Annex 1
Description of work

Sensitivity Analysis of the Impact of Geological Uncertainties on Production forecasting in clastic hydrocarbon reservoirs

SAIGUP

PROJECT NUMBER: NNE5-2000-20095
CONTRACT NUMBER: ENK6-2000-00073

Project Coordinator:

1 NUID/UCD:	National University of Ireland - Dublin/University College Dublin, Fault Analysis Group.	(IRL)

Contractors:

2 NR	Norwegian Computing Centre.	(NO)
3 HWU	Heriot-Watt University; Department of Petroleum Engineering.	(UK)
4 ICSTM	Imperial College of Science, Technology and Medicine; T. H. Huxley School for the Environment, Earth Sciences and Engineering.	(UK)
5 TNO	The Netherlands Institute of Applied Geoscience – National Geological Survey; Department of Geo-Energy.	(NL)
6 Badleys	Badley Earth Sciences Ltd.	(UK)
7 BG	BG; BG International Ltd.	(UK)
8 ROXAR	ROXAR Software Solutions ASA; ROXAR Software Development.	(NO)
9 SIEP	Shell International Exploration and Production; SIEP - SEPTAR.	(NL)
10 UL	Liverpool University; Stratigraphy Group.	(UK)

Duration: 36 months

Title

Sensitivity analysis of the impact of geological uncertainties on production forecasting in clastic hydrocarbon reservoirs.

Objectives and problems to be solved

The principal purposes of the project are: i) to quantify objectively the sensitivity of geological uncertainty on production forecasts, as a function of generic aspects of both the sedimentological architecture and faulted structure of clastic hydrocarbon reservoirs, and ii) to validate these results using real-case reservoir and production data. Because of the case-specific nature of existing production forecasting sensitivity studies, links between geological and production uncertainty cannot be made at present. These links are a prerequisite for early recognition of the most significant geological parameters influencing production forecasting uncertainty and are a necessary basis for establishing optimal methods for including geological uncertainty in reservoir modelling studies.

Description of the work

The project is a systematic assessment of uncertainty in reserves and production estimates within an objectively defined geological parameterisation encompassing the majority of European clastic oil reservoirs. A broad suite of shallow marine sedimentological reservoir types are indexed to continuously varying 3D anisotropy and heterogeneity levels. Structural complexity ranges from unfaulted to compartmentalised, and fault types from transmissive to sealing. Several geostatistical realisations each for the geologically diverse reservoir types covering the pre-defined parameter-space are up-scaled, faulted and simulated with an appropriate production strategy for an approximately 20 year period. The production and reserves uncertainty associated with geological uncertainty and methodological imprecision are quantified as a function of the underlying geology.

Production results and recovery factors are combined with the geological and development plan parameters in a relational database, allowing the levels and origins of production uncertainty to be defined within the full parameter-space. Existing and new static and dynamic heterogeneity measures and dimensionless parameters are tested against production results for their ability to discriminate between geological architectures and to predict production characteristics. Sensitivity analyses, performed using reservoir and production data from three North Sea fields, combined with results from the large suite of geological models test our principal technical findings.

Expected results and exploitation plans

The expected project results are i) quantification of the relative and absolute influences of sedimentology, structure and up-scaling on reserves estimation and production forecasting from reservoirs with different sedimentological and structural properties, and ii) definition of geologically relevant dynamic and static heterogeneity measures and dimensionless groups for improved production forecasting in faulted clastic reservoirs. Project results will be tested and implemented through the consulting and software roles of the two service companies and through the practical implementation of the methods developed by the two oil company partners. We expect these results and methods to contribute towards an improvement in the planning and execution of geological reservoir modelling programs, and towards a reduction of the economic risk associated with field development.

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1 OBJECTIVES

1.1. Scientific and technical objectives

SAIGUP addresses two fundamental questions asked in relation to the exploitation of hydrocarbon reservoirs. The first is asked by the oil company: "what is the best way of maximising profit from this asset?" The second question, asked by the governmental regulatory body which reviews the oil companies exploitation strategy, is: "does this proposed development plan optimise the reservoirs potential?" The answers to these questions are not straightforward, because forecasts of the reservoir's behaviour contain elements of uncertainty as they are based on limited information about the reservoir. The purpose of SAIGUP is to provide a means of quantifying this uncertainty on the basis of both the available geological information and on the reservoir production strategy, for a broad range of faulted shallow-marine reservoirs. Analysis in the project will include application of the methods developed to three North Sea case-studies, which will be used to verify the main conclusions derived from a comprehensive suite of synthetic models. The scope of the project is to understand and quantify the sources of uncertainty which arise at each step in the modelling work-flow. The project is therefore a Research rather than Demonstration project, and will have the following benefits:

Quicker and cheaper geological characterisation

SAIGUP will provide methods for allowing identification of the key geological parameters likely to influence the production behaviour of a field based on generic properties of the field's geological characteristics. Therefore, results will lead to a reduction in the complexity of reservoir modelling programmes, and hence a reduction in the time spent on it. This will lead to more representative geological models being passed onto flow simulation, and earlier definition of the specific reservoir uncertainties.

Identification and quantification of the influence of key geological parameters will allow the logging, testing and characterisation programmes for appraisal and production wells to target aspects that are of most significance to the particular reservoir. This will result in more focused and cost-effective data collection and better-constrained geological models. Combined, these objectives will promote quicker and cheaper geological modelling, contributing to the RTD priority of reducing time to first oil from 3 to 2 years.

Quicker and better development decisions

SAIGUP will provide an objective framework for analysing production results as a function the geological reservoir architecture and the development plan. This framework will allow for quantitative comparisons to be made between particular production strategies for the reservoir, including quantitative descriptions of the forecast uncertainty associated with each strategy. A study of 72 UK offshore oil-fields shows that a 50% increase or decrease of the initially estimated reserves some years after production is common, and 6 fields show an increase in reserves of over 100% (Department of Trade and Industry, 1976-1998). These changes reflect both the geological uncertainties associated with production forecasting and the combined effects of the geology and production strategy on recovery. SAIGUP aims to provide a means of quantifying this uncertainty as a function of these factors. This will allow for more optimal strategies to be chosen, resulting in the need for fewer development wells and therefore an associated reduction in initial field development costs. A 10% reduction in the number of wells needed to extract the same reserves impacts not only on drilling costs, but also on the associated platform infrastructure.

A better understanding of both the uncertainty on particular geological parameters and the influence of these parameters on production will ensure that history-matching exercises are performed within an objectively defined *a-priori* geological parameter-space. While this will not eliminate the general problem of non-uniqueness from the history-matched solutions, it will ensure that the uncertainty associated with production forecasting is defined as a function of geological variables that have been objectively recognised to have the greatest influence. Greater confidence in the predictive capabilities of history-matched reservoir models will lead to better development decisions and more cost-effective recovery with increase recovery factors.

1.2. Innovation

Studies comparing recovery from fields with different geological characteristics have shown a broad negative correlation between recoverable oil and geological complexity (e.g. Tyler and Finlay, 1991; Corrigan, 1993), but these studies have not addressed the uncertainty in forecast recovery for the different reservoir types. Studies assessing the uncertainty in reserves estimates and production forecasts have been performed for individual reservoirs (.g. Lia *et al*. 1997; Floris et al. in press), but conclusions from these studies cannot be generalised to other reservoirs with different geological characteristics. Hence quantitative links between generic aspects of geology and uncertainty in production forecasts are not available. These links are a pre-requisite to the early identification and quantification of the most significant geological parameters that will impact flow within and production from different faulted clastic hydrocarbon reservoirs. The links, therefore, are a necessary basis for establishing optimal methods for including geological uncertainty in reservoir modelling studies.

SAIGUP is an in-depth investigation of the uncertainties which arise within the reservoir characterisation to production forecasting work-flow. The principal innovations associated with SAIGUP include:

Definition of geological parameter space

Defining sedimentological and structural geological complexity as a function of a continuously varying parameter-space provides a novel approach towards integrating geological knowledge within quantitative applications. To a non-geologist a description such as, for instance, a "fluvially dominated delta" provides little information, but once this definition is tied to probability density functions defining the location in parameter-space of fluvially dominated deltas, the description becomes of greater quantitative value. Defining a parsimonious parameter-space which captures the geological structure most significant to reservoir production behaviour is an objective of the project. The relationships between the modelling parameters included in standard stochastic geological software and position in parameter space will also be characterised. This will permit both identification of geological structure within, and the ability to generate models which populate, this continuous parameter-space.

Definition of the workflow

The proposed workflow is an inclusive investigation of the sources and levels of production uncertainty. Integration of all elements of the work-flow, from geological characterisation and modelling through up-scaling to production forecasting allows the different sources of uncertainty to propagate through the work-flow, and allows for the individual contributors to be identified and quantified. Uncertainty associated with each element in the work-flow has been studied previously, but a comprehensive analysis covering such a broad section of the reservoir characterisation work-flow has no precedent. This will be possible by constructing and simulating the models on a tightly designed "assembly line" comprising three research groups with expertise in different aspects of the problem, who have previous experience in working together within the work-flow.

