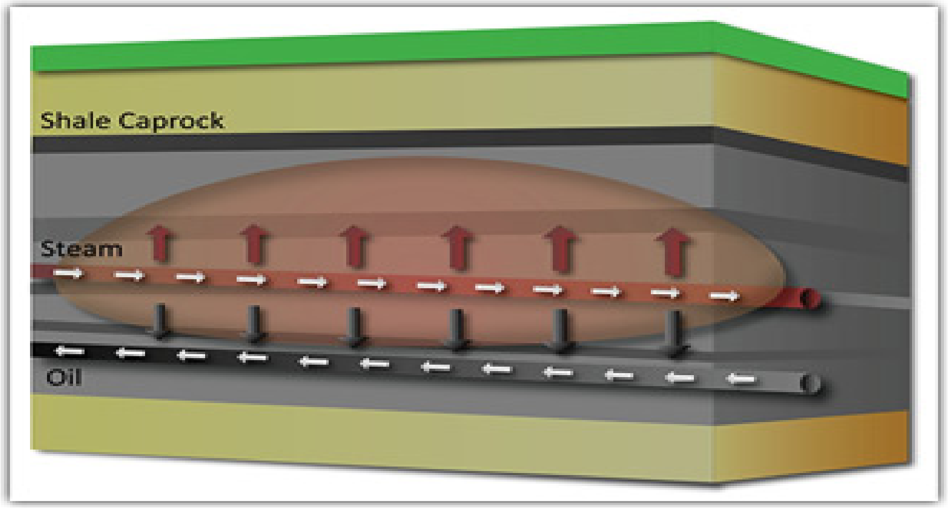

Effect of Steam-Related Heave on Groundwater-Surface Water Interaction

Brent Moore, M.Sc., P.Geol. (Devon Canada)
Nelson Molina Giraldo, Ph.D. (Matrix Solutions)

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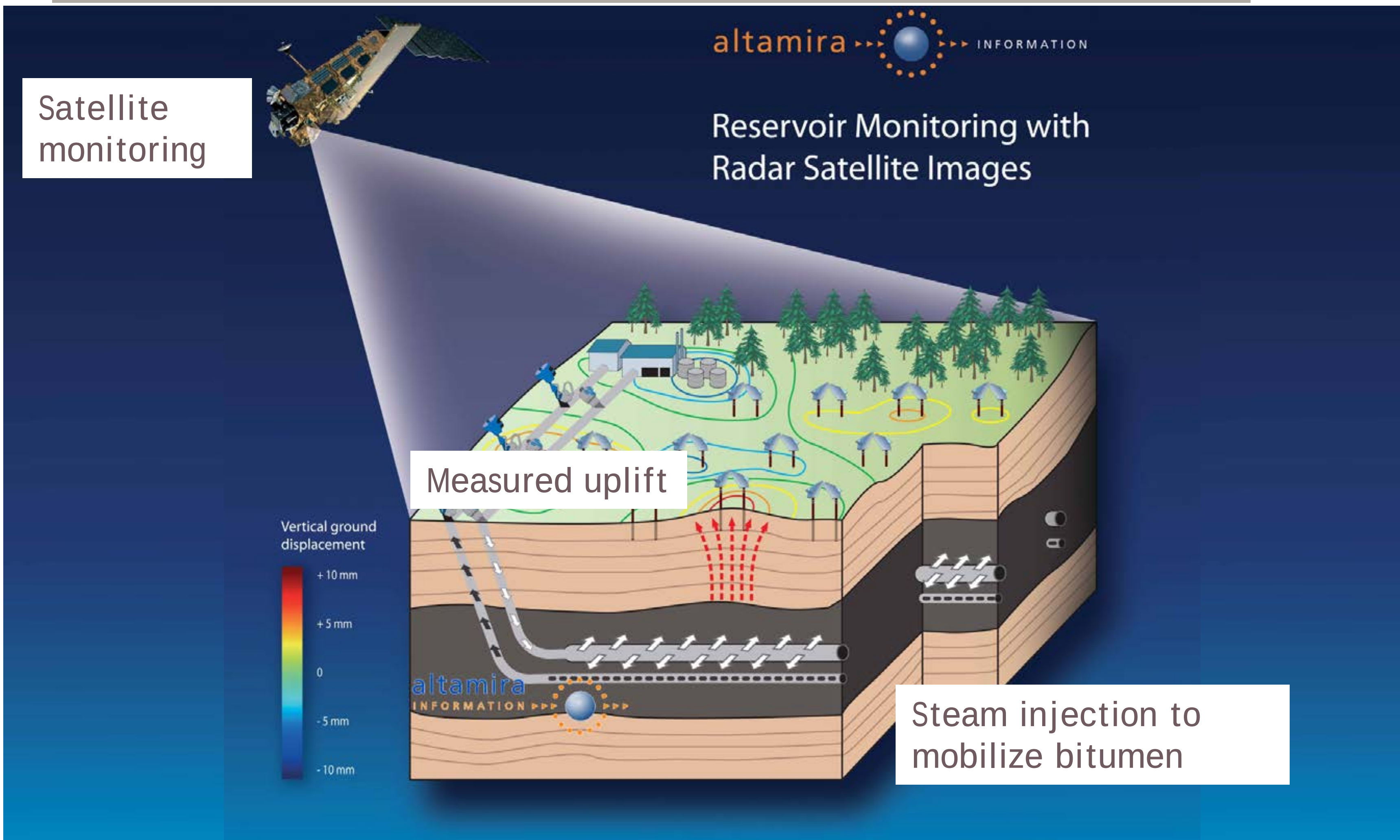
Outline

- Satellite Monitoring to measure heave
- Groundwater-Surface Water monitoring program
- Use of heat as tracer to estimate GW/SW interaction
- Results to date
- Next Steps

