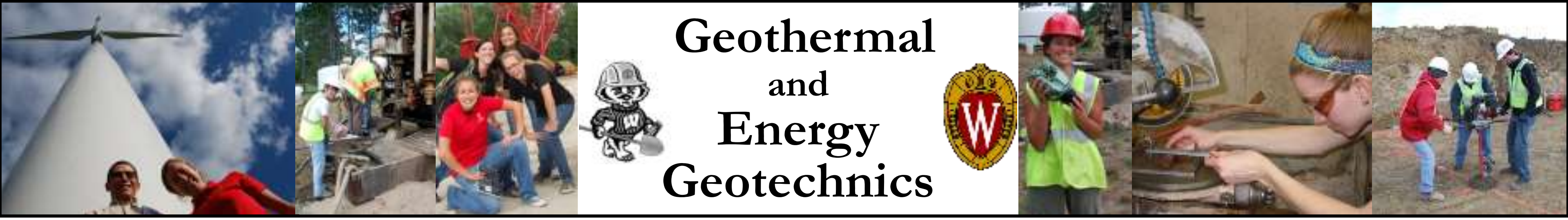

Geoscience Engineering Professional Development Geological Engineering Wisconsin Geological Survey

District-Scale Geothermal Exchange Fields

Modeling and Monitoring Results

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Outline

- Project Objectives and Justification
- Site Description
- Site Characterization
- Modeling Results
- Monitoring Results
- Future Work
- Q&A

Objectives

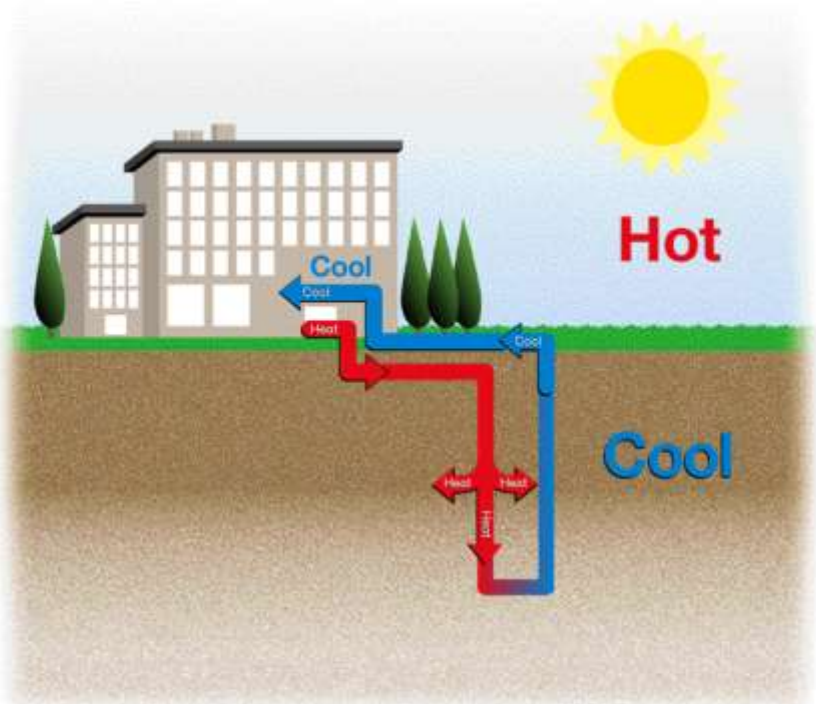
- Determine the effect, if any, geothermal heat exchange systems have on groundwater quality
- Use a combination of monitoring data and modeling results to predict short and long term environmental risks

Justification

- Temperature has a positive effect on scorodite ($FeAsO_4 \cdot 2H_2O$) dissolution
- Core samples indicate arsenic is present on site
- Arsenic has harmful short and long term health effects

Site Description

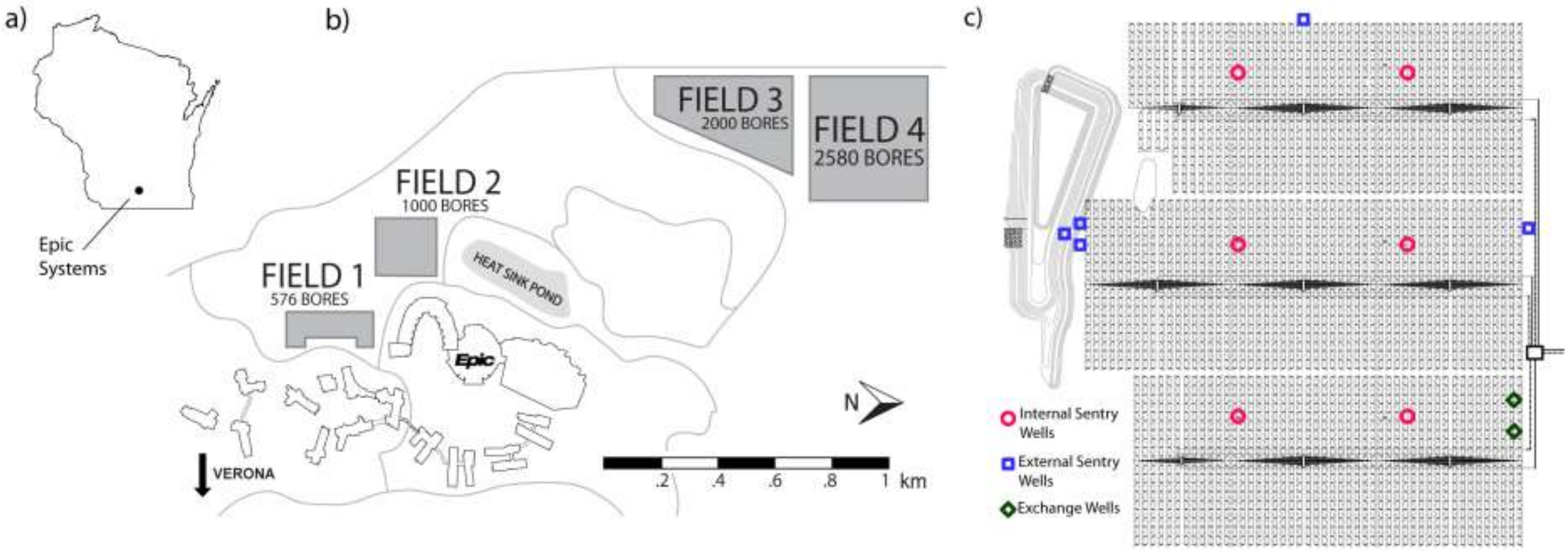
- To date, Epic Systems Corporation has installed over 5,500 boreholes
- Within each a fluid circulates to transfer energy
- Epic is cooling dominant; i.e. more heat is transferred to the ground than from it, causing a year over year temperature increase



