Use of Thermal Infrared (TIR) Imagery to Identify Potential Groundwater Discharge Areas Associated with Known Groundwater Contaminants of Potential Concern

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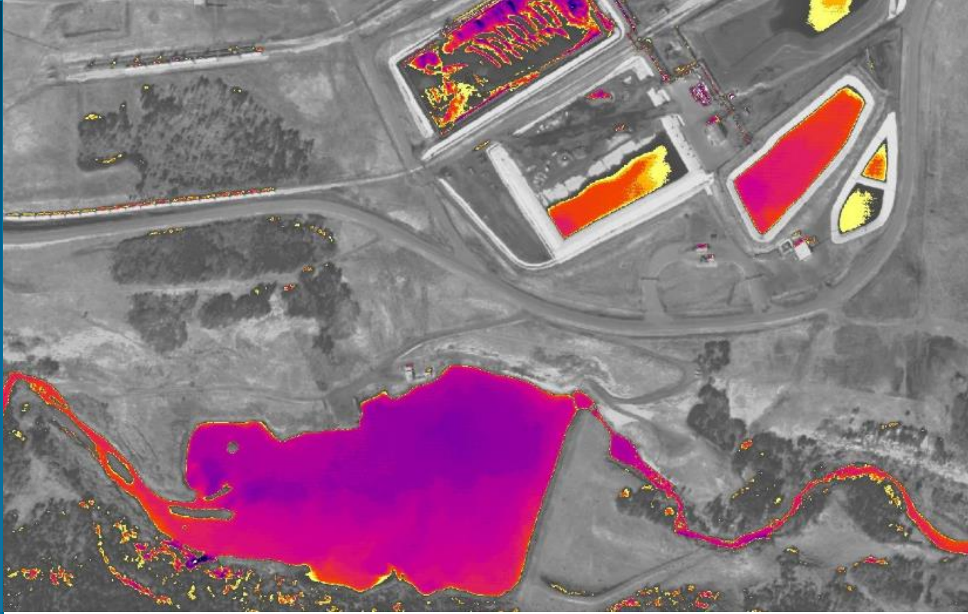
Agenda

- Objective
- Thermal Infrared Surveys – Concepts and Previous Studies
- Case Study Introduction & Aerial TIR Survey
- Desktop Mapping Approach & Results:
  - Terrestrial Seeps
  - In-stream Discharge Zones
- Sources of Uncertainty
- Summary & Next Steps



NV Spatial Inc. 2020

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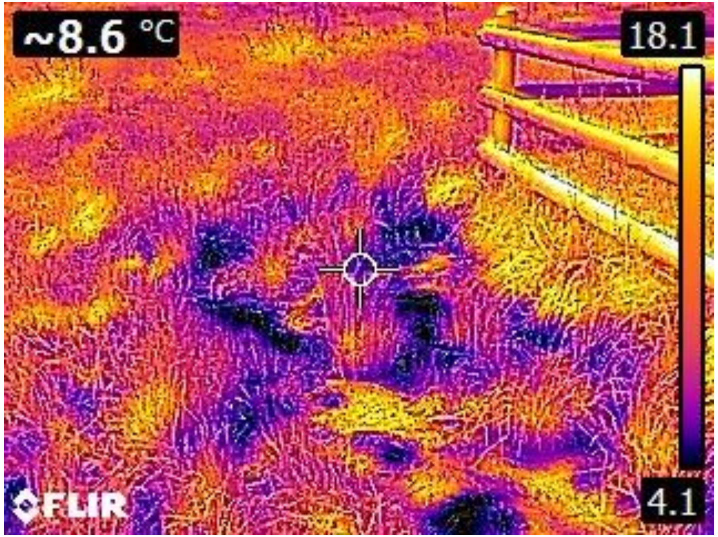
The Objective

