14 September 2008

Companies Announcements Office  
Australian Stock Exchange Limited  
10th Floor, 20 Bond Street  
SYDNEY NSW 2000

Dear Sir/Madam

Evaluation of Geosequestration potential in offshore Sydney Basin

MEC Resources Limited (ASX: MMR) is pleased to advise that investee company Advent Energy Ltd (“Advent”) and has initiated discussions with Australian Government authorities regarding the Company’s evaluation of the geosequestration potential for its Petroleum Exploration Permit 11 (PEP11) in the offshore Sydney Basin.

Potential geological structures have been identified less than 50 km from Newcastle and Sydney, and a recent Carbon Dioxide Cooperative Research Centre (CO2CRC) paper has demonstrated the potential for geosequestration and has outlined the potential benefit to New South Wales and Australia if PEP11 should prove suitable for anthropogenic carbon dioxide underground storage.

A summary of the paper follows below (Appendix 1) for shareholders’ information, and it is recommended that the CO2CRC paper which is attached to this release (Appendix 2) should be read in full.

Yours Sincerely

David Breeze
Executive Director

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MEC is an exploration investment company and relies on the resource and ore reserve statements compiled by the companies in which it invests. All Mineral Resource and Reserve Statements have been previously published by the companies concerned. Summary data has been used. Unless otherwise stated all resource and reserve reporting complies with the relevant standards. Resources quoted in this report equal 100% of the resource and do not represent MEC’s investees’ equity share.
APPENDIX 1


Summary

The attached paper from the Carbon Dioxide Cooperative Research Centre (CO2CRC), extracts of which are summarised below, demonstrates the need and potential for geosequestration and the enormous benefit to New South Wales and Australia if PEP11 should prove suitable for storage of anthropogenic carbon dioxide underground storage.

Potential geological structures have been identified less than 50 km from Newcastle and Sydney.

APPENDIX 2


Introduction

- New South Wales has the largest concentration of anthropogenic carbon dioxide (CO₂) emission sources in Australia, including oil refineries, coke oven and power stations. Future emissions projections solely from stationary sources are in the order of 705 Billion cubic metres or 24.9 Tcf of CO₂ in the next twenty years (Bradshaw et al. 2002). The Sydney Basin region, in particular, contains the largest number of stationary CO₂ emission sources in Australia. Eleven major stationary sources of anthropogenic CO₂ within the Sydney Basin alone contribute 34% of the total national emissions.

Petroleum Exploration & Potential

- The Sydney Basin contains the necessary ingredients for hydrocarbon accumulations, namely abundant source and seal rocks, adequate thermal history, and untested traps.
- Triassic reservoirs are the primary exploration target in onshore and offshore areas.
- The main source kitchen areas are in the deeper parts of the Lake Macquarie Trough, Macdonald Trough, Offshore Syncline, and Newcastle Syncline.
- Seal potential is one of the least critical factors in defining prospectivity in the Sydney Basin as thick shaly units with the potential to act as seals occur throughout the Sydney Basin.

Geosequestration

- Fair to good reservoirs are present in the shallow Triassic succession.
- Several large structures are present within the Sydney Basin that may have potential as geological sequestration options.
- No dry structure potential storage sites have been evaluated in the Sydney Basin despite the potential for substantial underground storage capacity (1-2 Tcf of CO₂ in large offshore structures).
- The Kulnura Anticline has been assessed for its potential to sequester all stationary anthropogenic CO₂ sources in the Sydney Basin. This would equate to at least 1.1 Tcf a year for a period of at least 20 years (ie. ~22 Tcf).

Conclusions

- The Sydney Basin is a major contributor to Australia’s greenhouse gas emissions. There are several geological sequestration options in the Sydney Basin that could help reduce these emissions.
- There are several closed structures in the onshore and offshore basin with the capacity to sequester between 0.1-2 Tcf of CO₂.

The attached paper should be read in full.
New South Wales - Deep Saline Aquifer Storage Potential

Annette Patchett and Rob Langford

CO2CRC Report No: RPT05-0020
Innovative Carbon Technologies Pty Ltd (ICTPL)
The commercial arm of the CRC for Greenhouse Gas Technologies

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New South Wales - Deep Saline Aquifer Storage Potential

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NEW SOUTH WALES - DEEP SALINE AQUIFER STORAGE POTENTIAL

Annette Patchett and Rob Langford (Geoscience Australia)

June 2005

Introduction

New South Wales has the largest concentration of anthropogenic carbon dioxide (CO₂) emission sources in Australia, including oil refineries, coke oven and power stations. Future emissions projections solely from stationary sources are in the order of 705 Billion cubic metres or 24.9 Tcf of CO₂ in the next twenty years (Bradshaw et al. 2002). The Sydney Basin region, in particular, contains the largest number of stationary CO₂ emission sources in Australia. Eleven major stationary sources of anthropogenic CO₂ within the Sydney Basin alone contribute 34% of the total national emissions (Bradshaw et al. 2002).

