South Australia Cooper Basin Joint Venture

Environmental Impact Report: Waterflood Pilot project

Santos

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1 Introduction

This chapter provides an overview of the Environmental Impact Report (EIR) for the waterflood pilot project proposed to be undertaken by the Santos Australia Cooper Basin Joint Venture (SACBJV) in Limestone Creek and association fields of the South Australian Cooper Basin.

This document fulfils the requirements of an EIR and has been prepared in accordance with current legislative requirements, in particular, with Section 97 of the South Australian *Petroleum Act* 2000 and Regulation 10 of the Petroleum Regulations 2000. Additionally, the Act and Regulations require the development and implementation of a Statement of Environmental Objectives (SEO). A draft SEO has been prepared in conjunction with this document.

This EIR covers only those issues that are specific to the waterflood pilot project. It does not cover environmental issues associated with drilling and well, production and processing or seismic operations as these are covered under existing arrangements including an interim *Drilling & Well Operations SEO* produced by PIRSA in August 2000, and 'Alternative Arrangements' relating to production and processing operations provided to Santos by PIRSA in following the enactment of the Petroleum Act. These interim measures are due to be reviewed by mid 2003.

Table 1-1: Environmental Impact Report Outline

Chapter	Title	Content
Chapter 1	Introduction	Introduces the purpose and format of this document.
Chapter 2	Background	Provides background history, includes resource and operations information and identifies the location of the proposed waterflood pilot project.
Chapter 3	Legislative Framework	Provides a brief description of the assessment process.
Chapter 4	Drilling and Well Operations	Describes the proposed waterflood pilot project in detail.
Chapter 5	Existing Environment	Describes the existing environment in the waterflood pilot project area.
Chapter 6	Consultation	Documents consultation process and strategies to date.
Chapter 7	Environmental Hazards and Consequences	Hazard identification, consequences and risk minimisation strategies.
Chapter 8	Environmental Risk Assessment and Management Strategies	Outlines risk assessment process and application.
Chapter 9	References	Lists reference material utilised in the preparation of this document.
Appendix A	Material Safety Data Sheets for the Waterflood Tracer	Contains information on the appropriate handling of the tracer material, toxicity, environmental fate and clean up actions.
Appendix B	Risk Assessment and Management Summaries	Contains risk assessment and management summaries for hazards identified in Chapter 8.

2 Background

This chapter introduces SACBJV participants in the waterflood pilot project, provides context for site location and outlines the operations to which this EIR will be applicable. SACBJV environmental management systems, including environmental objectives, key issues and policy framework are also discussed, in relation to the waterflood pilot project.

2.1 Santos Australia Cooper Basin Joint Venture (SACBJV)

SACBJV was founded in 1954 by a group of Adelaide businesspeople who believed that South Australia and the Northern Territory had oil and gas potential. This was eight years before any commercial quantities of hydrocarbons were found in Australia. The search proved to be a long and expensive one, but it was ultimately rewarded with the discovery of one of Australia's major petroleum provinces.

Since its first discoveries in the 1960s, and after the investment of billions of dollars, SACBJV has grown to become one of Australia's major energy providers. Currently SACBJV meets over one-third of the demand for domestic gas in Australia, as well as producing significant quantities of crude oil and petroleum liquids.

The Central Australia Business Unit (CBU) operates the Moomba processing plant and associated facilities on behalf of the 11 companies that comprise the Cooper Basin Joint Venture:

- Santos Limited
- Bridge Oil Developments Pty Ltd[1]
- Santos (BOL) Pty Ltd[1]
- Basin Oil NL
- Delhi Petroleum Pty Ltd
- Alliance Petroleum Australia Pty Ltd[1]
- Reef Oil Pty Ltd[1]
- Vamgas Pty Ltd[1]
- Origin Energy Resources Limited
- Novus Petroleum NL

2.2 Location

The waterflood pilot project will be undertaken in PL 36 Jena field located within the South Australian sector of the Cooper and Eromanga oil and gas producing basins, South Australia some 50km from the Moomba processing plant (refer Figure 2-1). The waterflood pilot project is located in the Strzelecki Desert, approximately 9 km from the Limestone Creek Oil Satellite.

[1] A wholly owned Santos Ltd subsidiary.

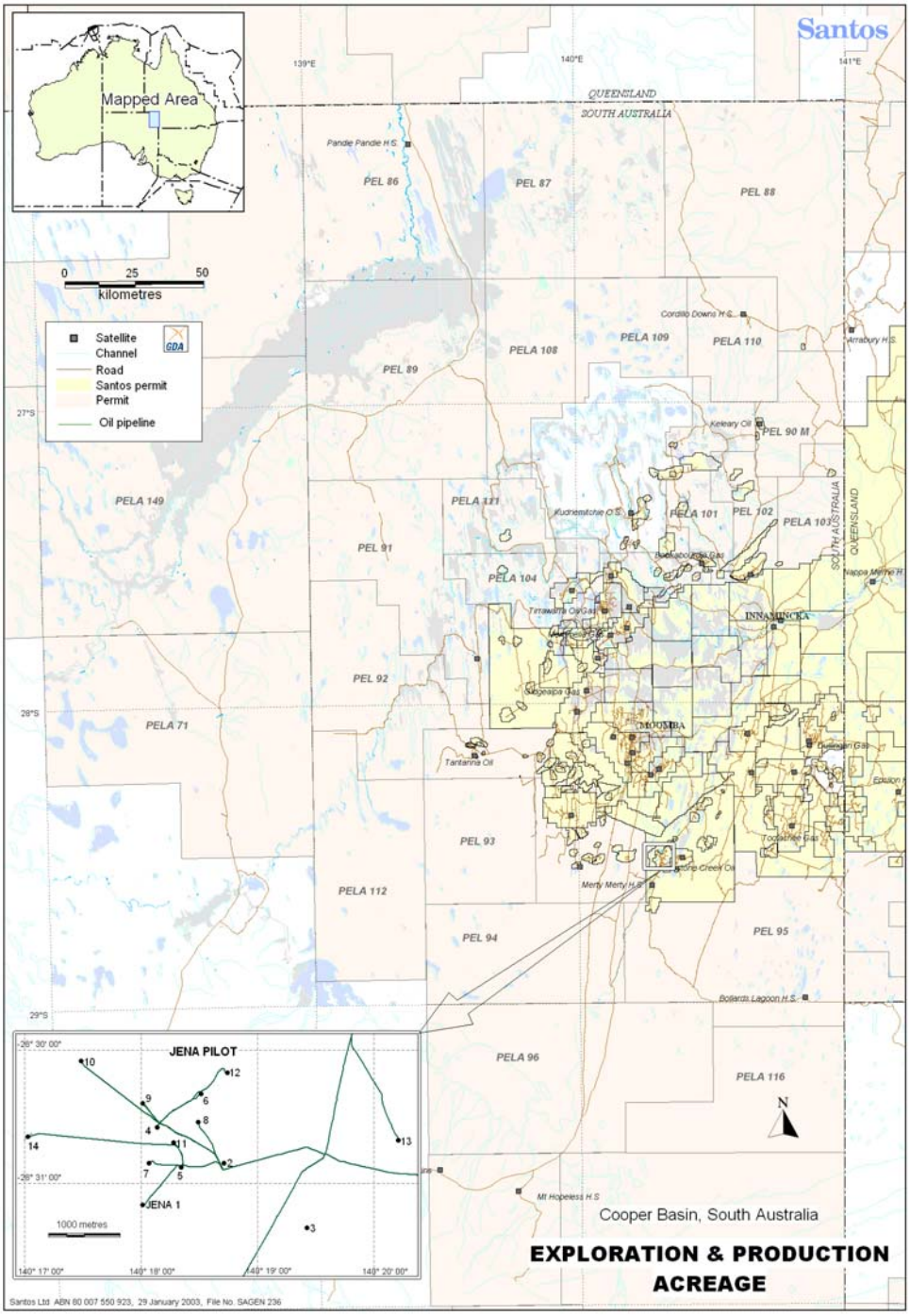


Figure 2-1: Exploration Permits in the Cooper and Eromanga Basins

2.3 Rationale for Waterflood Pilot Project

The waterflood pilot project is conducted to determine if the waterflood is effective in recovering incremental oil reserves. A tracer will be added to the injection water to trace where the injection water is moving in relation to the injection and producing wells. Ideally the water would move radially from the injection well but because of the varying reservoir porosities and permeability's there is no guarantee that the waterflood will behave that way. The pilot project will give the reservoir engineers a better idea of the reservoir characteristics and ultimately whether water flooding will increase the productivity of the Jena wells. A full description of the technical aspects of the waterflood pilot project are covered in Chapter 4.

2.4 Management Systems

Santos has developed the Santos Australian Environmental Management System (SAEMS) to provide the framework within which all aspects of the Company's environmental responsibilities are managed and specifies the minimum environmental requirements for the Company's Business Unit Environmental Management Systems. The key elements of SAEMS are described in The Santos Australian Environmental Management System and Corporate Requirements (Santos 2000b).

The CBU Management System aims to minimise business risk in its varied forms; including commercial, quality, safety, financial, and environmental and provides a framework to ensure that any process or activity is performed to requirements and continuous performance improvement is achieved. The SAEMS and the environmental component of the CBU Management System incorporate key elements of national and international environmental management standards. Principles of ecologically sustainable development provide a foundation for the systems. International Standards Organisation ISO 14001 Standard has been used as a guide in the ongoing development of SACBJV environmental management systems.

The Company's environmental management systems will continue to evolve in response to a number of internal and external factors and where required relevant procedures are developed for any new activities such as the proposed waterflood pilot project.

3 Legislative Framework

This chapter briefly describes the legislative framework that currently applies to petroleum licensing in South Australia.

This EIR has been compiled in accordance with the Petroleum Act 2000, Petroleum Regulations 2000 and in consultation with PIRSA.

3.1 Petroleum Act and Regulations 2000

The legislation governing onshore petroleum exploration and production in South Australia has recently been reviewed via an extensive process of industry and public stakeholder consultation that commenced in 1996 (Malavazos 2000). The review process led to the proclamation of the *Petroleum Act 2000* and *Petroleum Regulations 2000* on the 25 September 2000 (PIRSA 2001). The key objectives of the new legislation are:

- to protect the natural, cultural, heritage and social aspects of the environment from risks associated with activities governed by the Act;
- to provide for constructive consultation with stakeholders, including effective reporting of industry performance to other stakeholders; and
- to provide security of title for petroleum, geothermal energy, and other resources governed by the Act and pipeline licences.

The Act and Regulations are objective based rather than prescriptive (McDonough 2000). An objective based regulatory approach principally seeks to ensure that industry effectively manages its activities by complying with performance standards that are cooperatively developed by the licensee, the regulatory authority and the community. This contrasts with prescriptive regulation where detailed management strategies for particular risks are stipulated in legislation.

Regulated resources as defined in Part 1 of the Act are:

- a naturally occurring underground accumulation of a regulated substance;
- a source of geothermal energy; or
- a natural reservoir.

A reference in the Act to petroleum or another regulated substance extends to a mixture of substances of which petroleum or the other relevant substance is a constituent part. Regulated substances as defined in Part 1 of the Act are:

- petroleum;
- hydrogen sulphide;
- nitrogen;
- helium;
- carbon dioxide; or

- any substance declared by regulation to be a substance to which the Act applies.

Regulated activities as defined in Section 10 of the Act are:

- exploration for petroleum or another regulated resource;
- operations to establish the nature and extent of a discovery of petroleum or another regulated resource, and to establish the commercial feasibility of production and the appropriate production techniques;
- production of petroleum or another regulated substance;
- utilisation of a natural reservoir to store petroleum or another regulated substance;
- production of geothermal energy;
- construction of a transmission pipeline for carrying petroleum or another regulated substance; or
- operation of a transmission pipeline for carrying petroleum or another regulated substance.

As a requirement of Part 12 of the Act a regulated activity can only be conducted if an approved SEO has been developed. The SEO outlines the environmental objectives that the regulated activity is required to achieve and the criteria upon which the objectives are to be assessed. The SEO is developed on the basis of information provided in an EIR. The EIR is provided by the licensee and contains an assessment of the potential impacts of an activity on the environment.

PIRSA have published generic SEO's for the following regulated activities:

- Pipeline Preliminary Survey Activities in South Australia, 2001.
- Drilling and Well Operations in the Cooper/Eromanga Basin – South Australia, 2000 (interim document pending this EIR).
- Seismic Operations in the Cooper and Eromanga Basins South Australia, 1998.

3.2 Legislative Requirements

As a requirement of the recently enacted Petroleum Act 2000 and Petroleum Regulations 2000, the Cooper Basin operators are required to submit an EIR and draft SEO for the waterflood pilot project as it constitutes a new activity that is not covered under any existing approvals. This EIR has been prepared in accordance with Section 97 and Regulation 10 of the Act and Regulations respectively. This document relates only to the operations that are specific to the waterflood pilot project.

Operations that are specifically covered by this EIR include:

- injection of produced formation water for enhanced oil recovery in offset wells;

- storage, handling and use of a radioactive tracer to track movement of injected fluids through geological formations.

The following section outlines the specific requirements of the EIR as outlined within the Act and Regulations.

3.3 Environmental Impact Report

In accordance with Section 97 of the *Petroleum Act 2000*, the SACB Operators EIR must:

- take into account cultural, amenity and other values of Aboriginal and other Australians in so far as those values are relevant to the assessment;
- take into account risks inherent in the regulated activities to the health and safety of the public; and
- contain sufficient information to make possible an informed assessment of the likely impact of the activities on the environment.

As per Regulation 10 of the *Petroleum Regulations 2000* the EIR must include:

- a description of the regulated activities to be carried out under the licence (including their location).
- a description of the specific site features of the environment that can reasonably be expected to be affected by the activities, with particular reference to the physical and biological aspects of the environment and existing land uses.
- an assessment of the cultural values of Aboriginal and other Australians which could reasonably be foreseen to be affected by the activities in the area of the licence, and the public health and safety risks inherent in those activities (insofar as these matters are relevant in the particular circumstances).
- if required by the Minister - a prudential assessment of the security of natural gas supply.
- a description of the reasonably foreseeable events associated with the activity that could pose a threat to the relevant environment, including:
  - information on the following:
    - events during the construction stage (if any), the operational stage and the abandonment stage; and
    - events due to atypical circumstances (including human error, equipment failure or emissions, or discharges above normal operating levels).
  - information on the estimated frequency of these events; and
  - an explanation of the basis on which these events and frequencies have been predicted.
- an assessment of the potential consequences of these events on the environment, including:
  - information on the following:

  - the extent to which these consequences can be managed or addressed;
  - the action proposed to be taken to manage or address these consequences; and
  - the anticipated duration of these consequences.
- an explanation of the basis on which these consequences have been predicted;
- a list of all owners of the relevant land; and
- information on any consultation that has occurred with the owner of the relevant land, any Aboriginal groups or representatives, any agency or instrumentality of the Crown, or any other interested person or parties, including specific details about relevant issues that have been raised and any response to those issues, but not including confidential information.

3.4 Assessment and Approval

Once the EIR and draft SEO are submitted an assessment is made by PIRSA to determine whether the activities are to be classified as low, medium or high impact. This in turn determines the level of consultation required prior to final approval of the SEO.

'Low Impact' activities do not require public consultation, and an SEO may be approved after internal government approval.

'Medium Impact' activities, the EIR and proposed SEO are subject to a public consultation process, with comment sought for a period of at least 30 business days.

'High Impact' activities are required to undergo an environmental impact assessment under the provisions of the *Development Act 1993*.

The level of impact of a particular activity is assessed on the basis of the predictability and manageability of the impacts on the environment. Where the environmental impacts are predictable and readily managed, the impact of the activity is considered low. Where the environmental impacts are less predictable and are difficult to manage, the impact of the activity is potentially high.

Once the approval process is complete all documentation, including EIR and SEO, must be entered on an environmental register. This public register is available on the PIRSA internet so that community access is readily available (McDonough 2000).

4 Description of Operations

Santos is the designated operator for all activities conducted pursuant to the South Australian *Petroleum Act 2000* within the 160 Petroleum Production Licences (PPLs) held by the SACBJV within the South Australian sector of the Cooper Basin. PPL 36 is the only licence involved in which the proposed waterflood pilot project is to be undertaken.

This chapter provides a technical description of the proposed waterflood pilot project that is covered by this EIR and the accompanying SEO. It does not apply to activities relating to drill and well, production and processing, or seismic operations.

4.1 Water Injection (Waterflood)

Water flooding is a means of improving oil recovery by maintaining the pressure in the formation and improving the sweep efficiency. Maintaining the pressure is accomplished by injecting produced formation water back into the formation from which it was produced or injecting water from other produced wells that have compatible water quality into the target formation.

The waterflood pilot is comprised of the following activities:

1. Produced formation water (PFW) compatibility assessment.

2. Treatment and testing of PFW prior to use.

3. Reinjection (waterflood) of PFW into target formation.

Each of these activities is discussed in more detail below.