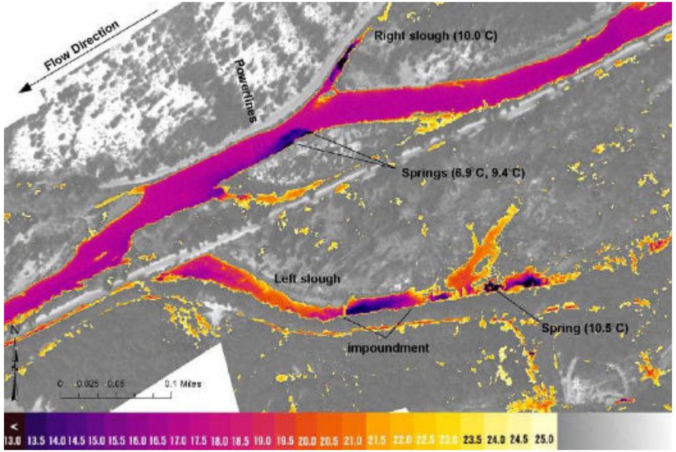
- In contaminated sites work, identifying how a contaminant could reach a potential receptor is key
- If that “outlet” is a groundwater discharge zone, how do we map it?
  - Field reconnaissance
  - Remote sensing techniques
- What parameter could we measure from remote sensing techniques to identify groundwater discharge?

Using Temperature to Identify Potential Groundwater Discharge Zones



The temperature of groundwater discharge zones reflects that of ambient conditions (Cartwright, 1974)

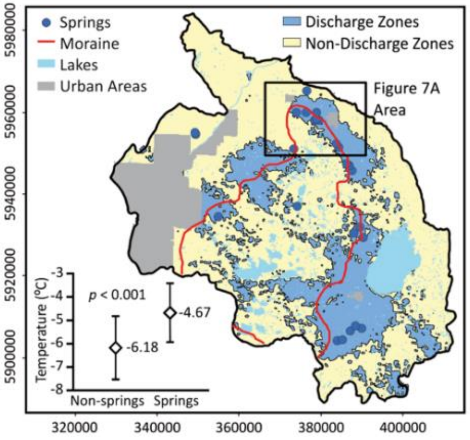
Aerial Thermal Infrared Surveys – Previous Studies

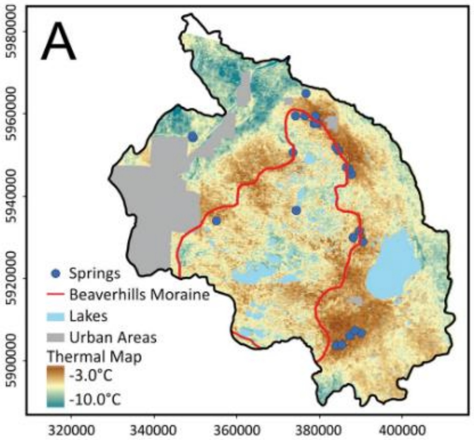


WSI 2007b

- Use of aerial TIR imagery to map spatial temperature patterns in surface water bodies to detect in-stream groundwater discharge (WSI 2006, 2007a, 2007b).

- Use of thermal satellite imagery from USGS Landsat archive to map regional groundwater discharge zones (Sass et al. 2013)

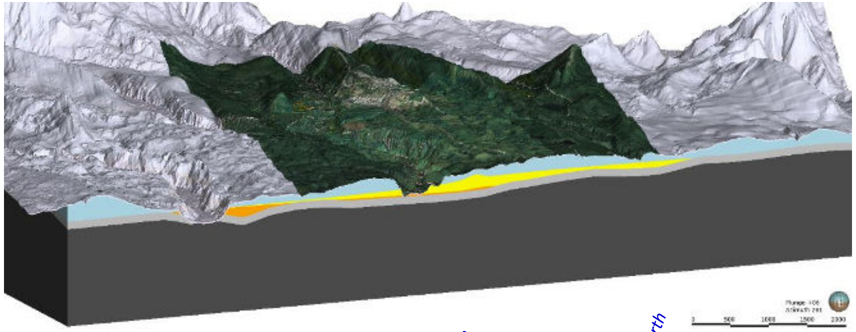




Sass et al. 2013

Question: can we use an aerial TIR survey to identify in-stream and terrestrial (i.e., land-based) groundwater discharge areas at a large site with other previously documented springs and seeps?

