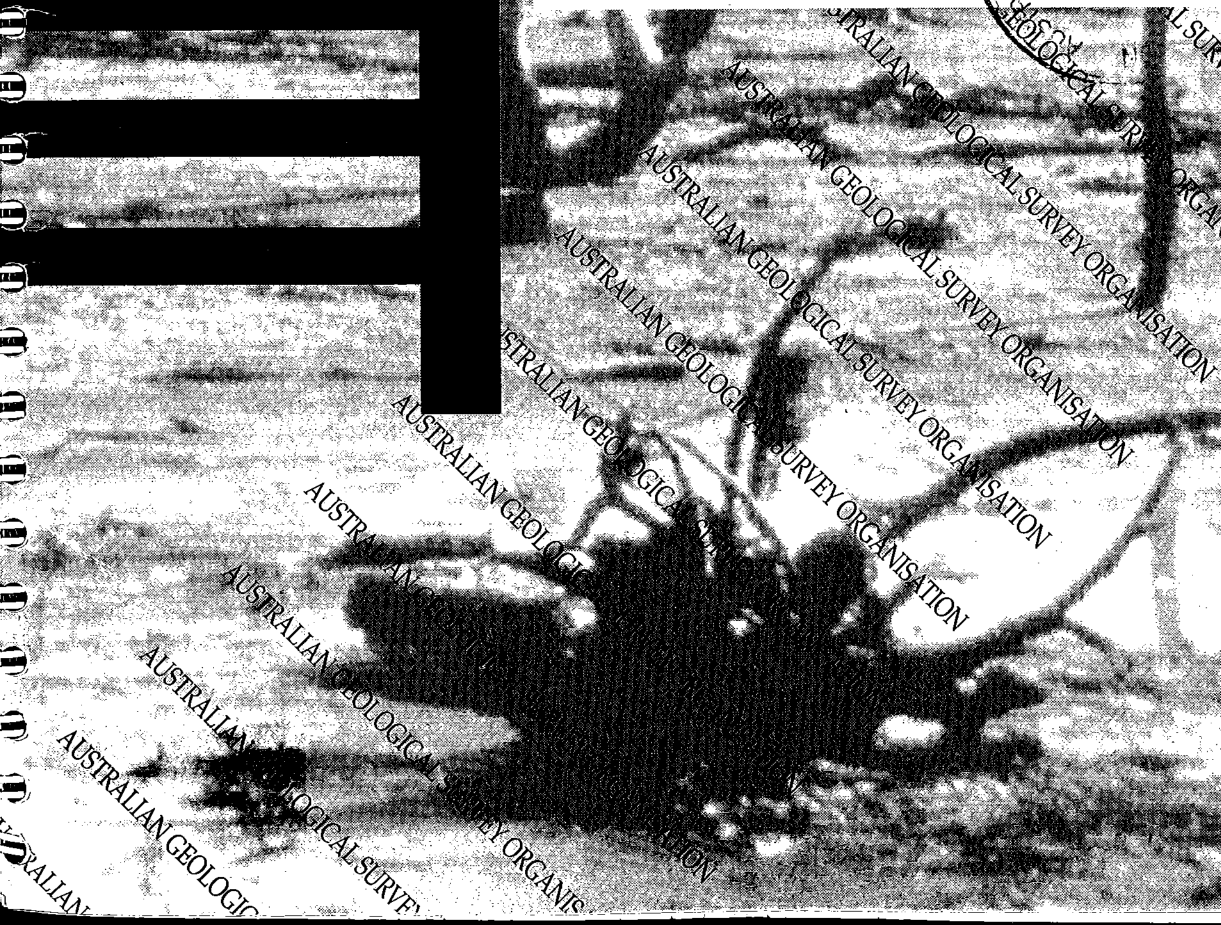
THE MOURQUONG GROUNDWATER DISCHARGE COMPLEX AND SALINE-WATER DISPOSAL BASIN, MURRAY BASIN, AUSTRALIA: LITHOSTRATIGRAPHY, HYDRODYNAMICS AND HYDROCHEMISTRY

RECORD 1997/17



AGSO
AUSTRALIAN
GEOLOGICAL SURVEY
ORGANISATION

Department of Primary Industries and Energy

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RECORD 1997/17

The Mourquong Groundwater Discharge Complex and Saline-Water Disposal Basin, Murray Basin, Australia: Lithostratigraphy, Hydrodynamics, and Hydrochemistry

Published as a contribution to the project:
"Managing Disposal Basins to Improve their Usefulness for Salt Storage"

A NRMS-funded collaborative project between the
CSIRO Centre for Environmental Mechanics
CSIRO Division of Water Resources
and
Australian Geological Survey Organisation

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister for Primary Industries and Energy: Hon. J. Anderson, M.P.
Minister for Resources and Energy: Senator the Hon. W.R. Parer
Secretary: Paul Barratt

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Executive Director: Neil Williams

ISSN: 1039-0073
ISBN: 0 642 25023 5

CONTENTS

FIGURES

ACKNOWLEDGMENTS

Special thanks are due to Mike Erny and Mike Williams of the Department of Water Resources, N.S.W. for the provision of near-site laboratory facilities, access to DWR data and a number of general discussions on the Mourquong area.

Field investigations were carried out with perseverance and skill by members of the Environmental Geoscience and Groundwater (EGG) Technical Resources Group, AGSO. Special thanks are due to Tim Ransley and Bill Keeley for their contribution to developing the special drilling techniques necessary for salt lakes. Eleanor Laing assisted with the surveying of profiles and boreholes and provided laboratory analyses. John Spring carried out some fieldwork and laboratory analyses. Members of the ESU Group at AGSO manufactured special equipment for the project at short notice and collaborated in its field testing. Diagrams for this record were prepared by the members of the cartography section, AGSO.

John Dighton, Peter Cook, and Andrew Herczeg manned the CSIRO rig for acquiring water samples and cores. Ted Cherry, Alan Porter, and Andrew Hinds manned the AGSO Denver-Gardner drill rig for the coring of the Parilla Sand and Bookpurnong Beds, as well as establishing the PS transect of deep piezometers across the discharge complex.

CONTRIBUTORS

James Ferguson, GLAW Program, AGSO, P.O. Box 378, Canberra City 2601.
Bruce Radke, "Eungella" Farringdon-Bombay Rd., Braidwood, NSW 2622.
Andrew Herczeg, CSIRO, Division of Water Resources, PMB 2, Glen Osmond,
SA 5064
Kumar Narayan, CSIRO, Division of Water Resources, PMB 2, Glen Osmond,
SA 5064.
Craig Simmons, CSIRO, Division of Water Resources, PMB 2, Glen Osmond,
SA 5064.
R. G. Cresswell, Dept. of Nuclear Physics, The Australian National University,
Canberra, A.C.T. 0200.
D. J. Whitford, CSIRO Division of Exploration Geoscience, P.O. Box 136, North
Ryde, N.S.W. 2113.
Rainer Grun, ANU Quaternary Dating Research.Centre, Canberra, ACT 0200.

SUMMARY

ABSTRACT

The physiographic features of the Mourquong groundwater discharge complex are an expression of subsidence in the underlying Koorlong Trough. The topographic depression was submerged by Lake Bungunnia about 2.4 ma ago, during deposition of the Blanchetown Clay. The subsequent evolutionary history included episodes of deflation, and lacustrine and fluvial deposition. These episodes were caused by periodic groundwater salinisation and migration of channels of the Murray River into the depression. Significant features resulting from these processes include an erosional window in the Blanchetown Clay and the widespread occurrence of Shepparton Formation sands overlying and intercalated with the Blanchetown Clay.

During the most recent natural phase, groundwater brines (e.g. 125,000 mg/L TDS) formed in sandy lacustrine Yamba Formation sediments in the topographically lower areas of the discharge complex. These brines formed by evaporation of two source waters: (1) incoming saline regional groundwater, and (2) saline surfacewater formed by dissolution of salt efflorescences deposited in the marginal areas. The resultant brines contain redissolved NaCl, $MgSO_4$ and Na_2SO_4 salts which had concentrated in the efflorescences at the margins during the seasonal evaporation/dissolution/deflation cycle. Salt from the brines formed in the discharge complex is moving downwards into the underlying regional Parilla Sand aquifer by diffusion through the intervening Blanchetown Clay. During previous relatively-wet climatic periods, brine moved from the discharge complex into the Parilla Sand by advective reflux through the vertically-permeable area where the Blanchetown Clay is missing. Three paleo-brines are identified in the Parilla Sand and the underlying clays of the Bookpurnong Beds. They have been tentatively dated at <50, 125-175 and 240-290 Ka.

The Mourquong saline water disposal basin occupies the western area of the discharge complex. It is generally hydrodynamically restricted by the Blanchetown Clay, but there are vulnerable areas in the southeast, where the clay is apparently missing, and at the western margin where deflation has greatly reduced its thickness.

Lateral movement within the discharge complex can occur readily through the sandy Yamba Formation sediments.

Vertical hydraulic gradients are downwards and relatively constant within the disposal basin but at the margins they change rapidly in response to rainfall recharge and flooding by disposal water. Lateral gradients are directed towards the discharge complex from the surrounding areas and from the disposal basin to the remainder of the discharge complex. Under the influence of these gradients disposal water has moved northwards about 300m into the non-flooded area of the discharge complex and westwards about 45m into the bordering dune.

Lateral gradients towards the discharge complex are highest in the irrigation-influenced areas to the south and lowest to the north. The limited available information suggests that the disposal water is laterally constrained to the discharge complex in the south but could eventually move more than 200-300 m beyond the northern margin.

SYNOPSIS

Mourquong is a natural groundwater discharge complex located close to the Murray River. The western part of the complex is used as a disposal basin for the Buronga Interception Scheme around Lock 11 on the Murray River.

This regional stratigraphic, structural, and hydrodynamic study of the area has two general objectives:

(1) to determine the conditions under which, in natural groundwater discharge complexes and in saline-water disposal basins, brines will form and descend into the substrate by advective reflux to form relatively stable brine pools in the underlying aquifer; and

(2) to contribute to the development of a lithostratigraphic classification of saline-water disposal basins which will allow first-order prediction of rates and directions of salt leakage.

Natural groundwater discharge complexes in the Murray Basin are commonly used for the disposal of saline groundwater from salt interception schemes. A major factor in the siting and management of these disposal basins has been the need to understand and, if necessary, control the way in which brines generated by evaporation of the saline water leak laterally into adjacent areas and/or vertically into the underlying regional aquifer. Vertically-moving brines which reach the regional aquifer may be partly dispersed and swept down gradient, or they could form relatively stable brine pools which remain beneath the disposal site.

Numerical models indicate that brine pools will develop where high sediment permeability favours advective reflux of lacustrine brines and, conversely, brine pools will not form if low permeability substrates restrict groundwater flow and salt moves by diffusion. Natural discharge complexes are complicated because the underlying aquifer may contain several generations of paleo-brines emplaced during former hydrodynamic regime(s) different to the present. Additionally, brines may be present in aquifers beneath discharge complexes that are mostly underlain by considerable thicknesses of Blanchetown Clay. In such scenarios, brine reflux may have occurred through fractures in the Blanchetown Clay, or brine reflux developed in small areas of the discharge complex where the Blanchetown Clay is missing and the underlying Parilla Sand is close to or in hydraulic connection with the lake surface.

To test these hypotheses and to provide additional information on the environmental conditions necessary for advective brine reflux, the mechanism and timing of brine reflux and salt diffusion which occurred under natural conditions in the Mourquong discharge complex have been investigated. A local stratigraphic context for these hydrodynamic events has been developed by relating brine reflux and stratigraphic evolution at Mourquong. A basin-wide context has been provided by relating the Mourquong hydrodynamic and stratigraphic events to those of discharge complexes elsewhere in the Murray Basin.

Mourquong Groundwater Discharge Complex

The Mourquong groundwater discharge complex forms a topographic depression with a semicircular outline some 8 kilometres in diameter. The complex contains a distinctive suite of landforms. A crescentic dune delineates the northern, eastern, and southern extent of the complex. The gently arcurate western margin is delineated by the eastern slope of a broad low ridge and the western margin of an active salina (now the disposal basin) that covers a relatively small area of the complex. East of this salina, and within the outermost circular dune, is a low-relief but dissected topography comprising pedestals of a sandy gypsiferous terrace and low lunettes. Most of these pedestals have one or more generations of lunette accretion on their western and northwestern margins. Some pedestals are variably covered by subdued hummocky red sand dunes. A lower sand-covered surface extends between these pedestals from the lunette margins of the existing lake to the outermost circular dune.

The stratigraphic sequence beneath the discharge complex comprises Bookpurnong Beds (calcareous clay), overlain by Parilla Sand with significant lateral relief, over-draping of Blanchetown Clay, overlying and intercalated Shepparton Formation sediments, and the uppermost saline lacustrine deposits of the Yamba Formation. A significant feature is an erosional window in the Blanchetown Clay, which may cover the entire southern end of the Mourquong depression. Highly permeable sand (Shepparton Formation) is extensive over the top of the Blanchetown

Clay within the central and eastern part of the complex. Shepparton Facies that would demonstrate connection to the Murray Trench probably occur to the east of the area investigated. As a generalisation, the lacustrine Yamba units show a progressive diminution in area and consequent younging westwards.

The Mourquong complex overlies the Koorlong Trough which has a western faulted margin along the Danyo Fault, against the Merbein Ridge immediately to the west. Dislocation of strata across the Danyo fault is evident in the pre-Tertiary sequence. Subsidence in the trough occurred throughout the Cainozoic and the broad physiographic features of Mourquong are an expression of this subsidence in the Koorlong Trough.

The evolutionary history of Mourquong discharge complex commenced when the topographic depression was submerged by Lake Bungunnia about 2.4 ma ago. Initially there was significant local reworking of Parilla Sand and the Irymple Sand member accumulated basally within the lacustrine Blanchetown Clay. Lake levels fluctuated and during low stands, fluvial deposition periodically predominated, producing sand lenses within the Blanchetown Clay. Continued differential subsidence after the demise of Lake Bungunnia maintained the subtle topographic depression. Salinisation by groundwater discharge from the Parilla Sand induced widespread deflation of the Blanchetown Clay. At some stage, the higher southern and eastern margins of the Mourquong depression were breached, and channels of the Murray River periodically migrated into the depression. Significant channel erosion extended over most of the basin and a permeability window was incised through the Blanchetown Clay into the underlying Parilla Sand in the southwestern area. Fluvial deposition (Shepparton Formation) extended across the depression, predominantly as channel-fill deposits with minor overbank deposits. With increasing aridity during the onset of Woorinen sand mobilisation, sandy beach deposits on the eastern margin were reworked into a large sandy lunette which forms the eastern margin of the complex. Saline groundwater discharge continued with the first-preserved accumulation of saline lacustrine sediments and a sandier facies as there was an increased flux of Woorinen-derived sand across the zone. A subsequent significant deflation event saw remobilisation of the sandier sediments to produce an additional large lunette that accreted in the southeastern margin against the western slope of the existing sand lunette. Yamba Formation saline-lake deposits accumulated intermittently with a variable contribution from remobilised Woorinen sand. Further deflation of lacustrine Yamba sediments produced several generations of gypsiferous lunette deposits over the eastern flats of the complex. The most recent deflation event mobilized predominantly Woorinen-derived sands with little gypsum content.

Under recent natural conditions in the discharge complex, brines developed predominantly in the topographically low parts of the active areas, forming from a combination of two sources: (1) incoming Parilla Sand groundwater which flowed from the margins to the topographically lower sites of brine formation either as groundwater moving laterally through permeable horizons and/or as surface water flowing from springs; and (2) saline water which formed at the margins as rainfall/runoff dissolved salt efflorescences formed by capillary evaporation of Parilla Sand groundwater, and then moved by surface flow to the sites of brine formation. Brines that formed predominantly from source (1) should have major-ion chemistries similar to those predicted from evaporation of the incoming Parilla Sand groundwater. In contrast, those formed from source (2) may be influenced by selective dissolution of the salts which form the efflorescences. Theoretically, evaporation to dryness of the incoming Parilla Sand groundwater at the margins should result in the transfer of the major-ion chemistry of the source Parilla Sand groundwater almost intact to the brines. In reality, a selection process operates at the lake margins as seasonal conditions change from regular washing/flooding during wet conditions to aeolian deflation of the surface sediment during extended periods of dryness. This selection process favours the incorporation of magnesium sulphate, sodium sulphate and sodium chloride minerals into the rainfall/dissolution brines. Thus, depending on the balance between processes (1) and (2), brines formed in discharge complexes range in composition from solutions of magnesium sulphate plus sodium chloride to only slightly modified concentrated Parilla Sand source waters. These various chemical signatures are transferred to the Parilla Sand aquifer with the diffusing salt and refluxing brines.

Natural groundwater in the Blanchetown Clay beneath the recently-active areas of the discharge complex have salinities that decrease approximately linearly with depth. This linearity is disrupted by higher salinities associated with groundwater moving laterally through relatively permeable carbonate-rich horizons. The linear relationship is indicative of downwards diffusion of salt from the natural shallow brines associated with the Yamba Formation/upper Blanchetown Clay towards the lower salinity groundwaters at the top of the underlying Parilla Sand. In the inactive areas where permeable lunette deposits blanket the discharge complex, rainfall recharge exceeds evaporation and the salinity increases downwards from the Yamba Formation into the Blanchetown Clay.

In the Parilla Sand beneath the discharge complex brines occur in the deeper parts of the sequence. The high salinities associated with these brines decrease upwards to a salinity minimum which underlies slightly higher salinity waters which occur immediately beneath the Blanchetown Clay. This salinity distribution is indicative of a hydrodynamic phase in which brine reflux is not active. It is consistent with the suggestion that salt from brines formed in the topographically low areas of the discharge complex is entering the Parilla Sand aquifer by downwards diffusion through the Blanchetown Clay.

The brines beneath the discharge complex have salinities up to 125,000 mg/L, and they occur in the lower parts of the Parilla Sand aquifer and have entered the underlying clays of the Bookpurnong Beds. The area of brines is offset towards the western margin, which is consistent with the hypothesis that reflux occurred through the area where the Blanchetown Clay is missing and, subsequently, the regional Parilla Sand hydraulic gradient assisted the spread of the brines to the north. Brines of salinity near 125,000 mg/L are common beneath discharge complexes in the Murray Basin, possibly because this is the salinity at which the density ratio of brine to underlying groundwater becomes sufficiently high for reflux to occur. If this hypothesis is correct, then almost unchanged remnants of original reflux brines are present in the Parilla Sand aquifer and the underlying Bookpurnong Beds beneath discharge complexes.

Although remnants of original reflux brines are present beneath the discharge complex, most of the brines and saline groundwaters in the Parilla Sand and Bookpurnong Beds are mixtures. The main components of these mixtures can be identified by their Mg/Br and Na/Br ratios, which reflect the amounts of redissolved Mg- and Na-containing salts which they contain. Based on these ratios, the brines and saline groundwaters in the Parilla Sand and Bookpurnong Beds have contributions from three components: (1) a low Mg/Br - low Na/Br water (weight ratios about 26 and 180, respectively); (2) a low Mg/Br - intermediate Na/Br water (about 24 and 220); and (3) a high Mg/Br - high Na/Br water (about 40 and 250). Within the triangular Mg/Br - Na/Br field defined by these three components, the Parilla-Bookpurnong brines of salinity 90,000 to 125,000 mg/L plot in a number of locations, which suggests that there have been several different episodes of brine reflux, each with a slightly different Mg/Br - Na/Br chemical signature.

The ^{36}Cl/Cl ratios of the groundwaters of the discharge zone and surrounding areas can be placed in three groups: 32-37 x 10^{-15}; 24-29 x 10^{-15}; and 16-21 x 10^{-15}, based on a frequency distribution analysis. The present-day input value of about 35 x 10^{-15} was taken to be that of groundwater in the Parilla Sand beneath a dunefield close to the south-western margin of the discharge complex. The Blanchetown Clay is relatively thin in this area and recharge by rainfall carrying aerosol-borne chloride is, presumably, high. Ratios comparable to the recharge value occur in the Blanchetown Clay beneath a lunette near the centre of the discharge complex, also a site of potentially high recharge. Ratios close to the recharge value occur in a brine found near the base of the Parilla Sand the window in the Blanchetown Clay. This brine (125,000 mg/L; ^{36}Cl/Cl, 35 x 10^{-15}) is overlain by lower salinity and lower ^{36}Cl/Cl groundwaters (e.g.

52,000 mg/L, 27.5 x 10^{-15}).

Low $^{36}Cl/Cl$ ratios (14-19 x 10^{-15}) occur in the Bookpurnong Beds near the centre of the western margin of the discharge complex, and in the Parilla Sand to the north-east of the discharge complex. This area of the Bookpurnong Beds is favourable for the retention of older waters because of the low permeability of the clays and its location just to the north of the brine-reflux area. The Parilla Sand beneath the area to the north-east of the discharge complex is similarly favourable because it is topographically high, and therefore relatively remote from a discharge complex, and because the underlying Blanchetown Clay sequence is thick, which limits vertical recharge and thus the introduction of more recent aerosol-borne chloride.

The age of the brines beneath the discharge complex can be determined from the ^{36}Cl data providing that: (1) the input values contemporaneous with the brine-reflux events are known; and (2) the brines which formed in the discharge complex from Parilla Sand source waters which had these contemporaneous $^{36}Cl/Cl$ ratios; and (3) mixing and/or diffusion beneath the discharge complex has not significantly altered the original brine $^{36}Cl/Cl$ ratios. These conditions are more likely to occur during periods of brine reflux, when conditions would have been wetter and the active area of the discharge complex much greater than it is today. Under wet (interglacial) conditions sea levels would be relatively high and the area of the Australian continent may have been similar to what it is today. If this is correct, then during wet interglacial periods the $^{36}Cl/Cl$ input values could have been close to those of the present-day. The Parilla Sand source waters discharging at the margins are less likely to contain older brine from beneath the discharge complex when the active area of the discharge complex is large and the lake margins are close to the maximum extent of the discharge complex. As discussed previously, brines with salinity near 125,000 mg/L are common beneath discharge complexes, which implies that the closer the salinity of the groundwater to this value, the more likely it is to be an original, unmixed reflux brine. If these assumptions are correct, then the calculated dates of the three periods of brine reflux are: 290, 146 and ≤ 50 ka. In comparison, a brine of salinity 125,000 mg/L beneath a discharge complex at Scotia dates at 89 ka, and brines of salinity 106,000 and 98,000 mg/L beneath the Nulla discharge complex date at 125 - 175 and 240 - 290 ka.

Theoretical predictions that brine reflux will be favoured by high-permeability lake-floor sediments are supported by the data from Mourquong. The area of brines is offset towards the western margin, which is consistent with reflux through the area where the Blanchetown Clay is missing and a tendency for the regional Parilla Sand hydraulic gradient to assist the brines to spread to the north. The presence of the highest concentrations of the most recent brine directly beneath this area further supports this hypothesis.

Mourquong Saline Water Disposal Basin

Lock 11 on the Murray River is sited within a highly permeable Parilla Sand substrate and the consequent raising of the local groundwater table has initiated or dramatically increased saline discharge from the Parilla aquifer further downstream. The Buronga Interception Scheme pumps saline groundwater from the Parilla Sand from the vicinity of, and downstream of the lock. This groundwater with an average salinity of 30,000 mg/l is pumped to an outfall at the southern margin of Mourquong swamp. The effluent flows northward along a partly-submerged channel cut through abandoned gypsum pits, to a standing lake. At the standard operating level of about 31.7m AHD, the lake comprises the narrow southern extension and a broad central-western area which occupies about the western 10% of the Mourquong depression.

The disposal lake is a former salina which lay against the western margin of the discharge complex, and presumably adjacent to the western flexure of the Cainozoic sequence from the Merbein Ridge over the Danyo Fault and dipping eastwards into the Koorlong Trough. The sequence rises gently further east to create both a structural and a topographic basin. Rapid facies changes in the Blanchetown Clay across the western flexure indicate the existing relief at the time of flooding of Lake Bungunnia. The basal sandy facies of the Blanchetown Clay, the Irymple Sand Member, is thicker and interdigitates laterally with the Blanchetown Clay on the western side. During the earlier development of the salina, deflation and probably lake-margin erosion has cut a notch into the Blanchetown Clay on the western lake margin, significantly thinning the effective permeability barrier separating the salina from the horizontally-permeable Irymple Sand to the west.

The thickness of the Irymple Sand thins and then thickens again eastwards to the centre of the depression before thinning significantly towards the eastern margin. Blanchetown Clay also thickens dramatically into the basin centre but upper erosional surfaces from Shepparton channel formation and later, Yamba deflation, have created local irregularities within the depression. Highly permeable sands of the Shepparton Formation infill erosional channels in the upper surface of the Blanchetown Clay. Over a topographic rise in this surface a thinner sequence of distinctively bedded sand-clay gradations is interpreted as overbank deposits of these channels. In the southwestern corner, the Shepparton Formation comprises well sorted sands which directly overlie Parilla Sand in the erosional window of the Blanchetown Clay. Limited stratigraphic control indicates that the Shepparton sands are most probably extensive across the southern portion of the depression and the northern erosional limit probably coincides with the southern margin of the main salina.

The floor of the salina is Yamba Formation, comprising three superimposed lacustrine units which overlie the Blanchetown Clay. These units are distinguished by the interlaying of thin sandier, aeolian deposits which represent a minor accumulation at the end of a deflation event. This sequence is stratiform, and can be correlated northwards beyond the top end of the disposal lake, although there is some local facies complication where the sequence has dune-like characteristics on a slight ridge on the upper surface of the Blanchetown Clay. This lake-margin configuration is comparable to that immediately east of the disposal lake.

Porosity in the sequence is predominantly interparticle porosity in sandier facies and intercrystalline porosity where displacive diagenetic gypsum has developed in muddier lithofacies. There is a lesser abundance of bioturbation and fracture porosity. The predominant types are by definition interconnected porosity types and create the permeability of the sediment. On this basis, the stratigraphic distribution of porosity can be approximated as permeability distribution.

The aquifers of the system, the Parilla Sand and the channel sands of the Shepparton Formation, have very high relatively-isotropic permeabilities.

The Blanchetown Clay has the lowest permeabilities in the sequence, but there is stratigraphic and spatial variability. Spatially the unit is tighter directly under the disposal basin in the central and northern areas. Eastwards, there is a pervasive moderate permeability over a large part of the sequence but a diminution is apparent at the inner margin of the discharge complex, with thicker intervals that lack porosity towards the base and into the Irymple Sand. The higher porosity of the Blanchetown Clay in this eastern region is due to more abundant and thicker bands of diagenetic gypsum, with inter crystalline porosity, which may be genetically related to the overlying Shepparton sand aquifer. At the southern margin, although the Blanchetown Clay has very low permeability, its distribution is unpredictable. One transect shows the clay thickening away from the basin, but absent and abutted by sandy Shepparton clays under the salina.

The Irymple Sand member lies at the base of, and interdigitates with the Blanchetown Clay, and directly overlies the Parilla Sand. In the central region this member has alternating high and low permeability bands and, consequently, a high lateral permeability, but with a lower vertical permeability. It forms a significant potential conduit on the western margin, especially where there is only a thin interval of Blanchetown Clay separating it from an incised notch, covered by reworked Woorinen sand on the salina margin. In the eastern and southern regions of the Mourquong depression, the member has thicker intervals of low permeability.

The Yamba formation has variable permeability both within the sequence and laterally. Most Yamba units have the full range of permeability.

The present disposal lake in the centre of the depression has several areas on its margins which are susceptible to leakage. The western margin to the lake in the central part of the depression has a notch incised into the Blanchetown Clay. This notch is now covered with high permeability sands. The thickness of clay is minimal between the lake and its lateral transition into horizontally-permeable Irymple Sand which lies against the Parilla Sand further to the west. Because the Blanchetown Clay has some intervals of low to moderate porosity, lateral hydraulic connection is highly probable. The eastern margin of the lake at standard operating level has hydrodynamic closure but further eastwards, the earlier Yamba units are more permeable and directly overlie Shepparton sands. In the southern part of the depression, the thin Yamba formation is moderately permeable and overlies the Shepparton Sand. In the southwestern corner, the Blanchetown Clay is absent and consequently highly permeable Shepparton sands overlie the Parilla Sand enabling direct hydrodynamic linkage of surface waters with Parilla Sand. The northern margin has lateral hydraulic connection to the northern area of the discharge complex through the Yamba Formation.

The vertical and lateral gradients associated with the disposal basin were measured along transects normal to the western, northern and eastern margins and at two locations on the southern margin. Measurements of hydraulic heads were made at one or two times in late summer (April 1995 or March/April 1995) and immediately after spring rain (October) when the basin operating level was about 0.5 m higher than during the late summer measurements.

Vertical gradients were determined from environmental water heads obtained from piezometer nests emplaced at various sites along the transects. Local, short-term effects on the vertical gradients occur close to the basin margins where rainfall/runoff can readily enter overlying permeable sands. The resultant vertical gradients vary widely (0.3 to -40 x 10^{-2} m/m - negative downwards). Vertical gradients associated with the usually-flooded areas of the disposal basin respond mainly to the relatively longer-term effects of changes in the basin operating level. Vertical gradients in the usually-flooded northern area of the disposal basin were almost constant in the period March-April 1995 (-5 to -7 x 10^{-2} m/m).

Lateral gradients were determined from fresh water heads at constant elevation. The constant reference elevations were chosen to be close to the water table. At these elevations, lateral hydraulic heads reflect mainly shallow groundwater processes influenced mainly by local rainfall recharge and the surfacewater in the disposal basin. The lateral heads on the eastern margin were not investigated in detail because the topographic situation is complicated by a dune which separates the main disposal basin from a topographically lower but partly-isolated overflow area to the east. This partly isolated area is flooded by disposal water only at very high basin operating levels. The lateral heads reflect this situation, showing a maximum in both the main and subsidiary basins and declining to a minimum beneath the intervening dune.

At the northern margin, the lateral heads indicate a gradient downwards from the disposal basin into the remaining area of the discharge complex to the north. The influence of the disposal basin heads probably extends some 150 to 500 m north of the flooded area. The lateral heads increase slightly from the discharge complex into the adjacent dunefield to the north, but at 200 m from the margin of the discharge complex they are still considerably below those in the disposal basin.

To the west, the landward boundary of the regularly flooded margin of the disposal basin abuts the colluvial sands which have been eroded from the adjacent duneface. Within the dune the lateral heads are not greatly different to those in the centre of the disposal basin but they were almost constant and did not reflect fluctuations in the basin operating levels.. In late summer there is a minimum in the lateral heads in the area close to the disposal basin margin. During periods of high rainfall water partly runs off the duneface and enhances recharge of the more permeable sands at the base of the dune, replacing the minimum with a low mound.

To the south, irrigation on the dunes has produced strong gradients in the lateral heads from the dunes to the discharge complex. Within the discharge complex, the lateral heads reach a minimum before rising slightly to the flooded ponds and channels of the disposal basin.

The data on lateral hydraulic heads described above has been used to estimate the limit to which the disposal water could move laterally before reaching hydrodynamic equilibrium with the surrounding groundwater system. This limit is approximately the distance at which the lateral head in the disposal basin is equal to that in the surrounding groundwater system. Estimates of this distance for the Mourquong disposal basin will be approximate because long-term average data for the basin and groundwater heads is not available. In addition, the surrounding groundwater heads may increase as the spreading disposal water and reduction in the evaporation of the natural groundwater in the discharge complex changes the magnitude and perhaps the direction of the gradients. This distance could not be calculated for the eastern margin, where the data is not available. To the north, it is more than 200m into the dunes to the north of the discharge complex. To the west, the situation is unclear because the head in the disposal basin is comparable to the maximum head encountered in the adjacent dune. To the south, the groundwater heads change rapidly with distance from the irrigated areas on the dunes, but the limit of lateral movement of disposal water is likely to be less than 50 m from the margin of the discharge complex.

Salinity, major ion-ratios to Br or Mg, and deuterium content were tested as indicators of the presence of disposal water in the natural groundwaters surrounding and underlying the disposal basin. Salinity is the best indicator, but its effectiveness is limited to the central and northern areas of the disposal basin.

The salinity of the surface water ranges widely (34,000 to >350,000 mg/L) depending on the season, the basin operating levels and the distance from the effluent outlet. Under low basin operating conditions in summer, the salinity in the disposal area increased progressively with distance northwards, from 34,000 mg/L in the inlet pipe to considerably more than 350,000 mg/L in isolated, almost dry, evaporite-rich brine ponds on the western side of the disposal area. Under high basin operating conditions in winter, the salinity in the disposal basin was much lower, decreasing in the centre of the basin from about 300,000 mg/L in summer to about 90,000 mg/L in winter. The winter salinity is considerably below that for halite saturation, which implies that almost all of the halite and more soluble salts precipitated in the disposal area during the previous summer were redissolved as the pool operating levels increased.

On the basis of the surface salinity patterns it appears that salinity is most likely to be a reliable indicator of disposal water in the topographically lower, central and northern parts of the usually flooded area of the disposal basin. Salinity will become an increasingly unreliable indicator with increasing distance from the usually-flooded area across the intermittently-flooded disposal basin margin because the higher areas will only be flooded at higher basin operating levels and hence lower salinities.

The presence of disposal water in the groundwater is indicated by two types of salinity versus depth profiles: (1) a profile typical of the usually-flooded central and northern areas of the disposal basin has an upper, disposal water-saturated, zone several metres thick in which the salinity is high and almost constant; an intermediate transition zone in which the salinity decreases sharply; and a lower, natural, zone in which the salinity decreases approximately linearly with depth; (2) a profile typical of the landward parts of the intermittently-flooded marginal areas and beyond is similar to that for the usually-flooded areas except that the high-salinity disposal water is overlain by lower salinity water and appears as a high salinity peak at several metres depth. The first profile is typical of vertical infiltration of disposal water. The second could reflect lateral flow of disposal water from the disposal basin or, less likely, it could indicate a situation in which lakewards-flowing lower salinity groundwater has overlain a vertical recharge-influenced area established during previous consistently higher basin operating levels.

On the eastern side of the basin, vertical recharge-influenced profiles are evident near the centres of both the main basin and its eastern arm, and in the regularly-flooded margin of the main disposal basin. Disposal water has not reached the centre of the dune which separates the main and eastern basins.

The profiles along the northern margin transect change from vertical-recharge-influenced, to possible lateral flow-influenced, to one of constant-salinity water throughout the profile. It appears that the disposal water has moved northwards marginally more than 300 m but definitely less than 650 m from the intermittently-flooded margin of the disposal basin. From the distance the disposal water has moved, the lateral hydraulic gradient over this distance, the time of basin operation, and the sediment porosity, the lateral hydraulic conductivity of the (mainly) Yamba Formation sediments has been calculated as 7 m/day. This value is reasonable considering the predominantly sandy nature of the Yamba Formation sediments.

At the western margin, disposal water has moved laterally only 25 to 55 m, which is consistent with the expected lower average landwards lateral hydraulic gradient in this area and a probable lower lateral hydraulic conductivity encountered as the disposal water reaches the Blanchetown Clay.

In the southern part of the disposal basin, iso-salinity contours show the presence of an anomalously low-salinity area next to disposal water ponded in a former gypsum-mining pit. This indicates some lateral movement of disposal water from the channels and ponds into the adjacent area of the discharge complex.

CONCLUSIONS

Mourquong Groundwater Discharge Complex

- The hydrodynamics of the Mourquong discharge complex are strongly influenced by two major lithostratigraphic features: (1) the widespread intercalation of fluvial and aeolian sands with the Blanchetown Clay and overlying lacustrine Yamba Formation. and; (2) the erosional window in the Blanchetown Clay, which may cover the entire southern end of the depression.
- The intercalated sands have a high lateral hydraulic conductivity which allows the water table in the discharge complex to respond relatively rapidly to changes in the regional water table. These changes are reflected in the relatively thick and well-resolved lacustrine Yamba Formation sequence.
- The erosional window is an area of high vertical and lateral hydraulic conductivity which, during periods of high water table, could act as a focus for the discharge of regional groundwater and, as the water table drops, for the reflux of brines to the underlying Parilla Sand aquifer.
- The hypothesis that paleo-brines which occur beneath the discharge complex refluxed through the erosional window rather than through cracks in the Blanchetown Clay is supported by their spatial distribution in the underlying aquifer.

- Theoretical predictions that high permeability favours advective reflux and low permeability favours diffusion are supported by the co-incidence of high vertical permeability and reflux brines, and by evidence of relict diffusion profiles in the Blanchetown Clay.
- Brines form in the discharge complex by a combination of evaporation of incoming Parilla Sand groundwater and saline water formed by rainfall-dissolution of salt efflorescences formed at the margins. The latter process selectively concentrates Mg- and Na-salts in the brines.
- Major-ion and ^{36}Cl data indicate the presence of at least three paleo-brines beneath the discharge complex.
- ^{36}Cl dating of these paleo-brines relies on the assumptions that they are not significantly mixed with other groundwaters and that the input values can be estimated. The resultant dates of brine reflux are consistent with thermoluminescence dating of deflation events from other discharge complexes but must be regarded with caution.
- Compared to other discharge complexes in the Murray Basin, Mourquong is intermediate between almost completely clay-enclosed salt lakes, such as Nulla Spring Lake, and mainly sand-based discharge complexes, such as that at Scotia, which lie beyond the periphery of the Blanchetown Clay. The Mourquong combination of significant permeability and a mainly Blanchetown Clay substrate favours a hydrodynamic regime which is more than usually responsive to changes in water table and consequent changes from diffusion- to reflux-dominated conditions. The strong fluvial influence of the nearby Murray River during its lithostratigraphic evolution is a major contributing factor to this responsiveness.

Mourquong Saline Water Disposal Basin

- The stratigraphic distribution of porosity can be approximated as permeability distribution.
- The floor of the disposal basin is Yamba Formation. This sequence is stratiform, and it can be correlated into the remainder of the discharge complex. It is distinguished by the interlaying of thin sandier, aeolian deposits. Most Yamba units have the full range of permeability.
- The Blanchetown Clay has the lowest permeabilities in the sequence, but there is stratigraphic and spatial variability. It thins dramatically from the basin centre to the western side, where it interdigitates with the Irymple Sand Member. Deflation and probably lake-margin erosion has cut a notch into the Blanchetown Clay on the

western lake margin, significantly thinning the effective permeability barrier separating the salina from the horizontally-permeable Irymple Sand to the west. At the southern margin, the Blanchetown Clay has very low permeability but its distribution is unpredictable. In the southwestern corner of the disposal basin, the Blanchetown Clay is absent and consequently highly permeable Shepparton sands overlie the Parilla Sand enabling direct hydrodynamic linkage of surface waters with Parilla Sand.

- The central area of the disposal basin has hydrodynamic closure to the underlying sequence. However, at the western margin of this area lateral hydraulic connection between the lake and the Parilla Sand is highly probable. The eastern margin of the basin at standard operating level has closure, but further eastwards the earlier Yamba units are permeable and directly overlie Shepparton sands.
- Vertical hydraulic gradients in the usually-flooded areas of the disposal basin were downwards and relatively constant during the measurement period. Gradients at the margins are affected by short-term processes such as rainfall recharge and flooding of the margins during rising disposal basin operating levels.
- Lateral hydraulic heads associated with shallow groundwaters are at a minimum in the unflooded areas of the discharge complex and increase towards the surrounding areas and towards the disposal basin. Where the discharge complex and disposal basin margins almost coincide, the zone of low heads is narrow and temporarily disappears when high rainfall recharge and disposal basin operating levels coincide.
- Salinity is a reliable indicator of the presence of disposal water in the central and northern areas of the disposal basin, but is at best a general indicator of disposal water in the southern areas near the outlet.
- In the central area of the disposal basin, the relatively-dense disposal water has moved advectively downwards into the permeable Yamba Formation sediments. In the underlying Blanchetown Clay, diffusion has created a transition zone between the disposal water and the lower salinity natural groundwaters. Downwards movement of disposal water is evident in the regularly-flooded disposal basin margins to the north and in the occasionally-flooded eastern arm of the disposal basin.
- Disposal water has flowed laterally 300 m into the discharge complex to the north of the basin. To the west, the distance is about 40 m, probably because the average landwards lateral hydraulic gradient is lower and part of the flowpath is through Blanchetown Clay, which should lower the average hydraulic conductivity. To the south, there are indications of a halo of disposal water in the groundwaters around the channels and ponds.

- In the centre of the disposal basin the Blanchetown Clay restricts the vertical movement of disposal water into the sediments. Overall, the stratigraphic control of the movement of disposal water appears weak, because it is detected occurs at similar elevations throughout most of the area.
- The potential for leakage of disposal water beyond the margins of the discharge complex appears to be small in the south and, probably, to the west. The northern areas appear most vulnerable, but it is not clear to what extent. No information on the situation to the east is available from this investigation.

INTRODUCTION

Mourquong is a natural groundwater discharge complex (Figure 1) which is used as a disposal basin for the Buronga Interception scheme around Lock 11 on the Murray River (Figure 2). The complex has a potentially large area for flooding, is of close proximity to the Murray River, and is apparently isolated hydrodynamically from the river.

The most recent regional stratigraphic, structural, and hydrodynamic study of the area was by Scott *et al.* (1991). Subsequent more detailed work by BMR and later AGSO produced a lithostratigraphy of the western side of the complex (Radke,1993) and an assessment of the geologic controls of permeability and hydrodynamics (Ferguson *et al.*, 1994). This study indicated the presence of probable Shepparton facies within the complex, with the implication that there may be hydraulic linkage with the present river. However the drilling program centred on the disposal basin and surrounds and omitted the eastern and southern areas of the Mourquong depression. Further detailed work by AGSO and CSIRO attempted to assess the stratigraphy of the entire complex, look for shallow aquifer and hydrodynamic connection with the river, and to trace the invasion of disposal water into the sediments of the complex. Additionally, deeper piezometric profiles were installed to test the brine reflux model of Wooding *et al.*(in press) by attempting to identify a brine pool at the base of the Parilla aquifer.

This report presents the stratigraphic and hydrodynamic overview of the Mourquong groundwater discharge complex, and then focuses on the stratigraphy and hydrodynamics of the disposal basin.

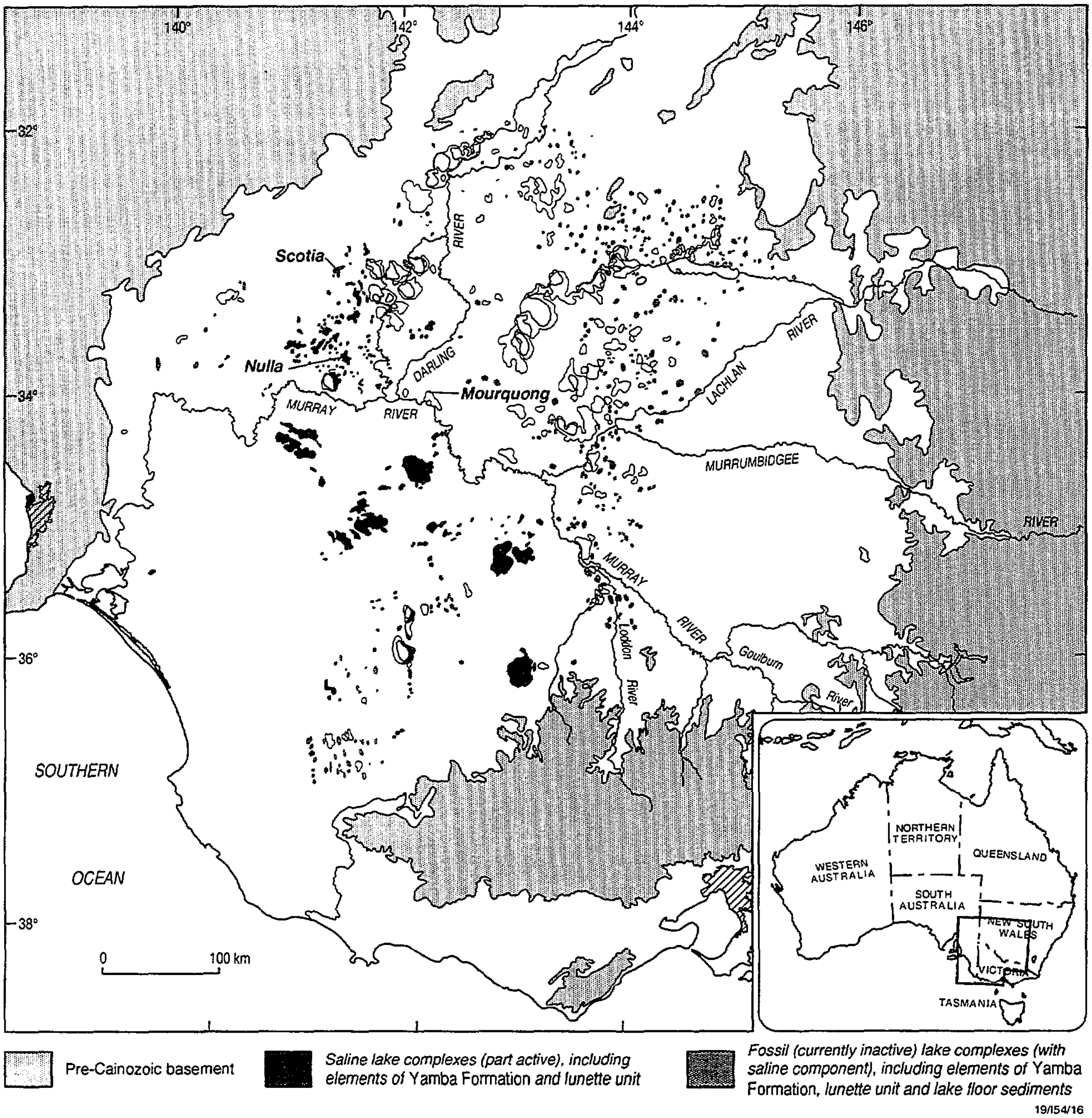

Figure 1. Location of the Mourquong discharge complex.

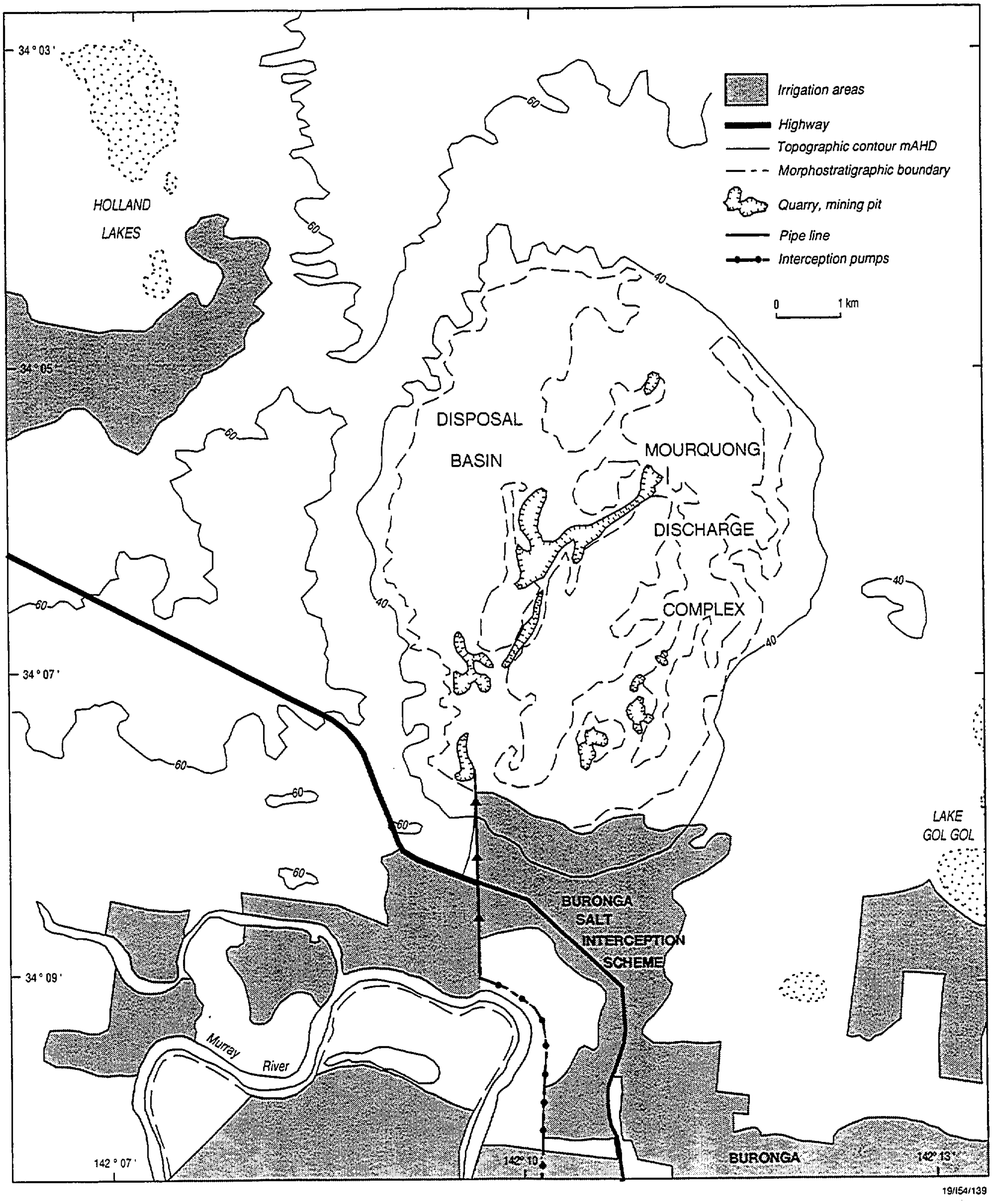

Figure 2. Relationship between the Mourquong discharge complex and the Buronga Salt Interception Scheme/disposal basin.

OUTLINE OF METHODOLOGY

Transects

Transects were surveyed and established at three scales: (1) a semi-regional scale designed to place the discharge complex in the context of its surrounding environment (e.g. the Coomealla-Tapio and MSWM-6 - Tapio transects, Figure 3); (2) discharge complex-scale transects (e.g. transect MNM, Figure 3); and (3) detailed transects normal to the margins of the disposal basin (e.g. transect MWM, Figure 4 and transect MRT, Figure 5).

Drilling and Pore Fluid Sampling/Analysis

Transect sites on the disposal basin margins and permanently-submerged areas were soft and wet, and for this project we used a specially-designed tripod-mounted rig assembled on site, with a hovercraft to transport the rig components. This drilling method is a variation of the penetrometer technique in which steel tubes are hammered into the sediments to 0.4 m depth. The Blanchetown Clay was readily cored by this method. Sediment samples for porewater analyses were obtained from the bottom 0.1m of each core to minimise the possibility of contamination by "float".

A rotary rig was used at several sites to drill to a depth of 10-15m with continuous augering and a retrievable wireline core barrel. Junctions of auger flytes had 'O' ring seals to minimize external water contaminating the core.

Salinity of the pore fluids was determined by optical refractometry using a portion of a small volume of porewater (typically ≤1 ml total) extracted from the sediments using a Manheim press. Cation analysis was by ICP, and ion chromatography was used for anion analysis.

Drillholes were cased as piezometers, and subsequently surveyed relative to the Australian Height Datum (AHD).

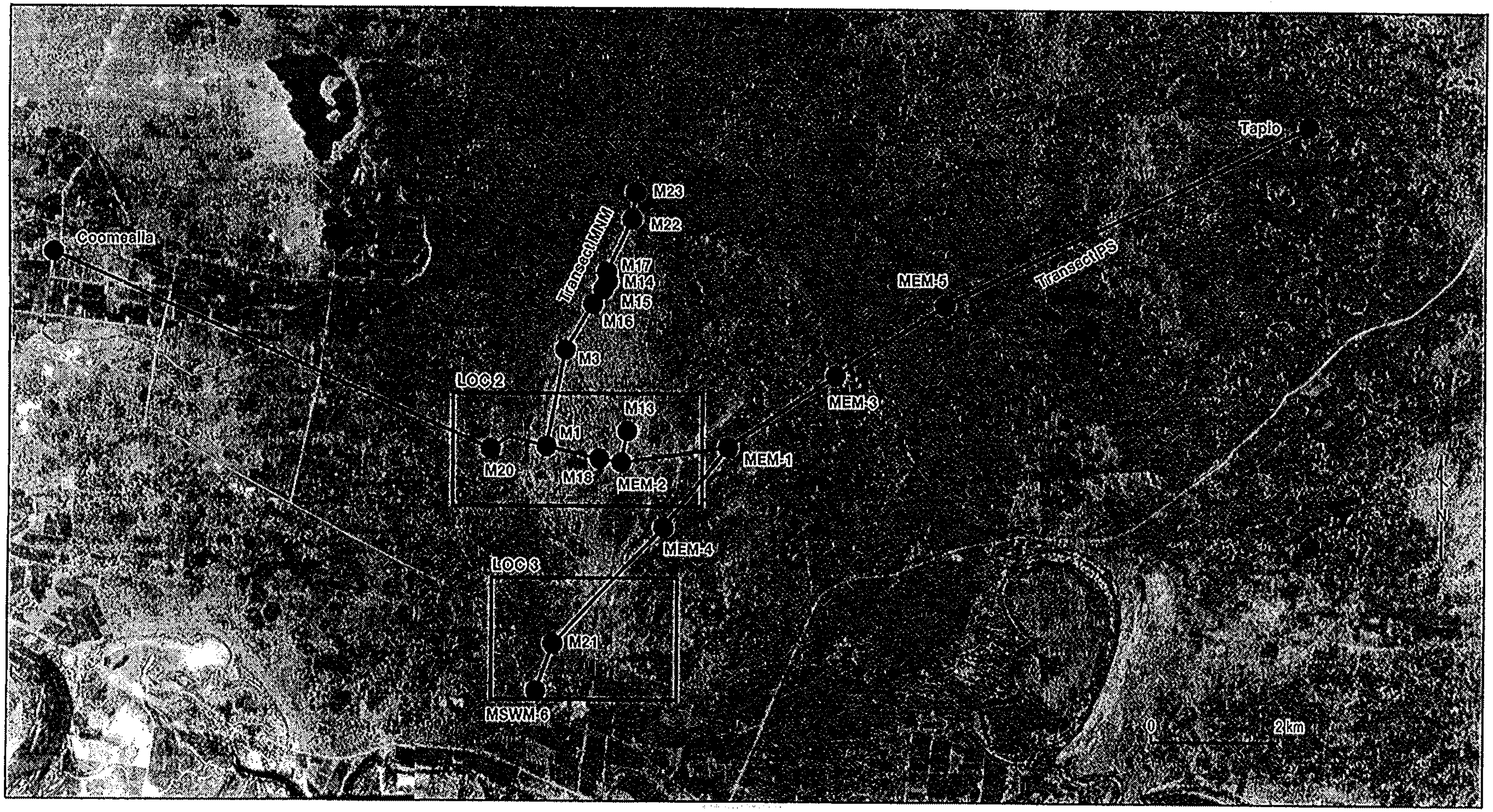

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Figure 3. Locations of transects at Mourquong.

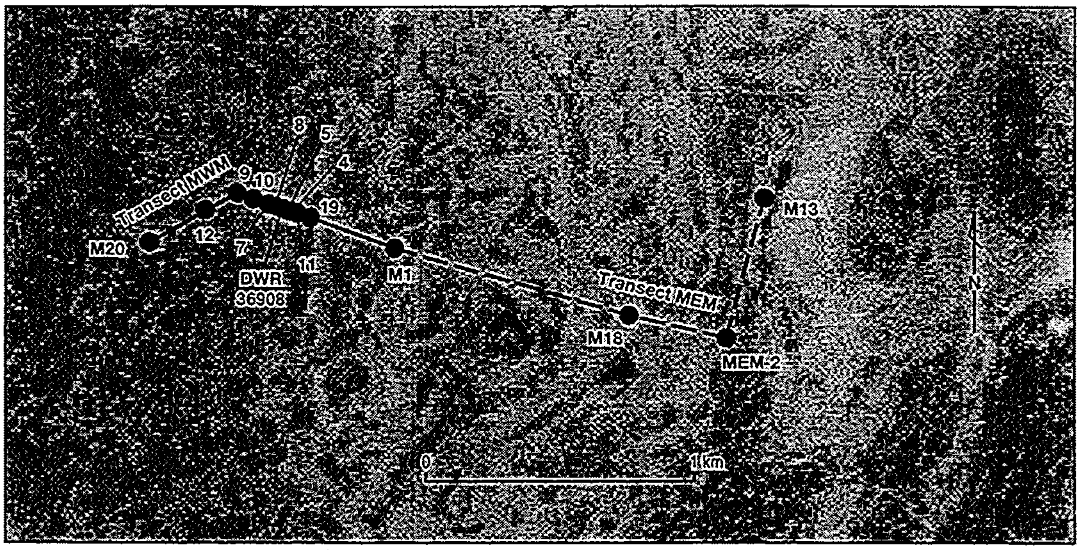

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Figure 4. Detail of the east-west transect in the vicinity of the Mourquong disposal basin

Figure 5. Detail of the transects at the southern margin of the Mourquong disposal basin/discharge complex.

Logging

Some 28 boreholes from AGSO & CSIRO investigations have been logged to provide the lithological framework for this work. Log formats and logs are outlined in Appendix II.

Estimation of Porosity and Permeability

Porosity abundance and type was qualitatively determined by visual assessment with binocular microscopy. As discussed in drilling methods, core material has come from three drilling methods, each with its own disturbance to sediment texture. The modification of original porosity by drilling artefacts is not consistent. As a generalisation, core material is more compressed by penetrometer coring and more expanded from the augering process.

Predominant porosity types recognized within these sediments are interparticle (IP), bioturbation (BO), intercrystalline (IC), fracture (FR) and fenestral (FE) types.

Porosity abundance categories have been arbitrarily selected for logging as 20-30%, 10-20%, 2-10%, <2%, and 0%. This reflects expected interparticulate porosity in sands. Although theoretical porosity in clays can be much higher, their effective porosity is very low to non-existent.

Determination of Hydraulic Heads and Gradients

Lateral and vertical hydraulic gradients associated with groundwater discharge complexes and disposal basins are typically small because of the flat topography. Consequently, the concepts of Lusczynski (1961) and Lusczynski and Swarenski (1966), which involve the separate determination of lateral and vertical gradients, are used to obtain accurate values for the hydraulic heads.

Vertical gradients were obtained from environmental water heads in piezometers set to different depths at the same location. Vertical gradients were difficult to obtain for the lake environments because the limited depth range of the tripod penetrometer-drilling techniques prevented the installation of piezometers at greatly differing depths. As a result, most of the meaningful vertical gradients have been obtained from the rotary-drilled piezometer nests.

Lateral gradients were determined from freshwater heads in piezometers which were set to a constant elevation (Macumber, 1991). In this investigation, minor deviations from constant elevation were corrected by interpolation or extrapolation using vertical gradients estimated from piezometer nests. If there was only one piezometer at the site, then small corrections were approximated by : (1) taking the freshwater head at the standing water level (SWL) in the piezometer as zero, (2) constructing a two-point line representing the change in freshwater head with elevation; and (3) reading the freshwater head at the required elevation from this line.

Identification of Disposal Waters

Identification of disposal water in groundwaters was based on a comparison between the salinity, major ion chemical composition and deuterium isotopic composition of surface disposal waters in the lakes and the composition of the natural groundwaters which surround and underlie the disposal basin.

The composition of the surface disposal water was obtained from samples collected in March 1995. The salinity and major-ion chemical composition of the groundwaters was obtained from the porewater samples extracted from the sediment cores obtained during drilling. The deuterium measurements were made on distillates of wet sediments. Although the differences between the surface disposal waters in the lakes and the natural groundwaters may not be great, the drilling methods used in this investigation (in particular the tripod penetrometer method) are capable of producing accurate and detailed records of relatively small changes in porewater composition with depth.

PART 1 - THE MOURQUONG GROUNDWATER DISCHARGE COMPLEX

PHYSIOGRAPHY

The Mourquong groundwater discharge complex is located due north of Mildura, in New South Wales between 2 and 10 kilometres north of the Murray River (Figure 1). It is adjacent to and directly north of the Stanley Wines winery on the Buronga-Dareton highway (Figure 2).

The discharge complex is a topographic depression with a semicircular outline some 8 kilometres in diameter, and with a gently arcuate western margin that trends north north-east along the eastern slope of a broad low ridge (Figure 6).

The complex contains a distinctive suite of landforms. A crescentic dune delineates the northern, eastern, and southern extent of the complex which appears to be entrenched within a fossil stranded lake complex on the upper Blanchetown Clay surface. The less arcuate western margin is delineated by both a slope down from the ridge which defines the western margin of an active salina that covers a relatively small area of the complex. The active lake floor lies at approximately 31.7 m AHD elevation. East of this salina, and within the outermost circular dune, lies a complex topography comprising pedestals of a former flat-topped gypsiferous sandy terrace. Most pedestals have one or more generations of lunette accretion on their western and northwestern margins. Some pedestals are additionally covered or partially covered by subdued hummocky red sand dunes. A lower sand-covered surface extends between these pedestals from the lunette margins of the existing lake to the outermost circular dune.

Longitudinal seif dunes of the Woorinen Formation overlie the sandy ridge to the west of the complex, and overprint the older, easternmost component of the crescentic dune

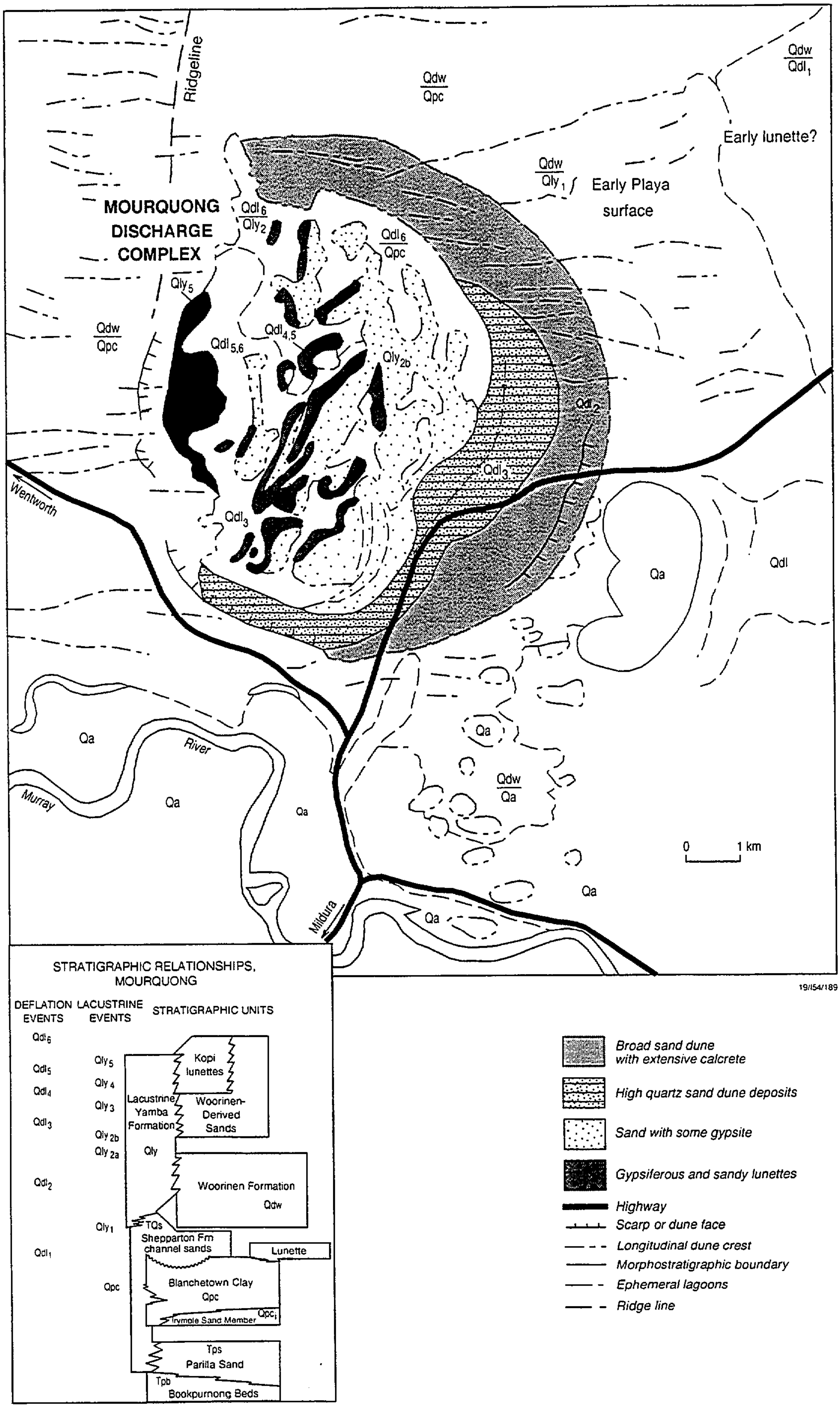


Figure 6. Morphostratigraphy of the Mourquong discharge complex.

on the eastern margin (Figure 6). Within the complex, seif dunes are absent but subdued hummocky sand dunes partially cover some of the pedestals.

Although less apparent, there appears to be a series of strandlines of low lunettes bordering the existing lake. Between these low lunettes and the dissected pedestal terrain to the east, there is a near-central north-south-aligned higher surface with erosional margins and lunette cover.

STRUCTURAL FABRIC

The Mourquong complex (Figure 6) overlies the Koorlong Trough which has a western faulted margin along the Danyo Fault, separating it from the Merbein Ridge immediately to the west (Figure 7). The location of this fault is placed further east of the active lake under the Mourquong Swamp by Scott *et al.*. (1991) although their stratigraphic cross-section enigmatically contradicts this position. Dislocation of strata across the Danyo fault is only below the Tertiary sequence and subsidence in the trough is apparent throughout the Cainozoic. Increased thicknesses of both the Blanchetown Clay and Yamba Formation confirm differential subsidence in the limited area investigated. The present physiographic features of Mourquong are also an expression of this subsidence in the Koorlong Trough.

LITHOSTRATIGRAPHY

The Stratigraphic sequence below Mourquong discharge complex has been investigated through an extensive reconnaissance drilling program (Figures 3,4,5) From detailed lithological logs (Radke, 1992 and Appendix II), lithofacies have been identified, and lithostratigraphic units interpreted. The units are described here in their interpreted chronostratigraphic order. The alphanumeric categories that are used, relate to the chronology of identified deflation and lacustrine events. Many of the units have been reinterpreted and revised after additional photogeological interpretation and stratigraphic drilling (Figures 8 and 9) since the stratigraphy proposed by Radke (1992), Radke (1993), Ferguson & Radke (1994), and Ferguson *et al.*. (1994). Consequently the unit symbols used in this report do not correspond with the lithostratigraphic units (and their symbols) documented in these earlier reports.

Where lithostratigraphic units can be correlated with the regional formal stratigraphy, documentation of the formal unit follows their description.

The interpreted stratigraphic relationships of the units which are described and reinterpreted below, are summarized in Figure 10. In the absence of any

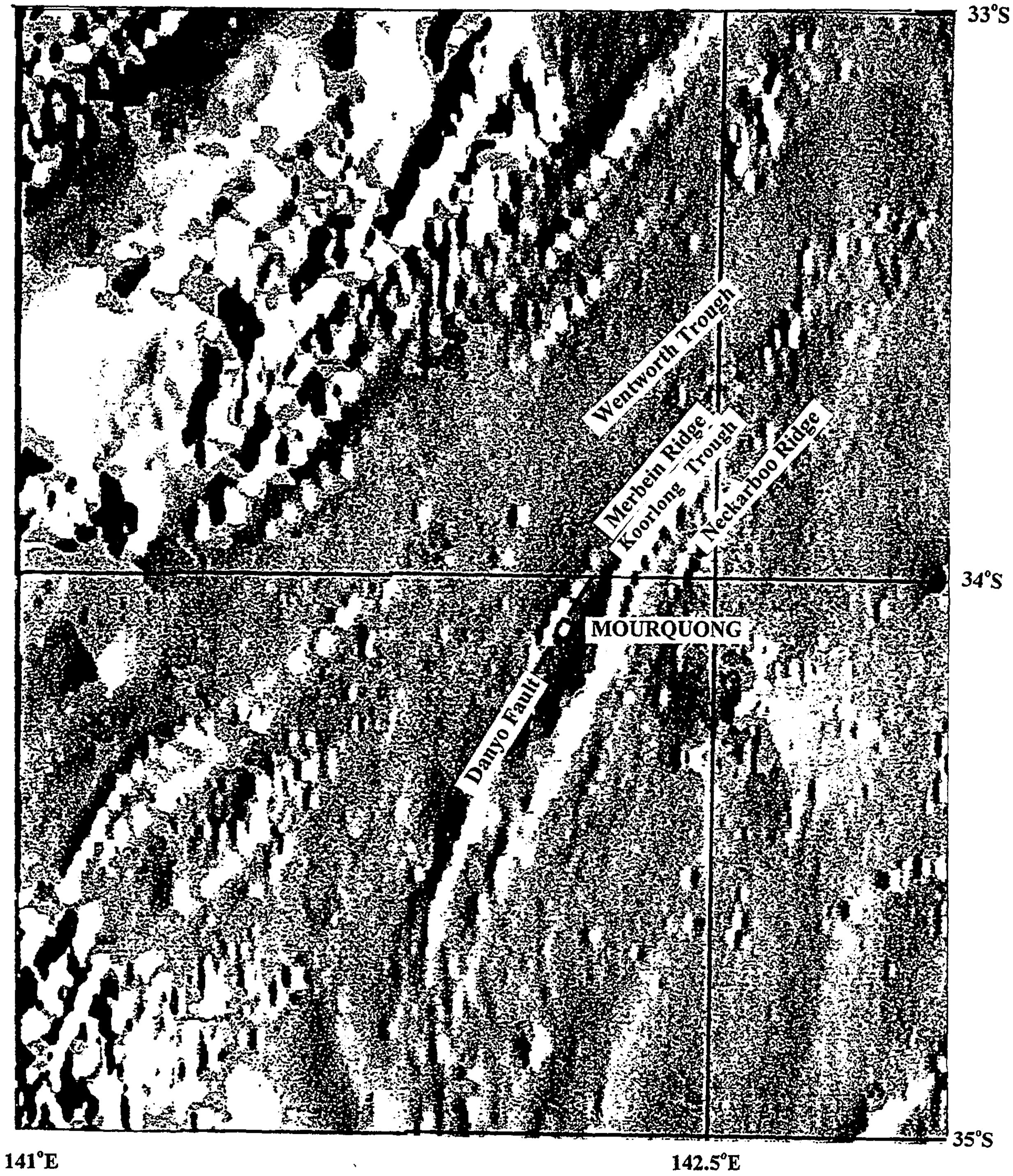


Figure 7. Location of Mourquong Discharge Complex over magnetic basement structure (TMI image). After Bureau of Mineral Resources (1985)

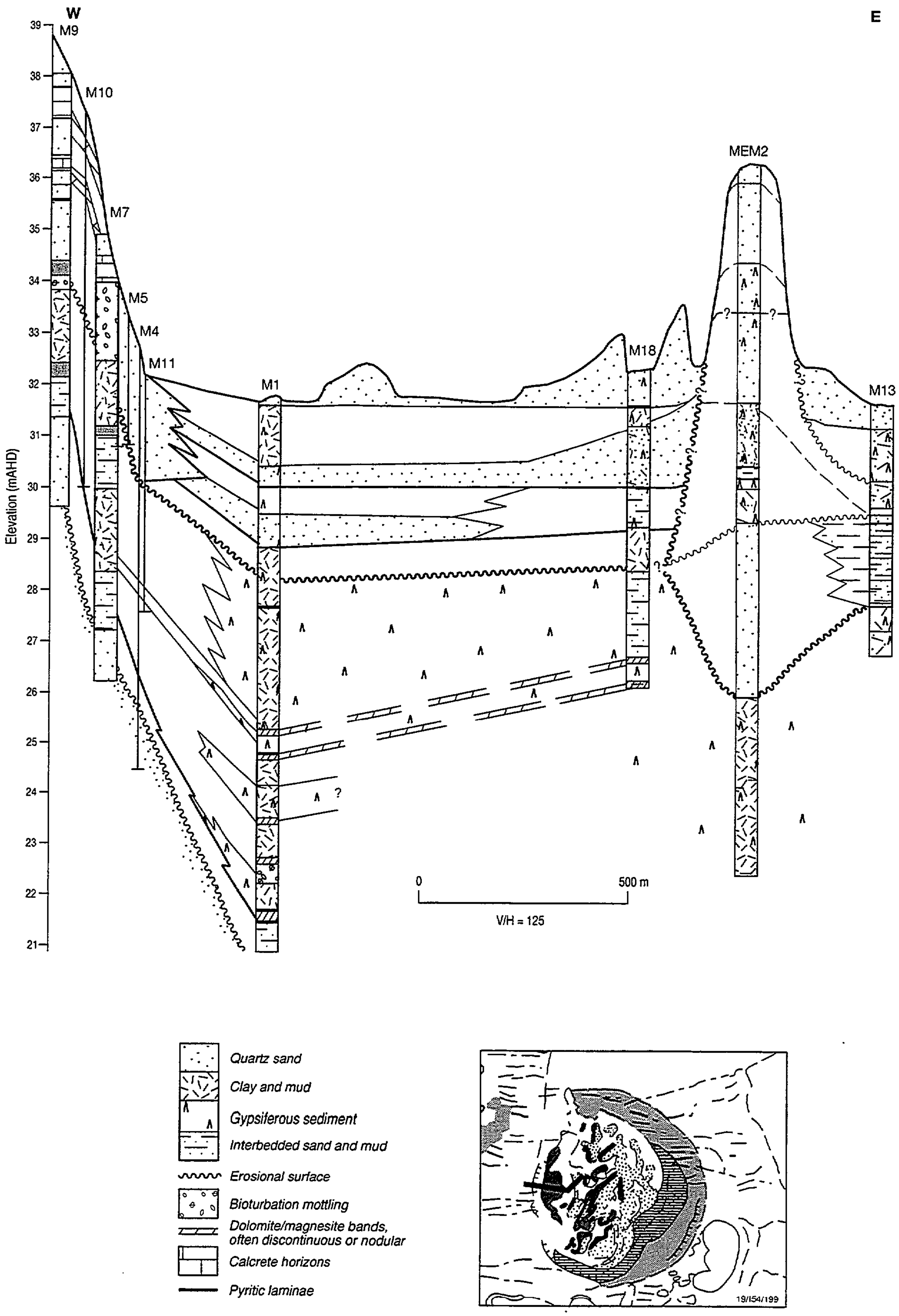


Figure 8. Lithofacies and lithostratigraphic correlation of MWM 9 - M13 transect.

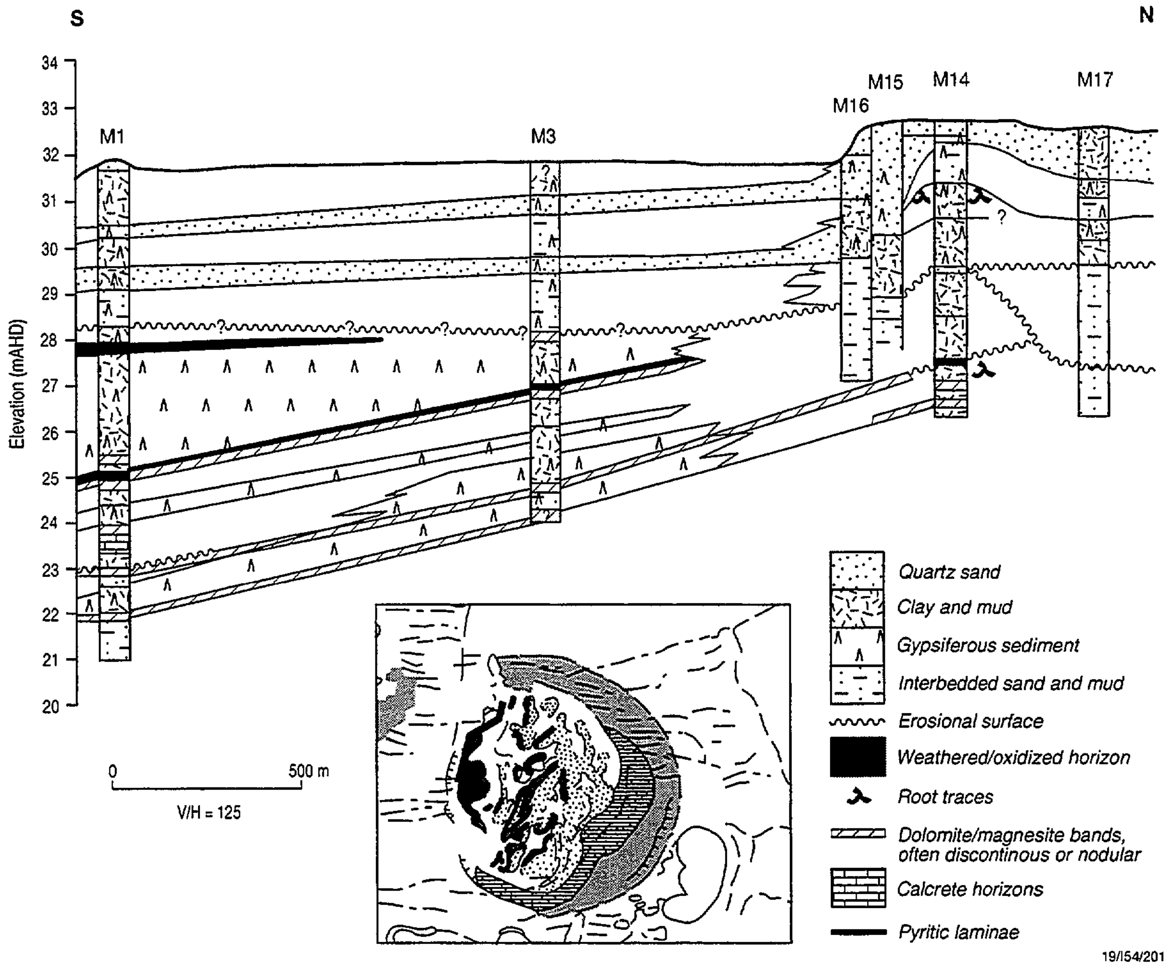


Figure 9. Lithofacies and lithostratigraphic correlation of MNM 17 - M1 transect.

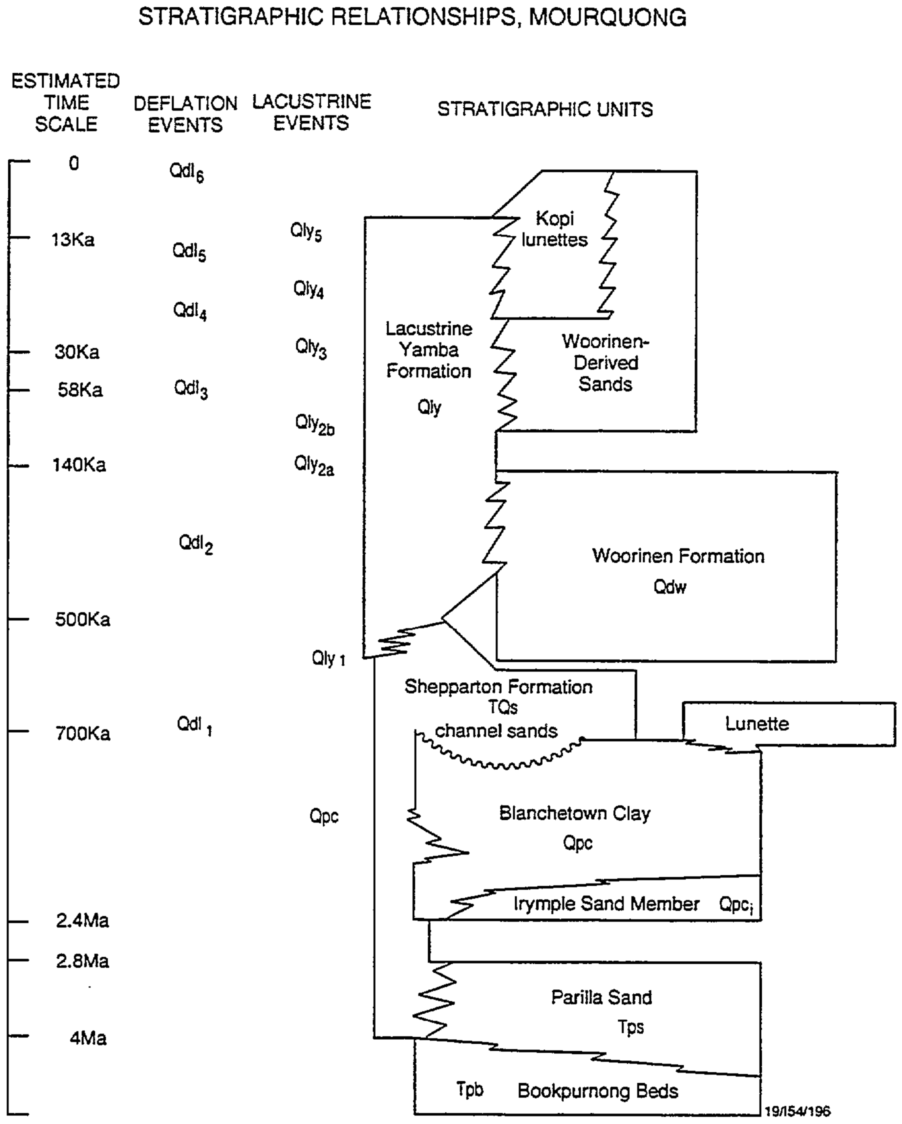


Figure 10. Stratigraphic relationships, Mourquong discharge complex.

chronostratigraphic work at Mourquong, an estimated and approximate time scale for these units has been constructed from Brown and Stephenson (1991) and thermoluminescence dating of the comparable sequence at Nulla groundwater discharge complex (Ferguson and Radke, 1993).

Unit Tpb

At Mourquong

Location in discharge complex: Underlies the Parilla Sand, and is presumed widespread (Brown & Stephenson, 1991). It is intercepted directly below the Mourquong depression in AGSO MEM 1(27m) and on the western margin in DWR Bore 36908 (35m+).

Geometry and thickness: Unknown but presumed to be a tabular unit with minimum thickness of 35m.

Description: Dark to medium grey sandy muds, olive grey to olive black plastic muds and some clay have approximately 15 to 30% horizontal bioturbation. Minor interlaminated sands occur in the upper 5 metres are light olive grey fine to very fine quartz sand with minor silt-sized mafics. Bioturbation of the muds in this upper interval are generally sand-filled, with minor framboidal pyrite. Below this zone, lamination from sandy partings is rare and bioturbation is preserved exclusively by framboidal pyrite precipitation and replacement of faecal pellets in the burrow tubes. Arsenopyrite may also be present with the framboids.

Stratigraphic relationships: Underlies the Parilla Sand with an interfingering transitional boundary.

Depositional Environment: Shallow-marine oxygenated conditions below wave base.

Discussion: The unit was only intercepted in four boreholes in the PS transect of piezometers, M21, MEM 4, MEM 1, and MEM 3. The Bookpurnong beds lie below 58.5m depth in MEM 1. The upper most 27 m of the beds were cored for 0.65m at every 5m in this interval. It is possible that the Bookpurnong beds - Geera Clay boundary was reached at 85m depth with the interception of a highly fossiliferous dolomite band containing glauconitic pellets, ostracods, gastropods, pelecypods, and echinoid and malacostratan fragments.

Regional Character

<u>Bookpurnong Beds</u>

Lithology: Poorly consolidated to plastic, brown or greenish-grey calcareous clay (marl), silt and minor sand. There is high carbonate content, with lesser glauconite and mica. Although clay is dominant, quartz sand and silty facies are locally important. The formation is carbonaceous in places. Shells and other fossil debris form a significant minor component of the Bookpurnong beds.

Distribution, thickness, and geometry: The beds are widely distributed throughout the depocentre of the central-western Murray Basin, but are more restricted than the underlying marine sediments of Late Oligocene to Middle Miocene age. To the southwest they onlap eroded limestones of the Pinaroo Block. Here their absence is probably from emergence during deposition. To the north, the Bookpurnong beds extend across those areas of western New South Wales which overlie pre-Cainozoic infrabasins; thought to be a result of differential subsidence (Brown & Stephenson, 1991).

The beds are roughly lenticular to tabular with maximum thickness in the central-west basin. Thicknesses range from a few metres near the margins to up to 50 metres at the tri-state border (Brown & Stephenson, 1986); the type section near Loxton, South Australia, is 15 metres thick. The unit is almost entirely confined to the subsurface.

Palaeontology: A rich macrofauna is dominated by bivalves, especially *Nucula, Nuculana, Leiopyga, Seripecten, Limopsis,* and *Ledella..* The gastropod *Turritella,* and the scaphopod *Dentalium* are also common. A rich microfauna is preserved and miliolid foraminifera are particularly common.

Age: Ludbrook (1957, 1961) initially assigned a Late Miocene age, but later changed this assignation to Early Pliocene. Lawrence (1966) and Brown (1983) thought the age ranged from Late Miocene to Early Pliocene. Brown (1985) related the deposition of the Bookpurnong beds and the Pliocene sands to a major transgressive-regressive cycle between 6.6 Ma and 2.8 Ma.

Characteristics: Lithology, stratigraphic position, and the presence of a distinctive shelly macrofauna are characteristic. However, the Bookpurnong beds show lithological similarities to both the Winnambool Formation and the Geera Clay and are only differentiated by palaeontology and especially a distinctive bivalve assemblage.

Environment of deposition: During a marine transgression, the beds were deposited under low-energy marine shelf conditions with little water agitation and low sedimentation rates. They represent a shallow-marine to lower shore face facies equivalent to upper shore face and littoral sediments of the basal Loxton-Parilla Sands

Stratigraphic relationships: The Bookpurnong beds overlie the Murray Group disconformably to unconformably. The beds underlie and partly interfinger to the east and north with the Pliocene Loxton-Parilla Sands.

Unit Tps

At Mourquong

Location in discharge complex: Extends uniformly below the discharge complex.

Geometry and thickness: Tabular with an average thickness of 50 metres. Below the complex, the thickness varies between 40 m centrally (in MEM 1) and an apparent 60 metres in the southwestern corner (in M21).

Description: Distinctively unconsolidated well-sorted, very coarse to very fine quartz sands of variegated colour ; moderate yellowish brown, dark reddish brown to moderate brown. A heavy mineral content is ubiquitous, usually defining lamination in otherwise uniform sand. In the lower part of the sequence the sands have a variable clay matrix of up to 15% and dark humic lumps. The sands have very high interparticle porosity.

Stratigraphic relationships : Overlies the Bookpurnong beds and underlies the Blanchetown Clay with disconformity.

Depositional Environment: Lowermost Parilla Sand has muddier sandy interbeds of low energy shallow-marine conditions. The upper sequence of well-sorted sands are probably near-shore and beach deposits, and possibly coastal dune sands.

Insufficient core was recovered to assess environmental character of the sands. The absence of an upper indurated or silicified surface on the Parilla Sand is compatible with deposition in a subsiding Koorlong Trough where Karoonda weathering could not have been as intense.

Discussion: In the southwestern corner of the complex, stratigraphic drilling has established the absence of Blanchetown Clay and the Parilla is overlain by channel sands of the Shepparton Formation. The apparent increased thickness of about 10 metres in the Parilla Sand in this area may be from misinterpretation of the Parilla Sand - Shepparton sand contact.

Regional Character

Parilla Sand

A blanket of sand and sandstone having a thickness of about 60m covers the whole of the marine Murray Basin. The upper surface of the sand forms long prominent ridges trending north-south in Victoria, generally regarded as having been formed as strandlines along a retreating late Tertiary sea (Blackburn, 1962).

Ludbrook (1961) described the type section at Loxton, South Australia, as characteristically bright yellow cross-bedded micaceous sands, grits and silty sands, and considered them deposited in estuarine or shallow water at the end of the Miocene. Firman (1966) split the

Loxton Sands into two units, the Lower Beds (estuarine and equivalent to the sands of the Loxton type section) and Upper Beds (fluviolacustrine) with a disconformity in between. Firman also recognized the Parilla Sand, disconformably overlying the Loxton Sands, having a similar lithology (though finer grained) but differing in having little or no cross-bedding. Firman considered the Parilla Sand unit to be fluviolacustrine, and the complete sequence to be Pliocene. Lawrence (1966) defined the Diapur Sandstone and considered it to be a variant of the Loxton Sands. The Diapur Sandstone differed to the Loxton Sands in structure (no strong cross-bedding), lithology (medium to fine-grained, only lightly micaceous sand), and lack of fossils. Lawrence suggested that the lower part of the Diapur Sandstone may have been offshore to littoral, and that the upper ridged sands were shoreline deposits. Lawrence subsequently recognized the equivalence with the Parilla Sand .

Lithology: The unit consists of yellow-brown, fine to coarse, well-sorted quartz sand and sandstone, with minor clay, silt, and pebble conglomerate. Locally the unit includes poorly-sorted, micaceous, quartz sand and gravel. The sands are weakly cemented and friable to unconsolidated, and in places have trace fossils of marine shells and burrows. The clay content is generally less than 15%, but increases towards the base of the unit . The quartz grains are equant and subrounded to rounded, the rest of the silt and sand-sized grains comprise the stable minerals zircon, tourmaline, ilmenite and rutile, either dispersed or concentrated (Lawrence, 1975, Brown and Stephenson, 1991).

