Can Thermal Remediation Be Sustainable? Use of Modelling to Optimize Design

James Baldock, Joanne Pennell and Jay Dablow

The business of sustainability

ERM

Introduction

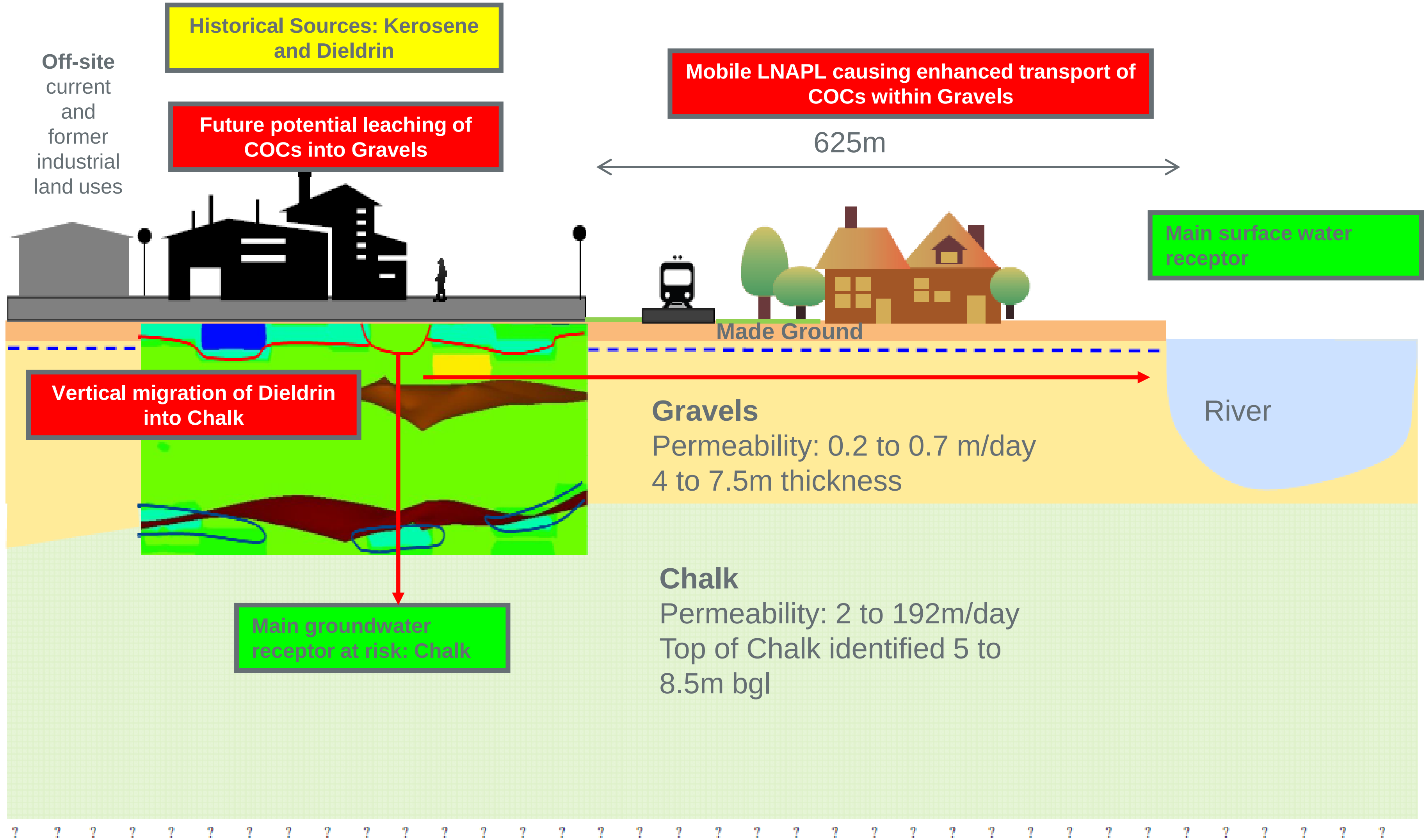
- Thermal models were constructed for two sites impacted by Light Non-Aqueous Phase Liquid (LNAPL) – one in the UK, one in the US

- The objectives of the modelling at both sites was to:
  - Evaluate heating methodology and associated heat energy consumption;
  - Predict heating duration;
  - Determine the optimum well spacing to achieve the Target Treatment Temperature (TTT) in the most energy efficient manner using CO_2 (equivalent footprint) as the primary indicator.

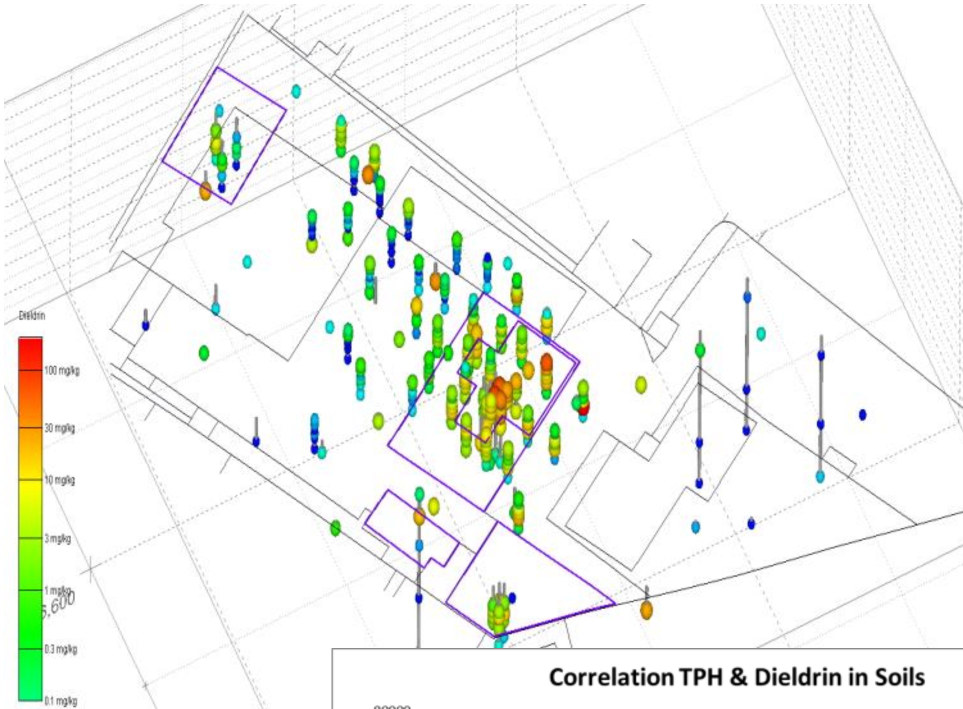
- Each thermal model was developed using PetraSim

