Modelling Heat Transfer in Buried Pipes

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MAKING KNOWLEDGE WORK

Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B.
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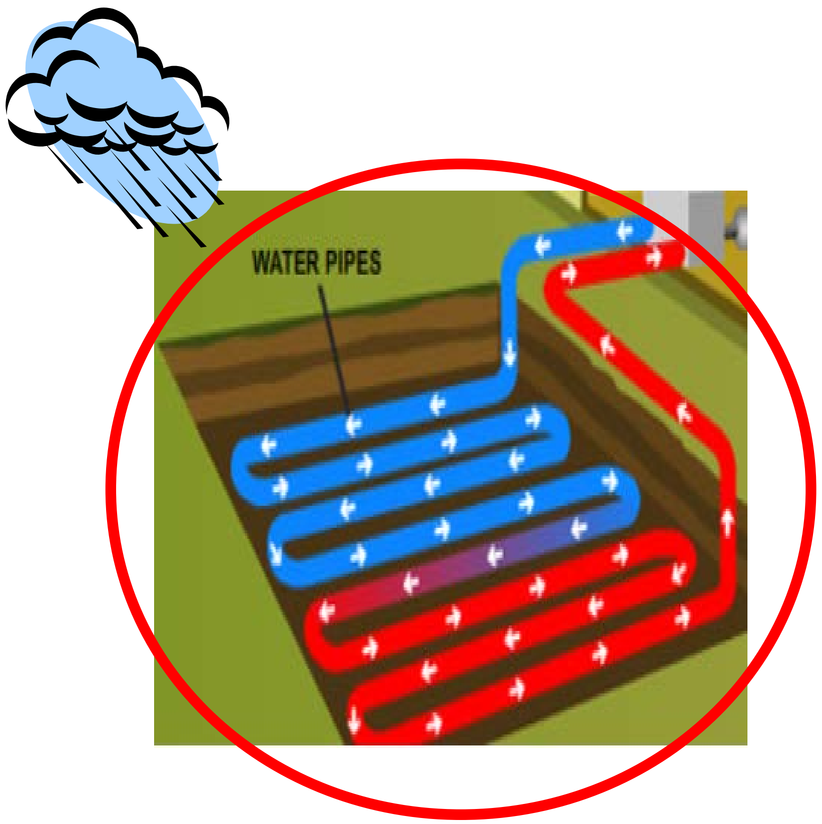
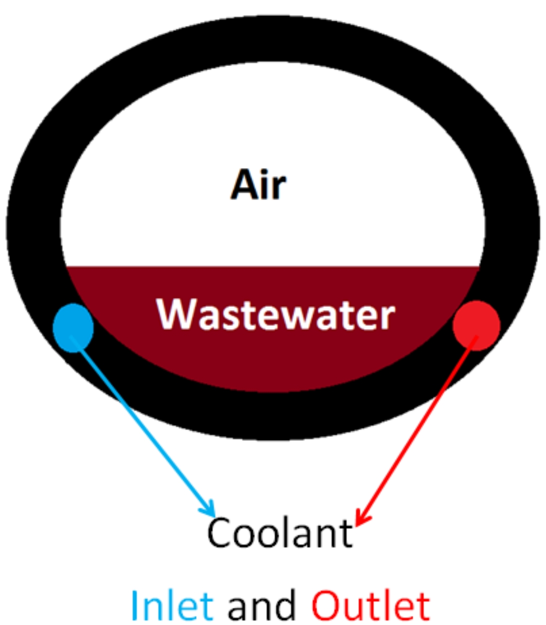
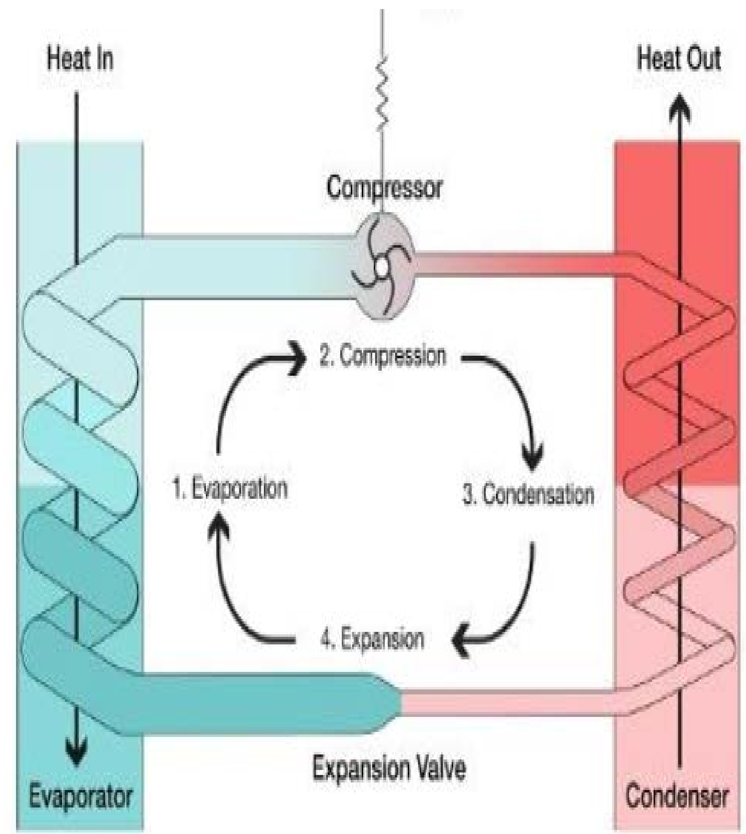
Scope

