Programme Area: Carbon Capture and Storage

Project: Storage Appraisal

Title: Well Penetrations and Production in Oil and Gas Fields

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 A4.2

Well Penetrations and Production in Oil and Gas Fields

Conducted for

The Energy Technologies Institute

By

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1 Well Penetrations and Production in Oil and Gas Fields: A Basis for Injectivity Prediction

This Appendix describes a methodology for using the analysis of potential well penetrations (presented in Work Package 2 Final Report), together with hydrocarbon production data from UKCS oil and gas fields, to calculate cumulative and peak production rates per well in hydrocarbon fields. This could subsequently be used as a basis for a rudimentary estimate of viable CO_2 injectivity for individual storage units.

1.1 Methodology

1.1.1 Current Status of Potentially Penetrating Wells

For each saline aquifer unit and hydrocarbon field the current status of potentially penetrating wells is summed. The potential well penetrations are determined according to the methodology described in Appendix A6.1. For every well that is identified as a potential penetration of a unit or hydrocarbon field, the current status of the well is recorded (as active oil, active gas, active water injector, active gas injector, suspended, abandoned, active miscellaneous, miscellaneous injector, or miscellaneous), according to the well header information.

This information is reported in CarbonStore in Data II / Oil & Gas Wells. There are several implicit assumptions within these analyses (see Limitations / Further Work) which mean that the number of well penetrations produced here are a maximum (excluding errors in the data).

The Data and Approach will not be discussed in full detail here as they are the same as the assessment of well containment risk, reported in detail in Appendix A6.1. A worked example however will be demonstrated in this section.

1.1.2 Well Production in Oil and Gas Fields

This technique has been applied to hydrocarbon fields only (not saline storage units). The aims are two-fold:

- to determine the year of maximum hydrocarbon production, the number of active wells at this time and hence calculate the maximum production per well averaged over a year

- to determine total hydrocarbon production over the field life and divide this by total number of active producing wells over field life, to get cumulative production per well

There are several implicit assumptions within these manipulations (see sections on Challenges / Limitations and Further Work) which mean that the number of well penetrations produced here are a maximum (excluding errors in the data).

1.1.3 Data

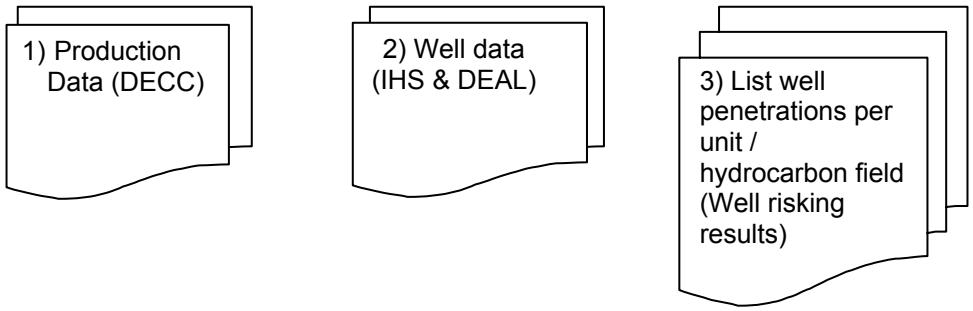


Figure A1.1: Detailing the Data used in the Analysis

1) DECC-sourced total monthly production data from 1975-2007 ("prod data.xls" from CarbonStore: UKSAP>WP1: Geosciences> Shared Documents) was summed to give annual totals, then merged with annual totals for 2009 and 2010 that were downloaded from the DECC website (https://www.og.decc.gov.uk/pprs/full_production.htm). This data included oil, associated gas (for condensate fields only), dry gas and produced water.

2) IHS well header data downloaded on 23/11/2011 with bottom hole location taken from DEAL CDA database. 5310 wells were given additional bottom hole locations from the DEAL CDA database.

3) List of well penetrations per hydrocarbon field (output dated 21/06/2011). These are the results of containment risk caused by wells (documented in Appendix A6.2 (1.4) Geospatial Research Limited).

1.1.4 Approach

The DECC-sourced monthly production data were summed to give annual totals and manually merged with the 2009 and 2010 production data downloaded from the website. Unit IDs were manually entered for each field.

The IHS well header data were augmented by adding the bottom hole location data from the DEAL CDA database. The wells from the IHS and DEAL databases were matched using well name (the format of the DEAL well names was modified to match the IHS well name). The DEAL wells with bottom hole location were re-projected in ArcGIS so they all had the same coordinate system. Any wells with errors or inconsistencies in the well name entry will not be matched.

