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EPP SA-1

OTWAY BASIN

1991 OTWAY 2D SEISMIC SURVEY
EPP SA-1
FINAL REPORT

Submitted by

BHP Petroleum

1993

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PRIMARY INDUSTRIES AND RESOURCES SA

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BHP PETROLEUM PTY LTD

EXPLORATION PERMIT FOR PETROLEUM SA-1

DECLARATION OF ENVIRONMENTAL FACTORS

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DECLARATION OF ENVIRONMENTAL FACTORS

1. INTRODUCTION

BHP Petroleum Pty Ltd, as operator of Exploration Permit for Petroleum No.SA-1 (EPP SA-1), held by BHP Petroleum (Victoria) Pty Ltd and Cultus Petroleum (Australia) NL submits the following Declaration of Environmental Factors (DEF) covering the proposed acquisition of 70 kilometres of marine seismic data within the area specified in the permit during July 1991. The DEF has been prepared in conformity with a condition of the permit and follows the requirements of the Petroleum Regulations under the *Petroleum Act*, 1940.

The relevant condition of the permit is as follows:

> Prior to undertaking any operation in the permit area the permittees shall submit for the approval of the Director-General, Department of Mines and Energy a Declaration of Environmental Factors and Code of Environmental Practice describing the natural environment in the area of the proposed operation and setting out procedures which will be undertaken to minimise impact on the environment.

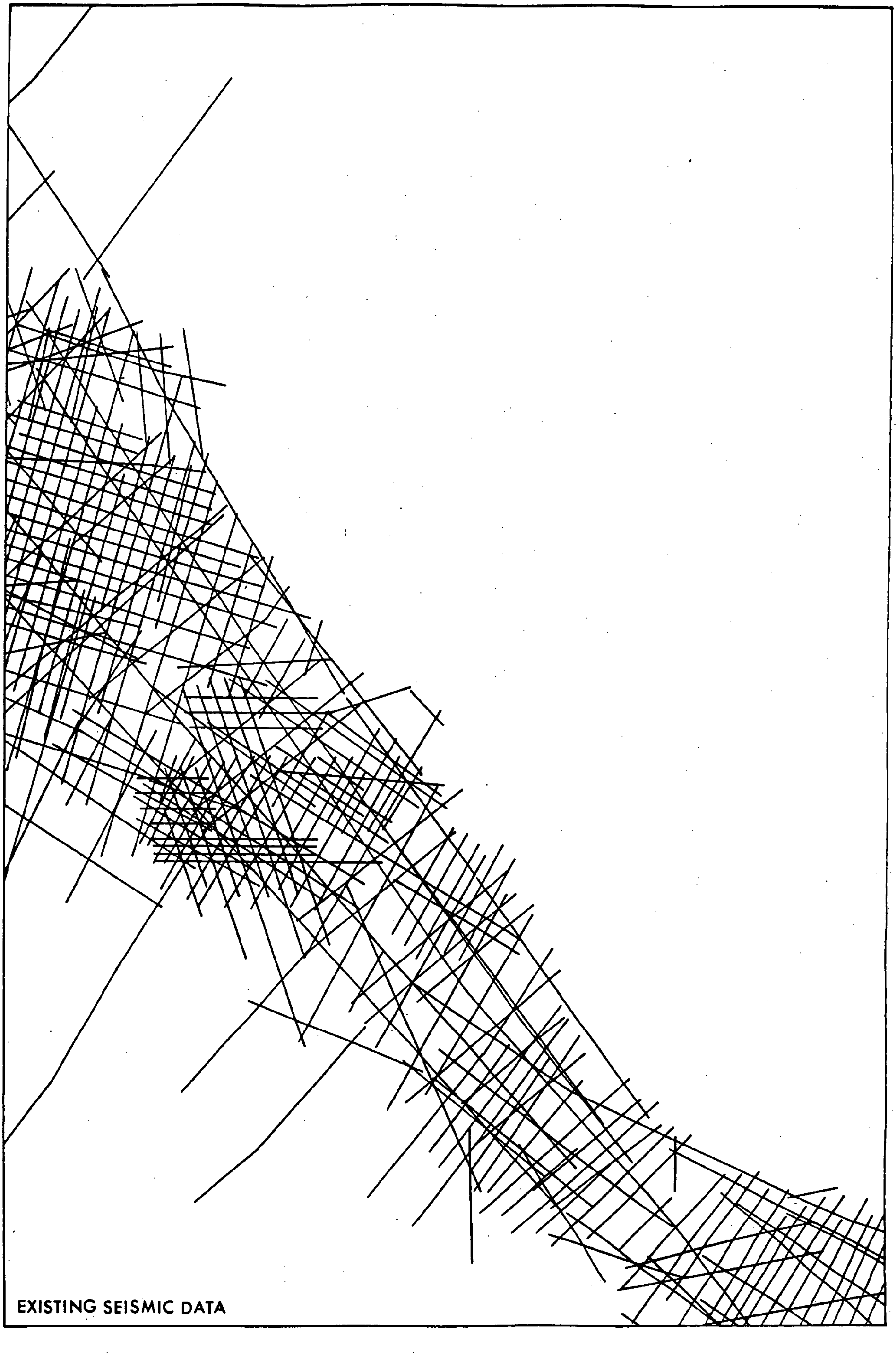
Regulation 16(1) imposes a general obligation upon an operator to undertake operations under a licence in such a manner that adverse impact on the environment is either avoided or minimised. To assist in the meeting of this obligation, the Petroleum Regulations provide for the preparation of a DEF by the licensee before the commencement of operations.

EPP SA-1 consists of a strip of coastline approximately 5.556 kilometres (three nautical miles wide), that extends approximately 130 kms south from Cape Thomas (near Robe) to Douglas Point (near Port MacDonnell). Figure 1 shows the coastline and coastal towns adjacent to EPP SA-1, as well as the water depths and some of the larger islands within the permit. The location of the proposed seismic lines is also indicated.

The map overlay indicates the lines of previous seismic surveys carried out in the same area.

1.1 Requirement for a DEF

As indicated above, the obligation to undertake a DEF arises by virtue of a condition imposed upon the operator through the Exploration Permit for Petroleum. The *Petroleum (Submerged Lands) Act*, 1982 contains no requirement for a DEF and therefore does not refer to the nature of such a document if it is required by the Minister for Mines and Energy.



EXISTING SEISMIC DATA

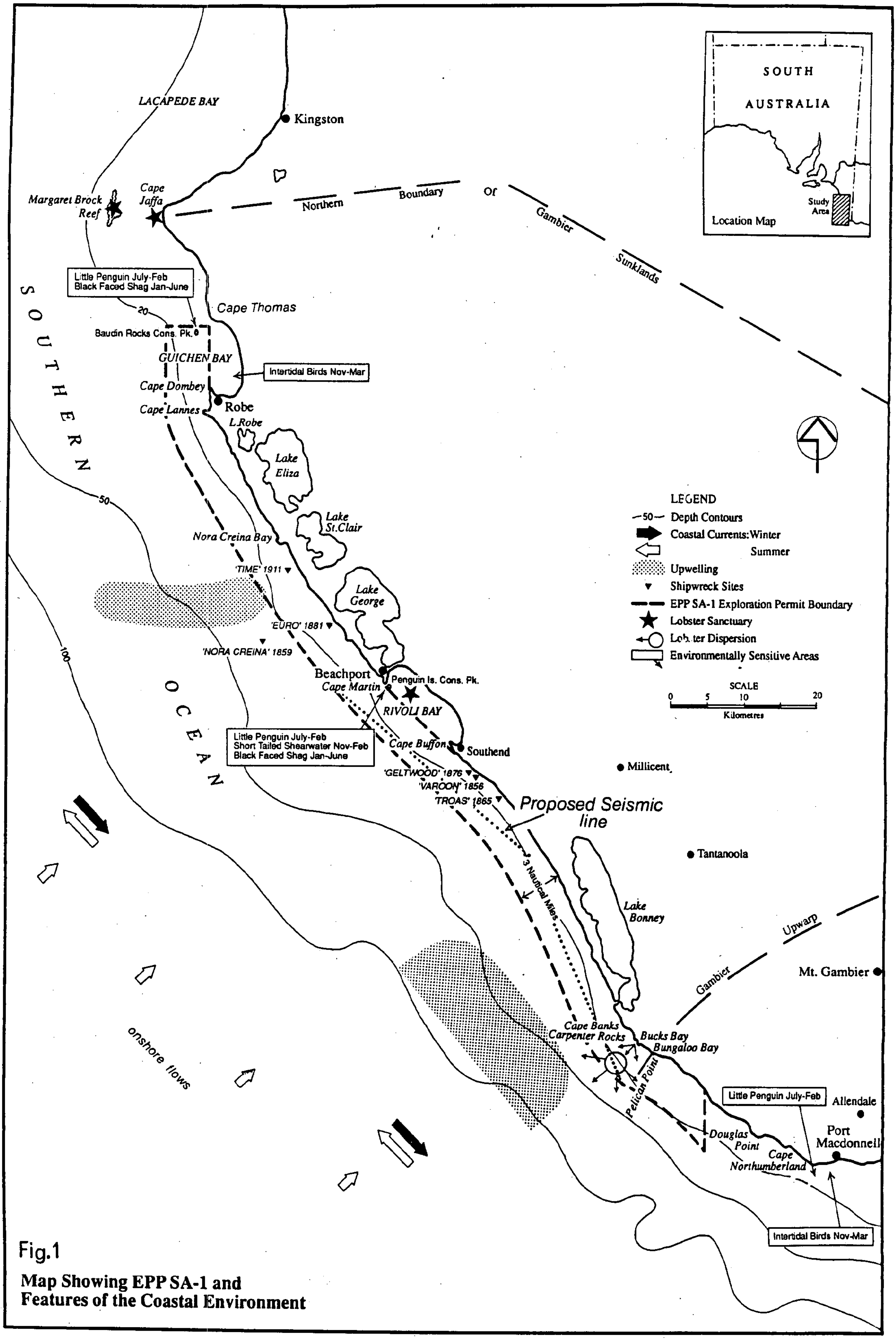


Fig.1

Map Showing EPP SA-1 and Features of the Coastal Environment

Consequently, the Department of Mines and Energy relies informally upon the specifications for a DEF contained in the Petroleum Regulations, 1989.

This DEF conforms, therefore, with the requirements of the Petroleum Regulation, 1989 (Regulation 16). It has been prepared in a manner and form regarded as acceptable by officers of the Department of Mines and Energy and reflects the structure and presentation of DEFs prepared by operators under the Petroleum Regulations. The following outlines the requirements for a DEF as specified in Regulation 16.

Prior to the commencement of surveying, an operator is required to submit for the approval of the Director-General of Mines and Energy a declaration of environmental factors (DEF) and may not commence surveying (or other specified activity) until the DEF has been approved.

In addition to the requirement for a DEF, it is also necessary to submit to the Director-General a code of environmental practice which addresses a range of occupational health and safety and environmental protection matters specified in Regulation 16(4) (a)-(d). The code has been incorporated into the DEF. It is necessary that the code be reviewed by the operator at least every three years and resubmitted for the approval of the Director-General (see Regulation 16(5) and (6). It is assumed that the Minister will apply similar conditions to his approval of this DEF.

The Director-General may apply conditions to a DEF or to a code of environmental practice.

In the case of a DEF prepared for an exploration programme permitted under the *Petroleum (Submerged Lands) Act*, a failure to comply with the approved DEF and any conditions imposed by the Minister would contravene the conditions of the permit and could thus result in the licence suspension and cancellation provisions of the *Petroleum (Submerged Lands) Act* being invoked.

1.2 Scope of Declaration

The declaration of environmental factors:

- describes the type of work to be undertaken;
- describes the vessel and other equipment to be used, including crew size and number of specialist personnel;
- describes the natural environment, with particular reference to the physical and biological features and present uses of these coastal waters;

- identifies specific sensitive areas or uses, including historic relics such as shipwrecks, lobster sanctuaries, whale migration routes, seabird rookeries;

- details the consultation and liaison undertaken with government departments and other responsible groups and interest groups;

- identifies concerns of these groups;

- evaluates environmental impacts of the proposed work;

- describes measures proposed to avoid or minimise environmental impacts; and

- submits a code of environmental practice covering:

  (a) worker health and safety and public safety;
  (b) protection of wildlife, fisheries, and sites of natural and historical significance.

2. THE WORK PROPOSED

2.1 Application of Legislation

The operations proposed by BHP Petroleum will be undertaken pursuant to the conditions of Exploration Permit for Petroleum No. SA-1 issued under the *Petroleum (Submerged lands) Act,* 1982. The condition requiring a DEF is reproduced in Section 1.

2.2 Location of the 70 km Seismic Survey

70 km of seismic data is to be acquired inside the three mile (5.556 km) zone along a strip of coast off Rivoli Bay (Figure 1). The permit does not include Rivoli, Guichen, or Nora Creina Bays.

The area to be surveyed lies within State waters, and within the South East Coast Protection District defined under the *Coast Protection Act,* 1972, which extends from the mean high water mark for a distance of three nautical miles seaward of the mean low water mark.

2.3 Timing of Survey

The inshore survey within EPP SA1 is part of a larger contract of some 11500 km of seismic data to be acquired off the South Australian and Victorian coastlines in the months of March-July 1991. The work in EPP SA-1 is proposed for early May 1991, after the closing of the rock lobster season at the end of April, and before the predicted coastal migration time of the Southern Right Whales.

The proposed survey work will require one to two days of favourable weather, so the exact date of the survey will be fixed at short notice, depending on an appropriate weather forecast. Arrangements for notification of the timing are detailed in Section 8.

2.4 Techniques and Equipment

The marine seismic method involves the generation of shock waves from a group of submerged seismic airguns, and the recording of shock wave echoes that bounce back from rock layers beneath the sea.

The shock waves used in modern marine seismic operations are produced from a group of compressed air "guns" towed some six metres below the sea surface and not from dynamite or other explosive charges as was used in the 1960's.

Each gun is attached to a surface float to prevent sinking. The seismic vessel contracted for EPP SA-1 uses an airgun group with a total volume of 2250 cubic inches and at pressures of 2000 pounds per square inch, produces a shock wave that would measure 258 deci-Bells (dB) with respect to one micro-Pascal (1 uPa) at a detector positioned one metre from the airgun group. A broaching whale, by comparison, generates shock waves of the order of 200 deci-Bells with respect to one micro-Pascal at one metre (Warren, 1989).

If pressure units of Bars are used, the source strength is equivalent to about 80 Bar at a distance of 1 metre (1 bar = 1×10^{11} micro-Pascals). As the distance from the source increases, the received level decreases, and for distances less than 3.5 km (3500m) is calculated from the formula:

$$\text{Level} = \frac{8 \times 10^{12} \text{ micro-Pascals}}{\text{distance in metres}}$$

The deci-Bell (dB) equivalent is 20 x Log (level).

For example, the shock wave which measures 258 dB at 1 m is equivalent to 188.6 dB at 3000 m (3 km) (see Appendix C).

During the seismic survey, the vessel proceeds in a straight line at a speed of 4-5 knots, firing at intervals of approximately 11 seconds. Echoes from rock strata beneath the sea are recorded by hydrophones embedded in a seismic cable towed behind the survey vessel.

The length of the seismic cable is determined by the depth of the rocks of interest, and operating conditions such as local currents and water depth. In open waters, the length used is the maximum the operating vessel can handle, about 3200 m for this survey. Within EPP SA-1, a shorter 1600 m cable may be used if the results of scouting suggest this will reduce the chance of the cable snagging any obstruction.

The depth at which the cable is towed can be adjusted by paravanes, and is chosen to minimise wave noise and false echoes from the surface while keeping well clear of the sea bed. The cable depth in open water is about 8 m but in the shallower EPP SA-1 area may be reduced to 4 m.

The tail end of the cable is marked by a buoy to aid recovery if lost from the ship.

The survey vessel will fly the appropriate towing signals to indicate that it cannot deviate from a straight course. The length of tow is indicated in the current notice to mariners, issued by the South Australian Department of Marine and Harbours.

2.5 The Survey Vessel

The Western Geophysical vessel 'M/V Western Odyssey' has been contracted by BHP Petroleum to acquire 70 km of seismic data in EPP SA-1 as part of a larger contract for some 11500 km of data off the South Australian and Victorian coastlines between March and July 1991.

The 'Western Odyssey' is 56.4 m long, weighs 894 tonne gross, and has a draft of 4.2 m. Complete specifications for the vessel are listed as Appendix B. Up to 36 staff and crew can be accommodated, with about half of these being scientific staff.

The Australian marine crew manning the ship will be replaced by a new crew every five weeks, with Portland (Vic) and Port Lincoln (SA) the likely ports for crew changeover, waste discharge and supplies.

The amount of waste produced is expected to conform to other vessels of similar size, and will be handled according to the IMCO and SOLAS International standards stipulated by the *Australian Navigation Act*. For example, all solid material is compacted and stored and all oily wastes such as bilge water and separated, stored and off-loaded correctly in port.

A single scouting vessel will be used throughout the survey within EPP SA-1 to check water depth information and the presence of obstacles such as crayfishing pots or shark nets. The 15.2 m crayfishing vessel 'Shelley Ann K', normally based in Port MacDonnell, will carry out this contract and will scout ahead of the seismic vessel.

3. THE NATURAL ENVIRONMENT

3.1 The Coastal Environment

3.1.1 The Physical Environment

The South Eastern Coast of South Australia referred to as the 'Bonney' Coast (Bye 1983) is characterized by the very narrow (<50 km wide) continental shelf which borders the southern ocean south of Cape Jaffa. North of Cape Jaffa the shelf widens to more than 150 km off Lacepede Bay, within the South Australian Sea.

The area covered by EPP SA-1 lies south of Cape Thomas at the northern end of Guichen Bay, and extends in a south-easterly direction to Douglas Point about 10 km north-west of Port MacDonnell. A detailed description of this portion of the coastline (Clark 1990) is attached as Appendix D. The coastal region lies within the Gambier Sunklands consisting of Mesozoic and Tertiary bryozoal limestones overlain by dune ranges of ocean beach sand extending more than 50 km inland.

The coastline is described by Lewis (1981) as a recent aeolianite ridge running from Margaret Brock Reef, at the northern end of EPP SA-1, south-east through Baudin Rocks, Cape Lannes, Cape Martin and Cape Buffon bounding Rivoli Bay, and then as a series of offshore reefs to Cape Banks. Sandy bays such as Guichen and Rivoli Bays represent breaches in this sand-rock ridge.

The 70 km of seismic lines will run roughly parallel to this shoreline between Cape Martin and Cape Banks, outside the coastal reefs and within three nautical miles of the shore. A seasonal cycle in the up-welling of nutrient rich water onto the narrow continental shelf (south of C. Jaffa) between January and March is induced by south-easterly winds which prevail between November and March, and may also be influenced by the presence of submarine canyons which extend to depths >1500 m (Lewis 1981).

Bye (1983) describes a notable feature named the Von Der Borch Canyon (38^{o} 25 S, 138^{o} 25'E) which lies about 100 km south-west of Beachport and extends from 3000-4500 m depth.

The same paper describes the mean monthly coastal currents which flow northwest in summer and south-east in winter (Figure 1) in response to the prevailing westward and eastward wind stresses on the Bonney Coast (Bye 1983). Onshore transports between Cape Jaffa and Cape Northumberland are related to the westerly flow of the deep ocean Flinders current.

3.2 Subtidal Communities

Seagrass communities predominate in the sandy bays such as Rivoli Bay, excluded from EPP SA-1. Outside of the bays, the aeolianite reefs, stepped to about 20 m, support bryozoan communities, with the large brown algae *Durvillaea* and *Macrocystis* occupying shallower outcrops (Lewis, *pers. comm.* Womersley 1987). These algae are characteristic of cold temperate coasts with considerable wave action.

The eroded limestone and aeolianite reefs along the shoreline of the 'Bonney' coast form extensive den/cave systems which shelter dense populations of the Southern rock lobster, *Jasus novaehollandiae.*

Lobsters lack defensive claws, relying on short body spines and cryptic day time behaviour for protection from predation. Consequently, the density of the lobster population is greatest in areas of favourable reef substrate, which is almost continuous parallel to the shoreline between Margaret Brock Reef and Carpenter Rocks at Cape Banks (Figure 1).

Areas at Cape Jaffa, Margaret Brock Reef and Rivoli Bay (including Penguin Island) have been declared lobster sanctuaries, where fishing is prohibited (Figure 1). Only the sanctuary in Rivoli Bay abuts EPP-SA-1. (see Section 4.2).

Abalone are also an important species colonizing inshore reefs, the two commercial species being *Haliotis ruber* (Black lip Abalone) and *Haliotis laevigata* (Green lip).

Both inshore and offshore waters harbour a diverse fish population including 148 species of 81 families (Glover 1983). Inshore species include Red snapper (*Trachichthodes gervardi*), Sweep (*Scorpis* sp.), Leatherjackets (*Monacanthidae* spp.) and Ling (*Genypterus blacodes*). Sport fishermen in the area also catch Flathead (*Platycephalus*), Snapper (*Chrisophrys unicolor*), Mackerel (*Scomber australasicus*), Australian salmon, King George Whiting, Garfish, Yellow-eye Mullet, Black Bream and Blue Pointer (Mako) shark (*Isurus oxyrinchus*). The region has been designated a high priority area for increased research effort (Glover 1983).

Occasional sightings of the Southern Right Whale have been made along this coast, but they are infrequent compared to the sightings north of Cape Jaffa and east of Portland.

The Southern Right Whale is on average about 15 m long, and weighs about 50 tonnes, cruising at a speed of 1-5 knots, ie, at a top speed similar to that of the survey vessel when towing the cable. The whales feed at or just below the surface, and dive for periods of 10-15 minutes before rising to exhale a characteristic v-shaped spout of water from each nostril. Their surface behaviour includes basking and rolling over on their backs, and slapping the surface with flippers and tails.

Whales do not generally appear along the southern coast of Australia before the end of May, and there are no reports of whales with calves until June, July and August (Warnecke 1989).

Only one of the fifty reported sightings in South Australian waters in 1990 was along the Bonney coast. Whales appear to favour the shallower sandy coastlines, and may by-pass the narrow continental shelf along this coast (J. Ling, *pers. comm.*).

3.3 The Commercial Fisheries

Robe, Beachport, South End and Port MacDonnell are major fishing ports in Zone S of the South Australian fishery. Within three nautical miles of the coastline, the most important commercial operations are the Rock Lobster and Abalone fisheries.

