SizeCUT™

Well Engineering

Technical Brochure

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Section 1

INTRODUCTION

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P R O B L E M S

- Has you EIA ever ***delayed*** drilling because of the quality of the cuttings dispersion study was unacceptable?
- Have you had problems with ***abandonment*** because the position of drill cuttings increased your ***costs*** due to damage / removal?
- Have you used dispersion modelling, but found the ***accuracy*** to be lacking?

B E N E F I T S

- Improved ***knowledge*** of where your cuttings are being dispersed on the seabed!
- Analysis from 'bit to bed' means the effect of drill cuttings size and tidal data ***enhance*** the output!
- A quality impact assessment means drilling can start ***on time***!
- Coverage of production infrastructure can be ***avoided***!
- Abandonment is achieved smoothly without ***additional costs***!

SizeCUT™ is a Drill-Cuttings Disposal System that integrates the engineering options that allow oil and service companies to select suitable disposal alternatives in a cost effective, environmentally sound and operationally safe manner. The system consists of a number of field proven engineering methodologies and models that consider two main disposal options: cuttings discharge into the sea and re-injection into an underground reservoir.

The sea discharge option is based on the prediction of the drill cuttings size and its use to compute discharge and dispersion into the sea according to the existing marine conditions. The re-injection option involves the utilisation of geomechanical models to determine the in-situ stress conditions to design the optimum re-injection technique required to dispose of the cuttings.

SizeCUT™ offers the following advantages:

1 *Introduction*

- Determination of the cutting volumes and size distribution for each particular well section (including top hole) based on actual drilling parameters.
- Accurate input in the preparation of the Environmental Impact Assessment - EIA.
- Modelling of the drill-cuttings dispersion process and determines the cuttings pile footprint on the seabed including cutting's density and distribution, pile's height, length and width.
- Identification of potential obstacles when performing underwater operations around offshore installations (manifolds, pipelines templates and subsea wellheads). This is critical for decommissioning and abandonment planning and operations.
- Selection of the optimum geological strata for cutting's injection and the appropriate treatments for cuttings disposal, fluid systems and volumes.
- Expected operational conditions during re-injection can be determined therefore, pressures, rates and horsepower requirements.
- Disposal well design, casing configuration and operational conditions can be determined.

