Geological Studies for Predicting Artesian Dewatering Requirements at Loy Yang Open Cut, Latrobe Valley, Victoria, Australia

By P. BOLGER[1] and J. BRUMLEY[1]

Coal Resources Division
Fuel Department
State Electricity Commission of Victoria
15 William Street, Melbourne, Victoria, 3000
Australia

ABSTRACT

The development of the SECV brown coal open cut at Loy Yang will require depressurisation of aquifers both within and below the coal seam sequence in order to maintain open cut stability.

Prediction of future open cut dewatering requirements at Loy Yang Open Cut and evaluation of the regional consequences of dewatering has required development of a detailed hydrogeological model of the Loy Yang area. The complex stratigraphy of the coal seam and aquifer/aquitard sequences at Loy Yang have been analysed and integrated with the hydrogeological concepts developed from regional groundwater studies to formulate a realistic hydrogeological model as a basis for finite-element flow modelling.

INTRODUCTION

The Latrobe Valley mining operations at Morwell, Loy Yang and Yallourn (Figure 1) are based on one of the world's largest brown coal deposits from which approximately 80% of Victoria's power is generated by the State Electricity Commission of Victoria (SECV).

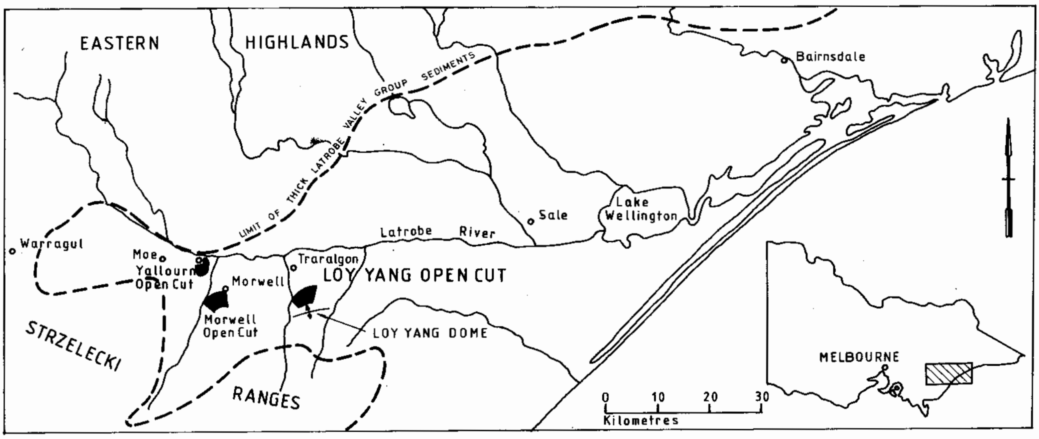

Figure 1 : Locality Map for Latrobe Valley Mining Operations at Morwell, Loy Yang and Yallourn

The available economic coal resources of the Gippsland Basin are estimated at some 65 000 Mt (Framework for the Future, 1987) of which some 32 000 Mt could be conveniently mined from conceptual open cuts (Kinhill 1987). Annual production is currently about 41 Mt and a total of some 970 Mt has been mined since the deposits were first worked in 1888 (Barton, 1988 in press).

Loy Yang Power Station is designed for an ultimate capacity of 4000 MW. The Loy Yang Open Cut (LYOC) is currently producing up to 18 Mt of coal per annum to supply the 4-unit 2000 MW Loy Yang A Power Station. A further 2 x 500 MW units are being constructed and completion of the final 2 x 500 MW units is recommended by a Parliamentary Natural Resources and Environment Committee Inquiry. The volume of coal required for the full 4000 MW development over a 30-year life is some 1050 Mt.

The Latrobe Valley coal seams occur within a thick (up to 770 m) Tertiary Sequence of clays, silts, sands and some basalt flows known as the Latrobe Valley Group (Gloe 1976, Hocking 1976). The economic importance of the coal deposits is due mainly to their proximity to Melbourne (approx 140 km), the low overburden to coal ratio in the mining areas (usually less than 1:5), the thick and extensive nature of the coal seams, the remarkably low ash content (less than 5%, dry basis) and the nature of the coal, overburden and interseam sediments which allow mining by bucket wheel excavators without the need for blasting. These attributes are offset to some degree by a relatively high moisture content, usually in the range of 53 to 67%, with a correspondingly low net wet specific energy of about 6.5 to 10.2 MJ/kg. In addition, there is the necessity to control high groundwater pressures in the confined aquifers beneath the coal seams to maintain stability of the base and batters of the open cuts.

Artesian pressure relief at Morwell Open Cut (MOC) has yielded a total of some 537 Gl over 27 years since pumping began in 1960. This amounts to 1.8 tonnes of water for every tonne of coal mined. Aquifer pressures have been reduced for up to some 50 km and regional subsidence is recorded up to 25 km from the open cut. Major artesian dewatering will also be required at LYOC and similar regional consequences are expected. The total rate at which artesian water will be pumped from both LYOC and MOC is expected to plateau at around 35 to 40 Gl per annum in the early 2000s.