- Part of Inners InterregIVB project: http://inners.eu/
- Heat recovery from buried pipes
- Modelling heat transfer in buried pipes
- Results
- Conclusions
- Future work

Source → Heat Pump → Distribution







Would saturated soil improve heat transfer efficiency?

Could we improve efficiency of small-scale shallow ground loops by infiltrating storm water?

Modelling heat transfer in buried pipes

- Heat transfer in ground loops was modelled in literature
- TEMPEST Model (ETH, Switzerland) incorporated air and soil moisture effects on heat transfer in sewer pipes
- Not much published data validate TEMPEST model
- Not much literature on effect of soil moisture on thermal conductivity of soil (k_{soil})

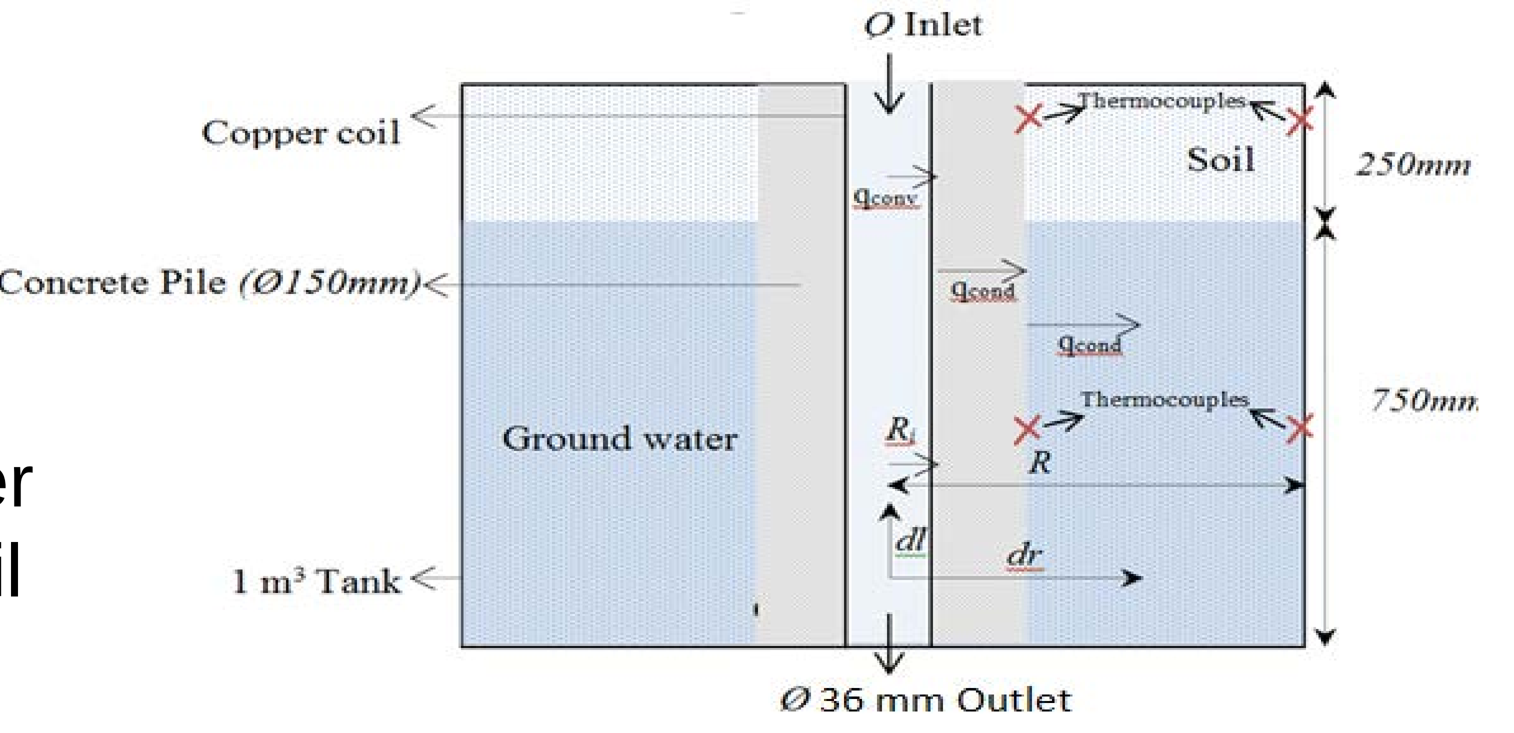
- Start with simple radial and length-wise heat transfer model for full-pipe flow, to see influence of soil moisture on heat exchange

Initial model calibration: laboratory data

1 x 1 m tank filled with soil, and partially saturated with water

Including concrete column with coil loop inside, hot water could be pumped through coil

Thermocouples fitted at start\end of coil loop, and at edge of column and in the surrounding soil