Section 2

SYSTEM STRUCTURE

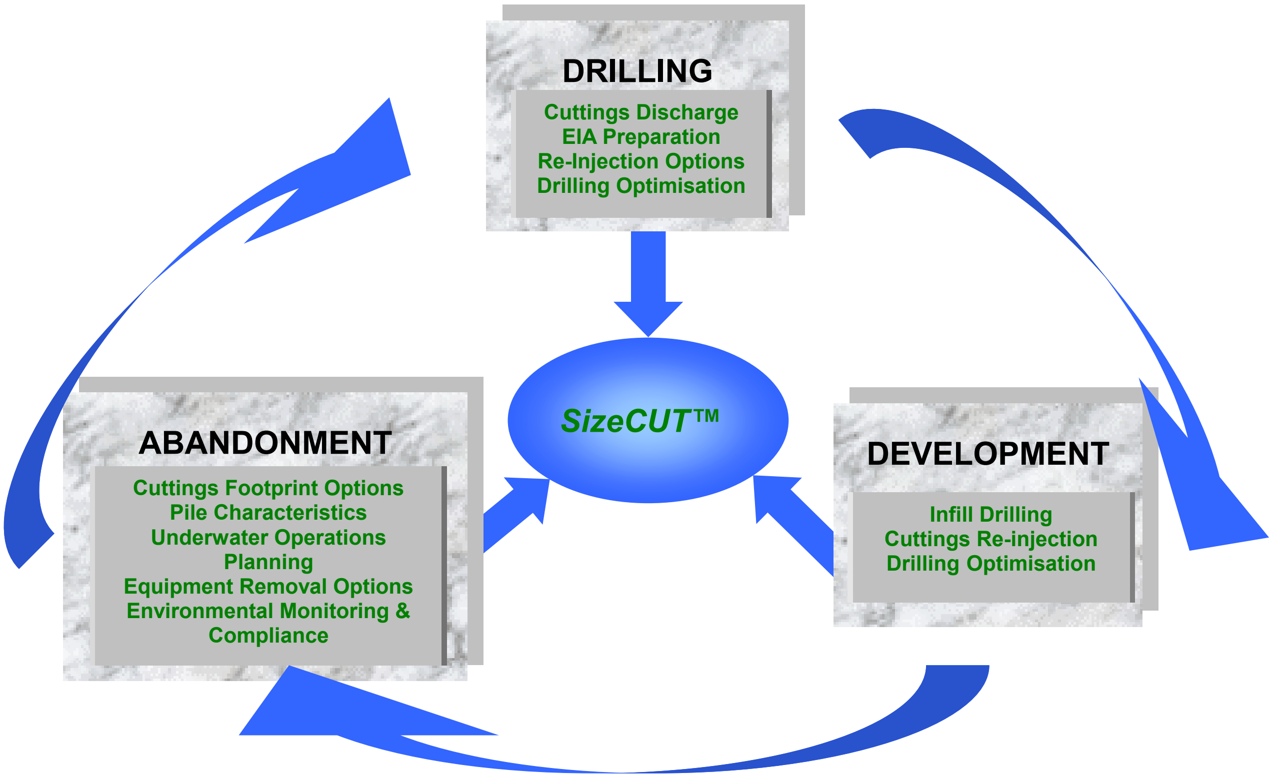
2

SizeCUT™ has been developed to address various conditions during the life cycle of field development. The model utilise drilling, geographical, marine, environmental and reservoir data to allow optimisation of the cutting's disposal options. The overall structure of the system is presented in the following paragraphs and illustrated in the next page.

2.1 DRILLING

SizeCUT™ can be used to select the optimum drill cuttings disposal option based on actual drilling parameters. The result of various years of research, ***SizeCUT™*** allows determination of realistic cutting's size distribution for every section of the well including the surface hole (36" & 26"). As a result, a suitable disposal option can be selected and the input data into either the dispersion or Geomechanical models can generate the following output from this module:

- Drill cutting volumes.
- Cuttings size and percentage of each size.
- Pile's footprint for the offshore discharge option.
- Settled cuttings profile, dimensions (height, width and length), cuttings concentration and density.
- Assessment of the effectiveness of cuttings treatment (grinding) offshore prior to discharge
- Re-injection volumes and disposal interval selection
- Re-injection operational parameters such as pressure, injection rates and equipment requirements
- Hydraulic fracture design and characteristics for cuttings disposal, height, half length, fluid system and procedures
- Robust engineering input into the Environmental Impact Assessment document.



SizeCUT™ *SYSTEM STRUCTURE*

2.2 DEVELOPMENT & PRODUCTION

Drill cuttings management and disposal has a major impact on the life cycle of a field. Environmental and cost issues can be optimised by selecting the appropriate option for the disposal of the drill cuttings as wells are being drilled and produced. SizeCUT™ contributes to this phase in the life of a well by allowing to:

- Optimise well design and in-fill drilling options during the life cycle of the field
- Enhance design of surface facilities for processing or disposal of drill cuttings
- Contribute to ensure environmental compliance
- Plan underwater work such as pipeline and facilities installation (templates, manifolds) will benefit from an accurate and realistic seabed cutting's footprint.

2.3 ABANDONMENT

Field abandonment particularly in the North Sea, has already started to take place. Accurate knowledge and technical data of the seabed is critical in order to be able to remove the different facilities in an effective manner avoiding additional surveys and delayed underwater operations due to drill cuttings pile. ***SizeCUT™*** can contribute to the abandonment process by:

- Defining the drill cuttings pile footprint taking into account the effect of time (erosion) and changes in the pile characteristics.
- Determining the top hole cutting's and cement profile in the pile, highlighting pile's interference and position in respect to the subsea facilities and the installation.
- Contributing to the design of the sampling program

Helping in monitoring cuttings pile behaviour and changes as part of the environmental compliance process.

