Soil Thermal Conductivity Testing: When and How?

Welcome!

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Gaia Geothermal

GeoCube™ Thermal Conductivity Test Equipment

About Gaia Geothermal, LLC

- USA-based software firm that develops geothermal loopfield design and TC/TRT analysis tools
- In business for over a decade
- Customers in approx. 60 countries
- www.gaiageo.com

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GeoCube™
Thermal Conductivity Test Equipment

Class Outline

- First things first: Is a geo system justified?
- Is a TC test necessary?
- What does a TC test look like in the field?
- TC test data analysis and report generation
- Typical errors and bad data sets

Learning Objectives

In today's presentation you will learn:

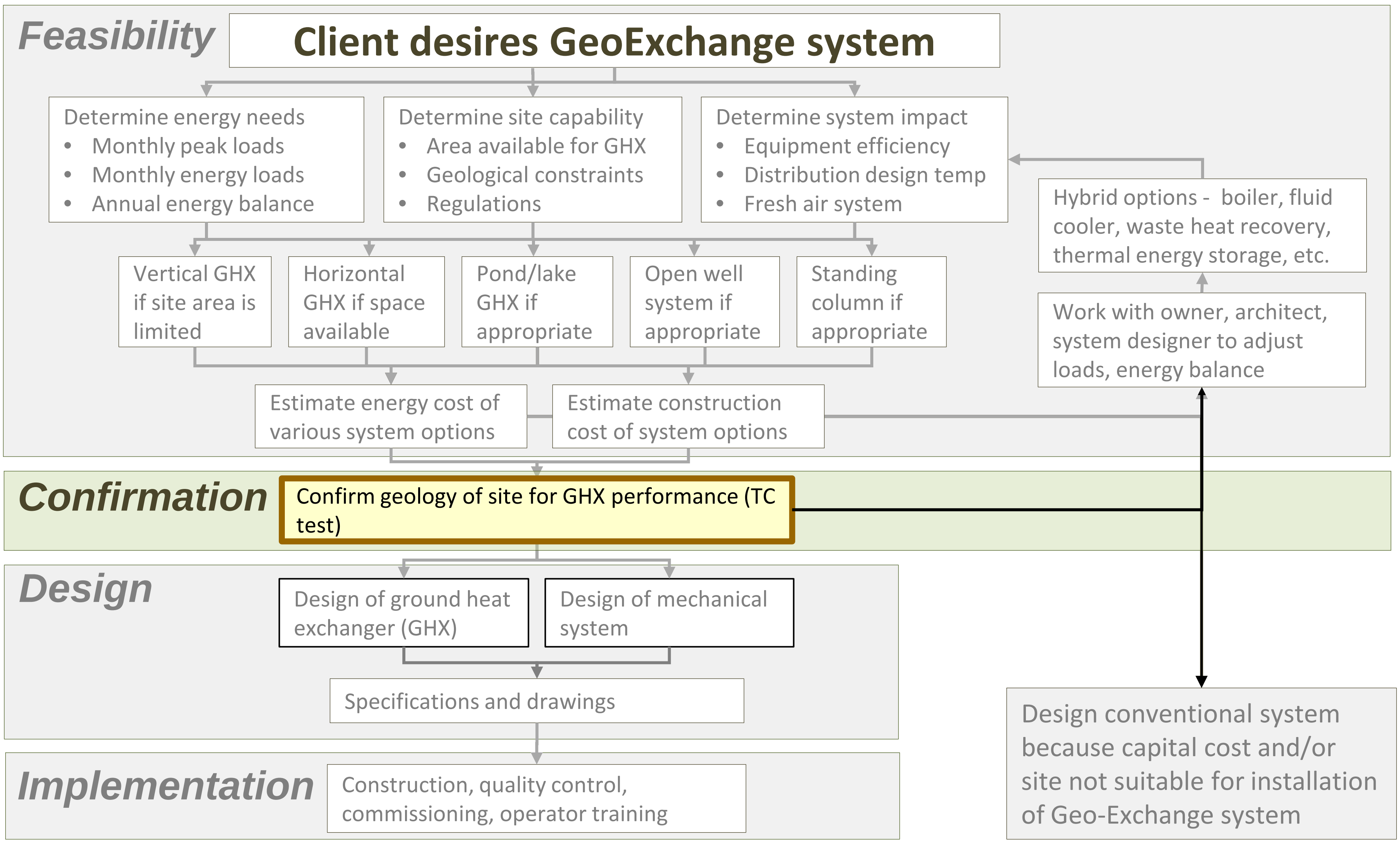
- A step-by-step process for determining if geo is a good fit for a project
- A step-by-step process for determining when it is important to conduct a TC test
- What a field TC test looks/feels like
- What good/bad TC test data look like

Is a Geo System Justified?

- Before you conduct a TC test it is important to first determine if a geothermal system is the right technology for the project
- If a geo system is a good solution a TC test is not always necessary
- There is a logical, analytic framework for determining:
  - is a geo system justified?
  - is a TC test warranted?

Is a Geo System Justified: An Example

Is a Geo System Justified?



Thanks to Terry Proffer of Major Geothermal

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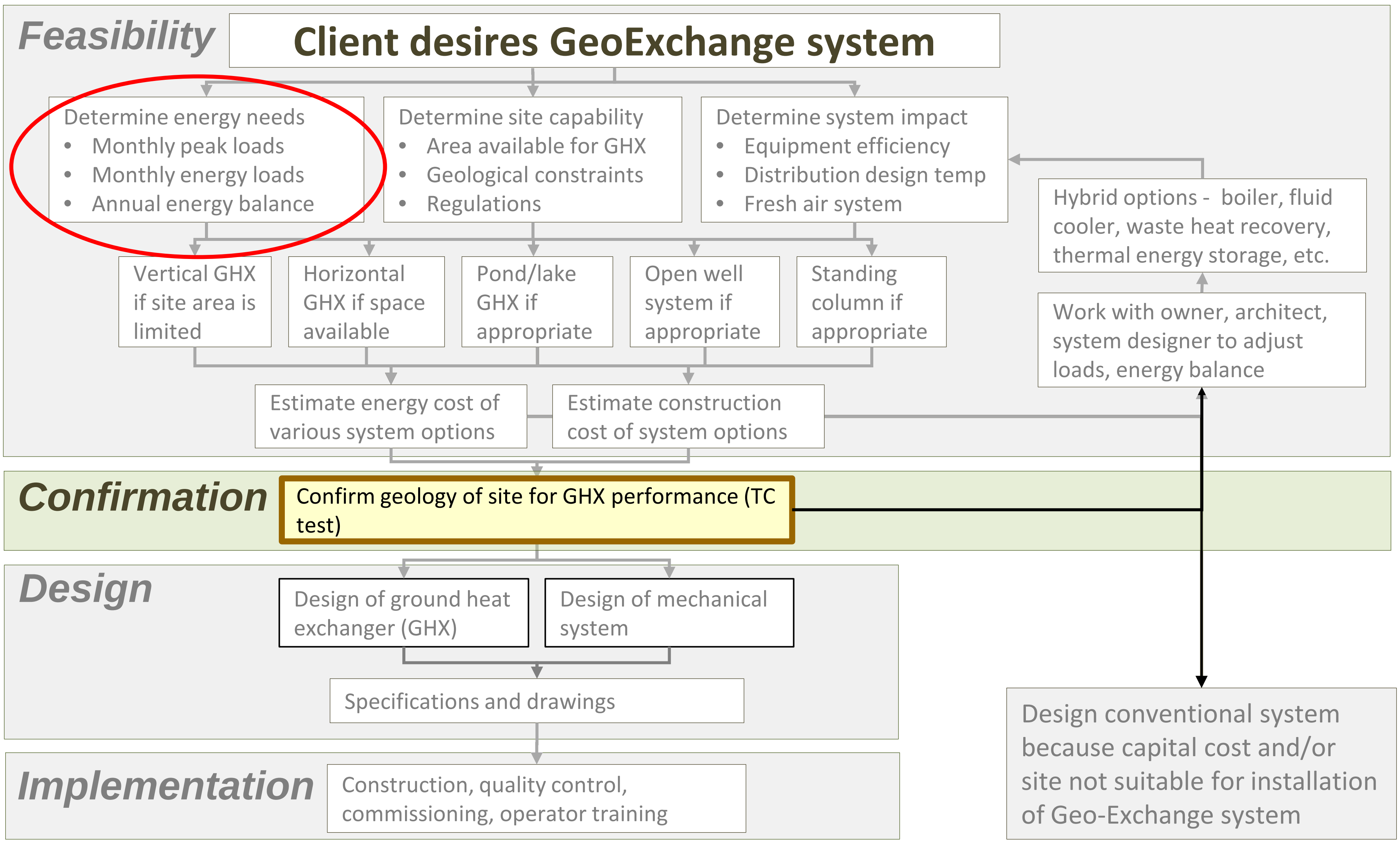
Is a Geo System Justified?



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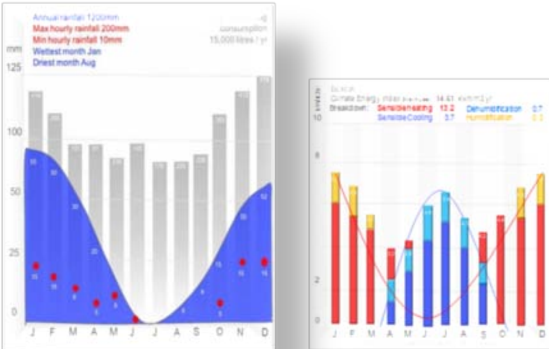
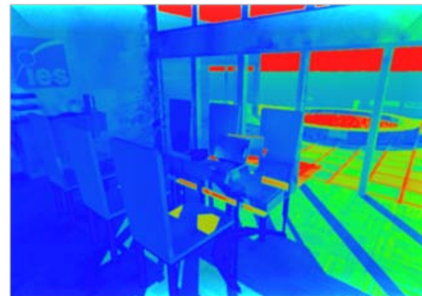
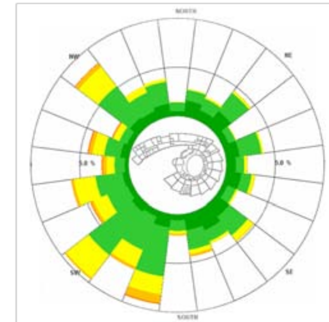
Is a Geo System Justified: Energy



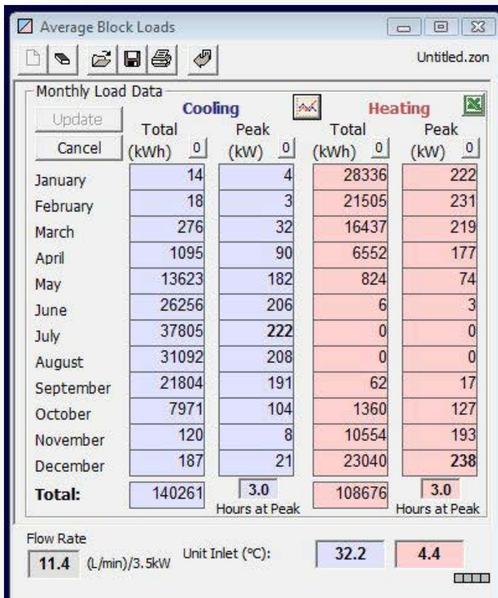
Monthly Energy Output*



Daylight contours



Climate Understanding



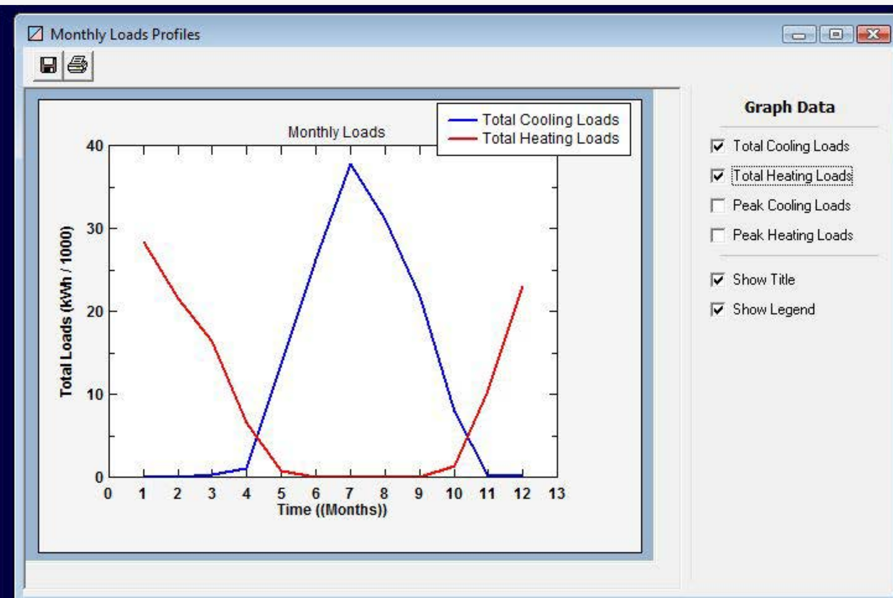
Average Block Loads

Untitled.zon

Monthly Load Data

	Cooling Total (kWh)	Cooling Peak (kW)	Heating Total (kWh)	Heating Peak (kW)
January	14	4	28336	222
February	18	3	21505	231
March	276	32	16437	219
April	1095	90	6552	177
May	13623	182	824	74
June	26256	206	6	3
July	37805	222	0	0
August	31092	208	0	0
September	21804	191	62	17
October	7971	104	1360	127
November	120	8	10554	193
December	187	21	23040	238
Total:	140261	3.0 Hours at Peak	108676	3.0 Hours at Peak

Flow Rate 11.4 (L/min)/3.5kW Unit Inlet (°C): 32.2 4.4



Is a Geo System Justified?

