Recognizing Natural Source Zone Depletion for a More Sustainable Approach to the Long-Term Management of Residual LNAPL at the Gogama Release Site

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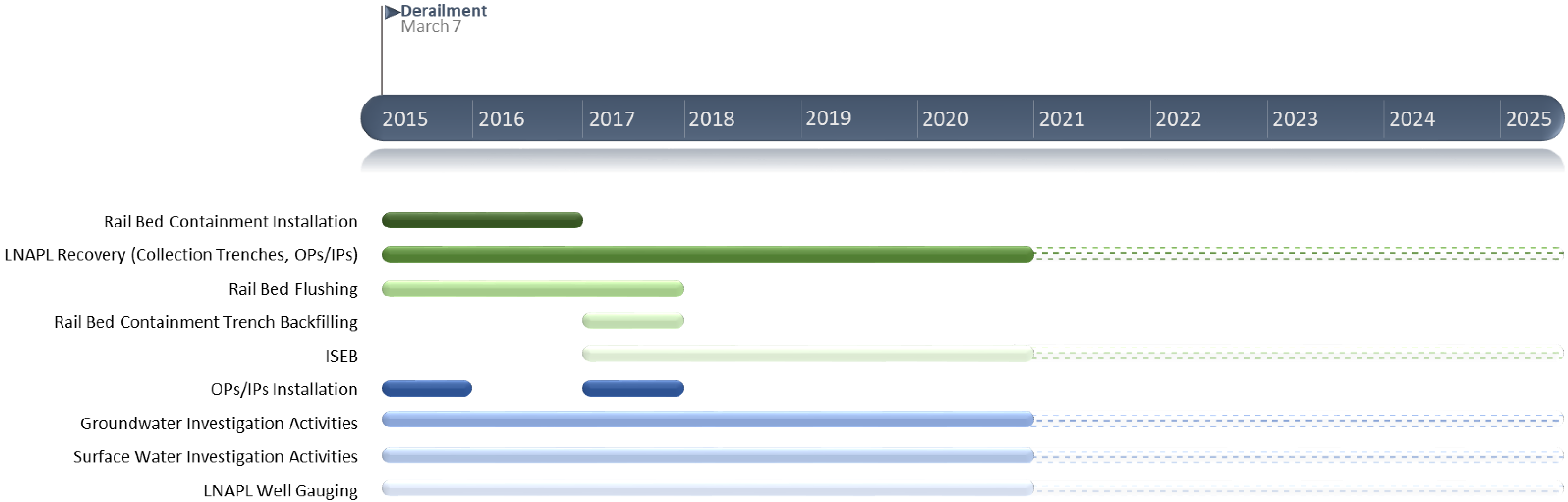
What happened

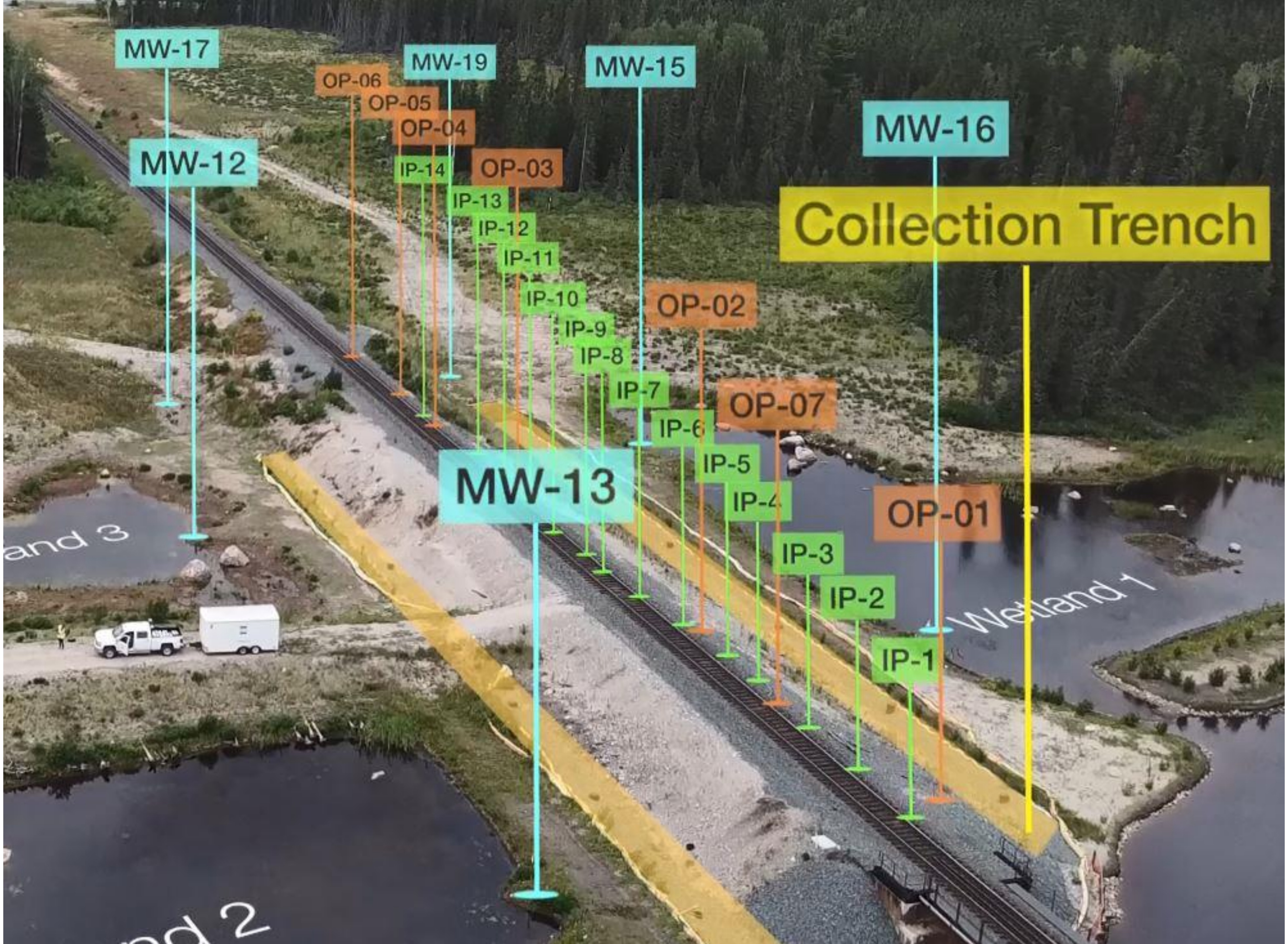
At around midnight on March 7, 2015, 37 railcars containing crude oil derailed and ruptured at Mile Point 88.7 on CN’s Ruel Subdivision, located northwest of the community of Gogama, Ontario.

