Static and Dynamic Particle Settling Effects of Super-Fine Particles: What's Important and Why

Terry Hemphill
High Impact Technology – Houston
Halliburton Energy Services / Baroid

Baroid

Why the Interest in Super-Fine Particles in Drilling Fluids?

- Reduced particle settling rates
- Reduced occurrence of barite sag
- Reduced circulating pressure drops
- Increased flexibility when drilling in narrow pore pressure / fracture gradient windows

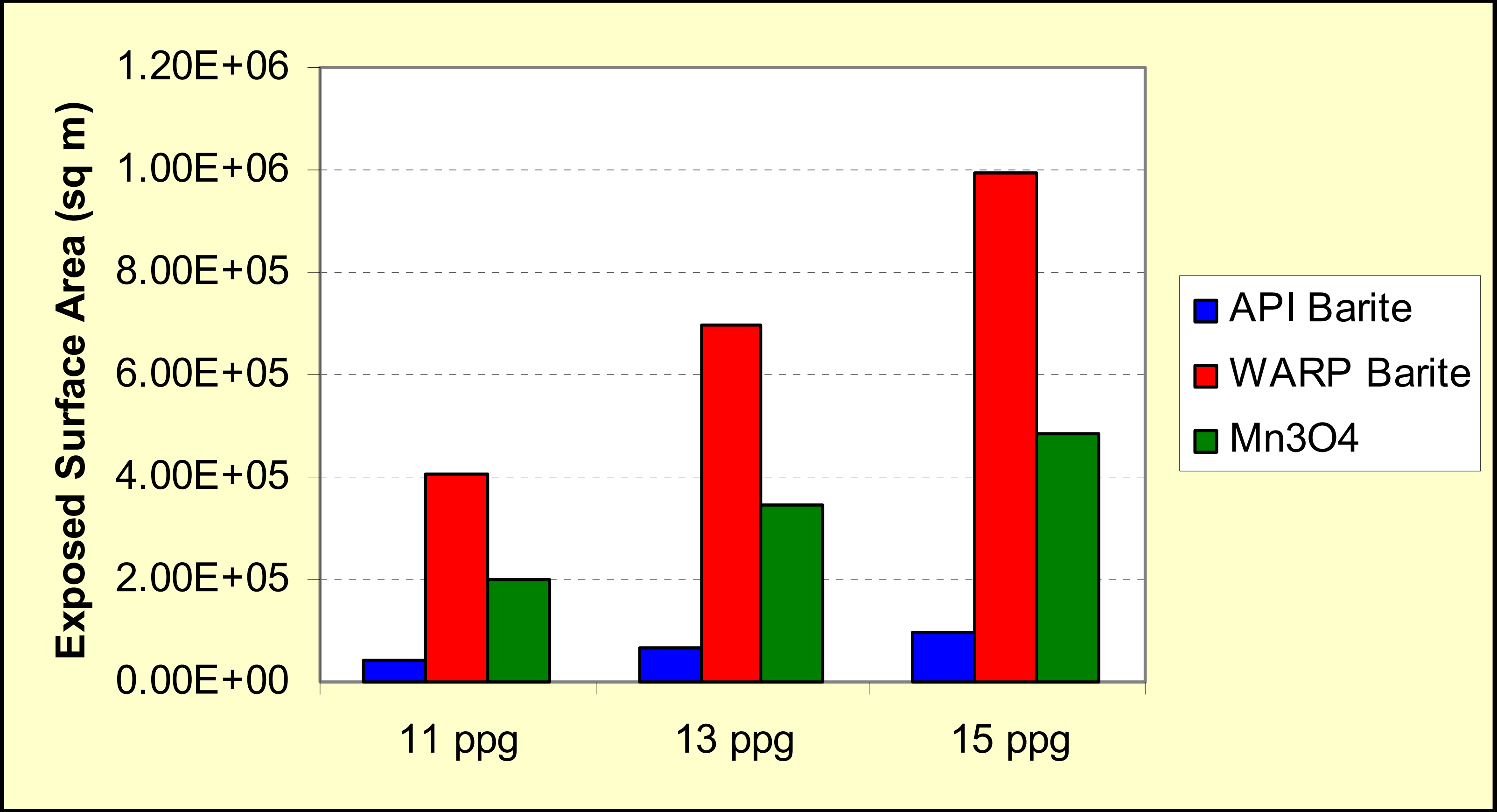
Average Weighting Material Particle Sizes

