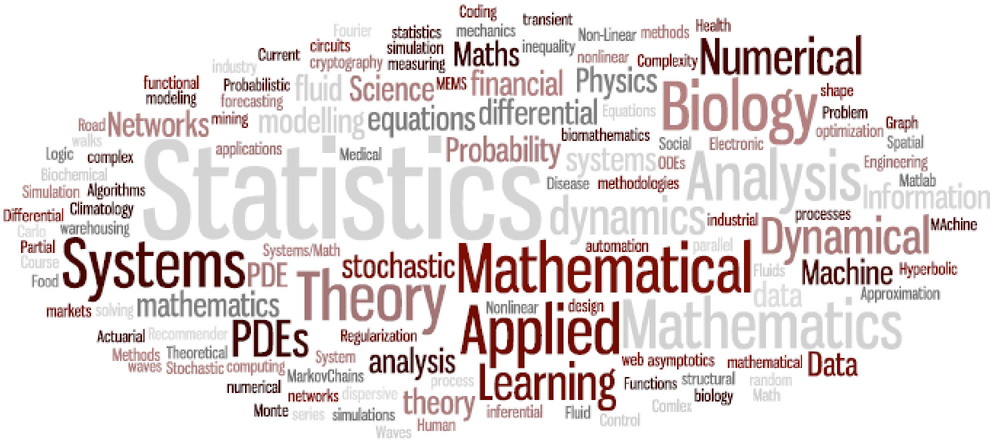

BOOK OF INDUSTRY PROBLEMS

102nd European Study Group with Industry

30 June – 4 July 2014

http://mathsci.ucd.ie/esgi/

School of Mathematical Sciences

University College Dublin, Ireland

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Tellus Border Electromagnetic Data
European Study Group with Industry ESGI102

Background

The collection of airborne electromagnetic (EM) data is a common surveying technique used to assist geologists to interpret subsurface geology, structure, mineralization and contamination. Airborne EM surveying is an induction technique where a known current is circulated in a coil (transmitter) and the response of the earth to this current is measured in another coil (receiver) – both coils are housed within the aircraft. EM surveys are commonly carried out in either the frequency domain (where the effects are measured at different frequencies) or in the time domain (where the effect of the current in the earth is measured at different times when the transmitting current is turned off). The former are often referred to as FEM while the latter are often referred to as TEM. In the case of FEM, two parameters for each frequency are measured – the in-phase component and the out of phase (or quadrature) component. The measurements are given in ppm (parts per million) of the transmitted field strength (measured in V or more commonly mV). Apparent resistivity, or its inverse apparent conductivity, and apparent depth can be calculated from these data which are more readily amenable to interpretation of the data in terms of geology, etc.

The Geological Survey of Ireland (GSI) along with the Geological Survey of Northern Ireland (GSNI) carried out a FEM survey over six counties in Ireland close to the border with Northern Ireland. The project is part of a larger project funded by the EU (INTERREG IVA) and known as the **Tellus Border** project.

Measurements were collected at four different frequencies (approximately 0.9, 3, 12 and 25kHz). Prior to presenting the data the raw data is 'corrected' for many factors, including altitude, temperature, instrument drift, etc.

The interpretation of this data is commonly carried out using specialist software packages where the data is used to produce resistivity models of the subsurface. These models are then interpreted in terms of rock types, their boundaries with one another, and other features such as mineralization or contamination. However, solutions are non-unique and it is helpful to have some *a priori* knowledge of the area being studied. Such information may come from outcrops, drill holes with depths to particular geological units, or physical property data such as the electrical resistivity of the different rock units. For each data point a 1D model can be determined which comprises resistivity variations with depth (down to a depth of about 50 to 60m in the case of the survey carried out by the Tellus Border project). The resistivity estimate is used to interpret (assign a rock type) the geological nature of the earth. This can be aided (constrained) by known rock units in the region.

Tellus Border Electromagnetic Data
European Study Group with Industry ESGI102

Problem to be addressed

When GSI, GSNI and its geophysical contractors and consultants have attempted to carry out interpretations of the EM data it has not been possible to develop sensible models. We have identified some issues: (i) Strong peaks of signal at the low-frequency readings, apparently correlated spatially but not due to human activity. (ii) Regions of high spatial variability of low-frequency readings, which look like noise.