Satellite Monitoring to Assess Surface Heave



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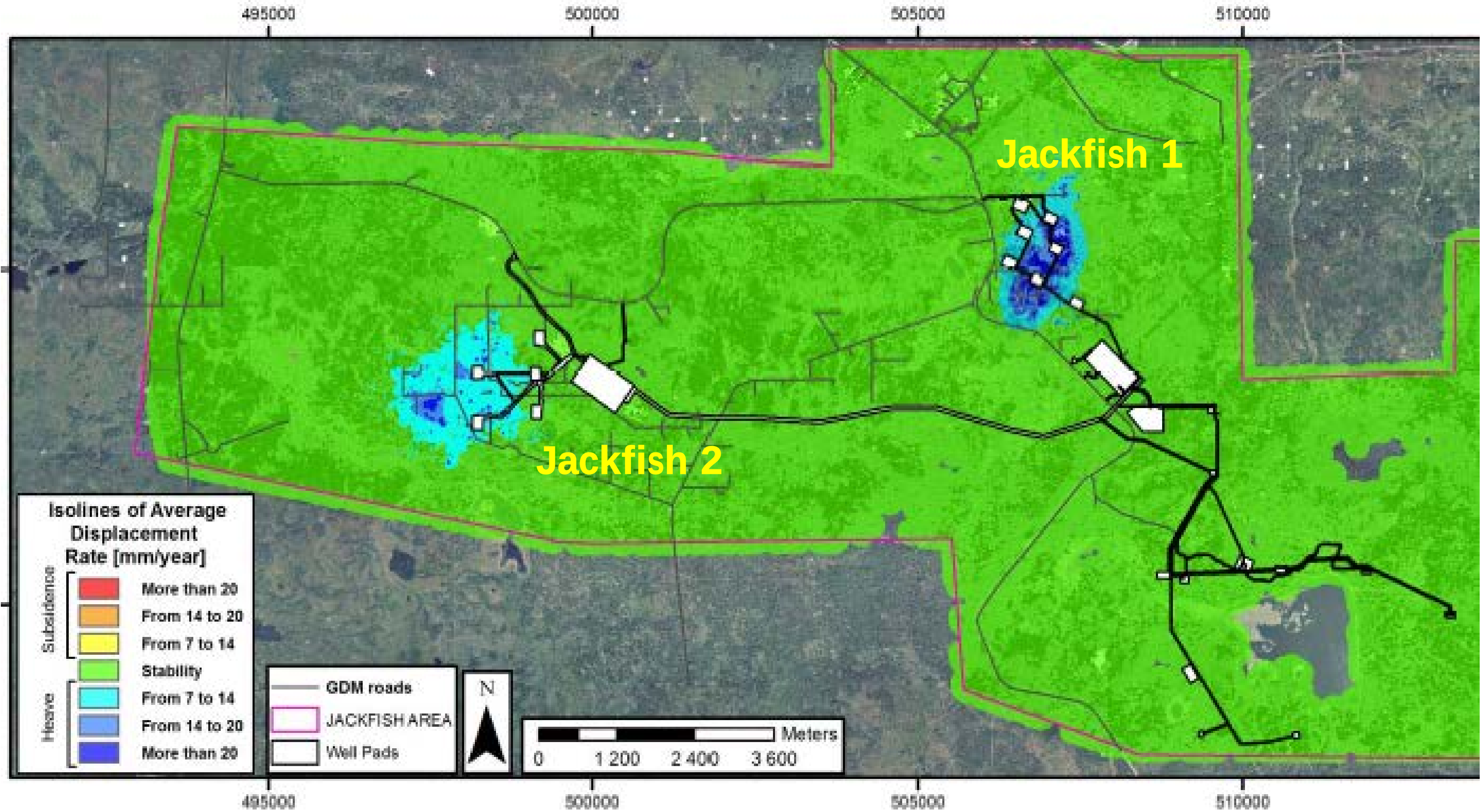
Jackfish Heave Displacement
0 to >20 mm/year



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Groundwater – Surface Water Monitoring Installations