2 *System Structure*

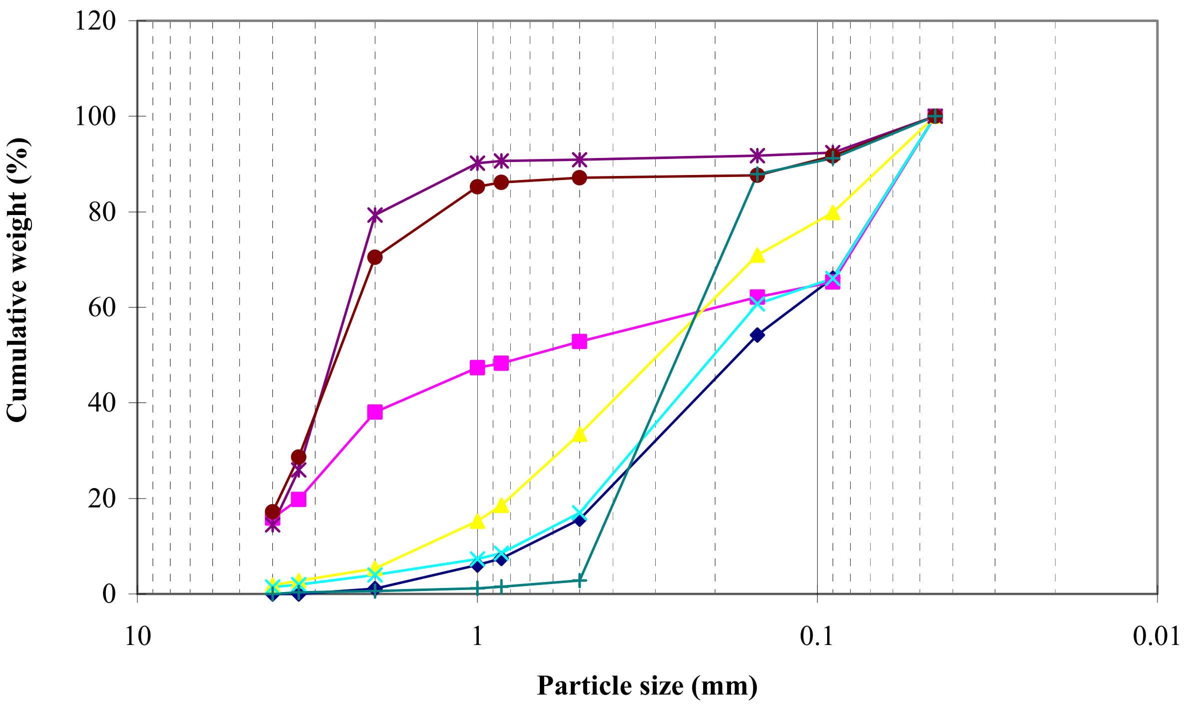
TECHNICAL DESCRIPTION

SizeCUT™ is composed of three (3) main modules; a brief description is included below to illustrate the physics behind the system.

3.1 DETERMINATION OF DRILL CUTTINGS SIZE

Previous models made assumptions concerning the size and shape of the drill cuttings. ***SizeCUT™*** utilises results from recent research that allows determination of the drill cuttings size based on the actual drilling process. The prediction is based on a correlation that links the actual drilling parameters such as type of mud and bit, ROP, stratigraphy and hole size. This was validated using samples from 52 wells in the UKCS and Norway. This program predicts the points of the cumulative curve of cuttings size distributions. These curves are different for each different set of drilling parameters. Once the drill cutting size distribution is obtained they are used as the input for the dispersion model. The following graph illustrates an output of this part of the system.

