Al-Ayen University
Petroleum Engineering College

Drilling Engineering 2
Fourth year

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Lecture -1

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Functions of a Drilling Fluid

1- Hole Cleaning
2- Pressure Control
3- Suspend Solids
4- Minimize Formation Damage
5- Isolate Fluids from Formation
6- Cooling and Lubrication
7- Power Downhole Tools
8- Environment
9- Maximum Hole Information
10- Corrosion
11- Support Part of DS
12- Cost

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Hole cleaning:

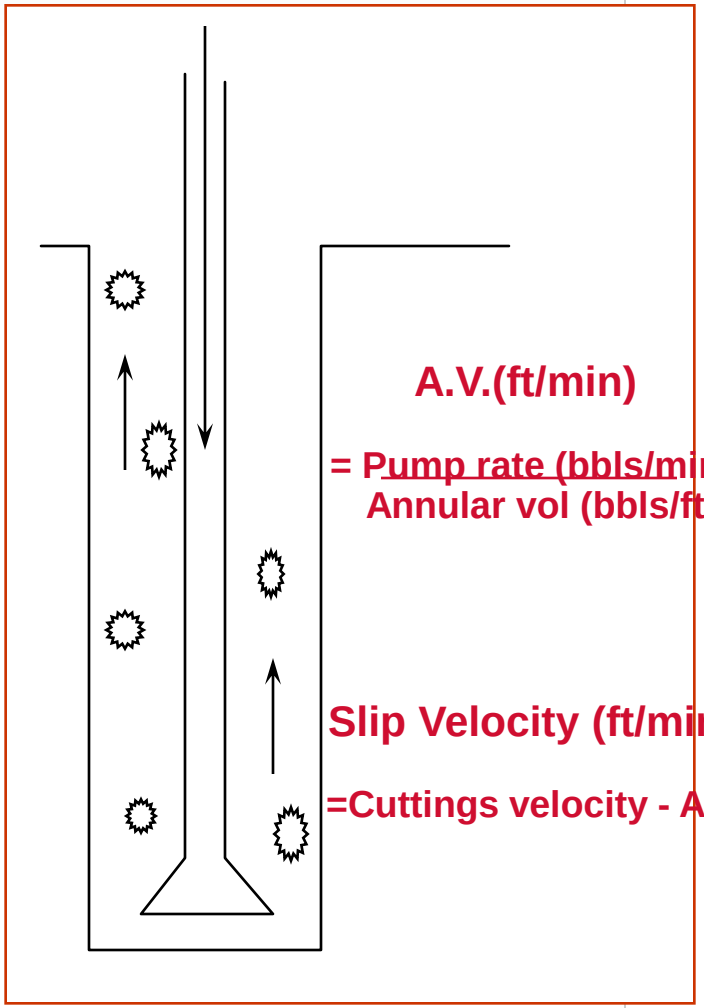
Remove Cuttings From the Well Bore

The most important parameter is the Annular Velocity (A.V.)

- Where possible the annular velocity should be 100 ft/min, higher in deviated holes.
- In large hole sections the A.V. can be as low as 20 ft/min.

If the A.V. is insufficient to clean the hole the viscosity must be increased

Cuttings removal is harder in deviated and horizontal holes as the vertical component of the mud is reduced.