The good quality artesian water is an important component of the SECV's water requirements, supplying approximately 16% of the annual consumption of some 140 Gl. Improved water management practices and the retirement of older less water efficient generating plant has reduced the nett water usage to around 23 Gl per annum per 1000 MW of electricity generating capacity.

The hydrogeology of the Loy Yang area is complex and presents a major challenge to the successful development of the open cut. This paper describes the hydrogeological modelling studies for LYOC with an emphasis on the stratigraphic basis for the model and the hydrogeological concepts involved.

REGIONAL HYDROGEOLOGICAL FACTORS

Since 1959 when heave in the floor of MOC was first noted, data has been steadily acquired to allow significant advances in understanding the major hydrogeological factors controlling groundwater behaviour in the Latrobe Valley. The information is mainly derived from regional stratigraphic drilling and from comprehensive Latrobe Valley groundwater and subsidence monitoring programs.

The first major advance was the recognition in the late 1960's that as well as dewatering the aquifer beneath the upper Morwell 1 coal seam, another extensive aquifer below the Morwell 2 coal seam existed which also needed dewatering. Currently, about 90% of the water extracted from MOC is derived from this deeper aquifer sequence and regional aquifer drawdowns up to 50 km to the east are documented.

Based on regional stratigraphic studies and detailed monitoring of regional aquifer pressures, it became possible in the early 1980's to delineate two major confined aquifer systems within the Morwell and the Traralgon Formations of the Latrobe Valley Group as shown in Figure 2 (Brumley and Reid, 1982). The systems are referred to as the Morwell Formation Aquifer System (MFAS) and the Traralgon Formation Aquifer System (TFAS). Delineation of the two confined aquifer systems is recognised as an idealised concept because leakage between the aquifer systems will occur at varying rates depending on the local stratigraphy and stress condition. For instance, leakage between the aquifers at MOC caused about 40 m reduction in the level of the deeper aquifer prior to direct extraction from this aquifer (Brumley et al 1981).

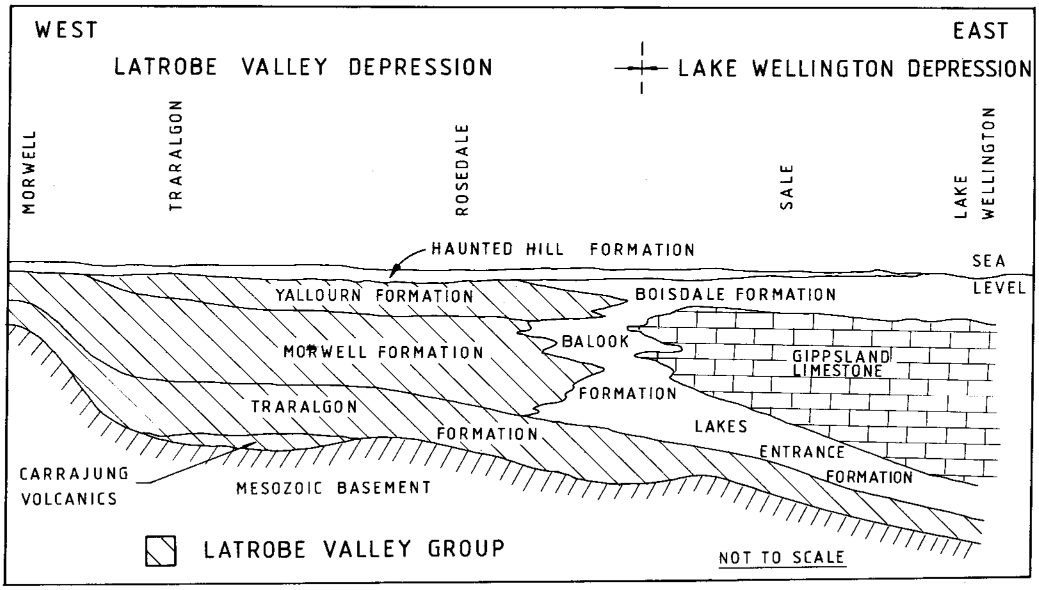

Figure 2 : Simplified E-W Geological Section of the Latrobe Valley

To establish a realistic hydrogeological model for the Latrobe Valley, it was necessary to establish a water balance model for water extracted from MOC. The relative proportion of water derived from recharge, from the aquifers and from the aquitards needed to be known. By attributing approximately 90% of the volume of regional subsidence to the yield from consolidation of the aquitards, Brumley and Reid (1982) demonstrated that aquitard yield represents approximately 30% of the total volume extracted from MOC. The concept was extended by Evans (1986) to show a linear relationship between subsidence and pumpage with time (Figure 3). On this basis, only 2/3 flow in the aquifers is used for mathematical model study predictions of aquifer drawdowns. The contribution from recharge was estimated by Brumley and Reid (1982) and refined by Evans (1986), by calculating a "potentiometric yield" from the aquifer sequence and deducting this volume together with the aquitard yield from the total volume extracted. The balance of approximately 45% of the water extracted was attributed to recharge and substantiated by field identification of recharge areas (Brumley et al 1981). These hydrogeological factors formed the basis for the regional mathematical model studies by Evans (1986) and Bolger (1987).