GSI asks the European Study Group with Industry:

1. **To determine if the FEM data can be used to obtain a sensible and robust resistivity model so that the data can be used to aid the geological interpretation of the subsurface; and**
2. **To develop approaches that can be used routinely to develop such models.**

The data collected over the whole survey area will be available for the Study Group. Moreover, data was collected along a test line where surveying flights at five different heights and on a number of dates were conducted throughout the project. This can be used to assist validation of the models.

Optimisation of Red Mud Filtration
European Study Group with Industry ESGI102

Introduction

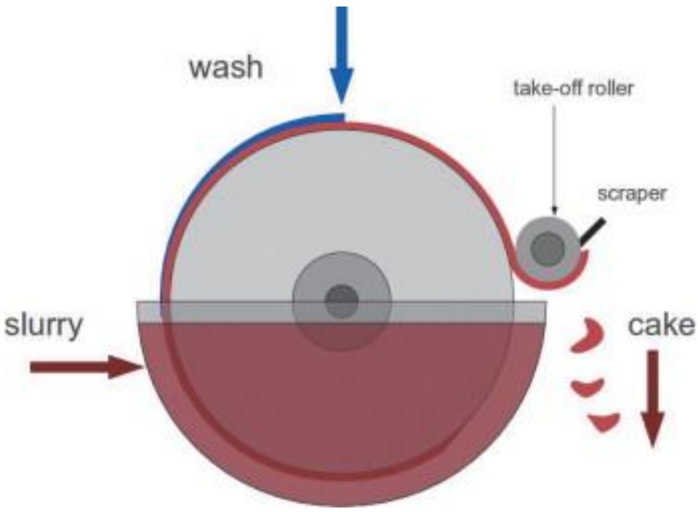
Aughinish Alumina (AAL) extracts Alumina from Bauxite using the Bayer process which results in the generation of bauxite residue. This bauxite reside is separated from the Alumina-rich process stream before it is sent to the Bauxite Residue Disposal Area (BRDA). The method of storage of bauxite residue is that of a dry stack which requires a high solids content. This is achieved through filtration. As part of the filtration step the mud is also washed to recover caustic before it is sent to the Bauxite Residue Disposal Area.

Background

The mud filtration area features 8 similar but not identical drum filters. The number of filters on line at any one time depends on the mud load but there is an allowance for one filter to be off for maintenance or re-clothing. The filters are fed slurry of typically 40% solids. An automated control valve maintains a level in the filter trough. The speed of each filter is also regulated by a variable speed drive. Each rotary drum filter is divided into cells or sections with the whole drum covered by a filter cloth and a backing cloth. Under vacuum and in the submerged trough, solids are deposited uniformly over the outer surface of the drum. A take-off roller strips the bauxite residue from the filter and the residue is then combed from the roller.

The capacity of these filters depends on factors such as but not limited to the filtration media condition, rotation speed, fouling, vacuum and wash flow.

The mud filters are taken offline every morning for washing. In general 2 filters are taken off at a time and it takes 60-120mins to wash them. The mud filters are also caustic washed every 6 weeks for approx. 12hrs. When a filter is on caustic wash it also utilises the same vacuum, reducing the capacity of the online filters.



Schematic of a typical Red Mud drum filter

RUSAL
AUGHINISH

Optimisation of Red Mud Filtration
European Study Group with Industry ESGI102

Existing Situation

Recent developments in the area have led to the introduction of a simple online capacity calculation which has helped to optimise the area. The online calculation looks at the performance over the previous 10mins and uses this to predict a filter capacity. An online control scheme utilises this calculated capacity to balance the flow across the available filters and maximise the wash.

Challenge

Mud filtration is very dynamic area and rarely in steady state. Over a typical 24hr period the area will go from times of being filtration capacity limited to having excess capacity.

It would be beneficial to be able to,

- Predict and plan the capacity of the area over a 24 hr period.
- Maximise the average wash per filter over a 24 hr period.

Ideally, this would then be integrated into an online control scheme.