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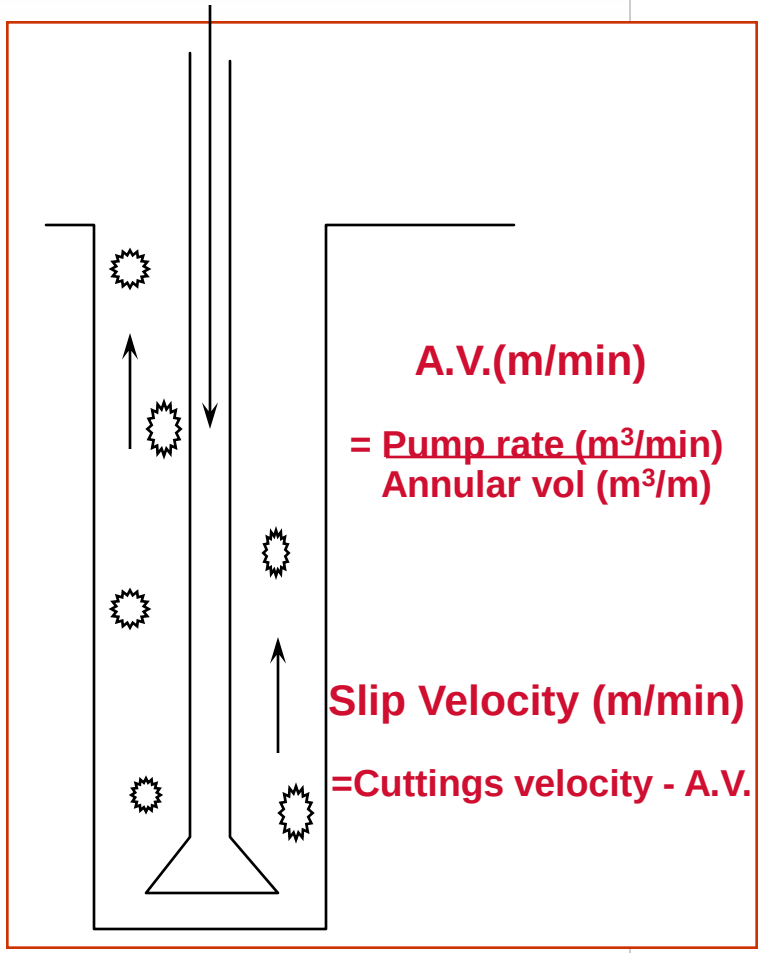
Remove Cuttings From the Well Bore

Cutting removal is a function of :

- **Cuttings size, shape and density**
- **ROP, drillstring rotation**
- **Viscosity and density of the drilling fluid**
- **For top hole high viscosities and sometimes high weight must be used.**



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Pressure Control

Balancing Sub-Surface Pressures

The pore pressure depends on:

- ✓ **The density of the overlying rock**
- ✓ **The pressure of the interstitial fluid**
- ✓ **Whether the rock is self supporting or is supported by the fluid.**
- ✓ **Surface terrain**
- ✓ **Tectonic activity**

If the fluid hydrostatic pressure does not balance the pore pressure the following may occur:

- ✓ **Influxes of formation fluid into the wellbore**
- ✓ **Lost circulation**
- ✓ **Hole Instability**
- ✓ **Stuck pipe**

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Balancing Sub-Surface Pressures

The pressure balancing the formation pressure is composed from the hydrostatic pressure under static conditions:

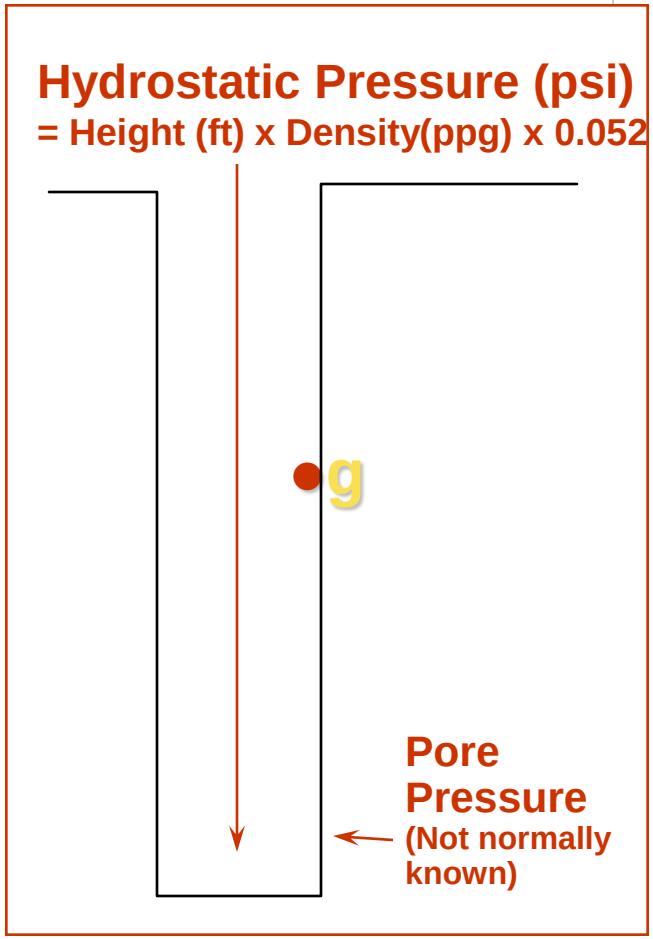
P = Depth (ft) x Density (ppg) x 0.052

P = Depth (m) x Density (sg) x 0.0981

Under circulating conditions the effective pressure is increased by the pumping pressure. This forms the Equivalent Circulating density (ECD):

$$ECD = Density\ (ppg) + \frac{Ann\ Press\ Loss}{Depth \times 0.052}$$

$$ECD = Density\ (sg) + \frac{Ann\ Press\ Loss}{Depth \times 0.0981}$$



Suspension of Solids

- **Drill solids from the well, cuttings, must be removed as quick as possible at surface**

- **Several properties and parameters influence cuttings removal rates :**

  - ✓ Viscosity
  - ✓ Gel strength
  - ✓ velocity

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Suspension of Solids

- A gel structure is required to suspend the cuttings under zero shear conditions:
  - ✓ The gel structure is caused by time dependant attractive forces which develop in the fluid.
  - ✓ The longer the fluid is static the stronger these forces become
  - ✓ The gel structure should be easily broken
  - ✓ The gel properties are especially important for deviated and horizontal wells as the distance solids have to settle is very small

Release Solids at Surface

- **Whenever the pumps are switched off solids will start to settle. This can result in:**
  - ✓ **Bridging off of the wellbore**
  - ✓ **Stuck pipe**
  - ✓ **Hole fill**
  - ✓ **Loss of Hydrostatic**
- **Solids equipment at surface :**
  - ✓ **Number of shakers**
  - ✓ **Screen size and type**
  - ✓ **Desilters and desanders**
  - ✓ **Centrifuges**

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Minimize Formation Damage

- **Damage to the formation while drilling to the reservoir:**
  - ✓ Formation swelling (Normally clay and Salt formations)
  - ✓ Washouts (Clay and Salt formations or any unconsolidated formation). This can result in:
    - ✓ Difficult directional control
    - ✓ Poor zonal isolation
    - ✓ Excess mud and cement costs
    - ✓ Poor Hole Cleaning
    - ✓ Stuck Pipe
    - ✓ Difficult fishing jobs

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Minimize Formation Damage

- **Damage to the reservoir will result in loss of production or the need for remedial treatment.**

This can result from:

- ✓Solids blocking reservoir pores
- ✓Emulsion droplets blocking reservoir pores
- ✓Swelling clays
- ✓Ions from the formation and drilling fluid forming insoluble salts

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Damage by Drilling Muds

Mud damage can occur by:

- ✓ Physical reduction of pore / pore throat size
- ✓ Relative permeability reduction

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Damage by Pore / Pore Throat Size Reduction

- ✓ Mud solids invasion
- ✓ Formation fines migration
- ✓ Clay swelling
- ✓ Adsorption / precipitation of mud polymers
- ✓ Reaction and precipitation (scale)
- ✓ ***Wax formation (paraffin, asphaltene)***
- ✓ ***Sludge formation (e.g. by reaction of crude & mud acid)***
- ✓ ***Stress-induced permeability change***
- ✓ ***Perforation plugging***