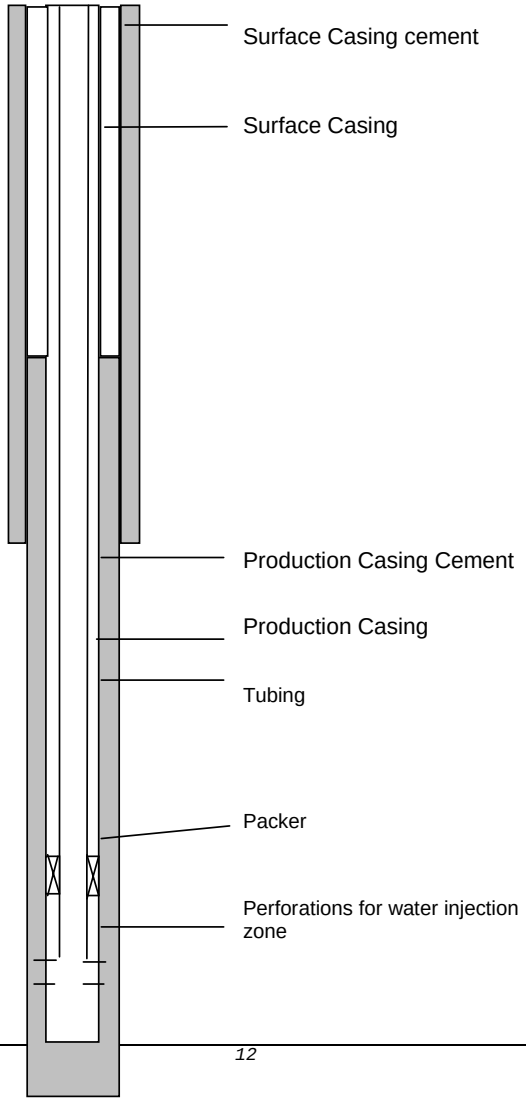
Prior to the water flood scheme being initiated the water is tested to meet certain requirements. The injected water must be clear, stable and be of similar quality to the water in the formation that it is to be injected into. It also must not be severely corrosive and must be free of materials that may plug the formation. In order to achieve this the PFW may be de-aerated, softened, filtered, chemically treated and/or stabilized.

Produced formation water is produced with the hydrocarbon production. The oil, gas and water are produced to a central facility where the total produced fluids are separated into gas, water, oil and sediment. The gas production flows into a compressor station or gas plant for further processing, the oil flows into tanks and is pumped to a refinery for further processing and the water is produced into tanks. Further separation to ensure that all the oil and sediment have been removed from the water prior to reinjecting into the formation is achieved using hydrocyclones. This is typically done with chemicals and/or heating.

Once the water has been separated it may be treated to kill any bacteria residing in the water or other chemicals may be added to eliminate the oxygen content or other components in the water that may cause corrosion of tubulars or incompatibility of the water injected formations. Finally, the water will then be filtered prior to being reinjected downhole.

The water is reinjected at pressures high enough to enter the formation injected into. This pressure required also takes into consideration the friction loss through the tubulars prior to entering the formation. Often the water injection pumping facility will have back up pumps in the event of one pump coming out of service for repair.

An injection well may be an existing well that was utilised previously for production and is converted to a water injection well or it may be specifically drilled for water injection. The injection wells may change over the course of the life of the field to ensure that the pool is swept in the most efficient manner. A typical water injection well is shown in Figure 4- 1.



PBTD

Figure 4-1: Typical Water Injection Well Diagram

The proposed water injection scheme will be a closed system comprised of an inverted 9 spot scheme which entails injecting water into one well surrounded by 8 producing wells (one less producer in this project). The water injection pump will inject approximately 250 m3/D of produced water. The pump is designed to discharge at 13800 kpa. Initially a tracer will be added to the injected water and monitored at the producing wells to determine if the water flood is sweeping the reservoir effectively and radially from the injection well. If the injection scheme is not effective in an inverted 9 spot then the pattern may be changed or the water injection may be halted.

4.2 Storage, Handling and Use of Tracer Material.

The injection well will have tracer injected into it to monitor the direction and effectiveness of the waterflood. Tracers are injected into the water injection well and special lab tests are conducted to pick up extremely low levels of the tritium tracer in the produced water.

The tritium tracer, which is effectively tritiated water (HTO), is a weak beta emitting isotope that has negligible external radiological effect. The radiotracer will be contained in a volume of less than 15 ml inside approved injection vessels therefore the internal radiological hazard from possible ingestion of tracer is negligible because it is in a sealed system. A beta emitting tracer (iodine 131) is added to the vessels to indicate when the tracer has moved through the vessels into the injection well.

The tritium tracer at the injection site and production site is not harmful to people or animals. The beta emitting tracer has a half life of 8 days and would also have negligible danger to humans and animals.

The tritium and iodine tracers are specifically used due to their low cost and safety. There is no MSDS for the tritium or the iodine. Chemically, from an MSDS point of view, Tritium is hydrogen, and I-131 is equal to Iodine.

5 Existing Environment

The site for the proposed waterflood pilot project is located within the dunefields of the Strzelecki desert. The region is generally described as arid with a uniform climate. This chapter provides a description of the environment (including landsystems, and geological and social environment) in the area of the proposed waterflood pilot project.

5.1 Landsystems

5.1.1 Floodplain

The Strzelecki Creek and associated floodplain branches off from the main channel of the Cooper Creek to the west of the township of Innamincka and flows south to Lake Blanche. The floodplain of the Strzelecki Creek is the main landsystem associated with the area of the proposed waterflood pilot project.

Geology, Soils and Landform

The Strzelecki floodplain consists of intricately braided channels, swamps and extensive outwash plains. Floodplain topography is relatively flat and consists of an extensive and extremely variable system of rivers and creeks (Blackley et al. 1996). In the area of the proposed waterflood pilot project the main channel of the Strzelecki Creek is well defined. Soils are characterised by deep, grey, self-mulching clays which are derived from fluvial mudstone and siltstone, and occasional fluvial sand and conglomerates in river and creek beds.

Geological units include undifferentiated fluvial and lacustrine sands of the Eurinilla Formation, clays and fine sands of the Tingana Clay, clays of the Milyera Formation, fluviatile sands of the Yandruwantha Sand (Mines and Energy 1994).

Hydrology

The flood plain area is comprised of ephemeral water courses and aside from general rainfall the area is generally dry.

The only time considerable flow is observed in the flood plain area is during flooding for which the flood frequency is approximately 1 in 10 years, based on the past forty years.

Flora

Woodland, often with a tall shrub layer, is characteristic of the major intermittent watercourses in the Cooper Basin, with Coolibah being the predominant woodland tree in the proposed waterflood pilot

project area. Shrubland of lignum, old man saltbush or Queensland bluebush may also extend into the coolibah woodlands, but tends to be characteristic of outer floodplains (Santos 1997b). Groundcover on floodplains has a high ephemeral component, with very rapid growth after flooding.

Fauna

Within the arid zone the most vital and important environmental areas are those connected with sites of permanent water. The Strzelecki Creek does not provide any such sites of permanent water in the vicinity of the area for the proposed waterflood pilot project. Generally watercourse habitat supports more mammal species than other habitat types in the basin. Thirty-five species of native mammal have been recorded from the floodplain areas of the greater north east region of South Australia. Notable species in South Australia include Forrest's mouse and the yellow-bellied sheath-tailed bat (Kemper 1990).

Birdlife along major watercourses is prolific and floodplains support a highly significant population of raptors. Breeding densities of raptors, calculated along Strzelecki Creek, are among the highest in the world. Especially significant is the occurrence of the grey falcon, black-breasted buzzard and letter winged kite. Aside from the terrespilot project avifauna, floodplain areas also support varied and abundant waterbird populations.

5.1.2 Dunefield

The dunefields of the Strzelecki Desert surround the floodplains of the Strzelecki Creek.

Geology, Soils and Landform

The development of the dunefields commenced approximately 18,000 years ago when a combination of low lake levels and extremely dry windy conditions created large, mobile dunes of lakebed and floodplain material (Twidale and Wopfner 1990). The process of dune development and migration continues today with sediment from river channels, floodplains and salt lakes being transported by the wind and shaped into dunes.

The Cooper Basin dunefields are characterised by parallel dunes of red, yellow or white aeolian sands of the Simpson Sand (Mines And Energy 1994), dominated by single crested linear sand ridges. Dunes are separated by flat interdune corridors (swales), which usually consist of claypans (Twidale and Wopfner 1990, Santos 1997b). Dunes range in height from 5m to 35m and trend approximately north east (Twidale and Wopfner 1990). Sand cover rarely exceeds 30m and a stony base is usually exposed in interdune areas.

Sand dunes have the potential to be affected by wind erosion as a result of disturbances brought about by production activities. In sandy desert areas the potential for wind erosion to effect soils disturbed by operations (particularly earthworks) poses a significant

environmental hazard. Red dunes are generally considered to be more susceptible to wind erosion than grey/brown sand dunes.

Water erosion is less likely on dunes as rainfall generally infiltrates rapidly into the sands before creating enough force to cause surface erosion. However where there is a fairly high proportion of clay in the sand, as for example at the base (or toe) of a dune, rilling and sheet erosion can occur (Santos 1997b).

Hydrology

The dunefields are extremely arid and lack any permanent surface water. Good quality groundwater can be found at shallow depths in dunefield areas adjacent to major watercourses such as the Strzelecki Creek. This water is non-artesian and contained within unconfined aquifers that are primarily recharged from surface stream flows.

Flora

Vegetation types alternate between the upper slopes and crests of dunes and interdune areas. Dune crests are often sparsely vegetated, depending on seasonal conditions, with tussock grassland species (eg. canegrass), needlebush, herbs and ephemeral forbs (Santos 1997b). Dune flanks are characterised by:

- lobed spinifex grassland;
- shrubland consisting of sandhill wattle; and
- shrubland species such as whitewood and narrow-leafed hopbush.

Vegetation in interdune areas depends largely on dune spacing. Narrowly spaced areas contain similar vegetation to dune flanks. Widely spaced dune areas, where gibber or floodplain soils are exposed, may contain low shrubland of saltbush or bluebush (Santos 1997b). In general interdune vegetation may consist of hummock grassland, chenopod shrubland, open shrubland or low open woodland.

Fauna

Despite the lack of free-water, dunefields provide important habitat for a range of wildlife including a variety of small mammals, reptiles and birds.

Thirteen species of mammals, including exotic species, have been recorded in the dunefields in the north east of South Australia. Common wildlife species include the fat-tailed dunnart, striped-faced dunnart, white-winged wren, white-backed swallow, Richards’s pipit; and the brown falcon. Common reptiles include geckos, skinks, dragons, blind snakes, elapid snakes and pythons (Tyler et al. 1990).

The dusky hopping-mouse is a nationally vulnerable species (EPBC Act) and occurs primarily in sand dunes along Strzelecki Creek in the vicinity of Lake Blanche (Morton et al. 1995). The entire known range of the eyrean grasswren is circumscribed by the limits of the Simpson, Tirari and Strzelecki Deserts. The species habitat requirements are tied to sandhill canegrass, which it uses for food, shelter and nesting (Reid et al. 1990).

5.2 Geology and Hydrogeology

A study into the reservoir characterisation of the Murta Reservoir in the Nappacoongee-Murteree Horst area by McAlpine Geosciences Ltd was completed in February 2002. The findings of this study relevant to the waterflood pilot project are provided in the following Section.

The Murta reservoir comprises lacustrine silty shales & sands, which are very thinly bedded to heterolithic. Typically the Murta comprises lake-floor deposits, exhibiting graded oscillation-ripple laminated sand beds and laminae with erosive bases. The sand content is sufficiently high in some intervals to suggest good sand to sand connectivity. A thin high permeability sand (HPS) occurs over most of the JALBU area as a broad belt, but with a maximum thickness of only two feet.

Consideration of all the above data suggests the Murta reservoir is a complex reservoir/waste-zone system in which the oil saturation strongly depends upon the height above the Free Water Level (FWL) and changes in reservoir quality, as illustrated in Figure 5.1.

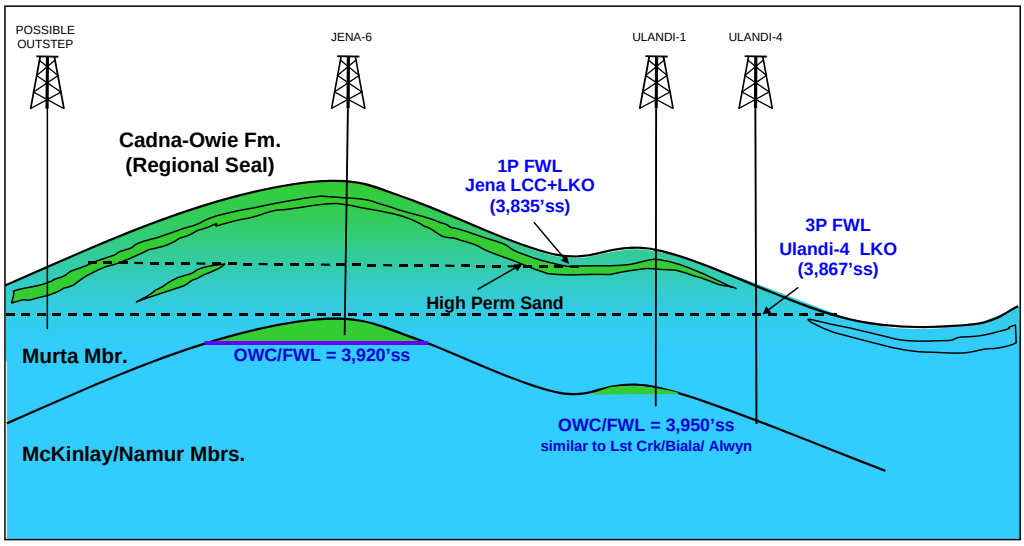


Figure 5-1: Current Model of Murta Hydrocarbon Accumulation Conditions

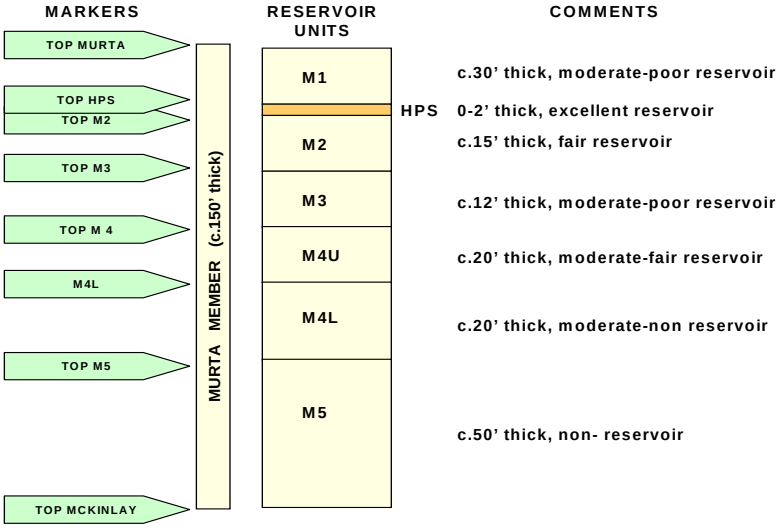
5.2.1 Reservoir Subdivision & Flow Units

The Murta Member was subdivided into reservoir units (M1 – M5) in all wells following the earlier scheme of Theologue (1995).

The M4 unit was found to comprise an interval of better reservoir in its upper part and poorer reservoir in its lower part. Further

subdivision of the M4 unit was therefore made into an upper (M4U) unit and a lower (M4L) unit.

The modified reservoir subdivision scheme used here is summarised below:



Correlation of the Murta is relatively straightforward. The background pattern in the Gamma-Ray log profile (excluding the low gamma-ray spikes caused by the siderite layers) and the resistivity logs proved most useful for correlation purposes.

Most markers coincide with extensive siderite layers. However, not all siderite layers are correlateable and cores and FMS logs commonly show evidence for the siderite layers being nodular and probably discontinuous. For this reason the siderite layers are considered less likely to act as severe vertical transmissibility barriers than suggested by Theologue (1995).

The High Permeability Sand layer (HPS), being mostly less than 2ft thick, is usually too thin be resolved on conventional wireline logs, despite some high-resolution logging passes having been made in some of the later wells. FMS logs were run in wells Jena-11 (where it resolved the HPS layer) and in Jena-12 (where it did not). In wells that fully cored (and fully recovered) the HPS layer – the HPS thickness could be precisely determined. In other wells, which had either incomplete core recovery or were not cored, the thickness of the HPS layer was estimated from careful examination of all available logs (particularly the MSFL, but including the calliper log, any available dipmeter curves, and the rate of penetration log). DST results were also reviewed to help confirm whether or not a high permeability interval was present.

5.3 Aquifer Use

Due to the dry climate of the region overlying the Great Artesian Basin in South Australia, groundwater is a particularly important resource. Land use is generally restricted to low intensity stock grazing (GABCC, 1998) and where accessible and of acceptable quality groundwater is used for both residential and stock watering purposes.

Due to the depth of the artesian aquifers in the centre of the basin the majority of pastoral water use from these aquifers in South Australia occurs along the southern and western margins of the basin where the majority of bores intersect artesian aquifers at less than 600m (GABCC, 1998). On the western margin these bores coincide approximately with the Oodnadatta track. There are also a number of flowing artesian bores used for stock watering along the Birdsville track. The use of artesian water in the central portions of the Cooper Basin is generally limited to converted petroleum wells due to the expense associated with drilling bores to the depth required to intersect the freshwater aquifers.