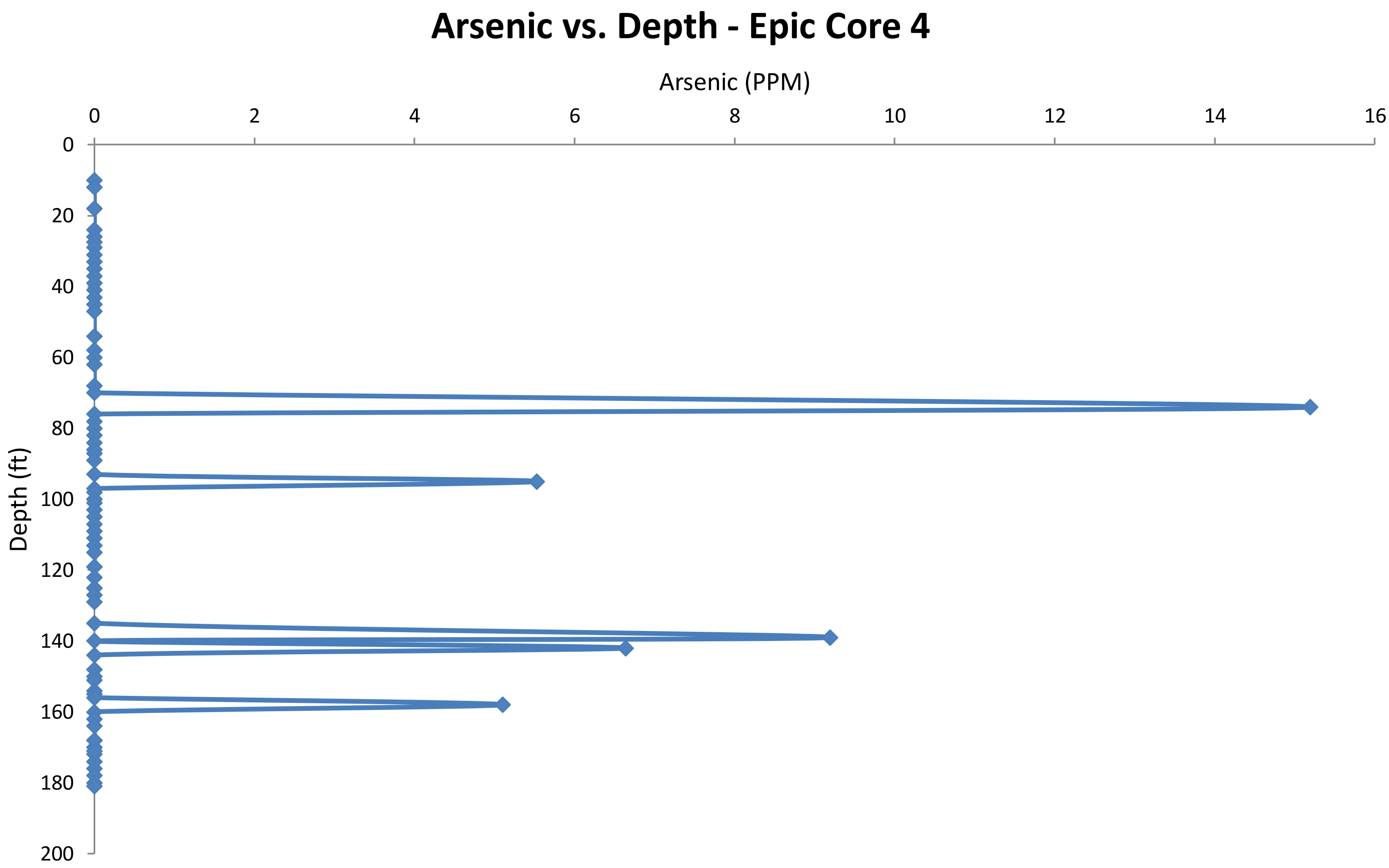
Site Description

Arial View of Epic Campus, looking south. (John Hart, State Journal Archives)