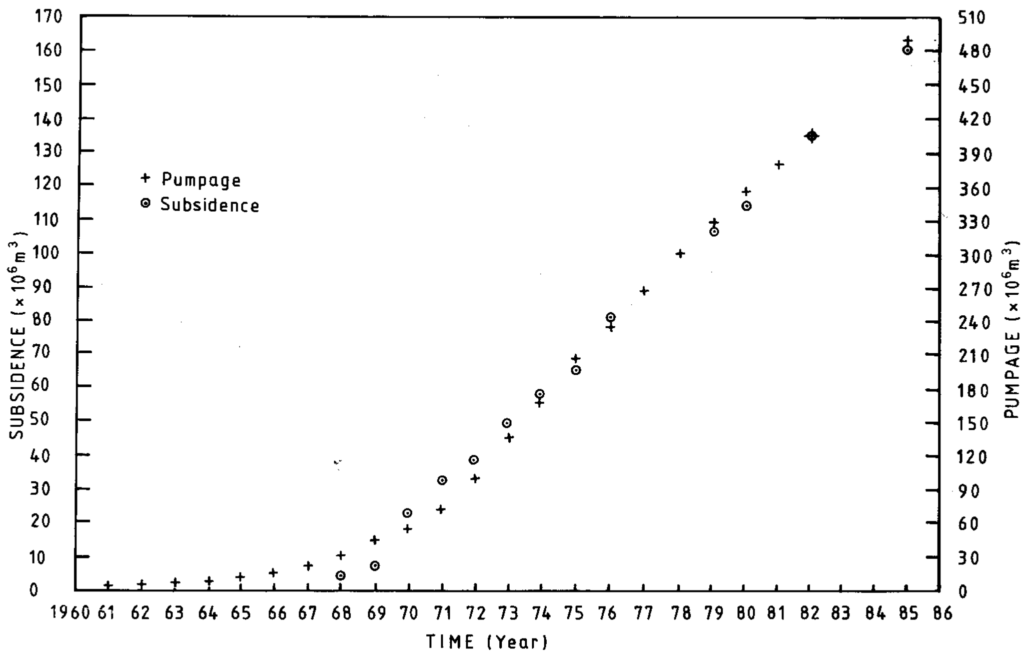

Figure 3 : Cumulative Volumes of Subsidence and Pumpage with Time at Morwell Open Cut. (After Evans 1986)

Other factors that need to be considered in the model include the contribution of the fractured basement rocks to the groundwater systems and the relationship between offshore oil/gas extraction and on-shore extraction of groundwater from the same stratigraphic sequence.

The current modelling studies of the Loy Yang region are based on the preceding concepts and results. The same water balance concepts will be used and stratigraphic units rather than discrete aquifers will be modelled.

LOY YANG AREA GEOLOGY AND HYDROGEOLOGY

a Setting of Loy Yang Open Cut

Loy Yang Open Cut is located on the northern flanks of a major east-west trending anticlinal structure known as the Loy Yang Dome (Figure 1). Lower Cretaceous sandstone and mudstone which form the local basement in the Loy Yang area comprise the core of the Loy Yang Dome, and are overlain by up to 600 m of Tertiary coal measure sediments comprising the Latrobe Valley Group.

Individual coal seams, which are up to 100 m thick, form well-defined marker horizons which allow interpretation of the stratigraphy and structure of the area. The major coal seams are the Yallourn, Morwell 1A, 1B, 2A, 2B and 2C and Traralgon seams. Interseam sediments are of variable thickness and include the major aquifers in the open cut and surrounding areas (Figure 4). A thick basaltic unit (the Carrajung Volcanics) occurs at the base of the sequence, particularly south of Loy Yang. East of the open cut near Rosedale, all but the Traralgon Seam grade laterally into sediments of the Balook and Boisdale Formations (Figure 2).

