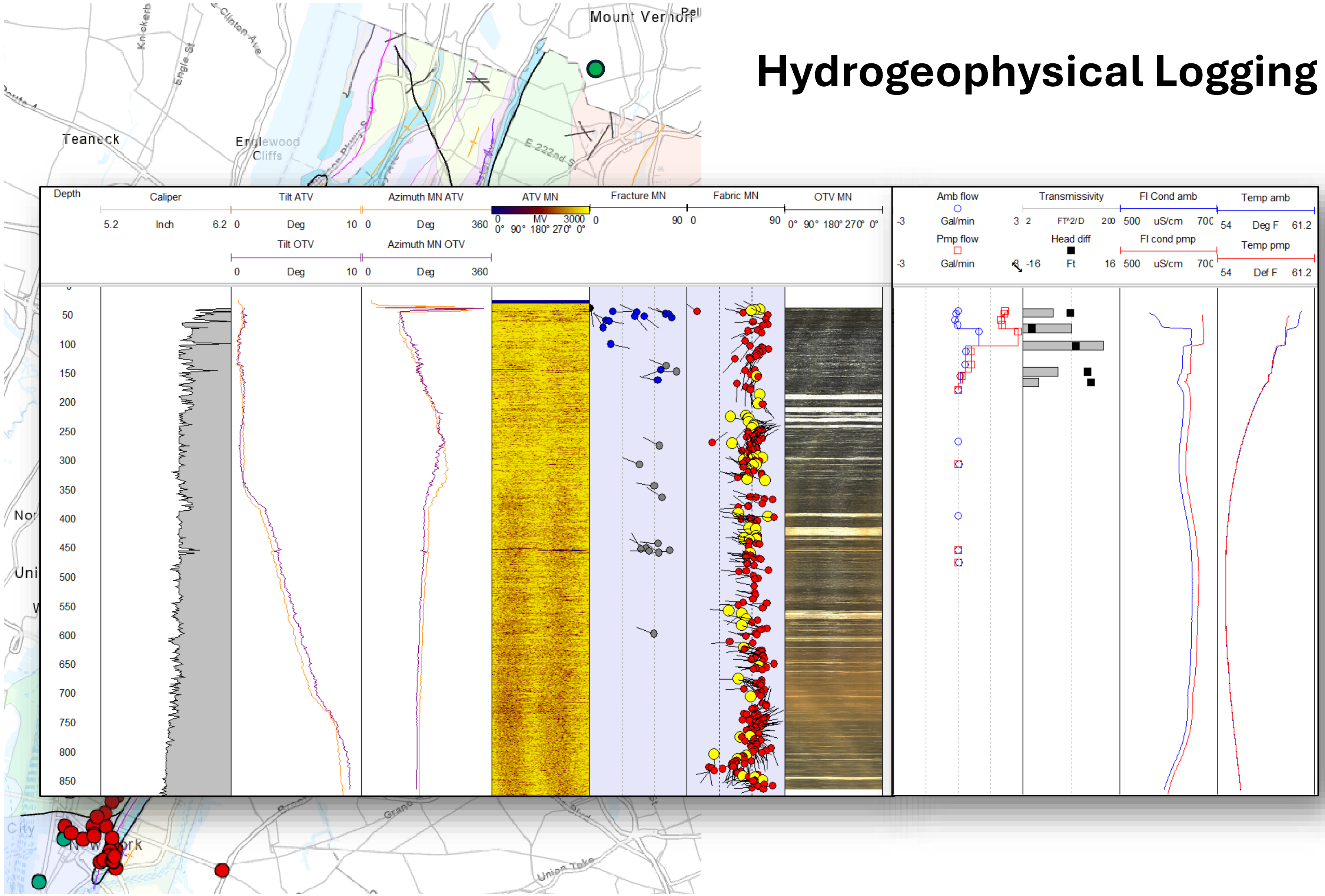
Baskerville(1994)

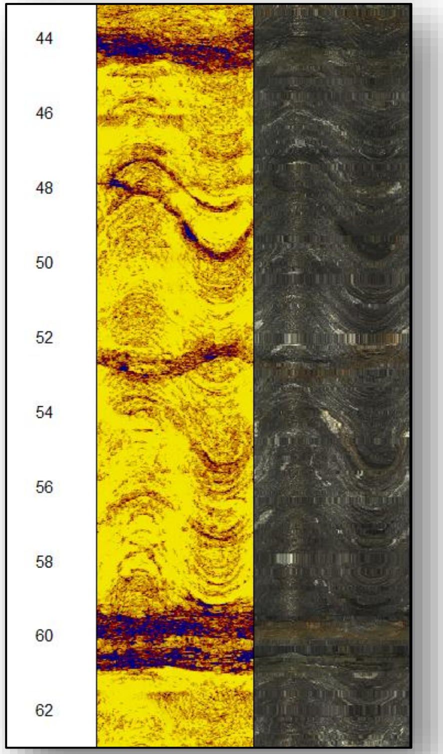


Merguerian and Moss (2006)

USGS

Hydrogeophysical Logging of Geothermal Bores



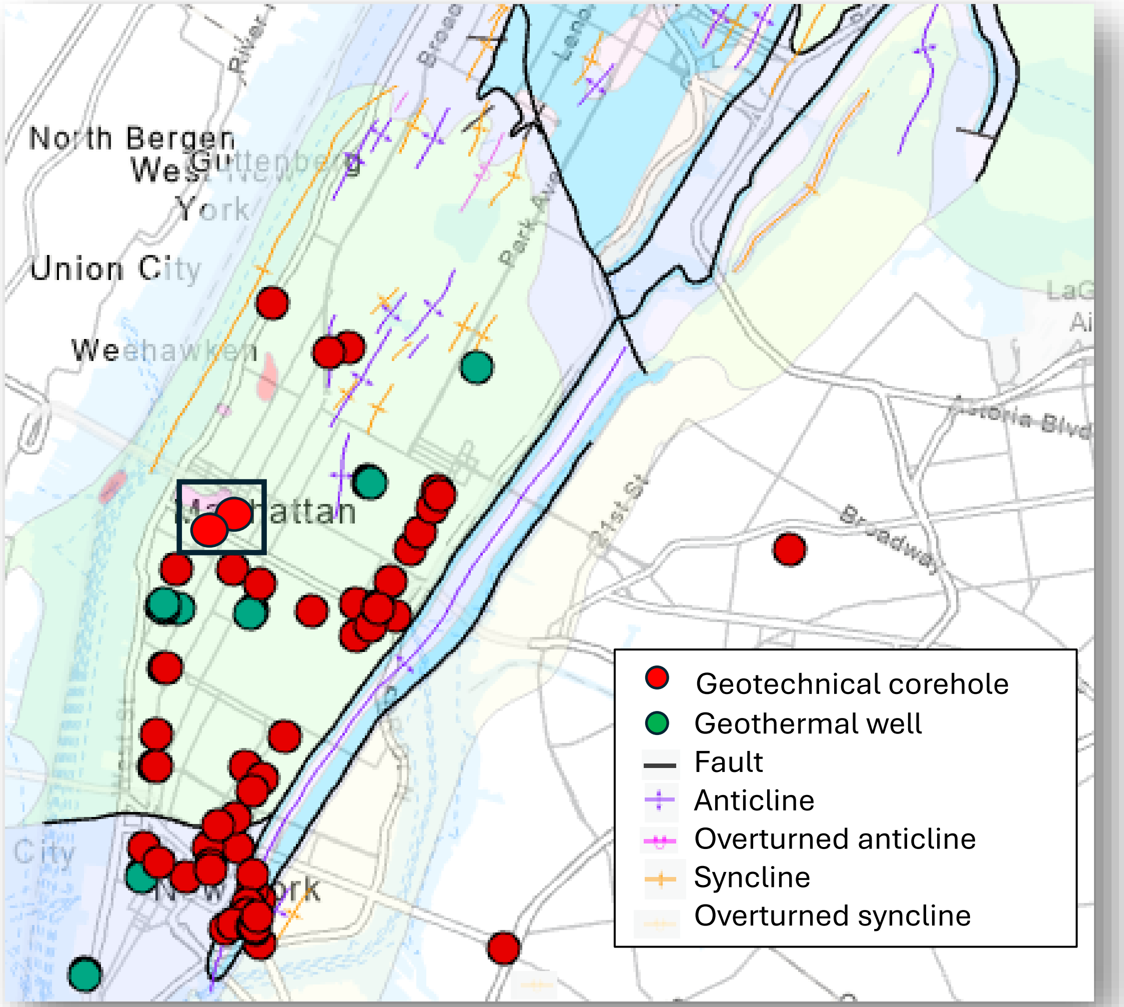


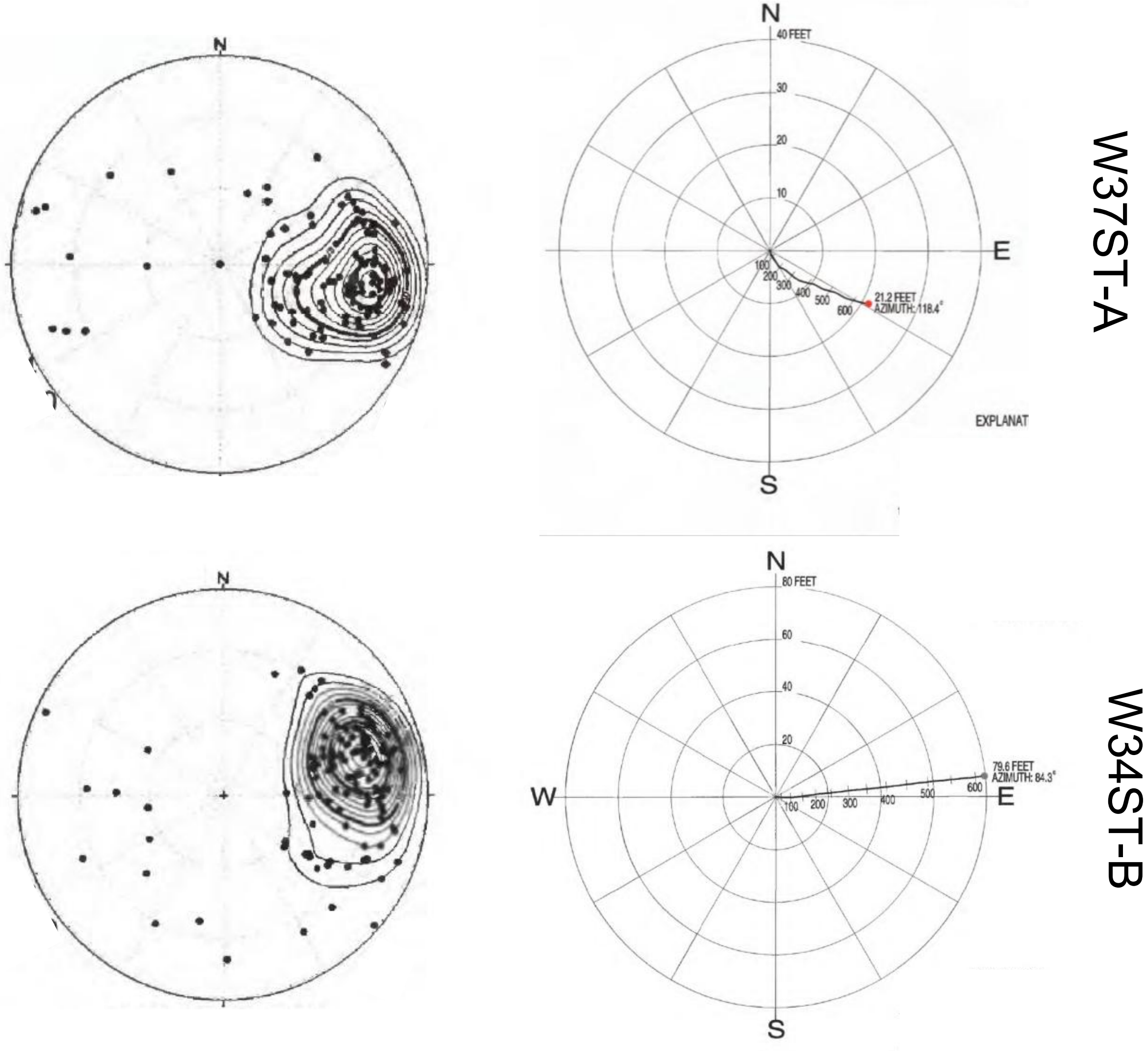
ATV and OTV images of fractures and foliation in schist