Bold type denotes mud-induced damage mechanisms

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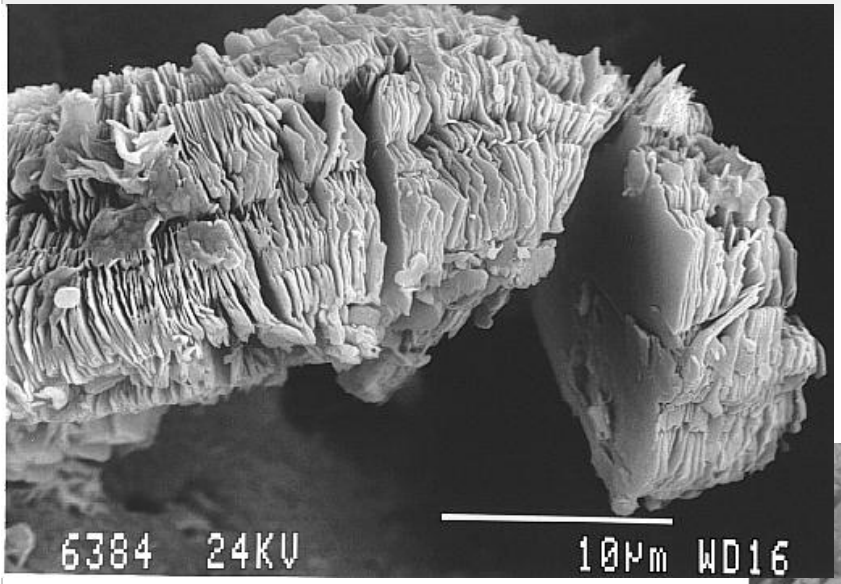
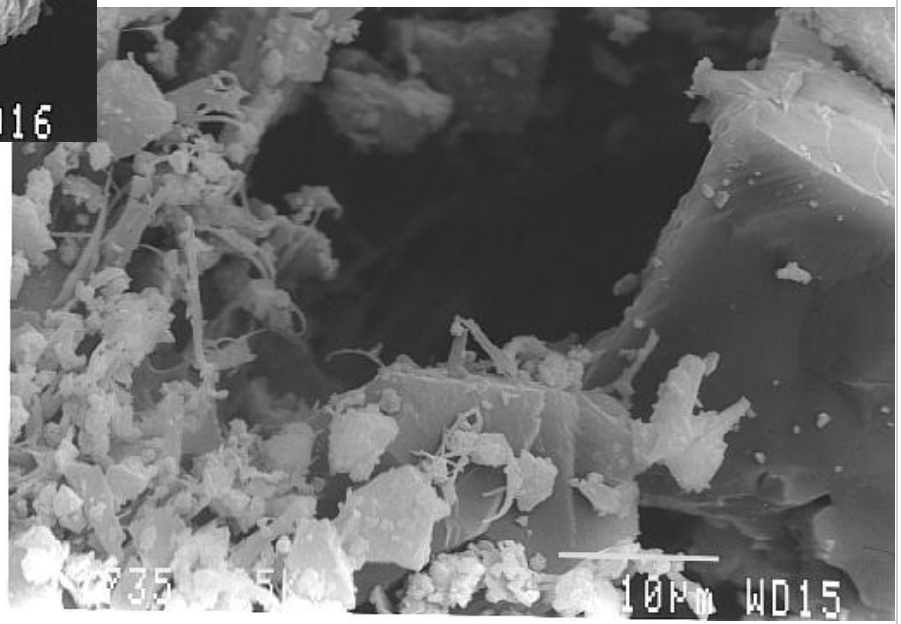
Formation Fines Migration



Conglomeration of loose material around pore throat

Kaolinite stack almost completely disaggregated



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Damage Due to Relative Permeability Reduction

- ✓ Wettability change
- ✓ Emulsion formation
- ✓ Fluid saturation change/fluid blocking
- ✓ *Water coning*
- ✓ *Gas breakout*
- ✓ *Condensate banking*

Bold type denotes mud induced damage mechanisms

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Depth of Invasion

- Mud composition & reservoir characteristics influence the *degree* of damage
- *Depth* of damage is influenced by
  - ✓Mud formulation
  - ✓Time in open hole
  - ✓Mud overbalance

Depth of damage is often less than the total depth of invasion due to depletion of damaging species