Feasibility

Client desires GeoExchange system

Determine energy needs
- Monthly peak loads
- Monthly energy loads
- Annual energy balance

Determine site capability
- Area available for GHX
- Geological constraints
- Regulations

Determine system impact
- Equipment efficiency
- Distribution design temp
- Fresh air system

Hybrid options - boiler, fluid cooler, waste heat recovery, thermal energy storage, etc.

Work with owner, architect, system designer to adjust loads, energy balance

Vertical GHX if site area is limited

Horizontal GHX if space available

Pond/lake GHX if appropriate

Open well system if appropriate

Standing column if appropriate

Estimate energy cost of various system options

Estimate construction cost of system options

Confirmation

Confirm geology of site for GHX performance (TC test)

Design

Design of ground heat exchanger (GHX)

Design of mechanical system

Specifications and drawings

Implementation

Construction, quality control, commissioning, operator training

Design conventional system because capital cost and/or site not suitable for installation of Geo-Exchange system

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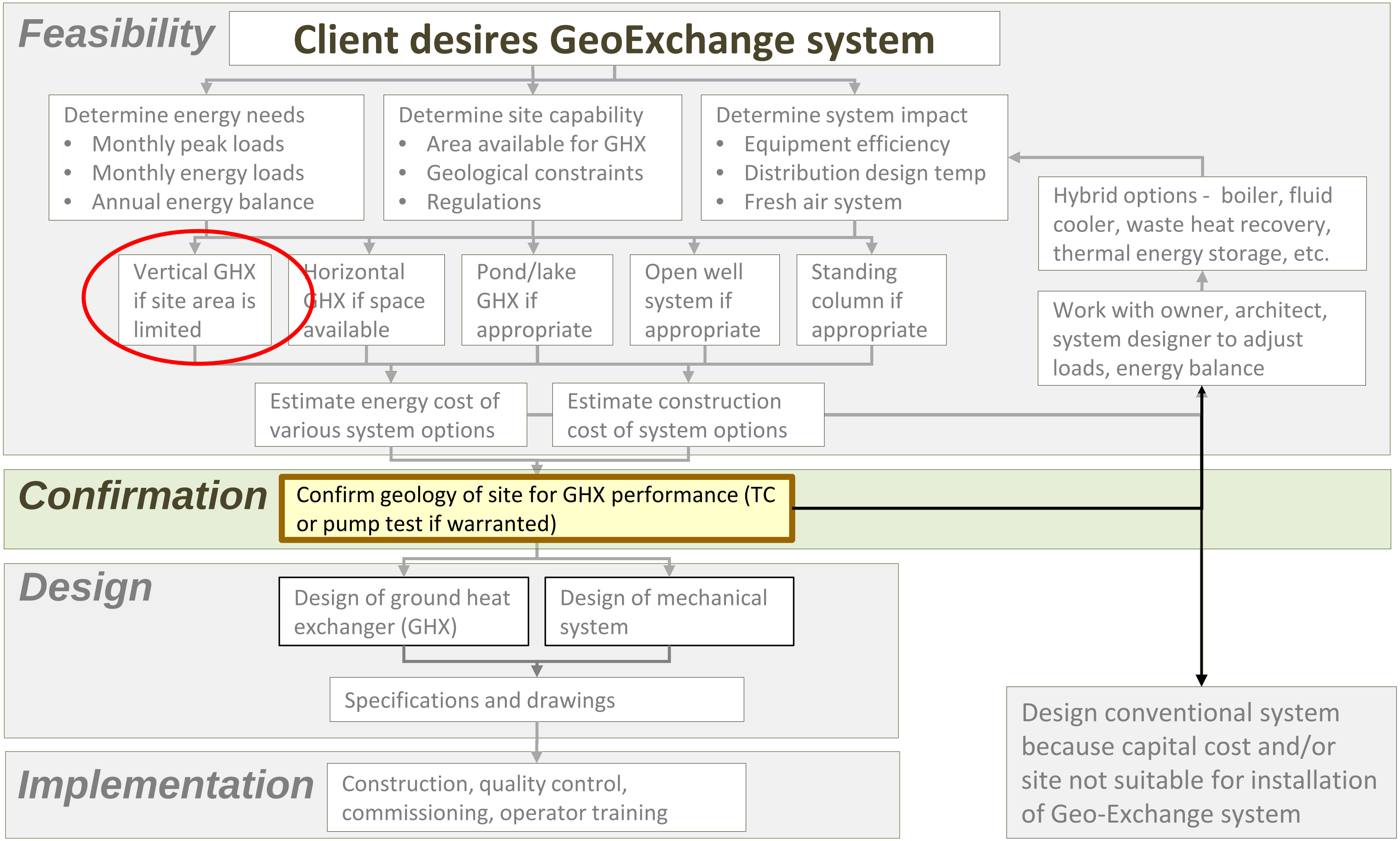
Is a Geo System Justified?



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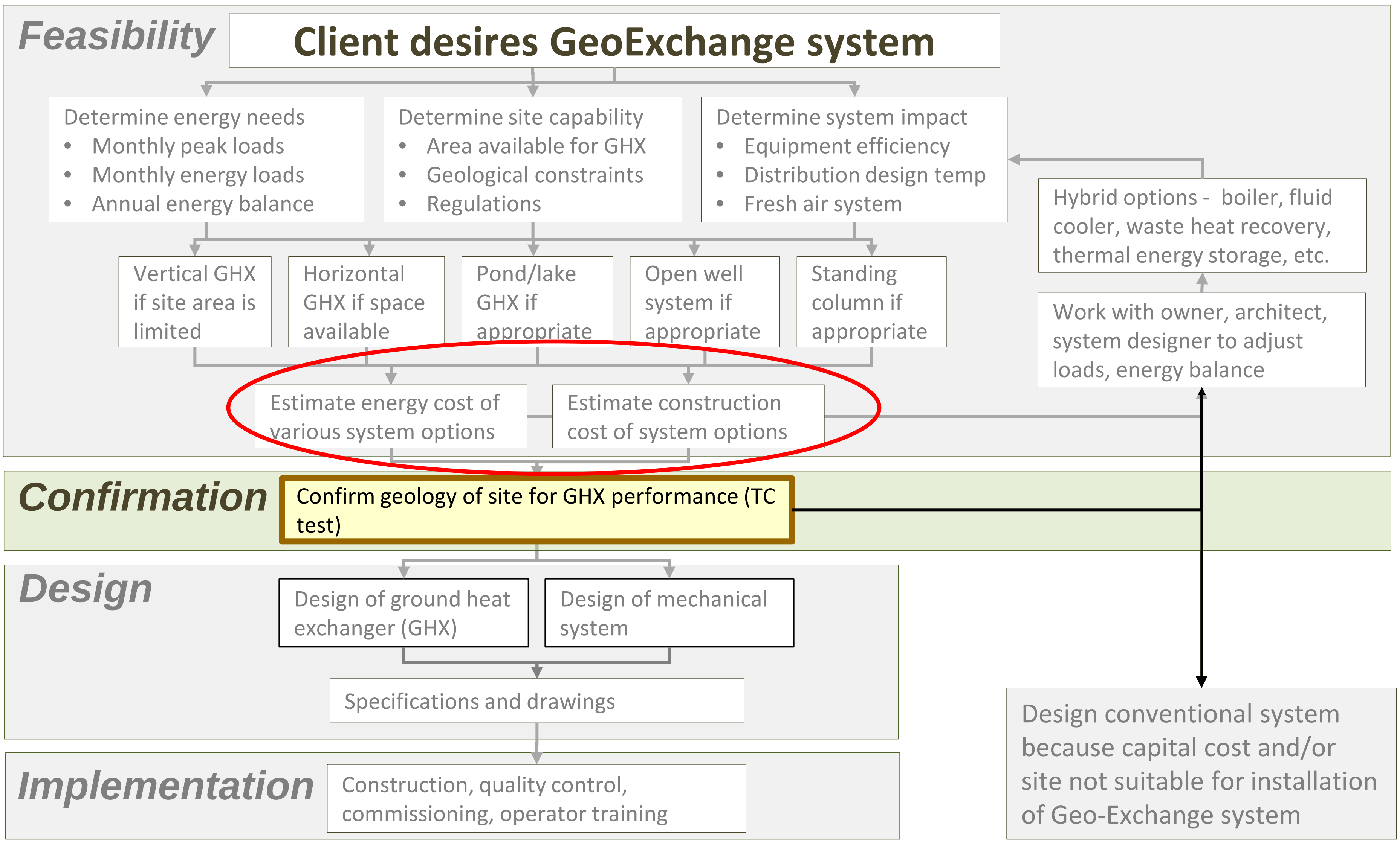
Is a Geo System Justified: The Site

Is A Geo System Justified?



