Carbon Sequestration to Stabilise Legacy Alkaline Waste

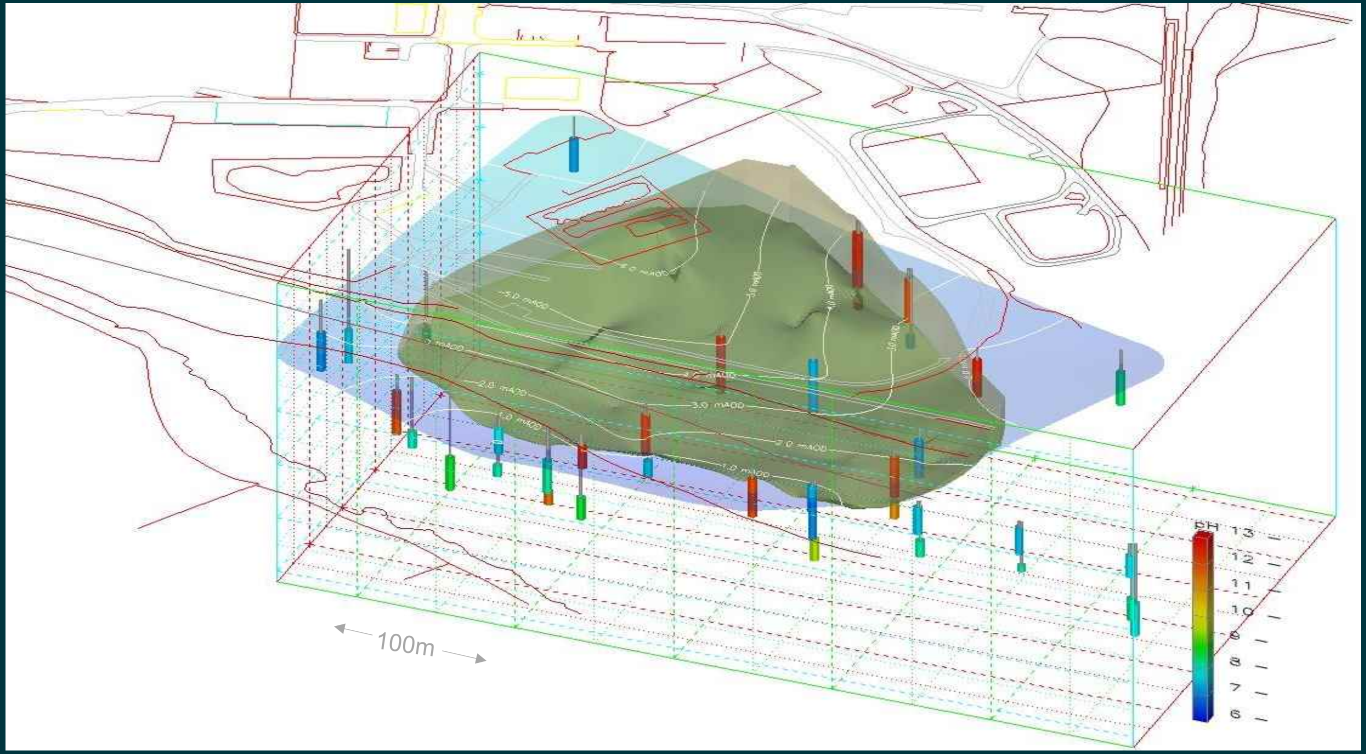
David Granger

Battelle - International Symposium on Bioremediation and Sustainable Environmental Technologies
May 8-11, 2023 | Austin, Texas

Why does this project represent best practice in green and sustainable remediation?

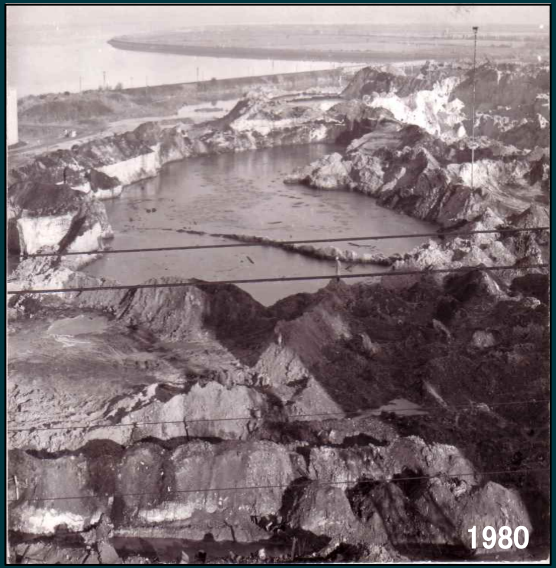
- Development and in-situ pilot trialling of carbon sequestration to neutralise legacy alkaline chemical waste
- Delivers both contaminant risk mitigation and action to address wider climate change impact