- API Barite – 15 microns
- WARP barite – 1.5 microns
- Manganese tetraoxide – 2 microns

Particle Statistics

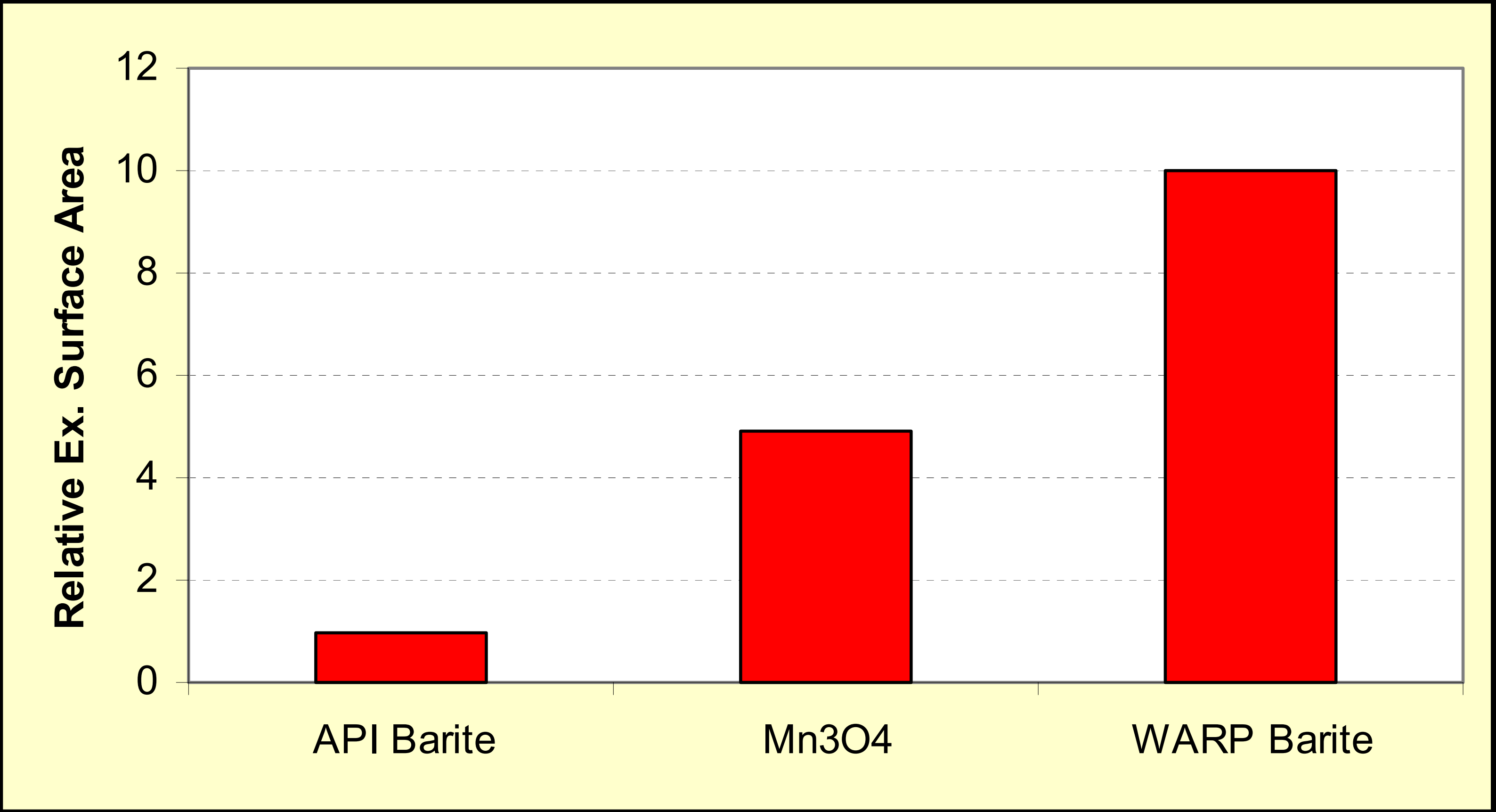
- Barite – 15 microns
  - Volume/particle: (m^3) 3.38 e-15
  - Surface area/particle (m^2): 1.35 e-9
- WARP barite – 1.5 microns
  - Volume/particle: (m^3) 3.38 e-18
  - Surface area/particle (m^2): 1.35 e-11
- Manganese tetraoxide – 2 microns
  - Volume/particle: (m^3) 4.19 e-18
  - Surface area/particle (m^2): 1.26 e-11

