MAUI APPRAISAL CAMPAIGN AND MAUI-B DEVELOPMENT PLANNING

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The Maui Field has been producing gas and condensate from Paleocene/Eocene sandstone reservoirs since 1979. In 1986 an appraisal campaign was undertaken to better define the reserves and to plan the further field development to meet gas supply obligations to the year 2009. The appraisal campaign included:

(a) Acquisition of 1600 km of dense seismic coverage. Interpretation included direct mapping of hydrocarbons using seismic reflection amplitudes.
(b) Drilling (with full evaluation) of three appraisal wells.
(c) Integrated Petroleum Engineering study of the field and regional aquifer. The resulting reservoir geological model was used to create 3-dimensional numerical simulation models with 3900 and 2200 active grid blocks for the 'C' and 'D' reservoirs respectively. Simulations were performed to predict amongst other things:
    - Required timing of Maui-B
    - Optimum location for Maui-B
    - Optimum Maui-B well number and design
    - Optimum field depletion policy.

Based on the results of the Maui Appraisal Campaign, detailed design work for Maui-B is now underway.

HISTORY

The Maui Field is located some 35 km off the Taranaki coast in 106 m water depth and is entirely contained within PML 1012.

Discovered in 1969 by well Maui-1, the field was initially appraised by wells Maui-2 and Maui-3 (Maui-4 was drilled outside the field). The field was further defined by wide spaced, irregular grid seismic. This initial seismic set finally incorporated six vintages ranging from 1970 to 1983.

Following discovery, several years of negotiation resulted in the *White Paper on the Development of the Maui Gas Field, October 1973*. Under this agreement the Crown acts as Buyer of the gas under a Take-or-Pay arrangement with Maui Development Limited, a joint venture between Shell, BP, Todd and Offshore Mining (initially Government owned), acting as Seller. The Seller is entitled to any liquids stripped from the gas.

By the time the field came on stream in 1979 from the Maui A platform, the field's configuration had been defined to consist of two structural highs, known as the A and B areas, both of which contain hydrocarbon reservoirs in two sands known as the C and D sands. A common hydrocarbon-water contact (HWC) was considered to exist between the A and B areas in the C sand whilst smaller separate hydrocarbon columns with different HWCs were known to exist in the D sands.

At the time of the signing of the White Paper two platforms were anticipated, one on each of the structural highs and to be known as the Maui A and B platforms. The second platform on the B area was originally expected to be completed by 1983, however lower projections for gas demand in early years led to a deferment of Maui-B and to upgrades to the existing Maui-A platform to cover contractual deliverability requirements. The timing of the second platform remained linked to the decline in the Maui-A platform deliverability as the result of declining reservoir pressure with continued production.

Estimates of gas-initially-in-place (GIIP) and identification of the reservoir production mechanisms associated with the A area reservoirs became integral to correct Maui-B timing to ensure long term contractual commitments could be met. Attempts were therefore made in 1984 and 1985 to improve definition of the field by seismic reprocessing. Due to the large surface area of the field and low structural dips, uncertainities in time-to-depth conversion led to significant differences in GIIP estimates, and the need for further studies was identified.

REQUIREMENTS FOR FIELD APPRAISAL AND SEISMIC

To narrow down the GIIP uncertainty, a densely spaced seismic survey of a single vintage supported by appraisal wells was necessary. Some 1600 km of seismic with a line spacing of 500 m was shot in 1986 and wells Maui-5 to Maui-7 were drilled in the same year. The data gathered would be used in an integrated Petroleum Engineering Field Study, to be carried out by Shell Internationale Petroleum Maatschappij (SIPM), acting as Advisor to MDL. The study would involve seismic, petrophysical, geological and reservoir engineering disciplines culminating in a detailed reservoir simulation model for the field. The model was to be used to define the optimum field development including Maui-B timing and capacity and field production policies.

APPRAISAL DRILLING CAMPAIGN

The major objectives of the appraisal wells were:
(a) Structural control.
(b) Sand development definition.
(c) Connectivity of sands and degree of connectivity between the A and B areas (i.e., how much of the B area gas could the A platform drain).
(d) Obtain a comprehensive suite of log and core data for geological and reservoir engineering purposes.
(e) Establish well productivities by testing suitable hydrocarbon zones (both oil and gas) particularly in the B area.
(f) Collect reservoir fluid samples for compositional analysis.

