The Oil Industry Today

There is a strong interest in the development of viable and environmentally sustainable bitumen/heavy oil recovery processes that are less energy intensive and use less water than steam-based processes

To Fulfill this Need …

- Focus on enhancing primary recovery processes.

- Developing improvements to primary production in horizontal wells → enhancing oil production rates and increasing recovery factors through the managed production of sand

Research Program

- Assessment of strategies for enhancing primary production in horizontal wells through managed sand production

- A comprehensive experimental research program was executed under laboratory conditions closer to field conditions than any previous work on this topic found in the literature

Findings and Contribution

- Increases in near-well permeability through managed sand production with low sand cuts
- Improvement includes a reduction of skin effects and the formation of high permeability channels
- Slot size selection and correct handling of production flow rates → key to managed sand production
- Opens the possibility of a successful primary heavy oil recovery process with sand in horizontal wells

Directions and Needs

Requirements → numerical modelling to forecast the impact of managed sand production on oil production rates

Sand on Demand: An Approach to Improving Productivity in Horizontal Wells Under Heavy Oil Primary Production

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Presentation Outline

- Introduction
- Process highlights
- Experimental program
- Results
- Conclusions

Process Highlights

Cold Production (CP)

Definition: CP is a primary non-thermal process used in unconsolidated heavy oil reservoirs. In this process sand and oil are produced together in order to enhance the oil recovery.

Highlights:

- First practiced in California in early 1900s
- Redeveloped in Lloydminster in 1980s
- Successful in vertical wells
- Much higher oil production rates
- Elevated recovery factor (~ 5-20%)
- Has not been applied commercially in horizontal wells

Process Highlights

Cold Production Mechanisms

- **Gas evolution from the oil (foamy oil)**

  A highly efficient solution gas drive mechanism, more complex than the conventional solution gas drive.

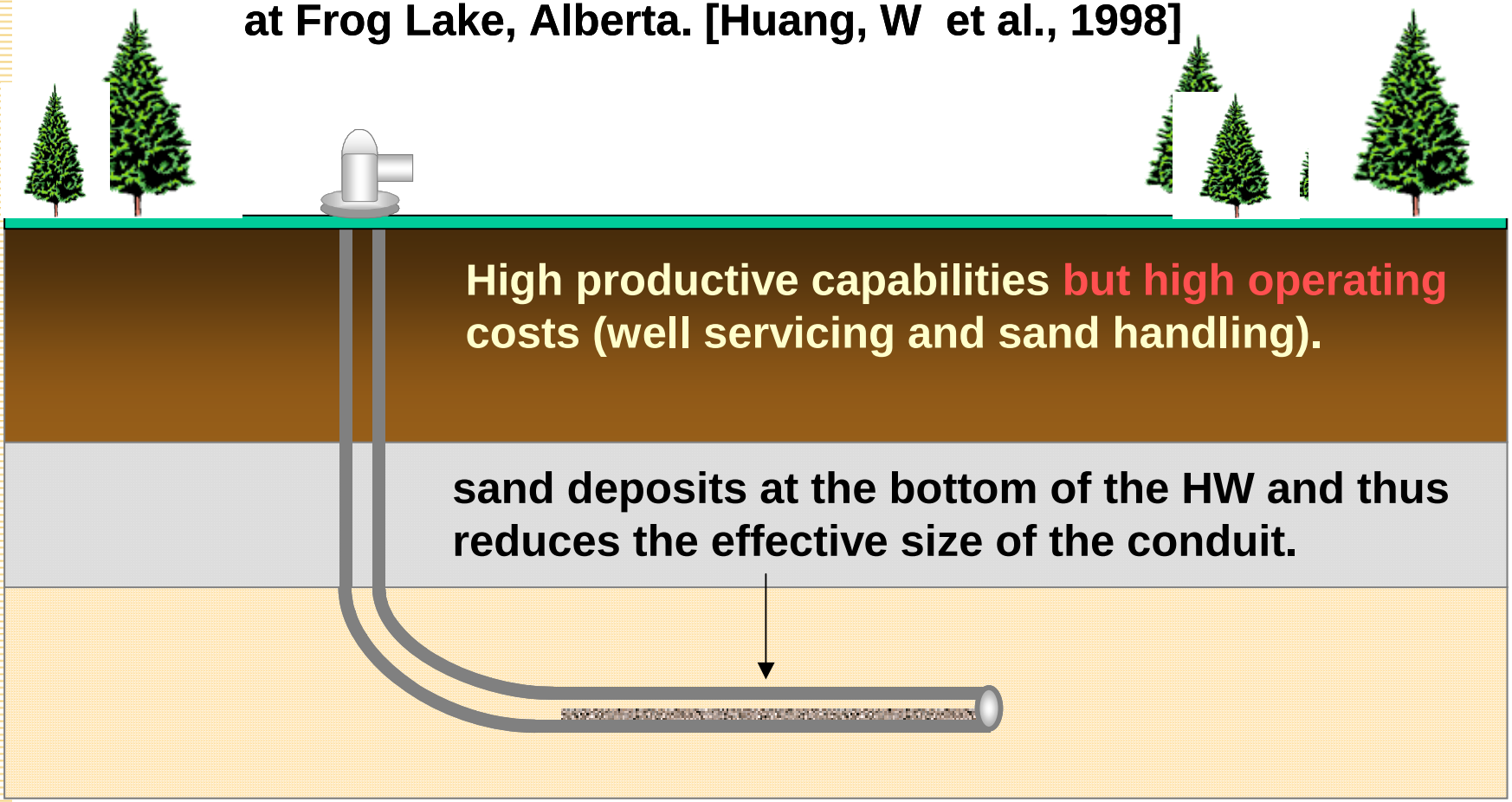
- **Sand production (channel development)**

  Improve the efficiency of the gas drive mechanism by altering the fluid flow characteristics into the wells in heavy oil reservoirs.

Process Highlights

Cold Production in Horizontal Wells

One pilot test using horizontal wells ⇒ Texaco Canada at Frog Lake, Alberta. [Huang, W et al., 1998]



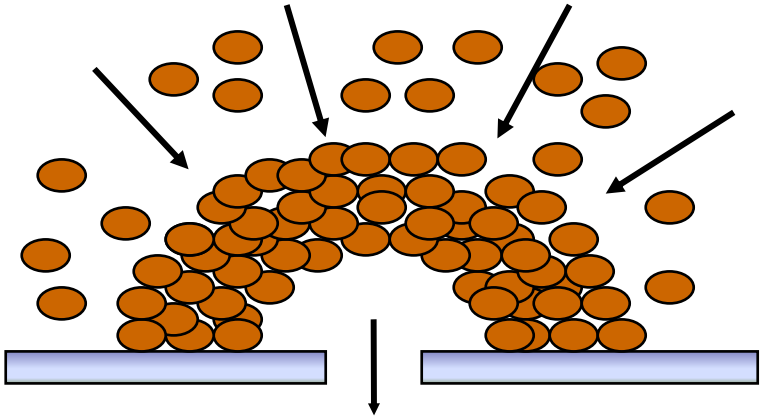
Process Highlights

Key Mechanisms

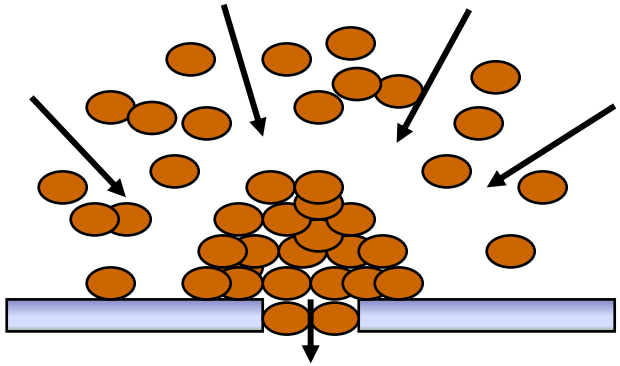
Sand arching/bridging ⇨ natural way to control sand production