5.4 Cultural Heritage

A study was undertaken by Santos for the waterflood pilot project area to identify any potential cultural heritage sites. No sites were identified during the investigations.

It should also be note that there are numerous non-aboriginal heritage sites scattered throughout the region, many of which are listed on the National Heritage Register. However, there are no registered sites in the immediate vicinity of the proposed waterflood pilot project area.

5.5 Land use and Tenure

The primary land uses in the basin are pastoralism, oil and gas exploration and production, conservation and tourism (Marree Soil Conservation Board 1997). The location for the proposed waterflood pilot project is on Merty Merty Station which is managed for beef cattle production on native pasture. Merty Merty has obtained certification under the NASAA Organic Beef Export (OBE). The OBE guidelines identify the maximum levels of chemicals (including metals and hydrocarbons) allowable in soil, consistent with allowing organic certification for beef exports. The Strzelecki and Innamincka regional reserves are located to the north and west of the waterflood pilot project location.

The proposed waterflood pilot project area is in an area of relatively intense oil and gas production, with significant developments proposed in the near future. The proposed waterflood pilot project is a component of this future development which is associated with the Limestone Creek Oil Satellite.

6 Consultation

It is a requirement under the *Petroleum Regulations 2000* that consultation with relevant landowners, government departments or agencies, Aboriginal groups or representatives, or any other interested person or parties be undertaken. This ensures that key stakeholders are aware of and understand the relevant issues associated with the operations in question.

As this EIR is for the waterflood pilot project, and this is only a trial, the consultation was limited to key stakeholders including the landowners associated with project area and government agencies including DWLBC, EPA and the PIRSA. Comments on the draft EIR were addressed accordingly.

7 Environmental Hazards and Consequences

This chapter identifies and assesses potential environmental hazards and subsequent consequences specific to the proposed waterflood pilot project. Environmental hazards and potential consequences have been identified to allow for the assessment of environmental risks and management requirements (Chapter 8).

A **hazard** is considered to be any source of potential environmental harm, or a situation or event with potential to cause loss (AS/NZS 4360 1999). To identify hazards, the various activities associated with the waterflood pilot project (i.e. water injection, storage of radioactive tracer etc.) were considered and the events that could lead to a hazardous situation, and the possible consequences of these events, were identified.

As information with respect to the magnitude and/or frequency of activities associated with the waterflood pilot project are not known, environmental hazards and consequences have been identified on the basis of petroleum industry experience of project personnel. The environmental hazards that have potential to result in the most significant environmental consequences are considered, based on the information available, to be:

- packer failure;
- spills/leaks associated with the transportation of waters from the production facility to the water injection well;
- injection of contaminated water into target reservoir or aquifer zones; and
- spill of waterflood tracer material.

Key potential environmental consequences associated with the above hazards are:

- contamination of soil
- injury to or loss of stock; and
- potential for loss of organic beef certification.
- cross flow, aquifer contamination or reduction/change in pressure in aquifers;

The extent of the consequence is determined by the character of the receiving environment (i.e. geology, land system etc.) and the size and nature of the hazard (eg. casing failure etc.). Potential environmental hazards and consequences associated with the operations are discussed further in the following sections.

7.1 Water Injection (Waterflood)

In early 2003 a water injection scheme is proposed to enhance the recovery of hydrocarbons from the oil project producing from the Murta formation in the Jena producing area.

The proposed water injection scheme will be an inverted 9 spot scheme which entails injecting water into one well surrounded by 8 producing wells (one less in this project). The water injection pump will inject approximately 250 m3/D of produced water. The pump is designed to discharge at 13800 kpa.

The major hazards associated with water injection and disposal schemes are packer failure, surface equipment failure, injection of non-compatible waters into the aquifer and the potential for spills of saline waters and/or any chemical product that may be used for treating the water prior to injection. The amount added to the water is miniscule in comparison to the volume of aquifer that it will be in contact with.

Packer failures are unlikely but the well maintenance crew will test the well every two years for leaks of the packer or tubulars. If the packer fails there is no hazard to 3rd parties or to the reservoir because there are no perforations above the packer in the Jena 4 injection well. This is therefore not considered to be an environmental hazard.

Other downhole issues such as well casing and cementing failure will not be affected by injecting the water into the formation at 13,800kpa as the casing and cementation is designed to withstand pressures up to approximately 70,000 kpa.

Spills and leaks associated with surface operations are not considered as part of the waterflood trial hazard analysis as they have already been covered by Drilling & Well and Production & Processing EIR and SEO documents.

The injection water, to be transferred from Limestone Creek to the injection well (Jena 4), will be transferred through a newly installed polyethylene line made from Vinidex PE80M PN12.5 (SDR11) medium density polyethylene manufactured to AS/NZS 4130:2001 standards and rated at 1250 KPag at 20 DegC and rated to 800 KPag at 50 DegC, which is well within the project requirements.

The water injection skid located at Limestone Creek will be equipped with high-low shut downs and will be constantly monitored by telemetry. The injection well also has continuous pressure monitoring with telemetry.

Based on the produced formation water quality (see Appendix B), environmental factors such as evaporation and seepage (in the event of a spill) and current Santos management practices, a spill of produced formation water is not considered to pose an environmental hazard to the surrounding environment or stock. This is also supported by the construction standard of the pipeline and Santos emergency response procedures.

Quality and compatibility testing has been conducted on the injection water to ensure that there is no contamination of the aquifer being injected into. Compatibility testing results are included in Appendix B. The injection water will have a scale inhibitor and a biocide added to it to condition the water which will not contaminate the aquifer. Water quality testing will be conducted weekly initially and frequently depending on the changes noted to ensure consistency of injection water quality.

The reservoir has good reservoir containment which ensures that the injection water will stays within the Murta formation, as indicated previously in Section 5.2.

Radiotracers are injected into the water injection well under controlled procedures by the trained contractors, Tru-Tec Services personnel. They will ensure that all aspects of the waterflood radiotracer injection programme are suitably supervised to enable the work to be undertaken in accordance with the relevant legislation and shall take the steps to ensure all local rules relevant to the works are observed. The Tru-Tec Services personnel will be appropriately trained and licensed to handle the radioactive material in a controlled area during injection.

The produced water will be analysed using specialist laboratory testing to identify extremely low levels of the tracer in the produced water. The tracer is indicated to be a weak beta emitting isotope that will be contained in a volume of less than 15 mls. inside approved injection vessels. A beta emitting tracer (iodine 131) is added to the vessels to indicate when the tracer has moved through the vessels into the injection well. The tritium and iodine tracers are specifically used due to their low cost and safety.

The tracer is indicated to have a negligible external radiological effect and both tracers are not considered to be harmful to people or animals. Details for the handling and safety of the radiotracer are provided in Appendix A. The severity of the hazard based on the injection method being a well managed and sealed system is considered negligible, and the likelihood is considered unlikely.

Table 7-1: Summary of Hazards and Potential Consequences Associated with water injection (waterflood)

Hazard	Potential Consequence/s
Injection of contaminated water into the target or other aquifer zones	▪ Aquifer or reservoir contamination
Spill of waterflood tracer	▪ Localised contamination of soil.

8 Environmental Risk and Management Strategies

8.1 Risk Management and Assessment

There are a range of potential environmental risks inherent in waterflood operations. An environmental risk is the chance that an environmental consequence will occur as a result of a hazardous situation or event. Given appropriate management measures, most risks can be avoided or reduced to a level that is acceptable. However, in some cases there may still be 'residual' risks that are retained after management measures have been implemented.

Environmental risk assessment evaluates the level of environmental risk associated with various operations and activities and provides a framework for assessing risk management priorities and options based on the level of each assessed risk. The main components of the environmental risk assessment process are illustrated in Figure 8-1.

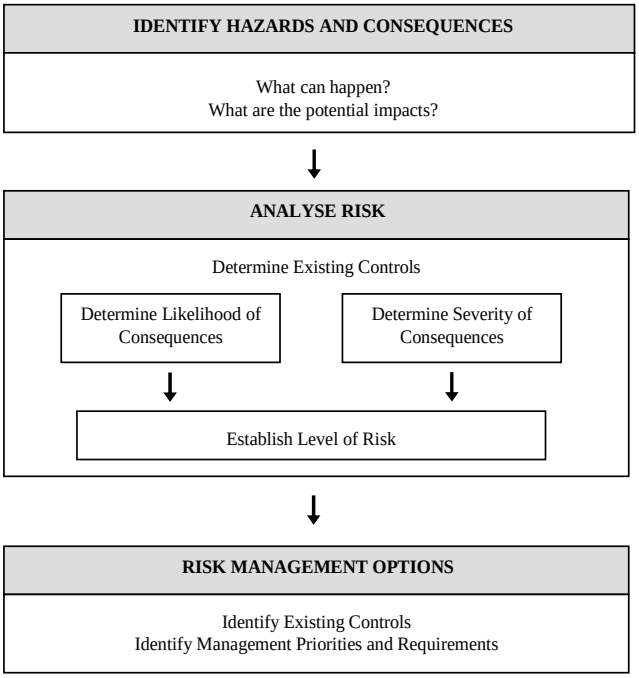


Figure 8-1: Framework for Environmental Risk Assessment

Risk assessment may be undertaken to various degrees of refinement depending upon the information and data available. Where possible, the frequency and severity of potential environmental consequences have been assessed on the basis of existing information. However, this information is not available with regard to all activities and associated consequences therefore a qualitative (i.e. descriptive) risk assessment process was considered to be the most appropriate method to adopt.

This approach uses descriptive scales to describe the likelihood of consequences (i.e. virtually certain to virtually impossible) and their severity (i.e. negligible to disastrous) and has been derived from Stoklosa (1999) and the Australian/New Zealand Standard (AS/NZS 4360:1999) for risk management.

Each phase of the risk assessment process is further discussed in the following sections.

The hazards and potential consequences assessed as being associated with the waterflood pilot are presented in Table 7-1.

In order to determine the level of risk associated with various hazards and potential consequences, both the likelihood and severity of hazards, and their associated consequences, have to be considered. Categories of likelihood and severity have been determined using subjective estimates of whether or not a particular event or outcome will occur. The Cooper Basin operation is an existing operation. Hence, environmental hazards and existing management measures are well understood and as such both likelihood and severity of consequences can be confidently predicted based on operating experience in the Cooper Basin and professional judgement as detailed in Appendix C.

Both the severity of consequences and their likelihood have been assessed in the context of proposed management practices.

Assessment of Severity

Environmental consequences can be categorised from negligible to disastrous, using the qualitative methodology described by Stoklosa (1999) (Table 8-1). These consequences are based upon definitions contained in AS/NZS 4360, but have been expanded to incorporate impacts to environmental values such as flora, fauna and biomass of biota.

Table 8-1: Severity of Consequences

Severity	Qualitative Description of Environmental Consequences
Negligible	Possible incidental impacts to flora and fauna in a locally affected land system but without ecological consequence. Possible incidental impacts to aquifers without ecological consequence in aquifers associated with the oil and gas formation.
Minor	Changes to the abundance or biomass of biota, and existing soil and/or water quality in the affected land system, but no changes to biodiversity or ecological function. Aquifers have a small amount of exposure from other sources of fluids, negligible volume movement in or out of formations or aquifers. No measurable change to aquifer water quality or pressure in local area.
Major	Changes to the abundance or biomass of biota, and existing soil and/or water quality in the affected land system, with local changes to biodiversity but no loss of ecological function. Detectable change to aquifer water quality and pressure in the local area.
Severe	Substantial changes to the abundance or biomass of biota, existing soil, and/or water quality and aquifers in the affected land system with significant change to biodiversity and change of ecological function. Eventual recovery of ecosystem possible, but not necessarily to the same pre-incident conditions. Substantial changes to aquifer water quality and pressure in the local area (i.e.: local drawdown adjacent to the oil and gas well or field).
Disastrous	Irreversible and irrecoverable changes to abundance/biomass and aquifers in the affected area. Loss of biodiversity on a regional scale. Loss of ecological functioning with little prospect of recovery to pre-incident conditions. Widespread effect of reduction in aquifer pressure (i.e.: reduced flow from bores in locations remote to operations. Contamination of aquifers remote to operations.

Assessment of Likelihood

The likelihood of occurrence of potential environmental cons

Consequences were qualitatively assessed and categorised according to the criteria outlined in Table 8-2.

Operation lifetime is relative to the well’s life expectancy. Companies are responsible for each well that they own indefinitely. For due diligence purposes the life of a well for this report will be 100 years.

Table 8-2: Likelihood of Consequences

Likelihood of Occurrence	Qualitative Description of Exposure
Virtually certain	Includes continuous emissions
Likely	Likely to occur during operation lifetime
Unlikely	Not likely during operation lifetime
Rare	Has occurred a few times worldwide
Virtually impossible	Has almost never occurred, but conceivably could

8.1.1 Environmental Risk Assessment

Severity and likelihood of consequences are combined to produce a level of risk for any given hazard. Table 8-3 shows an environmental risk assessment matrix that compares likelihood and severity of environmental consequences arising from the operations.

Table 8-3: Risk Matrix

			LIKELIHOOD OF CONSEQUENCE				
			1	**2**	**3**	**4**	**5**
			Virtually Impossible	**Rare**	**Unlikely**	**Likely**	**Virtually Certain**
SEVERITY OF CONSEQUENCE	**E**	**Negligible Effect**	LOW	LOW	LOW	LOW	LOW
	D	**Minor Effect**	LOW	LOW	MEDIUM	MEDIUM	MEDIUM
	C	**Major Effect**	MEDIUM	MEDIUM	MEDIUM	MEDIUM	**HIGH**
	B	**Severe Effect**	MEDIUM	MEDIUM	MEDIUM	**HIGH**	**HIGH**
	A	**Disastrous Effect**	MEDIUM	MEDIUM	**HIGH**	**HIGH**	**HIGH**

(Source: Stoklosa 1999)

The objective of the risk assessment process is to separate the minor acceptable risks from the major risks and to provide data to assist in the evaluation and management of risks.

A summary of the hazards and their associated risks is included in Table 8-4 below. Detailed risk assessment and management measures are outlined in Appendix C.

Table 8-4: Summary of Hazards and Risk Levels for Water Injection (Waterflood)

Hazard	**Severity**	**Likelihood**	**Risk**
Injection of Water into Artesian Reservoirs	Negligible	Unlikely	LOW
Spill of waterflood tracer	Negligible	Unlikely	LOW

8.2 Management of Environmental Risks

8.2.1 Management Systems

Management systems are a key tool in the management of SACBJV operations environmental responsibilities, issues and risks. Management systems provide a framework for the coordinated and consistent management of environmental issues by ensuring the:

- establishment of an Environmental Policy;
- identification of environmental risks and legal and other requirements relevant to drilling and well operations;
- setting of appropriate environmental objectives and targets;
- establishment of a structure and program to implement the Environmental Policy and achieve objectives and targets; and
- facilitation of planning, control monitoring, corrective action, auditing and review of activities to ensure that the requirements and aspirations of the Environmental Policy are achieved.

Standards for the SACBJV waterflood pilot project will follow world accepted good production practice and industry accepted standards:

8.2.2 Environmental Monitoring and Audits

Ongoing monitoring and auditing of injection well operations is necessary to determine whether significant environmental risks are being managed, minimised and where reasonably possible, eliminated. Monitoring programs should aim to assess:

- integrity of the well bore and packer tested once every two years;
- the injection well will have a baseline temperature log run and pressure will be monitored continuously by telemetry.
- The water quality will be tested weekly initially and then as required to ensure quality is maintained.
- The polyethylene pipeline from the production facility to the injection well will also have pressure monitoring to ensure competency.

8.2.3 Reporting

Internal and external reporting procedures are implemented by SACB operators to ensure that environmental issues and/or incidents are appropriately responded to. Internal reporting should cover:

- number, severity and close out status of incidents;
- monthly summaries of incidents;
- progress against key performance indicators;
- audit schedule and findings;
- works in progress;
- site and task force meetings; and

- external meetings and / or liaison with key stakeholders (i.e. PIRSA).

8.2.4 Continual Improvement

Continual improvement is driven by auditing and monitoring results. Management systems should be used to drive the process of continual improvement.

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Appendix A:

Material Data Safety Sheets for Waterflood Tracer, Biocide and Scale Inhibitor

OPERATING PROCEDURES AND RADIOLOGICAL SAFETY

ASSESSMENT FOR THE INJECTION OF WATERFLOOD RADIOTRACERS

INTO WELLS FOR SANTOS MOOMBA

C O N F I D E N T I A L

Author: **J. A. Rabe**

Date: **10 December 2002**

CONTENTS

INTRODUCTION

The technique of reservoir injection fluid flow monitoring using tracers has been applied in numerous fields throughout the world. Briefly this entails the introduction of a reservoir compatible species into injection water at the wellhead that is “foreign” to the system and monitoring for its presence at potential target producing wells throughout the field. Analysis of the resulting tracer concentration versus time curves from individual producing wells enables interwell flow characteristics to be determined so that improvements can be made to increase injection fluid sweep efficiency of the hydrocarbon reserve.

This document sets out the practical requirements for tracer use in order to establish injected water breakthrough and tracer concentration versus time information from water injection wells to associated target producers in the Field operated by Santos Limited.

All work will be undertaken in a responsible manner and will meet all relevant legislation and Codes of Practice.