Wind Forecast and the Single Electricity Market
European Study Group with Industry ESGI102

Background

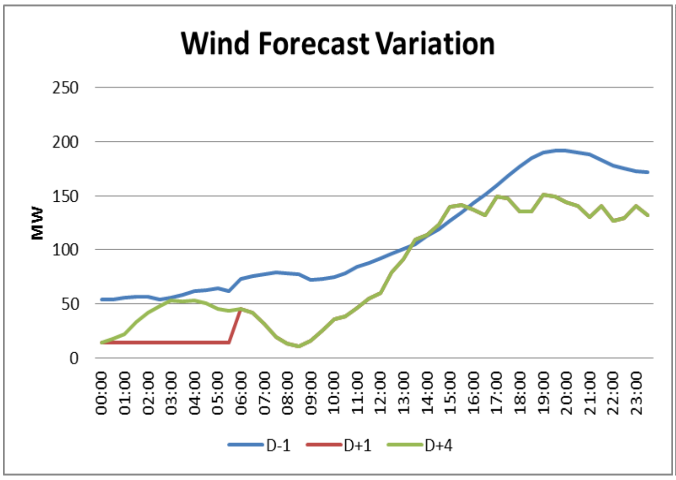
In Ireland there is a wholesale electricity market which has been in operation since November 2007. This market is known as the Single Electricity Market (SEM) and incorporates all generation on the Island of Ireland. The market was designed as a gross mandatory pool with ex-post pricing. This means that all generation over 10MW is obliged to participate in the market and that there are strict principles around the bidding of the generators within the market. The ex-post element means that the final revenues to the generators are only determined four days after the fact once all variable elements such as wind and demand are finally determined.

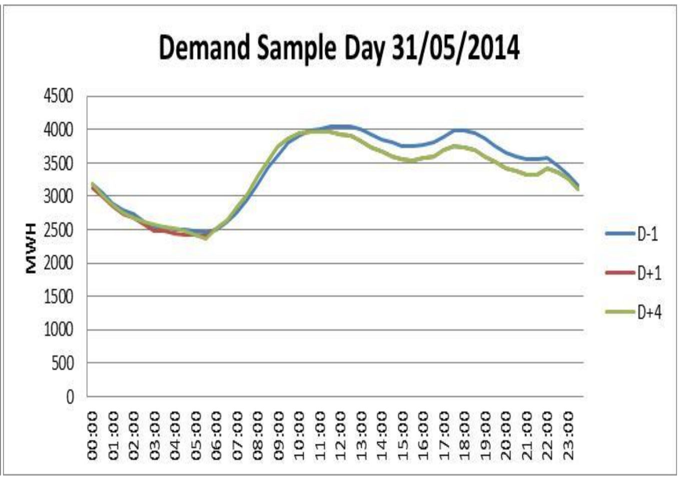
Variable renewable sources such as wind are a growing part of the generation portfolio. However, research has shown that the Root Mean Square Error for wind forecast is 4.5% Day Ahead (DA) and reduces to 3% intraday (ID)[1].

This variation in wind can cause significant changes in the prices in the market and open up exposures for generators. It will be more important in the future that the wind is forecast accurately and that its implications on prices are understood clearly for trading purposes.

There is a significant amount of data within the SEM. Currently the Market Operator (MO) publishes their expectations of wind and demand on a Day Ahead basis. They also publish their expectations as to what prices will outturn in the market. This is their Forecast or Ex-Ante view of the market. As more information becomes available these views are refined. One day after the fact an Initial pricing schedule is issued based on more refined data on wind generation, demand profiles and outages of plants. Finally, four days after the fact the MO publishes the actual wind, the actual demand and the actual prices in the market. These actual figures are the basis for trading within the SEM currently.

The following graphs show how wind forecast varies between the different timeframes (Day Ahead=D-1, One Day After = D+1 and Four Days After = D+4).