Both the Sydney and Gunnedah Basins contain deep saline aquifers which have potential for CO₂ storage and which could help reduce these emissions. Each of these options, however, has potential associated limitations that will make geological sequestration difficult. This report aims to provide an assessment of the potential for storage in deep saline aquifers in the Sydney and Gunnedah Basins.

PART 1: SYDNEY BASIN

The Sydney Basin (Figure 1) is the southernmost of three interconnected sedimentary basins extending for approximately 2000 km N-S along eastern Australia and referred to as the Sydney-Gunnedah-Bowen Basin system. At present, the basin occupies an area of approximately 52,000 km² of which about 15,000 km² is located offshore. The basin also hosts a significant economic resource base as one of the largest coal provinces in the world.

Geology

The Sydney Basin is a Permo-Triassic foreland basin that developed in front of the accreting New England Fold Belt (Stewart and Alder, 1995). Foreland loading probably commenced during the Early Permian and continued through the Triassic (Alder et al., 1998). Compressional stresses have dominated throughout the evolution of the basin and resulted in many large thrust-related features such as the Kulnura Anticline, Lochinvar Anticline, Lapstone Monocline, and the Offshore Uplift (Figure 2). Normal faulting is common in the southern and western portions of the onshore basin, while compressional structures dominate the northern onshore basin with Late Permian age reverse and strike-slip faults often associated with hanging wall anticlines and thrust ramps (Stewart and Alder, 1995; Alder et al., 1998). The dominant structural style in the offshore Sydney Basin is compression involving thrusting or transpressional movements in the Permian-Triassic. Cretaceous Tasman Sea rift-related structuring is subordinate to that of the earlier compressional and wrench-related structuring (Alder et al., 1998).
Onshore sediments form a wedge which onlaps the southwest margin of the basin away from the severely deformed Hunter Valley area adjacent to the New England Fold Belt in the northeast (Santos, 1987). Early Permian sediments (Shoalhaven and Dalwood-Maitland Groups) are dominantly marine, Late Permian sediments (Late Permian Coal Measures) are regressive marginal marine to non-marine, and Triassic sediments (Narrabeen Group, Hawkesbury Sandstone and Wianamatta Group) are dominantly fluvial (Figure 3). Little is known about offshore sediments due to a lack of well data. Onshore sediments attain a maximum thickness of about 4000m, while offshore sediments are up to about 5000m thick (based on seismic data; Stewart and Alder, 1995). Quartz-rich sediments from the Early Permian and Middle Triassic sequences were sourced from Palaeozoic metasediments and granites of the Lachlan Fold Belt to the west. Lithic-rich sediments from the Late Permian coal measures were sourced primarily from metasediments, granites, and volcanics of the New England Fold Belt (Santos, 1987). Tasman Sea rifting in the Early Cretaceous probably resulted in epeirogenic uplift and erosion of 2-3km of Jurassic and Cretaceous strata which were originally deposited over the Permo-Triassic Sydney Basin (Grybowski, 1992).

**Petroleum Exploration & Potential**

The Sydney Basin contains the necessary ingredients for hydrocarbon accumulations, namely abundant source and seal rocks (Early Permian marine shales/siltstones and Late Permian Coal Measures), adequate thermal history, and untested traps (Hamilton and Galloway, 1989; Alder et al., 1998). However, petroleum exploration has been modest with only 115 petroleum wells (all onshore) and no discoveries of a conventional producing petroleum field (Stewart and Alder, 1995; Alder et al., 1998). Operations have concentrated on shallow horizons above 1000m (69% of wells), with only seven wells drilled below 2000m and two wells drilled below 3000m (Santos, 1987). Reservoir quality has historically been the primary concern for hydrocarbon exploration, owing to the widespread distribution throughout the Sydney Basin of lithic, diagenetically altered, clay-rich sandstones (Hamilton and Galloway, 1989; Bai et al., 2001). There have also been concerns that the Sydney Basin is gas-prone (Alder et al., 1998).

Unsustained gas flows have been recorded in 41% of wells drilled since 1910 (Stewart and Alder, 1995). Most gas shows and the best gas flows are concentrated in wells with total depths between 400-800m and represent shallow, low pressure accumulations in the Narrabeen Group sandstones (Santos, 1987). There have been no gas flows from wells deeper than 2000m (Santos, 1987). Average flow rates for onshore wells are between 20-80 Mcf/day (Santos, 1987). Initial flow rates of up to 4 MMcf/day have not been sustained due to permeability reduction by mobile clays within pore spaces (Santos, 1987). The highest open gas flow rate was 2.5 MMcf/day recorded from the Narrabeen Group sands at Camden 7 (Stewart and Alder, 1995). Gas flows of <1 MMcf/day have been recorded in three wells drilled into Late Permian coal measures (Alder et al., 1998). 57% of gas flows have been recorded in the Triassic Narrabeen Group, 20% in the Late Permian coal measures, and 23% from Early Permian sandstones (Santos, 1987). Oil has been found in every stratigraphic level (Alder et al., 1998). However, only unconfirmed oil seeps have been reported in the Terrigal, Picton, and Shellharbour regions (Santos, 1987).