Arch is a curved structure spanning an opening ⇒ many grains

Bridge is a blockage across an opening ⇒ few grains



Arching



Bridging

Objective

- To explore the possibility of applying primary heavy oil production with sand using horizontal wells, through laboratory experiments examining the mechanisms involved in the flow of oil and sand around, into and through a slot

Experimental Program

Materials and their properties

Fluids

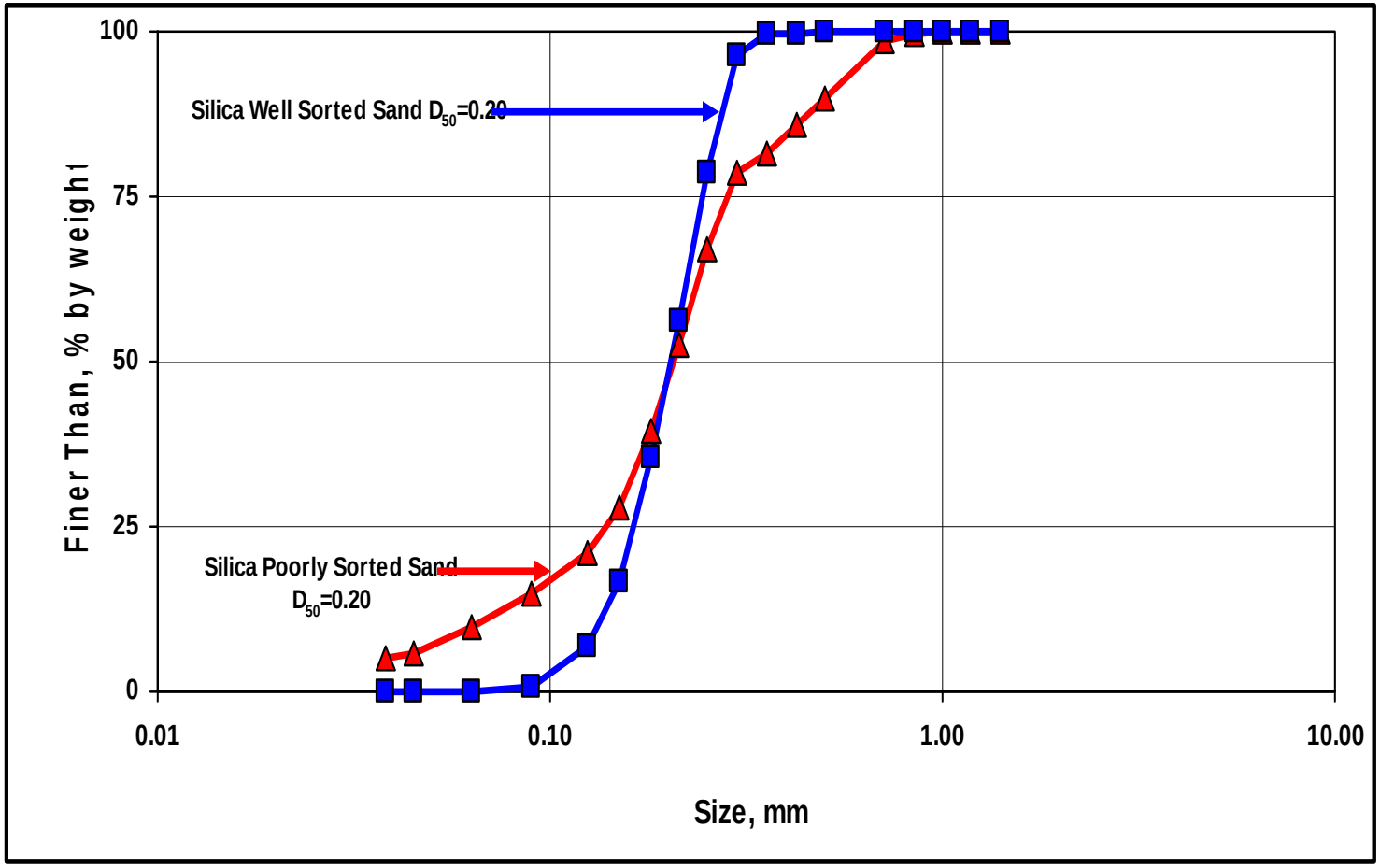
- Conventional heavy oil (Lloydminster)
- Distilled water

Sands

- Synthetic sand: crystalline silica sand
- Synthetic sand: Glass (soda lime) beads
- Reservoir sand: Husky sand