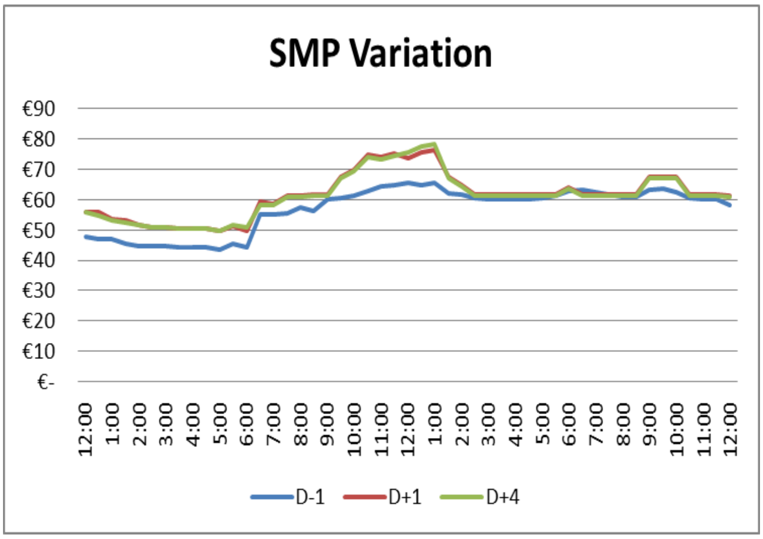




1 European Wind Energy Agency: Creating the Internal Energy Market

Wind Forecast and the Single Electricity Market
European Study Group with Industry ESGI102

Subsequently these variations in wind, demand and forced outage profiles for generators impact the actual prices in the market (called System Marginal Price or SMP) as demonstrated by the following graph.



Problems to be explored

1. **Given certain Day Ahead forecasts for wind and demand is there a relationship between these forecasts and the D+4 actual prices in the market (SMP)?**

2. **Can we identify wind and demand patterns that impact prices? An example of this would be wind starting off at very low levels at the start of the day and ramping up significantly in a very short time frame. Does a wind pattern such as this have a more significant impact on forecasts and subsequently prices?**

A possible extension to this problem would be to consider if these relationships could help improve decision-making when scheduling marginal generation based on different costs – more information will be provided on this point during the week.

Global Custody in Financial Markets
European Study Group with Industry ESGI102

Customer

Custody is a service in which a brokerage or other financial institution holds securities on behalf of the client. This reduces the risk of the client losing his/her assets or having them stolen. They are also available to the brokerage to sell at the client's demand. Like a bank, custody provides an investor a place to store assets with little risk. Unlike a bank, custodians are not allowed to use the items in safekeeping for their own ends. Assets in custody are not fungible for the brokerage because they remain on the client's name. For this reason, these institutions normally charge custodial fees for safekeeping services. A global custodian is a financial institution that provides customers with custody services for securities traded and settled in financial markets throughout the world.

Problem Definition & Challenge

When a client of the custodian bank engages in a transaction such as a trade, the custodian must engage in a reconciliation of the transaction in their accounts. The failure rates for trades and reconciliations is very small, of the order of substantially less than 1% of all transactions on a daily basis. However, as the bank is engaged in high numbers of reconciliations, these failed transactions pose a number of problems:

- Client behaviour leads to failure to meet SLA requirements having adverse impact on revenue.
- Compliance risks for clients with "depositary" responsibility.
- Operational costs increase due to manually intensive reconciliation cleansing.

The most common causes, amongst many others, for failed trade reconciliations are:

- Incomplete trade instructions.
- Impact of client specified trade counterparties.
- Location of trading (and subsequent system).
- Impact of securities types.

The key problem, which we challenge workshop members to answer, is to identify the transactions that are likely to fail, in advance of their failing, and to allocate these transactions to different risk consequence groupings, as defined by their value, probability of failure and regulatory impact.

We suggest the following problem solution format:

<u>Section I</u> Analyse Failed Settlements

We look at the 54x messages that have failed over the last 90 day period. We look at what the dominant reasons are for the failures, which include the following:

1. Settlement Date
2. Trade Date
3. ISIN
4. Designation
5. Nominal amount
6. Securities account
7. Counterparty
8. Sender's Client (optional)

9. Place of Settlement
10. Currency of Denomination
11. Delivering Agent
12. Deliverer's Custodian
13. Place of Settlement
14. Cash Amount
15. Buyer
16. Seller

Of interest is the frequency of each variable to failed settlements and the frequency of multiple variables, correlated to each other, on failures.