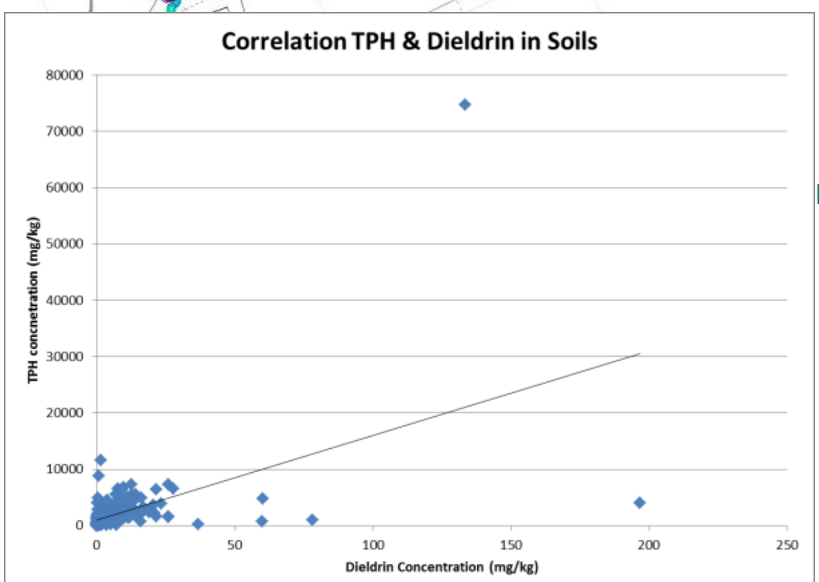
UK Site

Conceptual Site Model



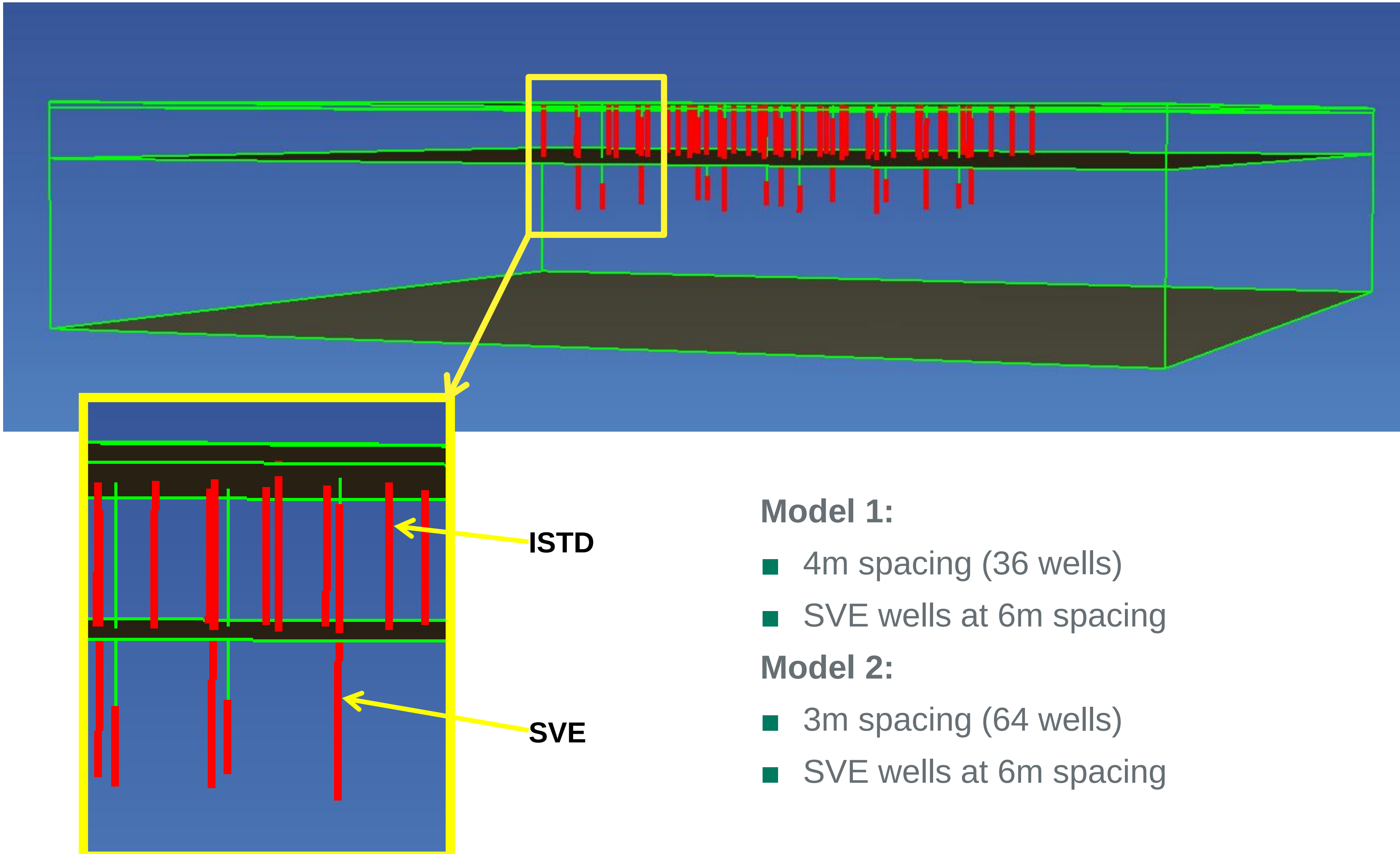
Contaminant Distribution





- Limited LNAPL in wells – but circa 8,000kg mass (mostly Kerosene)
- Lower Dieldrin mass – but was the risk driver
- Remedial options appraisal identified limited options
- Thermal considered most applicable, but target temperature challenges
- Boiling points:
  - Kerosene 150ºC (minimum)
  - Dieldrin 350ºC!
- Only applicable heating method for both therefore ISTD – Are these temperatures even achievable?!

ISTD Heating Models



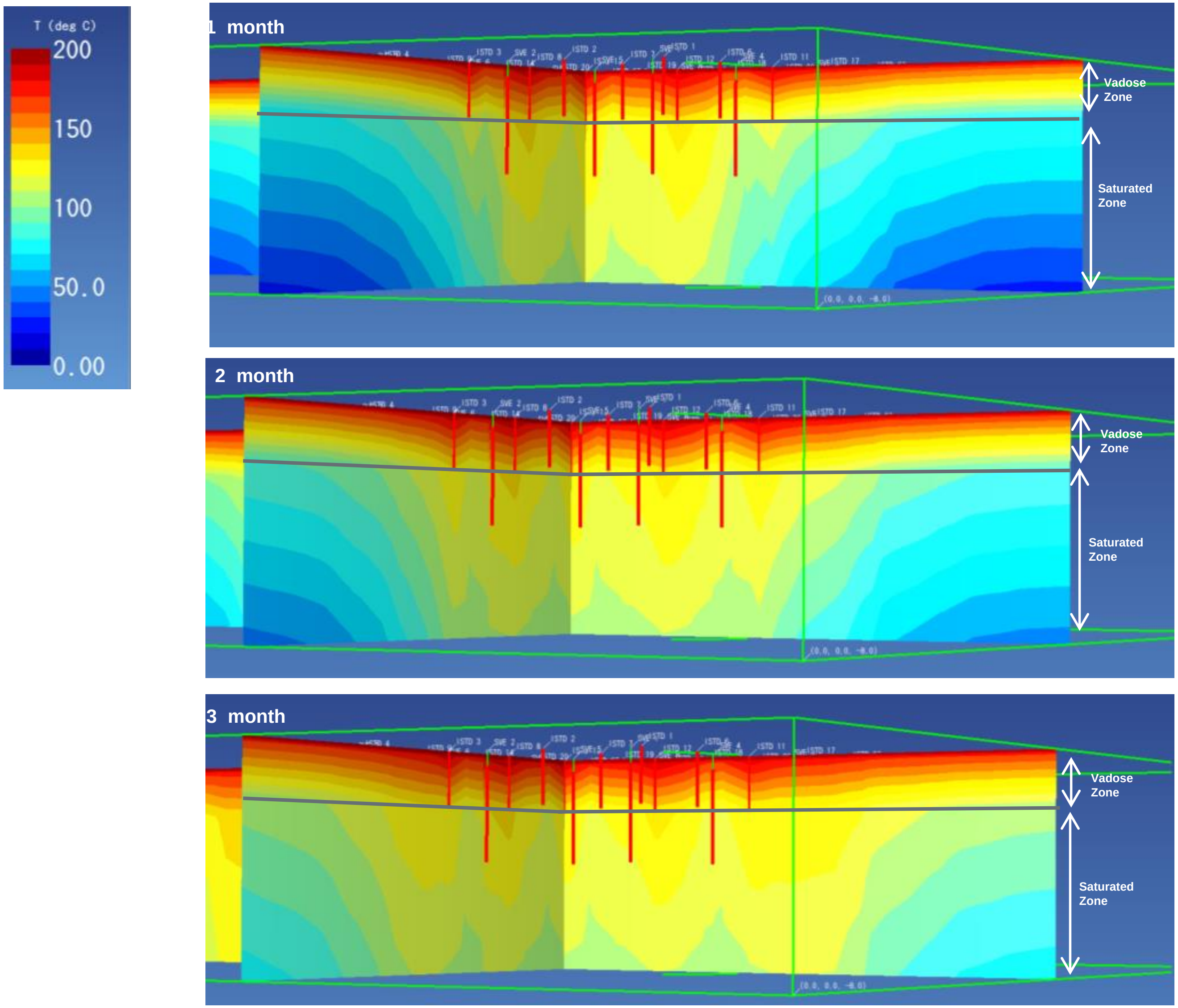
Model 1:

- 4m spacing (36 wells)
- SVE wells at 6m spacing

Model 2:

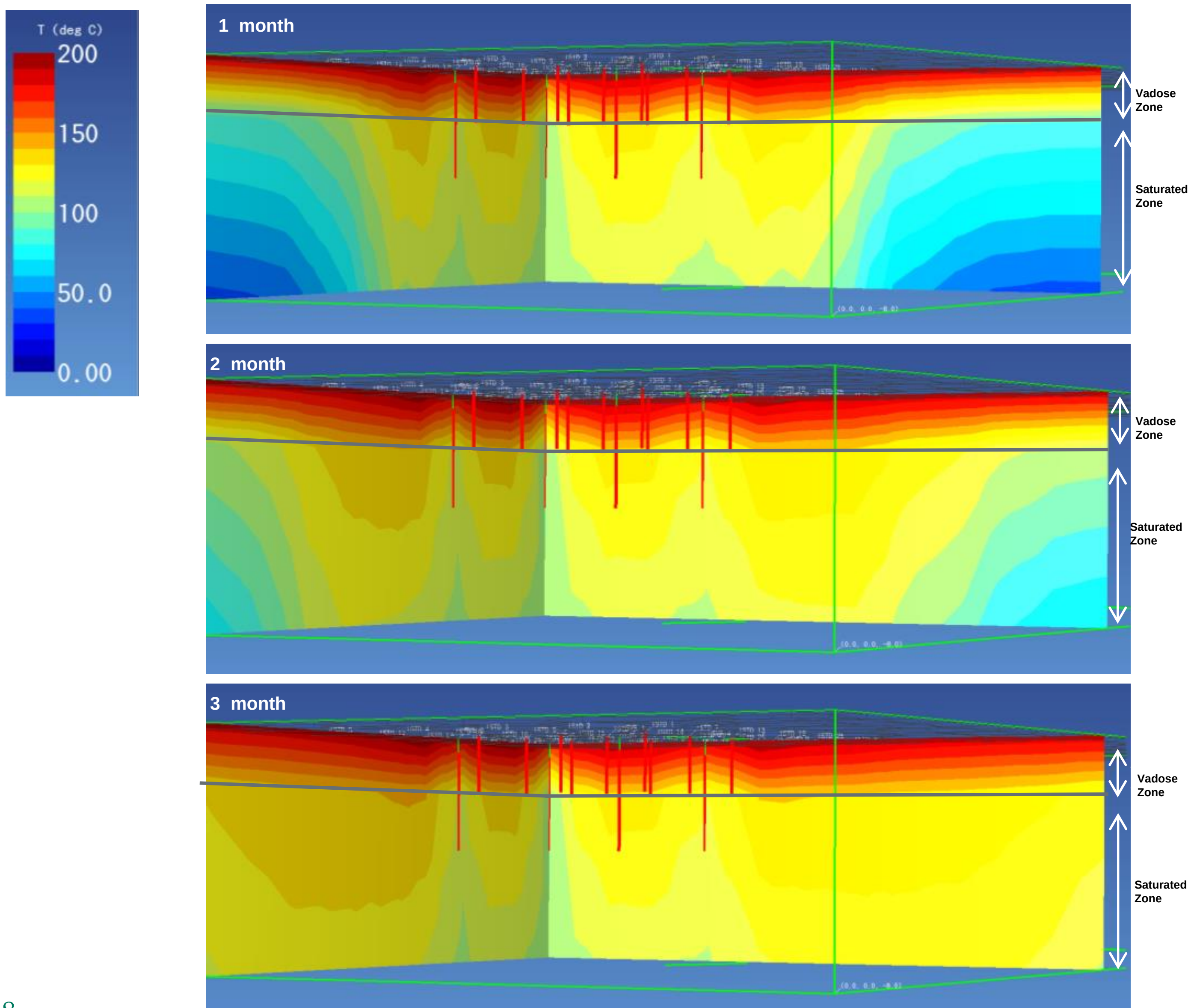
- 3m spacing (64 wells)
- SVE wells at 6m spacing

Model 1 Results (4m spacing)



After 3 months: 130 - 170°C

Model 2 Results (3m spacing)