USGS GeoLog Locator
txdata.usgs.gov/GeoLogArchiver/odata/Logs(53899)/

USGS

Bedrock Foliation and Hole Deviation





Bedrock foliation

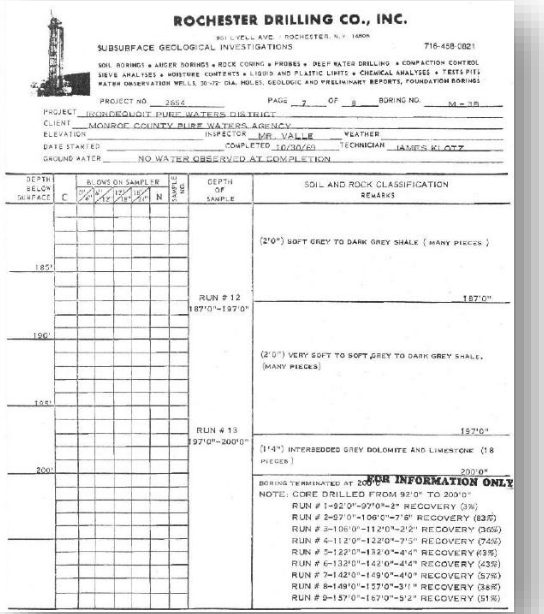
Borehole deviation

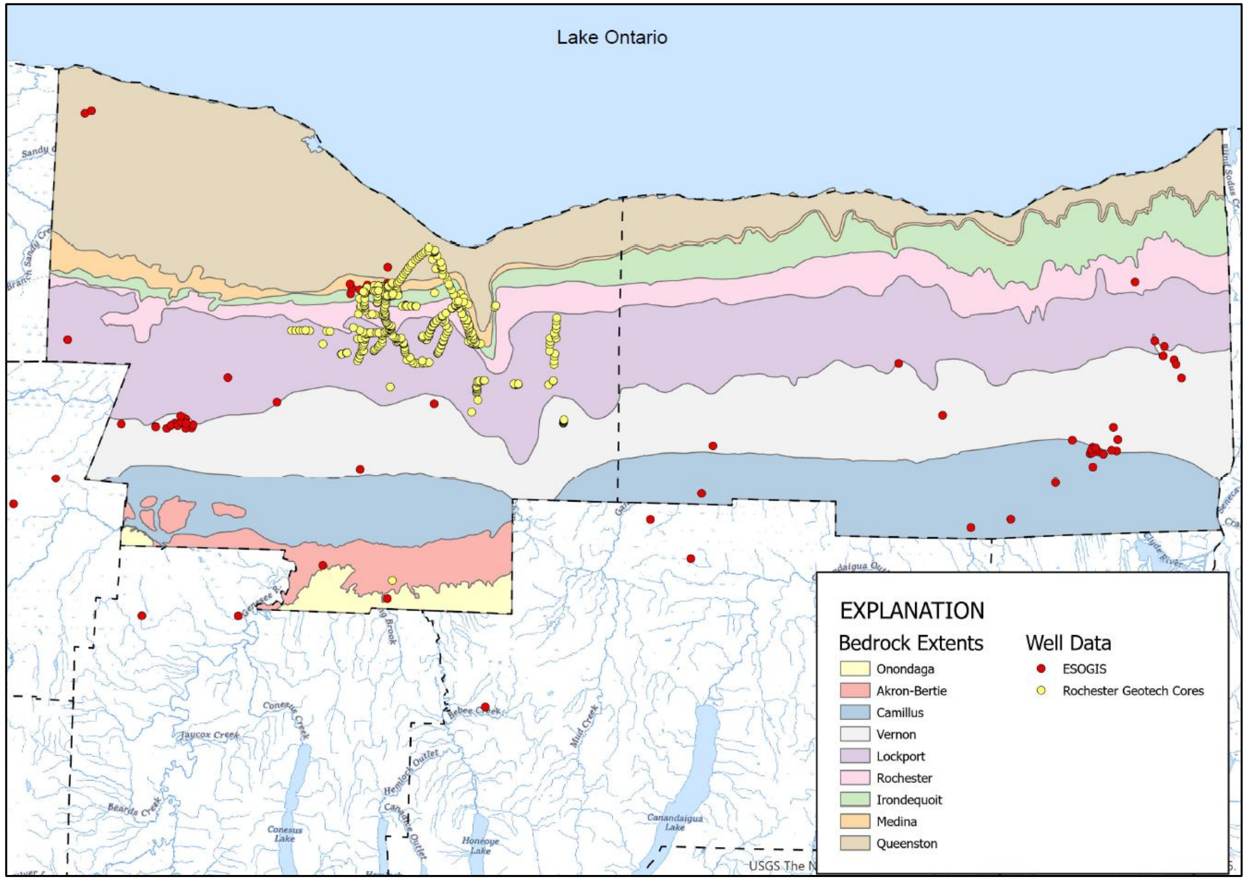
Stumm and others (2001)

USGS

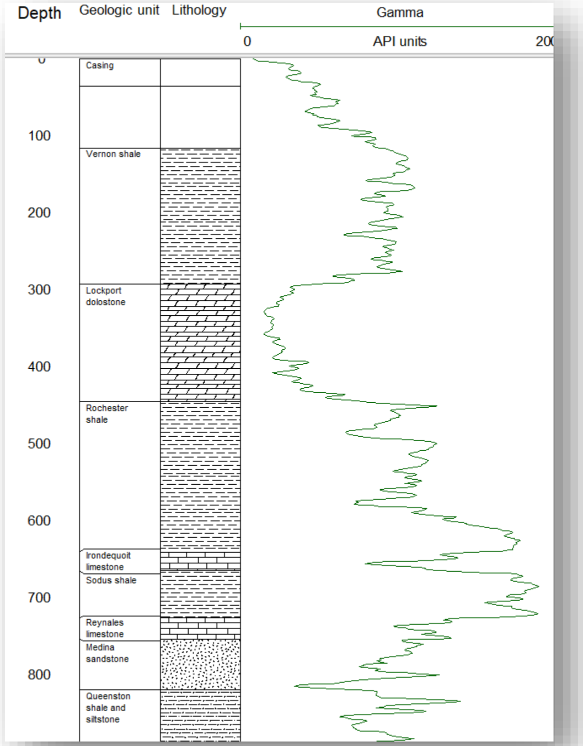
Bedrock Geologic Mapping

Geologist log of geotech corehole





Gamma log of gas well



Driller log of brine well

Wn 546; 8L, 13.1S, 0.7E; drilled by W. E. Sawyer in 1949; altitude 400 feet.

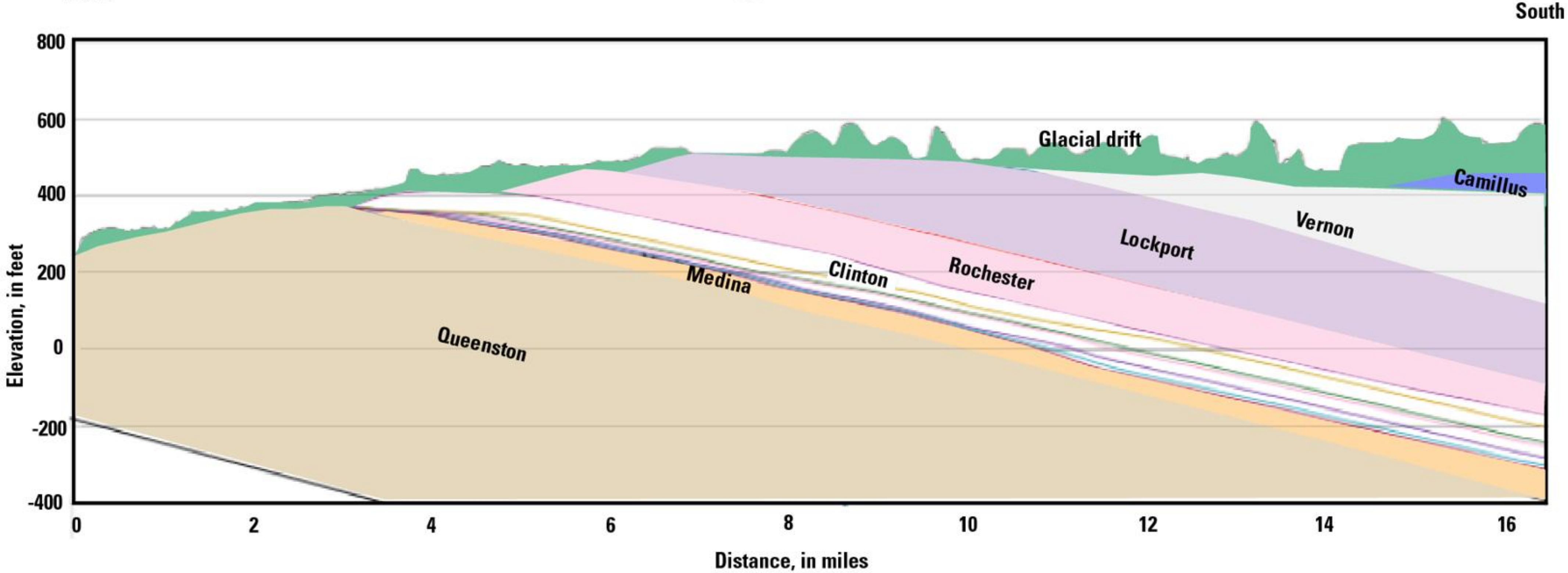
Topsoil	1	1
Clay hardpan	4	5
Sand and gravel	15	20
Sand, fine	10	30
Sand and clay	5	35
Sand	20	55
Gravel (water-bearing)	5	60
Shale	16	76
Sandstone (water-bearing)	8	84
Shale, gray and red	54	138
Shale, brown	18	156
Sandstone, gray	7	163
Shale, gray and red	196	359
Limestone	12	371

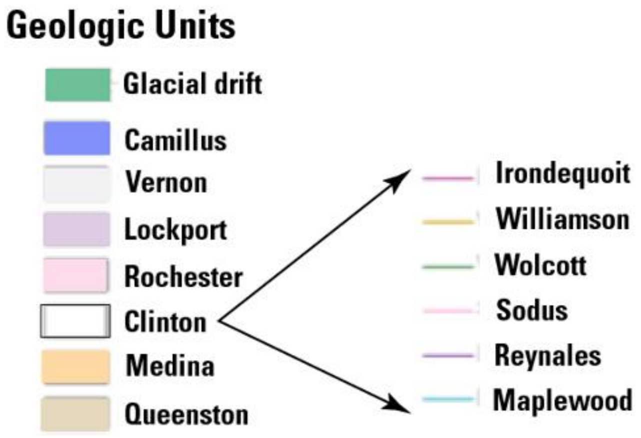
Driller log of gas well

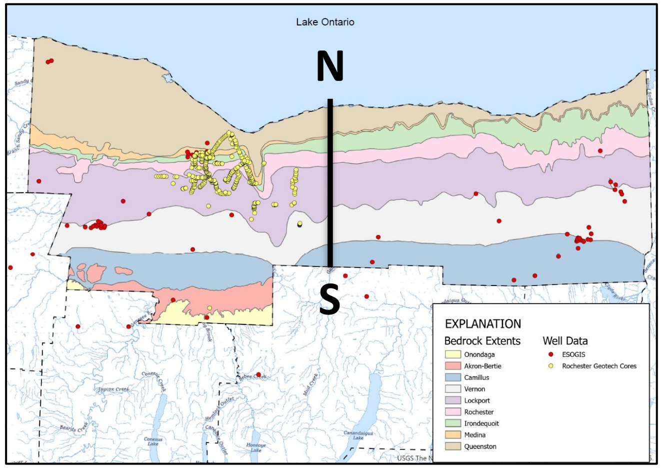
County	API Number			
Monroe	00669			
Depth top (ft bls	Depth bot (ft bls)	Unit	Notes	Source
0	92	Drift	Drift	ESOGIS
94		Onondaga	Flint	
170			Soft cavey	
287			Fresh water	
435			Fresh water	
438			Soft limestone	
490		Lockport	Niagara, "Smoke" Black water at 660 ft	
			Clinton (not recorded)	
960		Medina	Red Medina	
1045			Soft Medina, small amount of gas at 1123 ft	
			TD 1514 ft	