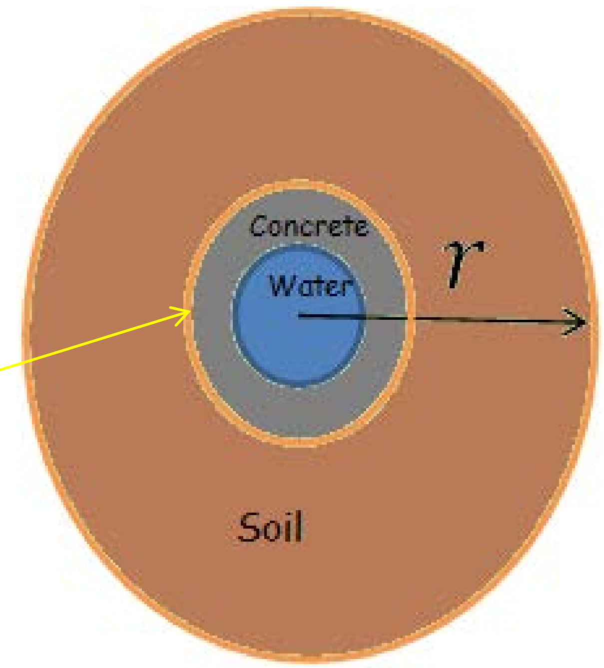


MSc by Z.A. Shaikh, 2010, University of Bradford

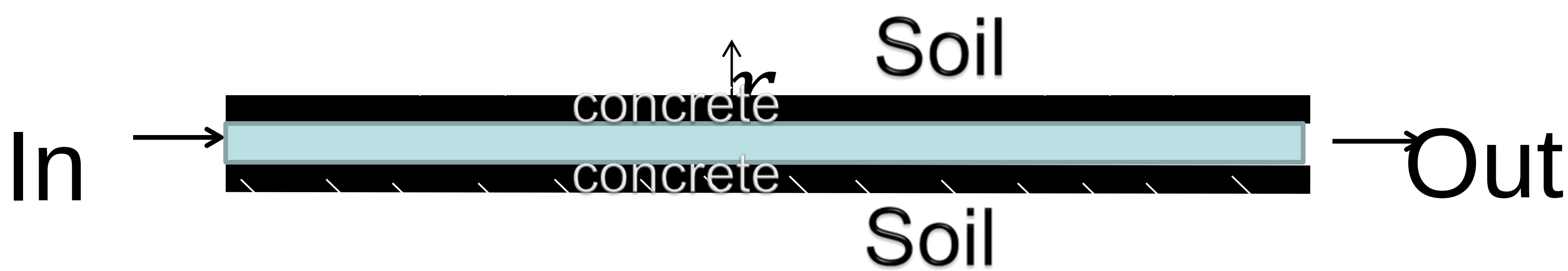
- **Radial model**

$$\frac{d^2T}{dr} + \frac{1}{r}\frac{dT}{dr} = 0$$