Most exploration drilling has been concentrated on structural targets with no success to date due primarily to poor seismic definition of structures (Stewart and Alder, 1995). Triassic reservoirs are the primary exploration target in onshore and offshore areas
(Grybowski, 1992). The main source kitchen areas are in the deeper parts of the Lake Macquarie Trough, Macdonald Trough, Offshore Syncline, and Newcastle Syncline (Santos, 1987; Alder et al., 1998). Seal potential is one of the least critical factors to defining prospectivity in the Sydney Basin as thick shaly units with the potential to act as seals occur throughout the Sydney Basin (Santos, 1987; Stewart and Alder, 1995). It is generally assumed that maturation and migration began relatively early and hence early structures are favoured as hydrocarbon traps (Stewart and Alder, 1995). Structural traps are believed to be widespread with Late Permian and Late Triassic anticlines and fault traps combined with Tertiary rejuvenation of older structures thought to be the major plays (Stewart and Alder, 1995). The Sydney Basin reached its maximum maturity level by the Early Cretaceous, and thus any structures which trapped hydrocarbons at that time would need to have retained their charge during subsequent epeirogenic uplift associated with Tasman Sea rifting to be prospective (Grybowski, 1992).

**Natural Carbon Dioxide Sources**

Currently, there are no conventional gas production fields in the Sydney Basin. Carbon dioxide can form a major component to gas reservoirs in the Sydney Basin, with concentrations up to 30.8% encountered in Narrabeen Group sandstones at Camden 11 (Stewart and Alder, 1995). Carbon dioxide has also form a significant component of Permian coal seam gas as demonstrated by Faiz and Hutton (1997). Most of the CO₂ has been derived from intermittent magmatic activity between the Triassic and Tertiary. This gas has subsequently migrated, mainly in solution, towards structural highs and accumulated in anticlines and near sealed faults.

It is therefore possible that at some stage in the future a high CO₂ gas field will be discovered and will require a geological sequestration option. The Sydney Basin is also the largest source of anthropogenic CO₂ in Australia, with ~21.9 Tcf of CO₂ anticipated from point sources (coal-fired power plants, oil refineries, and coke ovens) in the next 20 years. If the technology develops to separate CO₂ from these point sources, then a suitable geological sequestration option may soon be required in the basin to sequester these large anthropogenic CO₂ emissions.

**DEEP SALINE FORMATION SEQUESTRATION POTENTIAL**

**Diagenesis, Thermal & Burial History**

The Sydney Basin is a diagenetically complex basin sequence (Bai et al., 2001). Surface vitrinite reflectance increases from the north-west to the south-east Sydney Basin from approximately 0.6 in the north-west of the basin to 1 in the south-east where peak surface vitrinite reflectance occurs on the coast between Sydney and Wollongong (Figure 4). Such high surface values suggest either a strong heat source or deeper burial along the eastern margin of the basin. The surface vitrinite reflectance map further provides an indication of the areas of greatest erosion as more deeply buried rocks will have a greater coal rank (Middleton and Schmidt, 1982).

Reservoir potential has historically been a major concern owing to distribution of lithic, diagenetically-altered, clay-rich sandstones throughout the basin sequence. In north-eastern sediments, a combination of authigenic clay formation, grain suturing and quartz and carbonate cementation has eliminated virtually all primary porosity. Although
dissolution of feldspar, rock fragments and carbonate cements has led to the formation of some secondary porosity, these secondary pores have a scattered distribution which significantly reduces permeability.

Diagenesis has also been influenced significantly by sustained replenishment of meteoric waters. Continual flushing of meteoric water during burial encouraged extensive carbonate cement formation and dissolution. Subsequent rapid subsidence and associated temperature increase resulted in the development of quartz overgrowths and filamentous illite, with late dawsonite crystallisation following Tertiary magmatism (Baker et al., 1995).

K-Ar ages for authigenic clays in Narrabeen Group sandstones suggest that clay formation continued at greater depths and higher temperatures to the east of the basin, thus reducing primary porosity and in turn reservoir quality. This is also consistent with an increase in thermal/organic maturity towards the east (Bai et al., 2001). Fluid inclusion temperatures and thermal modelling from organic maturity also suggest that upwards of 1500m of section was eroded from the Sydney Basin during the mid-Cretaceous (Middleton and Schmidt, 1982; Faiz and Hutton, 1997).

Bai et al., (2001) modelled vitrinite reflectance as a maturity parameter to estimate maximum palaeotemperatures for the Sydney Basin, which are predicted to have been between 130° and 180°C across the basin. This suggests that palaeotemperatures in the Sydney Basin were approximately 80° to 110°C higher than the present day, reaching a maximum during the mid-Cretaceous, indicating greater burial and possible higher heat flow in the past. Figure 5 shows a burial and temperature history model for the Narrabeen Group and Illawarra Coal Measures for the Weromba-1 well. The model provides a general representation of the basin as heat flow and sediment thickness, both deposited and eroded, are variable across the basin. The model suggests that between 1.5 and 2 km of sediment has been eroded from the Sydney Basin, resulting in a marked decrease in temperature.