PART 1 – ALLOCATION OF TRACER TYPES TO WELLS

The tracer tritium in the form of tritiated water (HTO) has been chosen based upon the ALARA principle of radiation safety (As Low As Reasonably Achievable) and unique identification of water breakthrough in producing wells from the specific injection location.

WELL REFERENCE	TRACER	QUANTIFY	REASON FOR ALLOCATION
Jena 4	Tritium was water	500 GBq	Radiological considerations; largest potential dilution; cheapest tracer

PART 2 - OPERATING PROCEDURES

2.1 Selection of Tracers – Radiological Safety

Use of weak beta emitting isotope tritium removes the external radiation hazard since it is a pure beta emitter with a maximum energy of 18.6KeV. Relatively thin walled steel injection vessels are sufficient For complete shielding. The external radiological hazard from these

isotopes can therefore be dismissed. The internal radiological hazard from possible ingestion of tracer must be eliminated by the use of a sealed system of tracer injection. This has the additional benefit that, under normal operating conditions potential spillage of tracer is eliminated.

When using tritium, it is essential to add a very small quantity of gamma emitting "marker". This allows tracer injection progress from an injection vessel into a wellhead to be monitored to ensure complete injection of tracer prior to uncoupling injection equipment. Tru-Tec Services Australasia usually use a short lived gamma emitting tracer generated in-house in the HIFAR Nuclear Reactor. The isotope that would be used in this instance would be a very small amount (< 200 KBq) of iodine-131 (t½ = 8 days) as potassium iodide.

2.2 Tracer Containment

The radiotracer will be contained in a volume of less than 15 mls inside approved injection vessels. In the case of beta emitting tracer use, a gamma marker will also be added to the vessels. The volume of solution will be diluted to 100mls using water, the injection vessel valves sealed and end caps added. The injection vessels will be transferred into a Type 'A' transport container for shipment to the Field. The tracers can be transported as a Yellow-II label shipment (ie, surface radiation dose

<50 µSv/hr). The injection vessels will be transported at atmospheric pressure.

2.3 Transport Operations

The tracer materials and equipment will be transported to Santos Moomba by Dangerous Goods Management (contact: Allen Moffatt, tel 02 - 9567 5633).

The radioactive tracer materials will be transferred to the Field radioactive source store upon arrival. If no store is available a shipping container shall be used as a temporary store. Warning notices shall be attached to all sides and the container locked. Tru-Tec Services Australasia shall check the temporary store at least once per day

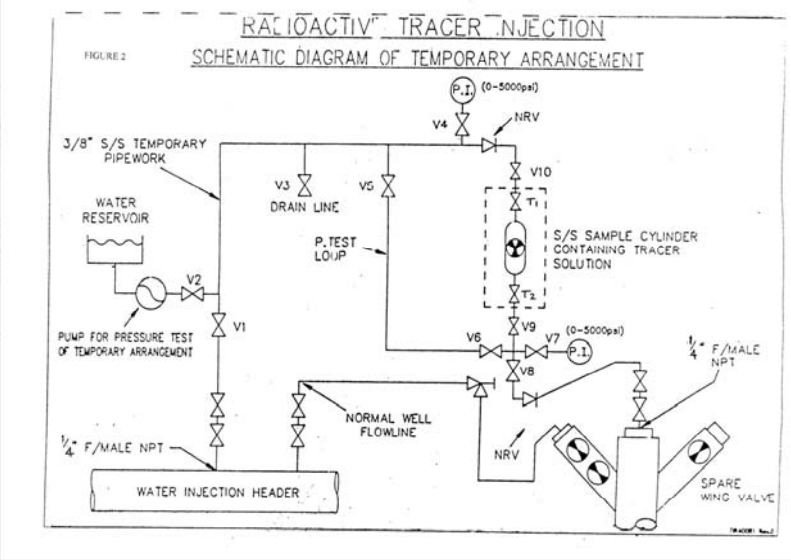
2.4 Waterflood Radiotracer Injection

2.4.1 Introduction

The tracer will be introduced into the wellhead using a sealed system of pressure injection. A temporary injection line will be established to ¼" NPT female connections on the tree cap and upstream injection system (see below). A

pressure differential will be achieved by reducing the aperture of a wing valve or choke allowing preferential fluid flow through the temporary injection unit. The pressure vessel containing the radioactive tracer will be connected into this circuit and remain isolated until satisfactory pressure testing of the system has been carried out.

The integrity of all joints up to the pressure vessel will then be tested off line. When it has been established that the system is leak tight, the pressure vessel will be opened to the injection flow and the contents of the vessel purged into the main injection line. This method has been satisfactorily tested in the field and minimises any potential for the uncontrolled release of radioactive material.



The injection time of the tracer is usually of the order of one minute. The pressure vessel containing the radiotracer material is currently certified to operate at pressures up to 5000 psi. The radiotracers used will be tritium, which cannot be readily detected external to the pressure vessel.

As indicated above, it is our normal practice to add a very small amount (< 200 KBq) of a short lived gamma emitting nuclide (Iodine-131 t½ = 8 days) to the material in the pressure vessel. The radioactivity emitted by this nuclide is readily detectable on the external surface of the vessel and injection pipelines using a sensitive radiation monitor, this technique will enable the passage of tracer to be monitored and facilitate in the decontamination procedure. The quantity of gamma radioactivity will be sufficient to provide a significant countrate using a sensitive radiation detector placed against the surface of the vessel.

Following radiotracer injection, Tru-Tec Services Australasia will conduct a complete radiation contamination survey of the injection area and tree. Results will be recorded and a

report given to the customer technical representative. Any radiation readings above those made during the background survey will constitute contamination and will be removed through water swabbing, collected and shipped back to the Lucas Heights laboratories.

2.5.1 2.4.2 Injection Procedure

a) Radiation readings (using a PCM 5 and PRI 90s) and swabs shall be taken to establish background levels at the following locations:-

- "X-mas tree" point of connection
- Floor area around "X-mas tree"
- Floor area where injection unit will be positioned.

b) The swab vials and a "Waterflood Radiotracer Monitoring" form will be marked with the location, well number, and Tru-Tec Services Reference Number (eg A, B, C, D etc). On the same form the radiation monitor readings will be recorded and the results of the survey reported to the customer technical representative.

c) The temporary injection system shall be installed as per the relevant attached schematic diagram shown in Part 3. Tru-tec Services will require ¼" Female NPT stainless steel connections to be fitted by Santos to the water injection system at the inlet and outlet points so that double isolation valves and hoses can be connected from the injection unit.

d) The well to be injected with tracer shall be confirmed by the Santos Technical representative to the Tru-Tec technologist. The technical representative and production supervisor must both check and confirm that the tracer injection systems are tied in to the correct injection well flowlines.

e) All valves in the system shall be checked to ensure that they are labelled as per schematic diagrams and are operative. The system shall be flushed through with water to remove any air. A 150% working pressure test shall be performed for 15 minutes (prior to hook up of the pressure vessel containing the tracer) using a Tangye pump or equivalent.

f) The area to be cordoned off during the injection shall be agreed with the production supervisor and technical representative in conjunction with Tru-Tec Services' representatives. All warning notices, barrier ropes, etc., shall be provided by Tru-Tec Services.

g) Radiation dosimeters shall be available for personnel associated with the injection programme. This shall be purely a precautionary measure since only Tru-Tec Services personnel shall be handling the container holding radioactivity.

h) Steps (a) – (g) must be performed to the satisfaction of the technical representative, production supervisor and the Tru-Tec Services Radiological Protection Supervisor.

i) Production ops/technical representative shall check that the water injection rate of the well is stable and rate noted on the Waterflood Radiotracer Injection Monitoring form. No further adjustments shall be made to water injection rates until all tracer has been injected.

j) Tru-Tec Services personnel shall open the 'A' type container and remove the pressure vessel containing the required tracer and a "Waterflood Radiotracer Injection – Radioisotope Well Allocation Certificate". Tru-Tec Services and Company personnel shall check the allocation of the radiotracer to the injection well by ticking the appropriate boxes and signing the form. This certificate shall be retained and included in the "end of job" report. Following confirmation of the tracer to be injected the pressure vessel shall be installed in the injection pipework as shown in schematic diagram in Part 3. The radiation count and dose rate on the side of the pressure vessel shall be noted on the "Waterflood Radiotracer Injection Monitoring" form.

k) Tru-Tec Services' technical representative shall conduct a 150% working pressure, 15 minute pressure test of the system to closed pressure vessel valves T2 and T3, with the Xmas tree connection point valves closed.

l) Once satisfactory pressure tests have been completed, excess pressure shall be bled down. The Xmas tree connection and up-stream tap-in point valves shall be opened. It shall be confirmed that there is free passage of injection water through the tracer injection unit into the well head.

m) Valve 5 shall be closed and main injection choke valve adjusted until a pressure differential is seen between the injection vessel pressure gauges of at least 400 p.s.i. The pressure differential shall be noted on the "Waterflood Radiotracer Injection Monitoring" form. Once this has been established, valve 5 shall be re-opened.

n) Tracer shall be injected into the well by closing valves V1, V5, V6 and opening valves V1, V10, T2, T3, V8. Valve V9 shall be slowly opened to control the rate of tracer injection. Radiation detectors shall be placed downstream of the injection point to monitor tracer flow.

o) The duration of the tracer injection should be over a period of approximately 60 seconds.

p) The starting time of this injection period shall be noted on the "Water flood Radiotracer Injection Monitoring".

q) The temporary system shall be flushed via the pressure vessel for a minimum of 120 minutes into the injection well by opening valve V9 fully. The Tru-Tec Services Supervisor shall check radiation levels throughout tracer injection and flushing stages.

r) When the pressure vessel and injection lines are considered completely flushed out, valves V10, T2, T3 and V9 shall be

closed and the pressure test loop flushed for 1 minute by opening valves V5 and V6. When complete, valves V1, V8 and spare wing valve shall be closed. The time of tracer flush shall be noted on the ”Waterflood Radiotracer Monitoring”.

s) The isolation valve shall be closed on the temporary connection to the wellhead.

t) Valve V1 shall be closed, the water injection supply to the temporary equipment and the water injection line isolated.

u) A 1 litre plastic container shall be placed at the drain point V3.

v) Valve V3 shall be opened slowly and pressure in the system allowed to drain down.

w) Valves V1, V5, V6, V8, V9 and V10 shall be opened.

x) When drainage is complete, valve V3 shall be closed.

y) The drain tube shall be swabbed and dried (retain).

z) Valves V1, V5, V6, V8, V9 and V10 shall be closed.

aa) Absorbent material shall be placed in the base tray of the injection equipment. The injection vessel shall be removed and end caps placed on the valves. The vessel can now be returned to the ‘A’ type container for shipment.

bb) Valves V9 and V10 end points shall be dried and swabbed (retain).

cc) The absorbent material shall be placed in the base tray and the tray dried.

dd) The flexible hose to the wellhead shall be disconnected at V8 and drained down into the polythene container. The flexible water injection supply hose shall be disconnected at valve V1.

ee) The flexible hose between the injection unit and injection point shall be placed in a polythene bag.

ff) Upon completion of the injection the work site shall be monitored as section (a). The safety officer shall be informed of the results of this survey by the Tru-Tec Services technologist. Once the area has been verified as contamination-free all warning signs and barriers rope/chain shall be removed and the well returned to normal production operations.

gg) On completing the injection of radioisotope tracer into the well, radiation levels on all equipment shall be monitored.

2.6 Produced Water Sampling

2.6.1 Produced Water Sampling – General

Once injected into the formation, the tracer will remain in the aqueous phase. Therefore, in order to monitor tracer progress, samples of produced water will be required to be

taken on a routine basis. The tracer will be produced over a protracted period in dilute form after undergoing substantial dispersion in the reservoir.

Sampling of produced water from wells shall be carried out on a monthly basis. Transport restrictions for radioactive materials will not apply to these samples (ie the concentration of tracer will be less than 74,000 Becquerels per litre of produced water). In the event that samples of produced water are identified as containing levels of tracer in excess of the above concentration, all subsequent samples of produced water will be transported as radioactive material until it has been demonstrated by analysis that such restrictions are no longer applicable.

Events which would lead to such concentrations of radiotracer arising in the produced water are in experience unprecedented but in the unlikely event of such an occurrence, appropriate instructions for the handling and despatch of such materials would be provided by Tru-Tec Services.

Produced Water Sample Point

Produced water samples are normally provided from the test separator following diversion of production fluid flow from the well under investigation. An alternative method of sampling may be possible at the wellhead with subsequent sample gravity separation in Santos' chemical laboratory.

Sample Volume Requirements

In order to determine levels of tritium as water to the lowest limits it will be necessary to provide at least 100ml samples of produced water. Samples should be shipped in sealed glass bottles, the water being covered by a layer of oil to prevent atmospheric contamination of the sample.

2.6.2 Analysis of Tracer

Use of ANSTO's radiochemical laboratories allows extremely low levels of radiotracer to be detected in produced water samples. This ensures that the lowest possible levels of radioactivity need only be added to the reservoir giving benefits both in terms of radiological safety and cost of radiotracer materials.

PART 3 – SAFETY

3.1 Legislation

There is a requirement to obtain permission in the form of licences to undertake waterflood radiotracer injection in oil fields within South Australia. In this instance, the licences will be obtained by Santos Ltd.

3.2 Radiological Supervision During Waterflood Tracer Injection

Tru-Tec Services shall ensure that all aspects of the waterflood radiotracer injection programme are suitably supervised to enable the work to be undertaken in accordance with the relevant State legislations and shall take steps to ensure all local rules relevant to the work are observed.

A team of two Tru-Tec Services personnel shall undertake the injection programme. This will ensure that if one of the team is incapacitated during tracer injection the other is able to make safe the radiation controlled area and supervise if radiological problems arise. The Tru-Tec Services personnel will be responsible for all matters relating to radiological safety, and all handling of radioactive material outside of the type 'A' containment will be done by Tru-Tec Services staff who will ensure that no radiation or contamination hazard arises or remains during or after the injection.

Both of the Tru-Tec Services personnel will be appropriately trained and licensed to handle radioactive material. An impervious coverall, double impervious gloves, a face-shield and half-face respirator shall be worn by the Tru-Tec operator whilst performing the injection, as a minimum supplement to standard PPE.

3.3 Controlled Area Allocation During Injection

It will be necessary to isolate (using barriers and notices) a small area of the injection site during handling of the tracers. This area will be established with due regard to the worst case accident scenario of total radiation release into the injection area and practical requirements of restricting access around the injection location. Access into this area will be kept to a minimum for non Tru-Tec Services personnel. Any entry into the area by Santos Ltd personnel will be logged and a dosimeter supplied by Tru-Tec Services, worn to record any exposure to ionising radiation.

If the injection area flooring is made up of grating then an area directly below the injection floor level will be segregated with barriers and notices and access restricted during injection. This will eliminate the chance of personnel contamination if leakage occurs during injection and fluids fall through the grating onto the lower floor area.

If a release of radioactive material occurs during injection then comprehensive monitoring around the injection area will be undertaken to determine surface and airborne contamination levels. A controlled area will be established using barrier tape and notices at any points with levels of radiotracer materials greater than 100Bq.m-3 in air or 100Bq.cm-2.

3.4 Radiological Incident Communication Procedures

In the event of an emergency situation arising involving use of the radiotracer materials in the waterflood tracing project the Tru-Tec Services technologist must take the following action:

If injury or immobilisation of personnel occurs then that person should be removed from a position of imminent radiological danger. All affected personnel shall be subjected to a contamination survey and treated as detailed in Tru-Tec's Operating & Emergency Procedures. Since the contamination will involve low levels of I-131 and higher levels of tritium, affected personnel will be drenched in a large excess of water.

An assessment should be made of the extent of the potential hazard.

The Santos Safety Officer will be alerted.

All measures should be taken to minimise immediate radiological hazards and the areas affected evacuated giving consideration to the probable dispersal pathways.

In a case where the situation cannot be promptly resolved, advice and assistance should be requested immediately from Tru-Tec's Base. The Tru-Tec technologist must report the incident to South Australian Radiation Health Department as soon as possible stating the nature of the occurrence and the manner of its resolution. He must determine names of all personnel involved and make an assessment of any likely dose they may have been exposed to.

In the event of any incidents arising that involve radioactive materials, then it will be the responsibility of Tru-Tec Services to make such notifications to Santos Ltd Safety Department.

3.5 Radiation Monitoring

Tru-Tec Services utilises several radiation detection devices capable of assessing all isotopes used in a waterflood tracer project. Monitors carried as part of the waterflood radiotracer injection equipment include alpha/beta/gamma contamination monitors (PCM5’s) and radiation dose monitors (PRI90s).

A thorough background survey will be undertaken prior to equipment set up at the radiotracer injection point to establish if any naturally occurring levels of radiation are present, using both types of monitor.

Monitoring during and after injection will be carried out using the PCM5 contamination monitor to assess tracer flow and possible contamination or leakage into the atmosphere during the flush period. All readings taken will be recorded and a copy given to the technical and safety contacts.

3.6 Environmental Impact Assessment

1. Doses received by members of the public due to the presence of radiotracer in produced water during normal operations.

Personnel not directly involved with the injection will be kept away from the control area. They would not approach closer than 3m to the injection vessel. During normal operations there will be no leakage of tritium and no dose exposure from this source.