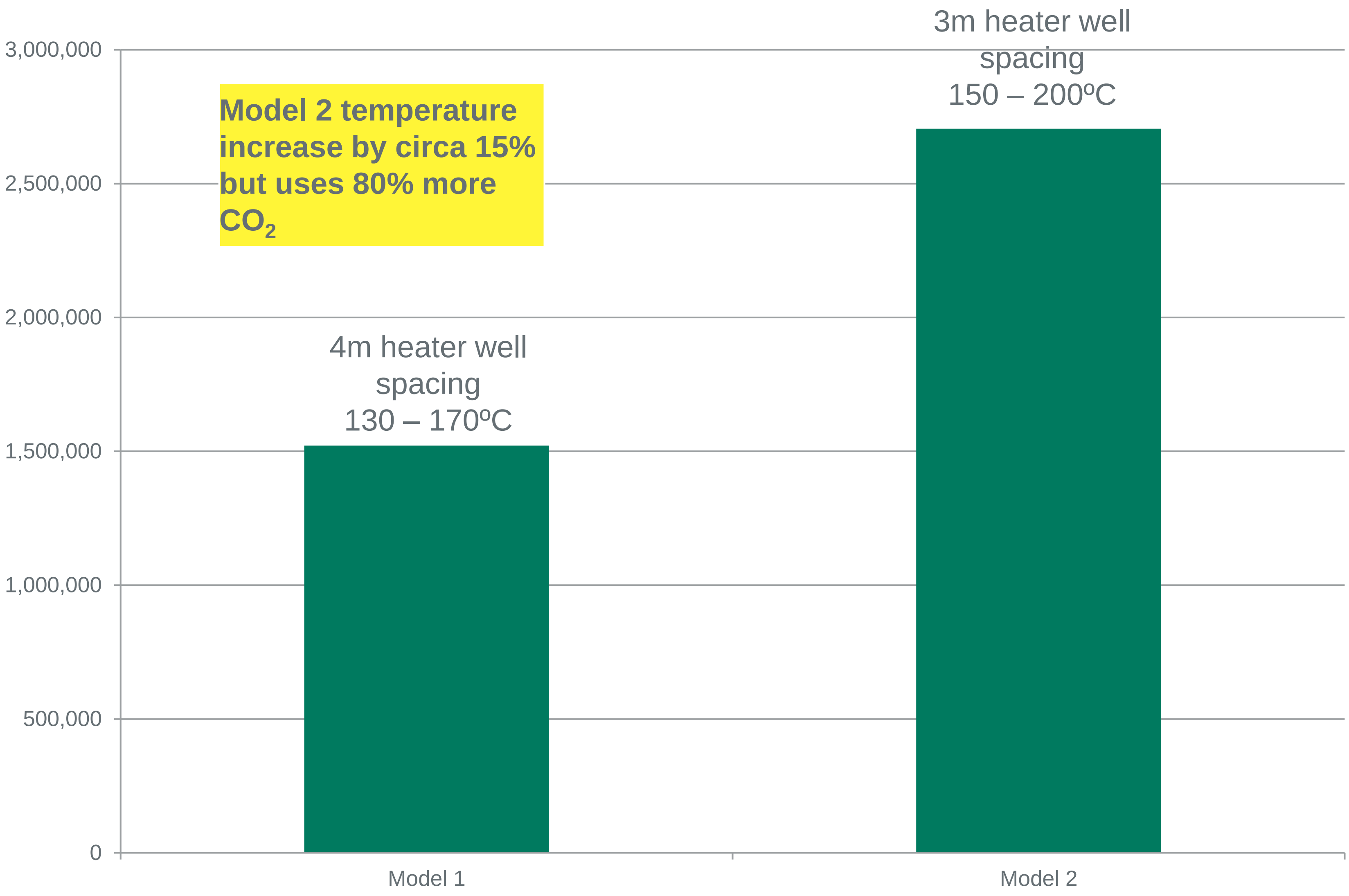


After 3 months:
150 - 200°C

Model Conclusions

- Maximum heat achievable in the unsaturated zone is 200°C (3m spacing)
- After 3 months, temperature stabilises and does not increase above the maximum predicted
- **Implication: Kerosene can potentially be volatilised, but Dieldrin cannot**
- Are there benefits to the closer spaced/higher temperature ISTD approach?

Carbon Footprint (kg CO2 eq)



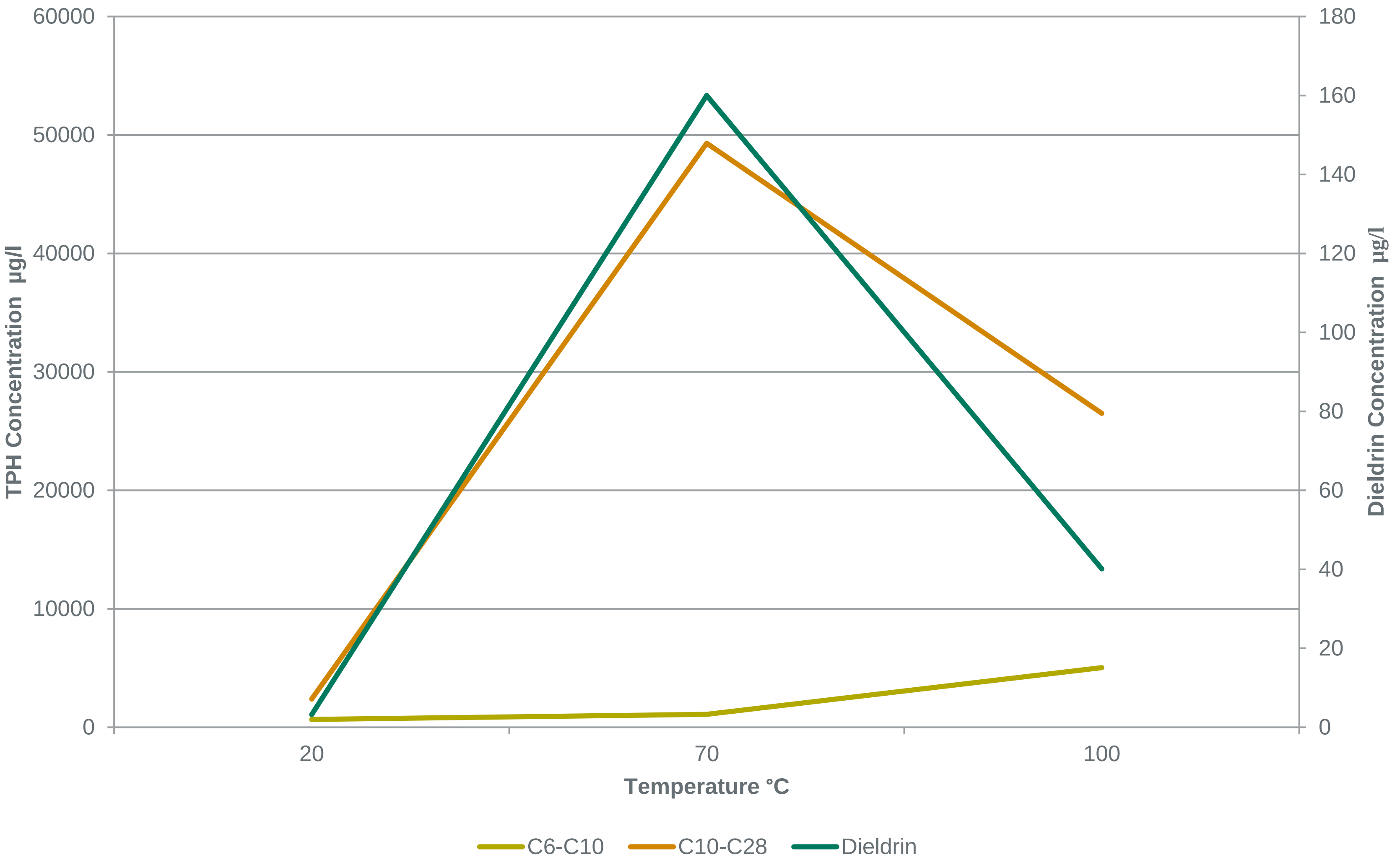
The business of sustainability

Remedial Approach based on the model?

- Remove Kerosene and then inject ISCO to deal with Dieldrin?
- OR could Kerosene be mobilised at lower temps/recover Dieldrin with it? - what would carbon footprint look like?