$$k_{concrete}\frac{dT_{concrete}}{dr} + k_{soil}\frac{dT_{soil}}{dr} = 0$$



- **Along pipe profile model**



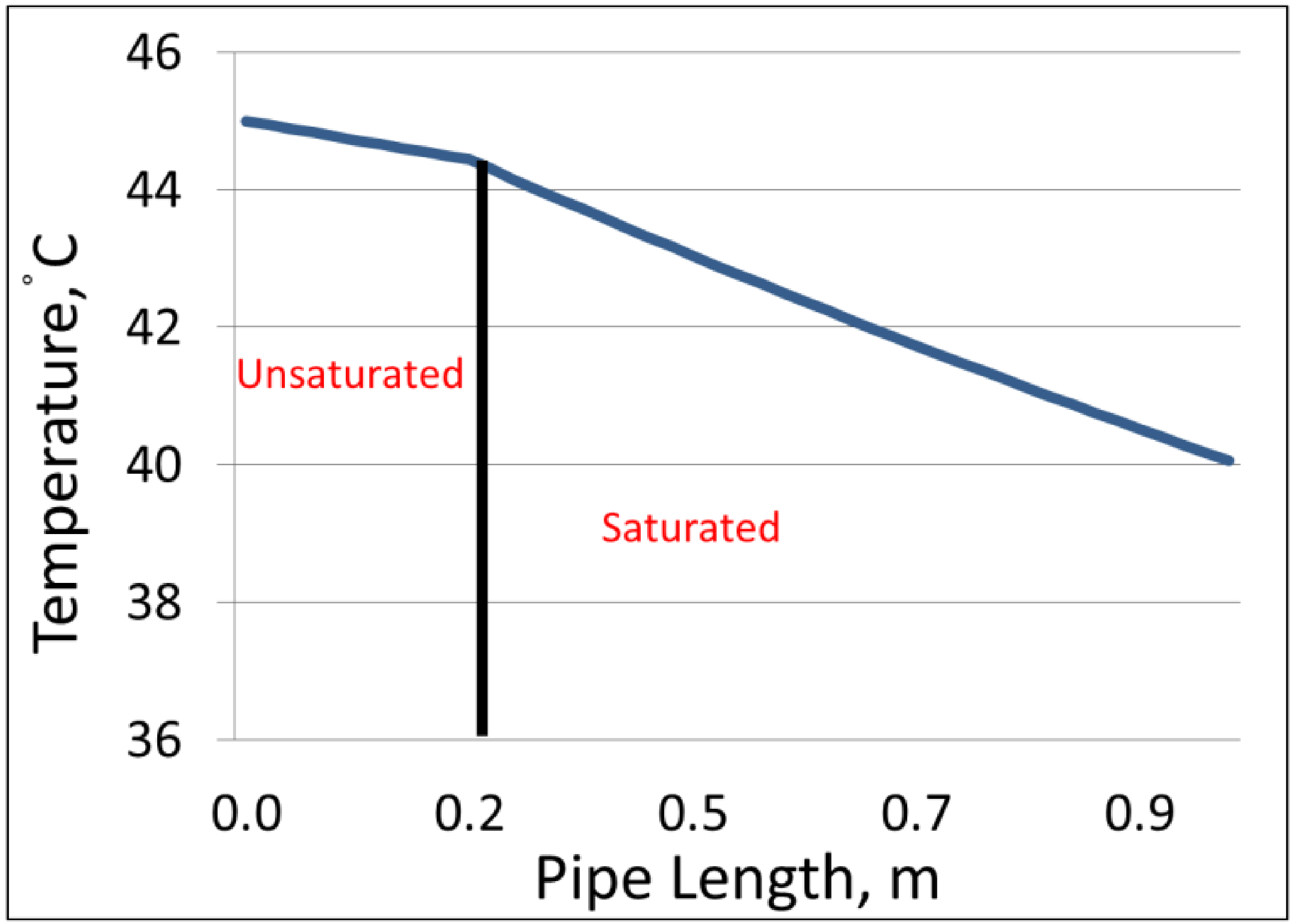
$$Q = mc_p(T_{out} - T_{in}) = \frac{(T_{soil} - T_{water})}{R_{th_n}}$$