Site Description

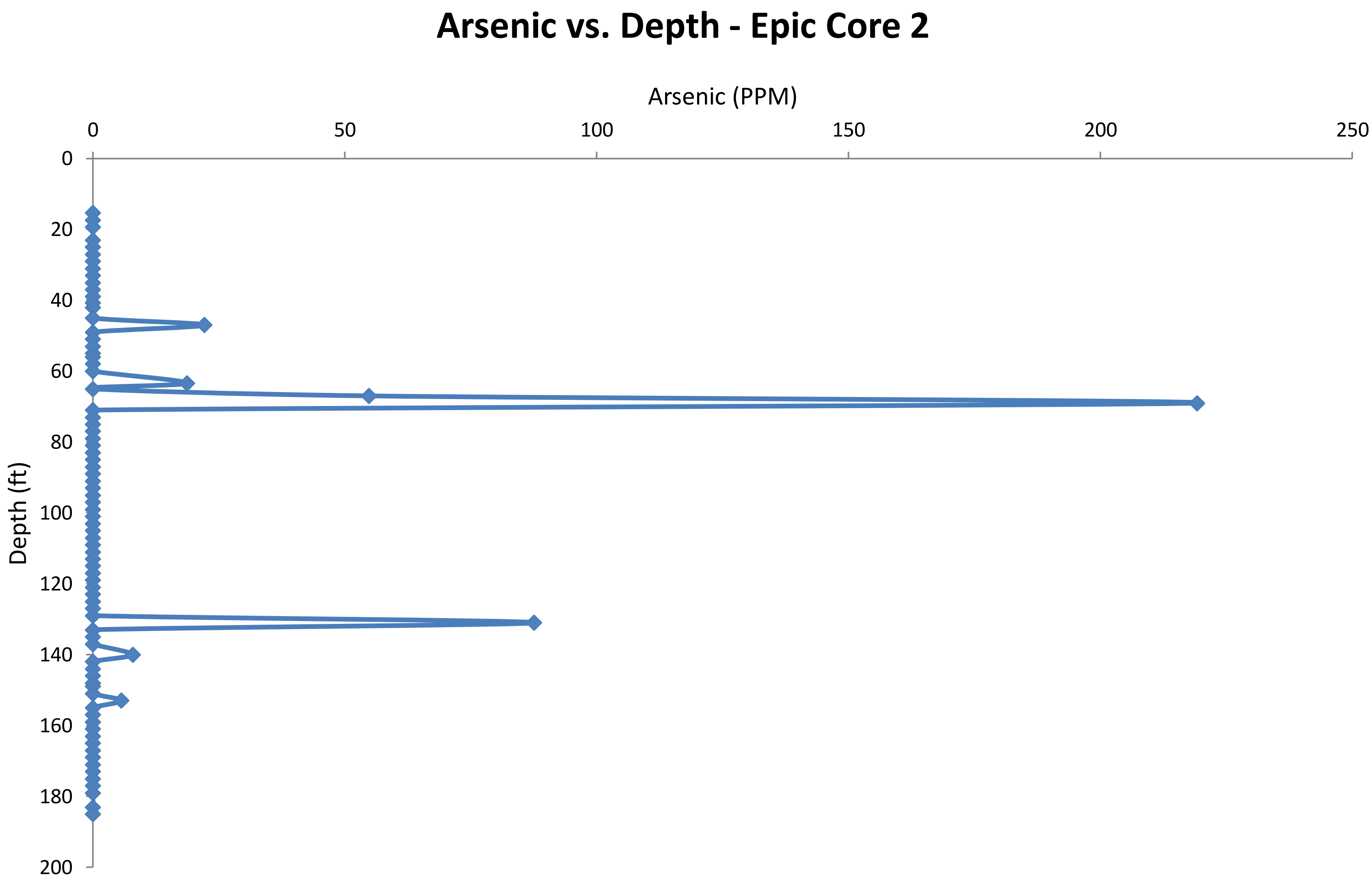


Site Characterization



XRF Measurements (Clay and Hart, 2014)