Sequestration potential for 85,000 TONNES of CO_2



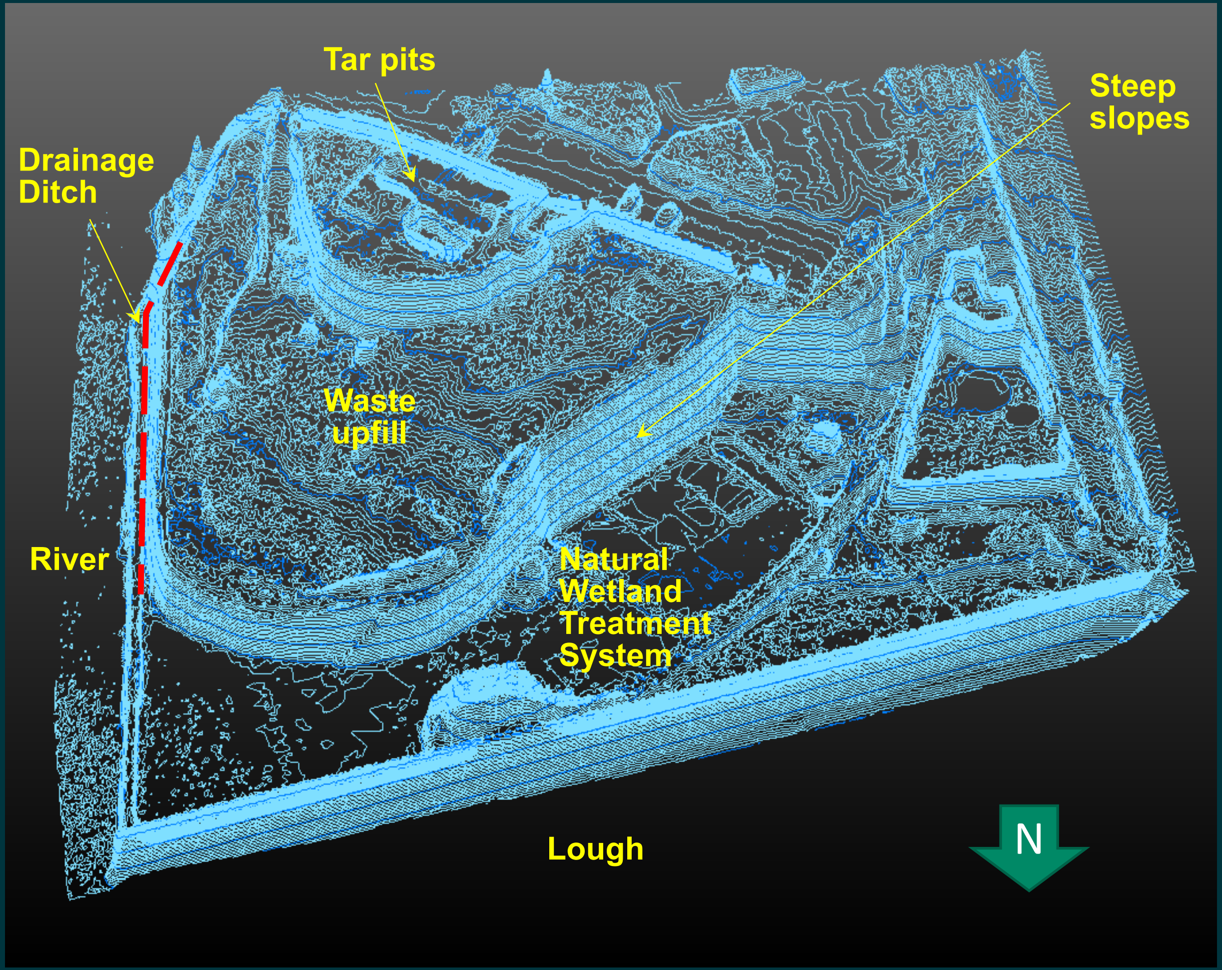
Site history

- Co-disposal of calcium hydroxide and tar from two historical acetylene manufacturing processes

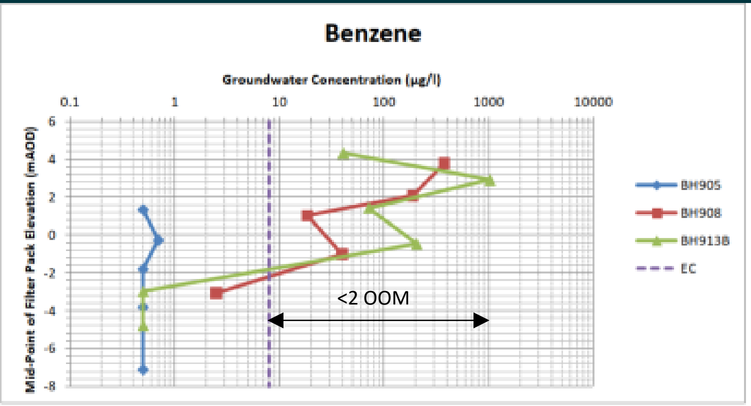


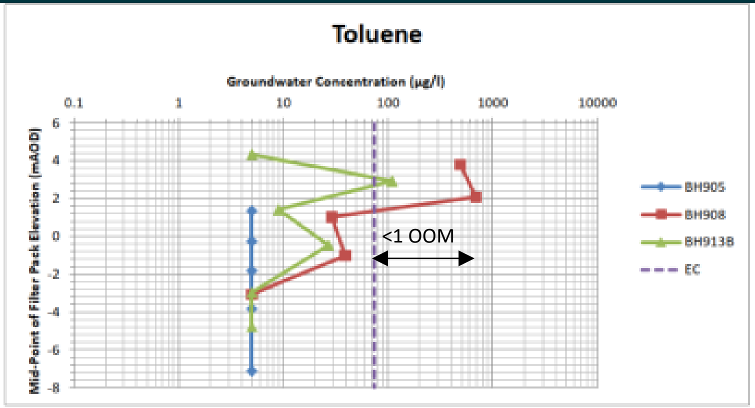
Current site layout

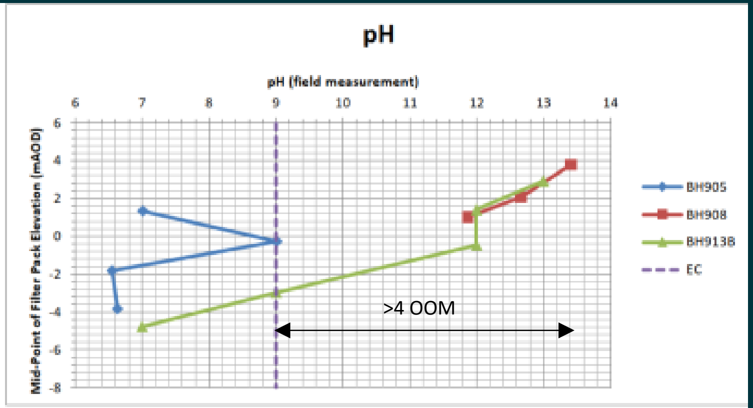
- Key features:

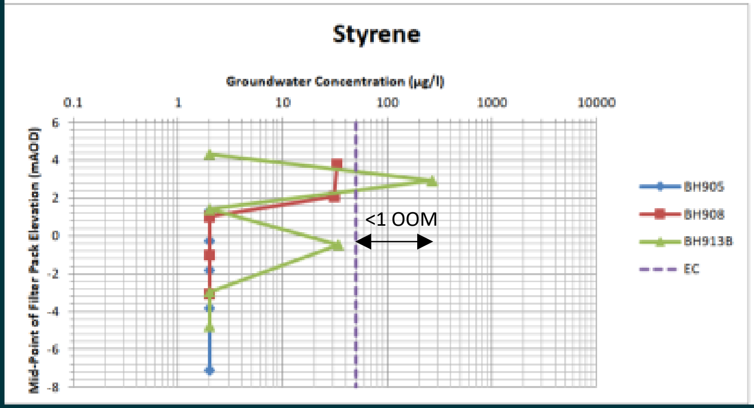


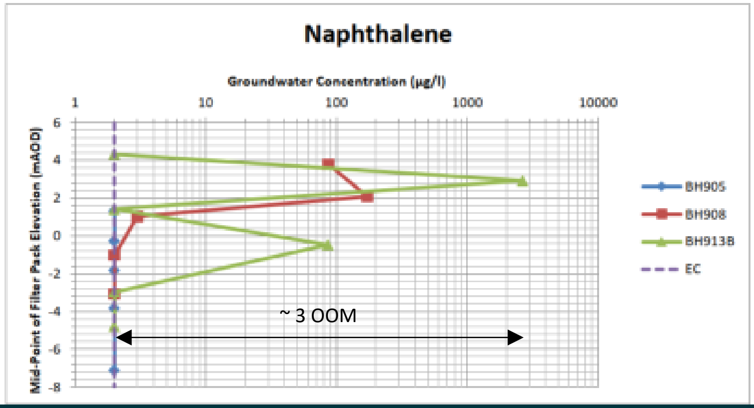
Chemicals of potential concern – vertical extent





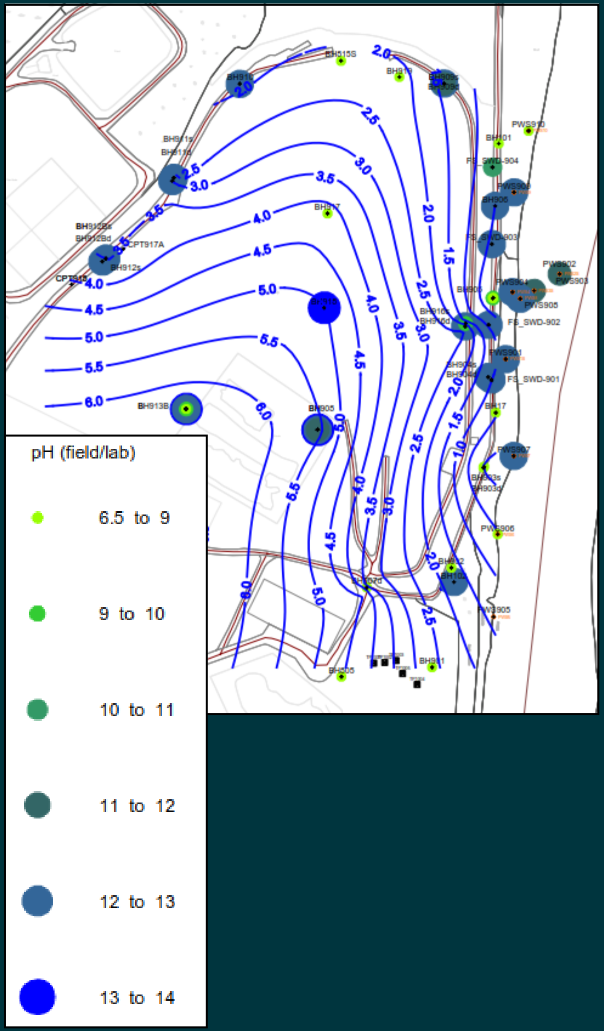


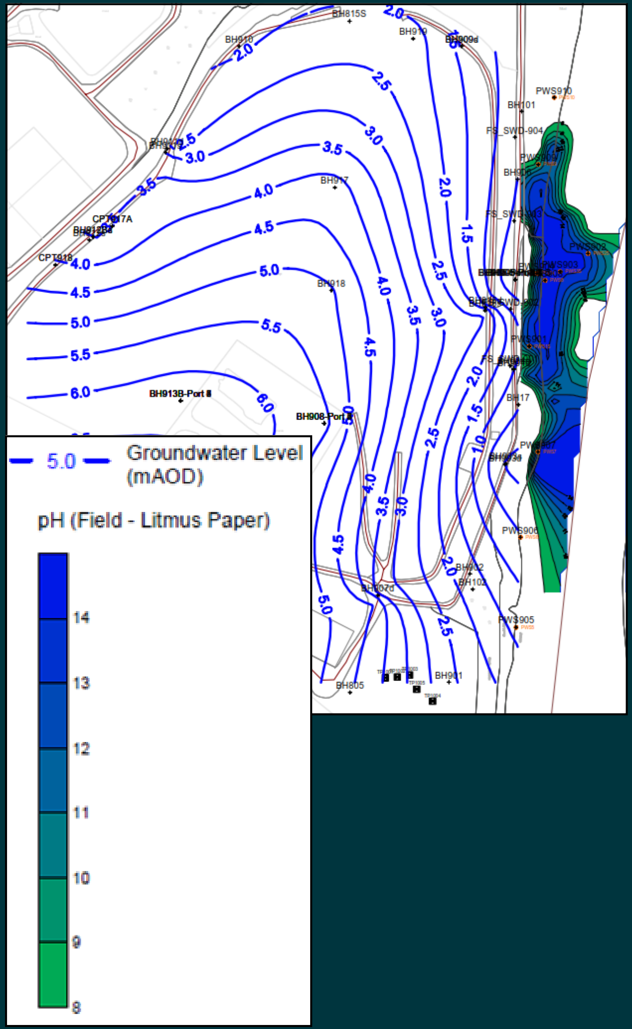




OOM – Order Of Magnitude

Chemicals of potential concern – pH



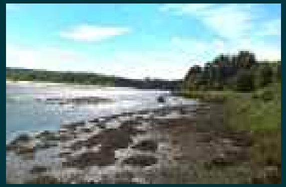


Risk assessment summary – risk drivers

Human health risk from exposure to high pH and PAHs in shallow soils

Human health risk from high pH in drainage ditch

Off site human health risk from high pH in sediment and pore water on foreshore



Safety hazards associated with tar pits and steep slope embankments

Acronyms:

- CoPC: Chemicals of potential concern
- PAHs: Polycyclic Aromatic Hydrocarbons

Environmental - minimize further entry of CoPC to groundwater and surface water

Remedial options appraisal

Remedial Target → **Long List** → **Short List** → **Short List (packages)** → **Selected Approach**

Remedial Target

- Isolate the source from potential contact with site and foreshore users
- Remove physical safety hazards
- Reduce CoPC mass discharge to groundwater and foreshore

Long List

31 Long-List options:

- Management / Control Methods
- Civil Engineering Methods
- Biological Methods
- Chemical Methods
- Physical Methods
- Stabilization and Solidification methods
- Thermal Methods

Short List

Permeable cap

& re-profiling & tar pit stabilisation/capping

Low permeability cap

& re-profiling & tar pit stabilisation/capping

GW cut-off wall

Carbon Dioxide (CO_2) sequestration

Short List (packages)

Permeable cap with CO_2 seq.

Re-profiling, tar pit stabilisation/capping & **GW cut-off wall**

Permeable cap no CO_2 seq.

Re-profiling, tar pit stabilisation/capping & **GW cut-off wall**

Low permeability cap with CO_2 seq.

Re-profiling, tar pit stabilisation /capping & **GW cut-off wall**

Low permeability cap no CO_2 seq.

Re-profiling tar pit stabilisation /capping & **GW cut-off wall**

Selected Approach

Low permeability cap ***(optional CO_2 sequestration)***

Re-profiling, tar pit stabilisation/capping **&** **cut-off wall** (diversion to the lagoons for treatment)

Acronyms:

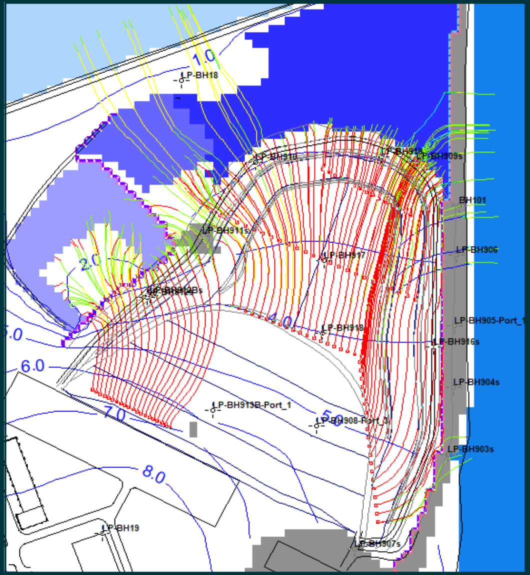
- GW: Groundwater
- CoPC: Chemicals of Potential Concern
- CO_2: Carbon Dioxide

Remedial options appraisal – selected approach

– Engineered pathway interception solution

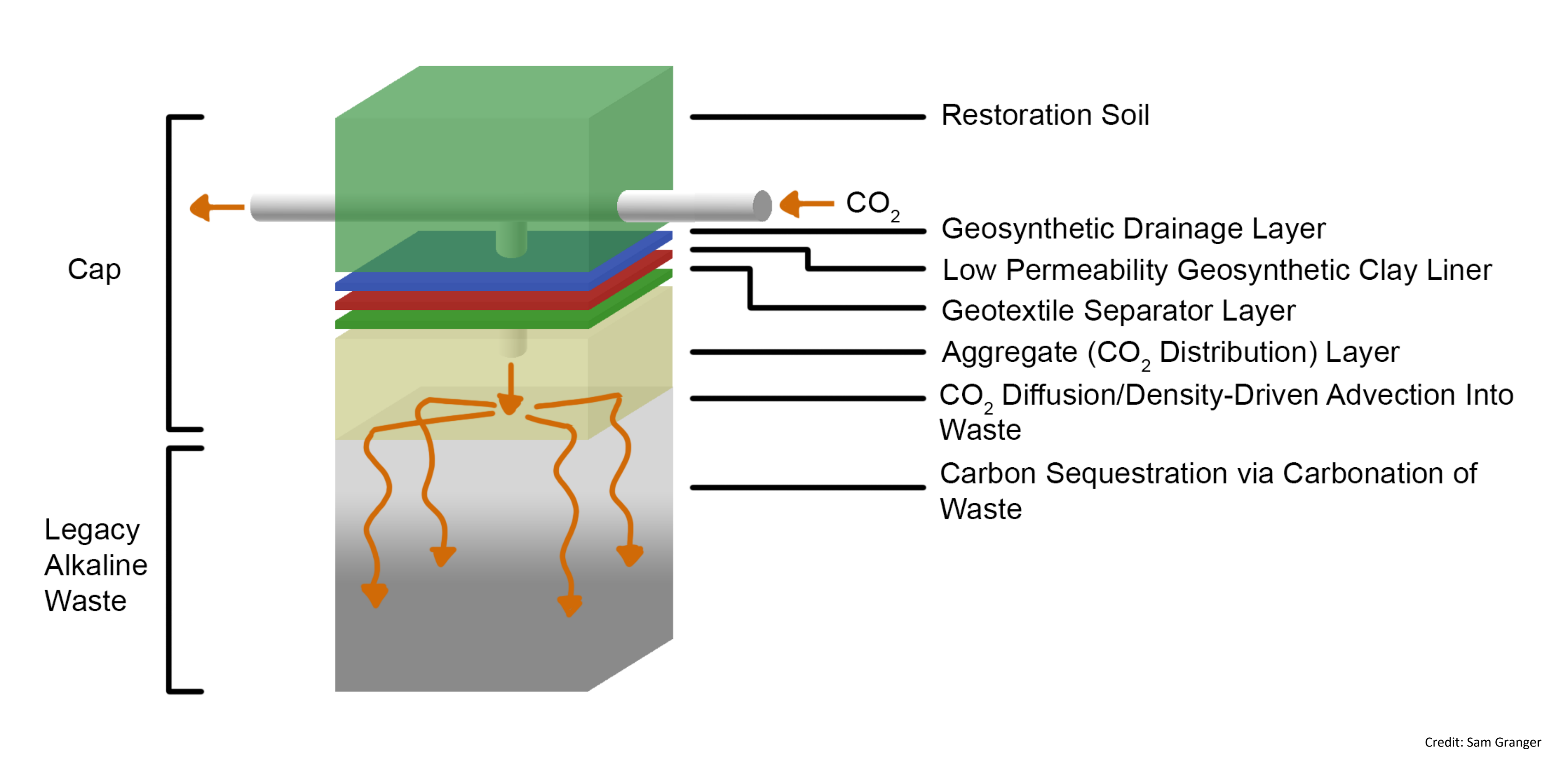
- Low permeability cap
- Down-gradient cut-off wall
- Leachate diversion via drains to natural wetland treatment system
- Tar pit stabilisation/capping
- Up-gradient groundwater interception