What happened

Approximately 2.63 million litres of crude oil was released to the environment (air, water, and ground), some of it directly into the Makami River and onto the ground surface north of the river, which then migrated into the river.

What’s been done

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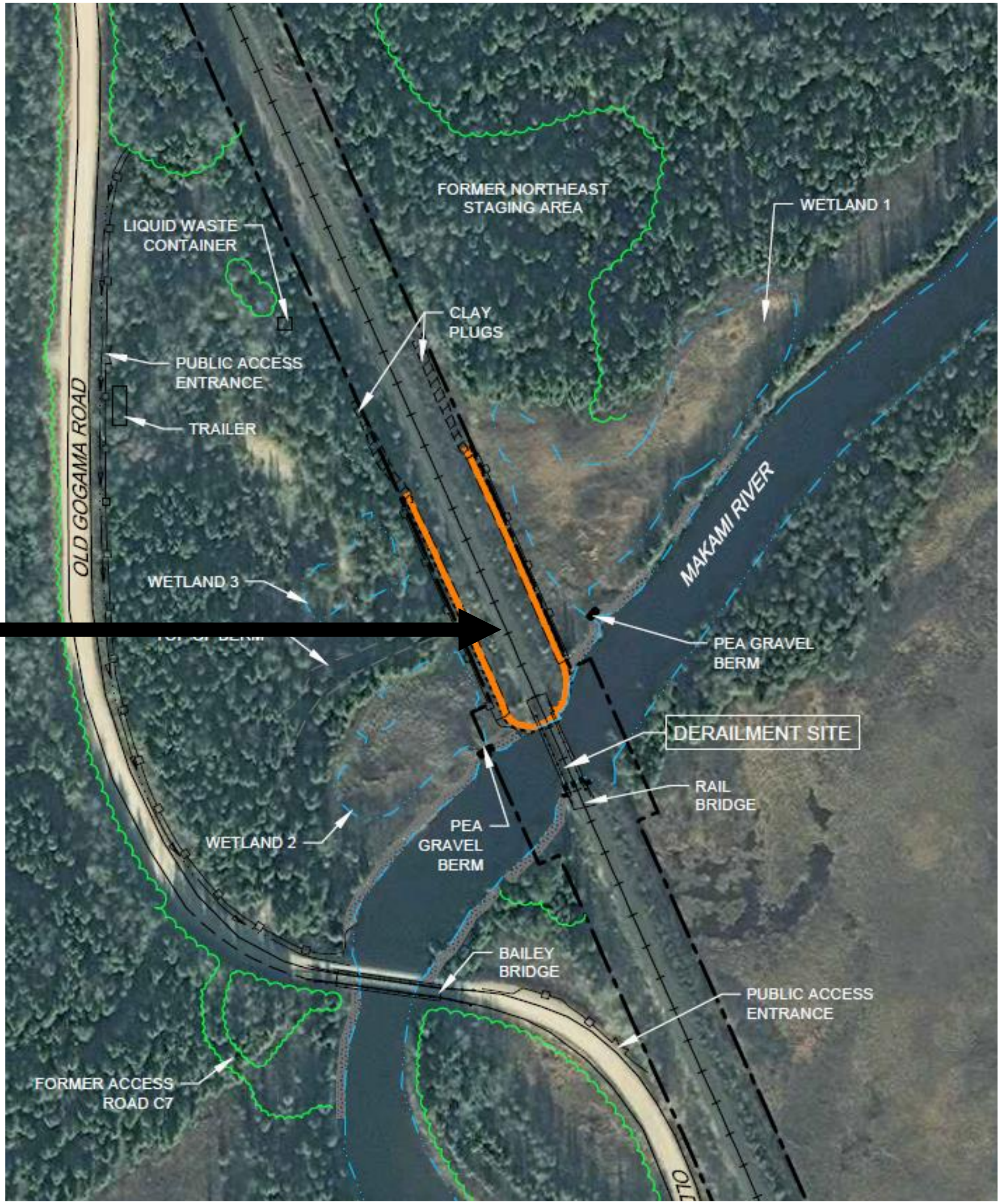
IP-3
IP-2
IP-1
Collection Trench
Wetland 1