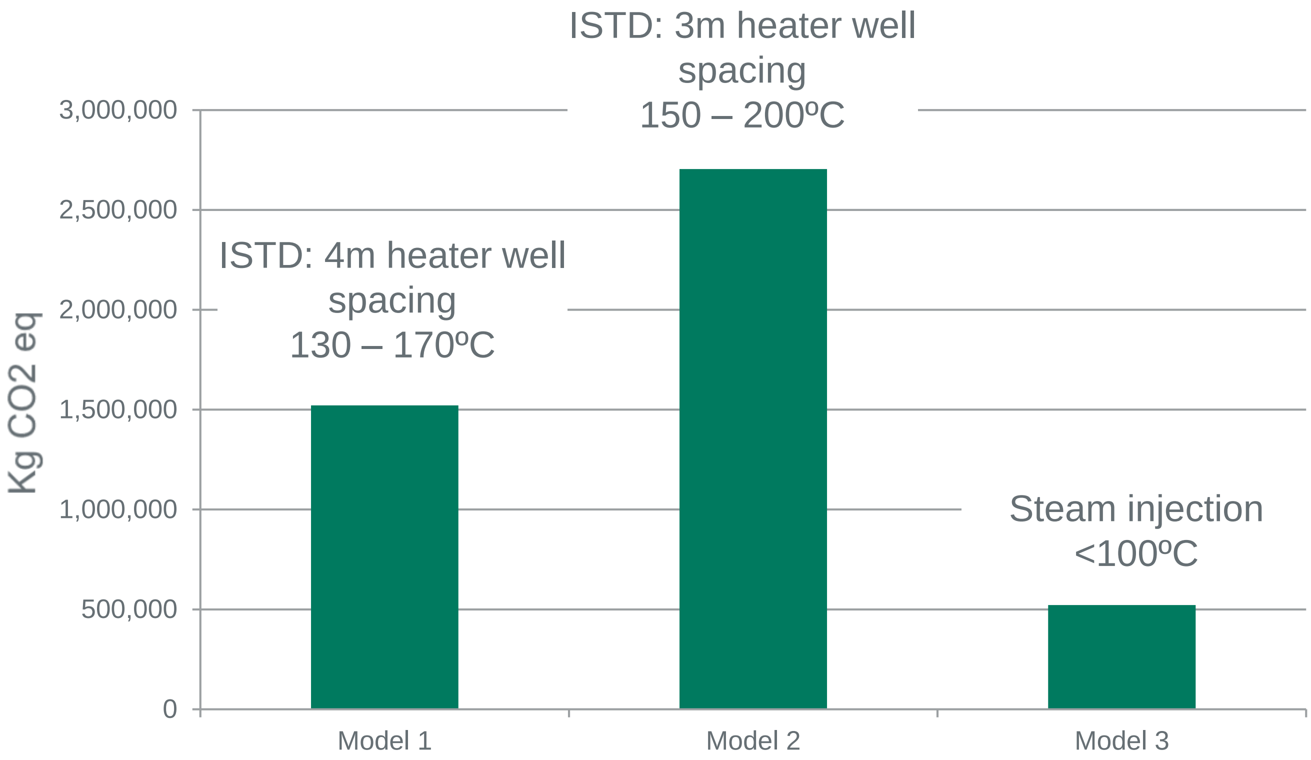
- Thermal bench test implemented:
  - Heating of each sample to temperatures of 70ºC, 100ºC, 125ºC and 150°C
  - TPH and OCP analysis on each heated soil sample, and each water sample on the two lower temperature tests

Thermal Bench Test Results



Effect on Remedial Strategy

- TTT reduced from 150 - 200°C to 70ºC
- Change in methodology meant steam rather than ISTD could be used to heat the subsurface (less wells and energy)
- Lowest carbon footprint heating approach developed using the model:



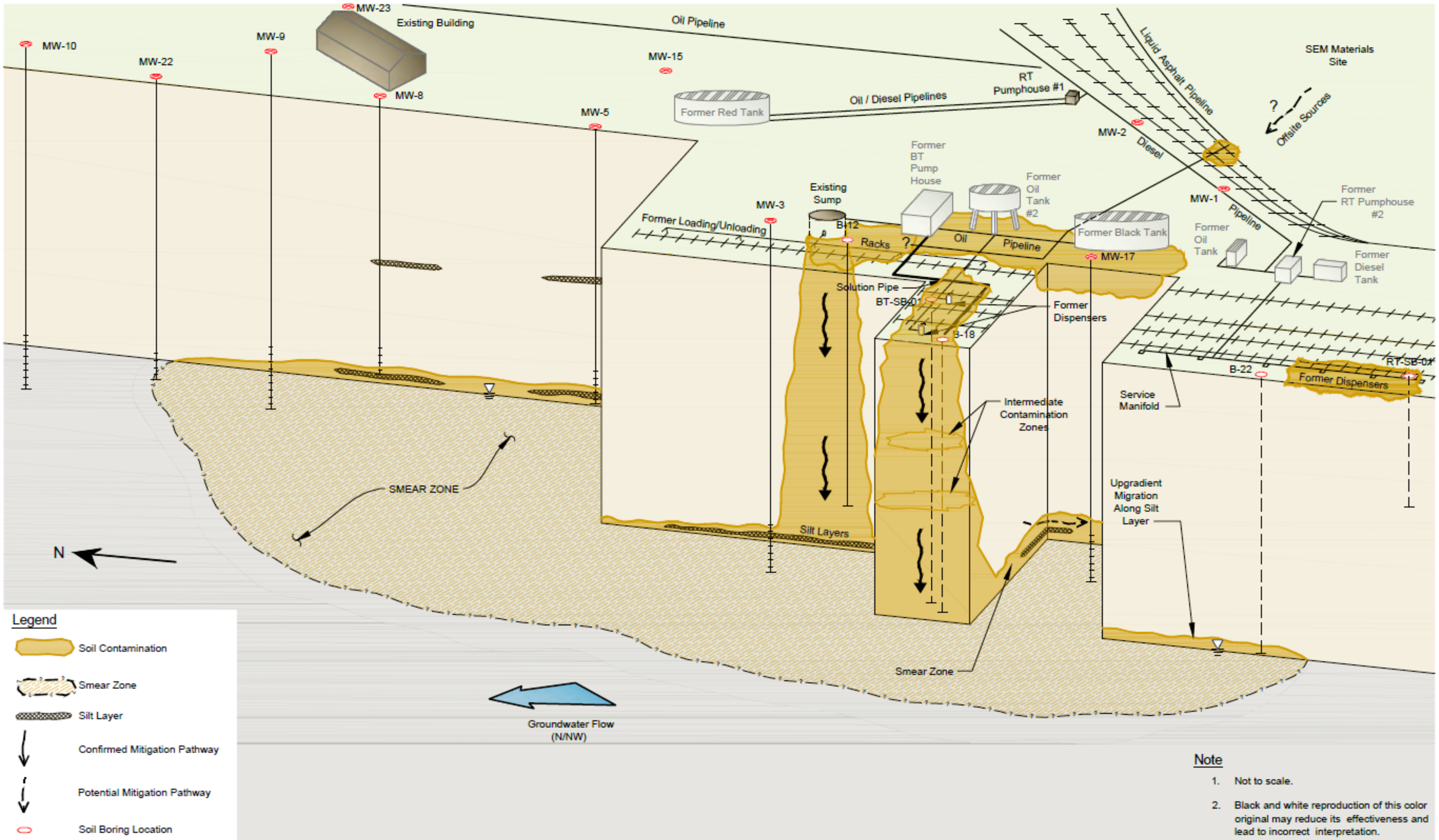
ERM

US Site

The business of sustainability

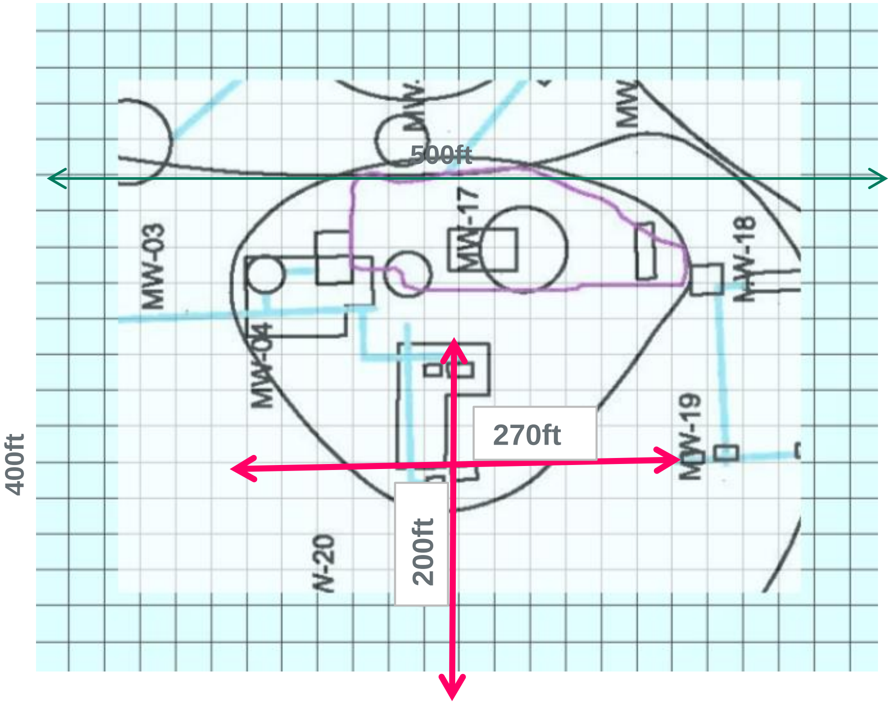
ERM

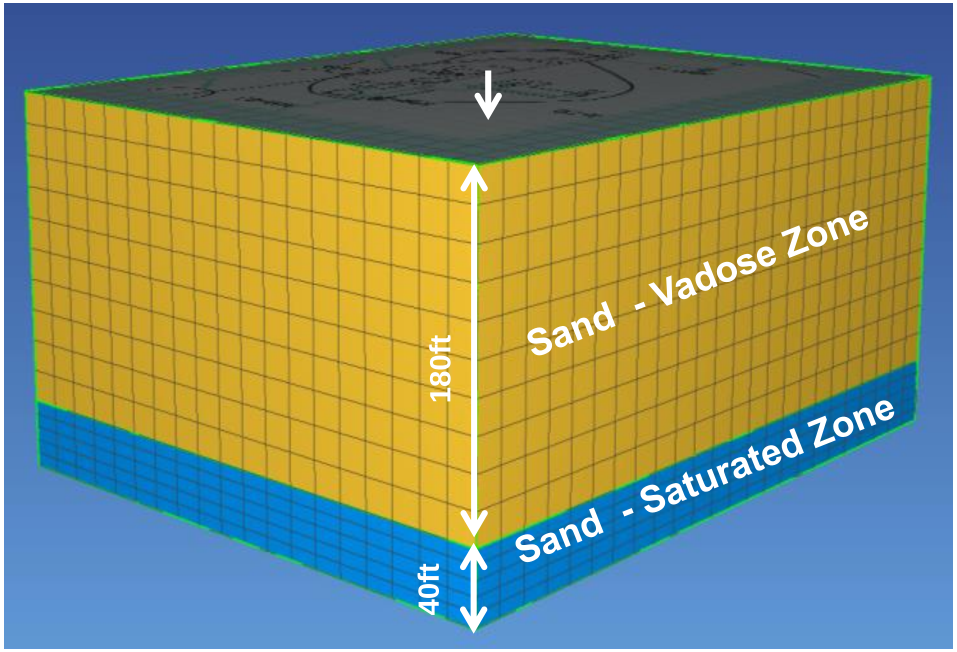
Conceptual Site Model



ERM

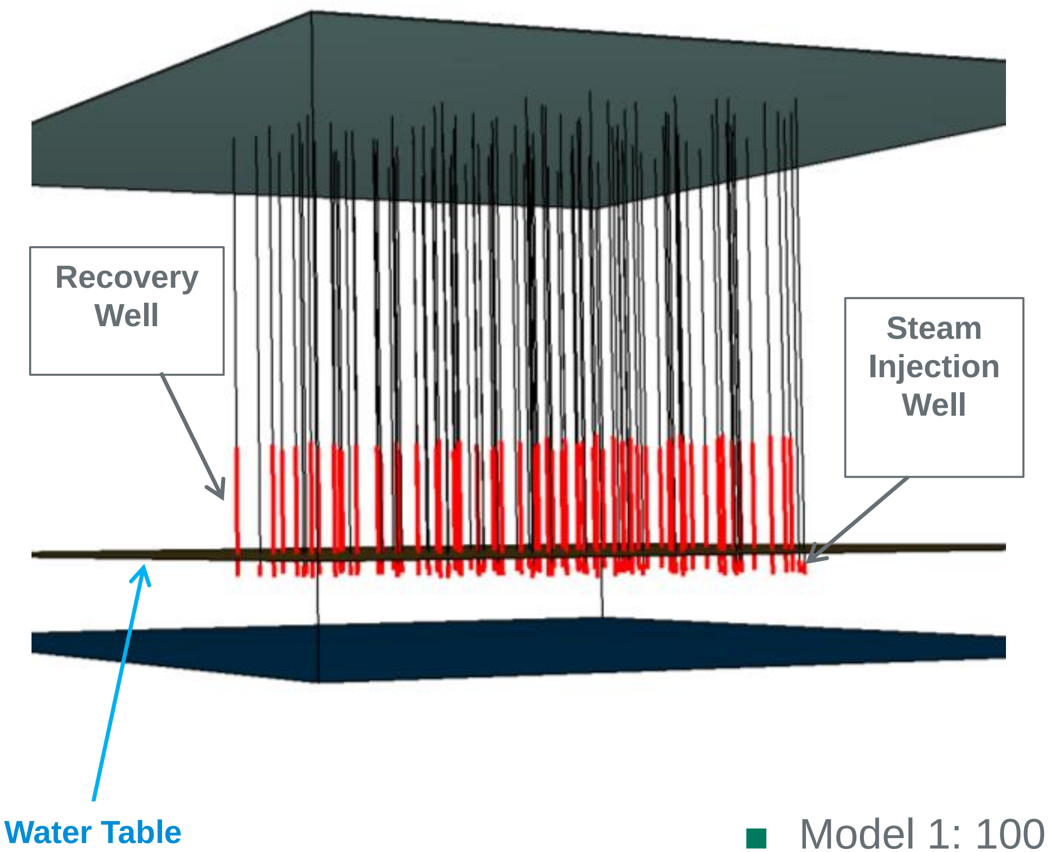
Contaminant Distribution