Exposed Surface Area of Weighting Materials in SBM / OBM



Baroid

Exposed Surface Area of Weighting Materials in OBM / SBM



Baroid

Particle Settling Rates – Key Factors

- Particle size and shape
- Particle density
- Density and viscosity of surrounding fluid
- Fluid velocity (dynamic cases)
- Particle concentration

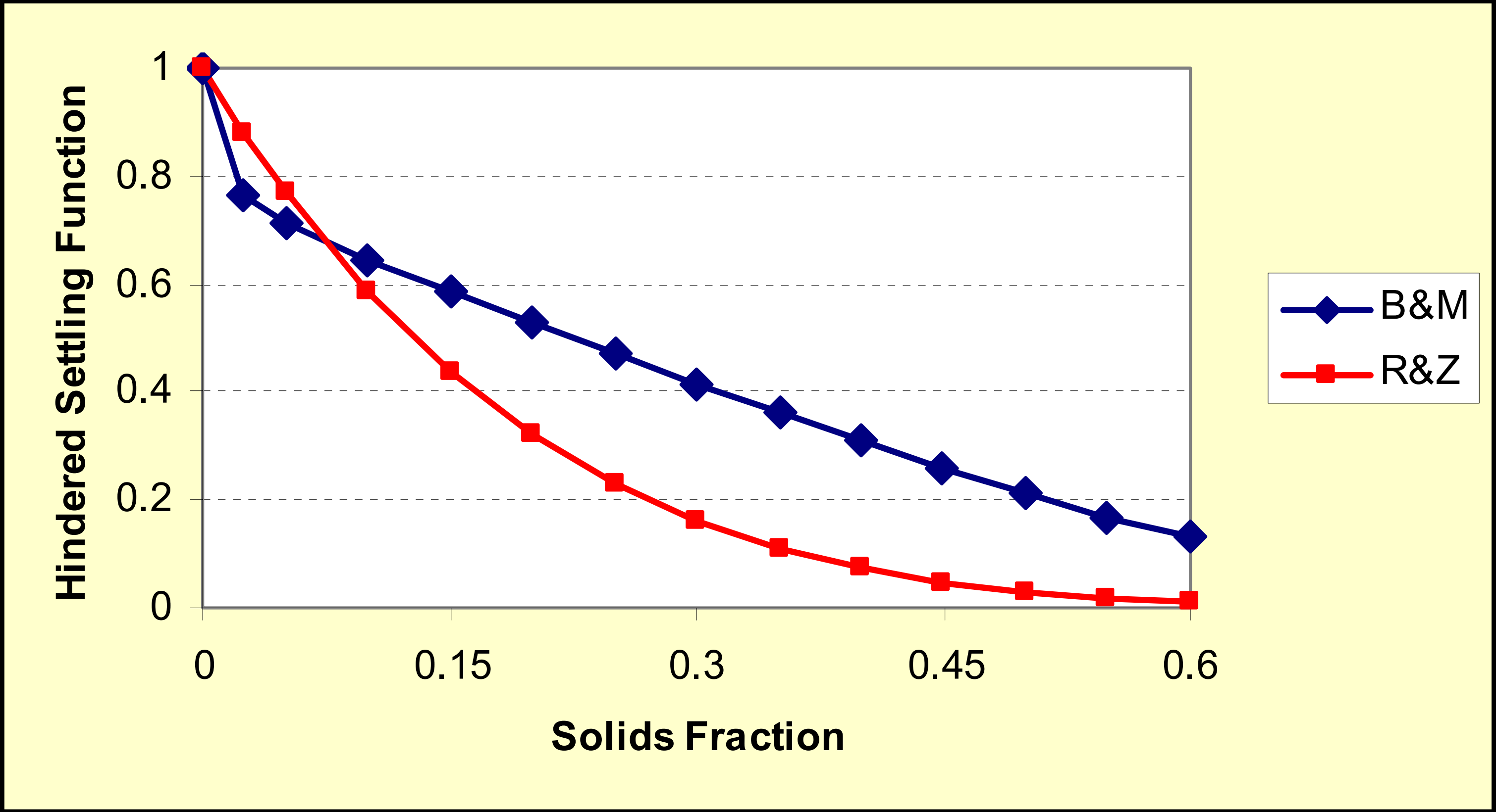
Particle Settling Rates Calculation Methods