Isolate the Fluid From the Formation

- **The differential pressure forces fluid into the wellbore, resulting in whole mud or filtrate entering the formation. Either, or both, of these is undesirable because:**
  - ✓The loss of whole mud into the wellbore is expensive and damaging
  - ✓The loss of filtrate into the wellbore may cause formation damage

Isolate the Fluid From the Formation

- **The flow of fluid is affected by the formation of a filter cake. The filter cake reduces the flow of fluid into the formation.**

Special additives are added to improve the cake quality:

Bridging material

Plate like material

Plugging material

The filter cake should be thin with a low permeability

✓ This avoids reducing the effective hole diameter

✓ It also reduces the chance of differential sticking

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Cooling and Lubrication

- **The drilling fluid removes heat from the bit which is then dispersed at the surface**
  - ✓ Fluid formulations are not changed to improve this function
  - ✓ Very occasionally the temperature of the fluid exceeds the flash point. In this case it is necessary to improve surface cooling
- **Extra lubrication may be required between the drill string and the casing or wellbore, especially in directional wells**
  - ✓ Liquid additives are used, or Oil based mud
  - ✓ Solid additives are sometimes used such as glass beads, plastic beads, graphite or nut plug
  - ✓ Drill pipe rubbers are sometimes added to reduce wear between the casing and drill pipe