Experimental Program

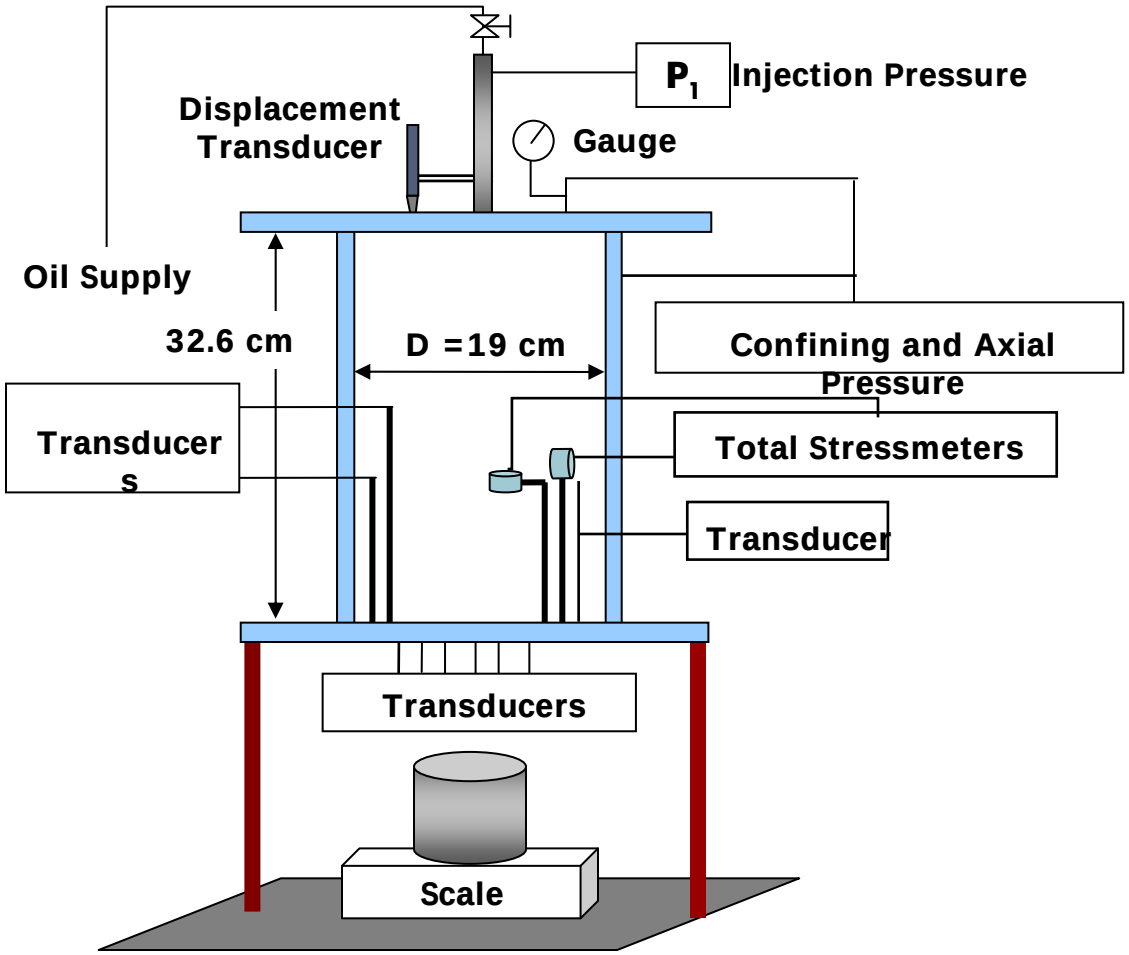
Grain Size Analysis Silica Sands



Experimental Program

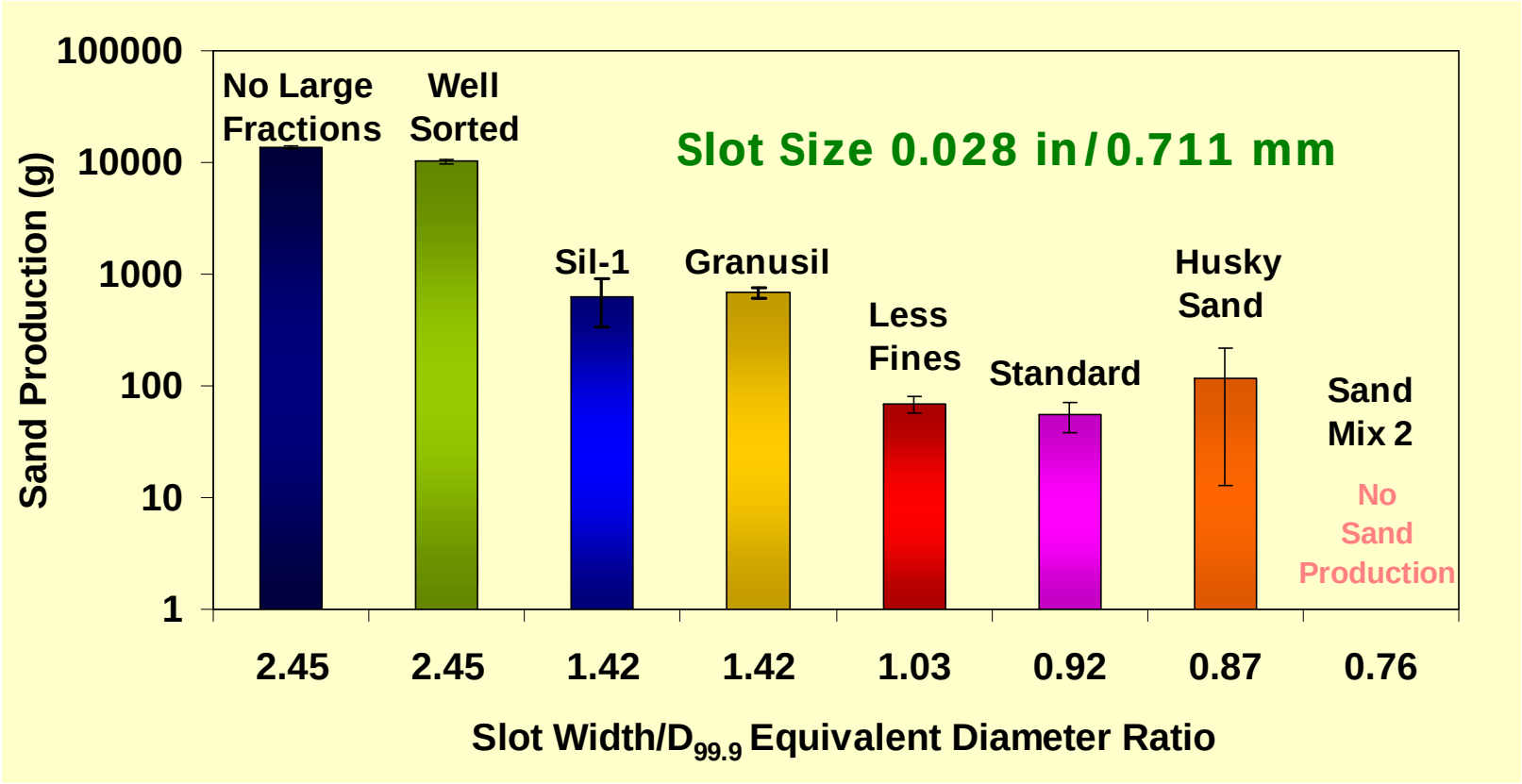
Sand Production Experiments

Experimental Apparatus



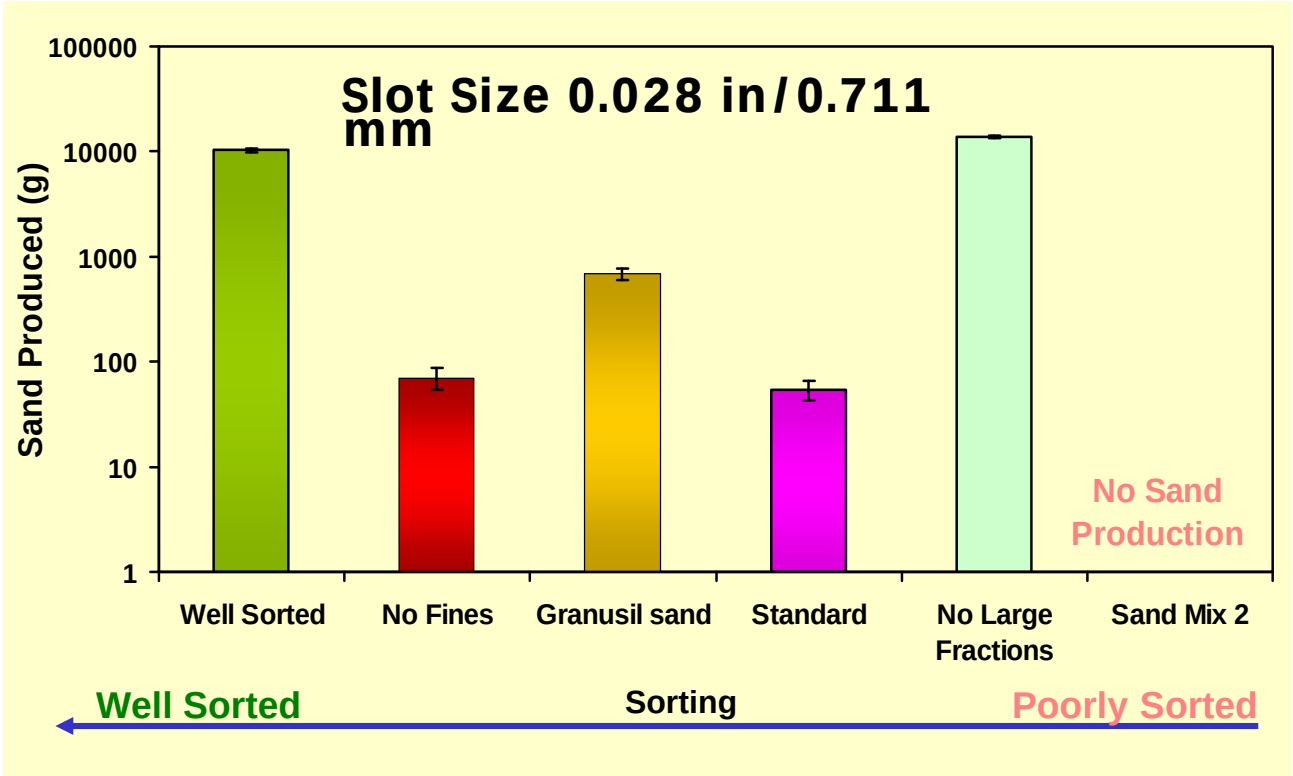
Experimental Program

Sand production through the slots can be controlled, depending more on Slot Width/Big Fractions Equivalent diameter ratios….