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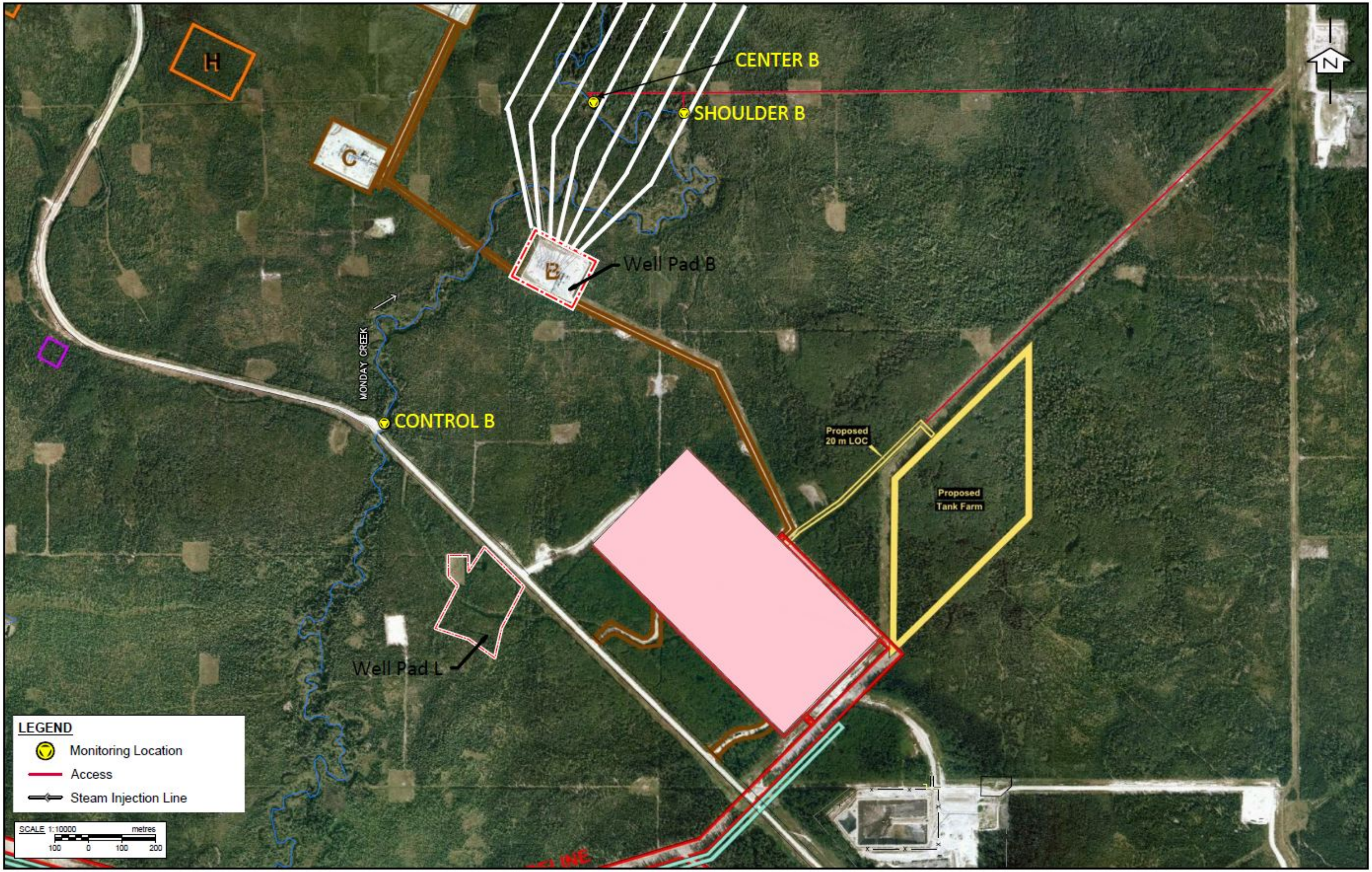
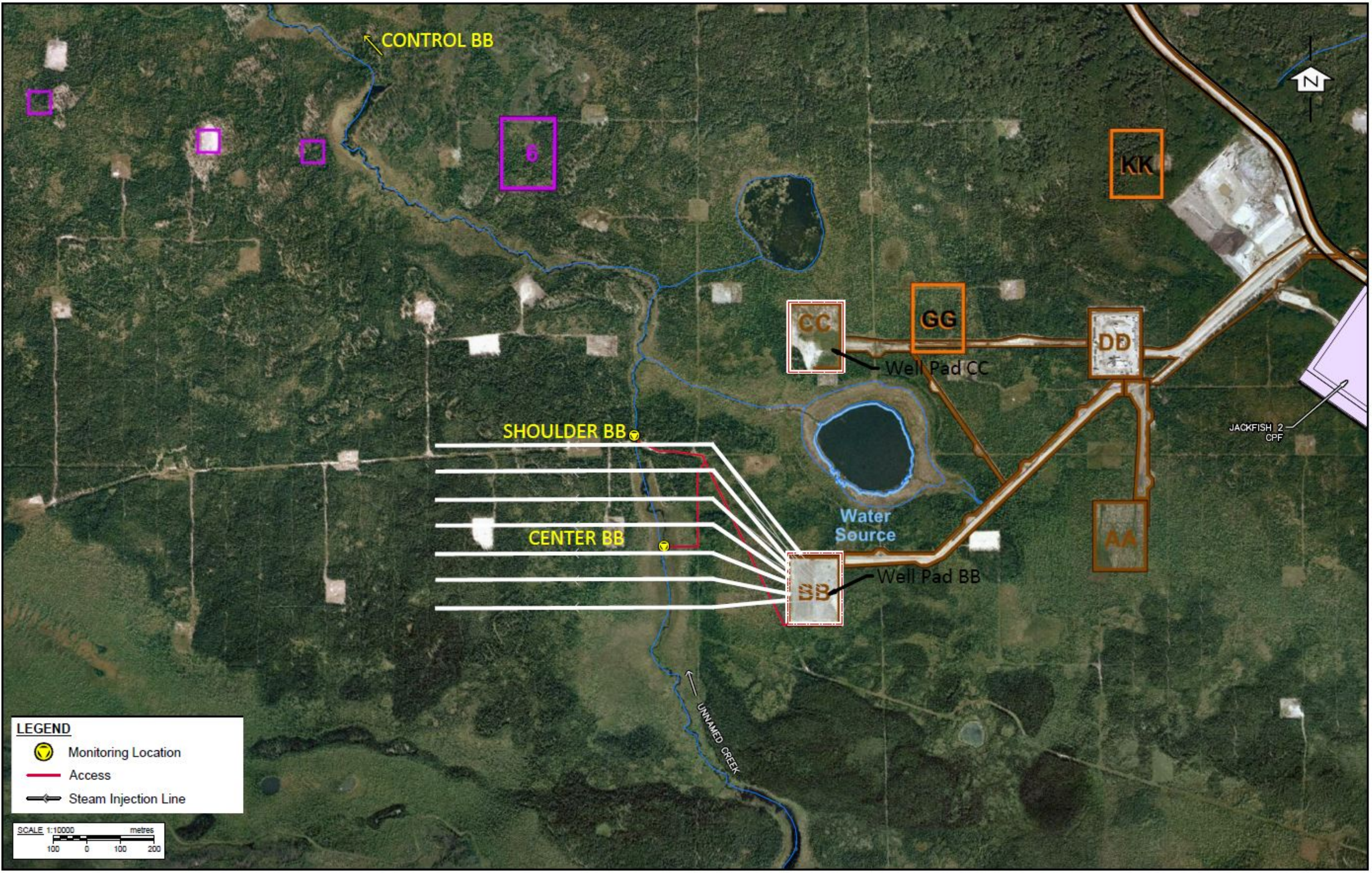
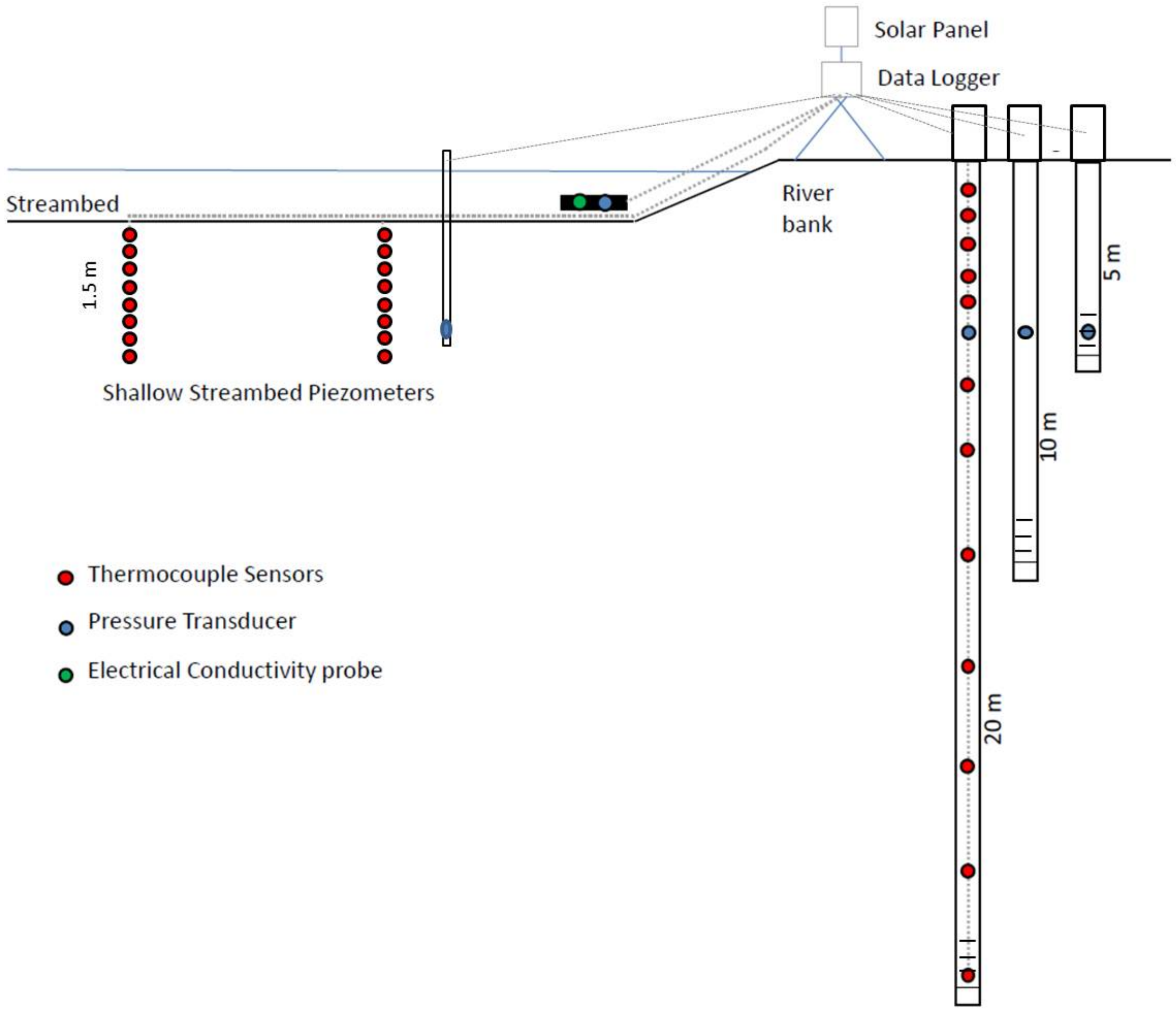
Monitoring Stations at J1 (Pad B) Monday Creek



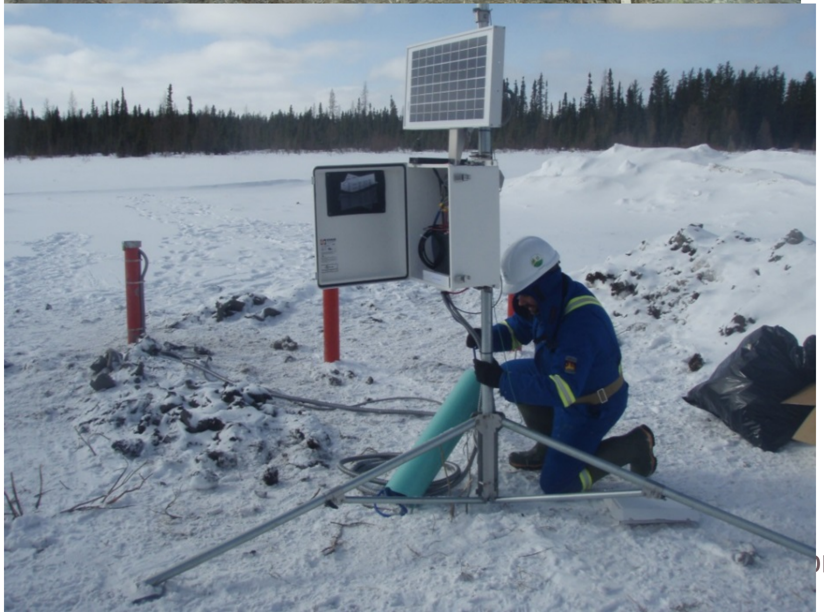
Monitoring Stations at J2 (Pad BB) Unnamed Creek