Depth and breadth of the analysis

Quantitative uncertainty analyses have previously been performed on a field by field basis, providing only case specific conclusions. The proposed treatment in SAIGUP is generic, addressing a wide range of geological architectures such that the relative and absolute uncertainties on production and reserves estimates associated with the same types of geological structure within different overall geological architectures and development plans can be compared.

SAIGUP will produce a database linking geological, up-scaling method, development plan and production characteristics for approximately 1000 geologically realistic synthetic models. This database will provide a unique testing ground for existing and new static and dynamic heterogeneity measures - particularly as we can define these measures at any level of detail we choose.

Analytical methods

Analysis of the results will include the use of established and novel static and dynamic heterogeneity measures and dimensionless groups which will be defined and applied to the results to establish their ability to discriminate between geological architectures on the basis of production characteristics, and their ability to predict production characteristics as a function of the geological architecture. Simultaneous treatments of the different aspects of the model (geological properties, development properties and flow histories) will allow for the introduction of formal Bayesian optimisation methods within performance predictors, providing a method for introducing a more relevant geological context to what are, at present, largely statistical heterogeneity measures.

2 PROJECT WORKPLAN

2.1. Introduction

The project is separated into 5 technical work-packages and will be performed by a consortium comprising four university research groups, two applied research institutes, two oil company research groups and two geological modelling software companies. Tables 2.1 to 2.4 list the project work-packages, timing, and deliverables, and section 2.2 summarises the over-all work-plan. More technical details of the work-packages are given in Tables 2.5.1 to 2.5.6, while Tables 2.6.2 to 2.6.3 show the contributions per partner on a year by year basis.

2.2. Work plan summary

Work-package 1 will define the parameter-space within which the sensitivity analyses will be performed, within an up-lifted footwall top-reservoir structure containing the same overall gross-rock volume. Clastic hydrocarbon reservoirs have been classified qualitatively into several types in an attempt to reflect differing connectivity. A more quantitative classification can be made in terms of their horizontal and vertical heterogeneity distribution, which is a function of sandbody geometries, their 3-D architecture, the presence of 'permeability extreme' facies (e.g. cemented zones) and structural deformation. Different combinations of these features can be related to, and partially predicted from, an understanding of the sedimentology and time-stratigraphic setting (sequence stratigraphy) of the reservoir. Figure 1a summarises this classification scheme which is representative of many important hydrocarbon producing intervals in the EU.

The sedimentological and stratigraphic models will be based on a deltaic/shallow marine setting, which has the following advantages: (i) A full range of the required combinations of horizontal and vertical heterogeneity, in sedimentary systems which have a basic commonality, rather than choosing completely unrelated environments (such as aeolian, fluvial and turbidite). (ii) A well established and proven sequence stratigraphic framework into which the different relationships of vertical and horizontal heterogeneity can be placed. These different models can then be stacked into geologically realistic, sequence stratigraphically valid combinations. (iii) Ranges of reservoir architectures which cover many of the EU's major oil reservoirs in mature provinces, for which the challenge is to extract the remaining oil.

The 3-D models will be able to incorporate (a) fundamental reservoir and non-reservoir rock geometries (e.g. channel bodies, barrier-shoreface systems, clinoform surfaces), (b) accurate dimensions, orientations and stacking relationships/reservoir architecture and (c) distributions of facies-controlled permeability extremes (eg. zero permeability shales/cemented zones and high permeability valley-fills and distributary channels). The basis of our quantitative sedimentological classification of these relationships will be a continuous parameter space representing 3D anisotropy and heterogeneity levels (Figure 1a). An important part of WP1 is to define this parameter space as a function of the Gaussian and object-based modelling parameters used to generate the sedimentological architectures. Structural complexity is represented on Figure 1b, ranging from unfaulted to highly compartmentalised, with fault properties ranging from transmissive to sealing. The fault models will be similar in respect of the locations of the main faults, but simpler structures will be distinguished from complex structures by having lower fault displacements on the larger faults, and by the removal of smaller faults: this exercise will provide for varying complexity and connectivity of the fault network.

The main geological and flow modelling will be performed within Work Package 2. For 9 positions within the sedimentological parameter-space, an average of 10 geostatistical realisations will be generated at 2,000,000 cell-resolution; each conditioned to approximately 8 exploration and appraisal wells defined as a function of the geological architecture. Each of these 90 realisations will be up-scaled to 100,000 grid-blocks and combined with a structural realisation derived from one of nine positions within Figure 1b. The resultant 810 simulation models will be produced with a primary and enhanced production plan tailored to the geological characteristics of the reservoir. Recoverable reserves will be indexed to the economic field life of each model reservoir, and production histories retained for analysis in WP4. Two phases of modelling are planned in WP2: in Phase 1, the parameter space will be sampled in proportion to perceived geological complexity. Following the analysis of Phase 1 results in WP4, the density of sampling required to obtain statistically representative results will be known. Phase 2 models will be generated according to this result. This workflow will be automated and performed within a virtual office environment involving three of the partners (NR, NUID/UCD, ICSTM) and using commercial software (RMS, TransGen, Eclipse).

Work Package 3 will address the specific uncertainties introduced as a function of sedimentological and structural up-scaling, based on a selection of the models run in WP2. Sedimentological up-scaling uncertainty enters the model at both the scale of the geological model and the full-field simulation model. The cells in the geological model can be considered to represent, in terms of increasing definition, all of the following: a) the lithofacies type, b) the structure, sizes and orientations of laminae, c) the lamina permeabilities d) the wettability, which can be a function of lamina permeabilities. These properties are usually modelled implicitly within anisotropic cell properties, and their variability modelled using Gaussian random fields within the geological bodies. This assumption will be revisited, and different up-scaling methods used to define the geological-model scale cell pseudo-properties as a function of predefined lamina-scale properties. Up-scaling from the geological to the simulation model is a necessary step within WP 2, where it will be performed using standard routines incorporated in the RMS package. The implications of using these routines will be addressed in WP3 by using four alternative up-scaling methods on each of the pseudo-property solution models, to give a total of approximately 36 solutions for each of 9 sedimentological realisations. Fault-property up-scaling uncertainty arises as a function of assigning transmissibility multipliers at the scale of the simulation model. The sensitivity of this assumption on production will be addressed for a selection of geological models using a suite of approximately 50 full-field simulation models.

Work package 4 includes the main data analysis using multivariate statistics, followed by supplementary studies using formal inversion and optimisation methods. The dynamic results will be combined with quantitative summaries of the geological realisations and of the development plans in a relational database. Standard and novel static and dynamic heterogeneity measures will be derived and used to study the inter-relationships between geological characterisation, up-scaling method and production behaviour within each realisation and as a function of the geological parameter space defined in WP1. Results will be available for several realisations with the same overall geological characteristics, and the relative uncertainties attached to each geological variable at each position within the continuously varying geological parameter-space will be quantified. Relationships established using classical statistics methods will not only provide a direct measure of the production behaviour in relation to geological, up-scaling and production factors, but together with mapping of production responses in relation to geological parameter space also provides a firm basis for the testing and further development of formal inversion and optimisation methods. An important aspect of the project is the necessity of deriving results from which generic, rather than case specific conclusions can be drawn. Dynamic heterogeneity measures and dimensionless parameter groups incorporating details of the development plan as well as of the geological architecture will be tested for their predictive and discriminatory capabilities.

The concepts developed throughout the project; in particular the streamlined numerical work-flow defined in WP1 and implemented in WP2, and the predictive analytical methods developed in WP4 will be tested on three geologically diverse North Sea reservoirs in WP5. The three fields will placed within the geological parameter space, and treated to a full uncertainty quantification analysis using their historical development plans. The results of the reservoir studies will be compared with results from the large suite of geological models to test our principal technical findings and analytical methods.

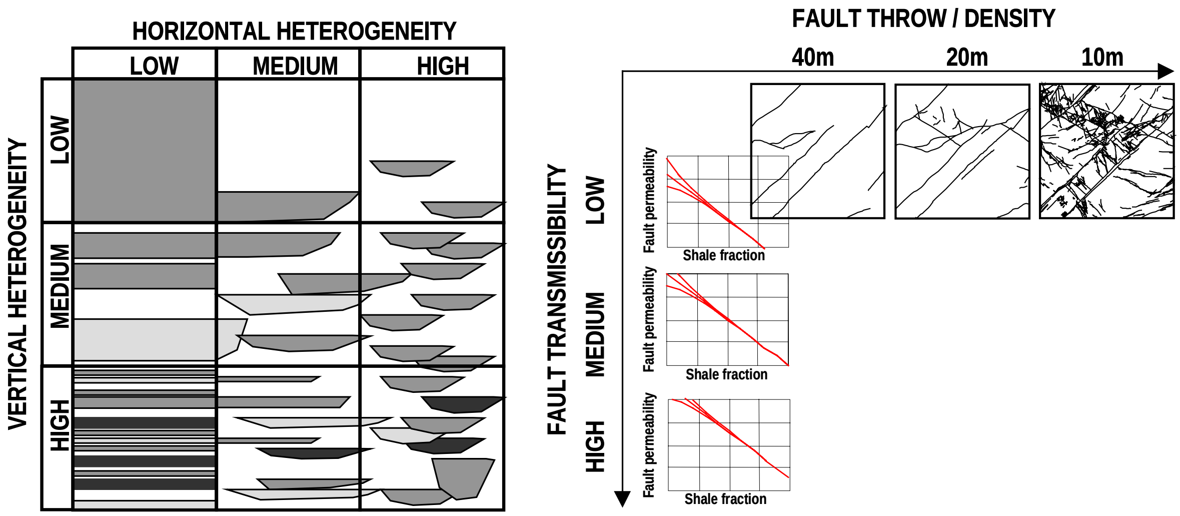


Figure 1. a) Matrix of sedimentological complexity (after Tyler and Finlay, 1991). b) Matrix of structural complexity: fault transmissibility vs. Lower limit of fault inclusion (Manzocchi et al. 1999). These 2D representations of continuously varying architecture provide the basis for a quantitative definition of geological parameter-space.