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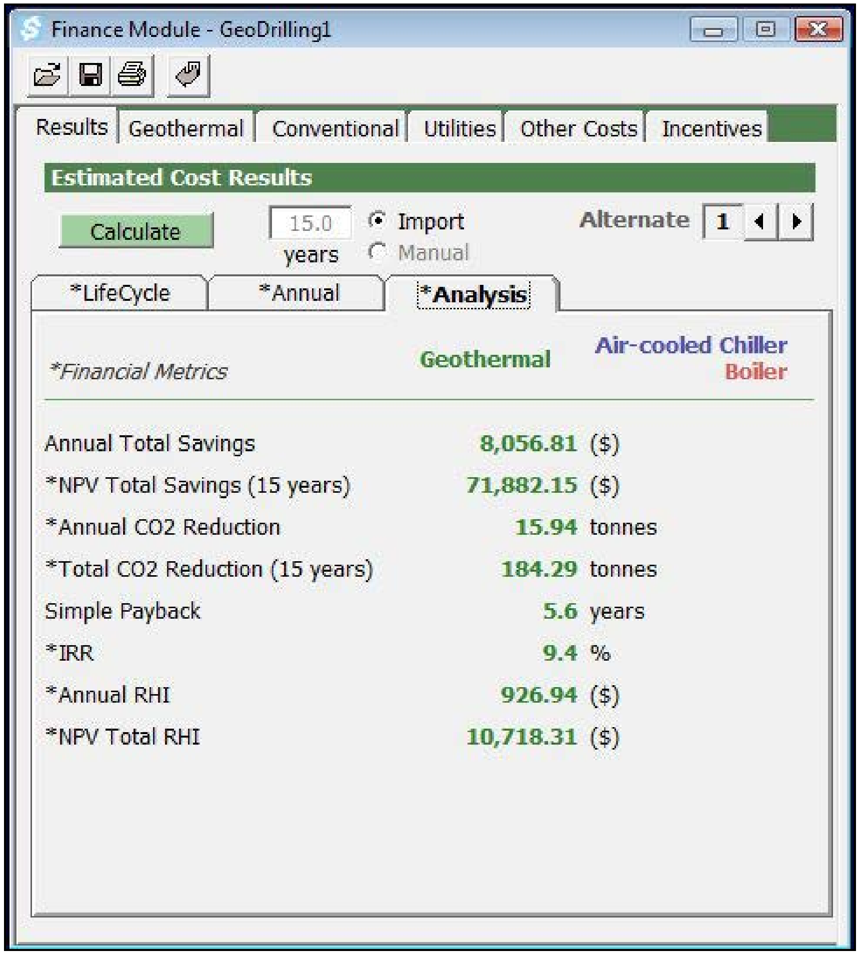
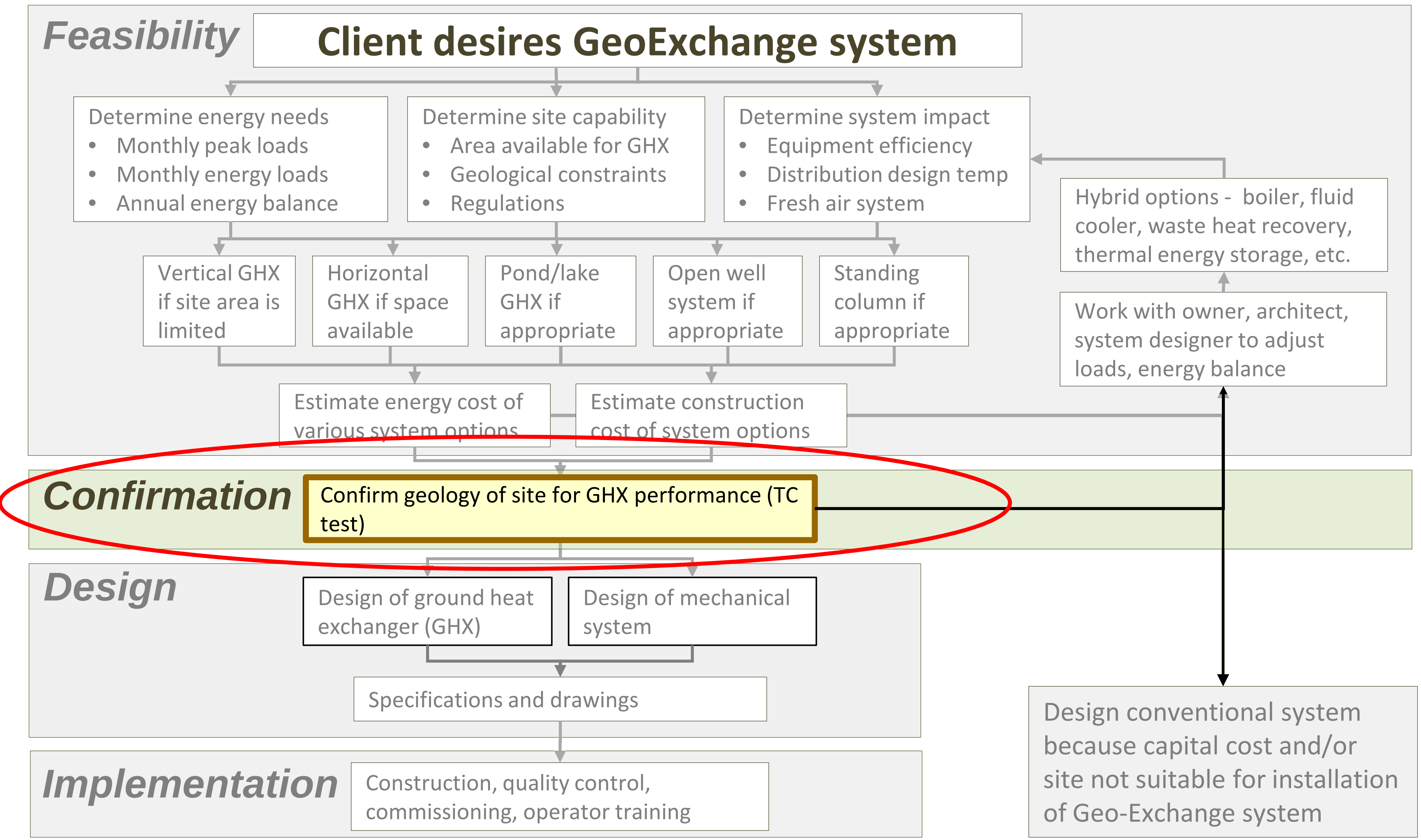
Is a Geo System Justified: Payback?



Using GLD, we can conduct a quick and comprehensive lifecycle analysis.

The Geo system payback looks good and the client decides to move forward with geo. Now, it is time to determine whether or not to conduct a TC test.

Is a TC Test Justified?

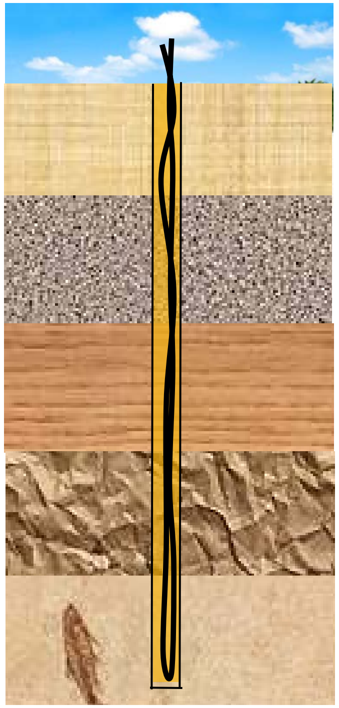


Is a TC Test Justified?

- Before you conduct a TC test it is important to first determine if it is necessary
- First estimate the conductivity
- Second, conduct a best case/worst case sensitivity analysis
- Third, compare the best case/worst case installation costs
- Determine whether or not to perform a TC test

Is a TC Test Justified: TC Estimates

Estimate the TC values from drill logs, data tables, geological data, etc.



Minnesota Unique Well No. **782101**

County: Hennepin
Quad: Hopkins
Quad ID: 104B

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
Minnesota Statutes Chapter 103I

Entry Date: 12/14/2010
Update Date: 03/07/2011
Received Date: 02/18/2011

Well Name DNR OB 27059
Township Range Dir Section Subsections Elevation: 118 22 W 32 ACAAAA — 972 ft.
Elevation Method: 7.5 minute topographic map (+/- 5 feet)

Well Depth: 953 ft. — Depth Completed: 953 ft. — Date Well Completed: 01/26/2011
Drilling Method: Dual Rotary

Drilling Fluid: Water
Well Hydrofractured? ☐ Yes ☑ No
From Ft. to Ft.

Use: Monitor well

Casing Type: Steel (black or low carbon) Joint: Welded Drive Shoe? ☑ Yes ☐ No Above/Below ft.

Casing Diameter	Weight	Hole Diameter
10 in. to 192 ft.	40.48 lbs./ft.	10.75 in. to 235 ft.
4 in. to 855 ft.	10.79 lbs./ft.	10 in. to 953 ft.

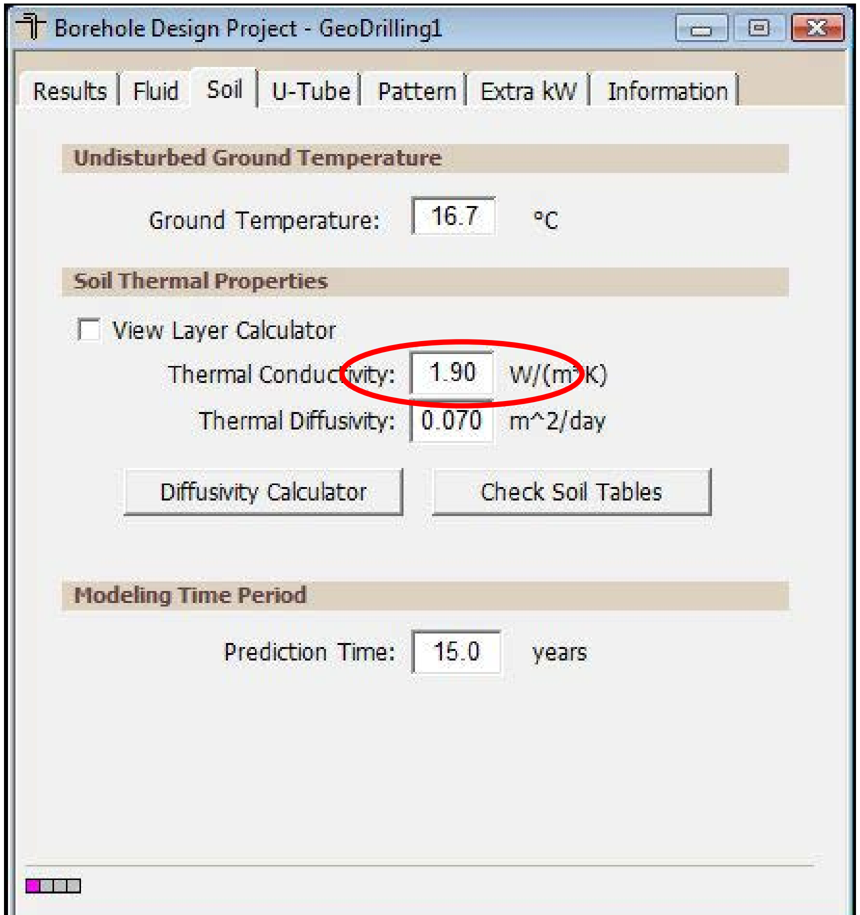
Open Hole from 855 ft. to 953 ft.

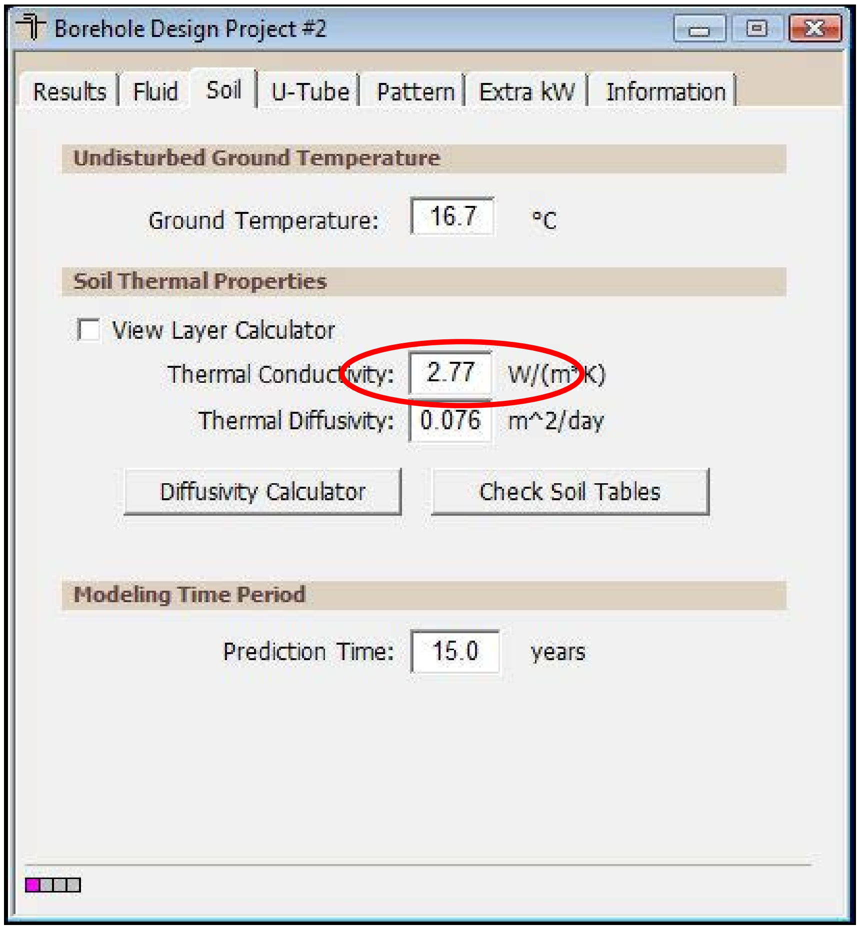
Screen NO Make Type

Geological Material	Color	Hardness	From	To
SAND	BROWN	SOFT	0	1
GRAVEL/CLAY	BROWN	SOFT	1	9
GRAVEL/SAND	BROWN	SOFT	9	33
FINE SILTY SAND	BROWN	SOFT	33	68
SAND, GRAVEL, CLAY, ROCKS	BROWN	SOFT	68	95
SAND, GRAVEL, ROCKS	BROWN	SOFT	95	129
CLAY & GRAVEL	BROWN	SOFT	129	155
CLAY & GRAVEL	GRAY	SOFT	155	170
MEDIUM SAND	BROWN	SOFT	170	182
GRAVEL	GRAY	SOFT	182	192
SHALE	BRN/GRN	SOFT	192	197
SANDSTONE	GRAY	SOFT	197	210
SANDSTONE	GRY/BRN	SOFT	210	226
SANDSTONE & SHALE	BRN/RED	SOFT	226	229
SANDSTONE & SHALE	VARIED	MED-HRD	229	235
LIMESTONE	TAN/PNK	MED-HRD	235	375
SANDSTONE	WHITE	MEDIUM	375	390
SANDSTONE	WHT/PNK	MEDIUM	390	407
SANDSTONE & SHALE LAYERS	VARIED	MEDIUM	407	425
SANDSTONE	WHT/PNK	MEDIUM	425	460
SANDSTONE & SHALE	GRY/GRN	MEDIUM	460	470
SANDSTONE & SHALE	TAN/GRN	MEDIUM	470	510