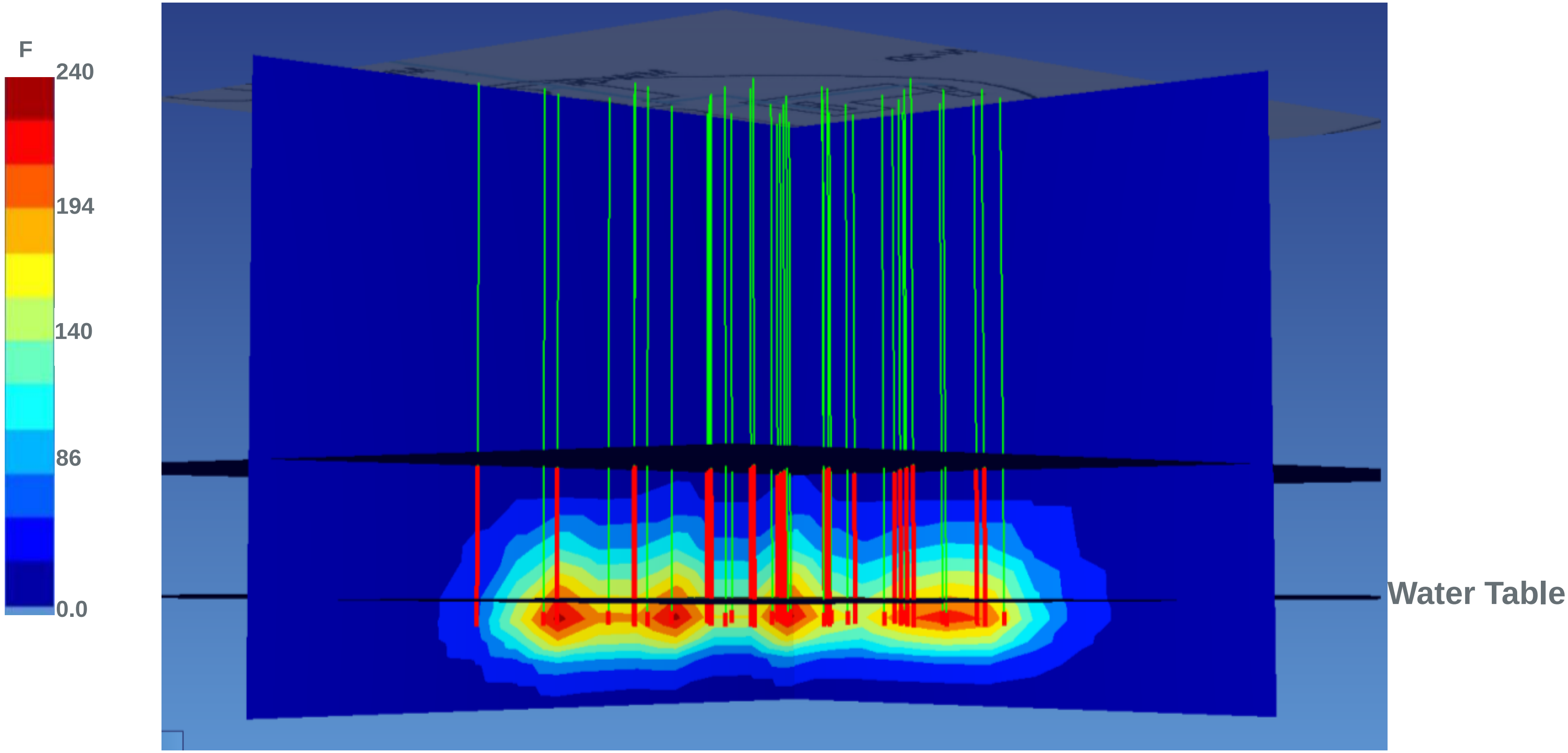
ERM

Steam Heating Models



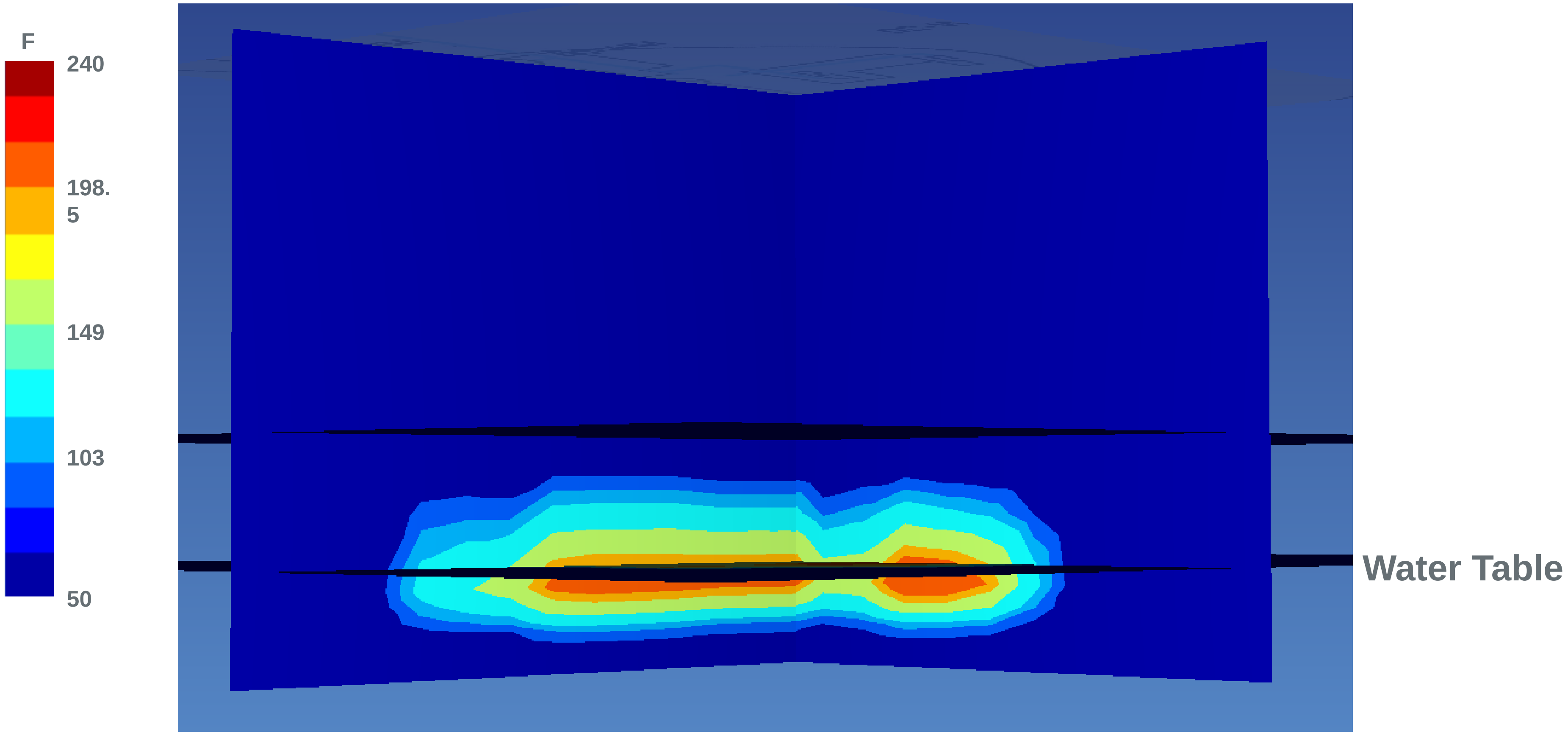
- Model 1: 100kg/hr steam per well, 16ft ROI, 50 steam injection wells
- Model 2: 50kg/hr steam per well, 23 ft. ROI, 41 steam injection wells