The Southern rock lobster fishery in the 1989-1990 season produced 1528 tonnes of lobster with a value of 22.5 million dollars. The fishery has yielded 1350-2140 tonnes annually since 1965, representing about 75% of the South Australian catch. The Zone S fishery was considered to be fully exploited by 1968, and increased closure periods and reduction in pot numbers have since been applied in an attempt to reduce fishing effort. The present fishing season closes at the end of April 1991, before the scheduled time of the seismic survey in May.

Zone S lobsters reach similar maximum lengths to those in Northern (west coast) waters but the growth rate is slower in Zone S, possibly due to lower water temperature and a higher stock density with more competition for available food. In Zone S female rock lobsters mature at three to four and half years, with a total carapace length of 75-80 mm (112-114 mm in Zone N). Females moult during June and July, and males during October and November (Lewis 1981).

After egg development, the first free floating larval stage commences in October-November, and settlement of the final larva, a miniature transparent rock lobster (*puerulus*) occurs in July-September with a minor settlement period in January. These observations have been consistent since 1973, when the current research in Zone S began (Lewis 1981).

After settlement, some movement in addition to short distance nocturnal foraging has been reported. Longer range dispersive movement of up to 28 km from the shallow inshore to offshore areas shown on Figure 1 are reported by Lewis (1981), and returns of tagged lobsters from the Kingston-Cape Jaffa region also suggests migrations of populations over long distances within a confined period of time.

The Abalone fishery in Zone S comprises a much smaller proportion of the annual State catch than the lobster fishery, around 15%, with most of the fishing carried out on the nearshore reefs. *Haliotus ruber,* the Black Lip Abalone, comprises about 90% of the catch (with the Green Lip *H. laevigata* making up the remainder.

In the 1989-90 season, 127 tonnes of Abalone were produced in Zone S with a value of more than two million dollars (excluding shell value). The total State catch was 957 tonnes.

Divers operate on a quota system, and for the current season, only two divers had not fished their quota by mid-March (J. Godden *pers. comm*).

The third important commercial fishery in Zone S is the shark fishery (for school and gummy sharks (*Galeorhinus australis* & *Mustelus antarcticus*)) which is carried out with set nets or long lines. This fishery operates mainly in Commonwealth waters outside the three nautical mile zone, so may not be affected by the survey in State waters.

A deep water trawl fishery taking principally Gem fish (*Rexea solandri*) and Blue Grenadier (*Macruronus novaezelandiae*) also operates at a depth of about 200 m at the edge of the continental shelf (Glover 1983), outside EPP SA-1.

The remaining commercial operations are small, such as hand lining inshore for Red Snapper, Sweep, Leatherjackets and Ling.

3.4 Environmental Legislation

A range of Commonwealth and South Australian environmental protection legislation applies within that area of EPP SA-1, which is State territorial waters. A detailed resume of that legislation appears in Appendix A. The following addresses those Acts which impose particular obligations upon BHP Petroleum in undertaking their seismic survey.

There are no aquatic reserves declared under the *Fisheries Act,* 1982 within the area subject to this DEF. However, it is an offence for an operation to disturb the sea bed or interfere with aquatic or benthic flora or fauna other than in conformity with the regulations or a permit. A penalty of \$1000 maximum for a first offence, \$2500 maximum for a second offence and \$5000 maximum for a subsequent offence is imposed by the Act.

The proposed exploration programme involves no risk of disturbance or degradation of aquatic flora or fauna or the seabed.

Waters at Rivoli Bay on the boundary of EPP SA-1 have been 'closed' under the *Fisheries Act* for rock lobster fishing. It is an offence to take a lobster from the area. The proposed exploration programme involves no taking of rock lobster from those areas, incidentally or otherwise.

Baudin Rocks and Penguin Island Conservation Parks have been constituted under the *National Parks and Wildlife Act*, 1972. The former is within EPP SA-1, the latter on the boundary (see Figure 1). As there is not yet a management plan for either reserve, behaviour on the islands is controlled by the regulations under the *National Parks and Wildlife Act.*

BHP Petroleum anticipate no reason for its crew to require access to either island.

The *Commonwealth Whale Protection Act*, 1980 has never applied to State waters in South Australia. Whales are protected through the provisions of the *Fisheries Act* constituting it an offence to 'take' a marine mammal, including whales. The term "take" includes killing or destroying and, in that event, a maximum fine of $2000 is applicable for a first offence and $5000 maximum for the second.

Whales are also protected under the *National Parks and Wildlife Act.* It is an offence to "take" any migratory mammal and under that *Act* "take" includes injury or killing. An offence attracts a maximum penalty of $2500 or imprisonment for six months.

4. SENSITIVE AREAS AND FEATURES

Some areas of the South East coast are accorded special recognition because of their particular environmental values.

4.1 Shipwrecks

The South East coast of South Australia contains a significant number of shipwrecks from the time of earliest exploration and settlement of the colony and many of the vessels where wrecked within three nautical miles of the coast.

4.1.1 Location of Wrecks

Between Robe and Rivoli Bay, within the Northern half of EPP SA-1, there are three documented shipwrecks, the sites of which have not been found.

Another three wrecks are reported south of Rivoli Bay (Figure 1). Brief notes on each appear in Appendix E.

The coastline between Cape Buffon, at the southern end of the Rivoli Bay, and Cape Banks, at the southern end of Lake Bonney is considered to receive the highest break of wave energy on the south east coast (Short and Hesp, 1979). Of the six documented wrecks within the survey area, the two from which there were no survivors occurred in this area.

Of the six wrecks between Robe and Cape Banks, the precise location of five are still unknown.

Only the wreck of the *Geltwood* has been located on a reef 1.5-2 km offshore from the northern end of Lake Bonney. The *Geltwood* is one of South Australia's most significant wreck sites, and is protected by the Commonwealth *Historic Shipwrecks Act,* 1976 (see below). It is regarded by the Heritage Branch of the Department of Environment and Planning as particularly fragile.

4.1.2 Application of Legislation

Shipwreck sites along the South Australian coast are protected by both the Commonwealth *Historic Shipwrecks Act,* 1976 and the South Australian *Historic Shipwrecks Act,* 1981. The former applies in all waters except bays defined using straight baselines (see Clark, 1990).

The operational area (EPP) for BHP Petroleum includes two such bays (Guichen and Rivoli). However, the eastern extremities of EPP SA-1 cut across those bays, essentially following the baseline. As BHP Petroleum does not propose exploring within those bays the South Australian Act does not apply.

As indicated above, there are several documented shipwreck sites within the territorial waters encompassed by EPP SA-1. However, only one, the Geltwood, has been declared an historic shipwreck pursuant to section 5 of the Act.

It is an offence pursuant to section 13 of the *Commonwealth Historic Shipwrecks Act* to, *inter alia*, damage, destroy or interfere with an historic shipwreck or relic. However, under section 15 of the Act, the Minister may issue a permit authorising that which is otherwise prohibited by section 13. The Minister may apply conditions to the permit.

Because the generation of shock waves in adjacent waters may constitute interference with the wreck site, a permit is required under the Commonwealth Act. It will be issued under the delegated authority of the Minister of Environment and Planning in South Australia.

4.2 Lobster Sanctuaries and Reserves

Three important habitats sheltering dense populations of the Southern Rock Lobster have been identified on the south-east coast, and declared sanctuaries under the management of the South Australian Fisheries Department. Only the sanctuary in Rivoli Bay, which includes Penguin Island and Cape Martin, abuts EPP SA-1. The sanctuaries at Cape Jaffa and Margaret Brock Reef are approximately 15 km north of the permit area, which begins at Cape Thomas, the northern end of Guichen Bay.

Two of the parks managed by the South Australian National Parks and Wildlife Services are located within three nautical miles of the coast and within or close to EPP SA-1.

The Baudin Rocks Conservation Park, also known as Godfrey Island, comprises several small rocky islands south-west of Cape Thomas, set aside to protect a breeding colony of crested terns (*Sterna berigii*) and little penguins (*Eudyptula minor*). The park is included in the northern end of EPP SA-1, which does not enter Guichen Bay.

Penguin Island Conservation Park, off the northern end of Rivoli Bay, is also a breeding ground of little penguins and crested terns, as well as silver gulls (*Larus novaehollandiae*) and black-faced shags (*Leucocarbo fuscenscens*). The island is surrounded by vertical cliffs 10-15 m high, and has a now disused lighthouse.

EPP SA-1 does not enter Rivoli Bay, but the boundary of the permit cuts across the mouth of the Bay and passes close to the seaward side of Penguin Island.

The waters surrounding Penguin Island and Cape Martin to the north are a Rock Lobster Sanctuary managed by the South Australian Department of Fisheries.

5. CONSULTATION

Identification of sensitive areas and possible impacts of the proposed survey includes consultation with government departments administering the appropriate environmental legislation, and consultation with representatives of local groups exploiting the area on a recreational or commercial basis.

A complete list of the people consulted as Government authorities and representatives of interest groups is included in Appendix F.

Subject matter for discussion included the following:

- Department of Mines and Energy:

  Condition No. 7 of Exploration Permit for Petroleum SA-1;
  The manner and form for the Declaration of Environmental Factors;
  Codes of Environmental Practice.

- Department of Marine and Harbours:

  Notice to Mariners concerning presence of vessel, clearance to be given for length of seismic cable, avoidance of vessel because of interference with seismic signals.

- Department of Environment and Planning

  - Assessments Branch:

    Impacts on the marine environment, flora and fauna;

  - Heritage Unit:

    The location of shipwrecks in the area and need for a permit for the proposed work;

  - Coastal Management Branch:

    EPP SA-1 is within the South East Coast Protection District, which extends from 100 m above the high water mark and includes all land to three nautical miles below the low water mark.

- Department of Fisheries:

  Impact on commercial fisheries in the area;
  Hazards due to commercial fishing gear;
  Avoidance of declared sanctuaries.

- The South Australian Fishing Industries Council:

  List of local representatives in Lobster, Abalone, Shark fisheries and general local fisheries for consultation. Identify any major fishing industry issues.

- South Australian Museum:

  Migration and sightings of the Southern Right Whale in the South East of South Australia;

  Timing of the survey.

Professional representatives of the three major commercial fisheries in the south east, the Rock Lobster, Abalone and shark fisheries were consulted regarding possible impacts on the fishing stocks, the gear used, on divers underwater, and the timing of the survey in relation to open seasons.

Representatives of the South East Professional Fishermens' Association and the Abalone Divers held meetings at which the survey work was explained, and professional operators were able to state any concerns or significant issues associated with the proposed seismic survey.

Table 5.1, provides a summary of the major concerns raised during consultation.

Table 5.1: Summary of Major Concerns of Interest Groups

Issue	Interest Group	Concerns
Notification of date & time of survey	Abalone divers may be working area in fine weather during which survey vessel will come inshore.	Will shockwaves excite sharks and cause attacks on divers? What is the effect of underwater shockwaves on eardrums of divers?
	Professional fishermen	Shark boats and other fishing boats need to keep well clear of survey vessel and tow.
Notice to Mariners	Department of Marine & Harbours	Notify other vessels of straight line course and length of tow. Keep clear of survey vessel.
Disturbance to fishing gear, nets and pots.	Professional fishermen	Shark nets may be deployed at right angles to shore. Pots may be left in area.
Disturbance/damage to fish stocks, especially juvenile lobsters	Professional fishermen	Shockwaves may cause damage to juvenile rock lobster during settlement stage or planktonic larval stages.
	Dept. of Fisheries	Effects of explosions on lobsters, sharks and fish, particularly juvenile stages.
Impact on migratory Whales.	Dept. of Environment and Planning	Effect of explosions on migration routes and behaviour. Disturb calving.
Protection of Carpenter Rocks area.	S.A. Fishing Industries Council (SAFIC)	An important spawning and recruitment area for whole S.E. lobster fishery. Impact of shock-waves not known so area should be avoided.
Historic shipwrecks	Depart. of Environment and Planning (Heritage Unit)	Possible damage to wreck of 'Geltwood' by shockwaves from airguns.

6. WORK PRACTICES

The *Petroleum (Submerged Lands) Act* requires that all petroleum exploration operations be carried out in a proper and workmanlike manner and in accordance with good oil-field practice (Section 96(1)). That section of the Act also requires that the permitted "shall secure the safety, health and welfare of persons engaged in those operations in or about the permit area."

BHP Petroleum will comply with all relevant provisions of the South Australian *Occupational Safety, Health and Welfare Act,* 1986. The company will appoint an employee as contact person for the purpose of maintaining communication with the Department of Mines and Energy with respect to occupational health and safety.

Work practices will be conducted by BHP Petroleum in conformity with its Safety, Health and Environment Management Programme (BHP Petroleum, 1989).

7. EVALUATION OF ENVIRONMENTAL IMPACTS

The survey will require 1-2 days of favourable weather in May, and be carried out within three nautical miles of the shoreline, on straight lines almost parallel to the coast.

7.1 Shock Waves from Airguns

The energy source used to generate shock waves entails the use of airguns, without chemical explosives. **Most concerns expressed by interest groups relate to the effect of the shockwaves from these guns.**

7.1.1 Fish

Although the shock waves have potential impacts on fish, birds and other animals at close range, experimental work carried out since 1973 reports no effect on fish exposed to seismic airgun releases at distances from 1-3m. Another experiment using a 300in^3 airgun operated at 2000-2200psi (138-152 bars) concluded that the lethal radius for this gun was 2-5feet (Warren 1989). The 2250in^3 airgun array to be used for this survey operates at the same pressure, produces a shockwave measuring 258 decibels with respect to 1 micro Pascal (uPa) at a detector positioned 1m from the guns, and would have a similar lethal radius.

Shock waves were found to injure eggs and larvae of several fish species if discharged within 5m (Warren 1989). Other work carried out in the 1940's using high velocity explosives (dynamite, which predated the airgun technique), tested the effect on several species of fish and custacea in cages at various distances from the explosive source. Fish with swim bladders suffered the most damage, but oysters and lobsters were very resistant to the dynamite explosions.

Tests carried out more recently using a 300in^3 airgun operated at 2000-2200psi (138 - 152 bars) and caged fish indicated that the lethal range for 50% mortality for this gun is 0.5 - 1.5m.

Sequential firings at intervals of 10-15 seconds did not change the result.

Similar results were obtained by other experiments, and conclude that fish are unlikely to be affected by airguns except at very close quarters (Kaneen 1982).

No studies of the effects of airguns on fish have been reported in South Australia, but there is no reason to expect that the findings would differ.

The dispersal of pelagic fish away from the seismic line may be encouraged by the preceding bow wave of the large survey vessel, which may clear most fish from the path of the guns by a distance of at least 5m on each side of the ship.

7.1.2 Effects on Lobsters

The limited experiments cited by Kaneen (1982) and Warren (1989) indicate that adult lobsters are extremely resistant to the effect of underwater explosives, as are molluses, but there are no reports of the effects on larvae, planktonic stages, or juvenile crustaceans.

The proposed survey within 3 nautical miles of the coast includes reefs with high population densities of lobsters, which are also recognized breeding, nursery and recruitment areas for this fishery. The effect of shockwaves fired at 11 second intervals parallel to one of the most productive reef areas in South Australia is therefore of considerable concern to the operators of this fishery. **Experimental work to determine the effects of seismic shockwaves on juvenile lobsters, particularly at planktonic and settlement stages of development is seen as a high priority by members of the industry.**

Mitigating circumstances of the proposed survey relate to the timing, which avoids the major periods of vulnerability of the lobster stocks, while being unable to avoid the little known movements or vulnerability of planktonic stages between December and July.

. The time of the survey, early May, avoids the known moulting seasons of the Southern Rock Lobster, June-July and October-November.

. The timing also avoids the major settlement period July-September and the minor settlement in January.

. The survey will be carried out in daylight hours, when lobsters retreat to their rock shelters. Lobsters are known to emerge from shelter to forage for food only at night, remaining hidden in daytime.

The rock crevices which shelter them from predators will also provide shelter from acoustic shock waves.

7.1.3 Impact on Divers

It is possible that divers working in the Abalone fishery would be diving on the inshore reefs in fine weather, coinciding with favourable weather for the inshore seismic survey.

Two possible concerns have been expressed regarding the effects of underwater shockwaves. One is the impact on divers eardrums. The other is the possibility that sharks disturbed or excited by the explosions may attack divers.

It is unlikely that the seismic vessel will be closer than 500m to any of the inshore reefs where divers work. Further, the thick wet suit hood worn by divers in this cold water zone would buffer any acoustic impact of shock waves at this distance.

The effect of shockwaves on the behavior of sharks is unknown.

The mitigating measure proposed is that:

. Divers will be informed prior to the day of the intention to carry out the onshore survey, and should avoid diving on that day.

Consultation with representatives of the Abalone divers suggests that this would not be a problem, as most if not all divers will have completed their quota of abalone by the end of April.

7.1.4 Impacts on Whales

Extensive research has been carried out to determine the impact of explosions from seismic surveys on whale populations, migrating whales, and whales with calves.

Much of the work has been carried out in the United States and Canada, particularly in the St. Georges Basin Alaska (US Department of the Interior 1983) and the Beaufort Sea (Richardson 1986).

The research deals primarily with Bowhead Whales, an endangered Arctic species, and a Baleen whale similar to the Southern Right Whale.

Aerial surveys and other sightings of the Southern Right Whale have been recorded in Southern Australia since 1942 in an attempt to determine the recovery of the species. The Whales have been protected from hunting since 1935, when they were nearing extinction. In addition to having legislative protection, they have been the subject of public education and whale watching programmes which have resulted in greatly increased awareness of their vulnerability to human intervention.

Conservation groups and Environmental authorities both perceive whale protection as a major issue in Environmental Management.

Prior to commencing the collection of 11500kms of marine seismic data off the South Australian and Victorian coast lines between March and July 1991, BHP Petroleum has engaged Dr John Richardson, a Canadian scientist who has carried out extensive research into the behavioural responses of Bowhead Whales to shockwaves from seismic airguns. Dr Richardson will advise the company on all possible impacts of the survey on the Southern Right Whale, which is reported to congregate along the southern coast between May and November each year. Near the Victorian border, at the southern end of the permit, whales with calves have not been sighted before June in the last eight years (Warnecke, 1989).

The Whales are reported to seek the shallow inshore areas over the continental shelf, and are thought to appear less frequently along the very narrow shelf south of Cape Jaffa (J. Ling, pers.comm.).

Detailed observations of the reactions of bowhead whales to seismic surveys were carried out by Dr Richardson on 21 occasions over four summers, 1980-1984. One test included a full scale seismic array of 30 airguns releasing shockwaves of 248dB re:1uPa at a closest distance of 1.5km. This release is equivalent to that proposed for this survey.

Observations of whale behaviour made from a circling aircraft 5-600m above sea level, indicated that:

(a) Bowheads began to veer away when the airgun array began to fire 7.5km away.

(b) Some whales were still bottom feeding when the guns were 3km away.

(c) Whales were displaced at 2km from the guns.

In general, bowheads appear to exhibit avoidance from seismic pulses stronger than 160dB re:1uPA.

The received level from the airgun source is inversely proportional to the distance, and can be calculated from the formula given in Appendix C. (Greene 1982). eg. A release of 258dB re: 1uPa at a distance of 1m, is reduced to 188.6dB re: 1uPa at 3 km, and to 173.2dB re: 1uPa at 5km.

On the basis of Dr Richardson's observations, whales would probably veer away from the seismic vessel at a distance of 5-6km when guns were firing.

Mitigating measures have been adopted for the survey to reduce or avoid any disturbance to whales in the area by:

- Timing the survey early in May before whales become frequent along the southern Australian coast.
- Keeping a lookout for whales from the seismic vessel and the scout boat.
- Shutting down airguns if whales are sighted within 5 km of the seismic vessel.
- Logging sightings.
- Resuming recording after two hours or when it is reasonably believed that whales are more than 10 km from the seismic vessel.
- Inshore survey will be carried out only in daylight, which facilitates sighting whales.

7.1.5 Impact on Seals

The impact of acoustic shockwaves on seals is poorly documented, with research on marine mammals concentrated on whales, dolphins and porpoises (cetaceae), which use 'echo-location' techniques, and 'acoustic language' at similar frequencies to airgun sources.

Seals frequent the close inshore reefs and beaches, and are unlikely to closely approach the survey vessel. There is insufficient information available to propose any strategies to mitigate possible impacts.

7.1.6 Sea Bird Rookeries

Those breeding areas which are considered significant are marked on the map (Figure 1), the most important being at Guichen Bay and Rivoli Bay. Only Rivoli Bay (Penguin Island) is likely to be within the survey area, but the survey boat is unlikely to come within 2-3km of the shoreline at this point. No impact is expected and no mitigating measures are proposed.

7.1.7 Recreational Uses

No impacts are expected due to reduced use of beaches for swimming and reduced use of diving trails during May. The survey vessel will remain outside the coastal reefs, and no other measures are proposed. Any cruising yachts and smaller craft in the area would be notified on the usual radio schedules.

7.1.8 Algae and Seagrasses

Seagrasses are generally confined to the sandy bays (Guichen, Nora Creina and Rivoli) which are outside the permit area.

However, the guns and seismic cable comprising the tow are fitted with floats or are neutrally buoyant so that they remain within the water column if the vessel stops and do not touch the sea bed.

The vessel remains well clear of reefs which support the large brown algae endemic to the area, and no disturbance is expected.

7.1.9 Historic Wrecks

There are six known wrecks in the area, but only one, the 'Geltwood', has been surveyed and is protected under the *Commonwealth Historic Shipwrecks Act.*

Some concern for the impact of acoustic shock waves on the fragile wreck structure has been expressed by the Heritage Unit of the South Australian Department of Environment and Planning.

It seems unlikely that the seismic survey will generate shockwaves more potentially damaging than the storms experienced on this shoreline, which has the highest wave energy environment on the south east coast. Except for the 6km south of Cape Buffon, there are few reefs to shelter the coast from the high energy south and southwest waves (Short and Hesp 1979).

In order to avoid any possible damage to the wreck, the survey vessel will remain at least 500m outside the documented wreck site.

7.2 The Survey Vessel and Towed Cable

The vessel will proceed along a straight course within 3 nautical miles of the shore between Cape Martin and Cape Banks.

The seismic cable towed behind the vessel is normally approximately 3.5 km in length. However, for inshore work the cable may be shortened to approximately 1.7 km in length, towed at a depth of 4-8m beneath the surface.

The presence of a large vessel, 54.6m long, 894 tonnes gross, with a tow of nearly 2km, within 5km of the shore, causes some concern to the professional fishermen.