2.3. Anticipated Project results

The principal milestones concern i) delivery of the flow modelling results (months 15, 18 and 27), ii) the analysis of the results (month 33), and iii) the uncertainty analyses of the field data (month 33). Expected results are i) quantification of the relative and absolute influences of sedimentology, structure and up-scaling on reserves estimation and production forecasting from reservoirs with different sedimentological and structural properties, and ii) definition of geologically relevant dynamic and static heterogeneity measures and dimensionless groups for improved production forecasting in faulted clastic reservoirs. Further details of the anticipated project results, and of potential exploitation of these results, are discussed in Section 3.

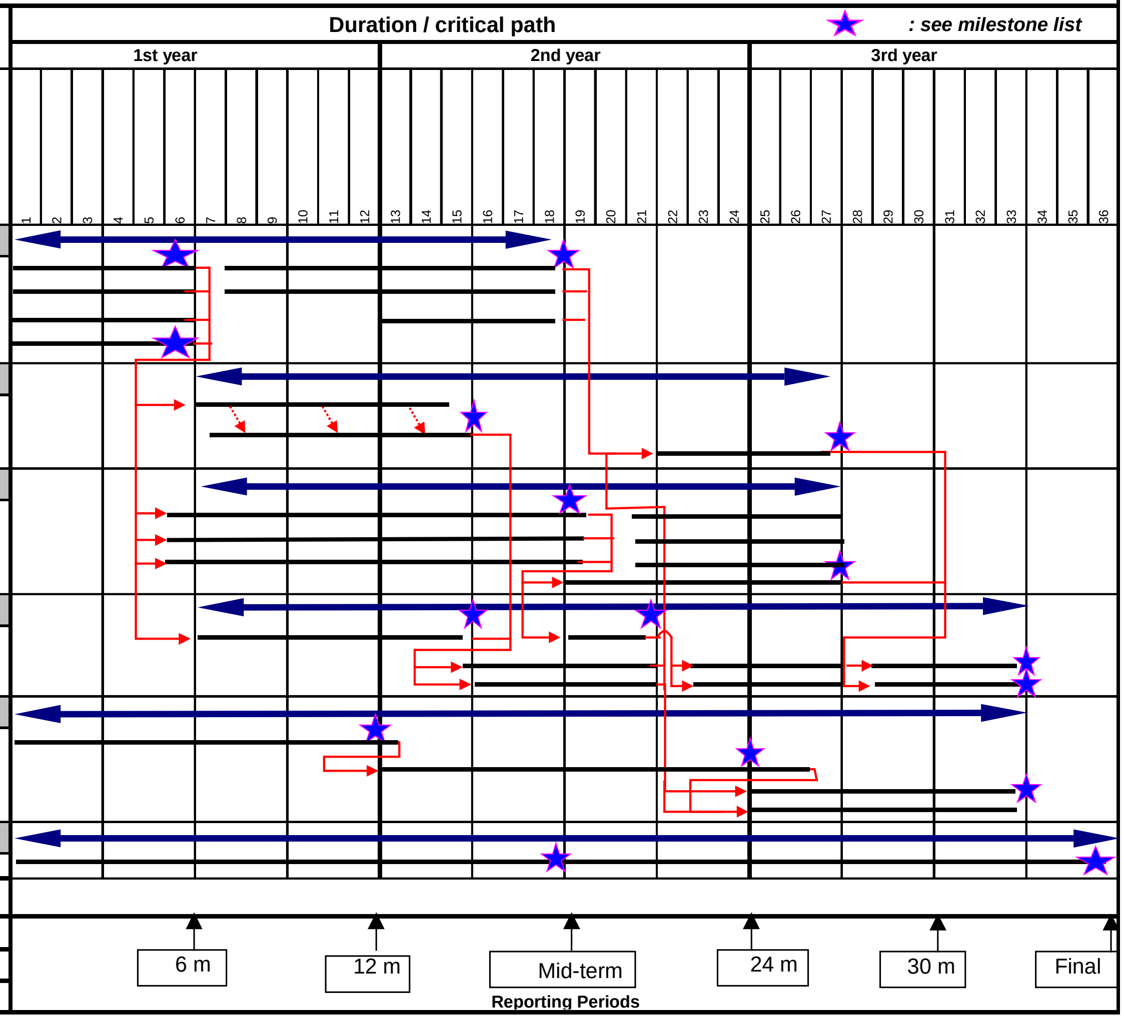
2.4. Project risks

There are no risks associated with the implementation of the modelling workflow proposed, which will apply, and where necessary streamline and improve, the current state-of-the-art reservoir modelling to production simulation work-flow. The number of flow simulation models to be processed is ambitious but, we believe, realistic. It may be, however, that this number is insufficient to characterise fully the production uncertainty associated with the full geological parameter-space we wish to study, and this is perceived to be the main project risk. Such a result in itself would be significant, as it addresses the unanswered question of how many realisations are required to characterise the behaviour of a reservoir. If we find that this is the case, then the scope of the Phase 2 models (see Table 2.5.2) will be towards a reduced parameter-space.

Table 2.1 SAIGUP - Project planning and timetable

WORKPACKAGE / MANPOWER BARCHART

Workpackage descriptions	TOTAL permanent	TOTAL additional
WP 1: Model definition	**5.8**	**32.1**
Task 1.1 Sedimentological parameterisation	4	12
Task 1.2 Structural parameterisation		8
Task 1.3 Engineering parameterisation	0.9	3
Task 1.4 Work-flow definition	0.9	9.1
WP2: Geological uncertainty modelling	**3.7**	**36.4**
Task 2.1 Model construction Phase 1	1	15.3
Task 2.2 Production simuation Phase 1	1.5	10.3
Task 2.3 Construction and Simulation Phase 2	1.2	10.8
WP3: Up-scaling uncertainty modelling	**5**	**36.8**
Task 3.1 Small-scale up-scaling	2	9.5
Task 3.2 Large-scale up-scaling	2	12
Task 3.3 Fault property up-scaling		9.3
Task 3.4 Sensitivity assessment	1	6
WP4: Sensitivity analysis	**4.3**	**41.8**
Task 4.1 Relational database construction	1	9
Task 4.2 Statistical analysis	0.5	15.3
Task 4.3 Comparative parametrisation	2.8	17.5
WP 5: Application to real datasets	**3**	**45.6**
Task 5.1 Data collection	1	7.1
Task 5.2 Sensitivity analysis	1	19.6
Task 5.3 Comparison to model results	1	11.4
Task 5.4 Production forecasting		7.5
WP 6: Mangement	**3**	**6**
Task 6.1 Project management	3	6
TOTAL PERSON MONTHS:	**24.8**	**198.7**
In year 1	8.3	67.7
In year 2	8.2	68.5
In year 3	8.3	62.5



NB: Permanent man-power allocations are those for permament staff, including academic and technidican, time at Univeristies.
An EU contribition is requested only for additional staff time for these partners.

