Introduction

Effective management of a conventional oil field involves employing capital efficiently to maximise production, arrest field decline and enhance production efficiency. The types of activities and decisions required to meet these objectives include the following:

- The location of infill wells
- The types of completions to install
- The field water injection strategy: the choice of wells or zones to prioritise
- Which existing production wells to use as donors for slot recovery
- Which zones to produce, either through downhole zonal control, or through interventions to shut off perforations or open new zones by perforating
- Risk assessment of producing wells for scaling tendency

These decisions may be supported by a reservoir model, the critical component of which is the subsurface view of the location of the remaining oil and the connectivity within the field. This connectivity – in terms of the subsurface system of conduits and channels between the wells – can be described as the field ‘plumbing’. An accurate picture of the field plumbing is essential in making effective field management decisions.

It is also important to create a shared picture of the reservoir between all Co-ventures. Having good alignment in subsurface interpretations facilitates a quicker and more effective decision-making process by all stakeholders.

This paper describes an innovative workflow to capture and assimilate relevant datasets to improve understanding of a field’s plumbing.

As a result of this work new opportunities were created including several infill well locations. The first of these has now been drilled resulting in a significant discovery of bypassed pay.

Plumbing Review Case Study

The case study in this paper shares an innovative approach to conduct a plumbing review of the Buzzard field, a giant mature oil field. Several benefits were realised from this approach, including the following;

- Concepts for several infill drilling targets were established during the plumbing review workshop, one of which has since been successfully drilled
- The Co-venture partnership developed an aligned interpretation of the reservoir, which supported collective decision making for field management decisions
- Key trends established in the production surveillance data led to the development of new conceptual geological models of the field and a higher quality geological model.

A specific challenge for the field in question is that the seismic imaging of the internal reservoir architecture is very difficult. This means that the understanding of connectivity within the field is heavily reliant on conceptual geological models validated by production surveillance. In addition, the Buzzard field has several zones from which production occurs, and often the production or injection is co-mingled so that allocating production to a specific zone is uncertain.

Given an established conceptual geological model for a field, the first step in testing that and deciphering the plumbing, is to review production surveillance history. However, this is a challenging task for the Buzzard field because of complexity in the multi-disciplinary datasets, such as the following.

- Geological data that provides the foundation of the conceptual geological models, such as core data, sedimentological descriptions and well correlations based on chemostratigraphy
- Geophysical data that provides plumbing information includes 4D time-lapse data
- Petrophysical data that provides information on field plumbing includes petrophysical properties such porosity thickness; formation pressure data acquired when wells were drilled; PLT data that shows vertical communication between zones and cased hole saturation data that shows development of the flood front through the field.
• Reservoir Engineering data that is incorporated into plumbing reviews includes well level production data, pressure interference data, production water chemistry and tracer data showing direct pathways between wells.

It is evident that each of these data types provide information at a different scale, some are relatable to several zones in a single well, while some relate to specific zones or sand units within a zone. These data types also have different levels of uncertainty, for example tracer data can be considered highly accurate while pressure interference between wells is more ambiguous. It is therefore challenging to integrate these data types in a consistent way. A key component of this plumbing review was firstly to organise the data and interpretations in a consistent fashion across the disciplines. Following this it was critical to develop an effective way to visualise the datasets in an intuitive way that made the interpretations accessible to multiple disciplines.

The approach taken to solve these challenges was to create a series of schematic network maps inspired by the London Tube map, first developed by Henry Charles Beck in 1931. A schematic map is a representation of the elements of a system using abstract, graphical symbols rather than realistic pictures. All details that are not relevant to the information are removed and the only elements added are there to aid comprehension without creating unnecessary visual clutter. This means developing a careful and creative scheme to convey the information in an intuitive and simple way. The maps may not need to be spatially correct, as areas with more information may be expanded to show more detail, if that proves useful.