- Single-particle settling usually assumed
- Static case
- API method: Chen (1994)
  - Settling shear rate
  - Quadratic equation, numerical solution
  - *SPE D&C*, December 1994
- Dynamic case usually not done, more complicated
- Hindered settling usually not considered

Importance of Hindered Settling

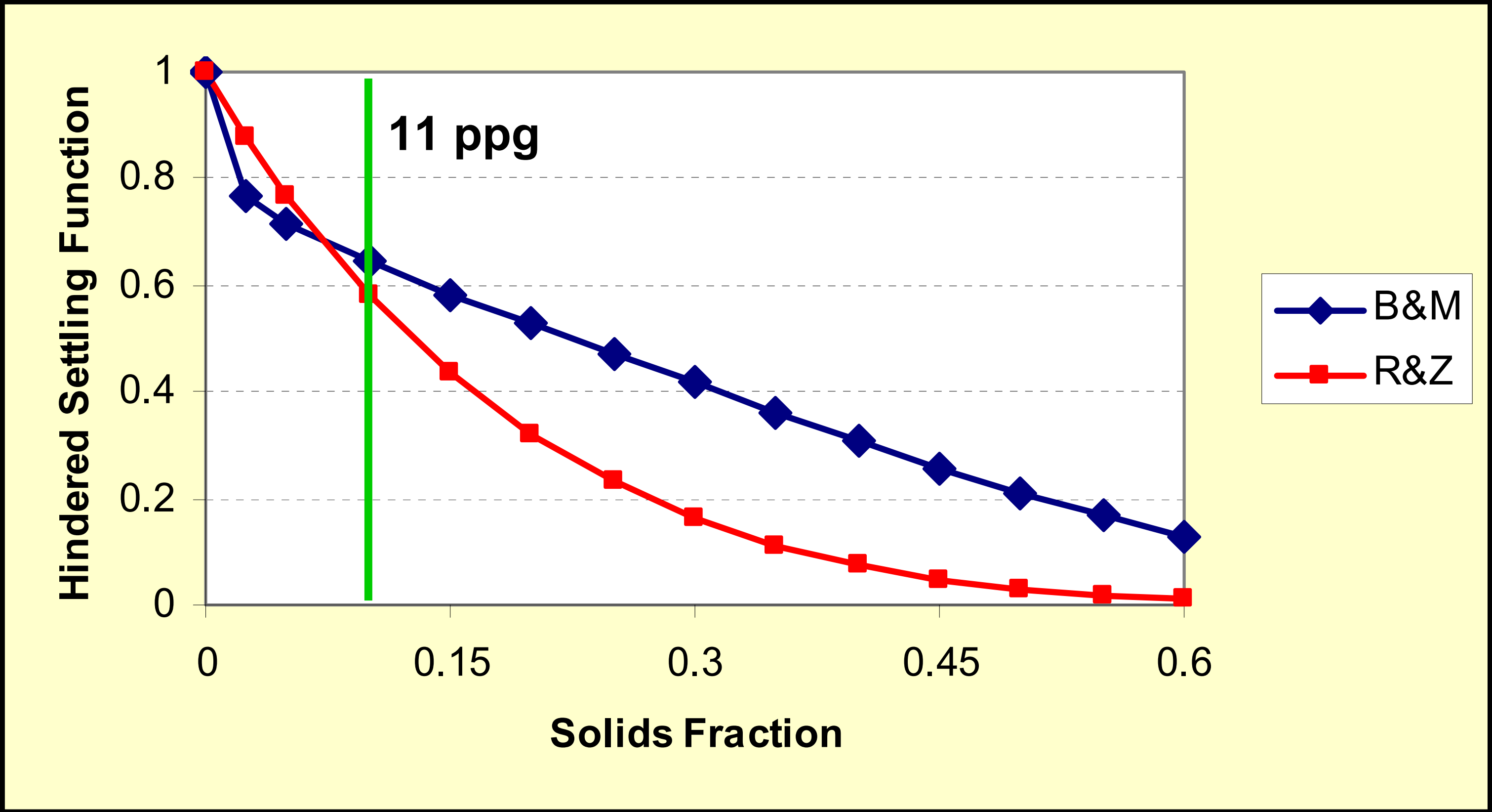
- Inter-particle collisions slow down settling rate
- Particle concentration in solution important
- At high enough concentration, particles become self-suspending
- Several models in literature
  - Barnea & Mizrahi (1973)
  - Richardson & Zaki (1954)
- Hindered PSV = PSV_{sp} * HSF