Monitoring Well Installations: Streambed / Streambank



Groundwater Monitoring Wells and telemetry installation



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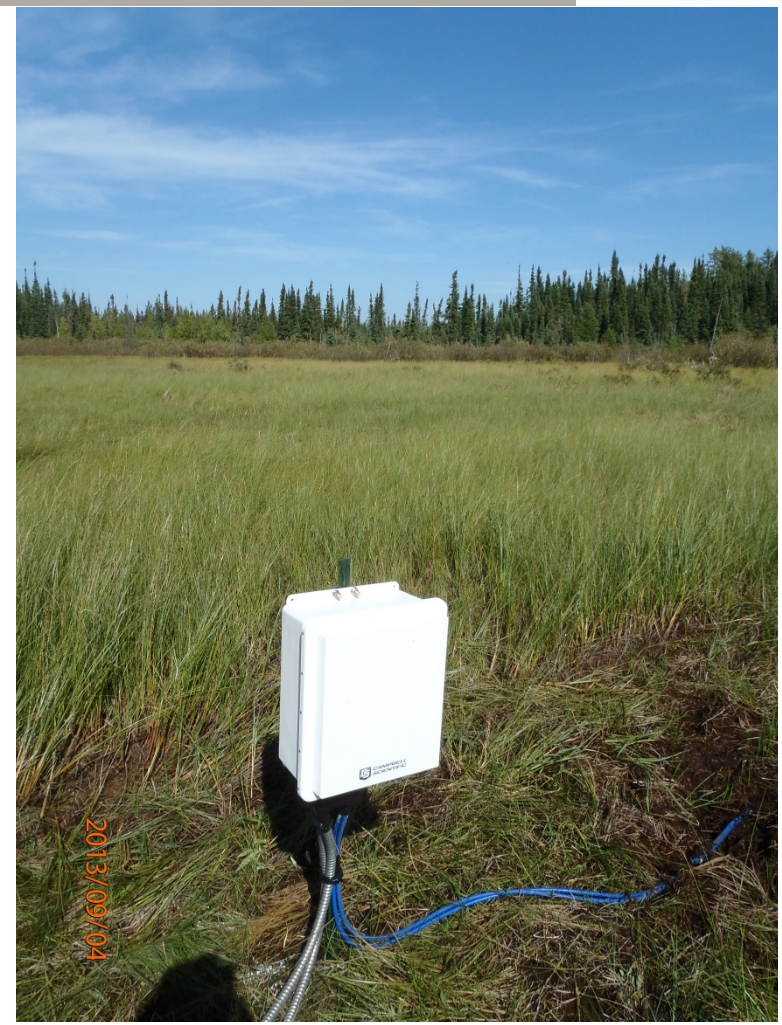
Stream Bed Monitoring



Some background theory...

Using Heat as a tracer to estimate GW/SW interaction

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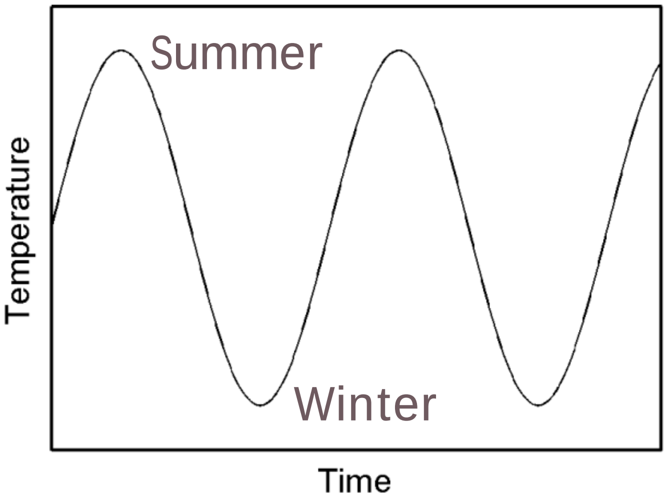
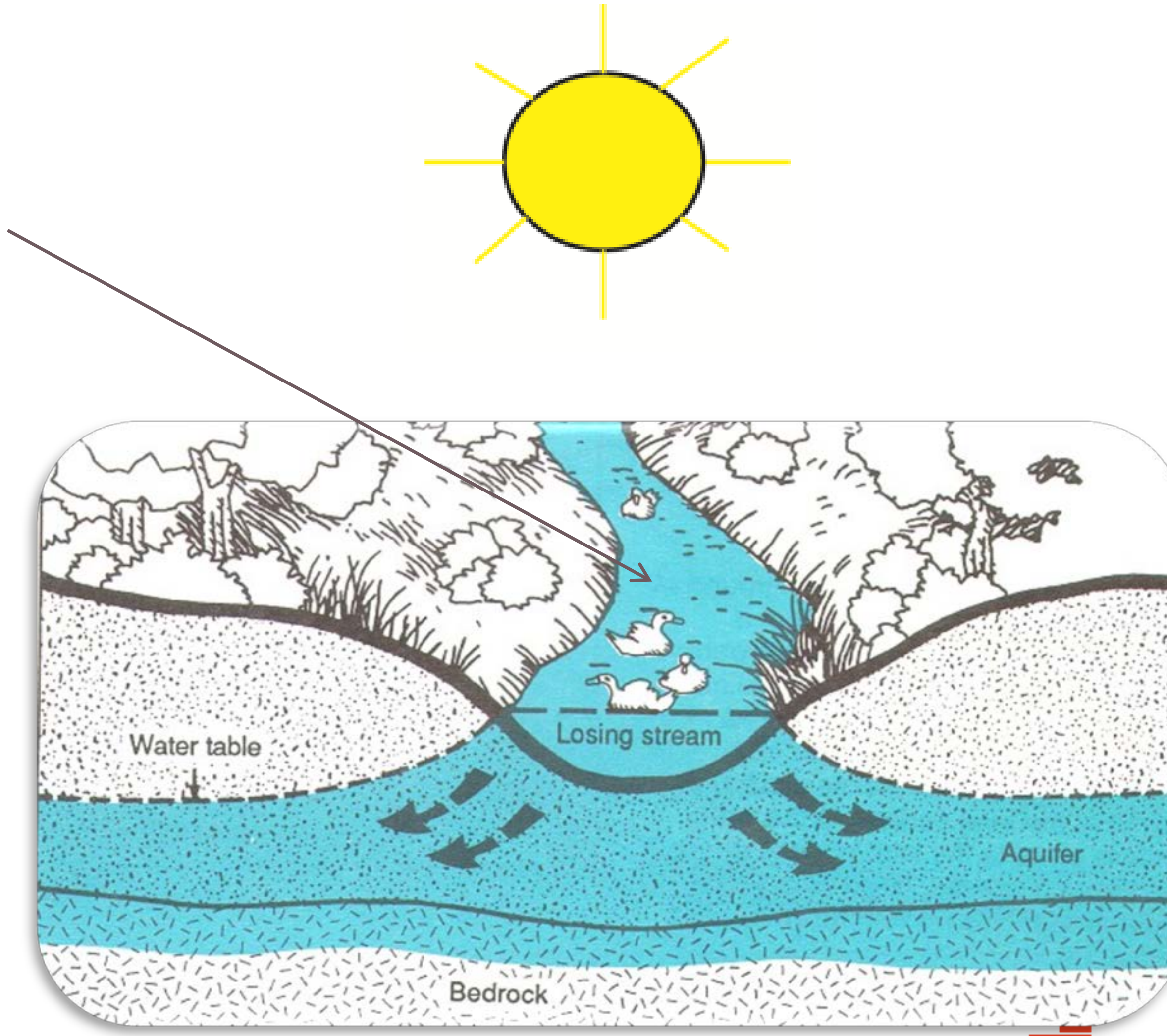
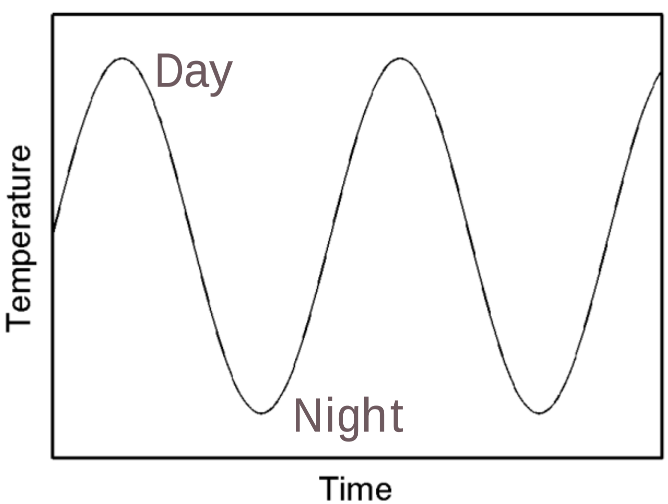
Temperature variability in SW-GW