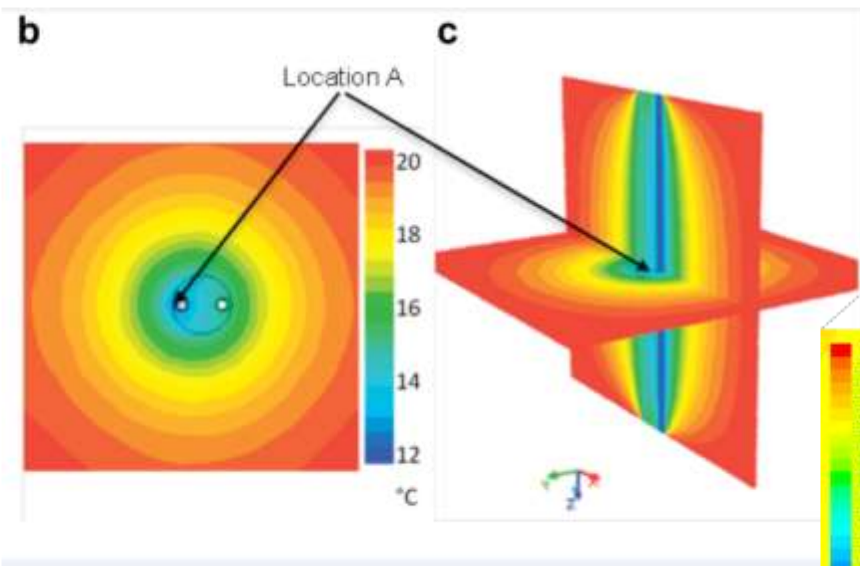
Site Characterization

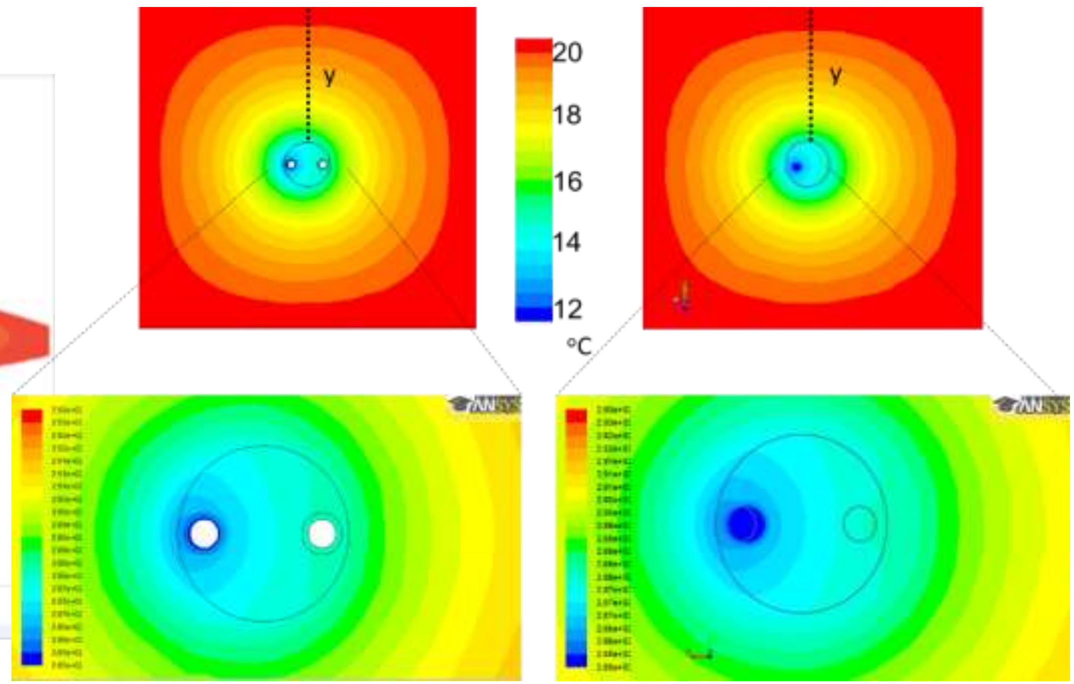


XRF Measurements (Clay and Hart, 2014)

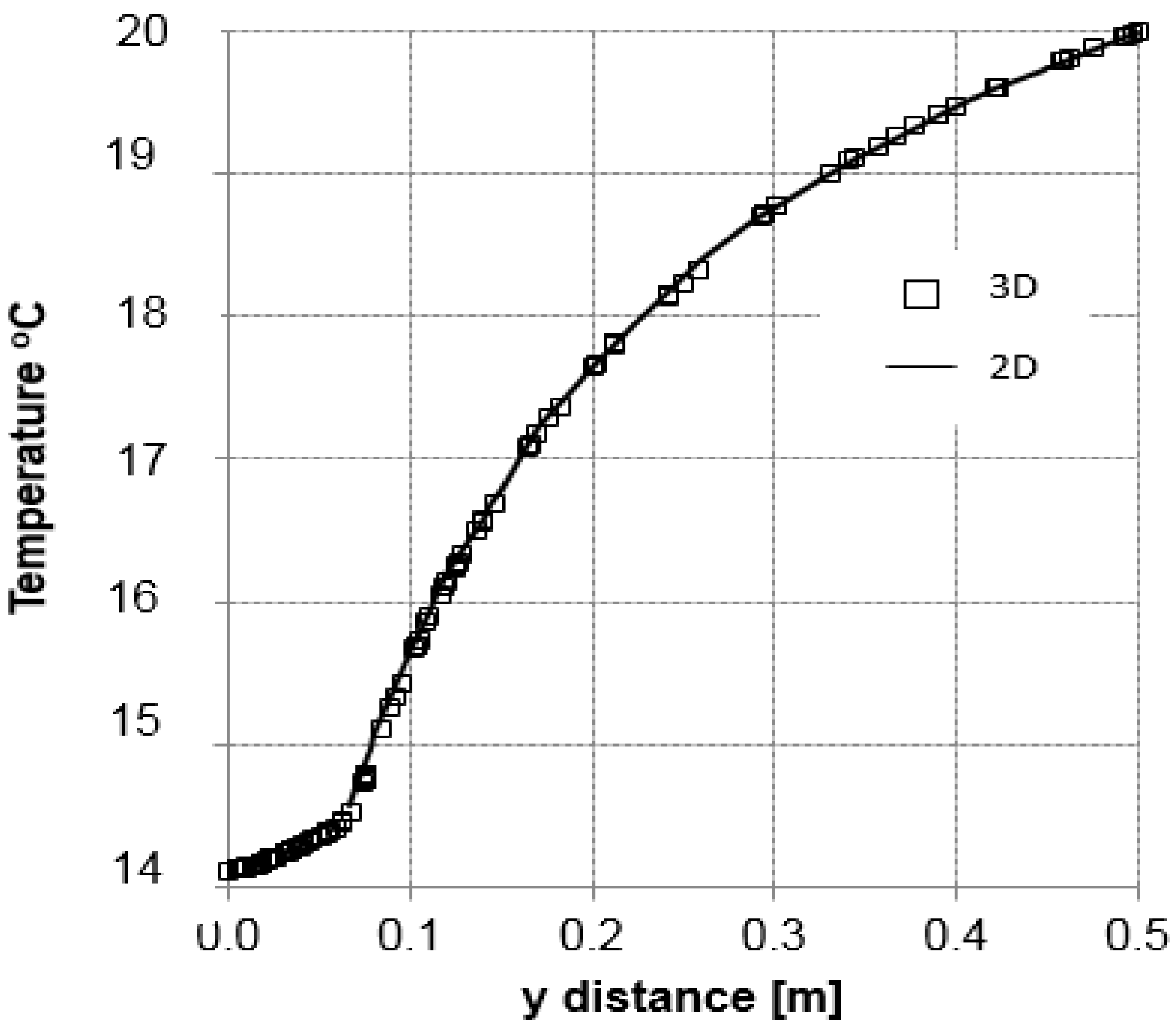
Modeling Results

- Computational fluid dynamics allows us to solve the PDE's that govern heat transfer
- In order to reduce computational time, we have verified that using 2D models as "slices" of 3D models will not introduce significant errors.