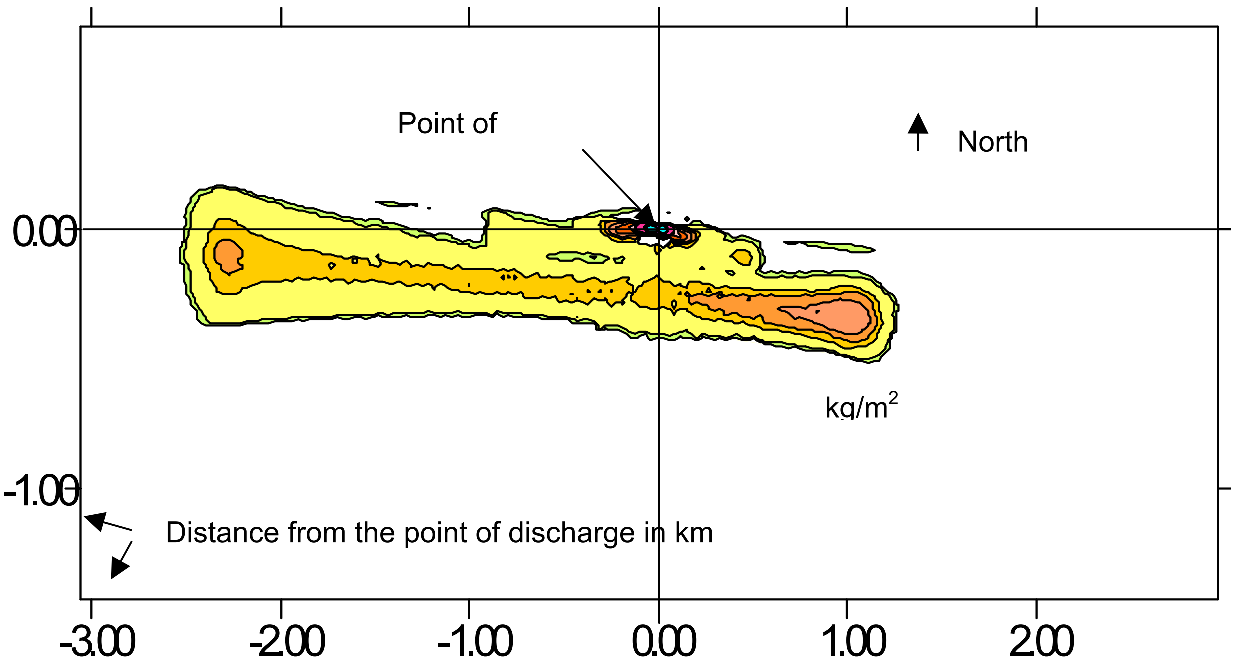
Drill-Cuttings Size Determination



3.2 CUTTINGS DISPERSION MODELLING

SizeCUT™ enables the calculation of possible contamination from a variety of agents in cuttings released under restricted open water conditions. The model considers two distinct zones. It deals firstly with the jet of drilling discharge and, after a transitional stage, with each individual particle. The jet contains a certain amount of kinetic energy that gradually decreases during its evolution. Once all this kinetic energy is spent, each individual particle will be subjected to the gravitational force and to the influence of the different currents and turbulent motions.

There are two formats for the data output: numerical and graphical. The numerical output includes parameters such as the total volume of waste discharged over a certain period of time. The graphical output is the concentrations of drill-cuttings or the thickness of the cuttings pile on the seabed.



SizeCUT™ *Output - Southern North Sea*

Firstly, the model assumes that the drilling discharge forms a jet with an initial velocity and momentum. This initial momentum depends upon the discharge rate or source strength. For this first stage, Fischer equations are used which describe a kinetic jet. Initially, the relative buoyancy and/or the relative speed of the waste discharged to the ambient water will be responsible for the initial mixing and dilution. The behaviour of such a discharge is controlled by a series of parameters. The most important in this case being:

$$Im = M3/4 / B1/2 \quad \text{and} \quad B = Q\ g\ \Delta\rho / \rho a$$

where:

B buoyancy flux (m4.s-2)

ρa density of the ambient fluid (kg/m3)

Δρ buoyancy difference between the effluent and the ambient fluid. (Δρ = ρdisc - ρa; with ρdisc = density of the discharge)