Shark nets usually deployed at right angles to the shore could be damaged by the vessel, as could craypots inadvertently left at sea after the close of the season on April 30.

. These concerns will be mitigated by the use of a scout vessel, the "Shelley Anne K", a 15.2m cray fishing vessel based at Port McDonnell, which will precede the survey vessel to check for obstructions in the water.

The Department of Marine and Harbours also required details of the length of tow and the survey vessel's course because of the wide berth which needs to be given the vessel by other ships in the area.

There are possible impacts for both the survey vessel and other ships arising from:

(a) The survey vessel's inability to change course, and the length of tow.

(b) Interference with the seismic echoes by engines of other ships.

. Both problems are mitigated by the Notice to Mariners, issued by the Department of Marine and Harbours to all ships, and by signals flown by the survey vessel, indicating that it cannot change course.

Table 7.2: Summary - Evaluation of Impacts of Seismic Shockwaves and Proposed Mitigation

Subject	Impact	Mitigating Measure
Pelagic fish	None outside the 5m range.	None proposed, incidental scatter by preceding vessel.
Lobsters	None.	Shelter in rock holes during day. Survey shot during day. Also protected by exoskeleton.
Lobsters - juvenile and larval stages.	Unknown.	Timing of survey avoids moulting and settlement periods, but not planktonic stages.
Abalone.	None.	Protected by shell.
Divers	Damage to eardrums by Seismic shockwaves. Disturbance to sharks and possible attacks.	Divers notified of day of survey so they can avoid diving on that day.
Whales	Disturbance at less than 3km.	Complete shutdown of survey if whales are sighted.
Seabird rookeries	No disturbance.	Survey more than 1 nautical mile from shore.
Benthic algae and seagrasses	No disturbance.	Cable neutrally buoyant and remains clear of bottom. Guns have floats.
Historic Wrecks	Damage to fragile structures by shockwaves.	Survey vessel to keep at least 500m clear of historic wreck site.

8. CODE OF ENVIRONMENTAL PRACTICE

8.1 The Natural Environment

This code is submitted under the terms of condition 7 of EPP SA-1 setting out procedures which will be undertaken to minimize impact on the environment.

8.1.1 General Principles and Practices

The general principles described in the Australian Petroleum Exploration Association's Code of Environmental Practice 1990, Section 4, have been followed in preparing the Declaration of Environmental Factors.

Environmentally sensitive areas have been identified, and strategies to avoid or mitigate adverse impacts have been planned.

8.1.2 Particular Strategies

Particular strategies adopted for the survey in EPP SA-1 are described below, with the impact they aim to avoid or mitigate.

Timing of the Survey

Chosen to avoid the commercial lobster fishing season and the major period of whale migration. Also avoids settlement period for lobster puerulus larvae. Daylight survey avoids nocturnal lobster foraging movements.

Notification of Local Fishermen and Abalone Divers

Notification of the exact day of the inshore survey is essential. This can be done through the usual radio schedules for commercial fishing boats, but for Abalone divers, two essential contacts are listed:

1. Mr. Peter Gurry (Executive Officer) (08) 362 4475
2. Mr. Graham Pollard (Liaison) (087) 38 7219; or
   Mr. Jim Godden (087) 34 4166.

The President of the Professional Fishermens' Association in each port should also be notified:

Kingston	-	Garry Peters	(087) 67 2121
Robe	-	Barry Bowyer	(087) 68 2395
Beachport	-	John Atkinson	(087) 35 8182
Pt MacDonnell	-	Ron Ollrich	(087) 25 3703

Shutdown of Survey if Whales are Sighted:

Both the scout vessel and the survey vessel will maintain a continuous watch for whales in the area. If whales are sighted, all firing will cease to avoid any impact on migratory whales.

Survey Vessel to Keep at Least 500m Clear of Historic Wreck Sites

This distance will reduce the impact of seismic shockwaves on the fragile wreck structure.

Reefs and shoals extend at least 1 nautical mile from shore at many points along the coast, so that the seismic survey will probably be carried out more than one mile from shore.

This distance will avoid disturbance to the conservation parks on Baudin Rocks and Penguin Island, and also to the lobster sanctuary at Cape Martin and Penguin Island.

All Shipboard Wastes will be handled as required by IMCO and SOLAS international standards as stipulated by the *Australian Navigation Act,* and will be offloaded correctly in Port (Portland or Port Lincoln). this procedure will avoid any pollution of waters in the survey area.

REFERENCES

Bye, J.A.T. 1983. *Physical Oceanography in "Natural History of the South East"* (Tyler *et al.* eds). Royal Society of S.A. Inc. Adelaide. 1983.

BHP Petroleum. 1989. *Safety, Heath and Environment Management Programme.* Corporate Safety, Health and Environment Department.

Clark, P. 1990. *Shipwreck sites in the South East of South Australia* (1838-1915). Australian Institute for Maritime Archaeology. Special Publication No 5. 1990.

Glover, C.J.M. 1983. *Freshwater and Marine Fish in "Natural History of the South East"* (Tyler *et al.* eds.) Royal Society of SA Inc. Adelaide. 1983.

Kaneen, R. 1982. *Task Force Report on Geophysical Operations.* California State Lands Commission. 1982.

Lewis, R.K. 1981. *Southern Rock Lobster (Jasus novaehollandiae)* - A review of Zone S fishery. Safic 5 (5) 31-43.

Lewis, R.K. 1983. *The Southern Rock Lobster, in "Natural History of the South East"* (Tyler *et. al.*, eds.) Royal Society of S.A. Inc. Adelaide. 1983.

S.A. Department of Fisheries 1991. *S.A. Fisheries production 1987/88 to 1989/90.*

S.A. Department of Fisheries 1982. *Catch, Effort and Value of Production of South Australian Fisheries.* Safic. 6 (1) 30-39.

Short, A.D. & Hesp, P.A. 1979. *Coastal Engineering & Morphodynamic Assessment of the Coast within the South East Coast Protection District.* Department of Environment and Planning. Coastal Management Branch. Adelaide. 1979.

Warnecke, R.M. 1989. *Review of Southern Right Whale Activity on the Victorian Coast 1942-1988.* Department of Conservation, Forests & Lands, National Parks & Wildlife Service, Australia.

Womersley, H.B.S. 1987. *The Marine Benthic Flora of Southern Australia.* Part 11. S.A. Government Printing Division, Adelaide December, 1987.

APPENDIX A1:

RELEVANT LEGISLATION

LEGISLATION CONSIDERED IN PREPARING THE DECLARATION OF ENVIRONMENTAL FACTORS

Commonwealth

Whale Protection Act, 1980

Historic Shipwrecks Act, 1976

South Australian

Coast Protection Act, 1972

Petroleum Act, 1940

Petroleum (Submerged Lands) Act, 1982

Native Vegetation Management Act, 1985

Fisheries Act

Planning Act, 1982

National Parks and Wildlife Act, 1972

Occupational Safety, Health and Welfare Act, 1986

APPENDIX A2

APPLICATION OF LEGISLATION

LEGISLATIVE REQUIREMENTS - NATURAL ENVIRONMENT

1. The *Native Vegetation Management Act*

In a recent decision of the South Australian Appeals Tribunal it was indicated by Judge Roder that marine vegetation within the territorial waters of the State constitutes vegetation for the purposes of the then *Native Vegetation Management Act,* 1985.

Nevertheless, native vegetation may be cleared where the clearance is incidental to exploratory or mining operations authorized under, *inter alia*, the *Petroleum Act.* Consequently, the clearance (including damage) of marine vegetation by BHP Petroleum does not require approval of the Native Vegetation Authority.

A Bill to replace the *Native Vegetation Management Act* is currently being introduced into Parliament. Discussions with officers of the Native Vegetation Management Branch suggest that the exemption provision referred to, above, is likely to remain.

2. The *Fisheries Act*

The *Fisheries Act,* 1982 contains provisions for the protection of aquatic habitat. The Governor may declare any waters or land and waters to be an aquatic reserve (see section 47). Entry onto a reserve is lawful only if it occurs in conformity with regulations under the Act or pursuant to a permit issued by the Director of Fisheries (see section 48(1)). It is also an offence to engage in an operation that disturbs the bed of "any waters", removes or interferes with aquatic or benthic flora or fauna of any waters or discharges, releases or deposits any matter in any waters except in conformity with the regulations or a permit (see section 48(2)).

An offence committed under section 48(2) attracts a maximum penalty of $1000 for a first offence, $2500 for a second offence and $5000 for a subsequent offence.

There are no aquatic reserves declared within the State territorial waters over which EPP SA-1 held by BHP-Petroleum extends. However, it would be possible for the operator to commit an offence in the event that its operations disturbed or degraded aquatic fauna and flora or the seabed. The proposed exploration programme involves no risk of disturbance or degradation of aquatic flora or fauna or the seabed.

It is an offence to take a fish of a class declared by regulation to be protected (section 42). The Fisheries (General) Regulations (Schedule 1, para 75) prescribe certain waters at Cape Jaffa, Margaret Brock Reef and Rivoli Bay (Penguin Island and Cape Martin) (Figure 1) from which the taking of southern rock lobster is an offence.

A first offence attracts a maximum fine of $2000. Each subsequent offence attracts a maximum fine of $5000.

The proposed exploration programme involves no taking of rock lobster from those areas, incidentally or otherwise.

3. The *Coast Protection Act*

For the purpose of the *Coast Protection Act*, 1972, the coast includes all land within and below three nautical miles of the mean low water mark (see section 4). Pursuant to section 19, the Governor may by proclamation constitute any part of the coast a "coastal protection district" for the purposes of the Act. Once this occurs, the Board is required to carry out investigations and prepare a management plan (section 20). A management plan for the South East Coast Protection District in which the EPP is located was approved by the Governor on 27 November, 1986.

Controls over activities and operations within coast protection districts are relatively limited. The carrying out of works of a prescribed nature cannot occur without the approval of the Coast Protection Board (section 26). However, no such works have been prescribed under the Act(?).

Although the *Planning Act*, 1982 permits the Minister for Environment and Planning to amend the Development Plan under the Act by including in the Plan a coastal management plan (or part thereof), that has not occurred in South Australia.

Generally, it may be concluded that the *Coast Protection Act* provides no restriction upon the proposed activities of BHP-Petroleum in the EPP.

4. *National Parks & Wildlife Act*

It is possible for the *National Parks and Wildlife Act*, 1972 to be used to create marine parks within the State's territorial sea. However, with one exception in South Australia (Dangerous Reef), this has not occurred. Protection of marine ecosystems is regarded principally as the responsibility of the Fisheries Department.

Pursuant to section 19 of the *National Parks & Wildlife Act,* Baudin Rocks and Penguin Island have been constituted conservation parks. Baudin Rocks falls within the area encompassed by EPP SA-1. Penguin Island is on the boundary (see Figure 1).

Currently there is no management plan for either park. However, a plan including the two islands is in preparation and should be released in draft form in approximately three to four months.

Meanwhile, behaviour within the two parks is controlled through the regulations under the *National Parks and Wildlife Act.*

5. The *Whale Protection Act*

The Commonwealth *Whale Protection Act,* 1980 has never applied to State waters in South Australia. There has been no declaration under section 7 of that Act prescribing State waters for the purpose of the Act.

Whales are protected in South Australia by virtue of the *Fisheries Act* and the *National Parks and Wildlife Act,* 1972.

Pursuant to section 42 of the *Fisheries Act* it is an offence to "take" a fish of a class declared by regulation to be protected. The Fisheries (General) Regulations define all marine mammals including whales to be a class of fish to which that section of the Act applies (Regulation 6).

The term "take" is defined in the Act to include, *inter alia,* "kill or destroy". The penalty for a breach of section 42 is $2000 for a first offence and $5000 for a subsequent offence.

Only in the event that the technique used by BHP-Petroleum killed or destroyed a whale would an offence have been committed.

It is an offence pursuant to section 51 of the *South Australian National Parks and Wildlife Act* to "take" a protected animal. To "take" includes injuring or killing (see section 5).

A protected animal is defined to include "any mammal . . . indigenous to Australia" and "any migratory mammal . . . that periodically or occasionally migrates to, and lives in, Australia" (see section 5). It is assumed that whales inhabiting or passing through the study area qualify as protected animals in one or other respect.

APPENDIX B:

SPECIFICATIONS OF SURVEY VESSEL

M/V WESTERN ODYSSEY

VESSEL SPECIFICATIONS

Owner	: WESTERN SEA SERVICES OF PANAMA, INC.
Flag	: Panama
Official No.	: 8775-PEXT-2
Call Sign	: HO-3498
Port of Registry	: Republic of Panama
Year of Construction	: 1980 Modified 1982
Length	: 185 feet (56.4 meters)
Beam	: 40 feet (12.2 meters)
Draft	: 13 feet (4.2 meters)
Hull	: Steel
Helideck	: 40 X 50 feet
Tonnage	: 894 gross/146 net
Speed	: 12 knots
Engines	: 2 X Caterpillar D-399 TA (Turbocharged) 1090 HP each
Propulsion	: 2 X Kamewa 50 X F/4 Control Pitch Propellors
Generators	: 2 X 1100 kw - for air compressors 2 X 175 kw - for ship's power 3 X 30 kw - for instruments
Radar	: 2 X Decca Model 926, 48 mile range
Gyro Compass	: Sperry Model 227 with auto pilot
Bow Thruster	: Kamewa SP 1300 with 350 HP electric motor
Stablization	: Flume Type with Anti-Roll Bilge Keel
Water Maker	: 1 X 6 tons/day capacity
Fuel	: 460 tons

Fresh Water	: 219 tons
Accommodation	: 36 plus two-man hospital
Endurance	: 45 days
Communications	: "INMARSAT" Satellite Terminal with Telex and Telephone facilities
	Sailor S.P. Programmable SSB Radio
	Sailor T124/R110 SSB Radio
	Sailor RT144 VHF
	Skanti Marinetta TRP1 Lifeboat Radio
	Collins 750 Ground-to-Air Radio
	Southern Avionics SS80A Non-Directional Aircraft Beacon

M/V WESTERN ODYSSEY

SEISMIC EQUIPMENT SPECIFICATIONS

A. Recording Instruments

Type of Instrumentation	: LRS-16A Kiloseis Digital Streamer System
Method of source synchronization	: LRS-100 Synchronizer
Derivation of time zero	: Time break when 62.5% of array volume has fired
Recording format	: SEG-D 6250 BPI

B. Energy Source

Source Type	: WESTERN CSM™ (Compact Sleeve Source) Airgun System
Source Configuration	: 4 sub-arrays of 8 guns per string
Source Volume	: 2250 cu. in.
Distance between pops	: 26.6 meters
Source Pressure	: 2000 PSI
Compressors	: 3 x LMF 280-E Primary Screw Compressors, plus 6 x Price "Double-Booster" Compressors

C. Streamer Cable

Type	: LRS 16A
Skin Material	: PVC
Length	: 3200 meters
Number of channels	: 240
Number of hydrophones per group	: 6 per 13.33 meters
Method of electrical interconnection cable	: Coaxial Cable

C. Streamer Cable (cont'd)

Length of active sections (group)	: 13.33 meters
Hydrophone	: LRS 2510 Model WM2-36
Depth Indicators	: Teledyne 28950
Depth Controllers	: Syntron RCL-2
Waterbreak Detectors	: LRS WMH-036
Tailbuoy	: Catamaran sled with Radar Reflector and Strobe Light
Cable Compass (optional)	: Syntron RCU-381 c/w Syntron CUS 8301 Compass Controller

D. Navigation

LRS "WISDOM" (WESTERN Integrated Survey Data Onboard Management) System comprising :

2 Hewlett Packard HP2117F Mini Computer
2 Hewlett Packard HP2649C Graphics Terminals
1 LRS Geoscience Data Unit
1 Hewlett Packard HP2671G Printer/Plotter
2 Telex 9250 1600/6250BPI Tape Transport and Formatter
1 Hewlett Packard HP2748B Paper Tape Reader
1 Magnavox 610 Doppler Sonar
1 Magnavox MX1107A Dual Channel Satellite Receiver
1 Grundy model 4031 Velocimeter
2 Gap Level Sensors
2 Sony VM4509 Video Monitors
2 Diablo 1760 Line Printers

E. Ancillary Equipment

VERSATEC Plotter 8222

SIE ERC 10C 64 Galvo Monitor Camera

EPC 4603 Single Trace Plotter (2 units)

LRS Airgun Solenoid Controller

WESTERN Microcomputer Header Expander System

WESTERN Energy Source Transducer Monitor System

LaCoste 6 Romberg Gravity Meter Model "S"

Marine Magnetometer Geometrics G801/3

Krupp-Atlas 640 Fathometer 0-5000 meter range

1 Simrad Model 802 Fathometer 0-1000 meter range

1 Simrad Model EX38D Fathometer 0-1000 meter range

F. Test Equipment Specifications

Tektronix 7603 Mainframe Oscilloscope with 4 Channels
Bandwith : 100 MHZ

Tektronix 465A Oscilloscope Dual Channel
Bandwidth : 100 MHZ

Quantum D.C. Binary Voltage Source

Adequate stock of spare parts and all operating supplies for above equipment.

APPENDIX C:

CALCULATION OF SHOCKWAVE LEVELS

FASCIMILE TRANSMISSION

TO: WESTERN GEOPHYSICAL - SINGAPORE

We normally estimate the received level from an airgun or airgun array as being inversely proportional to distance, as the distance from the source increases, the received level decreases. The airgun array you plan to use (the 2250ci sleeve gun array) has an output of about 80 Bar at a distance of 1 meter from the source. Although the geophysical industry uses pressure units of Bars, many other disciplines use the Pascal or micro-Pascal. It is easy to convert one to the other:

$$1 \text{ Bar} = 1 \times 10^{11} \text{ micro-Pascals}$$

Thus our source strength at a distance of one meter is:

$$80 \text{ Bar} = 8 \times 10^{12} \text{ micro-pascals}$$

Now to convert that to dB you do the following;

$20 \times \text{Log}(8 \times 10^{12}) = 20 \times 12.9 = 258$ dB with respect to 1 micro-Pascal

Now to compute the level at some distance R from the source

$$\text{Level} = \frac{8 \times 10^{12} \text{ micro-Pascals}}{R \text{ (in meters)}}$$

Then to convert it to dB you just do this;

$$\text{Level in dB} = 20 \times \text{Log(Level)}$$

For an example at 3000 meters

$$\text{Level} = \frac{8 \times 10^{12} \text{ micro-Pascals}}{3000} = 2.67 \times 10^{9} \text{ micro-Pascals}$$

which in dB is

$$\text{Level in dB} = 20 \times \text{Log}(2.67 \times 10^{9}) = 20 \times 9.43 = 188.6 \text{ dB with respect to 1 micro-Pascal}$$

Now we have a paper in which a study was done on seismic source measurements at fairly large distances from 3.5 to 40 km. For these larger distances they determined the following equation

$$\text{Level in dB} = 187.2 - 1.38 \times R - 10.12 \times \text{Log}(R).$$

This equation is for use beyond 3500 meters. The water depth in this study was 50 meters and the equation was derived to fit the data, not from theoretical principles. As an example, lets calculate the Level at 5000m.

$$\text{Level in dB} = 187.2 - 1.38(5) - 10.12 \times \text{Log}(5)$$

$$= 187.2 - 6.9 - 10.12 \times 0.699$$

$$= 187.2 - 6.9 - 7.07$$

$$= 173.23 \text{ dB with respect to 1 micro-Pascal.}$$

Note that R is enter in KM in this formula and the answer is already in dB. The paper was SEISMIC SURVEY SIGNALS IN THE BEAUFORT SEA, by Charles R. Greene or the Polar Research Laboratory presented at the 104th meeting of the Acoustical Society of America 8-12 November 1982.

Note you can compare this to the simpler calculation just related to distance at 5000 meters;

$$\text{Level} = \frac{8 \times 10^{12} \text{ micro-Pascals}}{5000} = 1.6 \times 10^{9} \text{ micro-Pascals}$$

$$\text{Level in dB} = 20 \times \text{Log}(1.6 \times 10\ ) = 184.1 \text{ dB.}$$

Thus our simpler formula gives a higher level than the other formula and is more of a worst case.

APPENDIX D:

DETAILED DESCRIPTION OF COASTLINE

The Coastal Environment

Clark, P. 1990. *Shipwreck sites in the South East of South Australia* (1838-1915). Australian Institute for Maritime Archaeology. Special Publication No 5.

Location and description

The south-east coast, so-called because it occupies the south-eastern corner of South Australia, is located between the entrance to the Murray River (138° 54' E) and the Victorian border (141° 57' E).

The northern section from the Murray Mouth to Kingston (about 180 km in length) is characterized by a steeply shelved sandy beach on the ocean side of the Younghusband Peninsula and extends into Lacepede Bay. This section of coast is backed by extensive areas of mobile, largely bare or sparsely vegetated sand dunes which spill over into the Coorong Lagoon system. These sand dunes are so much alike that it is difficult to identify any of them or any marks from the sea (Russell 1973: 116; National Parks and Wildlife Service 1984a: 21–25 and 34).

Lacepede Bay is contained between Granite Rocks (two prominent rocks situated on the beach close to the sea, the larger of which is six metres high) and Cape Jaffa. Its shoreline is formed by a sandy beach with sand dunes backing the beach for about 11.5 km south of the Granite Rocks. Port Caroline, the anchorage off Kingston, is situated about 5.5 km south of Maria Creek. Between Kingston and Cape Jaffa the shoreline is low and swampy with a wooded bank behind the sandy beach. Cape Jaffa is a low sandy point from which rocky ledges extend out for about 4.5 km. The sea breaks on them in numerous places, making it dangerous for vessels to pass. Remarkably, Lacepede Bay is a safe anchorage in all weather, even though it looks exposed to the ocean swell. The reasons for this appear to be the reefs off Cape Jaffa which break up the prevailing south-west swell, and the long distance of comparatively shallow water over which west and north-west swells have to travel before they reach the anchorage.

Margaret Brock Reef lies about 7.5 km to the west of Cape Jaffa and has depths of less than 9 m. There are at least two rocks which dry as well as the rock on which the light stands. Much of the rest of the reef breaks in bad weather. The reef has claimed at least two and probably three shipwrecks including the vessel after which it is named. The coastline for about 5.5 km south-east of Cape Jaffa is lined with sand dunes which then change into a low wooded bank which continues as far south as Cape Thomas. Rocks and foul ground extend for up to 3.5 km offshore (Russell 1973: 116–8).