USGS

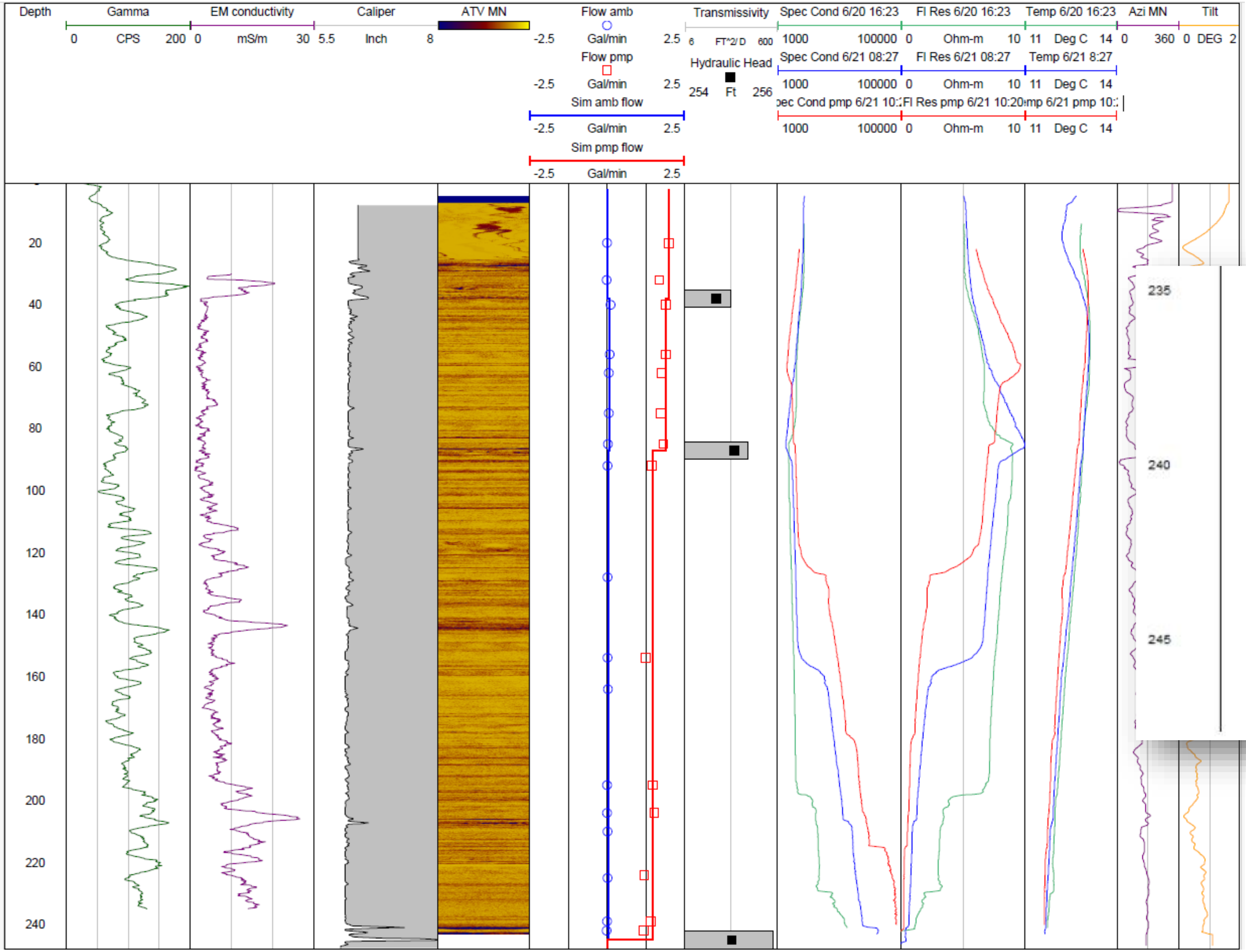
Geologic Section



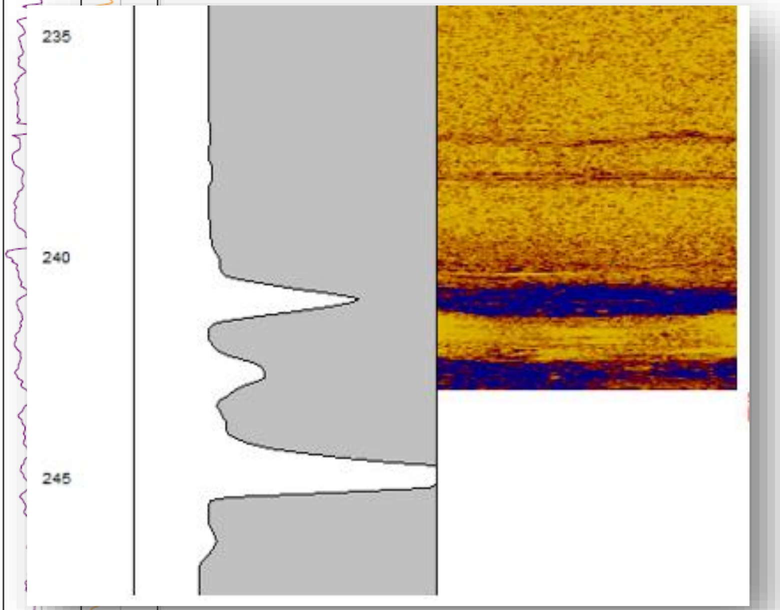




Hydrogeophysical Logs of Geothermal Test Borehole



Caliper and ATV image of salty water-bearing fracture zone

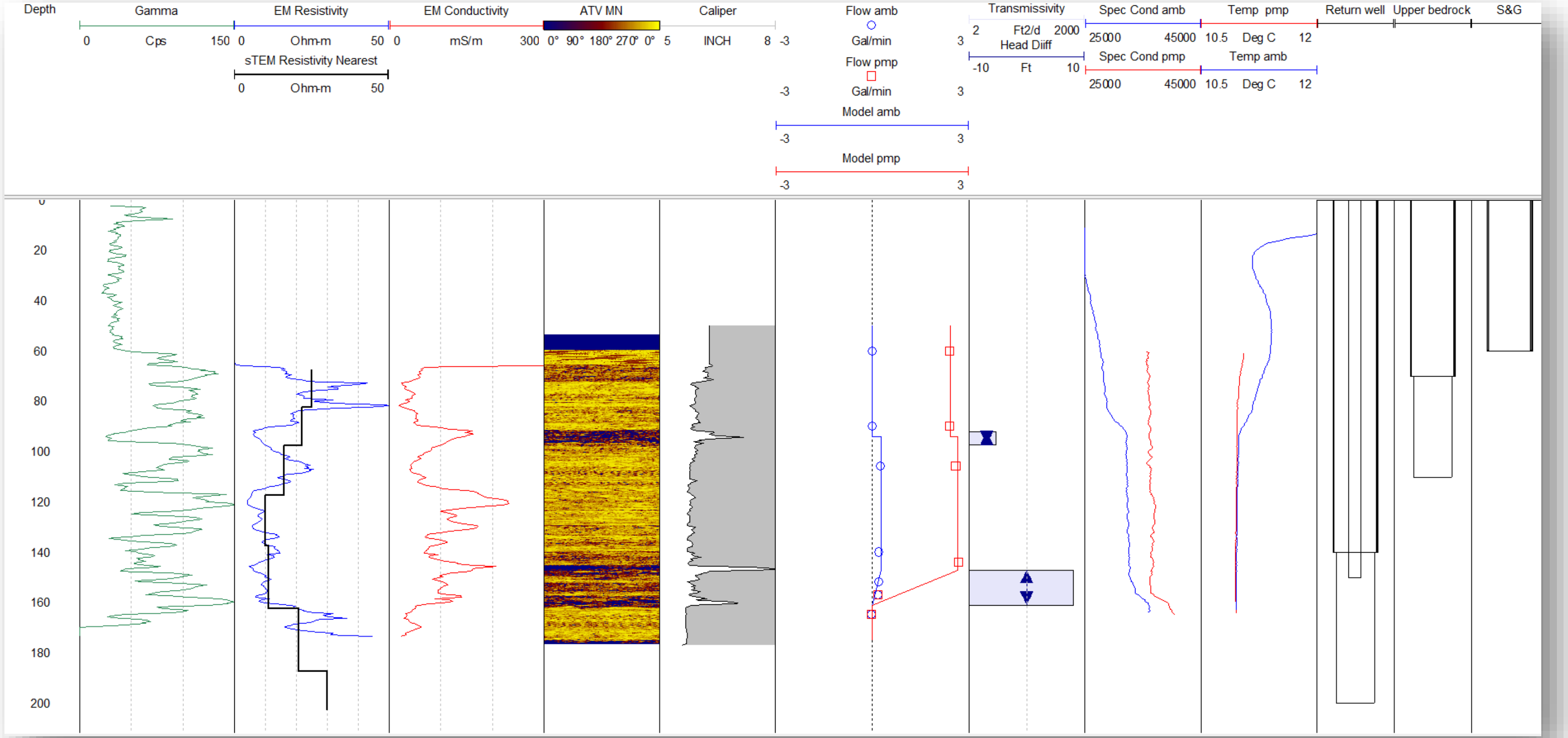


USGS GeoLog Locator
432702076325501_Ow-549

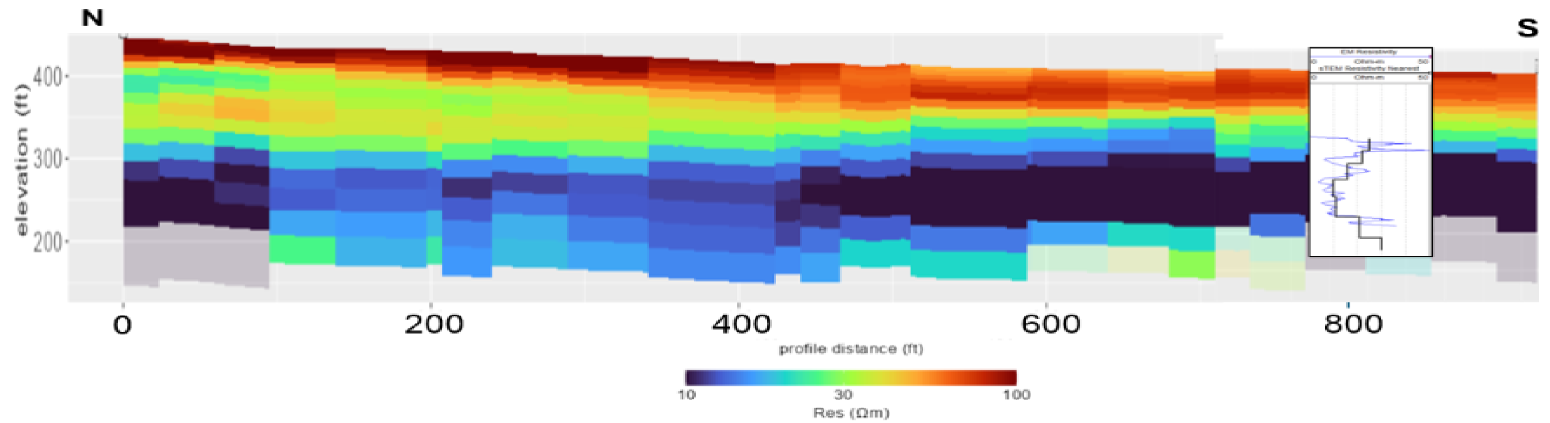
USGS

Hydrogeophysical Logs of Geothermal Test Borehole

Preliminary Information-Subject to Revision. Not for Citation or Distribution.



Injection and Monitoring Well Completions



Electrical resistivity profile from transient EM soundings

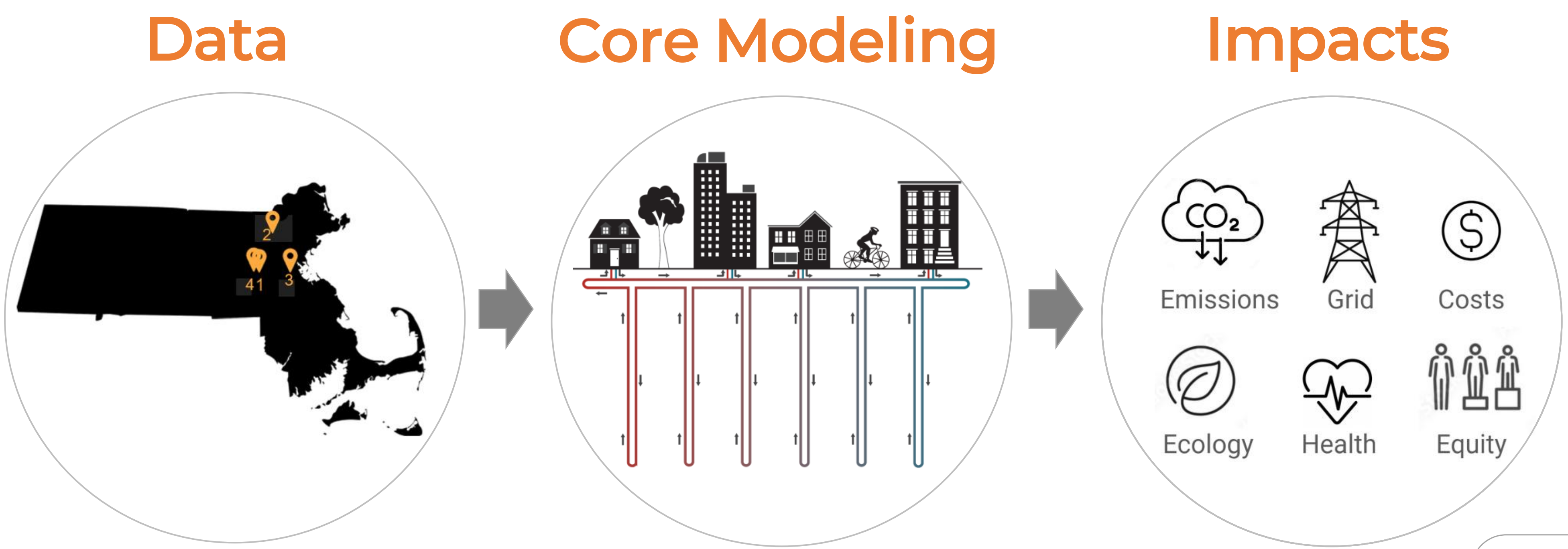
USGS

Learnings from Borefield Temperature Monitoring in an Operating GEN

Presented by Isabel Varela | HEET

Ground Heat Exchanger Science & Diagnostics Panel

NYGEO 2026 | Brooklyn NY | March 25, 2026



Learning from the Ground Up (LeGUp)

Research consortium on utility-scale geothermal networks

Goals:

- Collect & publish system data
- Create open tools for public, commercial, and research use
- Evaluate the potential and impacts of deploying TENs at a statewide scale in Massachusetts

Framingham Geothermal Pilot Project

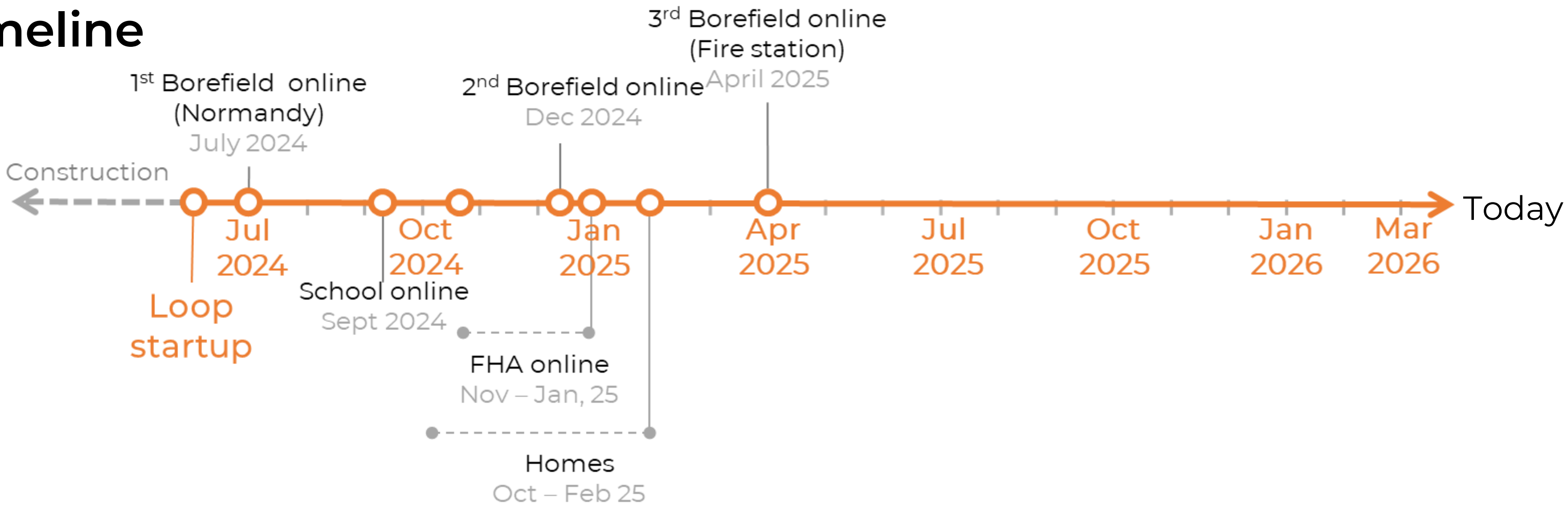
First utility-led retrofit geothermal energy network

System designed, owned and operated by Eversource

System Characteristics

- **Configuration:** Single-pipe ambient-temperature loop with geothermal boreholes
- **Main loop**: 1 mile
- **Buildings**: 36 total
    - 22 residential: single and multifamily homes
    - 9 Framingham Housing Authority apartments
    - 5 commercial: school, firehouse, gas station
- **Bore fields**: 3. **Boreholes**: 90
- **Fiber optic cable:** installed in 14 of the 90 boreholes to measure subsurface temperature

Commissioning Timeline



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SRG SOGA RESEARCH GROUP BERKELEY ENGINEERING
heet