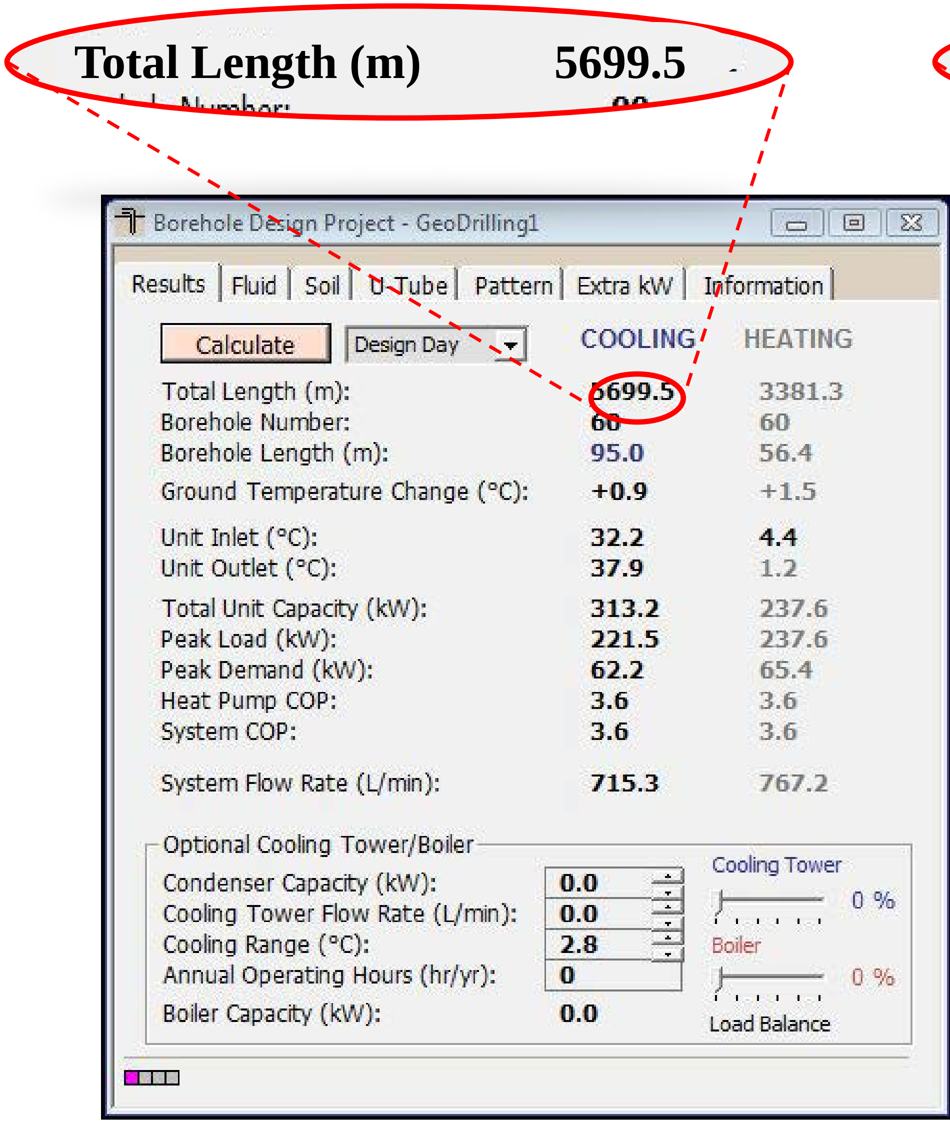
Is a TC Test Justified: Best Case/Worst Case

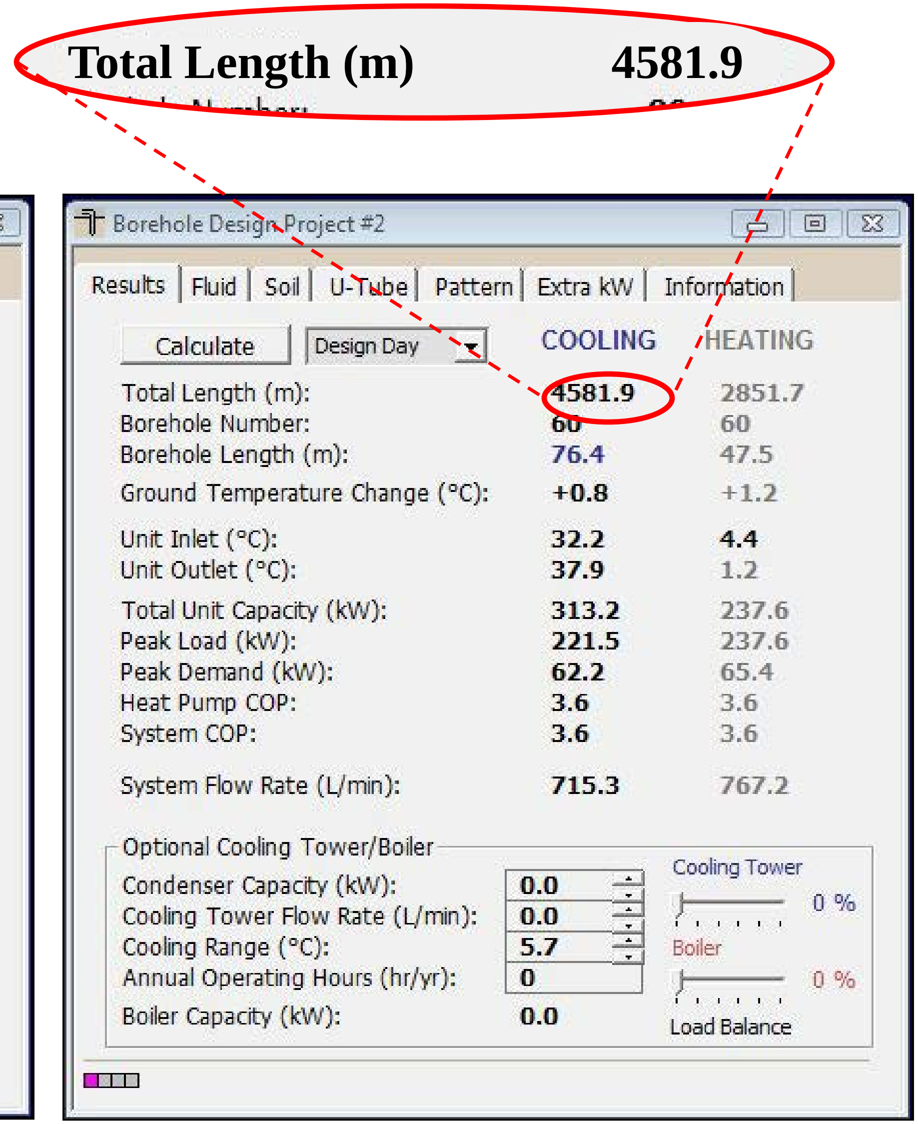
Enter the best case/worst case TC values into design software and calculate drilling requirements.





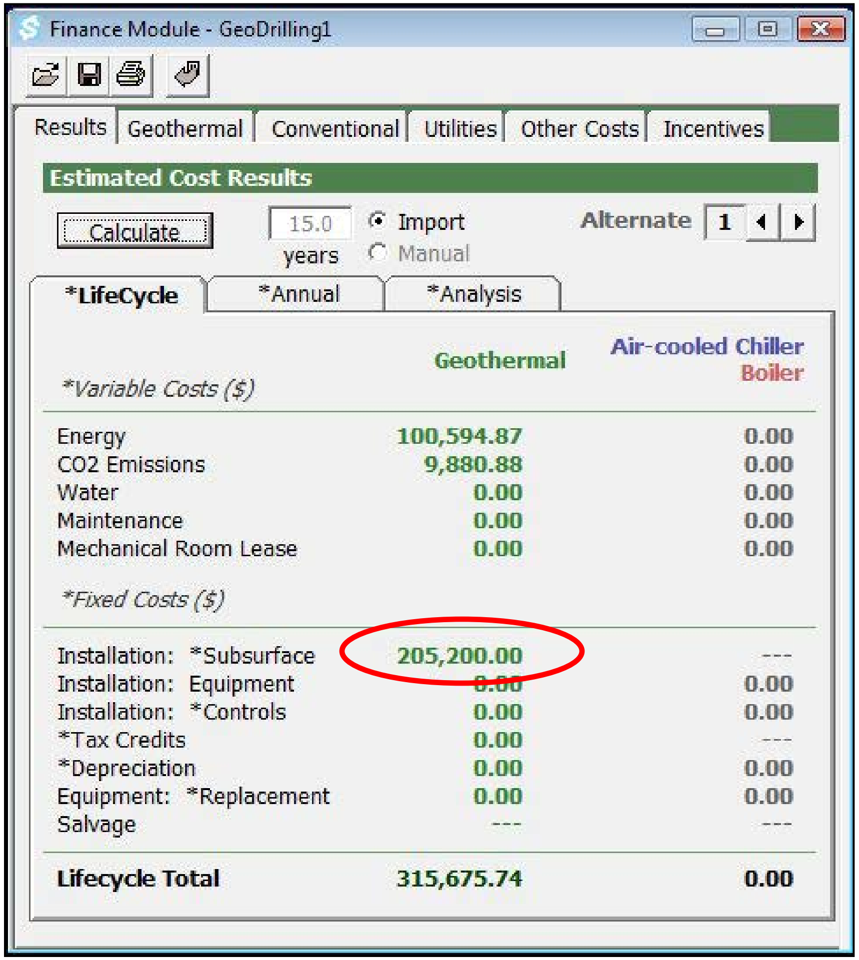
Is a TC Test Justified: Best Case/Worst Case

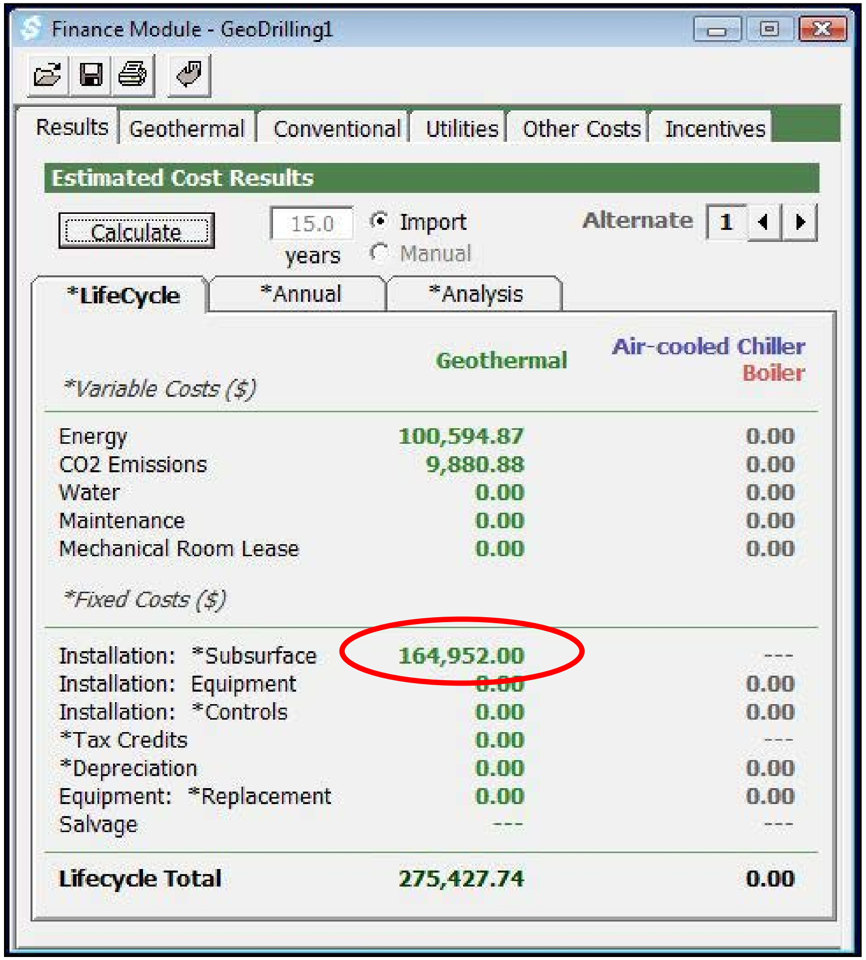




Is a TC Test Justified: Best Case/Worst Case

$205,200 - $164,952 = $40,248





Is a TC Test Justified: Best Case/Worst Case

Maximum loopfield cost difference:	$40,248
TC Test Cost:	$10,000
Difference:	$30,248

Perform a TC test? Absolutely!