An output detailing the potential well penetrations per field, which was produced in the assessment of the containment risk of wells, was used. This identified which wells potentially penetrate each hydrocarbon field, either at top hole or bottom hole location if both were available for the well. The header data from these individual wells were then analysed to define which wells were or had been active and over what time period (to the nearest year).

The general status of the well was identified from the IHS well header data. If this was 'Completed' then the well was counted as active from the end of the 'initial drilling' period of

operation. Injectors and wells which were Plugged & Abandoned or Suspended from the initial drilling period were not counted.

Complications arise if a well has a current status of Plugged & Abandoned or Suspended, and there is a difference (of greater than 1 year) between the date of the end of initial drilling operations and the last completion date. The well may have been Plugged & Abandoned or Suspended immediately after drilling, or it may have been an active producer initially which has since been abandoned or suspended. (This is common practice when drilling from platforms, where there are a limited number of slots in the drilling template. When well productivity tails off a well can be abandoned and sidetracked.) In order to catch these extra platform wells which have since been abandoned, a further filter has been applied to the well header data. If the current status of the well is Plugged & Abandoned or Suspended and the status does not record that the well was dry or only had shows, then a comparison between the date at the end of initial drilling operations and date of last completion is made. If this is greater than 1 year the assumption is made that the well was active for the time between the two dates. There will be some error associated with this assumption - specifically wells which were suspended immediately after drilling and then abandoned later; however this treatment is thought to capture the most numerous case (i.e. compared with other assumptions which would be made for different interpretations, the errors are believed to be fewer).

The number of wells active during the year of maximum production was produced for each field. The number of wells that were active over the whole life of the field, up to end 2010, was also produced for each field.

The final output included the total production of a field, the year of maximum production, the amount of maximum production (for the year), the number of active wells during the life of the field and during the year of peak production.

1.2 Worked Example: Potential Well Penetrations and their Current Status for the Buchan Field (Unit ID 152.001)

The Buchan oil field lies in the South Halibut Basin of the Central North Sea in blocks 020/05a and 021/01a. The first stage of the analysis is a comparison of the shapefile outline of the Buchan Field with well header data (both top hole and bottom hole location) to identify which wells might penetrate the reservoir.

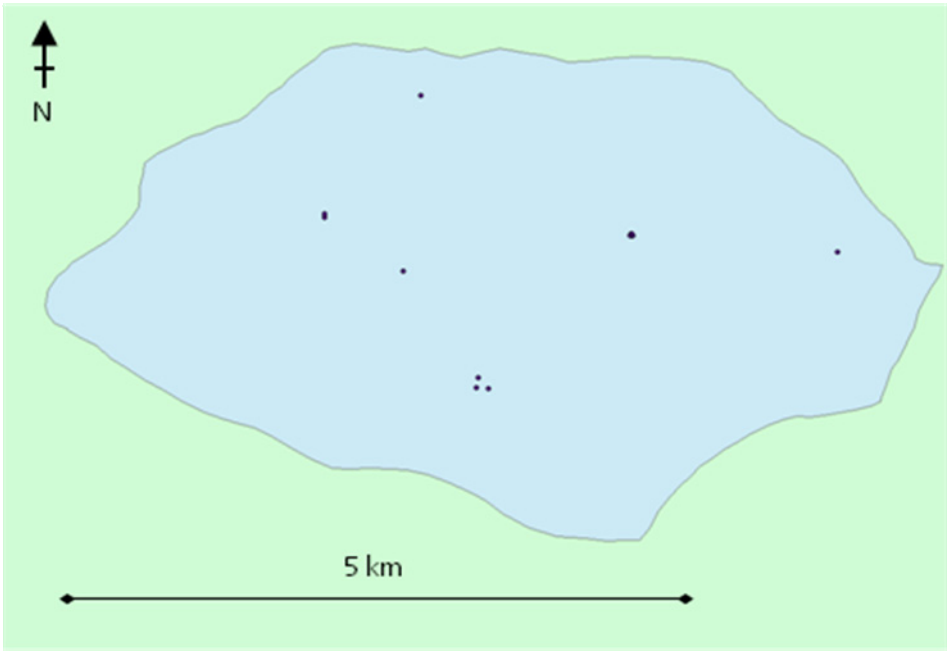


Figure A1.2: Buchan Oil Field Map View shown in Blue, with Wells which lie within this Map View shown as Purple Dots

(The field is 7km from east to west. Note - some of the wells are clustered together, so there is not an individual dot on this diagram for each potential penetration)

The total depth data (in measured depth) for each well are then compared with the minimum depth of the unit to see if the well can be deeper than the minimum depth of the unit. Even though the well may be deviated (so the total depth is not actually deeper than the minimum depth) or the unit deeper than the minimum depth, if these conditions are met the well is counted as a possible penetration.