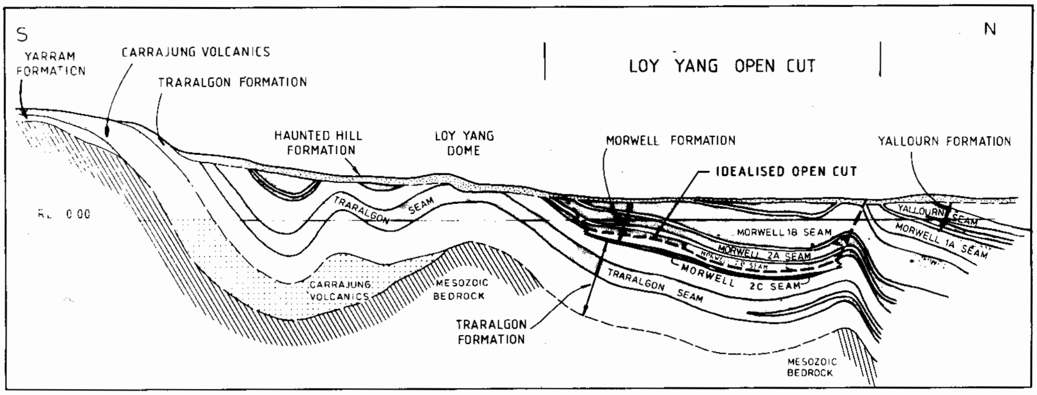

Figure 4 : Diagrammatic N-S Geological Section Through the Loy Yang Area Showing Schematic Position of the Open Cut

The Latrobe Valley Group is folded across and around the Loy Yang Dome, with dips up to 10°. A thin layer (< 30 m) of flat lying sediments called the Haunted Hill Formation overlies the folded Latrobe Valley Group (Figure 4). Faults in the basement rocks, Latrobe Valley Group and Haunted Hill Formation are common, particularly on the Loy Yang Dome.

The M1A, M1B, M2A and part of the M2B seam will be mined at LYOC (Figure 4). The open cut will reach a maximum depth of 170 m by the year 2000, requiring reduction in piezometric levels up to 130 m. Mathematical modelling studies based on the concept of two regional aquifer systems (MFAS and TFAS) predicted discharges in the order of up to 50 000 Ml/year (850 l/sec) by the year 2010 (Bolger 1987). However, the hydrogeology of the Loy Yang area is very complex and the mining operation will require depressurisation of all individual aquifers within each of the two aquifer systems and drainage of all aquifers intersected by the open cut. To provide more accurate estimates of future dewatering requirements, detailed stratigraphic analysis and interpretation of the hydrogeology within and around the open cut has been undertaken to develop a conceptual model as a basis for finite-element mathematical flow modelling.

b Aquifer Stratigraphy

In the Loy Yang area, the aquifer distribution and properties, and the degree of hydraulic connection between them are strongly controlled by the stratigraphic and structural relationships of the units as well as their depositional environments and resulting sedimentary facies. The hydrogeology is based on a hierarchical analysis of the stratigraphy, commencing with the Latrobe Valley wide concept of the MFAS and the TFAS (Figure 5). At Loy Yang, these regional aquifer systems are further divided into interseam layers in which individual aquifers are identified. Each of the interseam units and the individual aquifers within the interseams are described below. The hydraulic characteristics of the sequences above and below the Coal Measures are also described.

The <u>Haunted Hill Formation</u> is an extensive unconfined aquifer system overlying the folded Latrobe Valley Group sequence. It consists of sands, silts and clayey sediments. Sandy units vary in thickness and are often discontinuous. Clays are often fissured and contain root holes. Minor faults also intersect the Formation. The varied lithology suggests a wide range in hydraulic properties.