WELL POSITIONING AND DRILLING SEQUENCE

The objectives above required that at least three appraisal wells would be drilled.

At least one well would be required in the B area sufficiently distant from Maui-1 to provide a suitable structural and sand development spread over the area but with a sufficient hydrocarbon column for representative testing.

The northwest of the A area provided the major difference between the 1984 and 1985 GIIP estimates and a well in this area was therefore appropriate.

With the interpretation of a common C sand HWC prior to appraisal drilling the likelihood existed of a small (± 5 m) gas column in the saddle area between the A and B highs. The degree of connectivity such a column could provide was questionable. Accordingly the scope for drainage of the B area from the A platform, if any, was unknown. A third well was therefore planned in the saddle area.

(a) saddle	Location F
(b) NW A area	Location G
(c) B area	Location E or X

These locations, marked on the 1985 C sand top structure map are shown in Fig. 1.

DRILLING RESULTS

Maui-5 (Location F) encountered the objective Kapuni Formation some 7 m deeper than anticipated. Surprisingly a 9 m hydrocarbon column was encountered in the well indicating that the assumption of a common HWC throughout the C sands was not valid.

The well was drilled to a total depth some 100 m into the D sand. Approximately 100 m of the C sand was cored and an extensive logging suite run over the open hole section.

Sand development in both the C and D sands was much as seen in the Maui A platform wells with all the main sand bodies correlatable although of variable thickness. Extensive RFT pressure measurements indicated partial pressure depletion had occurred in both the C and D sands as the result of production from the Maui A platform. Significant depletion in the underlying massive aquifers was also evident.

No testing was performed since the deeper HWC suggested the well to have penetrated a small, localised accumulation, separating the main accumulations in the C sands of the A and B areas. The D sands were entirely water bearing.

Maui-6 (Location G) found the objective Kapuni Formation within 10 m of prognosis, however a marked deterioration in C sand quality compared with Maui A platform wells was observed. The gas column and GWC were as expected and RFTs indicated that good communication existed in some of the C sands whereas only partial communication existed for the D sands. Extensive coring and logging were successfully carried out.

On the basis of wells Maui-5 and Maui-6, and to maximise the chances of penetrating good sand development, Location E was selected for Maui-7. The Kapuni Formation was again encountered within 10 m of prognosis, although not all the sands found in the A area wells were present. Extensive cores and logs were again taken. FRTs confirmed partial depletion in the C and D sands in both the hydrocarbon zones and aquifer. A thin oil leg was encountered in the C sand, although the areal extent of this leg remains uncertain.

Four zones were separately production tested to establish potentials and collect fluid samples.

Zone 1	D1 Sand Gas
Zone 2	C2 Sand Oil
Zone 3	C1 Lower Gas
Zone 4	C1 Upper Gas

Production potentials were confirmed to be similar to comparable sands in the A area. Surface recombination or wellstream composition samples were gathered for all zones. Production testing and subsequent fluid analysis confirmed higher CGRs for the B area sands compared to the equivalent A area sands.

All wells were abandoned with cement plugs. From the appraisal wells the following conclusions/new data were derived:
(a) All depths showed a good match to the 1985 seismic interpretation being within 10 m of prognosis.
(b) Different C sand HWCs were established in the A area, B area and saddle.
(c) A small, low amplitude closure was present in the saddle area.
(d) A general sand deterioration occurred in the C sands to the NW.
(e) A thin oil leg was present in the B area C sands although its lateral extent remains uncertain.
(f) This oil leg if present over the entire B area would replace pore volume previously thought gas filled.
(g) Higher CGRs were established for B area sands with evidence of an increasing C sand CGR with depth.
(h) Some pressure depletion had occurred in all major sands, both hydrocarbon and water filled, due to A area production.
(i) The C sand displayed excellent connectivity particularly in the underlying C2/C3 aquifer whilst a poorer connectivity was evident for the D sands.