The gamma exposure from I-131 would be very small, and can be calculated from the specific gamma dose rate, the value of which is 4.14 x 10-8 Sv/h at 1 m

Since the maximum activity is 200 KBq the dose rate at 1m is 0.008 and 0.001 Sv/hr at 3 m. Since the injection will be of the order of 1 min, the dose rate would entirely negligible.

2. Doses received by members of the public following an instantaneous catastrophic release of radiotracer, possibly during injection.

During a catastrophic release situation, the tritium from the 300 mL sample cylinder would be released through a faulty valve or joint under pressure. The tritium would certainly be released as an aerosol. Exposure would be by inhalation. Since protective clothing would be worn during injection, exposure through the skin would be negligible.

Assuming that the 200 GBq of tritium is associated with 300 mL water, the specific activity is 0.66 GBq/mL water. Assume that the air is saturated at 25^0 C, the weight of water in 1 cubic metre (1000L) is 23 g. Assuming 100 L equivalent of air is inhaled with a dilution of 1 pert in 100 accompaning the release process and the transport between the leaking component and the member of the public. Under these circumstances, the volume of water would be [(100L x 0.01/1000L) x 23.1g] ie 0.023g. This would be equivalent to 0.023 g x 0.66 GBq/mL ie 0.015 GBq. Inhalation of 0.15 GBq tritium would result in a dose of **270 μSv,** since the dose conversion factor for tritium is 1.8 x 10^{-11} Sv/Bq.

In the above calculation, it was assumed 0.15 GBq tririum or 0.075 per cent of the inventory was inhaled. If the I-131 were transferred with the water, the amount inhaled would be 0.075% of 200 KBq (the inventory) ie 150 Bq. This is equivalent to **3 μSv**, since the dose conversion factor for I-131 inhalation is 2 x 10^{-8} Sv/Bq.

Hence the total absorbed dose under these catastrophic conditions is 270 + 3 ie **273 μSv.**

Catastrophic Release (Item 2)

Radionuclide pathways to radiation workers during a catastrophic release would be similar to those of non radiation workers. The major difference would be that the radiation workers would be within, say, 1 m of the leaking valve or joint, rather than 3m. Since the principal pathway is inhalation, the concentration of radionuclide and therefore the dose will fall off as the cube of the distance (ie a factor of 27) from the leakage point.

The dose to the most exposed radiation worker would be say 27 x 273 Sv ie 7.4 mSv. This would need to be compared to the ICRP60 recommended dose of 20 mSv/y for radiation workers. A detailed dose assessment would need to be made and the appropriate authorities notified.

MSDS for the Biocide

1 MATERIAL SAFETY DATA SHEET

Hazardous according to criteria of Worksafe Australia

Company Information

Company Name:	*Champion Technologies Pty Ltd*	
Address:	*Suite 1, 5 Brodie-Hall Drive*	*3130 FM 521*
	Bentley W.A. 6102	*Fresno, Texas, USA, 77545*
Telephone:	*(08) 9472 9400*	*+1 (281) 431 2561*
Facsimile*:*	*(08) 9472 9422*	*+1 (281) 431 1655*
ACN:	*008 079 614*	

After Hours Emergency Response Phone (Free Call) : 1 800 350 121

1.0. Product Identification

1.1. Trade Name

Bactron AUK-550

1.2. OTHER NAMES

Biocide, Tetrakishydroxymethyl Phosphonium Sulphate (THPS)

1.3. UN NUMBER, DANGEROUS GOODS AND HAZARD CLASSIFICATIONS

UN Number:	Not Listed	**Poison Schedule:**	None Assigned
Dangerous Goods Class:	None Assigned	**HAZCHEM:**	None Assigned
Packaging Group:	None Assigned	**Subclass:**	None Assigned
Label:	Bactron AUK-550	**EPG:**	None Assigned
Use:	Applied to petroleum liquid, gas or brine to prevent bacterial corrosion.		

1.4. PHYSICAL PROPERTIES AND DESCRIPTION

Appearance:	Clear, colourless to pale yellowish liquid.		
Boiling Point:	~100 ^{0}C	**Lower Explosive Limit (%):**	Not determined
Melting point:	N/A	**Upper Explosive Limit (%):**	Not determined
Vapour pressure (mmHg @ 20 ^{0}C):	Not determined	**Water Solubility:**	Soluble in all proportions
Flash point (PMCC)	None	**Specific Gravity (water = 1):**	1.33-1.38

1.5. OTHER PROPERTIES

pH:	5.5 – 7.0	**Bulk Density:**	1330-1380 kg/m3
Decomposition Temperature:	>160 °C	**Molecular Weight:**	Not determined

1.6. INGREDIENTS

Chemical Entities	**CAS No.**	**Proportion**
Tetrakishydroxymethyl Phosphonium Sulphate (THPS)	55566-30-8	> 60 %
Water	7732-18-5	balance

2.0. Health Hazard Information

2.1. ACUTE HEALTH EFFECTS

Swallowed

May irritate the mouth, nose and gastro-intestinal tract. Ingestion of large quantities may result in nausea and vomiting.

Eye

May cause severe eye irritation. If not washed out promptly, will injure the eye tissue, and possibly cause permanent damage.

Skin

May cause an allergic hypersensitivity reaction on skin contact.

Inhaled

May cause significant irritation of the nose and upper respiratory tract. Continued exposure may induce other systemic effects.

2.2. CHRONIC HEALTH EFFECTS

Repeated or prolonged skin contact may lead to skin sensitisation.

2.3. FIRST AID

Swallowed

Wash out mouth with water. Give water to drink to dilute. DO NOT induce vomiting. Seek medical attention.

Eye

Hold eye(s) open and flood with water immediately for at least 15 minutes. Seek medical treatment.

Skin

Wash thoroughly with soap and plenty of water. Remove contaminated clothing and launder thoroughly before re-wearing. Seek medical advice if skin appears irritated.

Inhaled

Remove to fresh air. If breathing is difficult, oxygen may be given by qualified personnel. If breathing stops, give artificial respiration. Seek medical advice.

2.4. FIRST AID FACILITIES

An eye wash station and a safety shower are recommended when handling this product.

2.5. ADVICE TO DOCTOR

Treat symptomatically. If poisoning occurs, contact Poisons Information Centre.

2.6. TOXICITY AND IRRITATION DATA

For 100% THPS - Oral LD50 (rat) = 575 mg/Kg

Dermal LD50 (rat) = > 2000 mg/Kg

Acute inhalation LC50 – 4 hour (rat) = 5.55 mg/l

3.0. Precautions for Use

3.1. EXPOSURE STANDARDS

Name	TWA (ppm)	TWA (mg/m^3)	STEL (ppm)	STEL (mg/m^3)
THPS	-	3 (rec)	-	-

Exposure standard means the average concentration of a particular substance in the worker's breathing zone, exposure to which, according to current knowledge, should not cause adverse health effects nor cause undue discomfort to nearly all workers.

TWA (Time Weighted Average) - is the time-weighted average airborne concentration over an eight hour working day, for a five day working week over an entire working life.

STEL (Short Term Exposure Limit) – the average airborne concentration over a 15 minute period which should not be exceeded at any time during a normal eight hour work day.

3.2. ENGINEERING CONTROLS

Ensure adequate ventilation to maintain air concentrations below the respective exposure standards.

Use engineering controls to prevent or reduce the generation of mist or spray.

3.3. PERSONAL PROTECTION

Eye

Chemical safety goggles / Safety glasses with Face Shield

Hands/Feet

Nitrile rubber gloves / Safety boots

Other

Long Sleeve Shirt and Trousers / Splash apron & respirator (if risk of high exposure to mist or spray exists)

3.4. FLAMMABILITY

This material is non flammable.

3.5. ADDITIONAL PRECAUTIONS

Avoid all personal contact, including inhalation. Wear protective clothing when risk of overexposure occurs. Use in a well-ventilated area. Always wash hands with soap and water after handling. Work clothes should be laundered separately. Use good occupational work practice. Observe manufacturer's storing and handling recommendations.

4.0. Safe Handling Information

4.1. STORAGE REQUIREMENTS

Containers must be clearly labelled and kept closed when not in use. Store in polylined steel drum or high-density polyethylene container in a cool place and out of direct sunlight. Store in a well-ventilated area away from heat and naked flames. Store away from strong oxidising agents, strong alkalis and foodstuffs.

4.2. TRANSPORTATION

This product is not classified as a dangerous good as assessed against the criteria of the Australian Dangerous Goods Code for the Transport of Dangerous Goods by Road and Rail (6th Edition, January 1998). As a precaution, not to be loaded with explosives (Class 1), oxidising agents (Class 5.1), organic peroxides (Class 5.2), or foodstuffs and foodstuff empties.

4.3. PACKAGING AND LABELLING

Product is typically packaged in 20 litre plastic pails, 205 litre drums (poly lined steel or HDPE), or 1000 litre intermediate bulk containers (IBC). Keep containers tightly closed.

UN No.:	**Not Listed**	Class:	**None Assigned**	Sub-risk:	**None Assigned**
Hazchem Code:	**None Assigned**	Pack group:	**None Assigned**	EPG:	**None Assigned**
Shipping Name:	**BACTRON IK-550 – NON HAZARDOUS LIQUID**				
Hazard:	NON HAZARDOUS				

Hazard Category: Harmful, Irritant

Risk Phrases: R20/22: Harmful by inhalation and if swallowed

R41: Risk of serious damage to eyes

R43: May cause sensitisation by skin contact

Safety Phrases: S24: Avoid contact with skin

S26: In case of contact with eyes, rinse immediately with plenty of water, seek

medical advice

S36/37/39: Wear suitable protective clothing, gloves and eye/face protection

4.4. SPILLS

Restrict access to the area and stop the flow of chemical, dike and contain to prevent spreading if it is safe to do so. Dilute with water in areas that cannot be readily contained. The recommended personal protective equipment must be worn when addressing the cleanup of any spill. Absorb with an inert absorbent material and scrape up the chemical and any contaminated soil and place in a sealable disposal container.

4.5. DISPOSAL

Recycle whenever possible.

Dispose of in accordance with all applicable local and national regulations.

4.6. FIRE FIGHTERS REPORT

Extinguishing Media

Should be governed primarily by other materials present.

Water Spray, Foam, CO_2 or Dry Chemical

Fire Fighting

Fire fighters should wear full protective clothing including self-contained breathing apparatus.

Fire and Explosion Hazards

This material is non flammable. Toxic fumes may be emitted if heated to temperatures above 160 C.

Move container from fire area if it can be moved without risk. Keep containers and surroundings cool with water spray. Fire fighters to wear self-contained breathing apparatus if risk of exposure to products of decomposition.

5.0. Other Information

5.1. ECOLOGICAL INFORMATION

Toxicity to bacteria: EC50 = 20 mg/l 2 hrs(Salmonella enteritidis)
Toxicity to algae: EC50 = 2 mg/l 2 hrs (Anacystis nidulans)
Toxicity to fungi: EC50 = 500 mg/l 24 hrs (Absidia Corymbifera)
Microtox Toxicity: EC50 No light loss = 12 mg/l in15 minutes

5.2 CONTACT

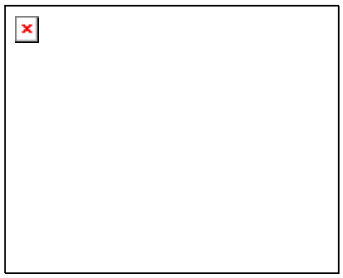
Champion Safety Manager Business hours phone (08) 9472 9400

After Hours Emergency Response (Free call) 1800 350 121

Poisons Information Centre 13 11 26

MSDS for the Scale Inhibitor

CHAMPION GYPTRON IT-109



Issue Date: Fri 20-Mar-1998
CHEMWATCH 58992

CD 2002/4

IDENTIFICATION

STATEMENT OF HAZARDOUS NATURE

Not classified as hazardous according to Worksafe Australia criteria. Not considered a dangerous substance according to directive 67/548/EEC, point 4; and not hazardous according to OSHA 29 CFR 1910.1200 (USA).

SUPPLIER

Company: Champion Technologies Pty Ltd
Address:
Ste 1, 5 Brodie-Hall Dr
Bentley
WA, 6102
Australia
Telephone: +61 8 9472 9400
Emergency Telephone: 1800 350 121
Fax: +61 8 9472 9422/ +61 8 8431 1277

Company: Champion Technologies Pty Ltd
Address:
122 Fullarton Rd
Norwood
SA, 5067
Australia
Telephone: +61 8 8431 1255

Company: Champion Technologies Pty Ltd
Address:
PO Box 263
Kent Town
SA, 5071
Australia

Company: Champion Technologies Pty Ltd
Address:
3130 FM 521
Fresno
Texas, 77545
USA
Telephone: +1 281 431 2561

CHEMWATCH HAZARD RATINGS

Min Max

Flammability: 0

Toxicity: 0

Body Contact: 0

Reactivity: 0

Chronic: 0

Min/Nil=0
Low=1
Moderate=2
High=3
Extreme=4

PERSONAL PROTECTIVE EQUIPMENT FOR INDUSPILOT PROJECT/COMMERCIAL ENVIRONMENTS

TRADE NAMES

3/97

MATERIAL DETAILS

CAS RN No(s):	None		
NIOSH No:	None	POISONS SCHEDULE:	None
UN No:	None	EPG:	NONE
DANGEROUS G. CLASS:	None	IERG:	NONE
SUB RISK:	None	IMO CLASS:	None
PACKAGING GROUP:	None	IMDG PAGE:	None
HAZCHEM:	None		
LABEL:	No class label assigned		

SHIPPING NAME

NONE

USE

Prevention of mineral deposition from produced formation waters. Downhole continuous injection into producing wells. Continuous injection into water injection wells, flowlines, water handling systems etc.

APPEARANCE

Light tan liquid with slight ammonia odour; mixes with water.

PHYSICAL PROPERTIES

Molecular Weight:	Not applicable.	Vapour Pressure (kPa):	Not available.
Boiling Range (C):	100	Volatile Component (%vol):	Not available
Melting Range (C):	Not available.	Relative Vapour Density (air=1):	Not available.
Specific Gravity (water=1):	1.05-1.15	Flash Point (C):	>79
Solubility in water (g/L):	Miscible	Lower Explosive Limit (%):	Not applicable
pH (as supplied):	7.0-8.0	Upper Explosive Limit (%):	Not applicable
pH (1% solution):	Not available	Autoignition Temp (C):	Not available.
Evaporation Rate:	Not available	Decomposition Temp (C):	Not available.
State:	Liquid		

INGREDIENTS

NAME	CAS RN	%
phosphonic acid salt		25-30

SYNONYMS

phosphonate scale inhibitor

HEALTH HAZARD

ACUTE HEALTH EFFECTS

SWALLOWED

The liquid is discomforting to the gastro-intestinal tract Ingestion may result in nausea, abdominal irritation, pain and vomiting Considered an unlikely route of entry in commercial/induspilot project environments

EYE

The liquid is discomforting to the eyes and capable of causing a mild, temporary redness of the conjunctiva (similar to wind-burn), temporary impairment of vision and/ or other transient eye damage/ ulceration

SKIN

The liquid is highly discomforting to the skin if exposure is prolonged and is capable of causing skin reactions which may lead to dermatitis from repeated exposures over long periods

INHALED

Not normally a hazard due to non-volatile nature of product

CHRONIC HEALTH EFFECTS

Primary route of exposure is usually by skin contact As with any chemical product, contact with unprotected bare skin; inhalation of vapour, mist or dust in work place atmosphere; or ingestion in any form, should be avoided by observing good occupational work practice.

FIRST AID

SWALLOWED

If poisoning occurs, contact a doctor or Poisons Information Centre. If swallowed do NOT induce vomiting. If vomiting occurs, lean patient forward or place on left side (head-down position, if possible) to maintain open airway and prevent aspiration. Observe the patient carefully. Never give liquid to a person showing signs of being sleepy or with reduced awareness; i.e. becoming unconsciousness Give water to rinse out mouth, then provide liquid slowly and as much as casualty can comfortably drink. Seek medical advice.

EYE

If this product comes in contact with the eyes: Wash out immediately with fresh running water. Ensure complete irrigation of the eye by keeping eyelids apart and away from eye and moving the eyelids by occasionally lifting the upper and lower lids. If pain persists or recurs seek medical attention. Removal of contact lenses after an eye injury should only be undertaken by skilled personnel.

SKIN

If skin contact occurs: Immediately remove all contaminated clothing, including footwear Flush skin and hair with running water (and soap if available). Seek medical attention in event of irritation.

INHALED

If fumes or combustion products are inhaled remove from contaminated area. Lay patient down. Keep warm and rested. Prostheses such as false teeth, which may block airway, should be removed, where possible, prior to initiating first aid procedures. Apply artificial respiration if not breathing, preferably with a demand valve resuscitator, bag-valve mask device, or pocket mask as trained. Perform CPR if necessary. Transport to hospital, or doctor.

ADVICE TO DOCTOR

Treat symptomatically.

TOXICITY AND IRRITATION

Not available for mixture or identified for ingredient(s) unless otherwise specified data extracted from RTECS - Register of Toxic Effects of Chemical Substances

PRECAUTION FOR USE

EXPOSURE STANDARDS

None assigned for mixture or identified for ingredient(s).