Guichen Bay, named by Nicholas Baudin in 1802 after Admiral de Guichen (Cockburn 1984: 92) is contained between Cape Thomas and Cape Dombey (Figure 4), with the town of Robe located in its south-west corner. The depth of water in the bay varies from between nine and eleven metres. The eastern shore of the bay (called Long Beach) extends for about 11 km from Cape Thomas and is a sandy beach backed by a low bank which falls back 5.5 km inland onto a wooded range about 30 m high. The south end of the bay between Long Beach and Cape Dombey is composed of rocky points and sandy bays with drying rocks that extend a short distance offshore. The anchorage at Guichen Bay is relatively safe during the summer months (November to April) when south-east winds prevail, however it is unsafe during a north-west or west winds, which are frequent during the winter (May to October).

Cape Lannes, the next major feature, lies about 2.7 km south of Cape Dombey and has a reef which extends for about 1.8 km west from its rocky point (Russell 1973: 118). The beach which divides these two Capes is sandy and is backed by steep cliffs rising to about twenty metres. The coast for the next 42 km from Cape Lannes to Cape Martin (at the northern end of Rivoli Bay) is characterized by alternating rocky points and sandy beaches backed by sand hills and dunes about 30–33 m high. Between Cape Dombey and Cape Rabelais (at the northern end of Nora Creina Bay) isolated rocks, both submerged and dry extend up to a mile off-shore, the sea breaks heavily on the coast, and it is impossible to land. Nora Creina Bay is a small bay where it is possible to make a landing, however it can be dangerous as the sea sometimes breaks across the entrance.

South-east of Nora Creina Bay a reef runs south-east for about 10.8 km parallel with the coast and at a maximum distance of about 2.7 km. The coast along this stretch is backed by bare sandhills that rise about ten to twenty metres above sea level. The remaining coast to Cape Martin (at the northern end of Rivoli Bay) has more cliffs and dunes, some bare and some covered with scrub. The coast about 3.5 km northwest of Cape Martin is fringed with reefs and submerged rocks which extend up to 3.5 cables offshore.

Rivoli Bay is an indentation in the coast between Cape Martin and Cape Buffon (10.8 km to the south-east). Two small towns, Beachport at the north-western end and Southend (Greytown) at the south-eastern end are located within Rivoli Bay. A long sandy beach (approx 17 km) forms the shore of the bay which is backed by sand dunes. The majority of the beach experiences surf up to half a kilometre off-shore except the south-west end near Southend where the approach is shallow and landing is good for about one kilometre along the beach. Both townships have jetties (750 m and 275 m respectively) which service local fishing vessels and can accommodate a limited number of others with a draft of less than 4.6 m at Beachport and slightly deeper at Southend. The central part of Rivoli Bay is obstructed by numerous reefs, rocks and shoals (Ringwood Reef, Lipson and Sherbert Rock, etc.) and is dangerous for navigation.

South-east of Cape Buffon, the coast for a distance of about 9 km has cliffs with rocks that dry extending for a distance of about half a kilometre offshore. For a distance of about 14.5 km further south-east the coast is formed by a steep sandy beach. The remaining 20 km or so to Carpenter Rocks, is characterized by a sandy coast with rocks above water a short distance of the beach. A reef on which the swell breaks, fronts the beach for the whole of this latter section lying about 1.8 km offshore. Lake Bonney, a large fresh water lake 1.8 km inland extends parallel with the coast for a distance of about 24 km

APPENDIX E:
SHIPWRECKS

NOTES ON HISTORIC WRECKS WITHIN EPP OF SA-1.

* The *Time* was a 300 foot long steel, screw steamship, weighing 2575 tons gross, carrying only 20 tons along shores from Port Pirie and 280 tons salt from Edithburg. At 6.30 pm on 13 January, 1911 it was reported off Cape Jaffa, and about 10.30 pm struck a reef about 1.5 miles from the beach and 7 miles west of Penguin Island (Figure 1). The vessel's set course was 5 miles from shore, but was set shorewards by heavy gales from the south-east and the strength of the current.

  The wreck site is based on newspaper reports at the time, and has not yet been found.

* The *Euro* was a smaller 165 foot long, 336 tonnes gross iron steamship built in 1874 in Scotland, and made regular trips between Port Adelaide and the South-East ports. On the afternoon of 24 August, 1881, enroute to Beachport, the vessel apparently struck a reef about 1.5 miles out from shore. The ship continued on course for about 15 minutes although rapidly taking water, then headed for shore in an attempt to beach the vessel. However, the engines failed half a mile from shore, where the ship finally sank. The site has not yet been found.

* The *Nora Creina,* 82.6 feet long and 171.8 tons, a wooden two masted Byzantine, was built in England in 1834. Carrying a cargo from Port Adelaide to Melbourne, she left Robe on 1 January, 1859. About six hours out of Robe (at an estimated speed of 4 knots), the vessel changed tack and struck a reef, and sank within 35 minutes. All crew and passengers reached Guichen Bay in the long boat. The location of the wreck about 10 km from shore is taken from newspaper reports at the time, and has not been found.

* The wreck of the *Geltwood* is protected under the *Commonwealth Historic Shipwrecks Act,* 1976. The three masted iron Barque, 216 feet long and 1091 tons gross, was launched in England in 1876. On its maiden voyage to Melbourne around 14 June, 1876, the ship was wrecked on a reef about a mile from shore and about 12 miles south of Rivoli Bay. All on board were drowned.

  Much of the ship's cargo of household goods was washed ashore and stolen by local residents but a considerable amount of material remains in situ, a possible source of relics of historical or cultural significance. The site of the wreck is marked on navigation charts of the area, see Figure 1.

* The *Varson* was a three masted wooden ship, 156 feet long, build in Scotland in 1853. Between late December 1885 and early January 1856, on a voyage from Manila to Sydney, the vessel was wrecked about 20 miles west of Cape Northumberland, off Lake Bonney, and there were no survivors.

  The location of the wreck is taken from newspaper reports at the time, and its present location has not been found.

* The *Troas* was a 663 ton wooden ship, 152 feet long, built in England in 1857. On a voyage from Port Adelaide to Foochow, in China, the vessel was totally wrecked 10-15 miles south of Rivoli Bay, off the northern end of Lake Bonney. The vessel had taken on mud ballast at Port Adelaide, which shifted during heavy south-west gales, making the ship unmanageable. Heavy seas drove the ship onto a reef, and over the reef to the shore. Contemporary reports state that "the ship was almost completely broke up by subsequent high tides". The site of the wreck has not been found.

APPENDIX F:

LIST OF PEOPLE CONSULTED

LIST OF AUTHORITIES AND PEOPLE CONSULTED

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Department of Environment & Planning
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S.A. Department of Fisheries. Mr Rob Lewis (08) 226 0603
Mr John Johnson (08) 226 0634

S.A. Fisheries Industry Council. Mr Peter Peterson (08) 344 9193

S.A. Museum. Dr John Ling (08) 223 8875

South Eastern Professional Fishermans Association.
Mr John Atkinson (President) Beachport (087) 35 8182
Mr Barry Bowyer (Pres. Robe Branch) Robe (087) 68 2395
Mr Garry Peters (Pres. Kingston/C.Jaffa Branch) Kingston (087) 67 2121
Mr Merv Braithwaite (delegate for Kingston/C.Jaffa) Kingston (087) 67 2430 or 67 2209.
Mr Terry Moran (Trawl fishery) Beachport (087) 35 8191

Port MacDonnell Professional Fishermans Association.
Mr Ron Ollrich (President) Pt. MacDonnell (087) 25 3703

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Mr Peter Gurry (Executive Officer) Adelaide (08) 362 4475
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BHP Petroleum

BHP PETROLEUM PTY. LTD.
A.C.N. 006 918 832

EPP SA-1

OFFSHORE OTWAY BASIN, SOUTH AUSTRALIA

EVALUATION REPORT

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D. Pickavance

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DATE: August, 1993

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1 SUMMARY

Permit EPP SA-1, Otway Basin South Australia, was awarded on 15th November, 1990 to BHP Petroleum (Victoria) Pty Ltd and Cultus Petroleum (Australia) NL. The Operator for the permit is BHP Petroleum Pty Ltd. EPP SA-1 covers the three nautical mile territorial waters between the coastline and the eastern boundaries of offshore permits EPP 24 and the relinquished EPP 23 and was essentially acquired as protection acreage for these permits. The first three year work program involved seismic data acquisition and processing, reprocessing of seismic data and office studies. Based on the seismic data acquired in the work program a detailed evaluation of the permit and surrounding area has been carried out by members of the Otway Basin Team.

This report summarises this work. The conclusions are that there are no drillable prospects identified in the permit and all identified leads have high structural risk due to limited seismic coverage, plus high seal risk and high gas risk. All leads require additional seismic control for possible upgrade to prospect status.

2 INTRODUCTION

The Otway Basin stretches 500 km along the South Australian and Victorian coastline from Robe in South Australia to Cape Otway in Victoria. The basin originated as an intra-cratonic rift in the Late Jurassic and evolved into a passive margin during the Late Cretaceous.

EPP SA-1 covers the three nautical mile territorial waters between the coastline and the eastern boundaries of offshore permits EPP 24 and the relinquished EPP 23. It extends from north of the township of Robe to immediately west of Douglas Point where it joins permit EPP SA2 (figure 1). The total area of EPP SA-1 is approximately 750km^2.

Water depths in the area are shallow, up to a maximum of 30 metres. The southern portion of the area west of Douglas Point and south of Lake Bonney has very shallow water depths, averaging between only 6 and 10 metres (Enclosure 1).

EPP SA-1 was issued by the Minister for Mines and Energy on 15th November, 1990. The Operator for the permit has been BHP Petroleum Pty Ltd with interests held by BHP Petroleum (Victoria) Pty Ltd (70%) and Cultus Petroleum (Australia) NL (30%). The permit commitments are summarised in Table 1.

3 EXPLORATION HISTORY

There are no wells in EPP SA-1, but there are several nearby onshore and offshore wells drilled since 1961 from which correlations have been made.

The first seismic program in the permit was conducted by Western Geophysical for Esso Standard Oil in 1968 using an Aquapulse source for 4 second records. The six 6-fold lines totalled 83 km and were of poor quality. These lines were reprocessed in 1981 by Western Geophysical for Ultramar Australia with some improvement in data quality. They were again reprocessed in 1991 by Tensor Pacific for BHP Petroleum as part of the permit commitment. Quality improved marginally from the 1981 sections with most improvement coming from a more appropriate display scale.

A few lines from the 073A Seismic Survey are located at the northern end of EPP SA-1. These lines have not been used in the present evaluation.

Two lines totalling 73.4 km were acquired by Western Geophysical for BHP Petroleum in 1991. The 6 second/60-fold lines were processed by Tensor Pacific and are of excellent quality. These lines are designated OH91C-601 and OH91C-602.

The tail ends of seismic surveys from deeper water permits recorded in 1982, 1985, 1986, 1990 and 1993 lie in the permit and have been invaluable for mapping and obtaining well ties.

Aeromagnetic surveys over the area were flown in 1961-62 for Haematite Explorations (BHP) and in 1993 for SADME.

4 GEOLOGY

4.1 Regional Geology

Three main depositional periods dominate the stratigraphic record of the Otway Basin and are represented by the Early Cretaceous Otway Group, the Late Cretaceous Sherbrook Group and the Tertiary Wangerrip/Nirranda/ Heytesbury Groups (Figure 2).

The Otway Group was deposited during the Early Cretaceous and represents the onset of rifting. Up to 7000m of sediments were deposited in this first period. The second main period spans the Late Cretaceous and may have been the result of an additional rifting phase. A maximum of 5000m of Sherbrook Group sediments were deposited in this period. The last depositional period took place during passive margin subsidence in the Tertiary and up to 2500m of sediments were deposited.

The Early Cretaceous Otway Group forms the focus of this report because these rocks were assessed to be the most prospective in EPP SA-1. Most of the permit is dominated by these sediments with the remainder of the permit covered by thick Late Cretaceous and Tertiary age units under which the prospectivity and distribution of the Otway Group is unknown.

The members of the Otway Group are best described in a rifting setting. Syn-rift deposition is represented by continentally-derived fluvio-lacustrine sandstones, siltstones, mudstones and coals of the Crayfish Subgroup. These sediments infilled a complex system of half graben in which the upper portion of the hanging wall has generally been rotated and partially eroded prior to the cessation of rifting. In contrast, the flat lying sediments of the post-rift Eumeralla Formation are more lacustrine in character and comprise fine grained clastics and coals which lie with angular unconformity on top of the Crayfish Subgroup.

EPP SA-1 provides a cross-section of the major onshore and offshore tectonic elements. Most of the permit covers the "Crayfish Platform", an area dominated by the Early Cretaceous Otway Group. The tectonic style is that of generally east-west trending rotated half graben filled with Crayfish Subgroup sediments and overlain with angular unconformity by the Eumeralla Formation. The Crayfish Platform is bounded to the northwest by the Padthaway Horst which forms the basin margin. The various horst and graben structures within the Crayfish Platform have been well documented from early onshore work eg Robe Trough, Lake Eliza High etc. A previously unnamed feature has been called the "Rivoli Trough" (Enclosure 5).

In the very south of the permit lies the "Voluta Trough". The tectonic style within the Voluta Trough is dominated by intensive down to the basin faulting over which the Late Cretaceous and Tertiary sections rapidly thicken. For this report, in EPP SA-1 the "Tartwaup Fault" is assumed to be the boundary between the Crayfish Platform and Voluta Trough.

Most fault movement occurred during Crayfish Subgroup deposition along graben-bounding growth faults and prior to Eumeralla deposition along these, reactivated basement and new faults. The Beachport Horst was growing (in a relative sense) during Crayfish time and the thin veneer of Crayfish sediments over this feature may represent a condensed/highly reworked section or a terminal section. Syn- and post-depositional faulting occurred during Eumeralla time as evidenced by the in places highly faulted internal structure of this formation. Most of the Eumeralla age faults do not penetrate the Crayfish Subgroup unconformity. Some faults reactivated prior to Tertiary deposition and many exhibit evidence of movement during the Tertiary to Holocene period and may still be active today.

A recent compressional event has partially inverted the 'Rivoli Trough' and apparently reactivated existing normal faults into a number of small reverse faults over and to the south of the Beachport Horst within and to the west of EPP SA-1. The amount of inversion increases onshore where reversal of the southern Beachport Horst fault has occurred. This compression may still be in progress today. No such features are seen on the northern side of the Beachport Horst and so it seems that this feature is shielding these areas from the compressive stress. There appears no obvious mechanism for this compression.

4.2 Well Results

Onshore

Robe-1 was drilled in 1915 by South Australian Oil Wells on a fossil backshore beach dune which was mistaken for anticlinal structure. The well was the deepest for its day in the basin and reached a TD of 1373 m. It disclosed for the first time the presence of coal-bearing Early Cretaceous sediments below the widespread Tertiary limestones (Sprigg, 1985) but failed to encounter any hydrocarbon.

Beachport-1 was drilled in 1961 by South east Oil Syndicate to test anticlinal drape of deep sediments over a strong gravity and magnetic high expected to be an igneous plug or a basement high at approximately 1220 m (Beachport High). Drilling terminated at 1208 m due to mechanical difficulties while still in Eumeralla Formation equivalent (Douglas, 1988). Minor gas shows occurred in the Eumeralla Formation.

With attention drawn by strandings of fresh bitumen/heavy oil in the area, the Beach Petroleum-operated **Geltwood Beach-1** was spudded in 1963. The well tested an anticlinal structure at Tertiary level expected to reach down to Cretaceous level. Nine shallow holes were drilled to verify the structure at the Tertiary level and confirmed an anticline plunging south east, 3.2 km wide & 9.7 km long with slight reversal in the north west and probable closure at depth. The Eumeralla Formation produced some significant gas shows, however no shallow petroliferous reservoirs were found. Crayfish Subgroup sandstones were still not reached at the TD of 3749 m. This remains the deepest onshore well in the Otway Basin.

Lake George-1, drilled in 1969 by Esso, was designed to test Crayfish Subgroup sandstones (Pretty Hill Sandstone) on a large anticlinal closure on the Beachport High basement horst. Original seismic interpretation suggested a prospect of area 363 km^2 with 853 m of vertical closure existed on the crest of the structure. Probably due to non-deposition, the structure was bald of Crayfish sandstones and the 1369 m well drilled straight from Otway Group mudstones into metasedimentary basement. No shows were recorded.

Lake Eliza-1, was also drilled by Esso in 1969 as a test of Crayfish Subgroup sandstones. It terminated at 1473 m in basement after drilling about ?400 m of Crayfish section. One DST flowed gas at RTSTM. Core porosity is in the range 20-25% but permeability is generally less than 15md and averages 3md.

General Exploration drilled **Lake Eliza-2** in 1973 to test draping of Crayfish Subgroup sandstones over a large positive gravity anomaly. Eumeralla Formation mudstones were expected to seal a trap of areal closure 155 square km and vertical closure 244 m. The well drilled to 1158 m and terminated in basement with a only a minor gas show recorded in the Crayfish section (about 100 m drilled). Visual and log porosity are described as good with assumed good permeability but a DST recovered only gas cut fluids.

Beachport East-1 was drilled by the John Henry company in 1973 and reached a TD of 1428 m in pre-Cretaceous basement. Some 47 m of fair to good quality Crayfish Subgroup was encountered but they were not tested.

Following a detailed photogeological study of the area south of Mount Gambier, a surface-expressed anticline was chosen as a test of the basal Tertiary Pebble Point Formation (Sprigg, 1985). **Douglas Point-1** was drilled by General Exploration in 1973 and terminated at 1206 m in Late Cretaceous 'Paaratte Formation' without encountering any hydrocarbon.

Lake Hawdon-1 was drilled by Hartogen in November 1988 and reached a TD of 2803 m. Numerous good reservoir sandstones were encountered in the Crayfish Subgroup (drilled 1589 m) but none were tested.

Hatherleigh-1 was drilled by SAGASCO in October 1990 and reached a TD of 1908 m. The proposed target was Crayfish sandstones onlapping a basement high but the well drilled from Eumeralla Formation into Devonian basalt thus missing the onlap edge.

St Clair-1 was drilled in April 1993 by a Gas & Fuel Exploration operated joint venture. The well TD'd at 3284 m within the Crayfish Subgroup without reaching expected good quality sandstones. The proposed "good quality sandstones" may occur deeper in the section (R. Hoare, Cultus Petroleum, pers. comm. 7/93).

Offshore

The offshore Esso well **Crayfish-A1** was drilled in September 1967 on the interpreted crest of a north east - south west trending anticline (Lake Eliza High) and reached a TD of 3200 m after drilling 1603 m of Crayfish Subgroup. It was mapped on what was thought to be a "Pre-Early Cretaceous unconformity" which actually was the top of the Crayfish Subgroup. With apparently adequate Eumeralla seal and reservoir sands of good porosity (18-24% average) and variable permeability (0-600md; clay choking dependent), only minor dissolved gas in an entirely water saturated sand section was discovered. A non-commercial dry gas flow was tested in the Crayfish Subgroup sandstones (FIT rec. 0.15 cu. ft. gas) and fluorescence and hydrocarbon cuts in cores and cuttings in the deeper Crayfish section are considered attributable to the presence of scattered asphalt-like material (Esso, Morum WCR, 1975). Following post drilling seismic interpretation, it was decided that a down-faulted block on the anticline crest had destroyed closure.

Esso drilled **Argonaut-1** in 1968 on the high side of a tilted fault block in a heavily faulted section (Sprigg, 1985). The well reached a TD of 3708 m in early Late Cretaceous 'Waarre Sandstone'. No shows were recorded. The Late Cretaceous section was sandier than expected and may not have provided cross-fault seals.

Neptune-1 was drilled in 1973 by Esso to test a high side fault closure along the offshore extension of the Lake Eliza High. The well TD'd at 2437 m within the Crayfish Subgroup (1015 m drilled). It was expected that the overlying Eumeralla would act as the seal and source to Crayfish reservoir sands but despite an apparently robust closure and adequate overlying and interbedded seals, no shows were recorded. Only one core was cut in a Crayfish sandstone which was of poor porosity and permeability. However it was decided from logs that this core was not representative of the Crayfish sandstones as a whole.

5 GEOCHEMISTRY

5.1 Source Rocks

Four potential source rocks intervals are considered relevant to the EPP SA-1 permit. The Late Jurassic/Early Cretaceous **Casterton Formation** has the potential to exist within unpenetrated sections of half-graben in the western Otway Basin. This formation is sparsely drilled with little information available on source potential, however carbonaceous lacustrine shales rich in algal material were penetrated in Robertson-1 to the east. Kopsen and Scholefield (1990) suggest that the Casterton sequence has its richest source potential in the South Australian portion of the Otway Basin where the volcanics content appears lower, however it should be noted that prolific kitchen areas may be irregularly distributed. The unit is considered to be both liquid and gas prone, and is the possible source for the oil discovery at the Sawpit-1 well, east of EPP SA-1.

The **Crayfish Subgroup** is intersected by most wells in the vicinity of EPP SA-1. The Crayfish Subgroup was deposited primarily in non-marine fluvial and occasionally lacustrine settings, with organic matter input predominantly humic in origin. TOC's within the Crayfish Subgroup range up to 15% but average below 1% with HI's typically in the range of 50-200 mg/g although these results are generally maturity effected. This group is therefore interpreted as gas-prone with very little liquids potential. The thickness of the Crayfish Subgroup and the potential for development of more lacustrine settings within the half-graben suggest that this unit has the potential to generate a significant amount of gas. This unit is interpreted to be the likely source of the gas in the Katnook field, located in the Penola Trough, east of EPP SA-1.

The **Eumeralla Formation** is probably the preferred and more recognised source interval in the western Otway Basin. Well developed coal facies at the base of the Eumeralla Formation are laterally extensive with TOC content averaging 30% in coals and 4% in siltstones, and HI averaging 250 mg/g in coals and 150 mg/g in siltstones. Both liquid and gas generation has been demonstrated from this unit. The remainder of the Eumeralla Formation contains fair source potential with gas and minor liquid generative capacity. Unfortunately this unit is relatively shallow near most of the mapped structures within EPP SA-1 and is therefore generally non-prospective.

The Late Cretaceous **Belfast Mudstone** is the youngest envisaged source rock for EPP SA-1. This unit was deposited as deltaic progrades, with low TOC and HI. This unit is typically gas-prone and is immature in the northern half of the permit but mature in the southern third of EPP SA-1.