Table 2.2 SAIGUP - Graphical representation of the projects components

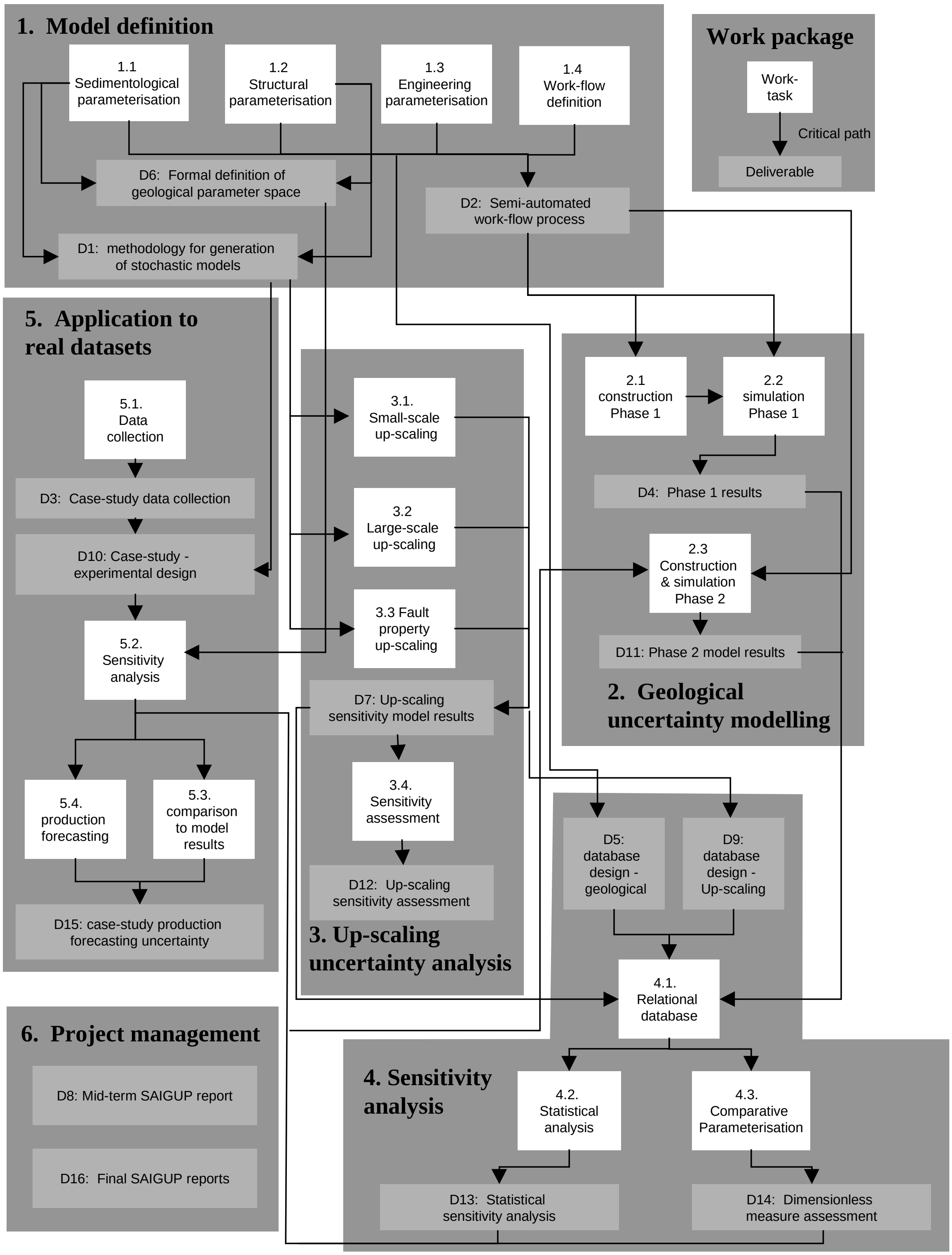


Table 2.3 SAIGUP - List of work packages

Work package No[1]	Work package title	Work package leader No[2]	Person-months[3]	Start month[4]	End month[5]	Deliverable No
1	Model definition	10: UL	32.1 + 5.8	1	18	D1, D2, D6
2	Geological uncertainty modelling	4: ICSTM	36.4 + 3.7	7	27	D4, D11
3	Up-scaling uncertainty modelling	3: HWU	36.8 + 5	7	27	D7, D12
4	Sensitivity analysis	2: NR	41.8 + 4.3	7	33	D5, D9, D13, D14
5	Application to real datasets	6: Badleys	45.6 + 3	1	33	D3, D10, D12
6	Project management	1: NUID/UCD	6 + 3	1	36	D8, D16
	TOTAL		198.7 + 24.8			

[1] Work package number: WP 1 – WP n.
[2] Number of the participant leading the work in this work package (ref. Form A3).
[3] The total number of person-months allocated to each work package. These number are given as additional staff + permanent staff
[4] Relative start date for the work in the specific work packages, month 0 marking the start of the project, and all other start dates being relative to this start date.
[5] Relative end date, month 0 marking the start of the project, and all end dates being relative to this start date.

Table 2.4 SAIGUP - Deliverables list

Deliverable No[6]	Deliverable title	Delivery date[7]	Dissemination level[8]
D1 (WP1)	Methodology for generation of stochastic models.	6	PU
D2 (WP1)	Semi-automated process of work-flow.	6	PU
D3 (WP5)	Case-study data collection.	12	RE
D4 (WP2)	Phase 1 model results.	15	PU
D5 (WP4)	Relational database design for geological parameterisation.	15	PU
D6 (WP1)	Formal definition of geological parameter-space.	18	PU
D7 (WP3)	Up-scaling sensitivity model results.	18	PU
D8 (WP6)	Mid-term SAIGUP report and preliminary TIP	18	PU / RE
D9 (WP4)	Relational database design for up-scaling parameterisation.	21	PU
D10 (WP5)	Case study experimental design.	24	RE
D11 (WP2)	Phase 2 model results.	27	PU
D12 (WP3)	Up-scaling sensitivity assessment.	27	PU
D13 (WP4)	Statistical sensitivity analysis.	33	PU
D14 (WP4)	Dimensionless parameters and heterogeneity measure assessment.	33	PU
D15 (WP5)	Case-study production forecasting uncertainty.	33	RE
D16 (WP6)	Final SAIGUP reports, Project seminar and Final TIP	36	PU / RE

[6] Deliverable numbers in order of delivery dates: D1 – Dn
[7] Month in which the deliverable will be available. Month 0 marking the start of the project, and all delivery dates being relative to this start date.
[8] Please indicate the dissemination level using one of the following codes:
PU = Public
RE = Restricted to a group specified by the consortium (including the Commission Services).
CO = Confidential, only for members of the consortium (including the Commission Services).

Table 2.5.1 SAIGUP: Work package 1 - Model definition

Work package No[9] : 1	**Start month[10]: 1**		**End month[11]: 18**				
Work package title: **Model definition**							
	Work package Leader (No) :	**Other participants with major involvement**					
Participant No :	UL	NUID/ UCD	HWU	ICSTM	NITG-TNO	Badleys	ROXAR
Person-months per participant: (additional + permanent staff time)	9 + 4.5	8	1	4+1.3	3	1	6.1

Objectives
(i) Definition of the sedimentological, structural and engineering parameters for the generation of 2,000,000 cell reservoir models covering a broad range of normally faulted shallow marine reservoir architectures.
(ii) Definition and implementation of the assembly line upon which the several hundred reservoir flow models will be processed through the geological modelling, up-scaling, and simulation phase of WP2 and 3.

Description of work (with sub-task titles where appropriate)

1.1: Definition of the stochastic modelling parameterisation required to generate sedimentological models varying from relatively simple architectures, characterised by low horizontal and vertical heterogeneity, through to more complex architectures, with high levels of heterogeneity. Reservoir thickness will be kept constant, but parameters such as net:gross will, necessarily, show a decrease from simple to complex sedimentary architectures.
1.2: Definition and generation of a suite of uplifted footwall top-reservoir structure models (typical of many Brent-type reservoirs, for example), providing the same structural closure and gross-rock volume but characterised by a range of fault densities/ displacements and fault properties. The fault models will be similar in respect of the locations of the main faults, but simpler structures will be distinguished from complex structures by having lower fault displacements on the larger faults, and by the removal of smaller faults, therefore providing variations in the complexity and connectivity of the fault network. The hydraulic properties of faults will also be varied from those impacting only the geometric juxtaposition of the reservoir sequence, through to those characterised by low (-zero) fault rock permeabilities.
1.3: Quantification of the impact of geology on reservoir production requires placing limits on, and some uniformity of, the underlying engineering properties and the production plan used for the flow modelling. This sub-task will define the engineering properties of the model (e.g. oil PVT properties, well placements and completions) which vary as a function primarily of the structural characteristics of the reservoir.
1.4: Definition and implementation of the assembly line upon which the several hundred models will be processed between partners for generation, up-scaling, and simulation. Much of this workflow will be automated, since each step is now implemented in existing software.

Deliverables

D1 Methodology for the generation of stochastic models (Month 6).
D2 Semi-automation of the work-flow for the generation, up-scaling and simulation of reservoir flow models (Month 6).
D6 Formal definition of geological architectures as a-priori probability density functions within a continuous parameter-space. (Month 18).

Milestones and expected results

Month 6 Semi-automation of the work-flow for the generation, up-scaling and simulation of reservoir flow.
Month 18 Implementation of objective methodology for the parameterisation of stochastic models, including model objects, to provide the broad range of both sedimentological and structural complexity.

[9] Work package number: WP 1 – WP n.
[10] Relative start date for the work in the specific work packages, month 0 marking the start of the project, and all other start dates being relative to this start date.
[11] Relative end date, month 0 marking the start of the project, and all end dates being relative to this start date.

Table 2.5.2 SAIGUP: Work package 2 Geological uncertainty modelling

Work package No[12] : 2	**Start month[13]: 7**		**End month[14]: 27**			
Work package title: Geological uncertainty modelling						
	Work package Leader (No) :	**Other participants with major involvement**				
Participant No :	ICSTM	NUID/ UCD	NR	NITG-TNO	ROXAR	UL
Person-months per participant: (additional + permanent staff time)	11.6 + 2.2	6.3	9.5	3	3	3 + 1.5

Objectives

To build, up-scale and simulate production within approximately 800 models containing geologically quantified sedimentological and structural heterogeneity.