Experimental Program

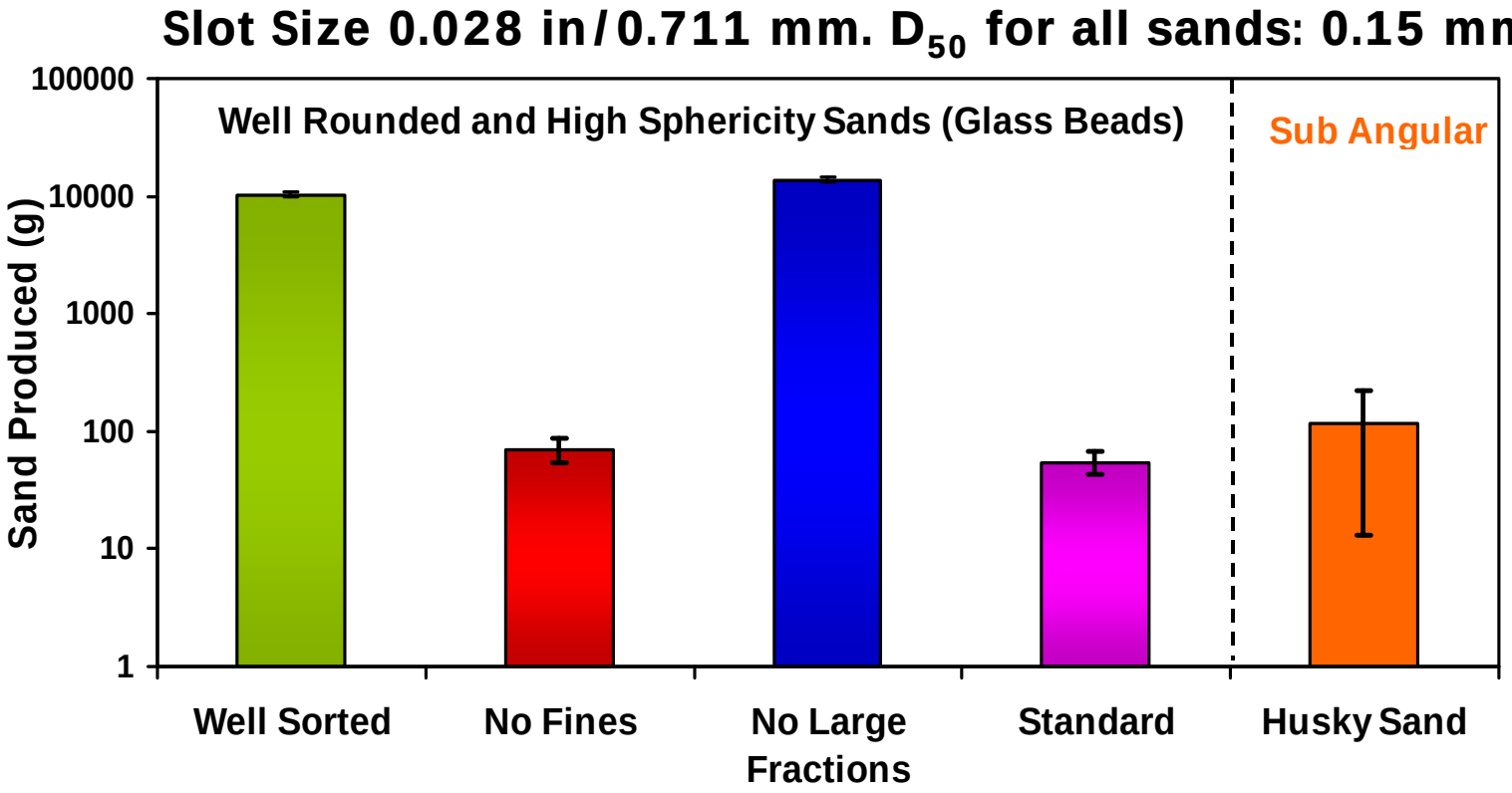
….than on the sand grain sorting…..



Sand	Well Sorted	Granusil	No fines	Standard	No Large Fraction	Mix 2
Uniformity Coefficient $\left(\frac{D_{60}}{D_{10}}\right)$	1.60	1.60	1.69	2.00	2.29	3.83

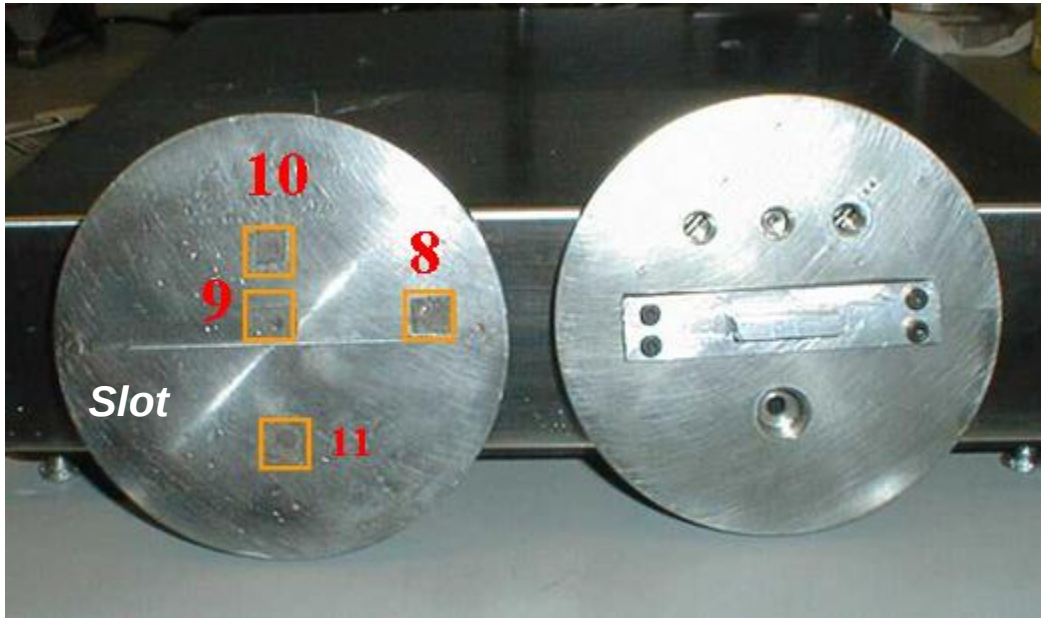
Experimental Program

….. the morphology of the grains or their average diameter (D_{50}).