How it looks now

How it looks now

Crude oil impacts remain in railbed material



LNAPL Conceptual Site Model

Extent: remaining LNAPL physically confined to the rail bed

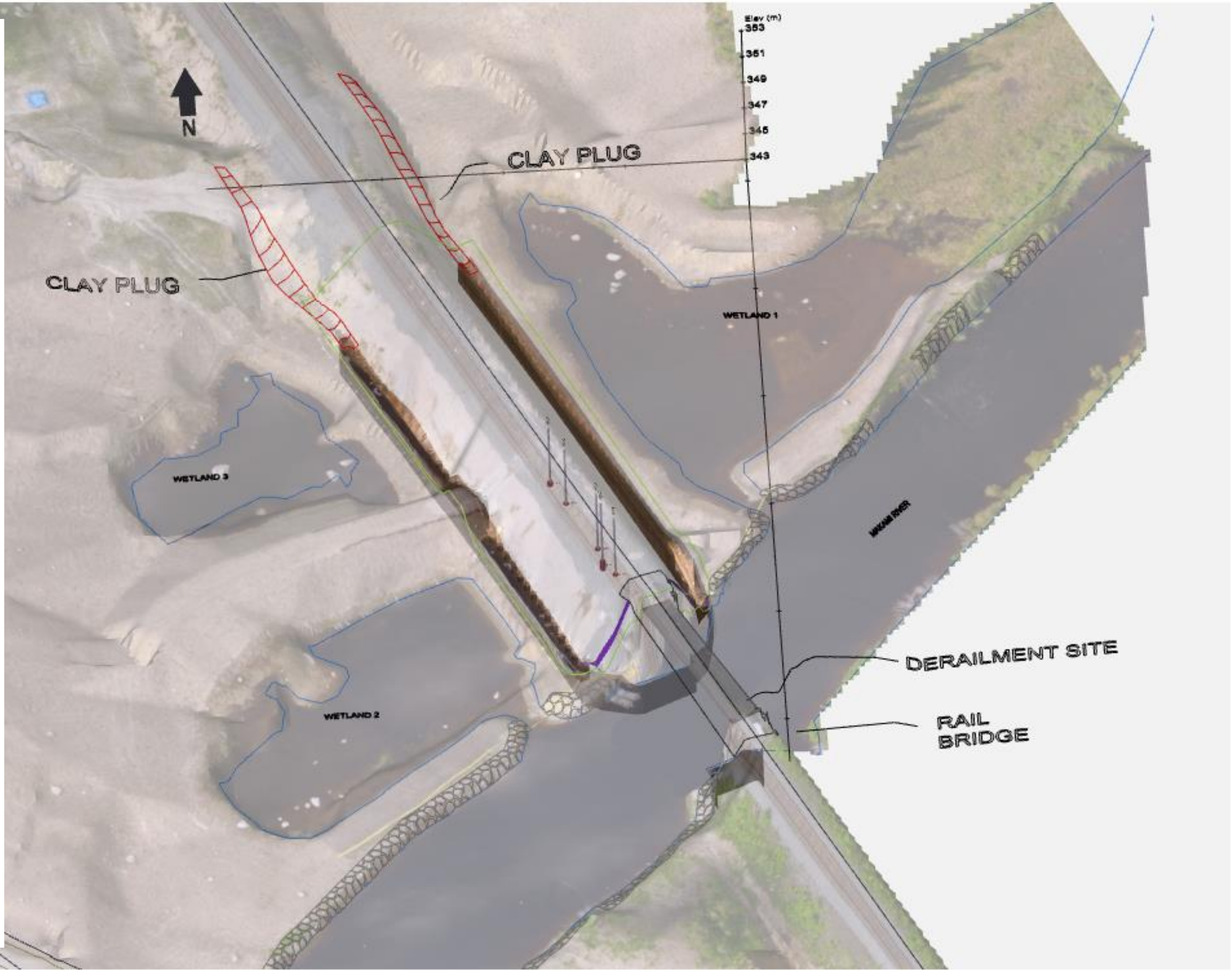
Hydrogeology: LNAPL exists under a mix of confined and unconfined conditions

Mobility/recoverability: LNAPL recovered to a practical extent, LNAPL in wells limited/sporadic, no LNAPL in trenches

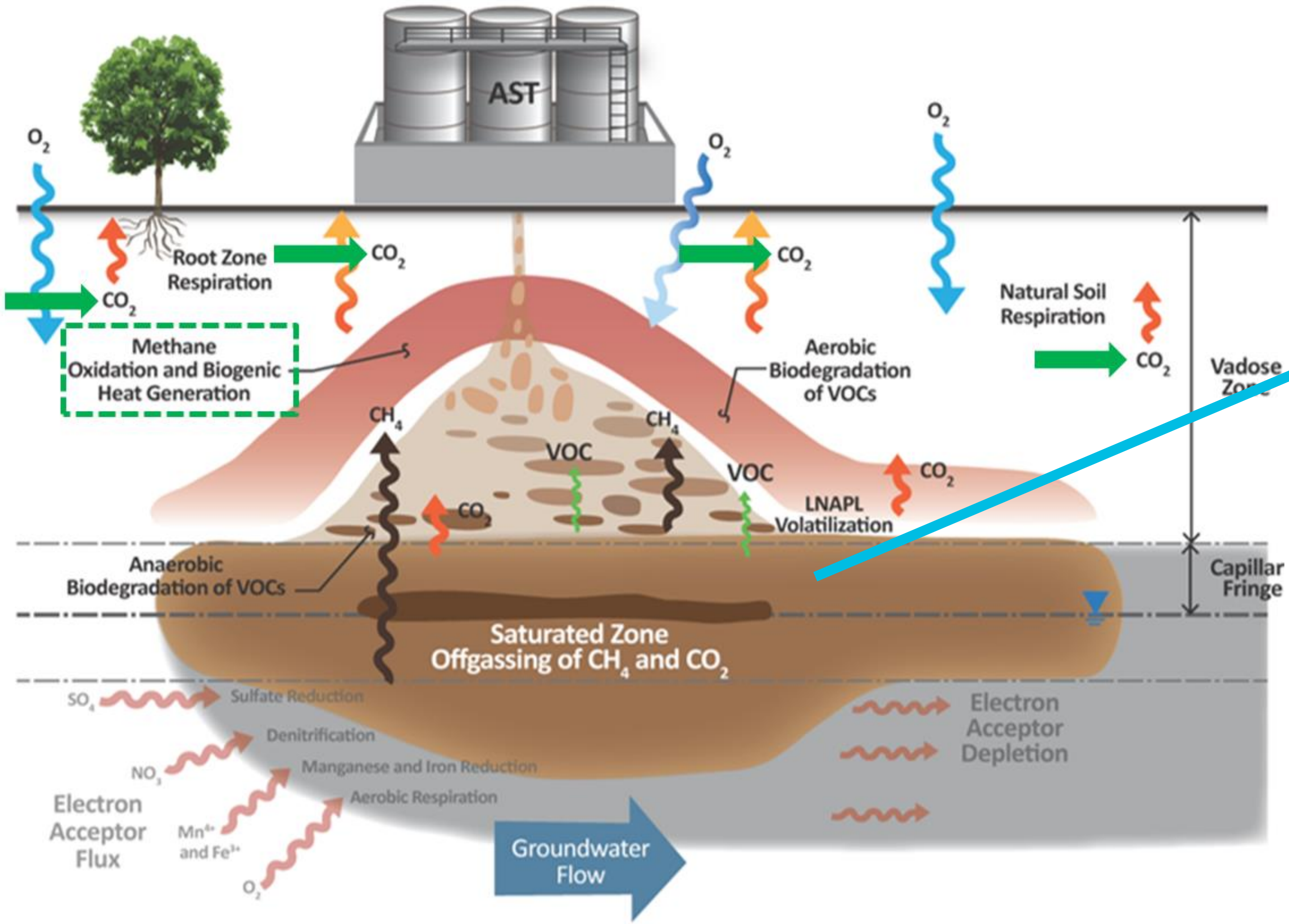
Stability: LNAPL is immobile/contained, dissolved plume concentrations/extent declining