Description of work (with sub-task titles where appropriate)

2.1: Model construction Phase 1. Multiple stochastic realisations will be generated for each of the nine sedimentological architecture types defined in WP1. Figure 1a is presented as a discrete matrix, but in reality represent a continuum. Many of the systems represented in the matrix cannot be modelled using purely Gaussian random fields, and object-based methods must be used for the geologically more complex portions of the matrix. The stochastic variability used to generate the realisations at each of the nine positions in the matrix will be sufficiently broad that the final models will represent a continuum of heterogeneity levels. The realisations will be examined *a posteriori* to determine the heterogeneity levels, and these levels will overlap, to provide a final continuous distribution of heterogeneity and anisotropy levels. Each realisation will be up-scaled using commercially available software and each up-scaled sedimentological realisation will be combined with each of the nine structural realisations. A total of approximately 400 models will be processed in Phase 1.

2.2: Appropriate (clusters of) primary and secondary production strategies will be defined for each of the sedimentological and structural types. Full-field flow simulation will be performed covering a 20-year production history for each model. Production histories will be compared on a well by well and on a model by model basis to address the spatial variability in performance of individual realisations as well as comparisons between realisations and geology. Recoverable reserves will be indexed to the economic field life of each model reservoir.

2.3: Model construction and simulation Phase 2. The number of initial sedimentological realisations required to fully characterise the variation in reserves for any particular sedimentological/structural combination will increase as a function of geological complexity. As the objective of WP 2 is to generate sufficient data to quantify this variation, additional realisations will be processed until the reserves uncertainty is quantified in a statistically robust manner. If the results from WP 4.2 indicate that this requires an unfeasible number of simulation models for the full 9x9 parameter matrix, then the focus will shift to particular combinations within the full parameter space. A further 400 models will be analysed in Phase 2.

Deliverables

D4 Phase 1 modelling completed. Geological, development and production parameters ready for database (Month 15)
D11 Phase 2 modelling completed. Geological, development and production parameters ready for database (Month 27)

Milestones and expected results

Month 15 400 synthetic full-field production simulation results prepared for charactersation in WP 4.
Month 27 A further 400 sets of results completed, allowing characterisation of production and reserves uncertainty within the predefined geological parameter-space.

[12] Work package number: WP 1 – WP n.
[13] Relative start date for the work in the specific work packages, month 0 marking the start of the project, and all other start dates being relative to this start date.
[14] Relative end date, month 0 marking the start of the project, and all end dates being relative to this start date.

Table 2.5.3 SAIGUP: Work package 3 Up-scaling uncertainty modelling

Work package No[15] : 3	**Start month[16]: 7**	**End month[17]: 27**			
Work package title: Up-scaling uncertainty modelling					
	Work package Leader (No) :	**Other participants with major involvement**			
Participant No :	HWU	NUID/UCD	NR	Badleys	UL
Person-months per participant: (additional + permanent staff time)	21+3	5.3	2.5	4	4 + 2

Objectives

(i) To apply diverse up-scaling methods on 9 of the models used in WP2, to produce and simulate production in approximately 200 models.

(ii) To quantify the influence of up-scaling sedimentological and structural properties and architectures on reserves and production uncertainty for diverse cases of geological heterogeneity.

Description of work (with sub-task titles where appropriate)

3.1: Small scale up-scaling. Uncertainty due to up-scaling enters the model at both the scale of the geological model and the full-field simulation model. A representative realisation will be selected for each of the nine sedimentological architectures. Different distributions of lamina- and bed-scale permeability contrast and capillary pressure within each facies (sedimentological facies are indexed to fine scale model grid-blocks) will be modelled, and these used to give approximately four different sets of relative permeability functions for each fine scale geological model.

3.2: Large-scale up-scaling. Up-scaling to the flow simulator scale is uncertain, owing to the boundary conditions which must be imposed on the volume which is being up-scaled. Four up-scaling methods (Kyte and Berry, steady state, Stone and a streamline-based method) will be applied to each of the 36 fine-scale models generated. Simulate production for these 150 models using the production plans defined in WP 2.2.

3.3: Fault-property up-scaling uncertainty arises as a function of the correlation lengths assumed for the fault heterogeneity, and the presence and frequency of fault relay structures. The sensitivity on production of small-scale fault structure will be addressed for a selection of sedimentological architectures using a suite of approximately 50 full-field simulation models. These models will be generated using the "TransGen" package at the scale of the flow simulation model. Simulate production using the production plans defined in WP 2.2.

3.4: Determination and quantification of the sources of up-scaling imprecision as a function of geological architecture and production strategy for different up-scaling methods.

Deliverables

D7 Up-scaling sensitivity modelling completed. Up-scaling, geological, development and production parameters ready for database (Month 18).

D12 Independent up-scaling sensitivity assessment (Month 27).

Milestones and expected results

Month 18 300 full-field production simulation results prepared for charactersation in WP 4.

Month 27 Identification of the optimal up-scaling algorithms for different dynamic and geological properties.

[15] Work package number: WP 1 – WP n.

[16] Relative start date for the work in the specific work packages, month 0 marking the start of the project, and all other start dates being relative to this start date.

[17] Relative end date, month 0 marking the start of the project, and all end dates being relative to this start date.

Table 2.5.4 SAIGUP: Work package 4 - Sensitivity Analysis

Work package No[18] : 4	Start month[19]: 7		End month[20]: 33			
Work package title: Sensitivity analysis							

	Work package Leader (No) :	Other participants with major involvement					
Participant No :	**NR**	**NUID /UCD**	**HWU**	**ICSTM**	**NITG-TNO**	**ROXAR**	**UL**
Person-months per participant: (additional + permanent staff time)	**7**	**6.3**	**2.4**	**6.2+1.8**	**12**	**2.9**	**5 + 2.5**

Objectives

(i) To quantify objectively the absolute and relative influences of sedimentological, structural and up-scaling uncertainty on reserves estimates for generic faulted clastic reservoirs.

(ii) To derive dimensionless groups and heterogeneity measure able to discriminate between geological characteristics on the basis of production data, and to predict the production characteristics from geological data.

Description of work (with sub-task titles where appropriate)

4.1: Relational database construction. The results from the models will be combined into a relational database. *A priori* characteristics will include the stochastic modelling parameters used to generate the realisations. For parameters describing the distributions of geological bodies modelled as discrete stochastic objects these include facies proportions and distributions, shale body, fault or channel size, shape and orientation distributions. Properties (permeability, porosity and saturation) within bodies will be modelled as Gaussian random fields for which means, standard deviations, correlation lengths, anisotropies etc. will be recorded. *A posteriori* analysis of the realisations will allow more global reservoir properties to be back-calculated, e.g. shale or channel connectivity, bulk property distributions and anisotropies, from which heterogeneity measures (e.g. Lorenz coefficient, Gelhar-Axness coefficient) will be determined. Oil production and water-cut curves will be included for each well, as well as cumulative oil production, and oil recovery factors for the whole reservoir.

4.2: Multivariate statistical analysis of the database. Analysis in 4.2. will focus on the purely statistical characteristics of the database; this is to say that no physical or geological understanding of the system will be included in the analytical methods which seek to establish the levels and origins of production uncertainty with respect to the full modelling space. The relative significance of each parameter used in the geostatistical definition of the models on production and production uncertainty will be determined. The analysis on the initial batch of model results will be used to identify which particular parameters require focused attention for the Phase 2 of intense numerical modelling (Task 2.3).

4.3: Analysis in 4.3 will focus on the use of dimensionless parameters and dynamic heterogeneity measures incorporating details of the geological complexity and of the production plan (e.g. correlation length / well spacing, correlation azimuth / global streamline azimuth) to allow generic conclusions to be drawn linking geological complexity to reserves sensitivity: we will identify what are the most important production data to collect to distinguish between the various geologies. This discriminatory analysis will include the formalisation of objective methodologies (inversion and optimisation schemes) for comparing parameters describing geological complexity and parameters describing the development plan. Examination of the sensitivity of production forecasting to production planning will be investigated for selected reservoir types and for a small suite of production scenarios.

Deliverables

D5, D9 Relational database designed for inclusion of geological, production, development-plan and up-scaling method parameters. (Months 15 &21).

D13 Multivariate statistical sensitivity analysis (Month 33).

D14 Dimensionless parameter and heterogeneity measure assessment (Month 33).

Milestones and expected results

Month 15 Phase 1 results available for analysis. **Month 21** Parameter-space sampling defined for Phase 2 models. **Month 33** Analyses completed.

[18] Work package number: WP 1 – WP n.

[19] Relative start date for the work in the specific work packages, month 0 marking the start of the project, and all other start dates being relative to this start date.

[20] Relative end date, month 0 marking the start of the project, and all end dates being relative to this start date.

Table 2.5.5 SAIGUP: Work package 5 - Application to real data

Work package No[21] : 5	**Start month[22]: 1**	**End month[23]: 33**			
Work package title: Application to real datasets					
	Work package Leader (No) :	**Other participants with major involvement**			
Participant No :	**Badleys**	**NUID/UCD**	**NR**	**HWU**	**NITG-TNO**
Person-months per participant:	**4**	**5**	**11.4**	**2**	**6**
Participant No :		**BG**	**ROXAR**	**SIEP**	**UL**
Person-months per participant:		**3.1**	**6**	**2.1**	**6+3**

Objectives

(i) To perform production forecast and uncertainty analyses on three North Sea reservoirs.
(ii) To verify the results and conclusions derived from the synthetic models using real-case examples.