Distribution and thickness: The unit forms an extensive blanket of sand underlying much of the Mallee region (Lawrence, 1975), and extending beneath parts of the central-western Riverine Plain and the lower Loddon Valley (Macumber, 1978). The blanket of sand has an average thickness of about 60 metres in Victoria. On the Anabranch 1:250 000 Sheet, the Parilla (Figure 11) thins regionally from the Central-Western Depocentre (or Renmark Trough) in the southwest (60 metres in Cal Lal 1 and 64 metres in Talgarry 1 (BMR Anabranch 7)), to the Lake Wintlow High in the northeast (less than 35 metres in Bore 1096). The greatest thickness gradient lies to the southwest of Nulla Discharge Complex. Figure 12 displays isopachs of combined Boorpurnong Beds and Parilla Sand. The Bookpurnong Beds comprise about 36% of the sequence in the Central-Western Depocentre and become more varied in thickness up onto shallower basement (8-36%). The Parilla shows significant relative thickness in the Tarrara, Bunnerungee and Wentworth Troughs half way diagonally across the Anabranch sheet, and greatly reduced thickness adjacent to these depressions on the Neckarboo Ridge, Lake Wintlow , Lake Victoria, and Flinders Range-Scopes Range Highs, indicating significant differential subsidence of the basement during this deposition. Additional to this subsidence control on

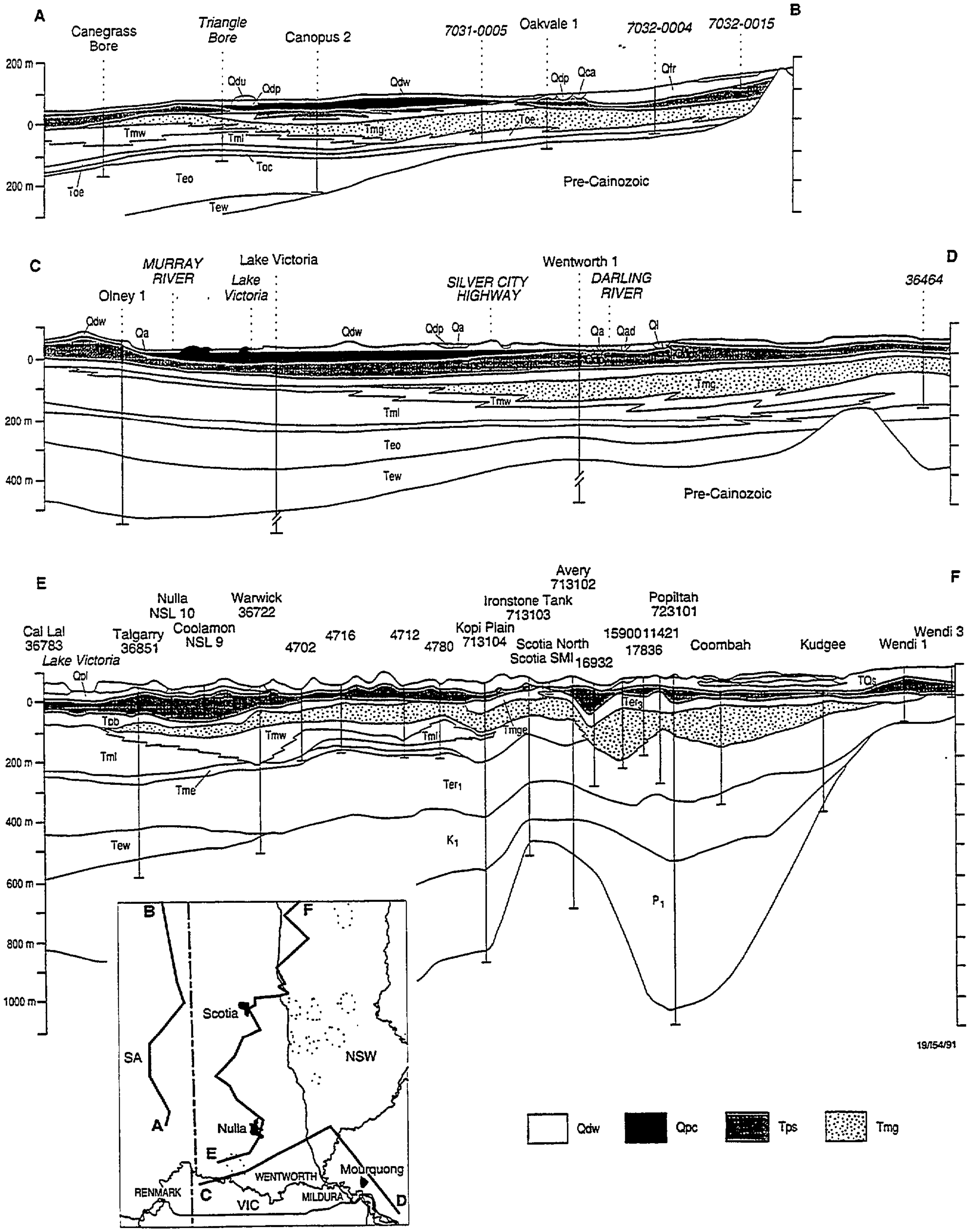


Figure 11. Regional stratigraphic framework.

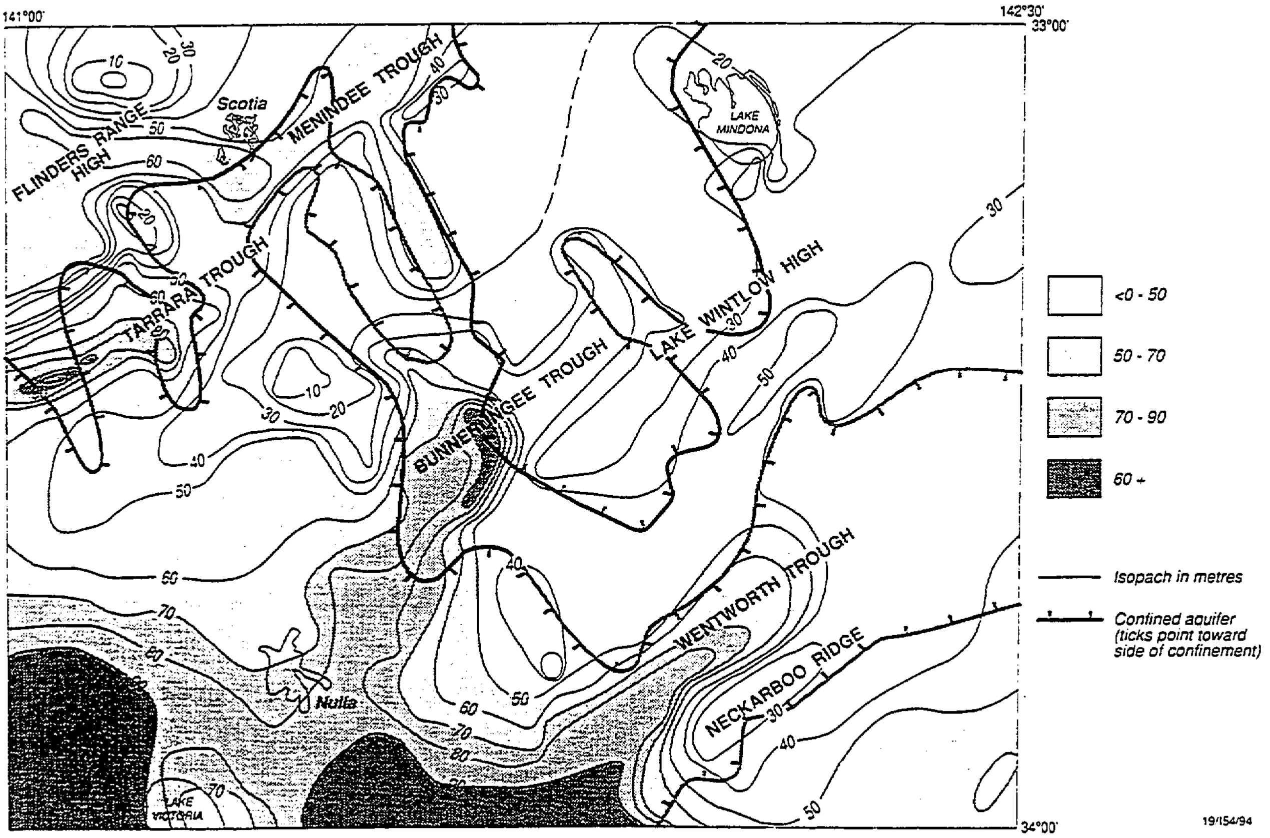


Figure 12. Thickness of Parilla Sand and Bookpurnong Beds on the Anabranch 1:250,000 Sheet area.

thickness, there is a superimposed fabric of northwest-southeast trending variations in thickness indicative of the upper strandline dune ridge and swale topography of the unit. This fabric is more apparent in the existing surface topography (Figure 13), TM imagery, and in structural contours of the upper Parilla surface (Figure 14).

Structure and topography: The upper Parilla surface has a ridge and swale palaeotopography with prominent ridges spaced 5 to 12 kilometres apart (Figure 13). In the Nulla - Warwick area, palimpsest Parilla strandlines are evident on composite thematic mapper (TM) imagery (BMR, 1989) and indicate an abnormally large ridge and swale set that extends from Nulla to the west, through the other discharge areas of Warwick, New Bluff, etc (Figure 11). On the basis of aerial size and extent, these dunes had significant relief and influenced the distribution and thickness of Blanchetown Clay.

This topography is not apparent over areas of higher variable subsidence as at Mourquong (Figure 7) and higher subsidence areas on the Anabranch sheet (compare Figures 12 and 13), probably because less sediment was available for reworking and dune building.

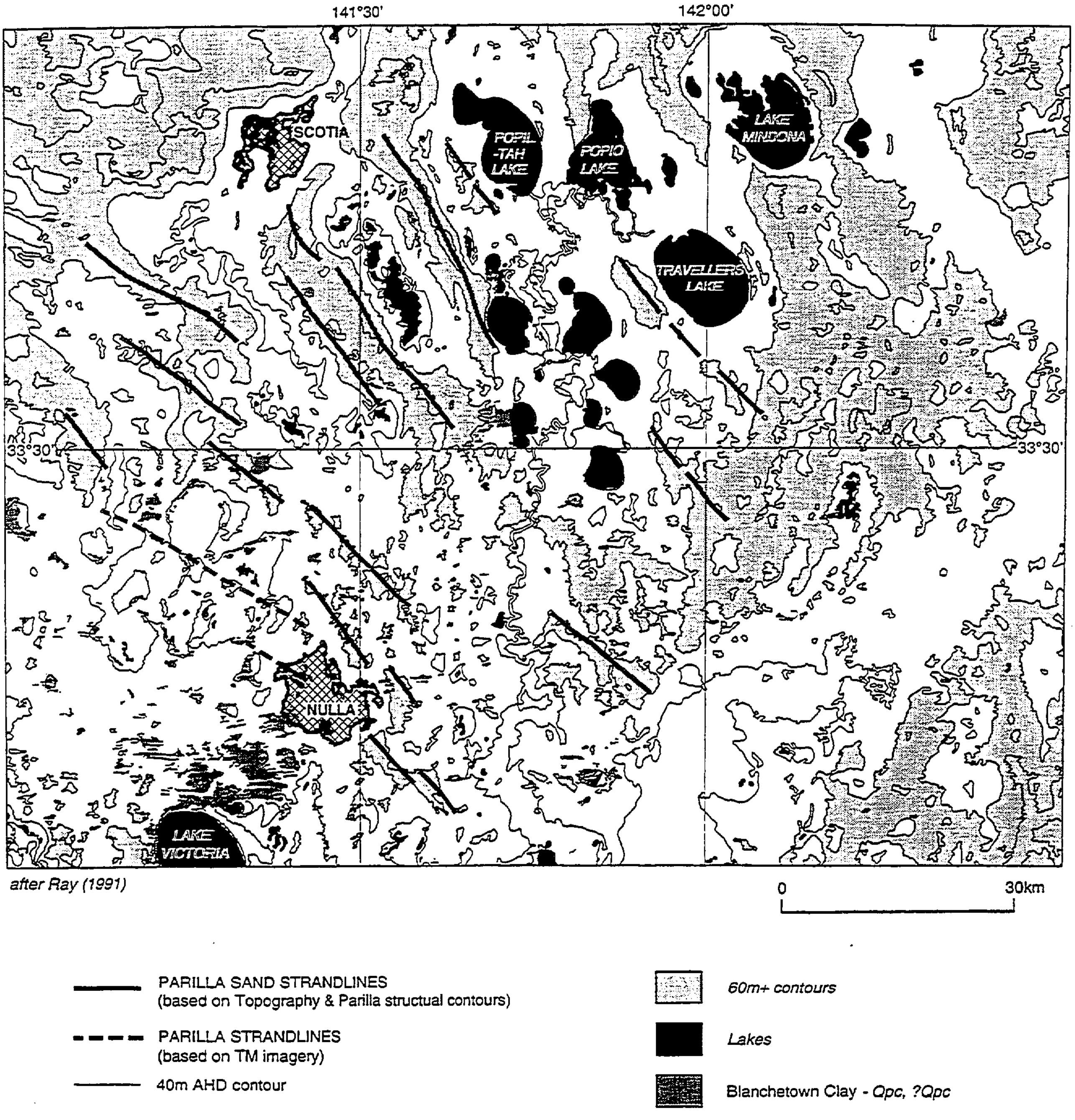
Palaeontology: No fauna has been observed in this area. Chapman (1916) regionally identified estuarine and shallow-water ostracods, sponge spicules and echinoid spines and plates, as well as undersized thin-shelled foraminifera which he interpreted as being mainly estuarine, with some brackish-water and marine shells.

Characteristics: The Parilla Sand is predominantly subsurface. No observed outcrop occurs locally to Nulla and Mourquong. At Scotia Lakes, Parilla Sand outcrop is highly ferruginized.

Brown and Stephenson (1991) state that it has not been yet possible to differentiate component units in the Mallee region.

The sands have often been interpreted as an entirely regressive sequence but Macumber (1978, 1983, 1991) describes a basal Kerang Sand Member further east as transgressive over the fluvial Calivil Formation, whereas the upper component is a regressive shoreline sequence of coarser micaceous sand with variable heavy mineral bands (Wandella Sandstone Member).

Firman (1966, 1972) subdivided the Loxton Sands in South Australia into the Lower Loxton Sands consisting of shallow-marine and estuarine sands, and the disconformably overlying Upper Loxton Sands consisting of fluvio-lacustrine sands. He also defined the overlying Upper Pliocene Parilla Sand as a younger, cross-cutting, entirely fluvial formation, partly entrenched within the Loxton Sands. Brown and Stephenson (1991) correlate the 'Parilla Sand' in Victoria as mainly an equivalent of the Loxton Sands, but include inter-ridge fluvial sediments which are probably equivalent to the Parilla Sand in South Australia. There is difficulty in differentiating these components from drillers logs



after Ray (1991)

19/154/92

Figure 13. Former Parilla Sand strandlines

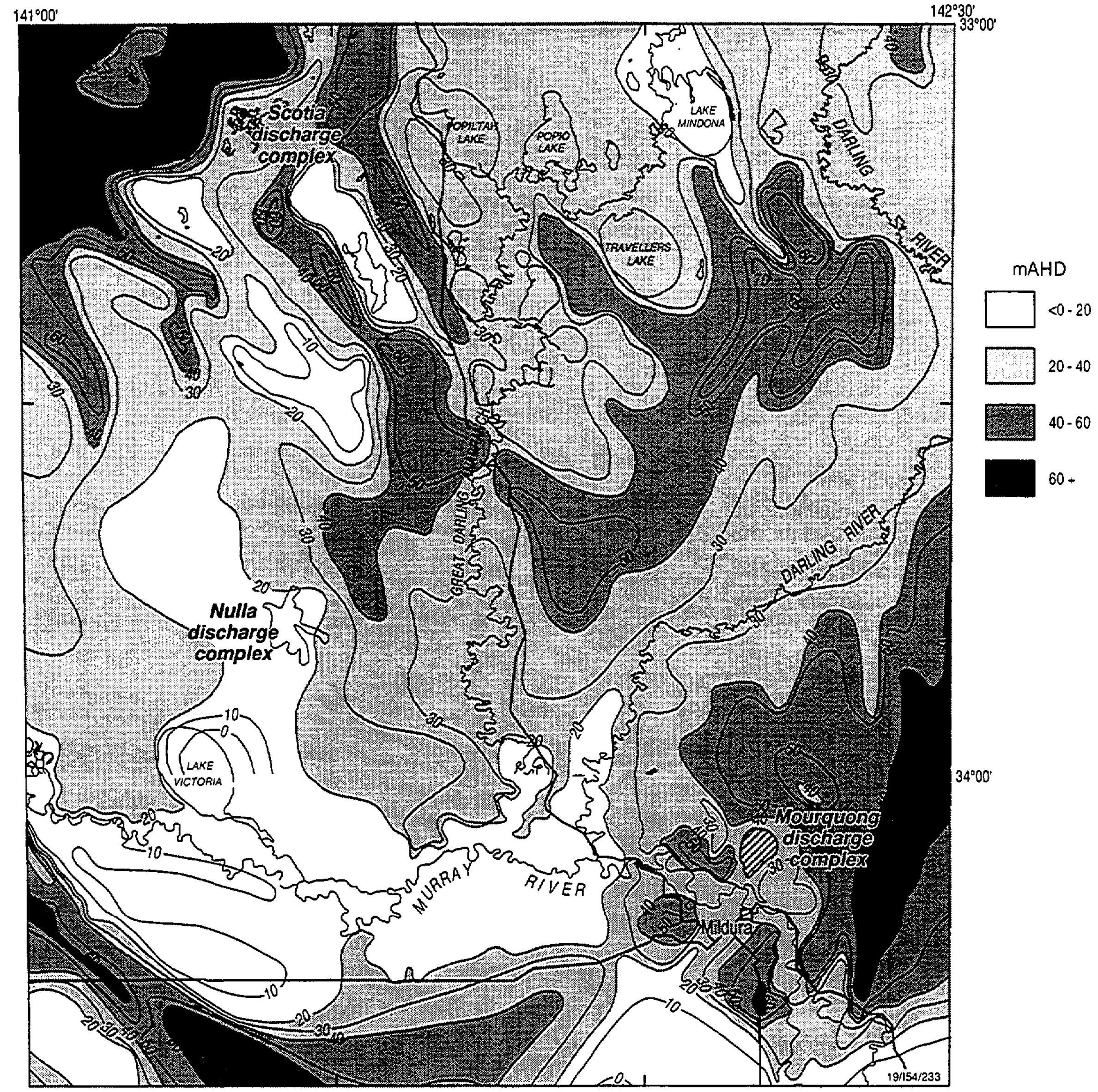


Figure 14. The upper surface of the Parilla Sand. Structure contours are in metres AHD (from Brodie, 1992).

and consequently they are viewed collectively as a composite sand sheet deposited in a complex of shallow-marine, littoral, and fluvial strandplain environments, and combined into a single Pliocene Parilla Sand unit.

Environment of deposition: Parilla deposits are shallow marine and coastal ridges and swales. The stranded ridges consist of a range of marginal-marine beach and offshore barrier-bar sediments, including inter-ridge estuarine and fluvial deposits, in addition to possible aeolian dune sands (Brown and Stephenson, 1991). In some areas, the general decrease in grain size with depth (Lawrence, 1966, 1975), local concentrations of disarticulated shells stacked convex down on bedding surfaces, and the presence of bands of heavy mineral sands, are consistent with deposition in regressive upward-coarsening shallow to marginal-marine and beach/barrier bar complexes. The resultant strandplain most probably included aeolian dune complexes of the type envisaged by Blackburn (1962) but it is probable that most of the deposits of this environment have been subsequently reworked by aeolian processes (Brown and Stephenson, 1991).

Stratigraphic relationships: The Parilla Sand is mainly underlain by the Bookpurnong beds with apparent conformity, but laterally replaces them to the east and north. It is probable that the basal Parilla Sand in eastern and northern areas are littoral equivalents of the upper part of the shallow-marine Bookpurnong beds.

Over the Central-Western Depocentre, the Parilla Sand is overlain with disconformity by the Blanchetown Clay, the lacustrine deposits of Lake Bungunnia. The maximum extent and depth of this lake remains conjectural but has been placed arbitrarily at between the 60 and 70 metre present-day topographic contour by Stephenson (1986). The higher ridges of the Parilla Sand on the Anabranch sheet were never completely inundated and as a result, including subsequent erosion over structural highs, the Parilla Sand has ridge and structurally oriented inliers within the Blanchetown Clay (Figure 12), Brodie (1992).

During the late Quaternary, the exposed near-surface Pliocene sands were subject to deflationary stripping, and were recycled into the overlying Quaternary dunes of the Mallee region as well as the dunefields and loess deposits of the eastern Murray Basin. In the Anabranch area these dunes are predominantly included in the Woorinen Formation.

Unit Qpci

At Mourquong

Location in discharge complex: This unit extends throughout the discharge complex.

Geometry and thickness: The overall geometry is lenticular, thickest in the central part of the Mourquong depression where it exceeds 5 m. The unit thins eastward to about 1m in MEM-3. On the southern margin of the disposal pond this unit both plunges and thickens southward from 0.3 to 1.5 metres between MRT-BM and MRT -3.

Description: The unit is characterised by thin-bedded to laminar alternations of quartz sand, muddy sand and clay. The pinkish to yellowish-grey sands can be of variable grainsize (very fine to coarse) and sorting, and commonly fine-upwards within each lamina. Interlaminated muds and sandy muds have variable colour across the extent of the unit, from medium-bluish grey to greenish-grey to light greenish-grey. These colour variations probably reflect the degree of oxidation influenced by groundwater movement within the permeable sands.

Stratigraphic relationships: Disconformably overlies Tps, and interfingers upwards with Qpc. On the steeper-dipping western margin of the complex, Qpc$_i$ both underlies Qpc and also interdigitates laterally with the upper part of Qpc.

Depositional Environment: This unit is seen as the initial lacustrine deposit when Lake Bungunnia began to fill.

The intermittent sand source for this unit was most probably from local landforms with exposed Parilla Sand. Erosion of the Parilla Sand contributed sands to the initial lacustrine deposits until all Parilla Sand surfaces within the catchment were inundated by the lake.

Discussion: Qpc$_i$ is the Irymple Sand member of the Blanchetown Clay. It is a gradational transition in permeability from the underlying Parilla Sand up to the Blanchetown Clay. On the western margin where there is considerable upward flexure of the facies over the Danyo Fault, this unit both underlies and laterally interfingers with the Blanchetown Clay. This effectively reduces the impermeable barrier of the Blanchetown Clay to the west.

Regional Character

Irymple Sand Member

Lithology: Lawrence (1972, 1975) & Lawrence & Goldberry (1973) described a number of sections of the Blanchetown Clay containing an Irymple Member, including the type locality consisting of clayey mottled, ferruginous, dark red to yellowish-brown sandstone; sand well-sorted, fine grained, with kaolinitic matrix; ironstone concretions present.

Distribution and thickness: The member is associated with the Blanchetown Clay along the course of the Murray River , northwestern Victoria from Robinvale to the South Australian border, and 10 metres thick in the type section.

Age: It is presumed to be mainly of Early Pleistocene age, based on its relationship with the Blanchetown Clay, but may extend from latest Pliocene to early late Pleistocene.

Interpreted depositional environment: This member is considered fluvial, probably being partly derived from the weathered zone of underlying Loxton-Parilla Sands (Brown & Stephenson, 1991).

Stratigraphic relationships: The member occurs as a sandy unit intercalated mainly with the lower Blanchetown Clay (sand is less common in the upper Blanchetown Clay); locally disconformable over Loxton-Parilla Sands. Firman (1966c, 1973) described the Chowilla Sand as bright yellow, poorly sorted fluvial sand underlying the Blanchetown Clay, whereas Gill (1973) correlated sands intercalated within the Blanchetown Clay with the Chowilla Sand. Thus the Chowilla Sand of Gill (1973), within the Blanchetown Clay is equivalent to and probably synonymous with the Irymple Member (Lawrence, 1972) of the Blanchetown Clay

Unit Qpc

At Mourquong

Location in discharge complex: The Blanchetown Clay is extensive below the discharge complex but is known to be absent in the southwestern corner. Within the depression, and along the southern margin, it may also be absent as inferred by a dramatic northward thinning in the MRT transect.

Geometry and thickness: Across the complex it is variable in thickness but generally thickens in the centre of the structure. It is absent in the southwest.

In the central west - east section (MWM - MEM) the unit thickens down structure from the western margin (1m) into the depression (7.5m thick) as a result of a facies change from the predominant Irymple Sand Member to the west. Within the depression the Clay is lenticular and thins eastwards (4 to 5.2m) towards the eastern lunette (Qdl_{2-3}). Further east, (see PS Transect) the Blanchetown Clay retains a presumed uniform thickness east of MEM 5 of 9m? At Tapio borehole the total thickness of clay is 30 m but this is interpreted as a composite of Blanchetown Clay and an overlying clay lunette.

In the northern end of Mourquong, the Blanchetown Clay was not fully penetrated but has a minimum thickness of 4m.

In the southwestern part of the depression (PS and MSWM-MWM Transects), the Blanchetown Clay is absent in M21. It is unknown how large this erosional window in the clay is. Irregularity in the overall circular outline of the complex may indicate that this window may be up to 2 sq. km, extending north of M21 for 1km, and east for 2 km. Along the southern margin (MSOM extended section) the Blanchetown Clay varies from 0 to 3 metres thick, and appears to thicken southwards away from the depression (MRT section).

Description: Dark to light bluish-grey clays and muds are homogeneous, colour mottled to laminated with fine black framboidal pyrite. Directly below the active salina, the sequence has abundant gypsiferous laminae. Here and elsewhere gypsum also occurs as coarser discoidal scattered crystals. Thin sand, dolomicritic and magnesitic beds are uncommon, but more predominant in the upper sequence.

Stratigraphic relationships: The Blanchetown Clay interdigitates with and overlies conformably the Irymple Sand Member. It is overlain with erosional disconformity by channel sands of the Shepparton Formation, the Woorinen Formation (Qdl2), and the Yamba Formation (Qly3).

Depositional Environment: Freshwater lacustrine but grading upwards below the depression to increasing frequency of saline and evaporitic conditions.

Discussion: As the main aquitard within the Mourquong discharge complex, the thickness and extent of the Blanchetown Clay is critical.

Regional Character

Blanchetown Clay

Lithology: The unit consists of greenish grey, red-brown or variegated, silty to sandy clay, with many local variations in lithology. It contains thin beds of quartz sand and some thin micrite lenses, and is commonly gypsiferous near the top. Gypsiferous, siliceous, and impure calcareous septarian nodules, and ostracod sands occur locally. In South Australia, coarse-grained sand and gravelly outwash have been included in the formation (Brown and Stephenson, 1991). Gill (1973) recorded white fine-grained dolomite and sandy dolomite. At the top of the unit in the western areas of the basin, a dolomitic limestone is differentiated as the Bungunnia Limestone. Intercalated sand units were correlated with the Chowilla Sand by Gill (1973). Lawrence (1975) placed these in the Irymple Member of the Blanchetown Clay.

Distribution and thickness: The remnant distribution on Anabranch is almost complete coverage in the southwestern region, but more patchy northwards, being constrained by the Late Pliocene topography (Stephenson, 1986). The unit locally attains a thickness in excess of 20 metres, but a thickness of a few metres is more common.

Geometry and topography: The geometry of the unit is a combined product of the Parilla ridge and swale topography at the time of deposition, and post-depositional erosion. It has both an irregular unconformable lower and upper contact

Palaeontology: Several genera of ostracoda, including the freshwater *Candonocypris* (McKenzie and Gill, 1968; Gill, 1973) locally form almost pure ostracod sands on the Murray River west of Wentworth. Gill (1973) also recorded fish spines, vertebrae and bones of a large marsupial. Worm tubes, crustacean fragments, and the fish *Neoceratodus* were recorded by Lawrence and Goldberry (1973).

Age: Late Pliocene to Pleistocene. The oldest part of the unit is more than 2.4 Ma and probably 3.2 Ma, and the youngest sediments less than 0.7 Ma, as determined by Bowler (1980) and Zhisheng *et al.* (1986) using magnetic reversal stratigraphy.

Characteristics: Blanchetown Clay is characterized by its lithology and stratigraphic position. Although it can be confused with the Shepparton Formation, they are mostly geographically separate with the Shepparton predominantly to the east and having sandier facies. Outwash deposits from the western ranges have been included within the Blanchetown Clay in South Australia (Rogers, 1978). This makes it locally difficult to distinguish from the Pooraka Formation (Brown and Stephenson, 1991). As the upper part of the unit is gypsiferous, the Blanchetown Clay is difficult to differentiate from the salt lake sediments of the Yamba Formation in drillcore.

Environment of deposition: Deposition was under fluvio-lacustrine conditions, with most sedimentation occurring in a large freshwater body, Lake Bungunnia (Firman, 1965). Sedimentological evidence of the sequence at Nulla Spring Lake suggests that Lake Bungunnia had a general evolution from initial low salinities, progressively increasing with dramatic short-term fluctuations, to late hypersaline conditions. Water salinities in the middle to later period of sedimentation ranged from 3 000 to 50 000 mg/l in intervals of the sequence where ostracoda are preserved (P. De Deckker, pers.comm., 1992). The extensive gypsiferous deposits at the top indicate evaporative hypersaline conditions at the drying up of the lake. Lake Bungunnia was apparently formed by tectonic damming of the ancient Murray River at about 2.5 Ma ago, and had a maximum extent of over 33 000 km^2 (Stephenson, 1986). The lake was shallow with a maximum depth of less than 70 metres, and minor climatic fluctuations caused large shoreline migrations and complex interfingering of lacustrine and fluvial components of the Blanchetown Clay near lake margins. Gypsiferous sediments at the top of the Blanchetown Clay can be related to the emptying and drying of the lake (Brown and Stephenson, 1991).

Stratigraphic relationships: The Blanchetown Clay overlies the Parilla Sand with disconformity and Brodie (1992) shows that Parilla inliers are the unconfined sites of local recharge into that aquifer. The upper surface of the Blanchetown Clay is disconformably overlain by the Woorinen Formation and younger dune sand derivatives. It is disconformably to unconformably covered by the Yamba Formation and associated aeolian-derived units over localized deflated depressions on groundwater discharge sites.

Unit TQs

At Mourquong

Location in discharge complex: The unit is widespread in the complex, except under the active disposal pond and its northern extension.

Geometry and thickness: Broad lenticular sand bodies and isolated channels are thought to predominate.

Across the central MWM - MEM Transect, the unit absent west of MEM-2 and beneath the disposal pond. It is 3.3m in MEM 2, 1.2m in M13, 3.6m in MEM 1, and pinches out eastwards towards MEM 3.

To the southwest, the sands thicken to 9 metres in MEM 4 and extends to the southwestern margin, M21, where it is possibly 4 metres thick. Eastwards, in CSIRO MSWM 3 which is landward of the southern margin, the Shepparton sands thin to 1.5 metres.

Description: Two facies are present.

Predominant sands - Uniform well-sorted micaceous, light olive-grey to yellowish, medium to fine-grained quarts sand. Fine to medium-sized euhedral gypsum is variably abundant, and more abundant in MEM 2.

Localized sand/clay-mud laminites - light olive grey muds alternate with pinkish grey to dark yellowish orange micaceous fine to medium quartz sands

Stratigraphic relationships:: The unit has erosional disconformity over Blanchetown Clay and directly over Parilla Sand in the southwestern and probably southern area. There is an upper erosional disconformity with various Yamba depositional events.

Depositional Environment: Broad fluvial channels and overbank deposits.

Discussion: Distribution has been determined from drilling as no surface exposures are known. Least known areas are within the complex in the southern and northeastern sectors. In M 21, where Shepparton sands lie directly over Parilla Sand, the contact level is not known with any certainty. Locally at M 13 sand/clay - mud laminites lie adjacent to and overlie channel sands.

Regional Character

Shepparton Formation

Lawrence (1966) defined the Shepparton Formation as being a thick sequence of fluvial and lacustrine sediments overlying the Calivil Formation. The sediments are principally brown and grey mottled clay and silt, with thin beds of fluvial sand - the shoestring sands of the prior streams. The Shepparton Formation is distinguished from the younger Coonambidgal Formation (Lawrence, 1966) by the latter being essentially deposits of existing streams or their recent ancestors in the Murray Basin. On the Loddon Plain, a clear distinction can often be made between a lower sequence of red and light grey clays and an overlapping suite of brown and grey clays, the boundary between the units being generally sharp but becoming less distinct up towards the highlands.

Locally in the buried Powlett Plains valley, very distinct red-brown and light grey clays occupy the same stratigraphic interval as the Parilla Sand immediately to the north where they also onlap the Parilla Sand (Macumber, 1991).

The colour distinction between the red clay and yellow-brown clay is seen by Macumber (1991) as having climatic and environmental significance, with the reddish colours indicating conditions that were conducive to ferruginisation. He makes a tentative correlation between the ferruginizing events on the Loddon Plain and the conditions which led to the silicified and ferruginized Karoonda Surface , developed on the Parilla Sand after its exposure to subaerial weathering (Firman, 1966).

Extensive distributary development prevailed on the Loddon River systems throughout Plio-Pleistocene times, when the Riverine Plain was being systematically aggraded: initially, in response to the marine transgression, and later, as a consequence of climatically controlled cycles of fluvial sedimentation (Lawrence, 1966, Macumber, 1968). As coarser sediments were deposited close to the highlands, there is a gradual fining northward across the Loddon Plain, until a point is reached beyond which stream loads were virtually reduced to suspension load: this allowed a predominantly clay plain to build up (Macumber, 1991).

Unit Qdl1

At Mourquong

Location in discharge complex: A north-northwest - south southeast trending broad band occurs on the easternmost margin of the complex, 10 km east of the disposal basin.

Geometry and thickness: The unit is presumed lenticular, with a thickness of about 20m.

Description: Clay, presumed to be pelleted clay.

Stratigraphic relationships:: Disconformably overlies Blanchetown Clay

Depositional Environment: The unit is the earliest and largest lunette of the saline discharge zone.

Discussion: This unit has only been identified from cuttings but regional physiographic patterns indicate this deposit to be the eastern lunette margin of the initial Mourquong discharge zone. The unit is the Qpc_d of Radke (1993) and Ferguson *et al.* (1994). It is regarded as an aeolian equivalent of the Yamba Formation, evidence of the earliest deflation event after Blanchetown Clay deposition.

Unit Qly1

At Mourquong

Location in discharge complex: Qly_1 is interpreted to extend east of the arcuate sand dunes $Qdl_{2,3}$, eastwards to Qdl_1.

Geometry and thickness: This unit is considered thin and tabular, but of unknown thickness.

Description: ? Unknown

Stratigraphic relationships:: Erosional disconformity over Blanchetown Clay, and overlain by Woorinen sands.

Depositional Environment: Saline lacustrine

Discussion: The existence of this unit is inferred from the physiographic evidence, but has not been tested by drilling. This is $Qpcl_1$ of Radke (1993) and Ferguson *et al.* (1994), and is interpreted as the initial phase of Yamba deposition..

Regional Character

Yamba Formation

The Yamba Formation (Firman, 1973) comprises an association of sediment types deposited in a range of local environments in or adjacent to saline lake complexes. These include successions reflecting seasonal interplay between aeolian pluvial and groundwater conditions. In detail the successions can vary from one lake setting to another (Brown and Stephenson, 1991).

The formation comprises friable, pale-grey to pale-brown gypsiferous clay, grey pelletal clay, gypsum-quartz sand aggregates and gypsum. At the margins of present day playa lakes and salinas, the upper surface consists of desiccated crusts of fluffy gypsite, halite and gypsum-clay pellets. These desiccated lacustrine sediments merge laterally with pale-cream, pale-brown and white gypsite/quartz sand/soil admixtures of the adjacent lunettes.

In modern playas the lake floor sediment comprises an upper layer of black sulphide-rich mud with an ephemeral salt crust. The mineral suite within the mud includes sulphide and gypsum-clay laminites, dolomite, dolomitic clay, and dolomite-cemented sand (Bowler and Teller, 1986). The black muds are mostly underlain by thicker sequences, up to 2-4 metres, of dark grey-blue water-saturated clay with beds of crystalline gypsum mush (Brown and Stephenson, 1991).

Modern and fossil saline lake deposits with associated gypsum and clay pellet sediments, are entrenched within the aeolian Mallee landscape and the western margins of the fluvial Riverine Plain.

The Yamba Formation accumulated in salinas within the arid landscape of the Murray Basin. Favourable conditions for this deposition relate to past climatic and lake water-level fluctuations, groundwater/lake-water interactions and consequent variations in salinity. Deposition was predominantly associated with drying phases during transitional wet to arid periods, with inherited high groundwater tables (Bowler and Wasson, 1984). These arid periods were coincident with glacial maxima (Galloway, 1965; Bowler, 1976). Detrital clastic clay sediments were probably deposited in wetter climatic conditions when lakes were deeper and of lower salinities. Evaporation, desiccation and deflation of lake floors were associated with drier windy climates when groundwater discharged into the lakes (Brown and Stephenson, 1991).

Unit Qdl$_2$

At Mourquong

Location in discharge complex: A semicircular arcuate band extends along the north, east, and southeast of the developed discharge complex deposits.

Geometry and thickness: Arcuate in plan, lenticular in section, this unit has a maximum thickness of approximately 12m.

Description: Reddish-brown quartz sands are commonly indurated by calcrete. Nodular, pisolitic and massive bands of calcrete are common in the upper section.

Stratigraphic relationships: Qly$_2$ overlies the Blanchetown Clay and possibly Qly$_1$ with disconformity. It is partly overlain on the western upper surface by Qdl$_3$.

Depositional Environment: A lunette initially developed during a high water level in the discharge complex and a precursive sandy beach deposit developed. During following aridity, the beach dune developed into a lunette which had its surface modified into seif dunes as the lake dried.

Discussion: Qdl_2 is physiographically related to a major deflation stage but is lithologically, and by time of origin, Woorinen Formation. This unit has not been tested with stratigraphic drilling. Lithological characteristics are based on surface examination only. This is the Qdl_{1a} of Radke (1993) and Ferguson *et al.* (1994).

Regional Character

Woorinen Formation

Lithology: Red-brown siliceous silty sand, red calcareous silty sand, and sandy clay are predominant. The unit characteristically contains well-developed horizons of platy and nodular calcrete. Younger components are mainly pale orange-red and have a lower clay content, whereas the older components are brick-red and have undergone a high degree of paedogenesis. The silt and sand components are locally admixed with clay pellet aggregates, and humic material consisting of leaf litter, twig debris, and remnant rootlets. The sand component consists of medium to fine-grained quartz grains, stained by sesquioxides and red clay cutans. The unit is largely unconsolidated, but has been subject to varying degrees of pedogenesis, which has resulted in a minor degree of consolidation of sand grains by interstitial clays. A few carbonaceous laminae and rare thin interbeds of charcoal are present. Red palaeosols, with sandy loams and sandy clay loams, are distributed throughout the formation and are associated with each of the component members, with the exception of the uppermost member. The degree of clay mobilization and leaching of calcite increases with the age of each of the soil profiles. In places the formation has fragmented tap root and filamental rhizoliths, and characteristically has soft gypsiferous glaebules, and soft to hard carbonate glaebules up to several centimetres in diameter. With depth, these grade to cemented calcrete hardpans, which locally coalesce to form massive brecciated sheets of calcrete rubble towards the base of the unit (Brown and Stephenson, 1991). The unit forms aeolian dunes and swales, in which the salt content of associated soils increases progressively from the sandy soils dominant at dune crests to the clays which are predominant in the swales (Churchward, 1960).

Distribution and thickness: The Woorinen Formation is widely distributed and underlies much of the aeolian landscape of the Mallee Region. The unit is also found along the northern flanks of the basin, and in small isolated dunefields located in the western and eastern margins of the Riverine Plain. Thickness is highly variable, but it is generally a thin blanket 2-3 metres thick, with dunefields being locally thicker. In the Anabranch Sheet the formation forms a thin veneer over Blanchetown Clay. Elsewhere, individual dunes can be several metres high, whereas the sediment in intervening swales may be less than 1 metre thick.

Structure and topography: Over most of its distribution, the formation is preserved as extensive dunefields and sand sheets characterized by discontinuous chains of east-west - oriented longitudinal dunes. Dunefields are well developed in the western and central areas of the basin. Towards the southern and northern margins, the dunes become increasingly subdued, form low mounds, and grade into a featureless sand sheet (Brown and Stephenson, 1991). Individual dunes within the fields have been extensively eroded, and are characterized by subdued and rounded crests, and low-angle flanking slopes. Several dune morphologies are preserved, the most characteristic being the elongate cigar-shape, which forms extensive dunefields in north-western Victoria. The larger dunes are a few hundred metres to 1 kilometre in length, up to 100 metres wide, and are only a few metres in height (2 - 3, but up to 10 metres). Transverse profiles are asymmetric, with a southern slope slightly steeper than the northern. Older components are aligned almost exactly east-west, whereas younger or reworked elements are oriented west-southwest to east-northeast. The younger dunes are less regular in orientation and are locally transitional with the irregular dune morphologies of the Molineaux-Lowan Sands. The finer-grained sediments of the swales are locally associated with deflated lacustrine and former groundwater discharge sites.

Steeply-dipping sets of crossbedded sands are preserved in the younger components of the formation. In older components, internal sedimentary structures have been largely destroyed by pedogenesis, and intrusion of the characteristically deep and extensive systems of the Mallee vegetation. Deeper levels of the formation contain carbonate rhizoliths and rhizoconcretions, some of which are vertically-oriented tap roots, while others are subhorizontal secondary rhizoliths (Brown and Stephenson, 1991). Particularly in the western are of its distribution, the base of the Woorinen is marked by the presence of a calcrete hardpan. Generally this consists of a re-cemented white or pale-grey brecciated calcrete, cross-cut by irregular anastomosing veins and fracture planes infilled with red-brown silty sand. Brecciation of this calcrete is locally associated with the intrusion of tree-root systems.

Palaeontology: The formation has abundant leaf and twig debris, as well as charcoal and intruding rootlet material. It also has remains of land snails, abundant fragmented bones of marsupials and introduced mammals.

Age: Little direct evidence is available. Palaeomagnetic data from the Blanchetown Clay suggests the aeolian landforms initially developed between 0.4 - 0.7 Ma. The identification of a number of members, separated by palaeosoils suggests several phases of mobilisation over the past 0.5 Ma. The high clay content, rubification of quartz grains, calcrete development, degree of erosion, and orientation of dunes all suggest that the older components of the unit date from the initiation of major aridity (Brown and Stephenson, 1991).

Characteristics: In comparison with the younger yellow siliceous sands of the Molineaux-Lowan Sands, the Woorinen sands contain a high calcareous clay and silt content, and consists of rubified sand grains. Characteristic are several palaeosoils, underlain by well-developed calcrete. Dune forms are generally subdued and rounded.

Environment of deposition: The formation accumulated in an aeolian environment, and was subsequently modified by pedogenesis and fluctuating groundwater tables (Brown and Stephenson, 1991). Several models have been proposed for both the source of sand and dune morphology. Lawrence (1966) suggested that the east-west orientation of the longitudinal dunes indicated initial deposition from winds blowing predominantly from the west, whereas the orientation of younger components suggests a shift to winds from the west-southwest. This orientation of the younger components is coincident with the present dominant winds. Bowler and Magee (1978) suggested that the clay content of the dunes can be explained by a process of deflation in the intervening swales and that both dune and swale morphologies could be maintained by this deflationary process. Bowler and Wasson (1984) related development of clay-pellet dunefields to the hydrologic conditions that prevailed during the transitional phase between humid-lacustral and arid aeolian-dominated conditions.

Presently the dunes are stabilized by low Mallee scrub with the exception of the younger components and some areas now cleared for agriculture. This suggests that the dunes formed during intervals when conditions were marginally more arid than at present. This aridity is generally attributed to periods of glacial maxima when conditions were cold but dry rather than hot and arid, and when groundwater tables were sufficiently deep below the ground surface to prevent development of pelletal clay aggregates. Stabilizing vegetation may have become sparse and the dunes mobile.

The Woorinen dunefields are best developed in the western areas of the basin, underlain by the Loxton-Parilla Sand - the deflation of which provided the primary source of quartz sand. Similarly, the deflation of the Blanchetown Clay was probably the source of the clay content in Woorinen Dunes (Brown and Sterphenson, 1991).

Stratigraphic relationships: In the western area of the basin, the unit forms a blanket deposit which disconformably overlies Blanchetown Clay, Bungunnia Limestone, and the buried ridge and swale surface of the Loxton-Parilla Sands. To the north, east and south, the formation disconformably overlies fluvial sediments of the Shepparton Formation.

Towards the northwestern margin of the basin, the Woorinen overlies and is partly intercalated with the upper part of the Pooraka Formation. In erosional gullies around the margins of saline lakes, the formation has been found to partially overlie, and to be partly intercalated with gypsiferous saline lake deposits of the Yamba Formation. Modern saline and non-saline lakes are locally incised within older components of the Woorinen Formation. Younger fluvio-lacustrine sediments of the Murray and Darling Rivers are also entrenched within the formation (Brown and Stephenson, 1991).

Unit Qly2a

Location in discharge complex: Qly2a is extensive, but absent from below the western margin and lake.

Geometry and thickness: The unit is generally tabular, but pinches out west of the western margin of Qdl_2. 2.2m in MEM 2, 1.8m in MEM 1. It is not present in MEM 3.

Description: Mud, gypsiferous mud, and gypsiferous clay are light olive grey to yellowish grey; with colour and textural lamination, with high intercrystalline porosity. Distinct varves are recognized.

Stratigraphic relationships:: Qly2a is disconformable over Tqs, and overlain conformably with Qly_{2b}. It is eroded and disconformably overlain by Qly_3 in M13, and completely eroded west of MEM 2.

Depositional Environment: Saline lacustrine.

Discussion: This unit is seen as the first preserved lacustrine event within the complex. Surprisingly, it is difficult to correlate sequences between boreholes and differentiation of depositional units within the complex is made with a low confidence factor. This early deposit has been stripped by erosion and is now only preserved below younger lunettes on the eastern half of the complex. It is a continuation of Yamba deposition.

Unit Qly2b

Location in discharge complex: Qly2b is extensive within the complex, but absent from the western margin and existing lake.

Geometry and thickness: The unit is tabular, varying from 1 to 1.5m thickness.

Description: Porous and friable light brown, fine to coarse quartz sand and coarse to very coarse gypsum crystal mush predominate with minor matrix of clay and halite. Some gypsum aggregate concretions are present.

Stratigraphic relationships:: The unit conformably overlies Qly_{2a}, and is disconformably overlain by lunette and dune deposits Qdl_{4-6}.

Depositional Environment: Qly2b accumulated under lacustrine conditions, with introduction of quartz sands presumably from western Woorinen sources.

Discussion: This unit appears to be the most consistent and extensive surface in the eastern part of the complex which has had considerable erosional dissection. Deflation of this unit contributed significantly to the second major lunette on the eastern margin (Qdl3). This unit is the Qly1 of Radke (1993) and Ferguson *et al.* (1994) and is a continuation of Yamba deposition.

Unit Qdl3

Location in discharge complex: This unit is an arcurate lunette on the western slopes of the Qdl2 lunette on the eastern and southeastern margin of the complex.

Geometry and thickness: Lenticular cross-section, a lunette up to 12m high

Description: Reddish to light brown quartz sand predominates.

Stratigraphic relationships:: Qdly3 disconformably laps onto the western upper surface of Qdl2.

Depositional Environment: Aeolian lunette

Discussion: This lunette appears to have been derived from the deflation of discharge zone sediments, especially Qly2b. Initial mobilisation of the sand may have been during high lake levels when the sand would have. This unit has only been recognized from its physiographic expression. The unit is the Qdl1b of Radke (1993) and Ferguson *et al.* (1994) - it is here regarded as an aeolian equivalent of the Yamba Formation.

Unit Qly3

Location in discharge complex: Qly3 occurs below the existing Mourquong lake, and in M 13.

Geometry and thickness: The unit is wedge-shaped, between 1 to 1.6m.

Description: Laminated mud and gypseous sands are variably coloured from light olive grey, very light yellowish grey, dark greenish grey, dark yellowish orange. Laminae are commonly wavy, and range from distinct to indistinct. The gypsum-rich sands are generally thicker-than the clay interlaminae. A marked upper surface has a medium to coarse yellowish grey sand of quartz and gypsum particles.

Stratigraphic relationships: Qly3 overlies Qly2a with disconformity, overlain by Qly4 with disconformity.

Depositional Environment: Qly3 is saline lacustrine with seasonal flood/evaporation cycles preserved in the sand/clay laminations.

Discussion: The unit is considered to be the first preserved lacustrine deposit below the present lake, as well as occurring in the eastern extension, intercepted by M13. This unit is part of the Qly_1 of Radke (1992) and part of the Qly_2 of Radke (1993) and Ferguson *et al.* (1994). It is a continuation of Yamba deposition.

Unit Qdl4

Location in discharge complex: The unit occurs in small lunettes within the central zone of the complex and is present in MEM 2, in a quarry section above MEM 1, and in MSOM 1-3.

Geometry and thickness: Up to 1.2m thick as lenticular to blanket deposits.

Description: The unit grades up from pale grey to moderate yellowish brown gypsum and quartz sand, to uppermost pinkish grey to white Kopi. The lower unconsolidated sands have yellow etched fragments and whole medium to coarse gypsum discoids, dominant over medium to coarse polished quartz. The upper kopi grades from a soft-flour texture with scattered centimetre-sized variably indurated gypsiferous and calcareous lumps, upwards to an indurated band about 0.3m thick, with upper centimetre-sized bioturbation infilled by a pinkish gypsum-quartz sand mixture.

The lower contact is usually slightly irregular and erosional over earlier aeolian sands.

Stratigraphic relationships: The unit disconformably overlies Qly_{2b}. Overlain by Qdl5 and or Qdl_6.

Depositional Environment: A deflation product from evaporative surfaces, it is deposited as aeolian dunes.

Discussion: This is the lowermost of up to three kopi sequences to be found in lunette deposits around the eastern half of the complex. Without dating, it is speculative as to how correlative these deposits are. The unit is part of the Qly_1 of Radke (1993) and Ferguson *et al.* (1994) and is regarded as an aeolian equivalent of the Yamba Formation.

Unit Qly4

Location in discharge complex: Within the discharge complex, Qly4 occurs only below the existing lake.

Geometry and thickness: The unit is wedge-shaped, and up to 1.3m thick.

Description: Light bluish grey homogenous puggy mud, light olive grey homogenous mud with large diagenetic gypsum crystals, and colour-laminated sandy mud.

Stratigraphic relationships:: Qly4 overlies Qly3 with disconformity, and overlain by Qly5.

Depositional Environment: The unit is saline lacustrine, with some seasonal flood-evaporative cycles apparent. The unit was terminated by a final deflation event.

Discussion: Distinction of Qly4 from the underlying Qly3 is difficult and is made only on demarcation by a permeable separating sand, and the lack of gypsum-mud lamination. The unit is part of the Qly1 unit of Radke (1992), and the Qly2 unit of Radke (1993) and Ferguson *et al.* (1994). It is a continuation of Yamba deposition.

Unit Qdl5

Location in discharge complex: Qdl5 comprises small lunettes within the central zone of the complex. It is present in MEM 2, in the quarry above MEM 1, and in MSOM 1-3.

Geometry and thickness: The lunettes have variable thickness up to 1.5m thick, as lenticular to blanket deposits.

Description: Basally light brown grading up to greyish-orange pink and very pale orange sand (fine to coarse quartz and medium to coarse gypsum discoids) grades up to pinkish-grey to white variably-indurated kopi. Calcareous cemented bands may be present in the profile.

Stratigraphic relationships:: Disconformably overlies Qdl4 and overlain by Qdl6.

Depositional Environment: The lunettes are an aeolian accumulation from the deflation of evaporitic gypsum, and mobilized dune sand.

Discussion: This unit is difficult to distinguish from Qdl4. It is equivalent to part of the Qly1 of Radke (1993) and Ferguson *et al.* (1994) and is seen as an aeolian equivalent of the Yamba Formation..

Unit Qly5

Location in discharge complex: The unit occurs at the surface, below the lake on the western side of the complex.

Geometry and thickness: It is probably wedge-shaped, and the sequence may be up to 0.7m thick.

Description: The sediments are greyish-orange, mottled and faintly laminated with dark yellowish-brown clayey gypseous sand. The gypsum content increases upwards with rapidly diminishing clay and quartz sand.

Stratigraphic relationships: Qly5 overlies Qly4 disconformably, and is partly covered by Qdl6 in patches across the lake.

Depositional Environment: Saline lacustrine.
Discussion: The unit is separated from the underlying sequence by the uppermost porous quartz-rich gypseous sand of Qly4. This is the equivalent of the Qly2 of Radke (1992) and the Qly3 unit of Radke (1993) and Ferguson *et al.* (1994). It is a continuation of Yamba deposition.

Unit Qdl6

Location in discharge complex: Scattered patches occur on the lake margin and there is thin blanket coverage on most other units.
Geometry and thickness: A thin to discontinuous tabular body, the unit has some local thickening in topographic depressions. It varies between 0.25 to 1m thick.
Description: Moderate to light brown calcareous friable sand to sandy silts with soil structures, rootlet bioturbation and minor gypsum cement. The sediment has high interparticle and bioturbation porosity.
Stratigraphic relationships:: This unit overlies all units, predominantly Qly5, Qdl5, Qly3. It may be laterally equivalent to Qly4 and Qly5.
Depositional Environment: This unit resulted from aeolian reworking of Woorinen sand and Yamba lacustrine and aeolian deposits.
Discussion: Qdl6 may be broad ranging in age as it always overlies other units, as well as being most probably contiguous with Qly4,5 and Qdl 4,5. This unit is the equivalent of the Qdl3 of Radke (1993) and Ferguson *et al.* (1994) and has also been referred to as a Woorinen derivative.

Discussion

Figure 15 shows the spatial distribution in plan of the Quaternary units described. The extent of many of the lacustrine events may have been more widespread but this is speculative due to their subsequent deflation/erosion. As a generalisation, the lacustrine units show a progressive diminution in area and consequent younging westwards. The related lunette deposits also show this younging westwards.

The most significant feature at Mourquong is the observed erosional window in the Blanchetown Clay, located in the southwestern corner. This is based on the section across M21 (Figures 16 and 17). The thinning of Blanchetown Clay northwards from the southern margin indicates that this window is possibly larger, up to 2 km^2, and may cover

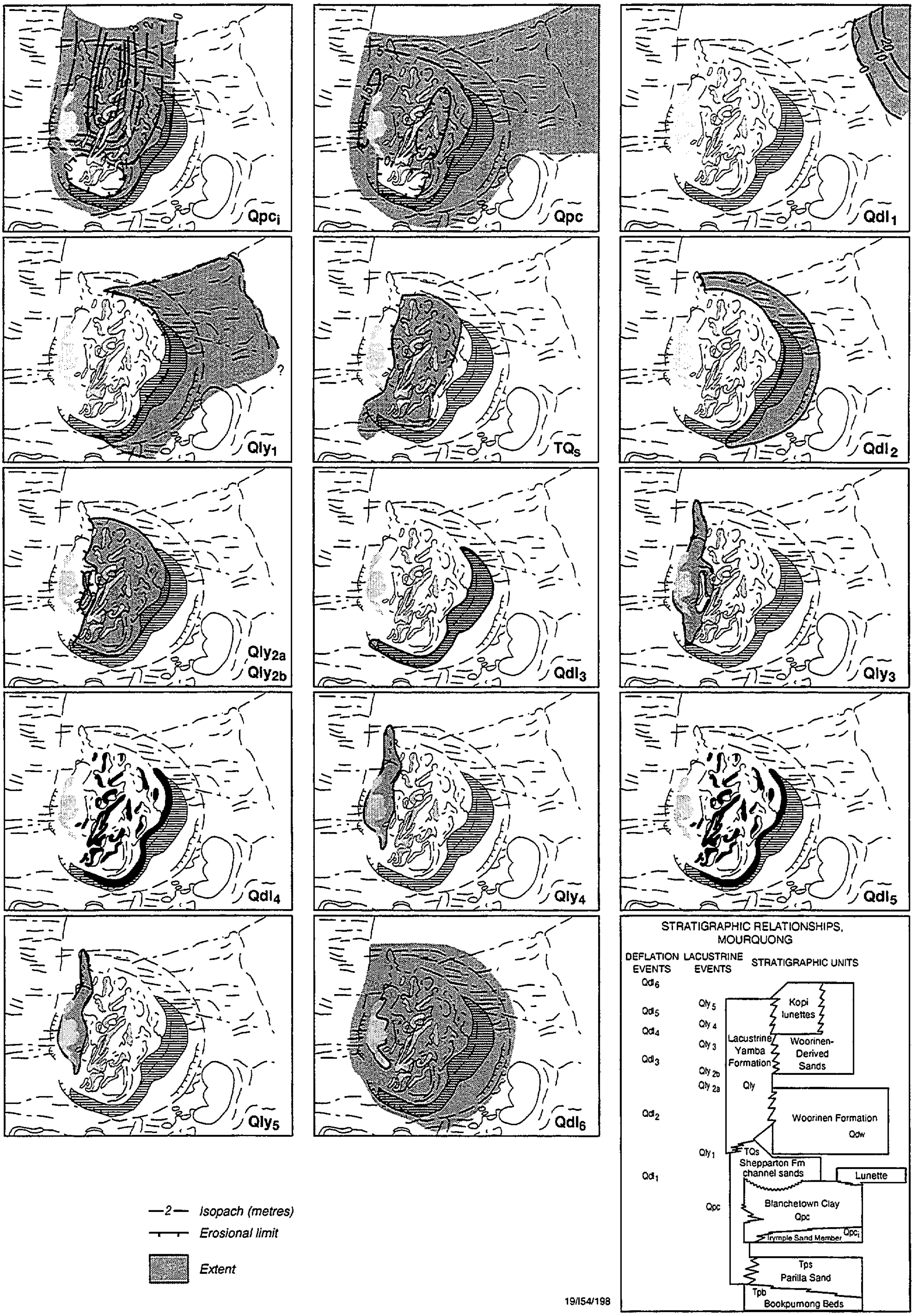


Figure 15. Distribution and thickness of lithostratigraphic units, Mourquong discharge complex.

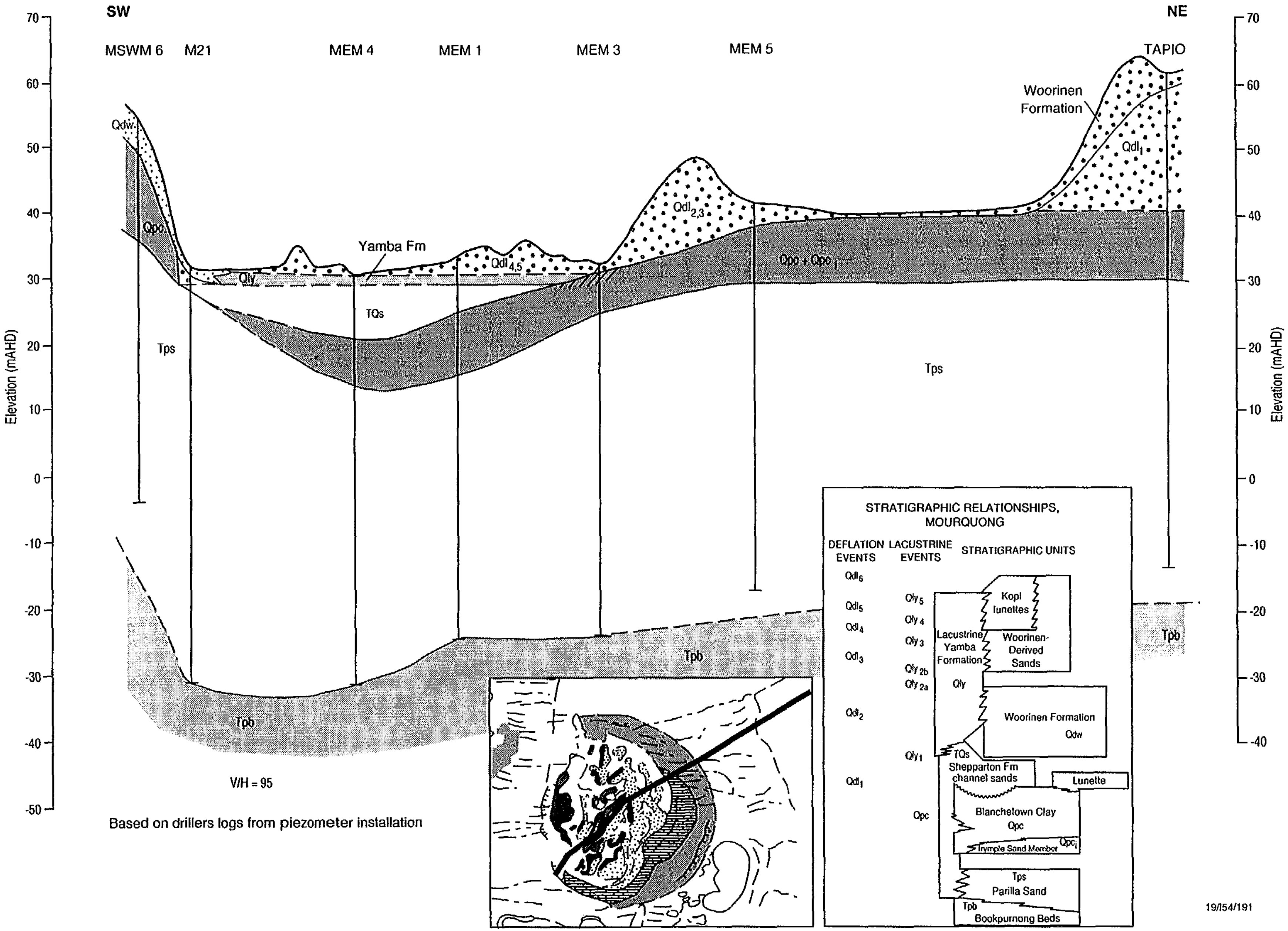


Figure 16. Stratigraphy of the MSWM-6 - Tapio transect, Mourquong discharge complex.

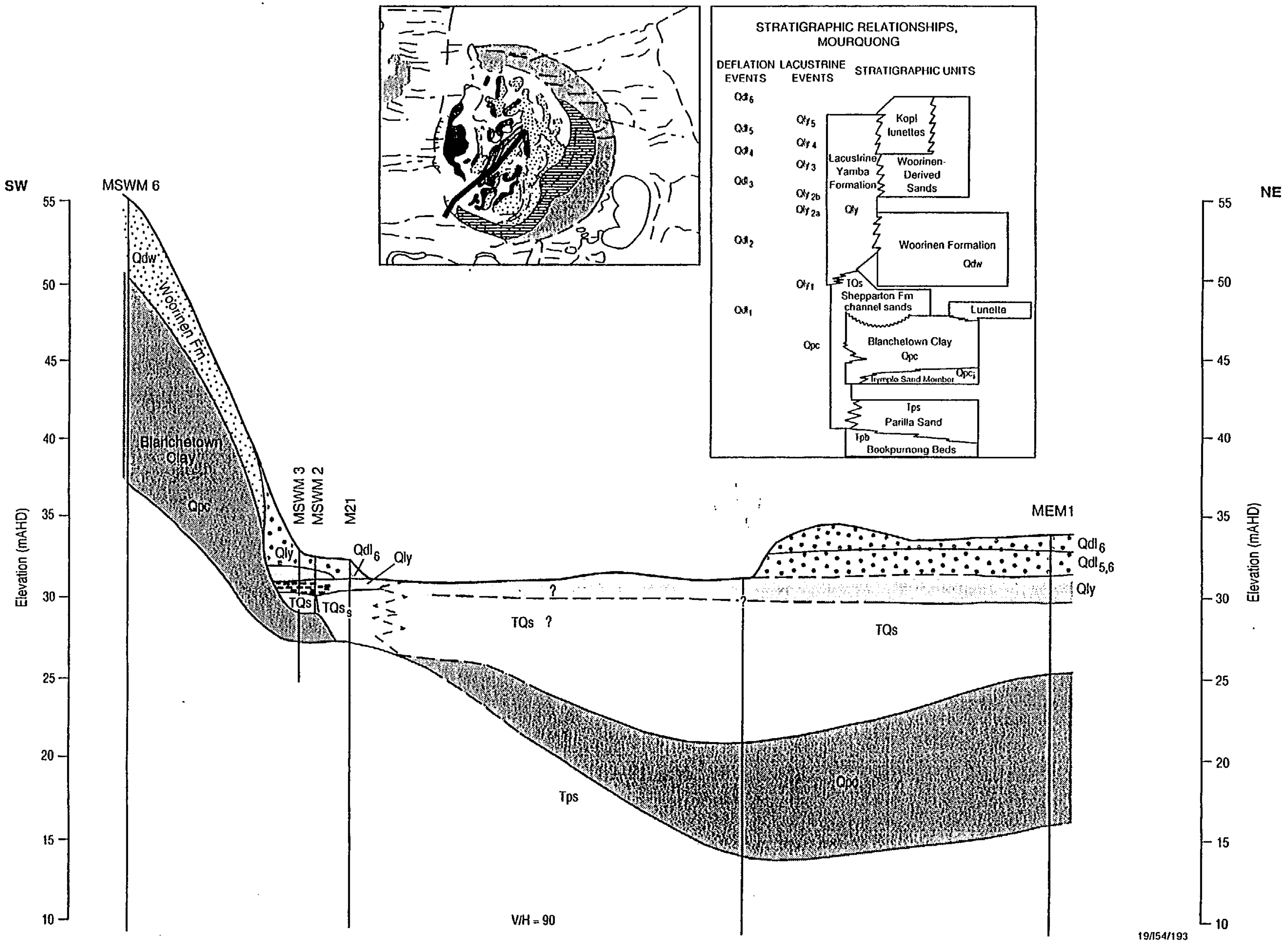


Figure 17. Stratigraphy of the MSWM-6 - Tapio transect, Mourquong discharge complex. Detail at the south-west margin of the discharge complex.

the entire southern end of the depression. Both the presence of the salina only over lacustrine muds in the central and northern end of the depression, as well as a biarcuate irregularity in the symmetry of the lunette Qdl$_3$, indicate a fundamental difference in character possibly in the permeability of the substrate to the swamp.

Highly permeable sands (Shepparton Formation) are extensive over the top of the Blanchetown Clay within the central and eastern part of the complex (Figures 15 to 19). It is most probable that coverage of the Mourquong depression was complete but the sands and minor sand-clay laminites have been eroded from the central-western side where muddy lacustrine Yamba sediments of variable permeability directly overlie the Blanchetown Clay. This is the area now covered by the disposal lake. The Shepparton sequence in M13 in the centre of the depression (Figure 20), and possibly in M17 (Figure 21) at the northern margin, is probably a laminated overbank deposit that constitutes lower vertical permeability.

Several drilling transects sited on the southern margin and east of M21 (MSWM, MRT, MSM, and MSOM; Figures 5, 15) failed to intersect Shepparton channel sand facies that would demonstrate direct connection to the Murray Trench. But light-coloured clays with thin sandy interbeds (interpreted as Shepparton overbank deposits) directly overlie Parilla Sand in this area (Figures 22 and 23) and indicate that a Shepparton channel connection possibly lies further east, as westwards there is a structural flexure over the Danyo Fault and the former terrain probably rose over the Merbein Ridge to the west.

In the absence of dates, Qdl 4 and Qdl 5 lunette deposits are almost identical and can only be differentiated by superposition. Recent deflation appears to have differentiated sediments and there may be overlap in timing of accumulation of these and Qdl$_6$ deposits.

STRATIGRAPHIC EVOLUTION OF MOURQUONG

The Mourquong Discharge Complex is a topographic depression which overlies part of the western side of the Koorlong Trough. Present-day physiography reflects differential subsidence of the Tertiary sequence, controlled by pre-Tertiary structure.

Figure 24 gives an evolutionary history of the Mourquong Discharge Complex.

The topographic depression was submerged by Lake Bungunnia about 2.4 ma ago. Initially there was significant local reworking of Parilla Sand (Tps) and the Irymple Sand member (Qpc$_i$) accumulated basally within the lacustrine Blanchetown Clay (Qpc). Lake levels fluctuated and during low stands, fluvial deposition periodically predominated, producing sand lenses within the Blanchetown Clay. The Mourquong depression acquired

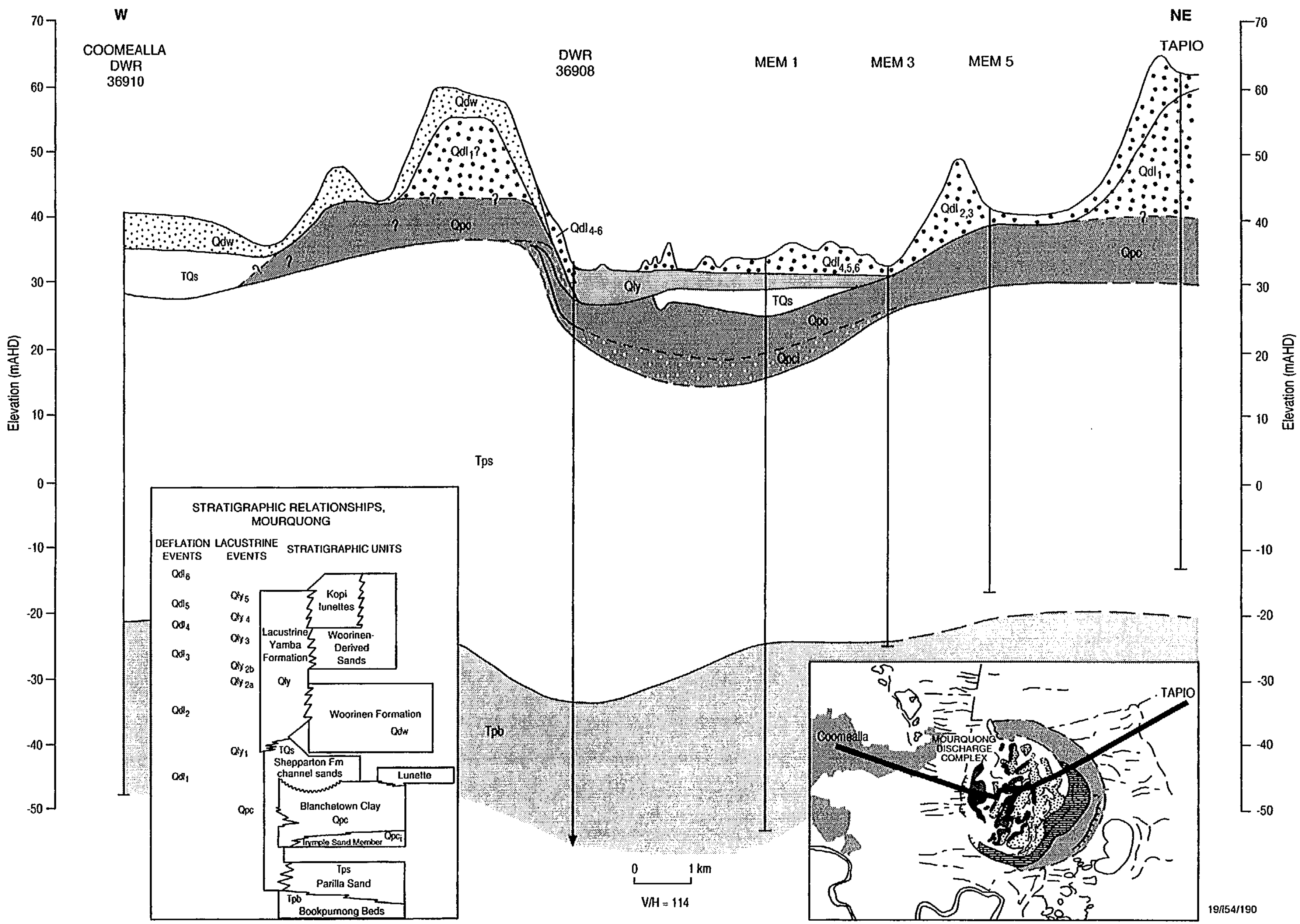


Figure 18. Stratigraphy of the Coomealla - Tapio transect, Mourquong discharge complex.

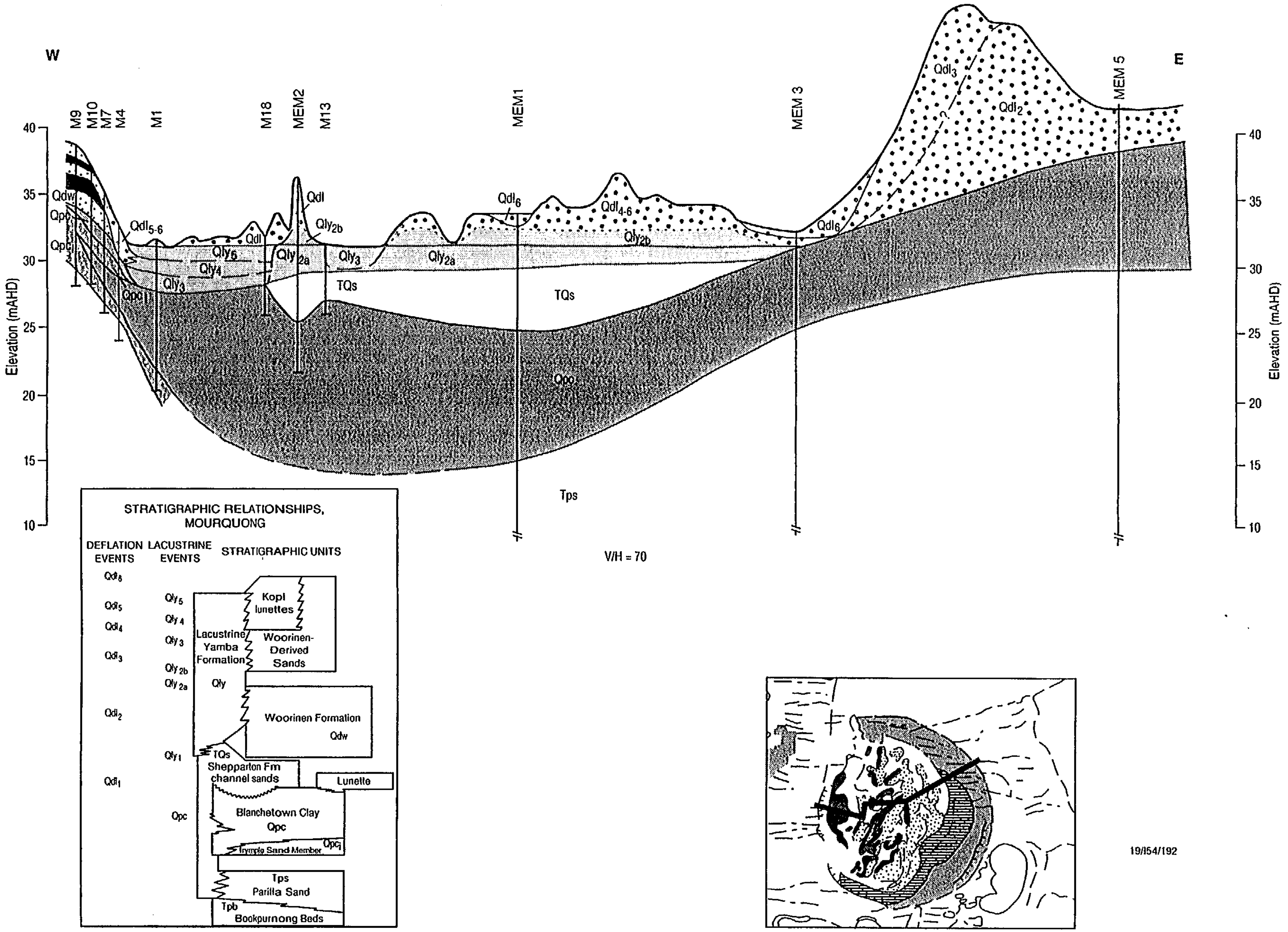


Figure 19. Stratigraphy of the Coomealla - Tapio transect; Mourquong discharge complex. Detail of the discharge complex.

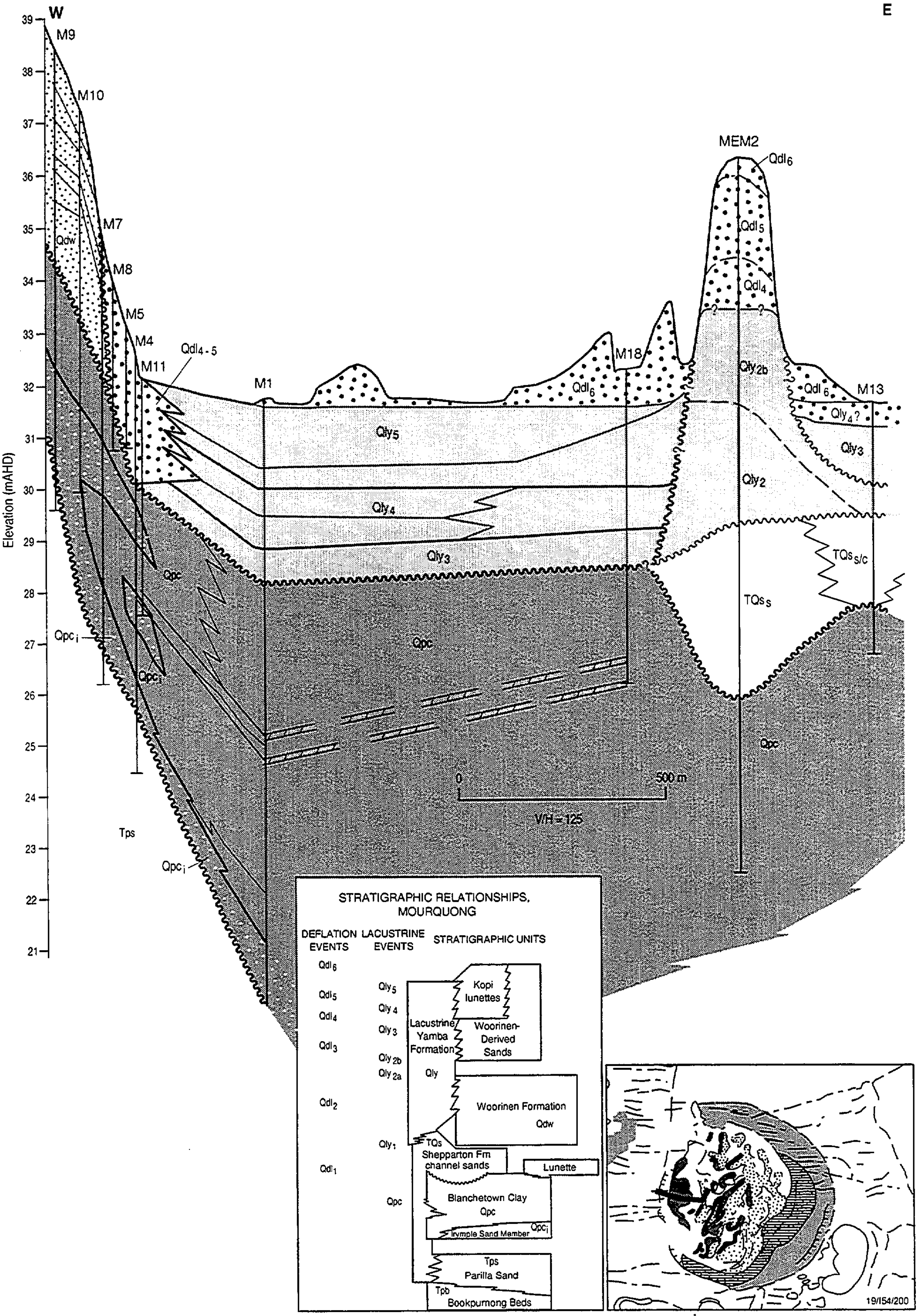


Figure 20. Stratigraphy of the M9 - M13 transect, Mourquong discharge complex.

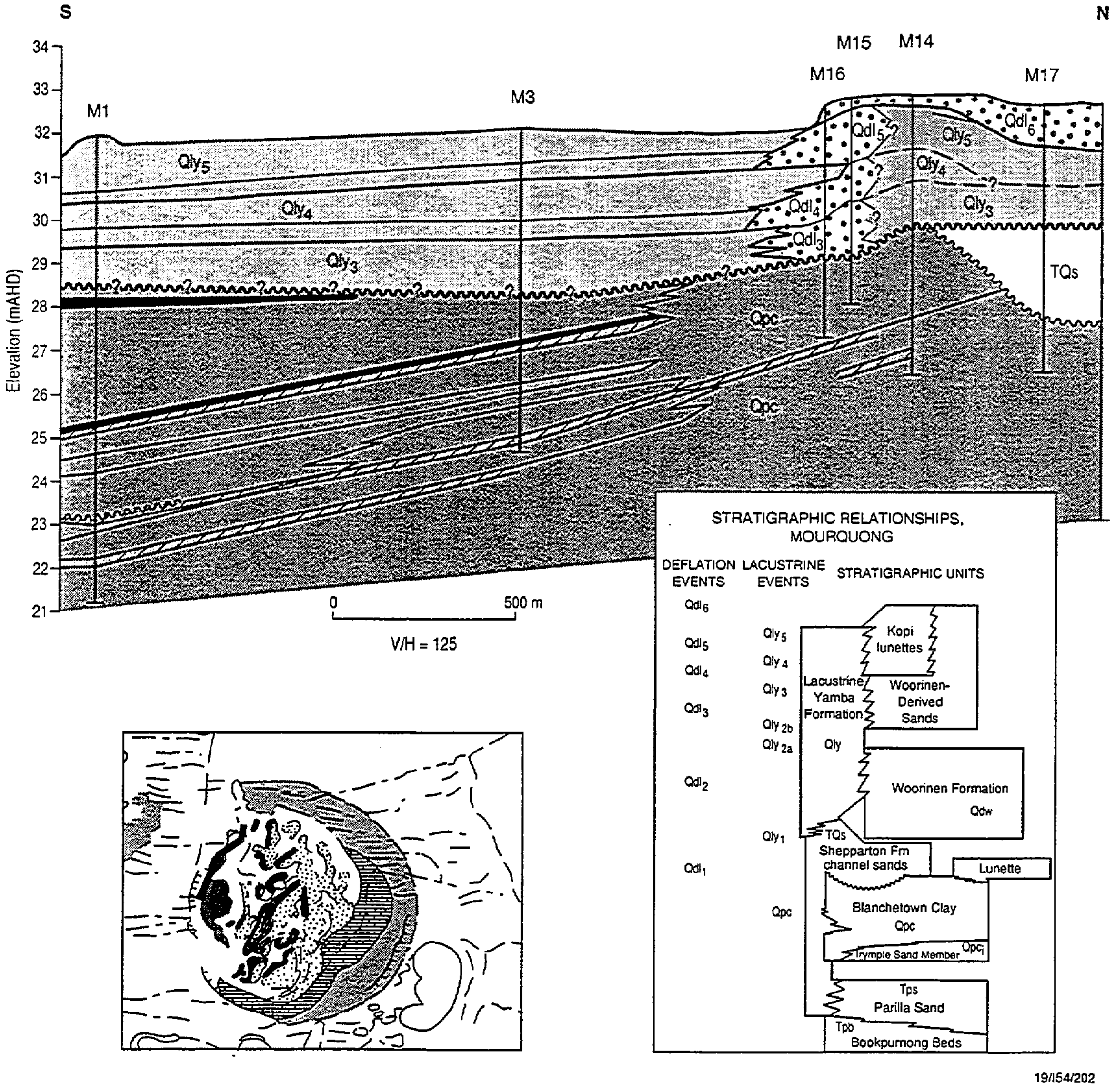


Figure 21. Stratigraphy of the MNM transect in the northern area of the Mourquong discharge complex.

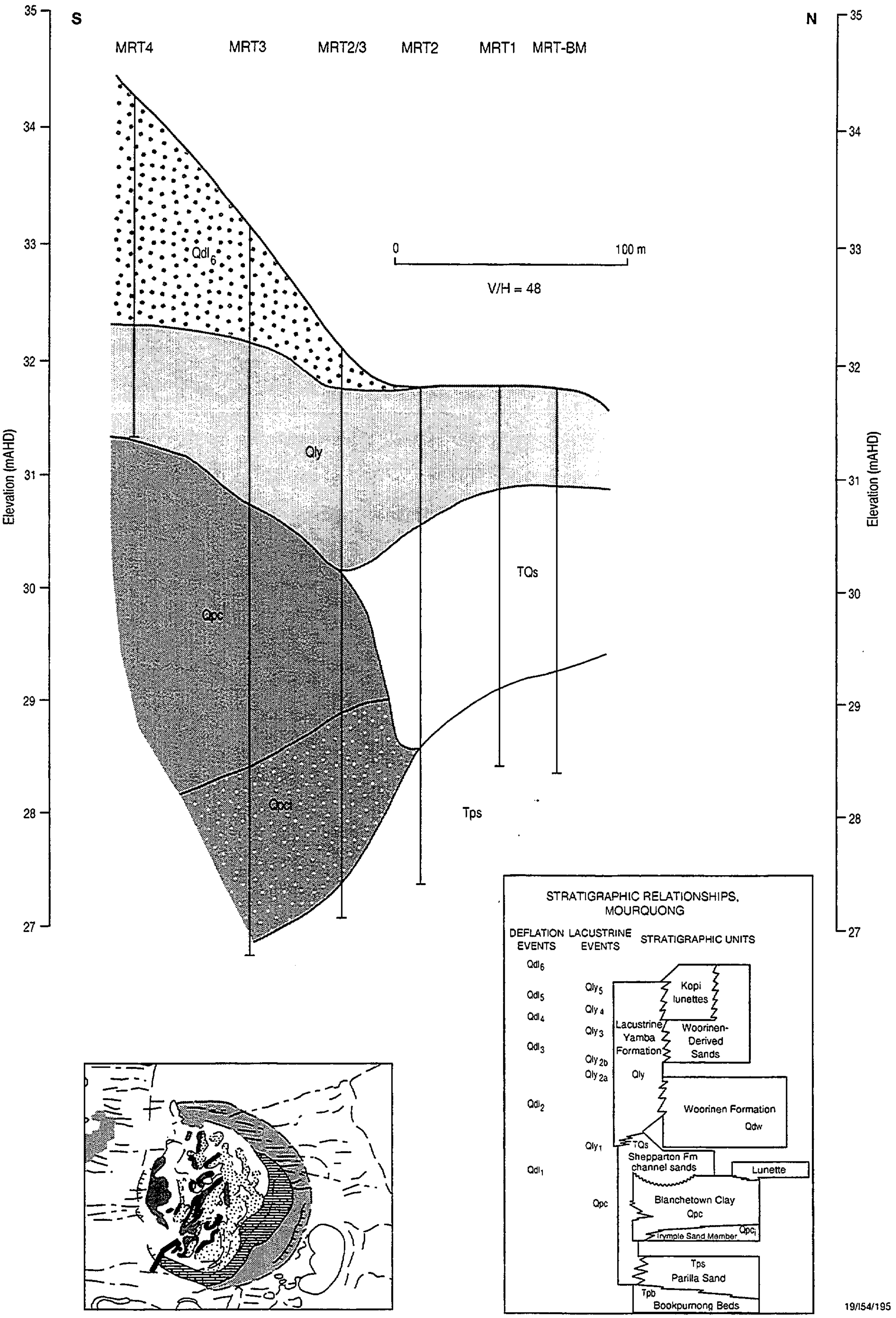


Figure 22. Stratigraphy of the MRT transect at the southern margin of the Mourquong discharge complex.

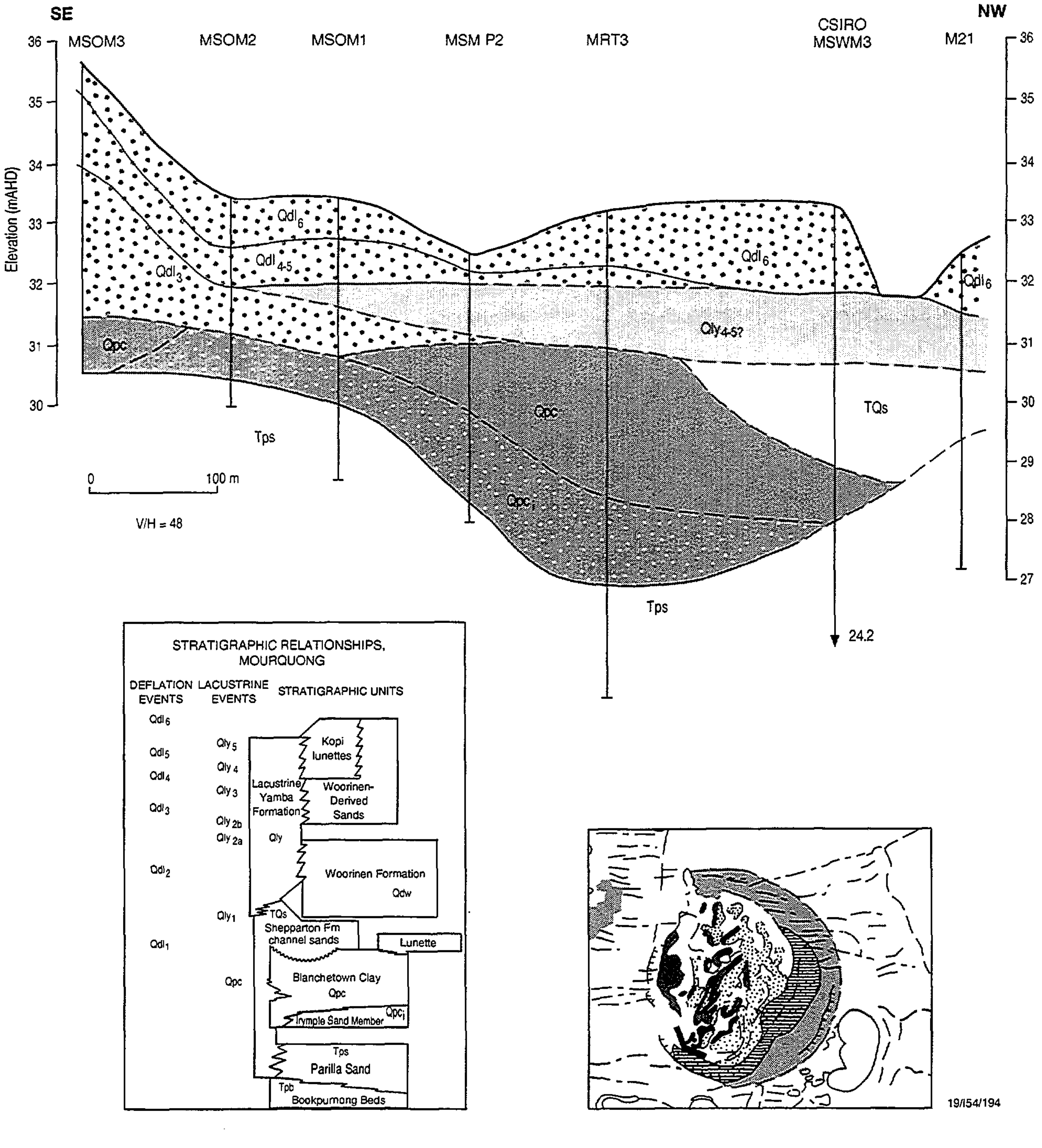
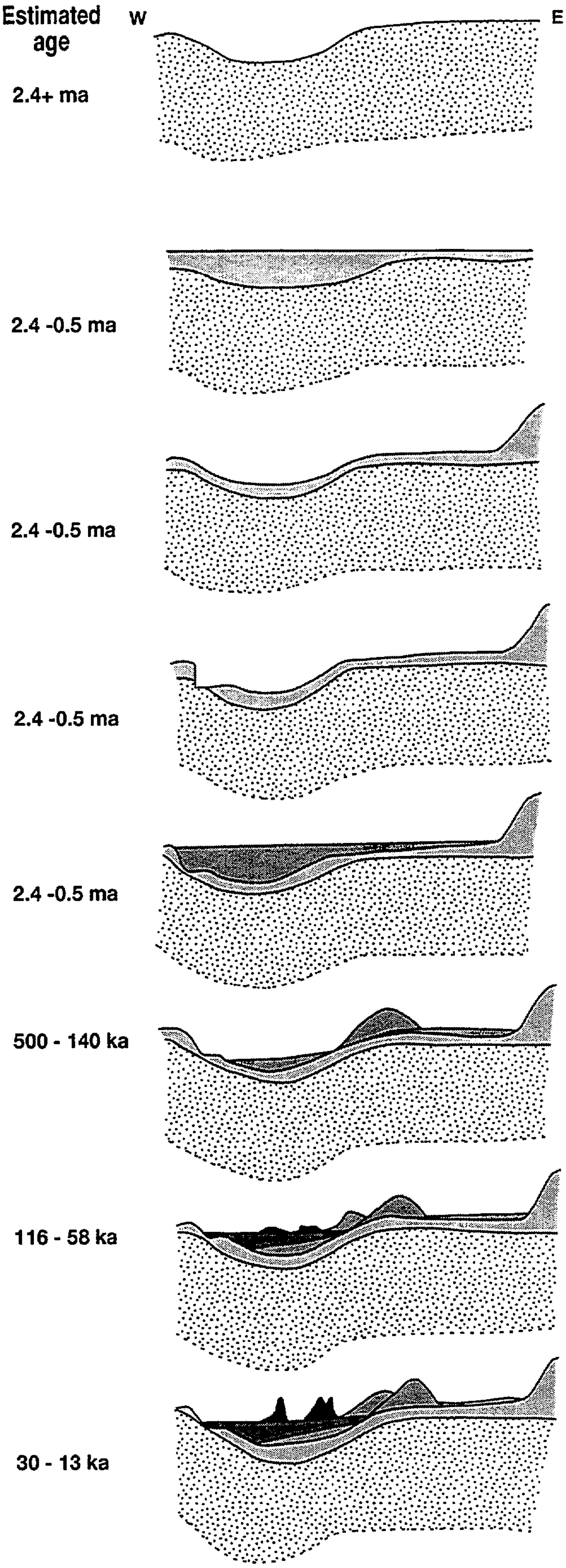


Figure 23. Stratigraphy of the MSOM-3 - M21 transect at the southern margin of the Mourquong discharge complex.