Experimental Program

Experimental Conditions and Parameter Selection



Slot Size

$$SW_{min} = 1.38*D_{99.9}$$

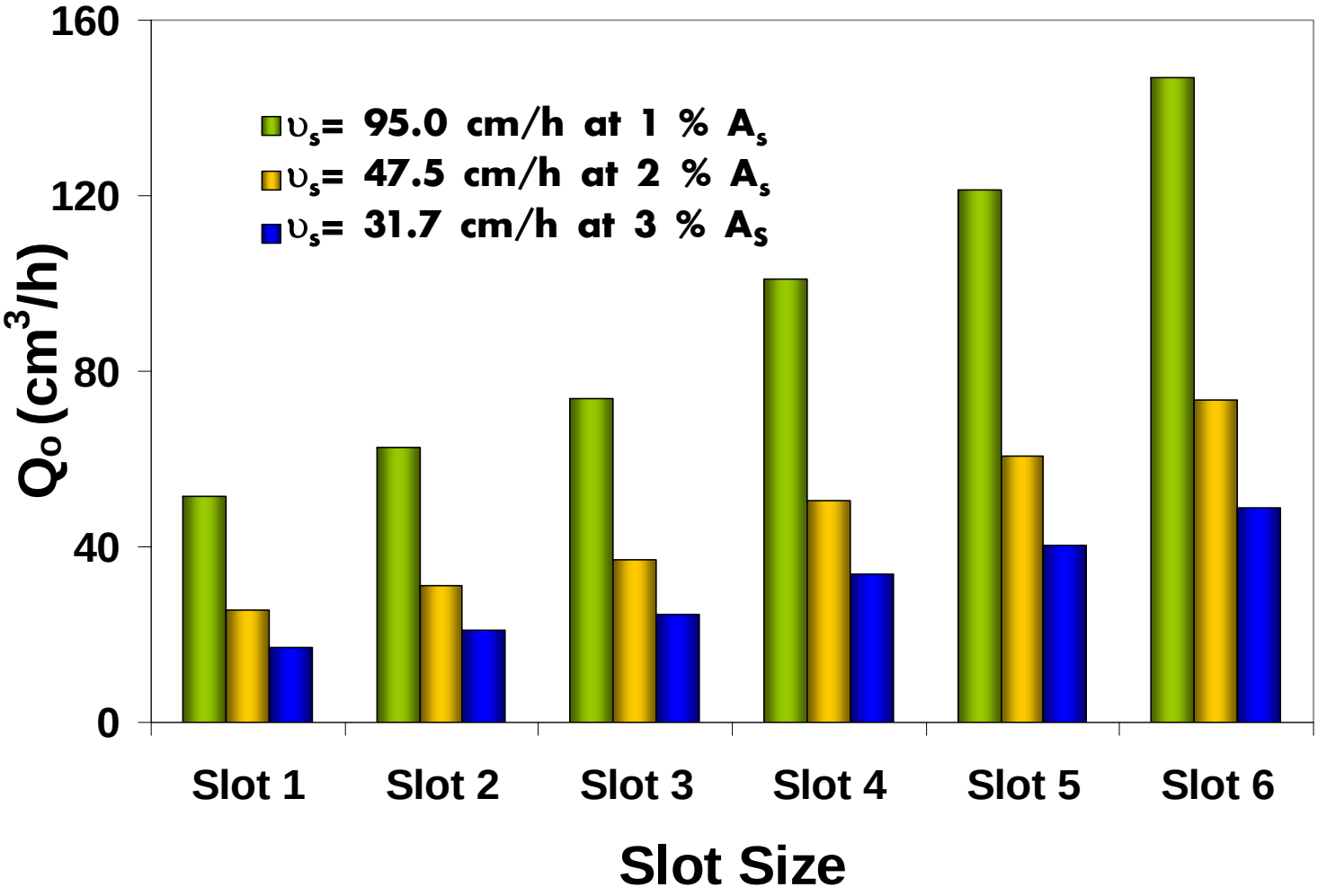
$$SW_{max} = 2.24*D_{99.9}$$

$$SW_{min} \leq SW_{csp} \leq SW_{max}$$

Conditions and Parameter Selection

Estimated Laboratory Flow Rate Q_o

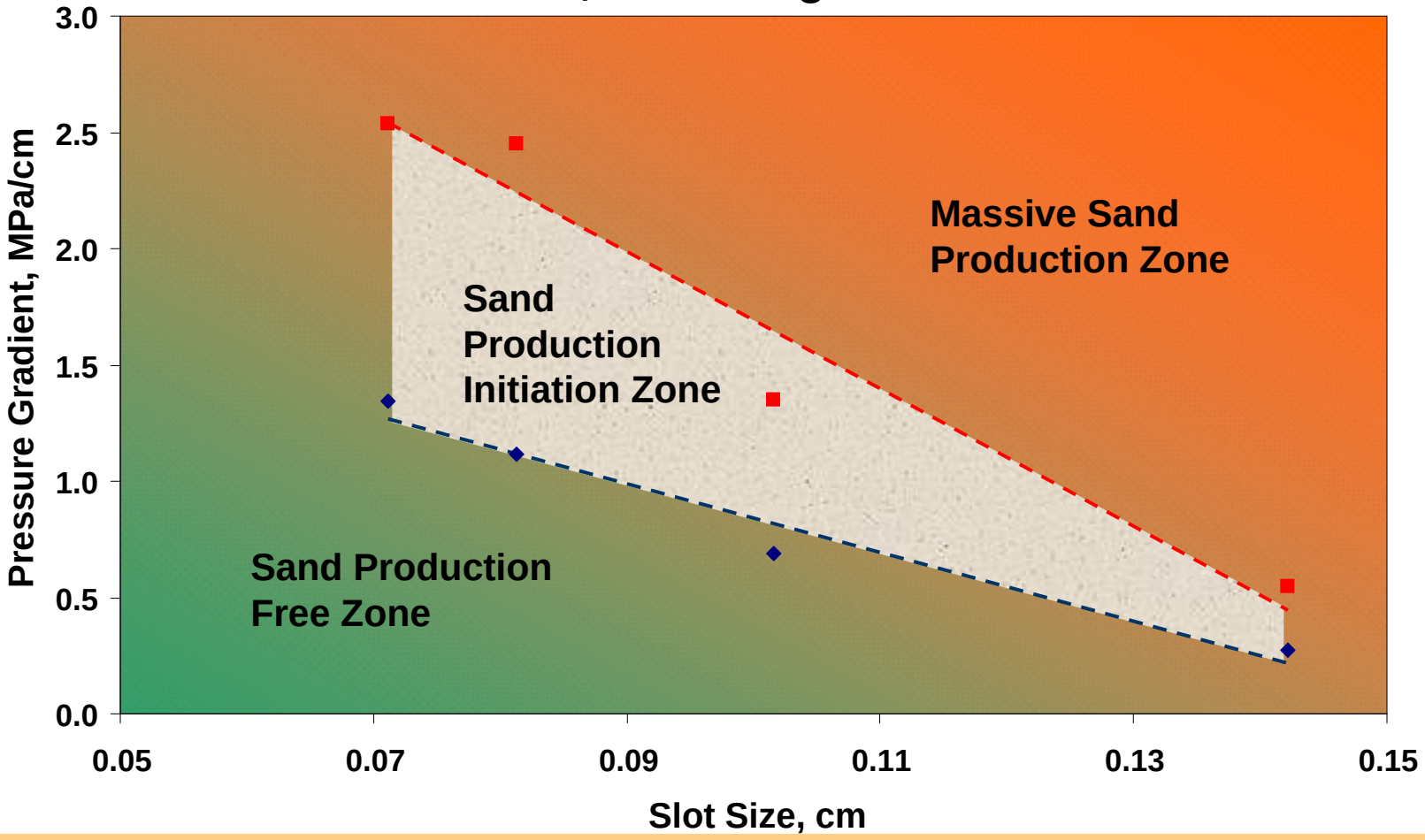
$\upsilon_{SE} = \upsilon_{SFC}$ → based on field Q_o of 100 m^3/d and HW length of 1000 m