Power Downhole Tools / Transfer information

- **Power Downhole motors**

  ✓ Turbines to turn the bit or power MWD / LWD equipment

Transfer information from measurement equipment to the surface

✓ **This is done with a pressure pulse**

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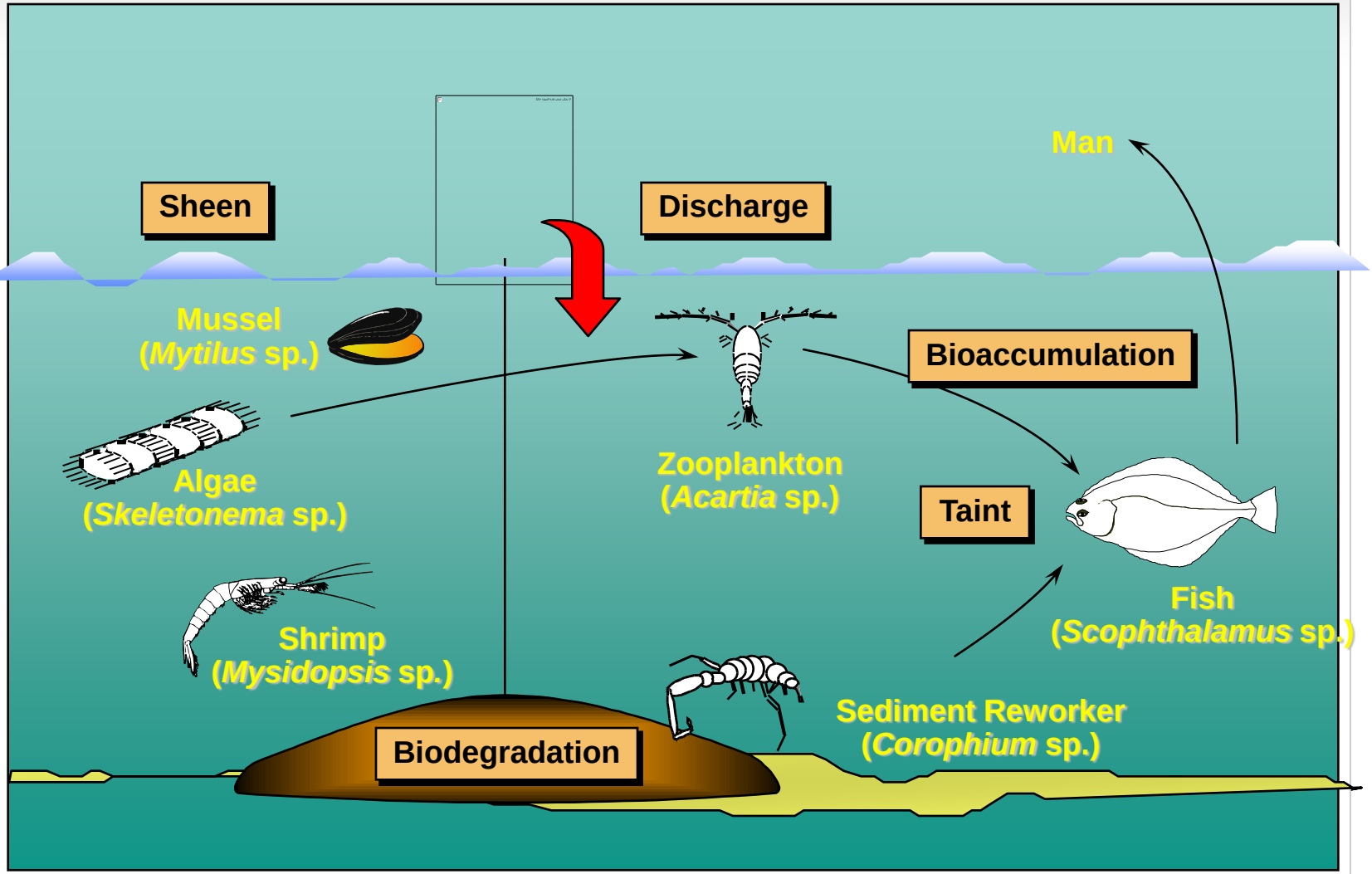
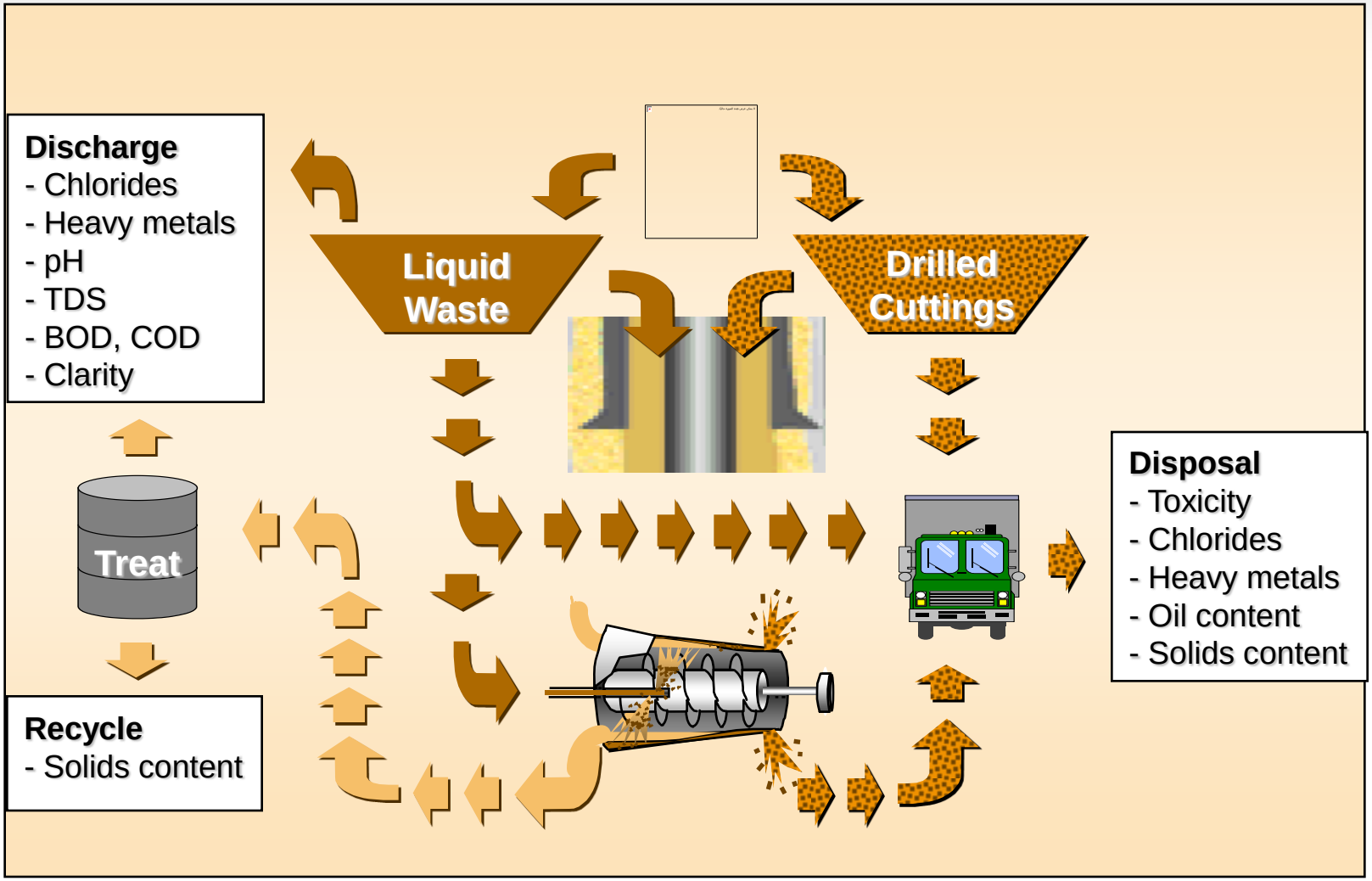
Environmental Impact - Offshore