Min depth	Well_Name	Well_TD	Gen_Status	Tech_Status	Intd_Date	Date last completion	Penetration
1716	020/05a-01	3317	Completed Oil	Completed	26-Apr-81	24-Nov-87	
1716	021/01a-03	3257	P&A/Suspended Oil	Suspended	27-Nov-75	27-Nov-75	
1716	021/01a-04	2626	P&A/Suspended Oil	Suspended	09-Dec-76	09-Dec-76	
1716	021/01a-02Z	3277	P&A/Suspended Oil	Suspended	10-Sep-75	10-Sep-75	
1716	021/01a-01	3331	P&A/Suspended Oil	Plugged & abandoned	26-Aug-74	26-Aug-74	
1716	021/01b-11	3509	Completed Oil	Completed	03-Nov-78	24-Nov-79	
1716	021/01b-10	3305	Completed Oil	Completed	05-Sep-78	27-Aug-82	
1716	021/01b-09	3405	Completed Oil	Completed	10-Aug-78	10-Dec-79	
1716	021/01b-07Z	3539	Completed Oil	Completed	02-May-78	24-Dec-79	
1716	021/01a-06	3360	Completed Oil	Completed	27-Dec-77	27-Dec-77	
1716	020/05a-05Z	3601	Completed Oil	Completed	21-May-90	21-May-90	
1716	021/01a-14	3577	Completed Oil	Completed	13-Apr-88	13-Apr-88	
1716	021/01b-08	3250	P&A/Suspended Oil	Suspended	09-Jul-78	09-Jul-78	
1716	021/01a-13	1200	P&A/Susp Dry/Shows	Plugged & abandoned	05-Mar-84	05-Mar-84	Well TD less than min depth of unit
1716	021/01a-09Z	3353	P&A/Susp Dry/Shows	Junked	27-May-01	27-May-01	
1716	021/01a-09Y	3353	P&A/Susp Dry/Shows	Junked	21-Jun-01	21-Jun-01	
1716	021/01a-09X	3353	P&A/Suspended Oil	Plugged & abandoned	03-Jul-01	06-May-02	
1716	021/01a-09W	3353	Completed Oil	Completed	20-Jul-01	20-Jul-01	
1716	021/01a-09V	3658	Completed Oil	Completed	19-May-02	19-May-02	
1716	021/01b-07	2470	P&A/Susp Dry/Shows	Junked	17-Mar-78	17-Mar-78	
1716	021/01a-13Z	3263	P&A/Susp Dry/Shows	Plugged & abandoned	07-Jun-84	07-Jun-84	
1716	020/05a-05	3256	Completed Oil	Completed	26-Mar-90	26-Mar-90	
1716	021/01a-02	1833	P&A/Susp Dry/Shows	Plugged & abandoned	24-May-75	24-May-75	