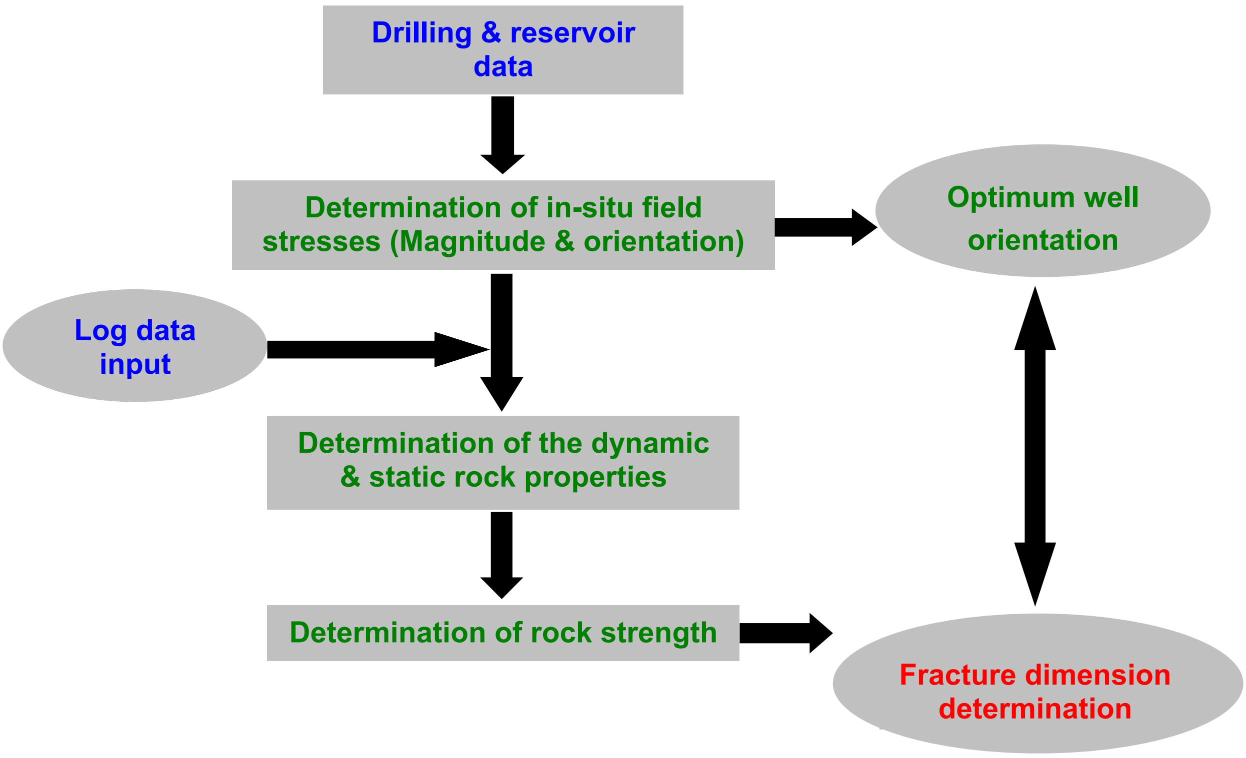
This distance describes the transition between “jet-like” and “plume-like” flows. Within this length from the discharge "point", the driving principle of the overall mixing is the shear stress between the plume and the surrounding water. The width of the "plume" is also calculated by the model, using Fischer theory again where

$$w \sim 0.24 * z$$

This is an empirical equation where w represents the horizontal width of the plume (m) and z the position (m) where the width of the plume is calculated. Throughout the simulation, the model assumes that the discharge fluid is a non-Newtonian fluid (fluid that exhibits variable viscosity and for which the shear rate/shear stress relationship is not proportional). Once the plume has reached a distance greater than I_m, the dispersion model uses the fluid individual particles, rather than deal with a jet, to determine the individual particle. The fall velocity of a “particle” is first calculated, based upon its density (within a particular range of size, the density is assumed to be constant) and size (meaning the diameter of a particle is assumed to be spherical). Then, as the depth of the point of discharge is known, the time of settlement can be determined. An error in the time of settlement is calculated and used to determine an additional error in the position of a “particle” deposition point. All these average positional footprints “overlap” each other to form the final contours that will be visualised in the graphical output. The contour profiles can be representative of the different concentrations of the drill-cuttings deposited on the seabed or of the thickness of the cutting pile on the seabed as can be seen in the graph presented above.

3.3 GEOMECHANICAL MODEL

The model developed is unique and the information and data utilised represents the geological, geomechanical and reservoir conditions relevant to a particular basin or field. The computational engine of the model is ***a pseudo 3D model*** extended to accommodate non-linear rock behaviour and *poro-elastic* effects acting upon a borehole or perforation cavity at any particular point during the life of the field. The computational model structure is presented below.



GEOMECHANICAL MODEL STRUCTURE

The model can determine the mechanical properties of the rock, in-situ field stresses and hence can determine fracture dimensions and operational parameters such as pressures and pump rates.

CASE HISTORIES

This section presents two case histories of work carried out using ***SizeCUT™***; they cover 3 different examples.