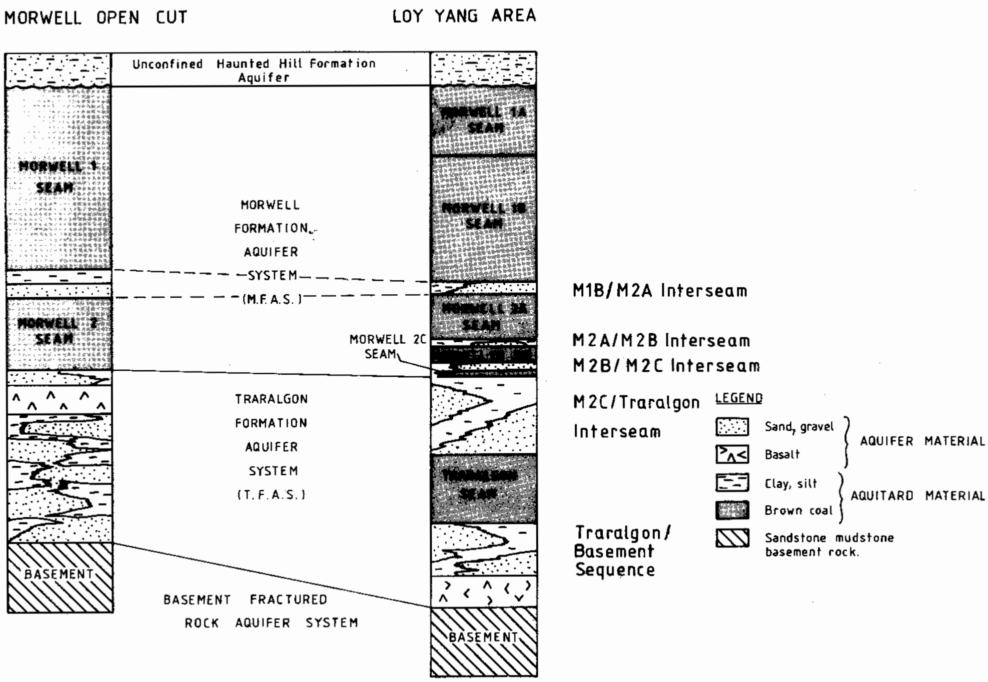

Figure 5 : Correlation of Aquifers and Aquifer Systems in the Morwell and Loy Yang Areas

Aquifers in the Latrobe Valley Group comprise the sands and silts within interseam units. The aquifers are named according to the coal seam directly overlying each interseam (Figure 5). Aquitard materials include coal seams, clays, silty clays and clayey silts. The coals are usually homogeneous, although where exposed in the open cut they display widely-spaced joints and stress relief in the open cut area induces the coal seams to behave locally as fractured rock aquifers rather than aquitards. The clayey sediments range from massive structureless clays to very thinly bedded and laminated silts and clays with a strong horizontal fissility.

The interval between the top of the Yallourn seam and the base of the M1A seam is a predominantly clay/coal facies (Holdgate 1985) and does not include major aquifers. The M1A/M1B, M1B/M2A and M2A/M2B interseams are thin and comprise mostly aquitard material in the open cut area (Bolger 1983). Only minor dewatering of these sediments is required. West of Loy Yang the M1A and M2 coal seams disappear and are replaced by clays. The associated aquifers are poorly developed in this area.

Very thick sands exceeding 30 m occur in the M1A/M1B and M2A/M2B interseams east of Loy Yang Open Cut where the coal seams wedge out and merge with the thick fine to medium sands of the Balook Formation near Rosedale (Figure 6). The M1B aquifer is a major regional aquifer in the area east of LYOC.

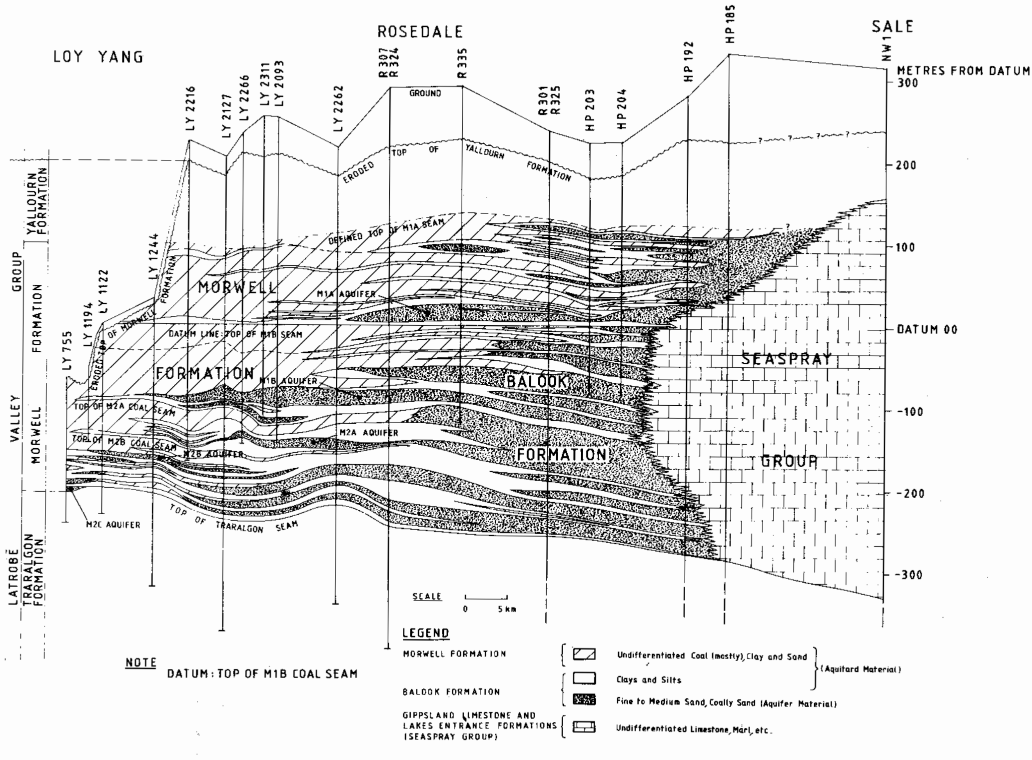

Figure 6 : Section Showing Facies Relationships Between Morwell Formation, Balook Formation and the Seaspray Group East of Loy Yang. (After Holdgate and Sluiter 1988, in Press)