Seasonal temperature signals





Diurnal temperature signals



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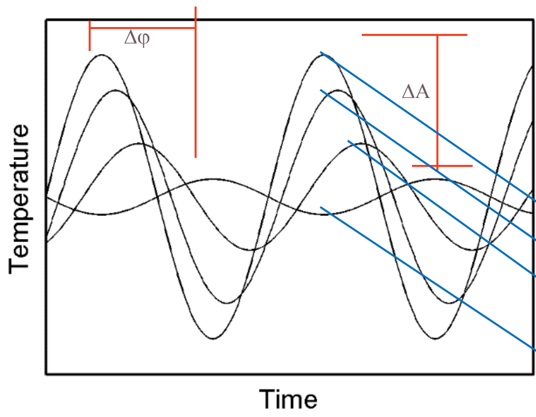
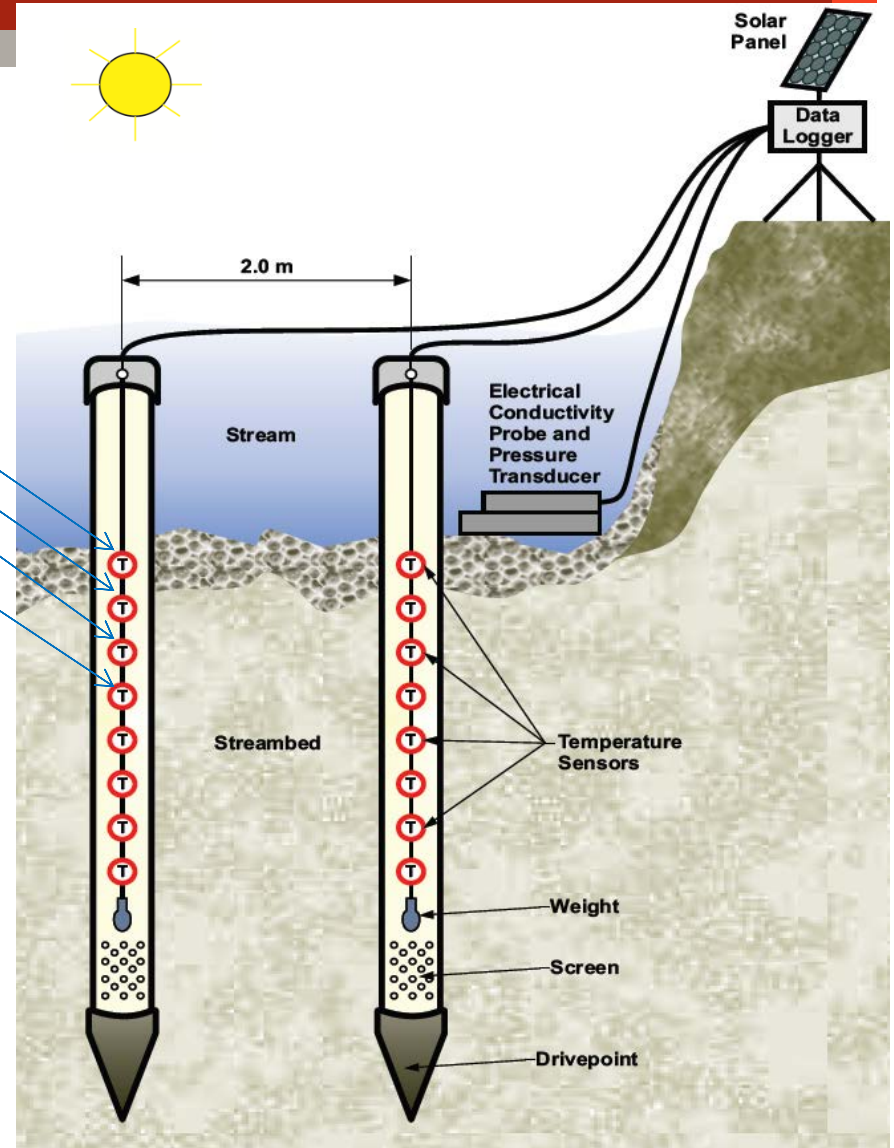
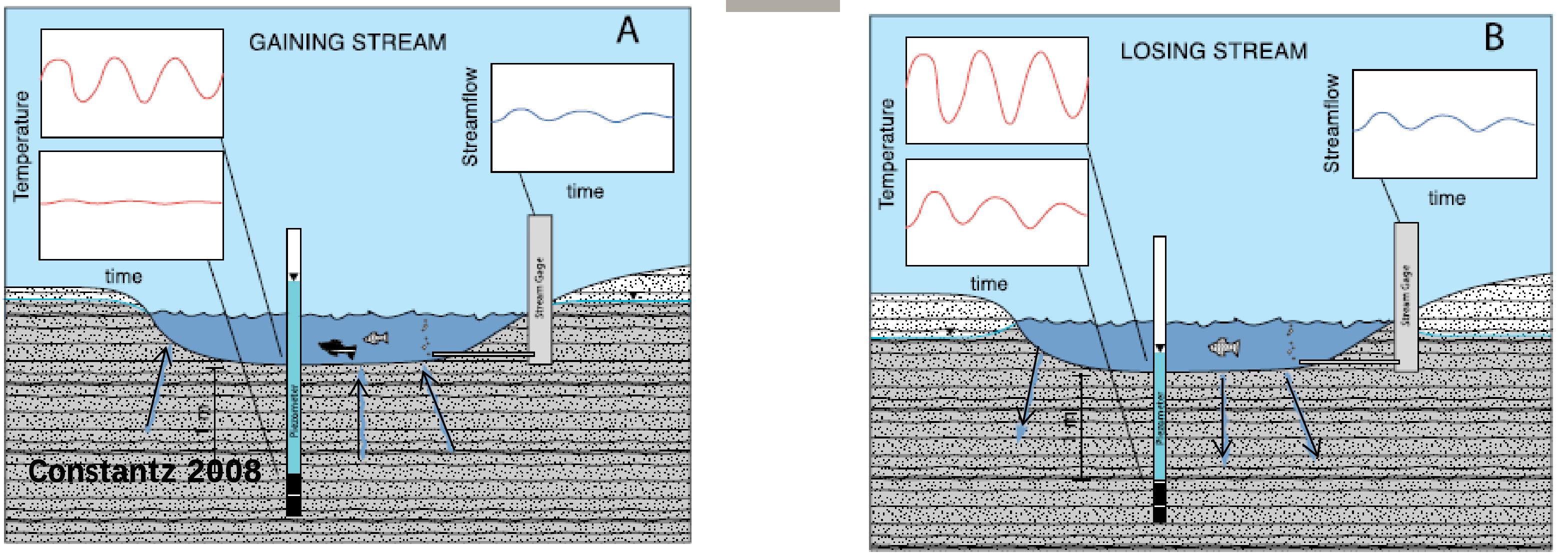
Temperature fluctuation vs. depth