Case Study – Sour Gas Processing Plant



- Active sour gas processing plant in Alberta
- Multiple CoCs associated with plant operations
- Several documented contaminated springs, seeps, and artesian conditions

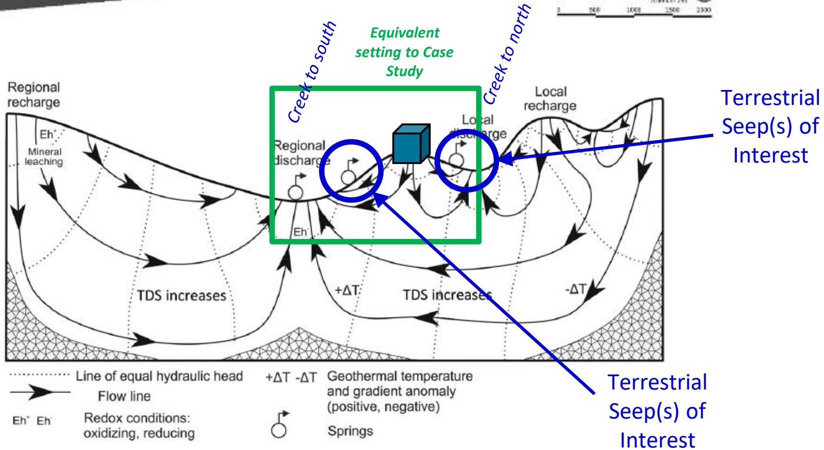


Figure 1. Conceptual understanding of distribution of groundwater recharge and discharge zones and associated chemical and thermal environment (modified from Tóth, 1999)

Sass et al. 2013

Objective: identify and map potential groundwater discharge zones from airborne TIR imagery:

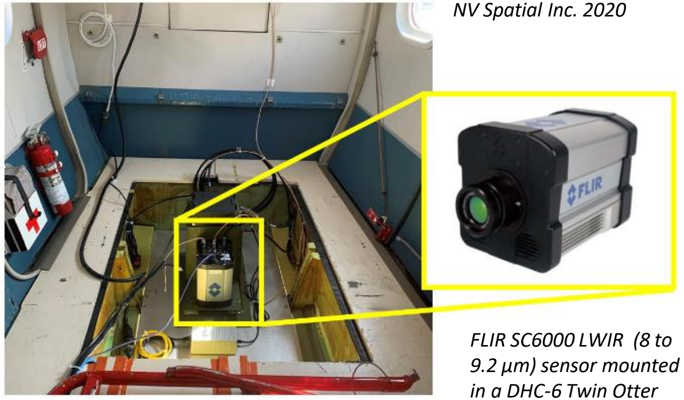
1. ***Seepage faces ("terrestrial seeps")***
2. ***In-stream discharge zones***

Case Study: Aerial TIR Survey

- Flown in September 2020

- Flew over section blocks of two creeks, adjacent to the operating sour gas plant
  - Block 1: ~15 km^2
  - Block 2: ~4 km^2

- Water temperatures were recorded by five in-stream temperature sensors during survey to calibrate the temperatures within the thermal imagery



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FLIR SC6000 LWIR (8 to 9.2 µm) sensor mounted in a DHC-6 Twin Otter fixed-wing aircraft