The major aquifers requiring depressurising in LYOC occur within the M2B/M2C, M2C/Traralgon interseams and the Traralgon/basement sequence. These units have a total thickness of up to 150 m between the base of the M2B coal seam and the basement rocks. The M2B aquifer is up to 20 m thick and occurs as thin, elongate overlapping sand units, separated by clays, and it often wedges laterally into sandy coal (Figure 7). The M2C/Traralgon interseam is up to 18 m thick near the open cut, but thickens eastwards. Elongated isolated sand bodies are located at several levels within the interval, with the most important at the base (Figure 7). These major sands join beneath the open cut to form an extensive aquifer up to 15 m thick. The M2B and M2C aquifers are very thick east of the open cut and like the M1A, M1B and M2A, they wedge into the Balook Formation to form a thick homogeneous aquifer system up to 400 m thick (Figure 6). The M2B and M2C aquifers consist mostly of relatively homogenous fine sand to coarse silt with thin interbedded medium to coarse sand layers. The fine grained deposits often coarsen upwards to medium grained sands. Limited pumping test data indicate hydraulic conductivities of 2-7 m/day and storage co-efficients in the range 10^{-3}-10^{-4} for the M2B and M2C aquifers (Thatcher 1976).

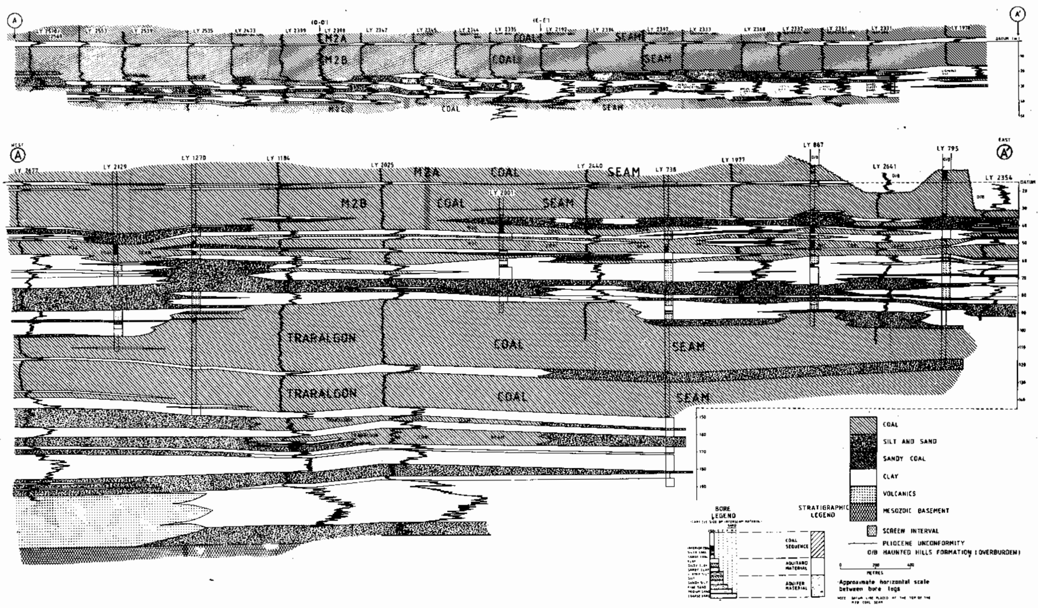

Figure 7 : Geological Sections at Loy Yang Open Cut Showing the Detailed Configuration of Aquifers Between the Morwell 2B Coal Seam and the Mesozoic Basement

The sediments below the Traralgon Seam differ from the overlying units in that they contain coarse sand to fine gravel aquifers often up to 20 m thick. They have correspondingly higher hydraulic conductivities in the range of 10-90 m/day and storage co-efficients of 10^{-4}-10^{-5} (Brumley et al 1981). The contrast in aquifer lithology reflects a change from a fluvial dominated depositional environment to a lower energy marginal-marine environment influence in the overlying sediments.

The Carrajung Volcanics occur at the base of the Tertiary sequence in the southern part of the Loy Yang area (Figure 4). They range from massive, non-vesicular basalt with sparsely spaced joints to granular weathered tuffs. Secondary minerals often fill joints and cavities. The hydraulic properties have not been evaluated.

Lower Cretaceous basement rocks of massive sandstone and mudstone contain widely spaced joints forming rectangular sets which, combined with bedding and faulting, comprise a fractured rock aquifer system. Secondary siderite fills some of the joints. South of Loy Yang, artesian groundwater is encountered in the basement bores; however, the aquifer characteristics have not been determined.