Section II Analysis of Failed (Repaired) Settlements

We then look at the frequency of each variable to repaired settlements. We will also look at the frequency of multiple variables, correlated to each other, on failures.

Section III Calculate Settlement Variable (SFV) Rules

The **Settlement Failure Variables** are the key attributes that contribute most to either settlement message repair, or settlement failure. The rules will identify probability of failures based on:

- A single instance of a very high risk of failure message attribute:
- An agent that has failed every time at the bank
- A combination of attributes, where the aggregate probability of failure is very high;

E.g. the combination of a variable such as security type, place of execution, agent (where a combination of execution location & type, and security type) have a large impact on failures.

Failure Rate Probability P(f) –

1. Query table looking for total settlement instructions, versus total failed (including repaired) settlement instructions for the last 90 days (rolling).

2. Query table looking for total settlement instructions versus failed settlements where last update minus feed update is greater than one day. Get total transactions and total fails for those transactions. Each query is grouped by date.

3. 90 day rolling average for both quantity and value from settlement failures can be superimposed.

4. The probability of a failure for each settlement failure item is predicted by analyzing the previous 90 Days.

5. This is repeated for a combination of dominant variables.

Section IV Risk Test

Based on the probability of risk from a combination of dominant variables, we filter the transactions with a greater than x% chance of failure. If less than x% probability, the message proceeds to settlement queue. If it is greater than this, it goes to the Risk Consequence Filter.

Section V **High Operational Risk – High Compliance Risk Filter:**

We then further filter the messages that have a high probability of failure that show the following characteristics: High Risk Consequences – High Operational Risk or High Compliance Risk and Medium Risk Consequences – Medium Operational Risk or Compliance Risk.

Section VI **High Consequence Queue:**

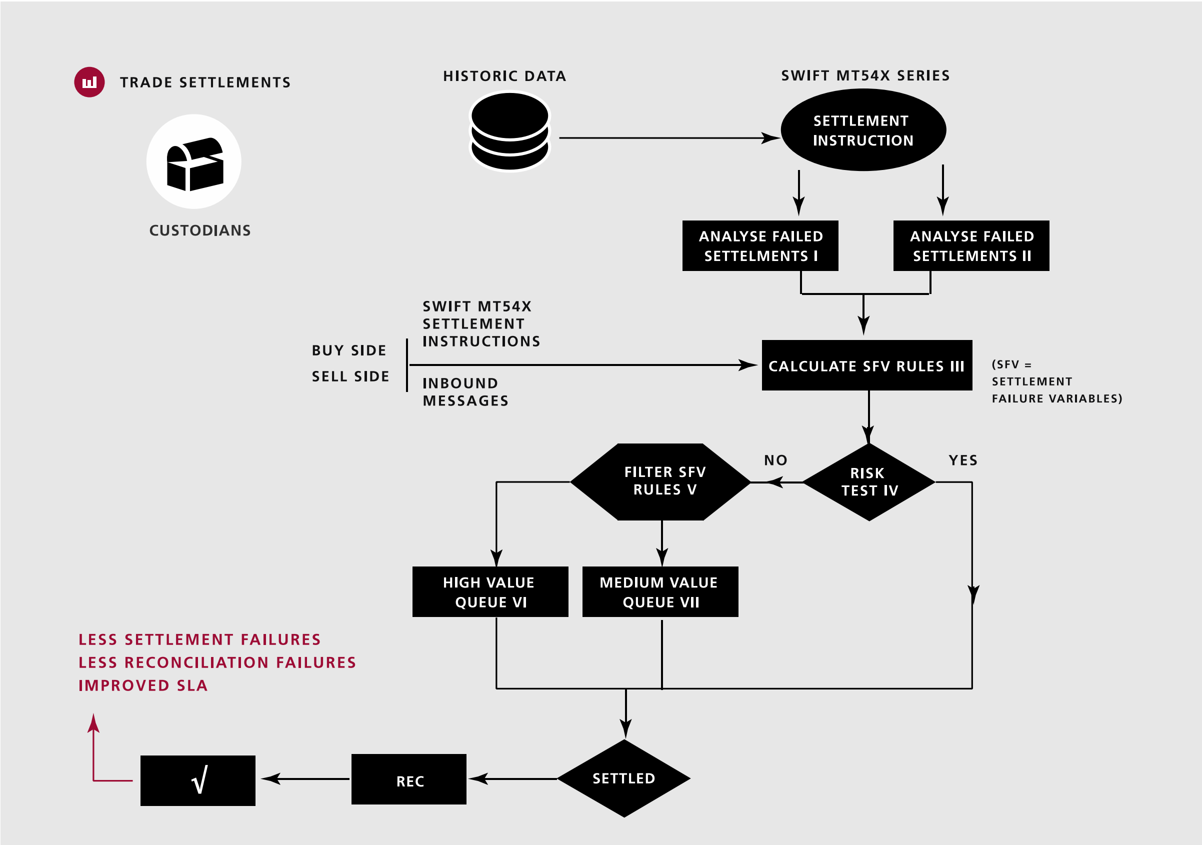
The potential failures with: very high probabilities (tbd) of failure AND High Value (tbd) transactions OR High (tbd) impact regulatory consequences will be placed in a High Consequence Queue.