In-stream logger at hydrometric station

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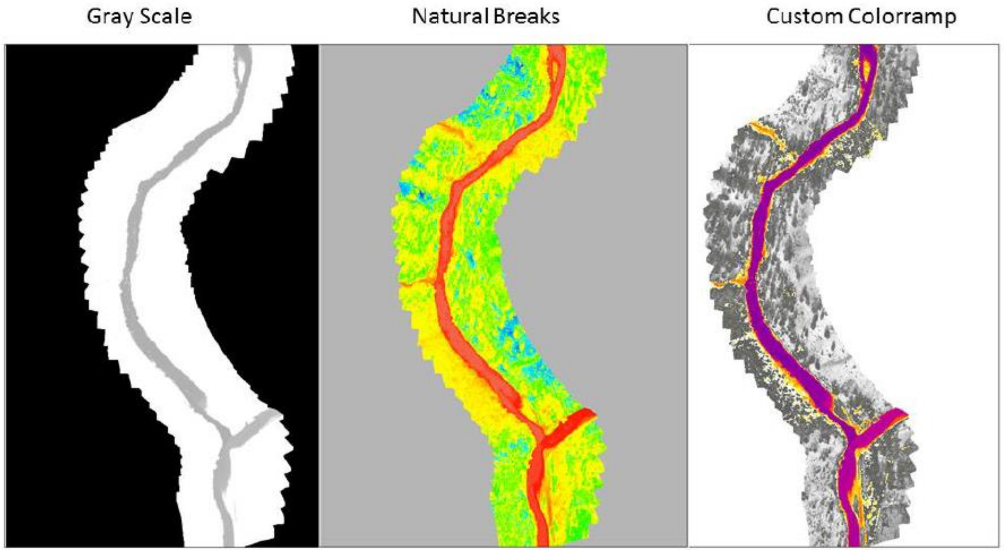
Case Study: Aerial TIR Survey

- ~50 cm resolution imagery acquired
- Final TIR imagery was mosaiced together to create seamless coverage for each survey block



Examples of different colour ramps applied to same TIR image

NV Spatial Inc. 2020

Approach – Desktop Mapping

Data acquired from survey

- TIR imagery (raster files)
- Various (vector) shapefiles – stream centrelines, accuracy checks, TIR image centre points, longitudinal temperature profiles (LTP) and significant feature sites (SFS)
- Colour ramp layer files (for use in ArcMap)

Desktop Mapping

- Overlay the TIR data with other potential indicators of groundwater discharge
- Different indicators were identified:
    1. Terrestrial Seeps
    2. In-Stream Discharge

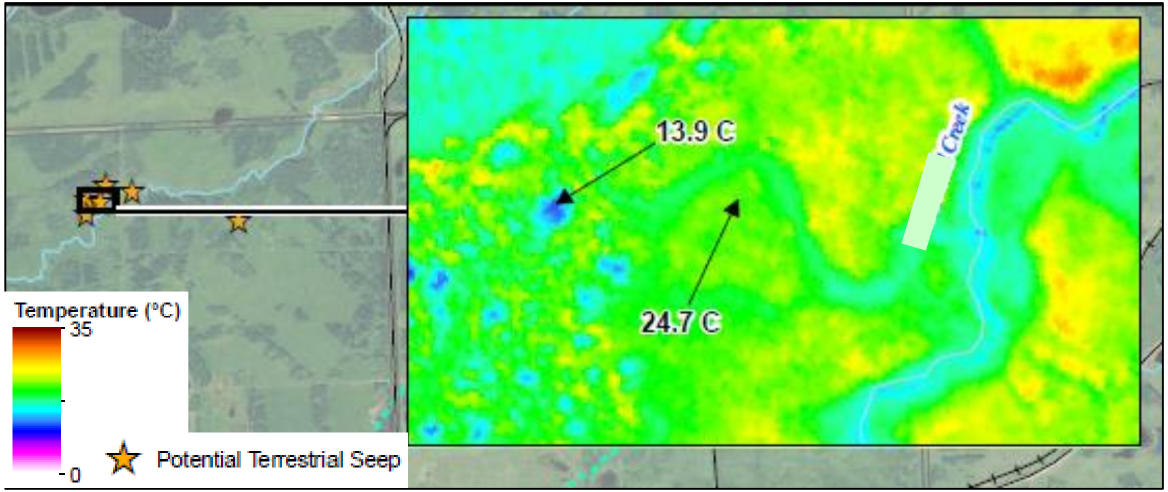
Approach 1 – Terrestrial Springs & Seeps

TIR Data Analysis

- Isolate cool areas
- ≥4^{o}C relative change from surrounding
- Compare signature to known (mapped) seep locations
  - What conditions are present at the known seep locations?