Why? You might save your clients $30,000!

What a Field Test Looks Like

What a Field Test Looks Like: Tools

What a Field Test Looks Like

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What a Field Test Looks Like

What a Field Test Looks Like

Native Ground Temperature: An Aside

- Direct measurement
  - Insert temperature measuring device into loop and record temperature every X meters and calculate mean
- Circulating temperature measurement
  - Set logging interval to two seconds and record circulating data for about ten minutes
  - Watch for pump heat

What a Field Test Looks Like

What a Field Test Looks Like

Purging Air From The System: An Aside

- Use bypass valve assembly
- Critical to test operation
- Critical to stable data collection
- Improper purging can cause damage to test equipment

What a Field Test Looks Like

- Verify all sensors are connected and communicating with the logger
- Start circulating pump and engage the heating elements
  – You want to obtain ~ 50- 75 Watts per vertical meter of bore
- Verify proper readings
- Secure and lock unit

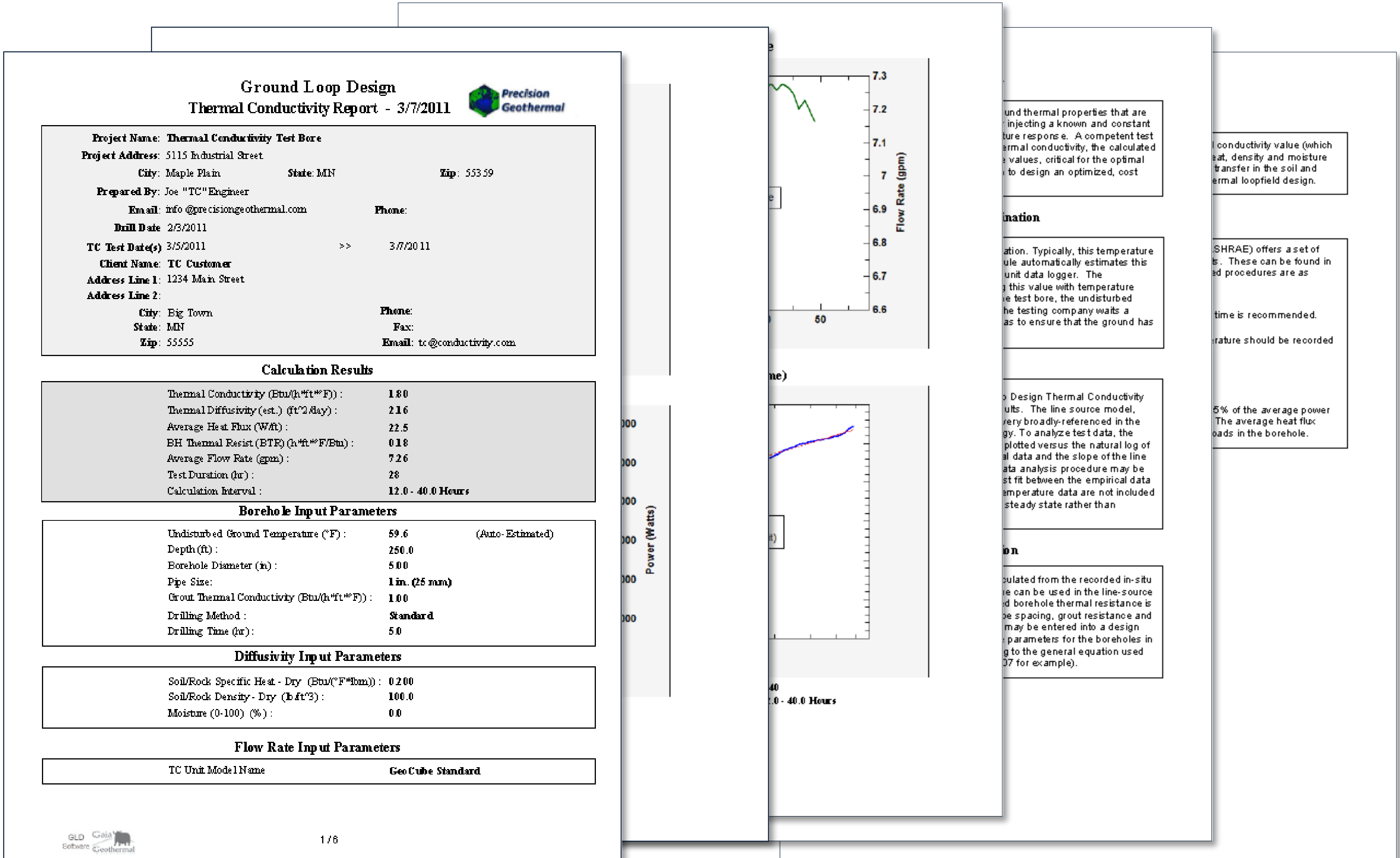
What a Field Test Looks Like

What a Field Test Looks Like

What a Field Test Looks Like

What a Field Test Looks Like

Data Analysis



Ground Loop Design
Thermal Conductivity Report - 3/7/2011

Precision Geothermal

Project Name:	Thermal Conductivity Test Bore		
Project Address:	5115 Industrial Street		
City:	Maple Plain	State: MN	Zip: 55359
Prepared By:	Joe "TC" Engineer		
Email:	info@precisiongeothermal.com	Phone:	
Drill Date	2/3/2011		
TC Test Date(s)	3/5/2011	>>	3/7/2011
Client Name:	TC Customer		
Address Line 1:	1234 Main Street		
Address Line 2:			
City:	Big Town	Phone:	
State:	MN	Fax:	
Zip:	55555	Email:	tc@conductivity.com

Calculation Results

Thermal Conductivity (Btu/(h*ft*°F)) :	1.80
Thermal Diffusivity (est.) (ft^2/day) :	2.16
Average Heat Flux (W/ft) :	22.5
BH Thermal Resist (BTR) (h*ft*°F/Btu) :	0.18
Average Flow Rate (gpm) :	7.26
Test Duration (hr) :	28
Calculation Interval :	12.0 - 40.0 Hours

Borehole Input Parameters

Undisturbed Ground Temperature (°F) :	59.6	(Auto-Estimated)
Depth (ft) :	250.0	
Borehole Diameter (in) :	5.00	
Pipe Size:	1 in. (25 mm)	
Grout Thermal Conductivity (Btu/(h*ft*°F)) :	1.00	
Drilling Method :	Standard	
Drilling Time (hr) :	5.0	

Diffusivity Input Parameters

Soil/Rock Specific Heat - Dry (Btu/(°F*lbm)) :	0.200
Soil/Rock Density - Dry (lb/ft^3) :	100.0
Moisture (0-100) (%) :	0.0