$$R_{th_n} = \frac{\ln(\frac{r_2}{r_1})}{2\pi k_n L} \quad K_{eff} = \frac{1}{\sum R_{th_n}}$$

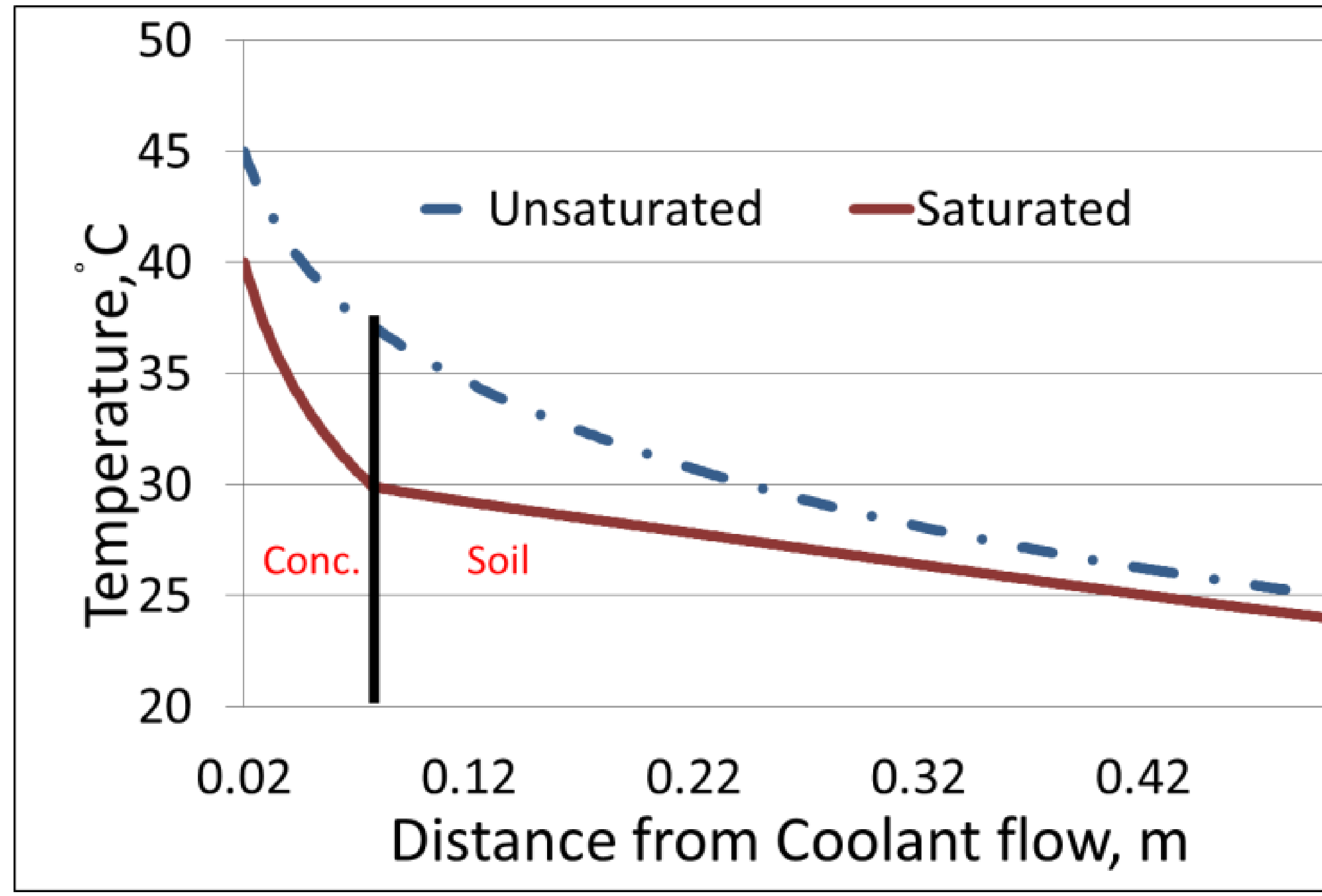
m= mass flow rate (g/s), C_p = thermal capacity (kJ/kg.°C), soil or concrete , R_{th}: thermal resistivity (°C.m/W), and are outer and inner radii respectively for soil and concrete (m), L: equivalent pipe length (m), K_{eff} is the effective thermal conductivity for the combination of soil and concrete (W/m. °C)

Initial Model calibration

Length-wise:



Radial:



Results of initial model calibration:

Thermal Conductivity, k	Model	Literature	Unit
Concrete	**1.2-1.3**	**1.0 - 1.8**	W/m.K
Soil (saturated)	**4.2**	**0.25 -2.5**	
Soil (dry)	**1.3**		