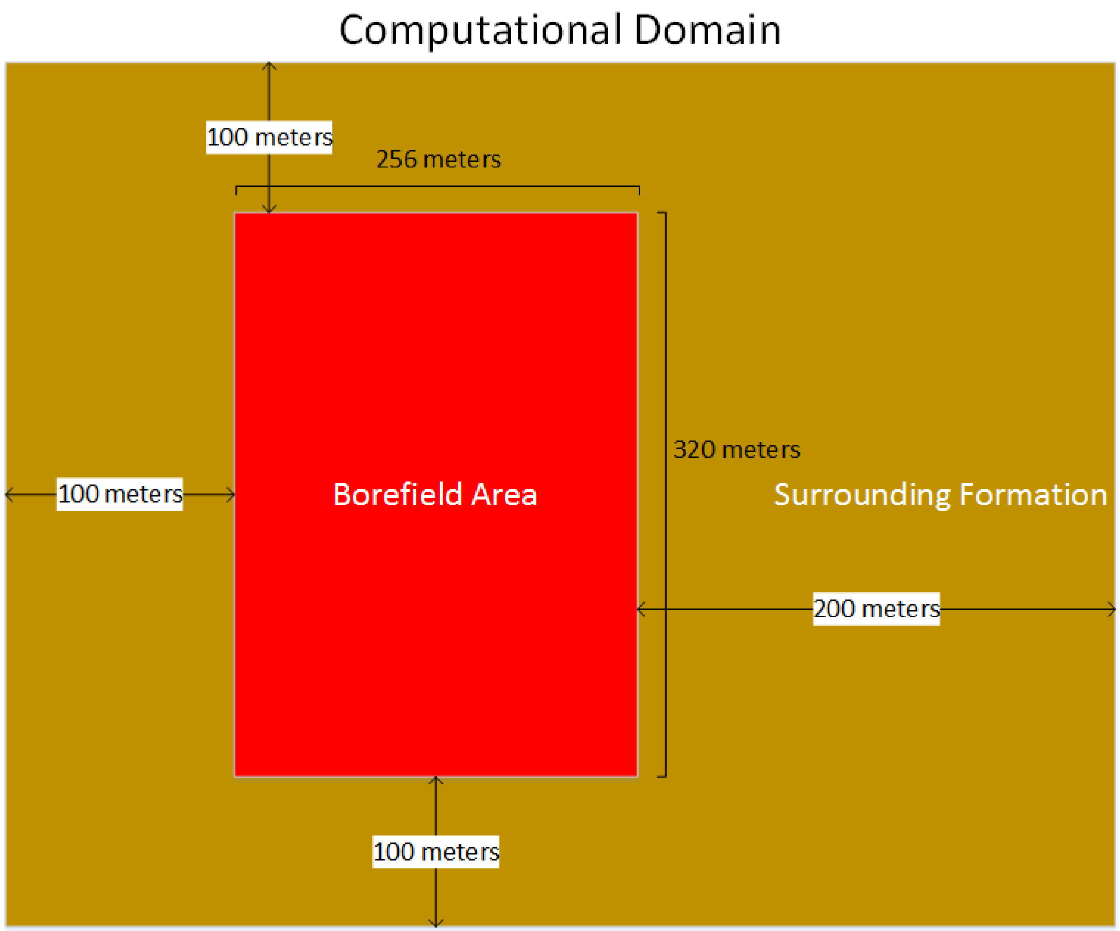
Comparison



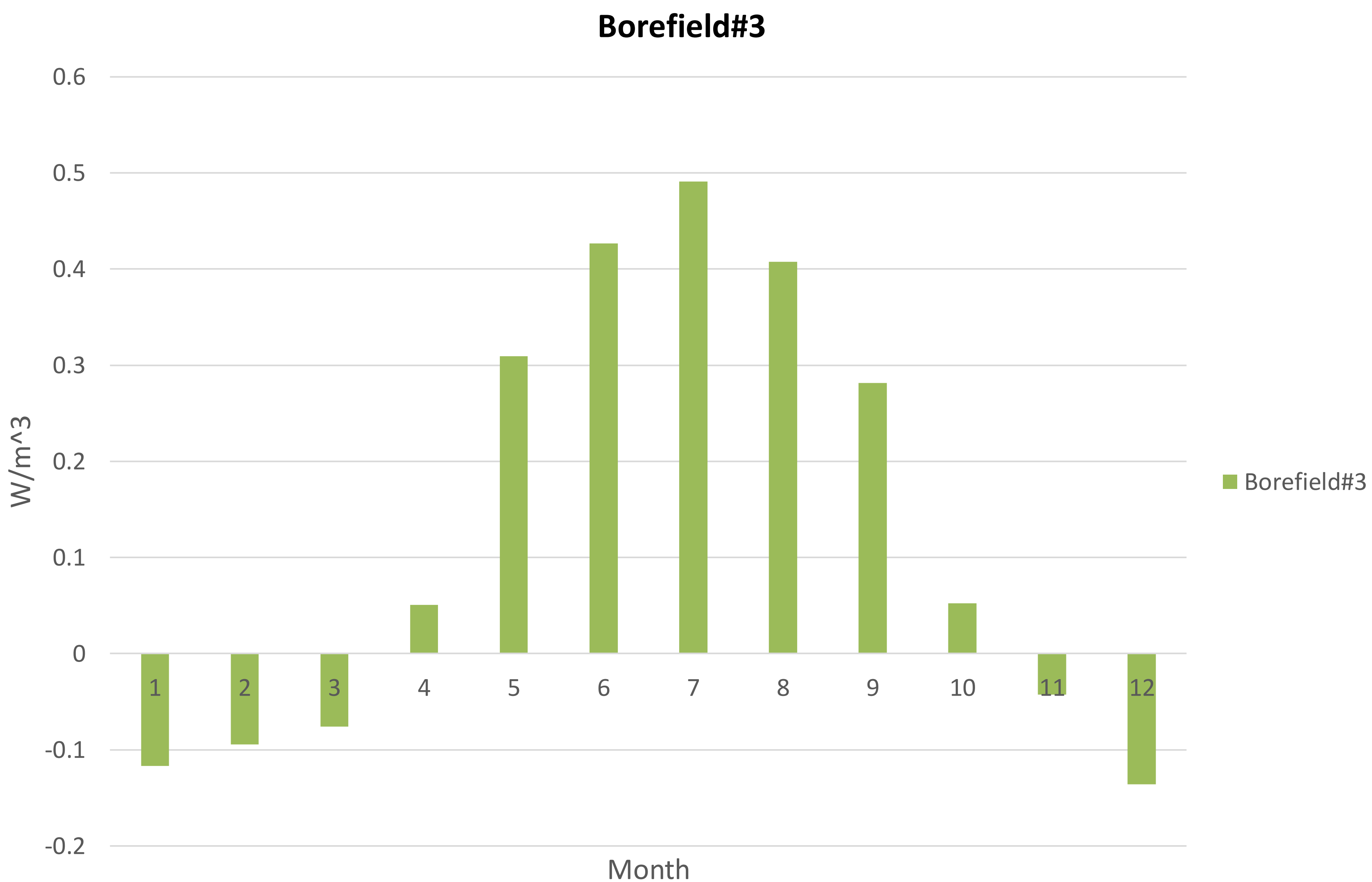
Temperature °C
20
19
18
17
16
15
14
0.0
0.1
0.2
0.3
0.4