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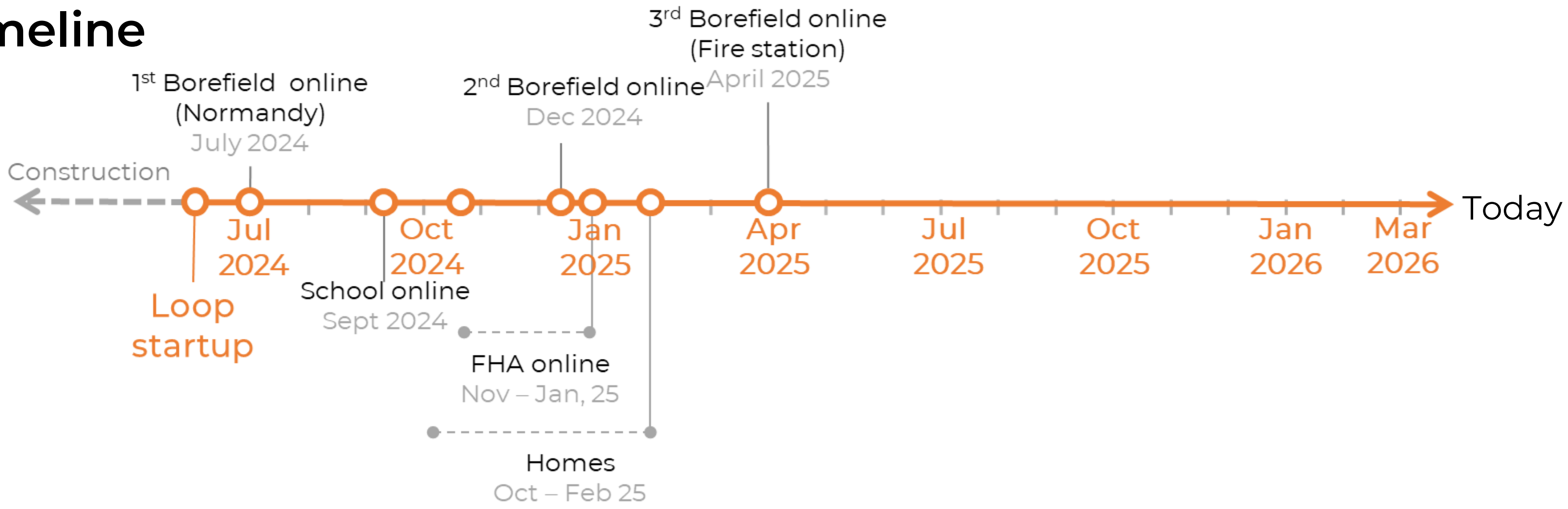

Framingham Geothermal Pilot Project

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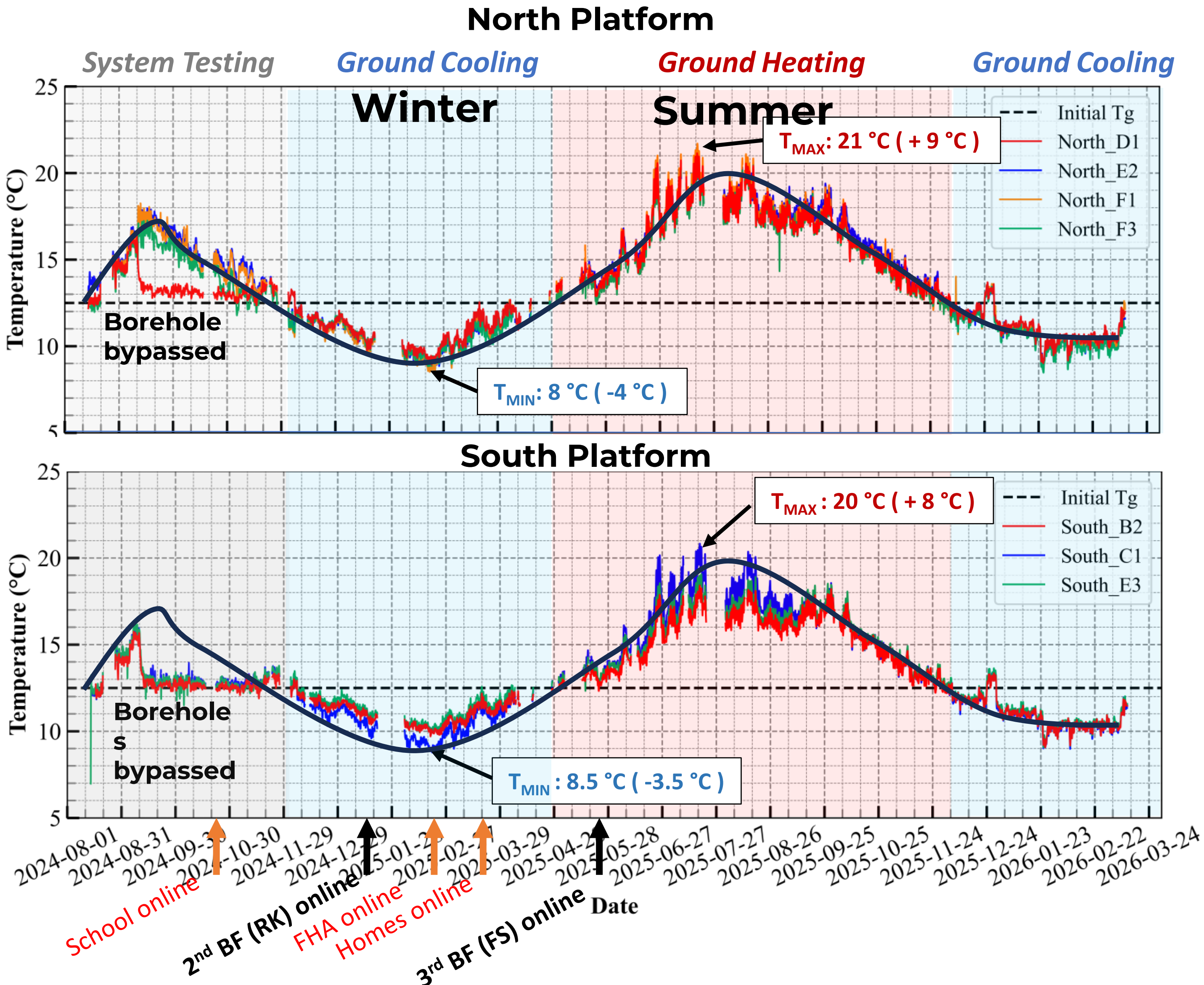
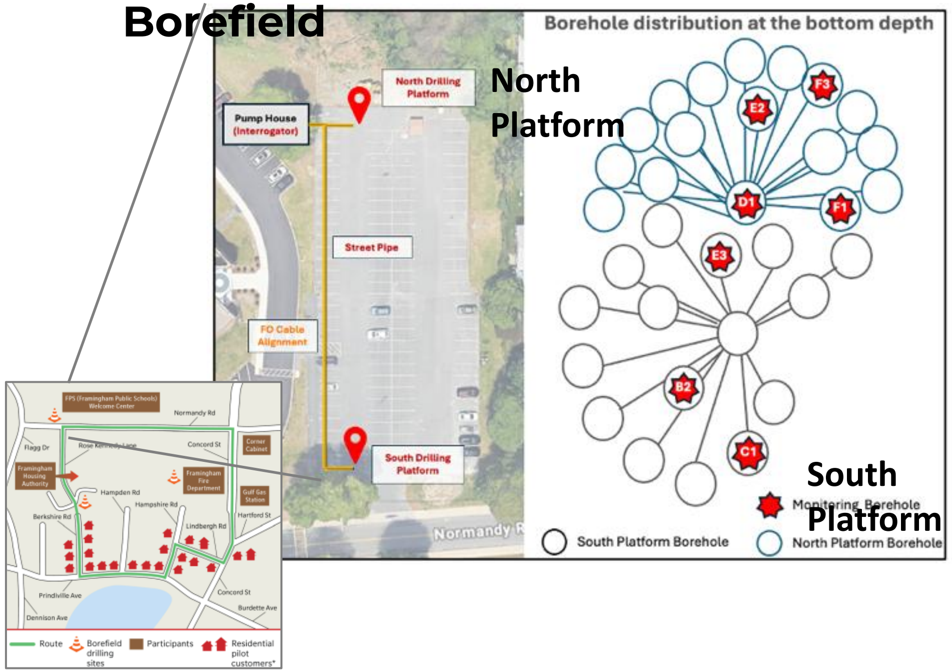
Framingham Temperatures – 1st Borefield (Normandy)

August 2024 to March 2026 (20 months)



Inclined Drilling at Normandy Borefield



Normandy is 1st borefield connected to loop

Unbalanced heating and cooling during commissioning year:

- system not fully commissioned
- use of backup electric resistance heating (?)
- more use of cooling (?)

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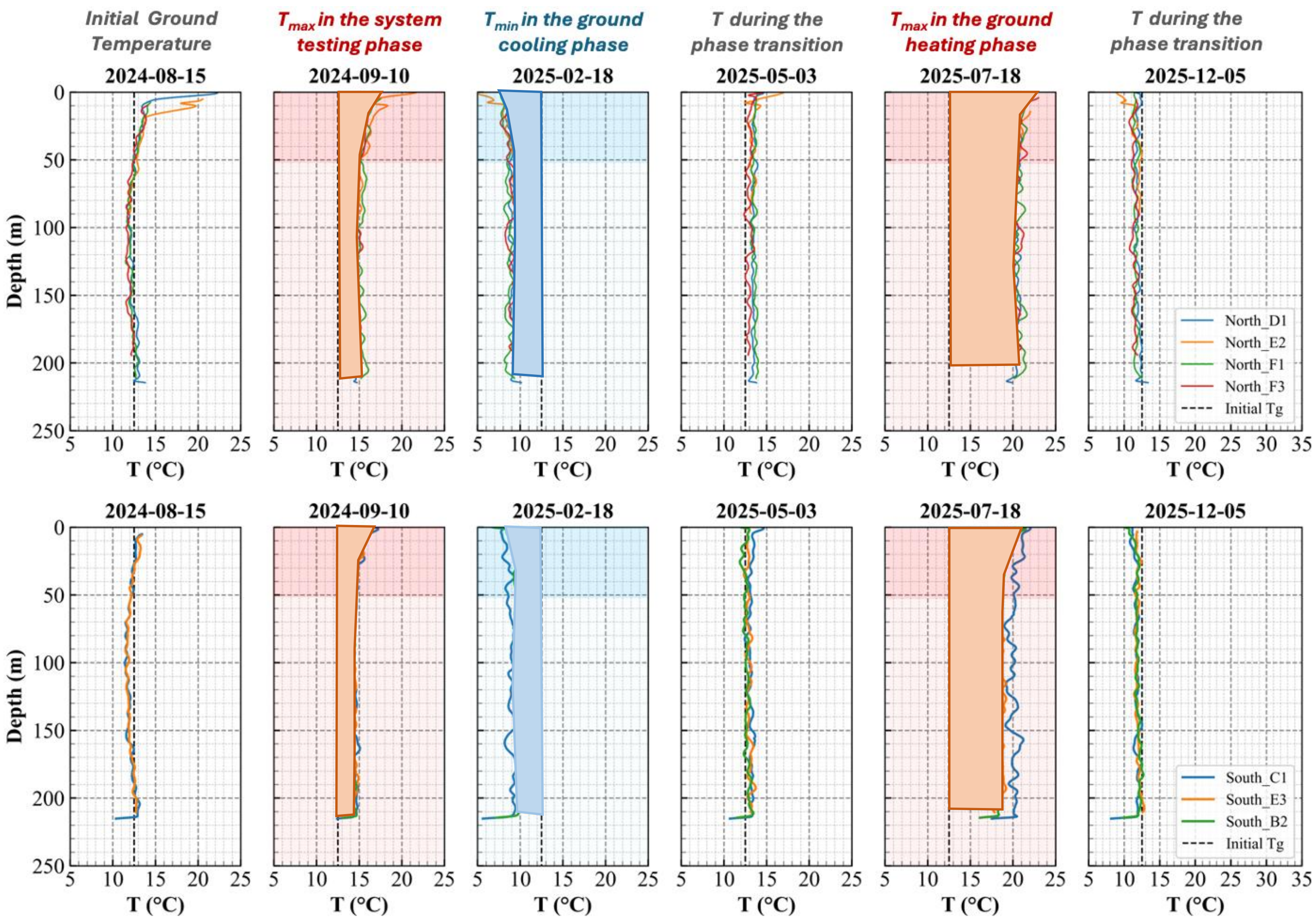
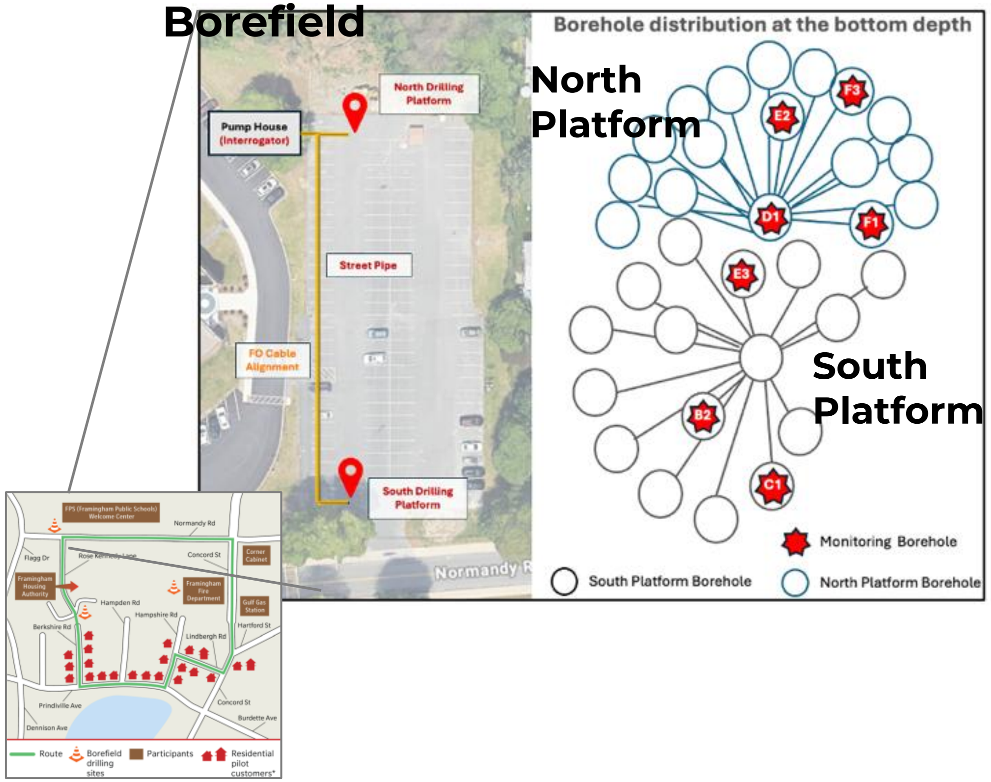
Framingham Temperatures – 1st Borefield (Normandy)

Borehole temperatures along the depth at selected times



Inclined Drilling at Normandy Borefield



- Strong thermal interaction at top 50 meters for inclined bores as expected.

