energy technologies institute

Programme Area: Carbon Capture and Storage

Project: Storage Appraisal

Title: Storage Unit Characterisation

Abstract:

This document is a supporting document to deliverable MS6.1 UK Storage Appraisal Final Report.

Context:

This £4m project produced the UK's first carbon dioxide storage appraisal database enabling more informed decisions on the economics of CO2 storage opportunities. It was delivered by a consortium of partners from across academia and industry - LR Senergy Limited, BGS, the Scottish Centre for Carbon Storage (University of Edinburgh, Heriot-Watt University), Durham University, GeoPressure Technology Ltd, Geospatial Research Ltd, Imperial College London, RPS Energy and Element Energy Ltd. The outputs were licensed to The Crown Estate and the British Geological Survey (BGS) who have hosted and further developed an online database of mapped UK offshore carbon dioxide storage capacity. This is publically available under the name CO2 Stored. It can be accessed via www.co2stored.co.uk.

UKSAP

Appendix A3.1

Storage Unit Characterisation

Conducted for

The Energy Technologies Institute

By

British Geological Survey

Author	Sam Holloway
Technical Audit	
Quality Audit	
Release to Client	Grahame Smith
Date Released	28th October 2011 (final)

File Location
Appendix 3.1 - Storage Unit Characterisation.doc

Contents

1 Storage Unit Characterisation 2
1.1 Populating the UKSAP Database........ 2
1.1.1 General Page........ 2
1.1.1.1 Storage Unit Type 2
1.1.2 Pore Volume Page........ 3
1.1.3 Static Capacity Page........ 3
1.1.3.1 % PV Occupied by Stored CO_2 (for 'open' units) 3
1.1.3.2 Depth to Centroid of Unit........ 4
1.1.3.3 Formation Temperature at Shallowest Depth 4
1.1.3.4 Formation Water Salinity........ 5
1.1.3.5 Pressures 5
1.2 Additional Data Entered into the Database by WP1 Assessors 6
1.2.1 Injectivity Page........ 6
1.2.1.1 Permeability........ 6
2 References 7

List of Figures

Figure A1.1: Calculating the Mean Centroid Depth........ 4

1 Storage Unit Characterisation

1.1 Populating the UKSAP Database

A unique unit ID was created for each storage unit and daughter unit. Three data pages were constructed for each storage or daughter unit:

- General
- Pore Volume
- Static Capacity

Data entry fields are present on each of these pages. The methodology used for populating each data field is described below.

1.1.1 General Page

The General page of the database contains the following data entry fields:

Unit designate - the unit designate classifies the unit as either a saline aquifer (saline water-bearing reservoir rock) or a hydrocarbon field.

Stratigraphy - this describes the geological age of the unit and its lithostratigraphic hierarchy. This information was obtained from the UKOOA lithostratigraphic volumes (Knox & Cordey, eds: 1992 – 2000).

Geographic area - the geographic area is the general area of the UKCS in which the unit occurs, e.g. Central North Sea, East Irish Sea Basin.

1.1.1.1 Storage Unit Type

Each unit was defined by one of three storage unit types: fully confined (a pressure cell), open with structural/stratigraphic confinement or open without stratigraphic/structural confinement (not a pressure cell). This subdivision is necessary to determine which modelling methodology should be used to determine the storage capacity of the unit (Sections 3 and 5 of main report).

Latitude and Longitude - once the storage unit has been identified a map of the distribution of the unit was created from a combination of existing maps, shapefiles, IHS well data and PGS interpreted surface data. From the mapped extent of the unit an ArcGIS shapefile was produced. The geographic location of the geometric centroid of the distribution shapefile was calculated in ArcGIS and its co-ordinates were entered into these data fields. Where this lies outside the unit (e.g. banana-shaped unit) its x coordinate was moved laterally along the x axis until it lay within the unit.

Description - the name of the unit is entered in this field, e.g. Bunter Sandstone Zone 5.

Water depth -in the pre-Cenozoic of the Central and Northern and North Sea, minimum, maximum and most likely water depths were calculated by averaging a range of water depths from the IHS well database. Elsewhere, the maximum, most likely and minimum water depths were obtained by overlaying the unit distribution shapefile on a bathymetry map.

1.1.2 Pore Volume Page

Area -the most likely area of the storage unit was considered to be the area of the storage unit distribution polygon. This was calculated in ArcGIS. The maximum and minimum values were taken as plus or minus 10% respectively of the most likely value.

Average gross thickness - the top and base of each storage unit was extracted from wells in the IHS well database lying within each storage unit. The maximum, most likely and minimum average thickness was calculated from these data.