5.2 Source Maturation and Hydrocarbon Migration

EPP SA-1 may be grossly subdivided into three disproportionate zones when examining source maturation. The northern zone is mature for Crayfish Subgroup generation, the middle zone contains very thin Crayfish Subgroup above basement, and the southern zone contains thick Late Cretaceous sediments where potential exists for mature Belfast Mudstone and Eumeralla Formation sediments.

The northern zone of EPP SA-1 contains Crayfish Subgroup sediments ranging in thickness from 2 to 4 km which potentially overly Casterton sediments of unknown thickness, although these have not been identified on seismic. The Crayfish Subgroup is thick enough to have ensured local maturation of the basal part of the subgroup plus any existing Casterton Beds, by the end of Crayfish deposition at Barremian times. This implies that structures which existed at the Barremian were able to be charged from the depths of the half graben up depositional slope at this time. Subsequent deposition of the Eumeralla Formation has pushed most of the Crayfish Subgroup through the oil window (approximately 2000 to 2500 m) during the remainder of the Early Cretaceous. Prospects located in this part of EPP SA-1 therefore have exposure to local sourcing from the Casterton Group and Crayfish Subgroup, although later deposition has matured a large section of sediments into the gas window. This implies that plays sourced by the Crayfish Group and Casterton Group have a high risk for gas flushing of any reservoired oil.

The middle and smallest zone of EPP SA-1 spans the Beachport Horst, where Crayfish Subgroup sediments thin dramatically and are probably not in the oil window. This section is therefore not interpreted to have source potential for the permit. To the west of the permit however the Crayfish Subgroup thickens away from the basement high. This section is likely to be fairly proximal in nature and is interpreted to have poorer source potential than that encountered elsewhere. However this section is likely to be mature and, as it drains primarily to the permit area, should not be overlooked as providing source potential to leads located in association with the Beachport Horst.

The southern largest zone of EPP SA-1 is overmature for liquid or gas generation from the Crayfish Subgroup. Early Cretaceous Eumeralla Formation and Late Cretaceous sediments thicken rapidly away from the Beachport Horst. The Lower Eumeralla Coal Measures (LECM) become mature for oil and subsequent gas generation in this area, although drainage direction may be oriented more towards onshore than towards identified leads. The Eumeralla poses the best liquid and similarly gas potential in the permit. The potential for oil charge to identified leads must not be overlooked, however the zone for oil mature Lower Eumeralla Coal

Measures is narrow and confined to an area near the Beachport Horst. Leads that have access to mature Eumeralla source would also have access to overmature Crayfish Subgroup sediments below the Eumeralla, indicating a further risk of gas charging. Further south of the onshore Geltwood Beach wells the Eumeralla Formation is pushed very deep by a rapidly thickening Late Cretaceous and Tertiary section controlled by a rejuvenation of fault activity. This zone becomes prospective for gas only, and in conjunction with the lack of available seismic in this area renders this part of the permit unprospective at the current stage of exploration.

Overall source potential in EPP SA-1 is considered fair for gas over much of the permit, and generally very poor for liquids excluding the southern flank of the Beachport Horst feature which is considered to have poor to fair liquids potential. The primary reason for high oil risk is subsequent gas flushing by overmature deeper source rocks.

6 GEOPHYSICS

6.1 Recent Surveys and Reprocessing

The two seismic lines recorded in 1991 (OH91C survey) represent the only useable structural dip lines in this permit for mapping events below the top Crayfish Subgroup unconformity. Line tails from out of the permit provide valuable well and interpretation correlations and are the only reliable source of structural strike line information in the permit.

Lines from several open file and traded onshore surveys have been used for fault and structural extrapolations in the absence of data in EPP SA-1. The quality of these lines is variable and in most cases inferior to the recent offshore lines. Surface conditions obviously have a major impact on the quality of onshore data.

The onshore lines have also been useful for 'locating' onshore wells within a similar structural/stratigraphic setting in EPP SA-1 to allow the results of these wells to contribute to the offshore interpretation.

As previously mentioned, six EU68 seismic lines totalling 82.9km were reprocessed by Tensor Pacific in 1991. Of this 59.2km are within the boundaries of EPP SA-1 and the remainder lie in EPP 24 and PEL 40. Considerable difficulties were encountered in reading the field tapes or copies of them. HGS in Sydney were eventually able to transcribe the original field tapes into SEG-Y format, albeit with only three seconds of the original four seconds of data. Due to the erratic shotpoint spacing of this survey much time was spent on establishing the correct geometries prior to processing. This was achieved by adopting binning techniques used for 3D seismic processing with shotpoint labels added in the appropriate places subsequent to processing. The final product shows an irregular shotpoint spacing to match the original acquisition.

6.2 Seismic Interpretation

Principal events mapped from EPP 24 into EPP SA-1 are :

<u>Base Tertiary</u> : Tied to Neptune-1 and Crayfish-A1 and followed as a high amplitude package generally a half to one cycle above true Base Tertiary. The Tertiary and Late Cretaceous sections have little exploration potential for most of EPP SA-1 and cannot be mapped in the southern part of the permit due to lack of data. No structure map has been produced for the Base Tertiary.

Top Eumeralla : Tied to Neptune-1 and followed as a high amplitude package. There is occasional angularity at this unconformity, but in general it gives a very good indication of intra-Eumeralla structure. The southern end of line OH91C-602 is 6.0km from the onshore well Geltwood Beach-1 which intersected the Eumeralla at 1231mSS. This depth roughly equates to 1150ms TWT and has been used to constrain the interpretation of the Top Eumeralla and Base Tertiary (543mSS/560ms) events in the southern area of EPP SA-1.

Top Crayfish Subgroup Unconformity : Tied to Neptune-1 and Crayfish-A1 and an easily identified regional event generally showing obvious erosional truncation. There was some difficulty identifying this event with certainty south of the Tartwaup Fault on line OH91C-602 due to poor data quality. Geltwood Beach-1 TD'd at 3750mSS within the Eumeralla Formation. In the absence of a seismic line tie or any well seismic data, the time-depth curves of various deep wells in the area were used to calculate an approximate TWT of 2500ms for this depth. A 'possible' Top Crayfish event was interpreted below the well TD.

Intra-Crayfish Subgroup : Two events were originally picked on line OC91C-601 for interpreting throughout the permit with only the most reliable to be mapped. There were some problems correlating these events either side of the Lake Eliza High and across large faults because of rapid changes in seismic character. In all cases, true dip information has been preserved to allow lead identification even if the correlation is not obvious. Events either side of the Beachport Horst cannot be directly correlated and so a reliable event at a similar level was selected for mapping on the southern side.

Basement : Basement cannot be directly tied to any offshore wells but its position can be interpreted with confidence through most of the permit, particularly where it is shallow. This event has been a useful lower constraint for the interpretation of the intra-Crayfish events and has provided valuable information on the structural history of the permit and surrounding area.

7 PLAY TYPES AND LEADS

7.1 Play Types

Several play types exist within the western portion of the Otway Basin, most of which are represented in EPP SA-1. The Crayfish Group forms the primary reservoir target for most leads mapped in the permit. Crayfish-A1 and Neptune-1 intersected good quality Crayfish Subgroup reservoirs to the west of EPP SA-1. A regional porosity versus depth curve is shown in Figure 3 and illustrates good reservoir quality at the depths required for EPP SA-1 plays. The earliest play in the permit involves Crayfish Subgroup reservoirs sealed vertically by intraformational claystones deposited in overbank and lacustrine settings. The potential for intraformational sealing is illustrated in Neptune-1 and Crayfish-A1 which demonstrate development of common 20-50 m thick and occasional 100 m thick claystone intervals within the Crayfish Subgroup. Net to gross of the Crayfish Subgroup in these wells is around 40-50%.

During deposition of the Crayfish Subgroup section, both normal and listric rollover faults provided mechanisms for the formation of traps. Rollovers were evident in the northern halfgraben as early as the ?Valanginian, during deposition of the middle of the Crayfish Subgroup. Tilted fault blocks were also developed at this time, although continued fault movement may have breached the vertical seal of these structures. These traps still retain closure integrity and are mapped as leads on newly acquired seismic. Crayfish Subgroup and possibly Casterton sediments deposited in the deeper parts of the half-graben became mature for hydrocarbon generation as early as the ?Valanginian. Updip migration to rollover structures and tilted fault blocks in shallower parts of the hangingwall provides an easy mechanism for hydrocarbon charging of the structures during their formation. Subsequent deposition of the Eumeralla Formation has pushed the source sediments through the gas window, with the potential for generation of large volumes of gas. The Intra-Crayfish structures must therefore be considered as gas targets only.

The second play utilises the base of the Eumeralla Formation as a seal rock draped over existing highs, and overlying and juxtaposed across tilted fault blocks of the Crayfish Subgroup. The Eumeralla Formation is considered to have fair to good seal potential, predominantly comprising claystones and coals at the base. Minor sandstones are often associated with the coal bearing sequences in the Lower Eumeralla but are more likely to behave as secondary reservoirs to the Crayfish Subgroup rather than acting as a breach of the seal. The basal Eumeralla has been proven as a seal for underlying Crayfish Subgroup in several discoveries in the basin.

Drape structures are interpreted as having been created at the time of deposition of the Eumeralla Group over regional highs. Tilted fault blocks at the top of the Crayfish group were formed prior to and during deposition of the Eumeralla Formation, many having been reactivated through time. Similar to the intraformational plays, Top Crayfish Subgroup reservoirs could be sourced from either mature ?Casterton and/or Crayfish Subgroup sediments from within half-graben. Overmaturity of these sources during deposition of the Eumeralla suggests that these must also be considered as gas plays. A thicker section of Eumeralla, Sherbrook and Tertiary sediments in the southern part of the permit pushes the base of the Eumeralla Formation into the oil window. This unit may act to source both liquids and gas to Top Crayfish reservoirs, but the large volumes of gas potentially generated by underlying Crayfish sediments is likely to have displaced any liquids migrating to the structures.

The third play involves Intra-Eumeralla reservoirs and seals. Sandstones of the Eumeralla Formation are of fair quality as shown by the regional porosity versus depth trend in Figure 3. Adequate porosity has been intersected in wells near the permit (such as Crayfish-A1) at depths similar to those proposed for leads in EPP SA-1. However permeability of the reservoirs is often very low due to diagenesis of the mainly volcaniclastic section. The best potential for fair quality reservoirs exists at the base of the Eumeralla Formation (Windemere Sandstone) often associated with coals, the Middle of the Eumeralla Formation (Heathfield Sandstone), and the upper section of the Eumeralla Formation which becomes more proximal in nature towards the top. The remainder of the Eumeralla Formation is considered to have fair potential to seal the Intra-Eumeralla reservoirs. Potential sources for an Eumeralla play comprises gas mature Crayfish Subgroup sediments in the northern part of the permit, and liquids/gas prone Eumeralla (particularly Lower Eumeralla) in the middle part. The southern area is considered too deep to be economically prospective. A Eumeralla play is considered to be of fairly poor prospectivity, with no analogs discovered in the basin.

The fourth and youngest play proposed for the permit is only viable in the southern part of the permit where Late Cretaceous sediments thicken across several down-to-the-basin faults. Argonaut-1 is located near the southern extent of EPP SA-1 and reached total depth at 3708 mRT in Late Cretaceous sediments of Coniacian to Early Santonian age ('Waarre Sandstone'). The well intersected fairly well developed sandstones below 500 m of well developed claystone, with sandstone porosities in the order of 8-15% and permeabilities ranging from nil to 25 md. This play is viewed as fairly prospective elsewhere in the basin and has been demonstrated successfully in the Eastern Otway Basin. However depth of burial of the reservoir section in EPP SA-1 is typically too great to preserve reasonable porosity and overmature Eumeralla Formation implies a primarily gas prone source. Lack of seismic data in this portion of the permit implies that at the current stage prospectivity of Late Cretaceous plays is low.

7.2 Leads

A number of leads have been identified at the Top Crayfish and Intra-Crayfish levels. All are poorly defined seismically, generally by only one or two lines, and none can be considered as prospects with existing data. The Intra-Crayfish leads have serious cross-fault and fault seal risks due to the generally sandy section and the Top Crayfish leads have serious fault seal risks. Summaries of sizes, possible hydrocarbon volumes and lead risks are contained in Tables 2,3 & 4. The location of these leads is shown on the enclosed structure maps and seismic sections.

Top Crayfish Leads

Lead CR1 A possible lowside fault play on the northern side of the Beachport Horst. It occurs in the gap between the two OH91C lines and is seen only on line EU68-1. Closure is more 'model-driven' than observed. Hydrocarbons would be generated within the Crayfish Subgroup in the St Clair Trough and migrate south updip into this lead. A trap, if present, would have existed since the early Aptian.

Lead CR2 A lead comprising two bumps overlying the Beachport Horst. One bump appears formed by drape over a basement feature, the other has been formed recently and is bounded to the south by a small reverse fault. The latter had some closure prior to the recent structuring as evidenced by thinning of the Eumeralla (approx 15ms). This lead is defined by one modern and four old/end lines and is moderately constrained. True closure is unconstrained shoreward. Actual Crayfish thickness is difficult to prove, but appears to be in the order of 70 to 100ms (100-150m). Reservoir quality is unknown. Hydrocarbons would be generated within the Crayfish Subgroup in the St Clair Trough to the north and west of this lead. Trap timing is complicated by the recent movements; about half of the mapped closure has existed since the early Aptian (drape), the remainder having been formed in the Late Tertiary - Holocene.

Lead CR3 A very encouraging lead on line OH91C-602 but which is not supported by parallel lines to the southwest. If real, the formation of this pinnacle structure is difficult to explain as it seems too large for footwall rebound and also predates the 'Rivoli Trough' inversion. Apparent onlap of the basal Eumeralla lends support to real structure however a component of its apparent structure may be due to over-migration. Hydrocarbon charge would come from the Crayfish Subgroup and possibly the basal Eumeralla within the 'Rivoli' and Voluta Troughs. Any trap would have existed since the early Aptian.

A lowside fault lead below CR3 is possible but has not been mapped due to poor quality data and uncertainty in the position of the Crayfish Subgroup.

Intra-Crayfish Leads

Lead IC1 An intra-Crayfish rollover into a fault defined by two lines and several end lines. True closure is unconstrained shoreward. Fault-independent closure is small and cross-fault seal cannot be demonstrated. Reservoir and intra-formational seals are expected to be adequate, as evidenced by the nearby wells. Hydrocarbon charge would come from the Crayfish Subgroup/Casterton section within the Robe Trough. Any trap may have existed since the ?Valanginian-Barremian but end Barremian fault movement provided the bulk of apparent closure.

Lead IC2 A poorly defined lead based on two seismic lines. Closure is unconstrained shoreward and is thus mostly 'model-driven'. The greatest risk with this lead is cross-fault seal as is it uncertain whether it requires basement of the Beachport Horst or Crayfish Subgroup sediments for seal. The former would be preferable but is the least likely of the two options. Hydrocarbon charge would come from the Crayfish Subgroup/Casterton section within the 'Rivoli' Trough and any trap may have existed since the ?Valanginian-Barremian.

To allow upgrade to prospect status all leads require more seismic, particularly normal to the coast for structural strike information. In the order of 70 to 150km of seismic would be required, depending on the leads and number to be defined.

8 CONCLUSIONS

At this stage the prospectivity of EPP SA-1 can be summarised to be primarily gas-prone plays within the Crayfish Subgroup with high trap risks due to sparse seismic coverage and fault seal requirements.

There are no leads identified in the adjoining EPP 24 which are likely to extend into EPP SA-1. This has two implications: the necessity for EPP SA-1 as protection acreage to EPP 24 is no longer valid (EPP 23 has already been relinquished) and any prospects proven in EPP SA-1 must stand on their own merits. The latter point makes the likelihood of discovering a stand-alone economic field in such a small area somewhat remote, particularly in the case of gas.

9 REFERENCES

ALLIANCE OIL DEVELOPMENT AUSTRALIA NL; 1978
Farmout Proposal, Petroleum Exploration Licence No 8 , State of South Australia. BHP Petroleum Code 12/3/003

BEACH PETROLEUM NL; 1965
Geltwood Beach No. 1 Summary of Data & Results. Published BMR. BHP Petroleum Code 12/1/Geltwood Beach 1/001

BHP PETROLEUM PTY LTD; 1990
Application For Offshore Area SA1 Otway Basin, South Australia. BHP Petroleum file ED.82.SA1.

BHP PETROLEUM PTY LTD; 1991
Evaluation Report, EPP 23 Otway Basin, South Australia BHP Petroleum Code 12/3/166

BHP PETROLEUM PTY LTD; 1991
EPP SA-1 First Year Annual Report (unpublished). BHP Petroleum file ED.82.SA1

BHP PETROLEUM PTY LTD; 1992
EPP SA-1 Second Year Annual Report (unpublished) BHP Petroleum file ED.82.SA1

ESSO EXPLORATION & PRODUCTION INC; 1969
Lake Eliza-1 Well completion Report (unpublished). BHP Petroleum Code 12/1/Lake Eliza 1/001

ESSO EXPLORATION & PRODUCTION INC; 1975
Neptune-1 Well Completion Report (unpublished) BHP Petroleum Code 12/1/Neptune-1/001

ESSO EXPLORATION & PRODUCTION INC; 1970
Lake George-1 Well Completion Report (unpublished) BHP Petroleum Code 12/1/Lake George-1/001

FELTON, A.E. and JACKSON, K.S.; 1987
Hydrocarbon Generation Potential in the Otway Basin, Australia. BMR Journal of Australian Geology & Geophysics, 10, pp 213-24.

GEOSURVEYS OF AUSTRALIA LTD for BEACH PETROLEUM N.L.; 1964
Geltwood Beach-1 Draft Report. BHP Petroleum Code

12/1/Geltwood Beach-1/003

JOHNSTON, J.J.; 1993
Permit EPP SA-1 Otway Basin, South Australia - Evaluation Report. Unpublished. BHP Petroleum Code OTW/3/183

KOPSEN, E. and SCHOLEFIELD, T.; 1990
Prospectivity of the Otway Supergroup in the Central and Western Otway Basin. APEA Journal, 30, pp 263-79.

LAING, S., DEE, C.N. & BEST, P.W.; 1989
The Otway Basin. APEA JOURNAL, p 417 - 429

PARKER, K.A.; 1992
The Exploration & Appraisal History of the Katnook & Ladbroke Grove Gas Fields, Onshore Otway. APEA JOURNAL, p 67-85

SOUTH EAST OIL SYNDICATE; 1962
Beachport-1 Well Completion Report (unpublished). BHP Petroleum Code 12/1/Beachport-1/001

SPRIGG, R.C.; 1986
A History of the Search for Commercial Hydrocarbons in the Otway Basin Complex. Second South-Eastern Australia Oil Exploration Symposium, Glenie. R.C. (ed) p 173 - 199

VICTORIAN DIVISION GEOLOGICAL SOCIETY OF AUSTRALIA INC.; 1988
Geology of Victoria. Chapter 7 by J.G. Douglas et al p 213 - 228
BHP PET/ER 55(ER) GEO.