Section VII **Medium Consequence Queue**

Potential failed trades with: a medium (tbd) level probability of failure AND a medium (tbd) transaction value OR a medium (tbd) impact regulatory consequences will be placed in a Medium Consequence Queue.

The Solution Flowchart

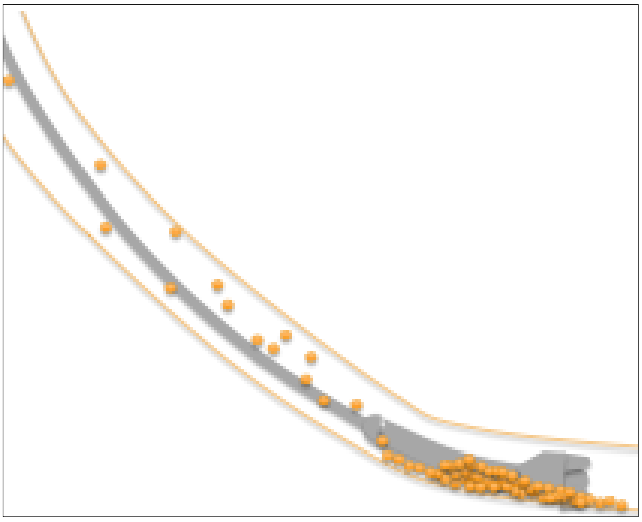
The operation of the below diagram is described at a high level in Sections I – VII.



Agglomeration and transport of drilling generated particles in the oilwell
European Study Group with Industry ESGI102

Background: Process Description

When drilling an oilwell, produced drilling cuttings are transported to the surface by the use of drilling fluid. Such a fluid is also known as drilling mud, due to the historical use of water with large clay content. Using powerful pumps, the drilling fluid is pumped from the surface through the hollow drill pipe, through the drill bit, and subsequently up the annulus of the well back to the surface, where the cuttings are separated from the drilling fluid using machinery known as shale shakers, containing one or multiple screens through which the drilling fluid is passed.



The drilling fluid is normally oil-based or water based, although synthetic fluids are also applied. The oil-based fluid consists of a water-in-oil emulsion, with the base oil as the main component. Water based drilling fluids are normally brine-clay solutions, where there also may be a smaller oil component present, forming an emulsion with the brine. The main additives are emulsifiers, solids weight material and viscosifiers such as clays and polymers. Due to the particle additives, the drilling fluids have non-Newtonian shear-thinning rheology characteristics which are beneficial for the transport. These fluids will also gel when static, enabling support of particles in fluid suspension. Another important mechanism for transport is the wetting of the cuttings particles in suspension, which may be influenced by the same chemicals used as emulsifiers [Caenn, 2011].

An oilwell may have significant inclination, as shown in the figure. The mechanisms governing the characteristics of cuttings transport depend on the inclination of the wellbore. Multiple mechanistic models exist for describing the behavior in the various sections of different inclination in the well [Kamp, 1999] [Pilhevari,1999] [Ramadan, 2005].