SEISMIC AQUISITION

The production sesimic survey programme is shown in Fig. 2 and consists essentially of 80 dip lines spaced at 500 m

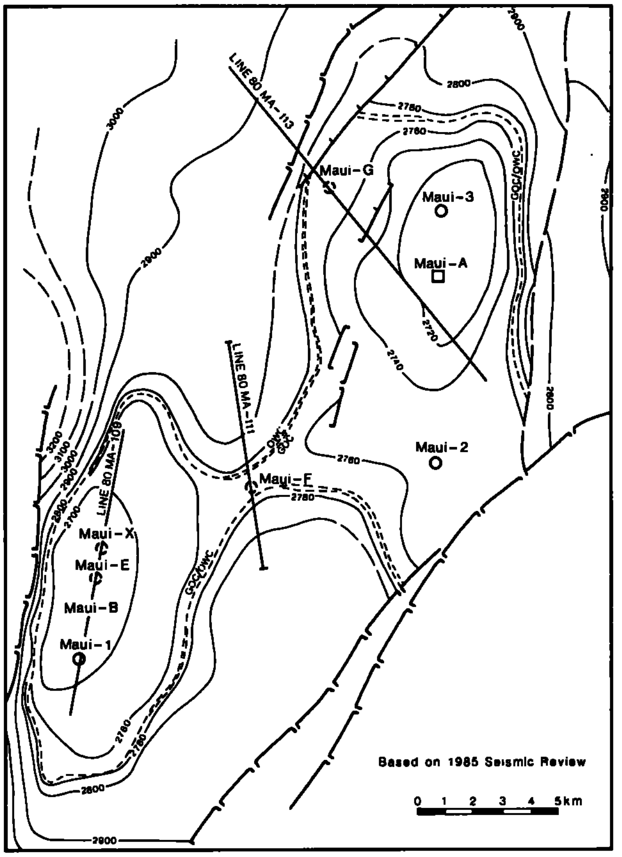

Fig. 1: Maui Field depth map: top of C1 Sands.

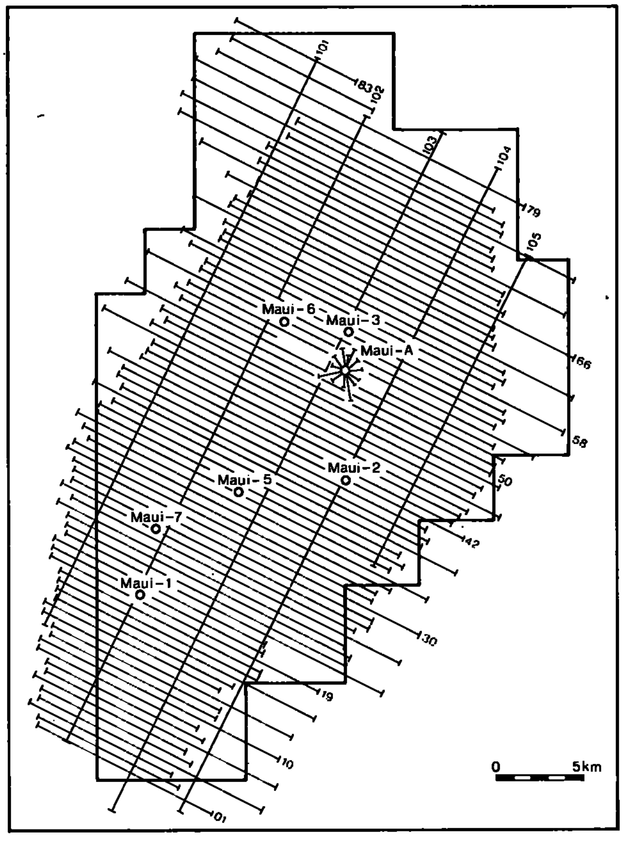

Fig. 2: Seismic line location map (1986) of the Maui Field, New Zealand.

intervals with five strike lines at 4 km intervals. The dip line direction was chosen to intersect the known fault patterns as near normally as possible in order to minimise errors introduced by migration processing.

The acquisition contractor was Western Geophysical using a high pressure airgun array (19 guns, 1530 in^3 at 4600 psi) firing every 26.67 m. A 240-channel digital streamer was used with a group spacing of 13.33 m and offsets ranging from 209 to 3396 m. Data were recorded to 5000 ms with one ms sampling using a multiplexed SEG D format. Demultiplexing, resampling to 4 ms and conversion to SEG Y format was carried out at the GECO facility in New Zealand.

PROCESSING/INTERPRETATION

Processing of the data was carried out by SIPM with the sequence designed to optimise data quality and preserve relative amplitude information. Additionally, since lateral velocity variations in the overburden were known to exist, the processing sequence included continuous velocity analyses of the entire data set to establish the velocity field for subsequent time-to-depth conversion.