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OTWAY BASIN

EPP SA-1 - LOCATION MAP & LEADS

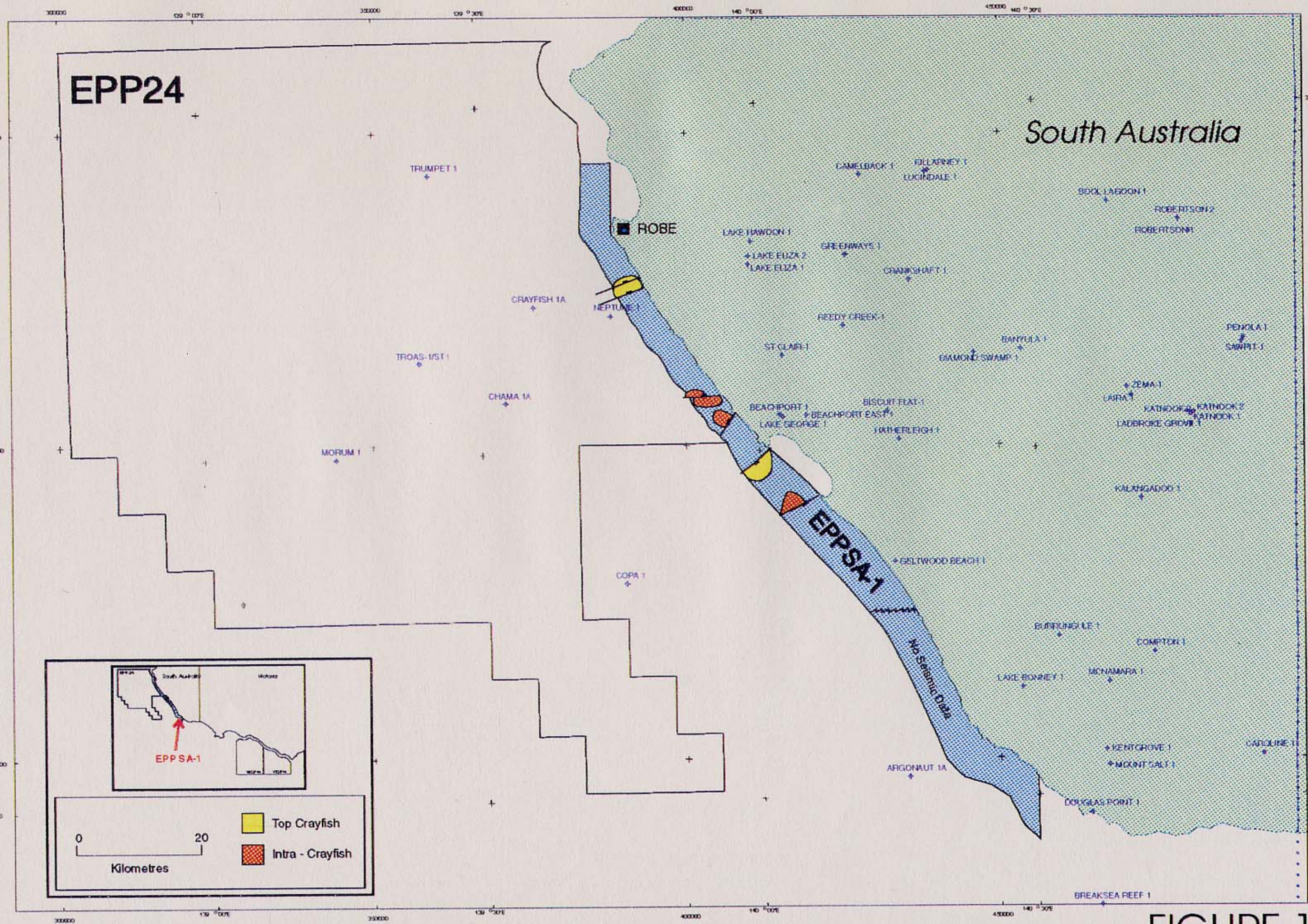
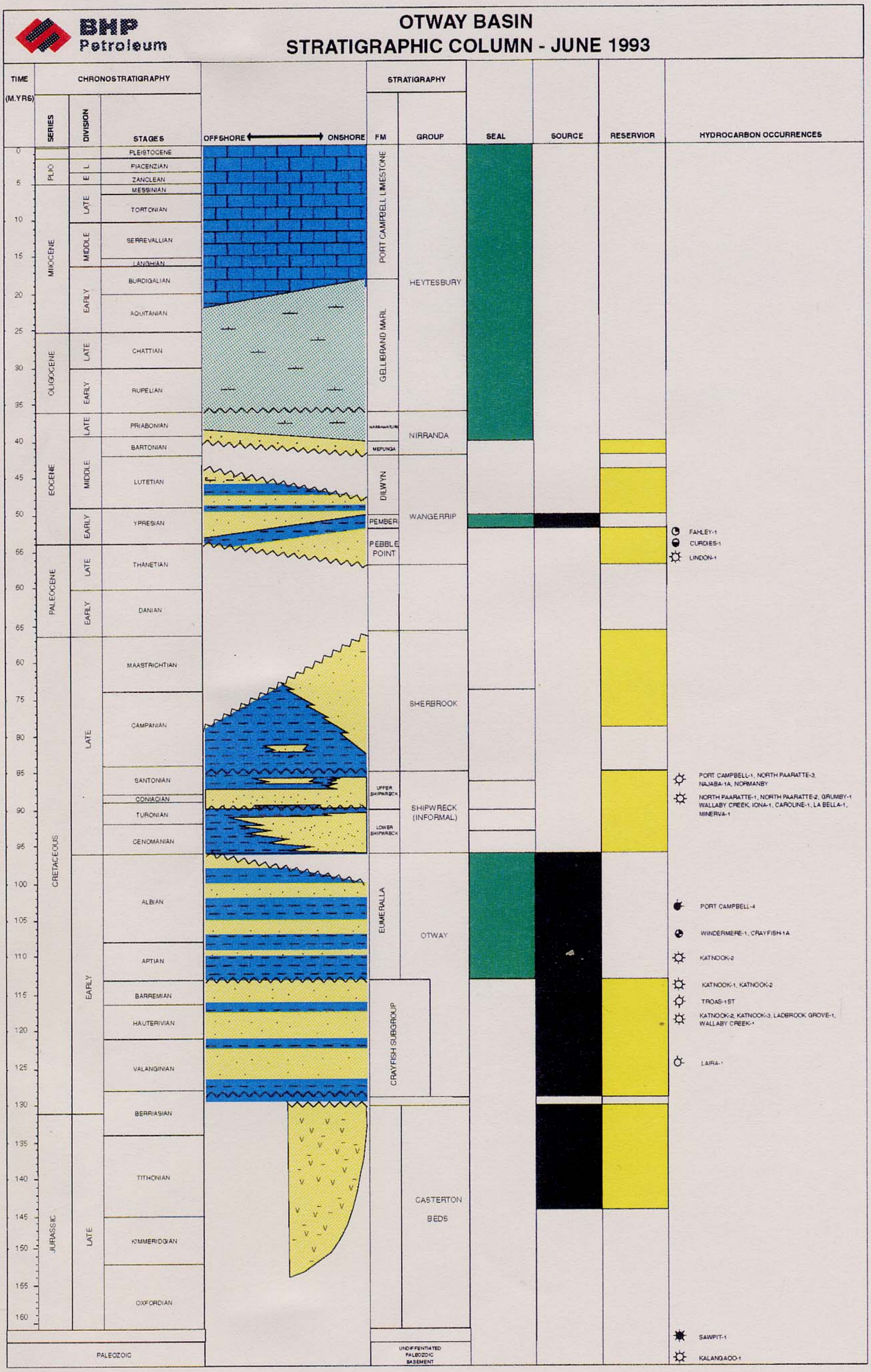


FIGURE 1

002_CDR_TD



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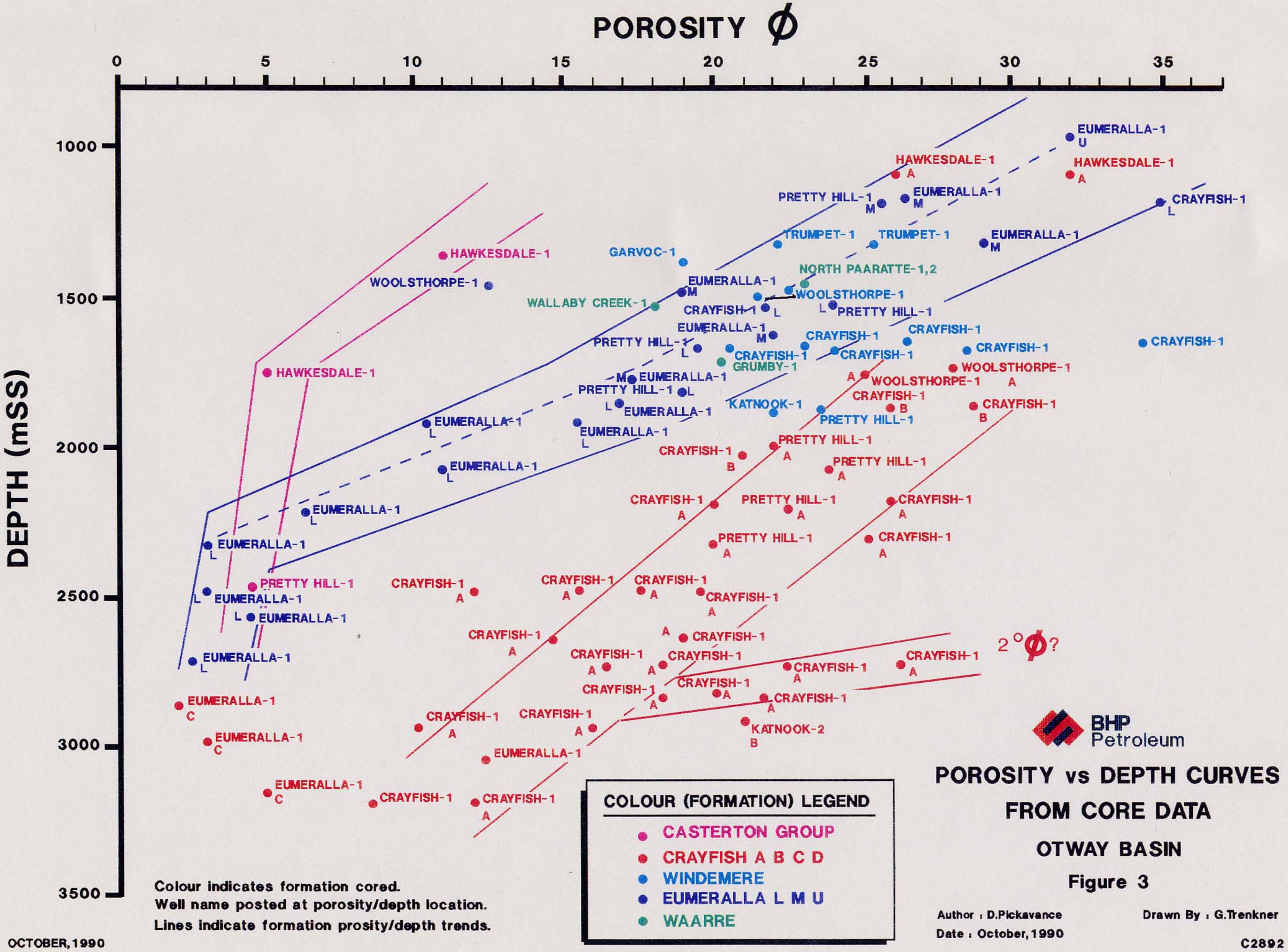
OTWAY BASIN
STRATIGRAPHIC COLUMN - JUNE 1993
TIME (M.YRS)
CHRONOSTRATIGRAPHY
SERIES
DIVISION
STAGES
OFFSHORE
ONSHORE
STRATIGRAPHY
FM
GROUP
SEAL
SOURCE
RESERVOIR
HYDROCARBON OCCURRENCES
PLEISTOCENE
PIACENZIAN
ZANCLEAN
MESSINIAN
TORTONIAN
SERRAVALLIAN
LANGHIAN
BURDIGALIAN
AQUITANIAN
CHATTIAN
RUPELIAN
PRIABONIAN
BARTONIAN
LUTETIAN
YPRESIAN
THANETIAN
DANIAN
MAASTRICHTIAN
CAMPANIAN
SANTONIAN
CONIACIAN
TURONIAN
CENOMANIAN
ALBIAN
APTIAN
BARREMIAN
HAUTERIVIAN
VALANGINIAN
BERRIASIAN
TITHONIAN
KIMMERIDGIAN
OXFORDIAN
PALEOZOIC
PLIO
MIOCENE
OLIGOCENE
EOCENE
PALEOCENE
CRETACEOUS
JURASSIC
PORT CAMPBELL LIMESTONE
GELLIBRAND MARL
HEYTESBURY
NIRRANDA
MEPUNGA
DILWYN
WANGERRIP
PEMBER
PEBBLE POINT
SHERBROOK
UPPER SHIPWRECK
LOWER SHIPWRECK
SHIPWRECK (INFORMAL)
EUMERALLA
OTWAY
CRAYFISH SUBGROUP
CASTERTON BEDS
UNDIFFERENTIATED PALEOZOIC BASEMENT
FAHLEY-1
CURDIES-1
LINDON-1
PORT CAMPBELL-1, NORTH PAARATTE-3, NAJABA-1A, NORMANBY
NORTH PAARATTE-1, NORTH PAARATTE-2, GRUMBY-1 WALLABY CREEK, IONA-1, CAROLINE-1, LA BELLA-1, MINERVA-1
PORT CAMPBELL-4
WINDERMERE-1, CRAYFISH-1A
KATNOOK-2
KATNOOK-1, KATNOOK-2
TROAS-1ST
KATNOOK-2, KATNOOK-3, LADBROOK GROVE-1, WALLABY CREEK-1
LAIRA-1
SAWPIT-1
KALANGADOO-1

Figure 2



POROSITY vs DEPTH CURVES FROM CORE DATA

OTWAY BASIN

Figure 3

Author : D.Pickavance
Date : October, 1990
Drawn By : G.Trenkner
C2892

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OTWAY BASIN

EPP SA1 WORK PROGRAM

PERMIT YEAR	MINIMUM WORK REQUIREMENTS	Estimated/ [Actual Expenditure] A$
FIRST 15/11/90 - 14/11/91	Reprocess, interpret and map at least 59.2 km of available seismic data (amended from 62.0 km) **Actual: 82.9 km reprocessing** (59.2 km in EPP SA1) **+ 73.4 km acquisition**	60 000 **[122 009]**
SECOND 15/11/91- 14/11/92	Acquire, process and interpret at least 70 km of seismic data **Actual: 73.4 km recorded in YEAR 1**	100 000 **[13 452]**
THIRD 15/11/92- 14/11/93	Review data *** in progress ***	50 000
FOURTH 15/11/93 - 14/11/94	Acquire, process and interpret at least 70 km of seismic data	800 000 - 1 000 000
FIFTH 15/11/94 - 14/11/95	Drill one exploratory well to at least 2500 m	6 000 000
SIXTH 15/11/96 14/11/97	Review data	100 000

TABLE 1

048_FLW_TD

EPP SA-1 LEAD RESERVOIR PARAMETERS

E1...3 - EUMERALLA RESERVOIRED PLAYS

CR1...3 - TOP CRAYFISH RESERVOIRED PLAYS

IC1, IC2 - INTRA-CRAYFISH RESERVOIRED PLAYS

	E1	E2	E3	CR1	CR2	CR3	IC1	IC2
GRV (MMm3)	101	130	172	339	628	500	646	2030
Net to Gross	0.3	0.3	0.3	0.25	0.25	0.25	0.5	0.5
Porosity	0.3	0.3	0.3	0.3	0.3	0.3	0.24	0.17
HC Saturation	0.85	0.85	0.85	0.85	0.85	0.85	0.8	0.8
Fm Vol Factor Oil	1.1	1.1	1.1	1.25	1.2	1.2	1.4	1.45
Expans Factor Gas	65	67	62	154	141	158	191	216

Table 2

EPP SA-1 PER[illegible]T EVALUATION

SCOPING RESERVES - OIL CASE

LEAD	OIP (MMBBLS)	RESERVES (MMBBLS)	RISK
E1	44	13	0.003
E2	57	17	0.003
E3	75	23	0.003
CR1	109	38	0.002
CR2	210	63	0.006
CR3	167	50	0.004
IC1	279	98	0.0007
IC2	599	180	0.0001

SCOPING RESERVES - GAS CASE

LEAD	GIP (TCF)	RESERVES (TCF)	RISK
E1	0.018	-	0.012
E2	0.024	-	0.012
E3	0.029	-	0.012
CR1	0.118	0.07	0.005
CR2	0.200	0.12	0.016
CR3	0.178	0.11	0.011
IC1	0.419	0.25	0.014
IC2	1.06	0.63	0.002

* From Otway Scoping Economics

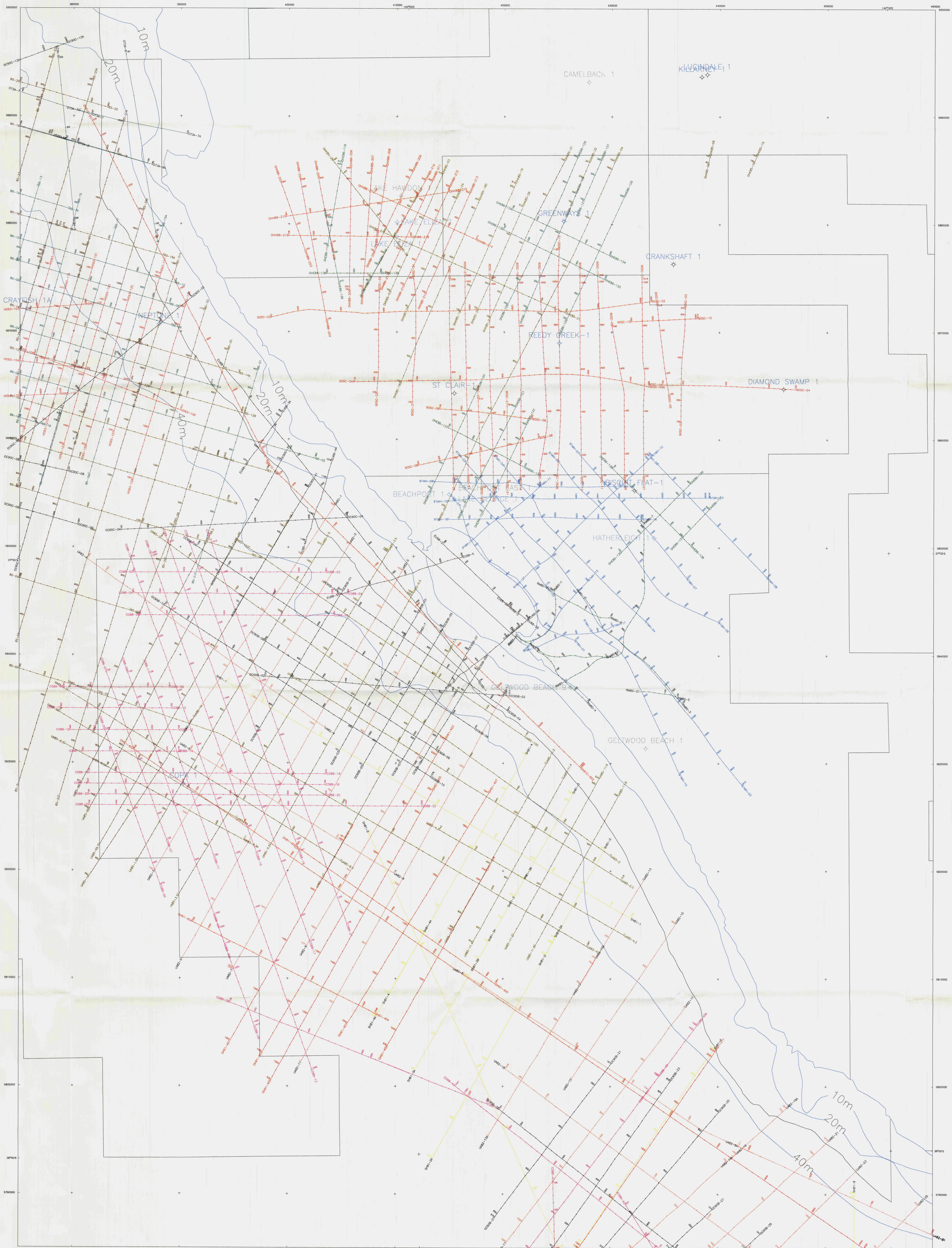
Table 3

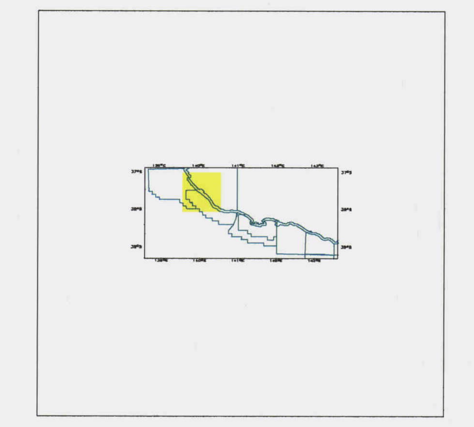
EPP SA-1 PERMIT EVALUATION

LEADS RISK SUMMARY

	E1	E2	E3	CR1	CR2	CR3	IC1	IC2
Trap	0.4	0.4	0.4	0.1	0.3	0.2	0.25	0.25
Source/Migration	0.4	0.4	0.4	0.3	0.3	0.3	0.5	0.25
Seal	0.3	0.3	0.3	0.5	0.5	0.5	0.4	0.1
Reservoir	0.3	0.3	0.3	0.5	0.5	0.5	0.3	0.3
Preservation	0.9	0.9	0.9	.095	0.95	0.95	0.95	0.95
Oil	0.2	0.2	0.2	0.3	0.3	0.3	0.05	0.05
Oil Chance	0.003	0.003	0.003	0.002	0.006	0.0040	0.0007	0.0001
Gas Chance	0.012	0.012	0.012	0.005	0.016	0.011	0.014	0.002

Table 4





Enclosure 1

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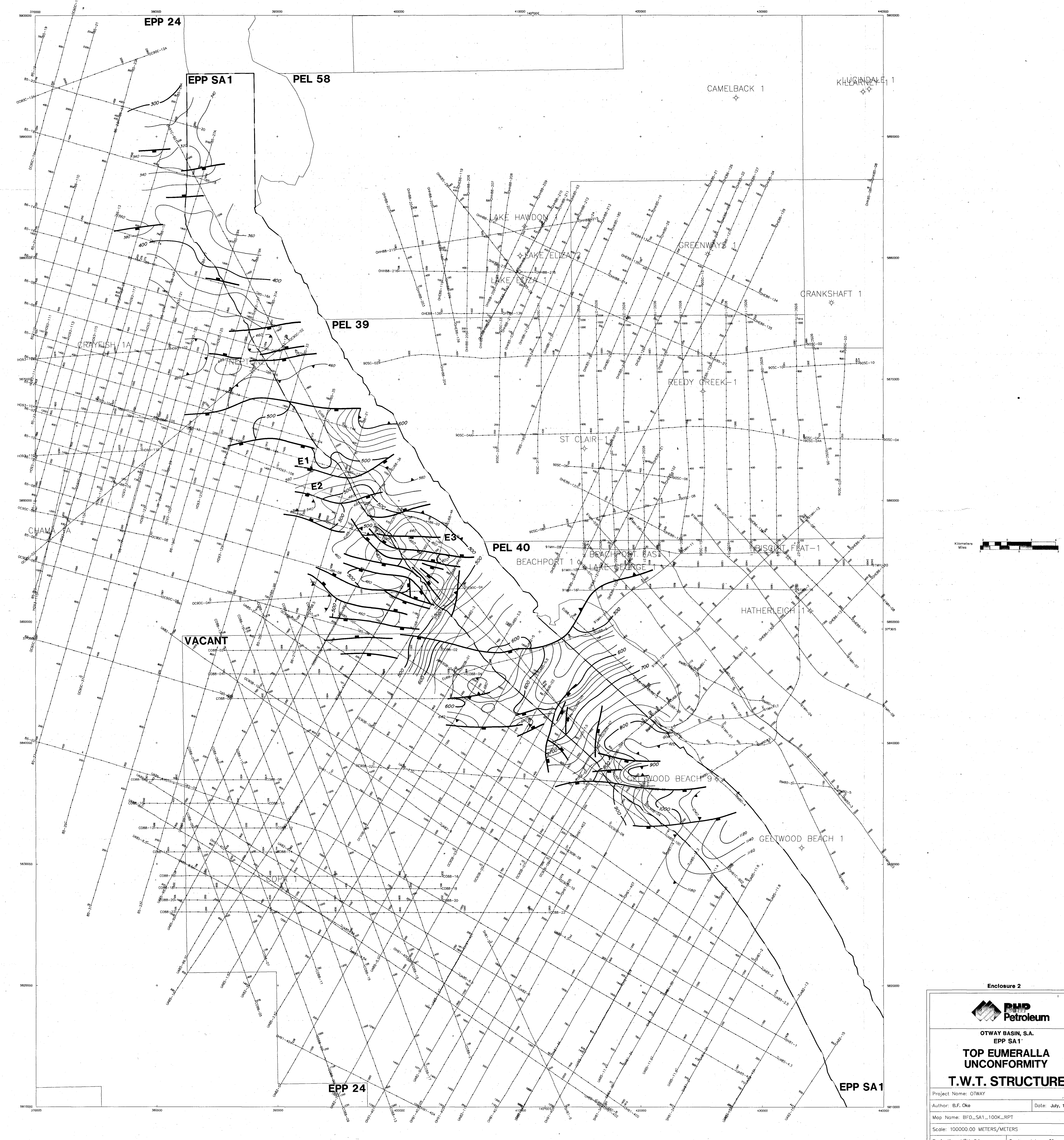
EPP SA-1

South Australia

SEISMIC BASEMAP

Project Name: OTWAY	
Author: AAOKEB	Date: 2/9/93
Map Name: BFO_SA1_100K_RPT	
Scale: 100000.00 METERS/METERS	
Projection: UTM-54	Contour Int:



Enclosure 2

BHP Petroleum

OTWAY BASIN, S.A.
EPP SA1

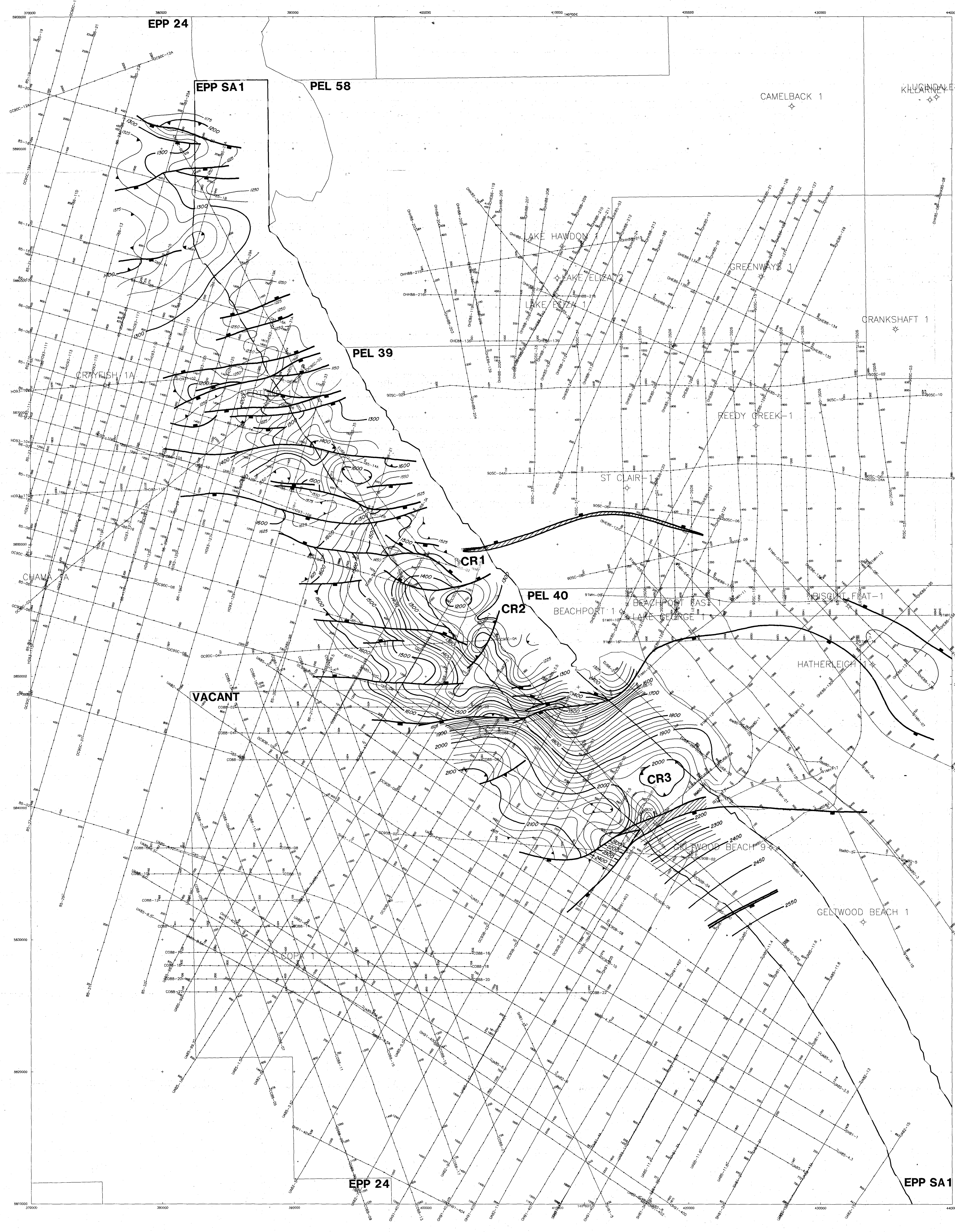
TOP EUMERALLA UNCONFORMITY

T.W.T. STRUCTURE

Project Name: OTWAY	
Author: B.F. Oke	Date: July, 1993
Map Name: BFO_SA1_100K_RPT	
Scale: 100000.00 METERS/METERS	
Projection: UTM-54	Contour Int: 20msec

Drawn By : Hammond Cartographics Pty. Ltd.

OG 29320
Base OG 29325



Enclosure 3

BHP Petroleum

OTWAY BASIN, S.A.
EPP SA1

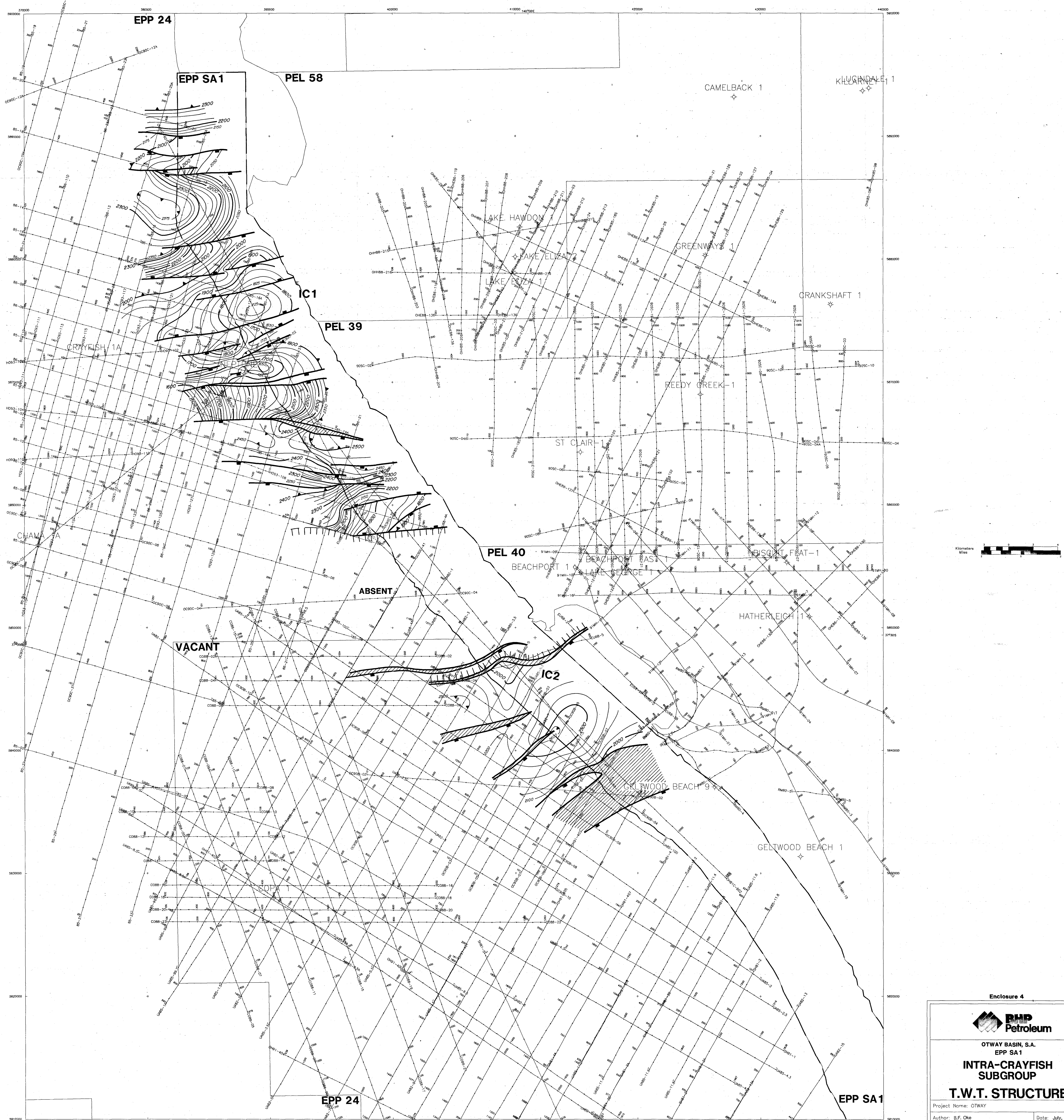
TOP CRAYFISH SUBGROUP

T.W.T. STRUCTURE

Project Name: OTWAY	
Author: B.F. Oke	Date: July, 1993
Map Name: BFO_SA1_100K_RPT	
Scale: 100000.00 METERS/METERS	
Projection: UTM-54	Contour Int: 25msec

Drawn By : Hammond Cartographics Pty. Ltd.

OG 29319
Base OG 29325



Enclosure 4

BHP Petroleum

OTWAY BASIN, S.A.
EPP SA1

INTRA-CRAYFISH SUBGROUP

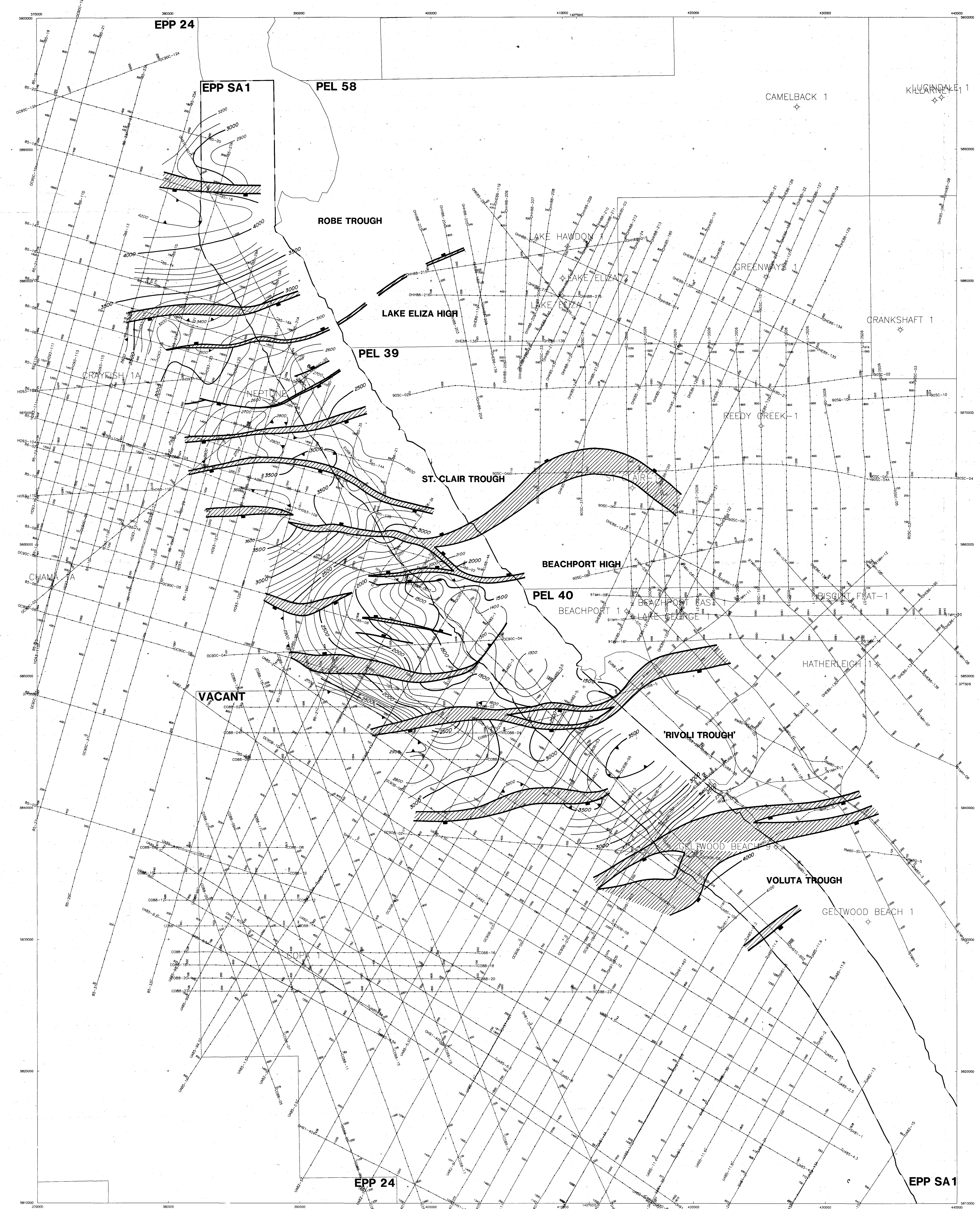
T.W.T. STRUCTURE

Project Name: OTWAY	
Author: B.F. Oke	Date: July, 1993
Map Name: BFO_SA1_100K_RPT	
Scale: 100000.00 METERS/METERS	
Projection: UTM-54	Contour Int: 25/100msec

Drawn By : Hammond Cartographics Pty. Ltd.

OG 29321

Base OG 29325



Enclosure 5

BHP Petroleum

OTWAY BASIN, S.A.
EPP SA1

BASEMENT

T.W.T. STRUCTURE

Project Name: OTWAY	
Author: B.F. Oke	Date: July, 1993
Map Name: BFO_SA1_100K_RPT	
Scale: 100000.00 METERS/METERS	
Projection: UTM-54	Contour Int: 100msec

Drawn By : Hammond Cartographics Pty. Ltd.

OG 29318

Base OG 29325

SR 27/2/101

LINE : OH91C-601

SHOT PTS. : 2221 - 939
AREA : OTWAY BASIN
PERMIT : EPP SA-1

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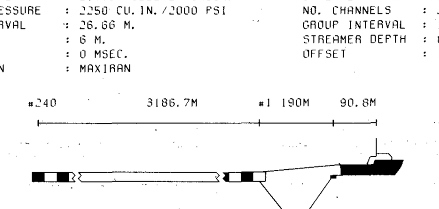
Enclosure 6

FILTERED MIGRATION

RECORDING PARAMETERS

RECORDED BY	: WESTERN GEOPHYSICAL CO.	DATE RECORDED	: APR 1991
VESSEL	: M/V WESTERN ODYSSEY	PARTY	: 86
RECORDING FORMAT	: SEG D (8024)	RECORD LENGTH	: 6 SECONDS.
PACKING DENSITY	: 6250	RECORDING INST.	: LRS16A
RECORDING FILTERS	: LOW CUT: 6HZ/ 18 DB/OCT.	SAMPLE RATE	: 2 MSEC.
	: HIGH CUT: 188HZ/156 DB/OCT.	GAIN MODE	: IFP.

SOURCE:		RECEIVERS:	
AIRGUN TYPE	: LITTON SLEEVE AIRGUN.	STREAMER LENGTH	: 3200 M.
VOLUME/PRESSURE	: 2250 CU. IN. /2000 PSI	NO. CHANNELS	: 240.
SHOT INTERVAL	: 26.66 M.	GROUP INTERVAL	: 13.33 M.
GUN DEPTH	: 6 M.	STREAMER DEPTH	: 8 - 11 M.
GUN DELAY	: 0 MSEC.	OFFSET	: 190.0 M.
NAVIGATION	: MAXIRAN		



PROCESSING PARAMETERS

TRANSCRIPTION : FROM SEG-D TO SEG-Y.

RESAMPLE : FROM 2MS TO 4MS.

GAIN CORRECTION : 8DB/SEC GAIN APPLIED FROM 0-4000MS.

F-K FILT : POLYGON PASS DESIGN. (REFER TO DIAGRAM)

ADJACENT TRACE SUM: 2 ON 1 SUM AFTER DIFFERENTIAL NMO. REDUCTION FROM 240 TO 120 CHANNEL.

INSTRUMENT DEPHASE : DFSV 6-188 HZ 18-156 DB/OCT CONVERTED TO MINIMUM PHASE.

WAVELET PROCESSING : DECONVOLUTION USING TANERS EXPONENTIAL METHOD. WAVELENGTH = 300 MS. OUTPUT SHAPE = MINIMUM PHASE 5-80 HZ 18-36 DB/OCT.

NMO VELOCITY ANALYSES : LOCATED AT APPROXIMATELY 1KM INTERVALS (GEOLOGICALLY DEPENDENT). ANALYSES COMPRISED OF 9 CDP GATHERS AND NMO STACKS OVER 15 ADJACENT CDPS.

DECONVOLUTION : 2 WINDOWS: 32/64 MS GAPS 240 MS OPERATOR.

BALANCE : PRE STACK TRACE BALANCE.

MUTE : SPACE VARIANT (DEPTH DEPENDENT). NOMINAL MUTES FOR 100M WATER DEPTH AS FOLLOWS:

OUTER TRACE MUTING OFFSET	TIME (MS)	INNER TRACE MUTING OFFSET	TIME (MS)
335	200	196	1000
600	500	970	2000
3400	2600	970	6000

NMO, DMO STACK : NMO APPLIED USING ANNOTATED NMO, DMO VELOCITIES. DMO TIME DIP PAIRS:

TIME (MS)	DIP (DEG)
0	30
700	30
1100	45
1500	60
6000	60

STATIC CORRECTION : +11.0 MS FOR GUN AND CABLE DEPTH.

F-K FILTER : POST STACK ANTI ALIAS F-K FILTER. (REFER TO DIAGRAM)

WAVE EQUATION MIGRATION : FINITE DIFFERENCE METHOD. % STACKING VELOCITIES:

TIME (MS)	RMS (%)
0	100.0
2000	100.0
3000	95.0
5000	85.0
6000	85.0

BANDPASS FILTERS : SPACE VARIANT (DEPTH DEPENDENT):

TIME (MS)	PASSBAND (HZ)
WBT + 0	8, 12 - 75, 90
WBT + 500	7, 10 - 70, 90
WBT + 1000	6, 9 - 65, 85
WBT + 1500	5, 8 - 60, 80
WBT + 2000	5, 8 - 55, 70
WBT + 2500	5, 7 - 50, 65
WBT + 3000	5, 7 - 45, 60
WBT + 4000	4, 6 - 35, 45
WBT + 5000	4, 6 - 35, 45
WBT + 6000	4, 6 - 30, 40

SCALING : SPACE VARIANT (DEPTH DEPENDENT): DUAL WINDOW AGC USING 2500MS AND

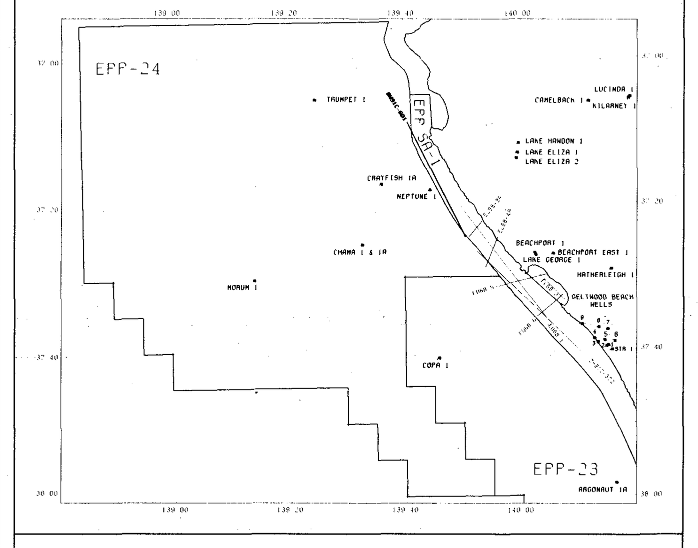
WINDOW LENGTH (MS)	START APPLY (MS)	END APPLY (MS)	MOVEDOWN (MS)
200	WBT + 0	WBT + 1000	100
500	WBT + 1000	WBT + 2500	250
1500	WBT + 2500	WBT + 6000	750

70% OF SHORT WINDOW AND 30% OF 2500MS

DISPLAY PARAMETERS

FILM DISPLAY : HORIZONTAL SCALE: 1:25000 (18.75 TRACES/CM).
VERTICAL SCALE : 10 CM/SEC.
GAIN = 1.4 : BIAS = 0.
SHOTPOINTS : ANNOTATED TO GUN POSITION
POLARITY : FIELD POLARITY (SEG STANDARD) MAINTAINED FOR PROCESSING AND DISPLAY.
WATER BOTTOM : SPIKE ANNOTATION ABOVE 120 MS.

0 KM 1 KM 2 KM



TENSOR PACIFIC PTY. LIMITED
VICTORIAN TECHNOLOGY CENTRE
283 NORMANBY ROAD. PORT MELBOURNE 3207
PHONE: (03) 647 9831
FAX: (03) 647 9835

DATE PROCESSED : OCTOBER 1991.
QUALITY CONTROL : [signature]

SR 27/2/101.

LINE : OH91C-602

SHOT PTS. : 2409 - 939
AREA : OTWAY BASIN
PERMIT : EPP SA-1

BHP Petroleum

Enclosure 7

FILTERED MIGRATION

RECORDING PARAMETERS

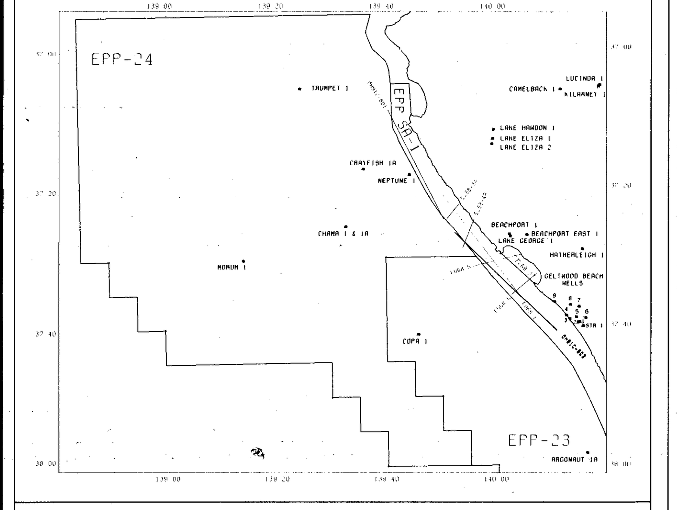
RECORDED BY	: WESTERN GEOPHYSICAL CO.	DATE RECORDED	: APR 1991
VESSEL	: M/V WESTERN ODYSSEY	PARTY	: 86
RECORDING FORMAT	: SEG D (8024)	RECORD LENGTH	: 6 SECONDS.
PACKING DENSITY	: 6250	RECORDING INST.	: LRS16A
RECORDING FILTERS	: LOW CUT: 6HZ/ 18 DB/OCT.	SAMPLE RATE	: 2 MSEC.
	: HIGH CUT: 188HZ/156 DB/OCT.	GAIN MODE	: IFP.