Shape Factor - Gross Rock Volume is calculated as the product of Area and Average Gross Thickness. To account for certain geometries (such as domes) a Shape Factor is also included.

Areal net sand - unless evidence was available indicating otherwise, it was assumed the most likely (and maximum) areal net sand fraction was 1.00. This is considered to be a reasonable assumption because the storage reservoirs are lithostratigraphically defined.

Vertical Net to Gross - where practical, e.g. in the Southern North Sea and the East Irish Sea Basin, vertical net to gross was calculated in Petrel using BGS-held gamma and sonic logs. For the Cenozoic of the Northern and Central North Sea, the net to gross was based on average values and ranges for the relevant Cenozoic reservoir using data from the IHS Fields database. For storage units without wells, values from public domain literature were used.

Porosity - the porosity of the storage units in the Southern North Sea and the East Irish Sea Basin was calculated in Petrel from BGS-held geophysical logs. For the storage units in the Cenozoic of the Northern and Central North Sea, porosities (Po %) are based on an analysis of IHS Cenozoic fields data (94 points), using model values from a derived linear equation, $Po = -0.0058 d + 38.538$, where d is the maximum, mean and minimum depth to top reservoir, in metres. For storage units with no well data, values from literature were used. In the pre-Cenozoic of the Central and Northern North Sea porosities were predominantly derived from the scientific literature.

Aspect Ratio - for storage units identified by the BGS, the aspect ratio was calculated in ArcGIS. A bounding rectangle was created around the distribution polygon of each storage unit and the ratio of the dip length to width was calculated.

1.1.3 Static Capacity Page

1.1.3.1 % PV Occupied by Stored CO_2 (for 'open' units)

These fields define the initial (or default) distribution of minimum, most likely and maximum % of the pore volume that is likely to be occupied by stored CO2 in ‘open’ units (non pressure cells). **Shallowest depth (at which there is closure)**. In storage units in the Cenozoic of the North and Central North Sea, Southern North Sea, East Irish Sea Basin and the Central English Channel, the most likely shallowest depth was obtained from contoured depth maps to top reservoir (contours at 100 m intervals), derived from the IHS well tops database and, if available, depth surfaces from PGS. Minimum and maximum values are based on the assessor’s best judgement. In the pre-Cenozoic of the Central and Northern North Sea, the shallowest depth was taken as the shallowest formation top within a storage unit. This was derived from the IHS well top database. When data points were not evenly distributed geographically throughout the storage unit, the minimum shallowest depth was taken from a data point that lay outwith the storage unit. The maximum shallowest depth was calculated by adding an arbitrary 5 m (measurement error) to the most likely shallowest depth.

1.1.3.2 Depth to Centroid of Unit

This was calculated in two steps. Firstly, the mean of the deepest and shallowest points on a unit's top surface was determined. Then half the most likely unit thickness was added to this to determine the most likely depth (**Figure A1.1**). In this example, the depth of the mean centre point for this storage unit is at 1000 m. This parameter was used to calculate the CO_2 storage density.