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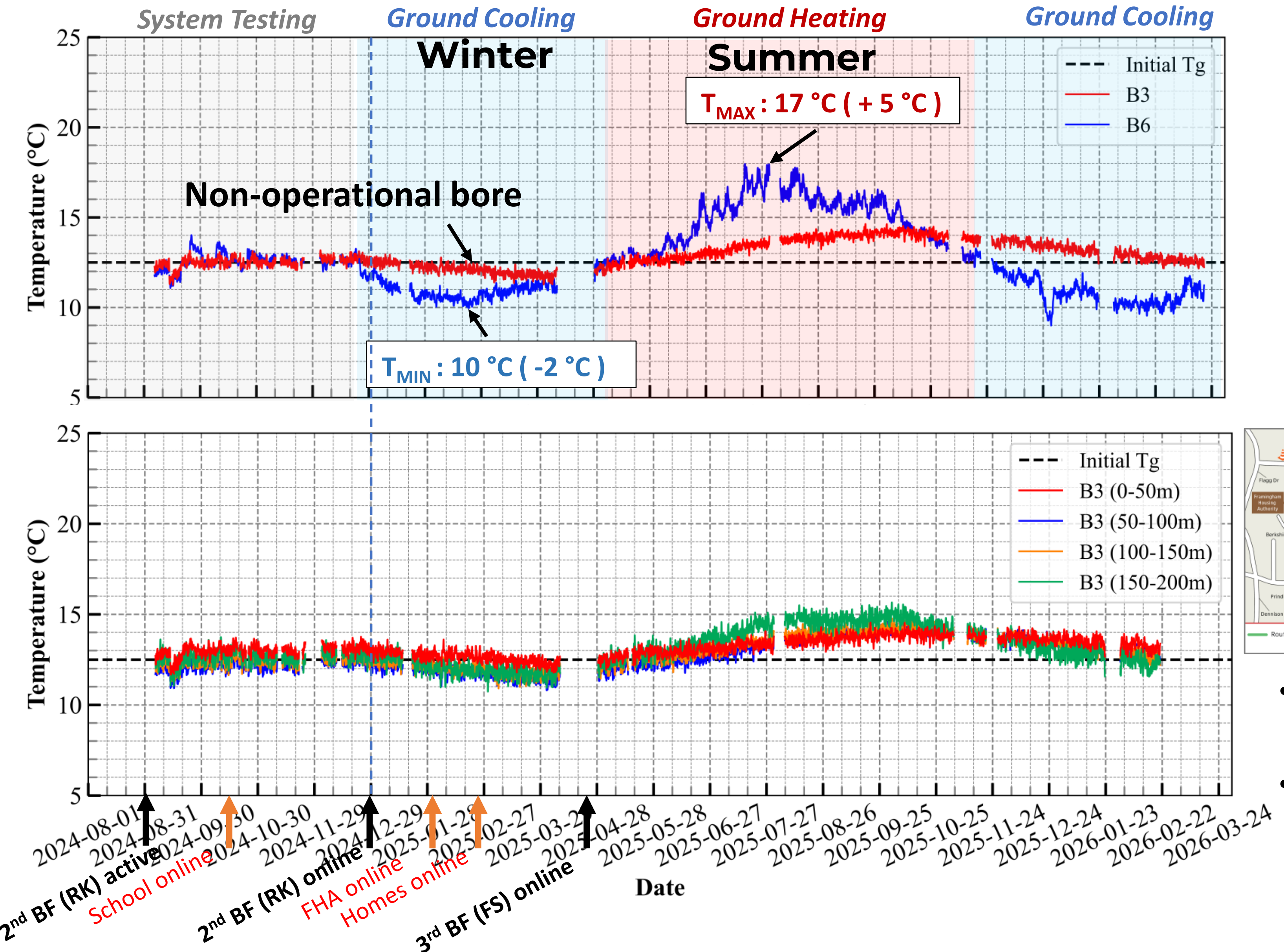
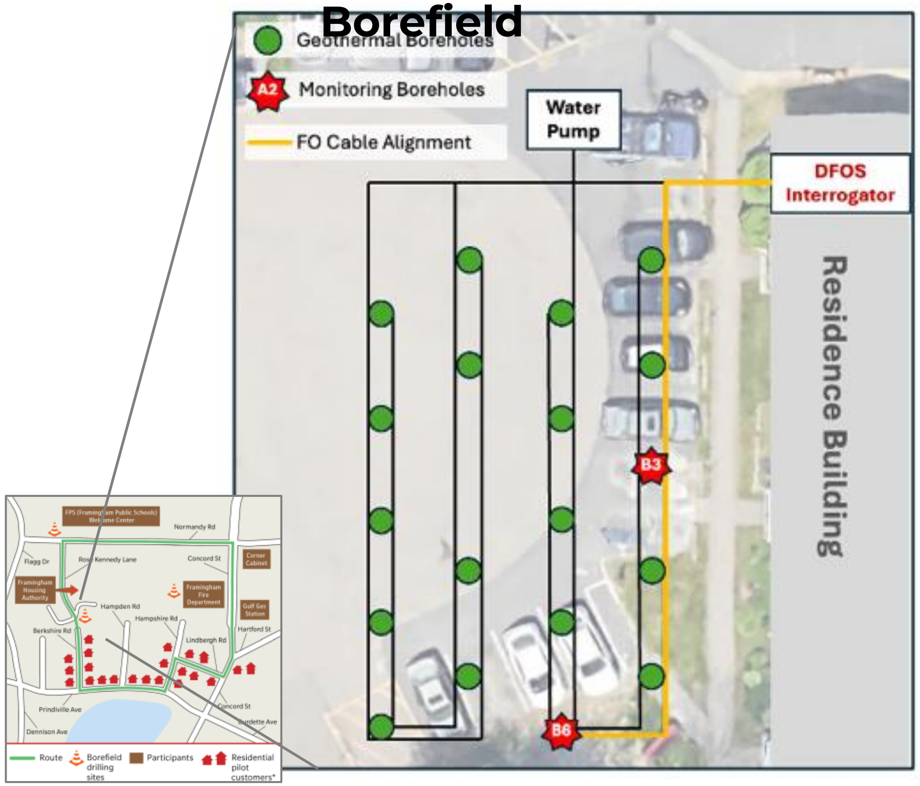
Framingham Temperatures – 2nd Borefield (Rose Kennedy)

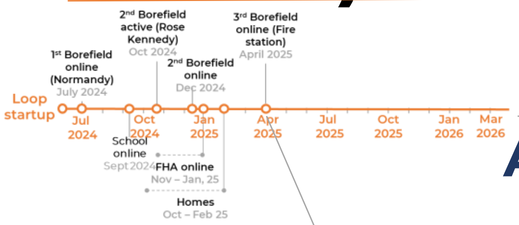


Rose Kennedy Borefield

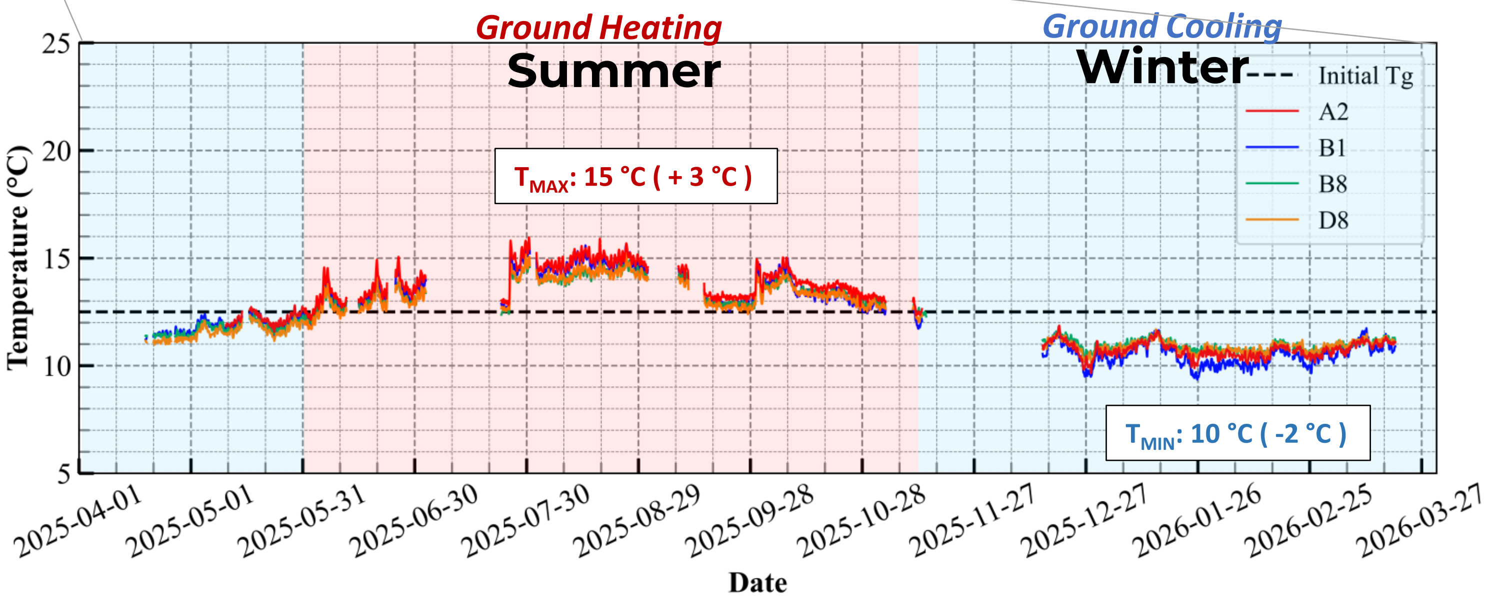


- Lower temperature change compared to 1st borefield (Normandy)
- Stronger thermal interaction below 150 meters

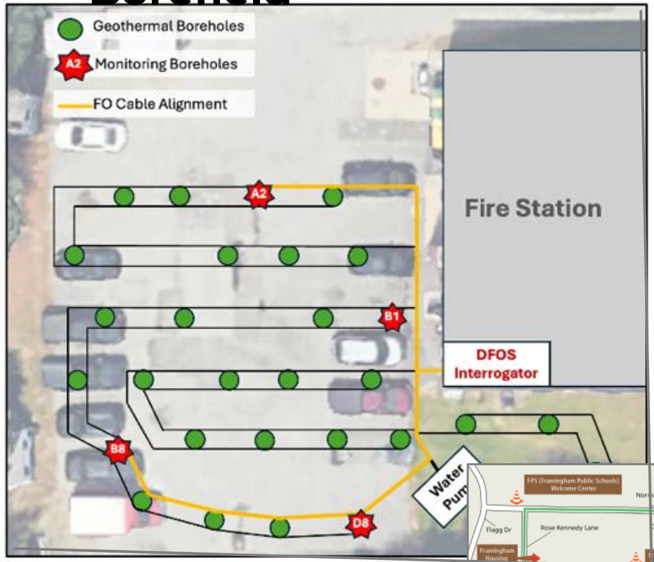
Framingham Temperatures – 3rd Borefield (Fire Station)



April 2025 to March 2026 (12 months)

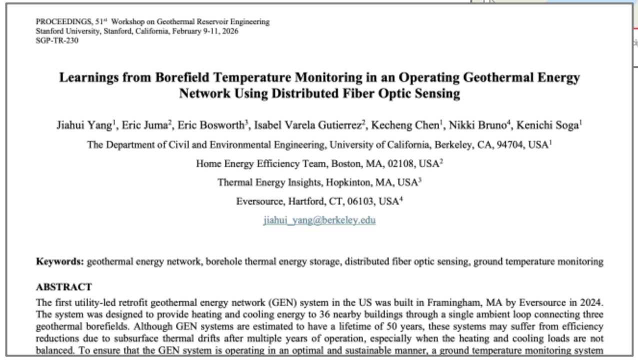


Rose Kennedy Borefield



Fire Station

- Last borefield to be connected to the loop.
- Smaller temperature change compared to 1st Normandy and 2nd (Rose Kennedy) borefields
- DFOS recording experienced several data gaps due to technical issues of the interrogator
- Operational monitoring boreholes at periphery of field


PROCEEDINGS, 51st Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, February 9-11, 2026
SGP-TR-230

Learnings from Borefield Temperature Monitoring in an Operating Geothermal Energy Network Using Distributed Fiber Optic Sensing

Jiahui Yang[1], Eric Juma[2], Eric Bosworth[3], Isabel Varela Gutierrez[2], Kecheng Chen[1], Nikki Bruno[4], Kenichi Soga[1]

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Keywords: geothermal energy network, borehole thermal energy storage, distributed fiber optic sensing, ground temperature monitoring

ABSTRACT

The first utility-led retrofit geothermal energy network (GEN) system in the US was built in Framingham, MA by Eversource in 2024. The system was designed to provide heating and cooling energy to 36 nearby buildings through a single ambient loop connecting three geothermal borefields. Although GEN systems are estimated to have a lifetime of 50 years, these systems may suffer from efficiency reductions due to subsurface thermal drifts after multiple years of operation, especially when the heating and cooling loads are not balanced. To ensure that the GEN system is operating in an optimal and sustainable manner, a ground temperature monitoring system