The burial history of the Sydney Basin presented herein is also consistent with currently preserved sedimentary sections, high vitrinite reflectance values in surface rocks (Figure 4) and fluid inclusion temperatures which are much higher than at present. Furthermore, the model is commensurate with magmatic overprinting common to many rock units across south-eastern Australia. Stabilisation of the overprint magnetisations has been attributed to rapid uplift and cooling at approximately 100 to 90 Ma and this is associated with the onset of rifting prior to sea floor spreading in the Tasman Sea (Bai et al., 2001).

Reservoirs

The Sydney Basin is a sand-rich repository in which much of the sandstone is at or below the threshold porosity and permeability values, generally regarded for conventional gas production (0.5-1.0 mD; Hamilton and Galloway, 1989). Reservoir units include fluvial sandstones of the Narrabeen Group, fluvial-deltaic coal sandstones from the Late Permian coal measures, and marine shoreline and shelf sandstones from the Early Permian Shoalhaven Group (Stewart and Alder, 1995). Little is known about the sub-surface distribution of these reservoirs (Stewart and Alder, 1995). Fair to good reservoirs are present in the shallow Triassic succession, while poor to fair porosities characterise Permian sandstones (Santos, 1987).
<table>
<thead>
<tr>
<th>Group</th>
<th>Age</th>
<th>Porosity (%)</th>
<th>Permeability (md)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrabeen Group</td>
<td>Early Triassic</td>
<td>3.82-19.4</td>
<td>0-4.7</td>
</tr>
<tr>
<td>Tomago Coal Measures</td>
<td>Late Permian</td>
<td>14 to 15</td>
<td>negligible</td>
</tr>
<tr>
<td>Cumberland Coal Measures</td>
<td>Late Permian</td>
<td>7 to 13</td>
<td>negligible</td>
</tr>
<tr>
<td>Illawarra Coal Measures</td>
<td>Late Permian</td>
<td>~16 (up to 36)</td>
<td>negligible</td>
</tr>
<tr>
<td>Capertee Group</td>
<td>Permian</td>
<td>6 to 10.5</td>
<td>0-5</td>
</tr>
<tr>
<td>Shoalhaven Group</td>
<td>Permian</td>
<td>1-12.2</td>
<td>0-12.9</td>
</tr>
<tr>
<td>Maitland Group</td>
<td>Early Permian</td>
<td>4 to 13</td>
<td>0 to 2.9</td>
</tr>
<tr>
<td>Greta Coal Measures</td>
<td>Early Permian</td>
<td>0.5 to 8.7</td>
<td>0 to 2.9</td>
</tr>
<tr>
<td>Dalwood Group</td>
<td>Early Permian</td>
<td>2.5 to 13</td>
<td>0 to 0.33</td>
</tr>
</tbody>
</table>

Table 1: Porosity and permeability data for the major units within the Sydney Basin (below 800m only). Data has been compiled from selected well completion reports.

**Narrabeen Group**

Hamilton and Galloway have shown that improved reservoir quality occurs in the shallow Triassic Narrabeen Group where sandstones are quartz-rich (>80% quartz), are medium- to coarse-grained, and have a mixture of remnant intergranular and leached secondary porosity. Best reservoir quality occurs in the quartzo-feldspathic sandstones of the Narrabeen Group in the south-western part of the basin. Potential reservoir sandstones are up to 20m thick, have permeabilities of 0-1330 mD and porosities of up to 19.4% (Table 1). However, Triassic reservoirs occur at depths <1000m and are the primary onshore exploration target. They are thus unsuitable for the geological sequestration of CO₂.

**Late Permian Coal Measures**

Late Permian sandstones experienced early diagenesis and are heavily cemented by authigenic chlorite, chlorite-smectite mixed layer clay, smectite, laumontite, and carbonate associations (Arditto, 1987). The high content of feldspar, volcanolithics, detrital clays, and abundant tuffs in the Late Permian coal measures has resulted in matrix-choked porosity and generally poor permeability (Grybowski, 1992). Notable quartzo-feldspathic sandstones with good reservoir potential occur as inter-seam units within Late Permian Coal Measures including the Tomago, Illawarra and Cumberland coal measures (Arditto, 1987). Late Permian coal measure sandstones are generally lithic-rich with porosities of up to 16% and negligible permeability (Stewart and Alder, 1995).