- Frequency (e.g., diurnal, seasonal)
- Thermal parameters of the sediments
- **Groundwater velocity (magnitude and direction)**



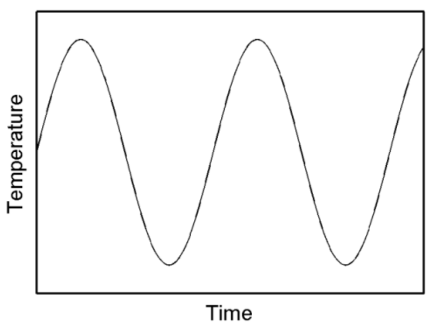
Using temperature to assess GW Flux

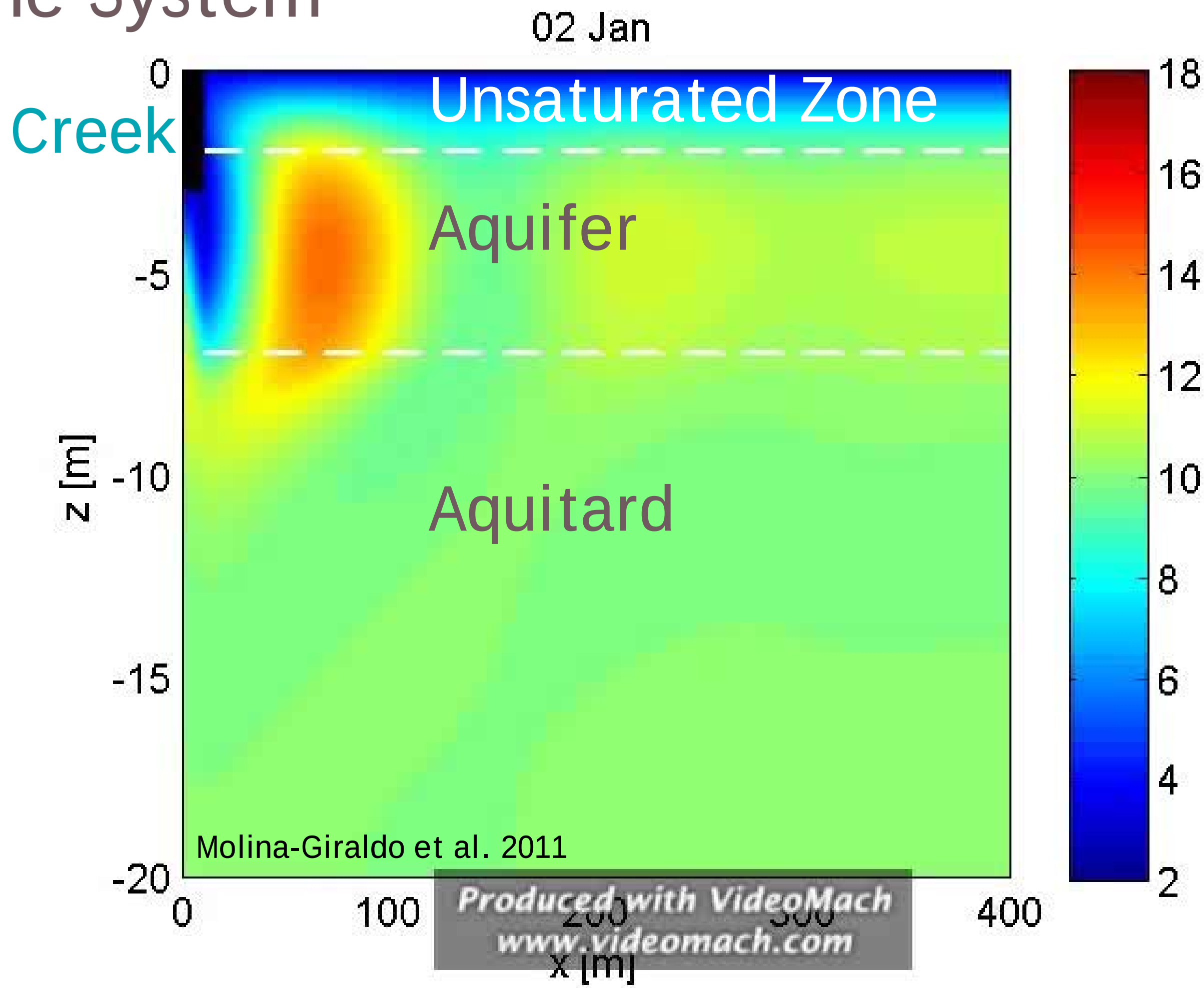


- Temperature signal is more attenuated in gaining streams (GW discharge)
- Temperature signal propagates deeper in losing streams (GW recharge)

Advantages of using Heat as a tracer

- Intrinsic to the System





Advantages of using Heat as a Tracer

- Temperatures can be continuously measured
- Heat can be used to estimate GW-SW flux direction and magnitude
- Heat can be used jointly with hydraulic head to estimate hydraulic conductivity

Modelling Heat to determine Groundwater Flux

Heat transport in porous media can be expressed by the 1D partial differential equation:

$$\frac{\partial T}{\partial t} = \frac{\lambda_m}{C_m}\frac{\partial^2 T}{\partial x^2} - q\frac{C_w}{C_m}\frac{\partial T}{\partial x}$$

Transient term

Conduction

Forced convection

T: temperature [°C],
q: Darcy velocity [m/s],
λ_m: the bulk thermal conductivity [W/m/°C],
C_m: volumetric heat capacity of the porous medium [J/m^3/°C] and
C_w: volumetric heat capacity of water [J/m^3/°C].