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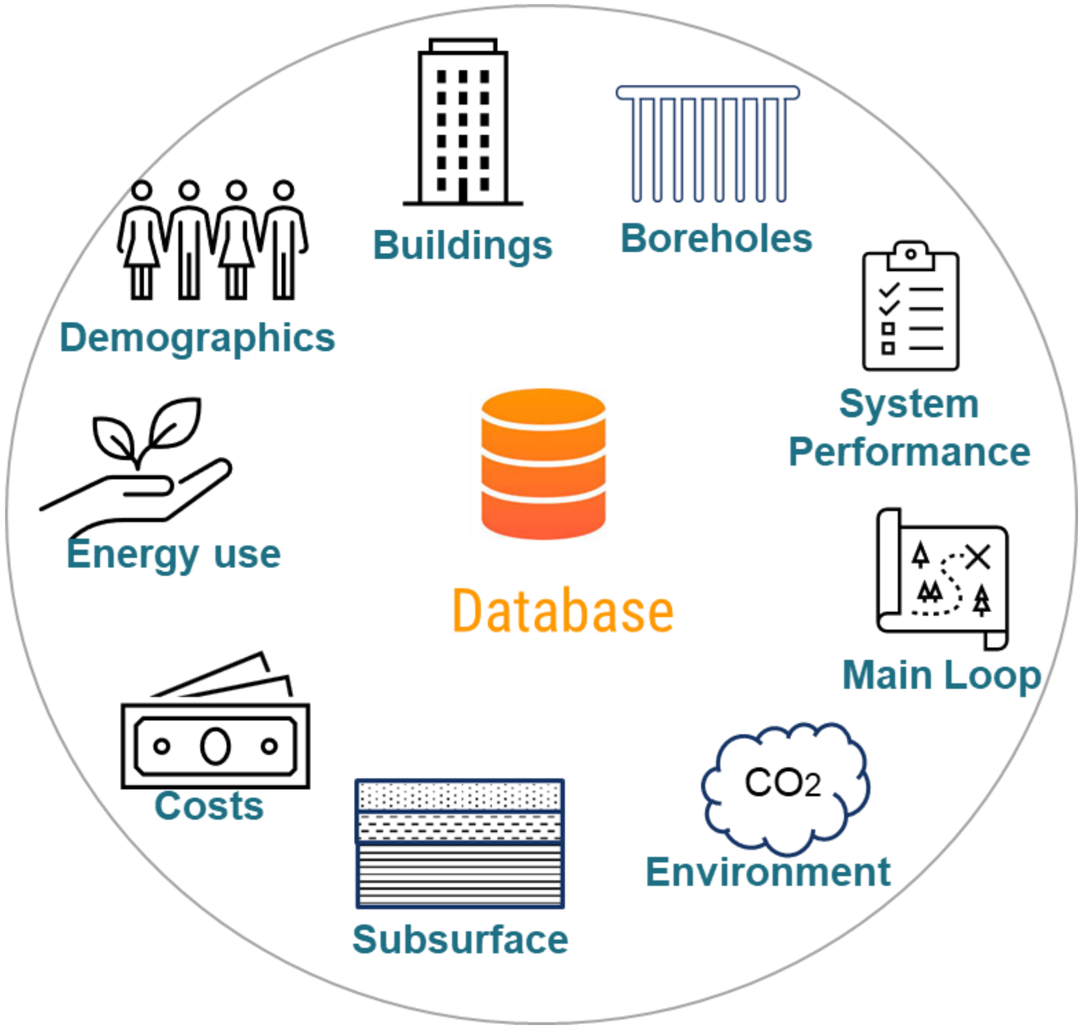
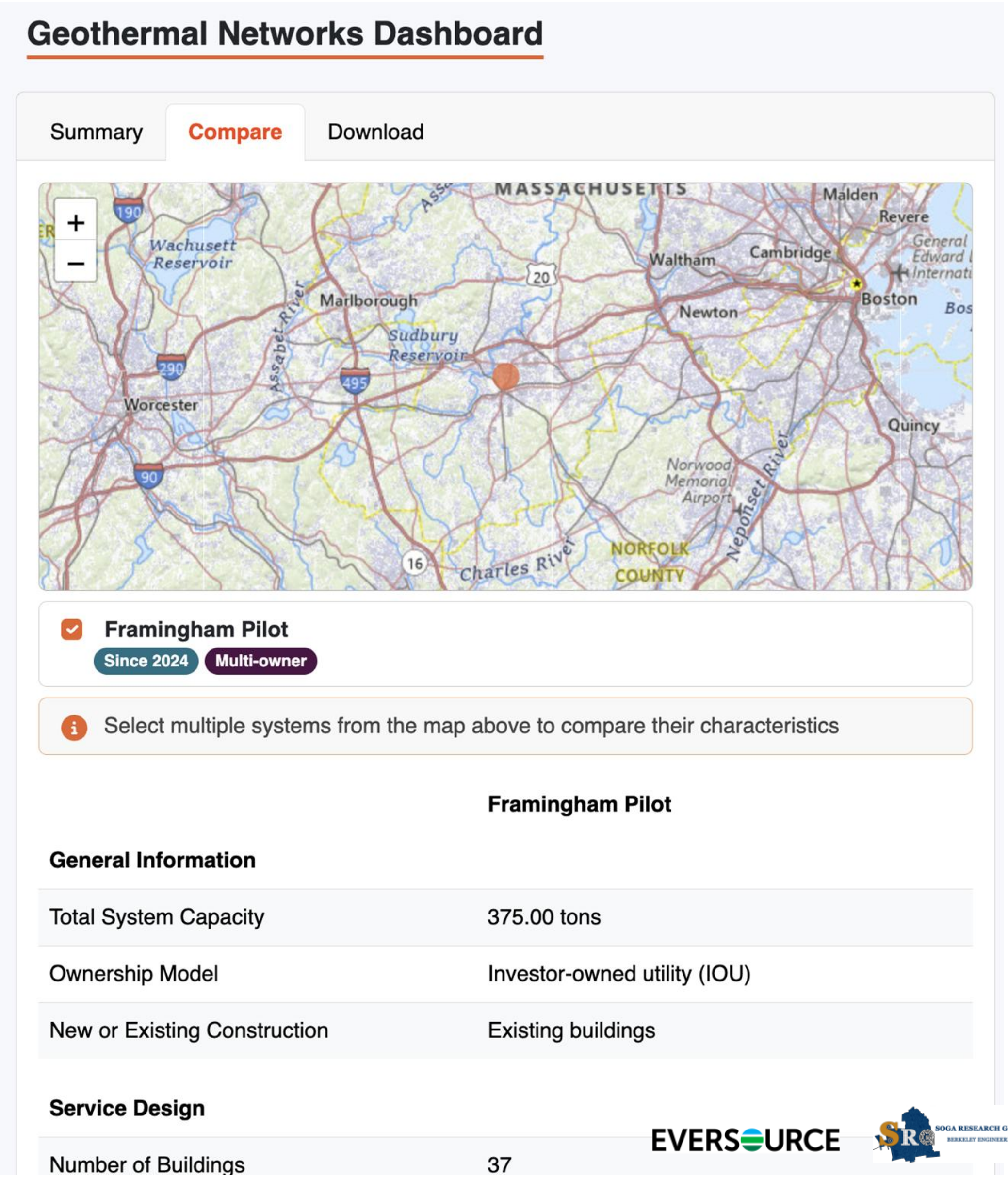
Geothermal Network Databank

heet.org/databank





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Learnings from Borefield Temperature Monitoring in an Operating GEN

Conclusions:

- System operating well within boundaries. Heating and cooling loads met without use of backup electric boiler.
- DFOS technology can help identify subsurface temperature patterns and inform system operations and optimization

What's Next

- Quantify and understand thermal storage components to inform load management and system operations.
- Further integration and analysis of interaction between subsurface and operations.
- Analyze causes of thermal imbalance and mitigation strategies

Ground Heat Exchanger Science & Diagnostics

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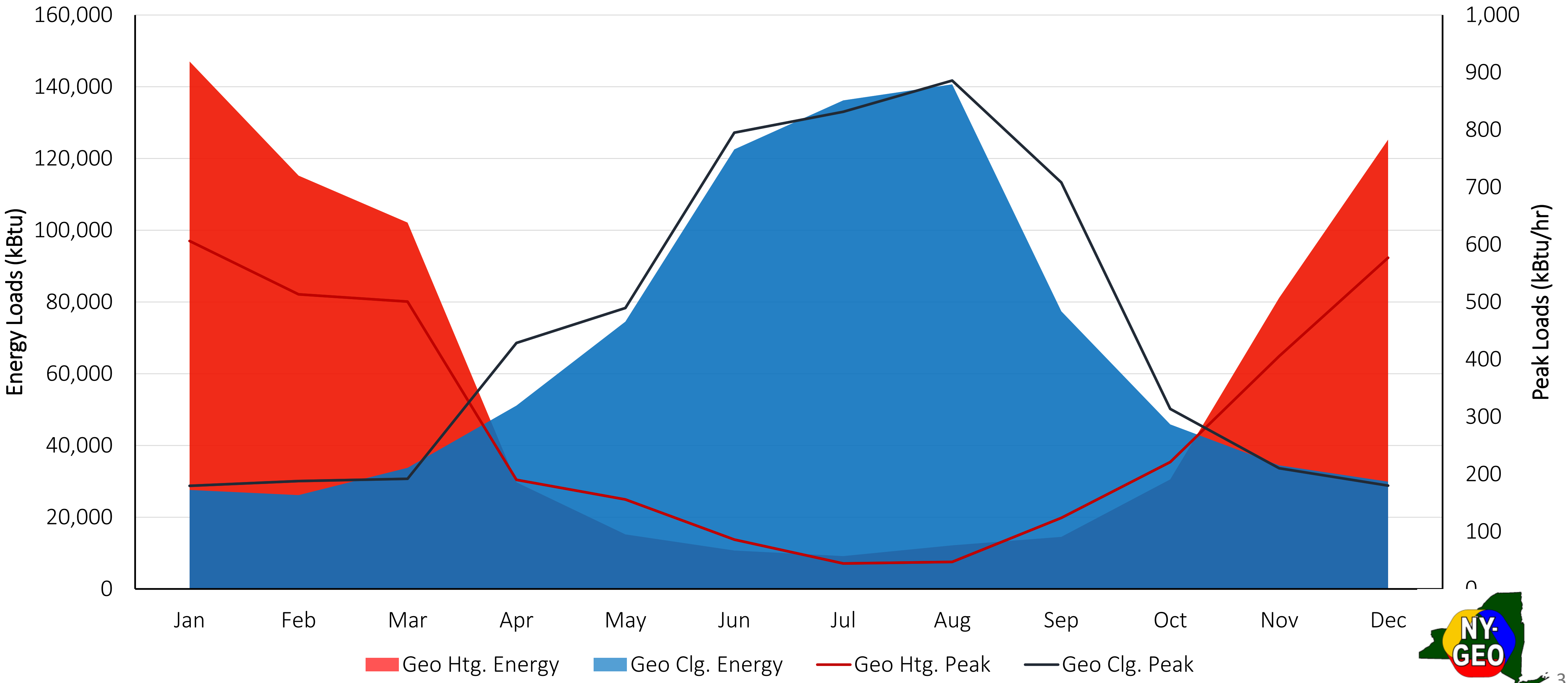
Typical Design Methodology



Typical Design Methodology

This report provides an overview of the test procedures and analysis process, along with plots of the loop temperature and input heat rate data. The collected data was analyzed using the "line source" method and the following average formation thermal conductivity was determined.

Formation Thermal Conductivity = 0.87 Btu/hr-ft-°F

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

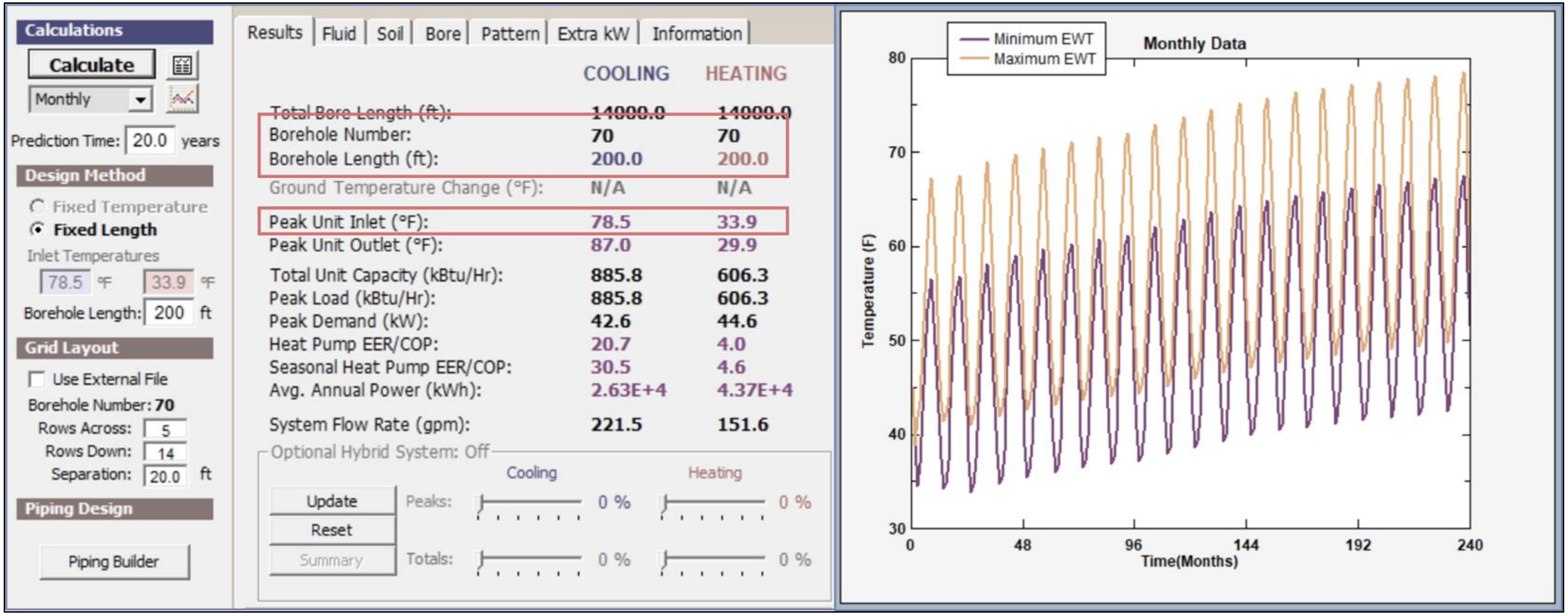
Formation Thermal Diffusivity ≈ 0.58 ft^2/day

The undisturbed formation temperature was measured by lowering a temperature probe into the water filled U-bend prior to the start of the test.