**Maitland Group**

The Maitland Group and equivalents contains several reworked clean quartzo-feldspathic sandstones including the laterally equivalent Murrumurra/Nowra Sandstones, the Cessnock Sandstone and the Snapper Point Formation (Stewart and Alder, 1995). The Nowra Sandstone is composed of a lower seaward thickening regressive sequence dominated by sandy, high energy shelf and offshore shoal sands, and an upper westward thickening transgressive sequence of nearshore and shoreface sands (Le Roux and Jones, 1994). It is dominated by quartz-rich, medium-grained sandstones with lateral lithofacies changes occurring over short distances.
Below 800m, the Nowra Sandstone has up to 12.2% porosity and permeabilities from 0-12.9 mD (Le Roux and Jones, 1994). Quartz and carbonates dominate sediments within the Shoalhaven and Maitland Groups, reducing the primary and secondary porosity of potential reservoir rocks (Figure 6). Diagenetic change results in silification and the formation of quartz overgrowths and pressure welding of quartz. Another diagenetic feature is the growth of authigenic crystals of calcite, dawsonite, and dolomite which has obliterated the primary porosity (Ozimic, 1979). Overall, Maitland Group sands have porosities from 4% to 13% and 0-2.9 mD permeabilities, while Shoalhaven Group sediments have porosities between 1% and 12.2% and permeabilities of 0-12.9 mD.

**Dry Structures**

Several large structures are present within the Sydney Basin that may have potential as geological sequestration options. Ozimic (1979) studied the potential for apparently dry onshore structures to store natural gas in Early Permian reservoirs from the Nowra/Muree Sandstones, and the Snapper Point Formation (Figure 7). These included the Stockyard Mountain and Woronora Structures in the southern Sydney Basin, and the Mulgoa, Dural South, Kurrajong Heights, and East Maitland Structures in the central and northern Sydney Basin. Of these, only Dural South and Stockyard Mountain have fault independent closure, the others being fault-bounded anticlines. Ozimic’s study was based on poor quality seismic data, and he notes having some reservations in calculations based on such data. It is thus possible that many of the structures will have less gas storage capacity than calculated by Ozimic (1979), and that they may not represent tested structures. Nevertheless, Ozimic’s gas storage data is still a useful indication of the degree to which structures in the onshore Sydney Basin may be able to store CO₂.

Ozimic’s (1979) gas storage capacity calculations were converted into potential CO₂ storage capacity by determining the compressibility of CO₂ vs natural gas at each structure. The results suggest that there are three structures with a potential to sequester moderate volumes of CO₂ (0.1-1 Tcf); Dural South, East Maitland and Kurrajong Heights. East Maitland and Kurrajong Heights will be risky options though given that they have fault-dependant closure. Dural South appears to be a good option for any moderate scale CO₂ emissions based on Ozimic’s calculations. However, remapping of the Dural South structure by AGL (1992) using modern seismic data shows that it may be a smaller structure than originally thought (8km² with 50m vertical closure at the top of Late Permian Coal Measures level, as opposed to the original estimates of 45.4km², with 148.2m of vertical closure at the top Nowra Sandstone level). Thus, the Dural South structure probably has a CO₂ storage capacity in the order of 100 Bcf. This storage capacity could probably be increased by including the Late Permian Marangaroo Conglomerate as an additional reservoir. However, remapping of the Dural South structure also shows that previous wells were drilled off structure and possibly intersected an oil-water contact. Thus there is the risk that Dural South is an untested hydrocarbon trap.

AGL (1992) have mapped several other previously unrecognised closed anticlines along the trend of the Kulmura Anticline. These include the Fiddletown Anticline, Mount Colah Dome, and the Canoealands Dome. No wells have been drilled on any of these structures. The Fiddletown Anticline and Mount Colah Dome are of similar size to Dural South and are also likely to have a storage capacity in the order of 100 Bcf each. However, the Canoealands Dome is a large structure with 40km² of aerial closure and
30m of vertical closure at the top of Late Permian Coal Measures level, which may have potential for ~0.5 Tcf of CO₂.

Ozimic (1979) also calculated the potential gas flow rate from the underground reservoirs. These range from 1.5-9.0 MMcf/day, with Dural South flowing gas at 4.6 MMcf/day. Ozimic (1979) notes that gas flow rates could be improved by up to 14% by using acidisation or by overpressuring the reservoir (Ozimic, 1979). However, it is unlikely that gas could be pumped into these reservoirs at a much faster rate as this would risk exceeding lithostatic pressure and thus fracturing the seal. Assuming that injection rates of up to 10 MMcf/day per well are possible, then each structure will require about 16 injection wells to meet the supply rates of a single CO₂ source such as a coal-fired power plant.

No dry structure potential storage sites have been evaluated in the Sydney Basin despite the potential for substantial underground storage capacity (1-2 Tcf of CO₂ in large offshore structures). This is largely because to date exploration drilling has not tested any of these large structures. The high potential to compromise petroleum resources would prevent these structures from being current sequestration option. The structures also need to be better defined through seismic surveys and exploration drilling to ensure potential reservoir and seal rocks are present, and to verify that closure occurs.

Hydrodynamic Traps
The Sydney Basin contains several sandy intervals overlain by thick regional seals. Sealed reservoir intervals are particularly common in Early Permian marine strata from the Shoalhaven and Mailland Groups. The geometry of the onshore Sydney Basin favours groundwater recharge around the elevated southern, western, and northern margins that should subsequently flow into the deeper and thicker central basin area. The Kulnura Anticline is a large structural high within the central basin area that has the potential to be a zone of hydrodynamic trapping.