Description of work (with sub-task titles where appropriate)

5.1: Data collection. The reservoir geological and production data will be provided by the partners. One dataset will the Gullfaks field, which is characteristic of high structural complexity and depending on the reservoir unit concerned varying sedimentological complexity. The second and third datasets are North Sea reservoirs which are relatively simple sedimentologically, but one is structurally relatively simple, the other quite complex.
5.2: Sensitivity analysis. Use existing and build new reservoir geological and flow simulation models for the reservoirs. For each dataset, analyse the geological parameter uncertainty and perturb these within up-scaled simulation models to find the sensitivity of each on production and reserves. Using existing production data from these reservoirs we will examine how the production history varies with complexity of sedimentology and structure.
5.3: Comparison of real cases to model results. A crucial element of this work package is to compare the main results of the reservoir studies and those of the large suite of geological models. This comparison will represent a test of our principal technical findings.
5.4: Production forecasting. Using both model results and reservoir data, outline uncertainties in production forecasting for real datasets.
Interpretation with respect to full parameter space. An examination the results of the 3 case studies with respect to predictions made as a function of their positions within the continuous heterogeneity matrices will allow demonstration of the global applicability of the results from WP 2 to WP 4.

Deliverables

D3 Sedimentological, structural and production history data provided to the consortium (Month 12).
D10 Experimental design for the case studies (Month 24).
D15 Production forecasting uncertainty analyses (Month 33).

Milestones and expected results

Month 12 Complete reservoir data available for analysis.
Month 24 Production simulation models built and *a-priori* geological uncertainty defined.
Month 33 Production forecasts and comparison of results to main conclusions.

[21] Work package number: WP 1 – WP n.
[22] Relative start date for the work in the specific work packages, month 0 marking the start of the project, and all other start dates being relative to this start date.
[23] Relative end date, month 0 marking the start of the project, and all end dates being relative to this start date.

Table 2.5.6 SAIGUP: Work package 6 - Project management

Work package No[24] : 6	**Start month[25]: 1**	**End month[26]: 36**			
Work package title: Project management					
	Work package Leader (No) :	**Other participants with major involvement**			
Participant No :	**NUID/UCD**				
Person-months per participant: (additional + permanent staff time)	**6 + 3**				

Objectives
(i) Plan and manage the project within schedule and resources.
(ii) Ensure adequate communication and interaction between the project partners.

Description of work (with sub-task titles where appropriate)

Established procedures will be employed throughout the project for maintaining high technical quality while controlling project costs and progress.

Plan project meeting and ensure that agendas and minutes reflect the needs and decisions of the consortium.

Monitor the project progress and identify and implement key actions needed for the smooth progression of the research programme.

Distribute project funds to the partners in accordance with the EU guidelines.

Encourage dissemination of project results.

Identify avenues for the commercial development of the project methodologies and results.

Liaise with EU, and deliver interim reports.

Compile final report and arrange technical seminar.

Deliverables
D8 Mid-term SAIGUP technical and implementation reports (Month 18).
D16 Final SAIGUP technical and implementation reports and project seminar (Month 36).

Milestones and expected results
Month 18 Mid-term progress review.
Month 36 Presentation of final results and technology implementation plan.

[24] Work package number: WP 1 – WP n.
[25] Relative start date for the work in the specific work packages, month 0 marking the start of the project, and all other start dates being relative to this start date.
[26] Relative end date, month 0 marking the start of the project, and all end dates being relative to this start date.

3. SCIENTIFIC AND TECHNICAL PROSPECTS

3.1. Application

The project will define generic links between uncertainty in geological charcterisation with uncertainty in production forecasting for a broad range of clastic reservoirs. We expect these results to contribute towards an improvement in the planning and execution of geological reservoir modelling programs, and towards a reduction in the economic risk associated with field development. The principal beneficiaries of SAIGUP will be oil companies, associated support companies and governmental regulatory bodies, however aspects of the research are applicable to other industries within the geo-sector. These include the groundwater and mineral (including coal) sectors which make use of risk assessment within geological systems.

3.2 Exploitation

Intellectual property rights arising from the research will remain with the partners who perform the research, but it is agreed by partners that all results from WP1 to WP4 will be publishable and remain in the public domain. Generic findings from the studies of propriety data (WP5) will be publishable, but will require the permission of the oil-company partners.

SAIGUP is a research project, and as such it is premature to speak of direct exploitation of the main project results in a commercial sense. Exploitation of the project results, through an integrated geological and production uncertainty management system, will require software development which can only be planned and initiated towards or after the end of the project as we cannot pre-empt the project results.

The streamlined workflow the projected modelling will follow will necessarily identify shortcomings and inadequacies in existing software which will need to be overcome within the project. All research code developed within the project for streamlining the work-flow and enhancing the modelling will be made available to other project partners who request it, and the software companies will have the opportunity for incorporating these developments within their modelling products. Three areas in particular have potential for enhanced capability of existing modelling packages:

(i) By defining quantitative links between sedimentological parameter-space and particular tools within stochastic modelling packages (WP1), the stochastic modelling process may be defined in a more generic fashion than is currently available. Stochastic reservoir models are built using the tools available within the modelling software, and the ways, quantities and order in which these tools are combined determines the architecture of the reservoir model. SAIGUP will define "recipes" for sedimentological architectures, and identify new tools necessary for particular architectures. Roxar, through their RMS v6.0 software (incorporating the functionality of the obsolescent software STORM) are optimally placed for incorporation in software of these developments.

(ii) Incorporation of fault properties in high-resolution geo-cellular models. In accordance with the work-flow detailed in WP2, fault properties will be added to the models once their sedimentological properties have been up-scaled. This is the current state-of-the-art, and will be performed using Badley's new TransGen product. The objective of task 3.3 is to investigate methods for improving this state-of-the-art, by dealing with fault properties at the scale of the geo-cellular model, rather than that of the flow model. RMS already has the functionality to incorporate fault surface information from Badley's FAPS software, and an anticipated development to be performed within SAIGUP is the operation of TransGen functionality on RMS models.

(iii) The third main area for software advances relies more directly on the successful outcome of the project research, and is probably the most innovative. In WP4, existing and new static and dynamic heterogeneity measures will be tested against production results, for their ability to discriminate between geological architectures and to predict production characteristics. Determination of these measures will require new software development in the project to simultaneously interrogate the geocellular, structural and flow models. This will be research code in the first instance, but there is certainly potential for commercial exploitation should the project results confirm the predictive value of these methods.

3.3. Dissemination

With the exception of the case-studies (WP5), all results will be in the public domain. The case-study results, particularly those of a generic rather than case specific nature will become public with the permission of the two oil company partners who make this data available to the partnership. Results from the other packages will be disseminated by presentation at conferences, by publication in scientific journals and by incorporation in software.

The nature of the research is reflected in the multidisciplinary scientific background of the consortium. Members of the consortium already present and publish in a range of specialist and general meetings and journals. This will ensure that SAIGUP results are presented in discipline-specific (e.g. geostatistics, sedimentology, structural geology, uncertainty management) conferences and journals as well as in those directed to a broader petroleum (e.g. EAGE, SPE) audience.

Towards the end of the project, SAIGUP plan to host a conference session or workshop at the EAGE Annual conference. This session will allow the results to be presented to a wide audience as an integrated whole, backed by the technical conclusions from various aspects of the project and by case-studies presented by members of the consortium and by others. This event will allow both the breadth and depth of the results to be presented orally at a level comparable with the final project report. Arrangements for this session will be the responsibility of the co-ordinator.

The co-ordinator will be responsible for managing the project web-site, which will contain both a public access area containing general information and pre-publication results from the project, and a private, password-protected area containing progress reports and information for the project participants. After the project end, the relational database containing the model details and results will be linked to the web-site and made available to any interested party.

Roxar and Badley's will be responsible for the inclusion of the results in software, discussed above. This will not only contribute towards the dissemination of the results, but also ensure technology transfer of the methods developed to the wider petroleum community.

Dissemination of the results will also be achieved by the two oil company partners through the case-studies. Oil companies are the principal end-users of the research, and their direct involvement in the application to case-studies of the SAIGUP results will facilitate technology transfer; as will the adoption of the methods by the two service companies in their capacity as consultants to the industry.

4 PROJECT MANAGEMENT

The purpose of the project management is to deliver a final product of high technical quality which matches the stated objectives within the time and budget proposed. The project plan, which is summarised on the Gantt chart on Table 2.1, is detailed on a year-by-year basis on Tables 4.1.2 to 4.1.4. The first four work-packages are intimately linked, requiring strict project planning. Many tasks in these packages rely on deliverables from other tasks, and the timing of these milestones are particularly important. Each milestone has an associated deliverable which falls into one of three classes:

a) Methodological deliverables, which improve the work-flow, refine the definition of the parameter-space or define predictive and discriminatory statistics.

b) Model input and results which are to be incorporated into the relational database and upon which the analytical work-packages rely.

c) Conclusions from the analyses of the synthetic and case-study results.