Undisturbed Formation Temperature = 46.5-47.3°F, 46.8°F average

The formation thermal properties determined by this test do not directly translate into a loop length requirement (i.e. feet of bore per ton). These parameters, along with many others, are inputs to commercially available loop-field design software to determine the required loop length.

Typical Design Methodology



Typical Design Methodology

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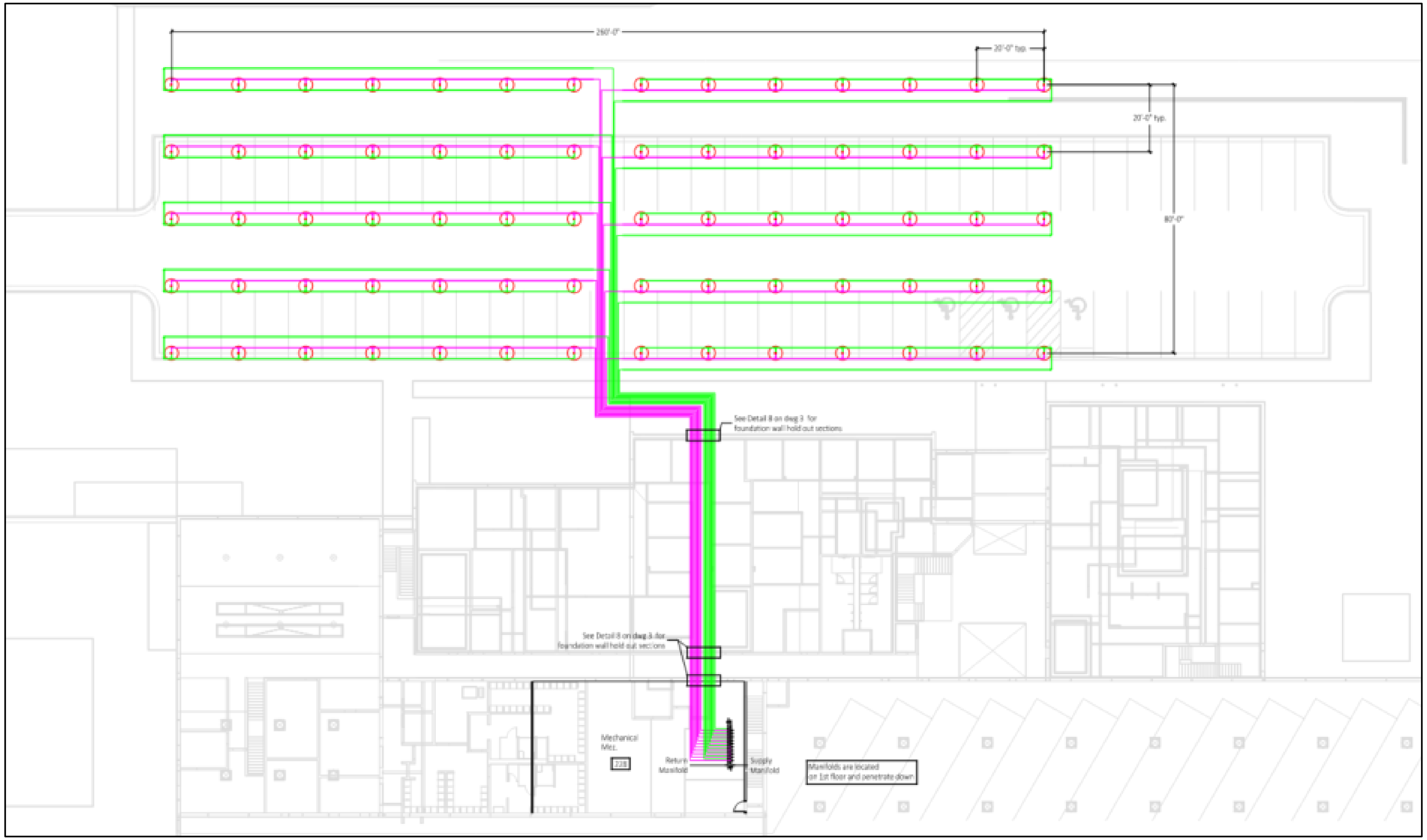

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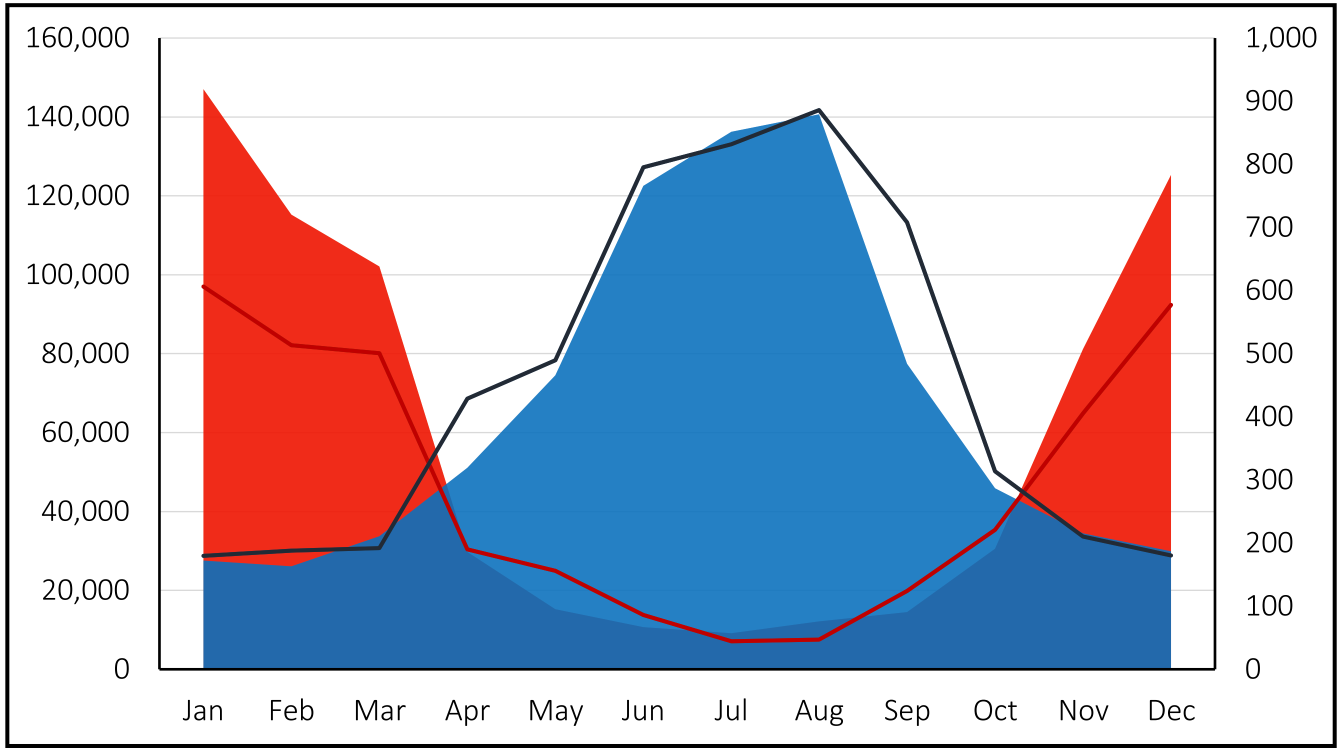
Typical Design Methodology

- Static models are often applied to dynamic systems
- GHX sizing relies on theoretical equations
- Industry standards prioritize simplicity



Data Informed Designs

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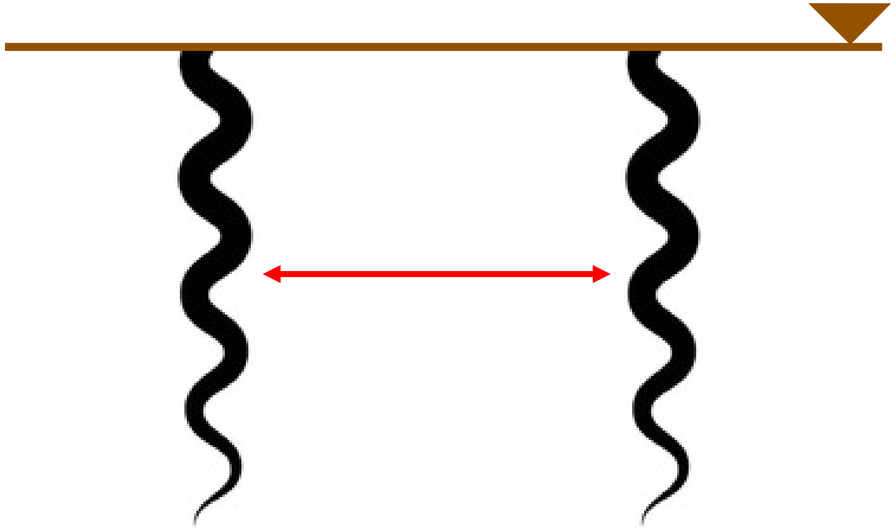
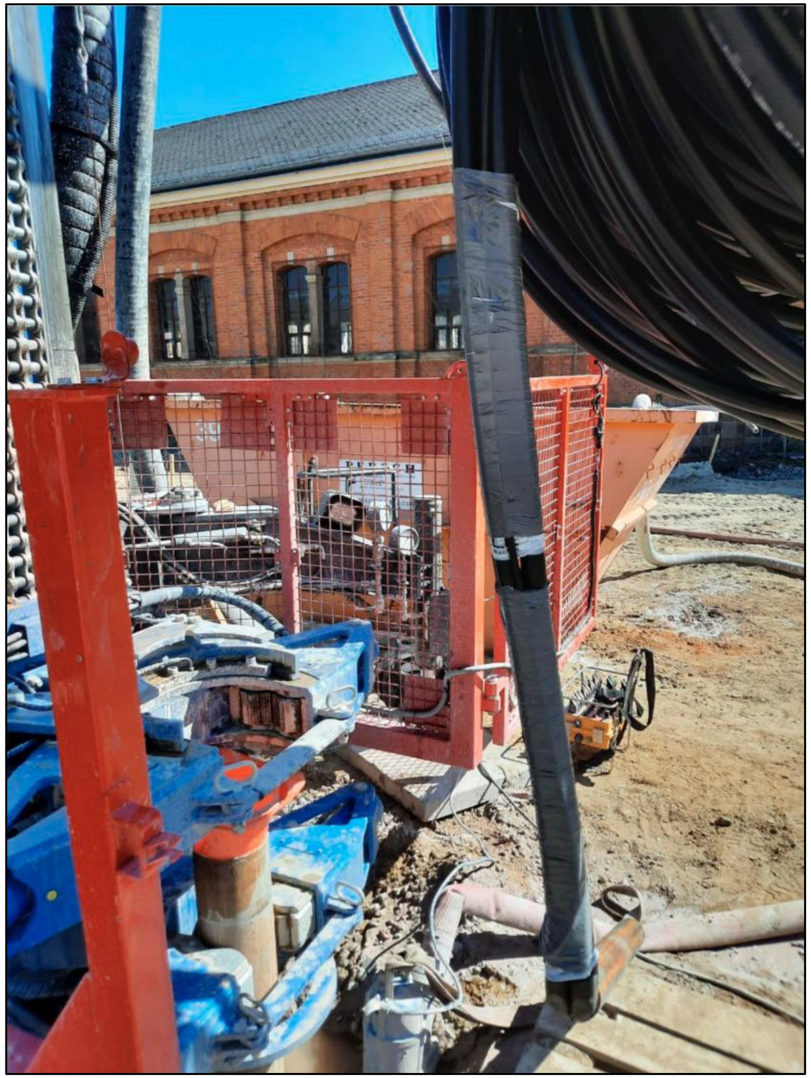
- Boreholes are often drilled in a helical pattern
- Borehole verticality measurement informs borehole spacing



Data Informed Designs

- Distributed temperature sensing (DTS) measure temperature every 0.5 – 2 ft

- DTS data inform the ideal borehole depth



Data Informed Designs

- Monitoring GHX energy informs future designs
- Theoretical models help with initial design
- Empirical models help validate performance

Example

- Toronto Condominium
- 40 boreholes @ 600 ft
- Water-to-air heat pumps in each suite
- Natural gas boiler for DHW heating