The Kulnura Anticline has been assessed for its potential to sequester all stationary anthropogenic CO₂ sources in the Sydney Basin. This would equate to at least 1.1 Tcf a year for a period of at least 20 years (i.e. ~22 Tcf). Only one reservoir interval, the Nowra Sandstone and equivalent Muree Sandstone, was used in the storage capacity calculations. Ozimic (1979) has previously investigated the potential of this stratigraphic interval for underground gas storage in the Kulnura Anticline region. His research shows that there is a net clean sand thickness of 16.6m at Dural South and an average porosity of 6.5%. The Kulnura Anticline is a large structure covering and area of about 1,010km², which helps offset the low porosity and moderate thickness of the reservoir interval. The potential storage capacity of the Nowra/Muree Sandstone over the Kulnura Anticline is calculated at 16.8 Tcf, less than half that required if all CO₂ emissions are to be sequestered. However, it will probably not be possible to capture all these CO₂ emissions, and a capacity of 14.3 Tcf should make a significant impact of Sydney’s greenhouse gas emissions.

The deeper Snapper Point Formation is not proposed for CO₂ storage as drilling at Dural South 1 shows it has poor reservoir quality in this area. Younger reservoirs from the Late Permian Coal Measures may help to increase the storage capacity of the Kulnura Anticline, particularly the quartzose Maranaroo Conglomerate and Thirroul Sandstone. However, these are also considered prospective strata in the Kulnura Anticline area. Higher quality reservoirs in the Triassic Narrabeen Group are not a viable sequestration
option as they are too shallow (<1000m) to store CO₂ in a supercritical state, and are the primary petroleum exploration target in the onshore Sydney Basin.

Injectivity is a major concern for the Kulnura Anticline (and indeed any geological sequestration option in the Sydney Basin), due largely to the likelihood of problems with injection wells meeting supply demands. The Nowra/Muree Sandstone contains extensively reworked, medium-grained, quartz-rich sands which should favour high reservoir quality. However, the reservoir quality is only fair to poor due to silicification and pressure welding of quartz grains which reduces permeability to an average of only 6.7 mD with a maximum of 23 mD. Ozimic (1979) calculated the potential gas flow rate from pressurised gas storage reservoirs in the Nowra/Muree Sandstone at 4.6 MMcf/day per well at Dural South. This rate could be improved by up to 14 % by dissolving carbonate cements present in some sands (Ozimic, 1979). However, given that CO₂ would be supplied at a rate of ~3000 MMcf/day from all CO₂ point sources in the Sydney Basin, then even a relatively high injection rate of 10 MMcf/day will require about 300 injection wells.

Containment is another key concern for the Kulnura Anticline. The structure should favour hydrodynamic trapping of CO₂ by groundwater flowing from the southern, western, and northern basin margins. Trapping of CO₂ should also be favoured by several closed structures that occur along the trend of the Kulnura Anticline (Dural South, Fiddletown Anticline, Mt Colah Dome, and Canoelands Dome), and the very thick regional seal formed by marine siltstones and shales within the Berry Formation and equivalent Mulbring Siltstone. Migration rates within the reservoirs are likely to be low given their low permeability and it will take a considerable time for the CO₂ to migrate away from the storage injection site. However, major fault systems with several hundred metres of throw have been mapped to the west of the Kulnura Anticline. There are also several faults possibly associated with the Kulnura Anticline, which form a series of wrench-related en-echelon anticlines (AGL, 1992). Thus there is the potential for fault breaches within or adjacent to the storage site. The Sydney Basin is a densely populated area and any potential for escape of CO₂ would be unacceptable. It will be necessary for the risk of fault breaches to be comprehensively evaluated before this could be considered a viable sequestration option.

Onshore exploration is focussed on shallow reservoirs (<800m), particularly within sandstones from the Triassic age Narrabeen Group. To date there has been no gas flows or oil shows from reservoirs drilled below 2000m. Given that the Nowra/Muree Sandstone interval is at depths of 2151-2180m, there is very little possibility that this would be considered a prospective interval. This potential storage option is also well beyond present and future depths for coal exploration (700-1000m), and thus will not be a risk to coal resources. Formation waters in the Nowra/Muree Sandstone have salinities of 30000 ppm, which is classified as saline and unlikely to be considered a groundwater resource in the Sydney Basin. As such, there is little if any potential for contamination of any existing resources.