Flow Rate Input Parameters

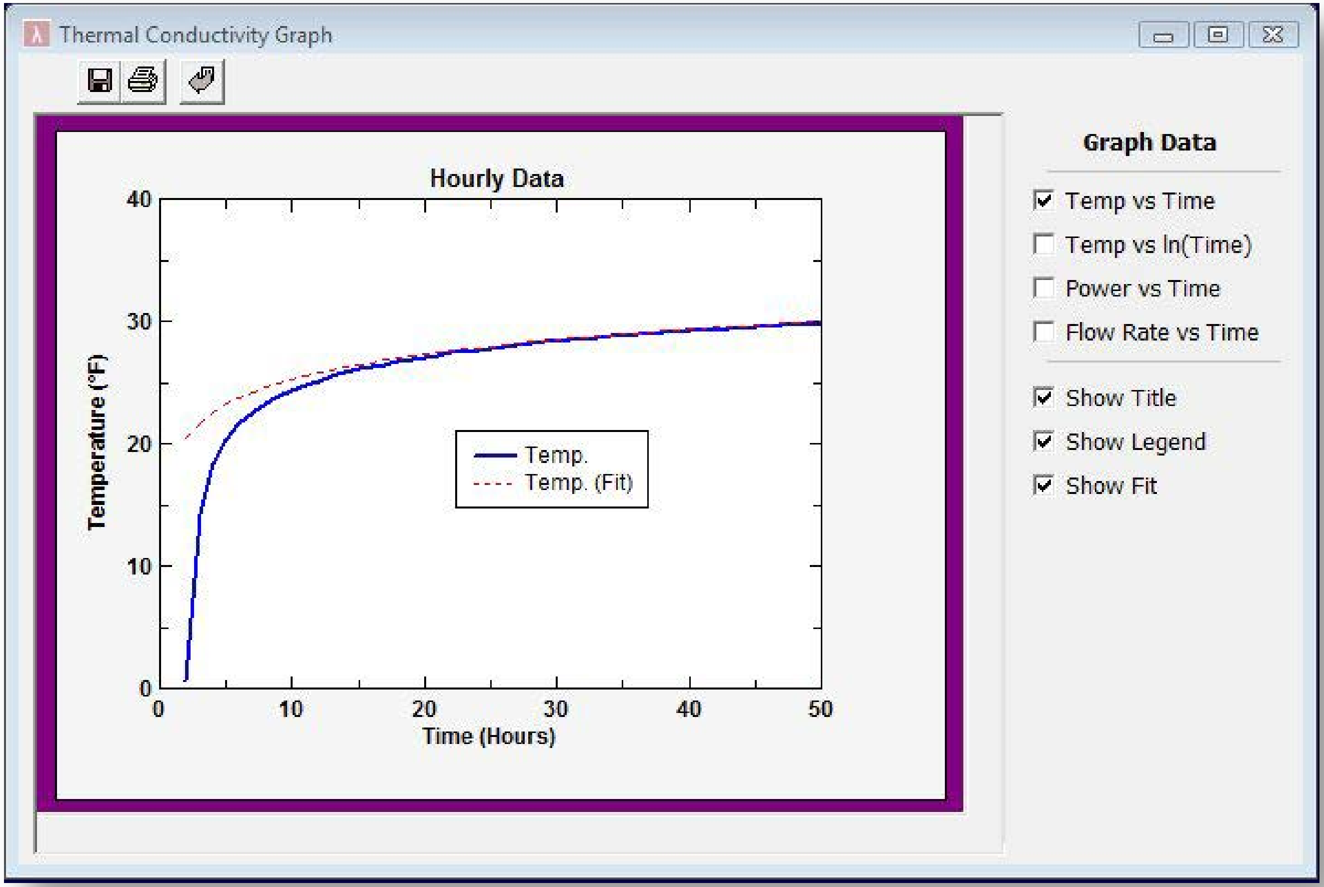
TC Unit Model Name	GeoCube Standard

GLD Software Gaia Geothermal 1 / 6

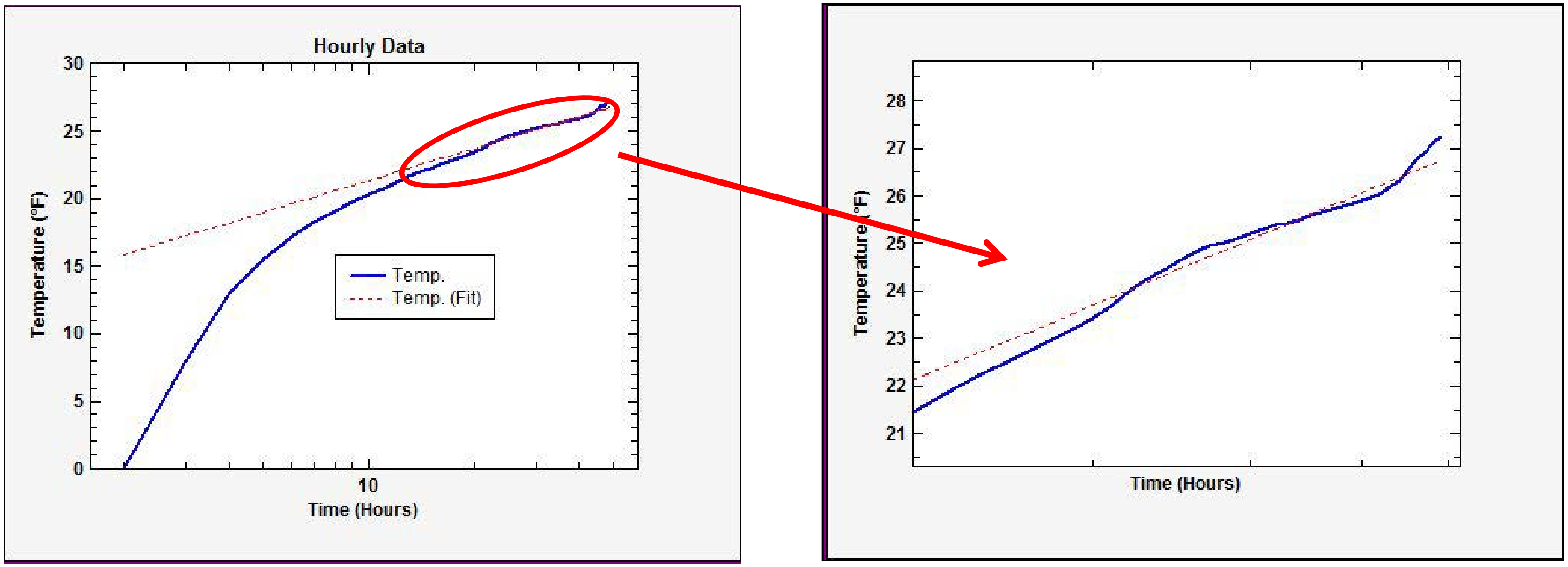
Data Analysis

- Check that all data is consistent before shutting down test
- Transfer data from logger into GLD or other software tool
- Analyze data set

Data Analysis



Data Analysis



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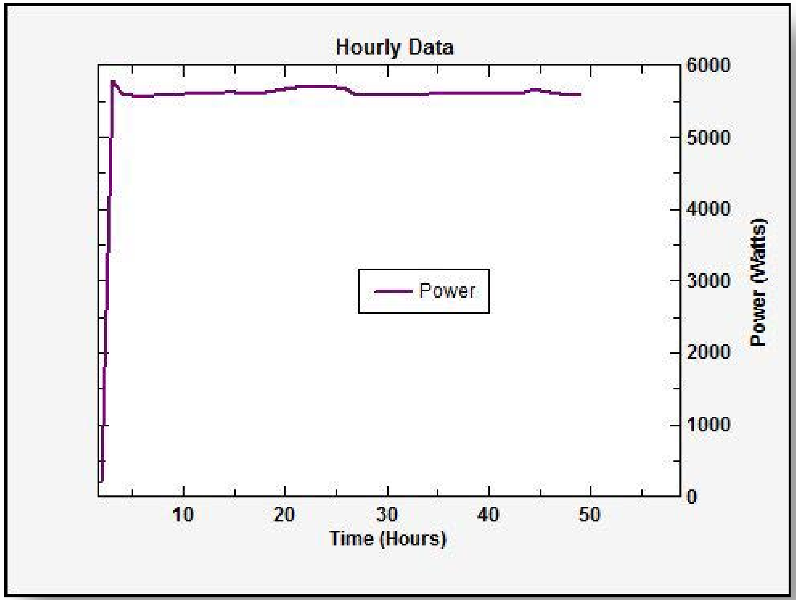

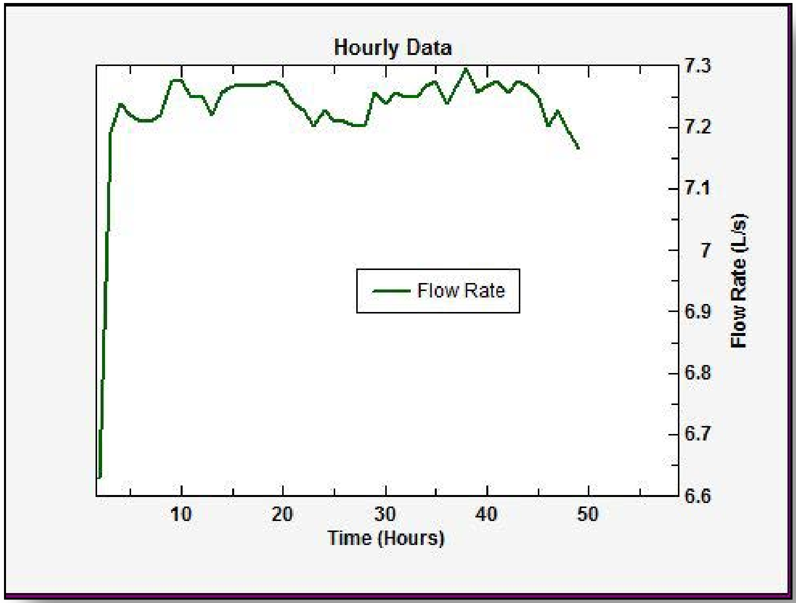

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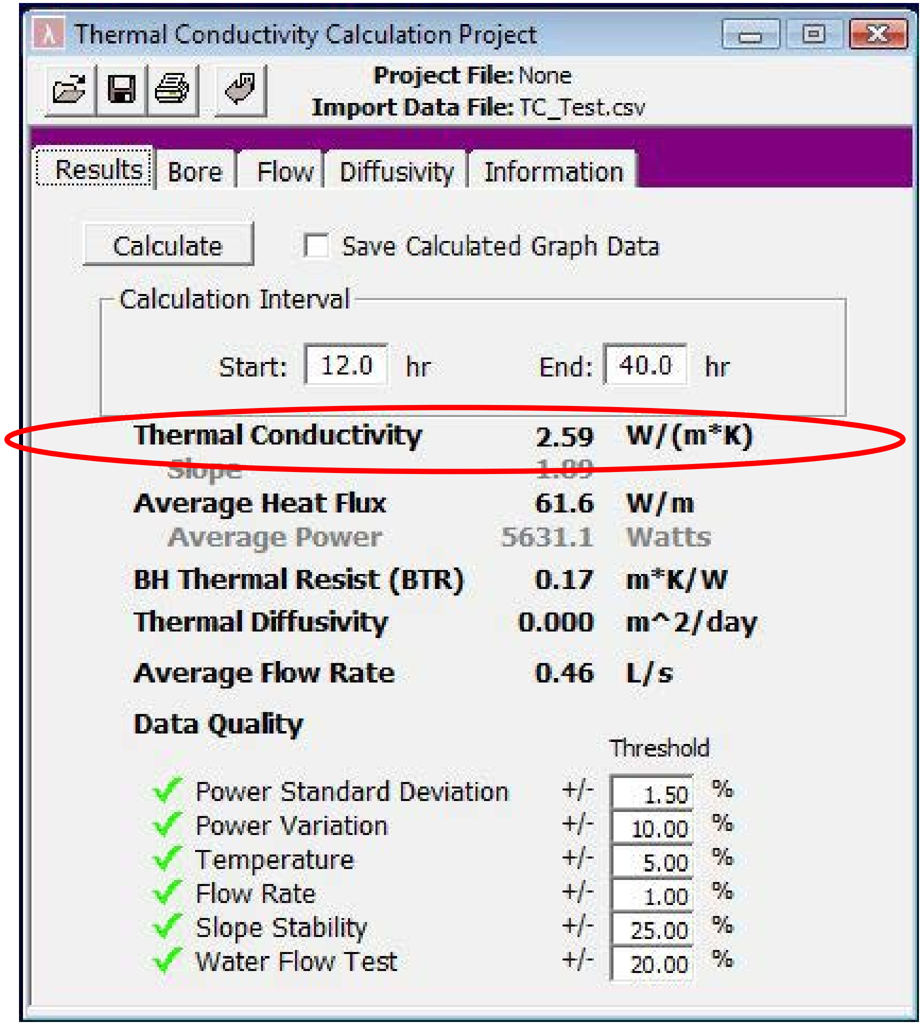
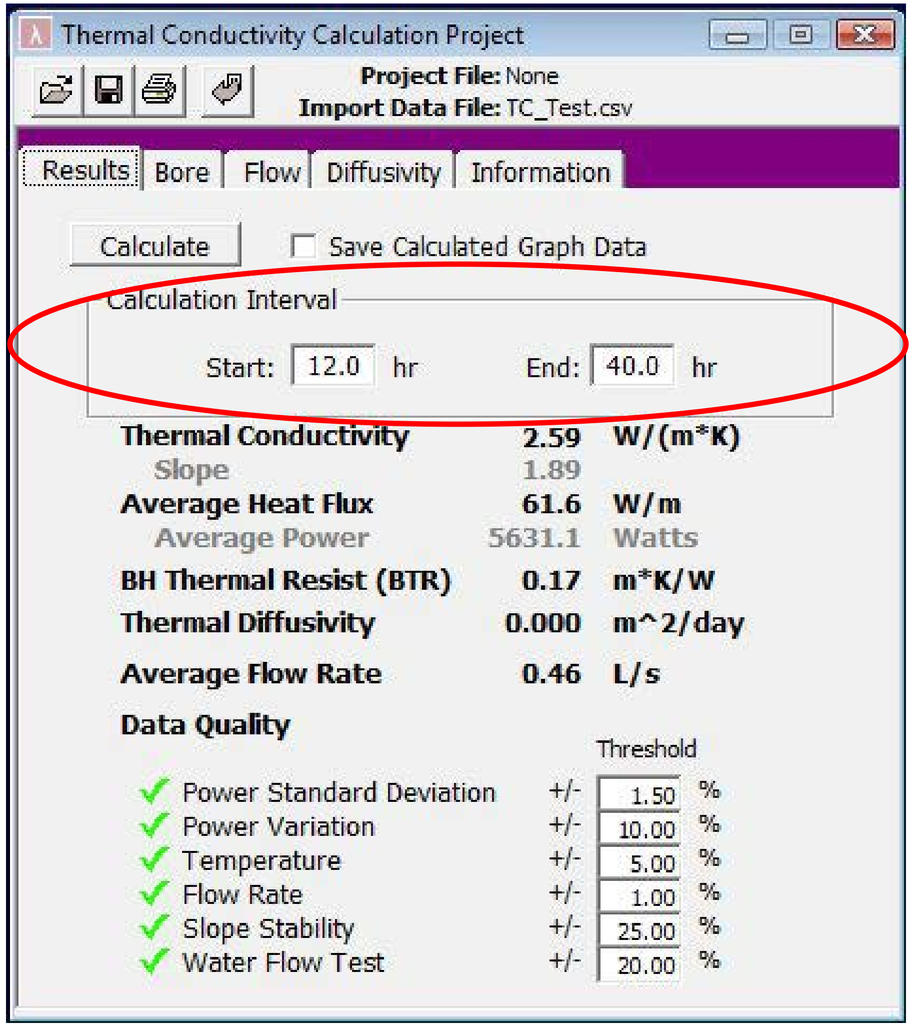
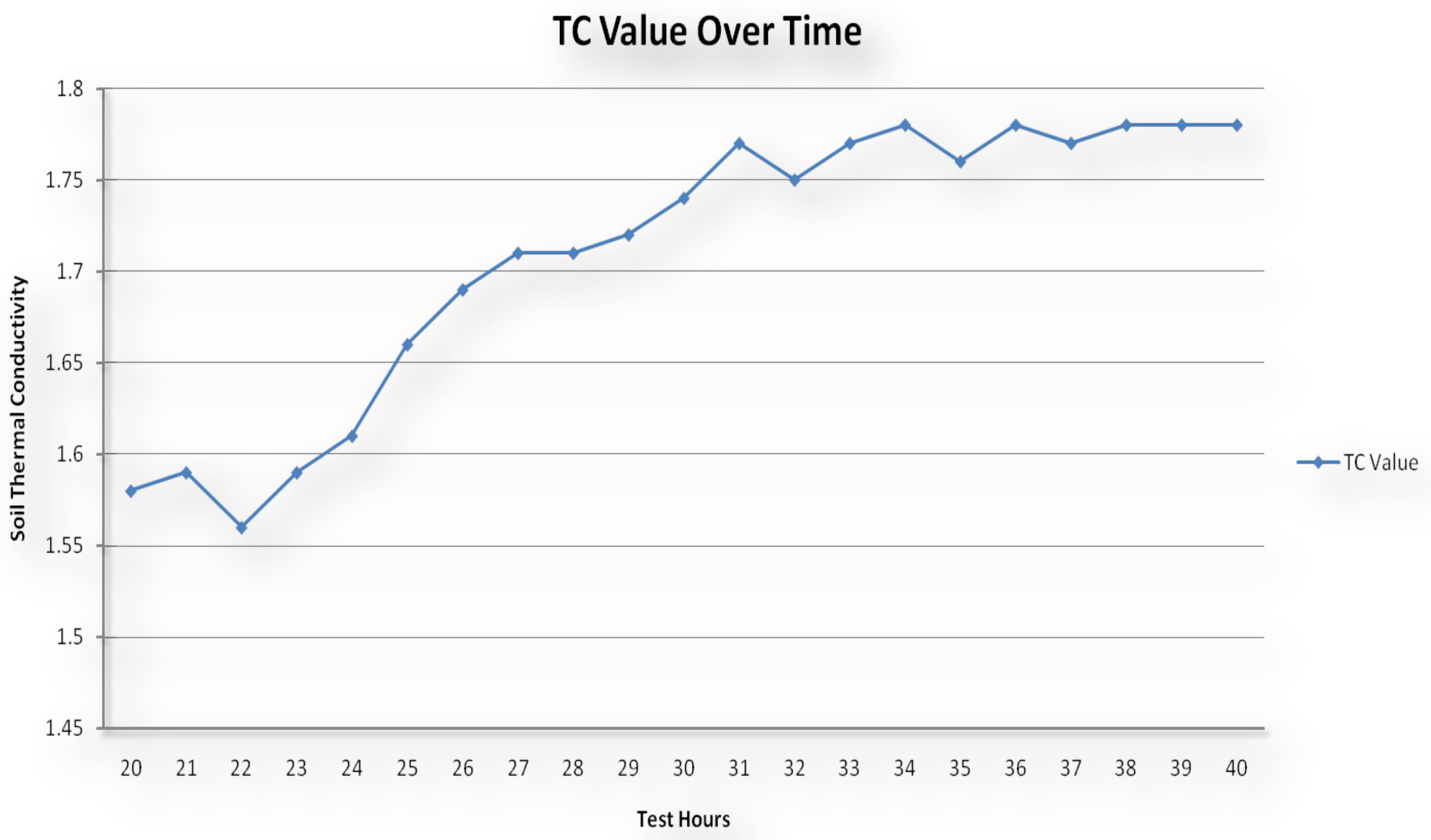