Molina-Giraldo et al. 2011 ,Keery et al. 2007, Stallman R.W. 1965

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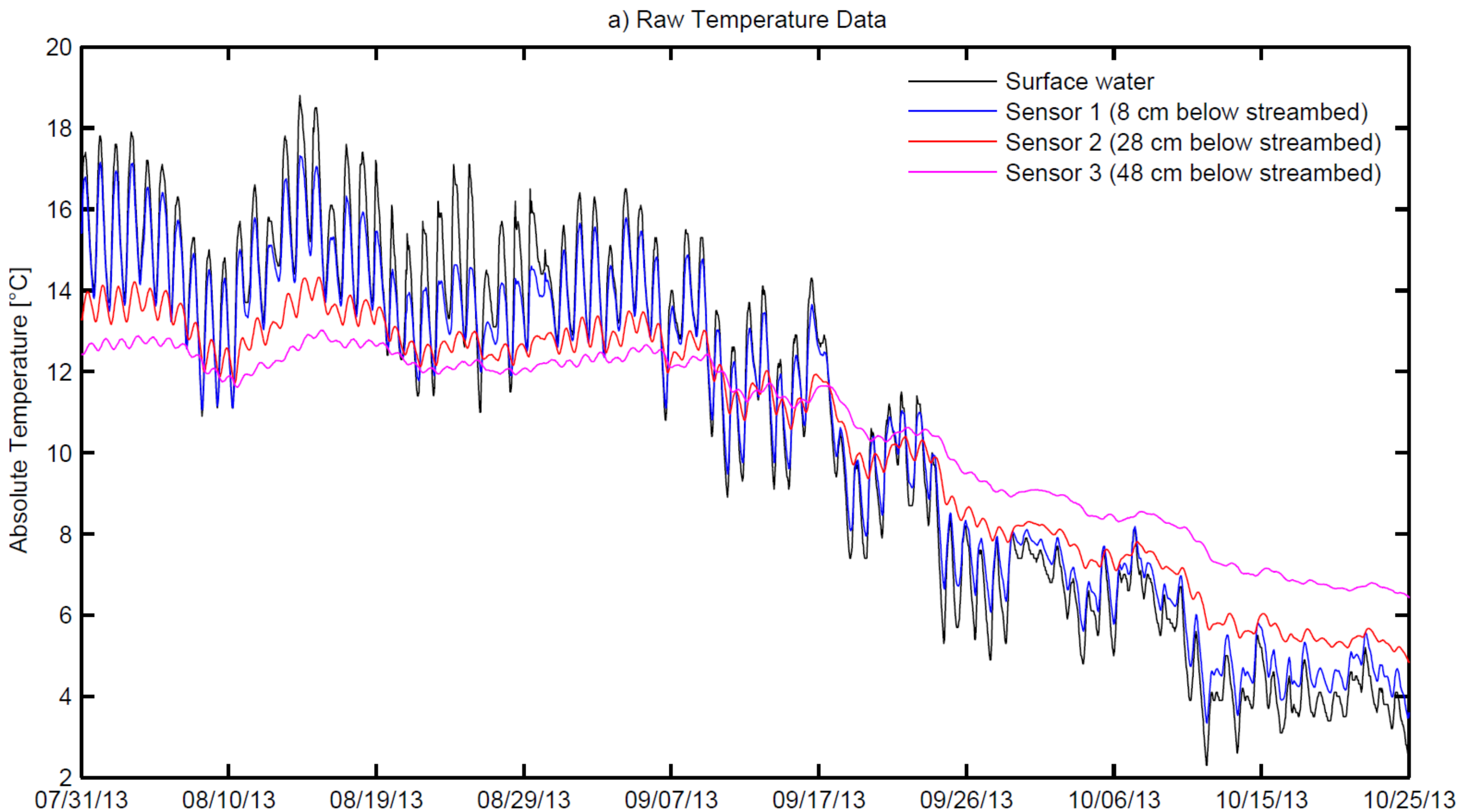
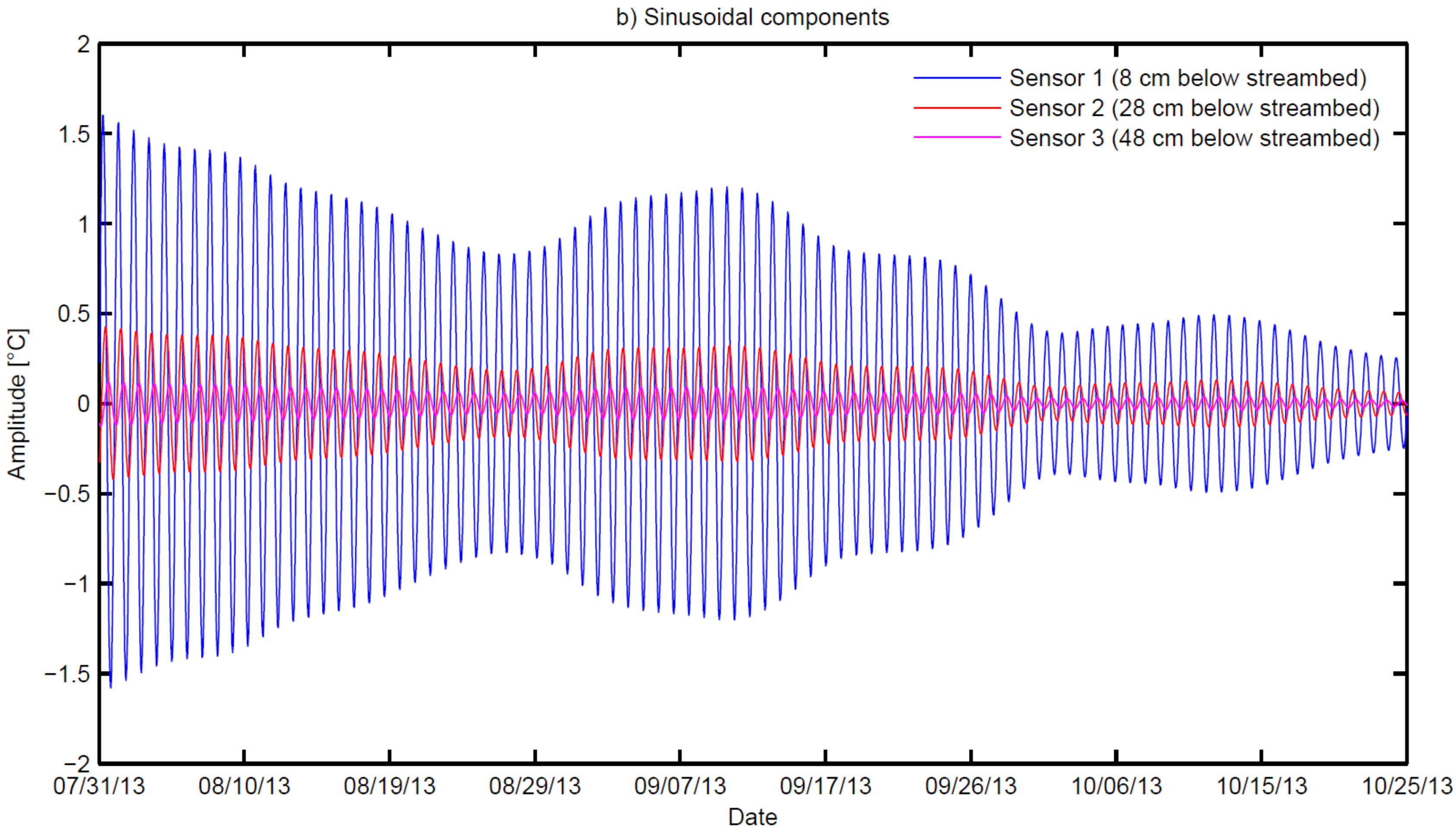
Data and Results