In terms of location, the Kulnura Anticline is well placed for sequestering CO₂ as it is central to CO₂ sources that are concentrated in Wollongong, Sydney, Newcastle and Maitland. There is also existing right of way for gas pipelines. Although there are significant concerns with injectivity and containment of CO₂, this is probably the best geological sequestration option given the current state of knowledge of the Sydney Basin. Injectivity and containment may be improved through further detailed mapping.
of reservoirs, seals and faults based on deep drilling and high quality seismic data from the Kulnura Anticline.
NORTH-WEST SYDNEY BASIN

The north-west Sydney Basin has a relatively low thermal maturity compared with the remainder of the Sydney Basin, possibly indicative of either shallower depths of burial and therefore lower diagenetic alteration (which decreases permeability and porosity) than occurred across the rest of the basin. Furthermore, meteoric waters entering the basin may have acted to enhance porosity thereby improving the quality of potential reservoir intervals. Consequently, the north-west part of the basin was investigated for its deep saline aquifer CO₂ storage potential.

In the southern Sydney Basin, thermal maturity increases significantly where surface vitrinite reflectance values increase to Rₐ>1.0 between Sydney and Wollongong (Figure 4). Potential reservoir intervals in this area are also located at significant depth. Consequently these diagnostically complex horizons are of poor reservoir quality and therefore probably unsuitable for CO₂ storage.

The Hunter and Newcastle regions in the northern Sydney Basin are structurally complex, having experienced recent tectonic activity, particularly along bedding-plane faults and fractures where coal acts as bedding-plane “lubricant”. Furthermore, shallow coals in both regions are under-saturated with methane indicating that gas has escaped from these coal seams. These areas were therefore both overlooked as they are considered geomechanically unstable and therefore not suitable for CO₂ storage (Brad Mullard pers comm., 2005).

NW Sydney Basin

The north-west Sydney Basin focus area lies to the west of the Muswellbrook Anticline and north-northeast of Lithgow. The sedimentary succession thickens significantly towards the east/north-east against the Hunter-Mooki Thrust. National Parks occupies a large proportion of the area, and a thick pile of Tertiary volcanics of the Liverpool Range form the northern boundary of the focus area.

Permian marine sands are the primary target interval for this assessment of potential CO₂ storage sites. Publicly available deep drilling data for the NW Sydney Basin is extremely limited. The majority of wells in the area have a total depth of less than 800m, having been drilled largely for CSM exploration. As such, these wells do not contain the relevant information necessary for a detailed study on deep saline aquifers.

<table>
<thead>
<tr>
<th>Well</th>
<th>Tertiary Volcanics</th>
<th>Narabeen Group</th>
<th>Wollombi C.M.</th>
<th>Wittingham C.M.</th>
<th>Maitland Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Dunlop 1</td>
<td>0 - 98.8</td>
<td>98.8 - 664.3</td>
<td>664.3 - 782.3</td>
<td>782.3 - 1093.8</td>
<td>-</td>
</tr>
<tr>
<td>Doolans Creek 1</td>
<td>-</td>
<td>0-329.04</td>
<td>329.04 - 449.02</td>
<td>449.02 - 859.37</td>
<td>859.37 - 946.59</td>
</tr>
<tr>
<td>Wybong 1</td>
<td>-</td>
<td>0 - 56.4</td>
<td>56.4 - 307.4</td>
<td>307.4 - 763.43</td>
<td>-</td>
</tr>
<tr>
<td>Goulburn River 1</td>
<td>-</td>
<td>-</td>
<td>0 - 106.7</td>
<td>106.7 - 610.1</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2: Depth intervals for major units in the NW Sydney Basin based on available well data.
Table 2 summarises the geological units and the depth intervals at which they occur across the area, collated from the available well data. All wells intersected Early Triassic Narrabeen Group sediments and the Late Permian Wollombi and Wittingham Coal Measures, except Goulburn River 1 in which the Narrabeen Group is notably absent. Doolans Creek 1 is the only well to have intersected Maitland Group sediments, although the well was terminated within the Mulbring Siltstone and did not penetrate either the Muree Sandstone or Branxton Formation, which were the main stratigraphic intervals of interest.
PART 2: GUNNEDAH BASIN

The Gunnedah Basin is located in north-eastern New South Wales, linking the Sydney Basin in the south with the Bowen Basin in the north. The Gunnedah Basin is located 300 km from CO₂ point sources and gas markets in the Sydney Basin (Figure 1). The proposed Dubbo-Tamworth gas pipeline will potentially connect the basin to these CO₂ sources and markets, and consequently it may have potential to sequester some of the large CO₂ emissions within the neighbouring Sydney Basin.

Geology
The Gunnedah Basin is bounded in the east along the Hunter-Mooki Fault System by the New England Fold Belt and to the west by an unconformable contact with the Lachlan Fold Belt. Much of the northern part of the basin is continuous with that of the Bowen Basin and lies unconformably beneath the thick Jurassic sediments of the Surat Basin, part of the Great Artesian Basin sequence. The basin is divided into the West Gunnedah Sub-basin and the Maules Creek Sub-basin (Figure 9) separated by the northerly trending Boggabri Ridge (Stewart and Alder, 1995).

The Gunnedah Basin contains up to about 1200m of marine and non-marine Permian-Triassic sediments overlying Early Permian volcanics and unconformably overlying the Palaeozoic Lachlan Fold Belt. The stratigraphy of the basin (Figure 8) has been reviewed and described in detail by a number of authors (Hamilton et al., 1989; Tadros, 1993; Stewart and Alder, 1995) and has been summarised below.