Data Analysis



Data Analysis



Good Data

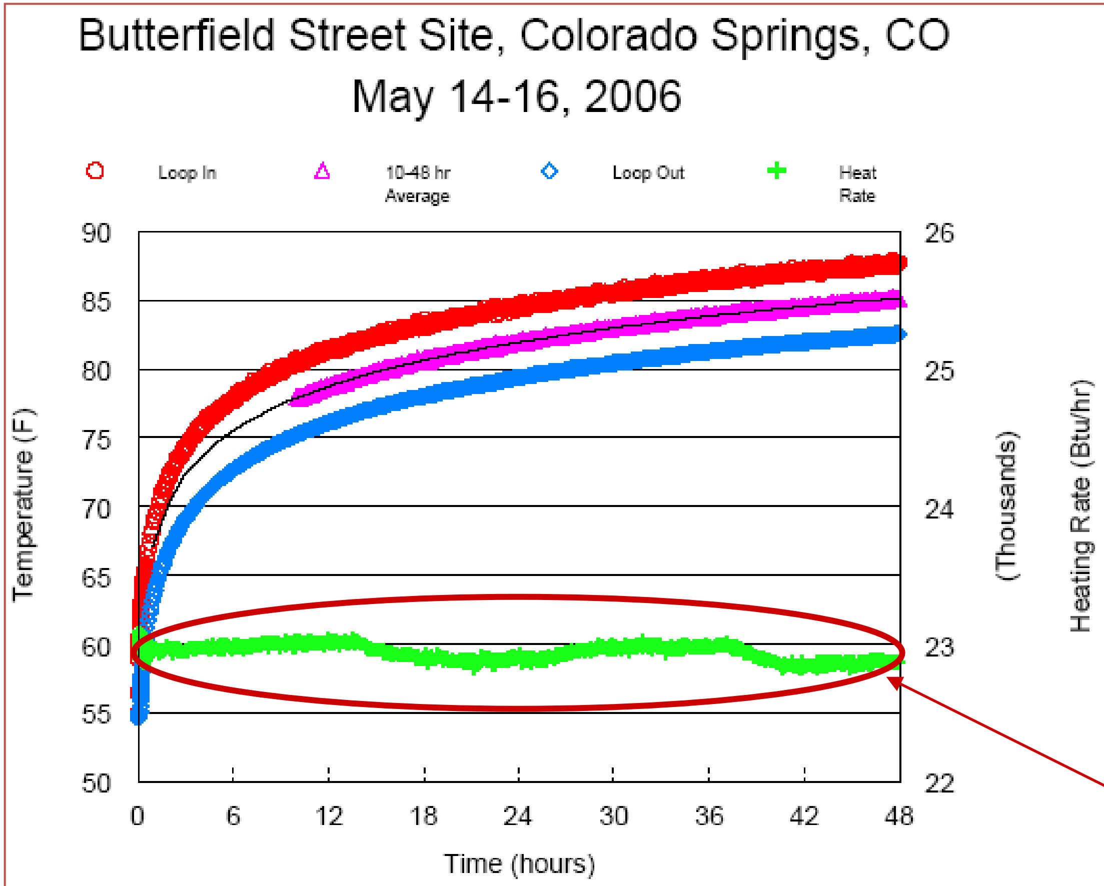


Figure 1: Temperature versus Time Data

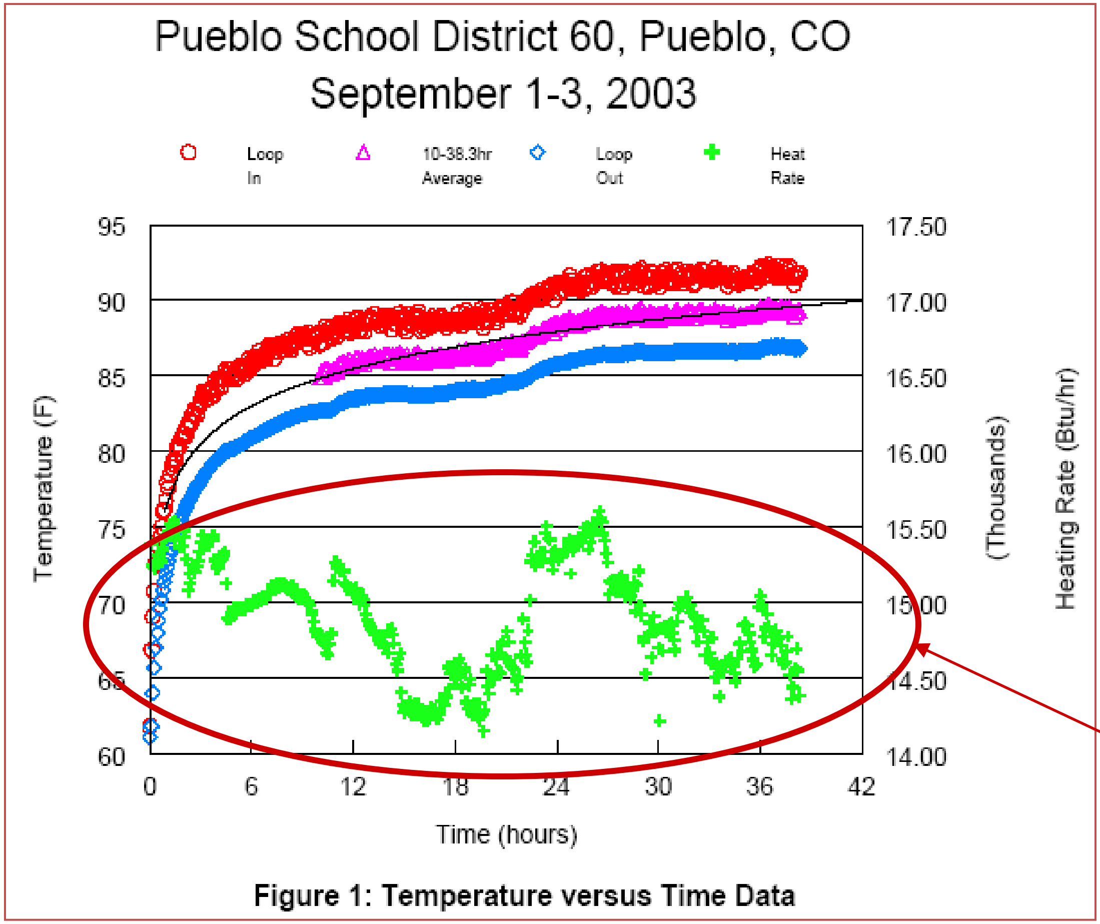
TC: 0.98 Btu/hr•ft•°F

TD: 0.62 ft^2/day

T: 55.5 F

Clean, consistent power

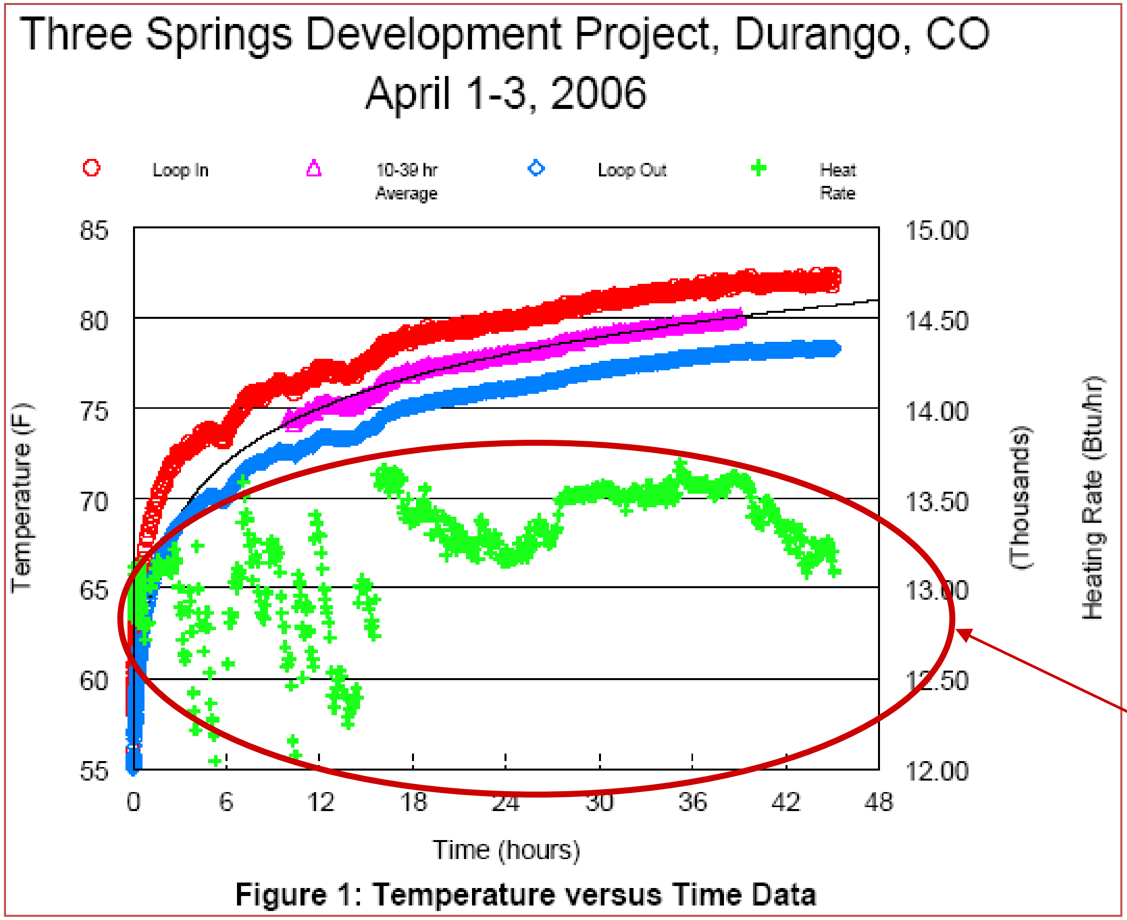
Bad Data



TC: 1.11 Btu/hr•ft•°F
TD: 0.82 ft²/day
T: 61.0 F

Irregular, inconsistent power

Ugly Data



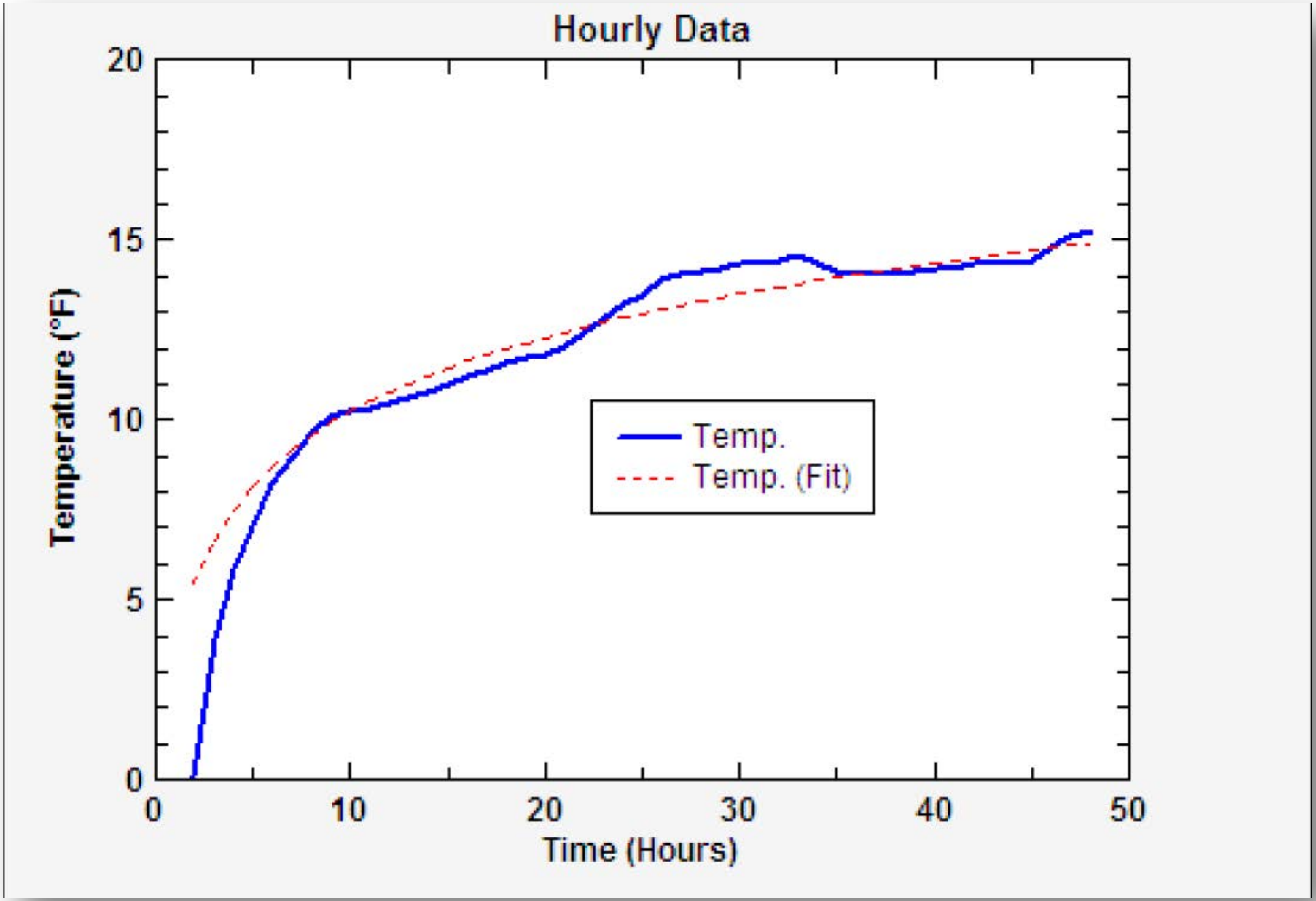
TC: 0.89 Btu/hr•ft•°F

TD: 0.65 ft²/day

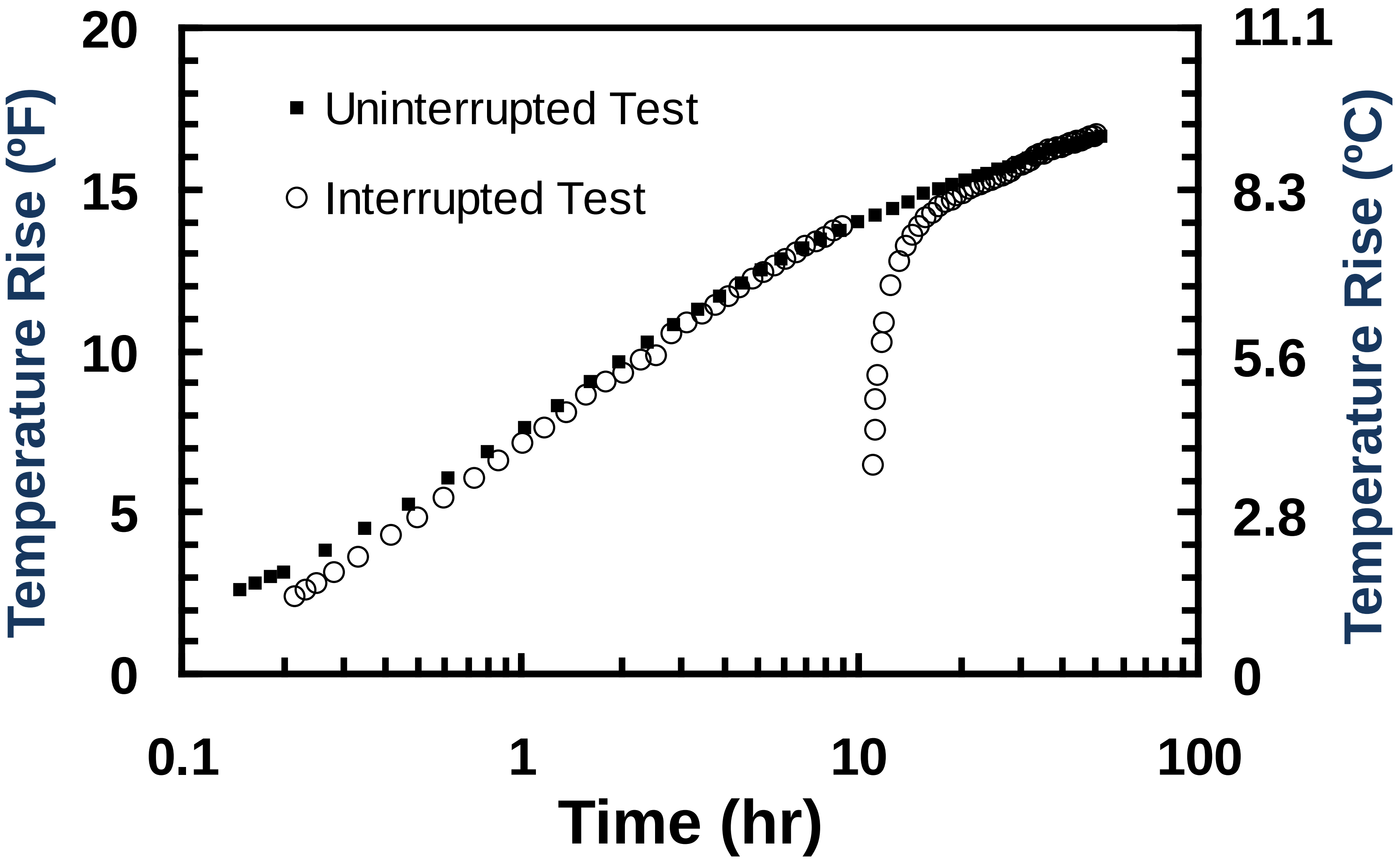
T: 54.0 - 57.0 F