Results

Effect of Slot size on Sand Production

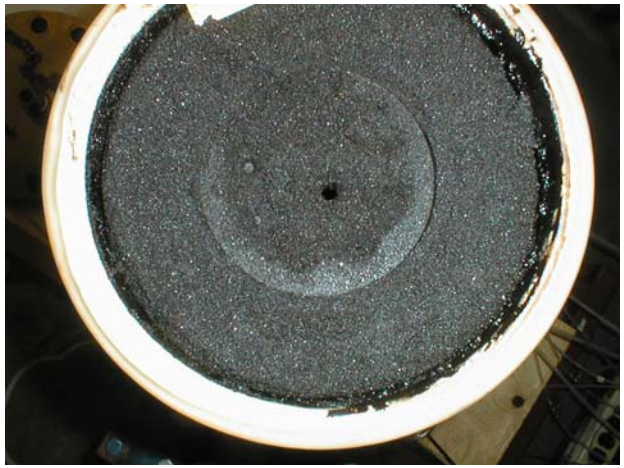
Operation-Completion Design Map for Controlled Sand Production
Well Sorted Sand, Confining Pressure: 500 kPa



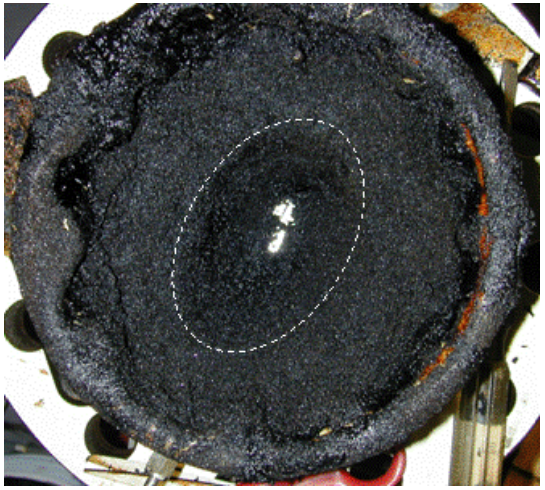
Sand Packs after Sand Production

Silica Well Sorted Sand

High permeability channel cast test 1



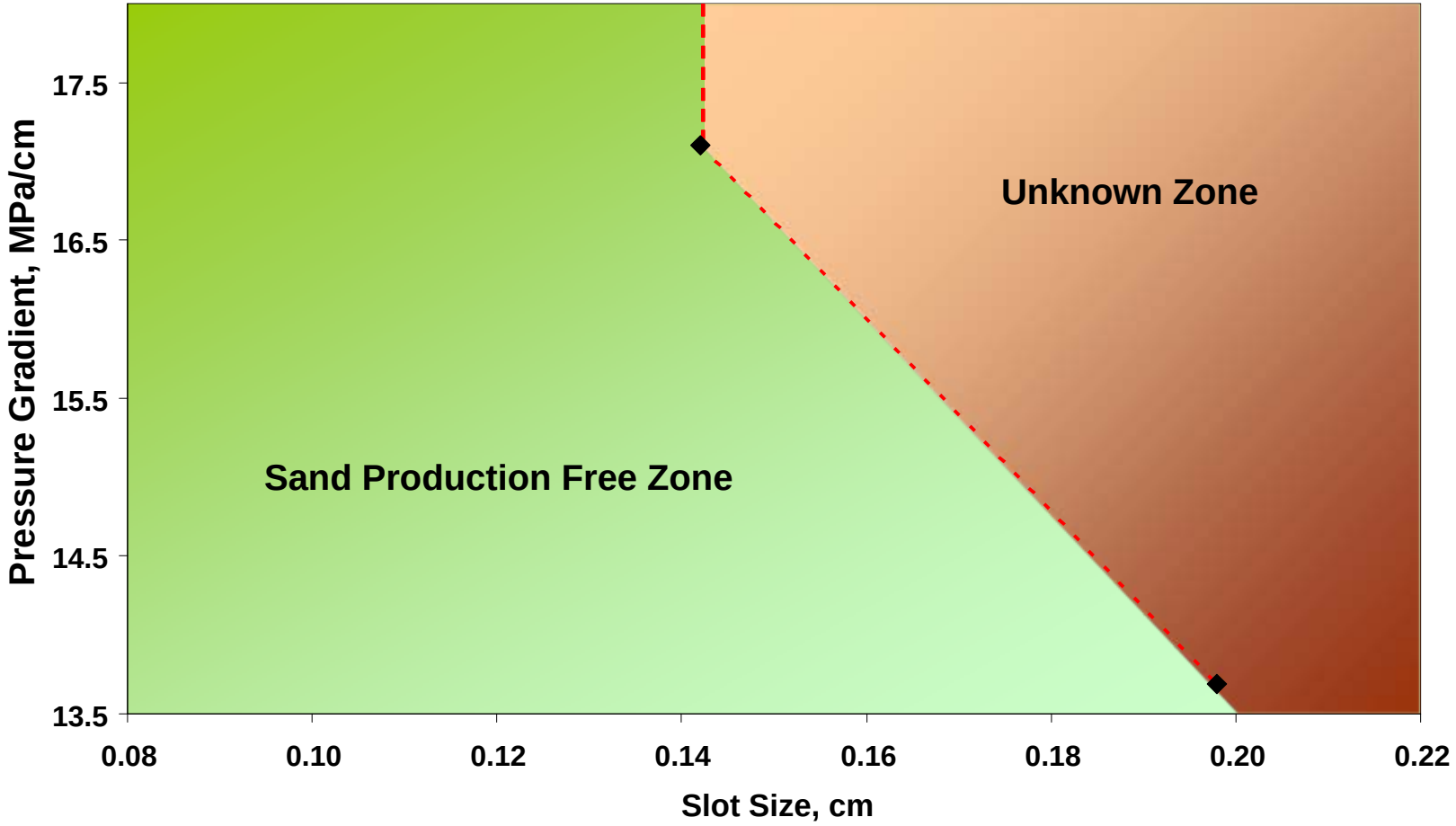