Risk: no adverse human health or ecological exposures identified

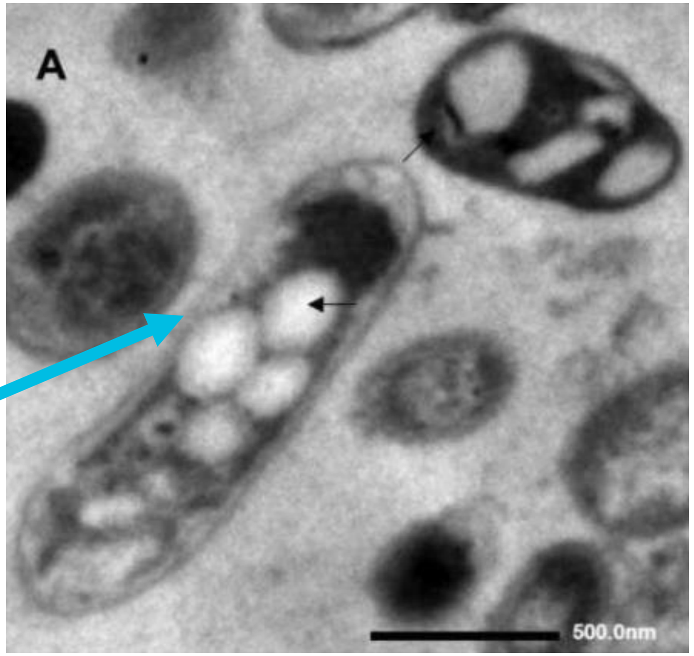
Natural Attenuation: dissolved phase areal extent/well-specific concentrations declining, large methanogenic zone in groundwater, **NSZD???**



Natural Source Zone Depletion (NSZD)



from: American Petroleum Institute Publication #4784

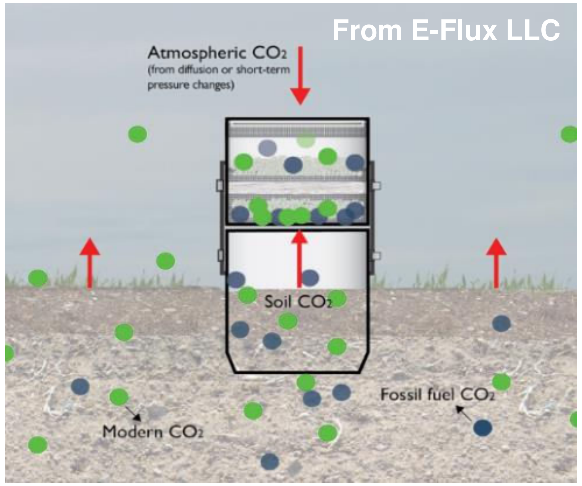


from: Ng et al 2014
doi: 10.1016/j.jconhyd.2014.04.006

Most of the activity will be direct NAPL microbial degradation

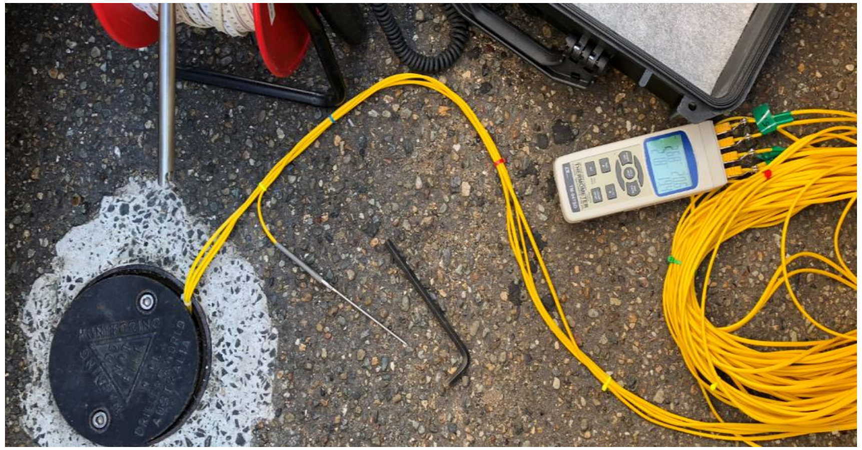
Technique 1: passive CO_2 traps

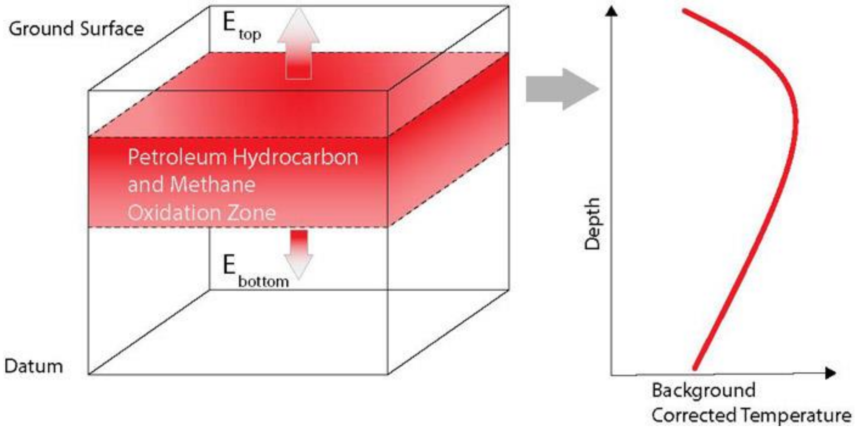
– Passive integrated sampling (≈ 2 weeks)
– Measure total CO_2, ^{14}C unstable isotope
– ^{14}C analysis provides built-in background correction
  - ^{14}C half-life ≈ 5,600 years
  - modern/background CO_2 is ^{14}C enriched
  - petrogenic CO_2 is ^{14}C depleted