4.1 SHELL EXPRO – BRIGANTINE FIELD - EIA

As part of the Environmental Impact Assessment – EIA by Shell EXPRO and responding to a concern highlighted by the JNCC* about the proximity of the proposed drilling locations(2) to the "Indefatigable Sand Bank" and how such a level of cuttings will impact on the environment. A characterisation of the expected drill-cuttings pile was required in order to evaluate impact on the surrounding environment. ***SizeCUT™*** was used to model the development of the pile as cuttings from the proposed drilling program were to be discharged into the sea. Shell's Brigantine field was to be located in an area of the Southern North Sea with strong currents on the North-West to South-East direction. The model predicted an estimated length of the pile of ~ 1.2 Km with drill-cuttings concentrations of up to 6.4 kg/m^2 concentrated nearby the point of discharge (250 m radius). The following table presents a summary of the project,

OBJECTIVE	Environmental Impact Assessment - EIA
OPERATOR	Shell EXPRO
TYPE OF WORK	Drill-cuttings dispersion modelling
No. WELLS	4
LOCATION	Southern North Sea - UKCS
WATER DEPTH	~ 25 meters
PILE CHARACTERISTICS	Length ~ 1250 meters Concentrations - @ 1250 m = 0.5 Kg/m^2 @ 250 m = 6.4 Kg/m^2
PROJECT DURATION	5 days
DELIVERABLES	Pile characteristics (footprint, locatio dimensions) Drill-cutting concentrations Evaluation of impact on the sand bank