ENGINEERING CONTROLS

General exhaust is adequate under normal operating conditions. If risk of verexposure exists, wear SAA approved respirator. Correct fit is essential to obtain adequate protection. Provide adequate ventilation in warehouse or closed storage areas. Air contaminants generated in the workplace possess varying "escape" velocities which, in turn, determine the "capture velocities" of fresh circulating air required to effectively remove the contaminant.

Type of Contaminant:	Air Speed:
solvent, vapours, degreasing etc., evaporating from tank (in still air)	0.25-0.5 m/s (50-100 f/min)
aerosols, fumes from pouring operations, intermittent container filling, low speed conveyer transfers, welding, spray drift, plating acid fumes, pickling (released at low velocity into zone of active generation)	0.5-1 m/s (100-200 f/min.)
direct spray, spray painting in shallow booths, drum filling, conveyer loading, crusher dusts, gas discharge (active generation into zone of rapid air motion)	1-2.5 m/s (200-500 f/min)

grinding, abrasive blasting, tumbling, high speed wheel generated dusts (released at high initial velocity into zone of very high rapid air motion).	2.5-10 m/s (500-2000 f/min.)

Within each range the appropriate value depends on:

Lower end of the range	Upper end of the range
1: Room air currents minimal or favourable to capture	1: Disturbing room air currents
2: Contaminants of low toxicity or of nuisance value only	2: Contaminants of high toxicity
3: Intermittent, low production.	3: High production, heavy use
4: Large hood or large air mass in motion	4: Small hood - local control only

Simple theory shows that air velocity falls rapidly with distance away from the opening of a simple extraction pipe. Velocity generally decreases with the square of distance from the extraction point (in simple cases). Therefore the air speed at the extraction point should be adjusted, accordingly, after reference to distance from the contaminating source. The air velocity at the extraction fan, for example, should be a minimum of 1-2 m/s (200-400 f/min.) for extraction of solvents generated in a tank 2 meters distant from the extraction point. Other mechanical considerations, producing performance deficits within the extraction apparatus, make it essential that theoretical air velocities are multiplied by factors of 10 or more when extraction systems are installed or used.

EYE

Safety glasses.

Safety glasses with side shields.

Chemical goggles.

Contact lenses pose a special hazard; soft lenses may absorb irritants and all lenses concentrate them.

HANDS/FEET

Wear chemical protective gloves, eg. PVC.

Wear safety footwear.

OTHER

Overalls.

Eyewash unit.

The local concentration of material, quantity and conditions of use determine the type of personal protective equipment required. For further information consult site specific CHEMWATCH data (if available), or your Occupational Health and Safety Advisor.

HANDLING PROCEDURES

Limit all unnecessary personal contact.

Wear protective clothing when risk of exposure occurs.

Use in a well-ventilated area.

Avoid contact with incompatible materials.

When handling, DO NOT eat, drink or smoke.

Keep containers securely sealed when not in use.

Avoid physical damage to containers.

Always wash hands with soap and water after handling.

Work clothes should be laundered separately.

Use good occupational work practice.

Observe manufacturer's storing and handling recommendations.

Atmosphere should be regularly checked against established exposure standards to ensure safe working conditions are maintained.

CONDITION CONTRIBUTING TO INSTABILITY

Presence of incompatible materials.

Product is considered stable.

Hazardous polymerisation will not occur.

SAFE HANDLING

STORAGE

SUITABLE CONTAINER

Polyethylene or polypropylene container. Packing as recommended by manufacturer

Check all containers are clearly labelled and free from leaks.

STORAGE INCOMPATIBILITY

Avoid storage with oxidisers

Corrosive to some metals, especially mild steel.

STORAGE REQUIREMENTS

Store in original containers.

Keep containers securely sealed.

Store in a cool, dry, well-ventilated area.

Store away from incompatible materials and foodstuff containers.

Protect containers against physical damage and check regularly for leaks.

Observe manufacturer's storing and handling recommendations.

TRANSPORTATION

No restrictions.

SPILLS

MINOR SPILLS

Clean up all spills immediately.

Avoid breathing vapours and contact with skin and eyes.

Control personal contact by using protective equipment.

Contain and absorb spill with sand, earth, inert material or vermiculite.

Wipe up.

Place in a suitable labelled container for waste disposal.

MAJOR SPILLS

Minor hazard.

Clear area of personnel.

Alert Fire Brigade and tell them location and nature of hazard.

Control personal contact by using protective equipment as required.

Prevent spillage from entering drains or water ways.

Contain spill with sand, earth or vermiculite.

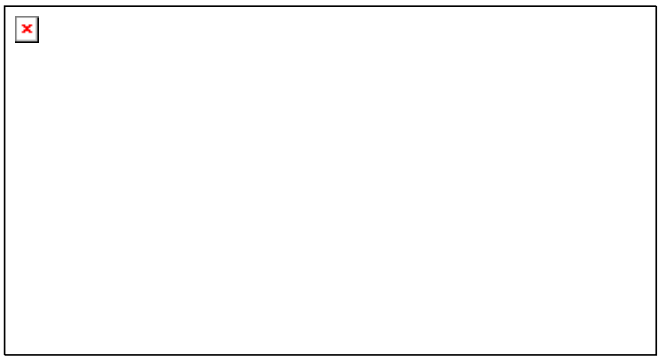
Collect recoverable product into labelled containers for recycling.

Absorb remaining product with sand, earth or vermiculite and place in appropriate containers for disposal.

Wash area and prevent runoff into drains or waterways.

If contamination of drains or waterways occurs, advise emergency services.

PROTECTIVE ACTIONS FOR SPILL



From IERG (Canada/Australia)

Isolation Distance -

Downwind Protection Distance -

FOOTNOTES

1 PROTECTIVE ACTION ZONE is defined as the area in which people are at risk of harmful exposure. This zone assumes that random changes in wind direction confines the vapour plume to an area within 30 degrees on either side of the predominant wind direction, resulting in a crosswind protective action distance equal to the downwind protective action distance.
2 PROTECTIVE ACTIONS should be initiated to the extent possible, beginning with those closest to the spill and working away from the site in the downwind direction. Within the protective action zone a level of vapour concentration may exist resulting in nearly all unprotected persons becoming incapacitated and unable to take protective action and/or incurring serious or irreversible health effects.
3 INITIAL ISOLATION ZONE is determined as an area, including upwind of the incident, within which a high probability of localised wind reversal may expose nearly all persons without appropriate protection to life-threatening concentrations of the material.
4 SMALL SPILLS involve a leaking package of 200 litres (55 US gallons) or less, such as a drum (jerrican or box with inner containers). Larger packages leaking less than 200 litres and compressed gas leaking from a small cylinder are also considered "small spills".
LARGE SPILLS involve many small leaking packages or a leaking package of greater than 200 litres, such as a cargo tank, portable tank or a "one-tonne" compressed gas cylinder.
5 Guide No guide found. is taken from the US DOT emergency response guide book.
6 IERG information is derived from CANUTEC - Transport Canada.

DISPOSAL

Recycle wherever possible or consult manufacturer for recycling options.
Consult State Land Waste Management Authority for disposal.
Bury residue in an authorised landfill.
Recycle containers if possible, or dispose of in an authorised landfill.

FIRE FIGHTERS' REPORT

EXTINGUISHING MEDIA

There is no restriction on the type of extinguisher which may be used.

FIRE FIGHTING

Alert Fire Brigade and tell them location and nature of hazard

Wear breathing apparatus plus protective gloves for fire only.

Prevent, by any means available, spillage from entering drains or water courses.

Use fire fighting procedures suitable for surrounding area.

DO NOT approach containers suspected to be hot.

Cool fire exposed containers with water spray from a protected location.

If safe to do so, remove containers from path of fire.

Equipment should be thoroughly decontaminated after use.

FIRE/EXPLOSION HAZARD

Non combustible.

Not considered to be a significant fire risk.

Expansion or decomposition on heating may lead to violent rupture of containers.

Decomposes on heating and may produce toxic fumes of carbon monoxide (CO).

May emit acrid smoke.

Other decomposition products include phosphorus oxides (POx)

FIRE INCOMPATIBILITY

Avoid contamination with strong oxidising agents as ignition may result

ENVIRONMENTAL

No data for Champion Gyptron IT-109.
Refer to data for ingredients, which follows:

CONTACT POINT

CONTACT

COMPANY CONTACT 1800 350 121

AUSTRALIAN POISONS INFORMATION CENTRE

24 HOUR SERVICE: 13 11 26

POLICE, FIRE BRIGADE OR AMBULACE: 000

NEW ZEALAND POISONS INFORMATION CENTRE

24 HOUR SERVICE: (03) 4747 000

NZ EMERGENCY SERVICES: 111

End of Report

Issue **Date:** Fri 20-Mar-1998

Print **Date:** Thu 09-Jan-2003

Appendix B:
Water Quality Data

Compatibility Analyses – JALBU Waterflood Sources

Water samples from the Hutton (Carmina 1), Murta (Jena 1), and McKinlay (Jena 5) formations were analysed to allow assessment of compatibility between the produced water from these reservoirs.

The water analyses results are displayed in the attached document 2A1157.REP.PDF.

- AR5480 = Carmina 1, Hutton formation water
- AR5481 = Jena 1, Murta formation water
- AR5482 = Jena 5, McKinlay formation water
- AR5483 = Limestone Creek Wash Tank

The water discharged from the Limestone Creek facility which is to be used as injection water appears to be Hutton formation water.

The results of the analyses were input to a scale prediction software package to confirm compatibility between the waters which will be commingled during injection of the produced water from Limestone Creek into the Jena field pilot waterflood.

Results of the computer predictions are given in the attached files which are summarised below:

MCKIN3.txt MURTA5.txt

	CaCO3 precipitated mg/kg fluid	
Mixture Hutton:Other	Murta	McKinlay
100:0	17.63	17.63
90:10	16.15	16.13
80:20	14.66	14.62
70:30	13.16	13.11
60:40	11.66	11.59
50:50	10.15	10.07
40:60	8.64	8.54
30:70	7.11	7.01
20:80	5.58	5.48
10:90	4.05	3.94
0:100	2.51	2.40

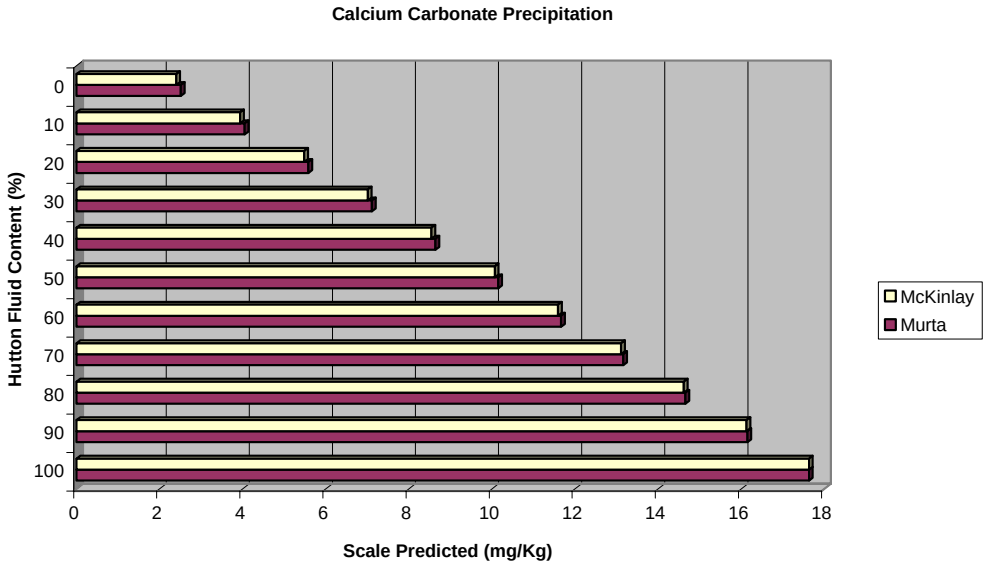
No other precipitates, barium sulphate, calcium sulphate, were predicted under the reservoir injection conditions by the scaling prediction software.

The quantities of calcium carbonate scale predicted are minimal and will be negated by the addition of Gyptron IT109 scale inhibitor.

These results are to be confirmed by laboratory testing using a selection of mixtures.

Conclusion

There are no fluid compatibility issues with injection of produced water from the Limestone Creek facility into the Jena field reservoirs.



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NATA Accredited Laboratory Number: 1464

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Facsimile: (02) 9482 1734

CERTIFICATE OF ANALYSIS

Contents :
1. Cover Pages (2)
2. Analysis Report Pages
3. QA/QC Appendix
4. Additional Reports - External (if applicable)
5. Chain of Custody (if applicable)

Report No. : 2A1157

Attention : Moomba Lab Supervisor

Client : Santos Ltd
: Santos Moomba Operations Camp
: GPO Box 563
: SA 5001

Samples : 4

Reference/Order : 1033

Project :

Received Samples : 30/11/02 **Instructions** : 30/11/02

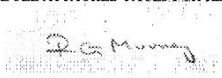
Date Reported : 05/12/02

PLEASE SEE FOLLOWING PAGE FOR METHOD LISTING

RESULTS

All samples were analysed as received. This report relates specifically to the samples as received. Results relate to the source material only to the extent that the samples as supplied are truly representative of the sample source. This report replaces any preliminary results issued. Note that for methods indicated with "*", NATA accreditation does not cover the performance of this service. Three significant figures (or 2 for < 10PQL) are reported for statistical purposes only. Where "Total" concentrations are reported for organic suites of compounds this is the summation of the individual compounds and the PQL is noted for reporting purposes only. This report has been auto-authorized by NATA signatories for PDF format. Refer to the method descriptions for further information.

PLEASE SEE ATTACHED PAGES FOR RESULTS



R. Mooney B.Sc.(Hons)Dip. FDA
Technical Services Manager Sydney

amdel

Job Number : 2A1157
Client : Santos Ltd
Reference : 1033
Project :

Analyte	Lab No	E11087	E11088	E11089	E11090	
	Sample Id	AR5480	AR5481	AR5482	AR5483	
	PQL					
E2380 Chloride in Water						
Chloride	**1**	890	430	440	840	
E2310 Total Alkalinity in Water						
Bicarbonate as CaCO3	**1**	1600	1400	1400	1300	
Carbonate as CaCO3	**1**	nd	nd	nd	nd	
Hydroxide as CaCO3	**1**	nd	nd	nd	nd	
Alkalinity as CaCO3	**1**	1600	1400	1400	1300	
E2550 Nitrate as N in Water						
Nitrate as N	**0.01**	0.01	nd	nd	nd	
E2600 pH in Water						
pH	**0.1**	7.5	8.1	7.7	7.4	
E2430 Conductivity (uS/cm at 25.0 C)						
Electrical Conductivity	**1**	4300	3300	3400	4600	
E2690 Total Dissolved Solids in Water						
TDS	**1**	2900	2300	2300	2900	
E2530 Total Hardness						
Total Hardness as CaCO3	**0.5**	52	27	28	47	
E2720 Sulphate in Water						
Sulphate	**1**	12	nd	nd	10	

PQL = Practical Quantitation Limit
LNR = Samples Listed not Received
nd = <PQL
-- = Not Applicable

Soils : mg/kg (ppm) dry weight unless otherwise specified
Waters : mg/L (ppm) unless otherwise specified in Method Header
Leachates : mg/L (ppm) in leachate unless otherwise specified in Method Header

Refer to Amdel standard laboratory qualifier codes for comments.

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Job Number : 2A1157
Client : Santos Ltd
Reference : 1033
Project :

Analyte	Lab No	E11087	E11088	E11089	E11090	
	Sample Id	AR5480	AR5481	AR5482	AR5483	
	PQL					
E4810 Dissolved Metals in Waters						
Sodium	**0.2**	1100	880	910	1100	
Magnesium	**0.1**	2.6	1.2	1.2	2.2	
Calcium	**0.1**	17	8.8	9.0	15	
Potassium	**0.1**	33	42	25	35	
Iron	**0.05**	0.47	2.61	0.67	0.61	
Barium	**0.05**	3.00	0.51	0.68	2.50	
Strontium	**0.05**	0.51	0.53	0.49	0.54	
E2530 Total Hardness						
Total Hardness as CaCO3	**0.5**	52	27	28	47	

PQL = Practical Quantitation Limit
LNR = Samples Listed not Received
nd = <PQL
-- = Not Applicable
Refer to Amdel standard laboratory qualifier codes for comments.

Soils : mg/kg (ppm) dry weight unless otherwise specified
Waters : mg/L (ppm) unless otherwise specified in Method Header
Leachates : mg/L (ppm) in leachate unless otherwise specified in Method Header

amdel

Report No. : 2A1157

Please note: Where samples are collected/submitted over several days, the date on which the last samples were analysed or extracted is reported.
Unless Ferrous Iron is determined on site, the possibility of a ferrous-ferric ratio change may occur.

Method	Description	Extracted	Analysed	Authorised
E4810	Dissolved Metals by ICP-AES	03/12/02	03/12/02	RMO 093
E2380	Chloride	03/12/02	03/12/02	NSA 101
E2310	Total Alkalinity	02/12/02	02/12/02	NSA 101
E2550	Nitrate-N	04/12/02	04/12/02	NSA 101
E2600	pH	02/12/02	02/12/02	NSA 101
E2430	Conductivity	02/12/02	02/12/02	NSA 101
E2690	Total Dissolved Solids	02/12/02	02/12/02	NSA 101
E2530	Total Hardness	03/12/02	03/12/02	RMO 093
E2720	Sulphate	03/12/02	03/12/02	NSA 101

Water Quality Model Data

HUTTON/McKINLAY MIXTURE

T(C) = 80.0 P(BAR) = 200.0 CONC.OPT.= 2 CA OPT. = 0

XCO2= .000 AQCO2= 70.