Technique 2: biogenic heat

- Existing wells or dedicated installations
- Measure temperature at multiple depths through methane-oxidation zone
  - determine temperature gradients up and down
  - heat flux = temperature gradient * thermal conductivity of soil/rock
  - NSZD rate = heat flux / heat of reaction
- Need to correct for background temperatures
  - test locations away from LNAPL

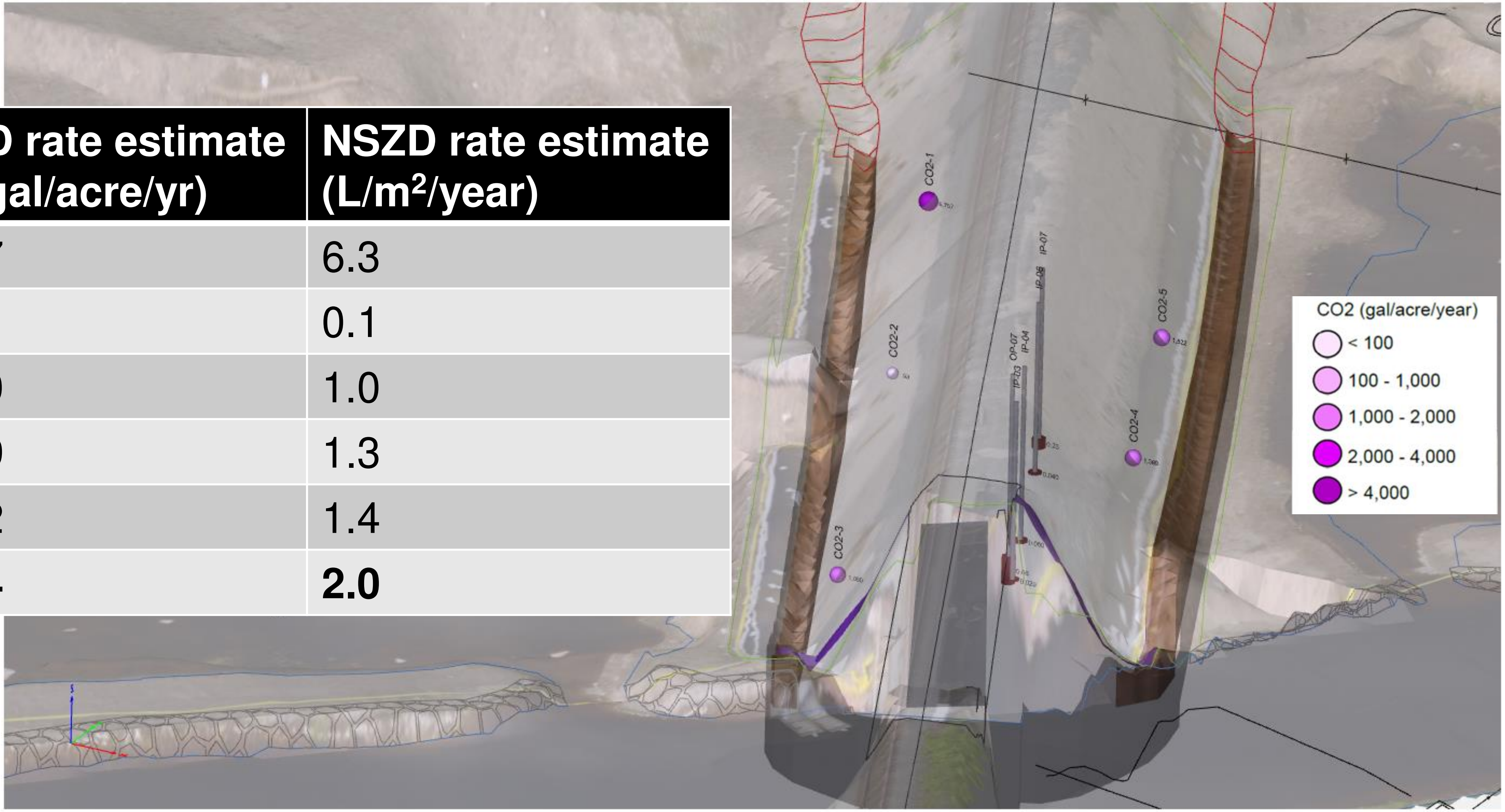




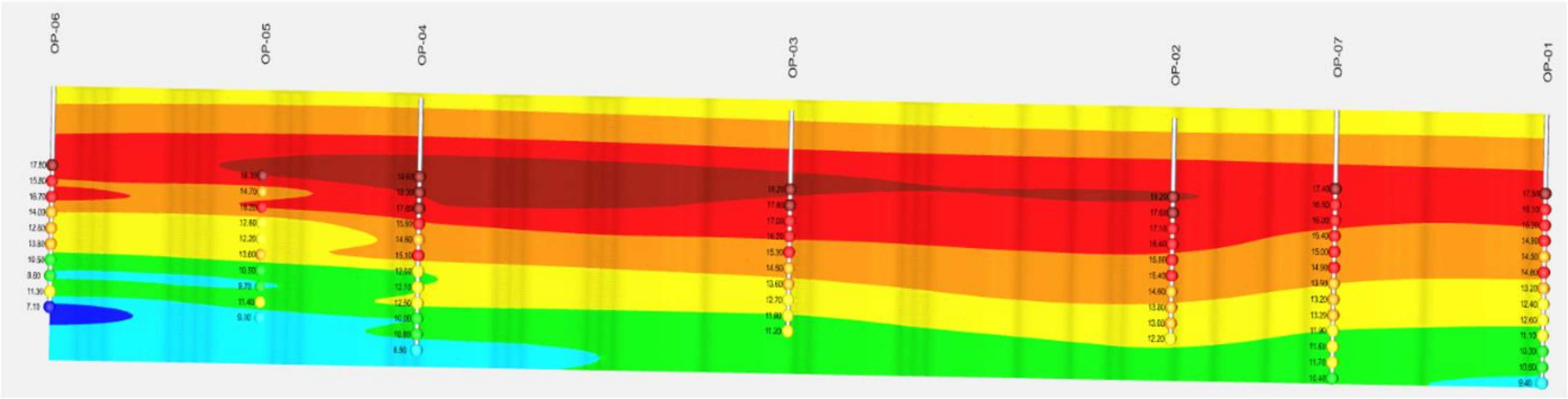
From ITRC LNAPL-3