Slight flexure of Parilla Sand over Koolong Trough after deposition of the sequence

Lake Bungunnia fills, Blanchetown Clay deposition commences. With initial reworking of underlying sediments, Irymple Sand member is deposited. Fluvial Shepparton deposition predominates during occasional drops in lake level.

As Lake Bungunnia finally deminishes, groundwater discharge from the Parilla Sand commences along the Danyo Fault and with salinisation, there is widespread deflation in and to the east of the Mourquong depression.

Channels of the Murray River periodically migrate into the depression and erode the Blanchetown Clay, creating a permeability window through the clay into the Parilla Sand on the southwestern margin.

Channel sands and minor spillover-fan deposits accumulate.

Possibly during a high-level lacustral phase of Mourquong, sands are redistributed on the eastern margin as a beach dune deposit. During Woorinen aridity, the surface of this dune is modified and acquires a seif dune overprint.

Saline discharge continues with accumulation of gypsiferous lacustrine Yamba sediments. Reflux of brines below the basin emplaces gypsum in the Blanchetown Clay underlying the complex. Deflation and dissection of an upper gypsiferous sand unit produces a second major lunette on the south-eastern margin.

Further deflation and gypseous lunette formation alternate with lacustrine Yamba accumulation. Reworked Woorinen dune sands continue to be redistributed as thin veneers across the complex.

19/154/197

Figure 24. Evolution of the Mourquong discharge complex.

a thicker sequence of Blanchetown Clay than surrounding areas. Continued differential subsidence after the demise of Lake Bungunnia maintained the subtle topographic depression. Groundwater discharge was most probably from the Parilla Sand, occurring laterally through permeable lithofacies along the flexure over the Danyo Fault and into the depression. With evaporative salinisation, widespread deflation of the Blanchetown Clay commenced from the floor of the basin and extended eastwards, most probably producing the thickened clay lunette? sequence at Tapio (Qdl$_1$).

At some stage, the higher southern and eastern margins of the Mourquong depression were breached, and channels of the Murray River periodically migrated into the depression. Significant channel erosion extended over most of the basin and a permeability window was incised through the Blanchetown Clay into the underlying Parilla Sand on the southwestern margin. Fluvial deposition extended across the depression, predominantly as channel-fill deposits with minor overbank deposits (TQs - Shepparton Formation). Eastwards of the depression, possible Shepparton and lacustrine deposits accumulated as a thin veneer across the deflated area west of Tapio (Qly$_1$).

Possibly during a high lake level of Mourquong, Shepparton sands were redistributed on the eastern margin as a beach-dune deposit. With increasing aridity during the onset of Woorinen sand mobilisation, this dune was modified and into an eastern lunette (Qdl$_2$) which subsequently acquired a seif-dune overprint. The dune forms a large symmetrical sand lunette which defines the eastern margin of the complex. Longitudinal dunes (Qdw) still cover the western slope down into the Mourquong depression and also the northern part of this eastern lunette.

Saline groundwater discharge continued with the first-preserved accumulation of saline lacustrine sediments (Qly$_{2a}$) and a sandier facies (Qly$_{2b}$) as there was increased introduction of Woorinen-derived sand into the zone. A subsequent significant deflation event saw remobilisation of Qly$_{2b}$ sediments to produce an additional large lunette (Qdl$_3$) that accreted in the southeastern margin against the western slope of the existing sand lunette (Qdl$_2$).

Yamba saline lake deposits accumulated intermittently with a variable contribution from remobilised Woorinen sand (Qly $_{3,4,5}$). Downward diffusion of brine from the salina has emplaced diagenetic gypsum in the Blanchetown Clay directly below the salina. Further deflation of lacustrine Yamba sediments has produced several generations of gypsiferous lunette deposits (Qdl $_{4,5,6}$) over the eastern flats of the complex. The most recent deflation event appears to have also mobilized Woorinen-derived sands as Qdl$_6$ is predominantly brown quartz sand with minimal gypsum content.

SALINISATION OF UNDERLYING REGIONAL AQUIFERS AND AQUITARDS BY BRINES FORMED IN THE DISCHARGE COMPLEX

Introduction

This part of the report describes the distribution and hydrochemistry of natural brines and saline groundwaters in the Mourquong discharge complex and the underlying and surrounding regional aquifers and aquitards.

Brines in the Groundwater Discharge Complex

The active salinas in the disposal complex occur mainly in the western area of the discharge complex. Their extent approximates that of the area presently used as a disposal basin (Figure 2).

Salinities in the Yamba Formation and the Blanchetown Clay

Natural groundwater salinities in the Yamba Formation sediments of the discharge complex and the underlying Blanchetown Clay remain to the north and east of the disposal basin and to some extent beneath the disposal basin, in the lower parts of the Blanchetown Clay where the disposal waters have not yet penetrated.

Away from the active areas, permeable lunette deposits blanket the discharge complex (e.g. Figures 18 and 19). Beneath these lunettes the salinity decreases downwards from the Yamba Formation into the Blanchetown Clay (Figure 25), indicating that rainfall recharge exceeds evaporation.

Beneath the active areas, the disposal water has not penetrated the lower parts of the Blanchetown Clay (Figure 25) and in this part of the sequence the natural salinity profile is preserved. At a site near the centre of the active area the natural profile consists of a approximately linear decrease in salinity with depth, disrupted at this location by higher salinities associated with groundwater moving laterally through relatively high permeability carbonate-rich horizons. Linear decreases in salinity with depth are known from the Blanchetown Clay beneath Nulla Spring Lake, in the Nulla discharge complex. These linear relationships are indicative of downwards diffusion of salt from shallow brines

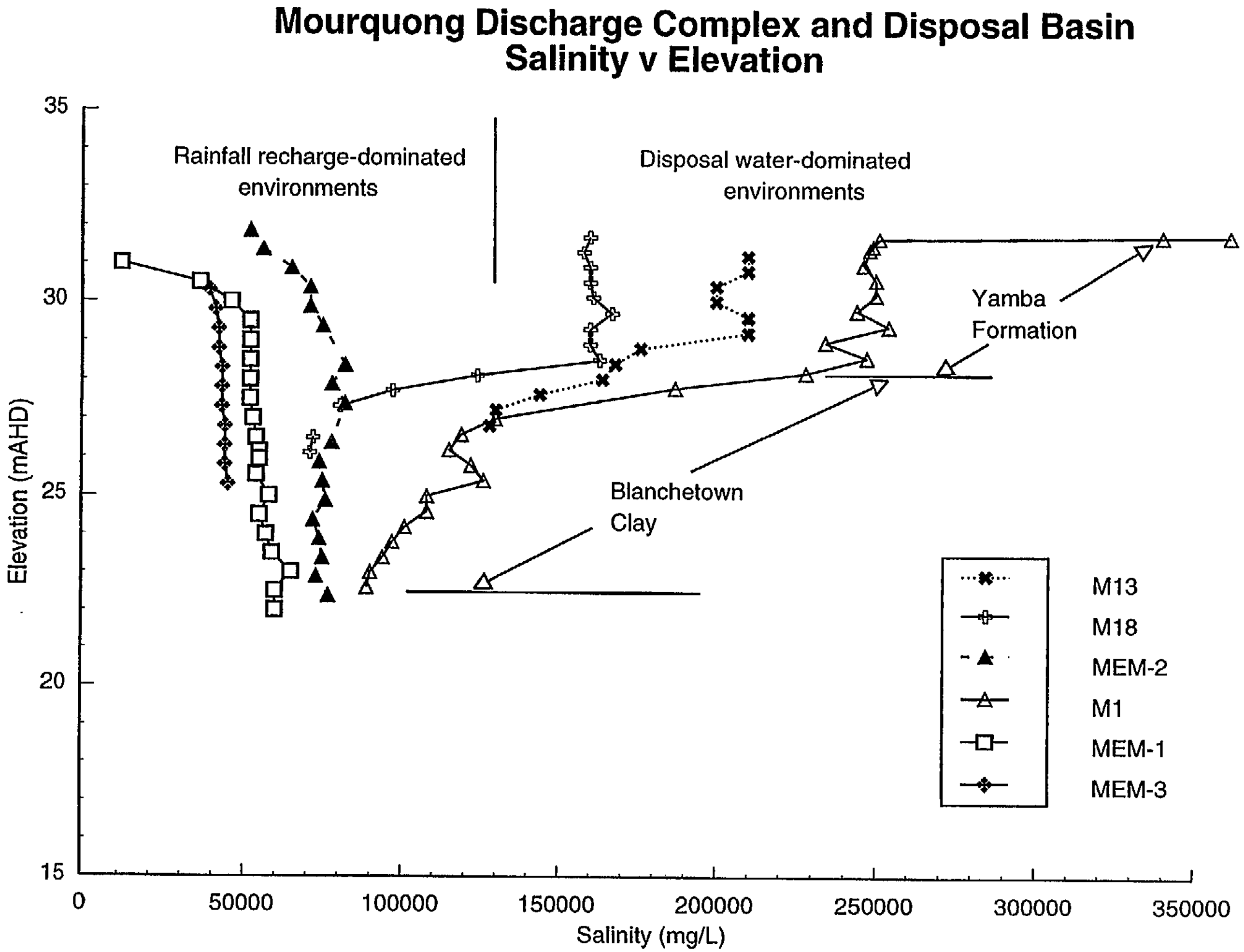


Figure 25. Salinity - elevation profiles for sites in the Mourquong disposal basin and lunette-covered discharge complex sites to the east.

associated with the Yamba Formation/upper Blanchetown Clay towards the lower salinity groundwaters at the top of the underlying Parilla Sand. Upwards extrapolation of the natural salinity - elevation profile to the top of the Blanchetown Clay gives a salinity of about 125,000 mg/L. This suggests that the Yamba Formation sediments near the centre of the active area contained a brine of salinity about 125,000 mg/L prior to the establishment of the disposal basin.

Hydrodynamics of Brine Formation

The salinity distribution of natural groundwaters in the Mourquong discharge complex and the underlying Blanchetown Clay and upper Parilla Sands is summarised schematically in Figure 26. The major site of brine accumulation is the permeable sediments of the Yamba Formation in the topographically lower parts of the active salina.

The hydrodynamic processes involved in the formation of the Mourquong brines are probably similar to those which occur in other discharge complexes where a surface layer of sandy sediments overlies more clayey deposits (Ferguson et al., 1994). The brines form by evaporation of a combination of Parilla Sand groundwater entering at the lake margins and/or local rainfall and runoff which has re-dissolved salts from the lake margins. Two processes are involved: (1) Parilla Sand groundwater enters the discharge complex at the margins and flows directly to the sites of brine formation either as groundwater moving laterally through permeable horizons and/or as surface flow of groundwater discharging from springs; and (2) Parilla Sand groundwater evaporates at the margins, forming salt efflorescences which are subsequently dissolved by rainfall/runoff which flows to the topographically lower sites of brine formation nearer the centre of the salina.

The hydrodynamics of the rainfall/dissolution process are summarised diagrammatically in Figures 27 and 28. A situation is envisaged in which winter rainfall-runoff from the higher ground around the lakes and rain falling directly on the marginal areas flows over the surface towards the topographically lower areas in the centre of the lake. There, the water rapidly infiltrates the sandy Yamba Formation sediments. Evaporation will be partly surface and partly capillary, allowing the brine to persist in the surficial sand for a large proportion of the year (Figure 27). During the seasonal transition from wet to dry conditions the lake margins will be washed by rainfall with gradually decreasing frequency and there will be correspondingly longer dry periods in which evaporation will be dominant and salt efflorescences will form at the surface before being washed into the lake by the next rainfall event. As the frequency of rainfall events decreases and the length of evaporation events increases, the surface sediment will dry completely

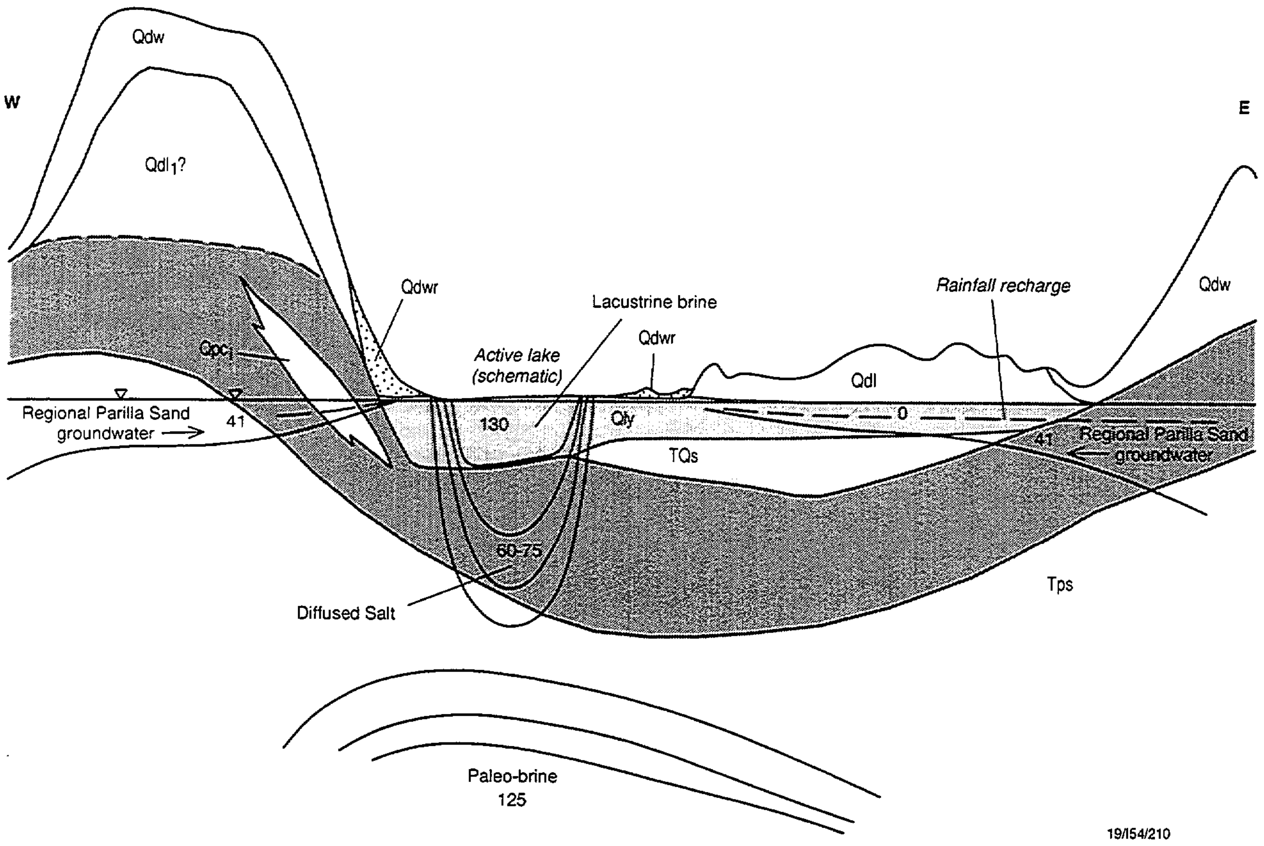


Figure 26. Schematic representation of the natural groundwater types and their salinities in the active area of the Mourquong discharge complex.

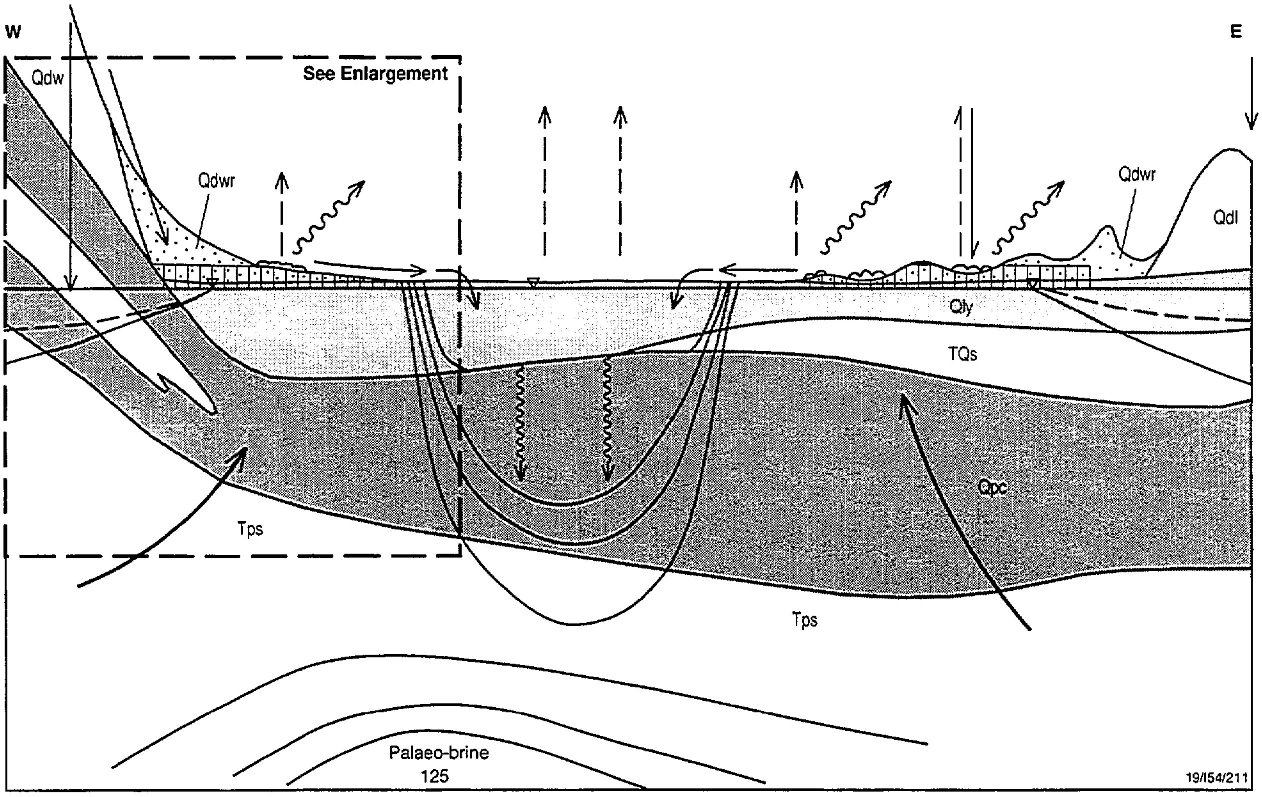


Figure 27. Hydrodynamic processes involved in the formation of brines in the Mourquong discharge complex.

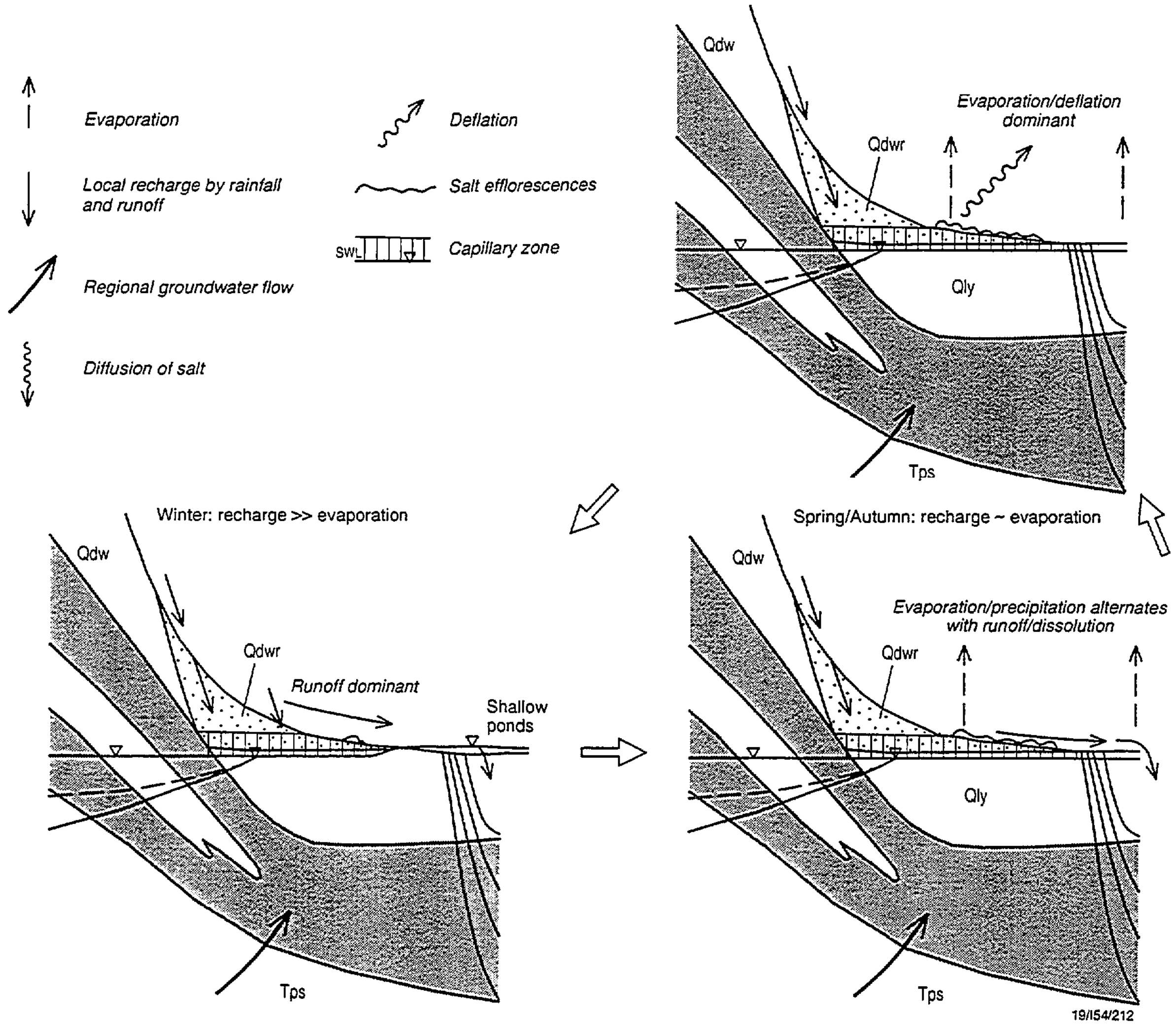


Figure 28. Detail of hydrodynamic processes involved in the formation of brines in the Mourquong discharge complex.

and be deflated from the discharge complex (Figure 28).

Hydrochemistry of the Brines

Major Ions

Brines formed predominantly by process (1) should have major-ion compositions similar to those predicted from evaporation of the incoming Parilla Sand groundwater. In contrast, those formed by process (2) could have major -ion compositions reflecting selective dissolution of both the transient and final salts precipitated at the margins during evaporation of the incoming Parilla Sand groundwater. Theoretically, under process (2) evaporation to dryness at the surface should result in the complete transfer of the major-ion composition of the source Parilla Sand groundwater to the brines formed from the rainfall/redissolved salt source waters. In practice, a selection process related to the seasonal cycle operates at the lake margins as conditions change from regular washing/flooding to aeolian deflation of the surface sediment. These selection processes favour the incorporation of magnesium sulphate, sodium sulphate and sodium chloride minerals into the rainfall/dissolution brines. Thus, depending on the balance between processes (1) and (2), brines formed in discharge complexes range in composition from solutions of magnesium sulphate plus sodium chloride to only slightly modified concentrated Parilla Sand source waters. These various chemical signatures are transferred to the Parilla Sand aquifer with the diffusing salt and refluxing brines.

Geochemical modelling (Chambers et al., 1995) of the equilibrium evaporation path of Parilla Sand source waters for the discharge complex (as approximated by the discharge water from the interception scheme) indicates that a more diverse suite of evaporites will form than that indicated by modelling the evaporation of seawater, and the order in which the evaporites form is different. In particular glauberite ($CaNa_2(SO_4)_2$) will form before the onset of halite precipitation, rather than after as occurs in seawater. With further evaporation, glauberite replaces anhydrite and then reacts with the brine to reprecipitate anhydrite and produce bloedite ($MgNa_2(SO_4)_2.4H_20$). Bloedite is then consumed in favour of epsomite ($MgSO_4.7H_20$), and a further reaction produces polyhalite ($K_2MgCa_2(SO_4)_4$). Clearly, this sequence will be modified if some of the products are removed during the evaporation process. Nonetheless, the sequence indicates that these minerals and halite are potential sources of Mg, Na, SO_4 and Cl for the brines formed in the topographically low areas of discharge complex.

The presence of these salts in the groundwaters of the discharge complex (Tables 1 to 4) is best determined by comparing their composition to that of evaporated source

Table 1. Chemistry of Parilla Sand Groundwater, Mourquong Discharge Complex & Environs. Transect PS and sites to the west.

Description	*Depth below GL m*	*Average Depth* below GL	*Elevation mAHD*	*Salinity mg/L (or TDS)*	*Lab. reference*	*Sr mg/L*	*Li mg/L*	*Ca mg/L*	*Mg mg/L*	*Na mg/L*	*K mg/L*	*Br mg/L*	*Cl mg/L*	*SO4 mg/L*	*Si mg/L*	*B mg/L*
DWR 36908/1 August 92			0.75	87298	920177	11.5	1.87	875	3490	25800	279	124	49200	7530		
DWR 36908/2 August 92			-19.4	123902	920178	9.69	2.32	807	6240	37500	380	175	68200	10600		
DWR 36908/3 (Bookpumong) DWR analyses			-39.4	103200				993	4708	30670	275		57720	8750		
DWR 36908/3 (Bookpumong) AGSO analyses			-39.4	102000	960027	12.5	1.39	766	4550	30700	258	158	55900	7910	2.33	1.51
DWR 36910/1 Coomeallah Irrig.Dist; DWR analyses		15	26	29565				269	1290	9130	96		16465	2315		
DWR 36910/1 Coomeallah Irrig.Dist; AGSO analyses			26	37000	960024	6.01	0.03	285	1450	10600	91.9	54.8	20900	2960	9.13	1.21
DWR 36910/2 Coomeallah Irrig.Dist; DWR analyses		38.5	2.5	47131				399	2122	13980	130		25990	4510		
DWR 36910/2 Coomeallah Irrig.Dist; AGSO analyses			2.5	53000	960025	9.03	0.495	412	2230	15600	124	73.7	29300	4910	7.02	1.61
DWR 36910/3 Coomealla Irrig.Dist; DWR analyses		59	-19	54853				588	2660	16735	130		29000	5740		
DWR 36910/3 Coomealla Irrig.Dist; AGSO analyses			-19	60000	960026	13.1	0.709	641	2910	17600	146	83.4	32600	6690	4.77	1.82
MEM-1 (1) 8 Nov 95		56.5	-22.75	111000	950476											
MEM-1 (1) March 96		56.5	-22.75	114000	960028	10.4	1.72	808	5420	32900	305	165	60900	10800	3.93	1.91
MEM-1 (2) 7Nov 95		45	-8.75	100000	950461	10.7	1.75	754	4820	36000	274	182	60700	9490	3.44	1.81
MEM-1 (3) 9Nov95		32	1.75	60000	950462	11.4	1.06	646	2200	19200	184	83.1	31600	5010	5.18	2.13
MEM-1 (4) 7Nov95		27.5	6.25	61000	950463	11.5	1.09	579	2260	20400	207	93.9	33500	5030	5.65	2.41
MEM-1 (5) 7Nov95		20	13.75	60000	950464	11.5	1	657	2130	19800	208	87.9	32200	5260	5.94	2.59
MEM-1; AGSO; 15.6 m below GL (sand layer in	15.6		18.4	56000	950534	n.d.	n.d.	1140	3250	21900	90.7	91.1	36400	9700		n.d.
MEM-1; AGSO; 60.15 m below GL (top Bookpu	60.15		-26.15	125000	950536	n.d.	n.d.	833	7520	46400	128	185	76200	13900		n.d.
MEM-1; AGSO; 62.23-62.65 m below GL (Bookpumong)		62.44	-28.44	121000	950537	n.d.	n.d.	834	7200	44300	144	161	73100	13000		n.d.
MEM-1; AGSO; 68.0-68.65 m below GL (Bookpumong)		68.32	-34.32	123000 (?)	950538	n.d.	n.d.	1200	8100	50200	293	202	85400	14100		n.d.
MEM-1; AGSO; 74.0-74.65 m below GL (Bookpumong)		74.32	-40.32	122000 (?)	950539	n.d.	n.d.	1110	6770	42100	<116	169	69700	11400		n.d.
MEM-1; AGSO; 80.65-81.3(1) m below GL (Bookpumong)		80.95	-46.95	115000	950540	n.d.	n.d.	1250	6580	40700	<116	165	69900	11300		n.d.
MEM-1; AGSO; 85.0-85.65(1) m below GL (Bookpumong)		85.32	-51.32	115000	950542	n.d.	n.d.	1390	6750	42200	<116	168	73200	11800		n.d.

Table 1 (continued). Chemistry of Parilla Sand Groundwater, Mourquong Discharge Complex & Environs. Transect PS and sites to the west.

Description	*Depth below GL m*	*Average Depth below GL*	*Elevation mAHD*	*Salinity mg/L (or TDS)*	*Lab. reference*	*Sr mg/L*	*Li mg/L*	*Ca mg/L*	*Mg mg/L*	*Na mg/L*	*K mg/L*	*Br mg/L*	*Cl mg/L*	*SO4 mg/L*	*Si mg/L*	*B mg/L*
MEM-4 (1) 10Nov95		24.5	7.5	51000	950465	13.4	0.656	570	2200	16600	156	74.6	27700	4700	6.87	2.18
MEM-4 (1) March 96			7.5	51000	960036	13.2	0.668	529	2100	15000	145	77.2	28600	4800	7.29	2.37
MEM-4 (2) 10Nov 95		45	-13	92000	950466	11.1	1.74	822	4210	27400	235	134	48300	8080	4.32	1.74
MEM-4 (3) 10 Nov 95		57	-25	ca.98000	no sample											
MEM-4 (3) March 96			-25	120000	960037	9.14	2.6	652	5380	35600	279	165	63200	11200	3.79	1.78
MSWM-6 (2) 11Nov95		40	15	30000	950467	6.57	0.33	365	1470	8870	103	40.8	15700	2650	11.5	1.03
MSWM-6 (3) 11Nov95		52	3	56000	950468	10.1	0.852	581	2230	18100	132	81.1	30400	4570	6.27	1.68
M21 (1) 13Nov95		21.5	10.5	52000	950469	10.6	0.651	537	1980	16300	117	73	28000	4110	7	1.73
M21 (2) 13 Nov 95		29.5	2.5	68000	950470	16.6	1.1	983	2750	20000	141	94.9	35200	5800	4.75	2.14
M21 (3) 13 Nov 95		37.5	-5.5	79000	950471	14.7	1.49	969	3340	24000	208	105	41600	6900	5.01	2.27
M21 (4) 13 Nov 95		48	-16	104000	950472	10.5	2.15	787	4620	30600	273	127	52500	8450	4.18	1.83
M21 (5) 13 Nov 95		57	-25	125000	950473	9.33	2.76	7.41	6010	39700	328	162	64600	10400	3.2	1.8
MEM-3 (1) 15 Nov 95		22	11	52000	950474	11.7	0.858	5.72	2160	16700	179	76.6	28000	4400	6.7	2.08
MEM-3 (2) 16 Nov 95		39.5	-6.5	83000	950475	11.4	1.24	711	4210	25400	206	111	43000	8390	3.85	2
MEM-3 (3) March 96		52	-19	90000	960035	11.4	1.13	711	4340	24900	202	111	44100	9030	3.76	2.09
Tapio-1			23	38000	960029	18.4	0.419	659	1500	10100	104	57.1	19200	3780	12.2	2.91
Tapio-2			4	43000	960030	17.9	0.66	607	1780	11600	124	62.1	22300	4850	6	3.02
Tapio-3			-8	44000	960031	18.3	0.54	628	1800	11600	128	63	22700	4930	6.26	3.3
MEM-5 (1) March 96	21		21	45000	960032	12	0.757	429	1620	13400	135	67.5	24800	3750	14.8	2.72
MEM-5 (2) March 96	39		3	55000	960033	11.3	0.828	518	2160	16200	148	78.8	29500	5020	5.96	2.42
MEM-5 (3) March 96	53		-11	65000	960034	11.3	0.811	603	2920	17400	159	85.5	33000	6550	4.98	2.04
MEM-2B (Blanchetown Clay)			22	78000	950277	16.2	2.6	850	2800	18000	200	77.8	29200	7420		

Table 2. Chemistry of Parilla Sand Groundwater - Ratios to Br. Mourquong Discharge Complex & Environs. Transect PS and sites to the west.

Description	*Elevation mAHD*	*Salinity mg/L (or TDS)*	*Lab. reference*	*Salinity/Br*	*Ca/Br*	*Mg/Br*	*Na/Br*	*K/Br*	*Cl/Br*	*SO4/Br*	*Li/Br*
DWR 36908/1 August 92	0.75	87298	920177	704	7.1	28.1	208	2.25	397	60.7	0.0151
DWR 36908/2 August 92	-19.4	123902	920178	708	4.6	35.7	214	2.17	390	60.6	0.0133
DWR 36908/3 (Bookpurnong) DWR analyses	-39.4	103200									
DWR 36908/3 (Bookpurnong) AGSO analyses	-39.4	102000	960027	646	4.8	28.8	194	1.63	354	50.1	0.0088
DWR 36910/1 Coomeallah Irrig.Dist; DWR anal	26	29565									
DWR 36910/1 Coomeallah Irrig.Dist; AGSO ana	26	37000	960024	675	5.2	26.5	193	1.68	381	54.0	0.0005
DWR 36910/2 Coomeallah Irrig.Dist; DWR anal	2.5	47131									
DWR 36910/2 Coomeallah Irrig.Dist; AGSO ana	2.5	53000	960025	719	5.6	30.3	212	1.68	398	66.6	0.0067
DWR 36910/3 Coomealla Irrig.Dist; DWR analy	-19	54853									
DWR 36910/3 Coomealla Irrig.Dist; AGSO anal	-19	60000	960026	719	7.7	34.9	211	1.75	391	80.2	0.0085
MEM-1 (1) 8 Nov 95	-22.75	111000	950476								
MEM-1 (1) March 96	-22.75	114000	960028	691	4.9	32.8	199	1.85	369	65.5	0.0104
MEM-1 (2) 7Nov 95	-8.75	100000	950461	549	4.1	26.5	198	1.51	334	52.1	0.0096
MEM-1 (3) 9Nov95	1.75	60000	950462	722	7.8	26.5	231	2.21	380	60.3	0.0128
MEM-1 (4) 7Nov95	6.25	61000	950463	650	6.2	24.1	217	2.20	357	53.6	0.0116
MEM-1 (5) 7Nov95	13.75	60000	950464	683	7.5	24.2	225	2.37	366	59.8	0.0114
MEM-1; AGSO; 15.6 m below GL (sand layer in	18.4	56000	950534	615	12.5	35.7	240	1.00	400	106.5	
MEM-1; AGSO; 60.15 m below GL (top Bookpu	-26.15	125000	950536	676	4.5	40.6	251	0.69	412	75.1	
MEM-1; AGSO; 62.23-62.65 m below GL (Book	-28.44	121000	950537	752	5.2	44.7	275	0.89	454	80.7	
MEM-1; AGSO; 68.0-68.65 m below GL (Bookp	-34.32	123000 (?)	950538	#VALUE!	5.9	40.1	249	1.45	423	69.8	
MEM-1; AGSO; 74.0-74.65 m below GL (Bookp	-40.32	122000 (?)	950539	#VALUE!	6.6	40.1	249		412	67.5	
MEM-1; AGSO; 80.65-81.3(1) m below GL (Bo	-46.95	115000	950540	697	7.6	39.9	247		424	68.5	
MEM-1; AGSO; 85.0-85.65(1) m below GL (Bo	-51.32	115000	950542	685	8.3	40.2	251		436	70.2	

Table 2 (continued). Chemistry of Parilla Sand Groundwater - Ratios to Br. Mourquong Discharge Complex & Environs. Transect PS and sites to the west.

Description	*Elevation mAHD*	*Salinity mg/L (or TDS)*	*Lab. reference*	*Salinity/Br*	*Ca/Br*	*Mg/Br*	*Na/Br*	*K/Br*	*Cl/Br*	*SO4/Br*	*Li/Br*
MEM-4 (1) 10Nov95	7.5	51000	950465	684	7.6	29.5	223	2.09	371	63.0	0.0088
MEM-4 (1) March 96	7.5	51000	960036	661	6.9	27.2	194	1.88	370	62.2	0.0087
MEM-4 (2) 10Nov 95	-13	92000	950466	687	6.1	31.4	204	1.75	360	60.3	0.0130
MEM-4 (3) 10 Nov 95		ca.98000	no sample								
MEM-4 (3) March 96	-25	120000	960037	727	4.0	32.6	216	1.69	383	67.9	0.0158
MSWM-6 (2) 11Nov95	15	30000	950467	735	8.9	36.0	217	2.52	385	65.0	0.0081
MSWM-6 (3) 11Nov95	3	56000	950468	691	7.2	27.5	223	1.63	375	56.4	0.0105
M21 (1) 13Nov95	10.5	52000	950469	712	7.4	27.1	223	1.60	384	56.3	0.0089
M21 (2) 13 Nov 95	2.5	68000	950470	717	10.4	29.0	211	1.49	371	61.1	0.0116
M21 (3) 13 Nov 95	-5.5	79000	950471	752	9.2	31.8	229	1.98	396	65.7	0.0142
M21 (4) 13 Nov 95	-16	104000	950472	819	6.2	36.4	241	2.15	413	66.5	0.0169
M21 (5) 13 Nov 95	-25	125000	950473	772	0.0	37.1	245	2.02	399	64.2	0.0170
MEM-3 (1) 15 Nov 95	11	52000	950474	679	0.1	28.2	218	2.34	366	57.4	0.0112
MEM-3 (2) 16 Nov 95	-6.5	83000	950475	748	6.4	37.9	229	1.86	387	75.6	0.0112
MEM-3 (3) March 96	-19	90000	960035	811	6.4	39.1	224	1.82	397	81.4	0.0102
Tapio-1	23	38000	960029	665	11.5	26.3	177	1.82	336	66.2	0.0073
Tapio-2	4	43000	960030	692	9.8	28.7	187	2.00	359	78.1	0.0106
Tapio-3	-8	44000	960031	698	10.0	28.6	184	2.03	360	78.3	0.0086
MEM-5 (1) March 96	21	45000	960032	667	6.4	24.0	199	2.00	367	55.6	0.0112
MEM-5 (2) March 96	3	55000	960033	698	6.6	27.4	206	1.88	374	63.7	0.0105
MEM-5 (3) March 96	-11	65000	960034	760	7.1	34.2	204	1.86	386	76.6	0.0095
MEM-2B (Blanchetown Clay)	22	78000	950277	1003	10.9	36.0	231	2.57	375	95.4	0.0334

Table 3. Chemistry of Parilla Sand Groundwater - Ratios to Mg. Mourquong Discharge Complex & Environs. Transect PS and sites to the west.

Description	Elevation mAHI	Salinity mg/L (or TDS)	Lab. reference	Salinity/Mg	Ca/Mg	Na/Mg	K/Mg	Cl/Mg	SO4/Mg	Ca/SO4	SO4/Cl	Na/Cl
DWR 36908/1 August 92	0.75	87298	950276	25.0	0.251	7.39	0.080	14.1	2.16	0.116	0.153	0.524
DWR 36908/2 August 92	-19.4	123902	950276	19.9	0.129	6.01	0.061	10.9	1.70	0.076	0.155	0.550
DWR 36908/3 (Bookpurnong) DWR analyses	-39.4	103200		21.9	0.211	6.51	0.058	12.3	1.86	0.113	0.152	0.531
DWR 36908/3 (Bookpurnong) AGSO analyses	-39.4	102000	960027	22.4	0.168	6.75	0.057	12.3	1.74	0.097	0.142	0.549
DWR 36910/1 Coomeallah Irrig.Dist; DWR analy	26	29565		22.9	0.209	7.08	0.074	12.8	1.79	0.116	0.141	0.555
DWR 36910/1 Coomeallah Irrig.Dist; AGSO ana	26	37000	960024	25.5	0.197	7.31	0.063	14.4	2.04	0.096		
DWR 36910/2 Coomeallah Irrig.Dist; DWR analy	2.5	47131		22.2	0.188	6.59	0.061	12.2	2.13	0.088	0.174	0.538
DWR 36910/2 Coomeallah Irrig.Dist; AGSO ana	2.5	53000	960025	23.8	0.185	7.00	0.056	13.1	2.20	0.084	0.168	0.532
DWR 36910/3 Coomealla Irrig.Dist; DWR analys	-19	54853		20.6	0.221	6.29	0.049	10.9	2.16	0.102	0.198	0.577
DWR 36910/3 Coomealla Irrig.Dist; AGSO analy	-19	60000	960026	20.6	0.220	6.05	0.050	11.2	2.30	0.096	0.205	0.540
MEM-1 (1) 8 Nov 95	-22.75	111000	950476									
MEM-1 (1) March 96	-22.75	114000	960028	21.0	0.149	6.07	0.056	11.2	1.99	0.075	0.177	0.540
MEM-1 (2) 7Nov 95	-8.75	100000	950461	20.7	0.156	7.47	0.057	12.6	1.97	0.079	0.156	0.593
MEM-1 (3) 9Nov95	1.75	60000	950462	27.3	0.294	8.73	0.084	14.4	2.28	0.129	0.159	0.608
MEM-1 (4) 7Nov95	6.25	61000	950463	27.0	0.256	9.03	0.092	14.8	2.23	0.115	0.150	0.609
MEM-1 (5) 7Nov95	13.75	60000	950464	28.2	0.308	9.30	0.098	15.1	2.47	0.125	0.163	0.615
MEM-1; AGSO; 15.6 m below GL (sand layer in	18.4	56000	950534	17.2	0.351	6.74	0.028	11.2	2.98	0.118	0.266	0.602
MEM-1; AGSO; 60.15 m below GL (top Bookpu	-26.15	125000	950536	16.6	0.111	6.17	0.017	10.1	1.85	0.060	0.182	0.609
MEM-1; AGSO; 62.23-62.65 m below GL (Book	-28.44	121000	950537	16.8	0.116	6.15	0.020	10.2	1.81	0.064	0.178	0.606
MEM-1; AGSO; 68.0-68.65 m below GL (Bookp	-34.32	123000 (?)	950538		0.148	6.20	0.036	10.5	1.74	0.085	0.165	0.588
MEM-1; AGSO; 74.0-74.65 m below GL (Bookp	-40.32	122000 (?)	950539		0.164	6.22		10.3	1.68	0.097	0.164	0.604
MEM-1; AGSO; 80.65-81.3(1) m below GL (Bo	-46.95	115000	950540	17.5	0.190	6.19		10.6	1.72	0.111	0.162	0.582
MEM-1; AGSO; 85.0-85.65(1) m below GL (Bo	-51.32	115000	950542	17.0	0.206	6.25		10.8	1.75	0.118	0.161	0.577

Table 3 (continued). Chemistry of Parilla Sand Groundwater - Ratios to Mg. Mourquong Discharge Complex & Environs. Transect PS and sites to the west.

Description	*Elevation mAHI*	*Salinity mg/L* (or TDS)	*Lab. reference*	*Salinity/Mg*	*Ca/Mg*	*Na/Mg*	*K/Mg*	*Cl/Mg*	*SO4/Mg*	*Ca/SO4*	SO4/Cl	Na/Cl
MEM-4 (1) 10Nov95	7.5	51000	950465	23.2	0.259	7.55	0.071	12.6	2.14	0.121	0.170	0.599
MEM-4 (1) March 96	7.5	51000	960036	24.3	0.252	7.14	0.069	13.6	2.29	0.110	0.168	0.524
MEM-4 (2) 10Nov 95	-13	92000	950466	21.9	0.195	6.51	0.056	11.5	1.92	0.102	0.167	0.567
MEM-4 (3) 10 Nov 95												
MEM-4 (3) March 96	-25	120000	960037	22.3	0.121	6.62	0.052	11.7	2.08	0.058	0.177	0.563
MSWM-6 (2) 11Nov95	15	30000	950467	20.4	0.248	6.03	0.070	10.7	1.80	0.138	0.169	0.565
MSWM-6 (3) 11Nov95	3	56000	950468	25.1	0.261	8.12	0.059	13.6	2.05	0.127	0.150	0.595
M21 (1) 13Nov95	10.5	52000	950469	26.3	0.271	8.23	0.059	14.1	2.08	0.131	0.147	0.582
M21 (2) 13 Nov 95	2.5	68000	950470	24.7	0.357	7.27	0.051	12.8	2.11	0.169	0.165	0.568
M21 (3) 13 Nov 95	-5.5	79000	950471	23.7	0.290	7.19	0.062	12.5	2.07	0.140	0.166	0.577
M21 (4) 13 Nov 95	-16	104000	950472	22.5	0.170	6.62	0.059	11.4	1.83	0.093	0.161	0.583
M21 (5) 13 Nov 95	-25	125000	950473	20.8	0.001	6.61	0.055	10.7	1.73	0.001	0.161	0.615
MEM-3 (1) 15 Nov 95	11	52000	950474	24.1	0.003	7.73	0.083	13.0	2.04	0.001	0.157	0.596
MEM-3 (2) 16 Nov 95	-6.5	83000	950475	19.7	0.169	6.03	0.049	10.2	1.99	0.085	0.195	0.591
MEM-3 (3) March 96	-19	90000	960035	20.7	0.164	5.74	0.047	10.2	2.08	0.079	0.205	0.565
Tapio-1	23	38000	960029	25.3	0.439	6.73	0.069	12.8	2.52	0.174	0.197	0.526
Tapio-2	4	43000	960030	24.2	0.341	6.52	0.070	12.5	2.72	0.125	0.217	0.520
Tapio-3	-8	44000	960031	24.4	0.349	6.44	0.071	12.6	2.74	0.127	0.217	0.511
MEM-5 (1) March 96	21	45000	960032	27.8	0.265	8.27	0.083	15.3	2.31	0.114	0.151	0.540
MEM-5 (2) March 96	3	55000	960033	25.5	0.240	7.50	0.069	13.7	2.32	0.103	0.170	0.549
MEM-5 (3) March 96	-11	65000	960034	22.3	0.207	5.96	0.054	11.3	2.24	0.092	0.198	0.527
MEM-2B (Blanchetown Clay)	22	78000	950277	27.9	0.304	6.43	0.071	10.4	2.65	0.115	0.254	0.616

Table 4. Chemistry of Parilla Sand Groundwater - 36-Cl and 87-Sr Isotopes. Mourquong Discharge Complex & Environs. Transect PS and sites to the west.

Description	*Lab. reference*	87Sr/86Sr	2 Sigma (%)	36Cl/Cl *10-15	*Cl mg/L*	36Cl*10^6 atoms/L	(+/-) atoms/L
DWR 36908/1 August 92	920177	0.711342	0.0018	24 (4)	49200	20,057	6151
DWR 36908/2 August 92	920178	0.710911	0.0016	26 (3)	68200	30,120	7692
DWR 36908/3 (Bookpurnong) DWR analyses					57720		
DWR 36908/3 (Bookpurnong) AGSO analyses	960027	0.710476	0.0014	18.6 (2.9)	55900	17,661	5226
DWR 36910/1 Coomeallah Irrig.Dist; DWR analyses					16465		
DWR 36910/1 Coomeallah Irrig.Dist; AGSO analyses					20900		
DWR 36910/2 Coomeallah Irrig.Dist; DWR analyses					25990		
DWR 36910/2 Coomeallah Irrig.Dist; AGSO analyses					29300		
DWR 36910/3 Coomealla Irrig.Dist; DWR analyses					29000		
DWR 36910/3 Coomealla Irrig.Dist; AGSO analyses					32600		
MEM-1 (1) 8 Nov 95	950476			25.1 (2.8)			
MEM-1 (1) March 96	960028	0.710784	0.0016		60900		
MEM-1 (2) 7Nov 95	950461	0.711072	0.0016	28.8 (3.5)	60700	29,695	7766
MEM-1 (3) 9Nov95	950462	0.711332	0.0017	27.4 (3.0)	31600	14,707	3669
MEM-1 (4) 7Nov95	950463	0.71137	0.0014	26.6 (3.6)	33500	15,136	4168
MEM-1 (5) 7Nov95	950464	0.711326	0.0015	30.5 (3.5)	32200	16,682	4250
MEM-1; AGSO; 15.6 m below GL (sand layer in Blanchetown)					36400		
MEM-1; AGSO; 60.15 m below GL (top Bookpurnong)					76200		
MEM-1; AGSO; 62.23-62.65 m below GL (Bookpurnong)					73100		
MEM-1; AGSO; 68.0-68.65 m below GL (Bookpurnong)					85400		
MEM-1; AGSO; 74.0-74.65 m below GL (Bookpurnong)					69700		
MEM-1; AGSO; 80.65-81.3(1) m below GL (Bookpurnong)					69900		
MEM-1; AGSO; 85.0-85.65(1) m below GL (Bookpurnong)					73200		

Table 4 (continued). Chemistry of Parilla Sand Groundwater - 36-Cl and 87-Sr Isotopes. Mourquong Discharge Complex & Environs. Transect PS and sites to the west.

Description	*Lab. reference*	87Sr/86Sr	2 Sigma (%)	36Cl/Cl *10-15	*Cl mg/L*	36Cl*10^6 (atoms/L)	(+/-)atoms/L
MEM-4 (1) 10Nov95	950465				27700		
MEM-4 (1) March 96	960036	0.711471	0.0016	25.3 (3.5)	28600	12,291	3421
MEM-4 (2) 10Nov 95	950466	0.711233	0.0015	32.2(3.6)	48300	26,418	6652
MEM-4 (3) 10 Nov 95							
MEM-4 (3) March 96	960037	0.711052	0.0011	24.3 (4.0)	63200	26,087	7946
MSWM-6 (2) 11Nov95	950467	n.d.		34.8 (4.0)	15700	9,281	2366
MSWM-6 (3) 11Nov95	950468	n.d.		34.5 (3.9)	30400	17,815	4508
M21 (1) 13Nov95	950469	n.d.		27.5 (3.5)	28000	13,079	3496
M21 (2) 13 Nov 95	950470	n.d.		27.5 (3.3)	35200	16,443	4275
M21 (3) 13 Nov 95	950471	n.d.		25.4 (3.2)	41600	17,948	4774
M21 (4) 13 Nov 95	950472	n.d.		27.2 (3.7)	52500	24,256	6695
M21 (5) 13 Nov 95	950473	n.d.		34.7 (3.6)	64600	38,077	9281
MEM-3 (1) 15 Nov 95	950474	n.d.		28.5 (3.8)	28000	13,555	3705
MEM-3 (2) 16 Nov 95	950475	0.711086	0.0012	29.0 (3.0)	43000	21,182	5157
MEM-3 (3) March 96	960035	0.71076	0.0012	24.7 (3.1)	44100	18,503	4913
Tapio-1	960029	0.710314	0.0019	25.6 (3.4)	19200	8,349	2278
Tapio-2	960030	0.710462	0.0014	17.2 (2.8)	22300	6,515	1973
Tapio-3	960031	0.710436	0.0012	22.1 (2.9)	22700	8,522	2311
MEM-5 (1) March 96	960032	0.71103	0.0015	25.9 (3.3)	24800	10,911	2918
MEM-5 (2) March 96	960033	0.711138	0.0016	25.9 (3.5)	29500	12,978	3571
MEM-5 (3) March 96	960034	0.711006	0.0015	26.6 (3.3)	33000	14,911	3937
MEM-2B (Blanchetown Clay)	950277	0.711089	0.0016	35 (4)	29200	17,360	4414

waters. However the discharge water from the interception scheme approximates only the present-day source waters, and the composition of these source waters could have changed significantly during the evolution of the discharge complex. For this reason, and because marine-influenced aerosols are probably the ultimate source of salts for the source waters, seawater composition has been used as the reference point in assessing the presence of additional salts in the discharge complex groundwaters.

Modification of the chemistry of seawater-like groundwaters by the addition of salts is reflected in increases in their Mg/Br, Na/Br, SO_4/Br and Cl/Br ratios. Conversely, the residual brines from which the salts have precipitated should have lower ratios. Figure 29 shows the effects that dissolution of simple salts such as $MgSO_4$, NaCl and Na_2SO_4 will have on plots of the ratios Mg/Br versus Cl/Br, SO_4/Br versus Cl/Br and NaCl versus Cl/Br. These ratios do not give a definite indication of the presence of added Na_2SO_4, except at Na/Cl ratios > about 0.66 (the ratio for pure NaCl). However, a small increase in Cl/Br accompanied by a major increase in Na/Cl indicates the involvement of Na_2SO_4 salts.

Figure 30 shows all of the data for the Blanchetown Clay, Parilla Sand and Bookpurnong Beds beneath the Mourquong discharge complex and surrounding areas. Figure 31 shows the data for the Blanchetown Clay beneath the discharge complex. Compared to seawater there is a clear enrichment in Mg, and SO_4, a lesser increase in Cl, and an increase in the Na/Cl ratio. These increases are qualitatively consistent with the addition of $MgSO_4$, NaCl and possibly Na_2SO_4 minerals.

A more quantitative approach can be taken by comparing the molar concentrations of the discharge complex groundwaters to those of seawater evaporated to the same Br concentration. For example, the groundwater sample from the Blanchetown Clay (MEM-1, 18.4 mAHD), has a total excess of [Ca+Mg+Na+K] over seawater of the same Br concentration of 470 mequiv/L. The corresponding [Cl+SO_4] excess is 410 mequiv./L. The excess Mg and SO_4 balance each other (130 mequiv/L Mg; 130 mequiv/L SO_4) and the excess Na and Cl are not greatly different (320 mequiv/L Na; 130 mequiv/L Cl). This suggests that $MgSO_4$ and NaCl are the main components of the added salts and addition of Na_2SO_4 is minor.

Isotopes

^{36}Cl/Cl and ^{87}Sr/^{86}Sr data has been obtained from the groundwater in the Blanchetown Clay beneath a permeable lunette near the centre of the discharge complex (Site MEM-2, Figure 4). This is an environment where recharge exceeds evaporation. the ^{36}Cl/Cl ratio of 35 (4) is amongst the highest obtained for the discharge complex and surrounds (Table 4) which is consistent with a major contribution of chloride from recent

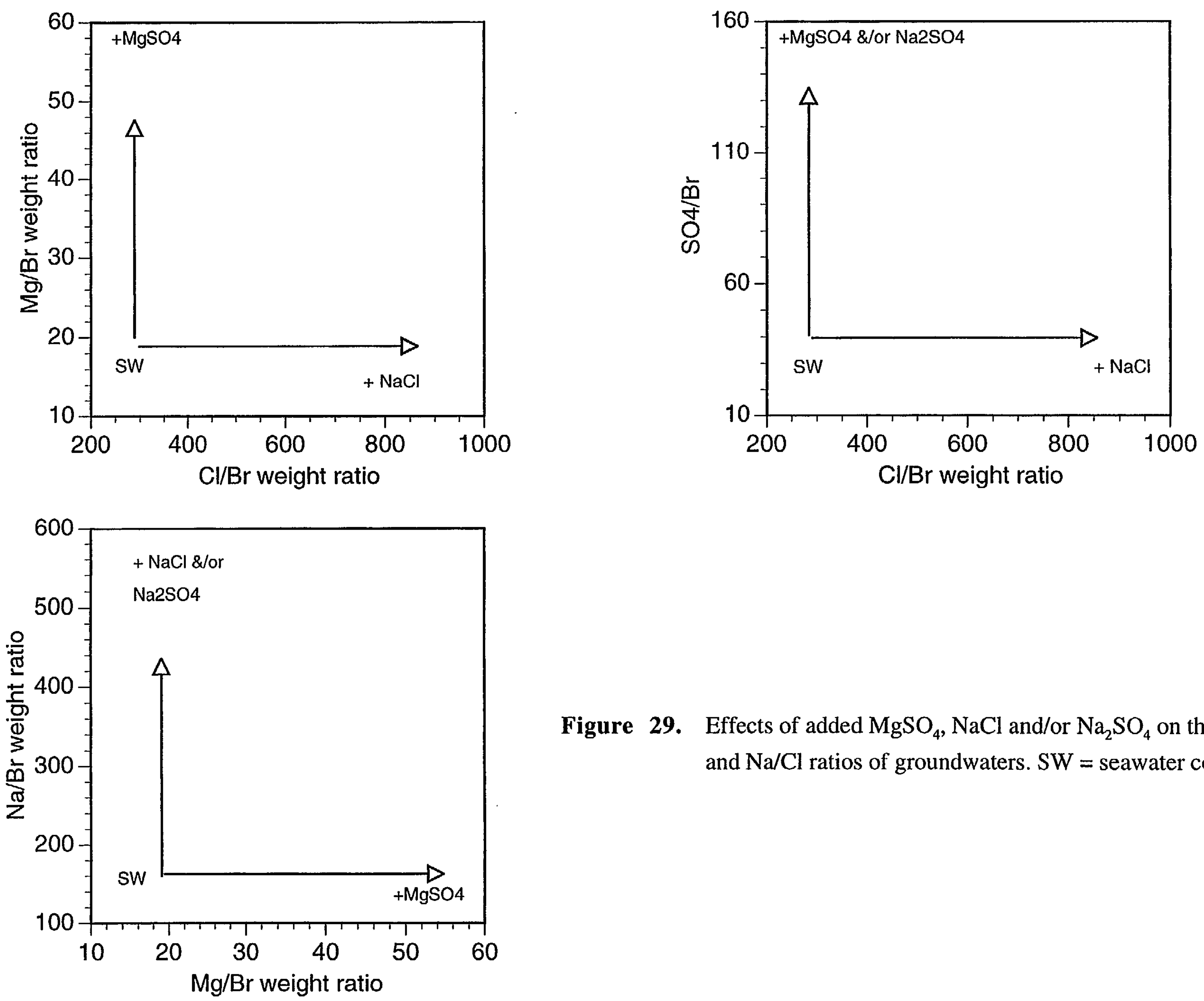


Figure 29. Effects of added $MgSO_4$, NaCl and/or Na_2SO_4 on the Cl/Br, Mg/Br, SO_4/Br and Na/Cl ratios of groundwaters. SW = seawater composition.

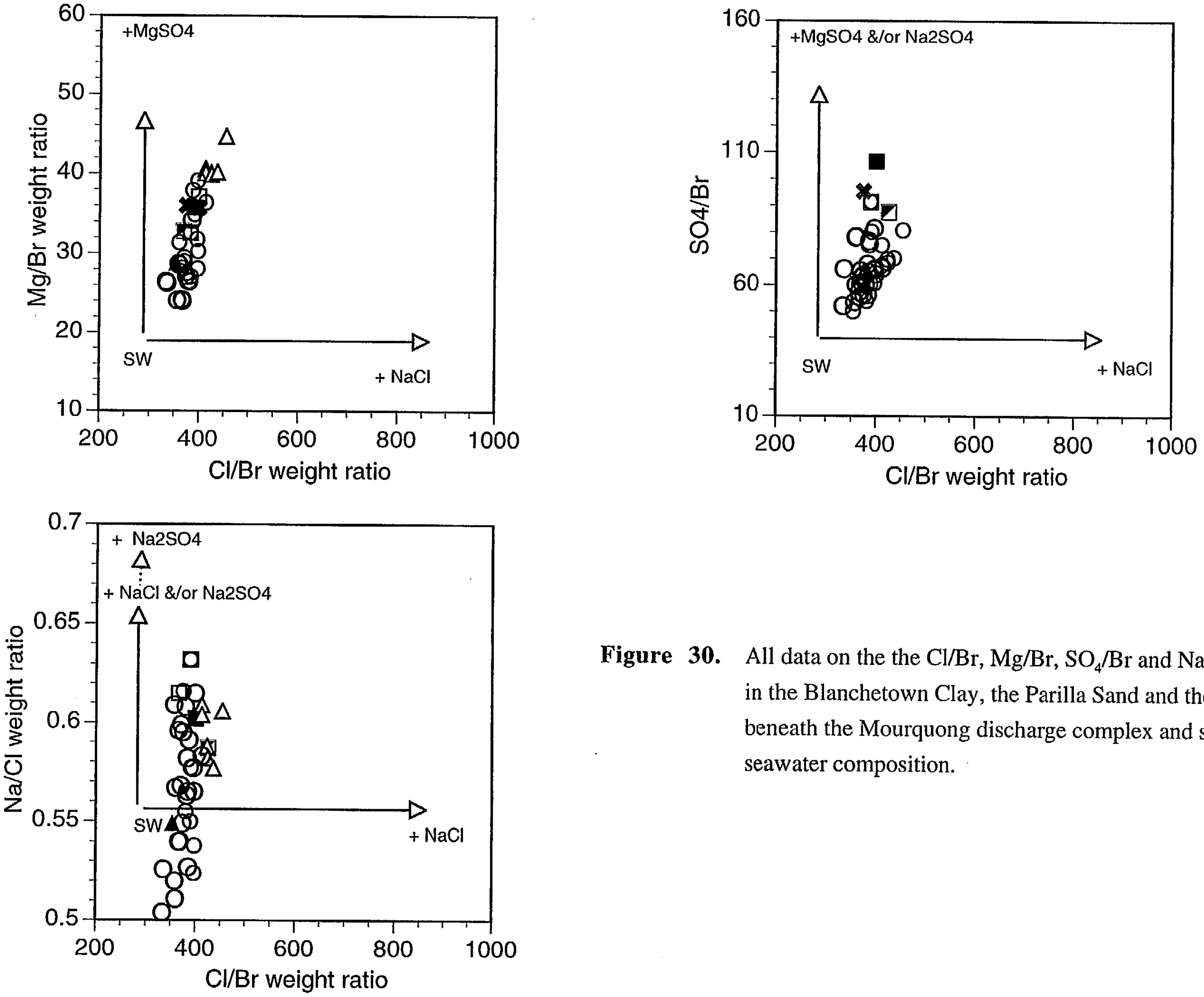


Figure 30. All data on the the Cl/Br, Mg/Br, SO_4/Br and Na/Cl ratios of groundwaters in the Blanchetown Clay, the Parilla Sand and the Bookpurnong Beds beneath the Mourquong discharge complex and surrounding areas. SW = seawater composition.

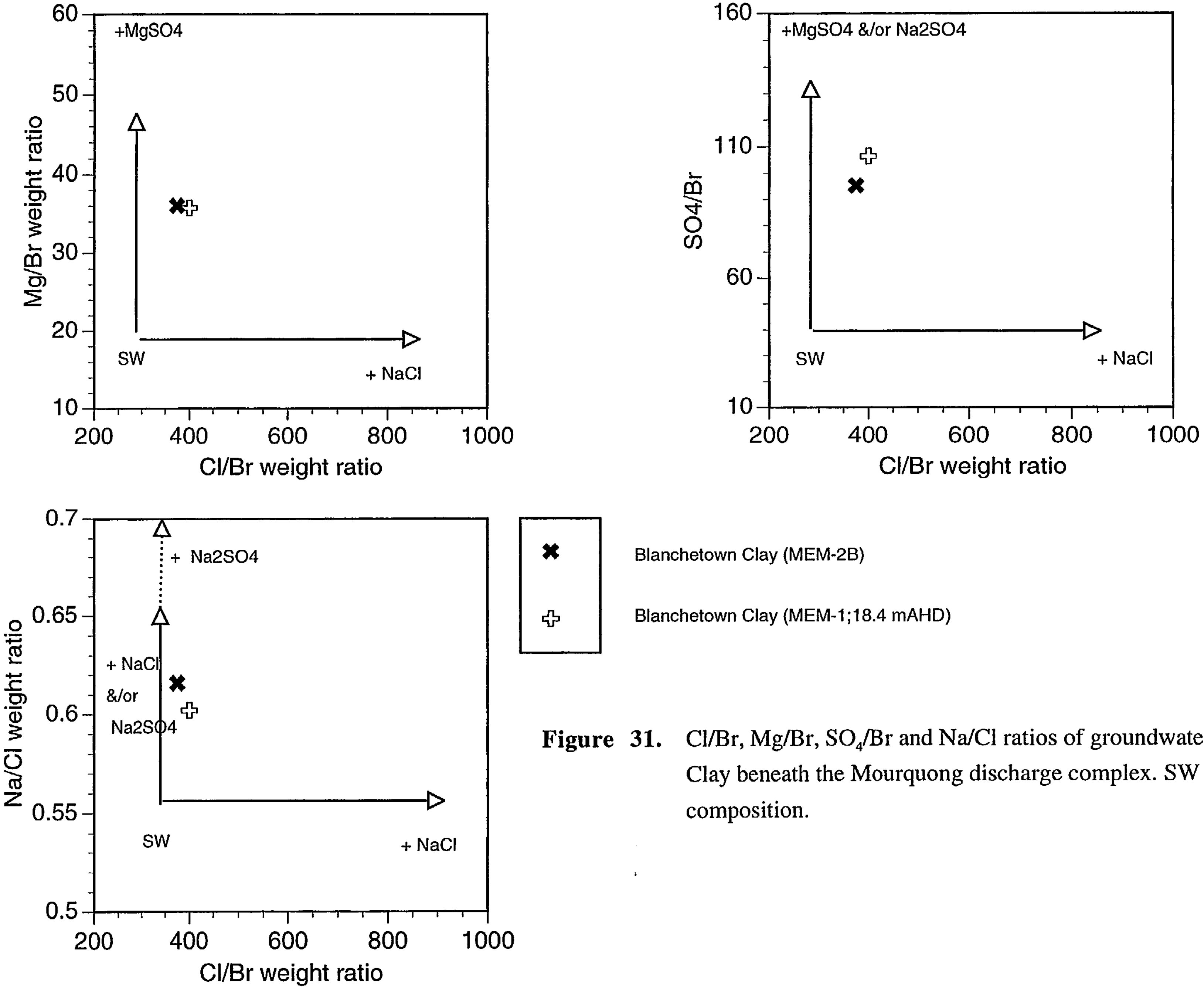


Figure 31. Cl/Br, Mg/Br, SO_4/Br and Na/Cl ratios of groundwaters in the Blanchetown Clay beneath the Mourquong discharge complex. SW = seawater composition.

rainfall recharge. The same sample has a $^{87}Sr/^{86}Sr$ ratio of 0.711089 (0.0016), which is more radiogenic than modern (0.70915) and older seawater.

Brines in the Parilla Sand and Bookpurnong Beds underlying the Groundwater Discharge Complex and environs.

Salinities in the Parilla Sand and the Bookpurnong Beds

The groundwater salinity sampling points for the transects MSWM-6 - Tapio and Coomealla - Tapio are shown in Figures 32 and 33, respectively. Iso-salinity contours for transect MSWM-6 - Tapio are shown in Figure 34.

The salinities at the top of the Parilla Sand immediately underlying the Blanchetown Clay are significantly higher beneath the recently active salina (now disposal basin) (e.g about 80,000 mg/L at M1 and M18B) than they are beneath the lunette-covered area of the discharge complex (60,000 mg/L at MEM-1). This higher salinity is consistent with downwards diffusion of salt from the discharge complex through the Blanchetown Clay to the top of the Parilla Sand aquifer. The highest salinity increases are located beneath the parts of the discharge complex with the longest and more recent history of brine formation.

Several features are apparent in the iso-salinity contours for the Parilla Sand and underlying Bookpurnong Beds (Figure 34):

(1) Brines of maximum salinity 125,000 mg/L occur in the Parilla Sand and Bookpurnong Beds underlying the discharge complex, and are overlain by lower salinity waters. The presence of lower salinity overlying waters indicates that these are paleo-brines and that diffusion is currently the main mechanism by which salt is transferred from the discharge complex into the underlying Parilla Sand aquifer.

(2) Relatively low salinity water occurs in the upper part of the Parilla Sand beneath the southern part of the dune which forms the western margin of the discharge complex (e.g. 30,000 mg/L at location MSWM-6; Figure 34). The Blanchetown Clay is relatively thin in this area, which favours recharge of the Parilla Sand by local rainfall and the concomitant introduction of contemporary aerosols.

(3) Away from the discharge complex the salinity in the Parilla Sand may be relatively low and change little with depth (e.g. 38,000 to 44,000 mg/L, Tapio; Figure 33), or it may be relatively low at the top of the aquifer and increase considerably with depth (e.g. 37,000 to 60,000 mg/L, DWR 36910; Figure 33). Limited local recharge is indicated by the considerable thickness of Blanchetown Clay at both sites. The site where the salinity is almost constant with depth is topographically high and therefore remote from any present

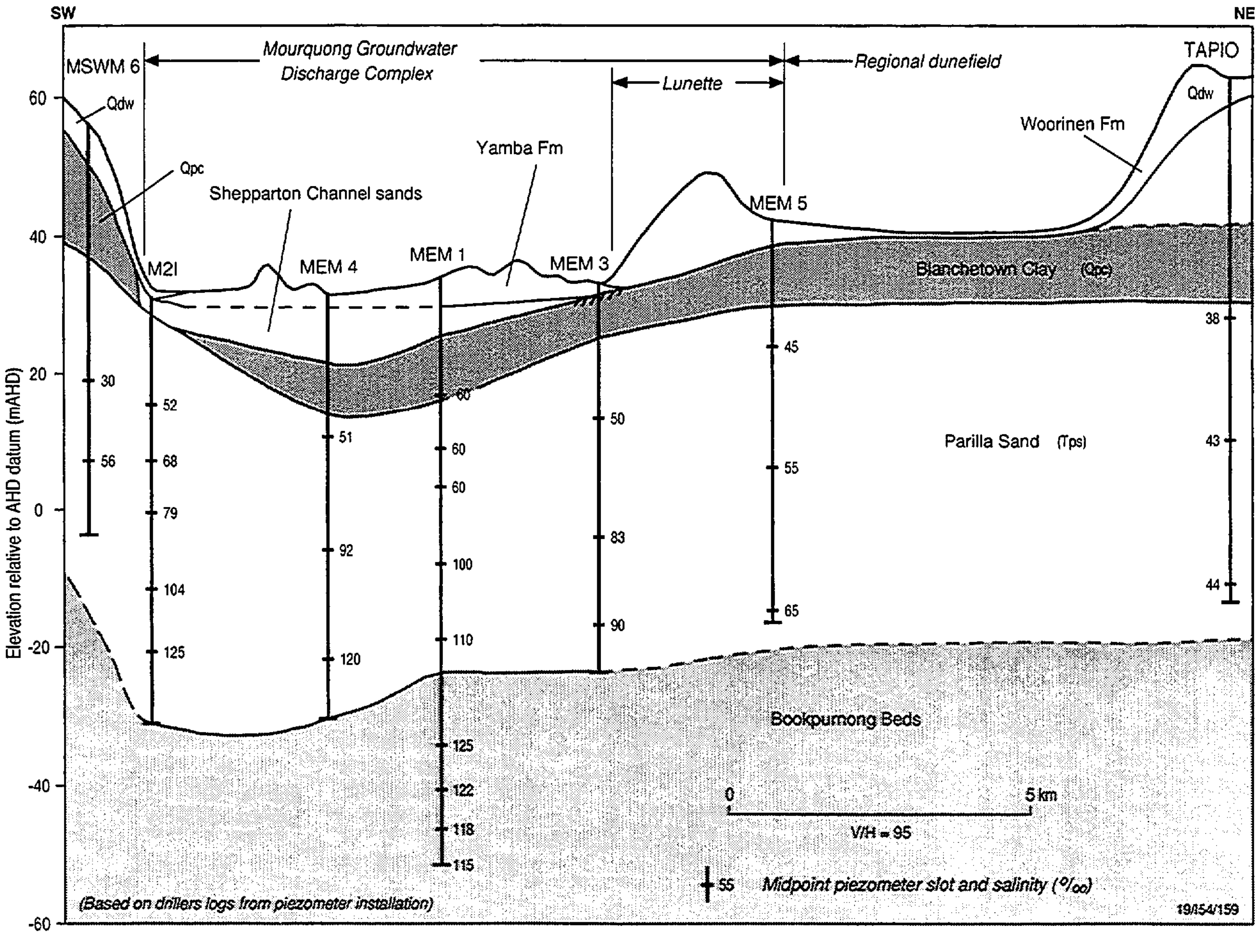


Figure 32. Salinity sampling points and salinity values for the Parilla Sand and Bookpurnong Beds, MSWM-6 - Tapio transect.

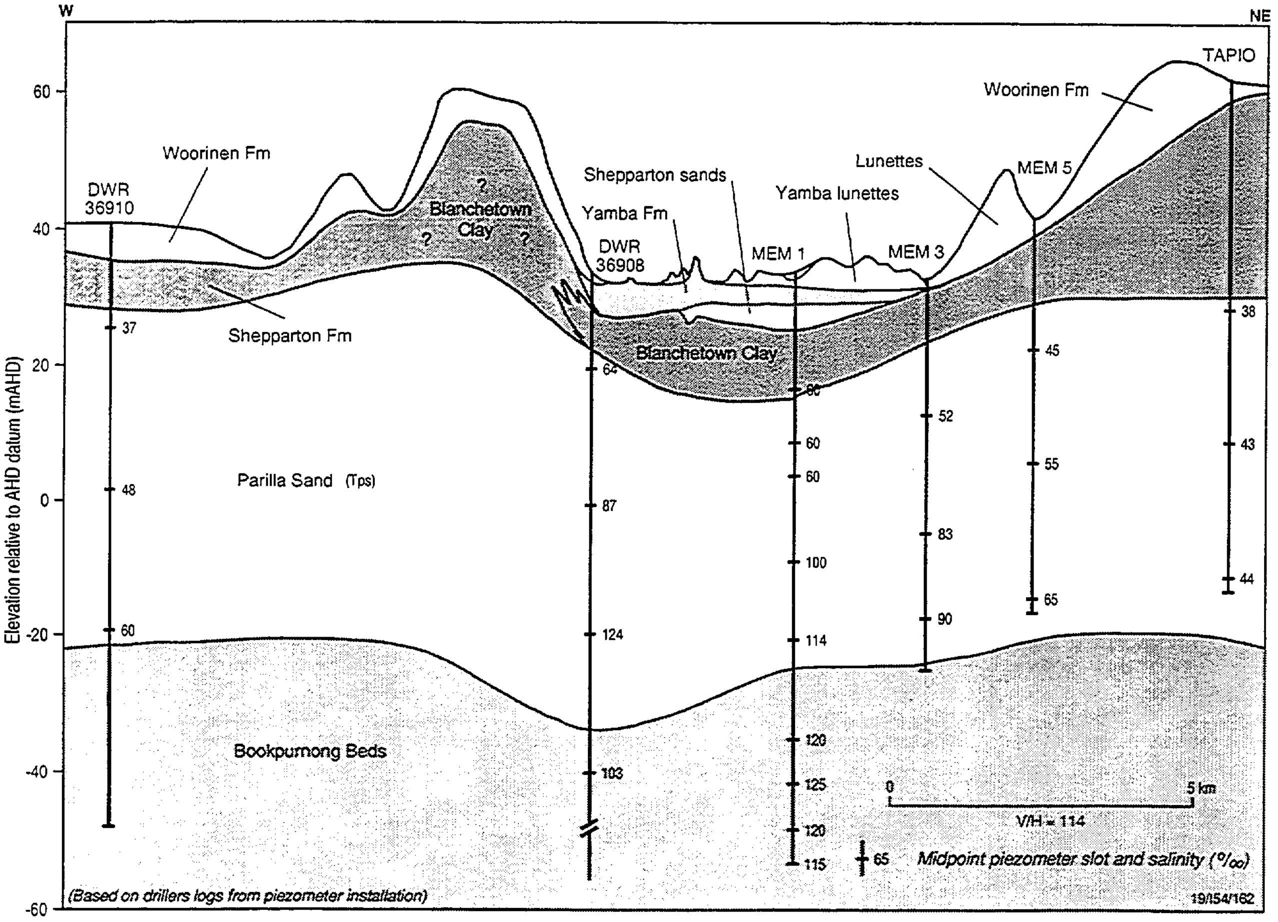


Figure 33. Salinity sampling points and salinity values for the Parilla Sand and Bookpurnong Beds, Coomealla - Tapio transect.

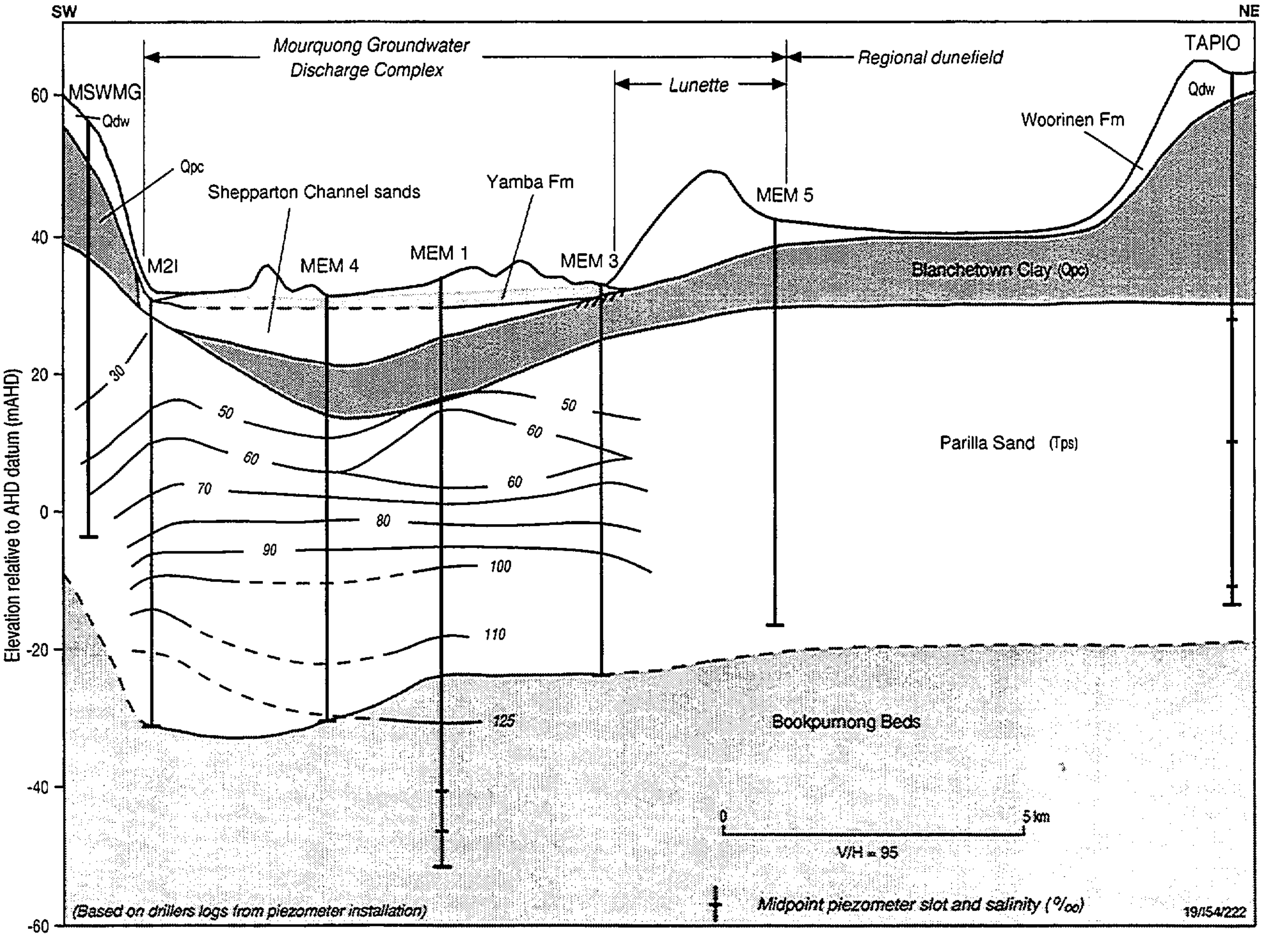


Figure 34. Iso-salinity contours for the Parilla Sand and Bookpurnong Beds, MSWM-6 - Tapio transect.

or past groundwater discharge activity. The site where the salinity increases with depth is lower and groundwater discharge activity is occurring or has occurred nearby, which suggests that the higher salinity deeper waters are vestiges of groundwater brines formed in nearby discharge areas.

The above information, plus that from other groundwater discharge areas can be generalised to describe four major hydrodynamic environments of the Parilla Sand (Figure 35). They are:

(1) Beneath the major, long established groundwater discharge complexes. There, salt is introduced to the Parilla Sand by advective reflux and/or diffusion and it then moves laterally by advection/diffusion and vertically by diffusion into the underlying clays of the Bookpurnong Beds.

(2) Beneath salinized interdunal areas where groundwater discharge has been sporadic and the consequent landforms poorly developed. In these areas recharge would be minimised by the moderately thick Blanchetown Clay sequence but the salinity at the top of the Parilla Sand would be increased by downwards diffusion of salt.

(3) Beneath permeable dunes where the Blanchetown Clay is missing, or is disrupted by sandy Shepparton Formation sediments, or is thin. In these areas, recharge of the top of the Parilla Sand can be sufficiently effective to superimpose contemporary rainfall and chloride signatures from aerosols over extensive areas of the aquifer. The Mourquong stratigraphy indicates that high recharge areas associated with permeable dunes and abnormally thin underlying Blanchetown Clay are likely to border the areas of the discharge complexes where the Blanchetown Clay is missing.

(4) Beneath topographically high areas underlain by thick sequences of Blanchetown Clay. Groundwater discharge would be minimal because of the high elevation, and rainfall recharge would be severely limited by the thick clay sequence. Groundwaters from older hydrodynamic events which have moved laterally will tend to be preserved in these relatively stagnant areas.

Evolution of Saline Groundwaters beneath Discharge Complexes in Response to Hydrodynamic Cycles of Diffusion and Reflux

The evolution of the groundwaters beneath and around groundwater discharge areas can be modelled by superimposing the effects of several alternating periods of diffusion and reflux. The evolution of the Parilla Sand groundwaters from the demise of Lake Bungunnia through two diffusion-reflux cycles is presented in Figures 36 (a) to (e).

This model incorporates four main assumptions:

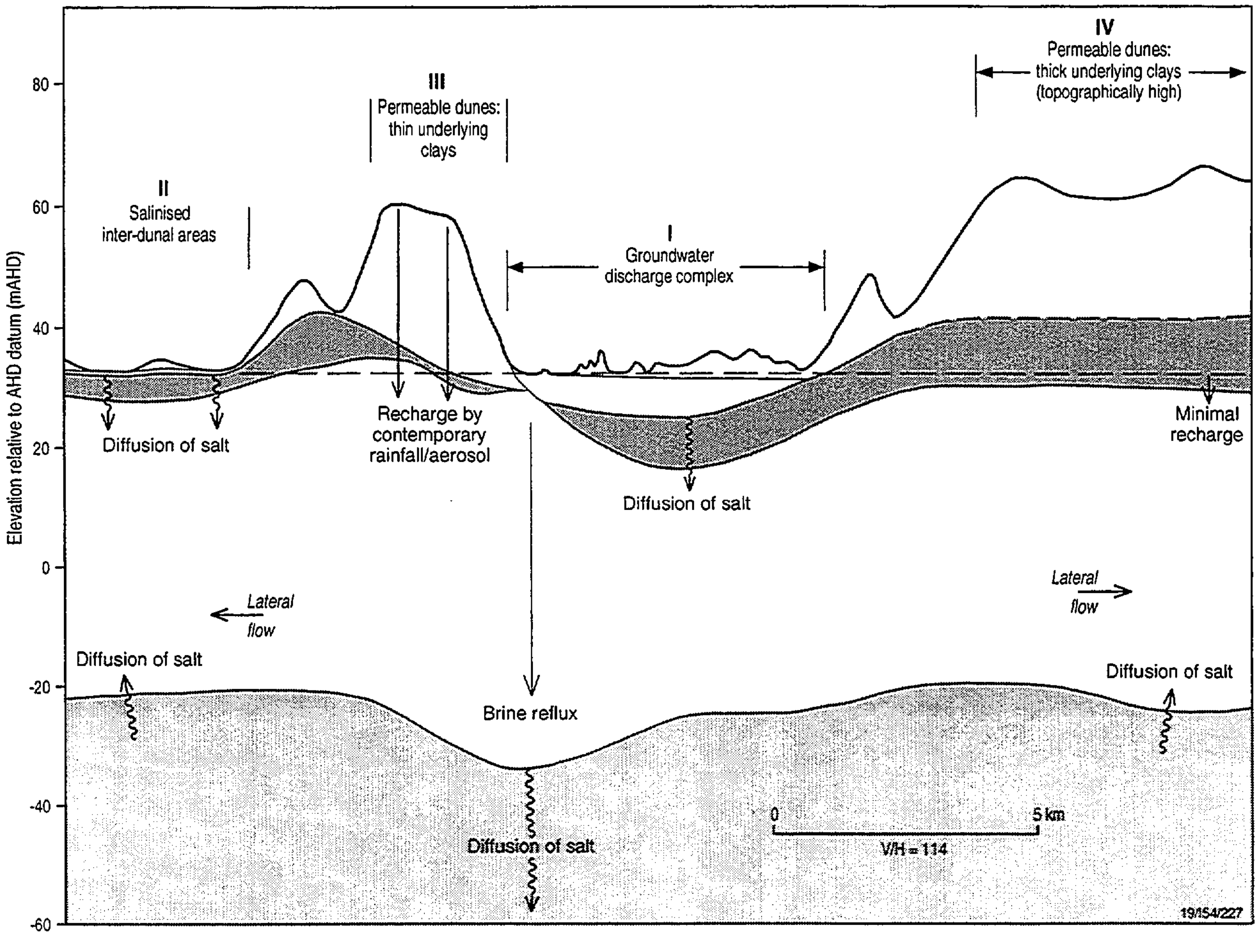


Figure 35. Schematic representation of the major hydrodynamic environments of the Parilla Sand in groundwater discharge areas.

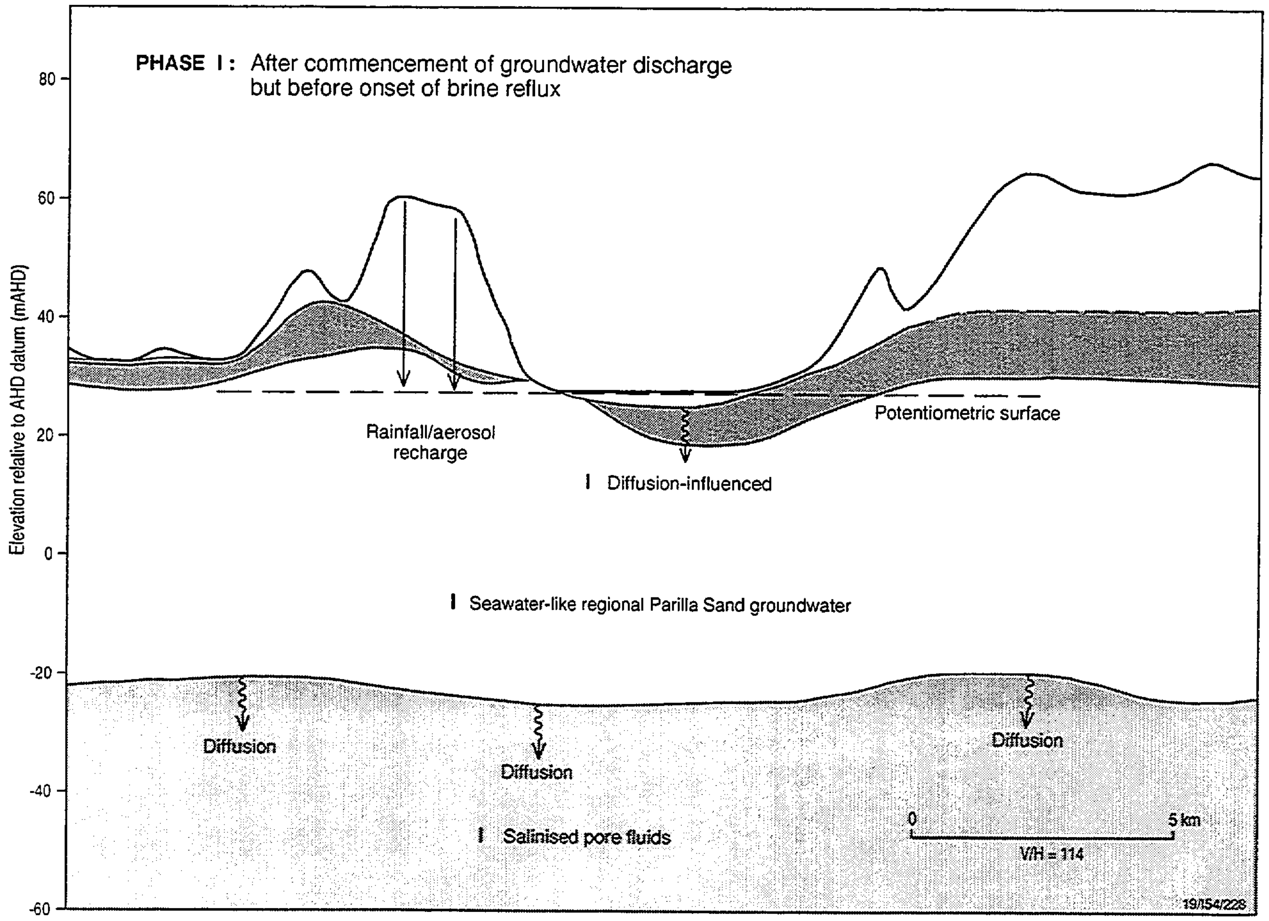
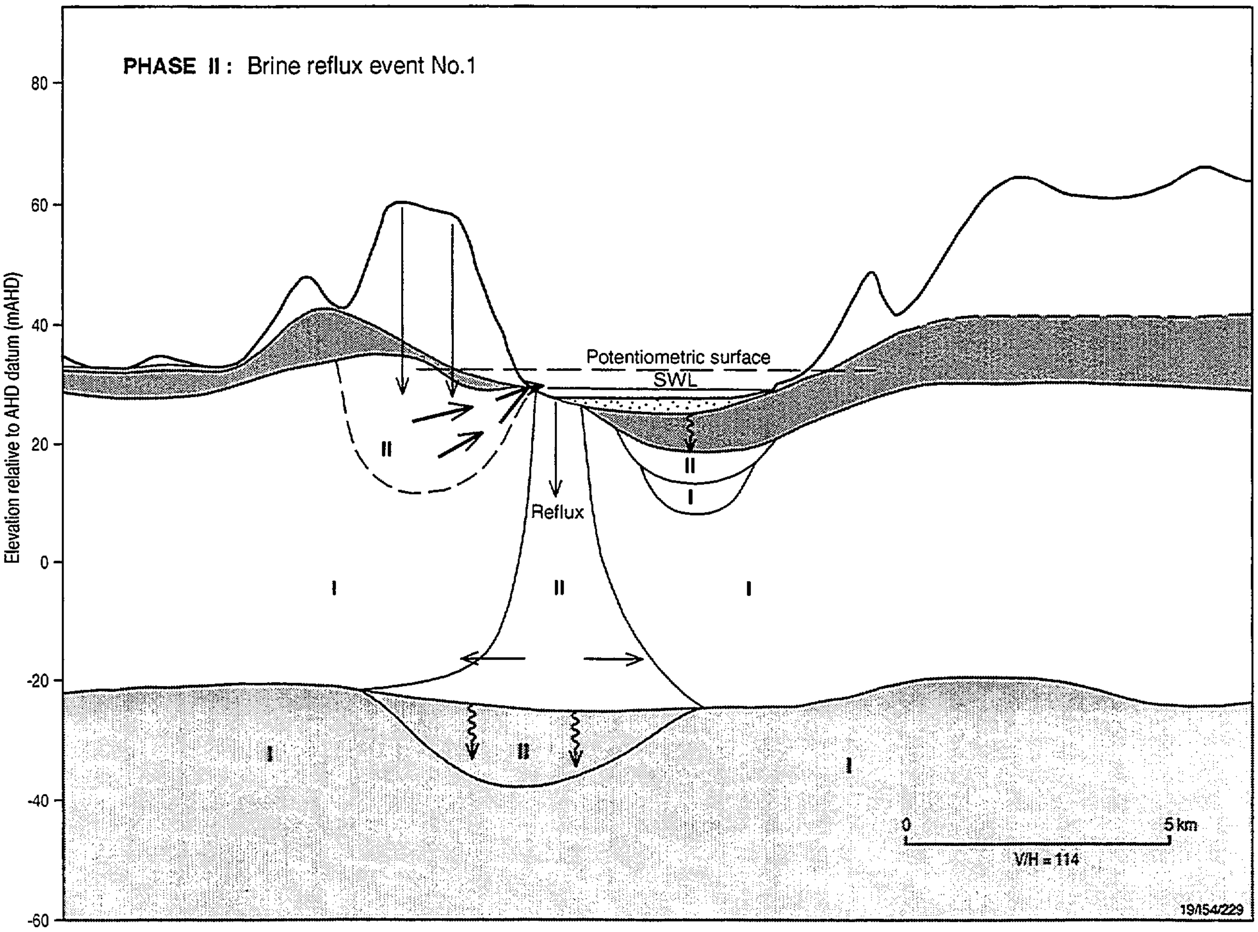


Figure 36. Schematic representation of the hydrodynamic evolution of the Parilla Sand aquifer in groundwater discharge areas.