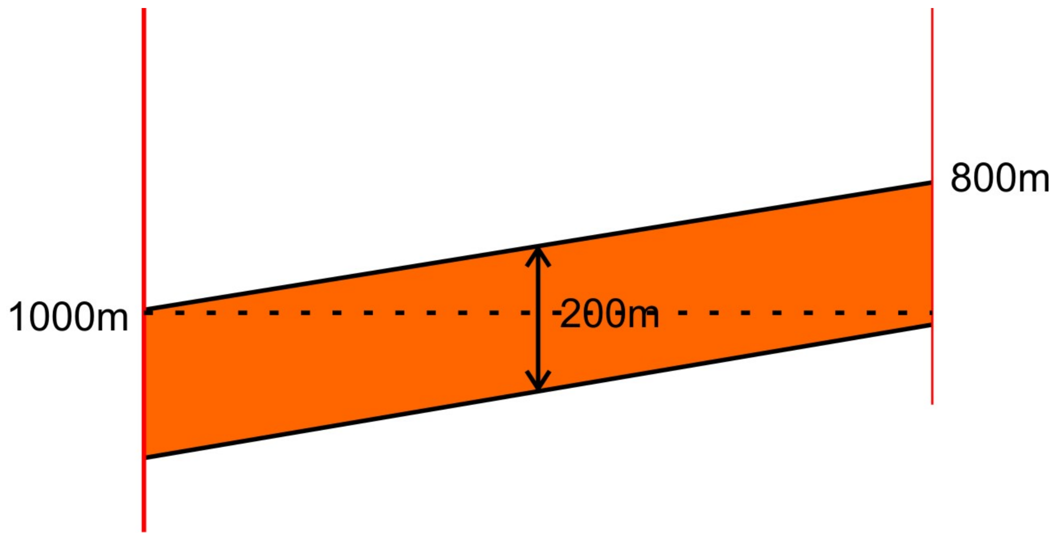

Figure A1.1: Calculating the Mean Centroid Depth

1.1.3.3 Formation Temperature at Shallowest Depth

Regional geothermal gradients and sea bed temperatures from publicly available sources were used to determine formation temperature. In the Southern North Sea the temperature was derived using a sea bed temperature of 10°C, and a geothermal gradient of 35°C/Km (ML), 30°C/km (Min) and 40°C/km (Max). In the pre-Cenozoic of the Central and Northern North Sea a sea bed temperature of 8°C was used along with a range of temperature gradients (29-41 °C/Km) which were derived from the Millennium Atlas temperature gradient maps. The formation temperature minimum, most likely and maximum values were all calculated at the most likely shallowest depth using the following equation:

$$T=Ts+(Z \times Q)$$

T - Formation temperature at shallowest depth

Ts - Temperature at the sea bed

Z - Shallowest depth

Q – geothermal gradient

1.1.3.4 Formation Water Salinity

Published data sources were used for the formation water salinity values. For Northern and Central North Sea Cenozoic units a representative salinity was derived from an average of 13 values from Cenozoic oil field reservoirs compiled in Gluyas and Hitchens (2000).

For storage units with no, or limited, publically available information, techniques derived in Geo Pressure Technology's Central North Sea Salinity database (2003) were employed to estimate formation water salinities in any given unit area. Average brine densities were used in the absence of specific data, together with corrected pressure and temperature data. Algorithms derived from the Western Atlas (1985) equations offer robust results. Where appropriate, existing values were extrapolated from adjacent areas. Pressure communication across units would suggest a common aquifer and therefore a shared salinity. Flushing, or freshening, of the formation waters may occur in hydrodynamically-active units, so pressure variation suggesting movement across units was considered before applying these averages. Lithological affects, such as proximity to evaporites, were considered.

1.1.3.5 Pressures

Pressures contained in the IHS pressure database were used by GPT to interpret aquifer overpressures, which were used in defining the pressure regime for each pressure cell. Maximum, most likely and minimum pore fluid pressures were entered into the database and within the reservoir interval were extrapolated along an average 0.01 MPa/m (0.445 psi/ft) aquifer gradient to shallowest depth. This offers the best estimation of pore pressure at top reservoir, or shallowest depth of closure, which is the datum to which all pressure values were calibrated. The method of estimating fracture and lithostatic pressures differed from one region to the next. Algorithms established in previous GPT regional pressure studies were used for units within, and units surrounding, regional study boundaries. In regions where no previous work had been carried out the basic principles and techniques established in these earlier studies were used to estimate pressures.As lithostatic pressure is a function of bulk density of the overlying sediments, understanding the local geology is key to estimating overburden pressures. For each region, general stratigraphic and lithostratigraphic information, together with density data if available, was consulted. Intervals with density data of similar character were grouped, the sum of which offers the best indication of lithostatic pressure at the datum. Leak-off test data from wells within the region were reviewed to derive a fracture pressure algorithm, in which a pore pressure to stress coupling ratio was incorporated.

Values of Aquifer Seal Capacity (ASC) are calculated within the CarbonStore database by subtracting the magnitude of the estimated pore fluid pressure from 90% of whichever is the lower of the fracture or overburden pressure at the depth of interest. In certain structural settings and/or at depth it is recognised that the orientation of least stress can change. This is seen on pressure/depth plots as a switch in position between the fracture gradient and overburden gradient.

1.2 Additional Data Entered into the Database by WP1 Assessors

1.2.1 Injectivity Page

1.2.1.1 Permeability

Permeability values from wells in the IHS-EDIN database were used where available. Published data sources were used for the remaining permeability values. In the Northern and Central North Sea the sparsity of data for the Cenozoic unit was an issue. Permeabilities are based on a compilation of Cenozoic data from the IHS fields database. Model values for each reservoir were calculated from a graphically-defined exponential equation:

$$k[mD] = 273007 \times e^{-0.003 \times Depth[m]}$$

2 References

1. Knox, R W O'B & Cordey, W G (Eds) 1992-4. Lithostratigraphic Nomenclature of the UK North Sea (7 volumes), British Geological Survey, Nottingham.
2. J. G. Gluyas & H. M. Hitchens (eds.), United Kingdom Oil and Gas Fields, Commemorative Millennium Volume, Geological Society (London) Memoir 20.
3. GeoPressure Technology's Central North Sea Salinity database (2003)
4. Western Atlas (1985)