DENS1 = .99891 PH1 = 7.0; DENS2 = .99844 PH2 = 7.5

IONS	Z	FORMULA WT	HUTTON CON1/PPM	McKINLAY CON2/PPM	CON1/MOLAL	CON2/MOLAL
SO4	-2	96.062	12.00	.10	.000125	.000001
MG	2	24.312	2.60	1.20	.000107	.000049
CA	2	40.080	17.00	9.00	.000425	.000225
SR	2	87.620	.51	.49	.000006	.000006
BA	2	137.340	3.00	.68	.000022	.000005
HCO3	-1	61.017	830.00	840.00	.013629	.013800
NA	1	22.990	1100.00	910.00	.047952	.039680
K	1	39.102	33.00	25.00	.000845	.000640
CL	-1	35.453	890.00	440.00	.025154	.012436
BR	-1	79.909	.00	.00	.000000	.000000

KMG = .73096E+03 KANH = .00000E+00 KGYP = .19750E-04
KCEL = .16798E-06 KBAR = .41145E-09
KCAL = .82296E-05 KHCO2 = .12628E-01

PERCENT OF THE McKINLAY WATER = .00

SO4	PPM =	12.00	MOLALITY =	.000125
MG	PPM =	2.60	MOLALITY =	.000107
CA	PPM =	17.00	MOLALITY =	.000425
SR	PPM =	.51	MOLALITY =	.000006
BA	PPM =	3.00	MOLALITY =	.000022
HCO3	PPM =	830.00	MOLALITY =	.013629
NA	PPM =	1100.00	MOLALITY =	.047952
K	PPM =	33.00	MOLALITY =	.000845
CL	PPM =	890.00	MOLALITY =	.025154
BR	PPM =	.00	MOLALITY =	.000000

CO2(G) FUGACITY = .1264 ; IONIC STRENGTH = .0452

GMG = .41202E+00 GANH = .00000E+00 GGYP = .26650E+00
GCEL = .32228E+00 GBAR = .32558E+00 GCAL = .66945E+00

** CACO3 MAY FORM !!!!! **

HCO3(-) FREE = 810.100

CA(2+) FREE = 9.958 CACO3 SOLID = 17.633

!! CASO4 UNDER SATURATED & CA (90273.6 MG/KG)100.% OFF SATURATION VALUE !!

```
  !  SRSO4 UNDER SATURATED & SR ( 1147.4 MG/KG)100.0% OF SATURATION VALUE !!

  !!  BASO4 UNDER SATURATED & BA (   1.3 MG/KG) 30.46% OF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =      11.858

          MG(2+) FREE  =       2.564     MGSO4 PAIR   =        .194



         PERCENT  OF  THE  McKINLAY  WATER  =  10.00
         -------  --  ---  ---------  -----    ------

     SO4       PPM =       10.81     MOLALITY =    .000113
     MG        PPM =        2.46     MOLALITY =    .000101
     CA        PPM =       16.20     MOLALITY =    .000405
     SR        PPM =         .51     MOLALITY =    .000006
     BA        PPM =        2.77     MOLALITY =    .000020
     HCO3      PPM =      831.00     MOLALITY =    .013646
     NA        PPM =     1081.00     MOLALITY =    .047125
     K         PPM =       32.20     MOLALITY =    .000824
     CL        PPM =      845.00     MOLALITY =    .023882
     BR        PPM =         .00     MOLALITY =    .000000


      CO2(G) FUGACITY =     .1264 ;   IONIC STRENGTH =   .0440

      GMG =  .41524E+00     GANH =  .00000E+00     GGYP =  .26768E+00
     GCEL =  .32373E+00     GBAR =  .32707E+00     GCAL =  .67233E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     812.976

       CA(2+) FREE  =       9.760          CACO3 SOLID  =      16.128
                                           --------------------------

  !!  CASO4 UNDER SATURATED & CA (  99282.7 MG/KG)100.% OF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 1261.8 MG/KG)100.0% OF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (   2.0 MG/KG) 41.64% OF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =      10.687

          MG(2+) FREE  =       2.429     MGSO4 PAIR   =        .169
```

```
         PERCENT  OF  THE  McKINLAY  WATER  =  20.00
         -------  --  ---  ---------  -----    ------

     SO4       PPM =        9.62     MOLALITY =    .000100
     MG        PPM =        2.32     MOLALITY =    .000096
     CA        PPM =       15.40     MOLALITY =    .000385
     SR        PPM =         .51     MOLALITY =    .000006
     BA        PPM =        2.54     MOLALITY =    .000018


     HCO3      PPM =      832.00     MOLALITY =    .013663
     NA        PPM =     1062.00     MOLALITY =    .046298
     K         PPM =       31.40     MOLALITY =    .000804
     CL        PPM =      800.00     MOLALITY =    .022610
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1264 ;   IONIC STRENGTH =   .0429

      GMG =  .41855E+00     GANH =  .00000E+00     GGYP =  .26889E+00
     GCEL =  .32521E+00     GBAR =  .32859E+00     GCAL =  .67528E+00


          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     815.858

       CA(2+) FREE  =       9.564          CACO3 SOLID  =      14.619
                                           --------------------------

  !!  CASO4 UNDER SATURATED & CA ( 110515.2 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 1404.4 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (   2.7 MG/KG) 51.95% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       9.516

          MG(2+) FREE  =       2.294     MGSO4 PAIR   =        .144

         PERCENT  OF  THE  McKINLAY  WATER  =  30.00
         -------  --  ---  ---------  -----    ------


     SO4       PPM =        8.43     MOLALITY =    .000088
     MG        PPM =        2.18     MOLALITY =    .000090
     CA        PPM =       14.60     MOLALITY =    .000365
     SR        PPM =         .50     MOLALITY =    .000006
     BA        PPM =        2.30     MOLALITY =    .000017
     HCO3      PPM =      833.00     MOLALITY =    .013680
     NA        PPM =     1043.00     MOLALITY =    .045470
     K         PPM =       30.60     MOLALITY =    .000784
     CL        PPM =      755.00     MOLALITY =    .021338
     BR        PPM =         .00     MOLALITY =    .000000
```

```
      CO2(G) FUGACITY =     .1264 ;   IONIC STRENGTH =   .0418

      GMG =  .42194E+00     GANH =  .00000E+00     GGYP =  .27011E+00
     GCEL =  .32671E+00     GBAR =  .33014E+00     GCAL =  .67830E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     818.746
       CA(2+) FREE  =       9.370          CACO3 SOLID  =      13.105
                                           -------------------------

  !!  CASO4 UNDER SATURATED & CA ( 124912.3 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 1587.2 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (   3.7 MG/KG) 61.36% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       8.343

          MG(2+) FREE  =       2.158     MGSO4 PAIR   =        .121



         PERCENT  OF  THE  McKINLAY  WATER  =  40.00
         -------  --  ---  ---------  -----    ------

     SO4       PPM =        7.24     MOLALITY =    .000075
     MG        PPM =        2.04     MOLALITY =    .000084
     CA        PPM =       13.80     MOLALITY =    .000345
     SR        PPM =         .50     MOLALITY =    .000006
     BA        PPM =        2.07     MOLALITY =    .000015
     HCO3      PPM =      834.00     MOLALITY =    .013697
     NA        PPM =     1024.00     MOLALITY =    .044643
     K         PPM =       29.80     MOLALITY =    .000763
     CL        PPM =      710.00     MOLALITY =    .020066
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1264 ;   IONIC STRENGTH =   .0406

      GMG =  .42543E+00     GANH =  .00000E+00     GGYP =  .27136E+00
     GCEL =  .32824E+00     GBAR =  .33172E+00     GCAL =  .68139E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     821.638

       CA(2+) FREE  =       9.177          CACO3 SOLID  =      11.588
                                           -------------------------

  !!  CASO4 UNDER SATURATED & CA ( 144034.0 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 1829.9 MG/KG)100.0% OFF SATURATION VALUE
!!
```

```
  !!  BASO4 UNDER SATURATED & BA (   4.8 MG/KG) 69.85% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       7.169

          MG(2+) FREE  =       2.022     MGSO4 PAIR   =        .099



         PERCENT  OF  THE  McKINLAY  WATER  =  50.00
         -------  --  ---  ---------  -----    ------

     SO4       PPM =        6.05     MOLALITY =    .000063
     MG        PPM =        1.90     MOLALITY =    .000078
     CA        PPM =       13.00     MOLALITY =    .000325
     SR        PPM =         .50     MOLALITY =    .000006
     BA        PPM =        1.84     MOLALITY =    .000013
     HCO3      PPM =      835.00     MOLALITY =    .013714
     NA        PPM =     1005.00     MOLALITY =    .043816
     K         PPM =       29.00     MOLALITY =    .000743
     CL        PPM =      665.00     MOLALITY =    .018795
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1264 ;   IONIC STRENGTH =   .0395

      GMG =  .42902E+00     GANH =  .00000E+00     GGYP =  .27263E+00
     GCEL =  .32980E+00     GBAR =  .33332E+00     GCAL =  .68456E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     824.535

       CA(2+) FREE  =       8.986          CACO3 SOLID  =      10.066
                                           --------------------------

  !!  CASO4 UNDER SATURATED & CA ( 170667.9 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 2168.1 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (   6.3 MG/KG) 77.40% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       5.994

          MG(2+) FREE  =       1.887     MGSO4 PAIR   =        .078


         PERCENT  OF  THE  McKINLAY  WATER  =  60.00
         -------  --  ---  ---------  -----    ------

     SO4       PPM =        4.86     MOLALITY =    .000051
     MG        PPM =        1.76     MOLALITY =    .000072
     CA        PPM =       12.20     MOLALITY =    .000305
     SR        PPM =         .50     MOLALITY =    .000006
     BA        PPM =        1.61     MOLALITY =    .000012
```

```
     HCO3      PPM =      836.00     MOLALITY =    .013731
     NA        PPM =      986.00     MOLALITY =    .042989
     K         PPM =       28.20     MOLALITY =    .000722
     CL        PPM =      620.00     MOLALITY =    .017523
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1264 ;   IONIC STRENGTH =   .0384

      GMG =  .43271E+00     GANH =  .00000E+00     GGYP =  .27393E+00
     GCEL =  .33139E+00     GBAR =  .33496E+00     GCAL =  .68780E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     827.437

       CA(2+) FREE  =       8.796          CACO3 SOLID  =       8.541
                                           --------------------------

  !!  CASO4 UNDER SATURATED & CA ( 210331.4 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 2671.7 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (   8.4 MG/KG) 83.97% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       4.818

          MG(2+) FREE  =       1.750     MGSO4 PAIR   =        .059



         PERCENT  OF  THE  McKINLAY  WATER  =  70.00
         -------  --  ---  ---------  -----    ------

     SO4       PPM =        3.67     MOLALITY =    .000038
     MG        PPM =        1.62     MOLALITY =    .000067
     CA        PPM =       11.40     MOLALITY =    .000285
     SR        PPM =         .50     MOLALITY =    .000006
     BA        PPM =        1.38     MOLALITY =    .000010
     HCO3      PPM =      837.00     MOLALITY =    .013748
     NA        PPM =      967.00     MOLALITY =    .042162
     K         PPM =       27.40     MOLALITY =    .000702
     CL        PPM =      575.00     MOLALITY =    .016251
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1263 ;   IONIC STRENGTH =   .0372

      GMG =  .43650E+00     GANH =  .00000E+00     GGYP =  .27525E+00
     GCEL =  .33301E+00     GBAR =  .33663E+00     GCAL =  .69114E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     830.344

       CA(2+) FREE  =       8.608          CACO3 SOLID  =       7.011
                                           --------------------------
```

```
  !!  CASO4 UNDER SATURATED & CA ( 275698.3 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 3501.7 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (  11.8 MG/KG) 89.53% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       3.640

          MG(2+) FREE  =       1.614     MGSO4 PAIR   =        .042



         PERCENT  OF  THE  McKINLAY  WATER  =  80.00
         -------  --  ---  ---------  -----    ------

     SO4       PPM =        2.48     MOLALITY =    .000026
     MG        PPM =        1.48     MOLALITY =    .000061
     CA        PPM =       10.60     MOLALITY =    .000265
     SR        PPM =         .49     MOLALITY =    .000006
     BA        PPM =        1.14     MOLALITY =    .000008
     HCO3      PPM =      838.00     MOLALITY =    .013766
     NA        PPM =      948.00     MOLALITY =    .041335
     K         PPM =       26.60     MOLALITY =    .000681
     CL        PPM =      530.00     MOLALITY =    .014979
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1263 ;   IONIC STRENGTH =   .0361

      GMG =  .44042E+00     GANH =  .00000E+00     GGYP =  .27660E+00
     GCEL =  .33467E+00     GBAR =  .33834E+00     GCAL =  .69455E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     833.255

       CA(2+) FREE  =       8.421          CACO3 SOLID  =       5.478
                                           --------------------------

  !!  CASO4 UNDER SATURATED & CA ( 403768.2 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 5127.8 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (  18.1 MG/KG) 94.05% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       2.462

          MG(2+) FREE  =       1.477     MGSO4 PAIR   =        .027
```

```
        PERCENT  OF  THE  McKINLAY  WATER  =  90.00
        -------  --  ---  ---------  -----    ------

     SO4       PPM =        1.29     MOLALITY =    .000013
     MG        PPM =        1.34     MOLALITY =    .000055
     CA        PPM =        9.80     MOLALITY =    .000245
     SR        PPM =         .49     MOLALITY =    .000006
     BA        PPM =         .91     MOLALITY =    .000007
     HCO3      PPM =      839.00     MOLALITY =    .013783
     NA        PPM =      929.00     MOLALITY =    .040507
     K         PPM =       25.80     MOLALITY =    .000661
     CL        PPM =      485.00     MOLALITY =    .013707
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1263 ;   IONIC STRENGTH =   .0350

      GMG =  .44445E+00     GANH =  .00000E+00     GGYP =  .27798E+00
     GCEL =  .33636E+00     GBAR =  .34008E+00     GCAL =  .69807E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     836.171

       CA(2+) FREE  =       8.236          CACO3 SOLID  =       3.941
                                           -------------------------

!!  CASO4 UNDER SATURATED & CA ( 768071.7 MG/KG)100.% OFF SATURATION VALUE !!
!!  SRSO4 UNDER SATURATED & SR ( 9753.6 MG/KG)100.0% OFF SATURATION VALUE !!
!!  BASO4 UNDER SATURATED & BA (  35.7 MG/KG) 97.51% OFF SATURATION VALUE !!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *
          SO4(2-) FREE =       1.281
          MG(2+) FREE  =       1.339     MGSO4 PAIR   =        .013



        PERCENT  OF  THE  McKINLAY  WATER  = 100.00
        -------  --  ---  ---------  -----    ------

     SO4       PPM =         .10     MOLALITY =    .000001
     MG        PPM =        1.20     MOLALITY =    .000049
     CA        PPM =        9.00     MOLALITY =    .000225
     SR        PPM =         .49     MOLALITY =    .000006
     BA        PPM =         .68     MOLALITY =    .000005
     HCO3      PPM =      840.00     MOLALITY =    .013800
     NA        PPM =      910.00     MOLALITY =    .039680
     K         PPM =       25.00     MOLALITY =    .000640
     CL        PPM =      440.00     MOLALITY =    .012436
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1263 ;   IONIC STRENGTH =   .0338

      GMG =  .44862E+00     GANH =  .00000E+00     GGYP =  .27939E+00
     GCEL =  .33809E+00     GBAR =  .34186E+00     GCAL =  .70168E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     839.090
       CA(2+) FREE  =       8.053          CACO3 SOLID  =       2.401
                                           -------------------------

!!  CASO4 UNDER SATURATED & CA (9806373.7 MG/KG)100.% OFF SATURATION VALUE !!
```

```
!!  SRSO4 UNDER SATURATED & SR (******* MG/KG)100.0% OFF SATURATION VALUE !!


!!  BASO4 UNDER SATURATED & BA ( 466.9 MG/KG) 99.85% OFF SATURATION VALUE !!
        *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *
          SO4(2-) FREE =        .099
          MG(2+) FREE  =       1.202     MGSO4 PAIR   =        .001
```

HUTTON/MURTA MIXTURE

T(C) = 80.0 P(BAR) = 200.0 CONC.OPT.= 2 CA OPT. = 0

XCO2= .000 AQCO2= 70.