0.5
y distance [m]
3D
2D

Borefield Scale

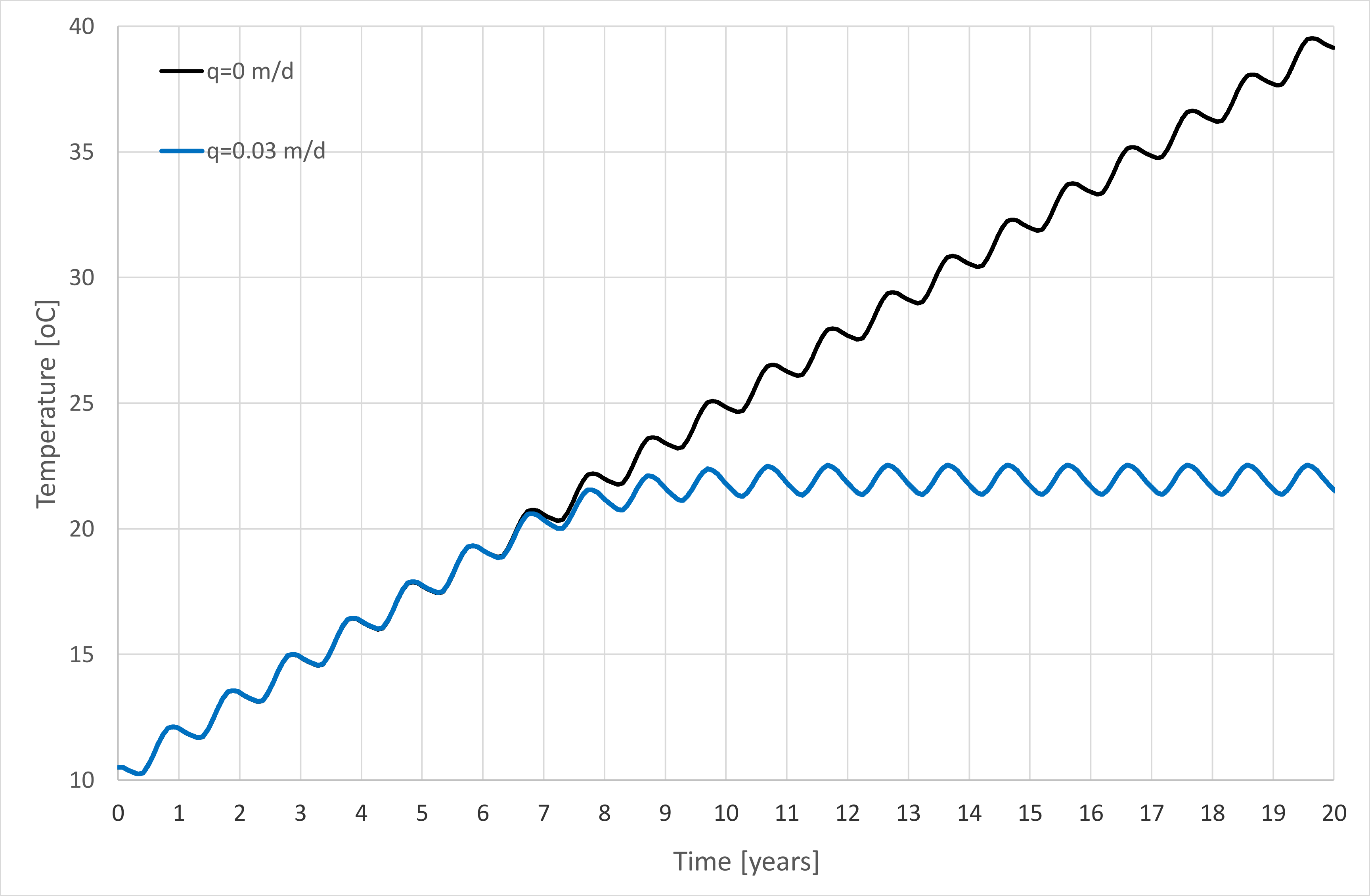
- Apply design data as a heat generation source to the field area