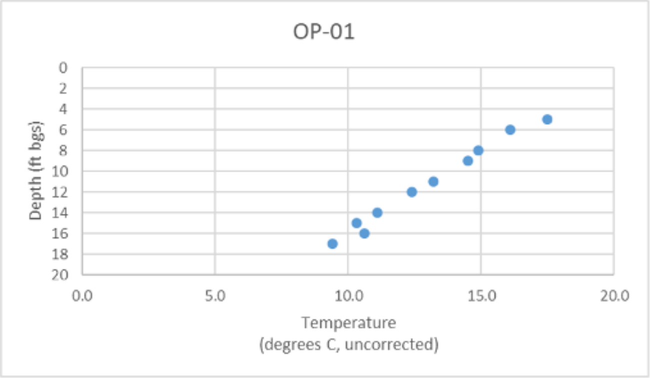
Technique 1: 2021 CO_2 trap results

CO_2 Trap ID	NSZD rate estimate (US gal/acre/yr)	NSZD rate estimate (L/m²/year)
CO2-01	6 757	6.3
CO2-02	93	0.1
CO2-03	1 050	1.0
CO2-04	1 399	1.3
CO2-05	1 522	1.4
Average	**2 164**	**2.0**



Technique 2: 2021 biogenic heat results





UNCORRECTED TEMPERATURE (Degrees C)

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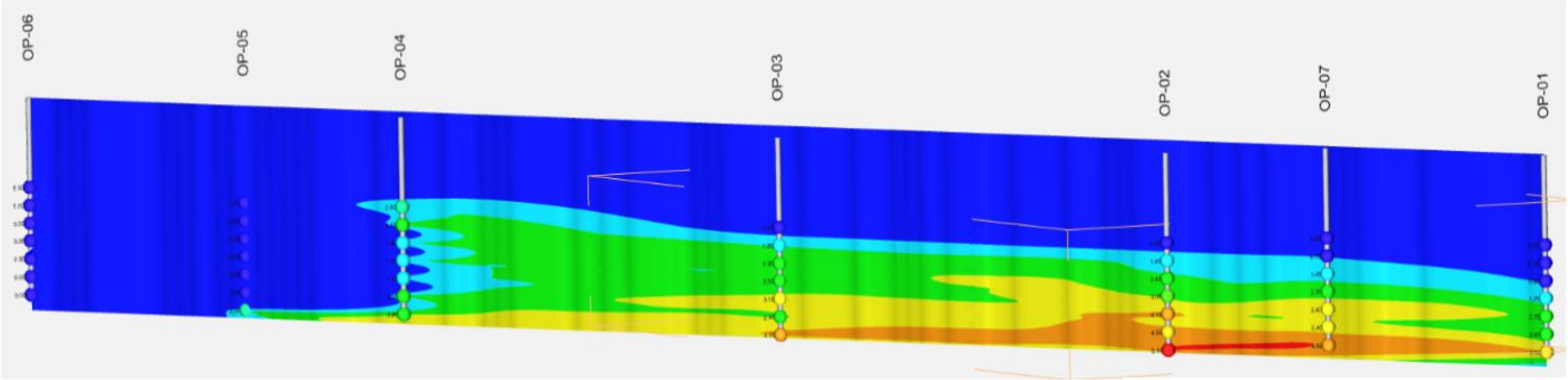
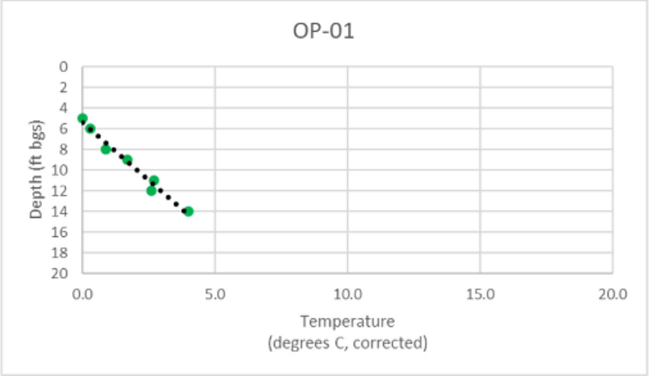