DENS1 = .99891 PH1 = 7.0; DENS2 = .99842 PH2 = 7.5

IONS	Z	FORMULA WT	HUTTON CON1/PPM	MURTA CON2/PPM	CON1/MOLAL	CON2/MOLAL
SO4	-2	96.062	12.00	.10	.000125	.000001
MG	2	24.312	2.60	1.20	.000107	.000049
CA	2	40.080	17.00	8.80	.000425	.000220
SR	2	87.620	.51	.53	.000006	.000006
BA	2	137.340	3.00	.51	.000022	.000004
HCO3	-1	61.017	830.00	850.00	.013629	.013964
NA	1	22.990	1100.00	880.00	.047952	.038372
K	1	39.102	33.00	42.00	.000845	.001076
CL	-1	35.453	890.00	430.00	.025154	.012153
BR	-1	79.909	.00	.00	.000000	.000000

KMG = .73096E+03 KANH = .00000E+00 KGYP = .19750E-04
KCEL = .16798E-06 KBAR = .41145E-09
KCAL = .82296E-05 KHCO2 = .12628E-01

PERCENT OF THE MURTA WATER = .00

SO4	PPM =	12.00	MOLALITY =	.000125
MG	PPM =	2.60	MOLALITY =	.000107
CA	PPM =	17.00	MOLALITY =	.000425
SR	PPM =	.51	MOLALITY =	.000006
BA	PPM =	3.00	MOLALITY =	.000022
HCO3	PPM =	830.00	MOLALITY =	.013629
NA	PPM =	1100.00	MOLALITY =	.047952
K	PPM =	33.00	MOLALITY =	.000845
CL	PPM =	890.00	MOLALITY =	.025154
BR	PPM =	.00	MOLALITY =	.000000

CO2(G) FUGACITY = .1264 ; IONIC STRENGTH = .0452

GMG = .41202E+00 GANH = .00000E+00 GGYP = .26650E+00
GCEL = .32228E+00 GBAR = .32558E+00 GCAL = .66945E+00

```
          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     810.100

       CA(2+) FREE  =       9.958          CACO3 SOLID  =      17.633
                                           -------------------------

  !!  CASO4 UNDER SATURATED & CA (  90273.6 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 1147.4 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (   1.3 MG/KG) 30.46% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =      11.858

          MG(2+) FREE  =       2.564     MGSO4 PAIR   =        .194



         PERCENT  OF  THE  MURTA  WATER  =  10.00
         -------  --  ---  ---------  -----    ------

     SO4       PPM =       10.81     MOLALITY =    .000113
     MG        PPM =        2.46     MOLALITY =    .000101
     CA        PPM =       16.18     MOLALITY =    .000404
     SR        PPM =         .51     MOLALITY =    .000006
     BA        PPM =        2.75     MOLALITY =    .000020
     HCO3      PPM =      832.00     MOLALITY =    .013663
     NA        PPM =     1078.00     MOLALITY =    .046994
     K         PPM =       33.90     MOLALITY =    .000868
     CL        PPM =      844.00     MOLALITY =    .023853
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1264 ;   IONIC STRENGTH =   .0440

      GMG =  .41539E+00     GANH =  .00000E+00     GGYP =  .26774E+00
     GCEL =  .32380E+00     GBAR =  .32714E+00     GCAL =  .67247E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     813.954

       CA(2+) FREE  =       9.731          CACO3 SOLID  =      16.151
                                           -------------------------

  !!  CASO4 UNDER SATURATED & CA (  99244.0 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 1261.3 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (   2.0 MG/KG) 41.97% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *
```

```
          SO4(2-) FREE =      10.687

          MG(2+) FREE  =       2.429     MGSO4 PAIR   =        .169



         PERCENT  OF  THE  MURTA  WATER  =  20.00
         -------  --  ---  ---------  -----    ------

     SO4       PPM =        9.62     MOLALITY =    .000100
     MG        PPM =        2.32     MOLALITY =    .000096
     CA        PPM =       15.36     MOLALITY =    .000384
     SR        PPM =         .51     MOLALITY =    .000006
     BA        PPM =        2.50     MOLALITY =    .000018
     HCO3      PPM =      834.00     MOLALITY =    .013696
     NA        PPM =     1056.00     MOLALITY =    .046036
     K         PPM =       34.80     MOLALITY =    .000891
     CL        PPM =      798.00     MOLALITY =    .022553
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1264 ;   IONIC STRENGTH =   .0428

      GMG =  .41885E+00     GANH =  .00000E+00     GGYP =  .26899E+00
     GCEL =  .32534E+00     GBAR =  .32873E+00     GCAL =  .67555E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     817.816

       CA(2+) FREE  =       9.507          CACO3 SOLID  =      14.661
                                           --------------------------

  !!  CASO4 UNDER SATURATED & CA ( 110427.6 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 1403.2 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (   2.8 MG/KG) 52.55% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       9.516

          MG(2+) FREE  =       2.294     MGSO4 PAIR   =        .144



         PERCENT  OF  THE  MURTA  WATER  =  30.00
         -------  --  ---  ---------  -----    ------

     SO4       PPM =        8.43     MOLALITY =    .000088
     MG        PPM =        2.18     MOLALITY =    .000090
     CA        PPM =       14.54     MOLALITY =    .000363
     SR        PPM =         .52     MOLALITY =    .000006
     BA        PPM =        2.25     MOLALITY =    .000016
     HCO3      PPM =      836.00     MOLALITY =    .013730
     NA        PPM =     1034.00     MOLALITY =    .045078
     K         PPM =       35.70     MOLALITY =    .000914
```

```
     CL        PPM =      752.00     MOLALITY =    .021253
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1264 ;   IONIC STRENGTH =   .0416

      GMG =  .42241E+00     GANH =  .00000E+00     GGYP =  .27028E+00
     GCEL =  .32691E+00     GBAR =  .33035E+00     GCAL =  .67871E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     821.688

       CA(2+) FREE  =       9.285          CACO3 SOLID  =      13.165
                                           --------------------------

  !!  CASO4 UNDER SATURATED & CA ( 124761.6 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 1585.2 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (   3.7 MG/KG) 62.17% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       8.343

          MG(2+) FREE  =       2.158     MGSO4 PAIR   =        .121



         PERCENT  OF  THE  MURTA  WATER  =  40.00
         -------  --  ---  ---------  -----    ------

     SO4       PPM =        7.24     MOLALITY =    .000075
     MG        PPM =        2.04     MOLALITY =    .000084
     CA        PPM =       13.72     MOLALITY =    .000343
     SR        PPM =         .52     MOLALITY =    .000006
     BA        PPM =        2.00     MOLALITY =    .000015
     HCO3      PPM =      838.00     MOLALITY =    .013763
     NA        PPM =     1012.00     MOLALITY =    .044120
     K         PPM =       36.60     MOLALITY =    .000937

     CL        PPM =      706.00     MOLALITY =    .019953
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1264 ;   IONIC STRENGTH =   .0404

      GMG =  .42607E+00     GANH =  .00000E+00     GGYP =  .27158E+00
     GCEL =  .32852E+00     GBAR =  .33200E+00     GCAL =  .68195E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     825.567

       CA(2+) FREE  =       9.067          CACO3 SOLID  =      11.662
                                           --------------------------

  !!  CASO4 UNDER SATURATED & CA ( 143798.8 MG/KG)100.% OFF SATURATION VALUE
!!
```

```
  !!  SRSO4 UNDER SATURATED & SR ( 1826.9 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (   4.9 MG/KG) 70.80% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       7.169

          MG(2+) FREE  =       2.022     MGSO4 PAIR   =        .099



         PERCENT  OF  THE  MURTA  WATER  =  50.00
         -------  --  ---  ---------  -----    ------

     SO4       PPM =        6.05     MOLALITY =    .000063
     MG        PPM =        1.90     MOLALITY =    .000078
     CA        PPM =       12.90     MOLALITY =    .000322
     SR        PPM =         .52     MOLALITY =    .000006
     BA        PPM =        1.76     MOLALITY =    .000013
     HCO3      PPM =      840.00     MOLALITY =    .013797
     NA        PPM =      990.00     MOLALITY =    .043162
     K         PPM =       37.50     MOLALITY =    .000960
     CL        PPM =      660.00     MOLALITY =    .018653
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1264 ;   IONIC STRENGTH =   .0393

      GMG =  .42983E+00     GANH =  .00000E+00     GGYP =  .27292E+00
     GCEL =  .33015E+00     GBAR =  .33369E+00     GCAL =  .68528E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     829.455

       CA(2+) FREE  =       8.851          CACO3 SOLID  =      10.152
                                           --------------------------

  !!  CASO4 UNDER SATURATED & CA ( 170313.9 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 2163.5 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (   6.4 MG/KG) 78.40% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       5.994

          MG(2+) FREE  =       1.886     MGSO4 PAIR   =        .079



         PERCENT  OF  THE  MURTA  WATER  =  60.00
         -------  --  ---  ---------  -----    ------
```

```
     SO4       PPM =        4.86     MOLALITY =    .000051
     MG        PPM =        1.76     MOLALITY =    .000072
     CA        PPM =       12.08     MOLALITY =    .000302
     SR        PPM =         .52     MOLALITY =    .000006
     BA        PPM =        1.51     MOLALITY =    .000011
     HCO3      PPM =      842.00     MOLALITY =    .013830
     NA        PPM =      968.00     MOLALITY =    .042204
     K         PPM =       38.40     MOLALITY =    .000983
     CL        PPM =      614.00     MOLALITY =    .017353
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1264 ;   IONIC STRENGTH =   .0381

      GMG =  .43372E+00     GANH =  .00000E+00     GGYP =  .27428E+00
     GCEL =  .33182E+00     GBAR =  .33541E+00     GCAL =  .68869E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     833.351

       CA(2+) FREE  =       8.638          CACO3 SOLID  =       8.636
                                           -------------------------

  !!  CASO4 UNDER SATURATED & CA ( 209799.3 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 2664.8 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (   8.5 MG/KG) 84.95% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       4.818

          MG(2+) FREE  =       1.750     MGSO4 PAIR   =        .060



         PERCENT  OF  THE  MURTA  WATER  =  70.00
         -------  --  ---  ---------  -----    ------

     SO4       PPM =        3.67     MOLALITY =    .000038
     MG        PPM =        1.62     MOLALITY =    .000067
     CA        PPM =       11.26     MOLALITY =    .000281
     SR        PPM =         .52     MOLALITY =    .000006
     BA        PPM =        1.26     MOLALITY =    .000009
     HCO3      PPM =      844.00     MOLALITY =    .013864
     NA        PPM =      946.00     MOLALITY =    .041246
     K         PPM =       39.30     MOLALITY =    .001007
     CL        PPM =      568.00     MOLALITY =    .016053
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1263 ;   IONIC STRENGTH =   .0369

      GMG =  .43772E+00     GANH =  .00000E+00     GGYP =  .27567E+00
     GCEL =  .33353E+00     GBAR =  .33716E+00     GCAL =  .69220E+00

          **    CACO3  MAY  FORM    !!!!!       **
```

```
       HCO3(-) FREE =     837.255

       CA(2+) FREE  =       8.427          CACO3 SOLID  =       7.113
                                           -------------------------

  !!  CASO4 UNDER SATURATED & CA ( 274870.9 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 3491.0 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (  11.9 MG/KG) 90.41% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       3.640

          MG(2+) FREE  =       1.614     MGSO4 PAIR   =        .042



         PERCENT  OF  THE  MURTA  WATER  =  80.00
         -------  --  ---  ---------  -----    ------

     SO4       PPM =        2.48     MOLALITY =    .000026
     MG        PPM =        1.48     MOLALITY =    .000061
     CA        PPM =       10.44     MOLALITY =    .000261
     SR        PPM =         .53     MOLALITY =    .000006
     BA        PPM =        1.01     MOLALITY =    .000007
     HCO3      PPM =      846.00     MOLALITY =    .013897
     NA        PPM =      924.00     MOLALITY =    .040288
     K         PPM =       40.20     MOLALITY =    .001030
     CL        PPM =      522.00     MOLALITY =    .014753
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1263 ;   IONIC STRENGTH =   .0357

      GMG =  .44185E+00     GANH =  .00000E+00     GGYP =  .27709E+00
     GCEL =  .33527E+00     GBAR =  .33896E+00     GCAL =  .69580E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     841.166

       CA(2+) FREE  =       8.219          CACO3 SOLID  =       5.584
                                           -------------------------

  !!  CASO4 UNDER SATURATED & CA ( 402359.1 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 5109.7 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (  18.2 MG/KG) 94.74% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       2.461
```

```
          MG(2+) FREE  =       1.477     MGSO4 PAIR   =        .027


          PERCENT  OF  THE  MURTA  WATER  =  90.00
          -------  --  ---  ---------  -----    ------

     SO4       PPM =        1.29     MOLALITY =    .000013
     MG        PPM =        1.34     MOLALITY =    .000055
     CA        PPM =        9.62     MOLALITY =    .000240
     SR        PPM =         .53     MOLALITY =    .000006
     BA        PPM =         .76     MOLALITY =    .000006
     HCO3      PPM =      848.00     MOLALITY =    .013931
     NA        PPM =      902.00     MOLALITY =    .039330
     K         PPM =       41.10     MOLALITY =    .001053
     CL        PPM =      476.00     MOLALITY =    .013453
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1263 ;   IONIC STRENGTH =   .0345

      GMG =  .44612E+00     GANH =  .00000E+00     GGYP =  .27855E+00
     GCEL =  .33705E+00     GBAR =  .34079E+00     GCAL =  .69951E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     845.085

       CA(2+) FREE  =       8.013          CACO3 SOLID  =       4.048
                                           --------------------------

  !!  CASO4 UNDER SATURATED & CA ( 765001.1 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR ( 9714.0 MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA (  35.7 MG/KG) 97.92% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =       1.281

          MG(2+) FREE  =       1.339     MGSO4 PAIR   =        .013


          PERCENT  OF  THE  MURTA  WATER  = 100.00
          -------  --  ---  ---------  -----    ------

     SO4       PPM =         .10     MOLALITY =    .000001
     MG        PPM =        1.20     MOLALITY =    .000049
     CA        PPM =        8.80     MOLALITY =    .000220
     SR        PPM =         .53     MOLALITY =    .000006
     BA        PPM =         .51     MOLALITY =    .000004
     HCO3      PPM =      850.00     MOLALITY =    .013964
     NA        PPM =      880.00     MOLALITY =    .038372
     K         PPM =       42.00     MOLALITY =    .001076
     CL        PPM =      430.00     MOLALITY =    .012153
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```
     BR        PPM =         .00     MOLALITY =    .000000

      CO2(G) FUGACITY =     .1263 ;   IONIC STRENGTH =   .0333

      GMG =  .45053E+00     GANH =  .00000E+00     GGYP =  .28004E+00
     GCEL =  .33887E+00     GBAR =  .34267E+00     GCAL =  .70333E+00

          **    CACO3  MAY  FORM    !!!!!       **

       HCO3(-) FREE =     849.011

       CA(2+) FREE  =       7.810          CACO3 SOLID  =       2.507
                                           --------------------------

  !!  CASO4 UNDER SATURATED & CA (9761814.1 MG/KG)100.% OFF SATURATION VALUE
!!

  !!  SRSO4 UNDER SATURATED & SR (******* MG/KG)100.0% OFF SATURATION VALUE
!!

  !!  BASO4 UNDER SATURATED & BA ( 464.9 MG/KG) 99.89% OFF SATURATION VALUE
!!

          *  NO SOLID SULFATES,  ONLY MGSO4 ION PAIRS  *

          SO4(2-) FREE =        .099

          MG(2+) FREE  =       1.202     MGSO4 PAIR   =        .001


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Appendix C:

Risk Assessment and Management Summaries

This appendix contains tabular summaries of risk assessments that have been undertaken for all environmental hazards associated with the Cooper Basin operations. Each table details information used to assess risk levels and the key management measures that are in place to manage risks.

Each table specifically outlines:

- the potential consequences of a hazard and an indication of the severity of their effect;
- the qualitative likelihood of occurrence;
- the level of assessed risk based on consequence and likelihood; and
- an outline of key risk management measures.

This appendix provides information required to qualitatively assess environmental risks and provides relevant background information for future review of risks and management priorities.

Table C-1: Injection of Water into Artesian Reservoirs

Risk Element	Details
Consequence	▪ Contamination of Aquifer
Management Strategies	Appropriate procedures and guidelines include: ▪ Frequent quality testing of injection waters ▪ Compatibility studies conducted prior to injection. ▪ Filtering of water to promote efficient injection into formation
Severity	**Negligible**
Likelihood	**Unlikely**
Level of Risk	**LOW**

Table C-2: Spill or leak associated with transportation of waters from the production facility to the water injection well

Risk Element	Details
Consequence	▪ Localised acidification and/or salinisation of soil. Given the nature of the receiving environment and low potential water volumes these consequences are considered unlikely.
Management Strategies	Appropriate procedures and guidelines include: ▪ New polypropylene pipeline tested to design conditions. ▪ Maintain register of spills/leaks ▪ Immediate clean-up and remediation
Severity	**Negligible**
Likelihood	**Unlikely**
Level of Risk	**LOW**

Table C-3: Spill of Waterflood Tracer

Risk Element	Details
Consequence	▪ Localised contamination of soil ▪ Danger to health and safety of employees and contractors
Management Strategies	Relevant procedures and guidelines include: ▪ Radiological Safety procedures conducted by specialists hired to conduct work. ▪ State controls on radiotracer substances followed. ▪ Conduct of regular inspections, and regular maintenance, follow specific operating procedures for working with tracers. Ensure individuals in areas of responsibility are trained to handle events. ▪ In the event of a spill or leak follow appropriate emergency response procedures
Severity	**Negligible**
Likelihood	**Unlikely**
Level of Risk	**Low**