The Permian Gunnedah Basin sequence contains Early to Late Permian coal measures, which form a significant coal resource. The Early Permian Maules Creek Formation is up to 800m thick and comprises lithic granule to pebble conglomerate, lithic and quartzose sandstone, siltstone and claystone, and numerous coal seams (some of which are up to 8m thick). The Late Permian coal measures, the fluvio-deltaic Black Jack Formation, comprises up to 470m of lithic conglomerate and sandstone, quartzose sandstone, siltstone, claystone, tuff and several coal seams.

The upper and lower coal measures are separated by a Late Permian marine sequence, the Porcupine and Watermark Formations, which generally conformably overlie the lower coal measures. The Upper Watermark Formation combines pro-delta and delta front sediments and together these form the basis of the major delta system in the lower part of the overlying Black Jack Formation.

The Triassic Gunnedah Basin sequence rests unconformably atop the Permian Black Jack Formation, with exception to the eastern and western margins where it overlies basement. The Digby Formation comprises fluvial lithic and quartz conglomerates, sandstones and minor finer grained sediments and is overlain conformably by the Napperby Formation. The thinly bedded claystone, siltstone and sandstones of the Napperby Formation represent the upper limit of the Gunnedah Basin sequence and can be correlated with the Hawkesbury Sandstone of the Sydney Basin.
Deep saline aquifer storage potential

The Gunnedah Basin has very limited potential to store CO$_2$ in deep saline aquifers due to the shallow nature of the basin succession. Potential storage reservoirs for CO$_2$ at a supercritical level, i.e. below 800m, are essentially restricted to minor areas in the basin (refer to Figure 10). Alluvial sandstones within the Maules Creek Formation are the main target storage interval. Recent drilling, however, has discovered economic conventional gas within this formation in a series of high relief anticlines (Morton, 2003). Considering the current state of exploration and development in this region, storage of CO$_2$ within the Maules Creek Formation would potentially compromise the existing natural resource. Recent drilling results in the Bohena Trough area suggest that the gas accumulations and potential storage capacity may also be somewhat limited.

CONCLUSIONS

The Sydney Basin is a major contributor to Australia’s greenhouse gas emissions. There are several geological sequestration options in the Sydney Basin that could help reduce these emissions once the technology develops to strip CO$_2$ from point sources such as power plants and industrial users. However, each of these options has potential limitations that will make geological sequestration difficult.

There are several closed structures in the onshore and offshore basin with the capacity to sequester between 0.1-2 Tcf of CO$_2$. However, to date none of these structures has been tested with most previous wells drilled off structure, and many structures still to be drilled. This option is thus on hold until structures are shown to be valid but dry structures by subsequent drilling.

The best current geological sequestration option is to hydrodynamically trap CO$_2$ beneath the large Kulnura Anticline structure located in the central onshore basin. This is the only option that can realistically have an impact on the large CO$_2$ emissions produced each year from the Sydney Basin. However, it is limited by uncertainty about the presence of fault breaches and the low permeability of reservoirs.

Current drill hole data limitations for Gunnedah and north-western Sydney Basin indicates that a complete assessment of the CO$_2$ storage potential is unknown. However, regional geological considerations, particularly diagenesis, suggest that the potential is low. In addition, conflict with existing and future urban development and national parks severely limits areas that are potential available for CO$_2$ storage.

The Gunnedah Basin has very limited potential to store CO$_2$ in deep saline formations due to the shallow nature of the basin succession. Recent economic conventional gas discoveries within the deepest part of the basin have further limited the storage potential of the basin.
Figure 1: The Sydney and Gunnedah Basins, NSW (from Stewart and Alder, 1995).
Figure 2: Structural elements of the Sydney Basin, includes the Kulnura Anticline, Lochinvar Anticline, Lapstone Monocline and the Offshore Uplift (from Stewart and Alder, 1995).
Figure 3: Chronostratigraphic table for the Sydney Basin (from Maung et al., 1997).
Figure 4: Contours of vitrinite reflectance for the surface of the Sydney Basin (from Middleton and Schmidt, 1989).
Figure 5: Model curves for (a) burial and (b) temperature history for the southern central Sydney Basin (after Bai et al., 2001).
Figure 6: Core plug permeabilities cross plot for the Nowra Sandstone from seven exploration wells. Although there are a few points with permeabilities between 1 and 5 mD, most are below 1 mD with porosities between 5% and 11% (from Arditto, 2001).
Figure 7: Potential dry structures suitable for subsurface gas storage in the Sydney Basin as identified by Ozimic (1979).
Figure 8: Stratigraphy of the Gunnedah Basin (modified from Tadros, 1993).
Figure 9: Structural elements of the Gunnedah Basin (after Stewart and Alder, 1995).
Figure 10: Cross sections of the Gunnedah Basin trending (a) north-south and (b) west-east (modified from Hamilton et al., 1989). Refer to Figure 9 for location of cross sections.
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