Interpretation of the data was carried out by SIPM using the SIDIS workstation to establish the fault patterns, to time pick selected horizons, and to generate amplitude maps. Synthetic seismograms were constructed for all exploration/appraisal wells in the field and were used to calibrate the seismic data. This facilitated not only identification of the seismic loops representing the main reservoir levels, but also helped in establishing a reservoir model in which areas of better reservoir development were identified.

During the processing and intepretation phases it became obvious that part of the peripheral area of the field was affected by extensive low-velocity shallow anomalies. These occur in a zone up to 3 km wide paralleling the Cape Egmont Fault and cause severe deterioration of the data quality and inaccurate velocity determination. The problem was further compounded by the large vertical displacement of the Cape Egmont Fault itself, hence the interpretation in this zone was less reliable than for the rest of the Maui structure.

Depth maps for the top C1 and D1 reservoirs were calculated from the picked times and the velocity information. Final adjustments to these maps were made using the well control supplemented by the C1 amplitude information which was useful in delineating the extent of the hydrocarbon accumulations.

Rapid changes in amplitude occurring systematically from line-to-line were interpreted to represent the HWC and their occurrence was used to adjust the C1 depth map. A number of small areas of relatively high amplitude in downflank locations are not explained by hydrocarbon accumulations, but probably relate to areas of relatively better (brine-filled) reservoir development.

Amplitude data for the D1 reservoir do not lend themselves to this type of feature analysis, as it appears that only the thickest parts of the hydrocarbon column are distinguishable.

The final top structure map for the C sands resulting from the seismic and appraisal drilling campaign is given as Fig. 3.