(a) Phase I (arid): Initial diffusion-dominant phase after the onset of groundwater discharge.

Parilla Sand becomes salinised after the extinction of Lake Bungunnia.
Marine aerosol origin for salts gives seawater-like chemistry .
Diffusion of salt commences from the discharge complex to the top of the Parilla Sand and from the base of the Parilla Sand into the underlying Bookpurnong Beds.



(b) <u>Phase II(wet)</u>; First brine reflux event.

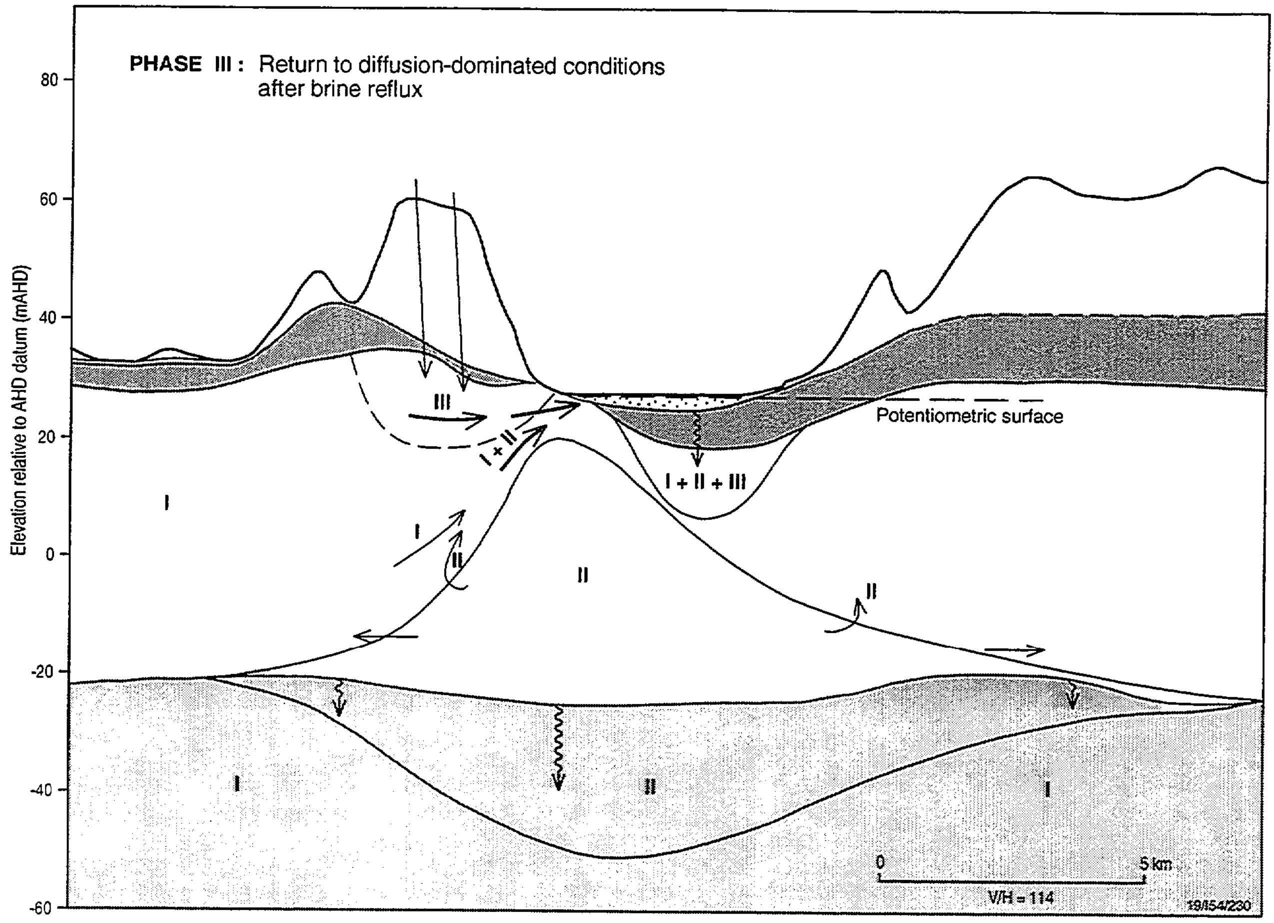
Recharge of the Parilla Sand by rainfall/aerosols increases as the climate becomes wetter and these contemporaneous waters are the main groundwater input to the discharge complex.

Brine sourced by the locally recharged Parilla Sand groundwater refluxes rapidly through the Blanchetown Clay-free areas to the base of the Parilla Sand and starts to spread laterally.

Elsewhere in the discharge complex downwards diffusion through the Blanchetown Clay continues.

Diffusion of salts from the reflux brine into the Bookpurnong Beds commences, displacing salts from Phase I.

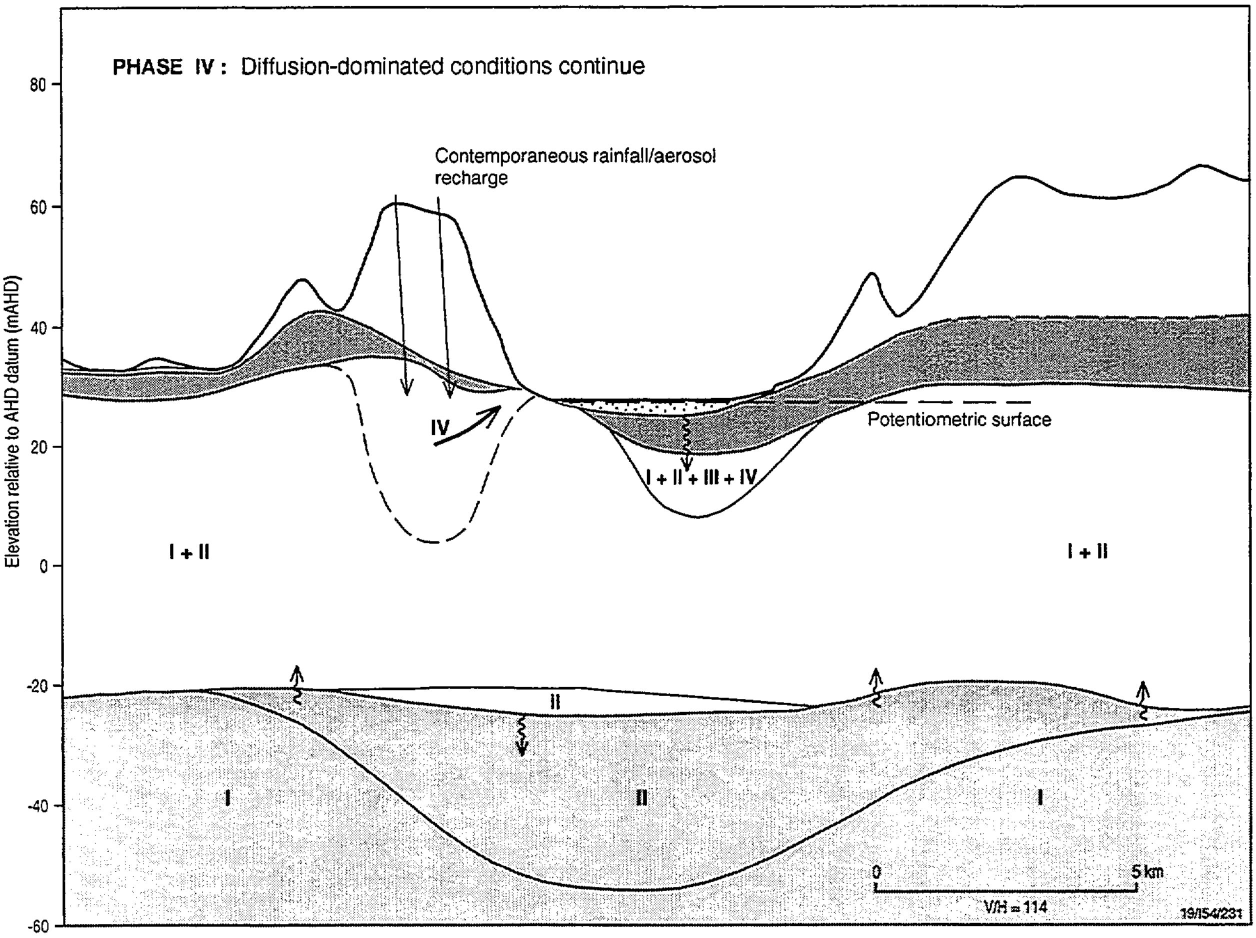
Contemporaneous (Phase II) groundwaters and marine aerosol chloride are the source for the discharge complex and reflux brines.



(c) Phase III(arid): Return to diffusion-dominated conditions.

After reflux ceases the brine continues to sink and spread laterally. and the area of the Bookpurnong Beds influenced by diffusion from this brine expands.

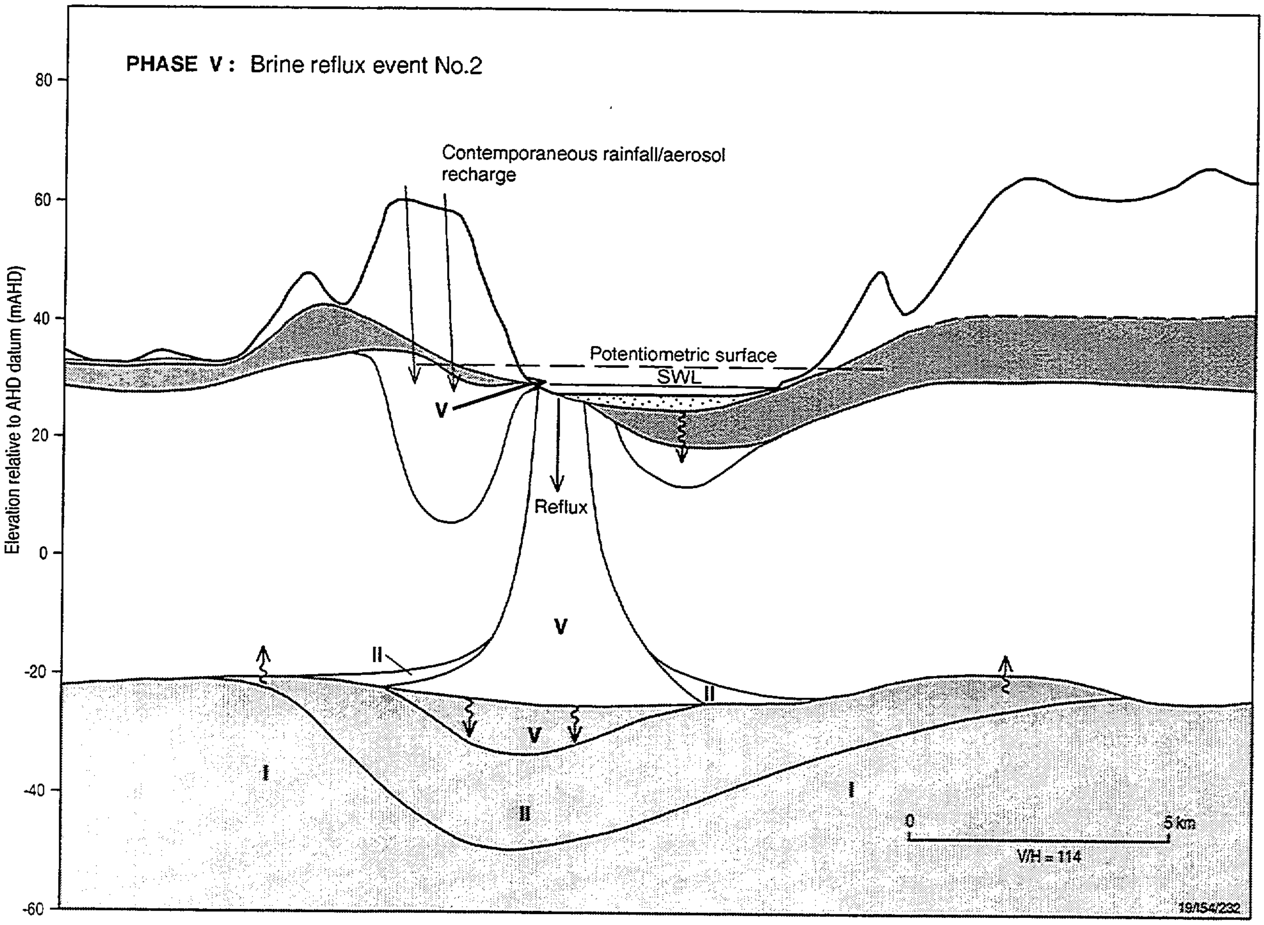
Under these circumstances, some of the dissipating brine may become entrained in the incoming groundwatewers, providing a mixed source to the discharge complex.



(d) Phase IV(arid): Diffusion-dominated conditions continue.

Dispersion of the reflux brine continues, leaving a diminishing pool at the base of the Parilla Sand.

In the distal areas the salinity gradient between the Parilla Sand and the Bookpurnong Beds is reversed as the salinity in the Parilla Sand decreases. Consequently salt (Phase II) diffuses from the Bookpurnong Beds back into the Parilla Sand.



(e) Phase V(wet): Second brine reflux event.

Recharge of the Parilla Sand by rainfall/aerosols increases as the climate becomes wetter.

A second brine reflux event sourced by these contemporary (Phase V) groundwaters is superimposed on the remains of the previous phase of brine reflux , leaving residues of this older phase at the periphery of the brine pool in the Parilla Sand and the underlying areas of the Bookpurnong Beds.

(1) Brine reflux occurs predominantly through the area of the discharge complex where the Blanchetown Clay is missing.

(2) Reflux is a rapid process involving minimal mixing of the brine with existing groundwaters and this rapid reflux is followed by slow dispersion of the refluxed brine during diffusion-dominant periods.

(2) Reflux will be associated with wetter and/or transition periods when water tables are high and the high permeability window is flooded, but evaporation is sufficiently high to generate brines. Diffusion will be dominant in arid periods when water tables are low and brine activity is restricted to the Blanchetown Clay-underlain areas.

(3) During periods of reflux the source groundwaters will comprise contemporary rainfall and aerosol-derived chloride from areas of high recharge located around the erosional window in the Blanchetown Clay.

(4) During periods of diffusion saline waters which have entered the Bookpurnong Beds during the preceding period of brine reflux can return to the Parilla Sand as the reflux brines dissipate and the salinity in the Parilla Sand decreases.

Under these circumstances, the most recent reflux brine will be centred at the base of the Parilla Sand under the Blanchetown Clay-free area. Spreading from this area laterally outwards in the Parilla Sand and downwards into the Bookpurnong Beds will be increasingly older and, potentially, more mixed waters from previous reflux regimes.

Evidence for the Preservation of Original Paleo-reflux Brines

Mixing in the Parilla Sand of the brines from different reflux events is favoured by circulation patterns which can be set up within the reflux brine by the groundwaters flowing towards the discharge complex (Barnes et al. 1991). However, this effect will diminish during diffusion-dominant periods to rates comparable with diffusion. Advection and diffusion should be even less effective in the Bookpurnong Beds, where the permeability and diffusivity are lower than in the Parilla Sand.

There is evidence from Mourquong and other discharge complexes that brines of salinity about 125,000 mg/L are common in the Murray Basin (Table 5 and Figure 37). This remarkable co-incidence of maximum salinity beneath a number of geographically and stratigraphically diverse discharge complexes suggests that brines with salinity about 125,000 mg/L may be original (not mixed) reflux brines from the discharge complexes.

If these are original brines, then it implies that brine reflux is triggered when the salinity of the brines in the discharge complex reaches 125,000 mg/L. This could occur if this salinity corresponds to a critical density at which the ratio of the density of the shallow brine in the discharge complex to that of the underlying groundwater becomes high enough

Table 5. *High-salinity Groundwaters in the Parilla Sand and Bookpurnong Beds in Groundwater Discharge Areas of the Murray Basin*

(a) Maximum Salinity Encountered Beneath Groundwater Discharge Complexes

Discharge Complex	*Site*	*Salinity (mg/L)*	*Reference*
Mourquong	M21(5)	125,000	This work
Nulla	NSL 5/60m	106,000	Ferguson et al., in prep.
Scotia	SSL/1	125,500	Ferguson et al. (1995)
Raak Plain	Bitterang 8001	123,500	Macumber (1991)
Timboram-Wahpool	Lianiduck 1001	126,900	Macumber (1991)
Pink Lakes	Mamengarook	110,000	Macumber (1991)
Tyrrell	Bimbourie 10002	265,300	Macumber (1991)

(b) High Salinity Groundwaters in Single-site Borehole Nests Near or Within Groundwater Discharge Complexes

Discharge Complex	*Site*	*Salinity (mg/L)*	*Reference*
-------	Talgarry 2	89,000	Kellett; unpublished
-------	Cal Lal 1	80,200	Kellett; unpublished
-------	Warwick 1	87,300	Kellett; unpublished
-------	Coombah 1	79,200	Kellett; unpublished
-------	Pomona 1	57,000	Kellett; unpublished
-------	Coomealla (36908/3)	55,000	This Work

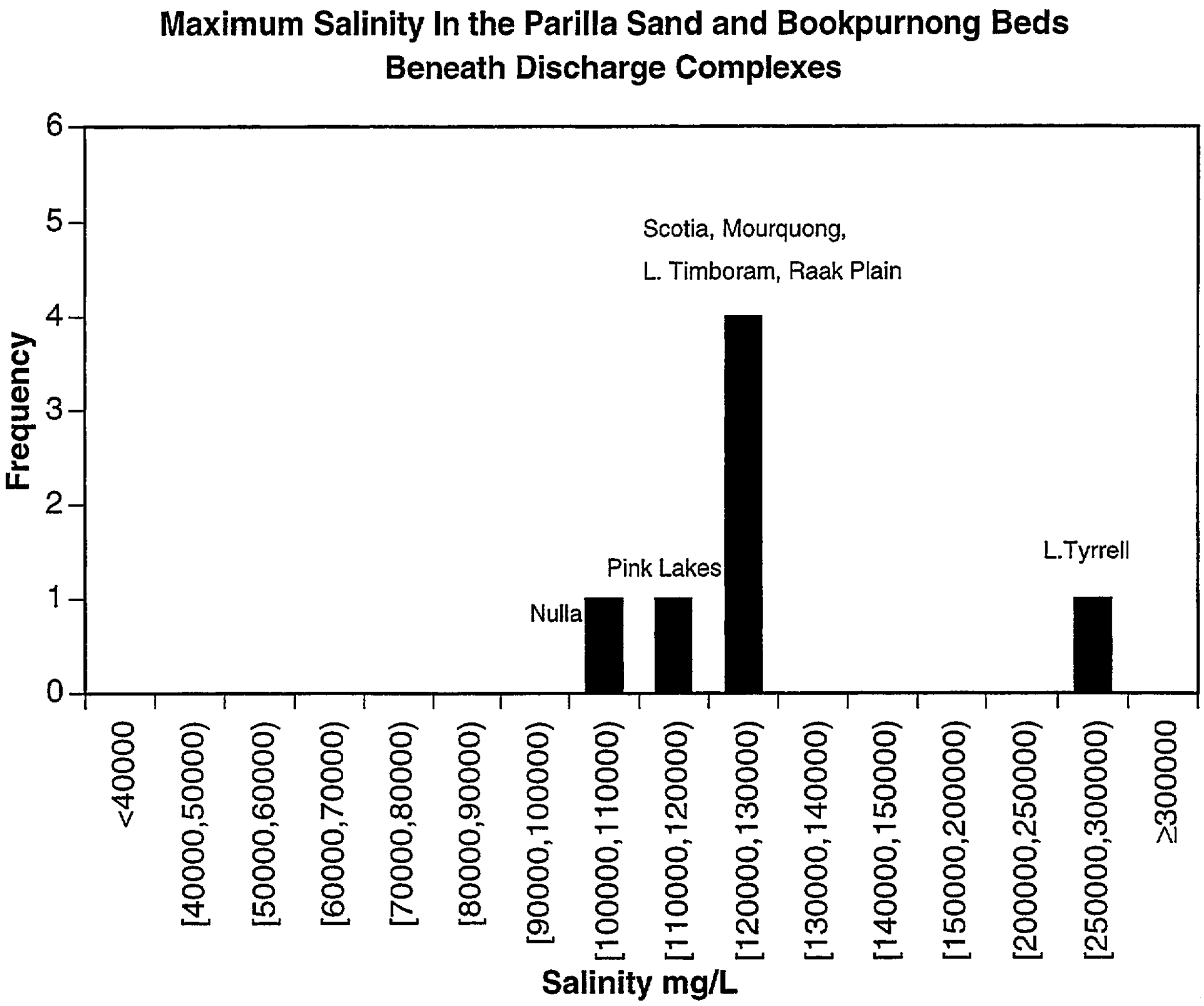


Figure 37. Maximum salinity encountered by moderate to extensive drilling of the Parilla Sand and Bookpurnong Beds underlying groundwater discharge complexes in the Murray Basin.

for reflux to commence. If this hypothesis is correct, then the much higher salinity of the reflux brines beneath Lake Tyrrell (Table 5) could result if the reflux event occurred while the underlying groundwaters were of considerably higher salinity than normal. These higher salinity groundwaters could have formed in nearby Lake Timboram and moved laterally underneath Lake Tyrrell. Under these circumstances, the brine in the discharge complex would have to reach a much higher salinity before the critical density ratio of the discharge complex brine to the underlying groundwaters was exceeded.

In addition to the original brines of salinity 125,000, there exists a range of groundwaters whose salinity is sufficiently high to make it likely that they contain a significant proportion of reflux brine. To further interpret the geochemistry of the groundwaters, brines of salinity 100,000 to 130,000 mg/L (Table 5) are considered to be similar in composition to the original reflux brines, and those of salinity 50,000 to 100,000 mg/L are treated as mixtures.

Major Ion Geochemistry of Groundwaters in the Parilla Sand and Bookpurnong Beds

The iso-salinity contours in the Parilla Sand/Bookpurnong Beds underlying the Mourquong discharge complex can be interpreted as a relatively simple system involving a single area of diffusion-influenced water in the upper parts of the Parilla Sand and a pod of brine in the lower Parilla Sand/Bookpurnong Beds (Figure 38). However the model of successive, alternating diffusion reflux events (Figure 36) indicates that each of these components should contain the products of several reflux/diffusion events. These different events they may be differentiated to some extent using Mg/Br, Na/Br, Na/Cl and SO_4/Br ratios.

Figure 39 shows the relationships of Mg/Br to salinity or elevation. The patterns are similar for the Na/Br ratios. The Mg/Br versus salinity or elevation plot for site MEM-1 is representative and, to simplify the presentation, the latter plot is also shown in Figure 39. Site MEM-1 is near the centre of the discharge complex (Figure 3) and intercepts brine in both the Parilla Sand and the Bookpurnong Beds. The MEM-1 profiles show that the groundwaters in the Blanchetown Clay have significantly different Mg/Br ratios from the groundwaters in the upper Parilla Sand but there is a continuum across the boundary in the Na/Br versus elevation and the Mg/Br v salinity and the Na/Br v salinity profiles. On balance this is consistent with downwards diffusion of salt from the Blanchetown Clay into the top of the Parilla Sand.

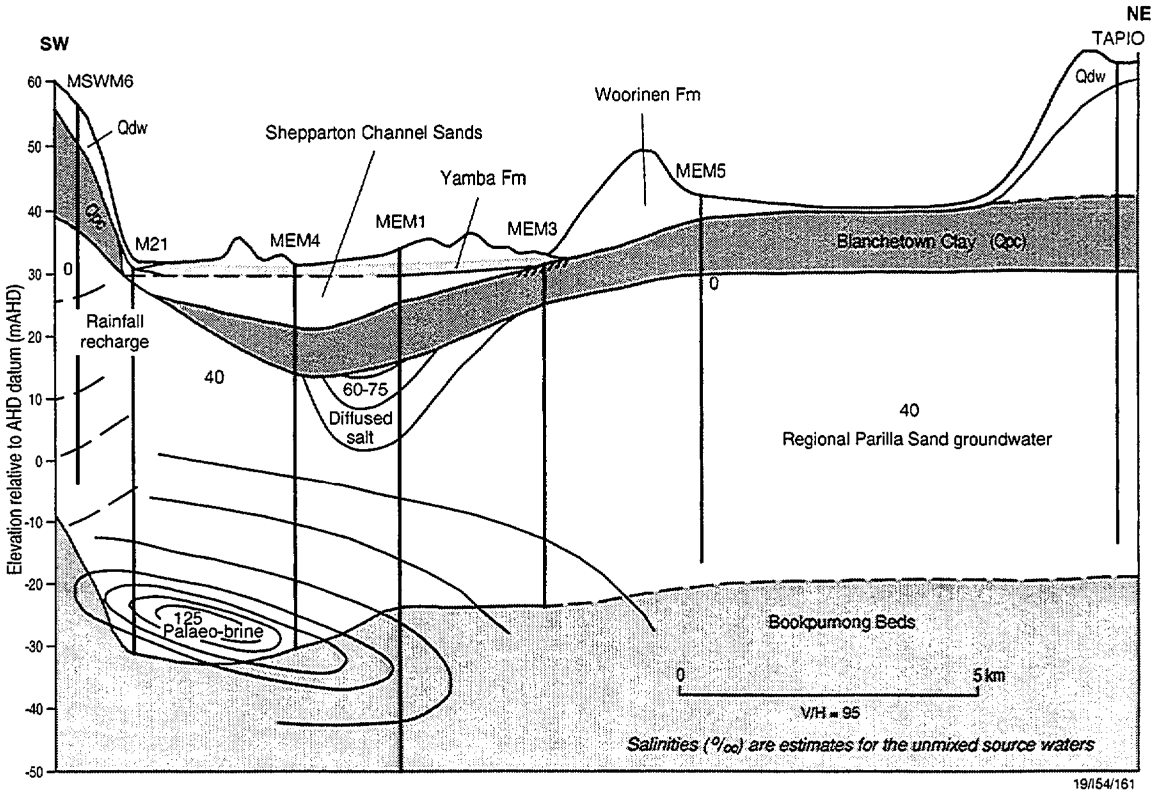
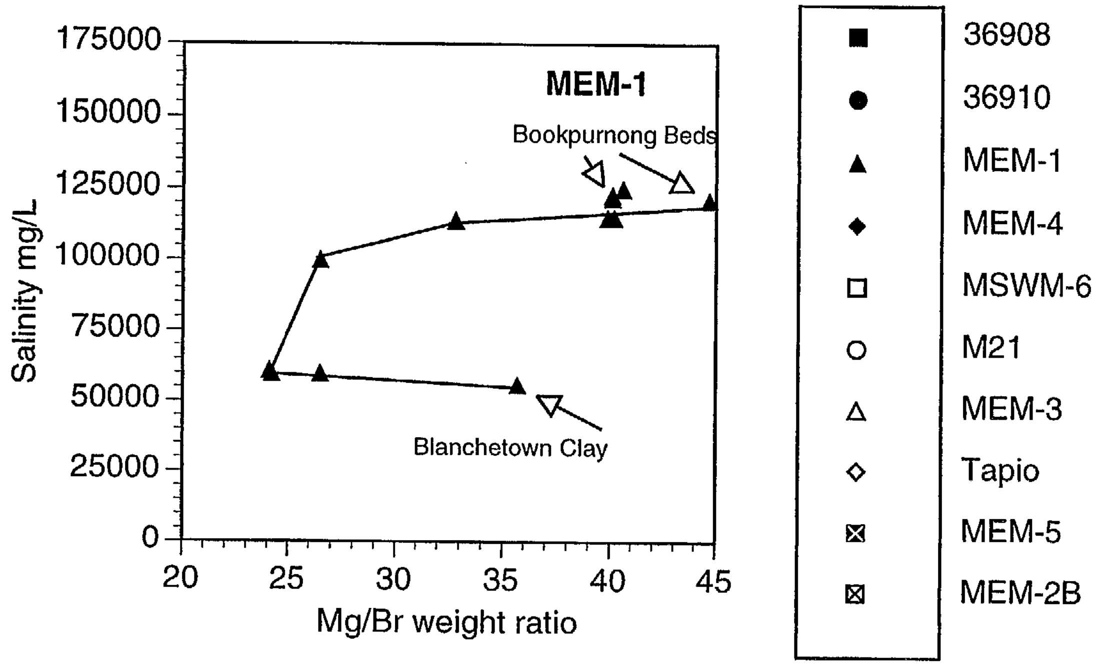
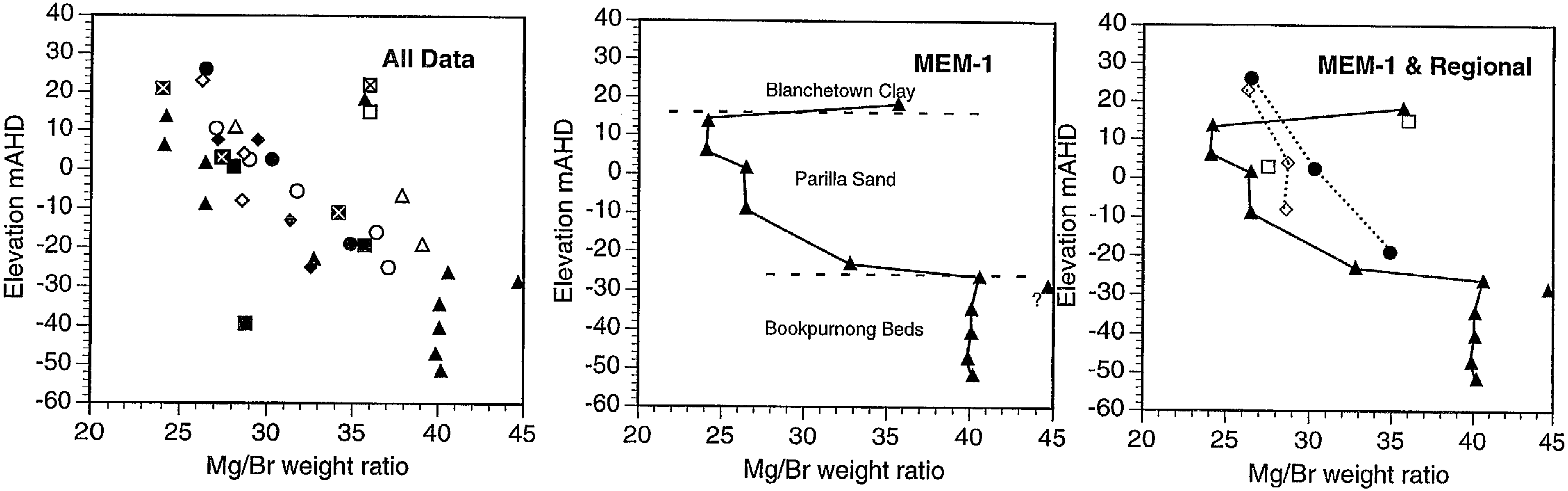


Figure 38. A simplified interpretation of the iso-salinity contours beneath and around the Mourquong discharge complex.

MOURQUONG

Figure 39. Relationships of Mg/Br ratios of Mourquong groundwaters to salinity or elevation.





In the Bookpurnong Beds at MEM-1, with the exception of one point, the Mg/Br (40) and Na/Br (250) ratios of the brines are almost constant, which points to the presence of one brine at this location. However, different ratios (Mg/Br, 29; Na/Br, 195) occur in a brine in the Bookpurnong Beds at location 36908, which is on the western margin of the discharge complex (Figure 4). i.e. there are at least two chemically different brines in the Bookpurnong Beds beneath the discharge complex. There also appears to be at least two chemically different brines in the Parilla Sand. At the base of the Parilla Sand at MEM-1 and MEM-4 there is a brine of slightly lower salinity (110,000 to 120,00 c/f 125,000 mg/L) but significantly different Mg/Br (33 and 33 c/f 40) and Na/Br (200 and 215 c/f 250) ratios to those in the underlying Bookpurnong Beds. At M21, the brine at the base of the Parilla Sand (salinity 125,00 mg/L) has Mg/Br and Na/Br ratios close to those of the MEM-1 brine in the Bookpurnong Beds.

As a first approximation, therefore, we can identify three different brines:
(1) the brine in the Bookpurnong beds at MEM-1 and at the base of the Parilla Sand at M21;
(2) the brine in the Bookpurnong Beds beneath the western margin (at 36908); and
(3) the brine at the base of the Parilla Sand at MEM-1 and MEM-4.

This grouping of three different types of brine is also evident on Na/Br v Mg/Br plots (Figure 40). On this plot, the data lie in an approximately triangular field, with the three points of the triangle formed by: (1) the brine in the Bookpurnong Beds at MEM-1 (Mg/Br, 40; Na/Br, 250); (2) the saline groundwaters in the upper Parilla Sand at MEM-1 (Mg/Br, 24; Na/Br, 220); and (3) the Parilla Sand groundwater remote from the discharge complex at Tapio (Mg/Br, 26; Na/Br, 180). This arrangement of data points suggests a three component mixing system. In this mixing system the similarity between the brines in the Bookpurnong Beds at MEM-1 and those in the lower Parilla Sand at M21 is evident, as is the difference between these brines and those in the lower Parilla Sand at MEM-1.

Comparison of Major Ion Geochemistry of the Blanchetown Clay and Parilla Sand Groundwaters at Mourquong

The groundwaters in the Blanchetown Clay at two locations are compared with those at the top of the Parilla Sand along a transect from the middle of the active salina, through the salina to the centre of the discharge complex (Figure 41). There is a strong similarity between the Mg/Br and Cl/Br ratios of the Blanchetown Clay groundwaters and those in the top of the Parilla Sand beneath the active area. The grouping is not as close for

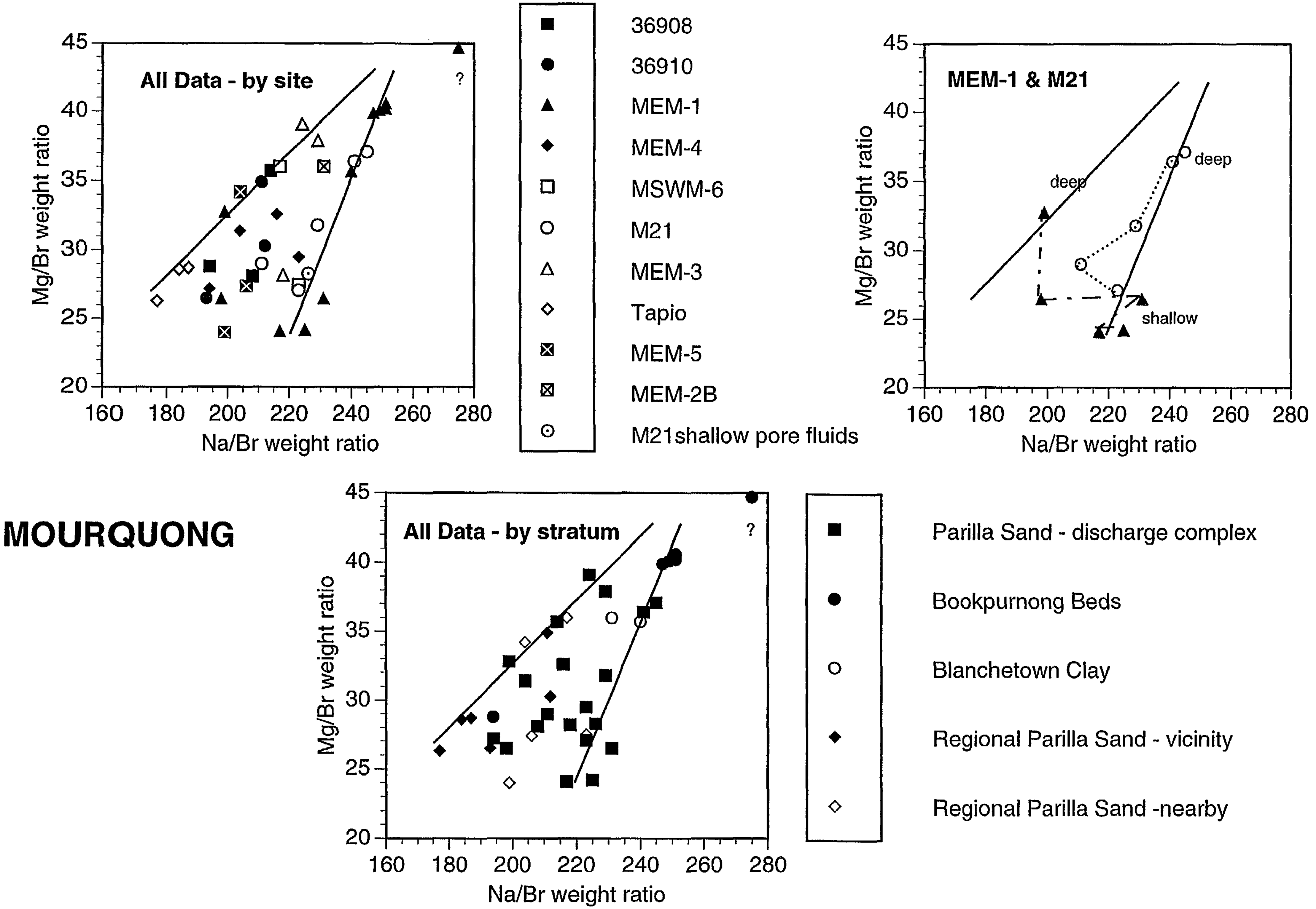


Figure 40. Relationships Na/Br to Mg/Br ratios for the Mourquong groundwaters.

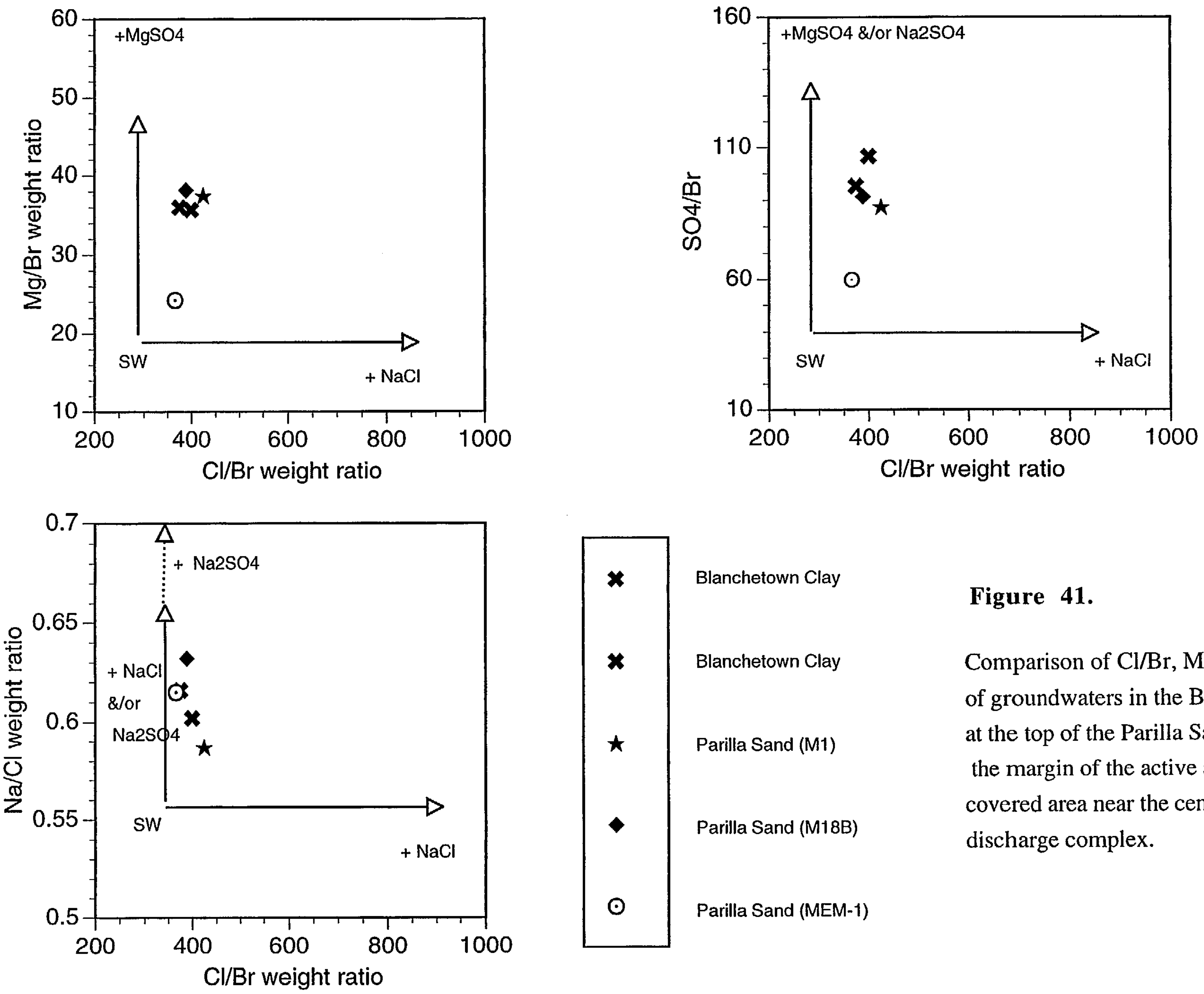


Figure 41.

Comparison of Cl/Br, Mg/Br, SO_4/Br and Na/Cl ratios of groundwaters in the Blanchetown Clay with those at the top of the Parilla Sand beneath the active area (M1), the margin of the active area (M18B) and in the lunette-covered area near the centre (MEM-1) of the Mourquong discharge complex.

the SO_4/Br ratios and there is a significant spread for the Na/Cl ratios. Together this data suggests that the amount of added $MgSO_4$ and NaCl is similar but there is some variation in the amount of added Na_2SO_4. The data are consistent with the downwards diffusion of salt from the active salina of the discharge complex through the Blanchetown Clay and into the top of the Parilla Sand.

Away from the active salina, at MEM-1 near the centre of the discharge complex, the groundwater at the top of the Parilla Sand is much more seawater-like than those in the Blanchetown Clay. Downwards diffusion of salt may have occurred in the centre of the discharge complex when it was active but the geochemical signature of these diffused salts has since been partly modified.

The brines which occur deeper in the Parilla Sand beneath the discharge complex also show the pattern of relatively little variation in Mg/Br ratios compared to SO_4/Br and Na/Cl (Figure 42). i.e. a major part of the chemical variation between the various generations of Parilla Sand brines is probably in the amount of added Na_2SO_4.

Comparison of Major Ion Geochemistry of Mourquong with Other Murray Basin Groundwater Discharge Complexes

The Mourquong groundwaters are similar in major-ion composition to a number of other groundwater discharge complexes in the Murray Basin (Figure 43), with the exception of the Scotia discharge complex, which has a much higher proportion of redissolved salts.

Scotia is a sand-based discharge complex in which the potential area of brine reflux would be much larger than those in which the substrate is mainly Blanchetown Clay. Consequently, reflux rather than diffusion could be the mechanism of salt movement from the topographically lower areas of the discharge complex. These are the sites where the brines most effected by redissolved salts accumulate.

Identification and Age of Brine Reflux Events Using ^{36}Cl data.

^{36}Cl data for the Mourquong discharge complex

The ^{36}Cl data for the discharge complex is in Table 4. Figure 44 contains a distribution analysis of ^{36}Cl/Cl values and plots of ^{36}Cl/Cl v salinity, Mg/Br or Na/Br.

The distribution analysis shows a large peak in the range 24 to 29 x 10^{-15} and two minor peaks in the ranges 32 to 37 x 10^{-15} and 16 to 21 x 10^{-15}. On the ^{36}Cl/Cl v salinity

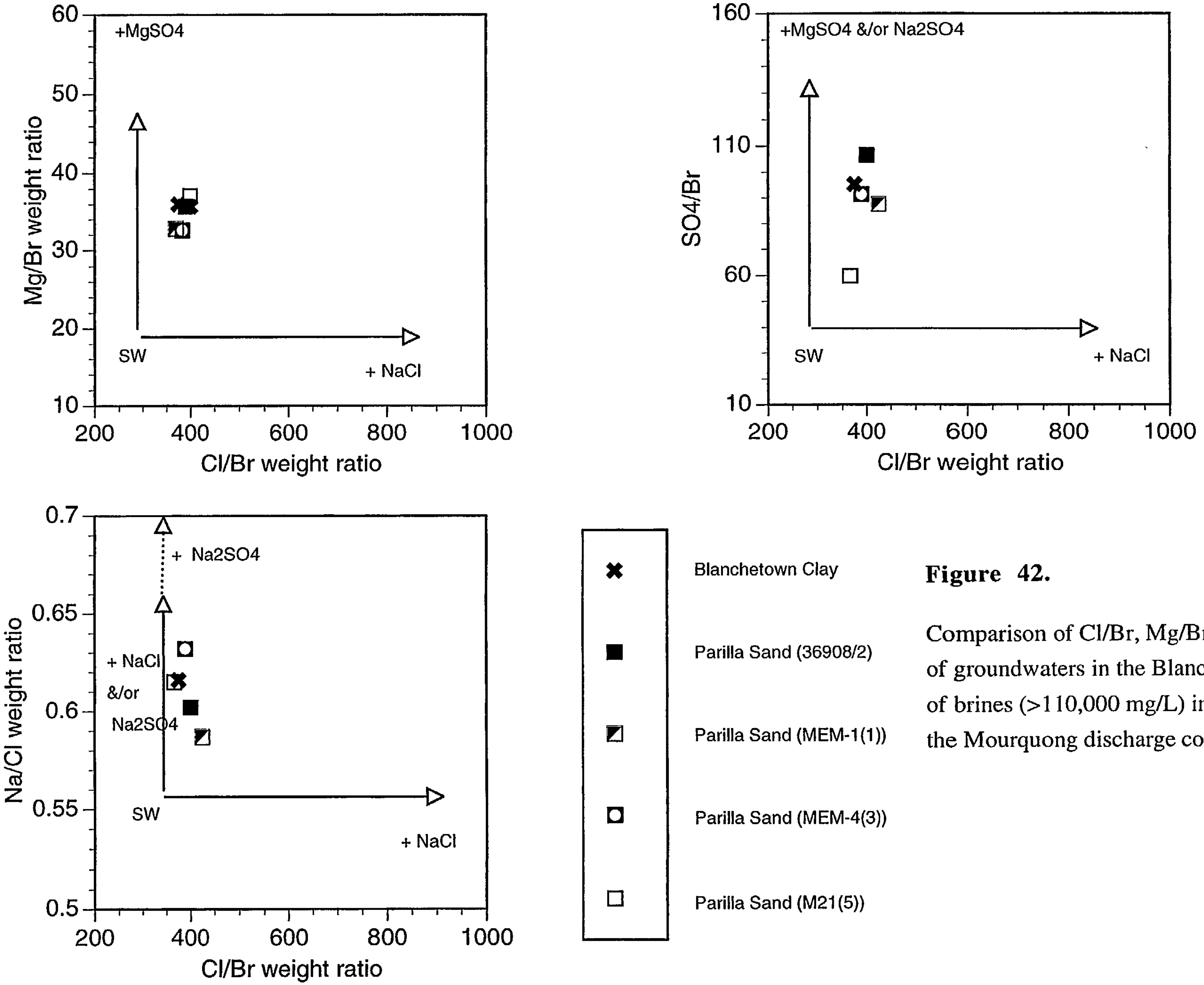


Figure 42.

Comparison of Cl/Br, Mg/Br, SO_4/Br and Na/Cl ratios of groundwaters in the Blanchetown Clay with those of brines (>110,000 mg/L) in the Parilla Sand beneath the Mourquong discharge complex.

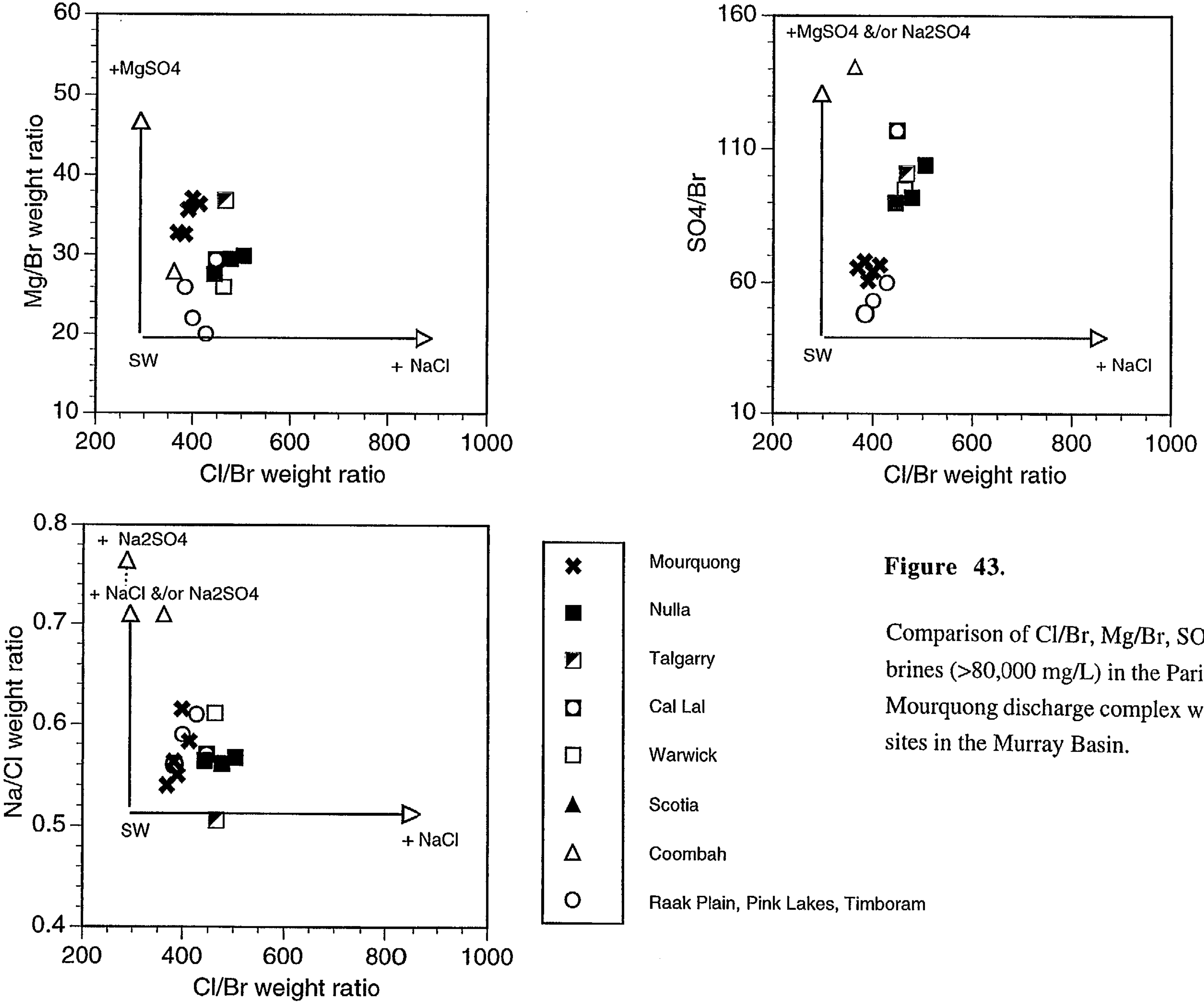


Figure 43.

Comparison of Cl/Br, Mg/Br, SO_4/Br and Na/Cl ratios of brines (>80,000 mg/L) in the Parilla Sand beneath the Mourquong discharge complex with those from other sites in the Murray Basin.

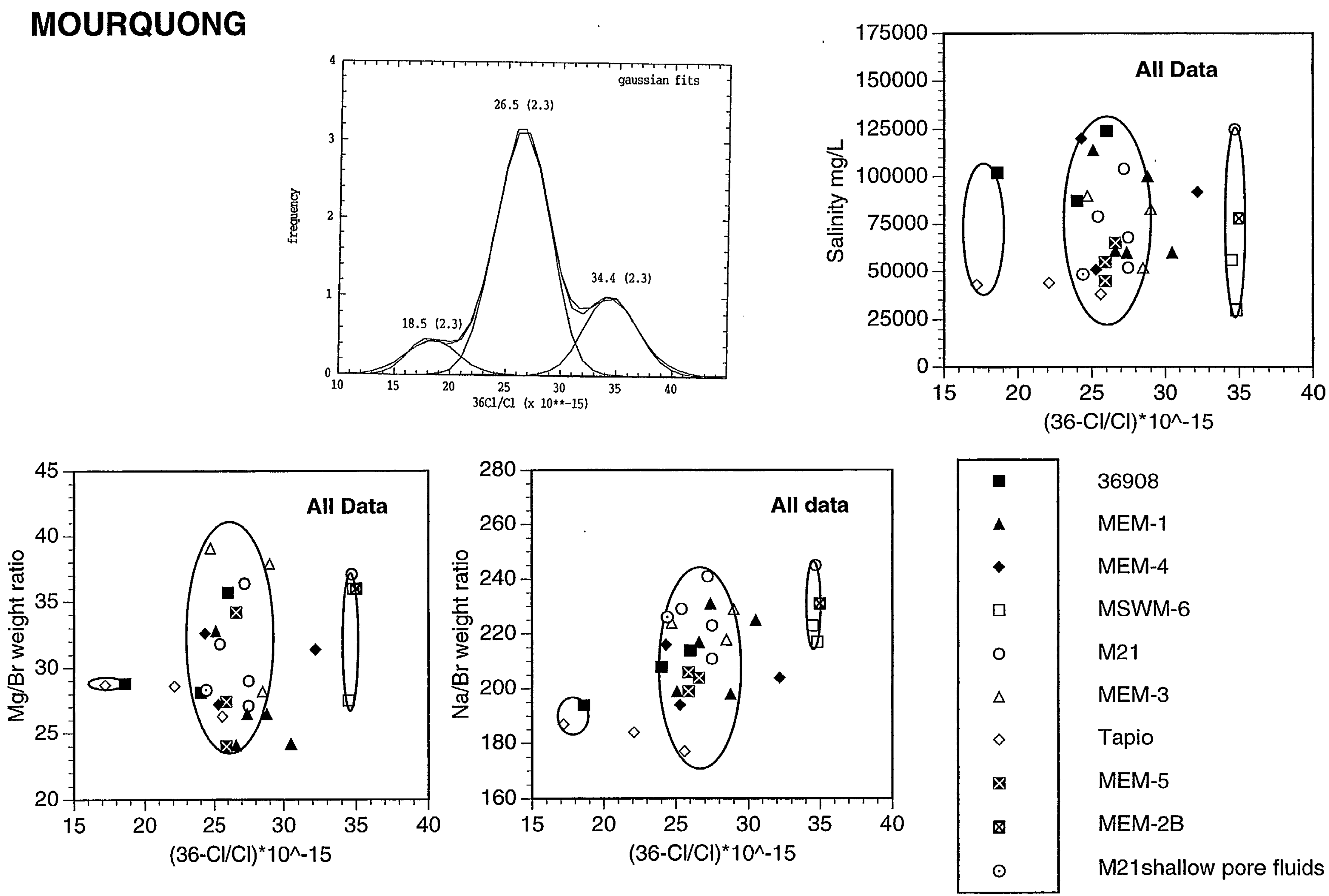


Figure 44. ^{36}Cl/Cl data for the Mourquong discharge complex and environs.

plot it can be seen that each of these groups contains groundwaters of a wide range of salinities. i.e. there are three brines of differing ^{36}Cl/Cl ratios beneath the Mourquong discharge complex. The three brines are (1) the brine near the base of the Parilla Sand at M21, which has a ratio of 35 x 10^{-15}; (2) the brine at the base of the Parilla Sand at DWR-36908, MEM-4, and MEM-1, the three samples of which have similar ^{36}Cl/Cl ratios of 25 x 10^{-15} and similar Mg/Br and Na/Br ratios of 35 and 210, respectively; and (3) the brine in the Bookpurnong Beds at DWR 36908, which has a ratio of 18 x 10^{-15}.

Plotted as iso-^{36}Cl/Cl contours (Figure 45), the data show clearly the presence of the highest ratios (29 to 35) in three places: (1) in the Blanchetown Clay beneath the discharge complex; (2) beneath the area of the western dune which borders the Blanchetown Clay-free part of the discharge complex; and (3) at the base of the Parilla Sand at M21. The presence of the highest ratio waters beneath the dune next to the Blanchetown Clay-free area is consistent with this being an area of high recharge by rainfall containing contemporary aerosols. The juxtaposition of lower ratio groundwaters overlying a higher ratio brine at M21 is consistent rapid reflux of brine to the base of the aquifer followed by diffusion-dominated conditions and the return of the older shallow Parilla Sand groundwaters to the area of reflux. The brine in the lower Parilla Sand at MEM-4, MEM-1 and MEM-3 has an almost constant ratio of 25. Unfortunately, no data is available for the brines in the Bookpurnong Beds at MEM-1, which obscures the spatial relationship of the ratio 35 x 10^{-15} brine to the ratio 25 x 10^{-15} brine.

Another feature of note in Figure 45 is the slightly higher ratio (31 x 10^{-15}) at the top of the Parilla Sand at MEM-1, which is consistent with downwards diffusion of chloride from the Blanchetown Clay. Also, the lowest ratio in this section occurs remote from the discharge complex at Tapio, and occurs at intermediate depths. This is consistent with a scenario in which the remains of older events are best preserved at low recharge locations remote from the discharge complexes.

Conditions Necessary to Date Reflux Brines from ^{36}Cl data

To determine the age of brine reflux events from ^{36}Cl data, two basic conditions must be met.

(1) The ^{36}Cl/Cl ratio of the brine at the time of reflux must be known. This ratio may or may not be the same as that of the contemporary aerosol input.

(2) During its residence time in the aquifer the reflux brine must not have mixed with saline groundwaters of significantly different ^{36}Cl/Cl ratio.

A priori, it seems that special conditions would be necessary for the above requirements to be fulfilled. For example, it is known from the Scotia discharge complex (Ferguson et al., 1995) that presently active areas which do not border the maximum

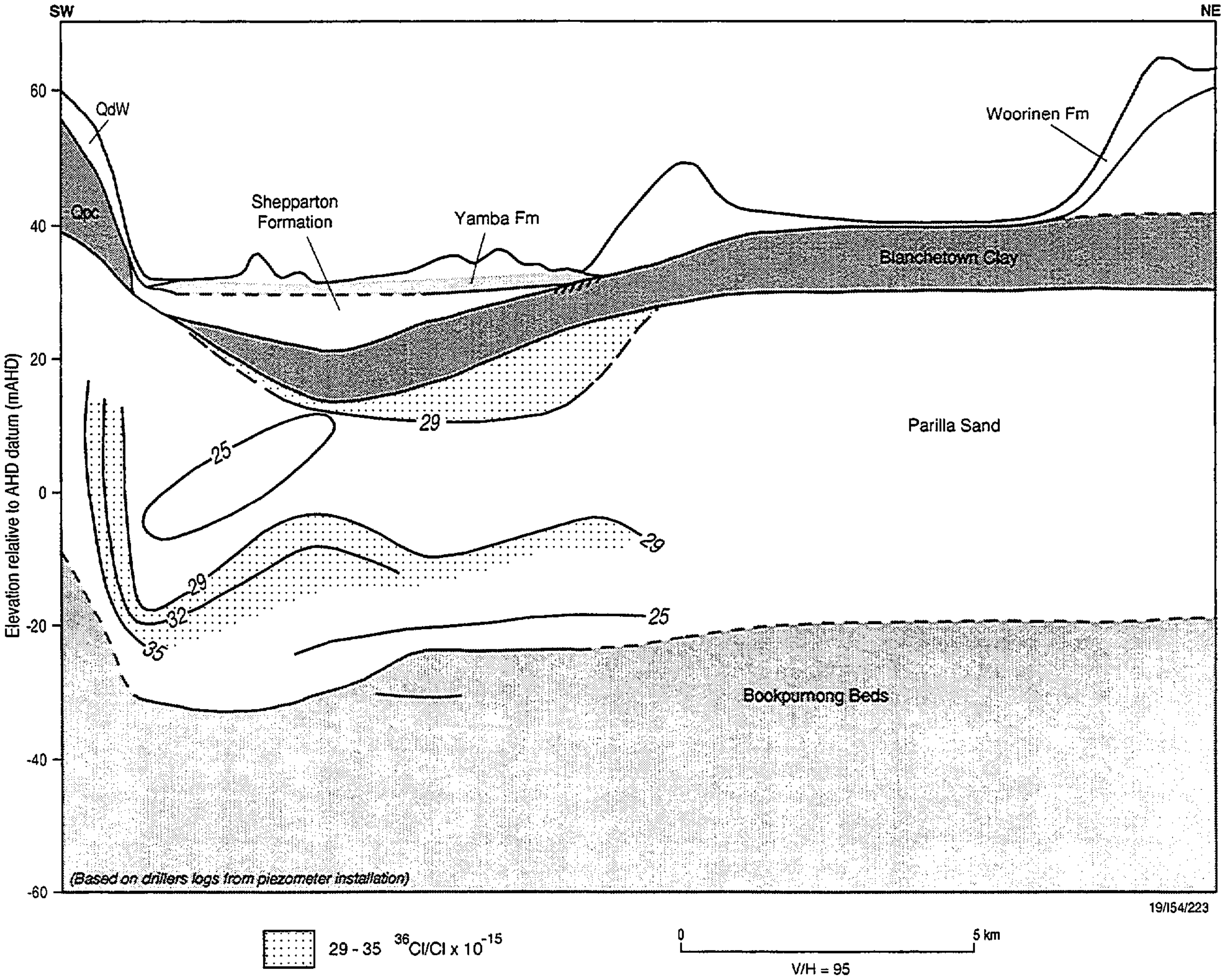


Figure 45. Iso-salinity contours of ^{36}Cl/Cl data for the Mourquong discharge complex and environs.

(former) extent of the discharge complex can be sourced by mixtures of incoming shallow Parilla Sand groundwater mixed with older brine from beneath the discharge complex. On the other hand, if the active area is sited at the margin of the discharge complex then, as indicated by the Scotia data, the incoming groundwater is likely to be mainly shallow Parilla Sand groundwater from the discharge complex margins. Brine reflux events are likely to occur nearer lake full than lake empty conditions, when the topographically slightly higher Blanchetown Clay-free areas will be inundated. Under these conditions, the main groundwater source may be from springs discharging at the margins of the Blanchetown Clay-free area. As discussed previously, these margins are likely to be sites of high rainfall/aerosol recharge and the shallow Parilla Sand groundwaters are likely to have contemporary ^{36}Cl/Cl ratios.

During the time the discharge complexes have been active, the aerosol input ^{36}Cl/Cl ratio to the source groundwaters for the Mourquong discharge complex could fluctuate considerably as the distance to the sea varied with changes in sea level. However, this effect would be minimised during wet (interglacial?) periods when sea levels may be higher and more consistent.

If the likely wetter conditions associated with brine reflux events produce source groundwaters with contemporary ^{36}Cl/Cl ratios, and these ratios do not change significantly with time, then the present-day ratios in the shallow Parilla Sand groundwaters beneath the dunes on the margins of the Blanchetown Clay-free area of the discharge complex can be taken as input ratios for the underlying reflux brines.

If data for the dunes bordering the Blanchetown Clay-free area of the discharge complex is not available, then an indication of the input function can be obtained from multi-piezometer nests at recharge sites in the vicinity where the Blanchetown Clay is thin or absent and the shallow groundwaters are influenced by recent recharge. In this case, the input ratio can be estimated by extrapolation of a plot of ^{36}Cl/Cl v Cl to very low chloride concentrations.

The condition of minimal mixing of the aquifer brines with other saline groundwaters is favoured by the predicted rapid descent of the reflux brines from the discharge complex into the Parilla Sand. These brines will be best preserved beneath the reflux area in the overlying discharge complex at the base of the Parilla Sand and in the underlying Bookpurnong Beds. For the Murray Basin groundwater discharge complexes a salinity value close to 125,000 mg/L is an indicator that the brine has not mixed significantly with the lower salinity regional Parilla Sand groundwaters.

Input ratios for the Mourquong, Nulla and Scotia Discharge Complexes

The estimated input ratios for the Mourquong, Nulla and Scotia discharge complexes are shown in Table 6. The Mourquong input ratio is that beneath the dune at the margin of the Blanchetown Clay-free area. The Nulla input ratio is estimated by extrapolation of data from piezometer nests located in a dunefield at Coolamon, which is located to the north-east of the discharge complex (Figure 46). At Scotia the Blanchetown Clay is absent and the input ratio is taken as that in the Parilla Sand beneath the dunefield at the northern margin of the discharge complex.

Figure 47 shows the relationships of: (1) Murray Basin-wide trends in ^{36}Cl/Cl ratios, as estimated from shallow groundwaters (Kellett *et al.*, 1992); (2) calculated ratios based on distance from the sea (Davie *et al.*, 1989); and (3) the estimated values for the discharge complexes and two values for the unconfined Parilla Sand aquifer near the basin margin to the north of the Scotia discharge complex. The two most northerly samples plot close to the calculated values whereas the others plot below this line and are close to the regional trend lines. Kellett *et al.* (1992) have ascribed the lower input values near the centre of the basin to atmospheric recycling of older chloride from the discharge complexes. The credibility of the input ratios assigned to the discharge complexes is enhanced by the correspondence between these ratios and the regional trends derived from basin-wide measurements on shallow groundwaters.

^{36}Cl Ages of the Mourquong, Nulla and Scotia Reflux Brines

The calculated ages of the Mourquong, Nulla and Scotia reflux brines are presented in Table 6.

The most noteworthy feature is that, despite the special circumstances needed for ^{36}Cl ages to be meaningful, there is reasonable agreement between the ages of the two older reflux events at Mourquong (146 ka and 290 ka) and the two identifiable events at Nulla (125-175 ka and 240-290 ka).

There is evidence of reflux events younger than about 150 ka at both Mourquong and Scotia. At Mourquong, the younger event has a ^{36}Cl/Cl ratio indistinguishable from that of the input value, which translates to ≤ 50 ka when the uncertainties in the measurements are taken into account.

In the Scotia discharge complex the Blanchetown Clay is absent and the lacustrine deposits are laminated sands and clays, with a high proportion of sand in some lakes. There are indications that brine reflux may be occurring at present in some of the topographically lower, sandier lakes in the complex. Two samples of shallow brines in the active lakes had ^{36}Cl/Cl ratios indistinguishable from that of the input value. Deeper in the Parilla Sand beneath the discharge complex a brine of salinity about 125,000 mg/L is

Table 6. Ages of Murray Basin Groundwater Brines Calculated from ^{36}Cl Data

Location	*Description*	*Salinity (mg/L)*	*^{36}Cl/Cl *10^{-15}*		*Age (ka)*[a]
			Input	*Brine*	
Mourquong	1 sample; Bookpurnong Beds	103,000	35[b]	18 (3)	290 (70)
	4 samples; base of Parilla Sand	90,000-120,000	35[b]	25 (2)	146 (25)
	1 sample; base of Parilla Sand	125,000	35[b]	35 (4)	≤ 50
Scotia	1 sample; Parilla Sand	125,000	70[b]	57 (4)	89 (30)
Nulla	1 sample; base of Parilla Sand	106,000	40-45[c]	23 (3)	240 - 290
	1 sample; base of Parilla Sand	98,000	40-45[c]	30 (3)	125 - 175

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[a] Calculated from the formula: Age = (301,000/ln2) x ln(Initial ^{36}Cl/Cl/Final ^{36}Cl/Cl). [b] Measured values from near the discharge complex.

[c] Calculated by extrapolating piezometer nest data to low chloride values; spread due to uncertainty in the extrapolation.

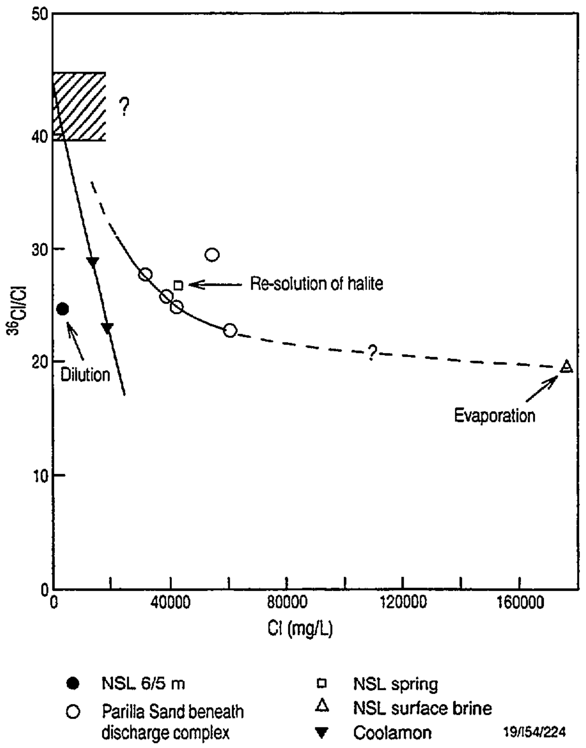

Figure 46. Estimation of ^{36}Cl/Cl input value for the Nulla discharge complex.

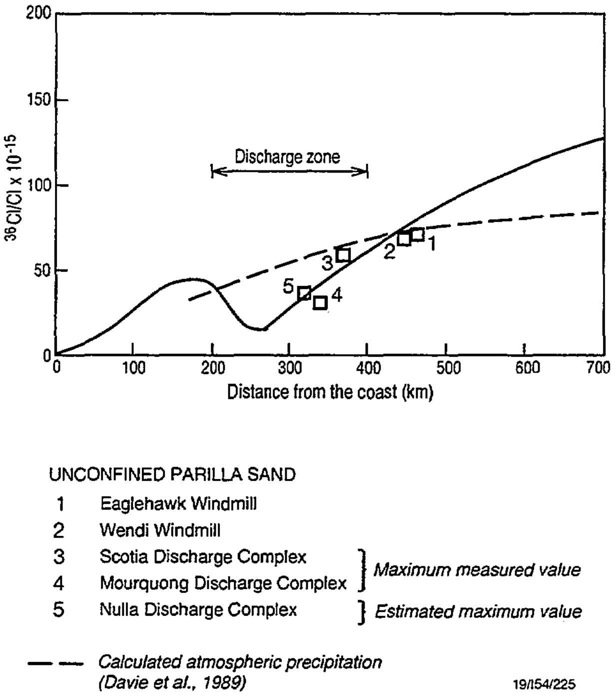

Figure 47. Relationship of Murray Basin regional trends in ^{36}Cl/Cl input values estimated from shallow groundwaters to those for discharge complexes and for two sites in the Parilla Sand aquifer near the northern margin of the basin.

widespread. This brine has an age of 89 ka. There is currently no other evidence which might help substantiate this date but reflux should occur more easily and therefore reflux events be more frequent in sandier discharge complexes.

Comparison of ^{36}Cl Ages of Reflux Brines With Other Paleoclimatic Information on the Murray Basin

In Figure 48 the ^{36}Cl Ages of the reflux brines are compared to the wet interglacial and arid glacial patterns derived from the deuterium content of the Vostok ice cores (Jouzel et al., 1987; Lorius et al., 1985), thermoluminescence dates of lithostratigraphic units in the Nulla discharge complex (B.Radke, unpublished results), and thermoluminescence dates of fluvial sedimentation in the Riverine Plain (Page and Nanson, 1996). The 89 ka date from the Scotia discharge complex falls within the 73 to 106 ka interglacial period indicated by the deuterium data and is within the Coleambally phase of paleo channel activity in the Riverine Plain. The later of the Mourquong/Nulla reflux events (146/125-175 ka) occurs close to the major glacial to interglacial transition which the deuterium data indicates was centred about 140 ka. The data of this reflux event is consistent with the Nulla thermoluminescence data in the sense that it occurs after a deflation event dated at 170 ka. The earlier of the Mourquong/Nulla reflux events (240-290 ka) is beyond the range of the deuterium data. It probably fits between two deflation events (second undated) inferred from the lithostratigraphy of Nulla, although this period is thought to be generally dry.

CONCLUSIONS

- The hydrodynamics of the Mourquong discharge complex are strongly influenced by two major lithostratigraphic features: (1) the widespread intercalation of fluvial and aeolian sands with the Blanchetown Clay and overlying lacustrine Yamba Formation. and; (2) the erosional window in the Blanchetown Clay, which may cover the entire southern end of the depression.
- The intercalated sands have a high lateral hydraulic conductivity which allows the water table in the discharge complex to respond relatively rapidly to changes in the regional water table. These changes are reflected in the relatively thick and well-resolved lacustrine Yamba Formation sequence.
- The erosional window is an area of high vertical and lateral hydraulic conductivity which, during periods of high water table, could act as a focus for the discharge of regional groundwater and, as the water table drops, for the reflux of brines to the underlying Parilla Sand aquifer.

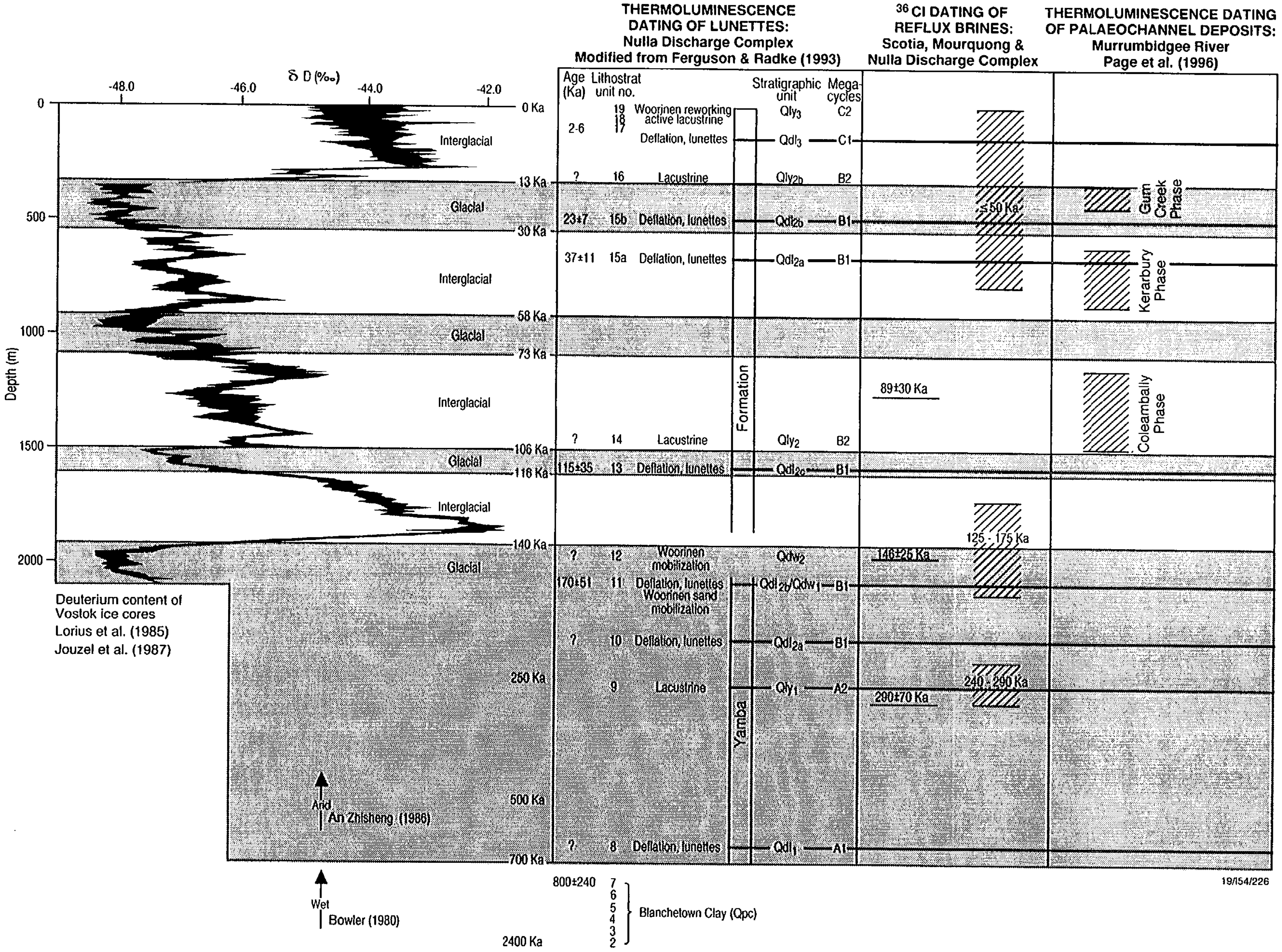

Figure 48. Relationship of ^{36}Cl/Cl dates of reflux brines to other paleoclimate data.

- The hypothesis that paleo-brines which occur beneath the discharge complex refluxed through the erosional window rather than through cracks in the Blanchetown Clay is supported by their spatial distribution in the underlying aquifer.
- Theoretical predictions that high permeability favours advective reflux and low permeability favours diffusion are supported by the co-incidence of high vertical permeability and reflux brines, and by evidence of relict diffusion profiles in the Blanchetown Clay.
- Brines form in the discharge complex by a combination of evaporation of incoming Parilla Sand groundwater and saline water formed by rainfall-dissolution of salt efflorescences formed at the margins. The latter process selectively concentrates Mg- and Na-salts in the brines.
- Major-ion and ^{36}Cl data indicate the presence of at least three paleo-brines beneath the discharge complex.
- ^{36}Cl dating of these paleo-brines relies on the assumptions that they are not significantly mixed with other groundwaters and that the input values can be estimated. The resultant dates of brine reflux are consistent with thermoluminescence dating of deflation events from other discharge complexes but must be regarded with caution.
- Compared to other discharge complexes in the Murray Basin, Mourquong is intermediate between almost completely clay-enclosed salt lakes, such as Nulla Spring Lake, and mainly sand-based discharge complexes, such as that at Scotia, which lie beyond the periphery of the Blanchetown Clay. The Mourquong combination of significant permeability and a mainly Blanchetown Clay substrate favours a hydrodynamic regime which is more than usually responsive to changes in water table and consequent changes from diffusion- to reflux-dominated conditions. The strong fluvial influence of the nearby Murray River during its lithostratigraphic evolution is a major contributing factor to this responsiveness.

Part 2. THE MOURQUONG SALINE WATER DISPOSAL BASIN

INTRODUCTION

Lock 11 on the Murray River is sited within a highly permeable Parilla Sand substrate and the consequent raising of the local groundwater table has initiated or dramatically increased saline discharge from the Parilla aquifer further downstream. The Buronga Interception Scheme intercepts and removes saline groundwater discharge from the Parilla Sand from the vicinity of, and downstream of the lock.

This groundwater with an average salinity of 30,000 mg/l is pumped to an outfall at the southern margin of Mourquong swamp. The effluent flows northward along a partly submerged channel cut through abandoned gypsum pits, to a standing lake. At the standard operating level of about 31.7m AHD, the lake comprises the narrow southern extension and a broad central-western area which occupies about the western 10% of the Mourquong depression. The southern region has been significantly modified by numerous pits from former gypsum mining, and a subsequent channel which provides a direct route from the outfall at the southern end of the depression, to the central-western shallow standing lake.

Prior to the disposal scheme, this lake was a natural salina.

STRATIGRAPHY

A detailed lithostratigraphy of the disposal basin and surrounds has been presented in Ferguson *et al.* (1994). Current stratigraphic interpretation of this sequence differs slightly from Ferguson *op.cit.* as a result of additional lithostratigraphic information on the eastern and southern margins. The reinterpreted stratigraphy is presented in Figures 16 to 23.

The disposal lake lies against the western margin of the complex, and presumed adjacent to the western flexure of the Cainozoic sequence over the Danyo Fault and up onto the Merbein Ridge. Over this western flexural margin of the trough, the sequence dips relatively steeply to the east into the Koorlong Trough and rises gently further east to create a structural as well as a topographic basin.

Rapid facies changes in the Blanchetown Clay across the flexure indicate the existing relief at the time of flooding of Lake Bungunnia. The basal sandy facies of the Blanchetown Clay, the Irymple Sand Member, is thicker and interdigitates laterally with the Blanchetown Clay on the western side (Figure 20). The thickness of the Irymple Sand thins and then thickens again towards the centre of the depression before thinning significantly out to the eastern margin (Figure 18). Blanchetown Clay also thickens dramatically into the basin centre but upper erosional surfaces from Shepparton channel formation and later, Yamba deflation, have created local irregularities within the depression. During the early stages of the salina, deflation and probably lake-margin erosion has cut a notch into the Blanchetown Clay on the western lake margin, significantly thinning the effective permeability barrier separating the salina from the horizontally-permeable Irymple Sand to the west (Figure 20).

Highly permeable sands of the Shepparton Formation infill erosional channels in the upper surface of the Blanchetown Clay which have been intercepted in MEM 2, MEM 1, and MEM 4. Over a topographic rise in this surface (M13) a thinner sequence of distinctively bedded sand-clay gradations is interpreted as overbank deposits of these channels. The Shepparton Formation has demonstrated distribution southwards (MEM 4) to the southwestern corner where well sorted sands directly overlie Parilla Sand in the erosional window of the Blanchetown Clay. Adjacent to this window, the bedded sand-clay facies has been intercepted in MSWM 2 and 3. Vibrocore drilling further north on the western side of the channel also intercepted only fine permeable sands. This limited stratigraphic control indicates that the Shepparton sands are most probably extensive across the southern portion of the depression and the northern erosional limit probably coincides with the southern margin of the main salina.

The floor of the salina is Yamba Formation, comprising three superimposed lacustrine units (Qly 3,4, &5), which overlie the Blanchetown Clay (as seen in M1, M18, Figure 20). These units are distinguished by the interlaying of thin sandier, aeolian deposits which represent a minor accumulation at the end of a deflation event. This sequence is stratiform, and can be correlated northwards to M14, beyond the top end of the lake, although there is some local facies complication in M15 and M16 where the sequence has dune-like characteristics on a slight ridge on the upper surface of the Blanchetown Clay. Adjacent to this ridge is an interpreted adjacent deposit of Shepparton Formation in M17 (Figure 21). This lake-margin configuration is comparable to that immediately east of the lake in the MWM - MEM transect (Figure 19).

PERMEABILITY and HYDRAULIC CONDUCTIVITY

The porosity of the sequence is predominantly interparticle porosity in sandier facies and intercrystalline porosity where displacive diagenetic gypsum has developed in muddier lithofacies. There is a lesser abundance of bioturbation and fracture porosity. The predominant types are by definition interconnected porosity types and create the permeability of the sediment. On this basis, the stratigraphic distribution of porosity can be approximated as permeability distribution.

Porosity distribution is presented for the west to east transect across the centre of the lake (MWM- MEM transect in Figure 49), the northern end of the lake (MNM transect in Figure 50). On the southern margin, radial porosity changes are indicated in MRT transect (Figure 51) and the tangential section to the margin, MSOM - M21 transect (Figure 52).

The aquifers of the system, the Parilla Sand and the channel sands of the Shepparton Formation, have very high relatively-isotropic permeabilities.

The distribution of porosity and permeability within the aquitards is most critical and is discussed in further detail..

Blanchetown Clay

The Blanchetown Clay has the lowest permeabilities in the sequence, but it does have variability stratigraphically and spatially. Spatially the unit is tighter directly under the disposal basin in the central and northern areas. Here thin bands and laminae of low (2-10%) to medium (10-20%) porosity occur within the upper and lower part of the aquitard. Eastwards, there is a pervasive moderate permeability over a large part of the sequence but a diminution is apparent at the inner margin (MEM 3) with thicker intervals that lack porosity towards the base and into the Irymple Sand. The higher porosity of the Blanchetown Clay in this eastern region is due to more abundant and thicker bands of diagenetic gypsum, with inter crystalline porosity, which may be genetically related to the overlying Shepparton sand aquifer. This is saline (>40,000 mg/l TDS) but may periodically

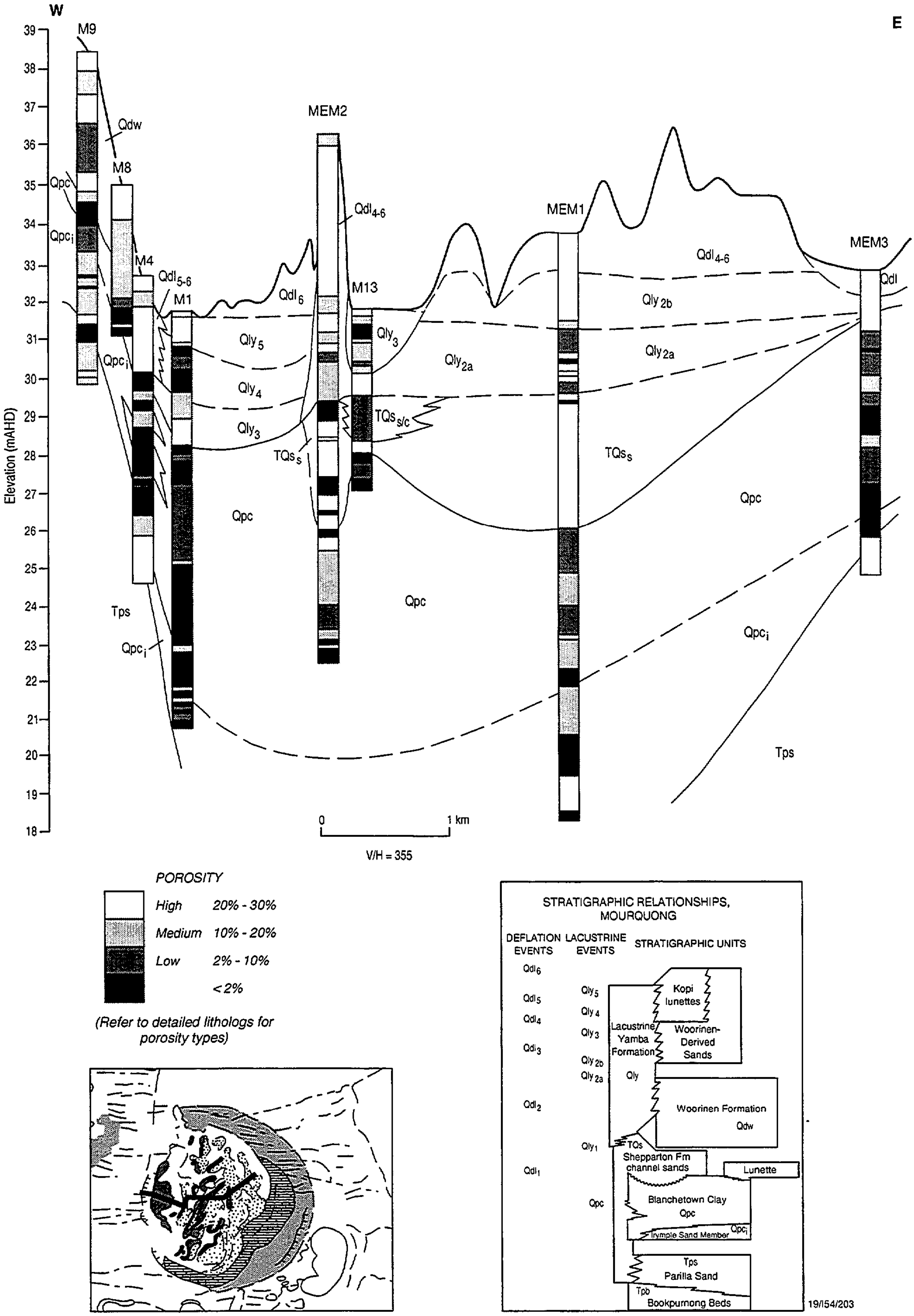

Figure 49. Porosity distribution in the central east-west (MWM-MEM) transect, Mourquong discharge complex

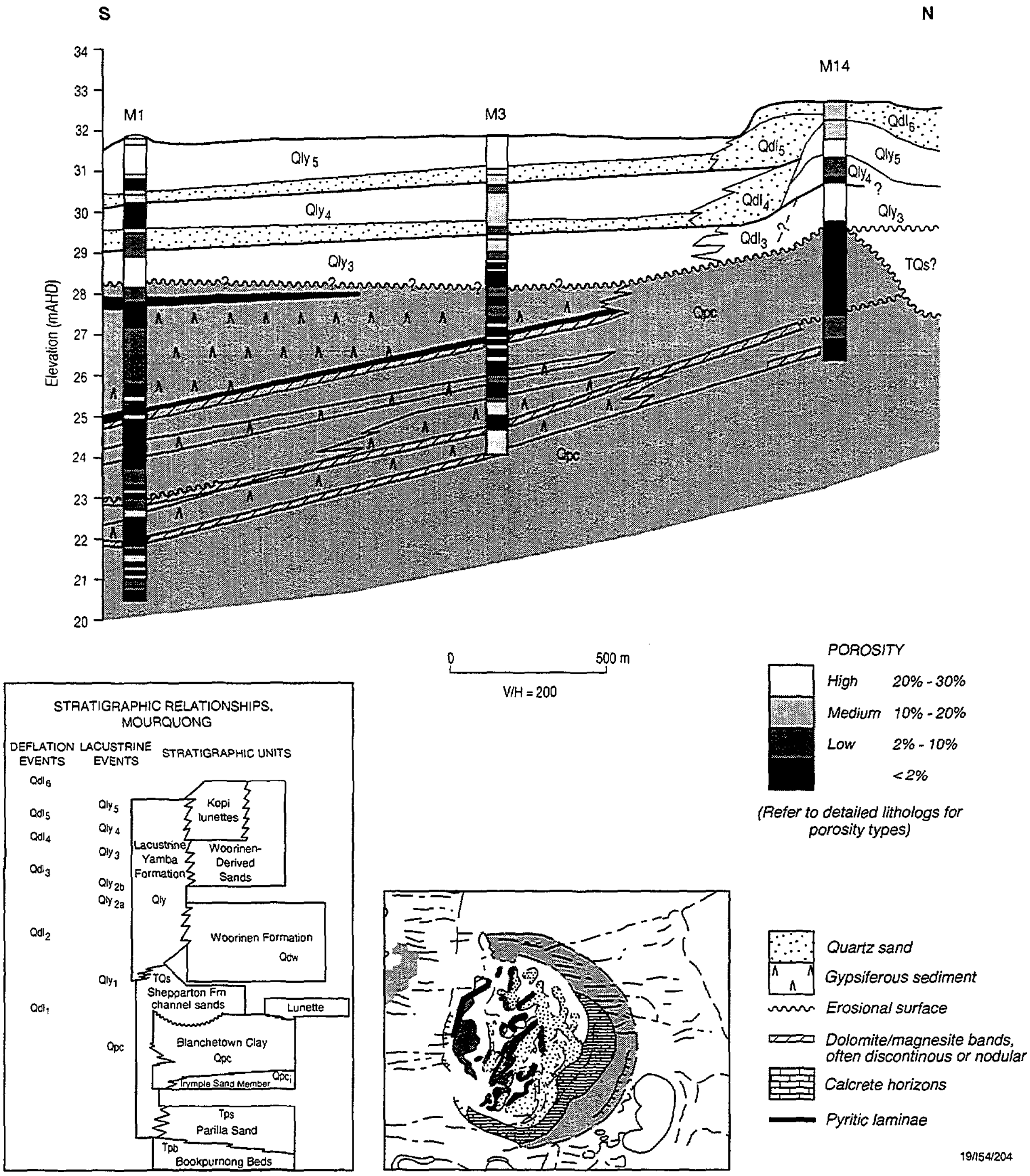

Figure 50. Porosity distribution in the northern (M1 - MNM) transect, Mourquong discharge complex.