SOURCE:		**RECEIVERS:**	
AIRGUN TYPE	: LITTON SLEEVE AIRGUN.	STREAMER LENGTH	: 3200 M.
VOLUME/PRESSURE	: 2250 CU.IN./2000 PSI	NO. CHANNELS	: 240.
SHOT INTERVAL	: 26.66 M.	GROUP INTERVAL	: 13.33 M.
GUN DEPTH	: 6 M.	STREAMER DEPTH	: 8 - 11 M.
GUN DELAY	: 0 MSEC.	OFFSET	: 190.0 M.
NAVIGATION	: MAXIRAN		

#240 3186.7M #1 190M 90.8M

PROCESSING PARAMETERS

DISPLAY PARAMETERS



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QUALITY CONTROL : [signature]

SEISMIC PROCESSING REPORT

1991 OTWAY 2D SEISMIC SURVEY
EPP/SA-1 OTWAY BASIN, AUSTRALIA

FOR

BHP PETROLEUM
120 COLLINS STREET
MELBOURNE
3000

BY

TENSOR PACIFIC AUSTRALIA LTD.
283 NORMANBY ROAD,
PORT MELBOURNE, VICTORIA, 3207

PREPARED BY:

Michael Hartley

MICHAEL HARTLEY
GEOPHYSICIST

APPROVED BY:

Mark Stanley

MARK STANLEY
CHIEF GEOPHYSICIST

CONTENTS

1.0 INTRODUCTION

Between August 1991 and September 1991, a total of 73.44 kms of 2D marine data was processed for BHP Petroleum Pty. Ltd. by Tensor Pacific Pty. Ltd.

The data was acquired in the Otway Basin, permit EPP/SA-1, by Western Geophysical Company between April 1991 and May 1991.

Initial testing was conducted by Tensor Pacific Australia Pty. Ltd. in conjunction with BHP Petroleum's representative. The final processing sequence and choice of parameters were confirmed by BHP Petroleum's representative.

2.0 ACQUISITION PARAMETERS

Recorded by:	Western Geophysical Company.
Date recorded:	April - May 1991.
Vessel:	Western Odyssey.
Party:	86
Recording system:	LRS16A
Recording format:	SEGD 8024 / 6250 bpi.
Recording filters:	Low cut 6Hz / 18db/octave.
	High cut 188Hz / 156db/octave.
Record length:	6 seconds.
Sample rate:	2.0 milliseconds.
Gain mode:	IFP.
Navigation:	Primary - MAXIRAN
	Secondary - TRBL 4000DL GPS
Source:	LITTON sleeve airgun.
Array volume:	2250 cubic inches.
Array pressure:	2000 p.s.i.
Gun depth:	6.0 metres.
Shotpoint interval:	26.66 metres.
Recording channels:	240.
Group interval:	13.33 metres.
Streamer depth:	8 - 11 metres.
Streamer length:	3200.0 metres.
Near offset:	190.0 metres.

3.0 LIST OF DATA PROCESSED.

LINE #	SP RANGE
OH91C - 601	2221 - 939
OH91C - 602	2409 - 939

4.0 COMPANY PERSONNEL.

CHIEF GEOPHYSICIST: Mark Stanley.
Twelve years experience in processing marine and land seismic data, the last eight years being on marine data from Australian waters. Areas worked on include Timor Sea, Gippsland Basin, Bonaparte Basin, Canning Basin, and most major exploration provinces of the Australian region. Specializes in problems associated with high velocity overburden and wavelet deconvolution / phase compensation procedures.

PROCESSING GEOPHYSICIST: Michael Hartley.
Four years of marine and land processing experience from most exploration provinces of the Australian region. Recently involved in the reprocessing of 2-D data from Otway Basin Permits VIC/P30 and VIC/P31 for BHP Petroleum.

GEOPHYSICIST: Raul Monzon.
Fourteen years experience in seismic data interpretation and marine data processing. Involved in interpretation and processing of data from China Sea, onshore Philippines, North Sea, Gulf of Mexico, and offshore Carnarvon Basin. Recently involved in the reprocessing of 2-D data from VIC/P30 VIC/P31 for BHP Petroleum.

5.0 PARAMETER TESTING.

The signal to noise ratio for the data acquired within the EPP 23 permit is extremely low. As a result the majority of the testing, and therefore processing sequence, was designed to improve this ratio. This high degree of noise is due to the acquisition parameters, with the survey being acquired in an area renowned for poor data quality. The permits were the basis for a study of acquisition parameters, undertaken by Cultus Resources Pty. Ltd. and published in the A.S.E.G. Conference Notes, Melbourne 1989. The report detailed the high levels of cable noise present when acquiring data in certain directions. The majority of data recorded in the OH91 survey was acquired in directions where the swell noise recorded on the cable was at a peak. This noise problem was dependent on both shooting direction and sea state, and as a result there was some variation in noise levels between two adjacent lines. Caution had to be observed in the pursuit of noise reduction so as to cause as little degradation of reflector energy as possible.

5.1 GAIN COMPENSATION.

Gain compensation is required to compensate for the effects of elastic and inelastic attenuation and spherical divergence. The initial gain trials were conducted on line OH91C - 601. Gains of 4, 6, 8, 10 and 12dB/second were applied to shot records with the results being analyzed by both gather plots and amplitude versus time profiles. A gain of 8dB/second to 4 seconds, with the last scalar value being held constant to 6 seconds, was found to achieve the most balanced distribution of amplitudes both in time and offset.

5.2 MULTICHANNEL FILTERING.

Using the gain test records from line OH91C-601, f-k analyses were performed. A shot gather was transformed into the f-k domain and a plot of the f-k spectral analysis was produced. From this analysis, various filters were designed and applied in an attempt to suppress unwanted linear noise identified within the f-k spectral analyses while minimalizing the effect on the data. Panels of data were stacked with the various filter designs. Four designs were tested and are outlined below:

	Design	Parameters
(i)	Fan reject	+6.0 +9.0 Dips(ms/trace) Cosine taper to 4.5 to 10.5 ms/trace
(ii)	Fan pass	+/-4.5 Dips(ms/trace) Cosine taper to +/-6.5 ms/trace
(iii)	Polygon pass	5% cosine taper proportional to frequency.

+ve K (cycles/km)	0.0	22.5	27.4	27.9	27.4	25.39	22.5	15.0	7.5	0.0
Frequency (Hz)	0.0	75.0	90.0	95.0	100.0	105.5	209.0	112.5	112.0	107.0
-ve K (cycles/km)	7.5	11.22	15.0	16.83	17.72	16.83	15.0	0.0		
Frequency (Hz)	99.5	94.0	85.0	77.5	70.0	60.0	50.0	0.0		

From the results, design (iii) was selected for production as the optimum design for suppressing linear noise while preserving data quality and character. All subsequent tests were performed with this f-k filter.

5.3 WAVELET DECONVOLUTION.

Source consistent wavelet estimation was performed on the test records using Taner's exponential decay approach to wavelet estimation. Instrument dephase based on an impulse response supplied by Western Geophysical Company for the LRS16A was applied before wavelet estimation.

Trials carried out on shot records included:

(i) Displays of wavelet power and amplitude spectra before and after deconvolution.
(ii) Trials on frequency limits used in shaping the output wavelet.

The following production parameters were chosen:

no. of analysis windows:	5 per trace
movedown:	300 ms
no. of offset regions:	1 per record
design window:	500 - 6000 ms (near trace) 2500 - 6000 ms (far trace)
output filter design:	minimum phase
output wavelet shaping:	5 - 80 Hz 18 - 36 dB/octave

The above design represents shaping the wavelet spectrum to a smoothed form with minimal amplitude gains by any one frequency band, therefore preventing noise from being increased.

5.4 DECONVOLUTION BEFORE STACK.

Deconvolution tests on the VIC/P30, VIC/P31 data set were used as a basis for selection of parameters on the EPP/SA-1 data set. The parameters described below were tested on line OH91C-601 and found to be suitable for production purposes.

	Window 1	Window 2
Gap (ms)	32	64
Operator (ms)	240	240
Design window (ms): Near trace:	300 - 2300	2000 - 400
Design window (ms): Far trace:	2000 - 4000	2200 - 4500
Apply window (ms): Near trace	0 - 2000	2000 - 6000
Apply window (ms): Far trace	2000 - 6000	2200 - 6000
Overlap	20%	20%

5.5 PRE-STACK SCALING.

From examination of the gathers prior to stacking, it was decided that some form of pre-stack balance was required to produce a more even distribution of amplitudes. Several different length windows were tested, with an offset dependent sliding 2000ms AGC being selected.

5.6 MUTE.

The mutes, both inner and outer trace, were picked from NMO corrected CDP gathers of line OH91C-601 and then tested by use of stack panels. Refer to 6.10 for mute application times used in production.

5.7 NMO-DMO STACK.

Dip moveout (DMO) was applied to the data using a one step NMO-DMO stack process (which is usually abbreviated to simply DMO stack). Testing of DMO was confined to the determination of the maximum allowable dip values of energy as a function of time..

The maximum allowable dips to be passed by DMO were tested on line OH91C-601. The dips passed were chosen to best suppress any remaining dipping noise (coherent noise due to scattering anomalies) while preserving structural diffractions for migration purposes. Trials, which consisted of DMO stack panels and migrated stack panels, were as follows:

(i) DMO stack using 15 degree maximum dip operator from 0 to 6 seconds.
(ii) DMO stack using 30 degree maximum dip operator from 0 to 6 seconds.
(iii) DMO stack using 45 degree maximum dip operator from 0 to 6 seconds.
(iv) DMO stack using 60 degree maximum dip operator from 0 to 6 seconds.
(v) DMO stack using 75 degree maximum dip operator from 0 to 6 seconds.
(vi) DMO stack using 90 degree maximum dip operator from 0 to 6 seconds.

After evaluating the various dip/time values on the test panel, the following parameters were chosen for production:

Maximum Dip (degrees):	30	30	45	60	60
Time (milliseconds):	0	700	1100	1500	6000
Velocity gradient value:	97%				

5.8 MIGRATION.

Migration trials were conducted on line OH91C-601 using 80%, 85%, 90%, 95%, 100%, 105%, and 110% of smoothed stacking velocities. The maximum time dip was 10 milliseconds per trace.

After examination of the various tests, it was decided to migrate the data using the following time variant percentage reduction of stacking velocities:

Time (ms)	Percentage of stacking velocity (%)
0	100
2000	100
3000	95
5000	85
6000	85

5.9 FREQUENCY FILTERS.

Filter panels were generated from a section of the migrated data of line OH91C-601. The filter scans consisted of data filtered with the following passbands:

(i)	NO FILTERS	(xi)	40/50-60/70 HZ
(i)	3/5-15/20 HZ	(xii)	45/55-65/75 HZ
(iii)	5/10-20/25 HZ	(xiii)	50/60-70/85 HZ
(iv)	10/15-25/30 HZ	(xiv)	55/65-75/90 HZ
(v)	15/20-30/35 HZ	(xv)	55/70-80/95 HZ
(vi)	20/25-35/40 HZ	(xvi)	60/75-85/100 HZ
(vii)	25/30-40/45 HZ	(xvii)	65/80-90/105 HZ
(viii)	30/35-45/50 HZ	(xviii)	70/85-95/110 HZ
(ix)	35/40-50/60 HZ	(xix)	75/90-100/115 HZ
(x)	40/45-55/65 HZ		

The final filters chosen are detailed in Chapter 6.18 .

5.10 SCALING.

Scaling tests were conducted after the selection of the final filters using various combinations of time variant windows, and the following time variant scaling windows were chosen for the final displays:

Window	Length(ms)		Apply Time	Movedown	Application
	Start	End	(ms)	(ms)	(%)
First	2500	0	6000	250	30
Second	200	0	1000	100	70
	500	1000	2500	250	70
	1500	2500	6000	750	70

6.0 PROCESSING SEQUENCE.

6.1 TRANSCRIPTION.

The data was recorded in SEGD format and reformatted by Tensor Pacific into their own internal processing format. It was then processed through all stages in Tensor Pacific's internal format until the generation of archive tapes, which were written in 32-bit, IBM floating point, SEGY format.

6.2 RESAMPLE.

The survey data was recorded at a 2.0 millisecond sample interval. After frequency analysis the data was resampled to a 4.0 millisecond sample interval with an anti-alias filter comprising a low-pass filter with the roll-off starting at two-thirds Nyquist and ending at the Nyquist frequency.

6.3 GAIN RECOVERY.

An exponential gain of 8dB per second from 0.0 seconds to 4.0 seconds, the last scalar being held constant from 4.0 to 6.0 seconds, was applied to the data.

6.4 F-K FILTER.

Direct arrival energy was attenuated by applying velocity filtering in the FK domain to source records. The filter applied to the data was a polygon pass design. The taper used was a cosine ramp of 5%. Filter points are outlined in Section 5.2, Design number (iii).

6.5 TRACE SUMMATION.

Two to one trace summation after differential NMO was applied to source records in order to reduce the data volume for subsequent processing. The 240 channel input data entering this phase was reduced to 120 channels on output.

6.6 INSTRUMENT DEPHASE.

The phase distortion of the data due to the recording instruments was removed by performing instrument dephase. The LRS16A instrument response, supplied by Western Geophysical Company, was applied to the data with the resultant output being converted to minimum phase.

6.7 WAVELET DECONVOLUTION.

Surface consistent wavelet estimation was carried out on an offset dependent basis for each shot gather. The method used for wavelet estimation was Taner's exponential decay approach. The analysis windows for each source gather started at 500 milliseconds on the near trace and 2500 milliseconds on the far trace. Each trace had 5 analysis windows with a 300 millisecond movedown to the start of the next analysis window.

The output filter design from the estimated wavelet for each gather was a minimum phase waveletshaping filter, shaping the amplitude spectrum to 5-80Hz and 18-36dB/octave.

6.8 PREDICTIVE DECONVOLUTION.

Dual window predictive deconvolution was applied using 240 and 240 millisecond operators with 32 and 64 millisecond predictive gaps for dereverberation purposes. The analysis and application windows were as follows:

	Near trace	Far trace
Design windows(ms)	300-2300,2000-4000	2000-3500,2200-4500
Application windows(ms)	0-2000,2000-6000	0-2200,2200-6000

6.9 TRACE BALANCE.

Traces were balanced using an offset dependent sliding 2000ms AGC to ensure a more even distribution of amplitudes in both offset and time..

6.10 INNER TRACE MUTE

The following inner trace mute was applied to the data prior to stacking:

Offset(m)	Application Time (ms)
196	1200
810	2000
836	6000

6.11 OUTER TRACE MUTE

An outer trace mute was applied usin offset - time pairs within the 'DMOSTAK' module. Values for all mute parameters are listed below:

Offset(m)	Application Time (ms)
335	200
600	500
3400	2600

6.12 VELOCITY ANALYSIS.

A single pass of velocities were run at 1 kilometre intervals. The analyses comprised 9 full NMO-DMO stacks over 15 adjacent cdps, and coherency picks over 7 adjacent cdps.

6.13 NMO-DMO STACK.

Normal moveout, dip moveout and stacking were all performed in the 'DMOSTAK' module. The specified maximum dips imaged by dmo are as follows:

Dip(degree)	Application Time (ms)
30	0
30	700
45	1100
60	1500
60	6000

6.14 BULK STATIC CORRECTION.

A bulk static correction of 11.0 milliseconds (cable depth 11 metres) was applied to the post-stack data to correct for gun and cable depths.

6.15 PHASE CONVERSION.

All modules to this stage of the processing sequence that affect the phase of the wavelet, such as instrument dephase, signature and gapped deconvolution, have been output as minimum phase. As the desired output is a zero phase wavelet, a phase operator was designed to correct the average amplitude spectrum of the data from minimum to zero phase.

6.16 WAVE EQUATION MIGRATION.

Migration was performed using a finite difference algorithm with a maximum time dip of 10ms/trace. A time variant adjustment to the stacking velocities was performed for migration as follows:

Time(ms)	Velocity(%)
0	100
2000	100
3000	95
5000	85
6000	85

6.17 BANDPASS FILTER.

The following frequency filters were applied to the data using a 20 per cent overlap between defined windows and tapering at the start of the first window and the end of the last window to avoid edge effects. Filters used are listed below:

Time(ms)	Frequency Limits(Hz)
0	10,15 - 80,90
600	10,12 - 80, 90
1200	8, 12 - 75,85
1700	8, 12 - 75, 85
2300	8, 12- 65, 75
3000	5, 10 - 55, 65
5000	5, 8 - 45, 55
dB Down	40, 0 - 0, 40

6.18 SCALING.

A dual window AGC was applied to the data, with the second window length being time varient. The windows were as follows:

Window	Length(ms)		Apply Time(ms)	Movedown(ms)	Application(%)
	Start	End			
First	2500	0	6000	250	30
Second	200	0	1000	100	70
	500	1000	2500	250	70
	1500	2500	6000	750	70

6.19 FILM DISPLAY.

The final filtered stacked and migrated sections were displayed with wiggle trace variable area and filmed using the following display parameters:

Horizontal Scale:	1:25000 (18.75 traces/cm)
Vertical Scale:	10 cm/sec
Gain:	1.4
Bias:	0.0
Shotpoints:	Annotated to gun position.
Polarity:	Negative numbers on tape displayed as a trough. (SEG Standard - Field polarity maintained for processing and display)

7.0 ARCHIVE TAPES.

Archive tapes were supplied for unscaled, unfiltered final stacks and unscaled, filtered migrated stacks on 2400 ft., 6250 BPI magnetic tapes. Recording format for all concatenation was SEGY. The following is noted:

(1) Key is located in byte 179-180 of tape header.
(2) Shotpoints are annotated at the gun position.
(3) The first sample on the tape is time zero.

RAW STACK

TAPE NUMBER - **RSKAR8**

LINE #	SP RANGE	CDP RANGE	KEY
OH91C-601	2221 - 939	1 - 2684	1
OH91C-602	2409 - 939	1 - 3060	2

FILTERED MIGRATION (NO SCALING)

TAPE NUMBER - **FMGR11**

LINE #	SP RANGE	CDP RANGE	KEY
OH91C-601	2221 - 939	1 - 2684	1
OH91C-602	2409 - 939	1 - 3060	2

8.0 SOFTWARE DESCRIPTION.

8.1 RDSEGD.

This program reads demultiplexed SEGD format data and reformats it into Tensor Pacific's internal processing format.

8.2 RESAMPLE.

Program RESAMPLE allows specification to a new sample rate. If the new sample rate is less than the input, the data is transformed into the frequency domain and an appropriate number of complex zeros are added before the data is inverse transformed.

8.3 STSHIFT.

STSHIFT retrieves values from the appropriate trace header locations and shifts the trace by that amount. STSHIFT also applies bulk static shifts as specified in a program run.

8.4 DBGAIN.

DBGAIN applies gain in the form of dB per second. It was used to compensate for spherical divergence and inelastic attenuation. True spherical divergence compensation is a non-linear process and is not appropriate for the designature methods using exponential decay to extract mixed phase wavelets.

8.5 PWAVEST.

Program PWAVEST is designed to extract the source wavelet from a given gather. The procedure is based on the assumption that a trace consists of the convolution of a white reflectivity series and a source wavelet. The source wavelet does not have to be minimum phase because PWAVEST can convert a mixed phase wavelet to minimum phase by applying an exponential decay function to it. Hence estimated source wavelets are obtained by averaging the autocorrelation of exponentially decayed data from several windows over several traces. The exponential decay factors are then removed to obtain the estimated mixed phase source wavelet.

8.6 PSHAPER.

Program PSHAPER designs an operator to correct a given wavelet to a more desireable wavelet shape. The output amplitude may be either unchanged or a pecified Butterworth bandpass. The phase spectrum may be unchanged or output as zero or minimum phase. The operator is then applied to the data. It is used for dephasing, signature deconvolution, and post-stack phase shaping.

8.7 FILTTWD.

This program performs two dimensional filtering. FILTTWD transforms data into F-K space, performs selected filtering options, then transforms the data back into X-T space. Filtering options may be specified as dips (ms/trace) or free form polygons. Tapering may be linear or cosine and the taper may be the same for all frequency or proportional to the frequency.

8.8 RAGC/RAGD

The program, RAGC, calculates and applies AGC in the normal fashion but saves the calculated scalars to be used in the RAGCD module, which removes the effect of the scaling. The modules are used when transforming the data to another domain, such as f-k, for filtering and thus reduces the smearing effects of spikes which may occur in the data. Generally used surrounding the FILTTWD module.

8.9 DECON.

This program uses the Weiner-Levinson algorithm to design and apply predictive deconvolution operators to seismic data. DECON can design and apply filters on a trace by trace basis or over several traces using an averaged operator.

8.10 AGCTG

Program TGAGC computes and applies a data dependent, time variant gain function to individual seismic traces to balance trace amplitudes.

8.11 DMOCOLL.

This program collects traces into ensembles for input to DMO velocity analysis. The input data only requires proper shot and receiver information to be in the appropriate trace header locations.

8.12 DMOVEL.

This program creates velocity analyses comprising stack panels and velocity amplitude spectra. An integral NMO-DMO approach is used with an accurate NMO algorithm to stack individual field traces directly into their corresponding post-DMO bins.

8.13 DMOSTAK.

Program DMOSTAK is a one step NMO-DMO process which uses interpolated velocity information and sorts the data simply by stacking traces into all bins using a DMO operator. The program can take data from each recorded line on a 3-D survey and sort each individual sample to its correct location usin shot and receiver information.

8.14 CMIG.

CMIG performs 60 degree finite difference migration post-stack. The migration can be cascaded many times to image dips up to 90 degrees.

8.15 FILTER.

Program FILTER applies time variant lowpass, highpass, and bandpass filters to seismic data.

9.0 HARDWARE DESCRIPTION.

The hardware utilised for seismic data processing in our Melbourne centre includes:

a) 2 processor CRAY Y-MP/2/216 with a 6 nanosecond clock speed; 64 bit word; 666 megaflops potential; vector processing.
b) 16 megaword main memory.
c) 8 megaword buffer memory.
d) 8 IBM 3420 (1600/6250 bpi) magnetic tape drives.
e) 6 StorageTek magnetic cartridge drives.
f) 8 DD49 disk drives (1.2 gigabyte capacity; 9.6 gigabyte total capacity).
g) VAX 11/780 front-end to CRAY system.
h) 200 dpi Versatec 8236-F (36-inch) electrostatic plotter.
i) Use of Scitex laser plotter (argon laser) up to 100 dots/millimetre resolution.