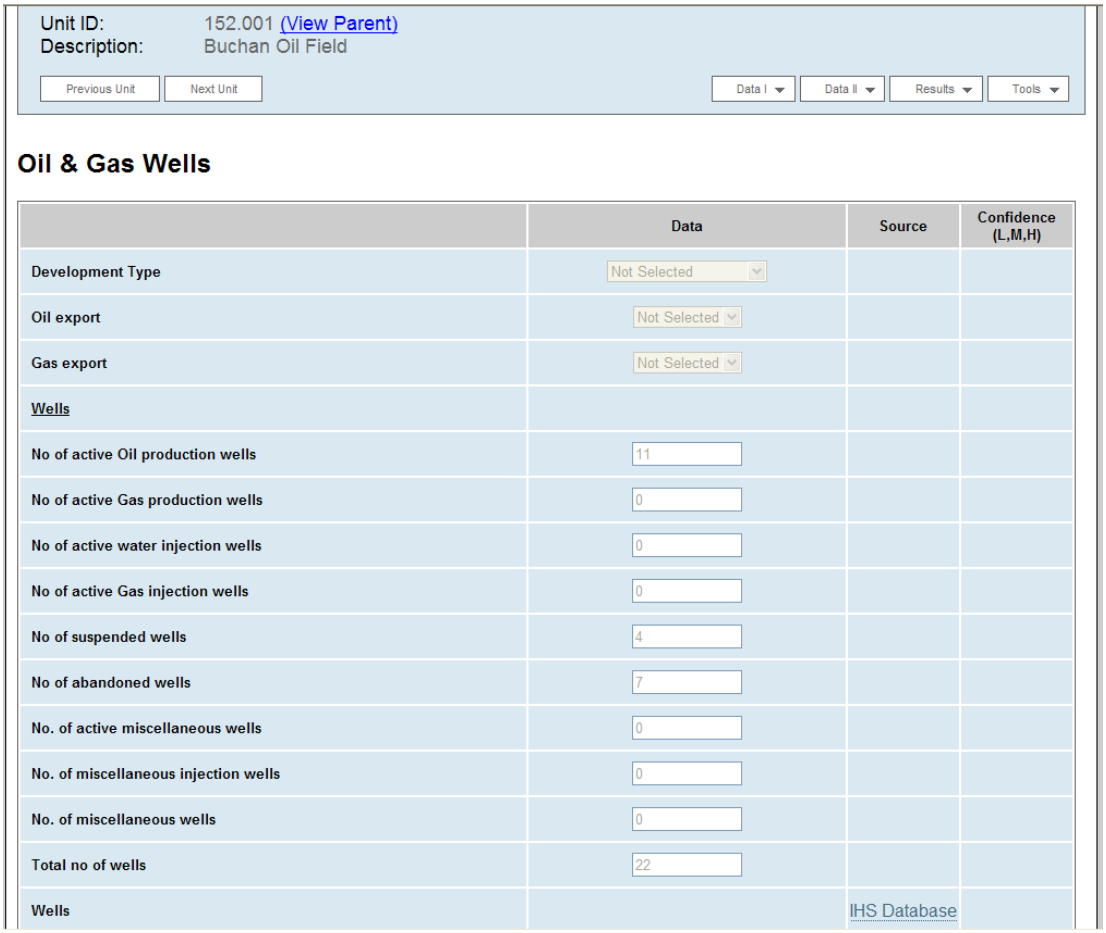
Table A1.1: Showing Output from Well Risking for Unit 152.001 – Buchan Oil Field

The minimum depth column refers to the shallowest depth entered in CarbonStore for the unit, well TD refers to the total depth of the well, measured in measured depth; Gen(eral) and Tech(nical) status indicate the current status of the well and its findings; Intd date is the date of the end of initial drilling operations and Date last completion refers to the date of the last completion, an entry in the Penetration column indicates the well does not penetrate the unit.

All possible well penetrations are shown in the table, however well 021/01a-13 is not counted in the final tally, as it is too shallow. There are 22 potential well penetrations for this field (which has been normalised for area and compared with other hydrocarbon fields and reported in UKSAP - Risk - Wells section).

Rather surprisingly in the results from Unit 152.001 Buchan reported above, some wells are named after block 021/01b (and by implication should lie within that licence area, which is to the south of the Buchan oil field). The coordinates of the wells plot within Buchan Field. The location of the well data has been verified on the DECC website (https://www.og.decc.gov.uk/information/bb_updates/maps/Q21.pdf - UKCS Oil & Gas activity by individual quadrant). It also appears from this website that there are no wells drilled in block 021/01b. It seems likely that the wells which are listed in the above table that are named '021/01b-' should instead begin '021/01a-'. This error will not have implications for the risking

or well count. It might have stopped matching of DEAL TD location if the error is in the IHS database rather than the operator's error at time of registration.



Unit ID: 152.001 (View Parent)
Description: Buchan Oil Field

Previous Unit | Next Unit | Data I | Data II | Results | Tools

Oil & Gas Wells

	Data	Source	Confidence (L,M,H)
Development Type	Not Selected		
Oil export	Not Selected		
Gas export	Not Selected		
Wells			
No of active Oil production wells	11		
No of active Gas production wells	0		
No of active water injection wells	0		
No of active Gas injection wells	0		
No of suspended wells	4		
No of abandoned wells	7		
No. of active miscellaneous wells	0		
No. of miscellaneous injection wells	0		
No. of miscellaneous wells	0		
Total no of wells	22		
Wells		IHS Database	

Figure A1.3: Entry in CarbonStore shows Summary of Current Status of the Wells (found under Data II – Oil & Gas Wells)

1.3 Worked Example: Active Wells and Production Data for Buchan Field (Unit ID 152.001)

Each well with a general status of 'completed' is counted as an active well beginning at the date of the end of initial drilling operations.