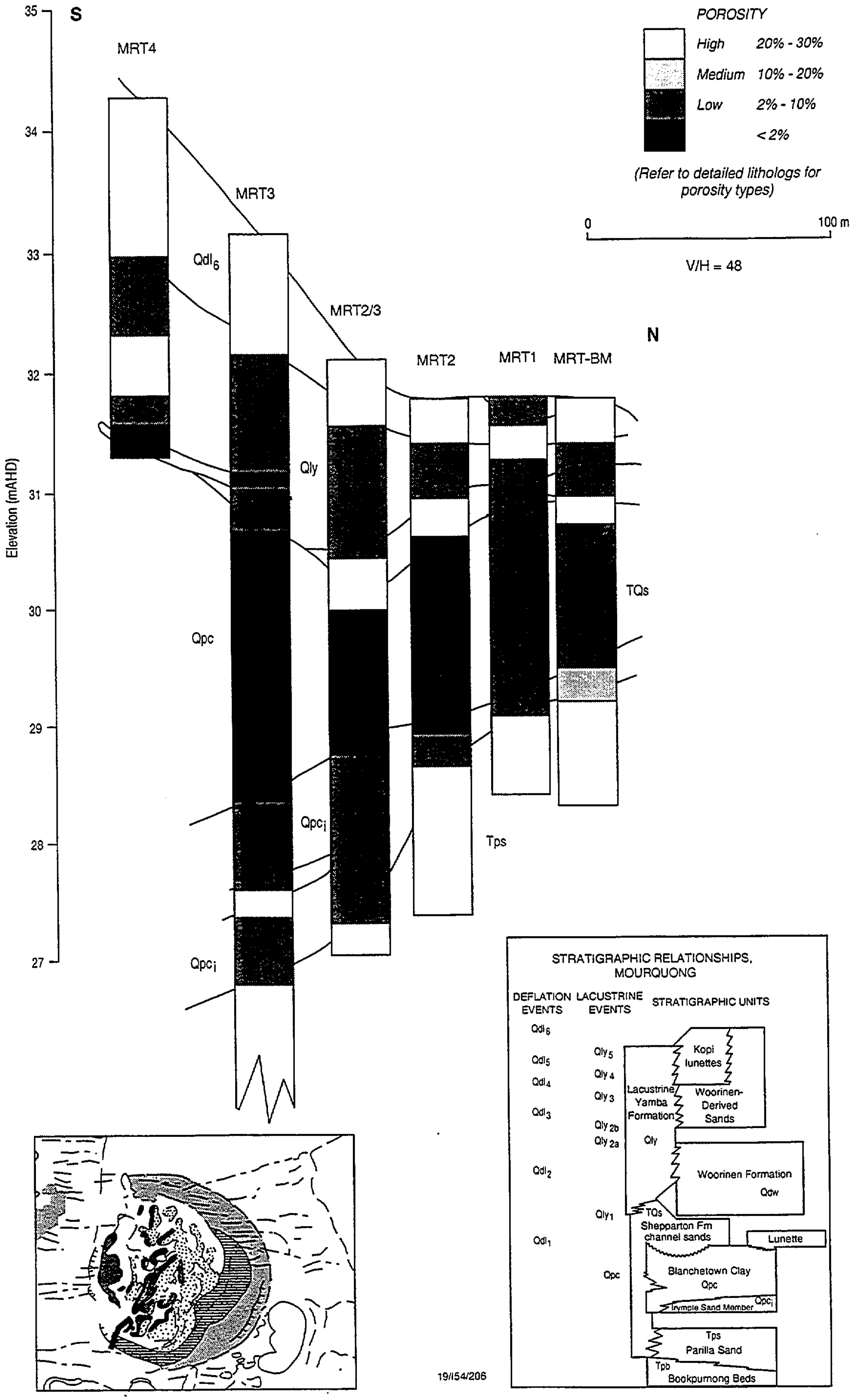

Figure 51. Porosity distribution in the southern margin (MRT transect), Mourquong discharge complex.

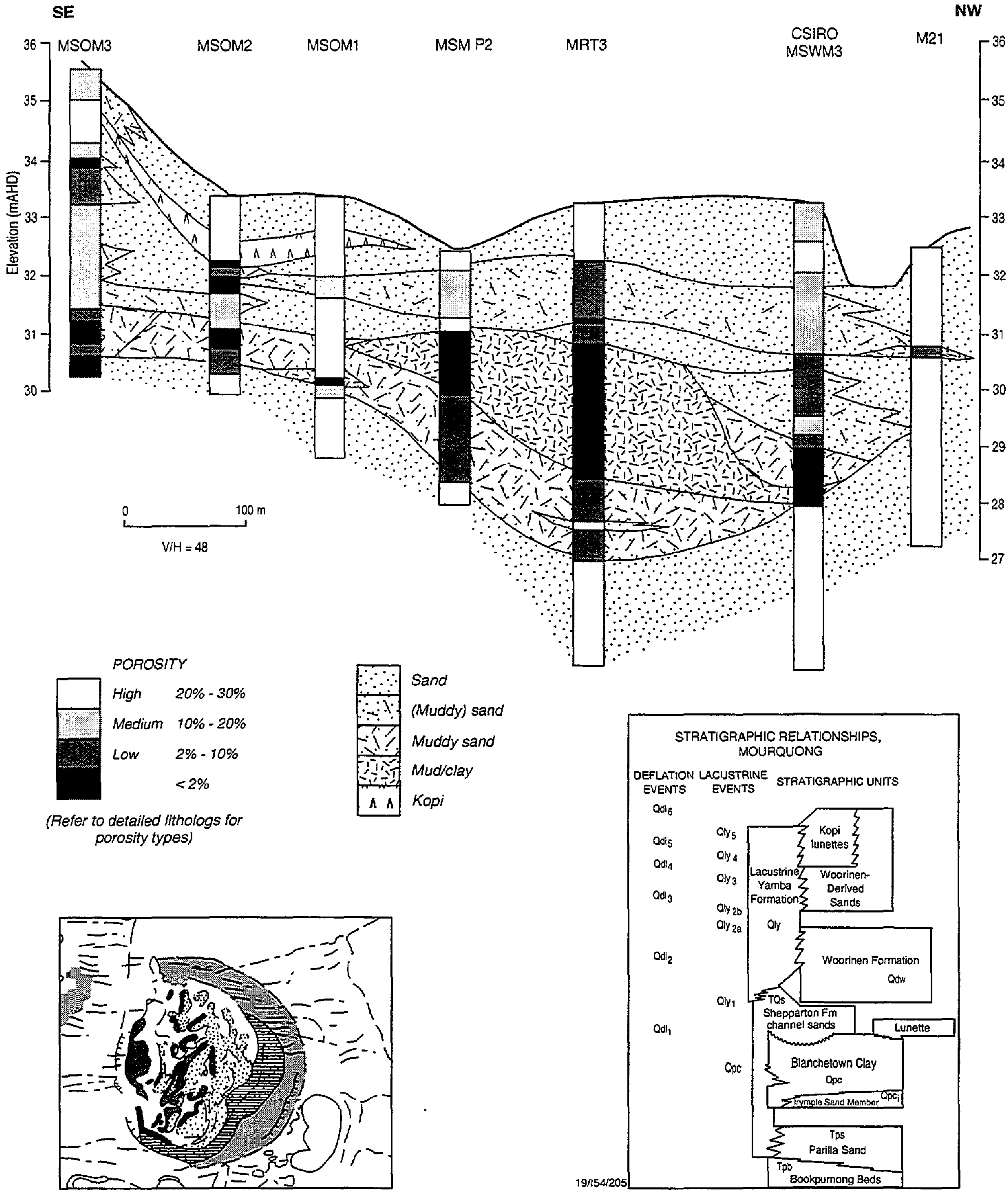

Figure 52. Porosity distribution tangentially along the southern margin (MSOM - M21) transect, Mourquong discharge complex.

fluctuated to much higher salinities formerly, initiating downward diffusion of salts and gypsum emplacement. At the southern margin, the Blanchetown Clay has very low permeability but its distribution is much more unpredictable (Figure 23). The MRT transect (Figure 22, 51) shows the clay thickening away from the basin, but absent and abutted by sandy Shepparton clays under the salina.

Irymple Sand Member

The Irymple Sand member lies at the base of, and interdigitates with the Blanchetown Clay, and directly overlies the Parilla Sand (Figure 18). This member is characterized in the central region by alternating high and low permeability bands and consequently has high lateral permeability, but with a lower vertical permeability. It forms a significant potential conduit on the western margin, especially where there is only a thin interval of Blanchetown Clay separating it from an incised notch, covered by reworked Woorinen sand (Qdl6) on the salina margin (Figure 20). In the eastern and southern regions of the Mourquong depression, the member has broader intervals of low permeability.

Yamba Formation

The Yamba formation has variable permeability both within the sequence and laterally. Most Yamba units have the full range of permeability. Unit Qly4 appears to have the lowest permeability throughout the basin and only at the northernmost area (M14) does it have a lower permeable sand (Figure 50).

The Margins to the Basin

The present lake in the centre of the depression has hydrodynamic closure. However, it has several susceptible areas on its margins- the western and eastern edges, and the southern end.

The western margin to the lake in the central part of the depression has a notch incised into the Blanchetown Clay. This notch is now covered with high permeability sands of Qdl6. The thickness of clay is minimal between the lake and its lateral transition into horizontally-permeable Irymple Sand which lies against the Parilla Sand further to the west. Because the Blanchetown Clay has some intervals of low to moderate porosity, lateral hydraulic connection is highly probable (Figure 20).

The eastern margin of the lake at standard operating level has closure. But from MEM 2 and eastwards, the earlier Yamba units $Qly2_a$, $Qly2_b$ are more permeable and directly overlie Shepparton sands (Figure 20).

In the southern part of the depression, the thin Yamba formation is moderately permeable and overlies the Shepparton Sand. In the Southwestern corner, the Blanchetown Clay is absent and consequently highly permeable Shepparton sands overlie the Parilla Sand enabling direct hydrodynamic linkage of surface waters with Parilla Sand (Figure 17).

Hydraulic Gradients

The vertical and lateral gradients associated with the disposal basin were measured along transects (Figures 3, 4 and 5) on the western (transect MWM) , northern (transect MNM), eastern (transect MEM) margins and at two locations on the southern margins (transects MRT and MSM). Compared to the situation described in the previous report on Mourquong (Ferguson *et al.*, 1995), transects MRT and MSM are new and transects MNM and MEM have been extended and infilled.

Measurements of hydraulic heads along these transects were made at one or two times in late summer (April 1995 or March/April 1995) and a time immediately after spring rain (October) when the basin operating level was about 0.5 m higher than those which pertained during the late summer measurements.

Vertical Gradients

Vertical gradients were determined from environmental water heads obtained from piezometer nests emplaced at various sites along the transects shown in Figures 53 to 56. Vertical gradients are best measured on piezometers set as far apart vertically as possible because the calculations involve obtaining the difference between two fairly large numbers. However, most disposal basin hydrodynamics deals with gradients in shallow sediments which may be partly shielded from the underlying regional groundwaters by intervening clay layers. The errors resulting from the limited differences in piezometer elevation can be compounded by complications arising from a combination of the short-term effects of local rainfall/runoff and the longer-term response times of piezometers set in clayey sediments. Local, short-term effects on the vertical gradients would be most likely to occur close to the basin margins where rainfall/ runoff can readily enter permeable sands at the base of adjacent dunes. Conversely, vertical gradients associated with the usually-flooded areas of

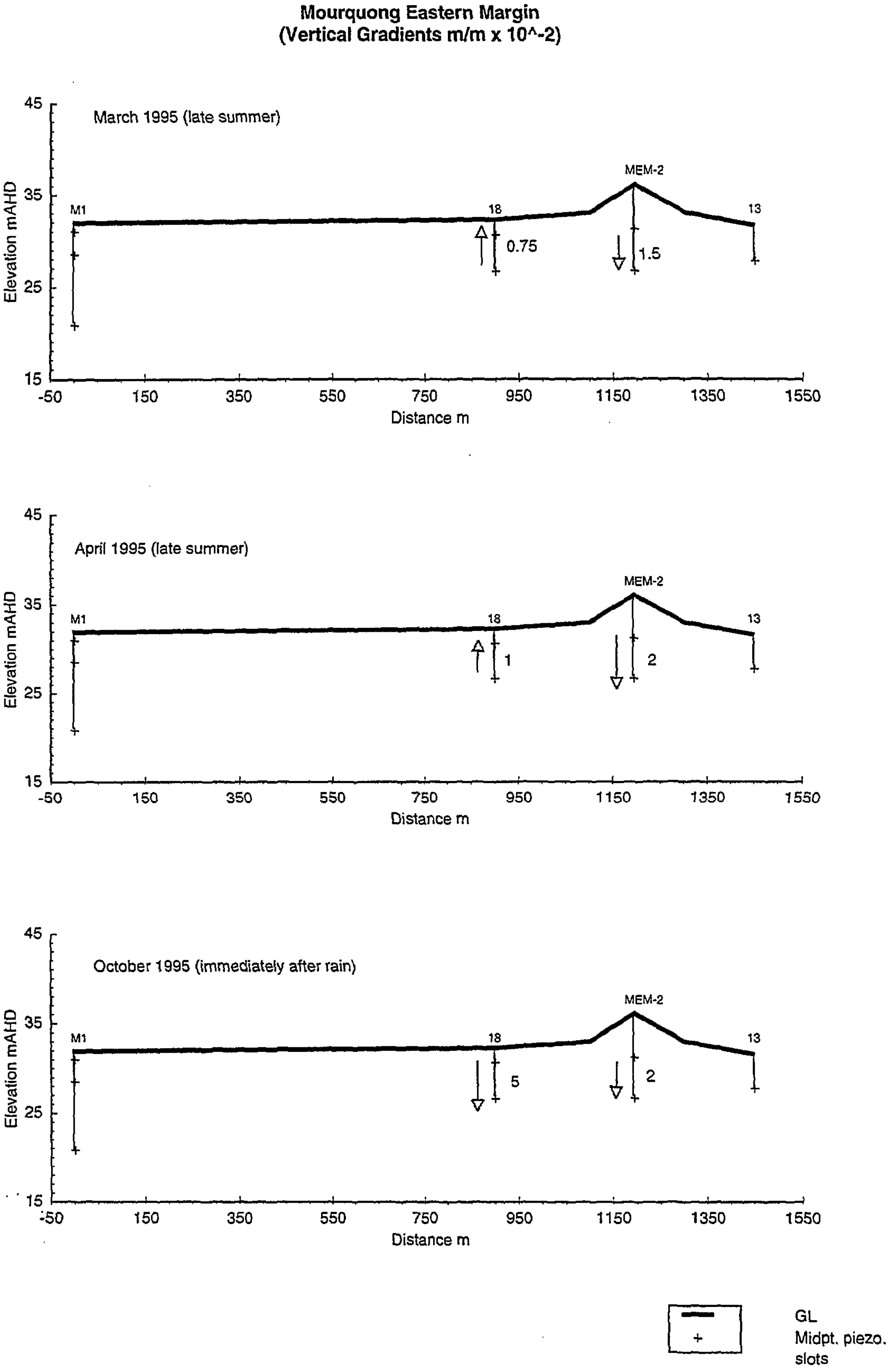

Figure 53. Vertical hydraulic gradients (calculated from environmental water heads); Mourquong eastern margin, transect MEM.

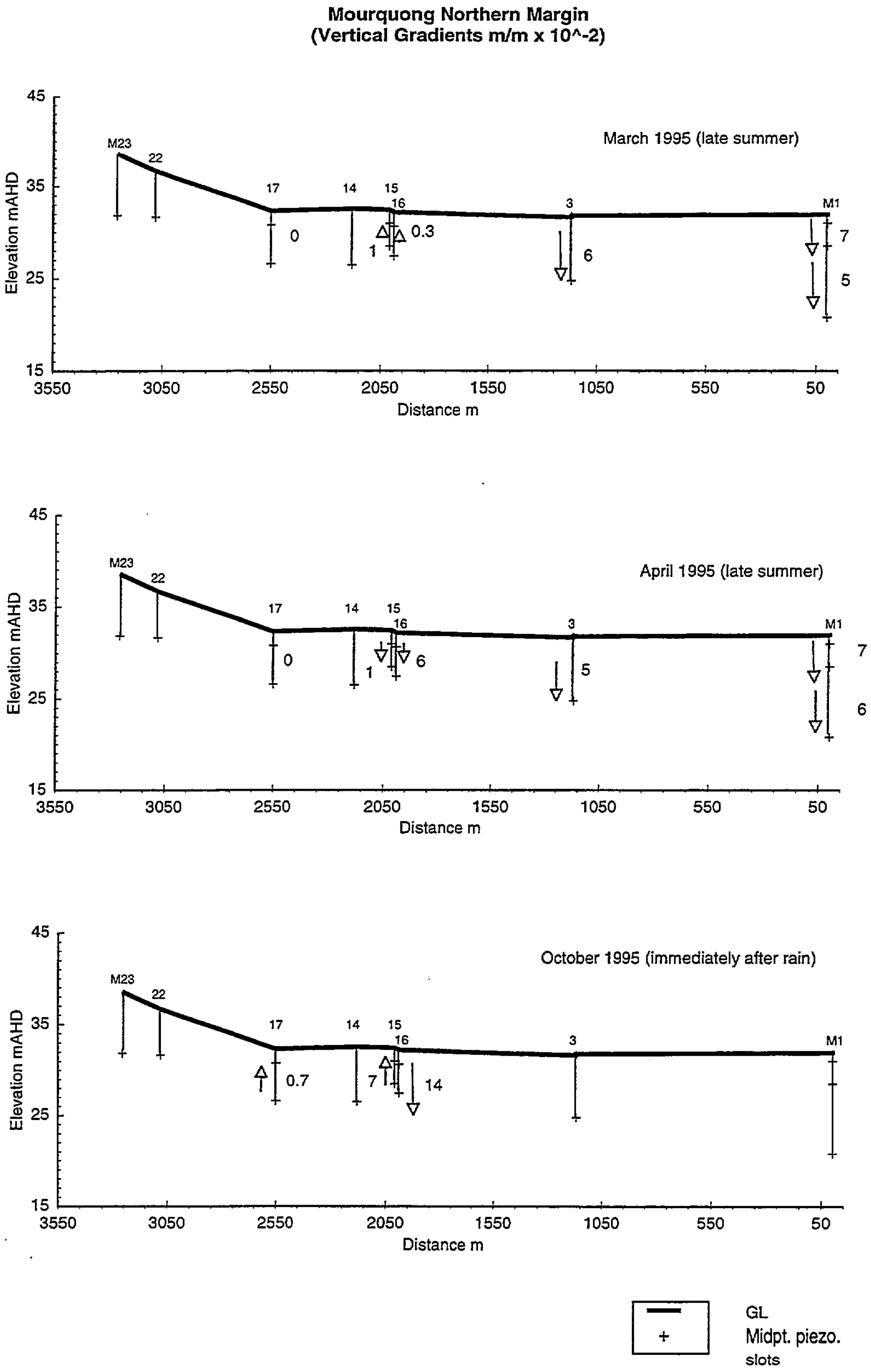

Figure 54. Vertical hydraulic gradients (calculated from environmental water heads); Mourquong northern margin, transect MNM.

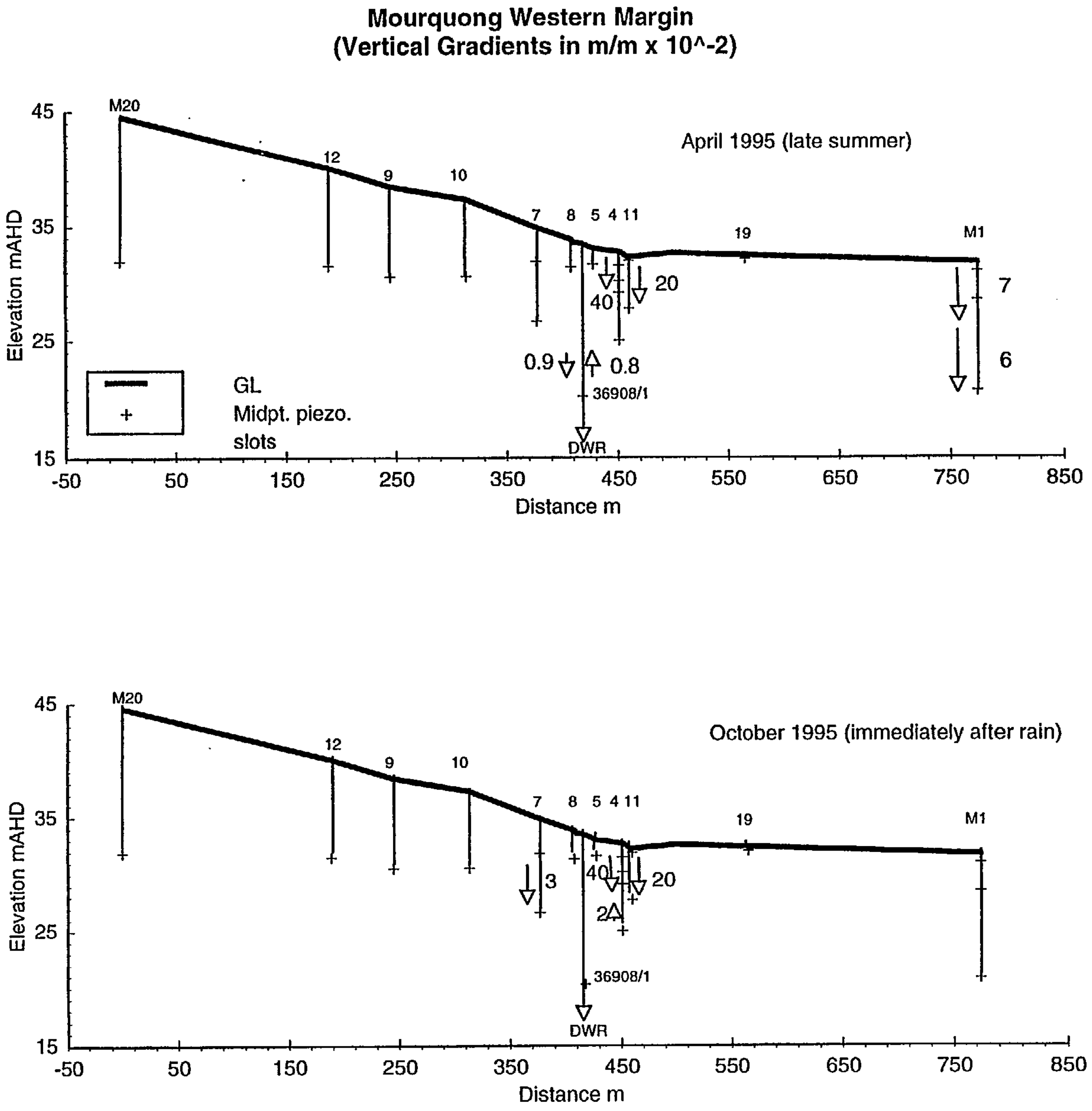

Figure 55. Vertical hydraulic gradients (calculated from environmental water heads); Mourquong western margin, transect MWM.

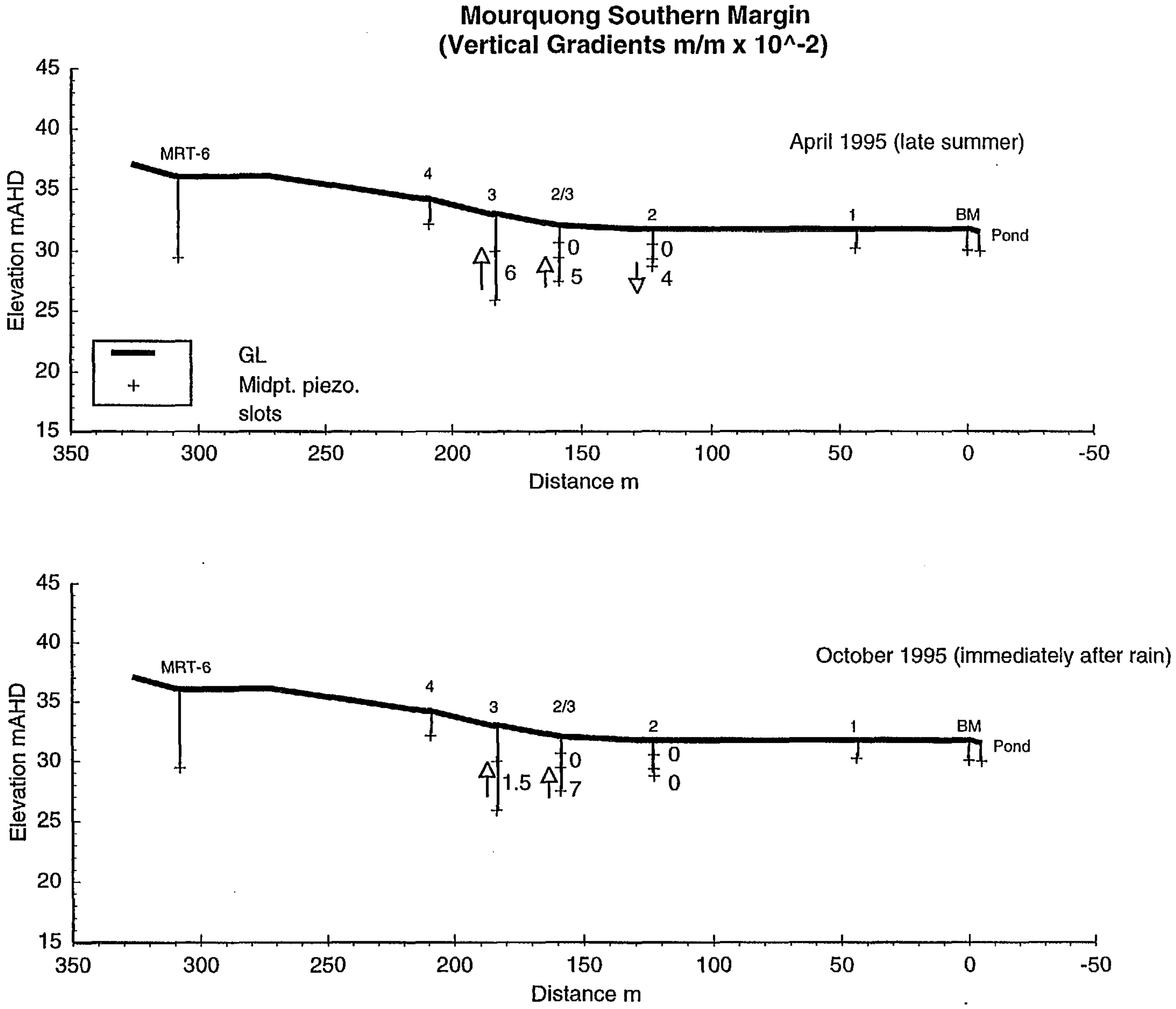

Figure 56. Vertical hydraulic gradients (calculated from environmental water heads); Mourquong southern margin, transect MRT.

the disposal basin should respond mainly to the relatively longer-term effects of changes in the basin operating level.

The available data are consistent with the scenario outlined above. Vertical gradients in the usually-flooded northern area of the disposal basin (Figure 54) were almost constant in the period March-April 1995 (-5 to -7 x 10^{-2} m/m at M1, and -5 to -6 x 10^{-2} m/m at M1). In the same period gradients associated with a low dune at the northern margin of the disposal basin ranged from 0.3 to -6 x 10^{-2} m/m; Figure 54). Maximum gradients of -40 x 10^{-2} m/m were obtained for the area at the base of the large dune to the west of the disposal basin, where rainfall/runoff from the duneface accumulates in permeable sands at the base of the dune.

Lateral Gradients

Lateral gradients were determined from fresh water heads at constant elevation (Figures 57 to 61). The shallow constant elevations chosen were 31.55 mAHD (transects MWM and MNM) and 30.00 mAHD (transects MRT and MSM). These elevations are close to the water table and probably reflect mainly shallow groundwater processes associated with the disposal basin and local recharge. For transect MWM, heads were calculated an elevation of 27.0 mAHD, where natural (pre-disposal) processes may be influential.

Eastern Margin Transect (MEM)

The lateral heads on the eastern margin have not been investigated in detail because of the topographic situation is complicated by a dune (at MEM-2, Figure 4) which separates the main disposal basin from an area to the east which is topographically lower but usually isolated. This partly isolated area (M13, Figure 57), is flooded by disposal water only at very high basin operating levels.

The lateral heads at 31.55 and 27.0 mAHD reflect this hydrodynamic situation. There a maximum in the lateral heads near the centres of the main and subsidiary basins, a decline to the margin and a further decline to a minimum beneath the intervening dune.

Northern Margin Transect (MNM)

Along this transect, the lateral heads at an elevation of 31.55 mAHD (Figure 58) slope downwards from the disposal basin into the remaining area of the discharge complex to the north. A similar pattern is shown by the lateral heads at 27.0 mAHD. The influence of the disposal basin heads extends some 150 to 500 m north of the flooded area of the disposal basin.

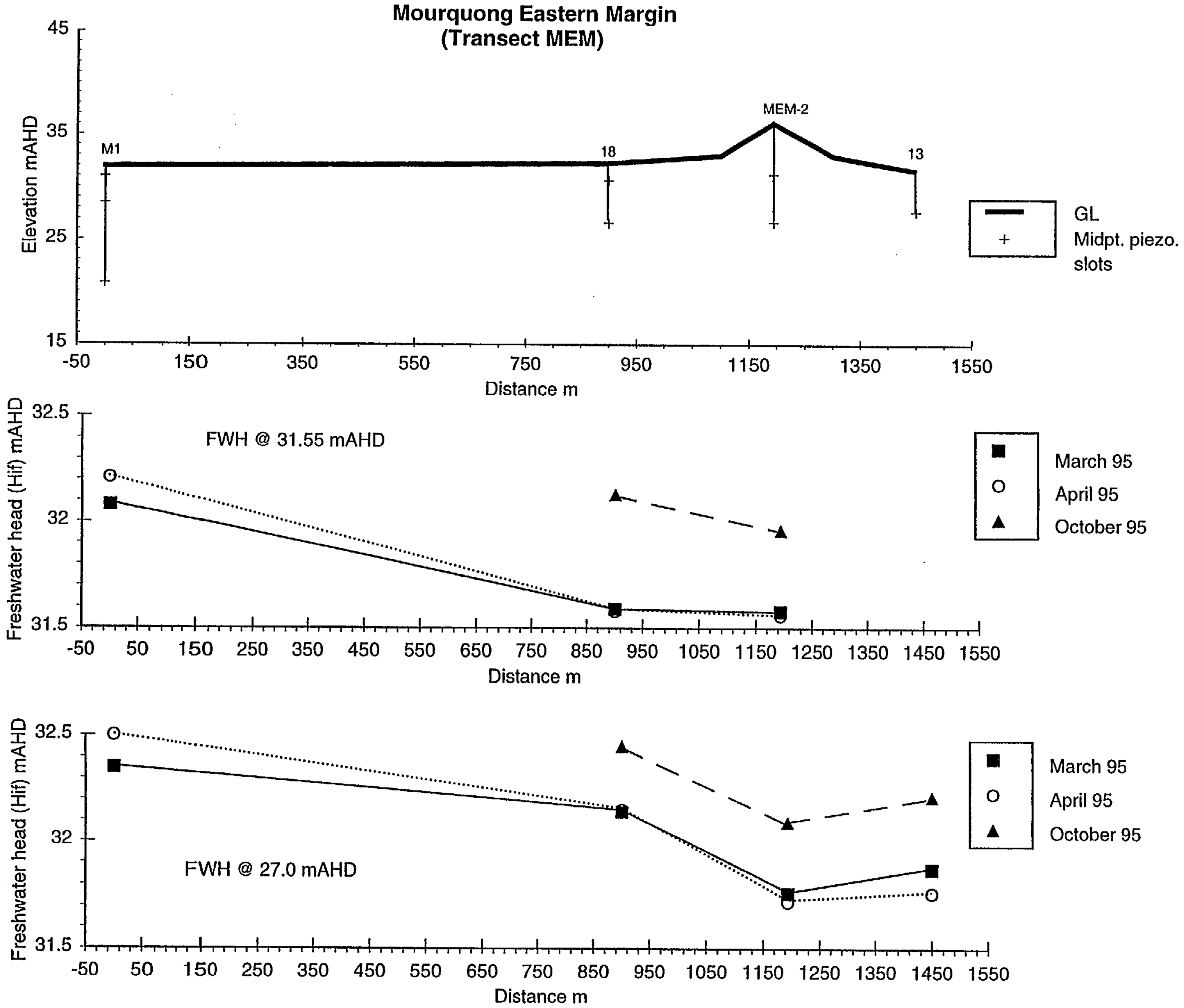

Figure 57. Lateral hydraulic heads (freshwater heads) at constant elevation; Mourquong eastern margin, transect MEM.

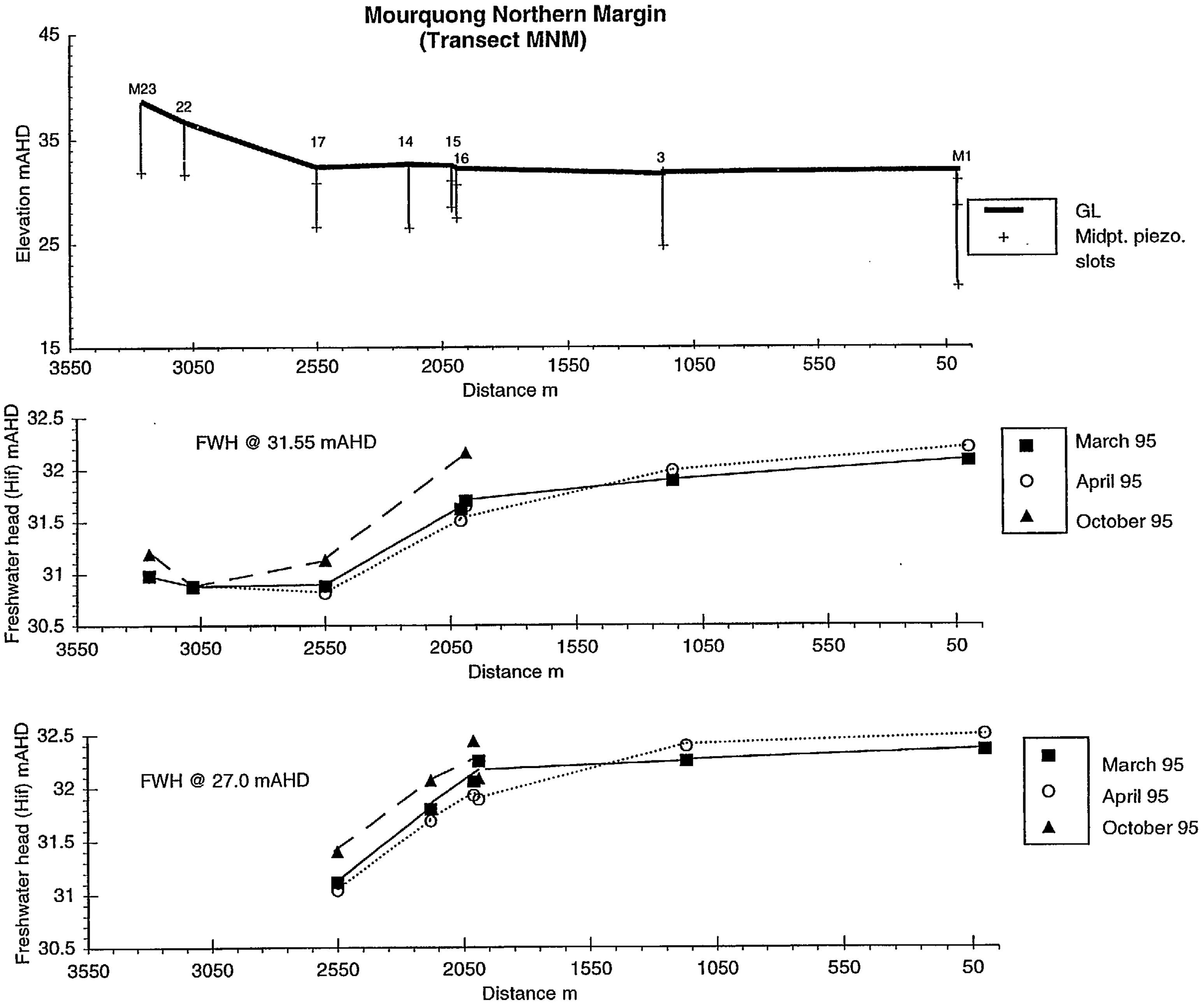

Figure 58. Lateral hydraulic heads (freshwater heads) at constant elevation; Mourquong northern margin, transect MNM.

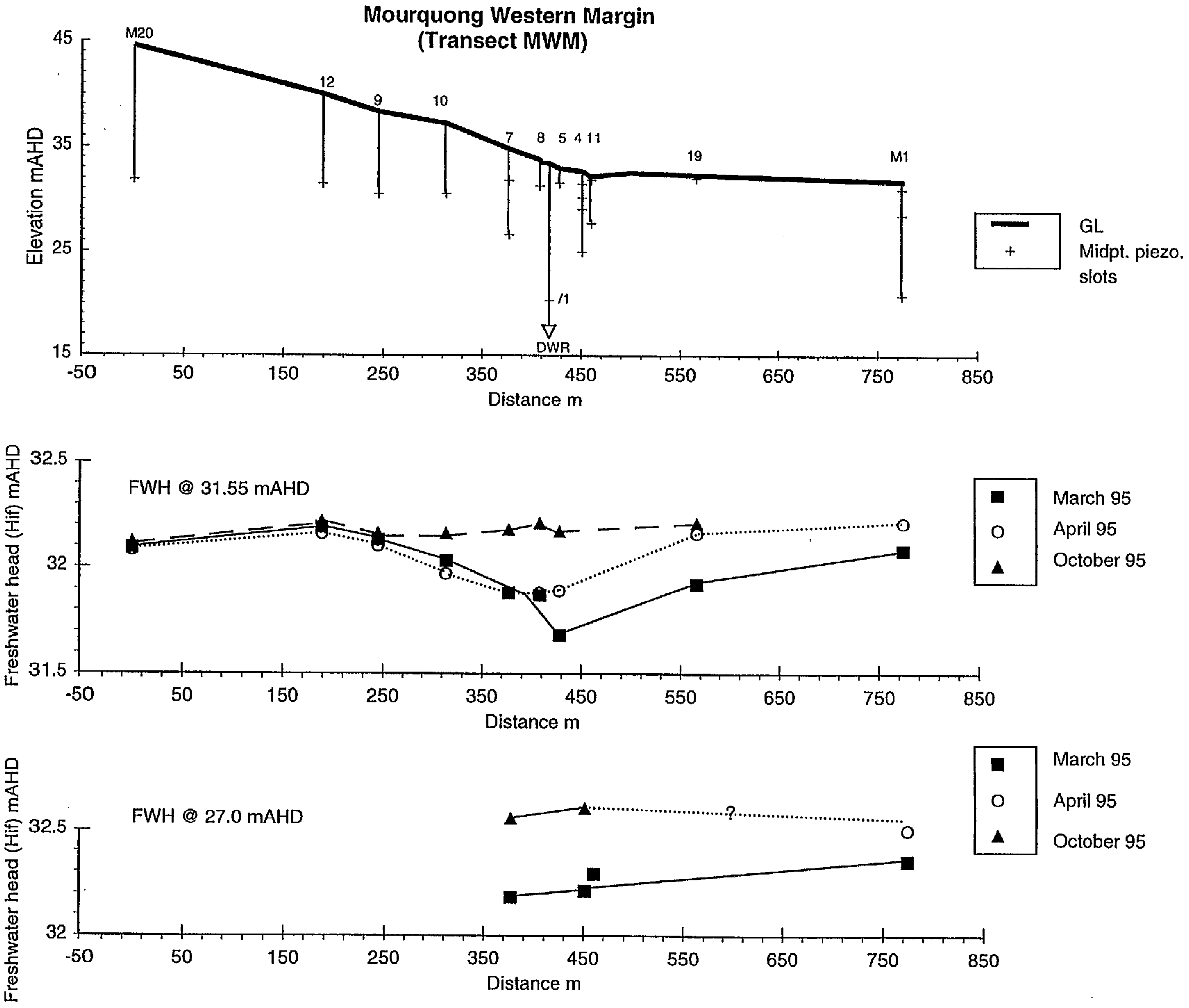

Figure 59. Lateral hydraulic heads (freshwater heads) at constant elevation; Mourquong western margin, transect MWM.

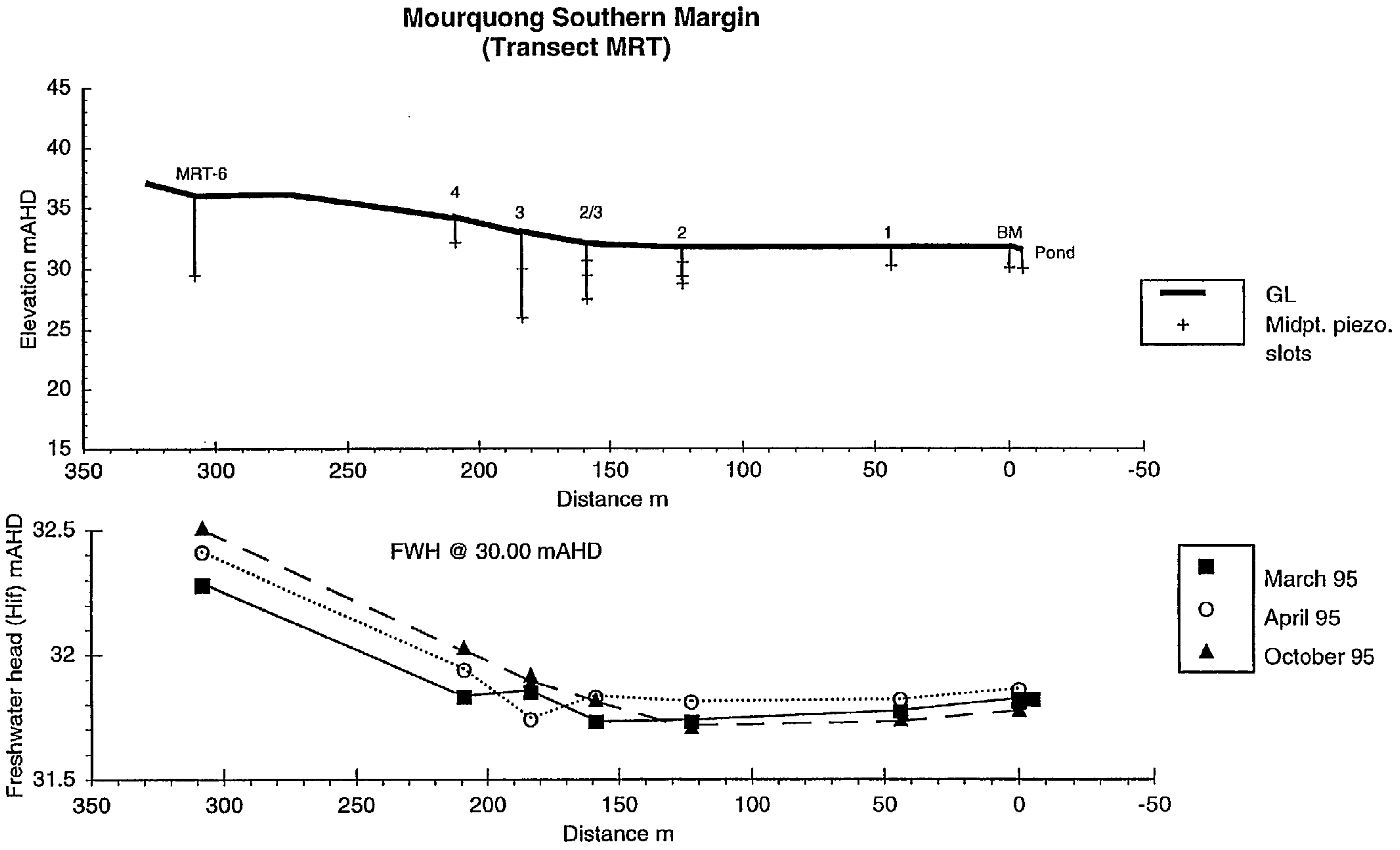

Figure 60. Lateral hydraulic heads (freshwater heads) at constant elevation; Mourquong southern margin, transect MRT.

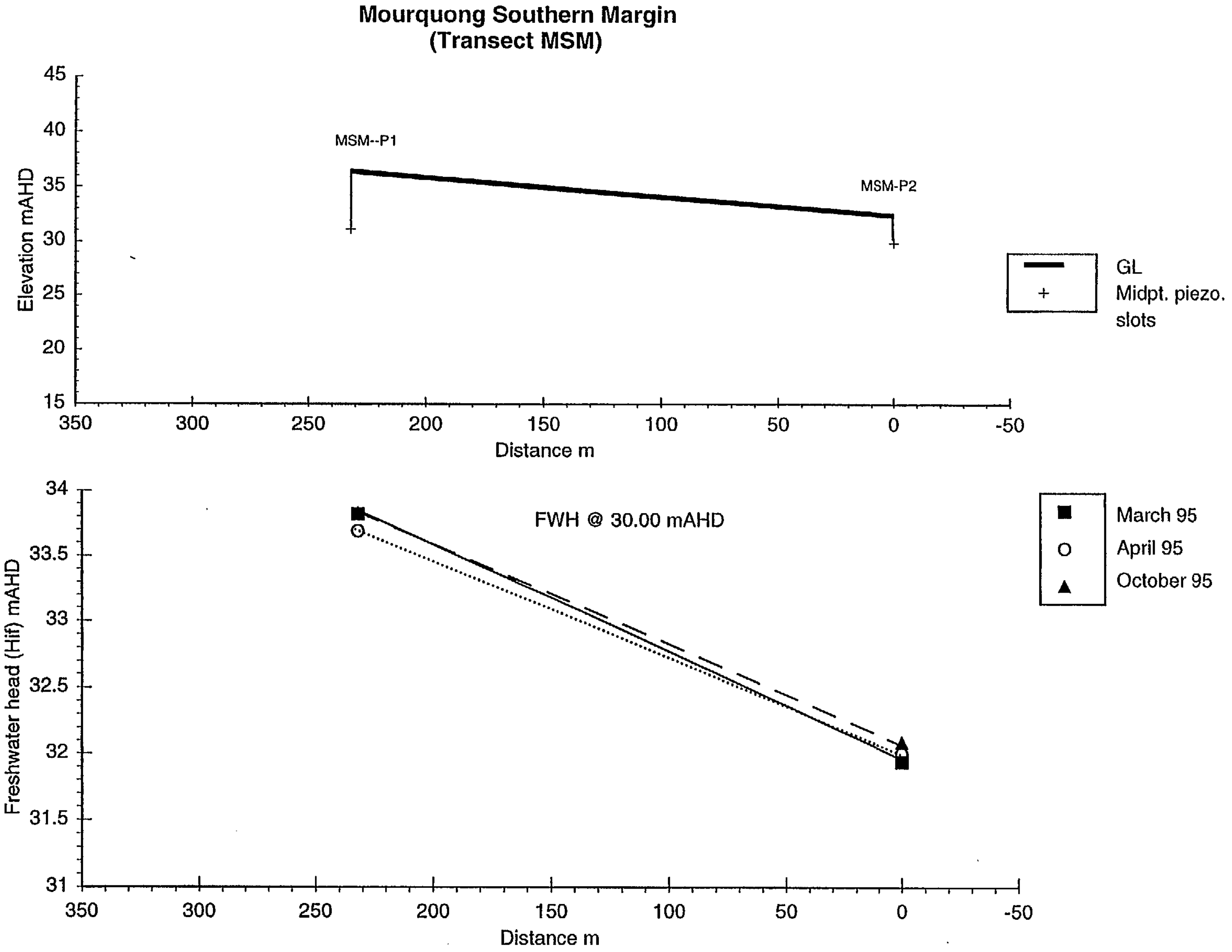

Figure 61. Lateral hydraulic heads (freshwater heads) at constant elevation; Mourquong southern margin, transect MSM.

The transect extends about 500 m into the dunefield at the northern margin of the discharge complex. There is a slight increase in the lateral heads (31.55 mAHD) in this area, but the maximum head is still considerably below that in the disposal basin.

Western Margin Transect (MWM)

At this location, the landward boundary of the regularly flooded margin of the disposal basin abuts the colluvial sands which have been eroded from the adjacent duneface. The presence of erosional gullies indicates that during periods of high rainfall water partly runs off the duneface and enhances recharge of the more permeable sands at the base of the dune. The changes in lateral heads along the transect (Figure 59) reflect a combination of the effects of rainfall recharge and changes in the disposal basin operating levels.

Two sets of measurements were made in late summer (March and April) when the rainfall was low but the freshwater head in the basin was increasing. A additional set of measurements was made in Spring (October), when the disposal basin level was similar to that in April but there had been moderately heavy rainfall over the preceding two days. At the landward portion of the transect (locations M9, M12 and M20; Figure 59) the lateral heads were almost constant over the measurement period, and were not greatly different to those in the centre of the disposal basin (M1). In late summer there was a minimum in the heads in the area close to the disposal basin margin. In Spring after rain, this minimum had disappeared and had been replaced by a slight mound.

The processes controlling the fluctuations in the lateral heads in the marginal/disposal basin areas are not clear. The main controls seem to the disposal basin levels and rainfall recharge through the sandy areas at the margins. Presumably, during the period of lowest disposal basin operating levels and lowest rainfall (not measured in this study) the lateral heads slope lakewards from the dune to the margin of the disposal basin and from there are almost horizontal or slope slightly towards the topographically lowest areas near the centre of the disposal basin. As disposal basin levels rise, initially in the topographically lower areas of the disposal basin, the heads will slope from the centre to the margin. As the basin filling process continues and rainfall increases, the minimum in the lateral heads is filled from the disposal basin by laterally flowing and vertically infiltrating disposal water and from the land by infiltrating and laterally moving rainwater. The rate of the changes in head induced by these processes seems high and it is possible some of the heads reflect the formation of localised, transient perched rainfall and/or disposal water tables.

The possibility that the landward heads beneath the dune developed from disposal water which has leaked laterally into the dune during high basin operating levels cannot be eliminated. However, the almost constant nature of the heads in the landward area of the transect contrasts strongly with the significant fluctuations in the marginal/disposal basin areas, and is more consistent with a natural groundwater mound developed by rainfall recharge.

The lateral heads at the deeper elevation of 27.0 mAHD slope from the centre of the disposal basin to the minimum at the margin.

Southern Margin Transect s (MRT and MSM)

Transect MRT is located 100 to 200 m to the west of irrigated areas on the southern margin of the discharge complex. The transect starts at a point about 100 m into the bordering dune, crosses about 150 m of the discharge complex and ends at a pond connected to the drainage channel which directs the effluent water northwards. The lateral heads at 30.0 mAHD (Figure 60) show a strong gradient from the dune to the discharge complex, presumably because the irrigation to the east has raised the water table in the dune. Within the discharge complex, the lateral gradient is slightly away from the pond.

Transect MSM is located considerably closer to the irrigated areas and, consequently, there is a very strong gradient from the dune to the discharge complex (Figure 61).

HYDROCHEMICAL IDENTIFICATION OF DISPOSAL WATER

Salinity, major ion-ratios to Br or Mg, and deuterium content were tested as indicators of the presence of disposal water in the natural groundwaters surrounding and underlying the disposal basin.

Salinity

Surface Water

As discussed previously (Ferguson *et al.*, 1995), the salinity of the surface water ranges widely (34,000 to >350,000 mg/L depending on the season, the basin operating levels and the distance from the effluent outlet.

Under low basin operating conditions in summer, the salinity in the disposal area increased progressively with distance northwards, from 34,000 mg/L in the inlet pipe to considerably more than 350,000 mg/L in isolated, almost dry, evaporite-rich ponds on the western side of the disposal area. Under high basin operating conditions in winter, the salinity in the disposal basin was much lower. For example, near M1 the winter value was about 90,000 mg/L which is less than one-third the comparable summer value of about 300,000 mg/L. The winter salinity is considerably below that for halite saturation, which implies that almost all of the halite and more soluble salts precipitated in the disposal area during the previous summer were redissolved as the pool operating levels increased.

The average disposal water salinity "seen" by the sediments will generally increase northwards.

At the regularly flooded margins of the disposal basin, the average salinity of the overlying disposal water will decrease as the outer limit of flooding is approached. This decrease occurs because the salinity decreases with increasing basin operating levels and the outer areas of the margins are only flooded during high basin operating levels.

On the basis of the surface salinity patterns it appears that salinity is most likely to be a reliable indicator disposal water in the topographically lower, northern areas of the disposal basin. Conversely, salinity will become an increasingly unreliable indicator as the point of effluent discharge is approached and with increasing distance from the edge of the usually flooded areas across the disposal basin margins.

Groundwater

Salinity versus depth profiles for various locations along the transects are presented in Figures 62 to 65.

Eastern Margin Transect (MEM)

Salinity versus depth profiles for sites M1, M18, MEM-2 and M13 are shown in Figure 62. MEM-2, which is sited in the dune which separates the main disposal basin from its occasionally flooded eastern arm shows a natural profile, the upper part of which is recharge-dominated. The other sites - M18 on the regularly flooded margin of the main basin and M13 close to the centre of the eastern arm - show the salinity profiles typical of vertical recharge by the lower salinity disposal water which is present at high basin operating levels.

Northern Margin Transect (MNM)

The profiles along the northern margin transect range from a disposal water-dominated site near the centre of the disposal basin (M3), to a site in the unflooded area of the discharge complex beyond the basin margin (M17) where there is no evidence of disposal water and the profile is that of constant-salinity water. Two sites in the regularly flooded disposal basin margin (Figure 63) show a similar profile to that at the usually flooded site M3, but the salinity of the disposal water in the upper section decreases landwards from about 300,000 mg/L at M3 to 150,000 mg/L at M16 and 120,000 at M15. As discussed previously, this pattern is expected from vertically infiltrating disposal waters. At a site further from the disposal basin (M14), there is a combination of a definite salinity peak overlain by groundwater whose salinity is high and constant. It appears that

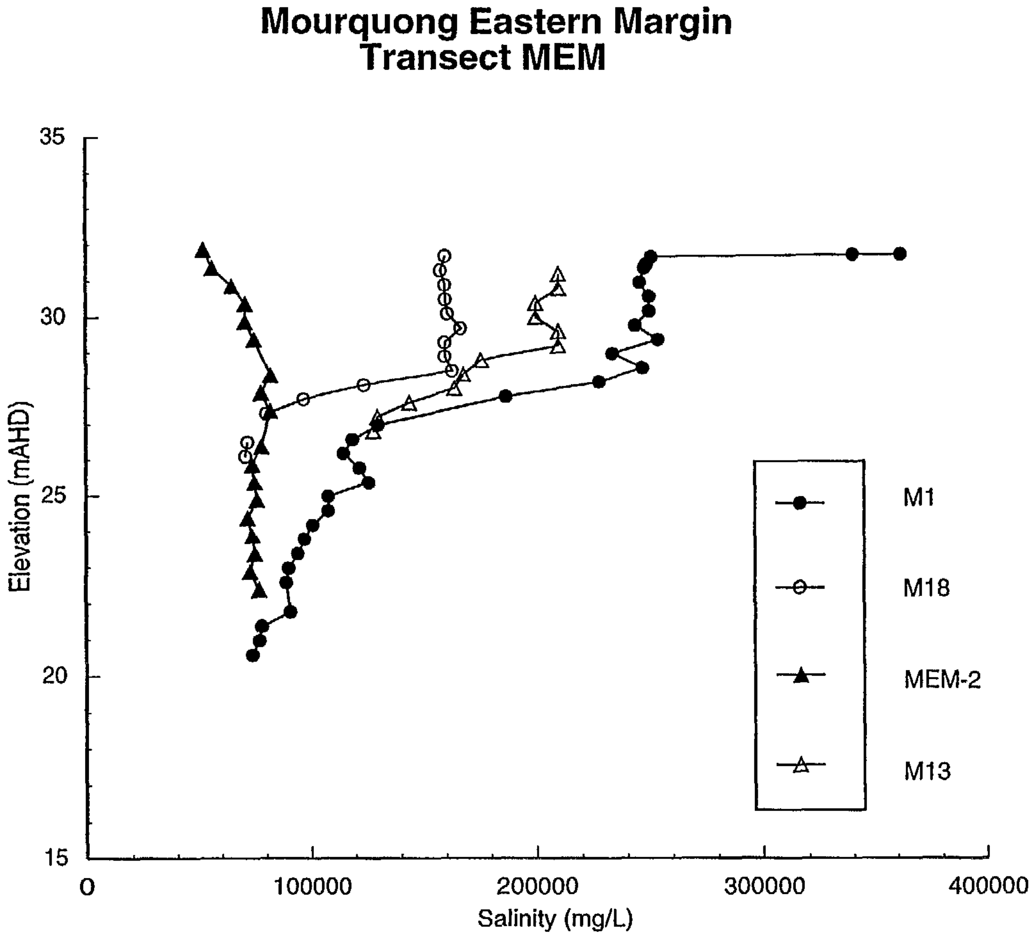

Figure 62. Salinity versus elevation profiles for sites on the Mourquong eastern margin, transect MEM.

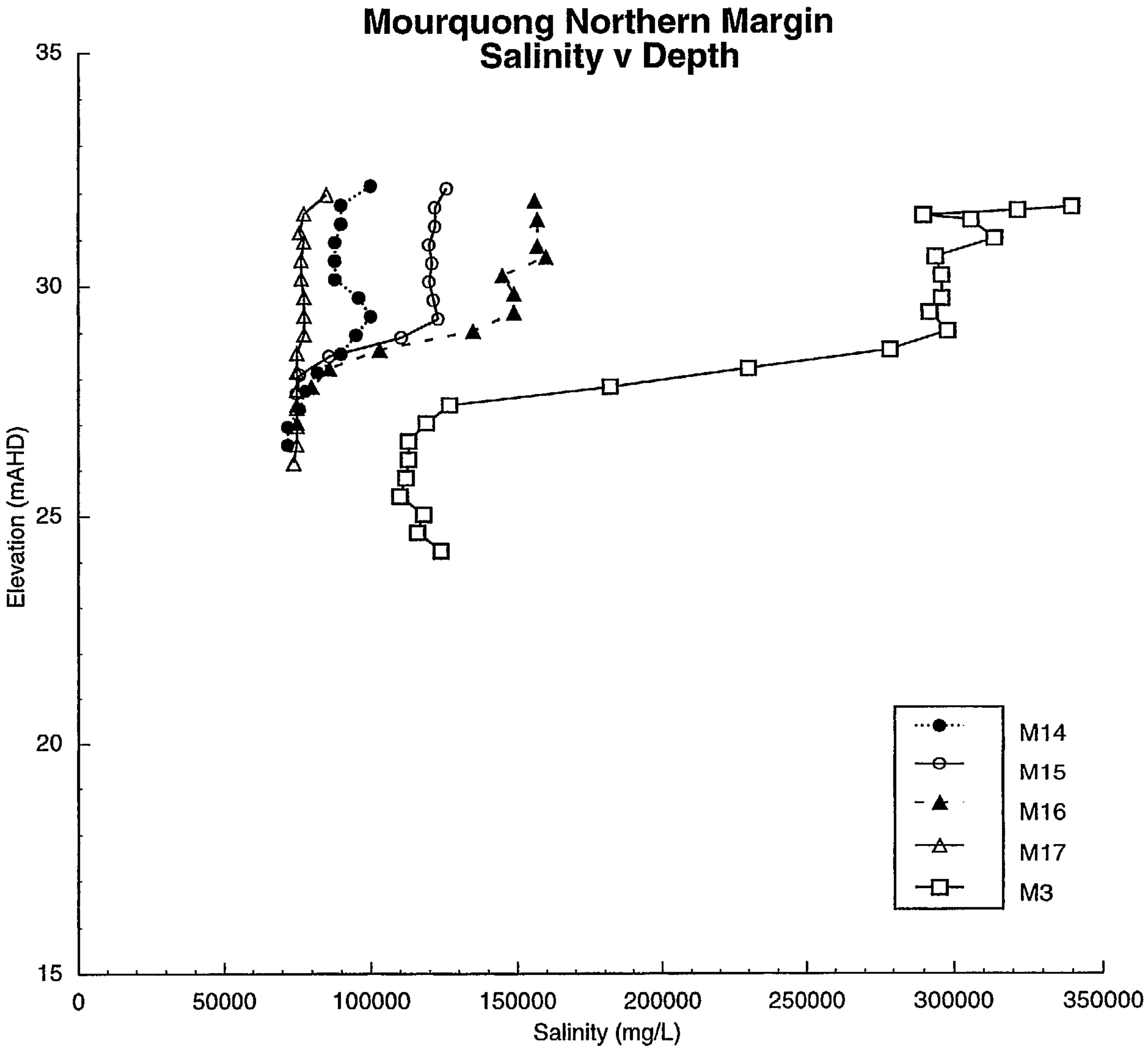

Figure 63. Salinity versus elevation profiles for sites on the Mourquong northern margin, transect MNM.

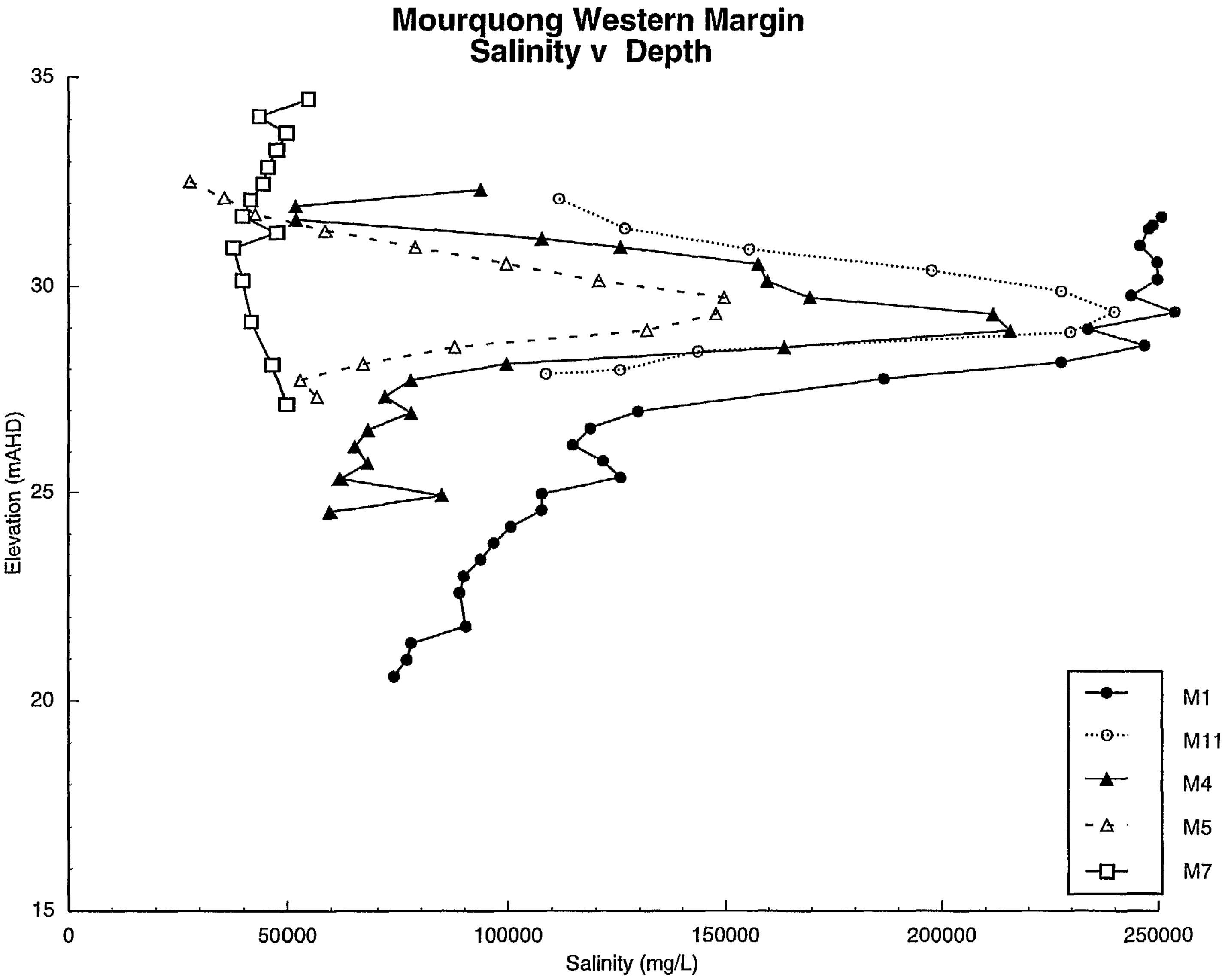

Figure 64. Salinity versus elevation profiles for sites on the Mourquong western margin, transect MWM.

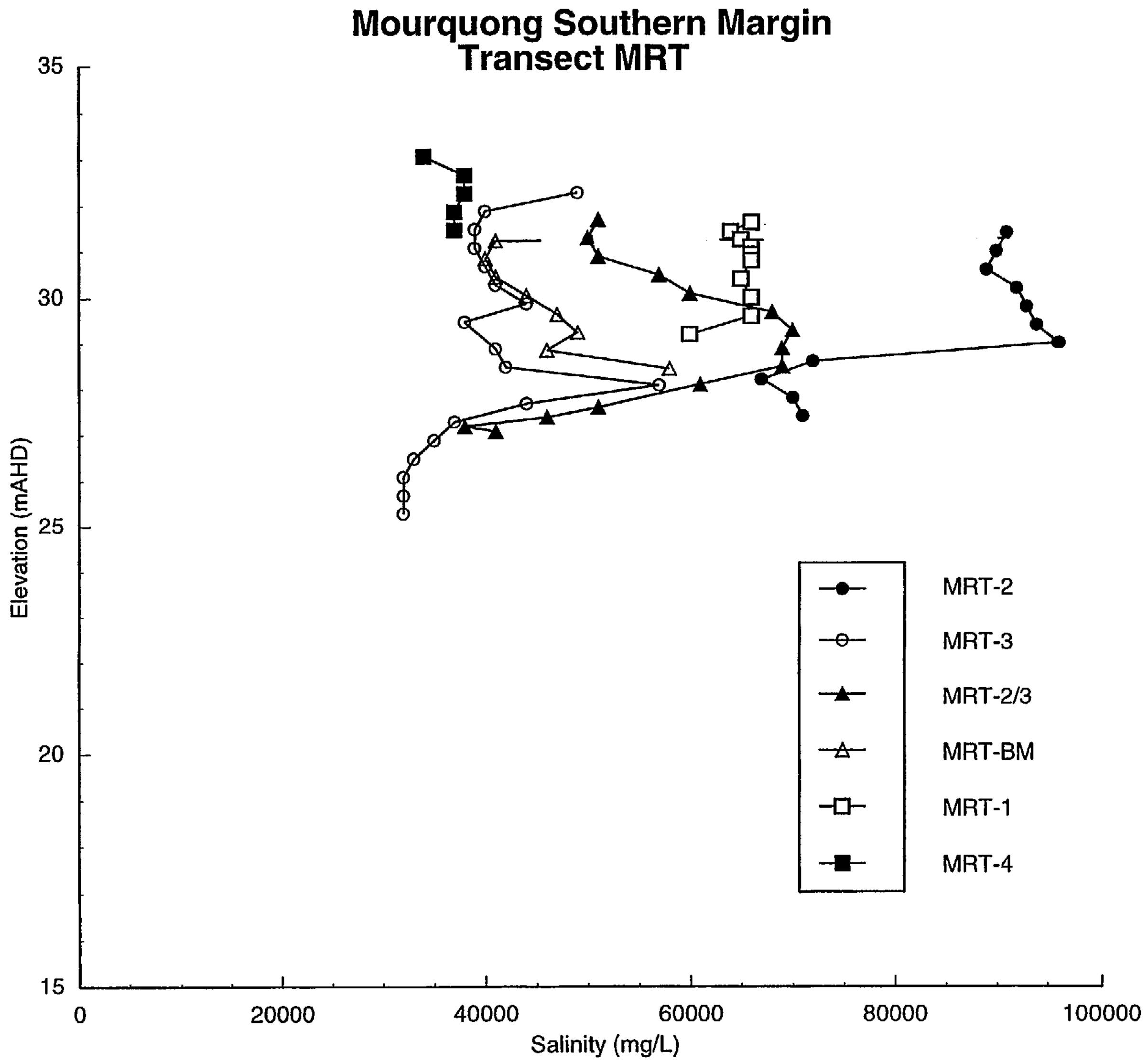

Figure 65. Salinity versus elevation profiles for sites on the Mourquong southern margin, transect MRT.

this location is affected both by vertical infiltration at high water level/low-salinity basin operating conditions, and by lateral groundwater flow of brine from the disposal basin.

Based on the position of the salinity peak, the disposal water has moved marginally more than 300 m but definitely less than 650 m from M16, which is in the regularly flooded part of the disposal basin.

From the distance the disposal water has moved ($\Delta L = 300$ m); the lateral hydraulic gradient over this distance ($\Delta h = 0.5$ m); the time of basin operation ($t = 15$ y); and the sediment porosity ($\mu = 0.2$); the lateral hydraulic conductivity (k) of the (mainly) Yamba Formation sediments can be calculated from the formula:

$$k = (V \mu \Delta L)/\Delta h$$

where $V = \Delta L/t$.

$$\text{i.e. } k = 20 \times 0.2 \times 300/0.5 = 7 \text{ m/day.}$$

This value is reasonable considering the sandy nature of the Yamba Formation sediments (e.g. Figure 49).

The considerably smaller distances the disposal water has moved at the western margin (25 to 55 m) is consistent with the lower average landwards lateral hydraulic gradient in this area and a probable lower lateral hydraulic conductivity encountered as the disposal water moves into the Blanchetown Clay.

Western Margin Transect (MWM)

The profiles along the western margin transect (Figure 64) range from that near the centre of the disposal basin where the presence of disposal water is clearly evident in M1, to a site at the base of the dune beyond the basin margin where there is no evidence of disposal water and the profile is that of lower-salinity recharge-influenced water overlying more saline natural groundwater. Intermediate sites show a salinity peak in the profile at what appears to be a constant elevation of about 29.5 mAHD.

The peak salinity decreases landwards from about 250,000 to 240,000 to 215,000 to 150,000 mg/L. An estimate of the original (pre-disposal) salinities in this part of the disposal basin can be made by extrapolating the natural diffusion profiles from the lower parts (< 27 mAHD) of the profiles. At M1 this value is about 140,000 mg/L and at M4 it is about 85,000 mg/L. The significant difference between the measured and estimated salinities is evidence that disposal water is present at all locations where a salinity peak occurs.

The lower salinities above the peaks could arise in two ways.

(1) Disposal water brine could be flowing laterally from the disposal basin into the surrounding lower salinity natural groundwaters.

(2) Previous disposal basin operating levels could have been significantly higher than today resulting in vertical infiltration of brine further landwards. As the basin operating levels were reduced, the natural groundwaters would return and gradually overlay the disposal basin brines.

On the basis of the available data it is difficult to determine which of these circumstances is correct but if the lateral flow hypothesis is correct, then the disposal basin brine has travelled between 25 and 55 m from site M11, which is close to the present-day edge of the disposal basin.

Southern Margin (Transect MRT)

Transect MRT extends from part-way up the dune at the southern margin of the disposal complex, across the discharge complex, to a pond which is flooded by disposal water flowing northwards from the point of effluent discharge. When the salinity measurements were made the pond had a salinity of 32,000 mg/L, which is similar to that of the effluent water. At this time the disposal water was contained within the system of ponds and channels but the presence of a thin deposit of salt on the area of the discharge complex between the pond and the dune suggests that this area is occasionally flooded by disposal water at high effluent discharge rates.

The salinity of the groundwater along transect MRT is shown as salinity versus depth profiles for selected individual sites (Figure 65) and in cross-section as individual sampling points (Figure 66) and iso-salinity contours (Figure 67). The iso-salinity contours show the presence of a narrow band of what appears to be natural relatively high salinity water (> 90,000 mg/L) centred in the discharge complex, close to the southern margin. On both sides of this band is relatively low-salinity water.

Beneath the dune, the lowest salinity detected was 35,000 mg/L. These groundwaters could be influenced by a combination of natural rainfall recharge and irrigation water from the nearby orchard to the east. In the salinity versus depth profiles, superimposition of relatively low-salinity rainfall/irrigation water on to pre-existing higher salinity natural groundwaters is most clearly seen at site MRT-3 on the dune.

The lower salinity area on the discharge complex side of the high salinity area appears to be associated with the disposal water pond. Since it is unlikely that a natural area of low salinity water would occur in this part of the discharge complex, this salinity pattern suggests that disposal water has moved laterally and vertically from the pond into the adjacent sediments but has not reached the margin of the disposal basin. In the salinity

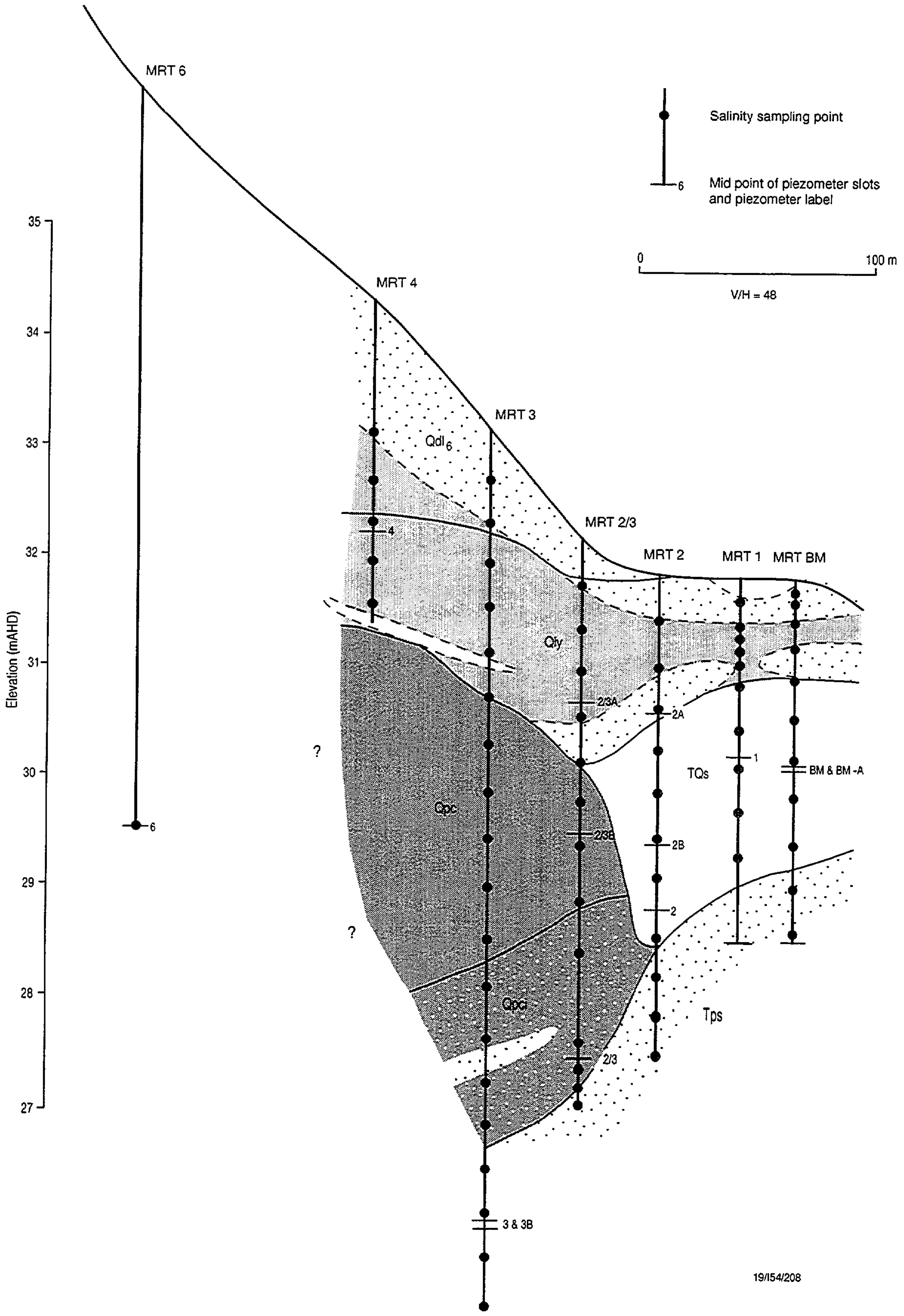

Figure 66. Salinity sampling sites and values; Mourquong southern margin, transect MRT.

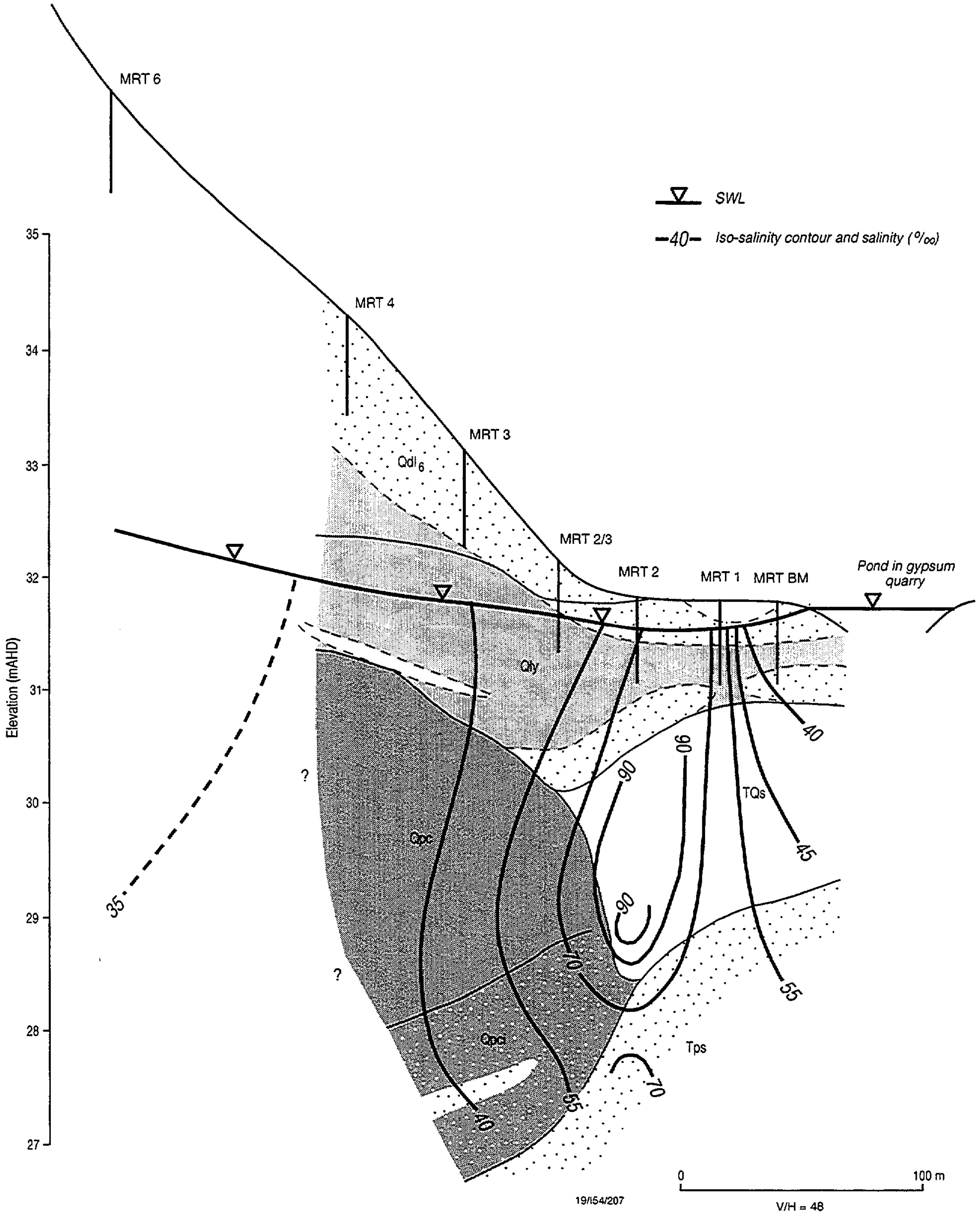

Figure 67. Iso-salinity contours; Mourquong southern margin, transect MRT.

versus depth profiles, superimposition of relatively low-salinity disposal water on to a pre-existing higher salinity natural waters is most clearly seen at site MRT-BM near the pond.

Southern Margin (Transects MSOM-MSWM)

These transects form a section extending approximately east-west along the dunes close to southern margin of the discharge complex. Between sites MSWM-3 and M21 a small inlet of the discharge complex is crossed. In this area, the thickness of the Blanchetown Clay ranges from about 3 m in MRT-3 to zero at M21 (Figure 68).

Iso-salinity contours across this area (Figure 68) show that higher salinity water is associated with the Yamba Formation sediments in the active area of groundwater discharge between MSWM-3 and M21 (122,000 mg/L), and with the Blanchetown Clay (50,000 mg/L). Close to the irrigation area very low salinities (5,000 mg/L) occur in the Parilla Sand where there are no overlying clays. Where the Blanchetown Clay is missing, low salinity (30,000 mg/L), presumably natural, groundwaters occur over at least the top 3 to 4 m.

Potential Limits of Lateral Movement of Disposal Water

The limit to which the disposal water could move laterally is the distance at which the lateral head in the disposal basin is equal to that in the surrounding groundwater system. Estimates of this distance for the Mourquong disposal basin will be approximate because long-term average data for the basin and groundwater heads are not available. In addition, the surrounding groundwater heads may increase as the spreading disposal water and reduction in the evaporation of the natural groundwater in the discharge complex changes the magnitude and perhaps the direction of the gradients.

The limited data indicate that the gradients at the southern margin are directed basin-wards, and are particularly strong near the irrigated area to the east. At the western margin the situation is unclear because the head in the disposal basin is comparable to the maximum head encountered in the dune. To the north, the gradient is directed from the disposal basin to the remainder of the discharge complex. The head some 200m into the bordering dune is significantly lower than that in the disposal basin, which indicates the potential limit of flow is an unknown distance further to the north. The gradients to the east are from the main basin to the eastern sub-basin but there is no data beyond this.

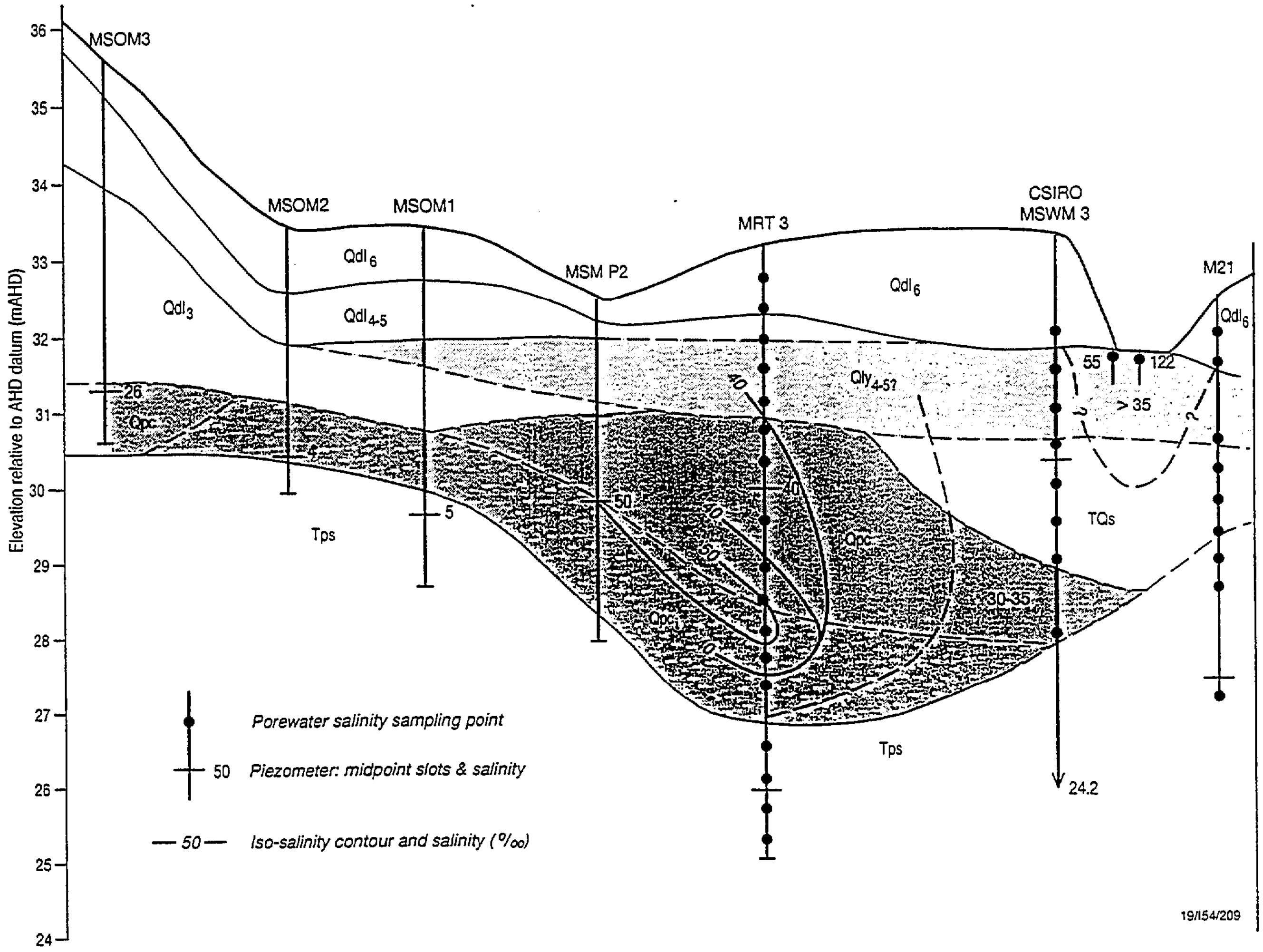

Figure 68. Iso-salinity contours; Mourquong southern margin, transects MSOM - MSWM.

CONCLUSIONS

- Current stratigraphic interpretation of the lithostratigraphy of the disposal basin and surrounds differs slightly from Ferguson *et al.* (1995) as a result of additional lithostratigraphic information on the eastern and southern margins.
- The basal sandy facies of the Blanchetown Clay, the Irymple Sand Member, is thicker and interdigitates laterally with the Blanchetown Clay on the western side. The thickness of the Irymple Sand thins and then thickens again towards the centre of the depression before thinning significantly out to the eastern margin. Blanchetown Clay also thickens dramatically into the basin centre but upper erosional surfaces from Shepparton channel formation and later, Yamba deflation, have created local irregularities within the depression.
- During the early stages of the salina, deflation and probably lake-margin erosion has cut a notch into the Blanchetown Clay on the western lake margin, significantly thinning the effective permeability barrier separating the salina from the horizontally-permeable Irymple Sand to the west.
- Highly permeable sands of the Shepparton Formation infill erosional channels in the upper surface of the Blanchetown Clay; distinctively bedded sand-clay gradations are overbank deposits of these channels; well sorted sands directly overlie the Parilla Sand in the erosional window of the Blanchetown Clay; and the bedded sand-clay facies occur adjacent to this window. The Shepparton sands are most probably extensive across the southern portion of the depression and the northern erosional limit probably coincides with the southern margin of the main salina.
- The floor of the salina is Yamba Formation, comprising three superimposed lacustrine units, which overlie the Blanchetown Clay. These units are distinguished by the interlaying of thin sandier, aeolian deposits which represent a minor accumulation at the end of a deflation event. This sequence is stratiform, and can be correlated northwards beyond the top end of the salina.
- The porosity of the sequence is predominantly interparticle porosity in sandier facies and intercrystalline porosity where displacive diagenetic gypsum has developed in muddier lithofacies. There is a lesser abundance of bioturbation and fracture porosity. The predominant types are by definition interconnected porosity types and create the permeability of the sediment. On this basis, the stratigraphic distribution of porosity can be approximated as permeability distribution.

- The aquifers of the system, the Parilla Sand and the channel sands of the Shepparton Formation, have very high relatively-isotropic permeabilities.
- The Blanchetown Clay has the lowest permeabilities in the sequence, but it has variability stratigraphically and spatially. Spatially the unit is tighter directly under the disposal basin in the central and northern areas. Eastwards, there is a pervasive moderate permeability over a large part of the sequence but a diminution is apparent at the inner margin of the discharge complex with thicker intervals that lack porosity towards the base and into the Irymple Sand. The higher porosity of the Blanchetown Clay in this eastern region is due to more abundant and thicker bands of diagenetic gypsum, with inter crystalline porosity, which may be genetically related to the overlying Shepparton sand aquifer. At the southern margin, the Blanchetown Clay has very low permeability but its distribution is unpredictable. The clay thickens away from the basin, but absent and abutted by sandy Shepparton clays under the salina.
- The Irymple Sand member is characterized in the central region by alternating high and low permeability bands and consequently has high lateral permeability, but with a lower vertical permeability. It forms a significant potential conduit on the western margin, especially where there is only a thin interval of Blanchetown Clay separating it from an incised notch, covered by reworked Woorinen sand on the salina margin.
- The Yamba formation has variable permeability both within the sequence and laterally. Most Yamba units have the full range of permeability.
- The present disposal basin in the centre of the depression has hydrodynamic closure. However, it has several susceptible areas on its margins - the western and eastern edges, and the southern end.
- The western margin to the lake in the central part of the depression has a notch incised into the Blanchetown Clay. This notch is now covered with high permeability sands of Qdl6. The thickness of clay is minimal between the lake and its lateral transition into horizontally-permeable Irymple Sand which lies against the Parilla Sand further to the west. Because the Blanchetown Clay has some intervals of low to moderate porosity, lateral hydraulic connection is highly probable.
- The eastern margin of the lake at standard operating level has closure. But eastwards of the main basin the earlier Yamba units are permeable and directly overlie Shepparton sands.

