THE DOWNHOLE VISUAL ANALYTICS COMPANY

Application of novel downhole video technology leads to the diagnosis and successful remediation of injectivity performance issues in deep saline CO2 storage well

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Petroleum Technology Research Centre

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AQUISTORE®

INTRODUCTION

About Aquistore

- **Injection and storage of CO_2** from Boundary Dam coal fired power station, Estevan, Saskatchewan
- **Facility owned by SaskPower** and Operated by the Petroleum Technology Research Centre (PTRC)
- **Construction commenced in 2012** with initial injection in April 2015 and full scale injection by end of 2015
- **Two wells drilled:** Injection well and offset monitoring well
- **CO_2 injection well designed to take up to 2,400 tonnes/day**
- **Over 393,000 tonnes of CO_2 injected to date**
- **A field lab for testing MMV technologies** for future CCS projects

INJECTIVITY PERFORMANCE

Reservoir

- **CO_2 is injected and stored in a highly saline formation** (>30% salt) circa 3,400m below surface
- **Four perforated intervals:** Black Island, Deadwood B, C, D

Injectivity issues and impact

- **Early injectivity rates stabilized at 400 to 600 tonnes/day**
- **High-rate CO_2 and Water injection tests performed**
- **Release of excess CO_2** that cannot be captured (or used for EOR)
- **Carbon emissions tax CAD$40 per tonne** with impact of >CAD$20,000 per day due to reduced performance

INJECTIVITY DIAGNOSTICS

Preliminary diagnostics

- **Fluid diversion treatment** performed in March 2015 with wireline conveyed pre/post injection logs
- **Total of 410 ball seal spheres** pumped to divert flow towards under-performing zones

Results

- **Logs revealed partial success** as inflow increased into Deadwood, but no improvement in Black Island
- **Overall injectivity was slightly improved** but remains far below the initial well test data
- **Remedial actions considered to improve injectivity**, such as re-perforation, acid treatment, or other stimulation
- **Video survey commissioned** to understand cause and identify which remediation would be most effective

VIDEO DIAGNOSTICS

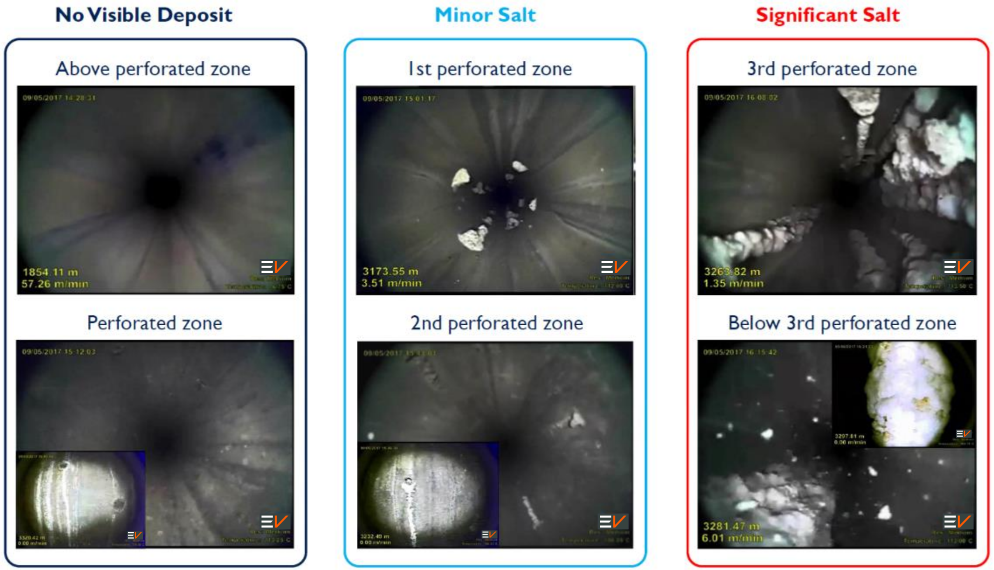
Video Survey

- First **video survey** recorded in **May 2017** with time-lapse survey performed in **August 2020**
- Objectives to **examine the perforated interval** and identify **factors affecting injectivity performance**

Results

- **Images revealed solids build-up in perforation tunnels and at perforation entry hole**
- **Solids identified in each of the perforated intervals with varying degree of severity**
- **Variety of features and characteristics of the observed solids suggest multiple mechanisms at work**
- **The solids were quickly diagnosed as salt precipitation with crystalline and highly porous appearance**