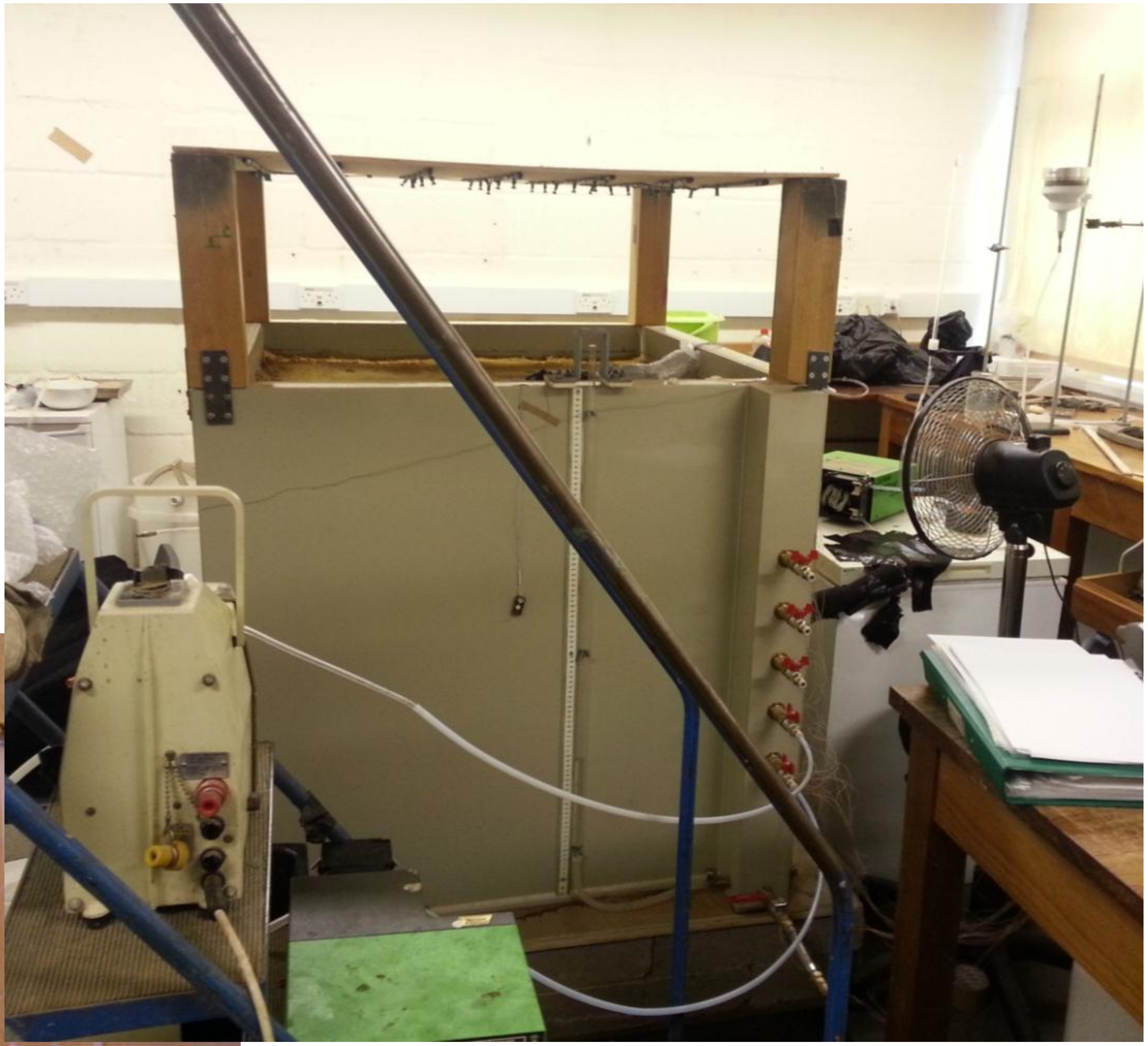
Conclusions initial model calibration

- Results agree with literature ‘k’ values concrete/dry soil
- Considerably more thermal energy extracted at saturated soil