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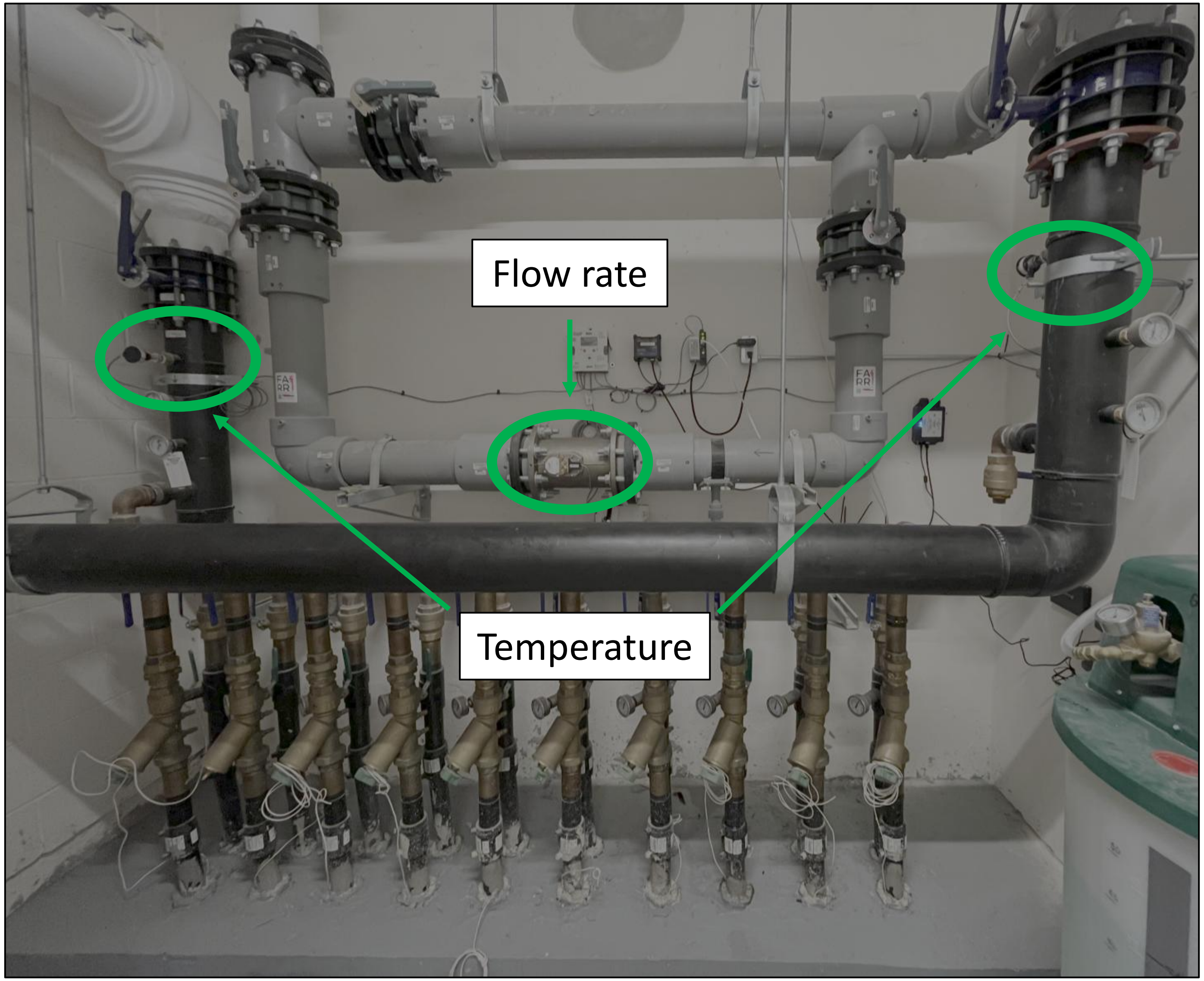
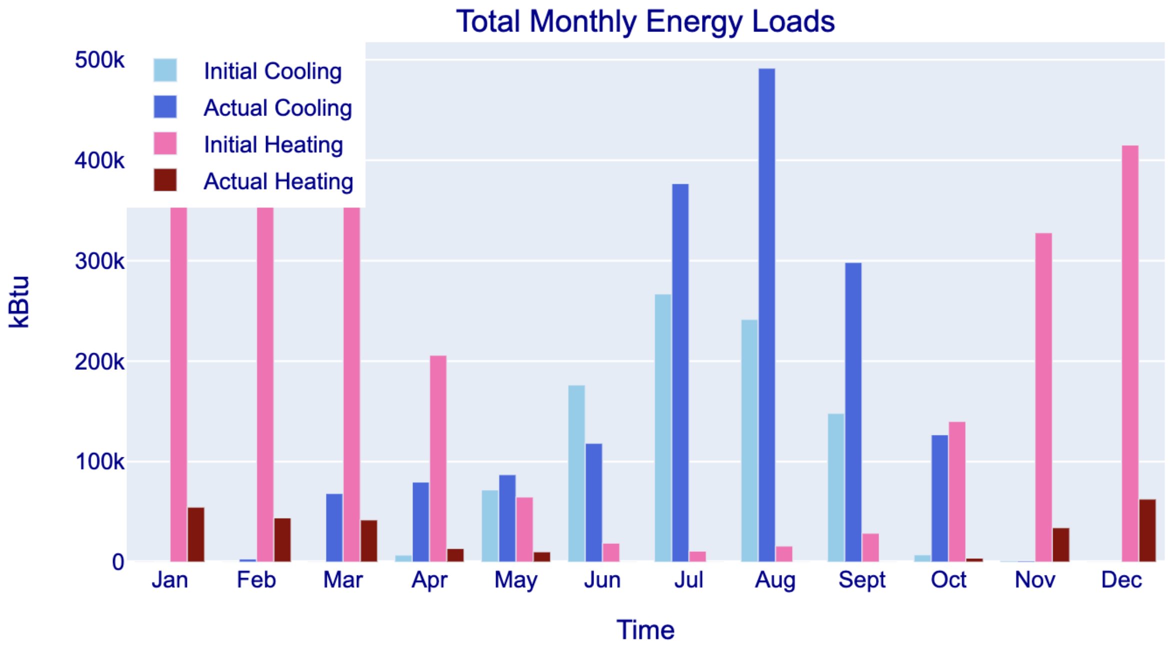
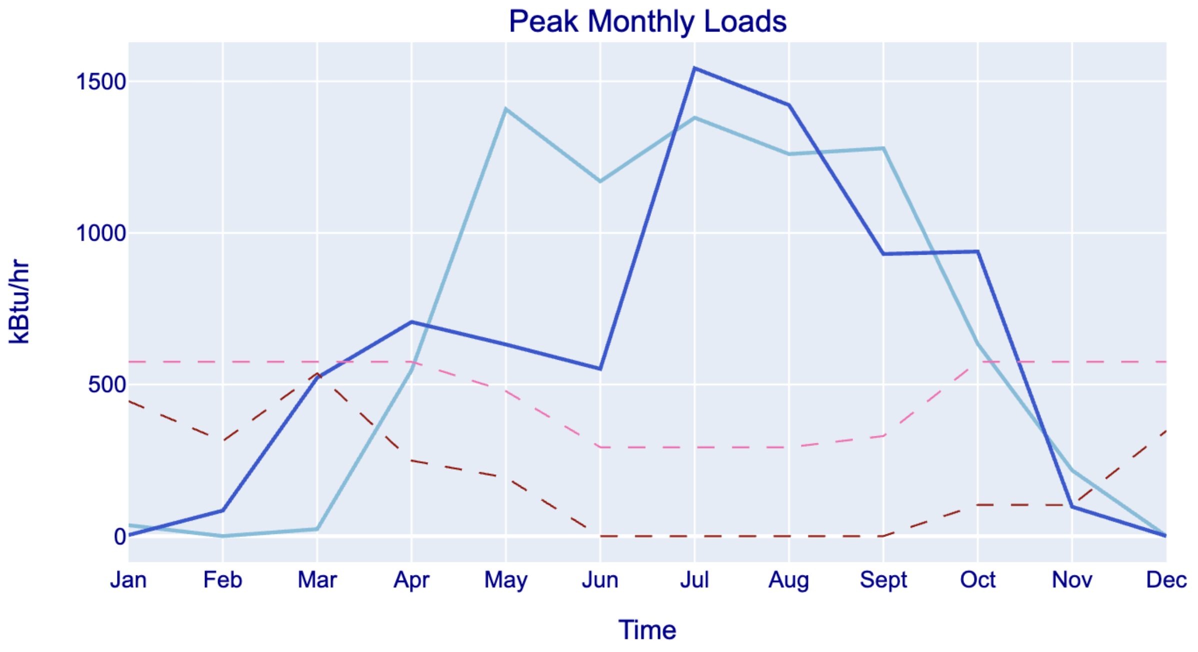


Building Load Profiles





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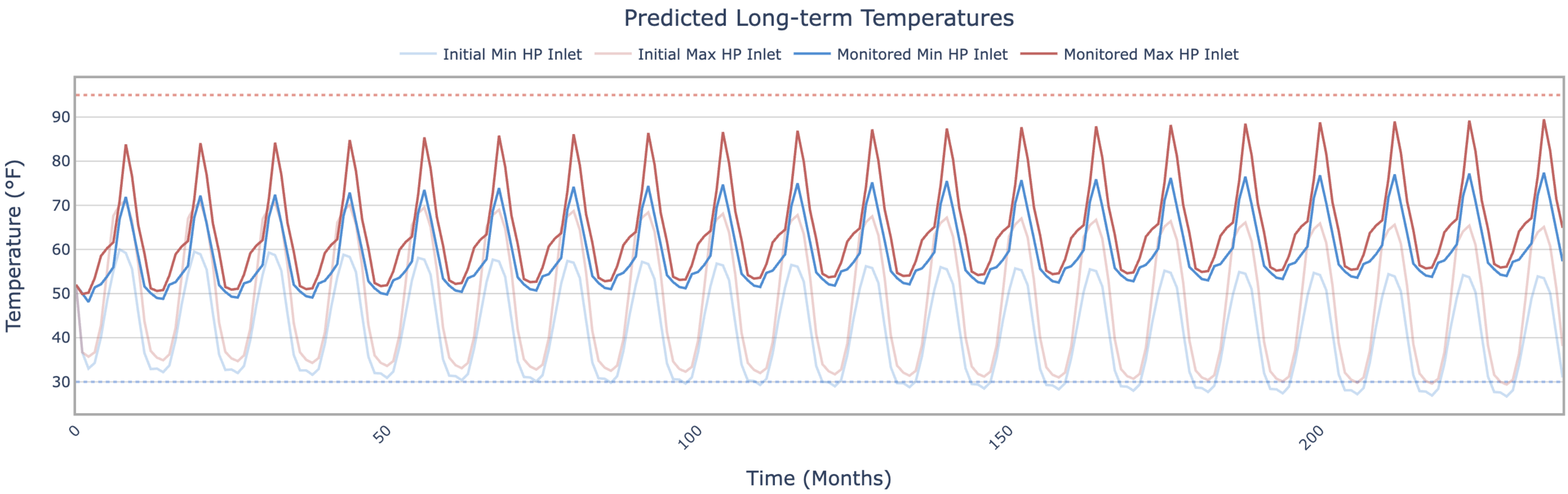

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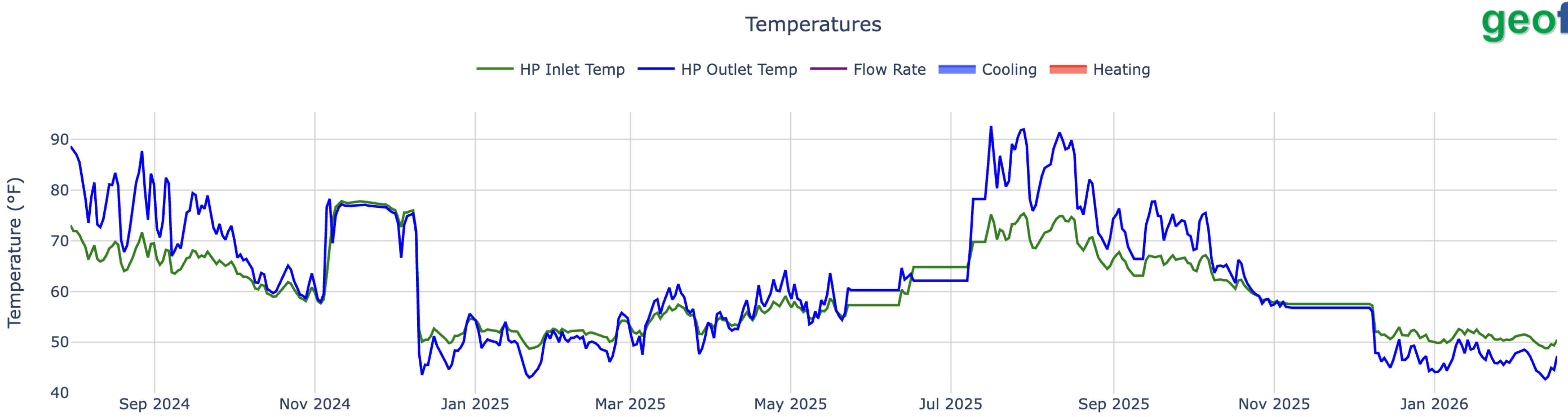
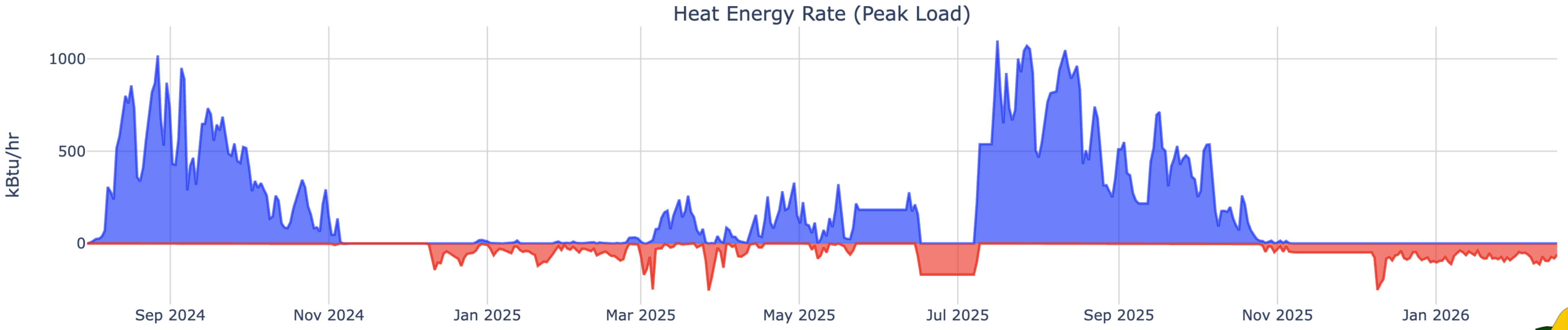

Temperatures
HP Inlet Temp
HP Outlet Temp
Flow Rate
Cooling
Heating
Temperature (°F)
90
80
70
60
50
40
Sep 2024
Nov 2024
Jan 2025
Mar 2025
May 2025
Jul 2025
Sep 2025
Nov 2025
Jan 2026


Heat Energy Rate (Peak Load)
kBtu/hr
1000
500
0
Sep 2024
Nov 2024
Jan 2025
Mar 2025
May 2025
Jul 2025
Sep 2025
Nov 2025
Jan 2026

Thank You!

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Ground Heat Exchanger
Science & Diagnostics

Moderator: Aeowyn Kendall / *Aztech Geothermal*

Panel: José Acuña / *KTH (Sweden)*
John Williams / *USGS*
Isabel Varela / *HEET*
Connor Dacquay / *GeoFease*