Approach 1 – **Terrestrial Seeps** Results

- An important factor influencing temperature changes = shadows (sun angle or vegetation)
- 31 sites identified as potential seep locations
- Trends:
  - Most potential locations are found on south facing slopes/toe of slopes
  - No shadow expected based on available data



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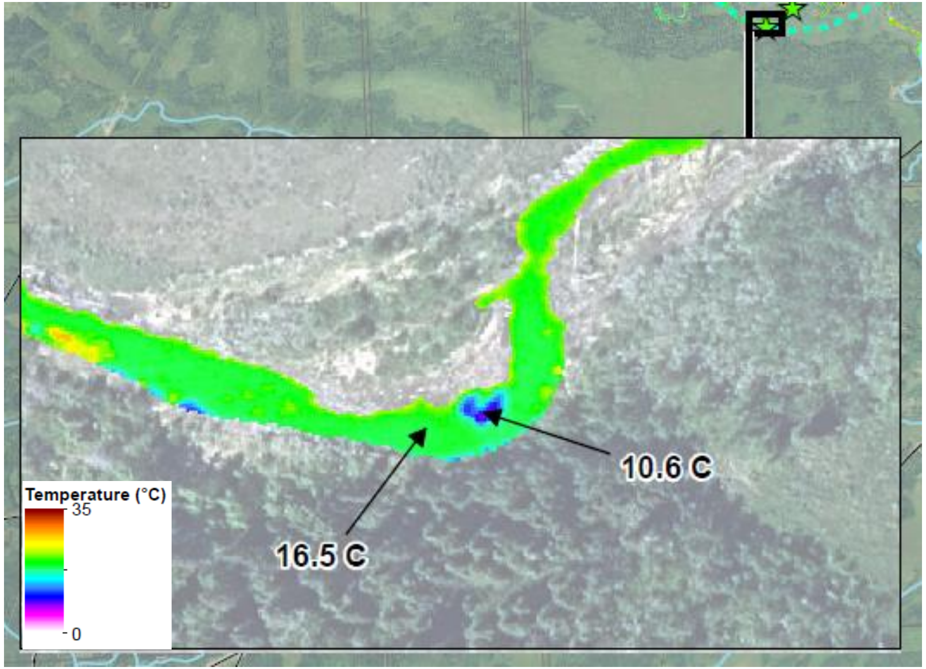
Approach 2 – In-Stream Discharge Zones

TIR Data Analysis

- Delineate stream channel using TIR, LiDAR, aerial imagery
- Isolate cool areas within stream channel
- ≥4^{o}C relative change from surrounding

Approach 2 – In-Stream Discharge Zones Results

- 16 sites identified as potential in-stream discharge zones along one of the creeks
- Trends:
  - > 4°C Temperature change and no gravel bar shadow expected
  - Majority of identified discharge zones are closer to north bank of creek