Environmental Impact - Land



Secure Maximum Hole Information

- **The operator will always require the following information:**

  Rock type being drilled

  ✓ **The cuttings should not dissolve or disintegrate**

- Analyses of gases

  ✓ **The gases should separate easily from the mud**

- The fluid should have a defined resistivity

  ✓ **Formation resistivity measurements need to be made**

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Control Corrosion

- **The fluid should be non corrosive to the:**
  - ✓ Drill string
  - ✓ Casing
  - ✓ Surface equipment

  Corrosion can lead to:
  - ✓ Wash outs
  - ✓ Twist offs
  - ✓ Pump failure
  - ✓ Surface Leaks

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Support Part of (DS) the Tubular Weight

- Aids in supporting part of the weight of the drill string and casing
- The degree of buoyancy is directly proportional to the density of the fluid.
  - The fluid density is <u>never</u> changed to increase the buoyancy

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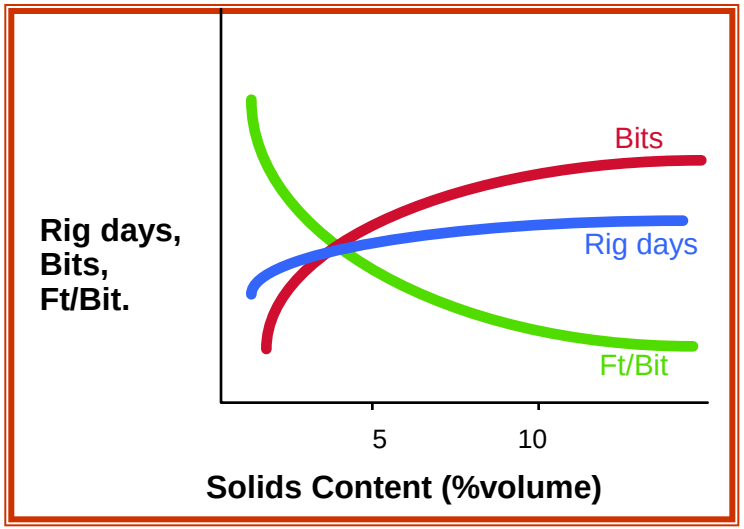
Cost

Maximize Penetration Rates

- The fluid properties greatly influence penetration rates by:
  - ✓ **Removing cuttings from below the bit and wellbore**
  - ✓ **Reducing the cushioning effect of solids between the bit teeth and the formation**
  - ✓ **Reducing the hydrostatic differential**
  - ✓ **Increasing the jet velocity**