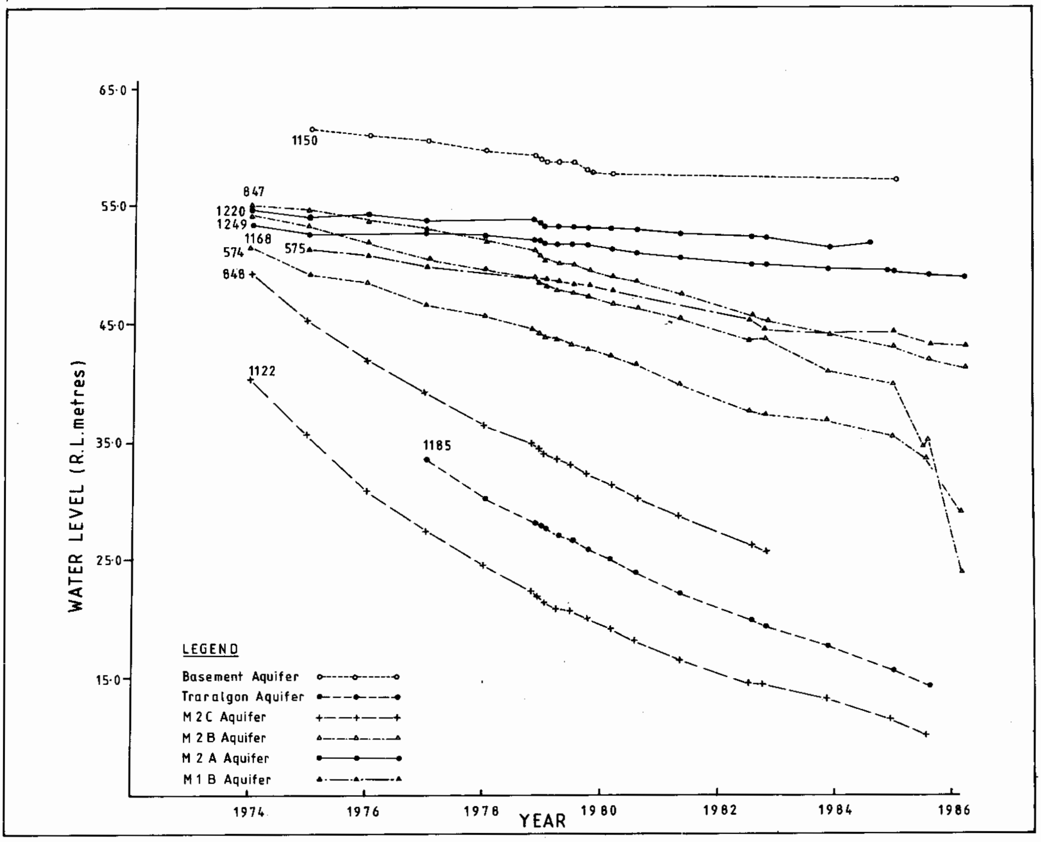

Figure 8 : Hydrographs for Selected Bores at Loy Yang Open Cut Showing Relative Drawdowns in Different Aquifers

c Groundwater Levels

The M2C/Traralgon interseam and Traralgon/Basement sequences are hydraulically connected to the Morwell 2 aquifer at Morwell Open Cut and show a steady decline in piezometric heads resulting from dewatering at MOC (Figure 8). Pressures in these aquifers have been lowered by up to 30 m at a rate of about 2 m/year. In fact, regional mathematical modelling by Evans (1986) and Bolger (1987) show the interrelationship between MOC and LYOC dewatering in the future. For instance, increased pumping from the TFAS at either one of the open cuts will cause a reciprocal reduction in the dewatering requirements of the other. The M2B aquifer also shows strong declines of about 2 m/year, and although it is defined as part of the MFAS at LYOC (Figure 5), it is connected to the TFAS where the M2B and M2C coal seams wedge out west of LYOC. Recent open cut dewatering at a rate of 30 l/sec has further lowered the M2B levels up to 20 m in the eastern part of LYOC.

The strong hydraulic connection that exists between the Traralgon Formation aquifers at Loy Yang and Morwell cannot be demonstrated for the Morwell Formation aquifers. The M1B aquifer at Loy Yang is not continuous with the thin M1 aquifer at MOC, although it is at the same stratigraphic level. In fact, the entire Morwell Formation is very clayey between Morwell and Loy Yang and pore pressures in the clays are high. However, to the north-east of LYOC, potentiometric levels in the MFAS, particularly in the M1B aquifer, are declining at a rate of 1 to 2 m/year. It is therefore considered possible that declines in the MFAS east of LYOC are due to downward flow from the M1B to the partially depressurised TFAS, particularly in the zone of interconnection with the Balook Formation. Water level declines of up to 10 m in the M1A, M1B and M2B aquifers in the LYOC area are also attributed to downward leakage into the partially depressurised TFAS.