Agglomeration and transport of drilling generated particles in the oilwell
European Study Group with Industry ESGI102

In order to drill an oilwell, strands of drill pipe must be continuously added as the well grows longer. In conventional drilling operations this requires stopping the mud-pumps to enable connection of the new strand to the top of the drill pipe. When the well is static the drilled cuttings may fall to the bottom (wall) of the inclined well, forming what is known as a cuttings bed. Through interaction with the drill pipe, drill bit and fluid flow, such cuttings beds may cause sticking of the drill pipe and packing off of the well, further leading to fracturing of the formation, fluid loss, and potential loss of the well. The drilling fluid composition and resulting properties shall both help avoid forming of cuttings beds, and further help move or dissolve these should they occur [Clark,1994] [Nazari,2010] [Cayeux,2014].

The mechanisms of the cuttings bed are poorly understood. Both fluid flow and drill pipe rotation help break up cuttings beds, but only qualitative mechanistic models exist for interpreting and predicting transport behavior in the well [Azar,1997] [Walker, 2000]. Further, the observed difference in cuttings bed and transport behaviour in oil-based and water-based drilling fluids is poorly understood. A better understanding of these mechanisms will help improve the quality, efficiency and success rate of drilling operations.

Problems to be explored

1. **Arrive at a physical and mathematical understanding of the problem through development of a complete mathematical description.**
2. **Analyse the characteristics of the problem and suggest initial asymptotic solutions through problem simplification.**
3. **Explain the key differences between oil-based and water-based drilling fluids for cuttings bed formation, dissolution, and cuttings transport.**

Possible mathematical simplifications

- We look on the fragment of the wellbore (last stand). Diameter of well could be considered as a constant (~50cm). Diameter of the pipe is ~12.5cm in its narrow part and ~25cm in its wide part.

- The system could be considered as a horizontal or slightly inclined tube with external and internal boundaries.

- The external boundaries correspond to the oil-well boundaries. The internal boundary is a rotating drilling pipe. The “left” boundary condition is outflow and the “right“ boundary condition is inflow.

- The source (fluid and cuttings) is located on the right boundary. The pipe rotates with approximately constant speed, than stops rotation and renews it after certain time -- this is a continuous process. The pipe drills for ~30m, stops for 5-15 min and restarts rotation and drilling.

IRIS International Research Institute of Stavanger

Agglomeration and transport of drilling generated particles in the oilwell
European Study Group with Industry ESGI102

Physical properties of the modeled process

- Cuttings in the suspension are advected and fall to bottom at the rate depending on viscosity density of the drilling fluid.

- Horizontal symmetry cannot be employed, as the gravitation force must be taken into account.

- Eccentricity of pipe should be considered as it exercises a force on the cutting bed.

- Two types of the drilling fluid should be considered: Water-Based and Oil-Based. Drilling fluids have varying rheology as a function of temperature, pressure and composition. Other features of the fluid are shear thinning, yield stress behaviour and gel formation. Common yield stress behaviour models: yield with linear plastic viscosity and yield with power law combined.

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Traffic Restrictions in Operation Mon-Fri Barriers closed from:	07.00-10.30 16.00-19.30

Gates Opening Times

N11 Entrance	24 hours
Clonskeagh Entrance, (Mon-Sun)	07.00-00.00
Owenstown Entrance (Mon-Sat)	07.00-00.00
Fosters Avenue Entrance	07.00-00.00
Richview Entrance (Mon-Fri)	07.00-00.00
(Sat)	07.00-18.00
Richview Newstead Gate (Mon-Sun)	24 hours
Roebuck Castle, Pedestrian Route	24 hours
Greenfield Park, Pedestrian Route	24 hours
Roebuck Road Gate Pedestrian Route (Mon-Fri)	07.00-18.00

Location Map

Belfield Campus Map

UCD Unicare:
our campus, our care...
Emergency Line:
(01 716) 7999

Belfield Campus Map, August 2013

LEGEND
- Traffic Barrier
- Fixed Traffic Barrier
- Primary Vehicle Route
- Secondary Vehicle Route
- Pedestrian Route