- In the southwestern corner of the disposal basin, the Blanchetown Clay is absent and consequently highly permeable Shepparton sands overlie the Parilla Sand enabling direct hydrodynamic linkage of surface waters with Parilla Sand.
- Vertical hydraulic gradients in the usually-flooded areas of the disposal basin were downwards and relatively constant during the measurement period. The gradients at the margins were much more variable because they are affected by short-term processes such as rainfall recharge and flooding of the margins during rising disposal basin operating levels.
- Lateral hydraulic heads associated with shallow groundwater systems decrease from the surrounding areas towards the margins of the discharge complex and continue to decrease into the discharge complex before rising towards the centre of the disposal basin. The zone of low heads is broadest to the north, where the margins of the discharge complex and the disposal basin are separated by several hundred meters, intermediate to the south, and narrow to the west, where the discharge complex and disposal basin margins almost coincide. Under the latter circumstances, the minimum temporarily disappears under high rainfall recharge/ disposal basin operating levels.
- Salinity is a reliable indicator of the presence of disposal water in the central and northern areas of the disposal basin. Its effectiveness decreases slightly in those areas of the margins which are only flooded at high basin operating levels and therefore lower salinities. In the southern channel/pond areas, salinity is at best a general indicator of disposal water.
- In the central area of the disposal basin, disposal water has entered the permeable Yamba Formation sediments, probably by downwards advection of the relatively dense brine. In the underlying Blanchetown Clay diffusion has created a transition zone between the high salinity disposal water and the lower salinity natural groundwaters.
- Vertically downwards movement of disposal water is evident in the regularly-flooded disposal basin margins to the north and in the occasionally-flooded eastern arm of the disposal basin. As expected, the salinity of the vertically-infiltrating disposal water is lower in those areas which are only flooded at high basin operating levels.
- Lateral movement of groundwater to the north has reached about 300 m from the disposal basin, which corresponds to a lateral hydraulic conductivity of about 7 m/day. To the west, the distance is about 40 m, probably because the average landwards lateral hydraulic gradient is lower and part of the flowpath is through Blanchetown Clay, which should lower the average hydraulic conductivity. To the south, there are

indications of a halo of disposal water in the groundwaters around the channels and ponds.

- There is evidence that in the centre of the disposal basin the Blanchetown Clay exercises some stratigraphic control on the vertical movement of disposal water into the sediments. However, disposal water occurs at similar elevations throughout most of the area, which suggests that stratigraphic control induced by variations in lateral hydraulic conductivity is weak.
- The potential for leakage of disposal water beyond the margins of the discharge complex depends on the average basin operating levels and the magnitude of the lateral gradients towards the discharge complex from the surrounding areas. The gradients from the surrounding areas are highest near the irrigated areas on the southern margin, intermediate in the western dune, and lowest to the north. Based on the limited information contained in this report, there appears to be little potential for leakage to the south and, probably to the west. The northern areas appear most vulnerable, but it is not clear to what extent. No information on the situation to the east is available from this investigation.

RELATIONSHIPS BETWEEN LITHOSTRATIGRAPHY and SALT MOVEMENT: COMPARISON WITH OTHER DISPOSAL BASINS

CLASSIFICATION

Mourquong swamp occupies a deflation depression within the Blanchetown Clay but with lateral variability, and directly overlies Shepparton and Parilla? Sand directly in the southern area.. Permeability characteristics of a basin are controlled by the enclosing host sequence, and the distribution and type of lining on the basin floor and margins. From the perspective of permeability, the host sequence at Mourquong has a pronounced asymmetry, with a sloping clay over sand contact. Additionally, the lake has variable to moderately thick lacustrine deposits lining the depression. This lining has both impermeable mud and permeable sand but the predominant lithology varies spatially..

The geometric configuration of this relationship of an irregular host sequence, lined with variable mud and sand can be categorized with an existing lithostratigraphic classification (Radke *et al..*, in prep.; Figure 69) as **i C/S, p (C>S)** to **i C/S, p (S>C).** This designation summarizes an irregular sloping contact (**i**) of clay over sand (**C/S**) host sequence, in this case the Blanchetown Clay over Shepparton sand. The lacustrine deposits which line this host are planar (**p**) with spatially changing predominance - mud over sand to sand over mud: **(C>S)** ranges to **(S>C).** Because of the amount of stratigraphic control available the situation is more complex but the error probability is low **(10).**

There has been a need to compare disposal basins throughout the Murray Basin on a standardised basis and this initiated development of a lithostratigraphic (as proxy for permeability). Lithostratigraphic settings of four discharge complexes, Nulla, Scotia, Mourquong and Lake Tutchewop have been used as a basis for developing this basin-wide classification. In a total comparison of basins as shown in Figure 70, Mourquong classifies into a very small category which has moderate to very high potential for leakage.

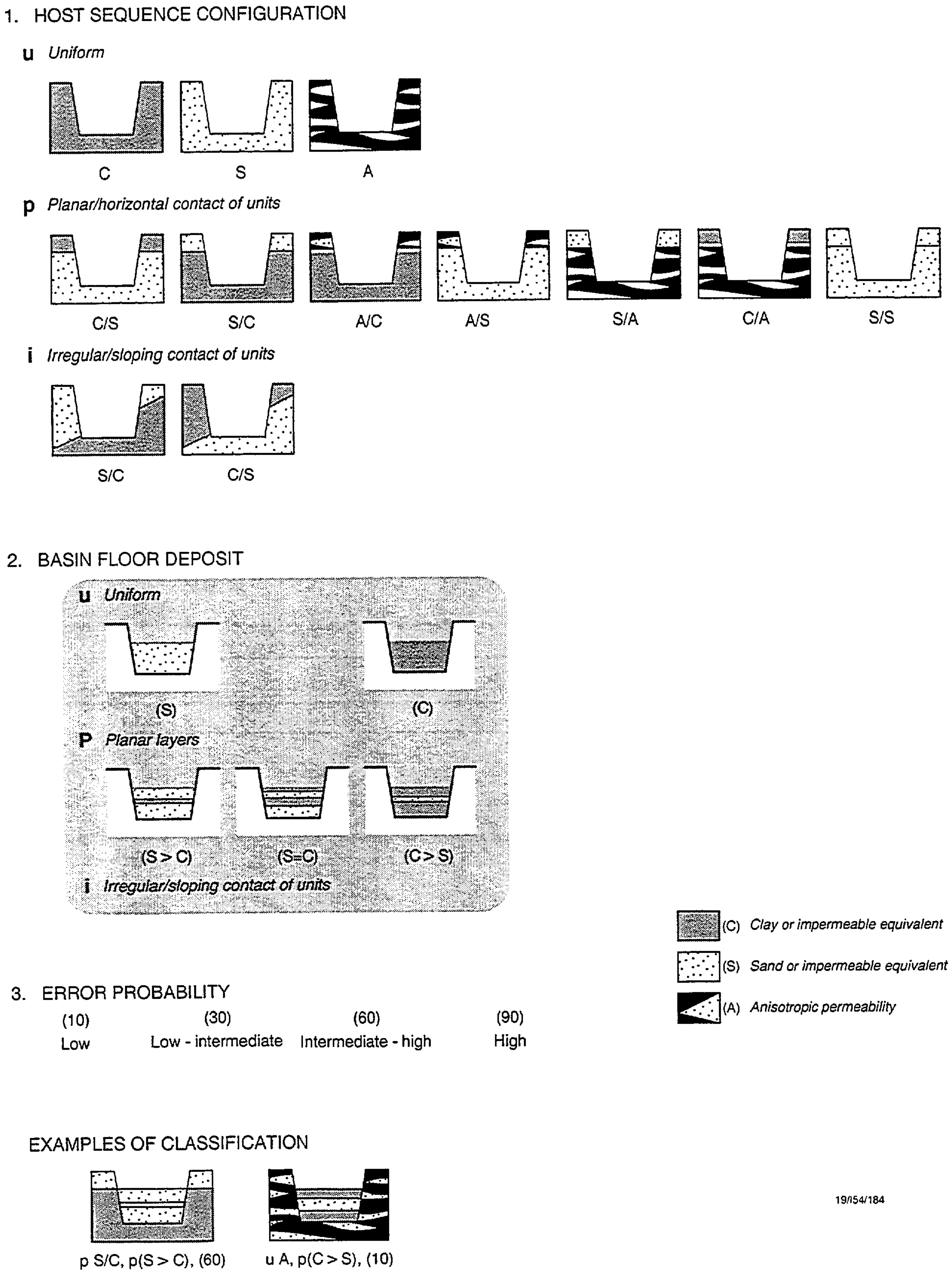

Figure 69. Lithostratigraphic classification of evaporation disposal basins. From Radke *et al.*, in prep.

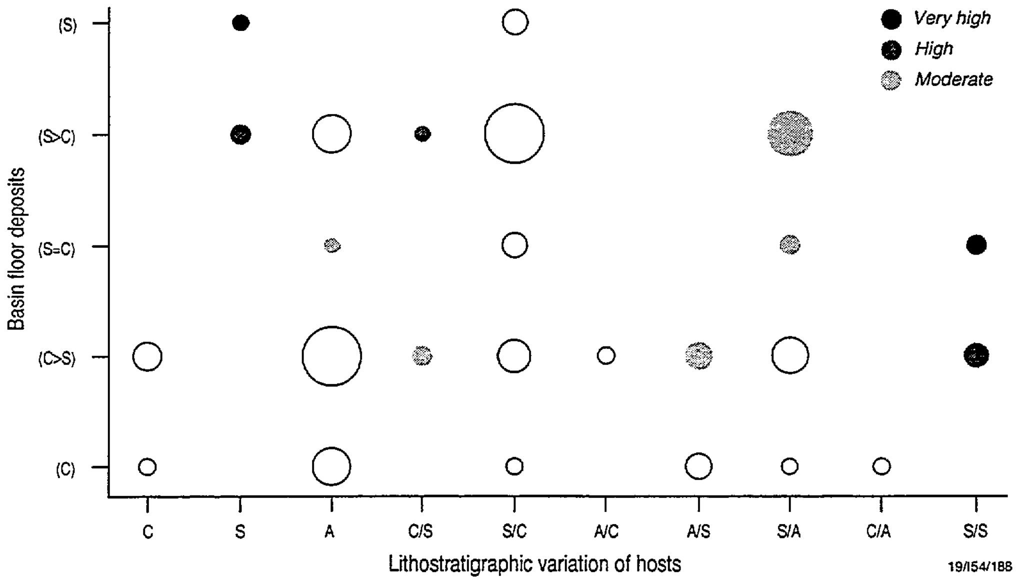

Figure 70. The potential for leakage from disposal basins of the Murray Basin. From Radke *et al.*, in prep.

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APPENDIX I

METHODS

Drilling Techniques and Sediment Storage

The following procedures were designed to sample lacustrine clays and sandy clays in playas and salt lakes. The drilling equipment was readily dismantled and transported between sites with vehicle access to the lake shore, and then either hand carried or ferried by hovercraft. Lake surface conditions which ranged from dry, through muddy, to surface water less than 0.5 m deep have been successfully drilled. Existing techniques would have to be modified to cope with greater water depths.

The drilling method employed is a variation of the penetrometer technique in which steel tubes (5 cm diameter; 0.5 m long) are hammered into the sediments to 0.4 m depth using a drop hammer. The hammer is operated by a motorised hoist and mounted on an aluminium tripod derrick. The tripod accommodates lifting tools in 3m sections.

In lakes where surface conditions were wet or muddy a 20 cm diameter PVC tube was used to protect the drill-hole from influx of surface water. A steel tube was then hammered into the lake sediments, the uppermost wet, unconsolidated sediment removed, and the core tube extracted. A lightweight portable auger was then used to enlarge the core hole to 10 cm diameter The next steel tube attached to a drill rod was inserted and hammered down a further 0.4 m. This alternating hammering and augering procedure was repeated to the limits of the ability of the equipment to retrieve the cores, or until changes in the nature of the sediment made the technique inappropriate.

Holes up to 11 m and typically 6 m deep were cored by this method. The degree of success is a function of the clay content of the sediments. In the Murray Basin, the Blanchetown Clay and the Shepparton Formation were readily cored, and there was some success with the clayey sands which occur at the transition from the lacustrine clays to the top of the Parilla Sand. Water-saturated aeolian-derived sands, such as those which occur interspersed with lacustrine sediments can be cored if they are less than about 0.5m thick.

Cores were sealed and transported in stainless steel core tubes. Clay sediments were extruded either on site or in the laboratory using a specially designed hydraulic extruder. Cores containing sandy sediments could not be extruded and the tubes were cut lengthwise. The cores were extruded onto lengthwise-cut 8 cm PVC tubing and split. Each section was then sealed into an evacuated plastic sleeve to provide medium-term preservation against dehydration.

Porewater Extraction and Analyses

To minimise the possibility of contamination by 'float', sediment samples for porewater analyses were obtained from the bottom 0.1m of each 0.5m tube. Salinity was determined by optical refractometry using a portion of small volume of porewater (typically ≤1 ml total) extracted from the sediments using a Manheim press or, occasionally for sandy sediments, by centrifugation.

Surface water samples were filtered through a disposable 0.45µ filter, and an aliquot (usually 10 ml) pipetted into a separate container for determination of alkalinity. A portion of the sample for determination of cations was preserved by addition of a small quantity of concentrated nitric acid.

Analyses of cations was by ICP and analysis of anions was by ion chromatography.

Installation of Piezometers

Piezometers used for water sampling and the determination of standing water levels in shallow holes were 8 cm - diameter PVC tubing, slotted over 1m in length. Where possible, the piezometers were cemented into place.

Piezometer Measurements

The standing water level and a two or three point salinity profile down the water column in the piezometer were measured and the salinity averaged if necessary. The density of the water in the piezometers was calculated from the salinity assuming a temperature of 20°C.

Calculation of Hydraulic Heads

Lateral and vertical hydraulic heads and gradients were determined separately using the concepts (Figure **62**) developed by Lusczynski (1961) and Lusczynski and Swarenski (1966). This concept implies that lateral gradients can be determined from freshwater heads in piezometers screened to the same depth relative to a datum, and that vertical gradients can be obtained from environmental water heads measured along a vertical.

Application of the Lusczynski and Swarenski (1966) concepts to the hydrodynamics of groundwater discharge complexes has been described by Macumber (1991). The lateral heads are freshwater heads, calculated from the equation:

$$\rho_f H_{if} = \rho_i H_{ip} - Z_i(\rho_i - \rho_f)$$

The vertical heads are environmental water heads, calculated from the equation:

$$\rho_f H_{in} = \rho_i H_{ip} - Z_i(\rho_i - \rho_a) - Z_r(\rho_a - \rho_f)$$

H_{if} is the freshwater head at the point 'i' in groundwater of variable density

H_{ip} is the pointwater head at 'i'

Z_i is the elevation of 'i', with measurements being positive upwards

ρ_i is the density of water at point 'i'

ρ_f is the density of fresh water

ρ_a is the average density of water between elevations Z_r and 'i'

H_{in} is the environmental water head at 'i'

Z_r is the elevation of the reference point from which the average density of water to 'i' is determined, and above which the water is fresh

In the calculations of H_{in}, Z_r was taken as equal to the top of the zone of saturation. Because this measurement was not known at most locations, the SWL in the topmost piezometer was used instead. The value for the freshwater density was taken as 1.00 g/cm^3. Macumber (1991) showed that, for brines beneath Lake Tyrrell brines, a change of the freshwater density from 1.03 to 1.00 g/cm^3 made less than 4 cm difference to the value of H_{in}.

The lateral and vertical velocities were calculated from the equations:

$$v_x = -K_x [\delta H_{if}/\delta x]$$

$$v_z = -Kz[\delta H_{in}/\delta z]$$

For this investigation, the horizontal gradients were determined from piezometers set as close as possible to a constant elevation, and the vertical gradients from nests of piezometers at different depths at the same location. Under field conditions, installation of the piezometers to constant depth was not always feasible and the freshwater head at the designated depth was approximated by interpolation or extrapolation assuming a linear change in pressure with depth between piezometers. Care was taken to use interpolated data only from piezometers in the same aquifer (e.g. the Parilla Sand) or the same aquitard (e.g. the Shepparton Formation). These interpolated or extrapolated pressures were then converted to freshwater heads. For locations where only one piezometer had been installed, it was assumed that $P_{actual} = 0$ at a depth equal to the SWL in the piezometer, and the interpolations and extrapolations made on this basis.

Logging

Core preparation

Core was stored under dark coldroom conditions in air-evacuated sealed plastic tubes. Where possible core was extruded from the steel core tubes using a hydraulic press, into PVC half tubes and cut with a putty knife. If the sediment was predominantly sand, or the core old and the internal steel partly corroded, the core tube and sediment was cut with a power jigsaw and the core manually transferred to PVC half tubes. The homogenised cut surface was cleaned by a variety of methods dependant on the sediment type, stiffness, induration, or desiccation; cutting or scraping with a putty knife, or brushing with a soft bristle brush.

Documentation

Where possible core was photographed immediately in colour. Methodical observation of the sediment, observation of sedimentary structures, and measurement of clastic sediment particle size used a Wild M5 field stereomicroscope with calibrated graticule. Particle-size assessment usually involved disaggregation of a small fraction in a watch glass using distilled water and dilute HCl where necessary. The mineralogical composition was assessed visually at this stage. Where clay composition or an unidentified component required identification, X-ray diffraction samples were taken. Colour assessment was always made of wet surfaces, by comparison with colour tiles of the Rock Colour Chart, and recorded using the Munsell system.

Information was recorded on graphic log and notations as described by Radke (1992). Porosity type and qualitative abundance was assessed visually.

The scale of logging was generally at 1:2 Scotia fully cored holes.

In the deeper, 60 metre stratigraphic holes, coring was only undertaken in the uppermost 5 metres, and cuttings taken in each subsequent metre to the bottom of the hole. These holes were logged at 1:200 scale.

Logging Reduction

With the detailed logging at 1:2, it was necessary to reduce these logs for generalisations to be made on the lithostratigraphy. The condensing process was based on a 25 cm interval in which all information was reduced to one statement per category and recorded at 1:33. Lithologies in this reduction were recorded in histogram format, and the reliability of each increment qualified by a core-recovery assessment.

Core Sampling

Where minerals could not be identified, XRD samples were taken, either as a segment of core for clays and fine-grained carbonates, or individual particles hand-picked in the case of trace components.

Petrographic samples were taken of characteristic sediments, or unusual structures.

The Mourquong Discharge Complex and Saline Water Disposal Basin: Hydrodynamics, Hydrochemistry & Lithostratigraphy

Compiled by J.Ferguson and B.M. Radke
AGSO, PO Box 378 Canberra, 2601

AGSO and CSIRO Division of Water Resources contribution to the NRMS-funded project:
"Managing Disposal Basins to Maximise their Usefulness for Salt Storage"

APPENDIX

Version: November 1995

MOURQUONG DISCHARGE COMPLEX

LOCATIONS

Figure A1. Location of drillhole/piezometer sites on transect PS (Parilla Sand) which is orientated NW-SE across the Mourquong Discharge Complex and environs.

Figure A2. Location of of drillhole/piezometer sites on transect MWM (Mourquong Western Margin) on the western side of the disposal basin.

Figure A3. Location of drillhole/piezometer sites on transect MEM (Mourquong Eastern Margin on the eastern side of the disposal basin.

Figure A4. Location of drillhole/piezometer sites on transect MNM on the northern side of the disposal basin.

Figure A5. Location of drillhole/piezometer sites on transects MSOM (Mourquong Southern Orchard Margin), MRT (Mourquong River Transect), MSWM (Mourquong South Western Margin) and MSM (Mourquong Southern Margin) to the south of the disposal basin.

SURVEY DATA and CROSS-SECTIONS

Table A1. Survey data, Mourquong Discharge Complex and environs. Transect PS.

Figure A6. Topography and drillhole/piezometer sites. Mourquong Discharge Complex and environs, transect PS.

Table A2. Survey data, Mourquong western margin . Transect MWM

• HYDRAULIC HEADS and GRADIENTS

Figure A41. Hydraulic conductivities. Mourquong western margin. Transect MWT.

- **DRILLHOLE LOGS**

Mourquong MEM-1
Mourquong MEM-2
Mourquong MEM-3
Mourquong MSWM-2
Mourquong MSWM-3

- **STRATIGRAPHIC CROSS-SECTIONS**

19/154/153

Figure A1 Location of drillhole/piezometer sites on Transect PS (Parilla Sand); orientated NW-SE across the Mourquong Discharge Complex and environs

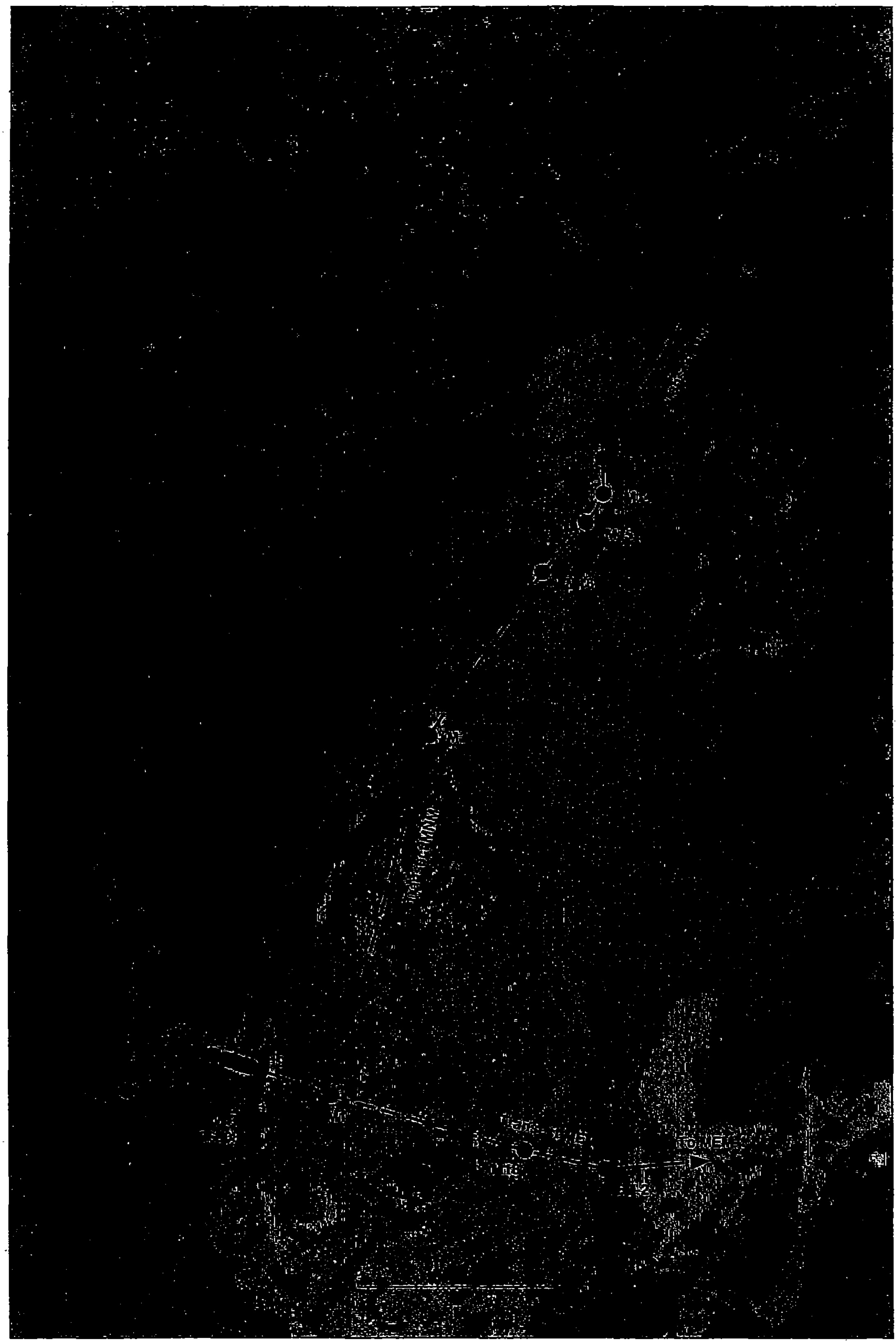

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Figure A2 Location of drillhole/piezometer sites on Transect MWM (Mourquong Western Margin) on the western side of the disposal basin

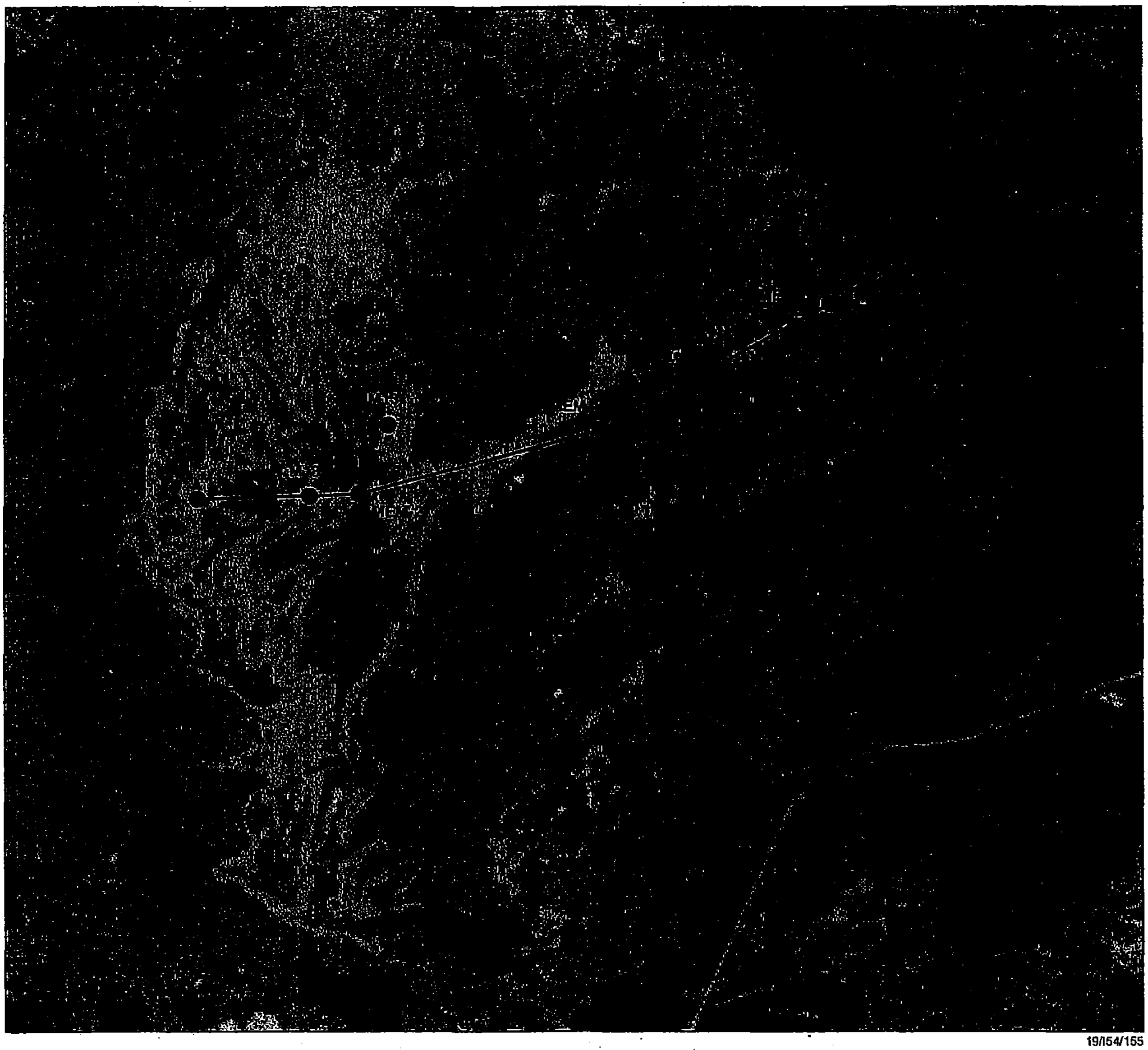

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Figure A3 Location of drillhole/piezometer sites on Transect MEM (Mourquong Eastern Margin) on the eastern side of the disposal basin

19/154/156

Figure A4 Location of drillhole/piezometer sites on Transect MNM (Mourquong Northern Margin) on the northern side of the disposal basin

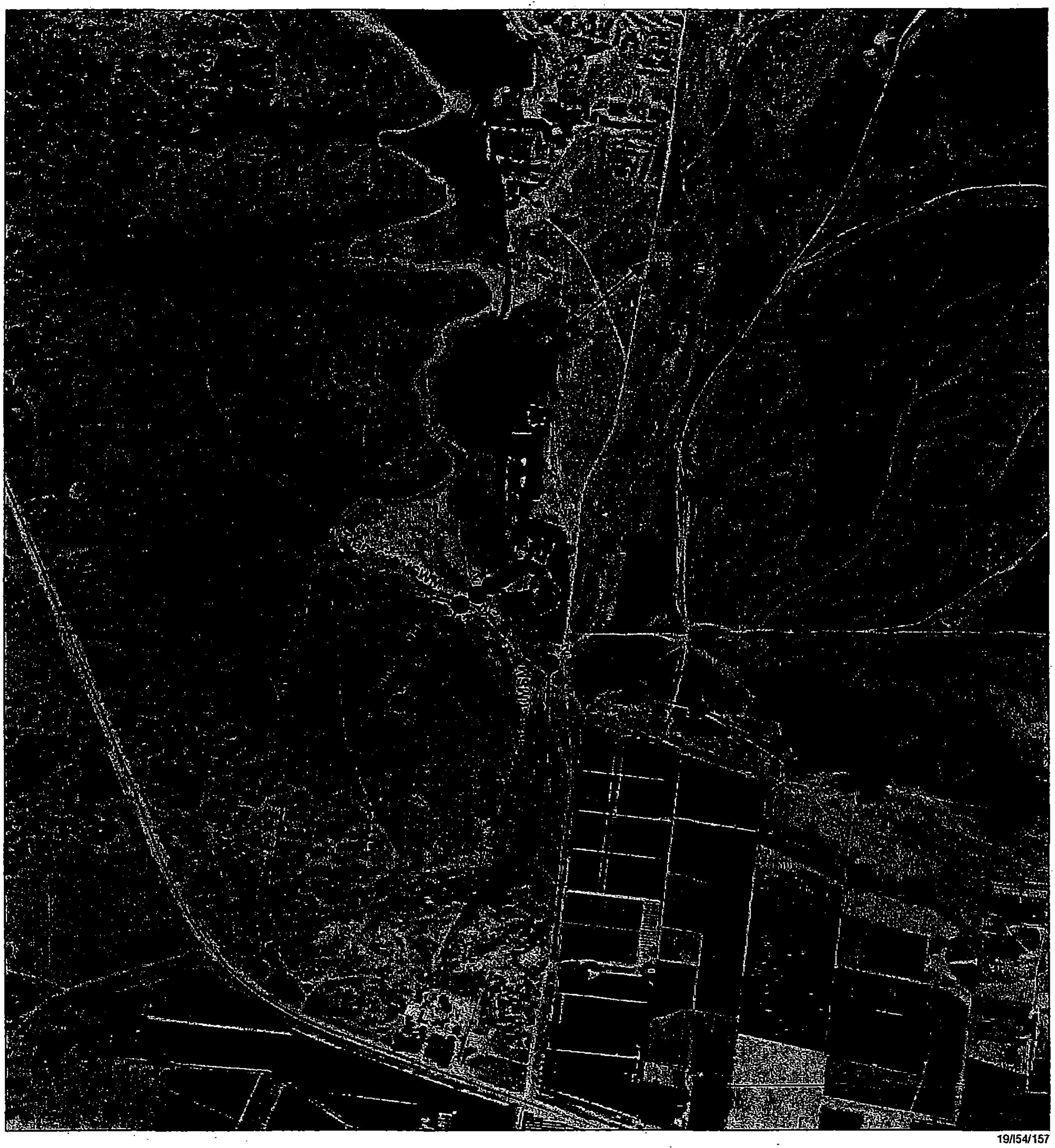

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Figure A5 Location of drillhole/piezometer sites on Transects MSOM (Mourquong Southern Orchard Margin), MRT (Mourquong River Transect), MSWM (Mourquong South Western Margin) and MSM (Mourquong Southern Margin) in the south of the disposal basin

Figure A6. Cross-section of Transect PS

Not yet available

Table A1. Survey Data, Mourquong Parilla Sand Transect (PS)

Site	Depth slots relative to GL	Distance from MEM-1 (m)	GL relative to MEM-1 (m)	GL mAHD	Top Stake to GL (m)	Piezometer Slots Range mAHD	Midpoint Slots mAHD	Distance from MEM-1 m
MSWM-6 Check if 7.604 is GL -GL; M21 to MSWM-6				40.01				about -4430
Survey M21toMSWM-6 is 922m								
MSWM-6; Hole 1; 15m clay	49 to 51					-9 to -11	-10	
MSWM-6; Hole 2	37 to 39					1 to 3	2	
MSWM-6: Hole 3	18 to 20					20 to 22	21	
M21 (EGG)				32.41		26.95 to 27.95	27.45	about -3676
M21; Hole 1; 0-3m clay	54 to 56					-21.5 to -23.5	-22.5	
M21; Hole 2	45 to 47					-12.5 to -14.5	-13.5	
M21; Hole 3	34 to 36					-1.5 to -3.5	-2.5	
M21; Hole 4	26.5 to 28.5					4 to 6	5	
M21; Hole 5	18.5 to 20.5					12 to 14	13	
MEM-4; Hole 1	54 to 56							about -1668
MEM-4; Hole 2	39 to 41							
MEM 4; Hole 3	21.5 to 23.5							
MEM-1; Hole 1	53.5 to 55.5					-19.75 to -21.75	-20.75	
MEM-1: Hole 2	42 to 44m					-8.25 to -10.25	-9.25	
MEM-1; Hole 3	29 to 31					2.75 to 4.75	3.75	
MEM-1; Hole 4	24.5 to 26.5					7.25 to 9.25	8.25	
MEM-1; Hole 5	17 to 19					14.75 to 16.75	15.75	
MEM-1; CSIRO		0	0	33.75		27.7 to 28.7	28.2	0
		35	0.118	33.868				
		65	0.548	34.298				
		120	1.688	35.438				
		180	2.885	36.635				
		230	3.74	37.49				
		295	2.76	36.51				
		375	-1.667	32.083				
		580	-2.272	31.478				
		630	-1.432	32.318				
		650	0.864	34.614				
		680	1.297	35.047				
		700	-1.262	32.488				
		730	-2.048	31.702				
		760	-1.933	31.817				
		790	-0.769	32.981				
		820	0.451	34.201				
		870	0.489	34.239				
		930	-0.288	33.462				
		970	0.484	34.234				
		1020	0.879	34.629				
		1070	0.204	33.954				
		1150	1.234	34.984				
		1200	2.245	35.995				
		1280	2.164	35.914				
		1320	1.164	34.914				
		1510	0.074	33.824				
		1620	2.379	36.129				
		1740	1.104	34.854				
		1760	-0.126	33.624				
		1840	-1.765	31.965				
MEM-3; CSIRO				32.76		26.4 to 27.4	27.9	2055
MEM-3; Hole 1	49 to 51			assume 32.5		-16.5 to -18.5	-17.5	
MEM-3: Hole 2	36.5 to 38.5			assume 32.5		-4 to -6	-5	
MEM-3; Hole 3	19 to 21			assume 32.5		11.5 to 13.5	12.5	
MEM-5; Hole 1	50 to 52							about 4112
MEM-5; Hole 2	36 to 38							
MEM-5; Hole 3	18 to 20							
Tapio; Hole 1; 3-32 clay	67 to 69							about 10464
Tapio; Hole 2	55 to 57							
Tapio; Hole 3	36 to 38							

Table A2. Survey Data, Mourquong Western Margin(MWM)

Site		Top stake mAHD	Top Casing mAHD	GL mAHD	Top Stake to GL (m)	Piezometer Slots Range mAHD	Midpoint Slots mAHD	Distance from M20 m	
M20			45.63	44.56		open at base	31.9	0	
M12			41	40.05		31 to 32	31.5	189	
M9			39.39	38.39		30.05 to 31.05	30.55	245	
M10			37.81	37.29		30.08 to 31.08	30.58	314	
M7			35.87	34.87		31.35 to 32.35	31.85	377	
M7A			35.66	32.6		26.15 to 27.15	26.65	377	
M8			34.825	33.825		30.85 to 31.85	31.35	408	
DWR 36908/2			34.73	33.55		-16.4 to -22.4	-19.4	410	
DWR 36908/1			34.74	33.55		-2.25 to 3.75	0.75	411	
DWR 36908/3			34.74	33.55		-36.4 to -42.4	-39.4	413.5	
DWR1011			33.66	33.44		19.8 to 20.8(assumed)	20.3	418	
M5A			33.82	32		31.35 to 31.85	31.6	428	
M4			33.72	32.72		29.9 to 30.5	30.2	451	
M4A			33.7	32.75		31.25 to 31.75	31.5	451	
M4B			33.72	32.75		24.5 to 25.5	25	451	
M4C			33.69	32.75		28.9 TO 29.4	29.15	451	
M11C			33.26	32.26		29.25 TO 29.75	29.5		
M11			33.57	32.15		27.55 to 27.95	27.75	460	
M11A			33.6	32.25		31.65 to 32.15	31.9	460	
M19			33.61	32.58		31.8 TO 32.3	32.05	566	
M1			32.31	31.76		20.55 to 21.05	20.8	774	
			32.94 (post Aug 92)						
M1A			32.83	31.83		28.25 to 28.75	28.5	774	
			33.17 (post Aug 92)						
M1B			32.34	31.94		29.9 to 31.1	31	774	
			33.06 (post Aug 92)						

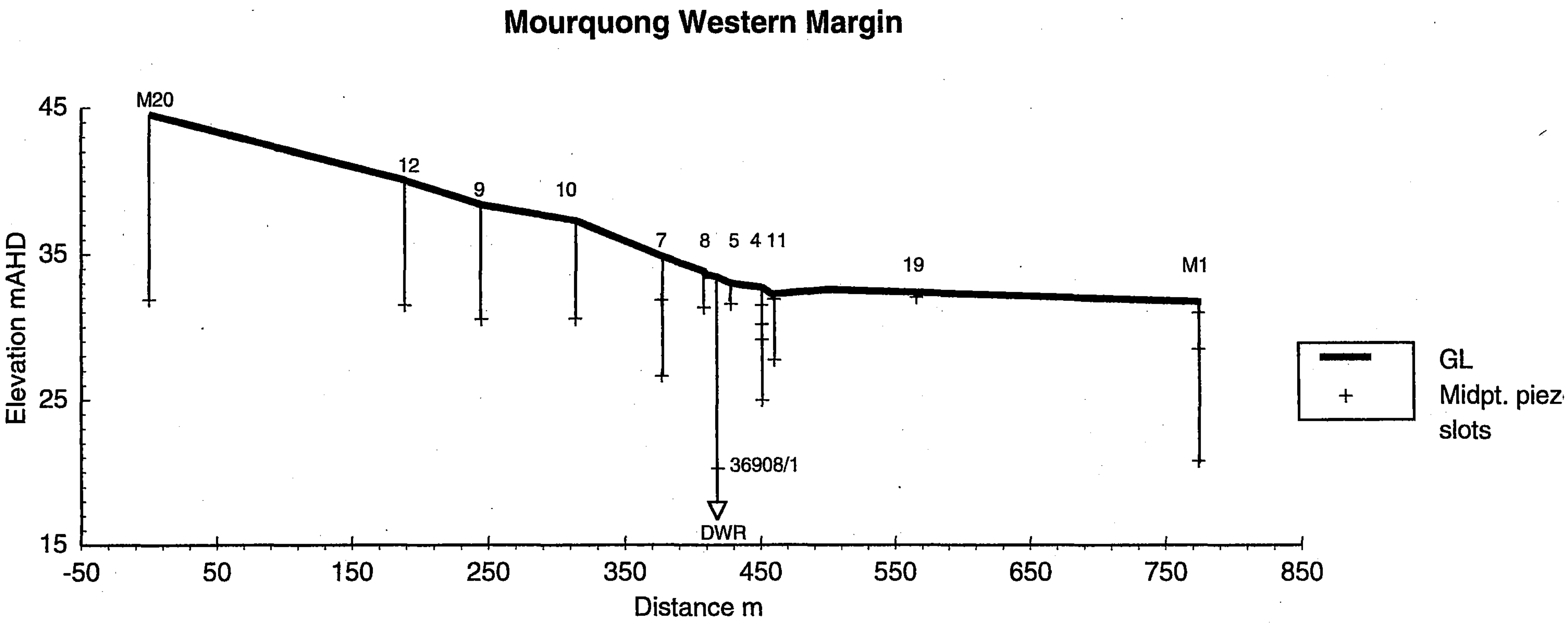


Figure A7. Topography and drillhole/piezometer sites. Mourquong western margin, transect MWM.

Table A3. Survey Data, Mourquong Eastern Margin(MEM)

Site		Top stake mAHD	Top Casing mAHD	GL mAHD	Top Stake to GL (m)	Piezometer Slots Range mAHD	Midpoint Slots mAHD	Distance from M1 m
M1			32.31	31.76		20.55 to 21.05	20.8	0
			32.94 (post Aug 92)					
M1A			32.83	31.83		28.25 to 28.75	28.5	0
			33.17 (post Aug 92)					
M1B			32.34	31.94		29.9 to 31.1	31	0
			33.06 (post Aug 92)					
M18B			32.93			26.15 to 27.15	26.65	ca.900
M18A			33.15			30.15 to 31.15	30.65	ca.900
			32.7 (after 1 March 95)					
M13			32.61			27.25 to 28.25	27.75	
MEM-2A; CSIRO			37.04	36.13		31 to 31.5	31.25	1194
MEM-2B; CSIRO			37.17	36.13		26.2 to 27.2	26.7	1194
				31.925				1254
				32.494				1484
				32.544				1964
				31.84				2079
				32.27				2164
				33.785				2224
				35.301				2234
				35.831				2261
				35.101				2309
				34.604				2314
				34.626				2334
				35.106				2359
				36.614				2379
				34.751				2454
				33.411				2474
				33.496				2509
				33.851				2559
				34.481				2594
				34.426				2609
				34.126				2629
MEM-1; CSIRO			34.19 (before damage)	33.75		27.7 to 28.7	28.2	2660
MEM-3; CSIRO	Survey MEM-1 to MEM-3 to be checked		33.89	32.76		27.4 to 28.4	27.9	

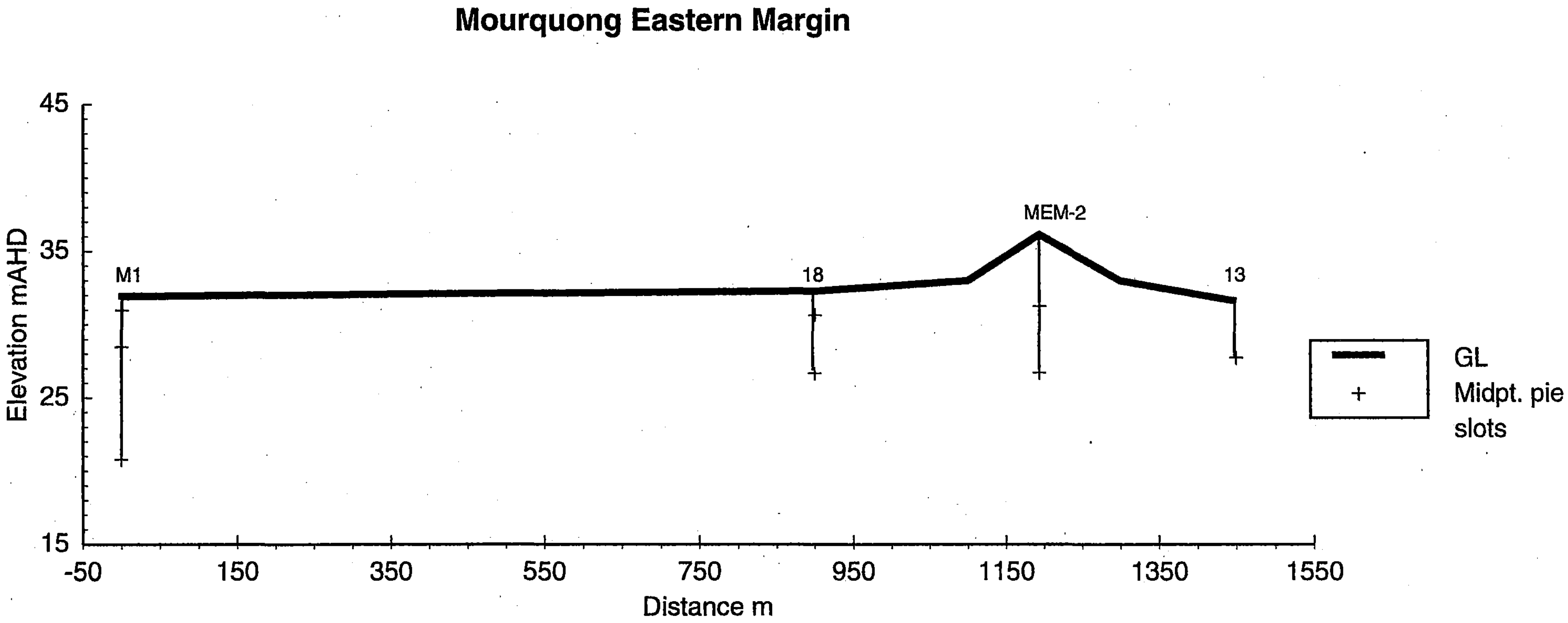


Figure A8. Topography and drillhole/piezometer sites. Mourquong eastern margin, transect MEM.

Table A4. Survey Data, Mourquong Northern Margin(MNM)

Site		Top stake mAHD	Top Casing mAHD	GL mAHD	Top Stake to GL (m)	Piezometer Slots Range mAHD	Midpoint Slots mAHD	Distance from M1 m
M2			32.36	32				
M1			32.31	31.76		20.55 to 21.05	20.8	
			32.94 (post Aug 92)					
M1A			32.83	31.83		28.25 to 28.75	28.5	
			33.17 (post Aug 92)					
M1B			32.34	31.94		29.9 to 31.1	31	
			33.06 (post Aug 92)					
M3			32.88	31.81		24.25 to 25.25	24.75	117
			33.08(after Aug 92)					
M3A			32.79	31.67		31.65 to 31.85	31.75	117
M16A			32.64			30.15 to 31.15	30.65	199
M16B			32.975	32.21		26.95 to 27.95	27.45	199
M15A			33.52			30.5 to 31.5	31	
M15B			33.4	32.47		28 to 29	28.5	ca. 2010
M14			33.8	32.59		26.0 to 27.0	26.5	218
M17A			33.36			30.3 to 31.3	30.8	255
M17B			33.11	32.34		26.1 to 27.1	26.6	255
M22			36.85	36.67		31.4 to 31.9	31.65	308
M23			39.01	38.58		31.6 to 32.1	31.85	325

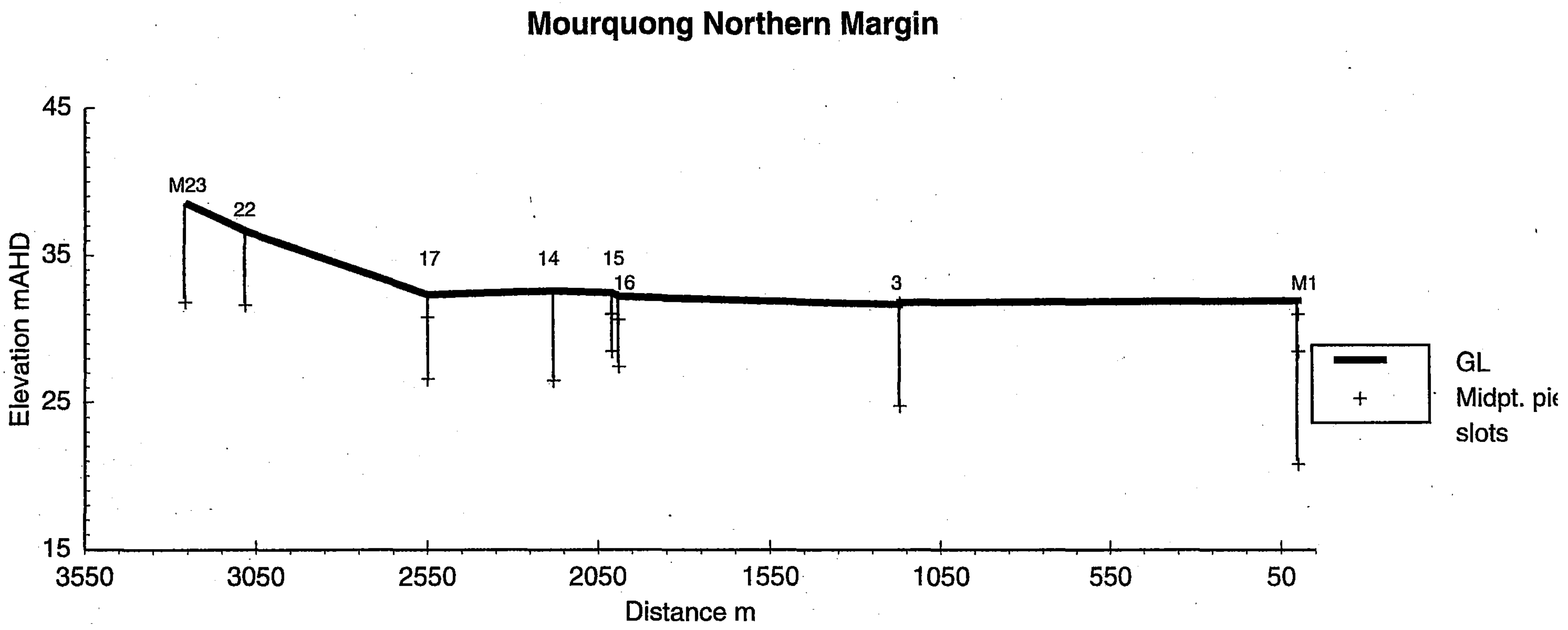


Figure A9. Topography and drillhole/piezometer sites. Mourquong northern margin, transect MNM.

Table A5. Survey Data, Mourquong River Transect (MRT)

Site	Top stake mAHD	Top Casing mAHD	GL mAHD	Top Stake to GL (m)	Piezometer Slots Range mAHD	Midpoint Slots mAHD	Distance from MRT-BM m
S-Pond (In pond)	32.41						-5
BM (lake)	32.67		31.83	34.222			0
Piezometer MRT-BM		32.75	31.85		29.85 to 30.35	30.1	0
Piezometer MRT-BM-A		32.79	31.79		29.8 to 30.3	30.05	0
S1 (lake)	32.47		31.79	34.062			65.2
Piezometer MRT1		32.96	31.78		30 to 30.5	30.25	44
S2 (lake)	32.63	32.54	31.79	34.223			122.8
Piezometer MRT-2		32.53	31.77		28.5 to 29.0	28.75	122.8
Piezometer MRT-2A		32.61	31.77		30.3 to 30.8	30.55	122.8
Piezometer MRT-2B		32.91	31.77		29.1 to 29.6	29.35	122.8
Piezometer MRT-2/3	33.38	32.75	32.08		27.25 to 27.75	27.5	158.8
Piezometer MRT-2/3A		32.77	32.08		30.4 to 30.9	30.65	158.8
Piezometer MRT-2/3B		33.16	32.09		29.2 to 29.7	29.45	158.8
S3 (base of dune)	34.07		33.06	34.39			183.6
Piezometer MRT-3		33.96	33		25.7 to 26.2	25.95	183.6
Piezometer MRT-3A		33.63	32.92		29.7 to 30.2		183.6
Piezometer MRT-3B		33.48	32.95		29.75 to 30.25	30	183.6
S4	35.11		34.24				209
Piezometer MRT-4		34.63	34.16		31.9 to 32.4	32.15	209
S5	37.24		36.09				271.9
S6	38.14		37.1				326.4
Piezometer MRT-6		36.74	36.03		29.2 to 29.7	29.45	308

Water level in pond: 6 March 95, 31.81mAHD

MRT-S6: top clay about 32mAHD; base lower than 29.7mAHD: (samples at 5.2,6.2 and 7.4mGL)

Effluent Drain : 34,000 mg/L
MRT-Pond, 6 March 95: 34,000 mg/L

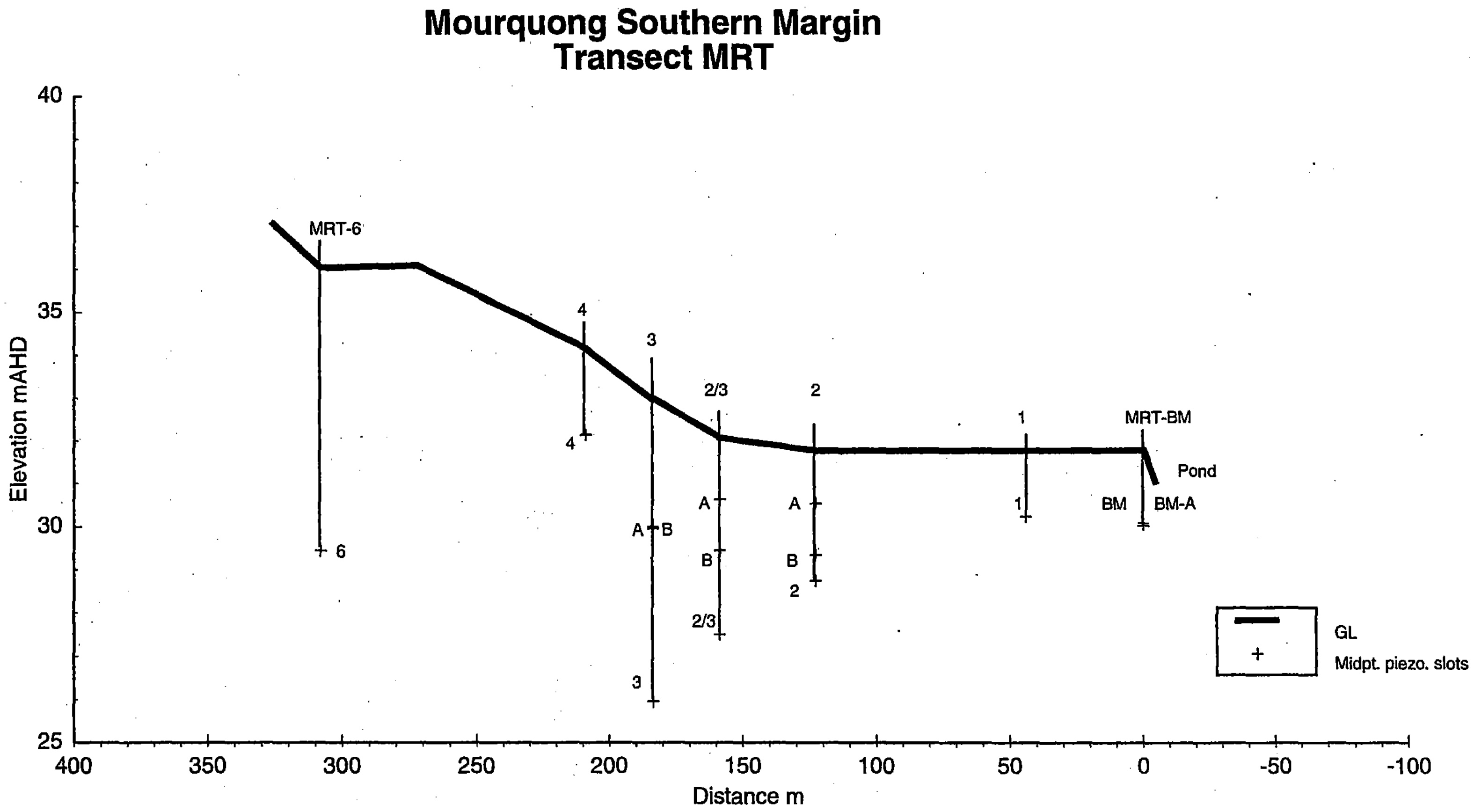


Figure A10. Topography and drillhole/piezometer sites, Mourquong southern margin, transect MRT

Table A6. Survey Data, Mourquong Southern Margin (MSM)								
Site		**Top Casing mAHD**	**GL mAHD**	**Top Stake mA**	**Piezometer Slots**	**Midpoint Slots**	**Distance from MSM-2**	
					Range mAHD	**mAHD**	**m**	
RWC 35		33.56						
MSM-P2		33.38	32.382		probably 29.4 to 30.4	probably 29.9	0	
			33.38					
track			34.201				107.5	
			33.38					
MSM-S1			36.322	37.164				
MSM-P1		36.56	36.399		30.6 to 31.6	31.1	232	

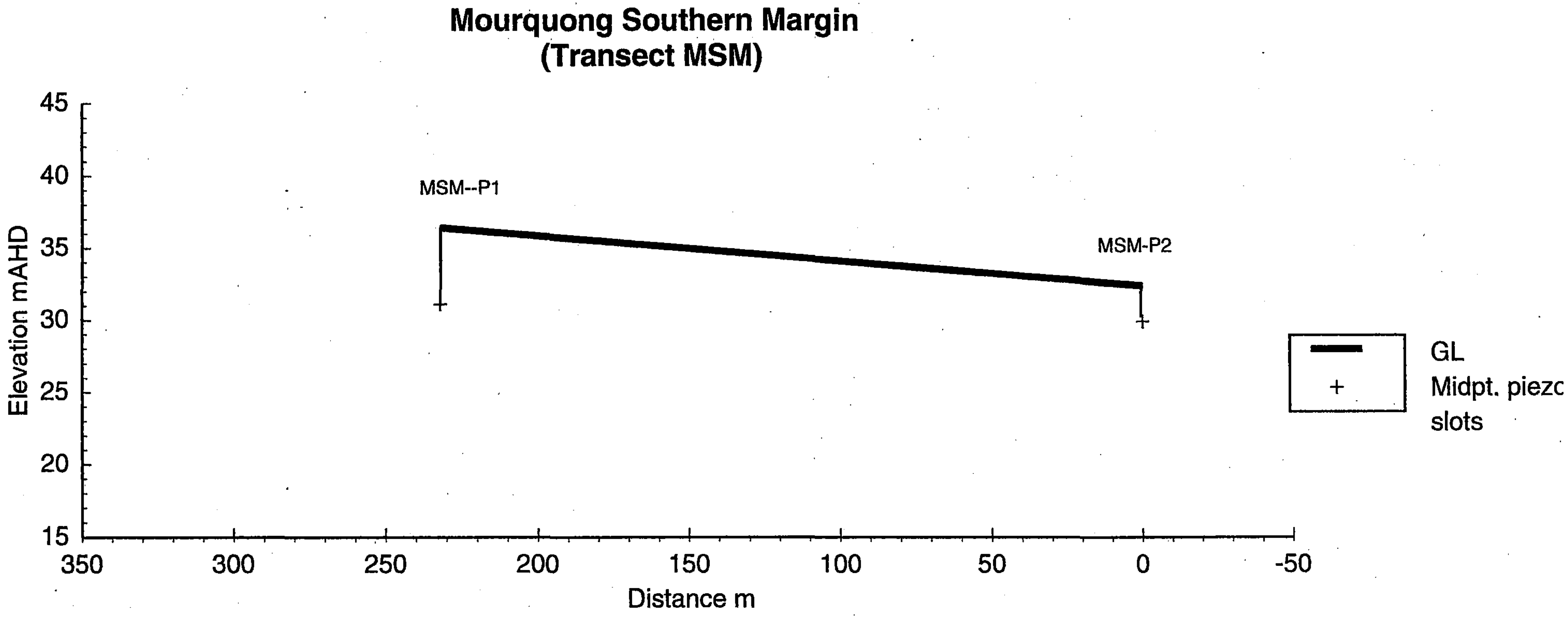


Figure A11. Topography and drillhole/piezometer sites. Mourquong southern margin, transect MSM.

Table A7. Survey Data, Mourquong Southern Orchard Margin (MSOM) and South Western Margin Transects

Site		Top stake mAHD	Top Casing mAHD	GL mAHD	Piezometer Slots Range mAHD	Midpoint Slots mAHD	Distance from MRT-3 m		Sandy clay	Clay	
M21 (0.5m sump;0.5m slots)		33.43	33.31	32.41	27.2 to 27.7	27.45	-388				
MSMW-CSIRO Piezo Blue Tape			34.71	33.2			243				
MSMW-CSIRO Piezo, highest PVC			34.82	33.2			244				
MRT-S3 (base of dune)		34.07		33.06		25.95	0				
MSOM-1			34.86	33.36	28.4 to 29.9	29.65					
MSOM-2			34.16	33.32	30.2 to 30.7	30.45					
MSOM-3			36.52	35.62	31.1 to 31.6	31.35					
MSOM-4				35.13					32.28 to 32.1	32.13 to	
MSOM-5				35.17					32.67 to 32.3	32.37 to	
MSOM-6				35.57					32.57 to 32.2	32.27 to	
MSOM-7				35.85					33.5 to 32.75	32.75 to 32.05	
MSOM-8				34.83					31.98 to 31.5	31.53 to	

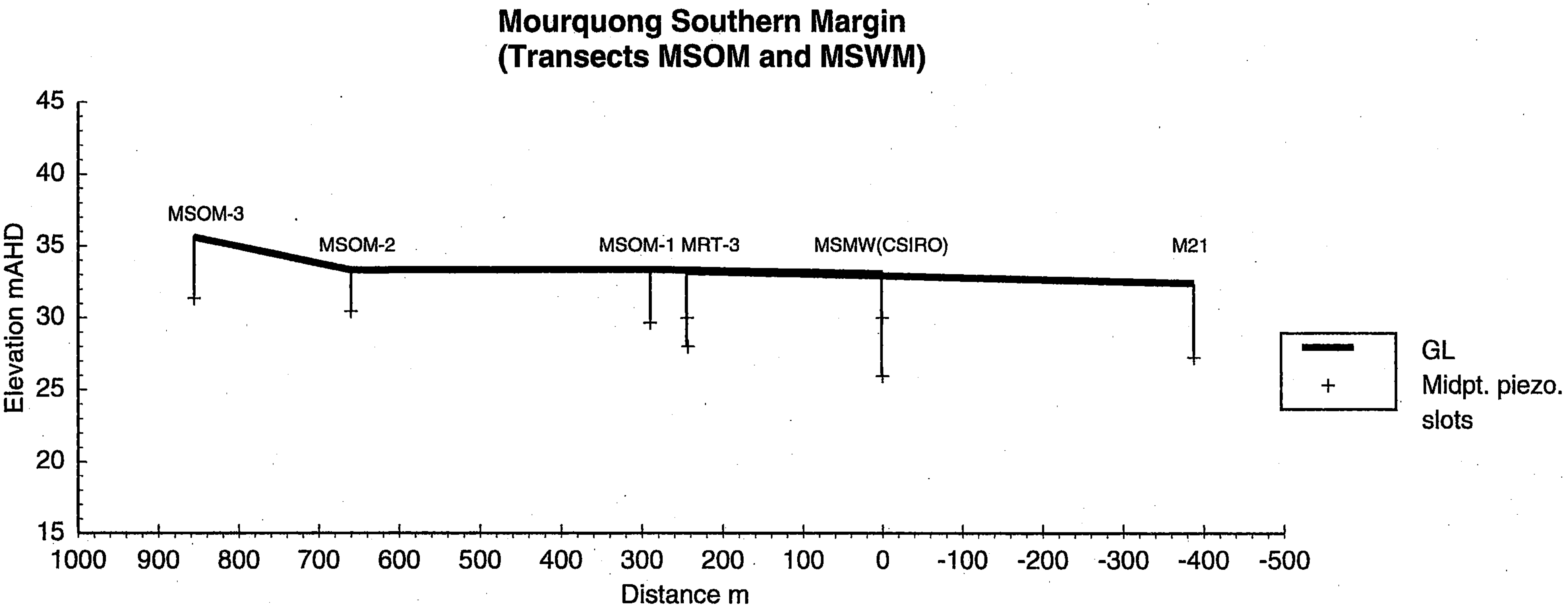


Figure A12. Topography and drillhole/piezometer sites. Mourquong southern margin, transects MSOM and MSWM

Table A8. Chemistry of Surface Water; Mourquong Disposal Basin

Description	*Depth below GL m*	*Average Dept below GL*	*Elevation mAHD*	*Salinity mg/L*	*Lab. reference*	*Sr mg/L*	*Li mg/L*	*Ca mg/L*	*Mg mg/L*	*Na mg/L*	*K mg/L*	*Br mg/L*	*Cl mg/L*	*SO4 mg/L*
OUT-1 CSIRO March 95				35000	950278	8.32	0.258	380	1590	10300	106	42.6	17800	3040
TRAN-1 CSIRO March 95				34000	950279	8.2	0.249	350	1500	9600	102	40.6	16700	2810
TRAN-2 CSIRO March 95				36000	950280	7.2	0.252	370	1500	9800	100	42.3	17100	2910
TRAN-3 CSIRO March 95				35000	950281	8.3	0.252	463	1910	12300	103	52.7	21500	3730
TRAN-4 CSIRO March 95				35000	950282	7.51	0.287	370	1510	9750	102	41.2	16600	2850
TRAN-5 CSIRO March 95				35000	950283	8.08	0.249	380	1500	9800	100	40.6	16500	2900
TRAN-6 CSIRO March 95				45000	950284	9.8	0.395	500	1980	13000	150	51.4	22100	3990
TRAN-7 CSIRO March 95				155000	950285	10.32	2.6	470	5200	36000	210	145	62900	9320
TRAN-8 CSIRO March 95; Cations O.K.; Balance -8.2%				124000	950286	11.6	1.94	630	4500	32000	190	140	65900	2750
TRAN-9 CSIRO March 95				196000	950278	10.6	3.37	570	6600	49000	300	191	85900	11100
MQG01 CSIRO March 95				158000	950272	5.8	3.2	740	6700	43800	430	170	79100	14000
MQG02 CSIRO March 95				170000	950273	8.9	5.1	700	7300	47400	450	173	82200	13500
MQG04 CSIRO March 95				212000	950274	6.56	4.37	600	9200	57100	440	198	106000	14100
MQGO5 CSIRO March 95				204000?	950275	6.1	4.5	340	5900	35600	250	147	61400	8490
MQGO6 CSIRO March 95				216000	950276	5.71	4.17	600	10500	64900	540	260	119000	17500

Table A11. Salinity of Groundwater; Mourquong Western Margin				
M5B				
Description	*Depth below GL m*	*Average Depth below GL*	*Elevation mAHD*	*Salinity mg/L*
Sand; red/brn		0.375	32.945	
Sand; red/brn		0.775	32.545	28000
Sand; red/brn		1.175	32.145	36000
Sand; red/brn		1.575	31.745	43000
Sand; mottled fawn/orange		1.975	31.345	59000
Sand; fawn		2.375	30.945	79000
Sandy clay; mottled fawn/orange		2.775	30.545	100000
Clay; fawn		3.175	30.145	121000
Sandy clay; grey		3.575	29.745	150000
Sandy clay; fawn/grey		3.975	29.345	148000
Sandy clay; fawn/grey		4.375	28.945	132000
Clay; mottled fawn/grey/orange		4.775	28.545	88000
Clay; mottled fawn/grey/orange + blue/grey		5.175	28.145	67000
Sandy clay; dark blue/grey		5.575	27.745	53000
Clay; blue/grey		5.975	27.345	57000

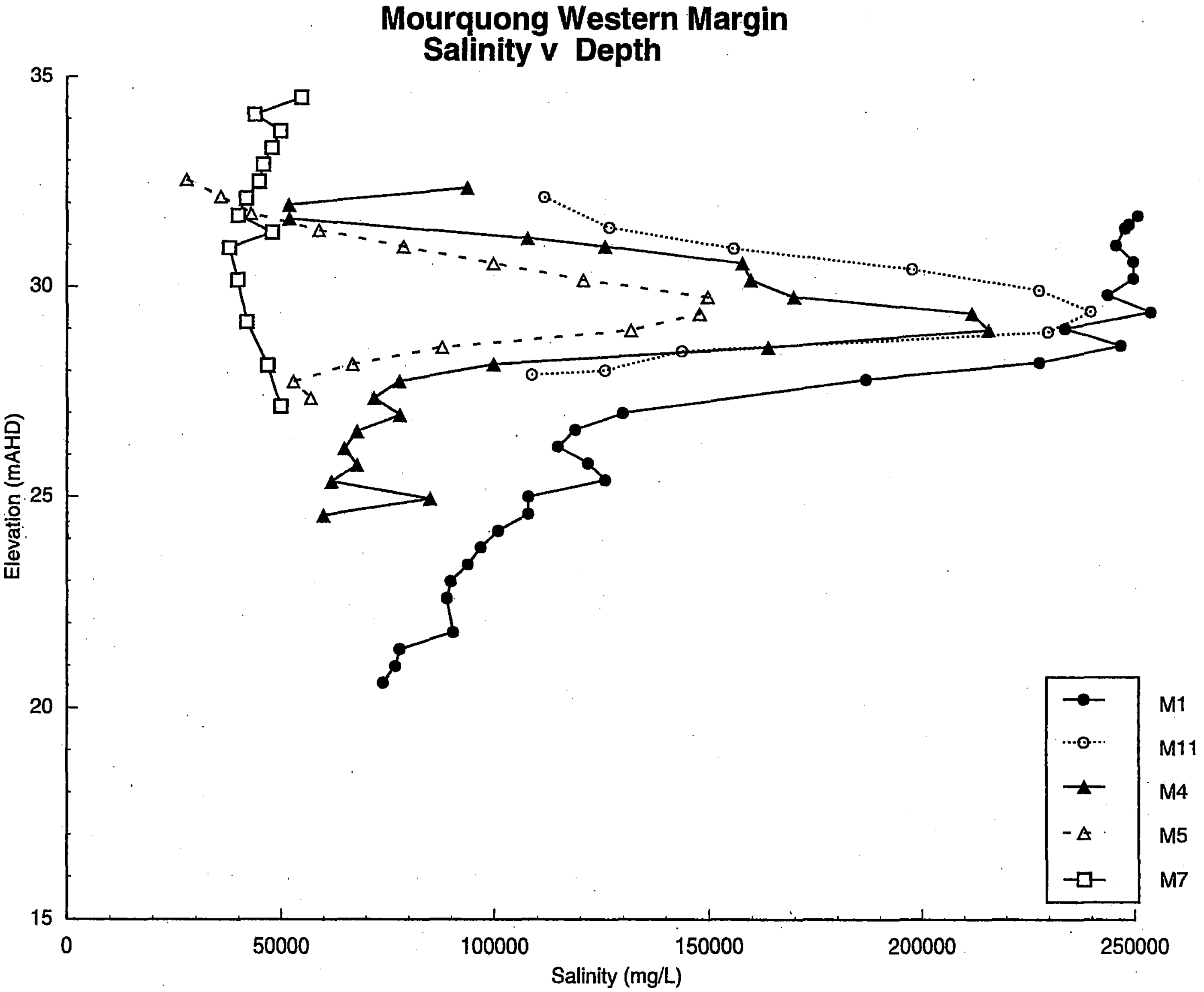


Figure 13. Salininity - depth profiles. Mourquong Disposal Basin, western margin

Table A12. Salinity of Groundwater; Mourquong Eastern Margin				
M18				
Description	*Depth below GL m*	*Average Depth below GL*	*Elevation mAHD*	*Salinity mg/L*
18A Piezometer CSIRO April 95				166000
18B Piezometer CSIRO April 95				79000
MEM-1: CSIRO				
Description	*Depth below GL m*	*Average Depth below GL*	*Elevation*	*Salinity mg/L*
Sand; orange	2.5-3.0	2.75	31	11000
Sandy clay;mottled fawn/org	3.0-3.5	3.25	30.5	36000
Sandy clay;mottled fawn/org	3.5-4.0	3.75	30	46000
Sandy clay;mottled fawn/org	4.0-4.5	4.25	29.5	52000
Fine sand; orange/fawn	4.5-5.0	4.75	29	52000
Fine sand; orange/fawn	5.0-5.5	5.25	28.5	52000
Fine sand; orange/fawn	5.5-6.0	5.75	28	52000
Fine sand; orange/fawn	6.0-6.5	6.25	27.5	52000
Coarse sand; orange/brown	6.5-7.0	6.75	27	53000
Coarse sand; orange/brown	7.0-7.5	7.25	26.5	54000
Coarse sand; orange/brown	7.5-7.7	7.6	26.15	55000
Sandy clay; fawn/org/cream	7.7-7.9	7.8	25.95	55000
Coarse sand; orange/brown	7.9-8.5	8.2	25.55	54000
Sandy clay;dark grey	8.5-9.0	8.75	25	58000
Sandy clay;dark grey	9.0-9.5	9.25	24.5	55000
Sandy clay;blue black	9.5-10.0	9.75	24	57000
Sandy clay;blue black	10.0-10.5	10.25	23.5	59000
Sandy clay; mottled blue black	10.5-11.0	10.75	23	65000
Sandy clay;blue black	11.0-11.5	11.25	22.5	60000
Sandy clay;blue black	11.5-12.0	11.75	22	60000
MEM-1: AGSO				
0.65m core: top clayey s	15	15	18.75	53000
0.65m core: bottom sand, si	15.6	15.6	18.15	56000
0.65m core sand	20.1	20.1	13.65	5000
0.65m core sand	20.6	20.6	13.15	4000
0.65m core sand	35.5	35.5	-1.75	5000
0.65m core sand	45	45	-11.25	5000
0.65m core sand	50.1	50.1	-16.35	111000
0.65m core sand	50.2	50.2	-16.45	116000
0.65m core sand	50.4	50.4	-16.65	120000
0.65m core top sand	55	55	-21.25	87000
0.65m core bottom sand	55	55	-21.25	35000
0.65m core Clay	60.05	60.05	-26.3	123000
0.65m core Clay	60.15	60.15	-26.4	125000
0.65m core Clay	60.39	60.39	-26.64	123000
0.65m core Clay	60.57	60.57	-26.82	121000
Drop core	62.2	62.2	-28.45	122000
0.65m core Clay (4)	62.33	62.33	-28.58	65000
0.65m core sand (3)	62.42	62.42	-28.67	58000
0.65m core Clay (2)	62.54	62.54	-28.79	118000
0.65m core sand (1)	62.61	62.61	-28.86	121000
Drop core sand	62.7	62.7	-28.95	35000
0.65m core clay (2)	63.13	63.13	-29.38	16000
0.65m core sand (1)	63.31	63.31	-29.56	119000
0.65m core clay (2)	68.36	68.36	-34.61	123000
0.65m core clay (1)	68.45	68.45	-34.7	126000
Drop core clay	68.85	68.85	-35.1	114000
0.65m core clay	74.4	74.4	-40.65	122000
Drop core clay	74.85	74.85	-41.1	122000
0.65m core clay low recovery	80.55	80.55	-46.8	118000
0.65m core clay (2)	81.07	81.07	-47.32	114000
0.65m core clay (1)	81.22	81.22	-47.47	115000
Drop core clay	81.5	81.5	-47.75	118000
0.65m core clay (2)	85.35	85.35	-51.6	111000
0.65m core clay (1)	85.58	85.35	-51.6	115000
MEM-2: CSIRO				
Description	*Depth below GL m*	*Average Depth below GL*	*Elevation mAHD*	*Salinity mg/L*
Sand, coarse, brn/orange	4-4.5	4.25	31.4 31.88	52000
Sand, coarse, brn/orange	4.5-5.0	4.75	31.4 31.38	56000
Sandy clay, cream/fawn	5.0-5.5	5.25	30.9 30.88	65000
Sandy clay, cream/fawn	5.5-6.0	5.75	30.4 30.38	71000
Sandy clay, mottled fawn/org	6.0-6.5	6.25	29.9 29.88	71000
Sandy clay, mottled fawn/org	6.5-7.0	6.75	29.4 29.38	75000
Sand, orange	7.5-8.0	7.75	28.4 28.38	82000
Sand, orange	8.0-8.5	8.25	27.9 27.88	78000
Sand; orange	8.5-9.0	8.75	27.4 27.38	82000
Sandy clay, mottled fawn/org	9.5-10.0	9.75	26.4 26.38	78000
Sandy clay, mottled fawn/org	10-10.5	10.25	25.9 25.88	74000
Sandy clay, blue-grey	10.5-11.0	10.75	25.4 25.38	75000
Sandy clay; mottled grey	11.0-11.5	11.25	24.9 24.88	76000
Sandy clay; mottled grey	11.5-12.0	11.75	24.4 24.38	72000
Sandy clay; blue grey	12.0-12.5	12.25	23.9 23.88	74000
Sand or sandy clay; mottled grey/cream	12.5-13.0	12.75	23.4 23.38	75000
Sand or sandy clay; mottled grey/cream	13-13.5	13.25	22.9 22.88	73000
Clay; blue-grey	13.5-14.0	13.75	22.4 22.38	77000
Piezometer MEM -2B CSIRO April 95				78000
MEM-3: CSIRO				
Description	*Depth below GL m*	*Average Depth below GL*	*Elevation*	*Salinity mg/L*
			32·6 (egL.)	
Sandy clay; mottled fawn/grey/orange	2.0-2.5	2.25	30·3	39000
Sandy clay; mottled fawn/grey/orange	2.5-3.0	2.75	29·8	41000
Sandy clay; mottled fawn/grey/orange	3.0-3.5	3.25	29·3	42000
Sandy clay; fawn	3.5-4.0	3.75	28·8	42000
Sandy clay;mottled fawn/org	4.0-4.5	4.25	28·3	43000
Sandy clay;mottled fawn/org	4.5-5.0	4.75	27·8	43000
Sandy clay;mottled fawn/org	5.0-5.5	5.25	27·3	43000
Clay;mottled fawn/org	5.5-6.0	5.75	26·8	44000
Sandy clay;mottled fawn/org	6.0-6.5	6.25	26·3	44000
Sandy clay;mottled fawn/org	6.5-7.0	6.75	25·8	44000
Sand; fawn/orange	7.0-7.5	7.25	25·3	45000

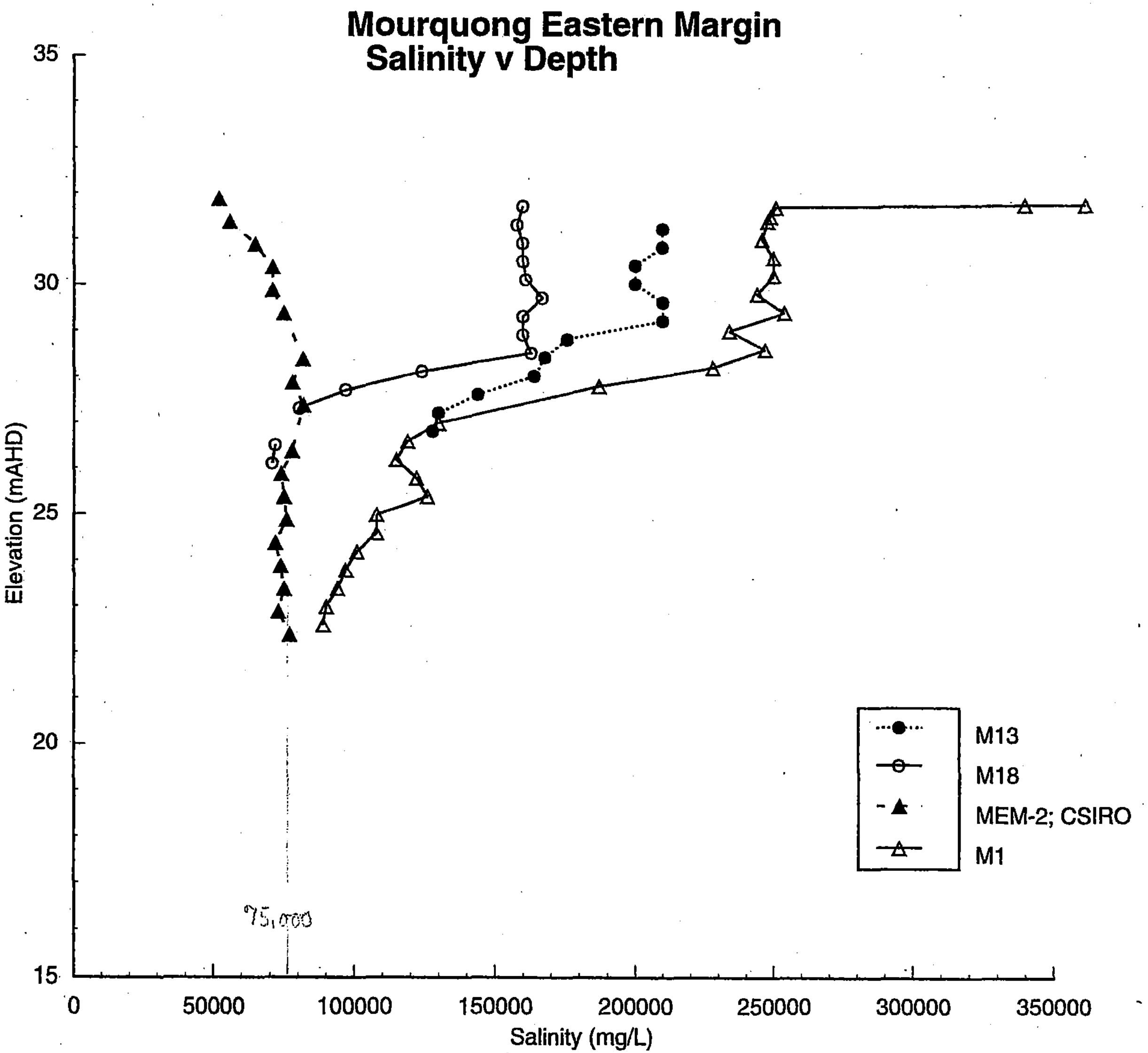


Figure 14. Salinity - depth profiles. Mourquong Disposal Basin, western margin

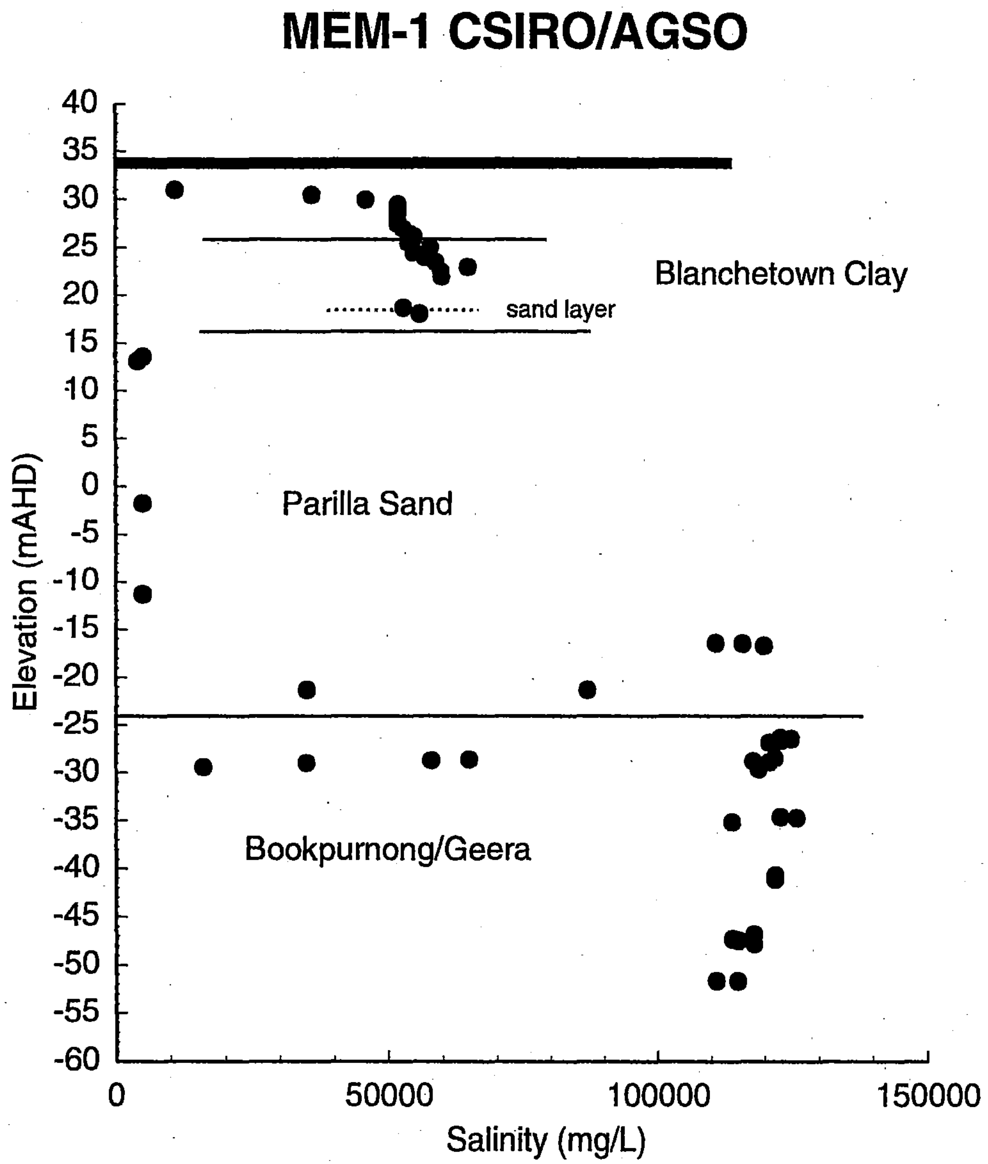


Figure 15. Salinity-depth profile.CSIRO & AGSO Cored holes, Mourquong Discharge Complex, transect PS.