4.1. Management structure

Project management resides with a management team consisting of the work package leaders (Table 2.3), chaired by the project coordinator. The partner representatives also play an important role in ensuring that the communications channels are broad.

The project coordinator carries the overall responsibility, he is also the primary contact with the Commission. The coordinator carries the responsibility of distributing project funds to the partners in accordance to the EU guidelines. The coordinator takes control in situations where no consensus can be reached; he tries to do so by majority voting between the partner representatives. When necessary, the coordinator will take a decision himself, if needed after consulting experts not belonging to the consortium and/or the Commission. The coordinator also carries end responsibility over project costs and progress. If the course of the project must change significantly, the coordinator will consult all participants and, if necessary, the Commission.

The work package leaders stay in contact with the collaborating participants' scientific officers, and have the responsibility for monitoring the progress of each work-task. They are free to solve problems within the packages and between the packages, and they will so inform the coordinator. It is important that communications between researchers involved in the same work-tasks are copied to the work-package leader so that he is aware of the work-package progress. It is the responsibility of the work-package leader to identify as early as possible any technical, scheduling or financial problems, so these can be resolved as soon possible.

In addition to being the recognised point of reference, the partner representative has a back-up role to the work-package leader in terms of ensuring that problems are identified and resolved quickly. All communications between researchers will be copied to their partner representatives.

4.2. Managerial milestones and assessment criteria

An essential element concerns the assessment of the project in terms of deliverables and the quality of these in view of the project's objectives. Apart from the assessment on the basis of the workpackage deliverables, two major assessment milestones have been defined: a mid-project evaluation and a final one. The central question in these assessments is in how far the project realises its objectives and what the implications of the research are towards further development and exploitation of the results.

The mid-term milestone is critical: by this time it is planned that Phase 1 of the synthetic reservoir modelling for geological sensitivity and the up-scaling sensitivity runs should have been completed, and the focus of the project will shift at this point from modelling and generation of results, to the statistical analysis and the development and testing of predictive measures. There is still a considerable amount of modelling planned in the second 18-month period, notably Phase 2 of the synthetic modelling, however by mid-term sufficient results should be available in the database for the analytical research programme (tasks 4.2 and 4.3) to commence in earnest.

4.3. Project monitoring

Project meetings will be held every 6 months with an additional kick-off meeting at the project start. 6-month progress reports will be submitted to the coordinator one month before each meeting; these will be collated and circulated to all partners at least one week before the meeting. All Partners therefore will have the latest updates on each partners progress allowing for informed discussion and assessment of technical aspects of the progress of the project. In addition, participants will be encouraged to post progress reports, results and queries on the project web-site, which provides a less formal environment for intra-project discussion and dissemination.

The progress of the project will be monitored by checking the actual progress against the work-plan. Participants have the obligation to inform the coordinator, as soon as possible, about problems that may affect the project's timing and deliverables. On the other hand, the coordinator will regularly contact the other scientific project leaders in order to detect possible execution problems and delays, and where possible to redistribute (sub)tasks. This complements the normal management reporting which serve to see what tasks and workpackages are within the planning and which are not. Furthermore, the coordinator has to foresee possible failings and he will develop alternatives if certain parts of the project do go wrong.

Apart these more formal forums of communication, the participants take care of communication within and between work packages, as defined in Section 2. It is the duty of the coordinator to check whether communication is indeed sufficient.

Table 4.1.1 SAIGUP Integrated manpower matrix

	NUID/UCD		NR	HWU		ICSTM		TNO	Badleys	BG	ROXAR	SIEP	UL		TOTAL
Staff type (Additional A or Permanent P)	A	P		A	P	A	P						A	P	
WP 1: Model definition															**37.9**
Task 1.1 Sedimentological parameterisation								3			1		8	4	16
Task 1.2 Structural parameterisation	7								1						8
Task 1.3 Engineering parameterisation						3	0.9								3.9
Task 1.4 Work-flow definition	1			1		1	0.4				5.1		1	0.5	10
WP2: Geological uncertainty modelling															**40.1**
Task 2.1 Model construction Phase 1	4.3		7.0								2		2	1	16.3
Task 2.2 Production simuation Phase 1						7.3	1.5	3							11.8
Task 2.3 Construction and Simulation Phase 2	2		2.5			4.3	0.7				1		1	0.5	12
WP3: Up-scaling uncertainty modelling															**41.8**
Task 3.1 Small-scale up-scaling				7.5	1								2	1	11.5
Task 3.2 Large-scale up-scaling			2.5	7.5	1								2	1	14
Task 3.3 Fault property up-scaling	5.3								4						9.3
Task 3.4 Sensitivity assessment				6	1										7
WP4: Sensitivity analysis															**46.1**
Task 4.1 Relational database construction	3							4					2	1	10
Task 4.2 Statistical analysis	1		4.0	2.4				4			2.9		1	0.5	15.8
Task 4.3 Comparative parametrisation	2.3		3.0			6.2	1.8	4					2	1	20.3
WP 5: Application to real datasets															**48.6**
Task 5.1 Data collection	1		2.0							1.1		1	2	1	8.1
Task 5.2 Sensitivity analysis	2		3.5	2				2	4	1	2	1.1	2	1	20.6
Task 5.3 Comparison to model results	2		2.4					2		1	2		2	1	12.4
Task 5.4 Production forecasting			3.5					2			2				7.5
WP 6: Mangement															**9**
Task 6.1 Project management	6	3													9
TOTAL PERSON MONTHS:	36.9	3	30.4	26.4	3	21.8	5.3	24	9	3.1	18	2.1	27	13.5	**223.5**

Table 4.1.2 SAIGUP Manpower matrix Year 1

Year 1	NUID/UCD		NR	HWU		ICSTM		TNO	Badleys	BG	ROXAR	SIEP	UL		TOTAL
Staff type (Additional A or Permanent P)	A	P		A	P	A	P						A	P	
WP 1: Model definition															**21.9**
Task 1.1 Sedimentological parameterisation								2					3	1.5	6.5
Task 1.2 Structural parameterisation	3								1						4
Task 1.3 Engineering parameterisation						1	0.4								1.4
Task 1.4 Work-flow definition	1			1		1	0.4				5.1		1	0.5	10
WP2: Geological uncertainty modelling															**22.7**
Task 2.1 Model construction Phase 1	3.3		6.1								2		2	1	14.4
Task 2.2 Production simuation Phase 1						5.3	1	2							8.3
Task 2.3 Construction and Simulation Phase 2															0
WP3: Up-scaling uncertainty modelling															**14.5**
Task 3.1 Small-scale up-scaling				4.3	0.5										4.8
Task 3.2 Large-scale up-scaling			2.0	4.2	0.5										6.7
Task 3.3 Fault property up-scaling	1								2						3
Task 3.4 Sensitivity assessment															0
WP4: Sensitivity analysis															**5.5**
Task 4.1 Relational database construction	1							3					1	0.5	5.5
Task 4.2 Statistical analysis															0
Task 4.3 Comparative parametrisation															0
WP 5: Application to real datasets															**8.4**
Task 5.1 Data collection	1		2.0						1	0.7		0.7	2	1	8.4
Task 5.2 Sensitivity analysis															0
Task 5.3 Comparison to model results															0
Task 5.4 Production forecasting															0
WP 6: Mangement															**3**
Task 6.1 Project management	2	1													3
TOTAL PERSON MONTHS:	12.3	1	10.1	9.5	1	7.3	1.8	7	4	0.7	7.1	0.7	9	4.5	**76**

Table 4.1.3 SAIGUP Manpower matrix Year 2

Year 2	NUID/UCD		NR	HWU		ICSTM		TNO	Badleys	BG	ROXAR	SIEP	UL		TOTAL
Staff type (Additional A or Permanent P)	A	P		A	P	A	P						A	P	
WP 1: Model definition															**16**
Task 1.1 Sedimentological parameterisation								1			1		5	2.5	9.5
Task 1.2 Structural parameterisation	4														4
Task 1.3 Engineering parameterisation						2	0.5								2.5
Task 1.4 Work-flow definition															0
WP2: Geological uncertainty modelling															**14.4**
Task 2.1 Model construction Phase 1	1		0.9												1.9
Task 2.2 Production simuation Phase 1						2	0.5	1							3.5
Task 2.3 Construction and Simulation Phase 2	1		1.5			3.3	0.7				1		1	0.5	9
WP3: Up-scaling uncertainty modelling															**15.3**
Task 3.1 Small-scale up-scaling				2.2	0.5								1	0.5	4.2
Task 3.2 Large-scale up-scaling			0.5	2.3	0.5								1	0.5	4.8
Task 3.3 Fault property up-scaling	2.3								2						4.3
Task 3.4 Sensitivity assessment				2											2
WP4: Sensitivity analysis															**15.6**
Task 4.1 Relational database construction	2							1					1	0.5	4.5
Task 4.2 Statistical analysis			2.1	1				2			2.4				7.5
Task 4.3 Comparative parametrisation			1.6					2							3.6
WP 5: Application to real datasets															**12.4**
Task 5.1 Data collection										0.4		0.3			0.7
Task 5.2 Sensitivity analysis			3.5	2				2	2	0.8	1	0.4			11.7
Task 5.3 Comparison to model results															0
Task 5.4 Production forecasting															0
WP 6: Mangement															**3**
Task 6.1 Project management	2	1													3
TOTAL PERSON MONTHS:	12.3	1	10.1	9.5	1	7.3	1.7	9	4	1.2	5.4	0.7	9	4.5	**76.7**