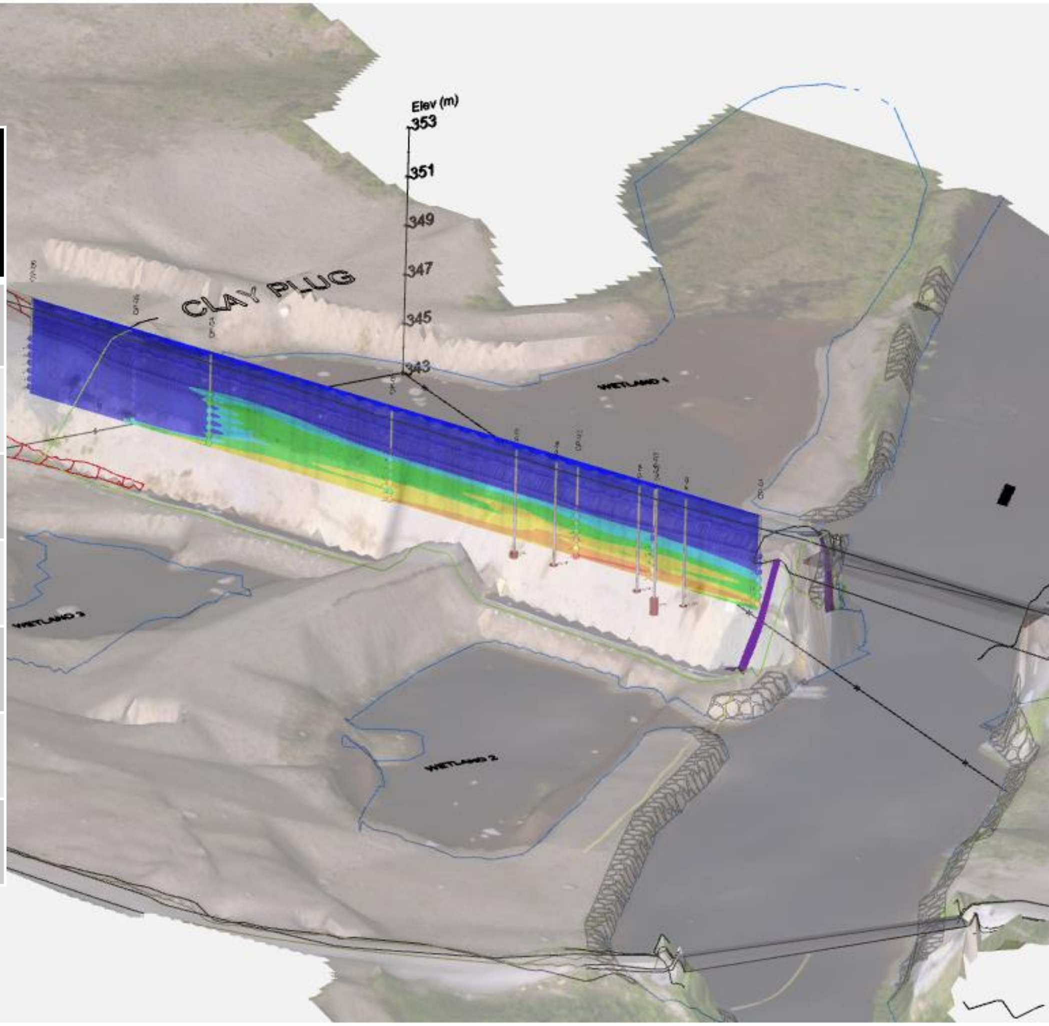


CORRECTED TEMPERATURE (Degrees C)