Irregular, inconsistent power

Ugly Data?

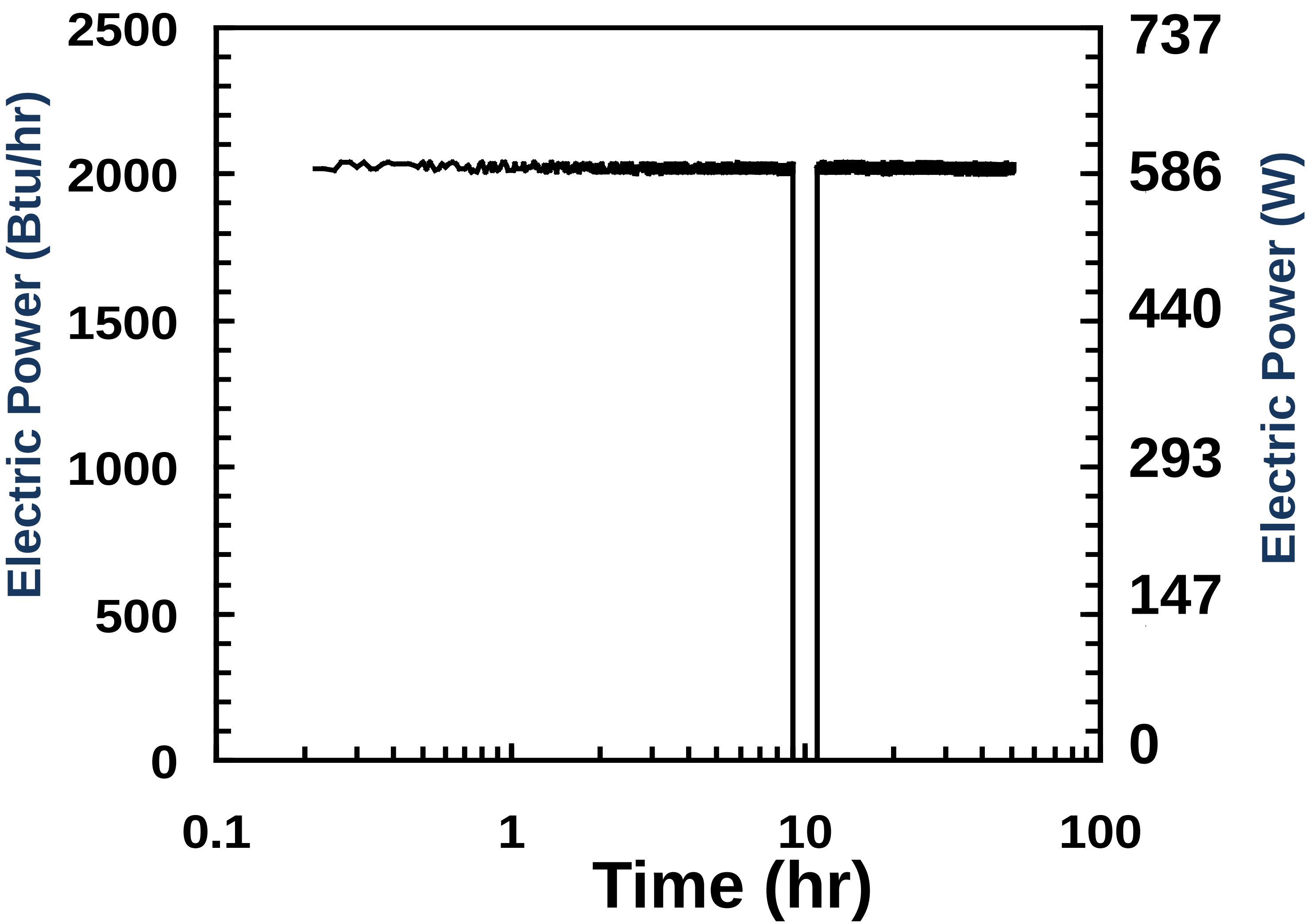

Hourly Data
Temperature (°F)
Time (Hours)
0
5
10
15
20
0
10
20
30
40
50
Temp.
Temp. (Fit)

Ugly Data?



Uninterrupted Test
Interrupted Test
Temperature Rise (ºF)
Temperature Rise (ºC)
20
15
10
5
0
11.1
8.3
5.6
2.8
0
0.1
1
10
100
Time (hr)

Ugly Data?


Electric Power (Btu/hr)
2500
2000
1500
1000
500
0
0.1
1
10
100
Time (hr)
737
586
440
293
147
0
Electric Power (W)

Thank You!

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Test Equipment