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Well Cost

Well Cost *($)*	=	***Daily Cost*** *(days x $/day)*	+	***Footage Cost*** *(ft x $/ft)*	+	***Once off and Other Costs*** *($)*
DFS Cost ($)	=	**Fluids Engineering** (days x $/day)	+	**Drilling Fluid** (ft x $/ft)	+	**Completion Fluid** ($)

- ✓ ***DFS direct cost is relatively small (5 to 10% of well cost)***
- ✓ ***Greatest savings achieved by improving Drilling Efficiency***

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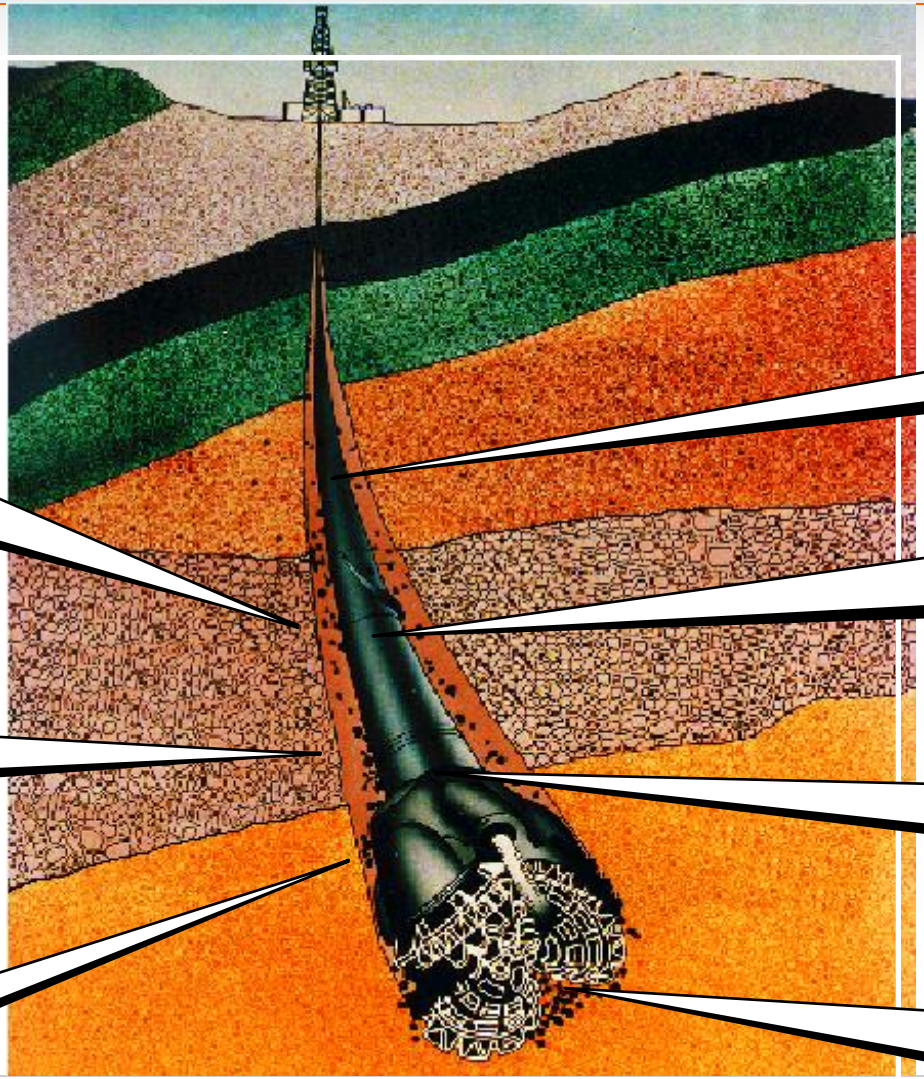
Key Drilling Fluid Issues



Minimise loss of fluid to the formation

Control formation pressure

Lubricate the drill string

Maintain borehole stability

Suspend barite under static and dynamic conditions

Remove drilling cuttings from the hole

Provide hydraulic horse power to the bit

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