Design Inputs

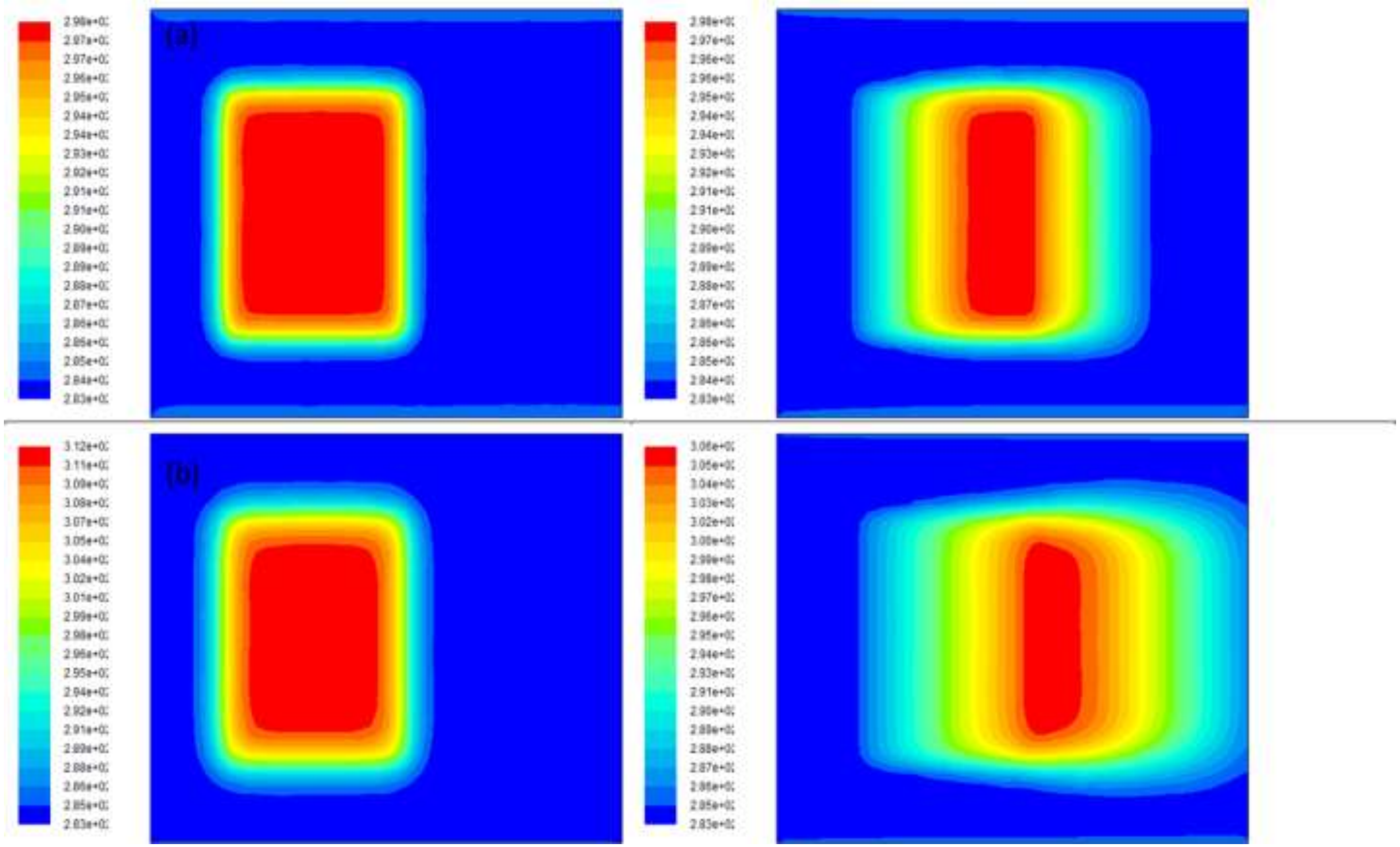


Results



40
35
30
25
20
15
10
Temperature [oC]
q=0 m/d
q=0.03 m/d
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Time [years]