VIDEO RESULTS 2017



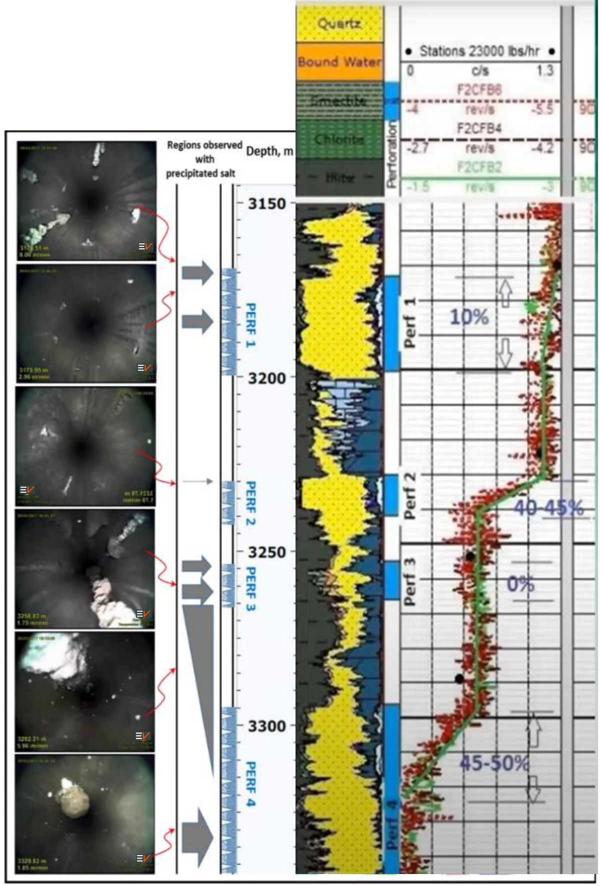
Formation	Interval (mKB)
Black Island	3173-3200
Deadwood	3230-3242
Deadwood	3255-3266
Deadwood/Precambrian	3296-3366

Perf Zone 1
Highest permeability at the bottom of the zone

Perf Zone 2
High, relatively constant permeability

Perf Zone 3
Low permeability
Plugged based on spinner survey

Perf Zone 4
Variable, low to ntermediate permeability



VIDEO RESULTS 2017

TYPE 1

ZONE 1 (BLACK ISLAND)

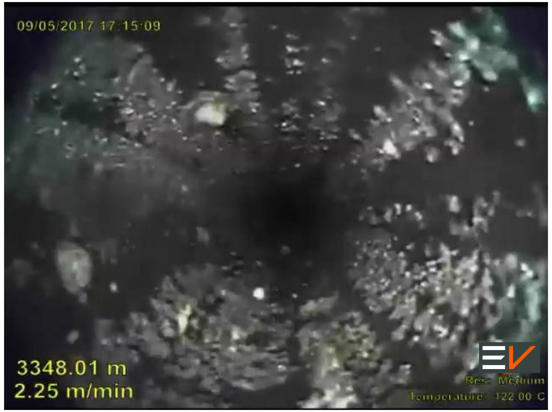
Localised precipitation at perforations
Limited impact on wellbore ID
Some travel along wellbore (50cm)

TYPE 2

ZONE 3 (DEADWOOD C)

Widespread precipitation
Significant impact on wellbore ID
Extensive travel along wellbore (50m)

TYPE 3



WELL BOTTOM

Widespread precipitation
Minimal impact on wellbore ID
Limited to gas/liquid interface

RESTORATIVE ACTIONS

Information and actions

- **Creation of highly saline Ca-Mg-Cl brines** through repeated drying/wetting cycles in operation
- Type 1 structures at **perforations with localised low porosity and permeability,** resulting in loss of injectivity
- Type 2 structures at **perforations within overall low permeability zones**, causing loss of injectivity to zone below
- Simple **warm water wash** would remove salt build-up, but **risk of unintended consequences** from change in chemistry
- **Focus shifted** from intervention **to management**

Further studies

- Core flooding, permeability analysis, microCT imaging and reactive transport studies performed
- **Understand mechanism and ways to limit flow-back**

NOVEL VIDEO TECHNOLOGY

The world's first array sideview camera for downhole applications:

- **360-degree continuous side-view camera footage**
- **Integrated down-view camera**
- **25 fps sample rate**
- **Real-time or memory configuration**
- **All conveyance types: slickline, e-line, coiled tubing, e-coil and e-line tractor**
- **2880 x ∞ pixel video resolution**
- **>5 GigaPixels processed per 30ft (at 15 ft/min)**

VIDEO RESULTS 2020

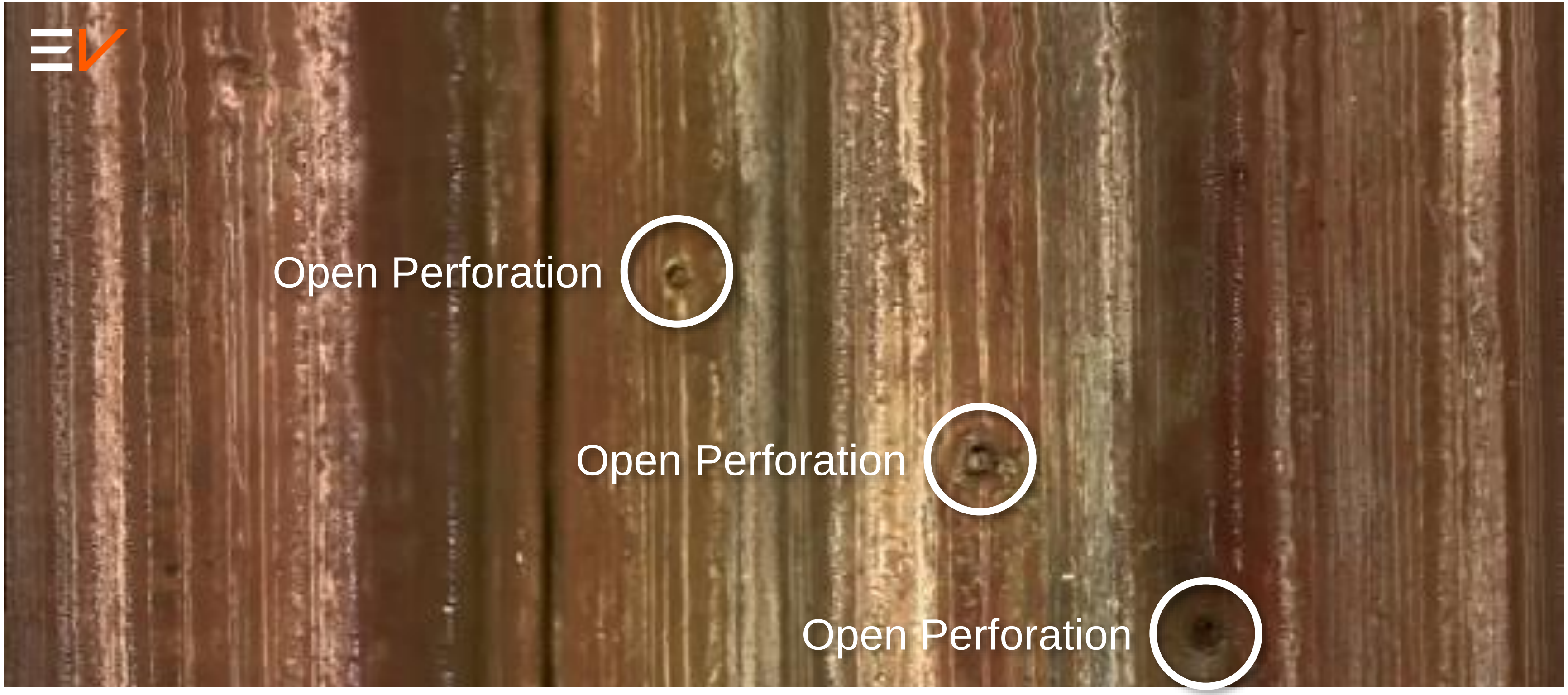
Side-view results

- Revealed more detailed images of solids structure
- Granular / porous texture confirmed at all zones
- 360° field of view allowed detailed imaging of every perforations in each zone