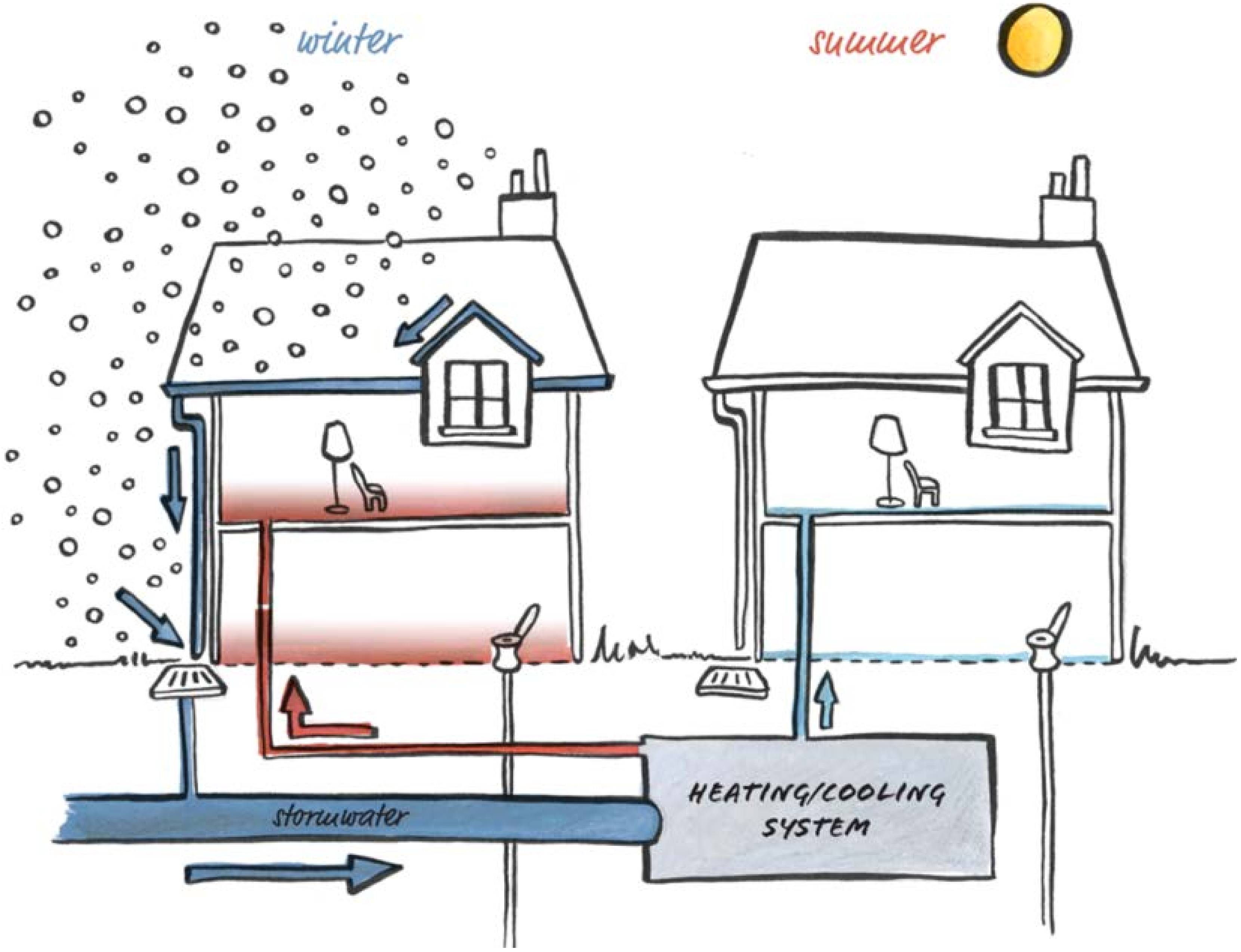
- Ground source heat pump systems could potentially be made more efficient by introduction of storm water to increase soil saturation
- Ground water could influence the potential heat recovery from urban drainage networks

Future Model extension and calibration

Current Lab work:
ground loop with variable water level and rain simulation



Future field work



- 2 x 18 pipes spaced at 0.16m with diameter of 40mm each
- Temperature sensors fitted on pipes
- 10 vertical temperature sensors at different depths

- Covering pipes with 300mm deep sand
- Ground water level sensor fitted

Covering sand with 750mm deep gravel for rainfall drainage

Gravel covered with soil up to finished garden level

Future Work

- Calibrate current model with new lab and field measurements
- Measuring soil thermal conductivity (KD2 Pro)
- Expand on literature review of heat transfer in wastewater

- Analysis sewer network flow and temperature data (Aquafin)
- Transient 2D model using Matlab / Infoworks
- Validate TEMPEST software

- Thank your for your attention

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