Hindered Settling of Particles Effect of Particle Concentration



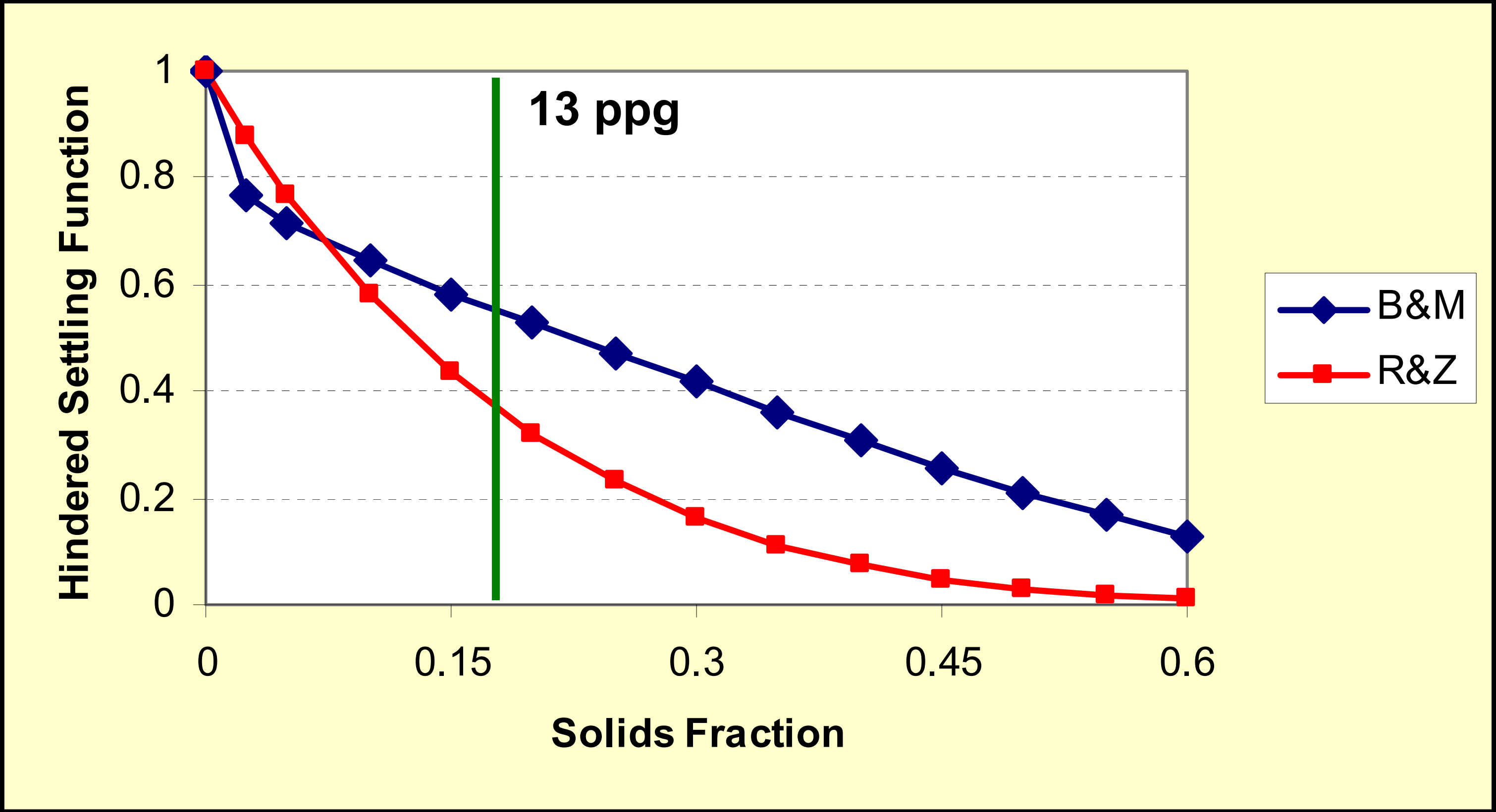
Baroid

Hindered Settling of Particles
Effect of Particle Concentration



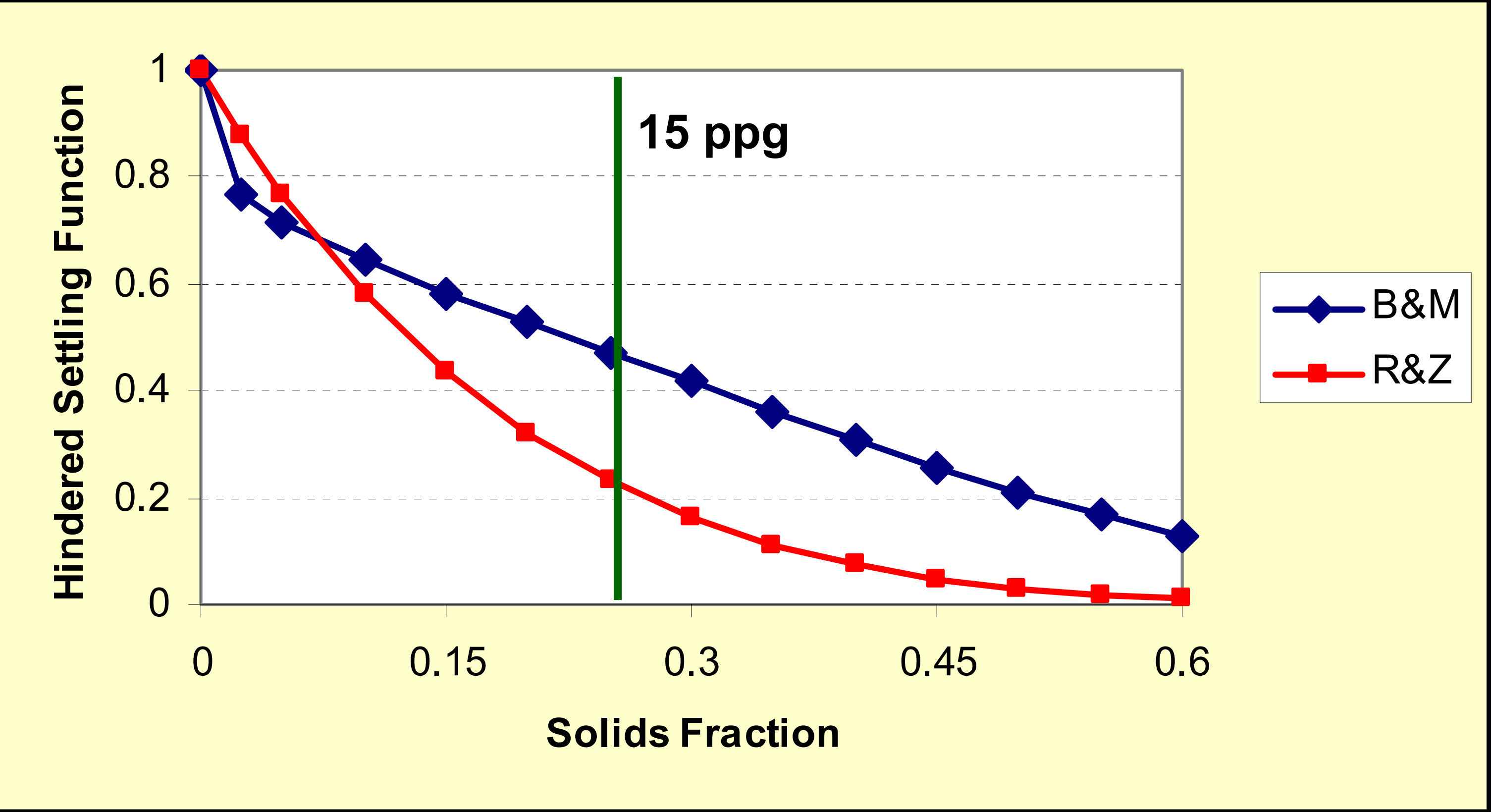
Baroid

Hindered Settling of Particles
Effect of Particle Concentration



Baroid

Hindered Settling of Particles Effect of Particle Concentration



Effect of Small Particle Systems on Hydraulics, ECD