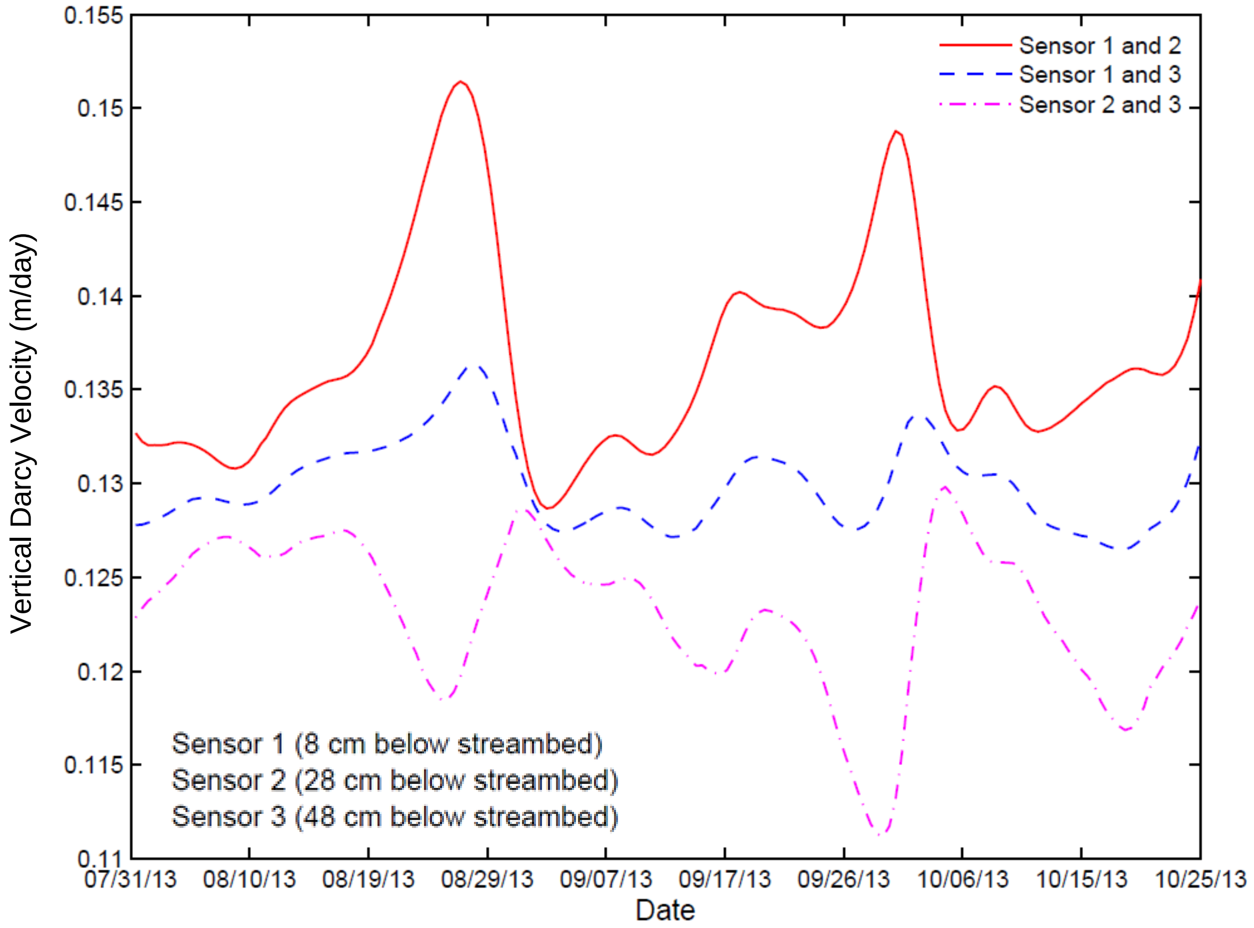
Temperature profile vs time in Streambed



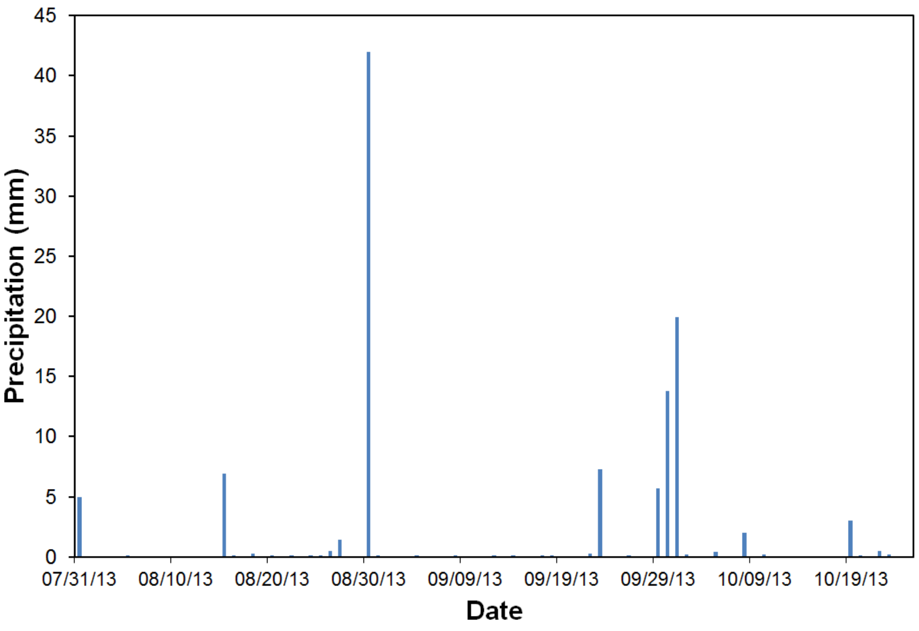
Sinusoidal components of water temperature fluctuation



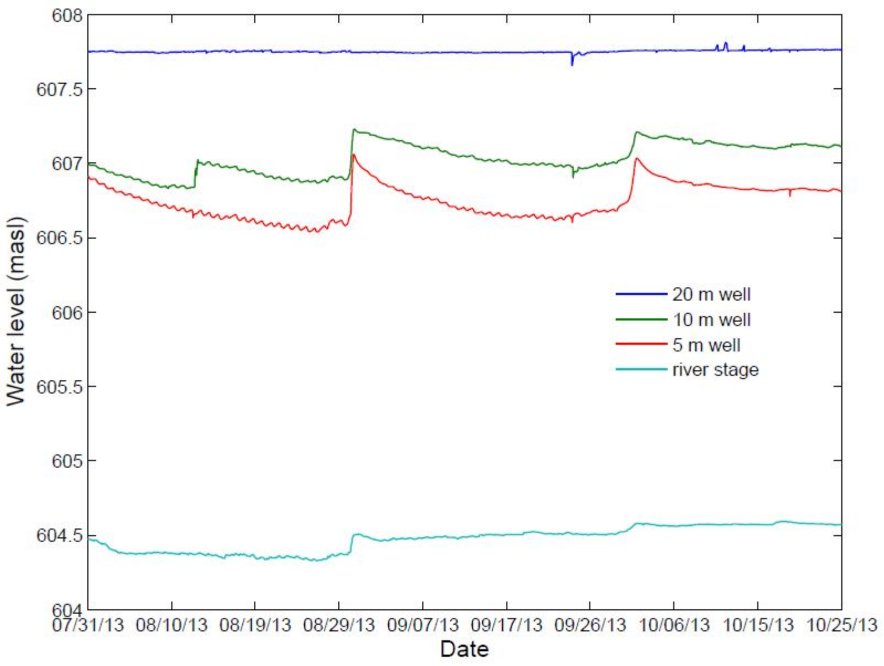
Vertical seepage flux (1D Analytical Solution)



Precipitation vs. Water Levels



Precipitation



Water levels in bank piezometers and creek

Project Summary – Next Steps

- Heat monitoring is a leading edge approach to monitor SW-GW interaction

- Long term monitoring will identify any heave-related effects on groundwater surface water interaction

- First full year round of dataset collection: August 2014

- Project timeline: 5 years

References

- Constantz, J., 2008. **Heat as a tracer to determine streambed water exchanges.** Water Resources Research 44, W00D10. doi:10.1029/2008WR006996.
- Keery, J., A. Binley, N. Crook and J.W.N. Smith. 2007. "**Temporal and spatial variability of groundwater-surface water fluxes: Development and application of an analytical method using temperature time series.**" *Journal of Hydrology* 336, No. 1-2: 1-16.
- Molina-Giraldo N., Bayer P., Blum P. and O.A. Cirpka. 2011. "**Propagation of seasonal temperature signals into an aquifer upon bank infiltration**." Ground Water. Vol. 49(4), 491-502.
- Stallman R.W. 1965. "**Steady one-dimensional fluid flow in a semi-infinite porous medium with sinusoidal surface temperature**." *Journal of Geophysical Research.* Vol. 70, No. 12: 2821-2827.