Each well with general status of Plugged & Abandoned is analysed to see if there is a difference of more than 1 year between the end of initial drilling operations and last completion date (**Table A1.3**). In the Buchan oil field example none of the Plugged & Abandoned wells have time differences of over a year. If there was a difference it would be assumed that the well had been active between the two dates (and added to the active well count for those years).

The production data over the life of the field to end 2010 are used to identify the total production to end 2010 and the year of maximum production. The production data and well data are then synthesised to enable final reporting of the year of peak production and number of wells, total production and total number of wells over the life of the field to end 2010.

Unit_ID	Year	Annual Oil Production m3	AnnualGas Production sm3	Annual Produced Water Volume m3	Total Hydrocarbons sm3	Active Wells Per year	Total Active Wells over field life
152.001	1981	1094992	0	0	1094992	6	
152.001	1982	1641409	0	0	1641409	6	
152.001	1983	1876206	0	69553	1876206	6	
152.001	1984	1236683	0	299233	1236683	6	
152.001	1985	1027171	0	104725	1027171	6	
152.001	1986	1287541	0	261204	1287541	6	
152.001	1987	1236193	0	299855	1236193	6	
152.001	1988	1231196	0	386420	1231196	7	
152.001	1989	735831	0	264681	735831	7	
152.001	1990	1014085	0	257098	1014085	9	
152.001	1991	949024	0	229062	949024	9	
152.001	1992	773310	0	139793	773310	9	
152.001	1993	614151	0	122165	614151	9	
152.001	1994	717860	0	145854	717860	9	
152.001	1995	590240	0	142093	590240	9	
152.001	1996	637840	0	131045	637840	9	
152.001	1997	529476	0	159009	529476	9	
152.001	1998	478343	0	161954	478343	9	
152.001	1999	409986	0	138299	409986	9	
152.001	2000	417801	0	126490	417801	9	
152.001	2001	458092	0	114869	458092	10	
152.001	2002	411640	0	180538	411640	11	
152.001	2003	400212	0	207619	400212	11	
152.001	2004	431044	0	177578	431044	11	
152.001	2005	396636	0	152072	396636	11	
152.001	2006	380175	0	168427	380175	11	
152.001	2007	333815	0	166558	333815	11	
152.001	2008	349391	0	203428	349391	11	
152.001	2009	305203	0	191883	305203	11	
152.001	2010	267502	0	186617	267502	11	
							11

Table A1.2: Annual Production Results and Active Well Count for each year of Buchan Oil Field

Production to end 2010 over life of field								
Total Oil+Gas Prod (sm3)	Total Oil (m3)	Total Gas (sm3)	Total Assoc_Gas (Condensate Fields ONLY sm3)	Total H2O (m3)	Total Active Wells	Max cum. Oil prod per well (sm3)	Max cum. gas prod per well (sm3)	Max cum. water prod per well (sm3)
22233048	22233048	0	0	5188122	11	2021186	0	471647
Peak hydrocarbon production								
Peak Hydrocarbon Prod (sm3/yr)	Year of Peak HC Prod	Oil (for Peak HC year) (m3/day)	Gas Prod (for Peak HC year) (sm3/day)	Water (for peak HC year) (m3/day)	Active Wells Max_OG	Average gross oil production rate per well (sm3/day)	Average gross gas production rate per well (sm3/day)	Average gross water production rate per well (sm3/day)
1876206	1983	5140	0	191	6	857	0	32

Table A1.3: Reported Results for Buchan Oil Field, Unit ID 152.001

These figures form the basis for an estimation of the CO_2 injection rate for oil and gas fields.

1.4 Challenges / Limitations

Some challenges / limitations from the first stage of the analysis (well risking) that will have implications are as follows (see Appendix A6.2 (1.4) for more detailed discussion):

- Erroneous well header data: there were errors apparent in some TD locations, top hole locations, well names as well as inconsistencies in naming conventions and cartographic projections of location data.

- Measured depth data have been used for the total depth of a well, not true vertical depth (due to initial uncertainty in TVD data). Thus the estimates of the number of potential well penetrations used here should generally be considered as maximum likely values.