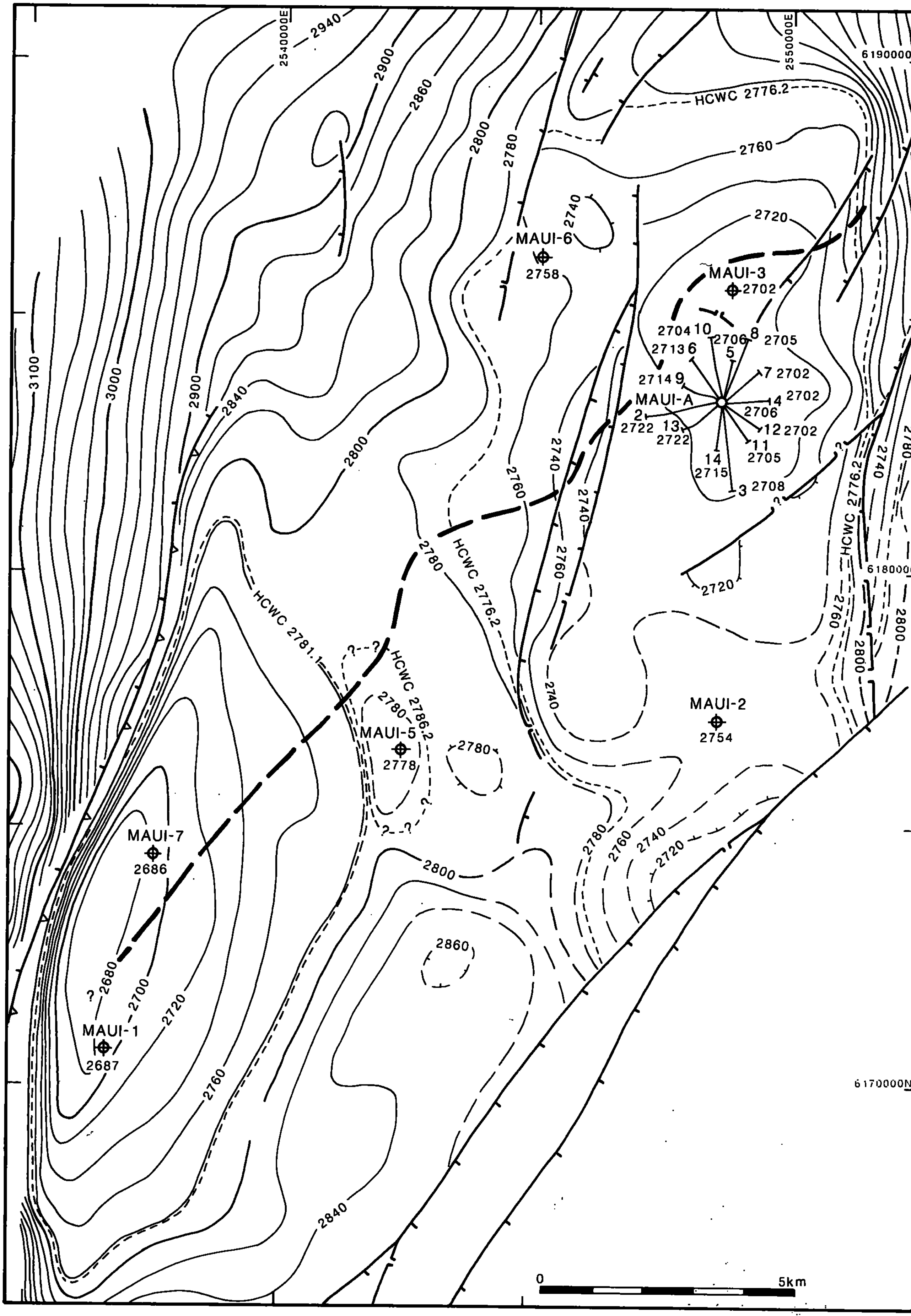

Fig. 3: Structure contour map at the top of C1 Sands, Maui Field, New Zealand.

INTEGRATED PETROLEUM ENGINEERING STUDIES

The above results formed the basis for the Integrated Petroleum Engineering Studies, carried out by SIPM, which included the construction of a geological model of the field, an integrated petrophysical review and reservoir engineering studies including a 3D reservoir simulation.

The reservoir geological study aimed to:

(a) Construct a reservoir model for hydrocarbon-in-place calculations and input to the reservoir simulation.

(b) Study the size, transmissibility and directional aspects of the aquifer.

Available data used in the study were seismic maps, log data including RFTs to define reduced transmissibilities and dipmeters for structural control, together with some 550 m of core from the field and some 40 m from aquifer wells.

For each reservoir layer isochore, average net/gross ratio, average in-situ porosity and average in-situ permeability maps were constructed. Map trends were modified as necessary to fit the interpretations of depositional environment.

Regional geological and seismostratigraphic studies were undertaken to define a potential aquifer area.

All these features were combined in a 26 x 12 x 14 block reservoir simulation model for the C sands and 26 x 12 x 8 block model for the D sands. Following history matching of the A area reservoir histories and RFT pressures measured in appraisal wells, various production scenarios were investigated with a view to optimizing field development.

FIELD DEVELOPMENT PLANNING

The results of approximately thirty simulation runs carried out with the full field model in SIPM have been used to define an optimum depletion policy, aiming at maximising ultimate recovery of gas and hydrocarbon liquids from the various Maui reservoirs.

The study has addressed such aspects as the required well pattern, the preferred policy with respect to zonal recompletions, the production capacity of individual wells and their required hardware configuration, the distribution of offtake between the A and B platforms, the predicted aquifer performance and watercut behaviour of individual wells and other relevant planning aspects.

Further simulation runs are planned to be carried out during 1989 and 1990 in SBPT to further fine tune field development planning based on the most recent production information available. In the long term the full field simulation model will be maintained in SBPT to act as a production planning tool with respect to future gas demand forecasts from Buyer. To this end the model will be updated after the drilling results of Maui-B are available.

Currently the model is being used to support the engineering design of Maui-B and its related facilities, which on the basis of current planning are foreseen to comprise the following elements:

(a) A 400 MMscf/d normally unmanned satellite gas production platform from which eight wells will initially be drilled. The wells will be completed with 7" tubing, which in view of the corrosive nature of the untreated gas will be 13% chromium. The platform will be a steel substructure with a wellhead module supporting a modular drilling package. Drilling will utilize a platform mounted derrick and power generation system, but all other equipment and facilities will be provided by a drilling tender.

(b) A single 20" corrosion resistant pipeline to transport the total combined wellstream to Maui-A where it will be separated and treated for transport to shore together with Maui-A production.

(c) Onshore facilities will comprise an additional fractionation train and new gas refrigeration equipment; both required to process the Maui-B wellstream with its higher liquid yields than Maui-A.

First gas from Maui-B is currently scheduled for early 1993.