Table A13. Salinity of Groundwater: Mourquong Southern Margin, Transect MRT

MRT-Pond					
Description	*Depth below GL m*	*Average Depth below GL*	*Elevation mAHD*	*Salinity mg/L*	
Pond March 95 AGSO				32000	
MRT-S2					
Description	*Depth below GL m*	*Average Depth below GL*	*Elevation mAHD*	*Salinity mg/L*	
	0	0	31.8 31.79		
Sand;brn/org	0.35-0.40	0.375	31.4 31.415	91000	
Sandy clay;brn/org	0.75-0.80	0.775	31 31.015	90000	
Sand?; mottled, fawn/org/brn	1.15-1.20	1.175	30.6 30.615	89000	
Clay; mottled, fawn/org/black	1.55-1.60	1.575	30.2 30.215	92000	
Clay; mottled org/fawn	1.95-2.00	1.975	29.8 29.815	93000	
Clay; mottled org/fawn	2.35-2.40	2.375	29.4 29.415	94000	
Clay; mottled org/fawn	2.75-2.80	2.775	29.0 29.015	96000	
Mixt. fawn sand org clay	3.15-3.20	3.175	28.6 28.615	72000	
Sand; orange	3.55-3.60	3.575	28.2 28.215	67000	
Sand; orange	3.95-4.00	3.975	27.8 27.815	70000	
Sand; orange	4.35-4.40	4.375	27.4 27.415	71000	
Piezometer 2A CSIRO April 95				92927	
Piezometer 2 CSIRO April 95				75000	
MRT-S3					
Description	*Depth below GL m*	*Average Depth below GL*	*Elevation mAHD*	*Salinity mg/L*	
	0	0	33.06		
Sand; red/brn	0.35-0.40	0.375	32.7 32.685	54000	
Sand; red/brn	0.75-0.80	0.775	32.3 32.285	49000	− 50
Sandy clay; mottled red/org/brn	1.15-1.20	1.175	31.9 31.885	40000	− 40
Sandy clay; mottled red/org/brn	1.55-1.60	1.575	31.5 31.485	39000	<40
Sandy clay;carbonate?, brn/fawn	1.95-2.0	1.975	31.1 31.085	39000	
Sandy clay; cream	2.35-2.40	2.375	30.7 30.685	40000	−40
Clay; compact mottled fawn/cream	2.75-2.80	2.775	30.3 30.285	41000	>40
Clay; mottled, fawn/blue-grey	3.15-3.20	3.175	29.9 29.885	44000	−40
Clay; mottled, fawn/blue-grey	3.55-3.60	3.575	29.5 29.485	38000	− 40
Clay; mottled, fawn/org/brn	4.15-4.20	4.175	28.9 28.885	41000	
Clay; mottled, fawn/org/brn	4.55-4.60	4.575	28.5 28.485	42000	−45
Sandy clay; mottled cream/fwn/org	4.95-5.00	4.975	28.1 28.085	57000	−50 −55
Sand, grey;minor clay, mottled gry/org	5.35-5.40	5.375	27.7 27.685	44000	−50 −45
Sandy clay;blue/grey	5.75-5.80	5.775	27.3 27.285	37000	40
Sandy clay;blue/grey	6.15-6.20	6.175	26.9 26.885	35000	−35
Sand; lt grey	6.55-6.60	6.575	26.5 26.485	33000	
Sand; blue grey	6.95-7.00	6.975	26.1 26.085	32000	
Sand; blue grey	7.35-7.40	7.375	25.7 25.685	32000	
Sand; blue grey	7.75-7.80	7.775	25.3 25.285	32000	[illegible]
Piezometer 3B CSIRO April 95				40000	
Piezometer 3A CSIRO April 95				40000	
Piezometer 3 CSIRO April 95				35000	
MRT-S2/3					
Description	*Depth below GL m*	*Average Depth below GL*	*Elevation mAHD*	*Salinity mg/L*	
Sand; red/brn (lumps)	0.35-0.40	0.375	31.7 31.705	51000	
Sandy clay, red/brn; carbonate	0.75-0.80	0.775	31.3 31.305	50000	
Sandy clay, red/brn; carbonate	1.15-1.20	1.175	30.9 30.905	51000	
Sandy clay; fawn orange	1.55-1.60	1.575	30.5 30.505	57000	
Sand; fawn org/blk mottle	1.95-2.00	1.975	30.1 30.105	60000	
Clay; mottled fawn	2.35-2.40	2.375	29.7 29.705	68000	
Clay; mottled fawn	2.75-2.80	2.775	29.3 29.305	70000	
Clay; mottled fawn/org	3.15-3.20	3.175	28.9 28.905	69000	
Sandy clay; mottled fawn org	3.55-3.60	3.575	28.5 28.505	69000	
Sandy clay; mottled fwn/org/grey	3.95-4.00	3.975	28.1 28.105	61000	
Sandy clay; mottled org/grey		4.47	27.6 27.61	51000	
Sandy clay; mottled org/grey		4.69	27.4 27.39	46000	
Sand; grey		4.89	27.2 27.19	38000	
Sand; blue-grey; mottled fawn		5	27.1 27.08	41000	
Piezometer 2/3B CSIRO April 95				56000	
Piezometer 2/3A CSIRO April 95				60299	
Piezometer 2/3 CSIRO April 95				38000	
MRT-4					
Description	*Depth below GL m*	*Average Depth below GL*	*Elevation mAHD*	*Salinity mg/L*	
Sand; red/brown		0.375	33.9 33.865		
Sand; red/brown		0.775	33.5 33.465		
Sand; orange		1.175	33.1 33.065	34000	
Sandy clay; orange		1.575	32.7 32.665	38000	
Sandy clay; red/orange		1.975	32.3 32.265	38000	
Sandy clay; red/orange		2.375	31.9 31.865	37000	
CLay red/brown; large calcrete		2.775	31.5 31.465	37000	

Table A13 (cont.). Salinity of Groundwater; Mourquong Southern Margin, Transect MRT				
MRT-BM				
Description	*Depth below GL m*	*Average Depth* below GL	*Elevation mAHD*	*Salinity mg/L*
Sand; fawn	0.09	0.09	31.7 31.74	68000
Sand; fawn	0.21	0.21	31.6 31.62	230000
Sand; interface fawn/grey	0.42	0.42	31.4 31.41	260000
Sandy clay; grey	0.59	0.59	31.2 31.24	41000
Sand; grey gypsum	0.95-1.0	0.975	30.9 30.855	40000
Sandy clay; grey	1.35-1.40	1.375	30.5 30.455	41000
Sandy clay; mottled fawn/org	1.75-1.80	1.775	30.1 30.055	44000
Sand, minor clay; mottled fawn/orange	2.15-2.20	2.175	29.7 29.655	47000
Coarse sand; bright orange	2.55-2.60	2.575	29.3 29.255	49000
Sand; orange	2.95-3.0	2.975	28.9 28.855	46000
Sand; yellow	3.35-3.40	3.375	28.5 28.455	58000
Piezometer BM-A CSIRO April 95				41000
Piezometer BM CSIRO 95				45000
MRT-1				
Description	*Depth below GL m*	*Average Depth* below GL	*Elevation mAHD*	*Salinity mg/L*
Sandy clay; mottled red/brown		0.15	31.6 31.64	66000
Sand, fine; brown		0.35	31.4 31.44	64000
Sandy clay?, gypsiferous; fawn		0.52	31.3 31.27	65000
Sandy clay; mottled fawn grey		0.68	31.1 31.11	66000
Sandy clay; mottled orange/fawn/black		0.84	31.0 30.95	66000
Sandy clay; mottled orange/fawn/black		0.975	30.8 30.815	66000
Sandy clay, fine; mottled fawn/orange		1.375	30.4 30.415	65000
Sandy Clay; fawn		1.775	30.0 30.015	66000
Sandy clay; mottled orange		2.175	29.6 29.615	66000
Sand, coarse; orange		2.575	29.2 29.215	60000
Piezometer 1 CSIRO April 95				66000
MRT-6				
Description	*Depth below GL m*	*Average Depth* below GL	*Elevation mAHD*	*Salinity mg/L*
Piezometer CSIRO April 95				33000

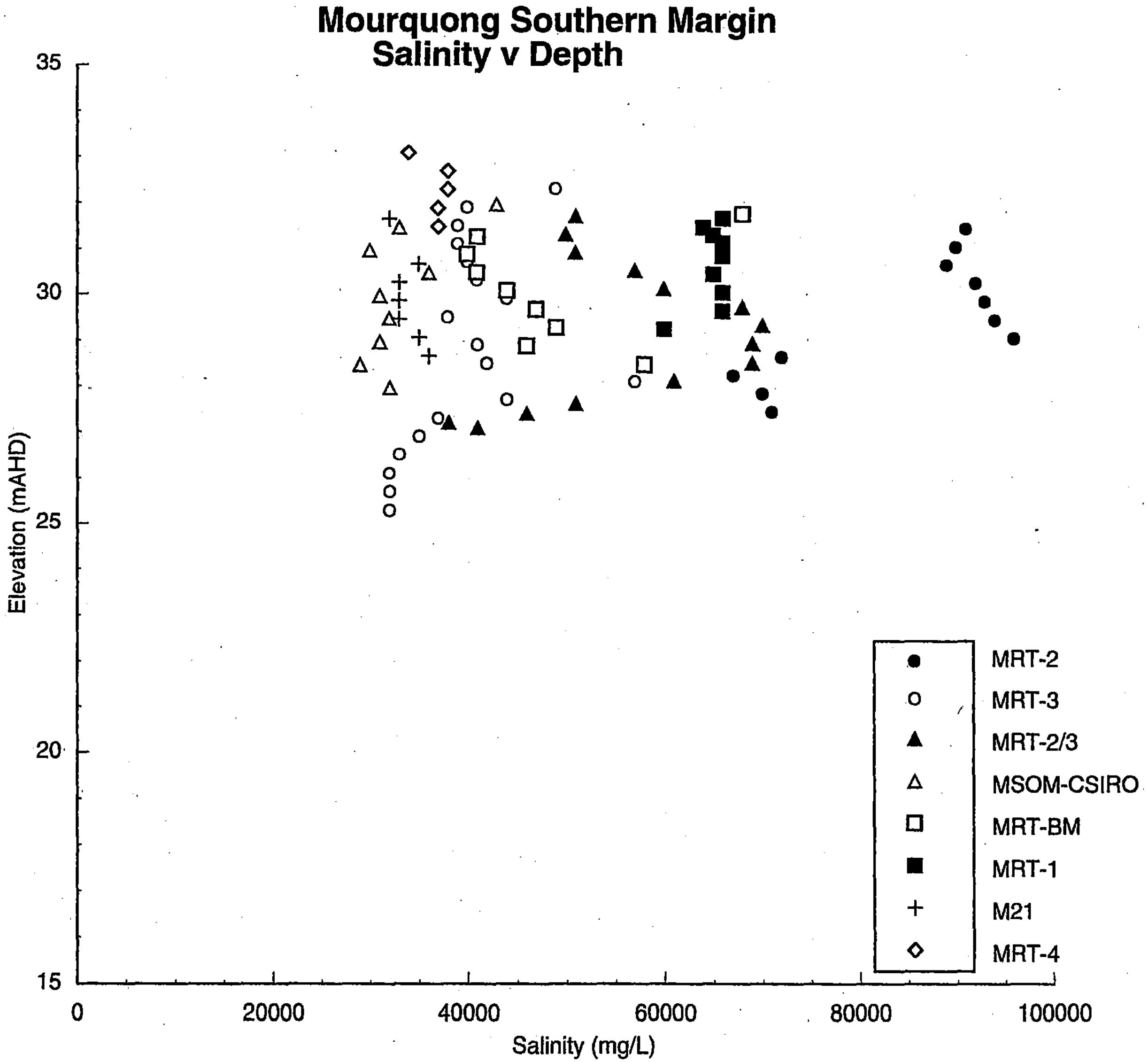


Figure 16. Salinity-depth profiles. Mourquong Disposal Basin, southern margin. All data.

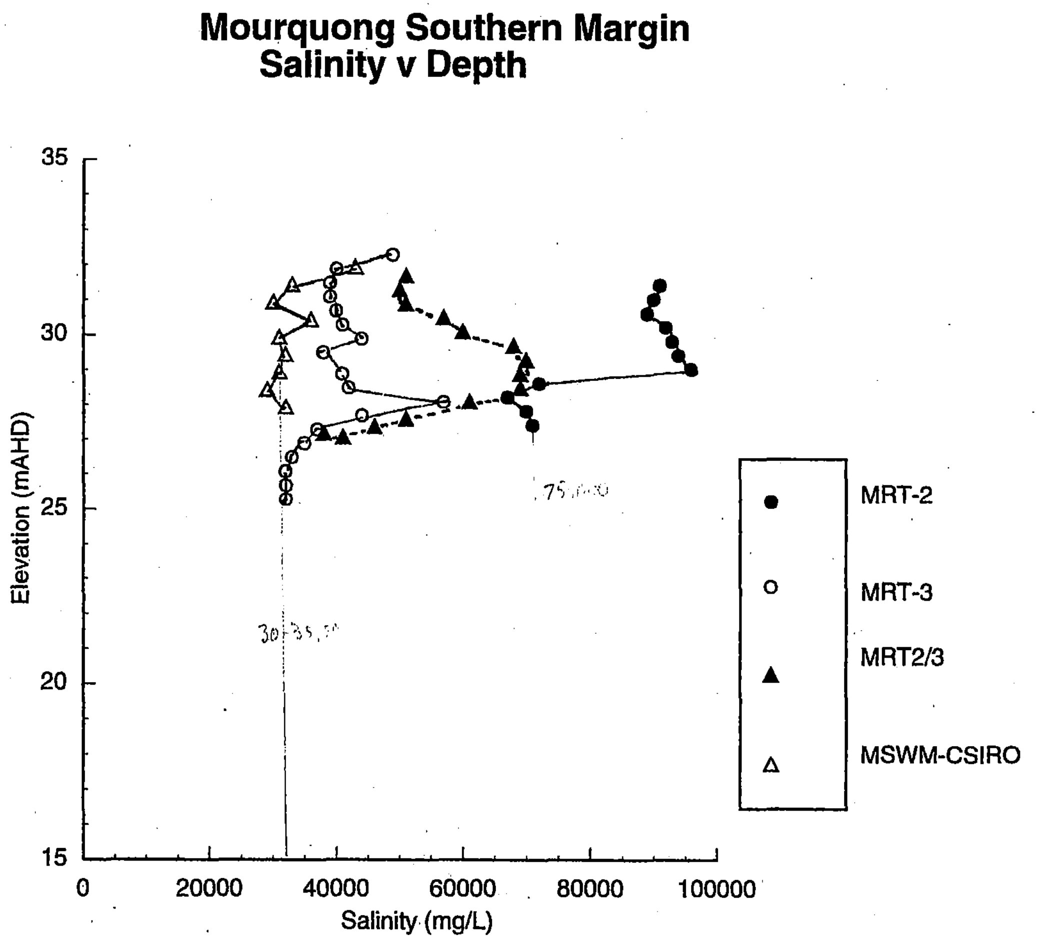


Figure 17. Salinity - depth profiles. Mourquong Disposal Basin, southern margin. Selected samples

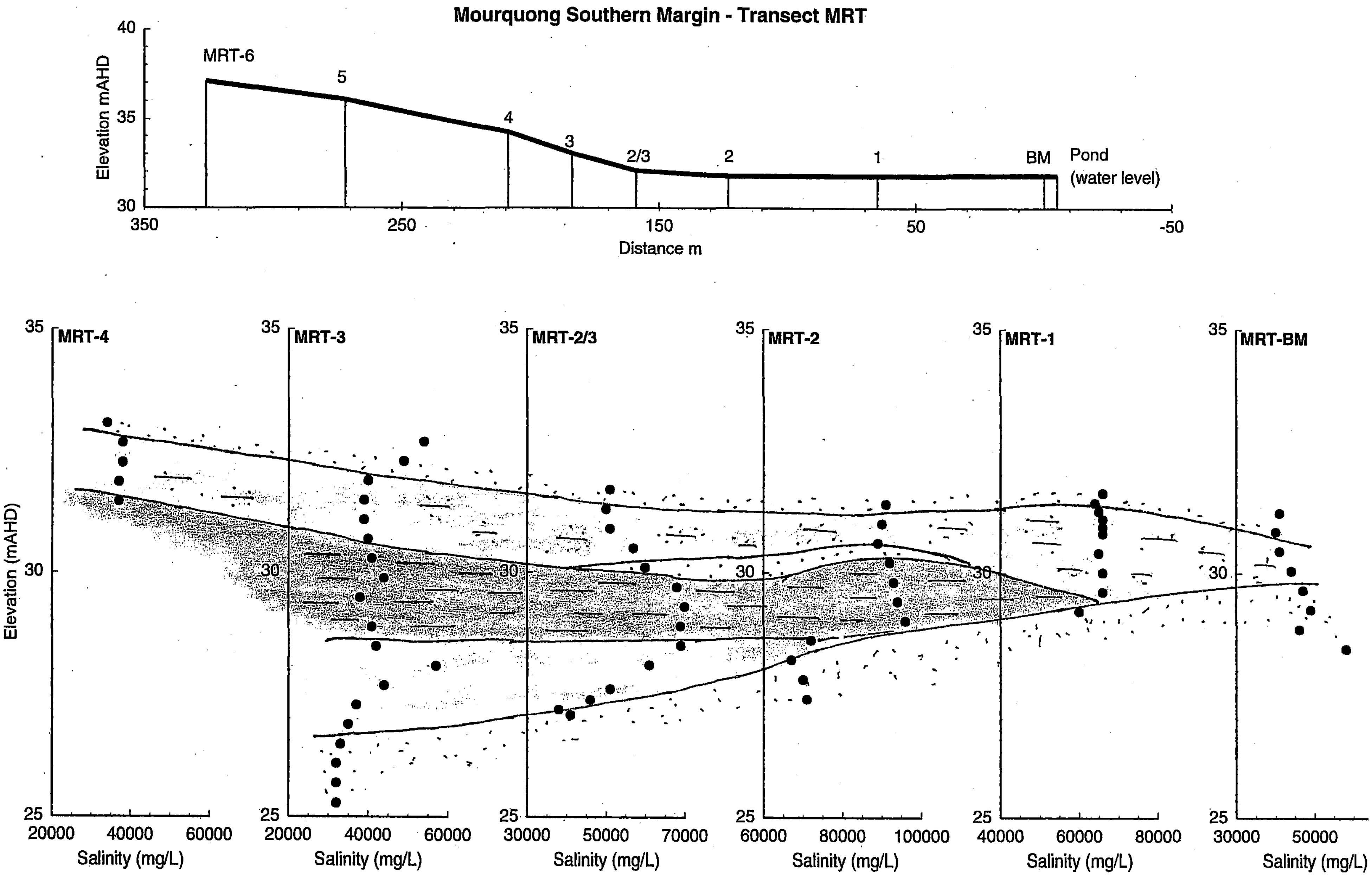


Figure 18. Salinity - depth profiles. Mourquong Disposal Basin, southern margin. Transect MRT.

Mourquong Eastern Margin
Salinity v Depth

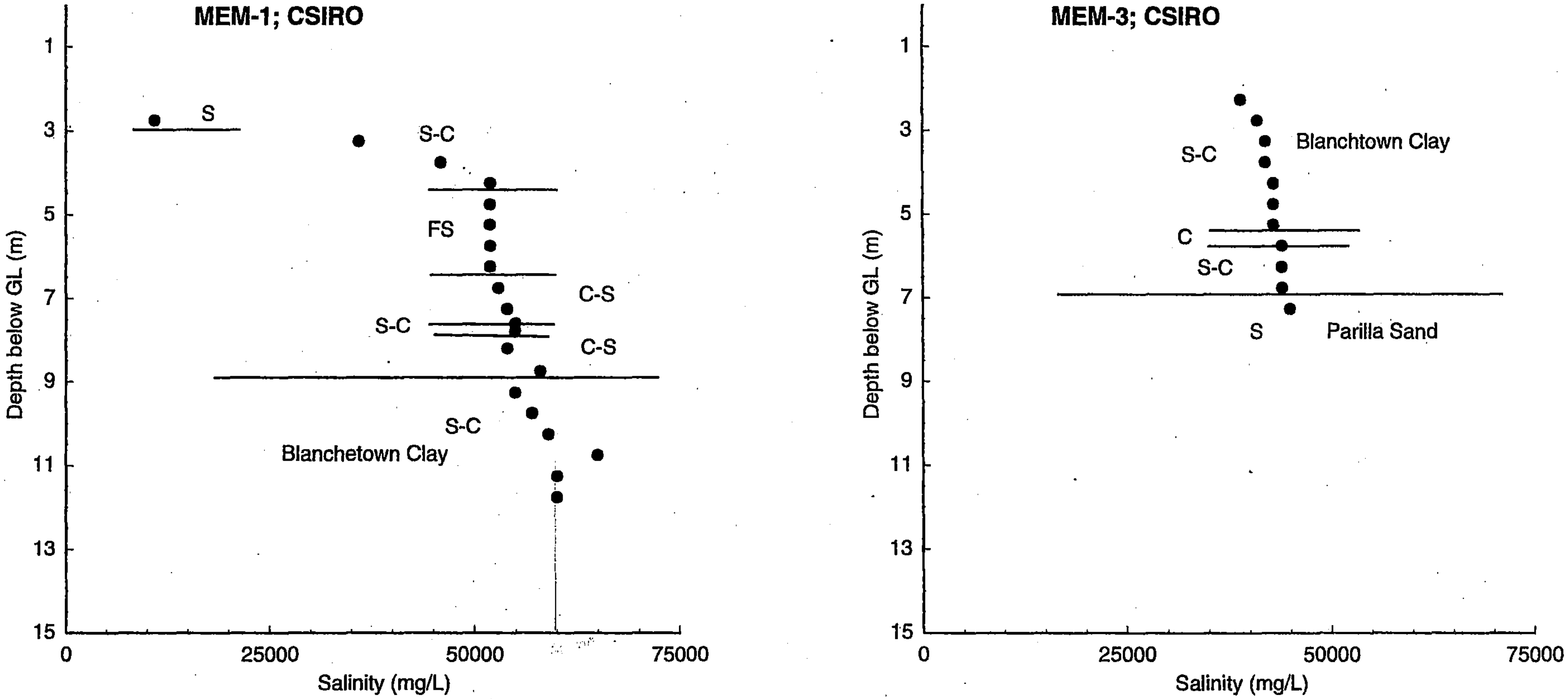
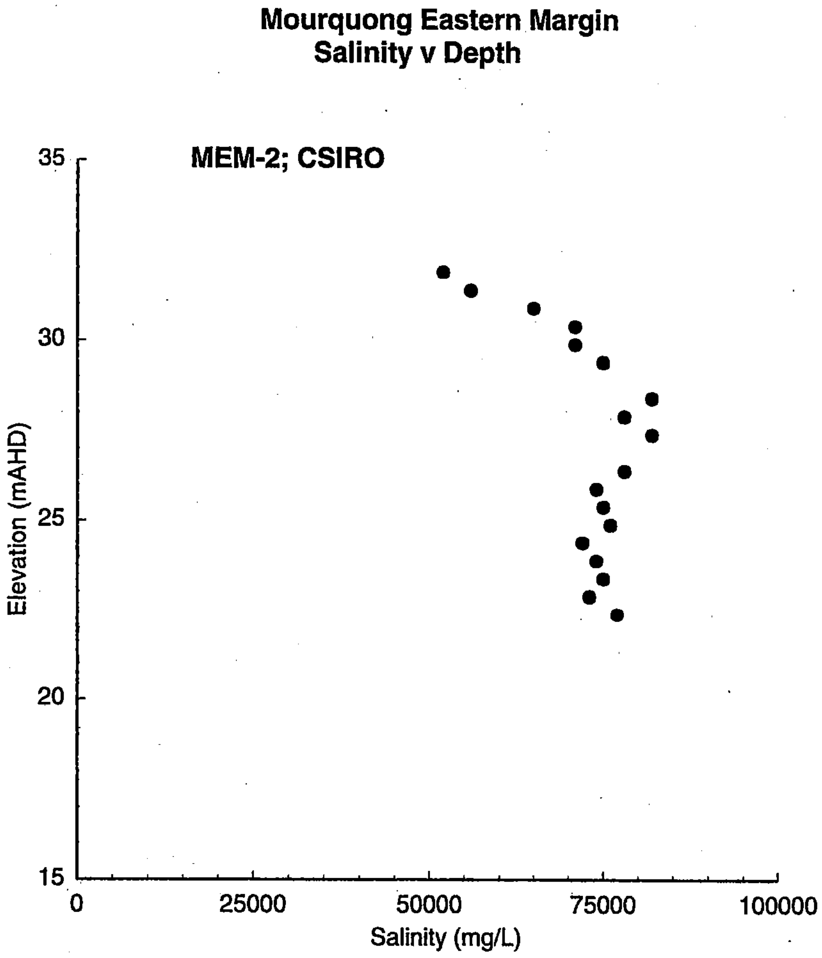


Figure19. Salinity - depth profiles. Mourquong eastern margin



Mourquong Eastern Margin
Salinity v Depth

Figure 20. Salinity - depth profiles. Mourquong eastern margin

Table A14. Salinity of Groundwater; Mourquong Southern Margin, Transect MSOM, and South Western Margin, Transect MSWM

M21				
Description	*Depth below GL m*	*Average Depth* below GL	*Elevation mAHD*	*Salinity mg/L*
Sand; dark red/brown		0.375	32 32.035	
Sand; orange/brown		0.775	31.6 31.635	32000
Sandy clay?; mottled orange/cream		1.775	30.6 30.635	35000
Sand, coarse; mottled orange/cream		2.175	30.2 30.235	33000
Sand; orange		2.575	29.8 29.835	33000
Sand; orange, some cream		2.975	29.4 29.435	33000
Sand; orange/cream		3.375	29.0 29.035	35000
Sand; orange, some cream		3.775	28.6 28.635	36000
Sand to 11m below GL: piezometer at :	26.8 to 27.3	5.35	27.06 27.06	
Groundwater in pit 'Lake 21" margin				55000
Groundwater in pit 'Lake 21" centre				122000
MSWM-CSIRO				
Description	*Depth below GL m*	*Average Depth* below GL	*Elevation mAHD*	*Salinity mg/L*
	0	0	33.2	
Sandy clay; mottled org	1-1.5	1.25	32 31.95	43000
Sandy clay; motted fawn/crm/org	1.5-2.0	1.75	31.5 31.45	33000
Sandy increasing clay; motted fawn/crm/org	2.0-2.5	2.25	31 30.95	30000
Sandy clay; motted fawn/crm/org	2.5-3.0	2.75	30.5 30.45	36000
Sandy clay; mottled fawn orange	3.0-3.5	3.25	30 29.95	31000
Sandy clay; orange	3.5-4.0	3.75	29.5 29.45	32000
Sandy clay; mottled fawn/org	4.0-4.5	4.25	29 28.95	31000
Sandy clay; mottled blue/gry/fwn/org	4.5-5.0	4.75	28.5 28.45	29000
Sandy clay; mottled blue/gry/fwn/org	5.0-5.5	5.25	28 27.95	32000

Mourquong Southern Margin, Transect MSWM
Salinity v Depth

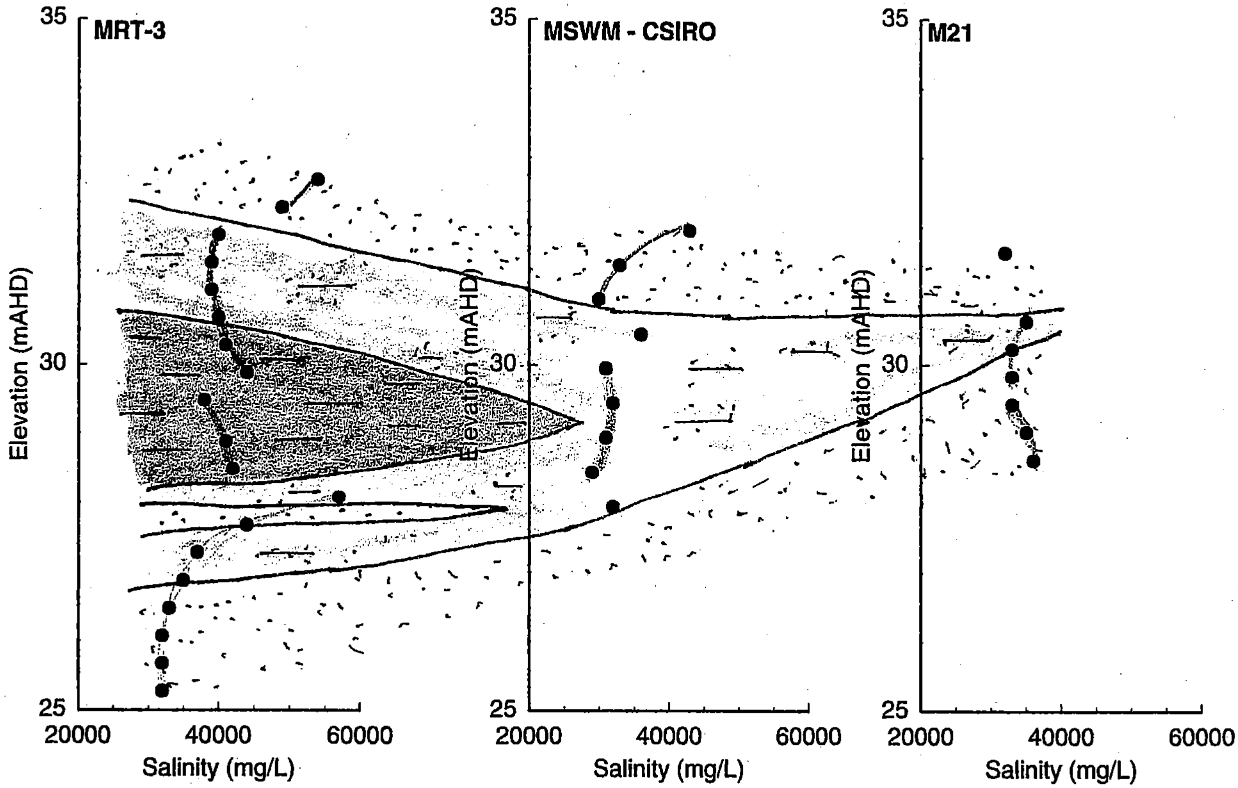


Figure 21. Salinity - depth profiles. Mourquong Disposal Basin. Southern margin, transect MSWM.

Table A15. Chemistry of Parilla Sand Groundwater, Mourquong Discharge Complex & Environs. Transect PS and sites to the west.

Description	*Depth below GL m*	*Average Depth* below GL	*Elevation mAHD*	*Salinity mg/L (or TDS)*	*Lab. reference*	*Sr mg/L*	*Li mg/L*	*Ca mg/L*	*Mg mg/L*	*Na mg/L*	*K mg/L*	*Br mg/L*	*Cl mg/L*	*SO4 mg/L*
DWR 36908/1 August 92			0.75	87298	920177	11.5	1.87	875	3490	25800	279	124	49200	7530
DWR 36908/2 August 92			-19.4	123902	920178	9.69	2.32	807	6240	37500	380	175	68200	10600
DWR 36908/3 (Bookpurnong) DWR analyses			-39.4	103200				993	4708	30670	275		57720	8750
DWR 36910/1 Coomeallah Irrig.Dist; DWR analyses		15		29565				269	1290	9130	96		16465	2315
DWR 36910/2 Coomeallah Irrig.Dist; DWR analyses		38.5		47131				399	2122	13980	130		25990	4510
DWR 36910/3 Coomealla Irrig.Dist; DWR analyses		59		54853				588	2660	16735	130		29000	5740
Parilla + some Bookpurnong														

Table A16. Chemistry of Parilla Sand Groundwater - Ratios to Br. Mourquong Discharge Complex & Environs. Transect PS and sites to the west.

Description	*Elevation mAHD*	*Salinity mg/L* (or TDS)	*Lab. reference*	*Salinity/Br*	*Ca/Br*	*Mg/Br*	*Na/Br*	*K/Br*	*Cl/Br*	*SO4/Br*
DWR 36908/1 August 92		87298	920177	704	7.1	28.1	208	2.25	397	60.7
DWR 36908/2 August 92		123902	920178	708	4.6	35.7	214	2.17	390	60.6
DWR 36908/3 (Bookpurnong) DWR analyses		103200								
DWR 36910/1 Coomeallah Irrig.Dist; DWR analyses		29565								
DWR 36910/2 Coomeallah Irrig.Dist; DWR analyses		47131								
DWR 36910/3 Coomealla Irrig.Dist; DWR analyses		54853								
Parilla + some Bookpurnong										

Table A17. Chemistry of Parilla Sand Groundwater - Ratios to Mg. Mourquong Discharge Complex & Environs. Transect PS and sites to the west.

Description	*Elevation mAH*	*Salinity mg/L* (or TDS)	*Lab. reference*	*Salinity/Mg*	*Ca/Mg*	*Na/Mg*	*K/Mg*	*Cl/Mg*	*SO4/Mg*	*Ca/SO4*
DWR 36908/1 August 92	87298	87298	950276	25.0	0.251	7.39	0.080	14.1	2.16	0.116
DWR 36908/2 August 92	123902	123902	950276	19.9	0.129	6.01	0.061	10.9	1.70	0.076
DWR 36908/3 (Bookpurnong) DWR analyses		103200		21.9	0.211	6.51	0.058	12.3	1.86	0.113
DWR 36910/1 Coomeallah Irrig.Dist; DWR analyses		29565		22.9	0.209	7.08	0.074	12.8	1.79	0.116
DWR 36910/2 Coomeallah Irrig.Dist; DWR analyses		47131		22.2	0.188	6.59	0.061	12.2	2.13	0.088
DWR 36910/3 Coomealla Irrig.Dist; DWR analyses		54853		20.6	0.221	6.29	0.049	10.9	2.16	0.102
Parilla + some Bookpurnong										

[illegible] Mg

0.074	0.08	14
0.061	0.061	11
0.049	0.058	⑫

Table A18. Chemistry of Parilla Sand Groundwater. Mourquong Discharge Complex & Environs

Description	*Depth below GL m*	*Average Depth* below GL	*Elevation mAHD*	*Salinity mg/L*	*Lab. reference*	*pH*	*Alk. meq/L*	*Sr mg/L*	*Li mg/L*	*Si mg/L*	*B mg/L*	*F mg/L*
DWR 36908/1 August 92				87298	920177	6.34	2.3	11.5	1.87	4.24	1.9	
DWR 36908/2 August 92				123902	920178	6.28	1.63	9.69	2.32	2.62	1.6	

Table A19. Chemistry of Groundwaters Associated with the Disposal Basin; Mourquong Discharge Complex

Description	Depth below GL m	Average Depth below GL	Elevation mAHD	Salinity mg/L	Lab. reference	Sr mg/L	Li mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Br mg/L	Cl mg/L	SO4 mg/L
M18														
18A Piezometer CSIRO April 95				166000	950270	12	4.37	700	5900	39400	340	150	68200	10300
18B Piezometer CSIRO April 95				79000	950271	15.1	2.37	800	2800	18000	190	73.3	28500	6700
MEM-2														
Piezometer MEM -2B CSIRO April 95				78000	950277	16.2	2.6	850	2800	18000	200	77.8	29200	7420
MRT-Pond														
Pond March 95 AGSO				32000	950087	8.63	0.33	462	1780	10380	81	47.9	18400	3440
MRT-S2														
Piezometer 2A CSIRO April 95				92927	950254	17.2	1.89	915	3850	24800	240	103	46400	16600
Piezometer 2 CSIRO April 95				75000	950253	15	1.6	902	2950	20200	210	<100	31600	4020
MRT-S3														
Piezometer 3B CSIRO April 95				40000	950260	9.8	0.511	620	1700	11500	106	45.7	21200	2190
Piezometer 3A CSIRO April 95				40000	950259	9.93	0.55	615	1650	11200	107	53.2	19900	2160
Piezometer 3 CSIRO April 95				35000	950258	7.4	0.414	447	1210	9490	83	41.9	16500	1570
MRT-S2/3														
Piezometer 2/3B CSIRO April 95				56000	950257	13.2	1.1	843	2350	16000	169	76.3	29300	2900
Piezometer 2/3A CSIRO April 95				60299	950256	14.3	1.43	955	2790	19800	245	83.2	32500	3910
Piezometer 2/3 CSIRO April 95				38000	950255	8.5	0.5	537	1440	11200	133	47.5	19700	1750
MRT-BM														
Piezometer BM-A CSIRO April 95				41000	950251	12.2	0.3	1160	1730	11000	73	48.3	19000	5050
Piezometer BM CSIRO 95				45000	950250	16	0.535	1080	1900	12600	101	48.9	21600	5500
MRT-1														
Piezometer 1 CSIRO April 95				66000	950252	16.8	1.18	1160	2810	18900	137	67	31000	6150
MRT-6														
Piezometer 6 CSIRO April 95				33000	950264	7	0.37	430	1100	8900	84	40.8	15700	1850
M21														
Groundwater in pit 'Lake 21" margin				55000	950085	9.18	0.993	636	2390	18700	269	86.6	32300	3930
Groundwater in pit 'Lake 21" centre				122000	950086	18.7	3.57	1350	6420	41300	446	172	71400	6400
Piezometer M1 CSIRO April 95				78000	950262	12.3	1.79	1100	3100	20600	190	82.6	35100	7230
Piezometer M1A CSIRO April 95				204000	950263	3.6	5.68	384	10500	54000	470	253	100000	17700
Piezometer M4 CSIRO April 95				170000	950264	13.3	2.34	750	7380	43600	330	174	80200	12300
Piezometer M4C CSIRO April 95				212000	950265	8.56	2.84	490	9100	57000	420	218	104000	14900
Piezometer M9 CSIRO April 95				57000	950266	10.3	0.9	460	2100	16000	170	67.7	19400	4090
Piezometer M10 CSIRO April 95				52000	950267	9.93	0.56	500	2150	16400	150	66.6	18100	3730
Piezometer M11 CSIRO April 95				204000	950268	7.4	2.89	470	9100	52700	390	208	94000	16000
Piezometer M11B CSIRO April 95				232000	950269	7.53	2.91	310	7900	48800	380	157	77400	12100

Table A20. Chemistry of Groundwaters Associated with the Disposal Basin - Ratios to Br; Mourquong Discharge Complex

Description	Elevation mAHD	Salinity mg/L	Lab. reference	Salinity/Br	Ca/Br	Mg/Br	Na/Br	K/Br	Cl/Br	SO4/Br
M18										
18A Piezometer CSIRO April 95		166000	950270	1107	4.7	39.3	263	2.27	455	68.7
18B Piezometer CSIRO April 95		79000	950271	1078	10.9	38.2	246	2.59	389	91.4
MEM-2										
Piezometer MEM -2B CSIRO April 95		78000	950277	1003	10.9	36.0	231	2.57	375	95.4
MRT-Pond										
Pond March 95 AGSO		32000	950087	668	9.6	37.2	217	1.69	384	71.8
MRT-S2										
Piezometer 2A CSIRO April 95		92927	950254	902	8.9	37.4	241	2.33	450	161.2
Piezometer 2 CSIRO April 95		75000	950253							
MRT-S3										
Piezometer 3B CSIRO April 95		40000	950260	875	13.6	37.2	252	2.32	464	47.9
Piezometer 3A CSIRO April 95		40000	950259	752	11.6	31.0	211	2.01	374	40.6
Piezometer 3 CSIRO April 95		35000	950258	835	10.7	28.9	226	1.98	394	37.5
MRT-S2/3										
Piezometer 2/3B CSIRO April 95		56000	950257	734	11.0	30.8	210	2.21	384	38.0
Piezometer 2/3A CSIRO April 95		60299	950256	725	11.5	33.5	238	2.94	391	47.0
Piezometer 2/3 CSIRO April 95		38000	950255	800	11.3	30.3	236	2.80	415	36.8
MRT-BM										
Piezometer BM-A CSIRO April 95		41000	950251	849	24.0	35.8	228	1.51	393	104.6
Piezometer BM CSIRO 95		45000	950250	920	22.1	38.9	258	2.07	442	112.5
MRT-1										
Piezometer 1 CSIRO April 95		66000	950252	985	17.3	41.9	282	2.04	463	91.8
MRT-6										
Piezometer CSIRO April 95		33000	950264	809	10.5	27.0	218	2.06	385	45.3
M21										
Groundwater in pit 'Lake 21" margin		55000	950085	635	7.3	27.6	216	3.11	373	45.4
Groundwater in pit 'Lake 21" centre		122000	950086	709	7.8	37.3	240	2.59	415	37.2
Piezometer M1 CSIRO April 95		78000	950262	944	13.3	37.5	249	2.30	425	87.5
Piezometer M1A CSIRO April 95		204000	950263	806	1.5	41.5	213	1.86	395	70.0
Piezometer M4 CSIRO April 95		170000	950264	977	4.3	42.4	251	1.90	461	70.7
Piezometer M4C CSIRO April 95		212000	950265	972	2.2	41.7	261	1.93	477	68.3
Piezometer M9 CSIRO April 95		57000	950266	842	6.8	31.0	236	2.51	287	60.4
										7l
Piezometer M10 CSIRO April 95		52000	950267	781	7.5	32.3	246	2.25	272	56.0
Piezometer M11 CSIRO April 95		204000	950268	981	2.3	43.8	253	1.88	452	76.9
Piezometer M11B CSIRO April 95		232000	950269	1478	2.0	50.3	311	2.42	493	77.1

Table A21. Chemistry of Groundwaters Associated with the Disposal Basin - Ratios to Mg; Mourquong Discharge Complex

Description	Elevation mAHD	Salinity mg/L	Lab. reference	Salinity/Mg	Ca/Mg	Na/Mg	K/Mg	Cl/Mg	SO4/Mg	Ca/SO4	Na/Cl
M18											
18A Piezometer CSIRO April 95		166000	950270	28.1	0.119	6.68	0.058	11.6	1.75	0.068	0.578
18B Piezometer CSIRO April 95		79000	950271	28.2	0.286	6.43	0.068	10.2	2.39	0.119	0.632
MEM-2											
Piezometer MEM -2B CSIRO April 95		78000	950277	27.9	0.304	6.43	0.071	10.4	2.65	0.115	0.616
MRT-Pond											
Pond March 95 AGSO		32000	950087	18.0	0.260	5.83	0.046	10.3	1.93	0.134	0.564
MRT-S2											
Piezometer 2A CSIRO April 95		92927	950254	24.1	0.238	6.44	0.062	12.1	4.31	0.055	0.534
Piezometer 2 CSIRO April 95		75000	950253	25.4	0.306	6.85	0.071	10.7	1.36	0.224	0.639
MRT-S3											
Piezometer 3B CSIRO April 95		40000	950260	23.5	0.365	6.76	0.062	12.5	1.29	0.283	0.542
Piezometer 3A CSIRO April 95		40000	950259	24.2	0.373	6.79	0.065	12.1	1.31	0.285	0.563
Piezometer 3 CSIRO April 95		35000	950258	28.9	0.369	7.84	0.069	13.6	1.30	0.285	0.575
MRT-S2/3											
Piezometer 2/3B CSIRO April 95		56000	950257	23.8	0.359	6.81	0.072	12.5	1.23	0.291	0.546
Piezometer 2/3A CSIRO April 95		60299	950256	21.6	0.342	7.10	0.088	11.6	1.40	0.244	0.609
Piezometer 2/3 CSIRO April 95		38000	950255	26.4	0.373	7.78	0.092	13.7	1.22	0.307	0.569
MRT-BM											
Piezometer BM-A CSIRO April 95		41000	950251	23.7	0.671	6.36	0.042	11.0	2.92	0.230	0.579
Piezometer BM CSIRO 95		45000	950250	23.7	0.568	6.63	0.053	11.4	2.89	0.196	0.583
MRT-1											
Piezometer 1 CSIRO April 95		~~78000~~	~~950277~~	23.5	0.413	6.73	0.049	11.0	2.19	0.189	0.61
MRT-6											
Piezometer CSIRO April 95		X 78000	950277	X 30.0	0.391	8.09	0.076	14.3	1.68	0.232	0.567
M21						8.1					
Groundwater in pit 'Lake 21" margin		55000	950085	23.0	0.266	7.82	0.113	13.5	1.64	0.162	0.579
Groundwater in pit 'Lake 21" centre		122000	950086	19.0	0.210	6.43	0.069	11.1	1.00	0.211	0.578
Piezometer M1 CSIRO April 95		78000	950262	25.2	0.355	6.65	0.061	11.3	2.33	0.152	0.587
Piezometer M1A CSIRO April 95		204000	950263	19.4	0.037	5.14	0.045	9.5	1.69	0.022	0.54
Piezometer M4 CSIRO April 95		170000	950264	23.0	0.102	5.91	0.045	10.9	1.67	0.061	0.544
Piezometer M4C CSIRO April 95		212000	950265	23.3	0.054	6.26	0.046	11.4	1.64	0.033	0.548
Piezometer M9 CSIRO April 95		57000	950266	27.1	0.219	7.62	0.081	9.2	1.95	0.112	0.825
							7.6				
Piezometer M10 CSIRO April 95		52000	950267	24.2	0.233	7.63	0.070	8.4	1.73	0.134	0.906
Piezometer M11 CSIRO April 95		204000	950268	22.4	0.052	5.79	0.043	10.3	1.76	0.029	0.561
Piezometer M11B CSIRO April 95		232000	950269	29.4	0.039	6.18	0.048	9.8	1.53	0.026	0.63

Table A22. Piezometer data, Parilla Sand aquifer. Mourquong Discharge Complex and environs.

Not yet available

Table A23. Freshwater Heads, Parilla Sand aquifer. Mourquong Discharge Complex and environs.

Not yet available

Figure 22. Freshwater heads. Mourquong Discharge Complex, transect PS.

Data not yet available

Figure 23. Environmental water heads heads. Mourquong Discharge Complex, transect PS.

Data not yet available

Table A24. Environmental Water Heads, Parilla Sand aquifer. Mourquong Discharge Complex and environs.

Not yet available

Table A25 . Piezometer Data, Mourquong Western Margin Transect

Site	Top Casing	Midpt. Slots	Date	TC-SWL	SWL	Salinity	Density	Freshwater Head
	mAHD	mAHD		m	mAHD	mg/L	g/cc	@ Midpt.Slots mAHD
		Zi			Hip		Rhoi	Hif
M20	45.63	31.9	17-Mar-95	13.56	32.07	50000	1.033	32.08
		31.9	25-Apr-95	13.57	32.06	52000	1.034	32.07
		31.9	9-Oct-95	13.53	32.1	50000	1.033	32.11
M12	41.004	31.5	1-Nov-92		32	44000	1.029	32.01
		31.5	23-Mar-93		32.1	45000	1.030	32.12
		31.5	1-Mar-95	8.83	32.17	48000	1.032	32.19
		31.5	25-Apr-95	8.86	32.14	45000	1.030	32.16
		31.5	9-Oct-95	8.8	32.2	44000	1.029	32.22
M9	39.39	30.55	1-Nov-92		31.99	55000	1.036	32.04
		30.55	23-Mar-93		32.07	54000	1.036	32.12
		30.55	1-Mar-95	7.27	32.12	59000	1.039	32.18
		30.55	25-Apr-95	7.3	32.09	55000	1.036	32.15
		30.55	9-Oct-95	7.24	32.15	55000	1.036	32.21
M10	37.812	30.55	1-Nov-92		32.05	43500	1.029	32.09
		30.55	23-Mar-93		32.02	42000	1.028	32.06
		30.55	1-Mar-95	5.77	32.04	44000	1.029	32.08
		30.55	25-Apr-95	5.83	31.98	44000	1.029	32.02
		30.55	9-Oct-95	5.65	32.16	44000	1.029	32.21
M7	35.868	31.85	1-Nov-92		32.09	45000	1.030	32.10
		31.85	23-Mar-93		31.9	42000	1.028	31.90
		31.85	1-Mar-95	3.955	31.86	42000	1.028	31.86
		31.85	25-Apr-95	4.01	31.86	42000	1.028	31.86
		31.85	6-Oct-96	3.71	32.16	42000	1.028	32.17
M7A	35.655	26.65	1-Nov-92		31.46	43500	1.029	31.60
		26.65	23-Mar-93		31.55	42000	1.028	31.68
		26.65	1-Mar-95	3.59	32.06	39000	1.025	32.20
		26.65	25-Apr-95			45000	1.030	
		26.65	6-Oct-96	4.26	31.4	48000	1.032	31.55
M8	34.825	31.6	1-Nov-92		32.13	40000	1.026	32.14
		31.6	23-Mar-93		31.84	38000	1.025	31.85
		31.6	1-Mar-95	2.96	31.86	44000	1.029	31.87
		31.6	25-Apr-95	2.95	31.87	42000	1.028	31.88
		31.6	6-Oct-96	2.64	32.19	45000	1.030	32.21
DWR 36908/1 (middle,30-36m)	34.74	0.75	1-Nov-92	3.01	31.73	82000	1.054	33.42
		0.75	28-Mar-93	2.97	31.77	81500	1.054	33.45
		0.75	25-Apr-95	2.95	31.79	84000	1.056	33.52
DWR 36908/2 (most westerly. 50-56m)	34.73	-19.4	1-Nov-92	3.15	31.58	55000	1.036	33.43
		-19.4	28-Mar-93	2.96	31.77	75000	1.050	34.32
		-19.4	25-Apr-95	2.86	31.87	74000	1.049	34.39
DWR 36908/3 (most easterly,70-76m)	34.74	-39.4	1-Nov-92	3.75	30.99	100000	1.066	35.66
		-39.4	28-Mar-93	3.76	30.98	100500	1.067	35.67
		-39.4	25-Apr-95	3.65	31.09	98000	1.065	35.68
DWR 1011	33.66	20.3	1-Mar-95	1.56	32.1	64000	1.042	33.46
		20.3	25-Apr-95					
M5A	33.816	31.6	1-Nov-92		31.71	52000	1.034	31.71
		31.6	23-Mar-93		31.63	42000	1.028	31.63
		31.6	30-Mar-93		31.77	42000	1.028	31.77
		31.6	1-Mar-95	2.15	31.67	50000	1.033	31.67
		31.6	25-Apr-95	1.95	31.87	52000	1.034	31.88
		31.6	6-Oct-95	1.68	32.14	55000	1.036	32.16
M4	33.723	30.42	1-Nov-92		32	128500	1.085	32.13
		30.42	23-Mar-93		31.71	107000	1.071	31.80
		30.42	1-Mar-95	2.02	31.7	163000	1.107	31.84
		30.42	25-Apr-95	1.89	31.83	165000	1.108	31.98
		30.42	6-Oct-95	1.66	32.06	175000	1.114	32.25
M4A	33.6959	31.5	1-Nov-92		32.1	71000	1.047	32.13
		31.5	23-Mar-93		31.72	58000	1.038	31.73
		31.5	1-Mar-95	1.46	32.23	82000	1.054	32.27
		31.5	25-Apr-95	1.325	32.34	65000	1.043	32.38
		31.5	6-Oct-95	1.07	32.63	68000	1.045	32.68
M4B	33.716	25.05	1-Nov-92		30.32	121000	1.080	30.74
		25.05	23-Mar-93		31.11	118000	1.078	31.58
		25.05	1-Mar-95	1.89	31.83	130500	1.086	32.41
		25.05	25-Apr-95	not recovered		142000	1.094	
		25.05	6-Oct-95	2.58	31.14	145000	1.098	31.72
M4C	33.69	29.15	17-Mar-95	2.04	31.65			
		29.15	25-Apr-95	1.89	31.8	188000	1.123	32.12
		29.15	6-Oct-95	1.67	32.02	210000	1.136	32.41
M11	33.57	27.75	1-Nov-92		31.77	203000	1.132	32.30
		27.75	23-Mar-93		31.71	208000	1.135	32.24
		27.75	1-Mar-95	1.84	31.73	210000	1.136	32.27
		27.75	25-Apr-95	not recovered		188000	1.123	
		27.75	6-Oct-95	1.55	32.02	195000	1.127	32.56
M11A	33.602	31.9	1-Nov-92		32.48	150000	1.099	32.54
		31.9	23-Mar-93		dry			
		31.9	1-Mar-95	1.47	32.13	144000	1.095	32.15
		31.9	25-Apr-95	1.26	32.34	110000	1.073	32.37
		31.9	6-Oct-95	1.06	32.54	134000	1.088	32.60
M11C	33.26	29.5	17-Mar-95	1.65	31.61	230000	1.148	31.92
		29.5	25-Apr-95	1.44	31.82	188000	1.123	32.10
		29.5	6-Oct-95	1.25	32.01	264000	1.168	32.43
M19	33.61	32.58	17-Mar-95	1.66	31.95	205000	1.133	31.87
		32.58	25-Apr-95	1.445	32.16	188000	1.123	32.11
		32.58	6-Oct-95	1.27	32.37	210000	1.136	32.34
Surface water; site M1		31.55	3-Aug-92		32.04			
		31.55	5-Aug-92		32.04	96000	1.064	32.07
Surface water; site M1B		31.55	9-Aug-92		32.1	96000	1.064	32.14
Surface water; near western shore.		31.55	7-Aug-92		32.1	91500	1.061	32.13
Surface water; site M1		31.55	1-Mar-95	1.1	31.84	248000	1.159	31.89
Surface water; site M1		31.55	25-Apr-95		ca. 32.51	> 160000		
Surface water; site M19		31.55	10-Oct-95	1.23	32.38	112000	1.074	32.44

Table A25. Freshwater Heads, Moutuong Western Margin Transect

Site	Date	Midpt. Slots mAHD Zl	Normalised Elevation mAHD	Zl actual - Zl normalised @ 31.55 mAHD	Slope m/m	Hf @ 31.88m	Zl actual - Zl normalised @ 27.00 mAHD	Slope m/m	Hf @ 27.00 mAHD m	Zl actual - Zl normalised @ 20.55 mAHD	Slope m/m	Hf @ 20.55 mAHD
M20	17-Mar-05	31.9	31.65	0.36	0.05	32.09						
	17-Mar-05	31.9	31.55	0.36	0.05	32.08						
	9-Oct-05	31.9	31.55	0.35	0.05	32.12						
M12	1-Nov-02	31.6	31.65	-0.06	0.05	32.01						
	22-Mar-03	31.6	31.66	-0.06	0.05	32.12						
	1-Mar-05	31.6	31.65	-0.05	0.06	32.19						
	25-Apr-05	31.5	31.66	-0.05	0.06	32.18						
	9-Oct-05	31.5	31.66	-0.06	0.05	32.22						
M9	1-Nov-02	30.65	31.56	-1	0.05	31.89						
	23-Mar-03	30.66	31.66	-1	0.05	32.07						
	1-Mar-05	30.65	31.66	-1	0.06	32.13						
	25-Apr-05	30.66	31.66	-1	0.05	32.10						
	9-Oct-05	30.65	31.53	-1	0.06	32.10						
M10	1-Nov-02	30.65	31.55	-1	0.06	32.04						
	23-Mar-03	30.65	31.66	-1	0.05	32.01						
	1-Mar-05	30.65	31.66	-1	0.05	32.03						
	25-Apr-05	30.66	31.66	-1	0.06	31.97						
	9-Oct-05	30.65	31.55	-1	0.06	32.19						
M7	1-Nov-02	31.86	31.66	0.3	0.05	32.11						
	23-Mar-03	31.86	31.65	0.3	0.06	31.92						
	1-Mar-05	31.86	31.66	0.3	0.06	31.89						
	25-Apr-05	31.85	31.55	0.3	0.05	31.88						
	9-Oct-05	31.86	31.65	0.3	0.06	32.18						
M7A	1-Nov-02	26.65					-0.36	0.086	31.67			
	23-Mar-03	26.66					-0.35	0.066	31.68			
	1-Mar-05	26.66					-0.35	0.085	32.18			
	25-Apr-06	26.65					-0.35	0.085				
	9-Oct-05	26.66					-0.36	0.085	31.63			
M8	1-Nov-02	31.6	31.55	0.05	0.05	32.16						
	23-Mar-03	31.6	31.65	0.05	0.06	31.95						
	1-Mar-05	31.6	31.55	0.05	0.05	31.87						
	25-Apr-05	31.6	31.65	0.05	0.05	31.88						
	9-Oct-05	31.6	31.55	0.05	0.06	32.21						
DWR 38008/1 (middle 20-28m)	1-Nov-02	0.75										
	28-Mar-03	0.75										
	25-Apr-05	0.76										
DWR 38008/2 (most westerly, 50-58m	1-Nov-02	-19.4										
	28-Mar-03	-19.4										
	25-Apr-05	-19.4										
DWR 38008/3 (most easterly 70-78m)	1-Nov-02	-39.4										
	28-Mar-03	-39.4										
	25-Apr-05	-39.4										
DWR 1011	1-Mar-05	20.3								-0.25	-0.0005	32.40
	25-Apr-05	20.3										n.d.
M6A	1-Nov-02	31.6	31.56	0.06	0.158	31.72						
	23-Mar-03	31.6	31.66	0.06	0.158	31.84						
	30-Mar-03	31.6	31.65	0.06	0.158	31.79						
	1-Mar-05	31.6	31.65	0.05	0.158	31.68						
	26-Apr-05	31.6	31.66	0.05	0.158	31.89						
	6-Oct-05	31.6	31.66	0.06	0.158	32.17						
M4	1-Nov-02	30.42	31.65	-1.1	0.106	32.02						
	23-Mar-03	30.42	31.66	-1.1	0.106	31.68						
	1-Mar-05	30.42	31.55	-1.1	0.106	31.72						
	25-Apr-05	30.42	31.66	-1.1								
	6-Oct-05	30.42	31.56	-1.1	0.106							
M4A	1-Nov-02	31.6	31.66	-0.05	-0.30	32.16						
	23-Mar-03	31.6	31.65	-0.06	-0.30	31.75						
	1-Mar-05	31.6	31.66	-0.06	-0.30	32.29						
	25-Apr-05	31.6	31.56	-0.05	-0.30	32.40						
	6-Oct-05	31.6	31.66	-0.06	-0.30	32.70						
M4B	1-Nov-02	25.05					-1.96	0.1050	30.54			
	23-Mar-03	25.06					-1.95	0.1055	31.38			
	1-Mar-05	25.06					-1.95	0.1050	32.21			
	25-Apr-05	25.05					-1.95	0.1050				
	9-Oct-05	25.05					-1.05	0.1050	31.62			
M4C	17-Mar-05	29.16										
	17-Mar-05	29.16										
	9-Oct-05	29.16										
M11	1-Nov-02	27.75					0.76	0.0283	32.32			
	22-Mar-03	27.76					0.76	0.0283	32.27			
	1-Mar-05	27.76					0.75	0.0283	32.29			
	25-Apr-05	27.75					0.75	0.0283				
	9-Oct-05	27.75					0.76	0.0283	32.58			
M11A	1-Nov-02	31.9	31.66	0.36	0.029	32.65						
	23-Mar-03	31.9	31.66	0.36	0.029							
	1-Mar-05	31.9	31.66	0.35	0.029	32.19						
	25-Apr-05	31.9	31.56	0.35	0.029	32.38						
	9-Oct-05	31.9	31.55	0.36	0.029	32.01						
M11C	17-Mar-05	29.6	31.65	-2.05	0.029	31.89						
	25-Apr-05	29.6	31.65	-2.05	0.029	32.04						
	9-Oct-05	29.6	31.55	-2.05	0.029	32.37						
M19	17-Mar-05	32.58	31.66	1.03	0.06	31.92						
	17-Mar-05	32.68	31.55	1.03	0.06	32.16						
	9-Oct-05	32.58	31.65	1.03	0.05	32.38						
Surface water: site M1	3-Aug-02	31.56	31.55	0								
	8-Aug-02	31.66	31.55	0								
Surface water: site M19	9-Aug-02	31.66	31.55	0								
Surface water: near western shore	7-Aug-02	31.55	31.66	0								
Surface water: site M1	1-Mar-05	31.69	31.56	0	0	31.89						
Surface water: site M1	25-Apr-05	31.65	31.55	0	0							
Surface water: site M19	10-Oct-05	31.56	31.55	0	0	32.44						

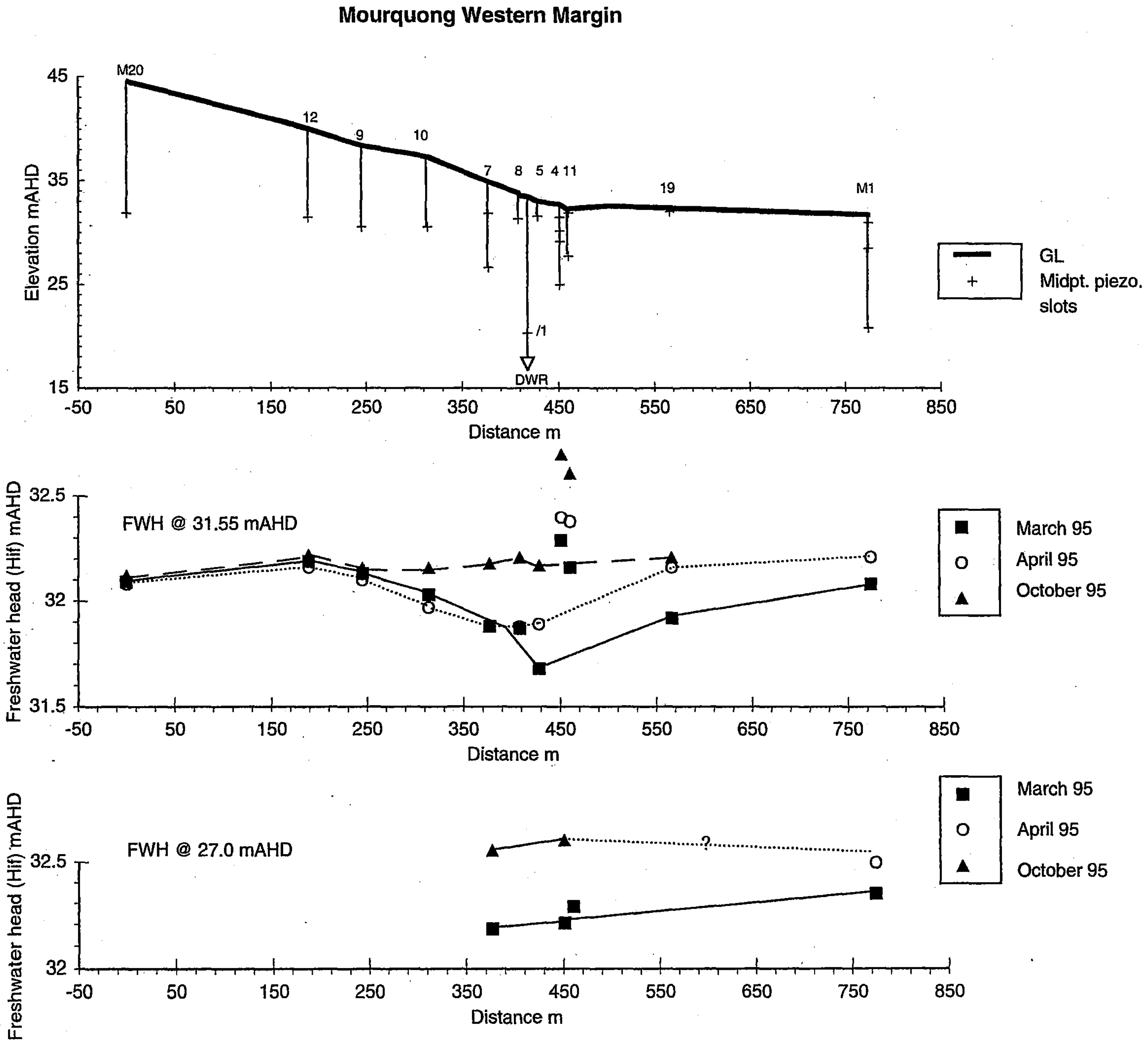


Figure 24. Freshwater heads, Mourquong western margin. Transect MWM.

Table A27. Environmental Water Heads, Mourquong Western Margin Transec

Site	Top of zone o saturation mAHD Zr	Average Density Rho a	Date	Environ,Water Head Hin Rho f = 1
M20	32.07		17-Mar-95	
	32.06		25-Apr-95	
M12	32		1-Nov-92	
	32.1		23-Mar-93	
	32.17		1-Mar-95	
	32.14		25-Apr-95	
M9	31.99		1-Nov-92	
	32.07		23-Mar-93	
	32.12		1-Mar-95	
	32.09		25-Apr-95	
M10	32.05		1-Nov-92	
	32.02		23-Mar-93	
	32.04		1-Mar-95	
	31.98		25-Apr-95	
M7	32.09	1.0296	1-Nov-92	32.09
	31.9	1.0296	23-Mar-93	31.90
	31.86	1.0296	1-Mar-95	31.86
	31.86	1.0296	25-Apr-95	31.86
	32.16	1.0296	6-Oct-95	32.16
M7A	31.46	1.033	1-Nov-92	31.44
	31.55	1.033	23-Mar-93	31.52
	32.06	1.033	1-Mar-95	32.02
		1.033	25-Apr-95	
	31.4	1.033	6-Oct-95	31.39
M8	32.13		1-Nov-92	
	31.84		23-Mar-93	
	31.86		1-Mar-95	
	31.87		25-Apr-95	
DWR 36908/1 (middle,30-36m)	31.73	1.0458	1-Nov-92	32.00
	31.77	1.0458	28-Mar-93	32.03
	31.79	1.0458	25-Apr-95	32.10
DWR 36908/2 (most westerly, 50-56m)	31.58	1.0481	1-Nov-92	30.98
	31.77	1.0481	28-Mar-93	31.86
	31.87	1.0481	25-Apr-95	31.92
DWR 36908/3 (most easterly,70-76m)	30.99	1.0511	1-Nov-92	32.07
(Bookpumong Beds)	30.98	1.0511	28-Mar-93	32.08
	31.09	1.0511	25-Apr-95	32.07
DWR 1011	32.1	1.0424	1-Mar-95	32.10
			25-Apr-95	
M5A	31.71	1.033	1-Nov-92	31.71
	31.63	1.033	23-Mar-93	31.63
	31.77	1.033	30-Mar-93	31.77
	31.67	1.033	1-Mar-95	31.67
	31.87	1.033	25-Apr-95	31.87
	32.14	1.033	6-Oct-95	32.14
M4	32	1.0571	1-Nov-92	32.04
	31.71	1.0571	23-Mar-93	31.73
	31.7	1.0571	1-Mar-95	31.76
	31.83	1.0571	25-Apr-95	31.90
	32.06	1.0571	6-Oct-95	32.15
M4A	32.1	1.033	1-Nov-92	32.11
	31.72	1.033	23-Mar-93	31.72
	32.23	1.033	1-Mar-95	32.25
	32.34	1.033	25-Apr-95	32.35
	32.63	1.033	6-Oct-95	32.64
M4B	30.32	1.0736	1-Nov-92	30.35
	31.11	1.0736	23-Mar-93	31.14
	31.83	1.0736	1-Mar-95	31.92
			25-Apr-95	
	31.14	1.0736	6-Oct-95	31.27
M4C	31.65	1.082	17-Mar-95	
	31.8	1.082	25-Apr-95	31.91
	32.02	1.082	6-Oct-95	32.18
M11	31.77	1.1176	1-Nov-92	31.83
	31.71	1.1176	23-Mar-93	31.78
	31.73	1.1176	1-Mar-95	31.80
		1.1176	25-Apr-95	
	32.02	1.1176	6-Oct-95	32.06
M11A	32.48	1.0807	1-Nov-92	32.49
	dry		23-Mar-93	
	32.13	1.0807	1-Mar-95	32.13
	32.34	1.0807	25-Apr-95	32.34
	32.54	1.0807	6-Oct-95	32.54
M11C	31.61	1.0944	17-Mar-95	31.72
	31.82	1.0944	25-Apr-95	31.89
	32.01	1.0944	6-Oct-95	32.20
M19	31.95		17-Mar-95	
	32.16		25-Apr-95	
Surface water; site M1	32.04		3-Aug-92	
	32.04		5-Aug-92	
Surface water; site M1B	32.1		9-Aug-92	
Surface water; near western shore.	32.1		7-Aug-92	
Surface water; site M1	31.84		1-Mar-95	
Surface water; site M1	ca. 32.51		25-Apr-95	

Mourquong Western Margin (Transect MWM)

April 95 (late summer)

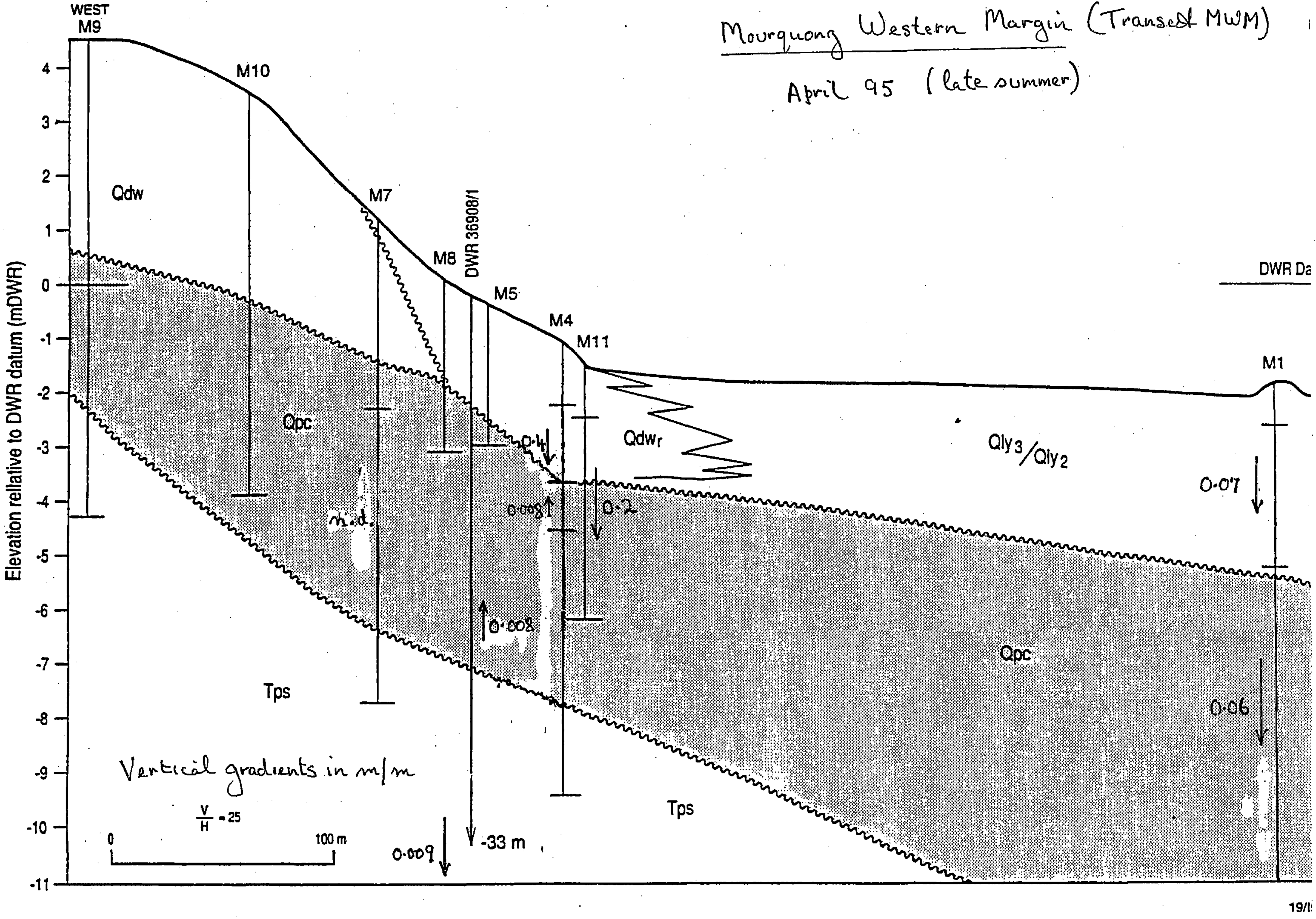
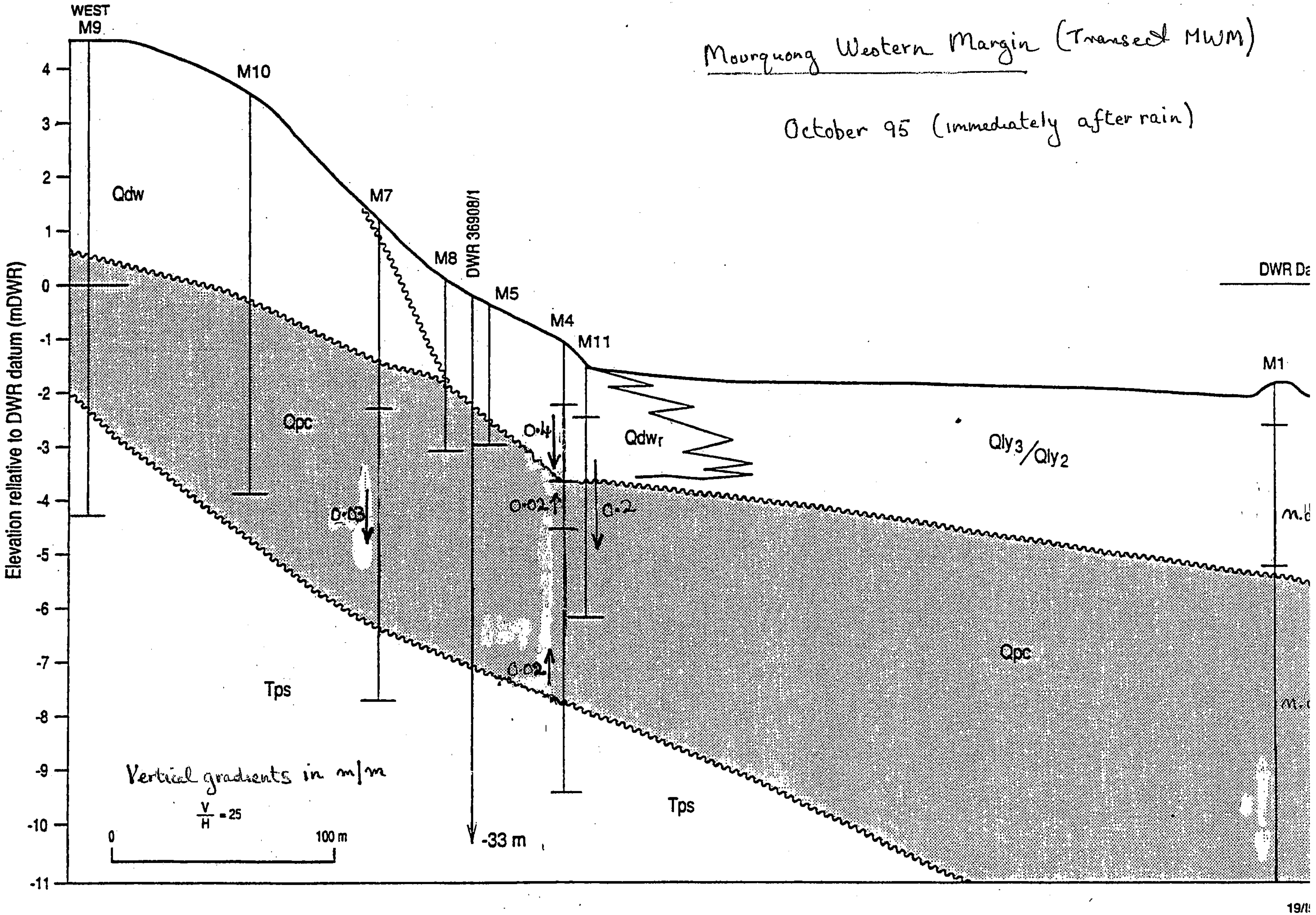


Figure 25. Environmental water heads, Mourquong western margin. Transect MWM.

(a) April 95 - late summer.



Mourquong Western Margin (Transect MWM)

October 95 (immediately after rain)

Vertical gradients in m/m

Figure 26. Environmental water heads, Mourquong western margin. Transect MWM.

(b) October 95 - after rain.

Table A28. Piezometer Data, Mourquong Eastern Margin Transect

Site	Top Casing mAHD	Midpt. Slots mAHD Zi	Date	TC-SWL m	SWL mAHD Hip	Salinity mg/L	Density g/cc Rho i	Freshwater Hea @ Midpt.Slots mAH Hif
M	32.31	20.8	1-Nov-92		31.76	91000	1.060	32.42
	32.94 (post Aug 92)	20.8	23-Mar-93		31.74	96000	1.064	32.44
		20.8	1-Mar-95	1.12	31.82	92500	1.061	32.50
		20.8	25-Apr-95	0.93	32.01	78000	1.052	32.59
M1A	32.829	28.45	1-Nov-92		32.05	210000	1.136	32.54
	33.17(post Aug 92)	28.45	23-Mar-93		31.83	220000	1.142	32.31
		28.45	1-Mar-95	1.34	31.83	224000	1.145	32.32
		28.45	25-Apr-95	1.185	31.985	210000	1.136	32.47
M1B	32.339	31.05	1-Nov-92		32.11	238000	1.153	32.27
	33.06(post Aug 92)	31.05	23-Mar-93		31.95	266000	1.170	32.10
		31.05	1-Mar-95	1.09	31.97	256000	1.164	32.12
		31.05	25-Apr-95	0.96	32.1	220000	1.142	32.25
M18B	32.93	26.65	1-Nov-92	not installed				
		26.65	29-Mar-93		30.17	92500	1.061	30.39
		26.65	31-Mar-93		30.68			
		26.65	1-Mar-95	1.05	31.88	88000	1.058	32.19
		26.65	25-Apr-95	1.14	31.92	78000	1.052	32.19
innundated : SurfaceWL 32.10		26.65	10-Oct-95	0.734	32.2	80000	1.053	32.49
M18A	33.13	30.65	1-Nov-92	not installed				
after 1 March 95	32.7	30.65	29-Mar-93		31.75	152000	1.100	31.86
		30.65	31-Mar-93		31.75			
		30.65	1-Mar-95	1.054	31.59	172000	1.113	31.70
		30.65	25-Apr-95	1.11	31.59	162000	1.106	31.69
innundated : Surface WL 32.09		30.65	10-Oct-95	0.62	32.08	165000	1.108	32.23
MEM-2A	37.04	31.25	17-Mar-95	5.46	31.58	70000	1.046	31.60
		31.25	25-Apr-95	5.48	31.56	60000	1.040	31.57
		31.25	8-Oct-95	5.1	31.94	60000	1.040	31.97
		31.25	10-Oct-95	5.09	31.95	60000		
MEM-2B	37.17	26.7	17-Mar-95	5.66	31.51	82000	1.054	31.77
		26.7	25-Apr-95	5.69	31.48	78000	1.052	31.73
		26.7	10-Oct-95	5.33	31.84	76000	1.050	32.10
		26.7	10-Oct-95	5.34	31.83	76000	1.050	32.09
M13	32.61	27.75	1-Nov-92		31.91	168000	1.110	32.37
		27.75	23-Mar-93		31.51	194000	1.126	31.98
		27.75	31-Mar-93		31.57			
		27.75	1-Mar-95	1.275	31.335	216000	1.140	31.84
		27.75	25-Apr-95	1.34	31.27	200000	1.130	31.73
innundated: Surface WL 31.67		27.75	10-Oct-95	0.92	31.69	190000	1.124	32.18
MEM-1; CSIRO	34.19	28.2	17-Mar-95	3.81	30.38	54000	1.036	30.46
		28.2	25-Apr-95					
		28.2	6-Oct-95		30.38	54000	1.036	30.46
After damage: temporary piezo.	34.15	28.2	8-Oct-95	3.78	30.37	54000	1.036	30.45
After damage: top stake.	34.24	28.2						
New casing 1.00m above GL (?)		28.2	10-Oct-95	4.35	30.3	55000	1.036	30.38
MEM-3; CSIRO	33.89	27.9	17-Mar-95	3.21	30.68	46000	1.030	30.76
		27.9	25-Apr-95					
J.F.		27.9	6-Oct-95	3.08	30.81	40000	1.026	30.89
WK +EL		27.9	8-Oct-95	3.125	30.76	40000	1.026	30.83

Table A29. Freshwater Heads, Mourquong Eastern Margin Transect

Site	Date	Midpt. Slots mAHD Zi	Normalised Elevation mAHD	Zi actual - Zi normalised @ 31.55 mAHD	Slope m/m	Hif @ 31.55 mAHD	Zi actual - Zi normalised @ 27.00 mAHD mAHD	Slope m/m	Hif @ 27.00 mAHD	Zi actual - Zi normalised @ 20.55 mAHD		Hif @ 20.55 mAHD
M	1-Nov-92	20.8								0.25	0.0234	32.43
	23-Mar-93	20.8								0.25	0.0234	32.44
	1-Mar-95	20.8								0.25	0.0234	32.50
	25-Apr-95	20.8								0.25	0.0234	32.60
M1A	1-Nov-92	28.45					1.45	0.0234	32.57			
	23-Mar-93	28.45					1.45	0.0234	32.34			
	1-Mar-95	28.45					1.45	0.0234	32.35			
	25-Apr-95	28.45					1.45	0.0234	32.50			
M1B	1-Nov-92	31.05	31.55	-0.5	0.077	32.23						
	23-Mar-93	31.05	31.55	-0.5	0.077	32.06						
	1-Mar-95	31.05	31.55	-0.5	0.077	32.08						
	25-Apr-95	31.05	31.55	-0.5	0.077	32.21						
M18B	1-Nov-92	26.65					-0.35	0.12				
	29-Mar-93	26.65					-0.35	0.12	30.34			
	31-Mar-93	26.65					-0.35	0.12				
	1-Mar-95	26.65					-0.35	0.12	32.14			
	25-Apr-95	26.65					-0.35	0.12	32.15			
	10-Oct-95	26.65					-0.35	0.12	32.45			
M18A	1-Nov-92	30.65	31.55	-0.9	0.12							
after 1 March 95	29-Mar-93	30.65	31.55	-0.9	0.12	31.75						
	31-Mar-93	30.65	31.55	-0.9	0.12							
	1-Mar-95	30.65	31.55	-0.9	0.12	31.59						
	25-Apr-95	30.65	31.55	-0.9	0.12	31.58						
	10-Oct-95	30.65	31.55	-0.9	0.12	32.13						
MEM-2A	17-Mar-95	31.25	31.55	-0.3	0.037	31.58						
	25-Apr-95	31.25	31.55	-0.3	0.037	31.56						
	10-Oct-95	31.25	31.56	-0.3	0.037	31.96						
MEM-2B	17-Mar-95	26.7					-0.3	0.037	31.76			
	25-Apr-95	26.7					-0.3	0.037	31.72			
	10-Oct-96	26.7					-0.3	0.037	32.09			
M13	1-Nov-92	27.75					0.75	0.04	32.40			
	23-Mar-93	27.75					0.75	0.04	32.01			
	31-Mar-93	27.75					0.75	0.04				
	1-Mar-95	27.75					0.75	0.04	31.87			
	25-Apr-95	27.75					0.75	0.04	31.76			
	10-Oct-95	27.75					0.75	0.04	32.21			
MEM-1; CSIRO	17-Mar-95	28.2					1.2	0.04	30.51			
	25-Apr-95	28.2					1.2	0.04				
	6-Oct-95	28.2					1.2	0.04	30.51			
	8-Oct-95	28.2					1.2	0.04	30.50			
MEM-3; CSIRO	17-Mar-95	27.9					0.9	0.04	30.80			
	25-Apr-95	27.9					0.9	0.04				
	6-Oct-96	27.9					0.9	0.04	30.92			
	8-Oct-95	27.9					0.9	0.04	30.87			

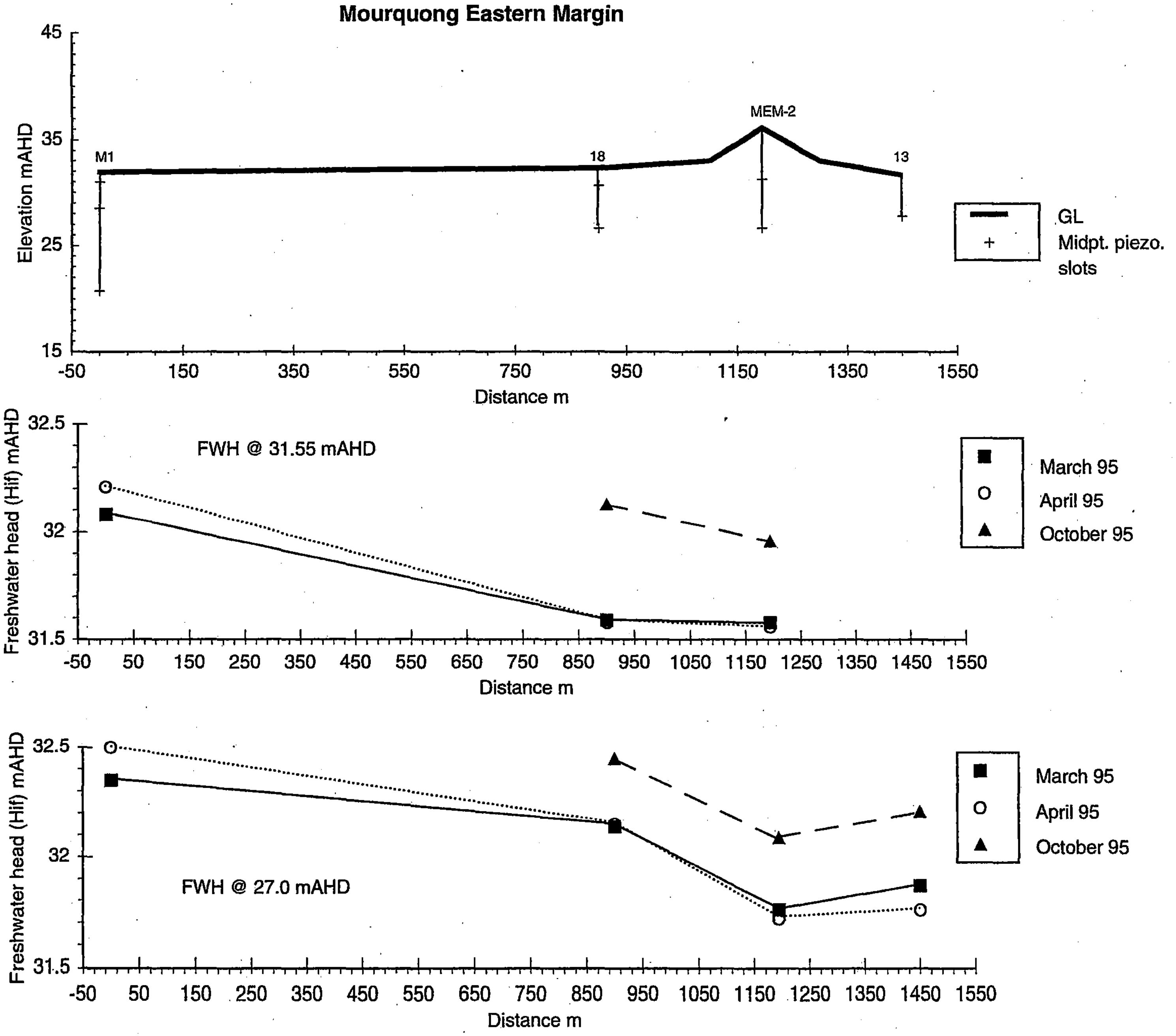
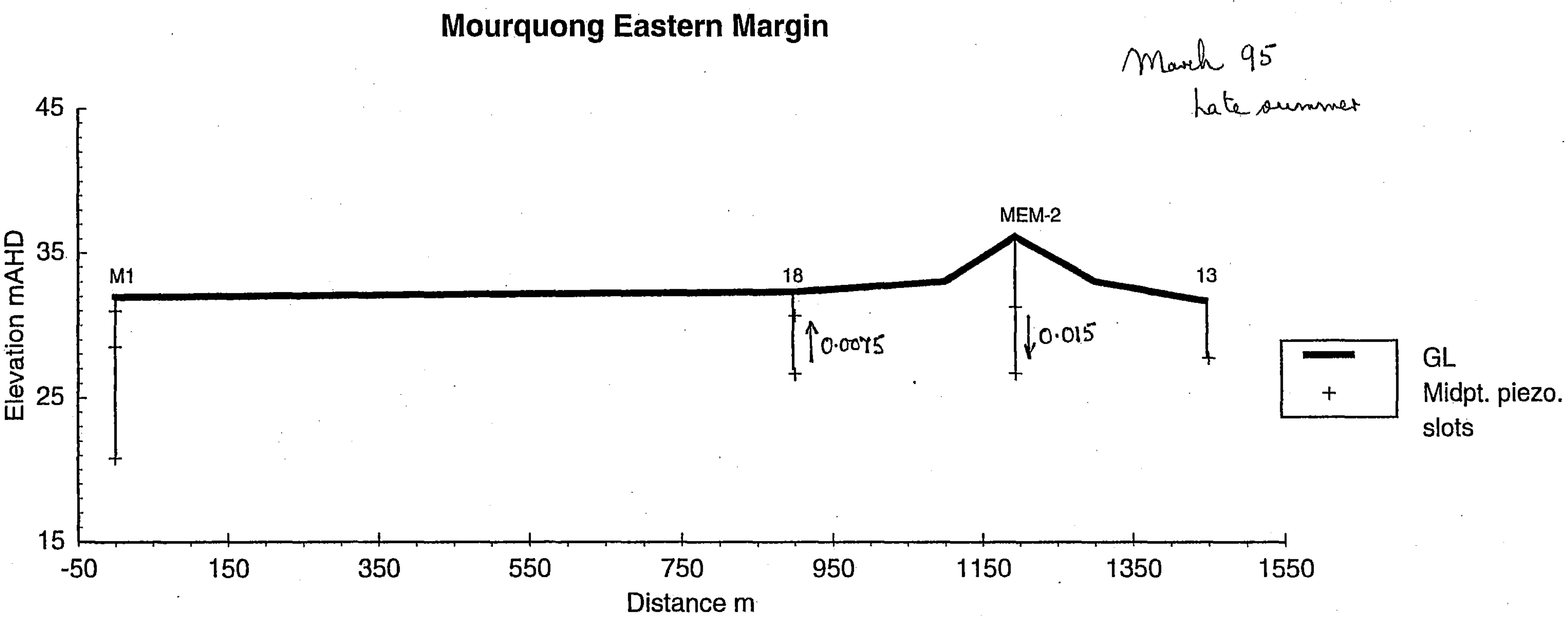


Figure 27. Freshwater heads, Mourquong eastern margin. Transect MEM.

Table A30. Environmental Water Heads, Mourquong Eastern Margin Trans

Site	SWL	Average Density	Date	Environ.Water Head
	mAHD			Hin
	Hip	Rho a		Rho f = 1
M	31.76	1.1	1-Nov-92	31.33
	31.74	1.1	23-Mar-93	31.34
	31.82	1.1	1-Mar-95	31.39
	32.01	1.1	25-Apr-95	31.47
M1A	32.05	1.1601	1-Nov-92	31.96
	31.83	1.1601	23-Mar-93	31.77
	31.83	1.1601	1-Mar-95	31.78
	31.985	1.1601	25-Apr-95	31.90
M1B	32.11	1.1601	1-Nov-92	32.10
	31.95	1.1601	23-Mar-93	31.96
	31.97	1.1601	1-Mar-95	31.97
	32.1	1.1601	25-Apr-95	32.08
M18B			1-Nov-92	
	30.17	1.105	29-Mar-93	30.02
	30.68	1.105	31-Mar-93	26.23
	31.88	1.105	1-Mar-95	31.64
	31.92	1.105	25-Apr-95	31.64
Innundated to 32.10	32.2	1.105	10-Oct-95	31.91
M18A			1-Nov-92	
after 1 March 95	31.75	1.0904	29-Mar-93	31.76
	31.75	1.0904	31-Mar-93	30.55
	31.59	1.0904	1-Mar-95	31.61
	31.59	1.0904	25-Apr-95	31.60
Innundated to 32.09	32.08	1.0904	10-Oct-95	32.11
MEM-2A	31.58	1.0465	17-Mar-95	31.58
	31.56	1.0465	25-Apr-95	31.56
	31.95	1.0465	10-Oct-95	31.93
MEM-2B	31.51	1.0538	17-Mar-95	31.51
	31.48	1.0538	25-Apr-95	31.47
	31.83	1.0538	10-Oct-95	31.82
M13	31.91		1-Nov-92	
	31.51		23-Mar-93	
	31.57		31-Mar-93	
	31.335		1-Mar-95	
	31.27		25-Apr-95	
MEM-1; CSIRO			17-Mar-95	
			25-Apr-95	
			6-Oct-95	
			8-Oct-95	
MEM-3; CSIRO			17-Mar-95	
			25-Apr-95	



March 95
Late summer

Figure 28. Environmental water heads, Mourquong eastern margin. Transect MEM.

(a) March 95 - late summer.

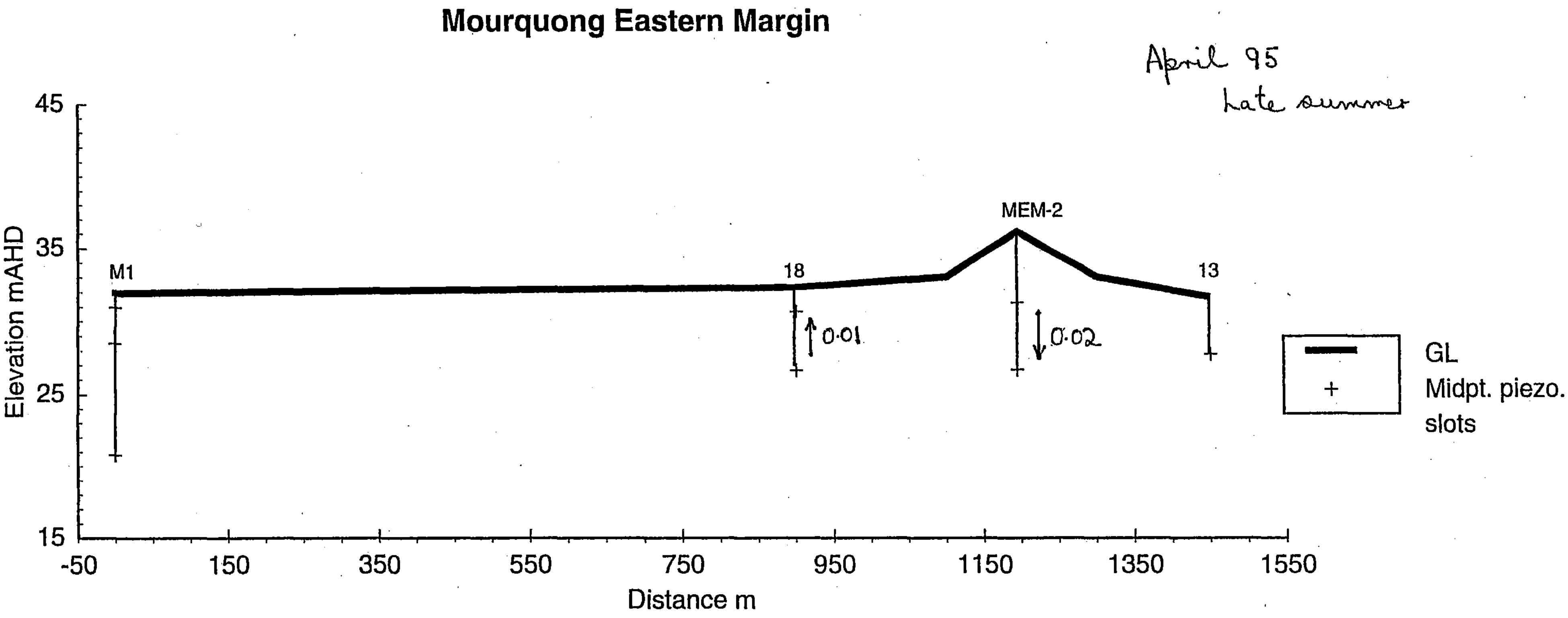


Figure 29. Environmental water heads, Mourquong eastern margin. Transect MEM.

(b) April 95 - late summer.