- Elevated levels of plastic viscosity
  - K in Herschel-Bulkley rheological modeling
  - 0.5 – 0.75 lbf/100 sq ft sec^n (240 - 360 eq cP)
  - Provided by solids or polymers in WBM / SBM / OBM
- Lower yield stress (τ_0) values reported
- Lower static particle settling rates
- Dynamic settling rates affected by fluid velocity
- Lower ECD reported from limited field use
  - Small volume systems such as TTRD, CTD
  - Limited exposure to reactive clays, gumbo

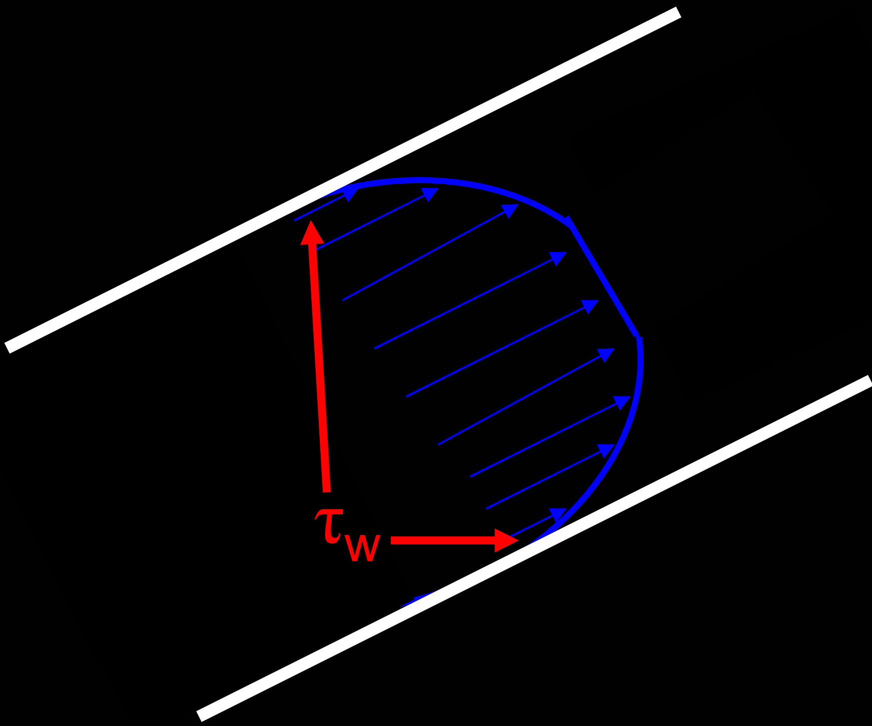
Effect of Small Particles on Weighting Material Sag

- Evaluate sag potential in terms of τ_{wall} values in circulating systems
  - Effect of eccentricity in annular calculations
  - Fluid rheological properties are not the only consideration
  - Relationship between τ_{wall} and low shear events