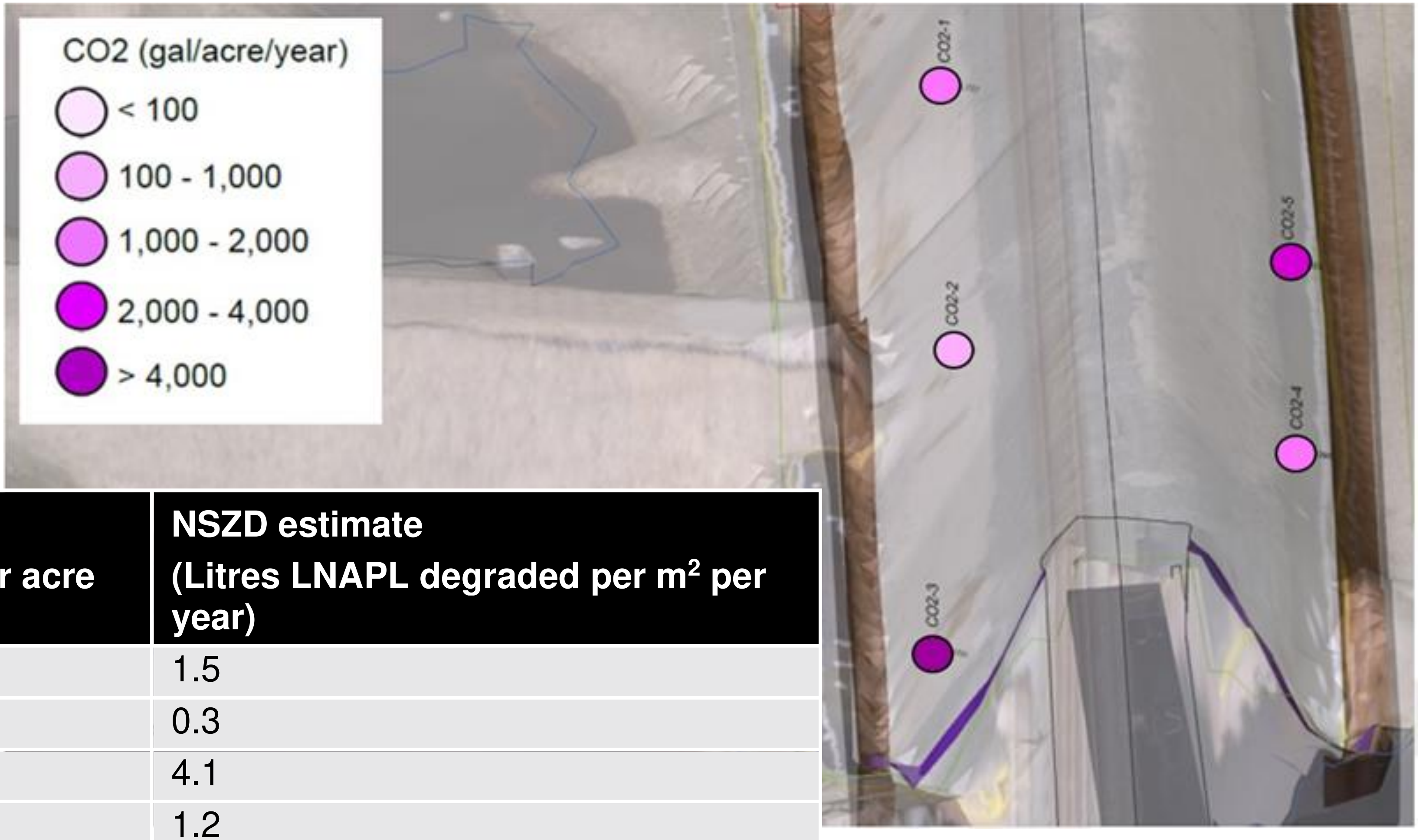
< 1	1 - 2	2 - 3	3 - 4	4 - 5	> 5

Technique 2: 2021 biogenic heat results

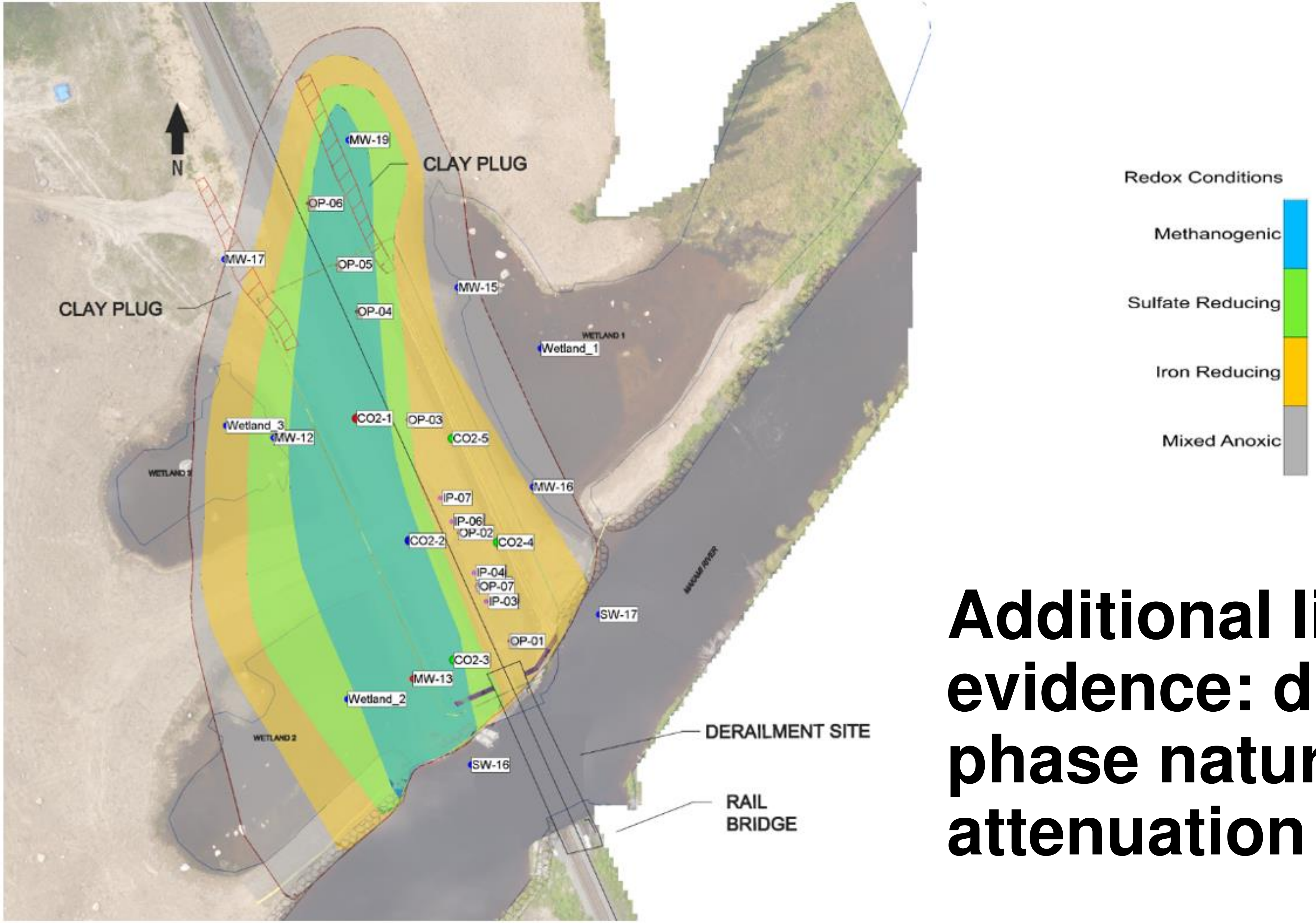
Location ID	NSZD rate estimate (US gal/acre/yr)	NSZD rate estimate (L/m²/year)
OP-01	1 600	1.5
OP-02	1 800	1.7
OP-03	1 500	1.4
OP-04	400	0.3
OP-05	3 200	3.0
OP-07	2 400	2.3
Average	**1 800**	**1.7**



Technique 1: 2022 CO_2 trap results



CO_2 Trap ID	NSZD estimate (U.S. gal LNAPL degraded per acre per year)	NSZD estimate (Litres LNAPL degraded per m^2 per year)
CO2-01	1,595	1.5
CO2-02	255	0.3
CO2-03	4,347	4.1
CO2-04	1,285	1.2
CO2-05	2,345	2.2
Average	**1,965**	**1.9**



Additional line of evidence: dissolved phase natural attenuation

Bottom Line

1. **Multiple lines of evidence support robust LNAPL biodegradation is occurring**

2. **In the 'zero order' phase of NSZD activity**
   - Estimates ≈ 2 litres of LNAPL degraded per square meter per year
   - Agreement across methods/events

3. **NSZD is a viable option for long-term residual LNAPL management/depletion**
   - LNAPL recovery diminished to a practical end-point
   - Microbes will access residual LNAPL that recovery systems cannot
   - <u>More sustainable</u>

* Thank You

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