– Groundwater modelling used to evaluate impact on CoPC discharge and optimise location and depth of cut-off walls



CO_2 sequestration concept

- Capture CO_2 from local emitters and store (sequester) within the site
- Neutralise caustic waste through carbonation



CO_2 sequestration - background

- XRD analysis of the waste materials identified 3 minerals with the potential to react and sequester CO_2 into carbonated products:

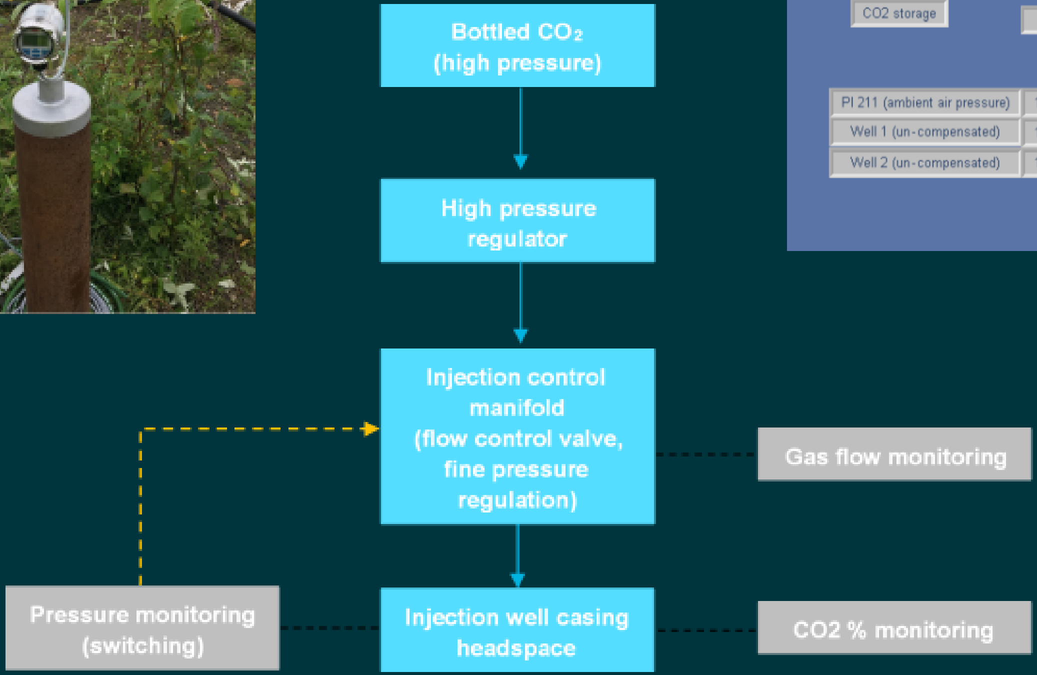
  - Portlandite ($Ca(OH)_2 + CO_2 \rightarrow \mathbf{CaCO_3} + H_2O$)

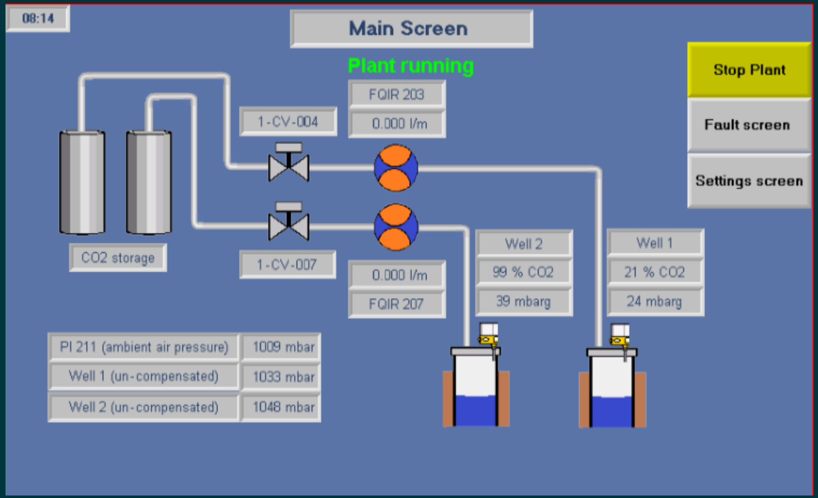
  - Ettringite ($Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26H_2O + 3CO_2 \rightarrow \mathbf{3CaCO_3} + 3[CaSO_4 \cdot 2H_2O] + Al_2O_3 \cdot xH_2O + (26-x)H_2O$)

  - Hydrocalumite ($2[Ca_2Al(OH)_6Cl \cdot 2H_2O] + 3CO_2 \rightarrow \mathbf{3CaCO_3} + Al_2O_3 \cdot xH_2O + CaCl_2 + (10-x)H_2O$)

CO_2 sequestration pilot trial - design

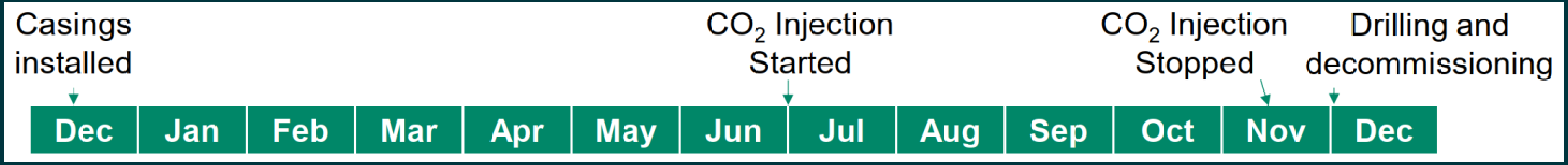
•





CO_2 sequestration pilot trial - operation

– 4 stages:



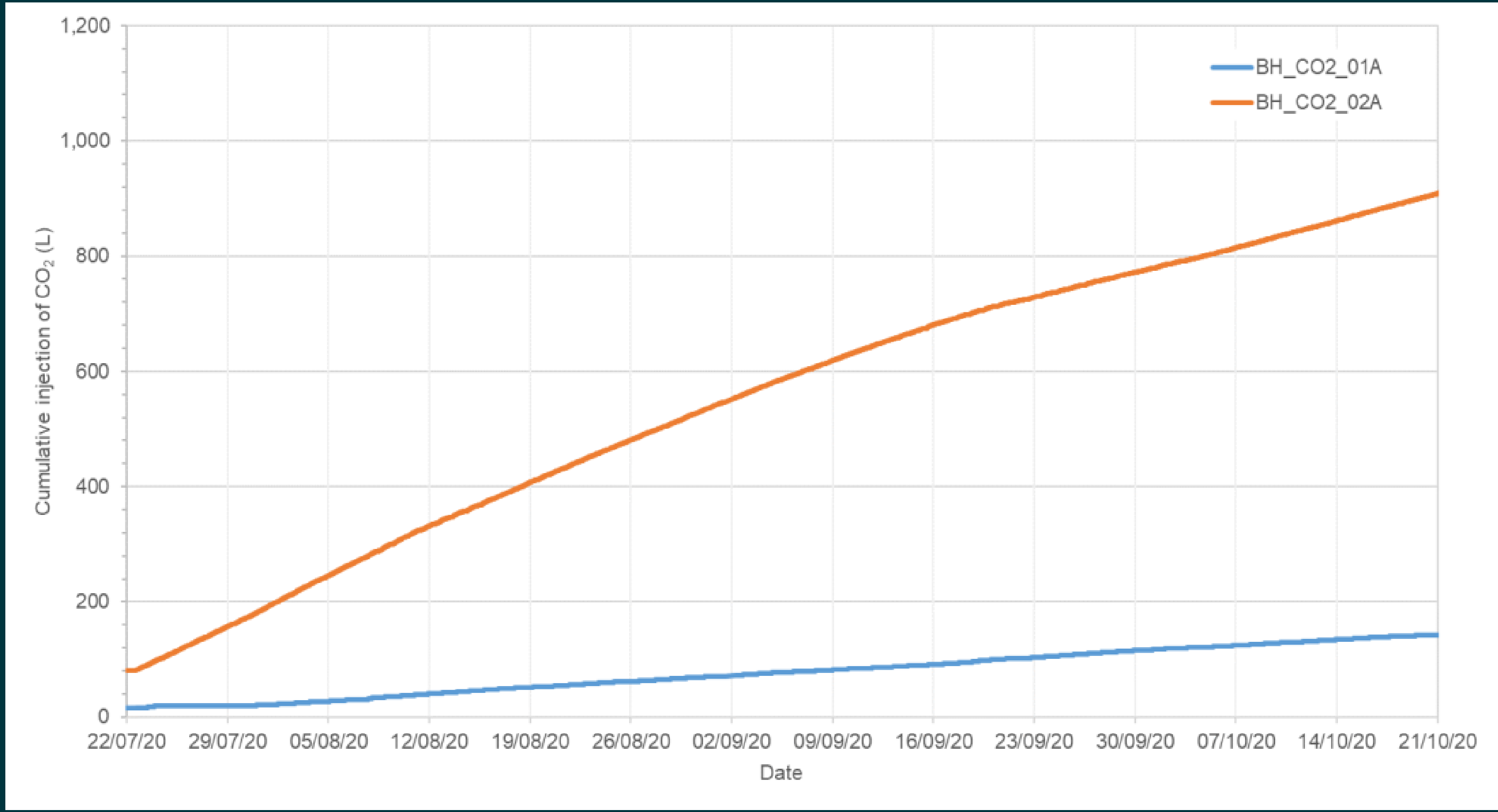
1. Installation of 4 casings: (10-11 Dec. 2019) to isolate columns of lime within the casing
2. Installation & operation of a CO_2 injection network to 2 casings by Cornelson Ltd. (Jul-Dec 2020)
3. Removal of casings and drilling of cores at each location (2-3 Dec. 2020)
4. Drilling of two additional boreholes for XRD analysis (2-3 Dec. 2020)

– System operated for a total of 108 days

– Power was main operational issue: larger solar array required and decline in daylight hours

CO_2 sequestration pilot trial - results

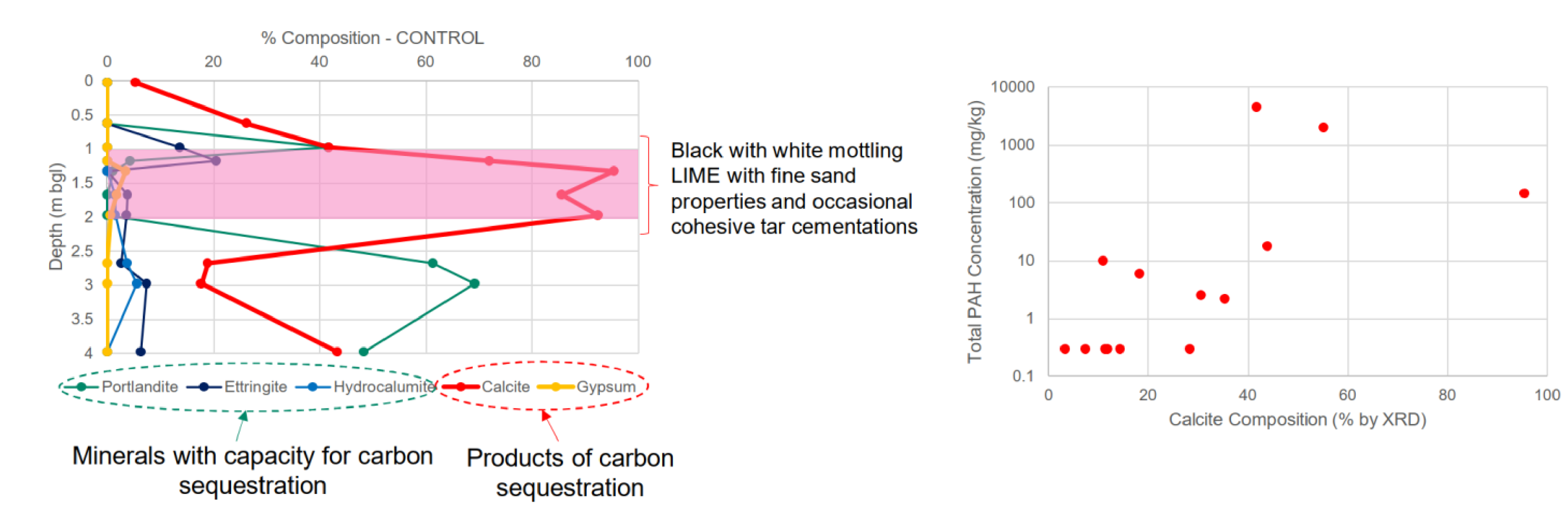
- 1,137 litres of CO_2 were injected into the waste at the two active locations
- Average rate of injection over the duration of the trial (normalized to unit surface area of the waste) ranged between 0.21-1.28 kg/m^2.day