Tip of the high k channel test 2



Dilated zone shape test 4

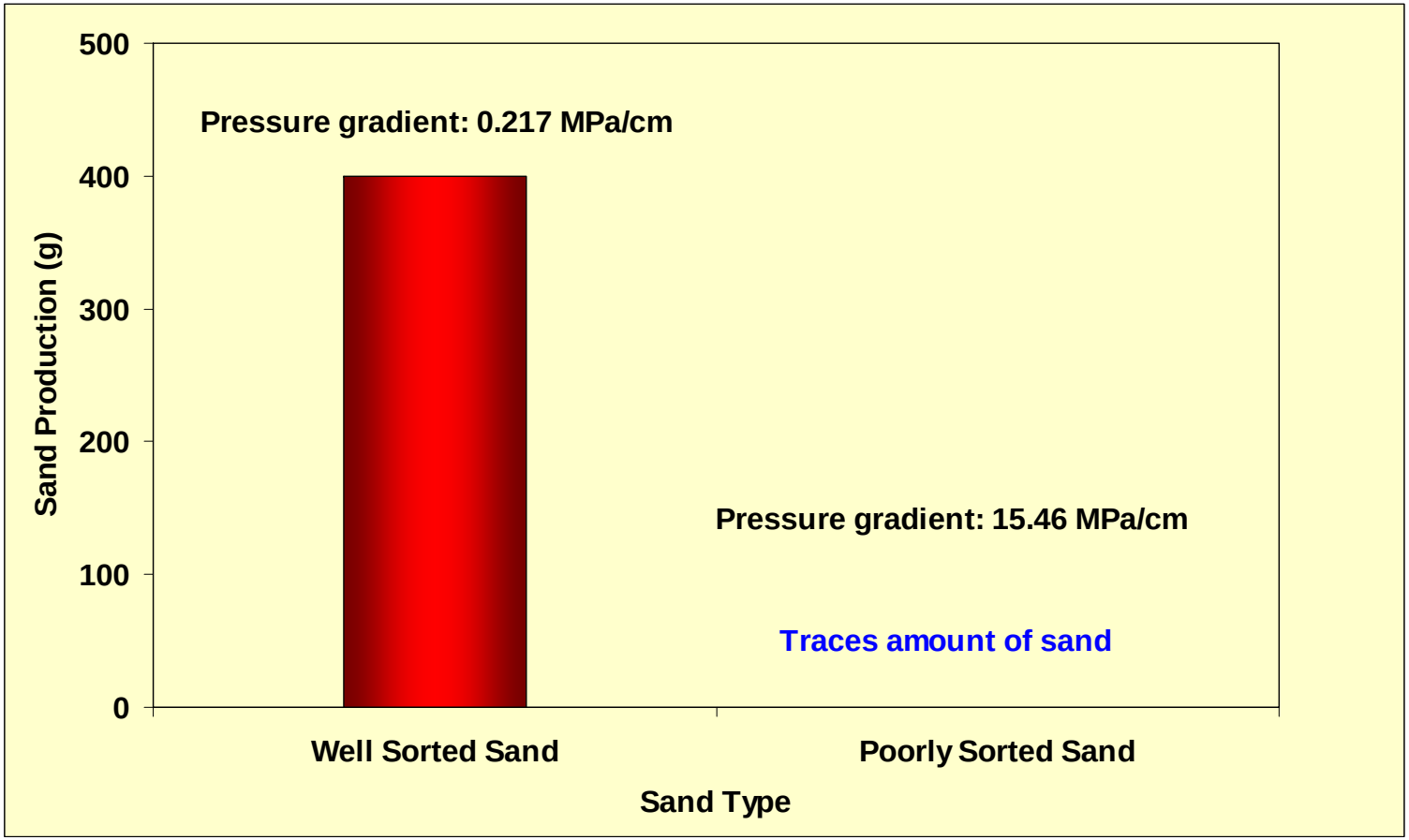
Effect of Slot size on Sand Production

Operation-Completion Design Map for Controlled Sand Production
Poorly Sorted Sand – Initial Confining Pressure 2,500 kPa



Effect of Grain Size on Sand Production

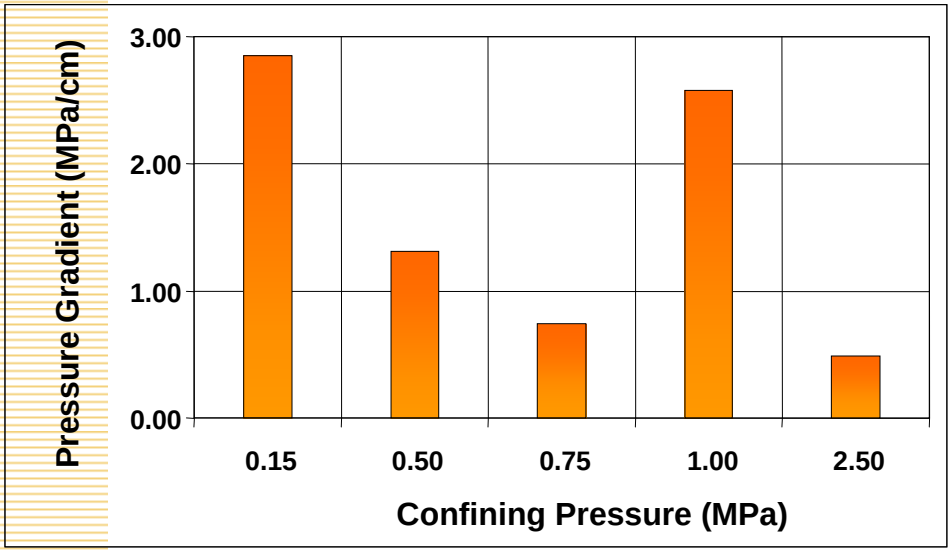
Slot Size: 0.056 in (0.142 cm). Confining Pressure: 2500 kPa