Table 4.1.4 SAIGUP Manpower matrix Year 3

Year 3	NUID/UCD		NR	HWU		ICSTM		TNO	Badleys	BG	ROXAR	SIEP	UL		TOTAL
Staff type (Additional A or Permanent P)	A	P		A	P	A	P						A	P	
WP 1: Model definition															**0**
Task 1.1 Sedimentological parameterisation															0
Task 1.2 Structural parameterisation															0
Task 1.3 Engineering parameterisation															0
Task 1.4 Work-flow definition															0
WP2: Geological uncertainty modelling															**3**
Task 2.1 Model construction Phase 1															0
Task 2.2 Production simuation Phase 1															0
Task 2.3 Construction and Simulation Phase 2	1		1			1									3
WP3: Up-scaling uncertainty modelling															**12**
Task 3.1 Small-scale up-scaling				1									1	0.5	2.5
Task 3.2 Large-scale up-scaling				1									1	0.5	2.5
Task 3.3 Fault property up-scaling	2														2
Task 3.4 Sensitivity assessment				4	1										5
WP4: Sensitivity analysis															**25**
Task 4.1 Relational database construction															0
Task 4.2 Statistical analysis	1		1.9	1.4				2			0.5		1	0.5	8.3
Task 4.3 Comparative parametrisation	2.3		1.4			6.2	1.8	2					2	1	16.7
WP 5: Application to real datasets															**27.8**
Task 5.1 Data collection															0
Task 5.2 Sensitivity analysis	2								1	0.2	1	0.7	2	1	7.9
Task 5.3 Comparison to model results	2		2.4					2		1	2		2	1	12.4
Task 5.4 Production forecasting			3.5					2			2				7.5
WP 6: Mangement															**3**
Task 6.1 Project management	2	1													3
TOTAL PERSON MONTHS:	12.3	1	10.2	7.4	1	7.2	1.8	8	1	1.2	5.5	0.7	9	4.5	**70.8**

5 DESCRIPTION OF THE CONSORTIUM

The SAIGUP project comprises geoscientists and engineers with a broad range of complementary expertise in the fields of sedimentology, structural geology, statistics, reservoir engineering and modelling and software development. The entire consortium contains leading international experts in all of the research disciplines required of the SAIGUP project. All partners have established research links with other partners through either current or recent collaborative research projects. Between them, the SAIGUP project partners have substantial experience in the conduct of large multi-partner projects funded both from industry and public sources, such as the EU.

University College Dublin are represented by the Fault Analysis Group (FAG) who relocated from Liverpool University in June 2000. The mission of FAG is to carry out basic research on all aspects of faults and related structures and to apply the results to practical problems principally within the hydrocarbon industry. FAG also develops improved techniques for reservoir characterisation, including software for 3-D visualisation, analysis and geometric/flow modelling of data from hydrocarbon reservoirs. Research results are disseminated in the form of published papers and reports, workshops and lectures and by incorporation into in-house and commercial software. FAG is the project coordinator, and will be responsible for the definition, construction and interpretation of structural aspects, including fault geometries and properties, of the modelling effort. FAG will also contribute to assessment of the impact of upscaling and to the analysis of the case studies.

Norsk Regnesentral (NR), is an institution for applied research and development in the fields of Object orientation, Interactive media, Security, Electronic Commerce and EDI, Statistical data analysis, Video analysis and Statistical/mathematical modelling, Remote sensing, and Business development with IT. The Institute has no interests in any commercial, manufacturing or supplying organisations. NR are represented by the SAND Group, which is internationally renowned in the fields of reservoir modelling and engineering. NR will be responsible for definition, generation and upscaling of the stochastic sedimentological models, and will make a significant contribution to the analytical components of the project.

The Department of Petroleum Engineering at Heriot-Watt University is the top rated (5*) department in the UK Mineral Engineering research assessment category. The Reservoir Description Group is concerned with improving our understanding of flow in geologically realistic situations. This Group has an international reputation in two-phase flow simulation and the associated upscaling processes, and has produced software to improve the workflow in this activity (the Geopseudo Atlas). The Group is also involved in developing detailed models of Genetic Sedimentary Units from outcrop analogues of a range of depositional environments. A large number of cross-disciplinary projects are sponsored by approximately 40 companies. HW are principally responsible for examining the effects of upscaling on flow, both in terms of sedimentology and faulting.

Imperial College of Science, Technology and Medicine (ICSTM) is the pre-eminent engineering university in the United Kingdom. The Centre for Petroleum Studies at ICSTM, with which the researchers on this proposed project are affiliated, and which is part of the T. H. Huxley School of Environment, Earth Sciences and Engineering, received a rating of 5 in the most recent UK Research Assessment Exercise. The Centre has several decades of experience in conducting research related to petroleum engineering, particularly in the areas of reservoir simulation, multiphase flow, and petrophysics. The principal responsibilities of ICSTM will be in the definition of production strategy parameters and the Phase 1 and 2 flow simulation, together with contributions to the analytical aspects via an examination of the influence of production strategies.

The Netherlands Institute of Applied Geoscience - National Geological Survey (TNO) is the central geoscience institute in The Netherlands for information and research to promote the sustainable management and use of the subsurface and its natural resources. It is also the geological survey of The Netherlands. The department of Geo-Energy, which is responsible for hydrocarbon projects, has a broad experience in the areas of production forecast uncertainty quantification database and decision support system design, upscaling and geomechanical modelling. The principal responsibilities of TNO in SAIGUP concern the development of formalism for dimensionless parameters, and database design.

Badley Earth Sciences is a UK-based company specialising in three areas of activity; (i) software development and marketing, (ii) structural geology and geophysical consulting, (iii) training courses. Their aim is to introduce *quantitative* analysis into exploration and development plans, and in doing so reduce the risk involved at all stages of prospect and reservoir evaluation. Badleys has an extensive world-wide client base of majors, independents and government departments. Badleys are the leading software developer/vendor in the areas of fault analysis and sealing (FAPS) and in fault transmissibility calculations (TransGen). Badleys will be primarily responsible for fault-related software implementation to streamline the project workflow and for case study analysis.

BG Technology and Shell are large petroleum companies with substantial expertise in the development and application of modelling methods to producing reservoirs, from both a research and an operational perspective. Their principal role in the project is to provide technical advice on the range of issues concerning the project and to provide access to case-study reservoir data.

ROXAR Software Solutions is a subsidiary of ROXAR. ROXAR is a commercial company offering the oil industry advanced products and systems for reservoir planning, reservoir optimization and production management. The company was formed summer 1999 by the merger of Smedvig Technologies and Multi-Fluid, both experienced contractors to the oil industry. ROXAR's strategy is to supply integrated solutions for reservoir management based on the company's products, software and services. Today ROXAR has a leading position in the area of multi-phase metering and strong market positions in the areas of software-based reservoir modelling and permanently installed down-hole equipment for production monitoring. In addition, the company has a range of advanced reservoir management products under development. Roxar's principal contribution to the project will be in software improvements/ implementations that streamline the reservoir modelling aspects of the project.

The University of Liverpool are represented by the Stratigraphy Group (STRAT) The group has been in the forefront of reservoir analogue outcrop studies of sediment body geometries and architecture worldwide for the last ten years. They have published over 50 papers, edited two books and hosted a major international sequence stratigraphy conference. A central research theme is the development and application of high resolution sequence stratigraphic concepts to ensure correct time-stratigraphic correlation of sandbodies in 3-D space and the inclusion of these rules in reservoir modelling software. The STRAT group will be responsible for the parameterisation of the sedimentological components of the reservoir models, and will also contribute to the interpretation of flow results, upscaling and the case studies.

6 OTHER INFORMATION

6.1. Cited references

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6.2. Related projects

Most members of the consortium have collaborated on a number of EU JOULE or THERMIE hydrocarbon projects, though neither SAIGUP nor any similar project has been submitted in this or any previous EU programmes.

Previous projects with the most direct relevance to SAIGUP are the two PUNQ projects (JOF3 -006 and JOF3 -0038) and the earlier Reservoir engineering / Geoscience II Project (JOU2-0182). Four of the ten SAIGUP partners were involved in the PUNQ project, and SAIGUP will benefit substantially from the expertise and cooperation gained during the PUNQ experience. SAIGUP has a much stronger geological focus than PUNQ, as manifest by the objectives of the project which are to develop a better understanding of the quantitative interactions between observed flow performance and underlying geological system. Rather than an extension to PUNQ, SAIGUP addresses questions which were deliberately outside the scope of PUNQ. SAIGUP integrates conclusions from geological characterisation research with the formal mathematical methodologies developed in projects such as PUNQ, with the aim of deriving an inclusive assessment of the sources and levels of production uncertainty.