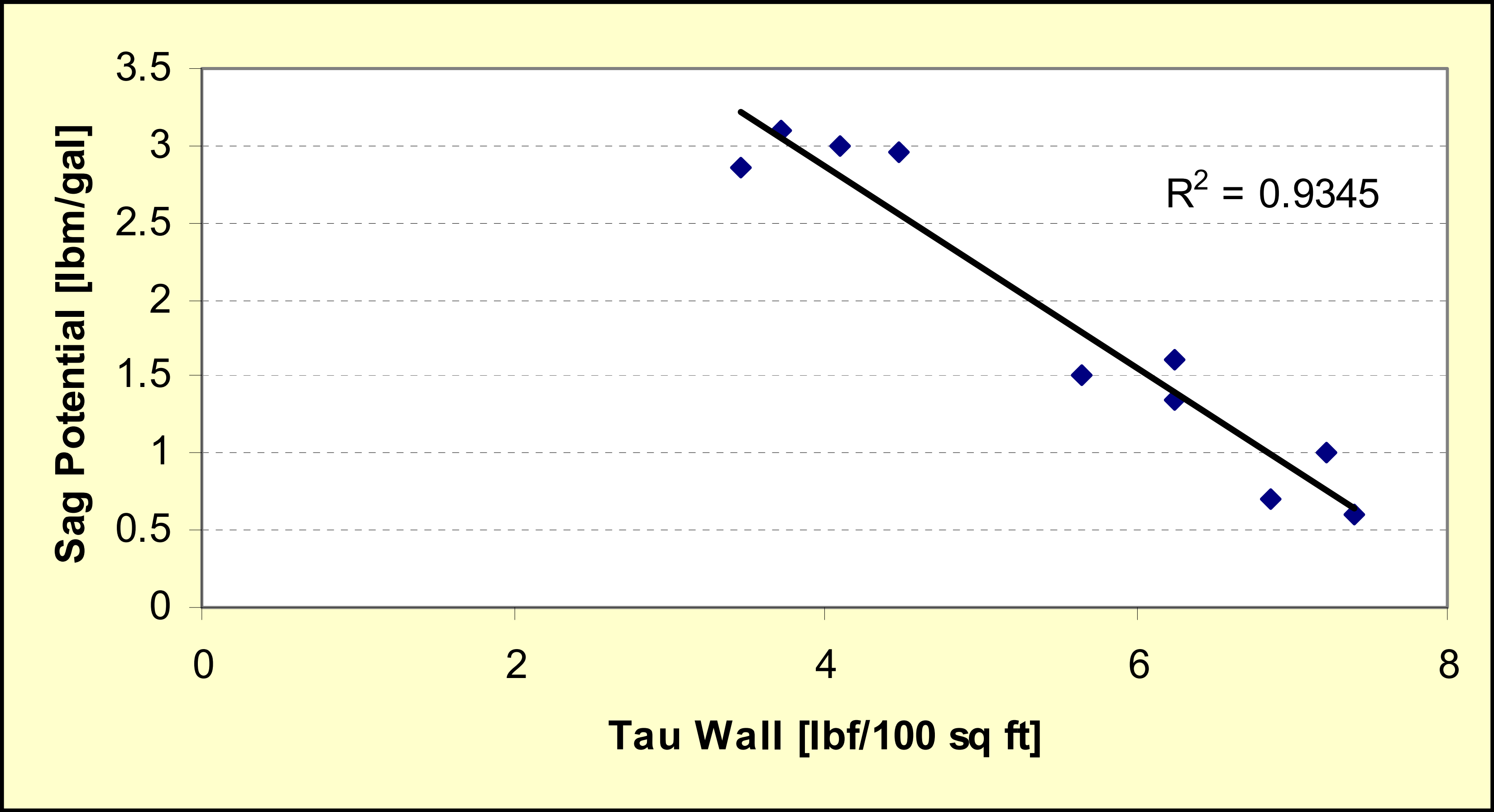
What Is Tau Wall?

- Tau $_{wall}$ is fluid shear stress at the wall
- In concentric annular geometry,

  $T_w = R * (dP/dL) / 2$
- In eccentric annular geometry, numerical methods needed to determine T_w



Tau Wall for Dynamic Systems and Sag Potential



Ref: AADE-04-DF-HO-20, April 2004; barite systems

Baroid

Potential Problems with Super-Fine Weighting Materials

- Control over fluid rheological properties
  - High surface area exposed
  - Contaminants
  - Reduced amount of free water / base oil for wetting
- Challenges for solids-separation equipment – weighting materials close to colloidals in size
- Settling out in very small cracks, corners
  - Plugging of equipment, connections, etc.

Potential Problems with Super-Fine Weighting Materials

- Charged surface area
  - wetting issues
  - Verified order of addition of products: extensive pre-testing needed (Mn_3O_4)
  - emulsifier consumption in SBM / OBM

- Very good sealants when dehydrated

Summary

- Tradeoffs with use of super-fine particles:
  - low particle settling rates vs large exposed surface area
  - Rheological instability with contamination – little free water (or free base fluid)
- Potential wetting problems qnd high emulsifier concentrations needed for SBM / OBM
- Limited use in highly reactive formations
- Barite sag potential can be managed without use of super-fines

The End

Any Questions?