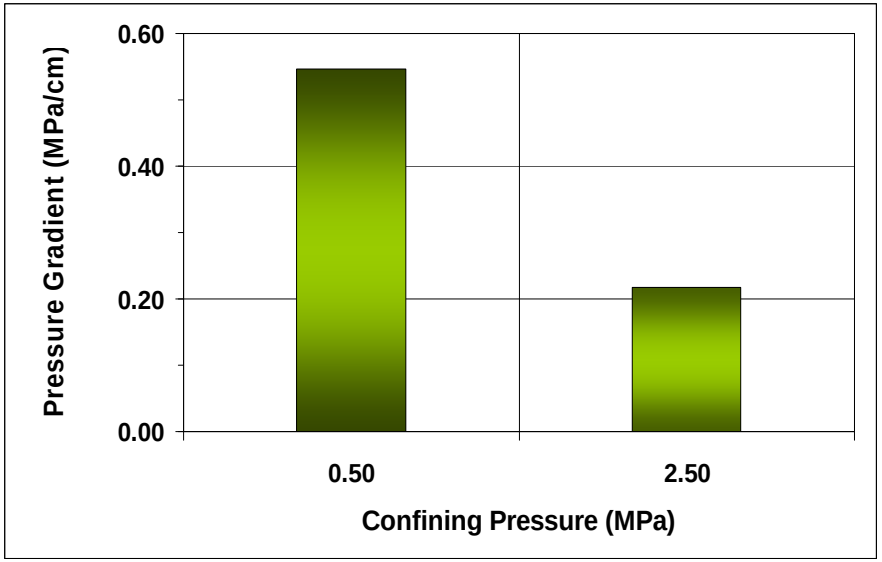


Results on Confining Stress

Effect of Confining Pressure on Sand Production Initiation

Well Sorted Sand

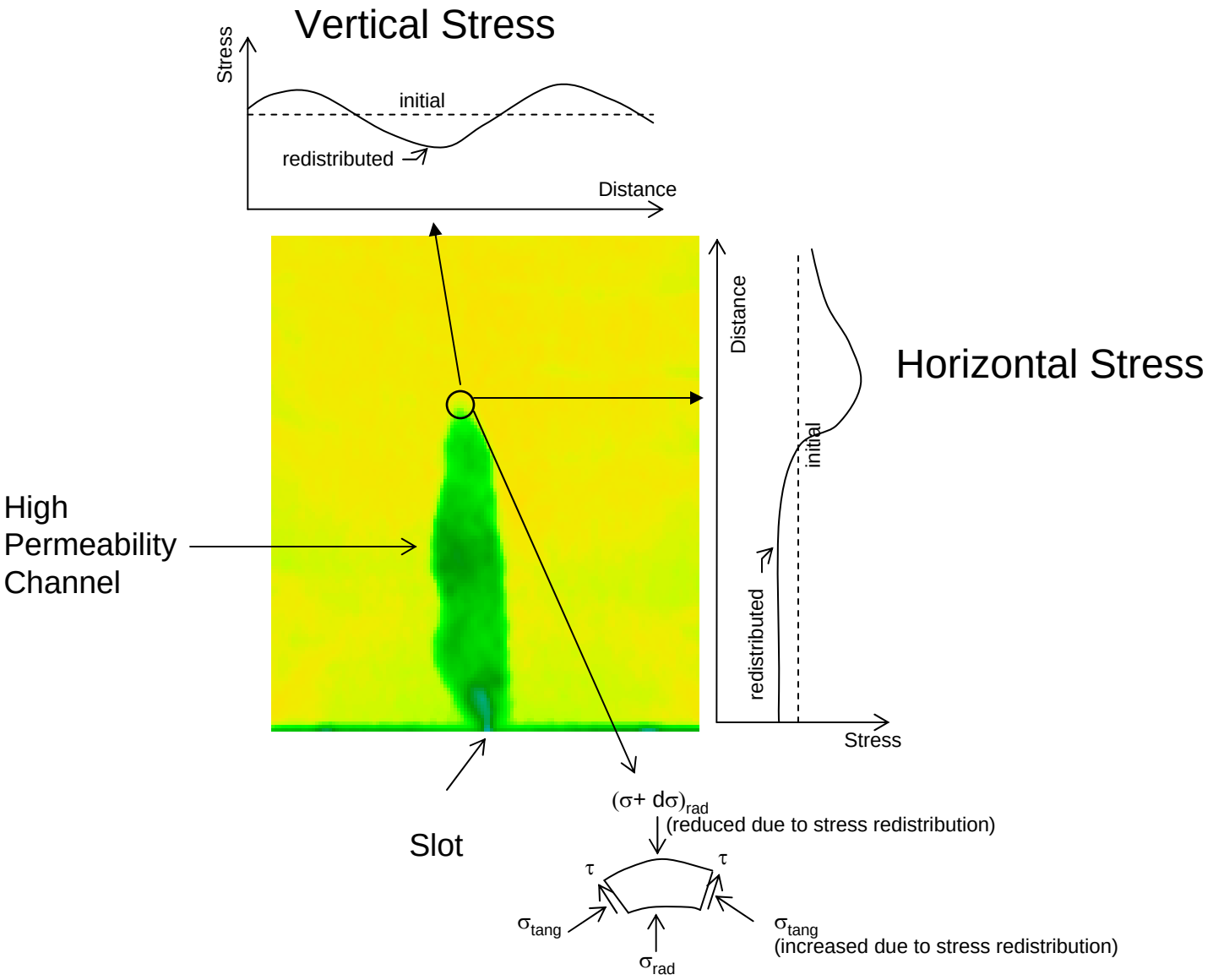




Slot size 0.041 in (1.041 mm)

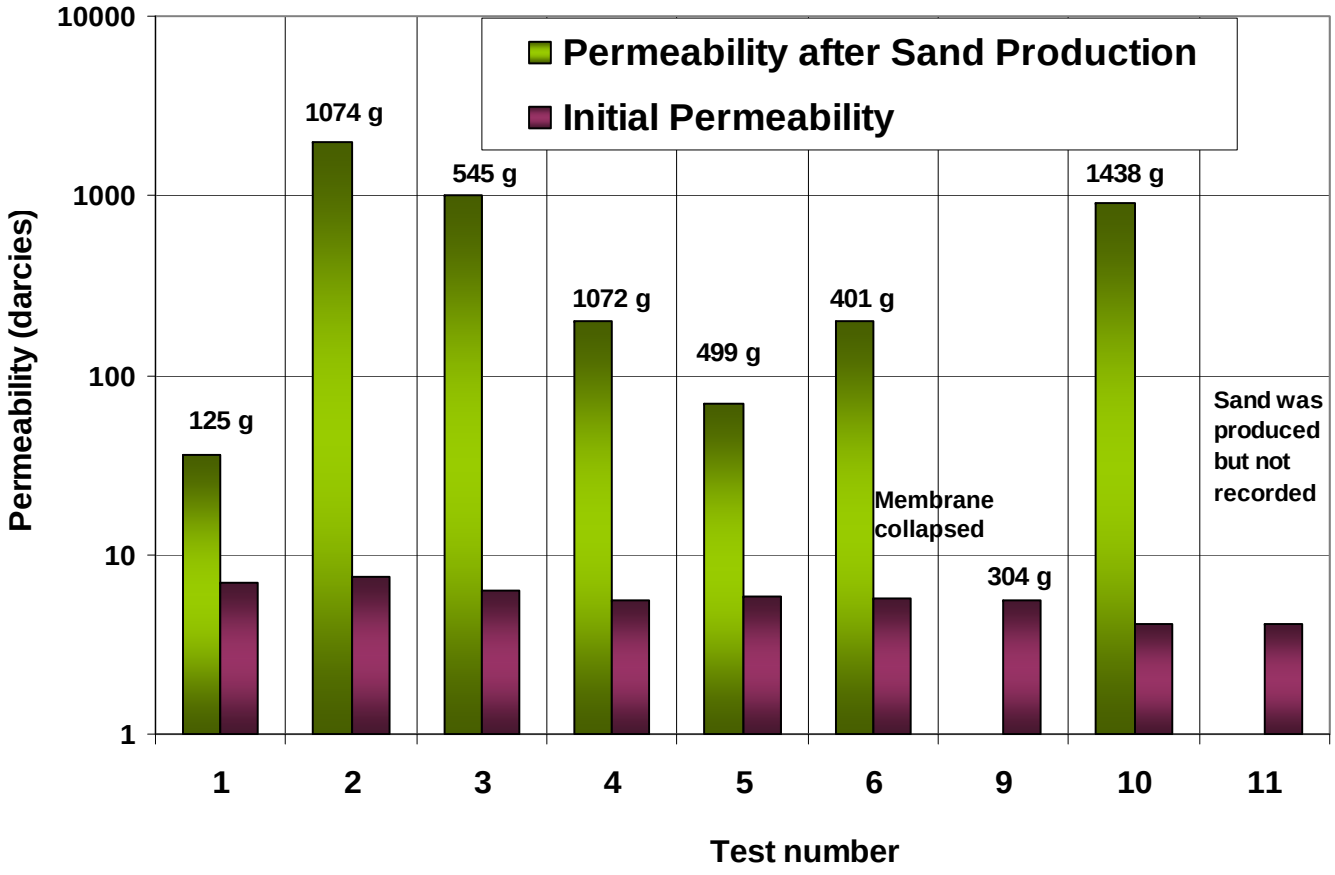
Slot size 0.056 in (1.422 mm)

Results on Confining Stress



Results on Properties of the Sand Pack

Effect of Sand Production on the Permeability



Conclusions

- Sand production behaviour is strongly influenced by a critical pressure gradient
- For the well sorted sand, three well-defined zones were identified that depended on the pressure gradient and the slot size
  - zone where sand production did not occur
  - zone where sand production was continuous and massive
  - zone where sand production could be initiated, but was intermittent

Conclusions

- Critical pressure gradient
  - much lower for a well sorted sand than for a poorly sorted sand
  - decreases with increasing slot size
  - decreases as confining stress increases
  - sufficiently large pressure gradient leads to persistent sand production and channel growth
- Slot size
  - correlated well with coarsest sand fraction ($D_{99.9}$) for well sorted sands
  - did not correlate consistently with coarsest sand fraction for poorly sorted sands

Acknowledgments

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