Results



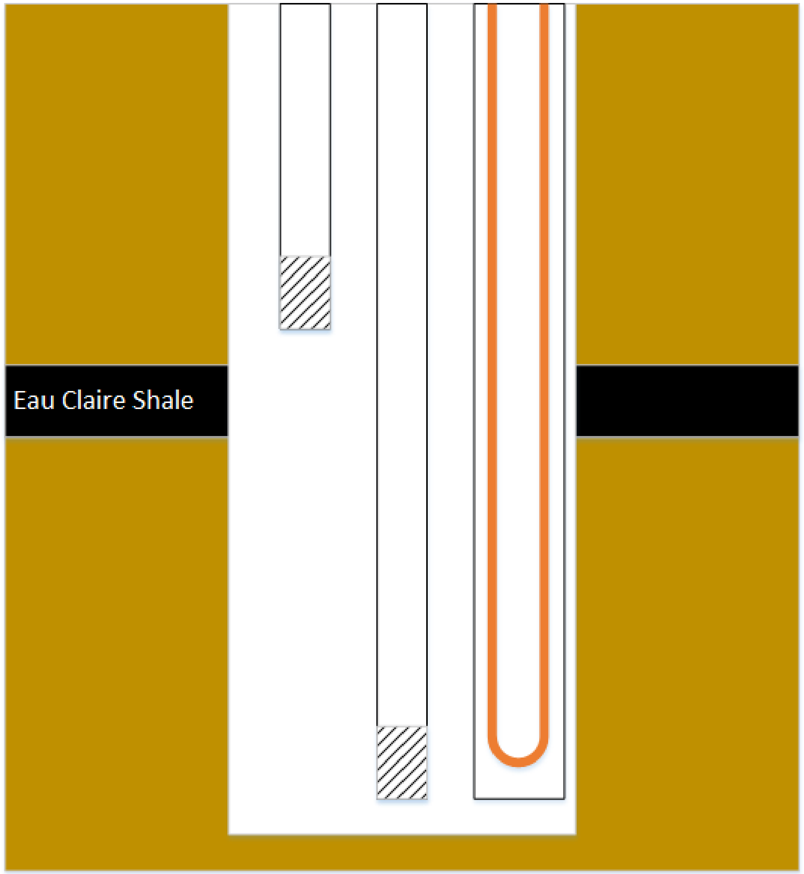
Temperature contours for conduction only (left) and with advection (right) for a Darcy's velocity of 0.3 m/day

Management Strategies

- Even under idealized conditions, ground temperatures still increase over 10° C
- Epic currently practices passive management; when a field temperature is too high, the field is temporarily shut down
- More active management may be needed for both the efficiency and sustainability of the system

Monitoring Results

- Currently 2 of the 5 planned monitoring wells are installed
- Each has shallow and deep piezometers and a blank for fiber optic installation
- Water samples prior to full-field activation for background levels



Example monitoring well installation.
Horizontal distance greatly exaggerated.

Monitoring Results

- Samples taken Aug. 27th and 28th, 2014
- Shallow and deep aquifer sampled at north and east wells

ALL DATA mg/l UNLESS NOTED		Nitrogen, Nitrate	Alkalinity	Chloride	Arsenic	Calcium	Copper	Iron	Potassium	Magnesium	Manganese	Sodium	Phosphorus	Lead	Sulfate	Zinc
Date Prepared		11-Sep	15-Sep	11-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep
Date Analyzed		12-Sep		12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep	12-Sep
Method		SM 4110 B	SM 2320 B	SM 4500 Cl-E	EPA 200.7	EPA 200.7	EPA 200.7	EPA 200.7	EPA 200.7	EPA 200.7	EPA 200.7	EPA 200.7	SM 4500 P-F	EPA 200.7	EPA 200.7	EPA 200.7
Lab #	Site															
474-14-1	East PZ-D	0.3	320	2.8	0.005	60.49	<0.002	0.090	1.89	42.581	0.01	3.2	0.043	<0.005	15.4	0.005
474-14-2	North PZ-S	12.3	340	37.8	0.005	82.55	<0.002	0.100	1.77	43.711	0.003	26.3	1.595	<0.005	22.7	0.002
474-14-3	North PZ-D	0.2	312	<0.5	<0.004	54.75	<0.002	0.07	1.18	40.38	0.007	3.5	0.13	<0.005	10.90	<0.002
474-14-4	North PZ-S	12.5	348	38.0	0.007	82.08	<0.002	0.52	1.78	42.96	0.006	29.0	1.81	<0.005	23.10	0
474-14-5	East PZ-S	11.2	336	39.5	0.005	85.05	0.03	0.89	6.15	44.59	0.011	34.3	0.74	<0.005	27.3	0.01

Highlighted Results

- Results typical for the area, with significantly higher Nitrate, Chloride, Sodium, and Sulfate levels in the shallow aquifer
- All samples show arsenic levels below EPA guidelines (<10 ppb)

Site	Nitrogen, Nitrate	Chloride	Phosphorus	Arsenic
East PZ-S	11.2	39.5	0.74	0.005
East PZ-D	0.3	2.8	0.043	0.005
North PZ-S	12.5	38.0	1.81	0.007
North PZ-D	0.2	<0.5	0.13	<0.004

All values mg/L

Future Work

- Drill and install 3 additional monitoring wells, nested to determine groundwater flow
- Continue collecting groundwater samples to establish background levels; after full field activation, additional samples will be used to monitor contaminant levels
- Quantify temperature effects on arsenic release and develop a coupled temperature and mass transport model for long term predictions of risk
- Develop and test management strategies to achieve lower, steady borefield temperatures

Acknowledgements

- Epic Systems Corporation and associated contractors (Bertram Drilling, Morse, MEP Associates, General Heating and Cooling, TEEL Plastics)
- Funding from the Wisconsin Groundwater Coordinating Council

Questions?