- The minimum depth of a unit has been used to identify penetration. This will not be correct for every location within a unit or oil or gas field and will result in an over-estimation of potential well penetrations.

Some challenges / limitations specific to this part of analysis:

- There are many manual steps in the analysis, so it is probable that some human error will still exist within the data. The data manipulation has been as systematic as possible and any spurious results have been investigated, however some human errors will probably remain.

- It is assumed that when given the same names the UKSAP and DECC oil and gas fields are the same. However, not all such field boundaries are identical. In these cases, unless it was a relatively simple matter of adding two fields together, it has not been possible to determine maximum or cumulative well production.

- Some fields are not assigned any active wells at any time during the field life. This is erroneous and reflects an error in well location, lack of TD location, error in well name (in either the IHS or DEAL databases), error in shallowest height of the parent unit, an error in the status assigned to the well, or, conceivably there could be an error as in some cases different cartographic projections having been used for shapefile creation, well location and this analysis.

- Water production has not been included. This assumes that water production was low relative to hydrocarbon production for each field. The year of peak production is identified based on hydrocarbon production alone. The cumulative production volumes do not include water production either.

- If monthly production data rather than annual data were used to identify peak production that might have increase the predicted peak injection rates. The format of the available online data within time scale of project directed the analysis**.**

1.5 Further Work

- The risking and well analysis should be re-run using total depth of a well as measured in true vertical depth (TVD).

- Contours of 3D surfaces describing the top of the units could now be generated and compared with well depth, to identify well penetration (rather than the current situation of assuming every well which extends deeper than the minimum depth counts as a potential penetration). This would reduce the number of extraneous wells being identified as potential penetrations (the results are likely to be more significant for storage units than hydrocarbon fields).

- The few oil and gas fields with no well penetrations assigned and which have the same name as the DECC data could be studied in further detail to see if it is possible to identify errors in the well header data that can be readily eliminated (e.g. naming / sign errors in well co-ordinates, etc).

- Fields which are divided differently according to DECC and the UKSAP cannot be analysed using this approach (as the production data have no direct significance to the UKSAP data), so no further work is proposed here.

- It may prove possible to incorporate water volumes into the well production figures.

1.6 Usability of the Data

The potential well penetrations generated tend towards over estimation of the number of actual well penetrations (especially in large, deep saline aquifers or below oil and gas fields). As the risks quoted are not quantities but a relative assessment this remains meaningful.

When using the actual figures of well penetrations in hydrocarbon fields (for example, the count for the number of well types per unit, or in predicting remediation costs or injectivity rates), the overestimation should not be as significant as for saline aquifer units. Within a hydrocarbon field, the majority of wells will, by design, penetrate the reservoir (so implications of using MD rather than TVD are less than for deep saline aquifer units) and hydrocarbon fields tends to be smaller than saline aquifer units, so the discrepancy between minimum depth and actual depth of the unit will be less.

Logical Routine Applied to Well Header Data to Identify Active Production wells

GEN_STATUS column	Assignment
==========	==========
Completed Gas	Active
Completed Oil & Gas	Active
Completed Oil	Active
Completed	Active
Gas Injector	Injector (don't need to count this)
Injector	Injector (don't need to count this)
P&A/Susp Dry/Shows	see Tech status
P&A/Susp Oil & Gas	see Tech status
P&A/Suspended Gas	see Tech status
P&A/Suspended Oil	see Tech status
P&A/Suspended	see Tech status
Unknown	unknown
Water Injector	injector (don't need to count)
Water	injector (don't need to count)
Well active	Active

If GEN_STATUS = P&A then…

TECH STATUS	Assignment
==========	==========
Completed	Unknown (statuses are contradictory)
Junked	Abandoned
Plugged & Abandoned	Abandoned – compare date of end initial drilling and date of last completion
Suspended	Suspended – compare date of end initial drilling and date of last completion
Unknown	Unknown

IF Gen status = P&A **AND** Tech status= {P&A OR suspended} **AND** do not see *Dry / Shows* in GEN_STATUS, **THEN** compare INTTD_DTTX and LTCMP_DTTX.

IF difference between dates less than 365 days, **THEN** use INTTD as age of well and status as given.

IF difference between dates greater than 365 **THEN** use INTTD as age of well **AND** assign well to active well count between these dates, **AND** LTCMP_DTTX as age of well abandonment.