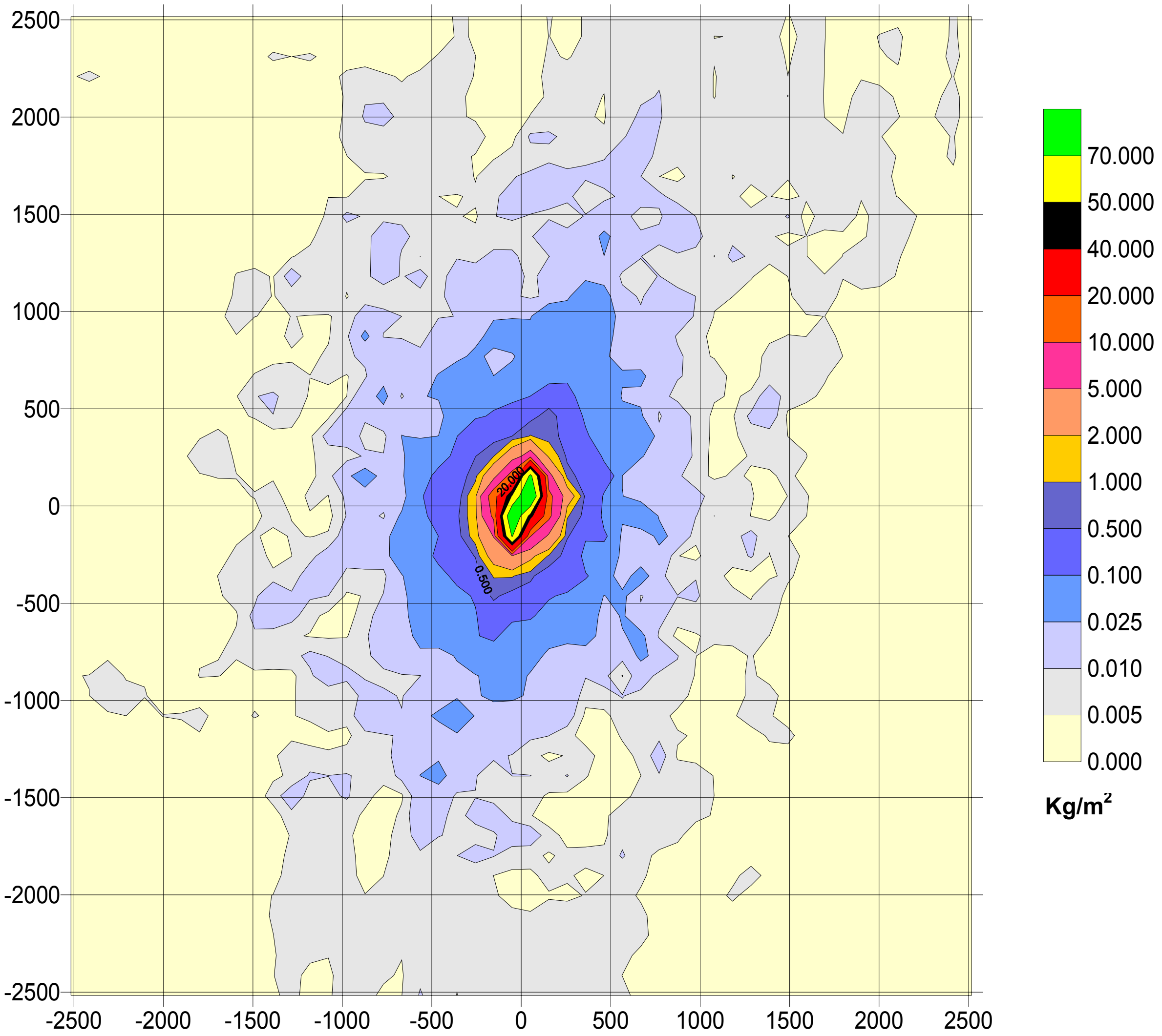
* Joint Natural Conservation Committee

4.2 AMERADA HESS LTD – DURWARD & DAUNTLESS FIELD – ABANDONMENT

The Durward & Dauntless field located in the central North Sea was developed from 3 drilling centres with 15 wells using a FPSO. Operator Amerada Hess Ltd decided to abandon the field and as part of the consultation process with the DTI the need for determining the potential extent of the drill-cuttings piles was identified. Issues such as pile's (3) location, dimensions, interference between piles and potential impact on the seabed facilities(templates, manifolds etc..) needed to be evaluated. ***SizeCUT™*** was used to predict the distribution of the piles on the seabed. Interference was identified between Northern and the central cluster piles, pile's height of up to 11 meters for the Durward central cluster pile was predicted. Dauntless cuttings pile was considered to be small reaching an area of ~ 500 meters radius from the point of discharge. From the abandonment point of view the height of the piles created during drilling the top hole sections (riserless) were also determined taking into consideration the impact of the excess cement volumes. The project was completed successfully to the operator and the DTI satisfaction, the following table summarise the main characteristics of the project.

OBJECTIVE	Field abandonment program
OPERATOR	Amerada Hess Limited
TYPE OF WORK	Drill-cuttings dispersion modelling
No. WELLS	15
LOCATION	Central North Sea - UKCS
WATER DEPTH	~ 90 meters
PILE CHARACTERISTICS	Dauntless : 2 Km length w/0.0025 Kg/m^2 N-E to S-W main axis Durward : 5 Km length w/0.0025 Kg/m^2 N-E to S-W main axis
PROJECT DURATION	12 days
DELIVERABLES	Pile characteristics (footprint, location dimensions) Drill-cutting concentrations Riserless sections footprint and dimensions

The following graph illustrates a footprint of the Durward Central cluster pile including the riserless sections.



DURWARD CENTRAL CLUSTER – DRILL CUTTINGS PILE FOOTPRINT

The pile footprint indicates a typical dispersion and settlement for the type of currents in the area. Clear interference between the Northern and Central cluster piles was observed. High cuttings concentrations around the point of discharge are clear and are restricted in this particular case to the area close to the point of discharge.

The following subsection list a number of projects carried out using ***SizeCUT™*** including EIAs, re-injection and abandonment.

4.3 ADDITIONAL PROJECTS

CLIENT	LOCATION	PHASE	APPLICATION
Talisman Energy	UKCS	Remedial	Cuttings Re-Injection
Oryx Energy	UKCS	Drilling	Cuttings Re-Injection
Conoco UK*	SNS	Drilling	EIA, Cuttings discharge
BHP*	Liverpool Bay	Drilling	EIA, Cuttings discharge
Conoco UK	SNS	Drilling	Cuttings discharge, grinding option
Shell EXPRO	SNS	Drilling	POM 15, Cuttings discharge
BHP	Liverpool Bay	Drilling	EIA, Cuttings discharge
Amerada Hess*	UKCS	Drilling	EIA, Cuttings discharge
Conoco UK	SNS	Drilling	EIA, Cuttings discharge
Amerada Hess	UKCS	Abandonment	DTI requirement
Conoco UK	UKCS	Drilling	EIA, Cuttings discharge

* Work carried out through ERT

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