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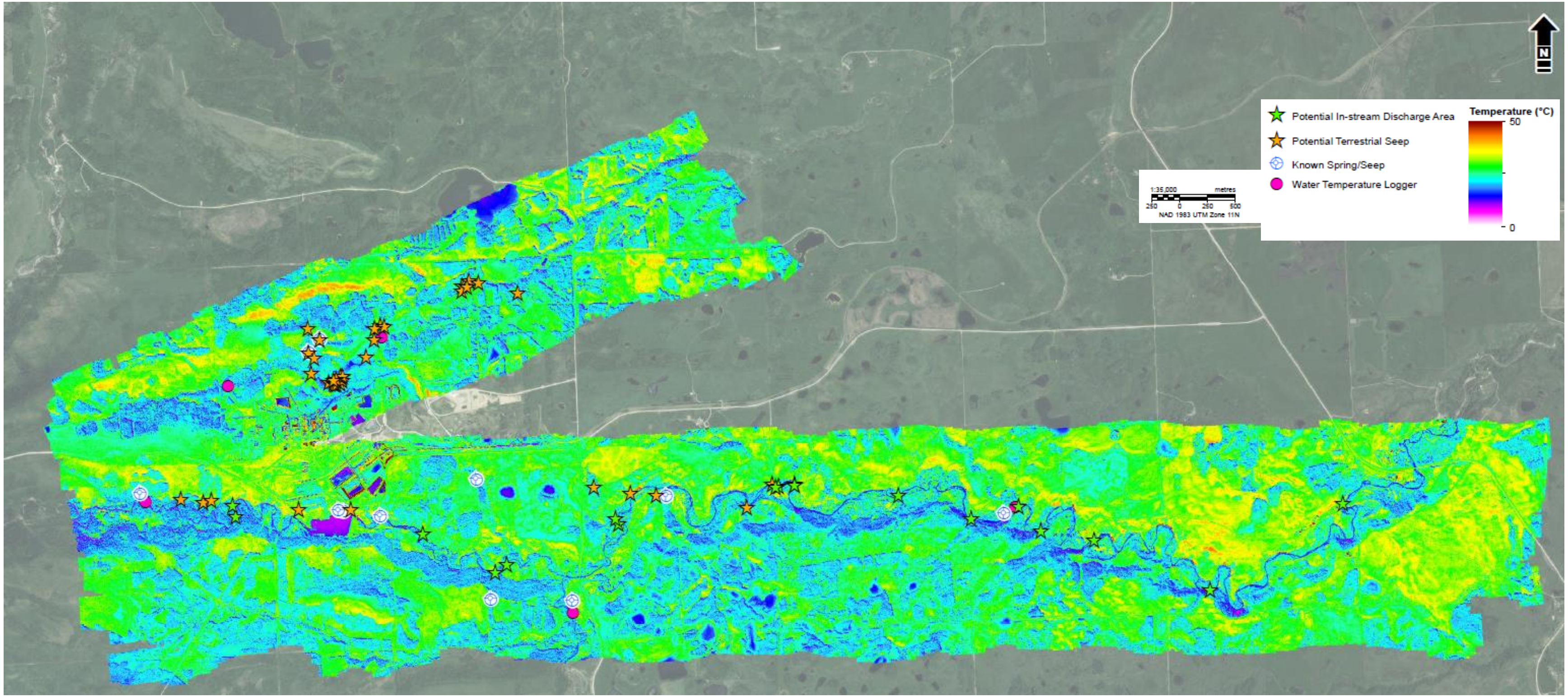
Desktop Mapping Results



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Sources of Uncertainty

- Shadows cast by landforms and vegetation – diligence in identifying potential discharge areas along north-facing slopes
- RGB imagery used to assess vegetation shadow effects was collected in July 2018, earlier in the year than the aerial TIR imagery
- Spatial resolution of the sensor
- Shadow length affected by time of year of the surveys, as sun angle is lower in September in southern AB compared to June through August

Summary and Next Steps

- An airborne thermal infrared survey was flown in September 2020
- After the survey, the resultant TIR imagery was analyzed for potential groundwater seepage and in-stream groundwater discharge zones
- 31 potential terrestrial seeps and 16 potential in-stream discharge zones were identified
- Ground truthing exercises commenced through 2021 and 2022 – potential terrestrial seeps and in-stream discharge zones were visited and sampled for CoCs

… stay tuned for a future Part 2 talk to share this story!

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