Model 1 Results



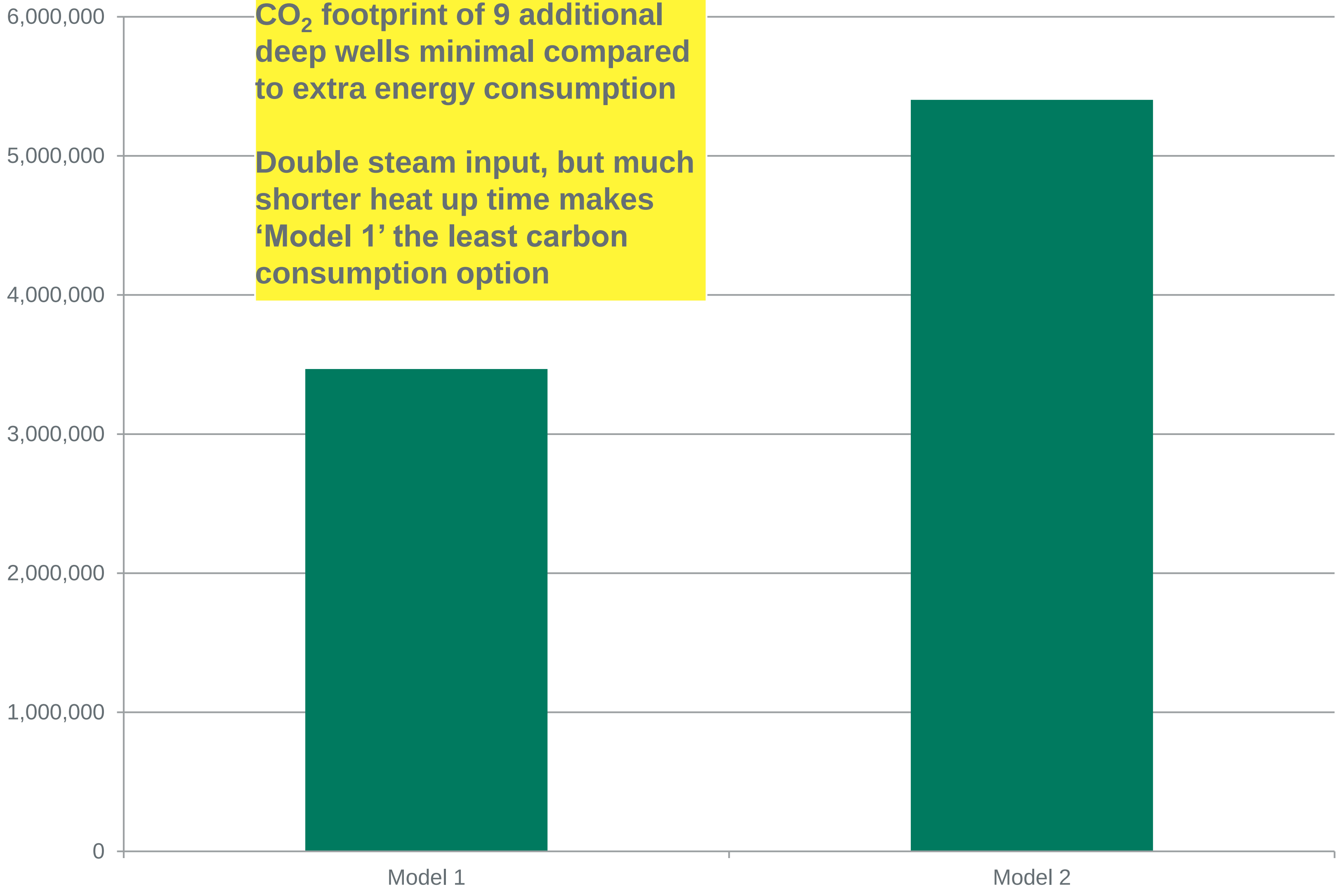
70ºC is predicted to be achieved after 5 weeks of heating

Model 2 Results



70ºC is predicted to be achieved after 19 weeks of heating

Carbon Footprint (kg CO2 eq)



CO_2 footprint of 9 additional deep wells minimal compared to extra energy consumption

Double steam input, but much shorter heat up time makes 'Model 1' the least carbon consumption option

Summary and Next Steps

ERM

Summary

- Key Benefits UK Site:
  - Energy consumption prediction assisted with the remedial strategy development – lowered carbon footprint (and costs)
  - Improved predictions also meant:
    - Energy use was ‘known’ – compare gas/electric - affected clients tariff
    - Predicting heat up time - process kit rental can be predicted/optimised
    - Improves certainty for stakeholders – the site is for sale - finishing remedial programme critical

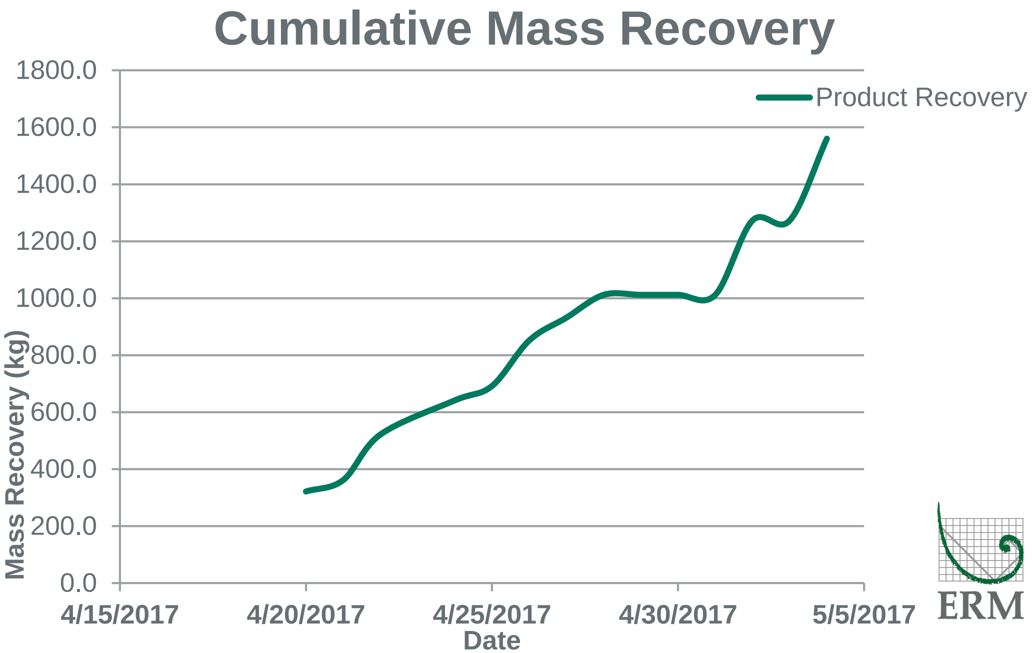
- Key Benefits US Site:
  - Key to optimising balance between wells spacing/numbers and energy consumption
  - Enabled a remedial cost estimate to be generated with greater certainty and comparison to ambient temperature biodegradation

Conclusion

- Overall modelling helps improve thermal remediation sustainability
- However, it does needs to be applied with other lines of evidence to lower carbon footprint to the extent possible – such as:
  - Bench tests to confirm concepts of what is being modelled
  - Real time field data to confirm predictions

Next Steps – UK Site

- Quantify actual carbon footprint
- Confirm modelled versus observed predictions



Next Steps – US Site

- Model confirmed thermal could be cost viable (initial thoughts were it would be cost prohibitive)
- Single well steam propagation test to be carried out to confirm model results
- Could be a thermal/biological remediation combination

Questions?

ERM