The concept of a ‘Tube map’ was applied to this giant oil field, as a tool to organise and visualise the production surveillance and geological datasets. Individual maps, in the same style, were created for tracer data, pressure interference, geological deposition, RFT and PLT interpretations, and both 3D and 4D seismic interpretations, such as Figure 1 below.

![Figure 1 An example of a Tracer Detection Map is shown (well names removed). This illustrated the “pipes” or flow conduits in the field across the full stratigraphy.](image)

The plumbing map started with bubble plots to indicate zonal thickness of key intervals, colour coded by the zone present – these were the ‘tube stations’. A scheme to show which zones were completed and when completion changes occurred was also included. In a field with multiple reservoir zones this allowed well level production surveillance information to be appropriately allocated to different intervals, as shown in Figures 1 and 2. Connections between wells, interpreted from production surveillance data, were colour coded according to the zone that they related to, analogous to different lines on a tube map. For example if a tracer was travelling in the upper most sand interval it was colour
coded yellow, allowing a plumbing map showing tracer connections to be easily compared to a plumbing map that showed pressure interference, such as Figure 2.

![Field map](image)

**Figure 2** An example of a Pressure Interference Map is shown (well names removed). This illustrated the “pipes” or flow conduits in the field across the full stratigraphy.

The innovative visualisation of the production surveillance, geological and geophysical data in this format facilitated robust multi-disciplinary interpretation of the key plumbing trends, such as sweep pathways and potential infill well locations. Once the schematic maps had been created and organised for each data-set, a series of multi-disciplinary workshops were held with the subsurface teams from the Buzzard Co-Venture Partnership.

The framework for the workshops was firstly to focus in an intra-disciplinary way on each plumbing dataset or map, to develop a common understanding of that specific dataset, including the uncertainties associated with the interpretation and the key production trends established from that specific perspective. This interrogation was then repeated for each type of dataset.

The second part of the workshop involved break-out groups to develop geological conceptual models that were consistent with the key trends observed in each production surveillance dataset. This activity was completed for each specific zone or area of the field. Each group then fed back their geological concept, the uncertainties and opportunities they had identified and areas of further work. Effective facilitation of these workshops was essential to capture the insight that was developed.

A focus of the plumbing review was to develop a list of opportunities such as the location of bypassed oil. Concepts for several infill wells were created in the workshop and have since been matured and successfully drilled as part of the extended infill campaign.

Conceptual geological models were tested and incrementally developed through the plumbing review workshops to incorporate all the insight gained from close interrogation of the production surveillance data. Following the plumbing review geological sketches were created for each reservoir zone, that incorporated the best understanding of the field behavior. Internal reservoir architecture, conduits and baffles that were identified in the plumbing review were also included in the geological sketches, an example of which is shown in Figure 3.
Figure 3 An example of a Geological concept sketch which was an output from the plumbing review. These concept sketches were used to identify and plan infill well for the field.

These conceptual geological sketches then formed the foundation of a new geological static model, such as Figure 3. The initial architecture was tested through stream-line simulation workflows in which the plumbing maps, as shown in Figures 2 and 3, were used to validate model design choices. The quality of the history match of the initial model demonstrated the value of building in the field production behavior identified in the plumbing review.

Conclusions

The result of the plumbing review was an improved understanding of the reservoir shared by the Buzzard partnership, making development decisions easier to agree on. The plumbing maps are a record of the production surveillance data and will be updated with new surveillance information or wells, acting as a valuable tool going forward in the life of the Buzzard field. Significant opportunities were created through this process including several infill wells and intervention opportunities. The other significant output of the plumbing review was a strong foundation for the new reservoir model. Developing a sequence of intuitive plumbing maps that illustrate each of the production surveillance datasets helped to enhance multi-disciplinary collaboration and was key to the success of this approach in revealing the field plumbing.

Acknowledgements

The authors of this work would like to thank the Buzzard partnership (CNOOC International, ONE-Dyas B.V., Chrysaor Ltd, Suncor Energy U.K. Ltd) for their enthusiasm, contribution during the plumbing reviews and their permission to publish this work.

References