Key observations

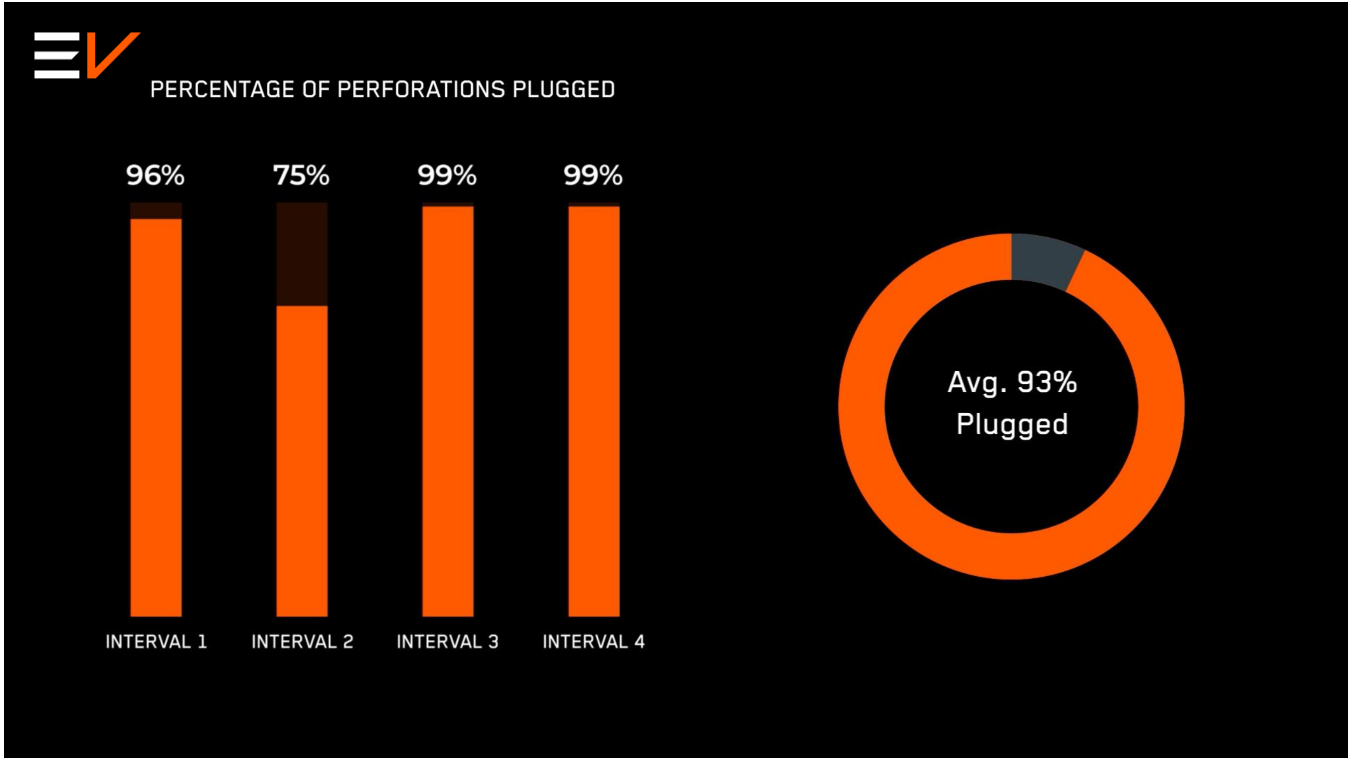
- No "Type 2" structures: Deadwood C wellbore clean
- Type 1 structures evident in all perforated zones
- Degree of precipitation variable across each zone

VIDEO RESULTS 2020



VIDEO RESULTS 2020

QUANTITATIVE EVALUATION



Results

- Each perforation analysed for presence of solids
- Statistical database created for each perforation and zone
- Up to 99% of perforations in some zones affected
- Average of 93% of perforations affected by solids

OUTCOME & LESSONS LEARNED

Remedial action

- Analysis of salt samples suggested ability to break down salt deposits with further injection
- Surface data and downhole video analysis supports this self-healing proposition as injectivity increasing
- Plan regular video surveys for time-lapse monitoring

Preventative action

- Simulations reveal backflow and precipitation severely reduced by maintaining continuous injection
- Processes changed to limit shut-in periods and establish minimum operating injection rates

Recommendations

- Ensure consideration given to onset of scale development during planning phase
- Consideration to be made for conditions that may result in flow-back of water into injection well
- Prevent prolonged shut-in periods and maintain high volume of injection

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Thank you

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