CO_2 sequestration pilot trial – sampling post injection

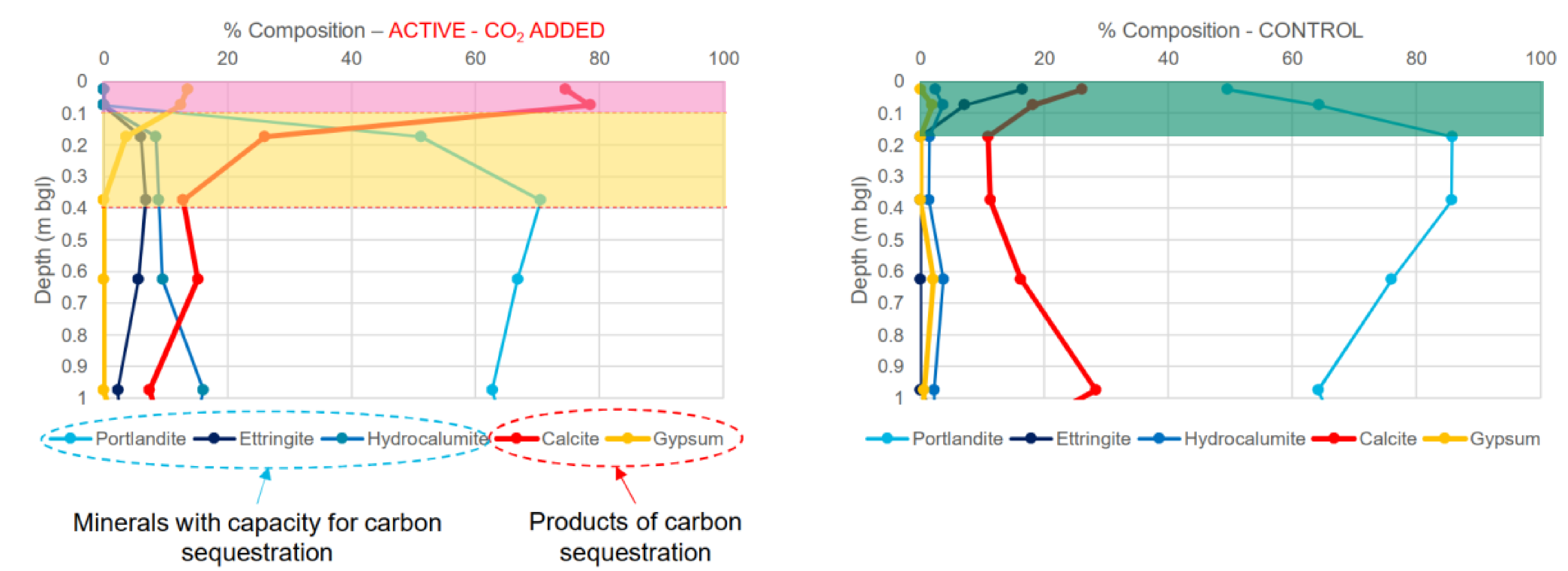
CO_2 sequestration pilot trial - results

- Significant variability was also noted in minerals with potential for CO_2 sequestration and calcite contents between locations and within locations.
- Inferred to potentially relate to localised carbonation from CO_2 produced by mineralisation of organic contaminants in the lime.



CO_2 sequestration pilot trial - results

- Complete carbonation of minerals in the upper 0.1 m and increased proportion of carbonated minerals to a depth of 0.4 m



CO_2 sequestration – capacity

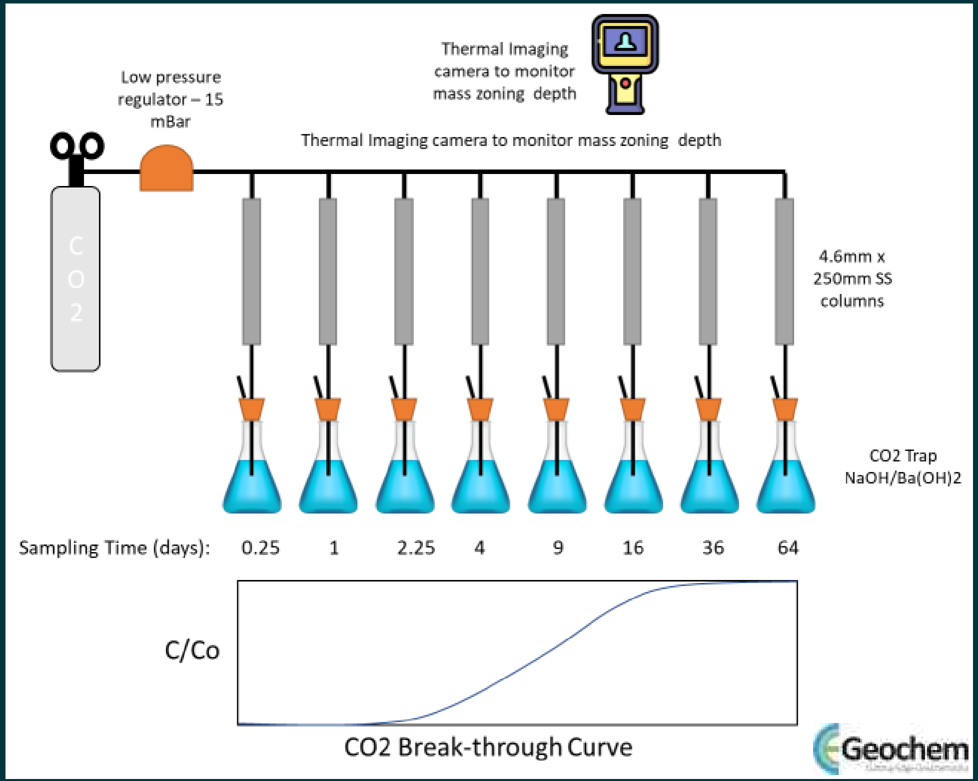
- CO_2 sequestration capacity calculated to be 85,000 tonnes