Recharge to the Loy Yang aquifers, particularly the M2B, M2C and Traralgon aquifers, is strongly influenced by the geological structure. Potentiometric surface contours show that the predominant recharge to these aquifers occurs in the hills south of LYOC. Recharge also occurs when the aquifers subcrop below the Haunted Hill Formation on the crest and flanks of the Loy Yang Dome. The Haunted Hill Formation behaves as a shallow unconfined aquifer with perched water tables (Pedler & Raisbeck 1985). Infiltration through the Haunted Hill Formation, although unquantified, occurs through fissures and sandy zones into the regional confined aquifers.

CONCLUSIONS

Artesian dewatering at LYOC is an important aspect of the open cut development. Prediction of future dewatering requirements, based on mathematical modelling at a scale consistent with the operation of the open cut, requires the development of a realistic hydrogeological model. To achieve this in the Loy Yang area, a detailed study of the stratigraphy and the regional hydrogeology has been undertaken.

At Loy Yang, the degree of hydraulic connection and groundwater flow, both at the local and regional scale are strongly influenced by the complex stratigraphic relationship between coal seams and aquifer/aquitard sequences. In addition, the marked lateral and vertical changes in sediment lithology, the irregular geometry of aquifer sand lenses and the low permeability of the strata are important factors affecting the model.

Regional hydrogeological studies, based on a comprehensive groundwater monitoring program, have indicated that open cut dewatering at MOC has reduced piezometric levels in aquifers at LYOC. The studies have also delineated major areas of groundwater recharge. These factors indicate the importance of evaluating the regional groundwater system in the planning and development of individual open cuts.

ACKNOWLEDGEMENTS

The authors wish to thank Mr G Holdgate for the important contribution he has made to interpreting the stratigraphy of the Loy Yang area. The help from Dr C Barton in facilitating preparation of the paper is also appreciated.

The paper is published with the permission of The State Electricity Commission of Victoria.

REFERENCES

Barton, C M, 1988. In Bicentennial Volume on Coal in Australia, ed C R Ward. Geological Society of Australia Special Publication, (in press).

Bolger, P F, 1983. Reassessment of Aquifer Sand Isopachs at Loy Yang. SECV, Fuel Dept, Coal Resources Div, Tech Note 103.

Bolger, P F, 1987. Regional Groundwater Investigation of the Latrobe Valley, Stage III Mathematical Modelling Studies. SECV, Geological Report No 41 (unpubl).

Brumley, J C, Barton, C M, Holdgate, G R and Reid, M A, 1982. Regional Groundwater Investigation of the Latrobe Valley 1976-1981. Joint SECV/DMEV Rept (unpubl).

Brumley, J C and Reid, M A, 1982. An Investigation of the Groundwater Resources of the Latrobe Valley, Victoria. Aust Coal Geology Vol 4 Pt (2).

Evans, R S, 1986. A Regional Groundwater Model for Open Cut Coal Winning in the Latrobe Valley, Victoria. AWRC Conf Groundwater Systems Under Stress, Brisbane.

Framework For The Future, 1987. Ministry of Industry, Technology and Resources and Ministry for Planning and Environment, Latrobe Region Final Report, Oct 1987.

Gloe, C S, 1976. Brown Coal. In Geology of Victoria, eds J G Douglas and K A Ferguson. Geological Society of Australia Special Publication No 5, pp378-386, No 5. pp378-386.

Hocking, J B, 1976. Definition and Revision of Tertiary Stratigraphic Units, Onshore Gippsland Basin. Rep. Geol. Survey Vict 1976/1.

Holdgate, G R, 1985. Latrobe Valley Brown Coals - Their Geometry and Facies Equivalents as a Guide to Depositional Environments. Aust. Coal Geology, v.5, pp53-68.

Holdgate, G R, and Sluiter, I R K, 1988. Oligocene-Miocene Marine Incursions in the Latrobe Valley Depression, Onshore Gippsland Basin, Evidence, Facies Relationships and Chronology in De Dekker, P and Williams, M A J (eds), The Cainozoic of the Australian Region - A Reappraisal of the Evidence. Blackwell Scientific, Melbourne (In Press).

Kinhill, 1987. Report to the Coal Corporation of Victoria on the Effects of IDC Coalfield Categorisation on the Economically Winnable Coal Resource of the Latrobe Valley and South Gippsland, August 1987.

Pedler, I V, 1985 and Raisbeck, D, 1985. Loy Yang 'A' Power Station - Foundation Investigation Report. SECV, DEE Dept, Geotech Div, Rept GD33.

Thatcher, R C, 1976. Loy Yang Project : Aquifer Characteristics From Pump Tests Conducted During 1975. SECV Fuel Dept, Dev Div, Report III (unpubl).