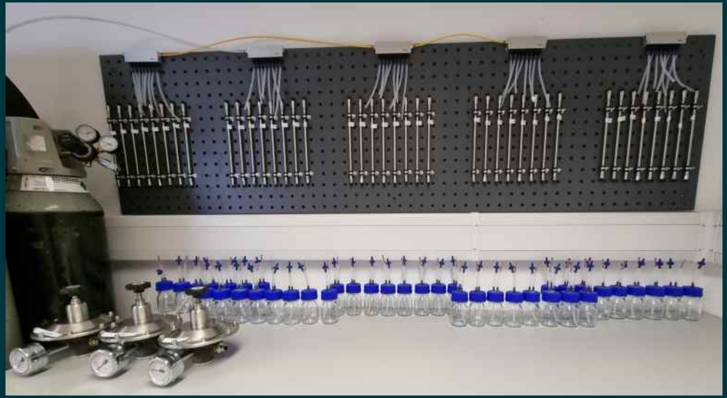
Parameter	Units	Value
Estimated Volume of Waste from 3D Geological Model (EVS)	m^3	264,630
Mean Calcium Hydroxide Content (49 samples XRD)	v/v	55.4%
Mean Ettringite Content (49 samples XRD)	v/v	5.9%
Mean Hydrocalumite Content (49 samples XRD)	v/v	4.0%
Dry Bulk Density of Lime (3 samples - triaxial test)	kg/m^3	994
Mass of Calcium Hydroxide in Upfill	t	145,725
Mass of Ettringite in Upfill	t	15,519
Mass of Hydrocalumite in Upfill	t	10,522
Capacity for CO_2 Sequestration from Calcium Hydroxide	kg	8.66E+07
Capacity for CO_2 Sequestration from Ettringite	kg	1.63E+06
Capacity for CO_2 Sequestration from Hydrocalumite	kg	2.48E+06
Combined Capacity for CO_2 Sequestration	t	90,667
CO_2 Potentially Available from Tar Biodegradation	t	5,268
Remaining Capacity for CO_2 Sequestration	t	85,399

- At the observed rates of carbonation/CO_2 injection complete carbonation could take 4-20 years
- Cost benefit analysis indicated a net benefit for full-scale deployment for a number of cost-carbon price combinations

Next steps

- Currently in progress:
  - Laboratory study to establish parameters for modelling full carbonation of waste
  - Discussion with regulators over implications of full-scale implementation
  - Discussion with verifiers to understand evidence required for certification as carbon sink
- Planned:
  - Larger-scale, longer-duration field pilot trial to assess CO_2 distribution and vertical penetration from injection below cap





CO_2 sequestration in alkaline waste – a broader picture

- Alkaline wastes produced by a number of industries (e.g. steel, aluminium, construction and paper industries, coal-fired power plants and waste incineration)
- Offer significant potential for carbon sequestration
- This project offers the opportunity to take one small, but important, step in realising this potential

Pan et al., Aerosol and Air Quality Research, 12: 770–791, 2012

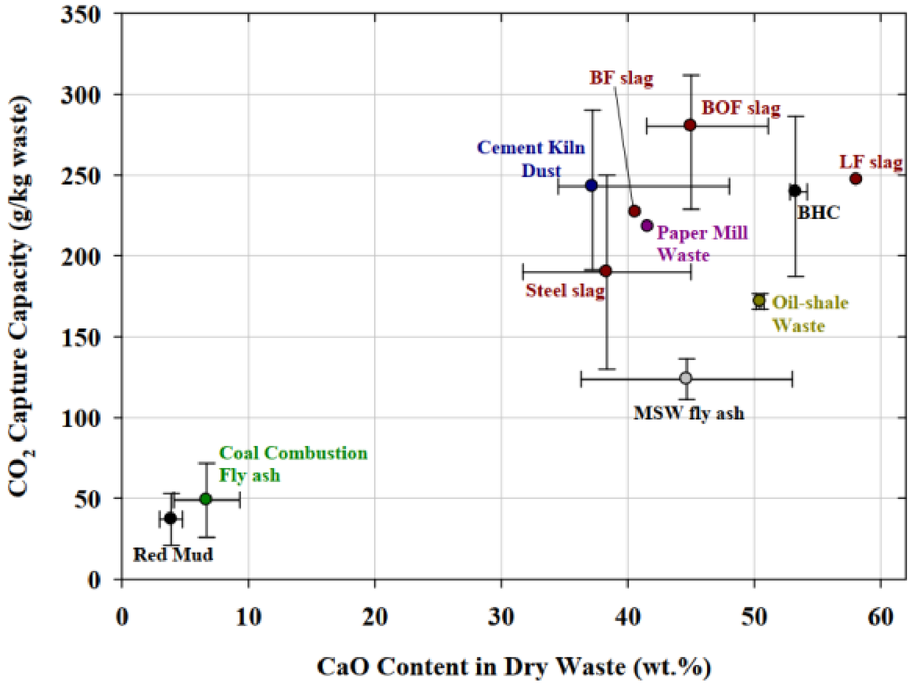


Fig. 3. Comparison of actual CO_2 capture capacity with the CaO content in solid for different types of wastes.

Thank You!

david.granger@aecom.com