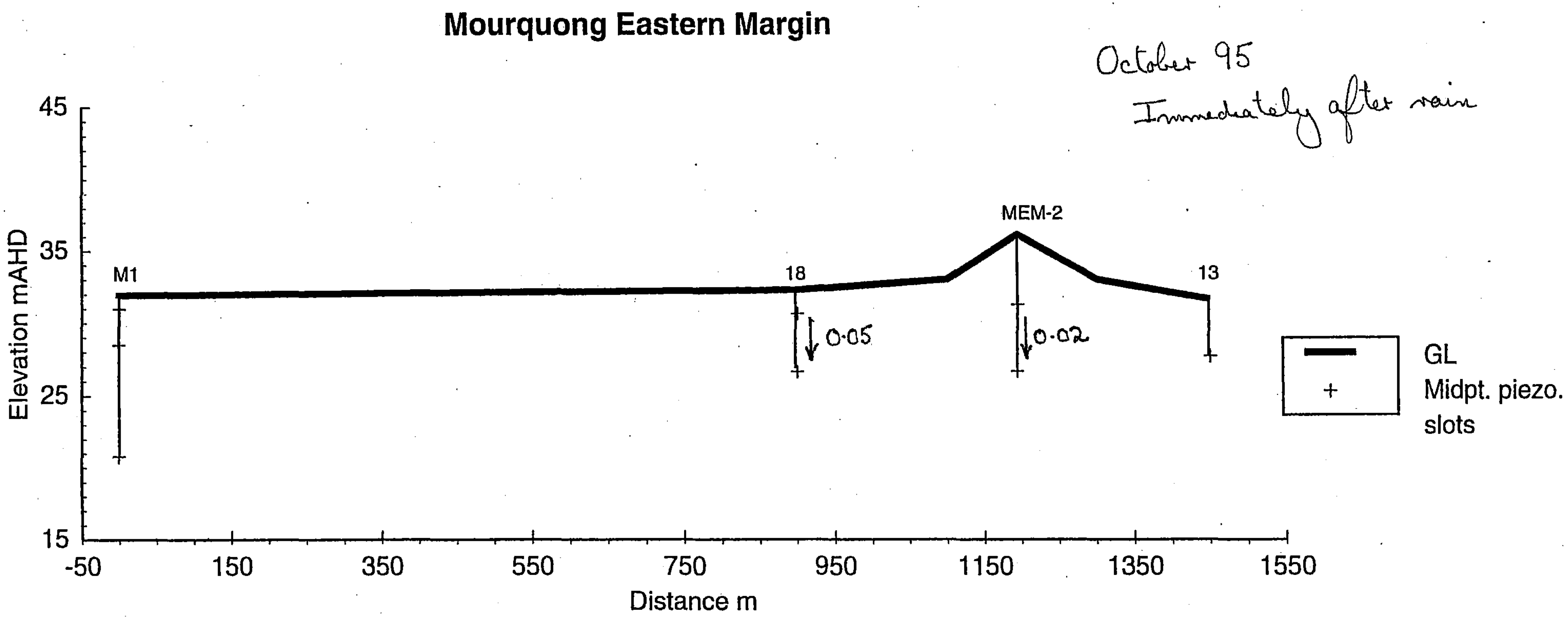


Figure 30. Environmental water heads, Mourquong eastern margin. Transect MEM.

(c) October 95 - after rain.

Table A31. Piezometer Data, Mourquong Northern Margin Transect

Site	Top Casing mAHD	Midpt. Slots mAHD Zi	Date	TC-SWL m	SWL mAHD Hip	Salinity mg/L	Density g/cc Rhoi	Freshwater Head @ Midpt.Slots mAHD Hif
M2	32.36				n.d.			
M	32.31	20.8	1-Nov-92		31.76	91000	1.060	32.42
	32.94 (post Aug 92)	20.8	23-Mar-93		31.74	96000	1.064	32.44
		20.8	1-Mar-95	1.12	31.82	92500	1.061	32.50
		20.8	25-Apr-95	0.93	32.01	78000	1.052	32.59
M1A	32.829	28.45	1-Nov-92		32.05	210000	1.136	32.54
	33.17(post Aug 92)	28.45	23-Mar-93		31.83	220000	1.142	32.31
		28.45	1-Mar-95	1.34	31.83	224000	1.145	32.32
		28.45	25-Apr-95	1.185	31.985	210000	1.136	32.47
M1B	32.339	31.05	1-Nov-92		32.11	238000	1.153	32.27
	33.06(post Aug 92)	31.05	23-Mar-93		31.95	266000	1.170	32.10
		31.05	1-Mar-95	1.09	31.97	256000	1.164	32.12
		31.05	25-Apr-95	0.86	32.1	220000	1.142	32.25
M3A	32.792	31.75	1-Nov-92		31.93			
		31.75	23-Mar-93		31.84	304000	1.192	31.86
		31.75	1-Mar-95	0.94	31.85	314000	1.197	31.87
		31.75	25-Apr-95	0.84	31.95	170000	1.111	31.97
M3	32.88	24.75	1-Nov-92		29.4	119000	1.079	29.77
	33.08 (post Aug 82)	24.75	23-Mar-93		30.47	118000	1.078	30.92
		24.75	1-Mar-95	1.19	31.89	114000	1.076	32.43
		24.75	25-Apr-95	1.09	31.99	121000	1.080	32.57
M16B	32.975	27.45	not installed					
		27.45	25-Mar-93		31.54	142000	1.094	31.92
		27.45	1-Mar-95	1.26	31.71	160000	1.105	32.16
		27.45	25-Apr-95	1.5	31.475	122000	1.081	31.80
		27.45	8-Oct-95	1.26	31.715	99000	1.068	32.00
M16A	32.64	30.65	not installed					
		30.65	31-Mar-93		31.61	146000	1.096	31.70
		30.65	1-Mar-95	1.01	31.63	166000	1.109	31.74
		30.65	25-Apr-95	1.06	31.58	170000	1.111	31.68
		30.65	8-Oct-95	0.6	32.04	176000	1.114	32.20
M15B	33.4	26.55	not installed					
		28.55	31-Mar-93		31.64	116000	1.077	31.88
		28.55	1-Mar-95	1.73	31.67	114000	1.076	31.91
		28.55	25-Apr-95	1.84	31.56	110000	1.073	31.78
		28.55	8-Oct-95	1.38	32.02	115000	1.076	32.28
M15A	33.52	30.95	not installed					
		30.95	31-Mar-93		31.6	124000	1.082	31.65
		30.96	1-Mar-95	1.89	31.63	118000	1.078	31.68
		30.95	25-Apr-95	2	31.52	132000	1.087	31.57
		30.95	8-Oct-95	1.54	31.98	78000	1.052	32.03
M14	33.8	26.55	1-Nov-92		31.7	82500	1.055	31.98
		26.55	23-Mar-93		31.54	78500	1.052	31.80
		26.55	1-Mar-95	2.25	31.55	85000	1.056	31.83
		26.55	25-Apr-95	2.345	31.455	82000	1.054	31.72
		26.55	8-Oct-95	1.99	31.81	82000	1.054	32.10
M17B	33.11	26.65	not installed					
		26.65	31-Mar-93		30.86	73500	1.049	31.07
		26.65	1-Mar-95	2.2	30.91	76000	1.050	31.13
		26.65	25-Apr-95	2.26	30.85	76000	1.050	31.06
		26.65	8-Oct-95	1.93	31.18	78000	1.052	31.41
M17A	33.36	30.85	not installed					
		30.85	31-Mar-93		30.94	74000	1.049	30.94
		30.85	1-Mar-95	2.45	30.91	78000	1.052	30.91
		30.85	25-Apr-95	2.51	30.85	78000	1.052	30.85
		30.85	8-Oct-95	2.21	31.15	78000	1.052	31.17
M22	36.85	31.65	17-Mar-95	5.97	30.88	20000	1.012	30.87
		31.65	25-Apr-95	5.97	30.88	16000	1.010	30.87
		31.65	8-Oct-95	5.98	30.87	18000	1.011	30.86
M23	39.01	31.85	17-Mar-95	8.02	30.99	40000	1.026	30.97
		31.85	25-Apr-95	8.025	30.985	35000	1.023	30.97
		31.85	8-Oct-95	7.82	31.19	28000	1.018	31.18

Table A32. Freshwater Heads, Mourquong Northern Margin Transect

Site	Date	Midpt. Slot mAHD Zi	Normalised Elevation mAHD	Zi actual - Zi normalised @ 31.55 mAHD	Slope m/m	Hif @ 31.55 mAHD	Zi actual - Zi normalised @ 27.00 mAHD	Slope m/m	Hif @ 27.00 mAHD
M2									
M	1-Nov-92	20.8							
	23-Mar-93	20.8							
	1-Mar-95	20.8							
	25-Apr-95	20.8							
M1A	1-Nov-92	28.45					1.45	0.0234	32.57
	23-Mar-93	28.45					1.45	0.0234	32.34
	1-Mar-95	28.45					1.45	0.0234	32.35
	25-Apr-95	28.45					1.45	0.0234	32.50
M1B	1-Nov-92	31.05	31.55	-0.5	0.077	32.23			
	23-Mar-93	31.05	31.55	-0.5	0.077	32.06			
	1-Mar-95	31.05	31.55	-0.5	0.077	32.08			
	25-Apr-95	31.05	31.55	-0.5	0.077	32.21			
M3A	1-Nov-92	31.75	31.55	0.2	0.08	0.02			
	23-Mar-93	31.75	31.55	0.2	0.08	31.67			
	1-Mar-95	31.75	31.55	0.2	0.08	31.89			
	25-Apr-95	31.75	31.55	0.2	0.08	31.99			
M3	1-Nov-92	24.75					-2.25	0.08	29.59
	23-Mar-93	24.75					-2.25	0.08	30.74
	1-Mar-95	24.75					-2.25	0.08	32.25
	25-Apr-95	24.75					-2.25	0.08	32.39
M16B	not installed	27.45					0.45	0.2	
	25-Mar-93	27.45					0.45	0.2	32.01
	1-Mar-95	27.45					0.45	0.2	32.25
	25-Apr-95	27.45					0.46	0.2	31.89
	8-Oct-95	27.45					0.45	0.2	32.09
M16A	not installed	30.65	31.55	-0.9	0.04				
	31-Mar-93	30.65	31.55	-0.9	0.04	31.67			
	1-Mar-95	30.65	31.55	-0.9	0.04	31.70			
	25-Apr-95	30.65	31.55	-0.9	0.04	31.65			
	8-Oct-95	30.65	31.55	-0.9	0.04	32.16			
M15B	not installed	28.55					1.55	0.1	
	31-Mar-93	28.55					1.55	0.1	32.03
	1-Mar-95	28.55					1.56	0.1	32.06
	25-Apr-95	28.55					1.55	0.1	31.93
	8-Oct-95	28.55					1.55	0.1	32.44
M15A	not installed	30.95	31.55	-0.6	0.1				
	31-Mar-93	30.95	31.55	-0.6	0.1	31.59			
	1-Mar-95	30.95	31.55	-0.6	0.1	31.62			
	25-Apr-95	30.95	31.55	-0.6	0.1	31.51			
	8-Oct-95	30.95	31.65	-0.6	0.1	31.97			
M14	1-Nov-92	26.55					-0.45	0.07	31.95
	23-Mar-93	26.55					-0.45	0.07	31.77
	1-Mar-95	26.55					-0.45	0.07	31.80
	25-Apr-95	26.55					-0.45	0.07	31.69
	8-Oct-95	26.55					-0.45	0.07	32.07
M17B	not installed	26.65					-0.35	0.052	
	31-Mar-93	26.65					-0.35	0.052	31.05
	1-Mar-95	26.65					-0.35	0.052	31.11
	25-Apr-95	26.65					-0.35	0.052	31.04
	8-Oct-95	26.65					-0.35	0.052	31.40
M17A	not installed	30.85	31.55	-0.7	0.052				
	31-Mar-93	30.85	31.55	-0.7	0.052	30.91			
	1-Mar-95	30.85	31.55	-0.7	0.052	30.88			
	25-Apr-95	30.85	31.55	-0.7	0.052	30.81			
	8-Oct-95	30.85	31.55	-0.7	0.052	31.13			
M22	17-Mar-95	31.65	31.55	0.1	0.052	30.88			
	25-Apr-95	31.65	31.55	0.1	0.052	30.88			
	8-Oct-95	31.65	31.55	0.1	0.052	30.87			
M23	17-Mar-95	31.85	31.55	0.3	0.052	30.98			
	25-Apr-95	31.85	31.55	0.3	0.052	30.98			
	8-Oct-96	31.86	31.55	0.3	0.052	31.19			

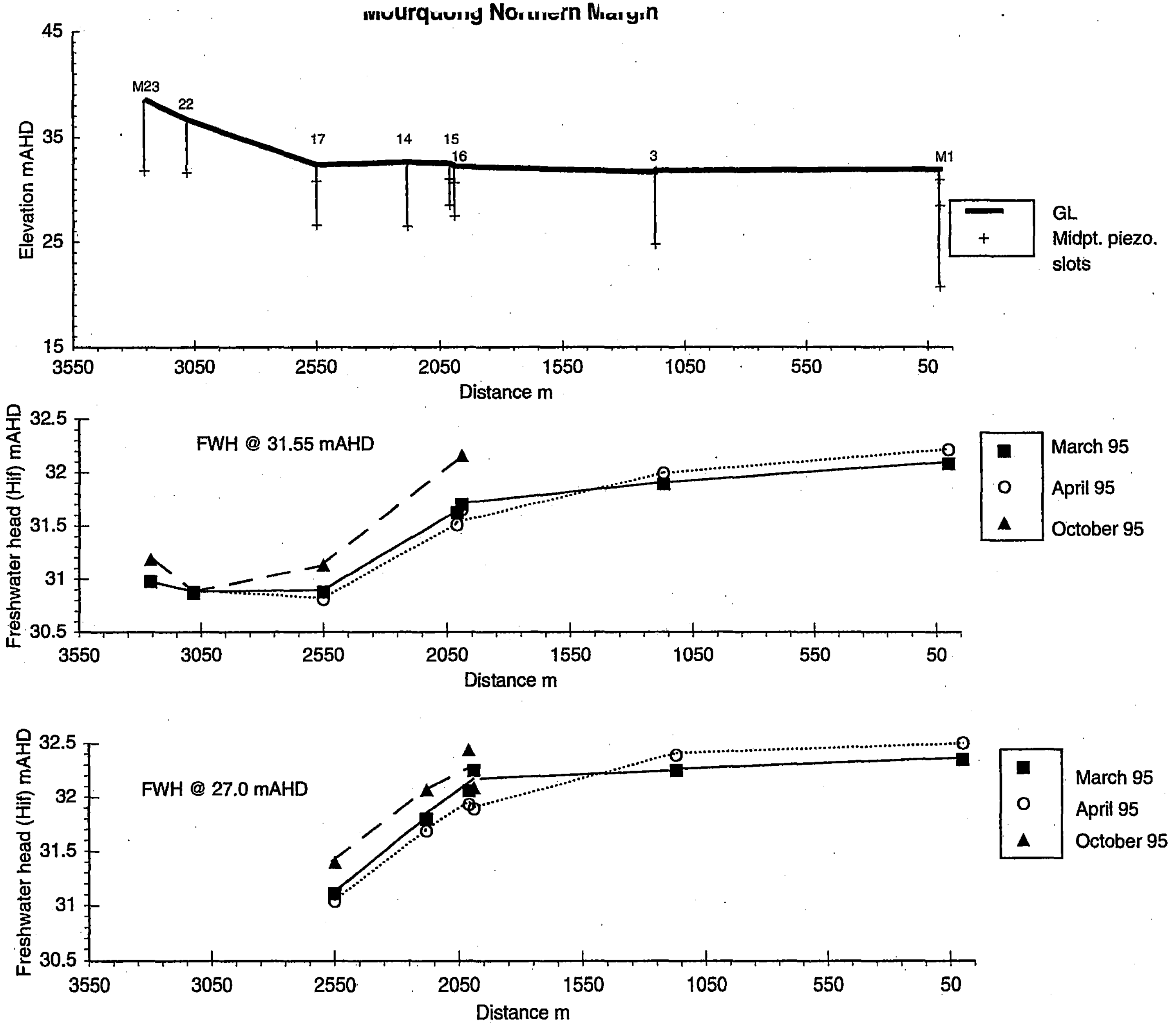


Figure 31. Freshwater heads, Mourquong northern margin. Transect MNM.

Table A33. Environmental Water Heads, Mourquong Northern Margin Transect

Site	SWL	Average Density	Date	Environ.Water Head
	mAHD			Hin
	Hip	Rho a		Rho f = 1
M2	n.d.			
M	31.76		1-Nov-92	
	31.74		23-Mar-93	
	31.82		1-Mar-95	
	32.01		25-Apr-95	
M1A	32.05		1-Nov-92	
	31.83		23-Mar-93	
	31.83		1-Mar-95	
	31.985		25-Apr-95	
M1B	32.11		1-Nov-92	
	31.95		23-Mar-93	
	31.97		1-Mar-95	
	32.1		25-Apr-95	
M3A	31.93	1.1864	1-Nov-92	31.72
	31.84	1.1864	23-Mar-93	31.84
	31.85	1.1864	1-Mar-95	31.85
	31.95	1.1864	25-Apr-95	31.93
M3	29.4	1.1385	1-Nov-92	29.12
	30.47	1.1385	23-Mar-93	30.12
	31.89	1.1385	1-Mar-95	31.44
	31.99	1.1385	25-Apr-95	31.57
M16B			not installed	
	31.54	1.1038	25-Mar-93	31.53
	31.71	1.1038	1-Mar-95	31.71
	31.475	1.1038	25-Apr-95	31.46
	31.715	1.1038	8-Oct-95	31.67
M16A			not installed	
	31.61	1.0872	31-Mar-93	31.64
	31.63	1.0872	1-Mar-95	31.70
	31.58	1.0872	25-Apr-95	31.65
	32.04	1.0872	8-Oct-95	32.14
M15B			not installed	
	31.64	1.0807	31-Mar-93	31.64
	31.67	1.0807	1-Mar-95	31.67
	31.56	1.0807	25-Apr-95	31.56
	32.02	1.0807	8-Oct-95	32.02
M15A			not installed	
	31.6	1.0768	31-Mar-93	31.63
	31.63	1.0768	1-Mar-95	31.64
	31.52	1.0768	25-Apr-95	31.57
	31.98	1.0768	8-Oct-95	31.84
M14	31.7		1-Nov-92	
	31.54		23-Mar-93	
	31.55		1-Mar-95	
	31.455		25-Apr-95	
M17B			not installed	
	30.86	1.0511	31-Mar-93	30.86
	30.91	1.0511	1-Mar-95	30.91
	30.85	1.0511	25-Apr-95	30.85
	31.18	1.0511	8-Oct-95	31.18
M17A			not installed	
	30.94	1.0505	31-Mar-93	30.90
	30.91	1.0505	1-Mar-95	30.91
	30.85	1.0505	25-Apr-95	30.85
	31.15	1.0505	8-Oct-95	31.15
M22	30.88		17-Mar-95	
	30.88		25-Apr-95	
M23	30.99		17-Mar-95	
	30.985		25-Apr-95	

March 95

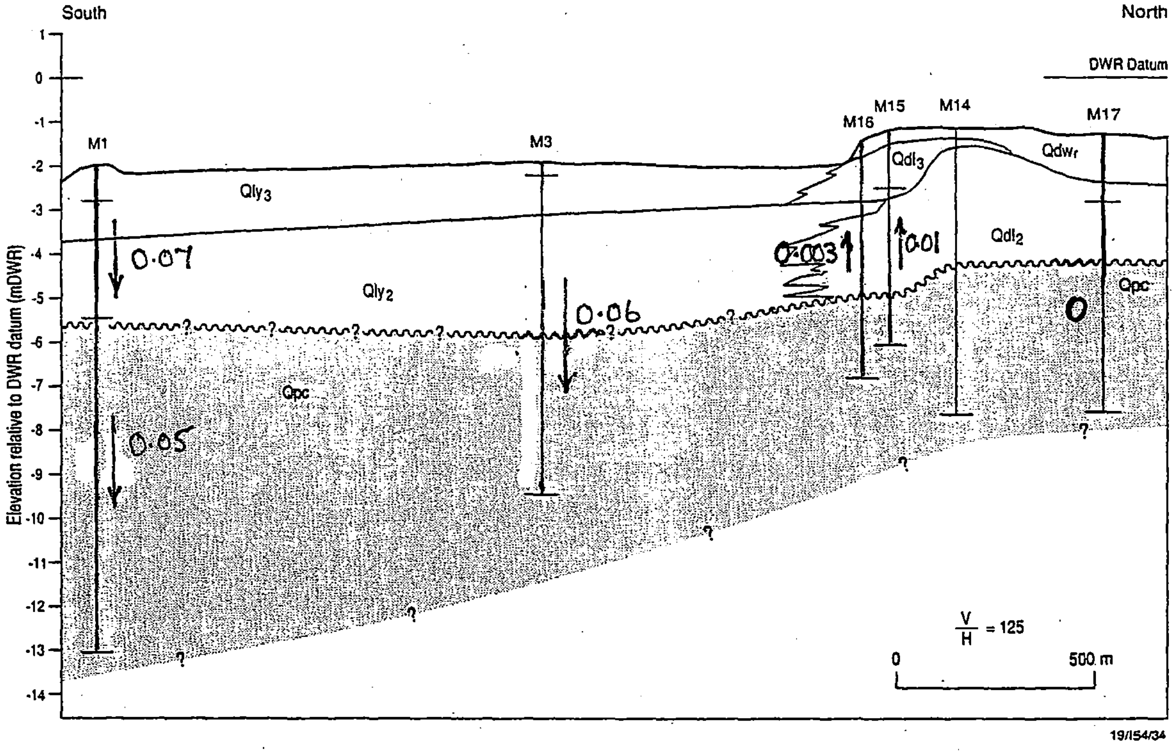


Figure 32. Environmental water heads, Mourquong northern margin. Transect MNM.

(a) March 95 - late summer.

April 95
Late summer

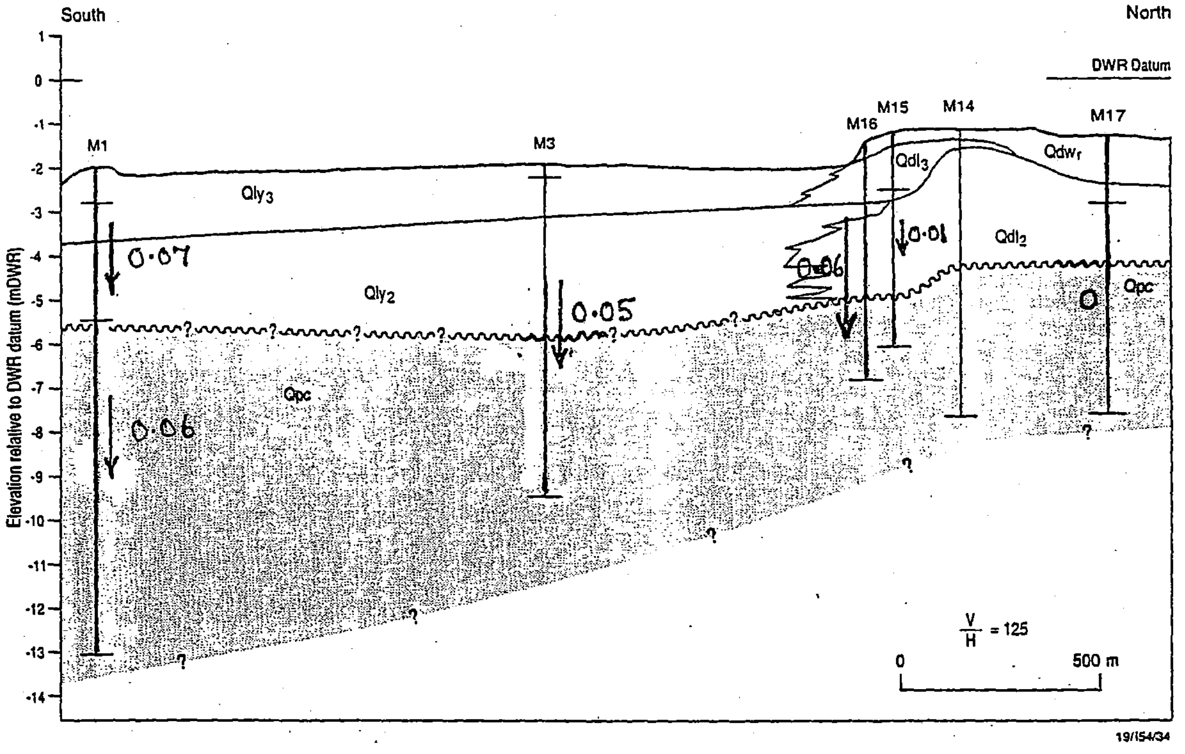


Figure 33. Environmental water heads, Mourquong northern margin. Transect MNM.

(b) April 95 - late summer.

October 95
Immediately after rain

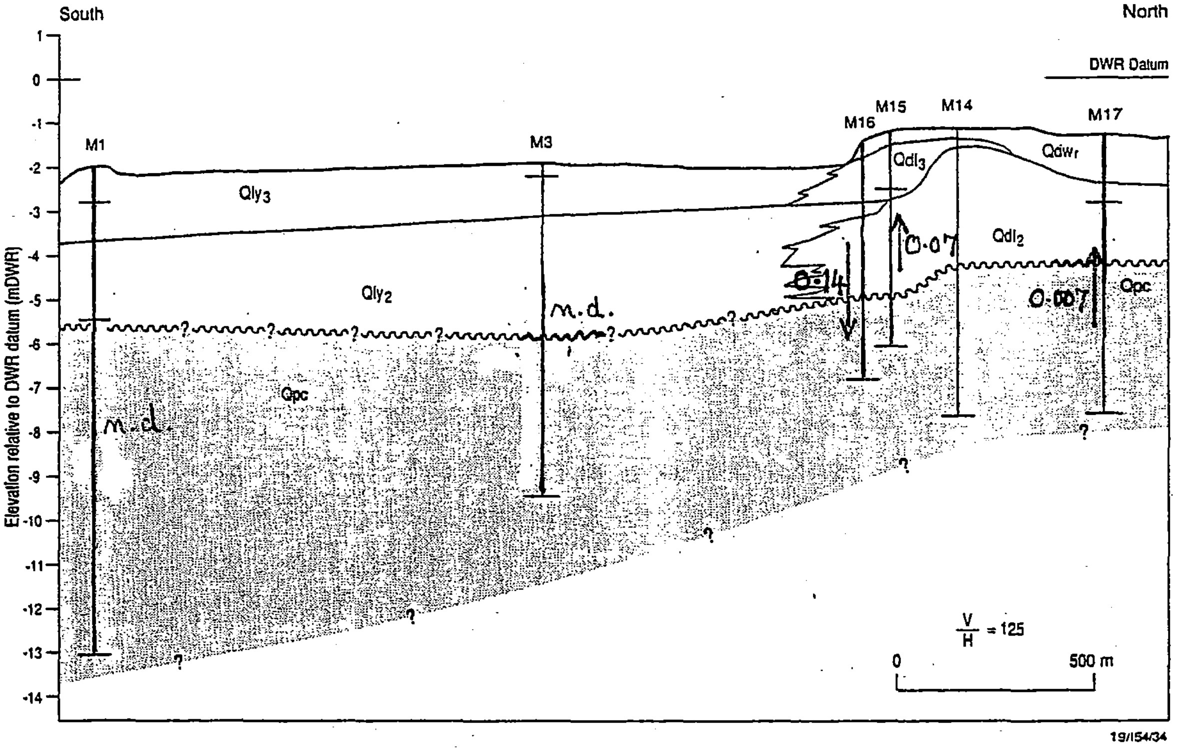


Figure 34. Environmental water heads, Mourquong northern margin. Transect MNM.

(c) October 95 - after rain.

Table A34. Piezometer Data, Mourquong River Transect (MRT)

Site	Top Casing mAHD	Midpt. Slots mAHD Zi	Date	TC-SWL m	SWL mAHD Hip	Salinity mg/L	Density g/cc Rho I	Freshwater Head @ Midpt.Slots mAHD Hif
Pond	32.41	nominal 31.55	6-Mar-95		31.81	34000	1.022	31.82
			25-Apr-95	0.05 above GL				
MRT-BM	32.75	30.1	17-Mar-95	0.99	31.76	48000	1.032	31.81
		30.1	25-Apr-95	0.945	31.805	46000	1.030	31.86
		30.1	9-Oct-95	1.02	31.73	46000	1.030	31.78
MRT-BM A	32.79	30.05	17-Mar-95	1.03	31.76	41000	1.027	31.81
		30.05	25-Apr-95	0.98	31.81	40000	1.026	31.86
		30.05	9-Oct-95	1.06	31.73	45000	1.030	31.78
MRT-1	32.96	30.25	17-Mar-95	1.26	31.7	65000	1.043	31.76
		30.25	25-Apr-95	1.215	31.745	70000	1.046	31.81
		30.25	9-Oct-95	1.29	31.67	65000	1.043	31.73
MRT-2	32.53	28.75	17-Mar-95	0.88	31.65	75000	1.050	31.79
		28.75	25-Apr-95	0.815	31.715	76000	1.050	31.86
		28.75	10-Oct-95	0.88	31.65	83000	1.055	31.81
MRT-2A	32.61	30.55	17-Mar-95	0.97	31.64	99000	1.066	31.71
		30.55	25-Apr-95	0.905	31.71	102000	1.068	31.79
		30.55	10-Oct-95	0.99	31.62	100000	1.066	31.69
MRT-2B	32.91	29.35	17-Mar-95	1.25	31.66	93000	1.062	31.80
		29.35	25-Apr-95	1.195	31.715	95000	1.063	31.86
		29.35	10-Oct-95	1.28	31.63	90000	1.060	31.77
MRT-2/3	32.75	27.5	17-Mar-95	0.87	31.88	37000	1.024	31.99
		27.5	25-Apr-95	0.83	31.92	42000	1.028	32.04
		27.5	10-Oct-95	0.78	31.97	38000	1.025	32.08
MRT-2/3A	32.77	30.65	17-Mar-95	1.11	31.66	66000	1.044	31.70
		30.65	25-Apr-95	1.02	31.75	70000	1.046	31.80
		30.65	10-Oct-95	1.03	31.74	73000	1.048	31.79
MRT-2/3B	33.16	29.45	17-Mar-95	1.49	31.67	56000	1.037	31.75
		29.45	25-Apr-95	1.4	31.76	56000	1.037	31.85
		29.45	10-Oct-95	1.39	31.77	50000	1.033	31.85
MRT-3	33.96	25.95	17-Mar-95	2.12	31.84	34000	1.022	31.97
		25.95	25-Apr-95	2.075	31.885	35000	1.023	32.02
		25.95	10-Oct-95	2.03	31.93	33000	1.021	32.06
MRT-3A	33.63	29.95	17-Mar-95	1.7	31.93	40000	1.026	31.98
		29.95	25-Apr-95	1.825	31.805	42000	1.028	31.86
		29.95	10-Oct-95	1.79	31.84	39000	1.025	31.89
MRT-3B	33.48	30	17-Mar-95	1.78	31.7	40000	1.026	31.74
		30	25-Apr-95	1.68	31.8	40000	1.026	31.85
		30	10-Oct-95	1.61	31.87	40000	1.026	31.92
MRT-4	34.63	32.15	17-Mar-95	2.9	31.73	36000	1.023	31.72
		32.15	25-Apr-95	2.785	31.845	38000	1.025	31.84
		32.15	10-Oct-95	2.7	31.93	37000	1.024	31.92
MRT-6	36.74	29.45	17-Mar-95	4.49	32.25	32000	1.021	32.31
		29.45	25-Apr-95	4.36	32.38	32000	1.021	32.44
		29.45	10-Oct-95	4.28	32.46	38000	1.025	32.53

Table A36. Environmental Water Heads, Mourquong River Transect (MRT)

Site	SWL	Average Density	Date	Environ.Water Head
	mAHD			Hin
	Hip	Rho a		Rho f = 1
Pond	31.81		6-Mar-95	
			25-Apr-95	
MRT-BM	31.76		17-Mar-95	
	31.805		25-Apr-95	
MRT-BM A	31.76		17-Mar-95	
	31.81		25-Apr-95	
MRT-1	31.7		17-Mar-95	
	31.745		25-Apr-95	
MRT-2	31.65	1.0611	17-Mar-95	31.62
	31.715	1.0611	25-Apr-95	31.68
	31.65	1.0611	10-Oct-95	31.63
MRT-2A	31.64	1.0598	17-Mar-95	31.65
	31.71	1.0598	25-Apr-95	31.72
	31.62	1.0598	10-Oct-95	31.63
MRT-2B	31.66	1.0604	17-Mar-95	31.66
	31.715	1.0604	25-Apr-95	31.72
	31.63	1.0604	10-Oct-95	31.63
MRT-2/3	31.88	1.0411	17-Mar-95	31.81
	31.92	1.0411	25-Apr-95	31.86
	31.97	1.0411	10-Oct-95	31.90
MRT-2/3A	31.66	1.0336	17-Mar-95	31.67
	31.75	1.0336	25-Apr-95	31.76
	31.74	1.0336	10-Oct-95	31.76
MRT-2/3B	31.67	1.037	17-Mar-95	31.67
	31.76	1.037	25-Apr-95	31.76
	31.77	1.037	10-Oct-95	31.76
MRT-3	31.84	1.0272	17-Mar-95	31.81
	31.885	1.0272	25-Apr-95	31.86
	31.93	1.0272	10-Oct-95	31.90
MRT-3A	31.93	1.0282	17-Mar-95	31.93
	31.805	1.0282	25-Apr-95	31.80
	31.805	1.0282	25-Apr-95	31.84
MRT-3B	31.7	1.0282	17-Mar-95	31.70
	31.8	1.0282	25-Apr-95	31.80
	31.8	1.0282	25-Apr-95	31.87
MRT-4	31.73		17-Mar-95	
	31.845		25-Apr-95	
MRT-6	32.25		17-Mar-95	
	32.38		25-Apr-95	

April 95
late summer

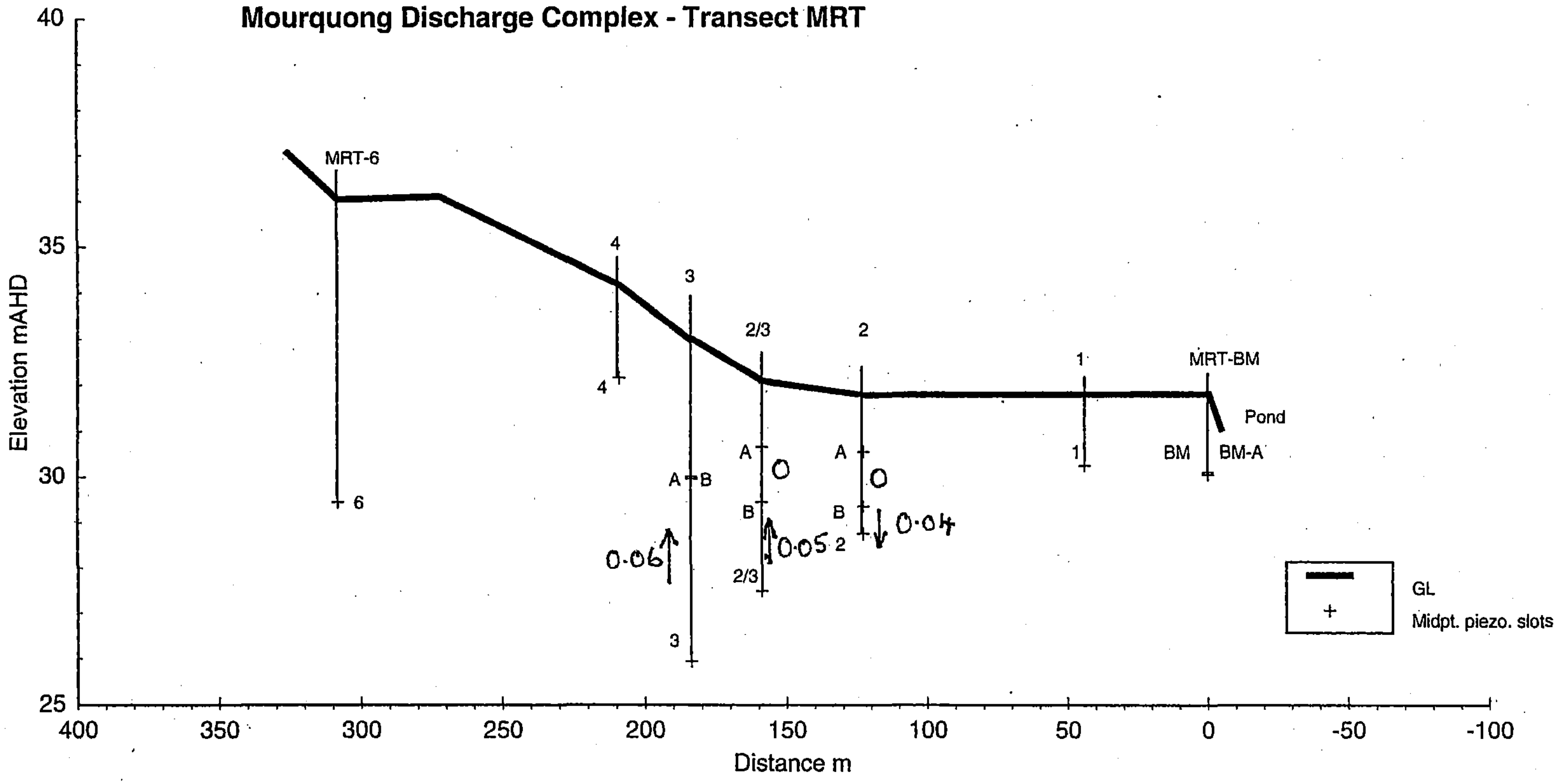


Figure 36. Environmental water heads, Mourquong southern margin. Transect MRT.

(a) April 95 - late summer.

October 95
Immediately after rain

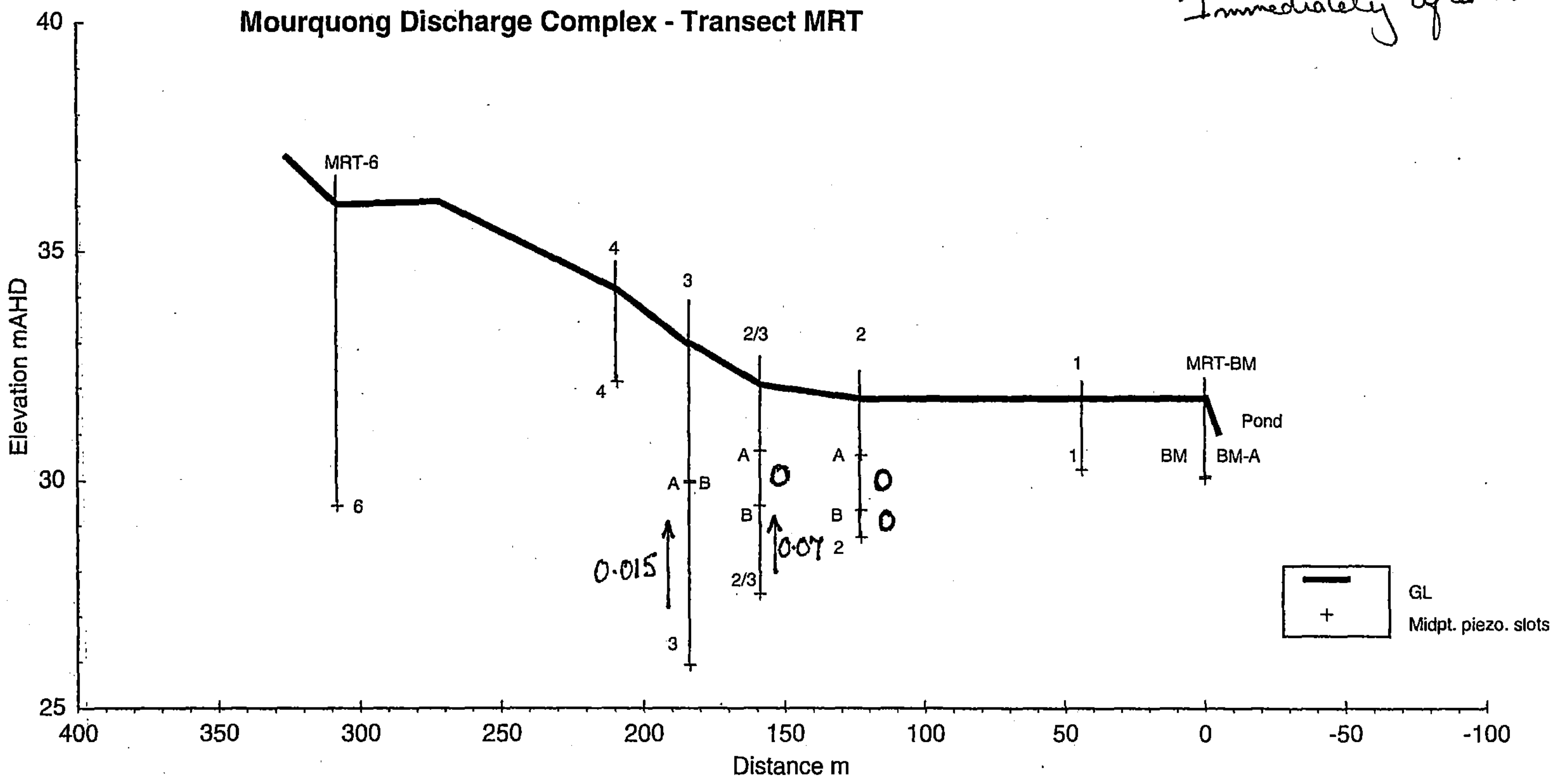


Figure 37. Environmental water heads, Mourquong southern margin. Transect MRT.

(b) October 95 - after rain.

Table A37: Piezometer Data, Mourquong Southern Orchard Margin (MSOM) and Southern Margin (MSM) Transects

Site	Top Casing mAHD	Midpt. Slots mAHD Zi	Date	TC-SWL m	SWL mAHD Hip	Salinity mg/L	Density g/cc Rho i	Freshwater Head @ Midpt.Slots mAHD Hif
M21	33.31	27.45	17-Mar-95	1.58	31.73	34000	1.022	31.82
		27.45	25-Apr-95	1.57	31.74	46000	1.030	31.87
		27.45	10-Oct-95	1.485	31.82	36000		
MSMW- Blue tape (4A) short PVC	34.71	27.7	17-Mar-95	2.13	32.58	30000	1.019	32.67
		27.7	25-Apr-95	2.065	32.645	32000	1.021	32.75
		27.7	10-Oct-95	2	32.71	31000		
MSMW- (4) long PVC	34.82	30.8	17-Mar-95	2.59	32.23	33000	1.021	32.26
		30.8	25-Apr-95	2.53	32.29	32000	1.021	32.32
		30.8	10-Oct-95	2.44	32.38	33000		
MRT-3	33.96	25.95	17-Mar-95	2.12	31.84	34000	1.022	31.97
		25.95	25-Apr-95	2.075	31.885	35000	1.023	32.02
		25.95	10-Oct-95	2.03	31.93	33000	1.021	32.06
MRT-3A	33.63	29.95	17-Mar-95	2.7	31.93	40000	1.026	31.98
		29.95	25-Apr-95	1.825	31.805	42000	1.028	31.86
		29.95	10-Oct-95	1.79	31.84	39000	1.025	31.89
MRT-3B	33.48	30	17-Mar-95	1.78	31.7	40000	1.026	31.74
		30	25-Apr-95	1.68	31.8	40000	1.026	31.85
		30	10-Oct-95	1.61	31.87	40000	1.026	31.92
MSM-P1 (dead tree)	36.56	31.08	1-Mar-95		33.74	15000	1.009	33.76
		31.08	25-Apr-95	2.945	33.615	12000	1.007	33.63
		31.08	5-Oct-95	2.81	33.75	14000	1.008	33.77
MSM-P2 (near effluent drain)	33.38	29.88	1-Mar-95		31.88	49000	1.032	31.94
		29.88	25-Apr-95	1.435	31.945	48000	1.032	32.01
		29.88	5-Oct-95	1.36	32.02	53000	1.035	32.09
MSOM-1	34.88	29.65	17-Mar-95	4.61	30.27	6000	1.003	30.27
		29.65	25-Apr-95	2.565	32.315	5000	1.002	32.32
		29.65	5-Oct-95	2.44	32.44	4000	1.001	32.44
MSOM-2	34.16	30.45	17-Mar-95	2.65	31.51	6000	1.003	31.51
		30.45	25-Apr-95	2.03	32.13	4000	1.001	32.13
		30.45	5-Oct-95	1.86	32.3	4000	1.001	32.30
MSOM-3	36.52	31.35	17-Mar-95	4.53	31.99	26000	1.017	32.00
		31.35	25-Apr-95	2.815	33.705	25000	1.016	33.74
		31.35	5-Oct-95	2.59	33.93	26000	1.017	33.97

Table A38. Freshwater Heads, Mourquong Southern Orchard Margin (MSOM) and Southern Margin (MSM) Transects

Site	Date	Midpt. Slots mAHD Zi	Normalised Elevation mAHD	Zi actual - Zi normalised @ 30.00 mAHD	Slope m/m	Hif @ 30.00 mAHD
M21	17-Mar-95	27.45				
	25-Apr-95	27.45				
MSMW- Blue tape (4A) short PVC	17-Mar-95					
	25-Apr-95					
MSMW- (4) long PVC	17-Mar-95					
	25-Apr-95					
MRT-3	17-Mar-95	25.95				
	25-Apr-95	25.95				
MRT-3A	17-Mar-95	29.95				
	25-Apr-95	29.95				
MRT-3B	17-Mar-95	30	30	0	0.05	31.74
	25-Apr-95	30	30	0	0.05	31.85
	10-Oct-95	30	30	0	0.05	31.92
MSM-P1 (dead tree)	1-Mar-95	31.08	30	1.08	0.05	33.82
	25-Apr-95	31.08	30	1.08	0.05	33.69
	5-Oct-95	31.08	30	1.08	0.05	33.83
MSM-P2 (near effluent drain)	1-Mar-95	29.88	30	-0.12	0.05	31.94
	25-Apr-95	29.88	30	-0.12	0.05	32.00
	5-Oct-95	29.88	30	-0.12	0.05	32.09
MSOM-1	17-Mar-95	29.65	30	-0.35	0.05	30.25
	25-Apr-95	29.65	30	-0.35	0.05	32.30
	5-Oct-95	29.65	30	-0.35	0.05	32.43
MSOM-2	17-Mar-95	30.45	30	0.45	0.05	31.54
	25-Apr-95	30.45	30	0.45	0.05	32.15
	5-Oct-95	30.45	30	0.45	0.05	32.32
MSOM-3	17-Mar-95	31.35	30	1.35	0.05	32.07
	25-Apr-95	31.35	30	1.35	0.05	33.81
	5-Oct-95	31.35	30	1.35	0.05	34.04

} ≈ 33.78

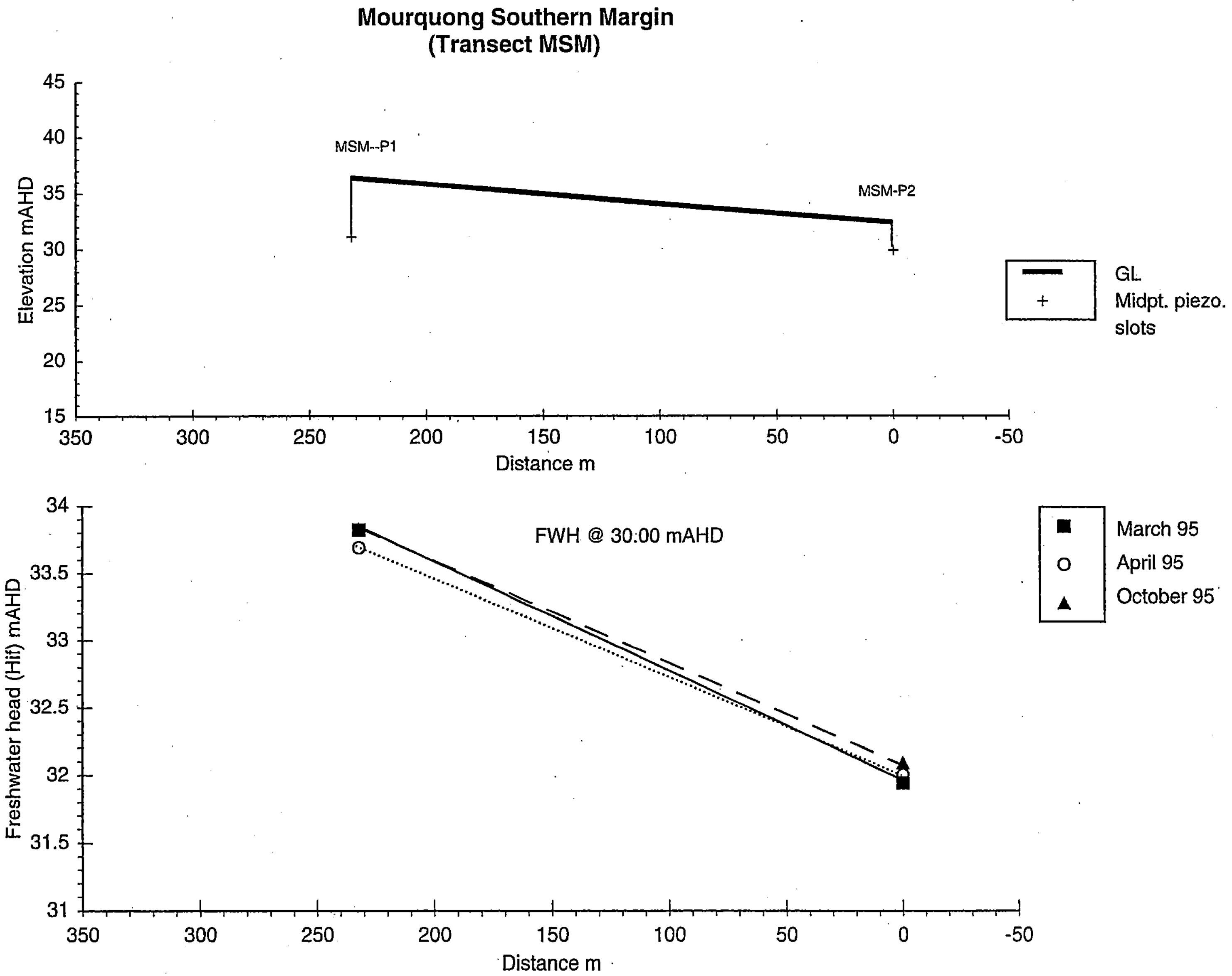


Figure 38. Freshwater heads, Mourquong southern margin. Transect MRT.

Table 39. Summary of Vertical Hydraulic Heads (Environmental Water Heads, Hin), Mourquong Discharge Complex.

Mourquong		Aquifer	Midpl. Slots	Difference	Hin : Nov 92	Difference	Gradient m/m	Hin : March 93	Difference	Gradient m/m	Hin : March 95	Difference	Gradient m/m	Hin : April 95	Difference	Gradient m/m	Hin : October 95	Difference	Gradient m/m
Western margin transect:																			
M7			31,85		32,09			31,9			31,86			31,86			32,16		
				5,25		-0,65	-0,13		-0,38	-0,07		0,16	0,03		n.d.	n.d.		-0,14	-0.03
M7A			26,65		31,44			31,52			32,02			n.d.			32,02		
M5A			31,6		31,7			31,77			31,67			31,87			32,14		
				11,3								0.43	0,04						
DWR 1011			20,3			0,33	0.01				32,1			n.d.	M5A/DWR/1: 0.23	0,0075	n.d.		
				19.55															
DWR 36908/1			0,75		32			32,03						32.1			n.d.		
·				20,15		-1,02	-0,05		-0,17	-0,008					-0,18	-0,009			
DWR 36908/2			-19,4		30,98			31,86						31,92			n.d.		
				20		1,09	0,05		0.22	0,01					0,15	0,0075			
DWR 36908/3			-39,4		32,07			32.08						32,07			n.d.		
M4A			31,5		32,11			31,72			32,25			32,35			32,64		
				1,08		-0,07	-0,06		0,01	0,009		-0,497	-0,457		-0,45	-0,42		-0,39	-0,36
M4			30,42		32,04			31,73			31,76			31,8			32,15		
M4C			29,15	5,37		-1,69	-0,31		-0.59	-0,11		0.16	0,03		M4/4C 0,01	0,008	32,18	M4/4C 0,03	0,02
M4B			25,05		30,35			31,14			31,92			M4C 31,91			31,27	M4C/4B 0,09	0,02
M11A			31,9		32,49						32,13			32,34			32,54		
M11C			28,5	3,15		-0,66	-0,16					-0,33	-0,08		-0,54	-0,17	32,37	-0,48	-0,15
M11			27,75		31,83						31,8			31,8			32,06	M11C/11	-0,18
M1B			31,05		32,1			31,96			31,97			32.08			n.d.		
				2,6		-0,14	-0,05		-0,19	-0,07		-0,19	-0,07		-0,18	-0,069			
M1A			28,45		31,96			31,77			31,78			31,9			n.d.		
				7,85		-0,63	-0,08		-0.43	-0,06		-0,39	-0,05		-0.43	-0,056			
M1			20,8		31,33			31,34			31,39			31,47			n.d.		
Eastern margin transect:																			
M18A			30,65								31,61			31,6			32,11		
				4								0,03	0,0075		0,04	0,01		-0,2	-0,05
M18B			26,65								31,64			31,64			31,91		
MEM-2A			31,25								31.58			31,56			31,83		
				4,55								-0,07	-0,015		-0,08	-0,02		-0,11	-0.02
MEM-2B			26,7								31,51			31,47			31,82		
Northern margin transect:																			
M3A			31,75		31,72			31,84			31,85			31,83			n.d.		
				7		-2,67			-1,727			-0,41	-0,06		-0,36	-0,051			
M3			24,75		29,12			30,12			31,44			31,57			n.d.		
M16A			30,65					31.64			31,7			31.65			32,14		
				3,25					-0.11	-0,04		0,01	0,003		-0.19	-0,058		-0,47	-0,14
M16B			27,45					31,53			31,71			31,46			31,07		
M15A			30,95					31,63			31,64			31,57			31,84		
				2,45					0,01	0,004		0,03	0,01		-0,01	-0,004		0,18	0,07
M15B			28,55					31,64			31,67			31,56			32.02		
M17A			30,85					30,9			30,81			30,85			31,15		
				4,25					-0,04	-0,01		0	0		0	0		0,03	0,007
M17B			26,65					30,86			30,91			30,85			31,18		
Southern river transect																			
MRT-2A			30,55								31,65			31,72			31.63		
				1,25								0,01	0.01		0			0	0
MRT-2B			29,35								31,66			31,72			31,63		
				0,6								-0,04	-0,07		-0,04	-0,07			
MRT-2			28,75								31,62			31,68			31,63	0	0
MRT-2/3A			30,65								31,67			31.76			31.76		
				1,2								0	0		0			0	0
MRT-2/3B			29,45								31,67			31,76			31,76		
				1,95								0,14	0,07		0.1	0,05		0,14	0,07
MRT-2/3			27,5								31,81			31.86			31,9		
MRT-3B			30								31,7			31,8			31,87		
				0,05											0			-0,03	-0,6
MRT-3A			29,95								31.93	3B/3: 0,11	0,02	31,8			31,84		
				4											0,06	0,015		0,06	0.015
MRT-3			25,95								31,81			31,86			31,8		

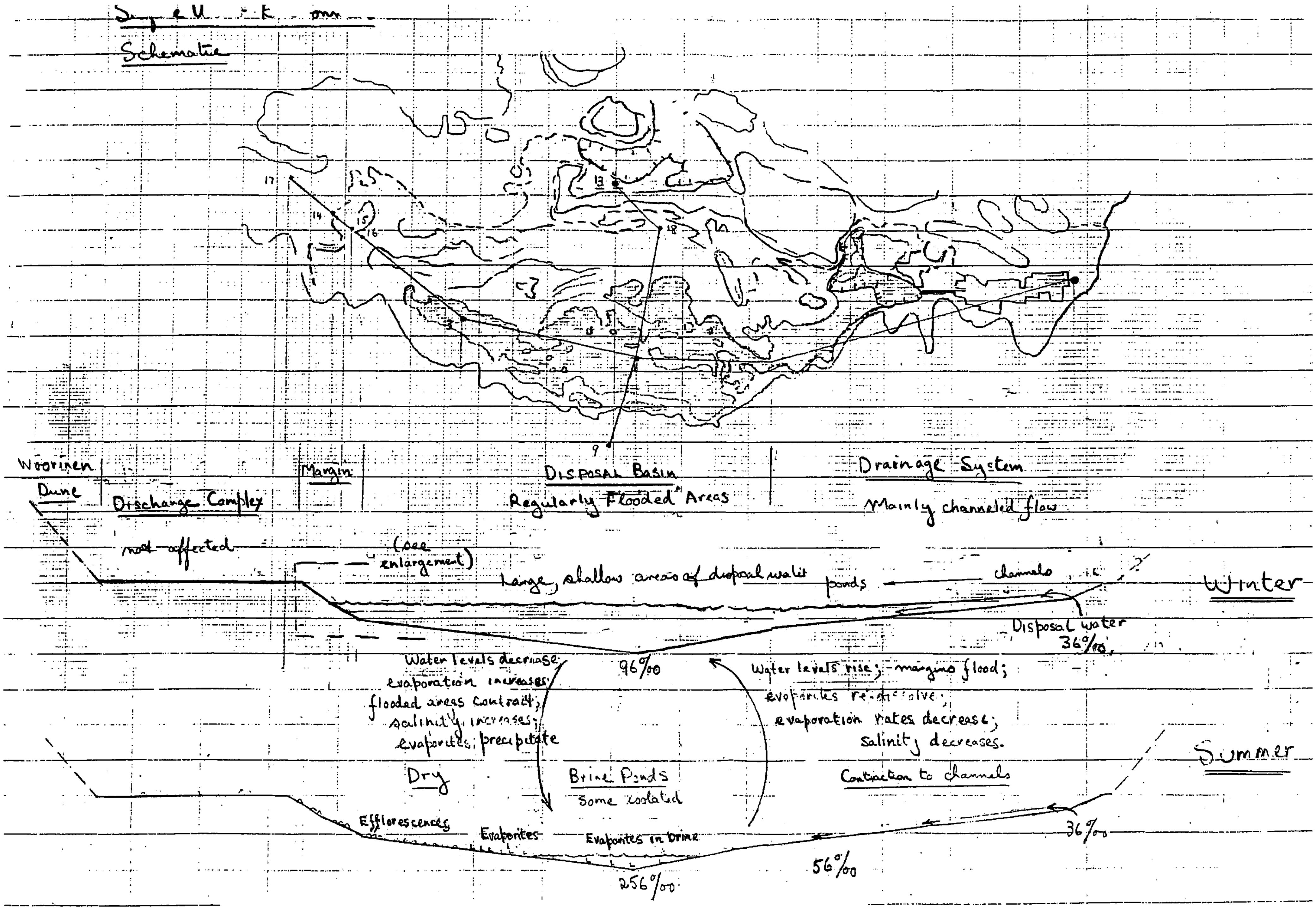


Figure A39. Seasonal changes in surface water environments. Mourquong disposal basin.

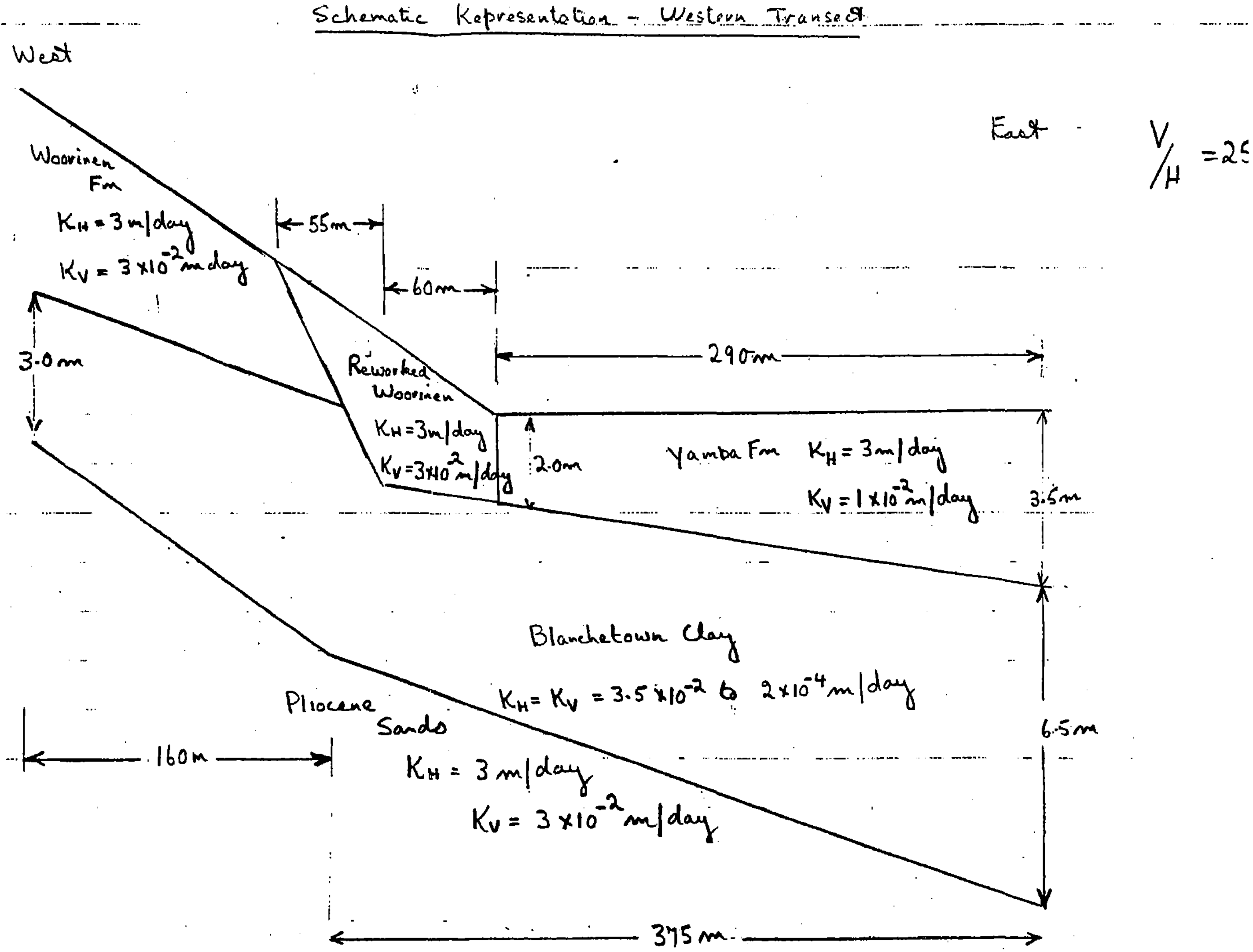


Figure A40. Hydraulic conductivities. Mourquong western margin. Transect MWT.

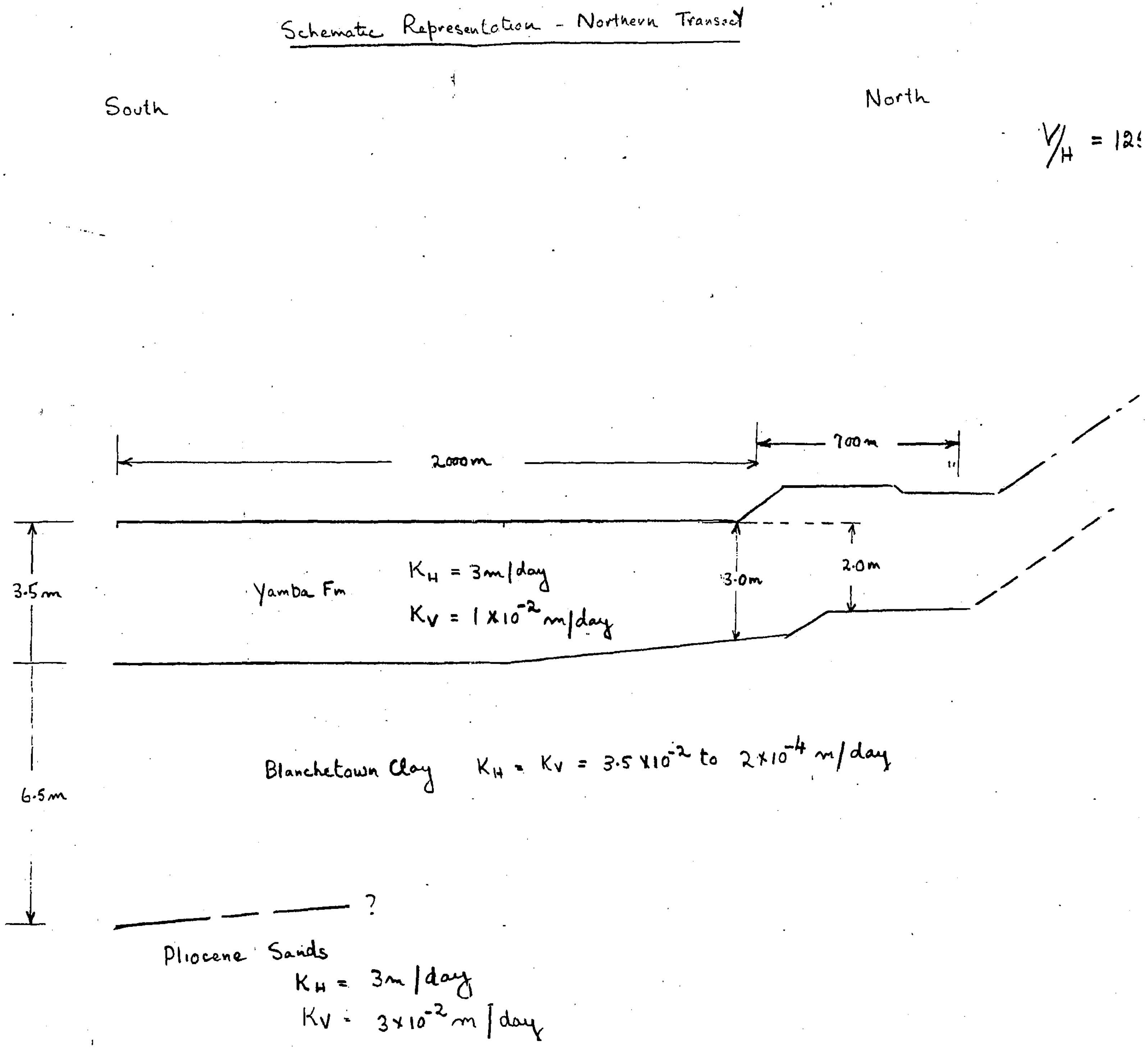
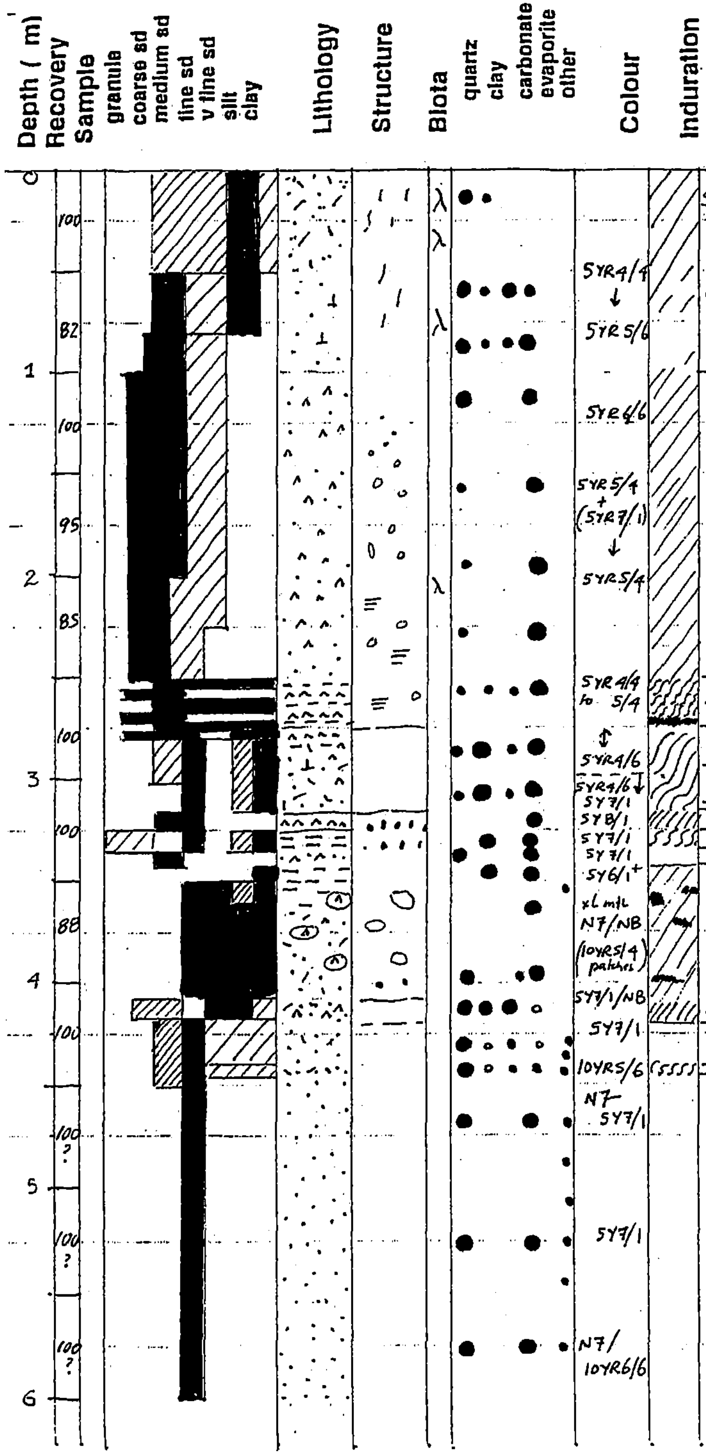


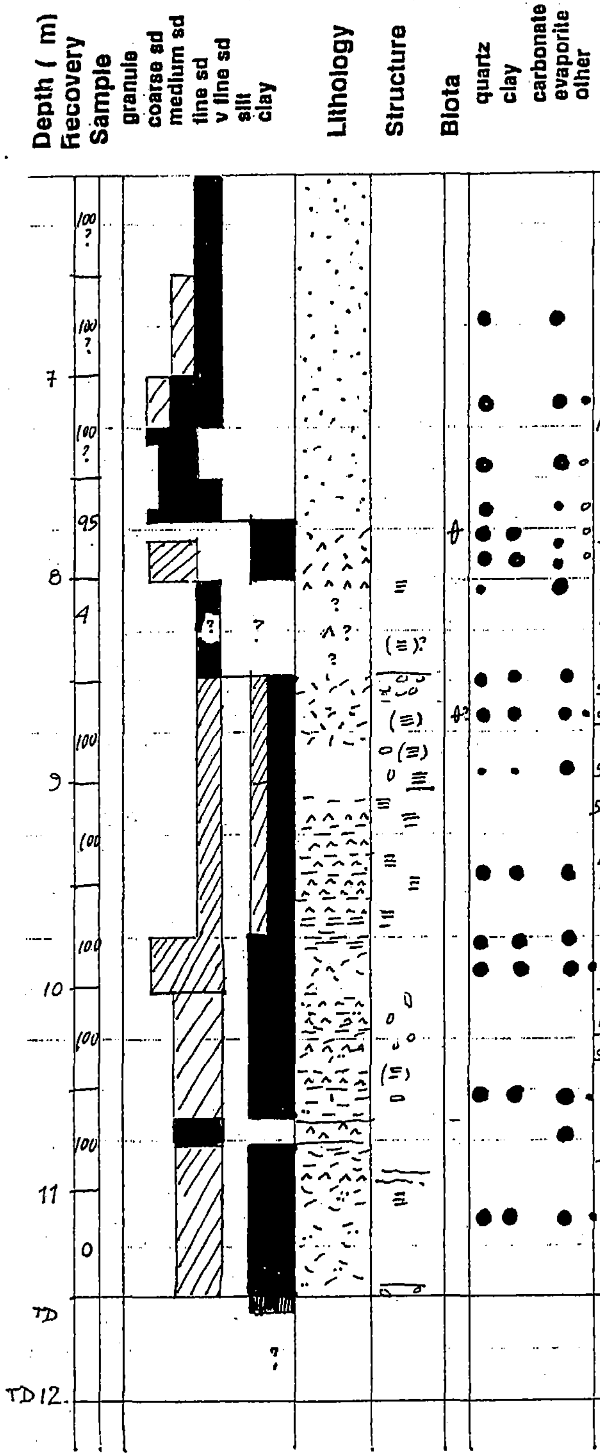
Figure A41. Hydraulic conductivities. Mourquong western margin. Transect MWT.

MOURQUONG MEM 1



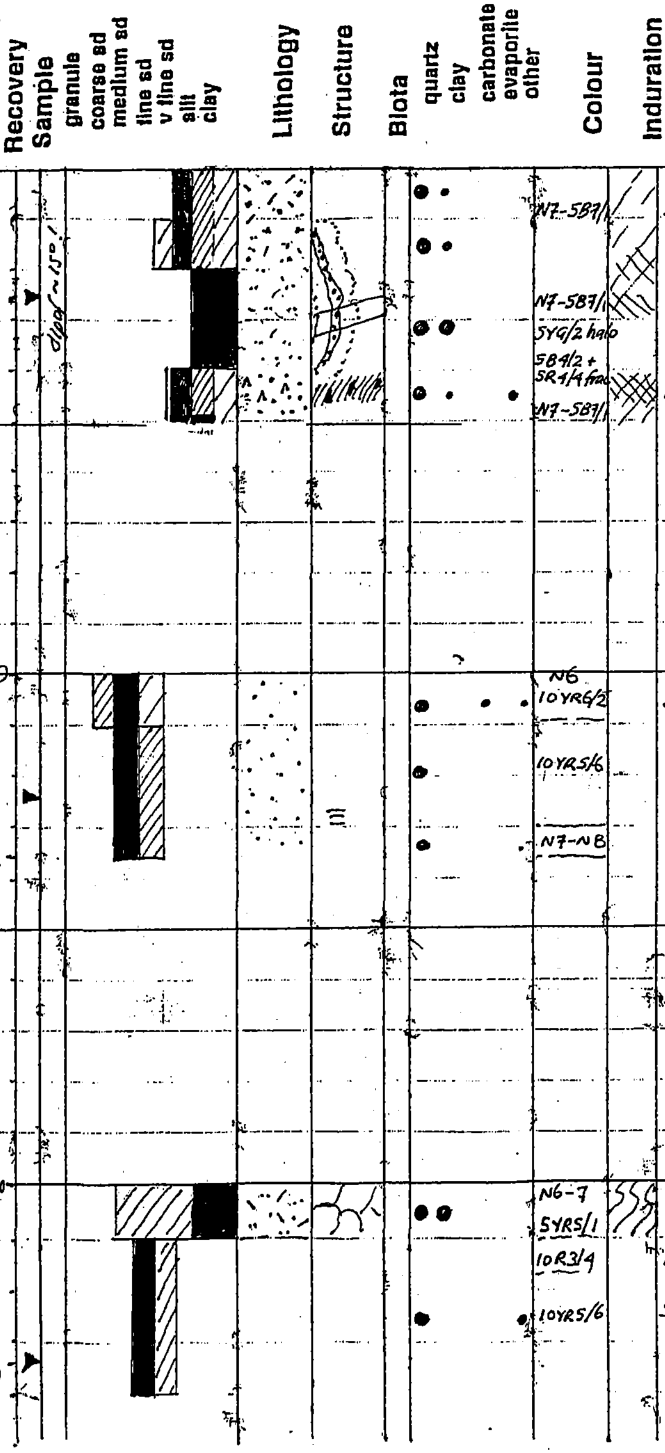
Description	Porosity	Diagenetic features	Interpretation
Silt, friable, clayey; as med soil aggregates [silt + clay; subsph], gypsum cement ? root tubule porosity vf, vertical, open.	IP BO		soil
Ginst, soil aggregates [c], porous, friable	IP, Bo	carbonate (calcite) dust	reworked Woorinen parna?
Sandy gypsum [discoids, c-(vc)], qz			YAMBA FAN
Sand (ind.), gypsum [euhedral discoids, c xl], qz [f-vf, orn], gypsum cement. Downward increase in c xl & nodules of interpenetrating discoid gypsum crystals	IP, IC	(gypsum cement) ↓mm-sized gypsum nodules gypsum rosettes	lacustrine/aeolian
Sand, gypsum [discoid xl]; indurated laminae sloping ?	IC, IP IP	gypsum cement induration in laminae	lacustrine/aeolian
Ginst, gypsum [discoids, m-vc], (clay); clayey laminae have finer gypsum xls. cemented aggregates	(IC)	gypsum cement on v lrg gypsum xls	hypersaline lacustrine
Sand, muddy, gypsum [f-m], qz? [f], (calcareous). to sandy Mud	(IP)	oxidation ↑↓ reduction	lacustrine
Sand, gypsum [m xl]	IC		lacustrine
Mud, gypseous, with laminae of lrg disc. xls Sand		displ. v lrg. gypsum xl	lacustrine
Mud, calcareous Mud, gypsiferous with porous bands [Fe stained] Varves of vf sand gypsum, clay; sand alternations; m xl gypsum overprint [almost fibrous appearance] Sand, qz? [vf], gypsum [m-(vc) xl discoids]	IC IC IC (IC)	framework of crystals c xlline gypsum in bands	hypersaline lacustrine
Sand, qz [f-m, unif], mafics [vf-silt, ~0.5%], musc [m]; unif, minor clay at top	IP		fluvial sand
Sand as above; clay matrix; c gypsum xl	(IP)	oxid mttl; displ gyps xl	
Sand, clean, unif, qz [f, subsph, ang], gyp [f, ang], mica [f, musc. + phlog], mafics [~1%, f. ang]; faint laminae defined from sl. increase in mica or mafic [to 5%] content. ↓ matrix [~1%]	IP IP IP	f euhedral gypsum in situ growth ochreous Fe staining of sand	fluvial sand IRYM. SAN. IRYMPLE SAND

MOURQUONG MEM 1

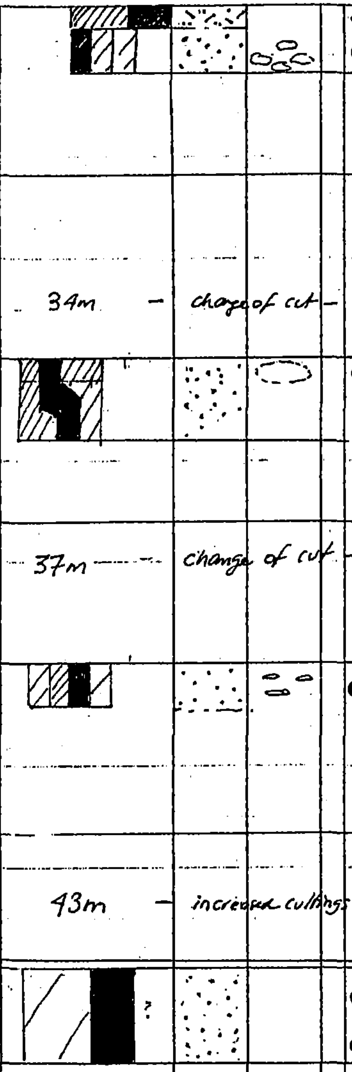


Colour	Description	Porosity	Diagenetic features	Interpretation
5Y6/2	Sand, gb[vari, clear, milky, yel; subsph], musc., (mafics); as above. srt			
5Y6/2 ↓		IP	increasing size of diagenetic gypsum	
10YR6/4	Sand, srt, gb[vari color; rndd, m-f], gyps.[ang, m](lithic), mafic[f-m, sg] musc; vari gb size in bands	IP	gypsum vari sized, etched	
	Sand, gb [rndd, subsph, vari colour], (srt)	IP	gypsum etched	IRYMPLE SAND
5GY6/1	Mud, uniform, sandy [c, gb]; subhorz Biotrbn? [sand infill]; mud grades down to gypsum impregnated Mud.	(IC)	gypsum discoids (c, subhorz patches	
5Y 7/1 10YR6/4	Gypsite, dense, granular [m-f, clear], laminar ↓?	(IP)	gypsum o/growths	gypsum evaporitic varves BLANCHETOWN CLAY?
5GY4/1	Clay, (Mud) laminated gypsum xl [srt, f, clear]	IC	redn, pyrite? black marks in gypsum	evaporites BLANCHETOWN CLAY
5B?/1–4/1 (mtl)	less defined laminae; biotrbn [gyps. + sand infill]"	(IC)	suc white discoids ⇒ bipyramidal	
5B4/1/N8	Gypsite [f-vf xl, srt], interlaminated Clay [gypsif.]	(IC)	authigenic gypsum.	lacustrine
5GY4/1 + N7 N4/N8 laminae	equant gypsum NOT discoidal ↓	IC	equant gypsum	hypersaline lacustrine
N4		IC		
5G5/1	Mud, compact, mtl colour, scattered m-c discoidal gypsum	–	pyrite, Jarosite efflorescence	
5G5/1 5B5/1 mtl	Mud with laminae of gypsum crystals	(IC)		
N7		IC		
5GY4/1 5GY5/1 5G5/1	Laminites, mud/gypsum seasonal alternations.	IC	pyrite?, Jarosite efflorescence on gypsum xls.	
	Clay, blue-grey, dry ?			

MOURQUONG MEM 1

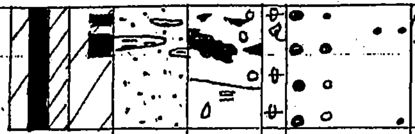


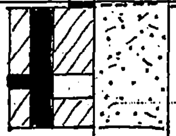
Depth (m)	Colour	Description	Porosity	Diagenetic features	Interpretation
15.0	N7-5B7/1	Silt, clayey, uniform ; vf Sand, qz [clear, vf], mafics [flakes?]	IP	pyritic flakes?	fluvial / lacustrine ? Qpc / Shepparton ?
	N7-5B7/1 5YG/2 halo	Mud, compact, fractured, sandy ; vertical fracture sand filled [f qz sand with iron oxidation]	FR, ((IP))	fractures iron stained red, and oxidation halo	
	5B4/2 + 5R4/4 frac N7-5B7/1	Sand, silty, qz [vf – silt, unif], black flakes [~5%], (musc) [flakes] Silt, uniform	ID	non-oxidized & ferruginous porous bands	colour - enhanced porosity
16.0		[Recovery approx 70%]			
20.0	N6 10YR6/2	Sand, unif., qz [m – c, ang, clean, faint yel], srt, (mafic) [<0.5% vf-c], ((musc))	IP		float Parilla Sand
	10YR5/6	Sand, m, qz [subrndd, (yel)]; (gypsum?) [ang., crystalline], uniform ; faint colour lamination down ; variably angular.	IP	colour oxidized (yellow re stained)	
20.65	N7-NB	Sand, qz [m + f, clear, subang - subrndd, minor opaques, minor rutilated qz], ((mafics)) [<0.5%, m – c, subangular].	IP	v clean.	
3		[Recovery approx 50%]			
4 25.0	N6-7 5YR5/1	Mud, lt gy, unif, [silt]; Silt, clayey, v lt. gy, porous, brittle facture ; Mud, sandy to Sand, muddy [brnsh, gy]	—		float of compac cuttings
	10R3/4	Sand, unconsolidated	IP	varying oxidation state of limonitic gel matrix; gives varying rust-ochre colouration	
25.65	10YR5/6	Sand, unconsolidated, qz [m – f, srt, vari. in bands; subang, subrndd, yel. or rust-stained], (mafics) [vf – silt, rndd, < 0.5%], gel matrix [yel to red]	IP		Parilla Sand
		[Recovery approx 40%]			

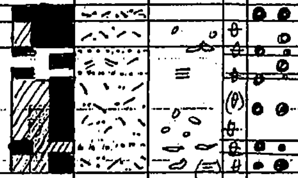


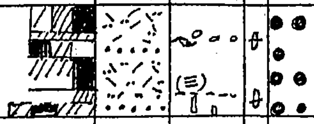
Depth (m)	Colour	Induration	Description	Porosity	Diagenetic features	Interpretation
30·0	~N7 5YR3/4 5YR4/6	SSS	Mud, sandy, vari compact ; Sand, muddy ; clay Sand, qz [m-f, subang, subsph], mafics [~5-10-70%, f, submdd]; ferrug cemented nodules [cm-size]; Vcoarse sand size of mafic % → laminae; indurated bands have highest heavies content	— IP – IP	Fe indurated cm-size lumps	Float – compaction cuttings Parilla Sand — heavy mineral, beach ches 2-70%!
30·65			[Total Recovery 30%]			
34m			— change of cut — black ; mud thickened up considerably.. —			
35·0	5YR2/1 5YR3/1		Sand, qz [vc-c-f, vclean; ang-submdd, nonsph], black matrix [soft, fluid]; (srt) Sand, srt, qz [vc-m-f, clean, clear, ((milky)); subang, nonsph.]; humic ? matrix + c-vc sand nonsph but polished, rndd.	IP IP	no iron: humic malated? humates ?	Parilla Sand – paralic facies
35·65			[Recovery 48%]			
37m			— change of cut — darker mud + fluffy peaty cuttings			
40·0	5YR2/1 c̄ flecks N7 + 10R3/2	---	Sand, unconsol., qz [m-vc, -(f), clear +(red), nonsph, subrndd], musc ? [f]; ((matrix)) [black humus]; srt ; uniform ; laminar flecks of ? ltgy clayey or reddish ferrug. mafic-rich sand [contaminants]	IP	humus matrix	Parilla – paralic + float?
40·65			[Recovery 13%]			
43m			— increased cuttings of peat ['fluffy'] & compact fractured ltgy muddy silt.			
45·0	5Y4/1 uniform		Sand, uniform vf-f, as below; mafics [vari ~2 → <·05%, vf, rndd] Sand, unif, qz [vf-f, clean, subang.], (musc) [vc flakes], ((mafics)) [silt-f, <·05%]; peat lumps [f-vf], unconsol. [Recovery 56%]	IP IP	gy colour from humus??	Parilla Sand ; marine tidal-sub -subtidal
45·65						
~49.5m			— clayey sediment			

MOURQUONG MEM 1



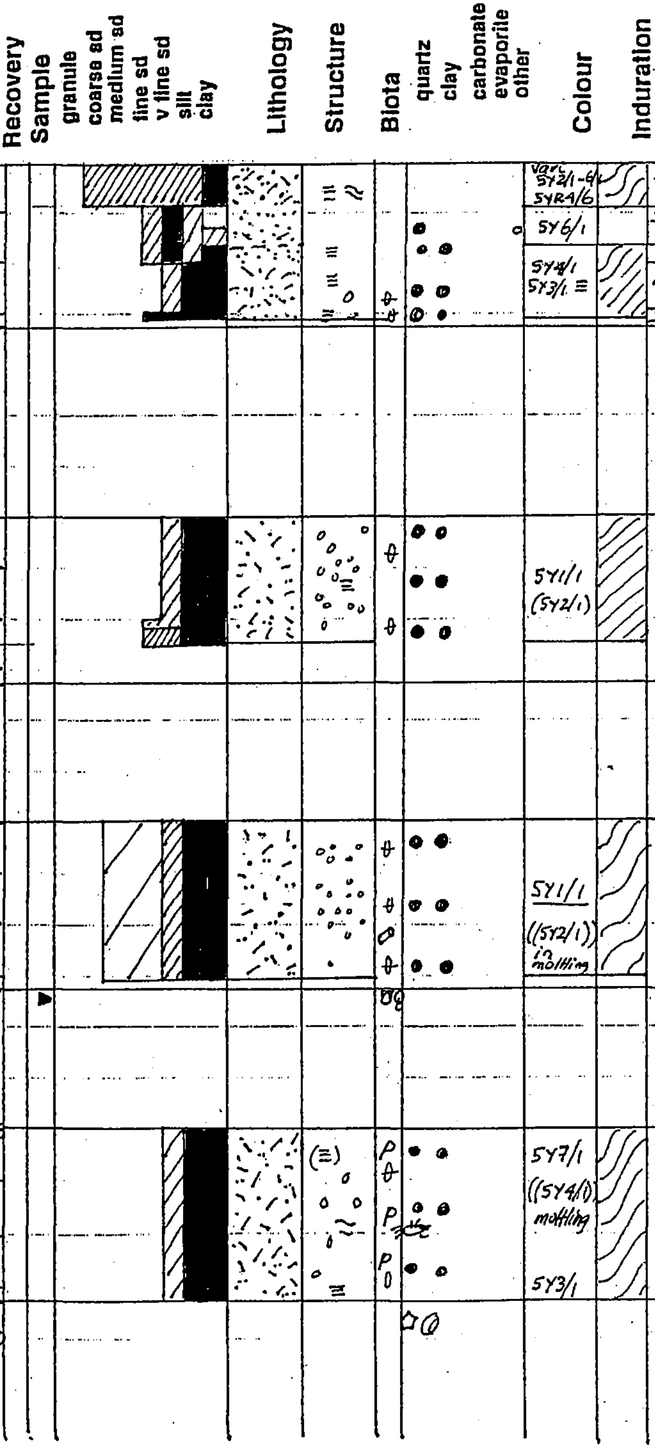




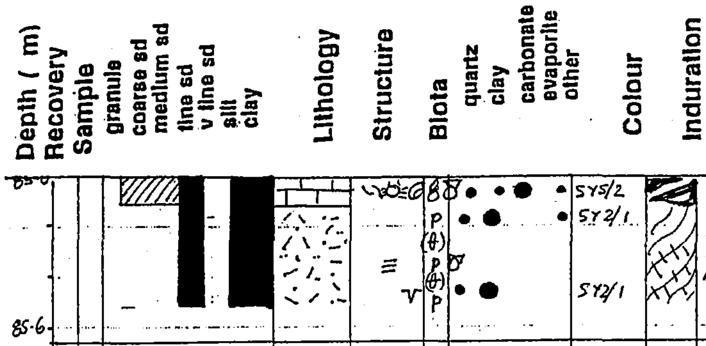


Depth (m)	Recovery	Sample	granule coarse sd medium sd fine sd v fine sd silt clay	Lithology	Structure	Blota	quartz clay carbonate evaporite other	Colour	Induration	Description	Porosity	Diagenetic features	Interpretation
50								N3 sand 5Y3/1 clay		Sand, bioturbated, qtz [f–vf–m, clear, ang, nonsph], (musc) [m flakes], mud [indd peat lumps]; wisps of peaty sand; irreg. infill by foetid Clay sandy clay; scattered tubules [open, < 0.5mm D][subhoriz].	IP (Bo)	gypsum x/s	Parilla Sand paralic – bioturbated facies
								5Y4/1		Lamination from improved sorting & vari mafic content Sand, uniform, f–vf, (muddy), musc. ; as above	IP		
50·65										[Recovery 70% with drilling mud]			
55·0								5Y2/1		Clay, uniform, homog., v dark	–	dissem. sulphide	
								5Y5/1		Sand, uniform, sl. plastic, qtz [f–vf, subsph, subang, clean], mafics [vf, ~1% ang] + matrix? ~15% v faint lamination incr. downwards [from matrix mafic variations]; v fine vertical black root? tubules; bioturbation [clean sand infill]	IP	—	Parilla Sand subtidal reworking of dune sand
								5Y5/1		Sand, banded with matrix content; minor bioturbation [clean sand infill] Sand, qtz [f–vf, clear, subsph, subang?], mafics [vf, ang – subsph], matrix variation [5–15% clay?]	IP	—	subtidal?
55·65										[Recovery 76% with drilling mud]			
			58.5m — Heavy clay intercepted										
60								N4		Mud, sandy, qtz [silt – vf, clean]	–		float
								N3		Mud, sandy, qtz [silt – vf]; compacted biotrbn [hum., ~5mm D, vfin sand infill, por]	(Bo)	pyritic concretion in Biotrbn (calcite)	Bookpurnong Beds
								5Y2/1		Sand, por, sat qtz [vf]; Biotrbn – Zoophycus? subhorizontal	BO		
								N3 5YR2/1		Mud, (sandy) with biotrbn [subvertical, some pyritic] flaser sands	Bo	frmbdl pyrite in Biotrbn.	
								N3/ 5Y3/1		Mud, sandy, qtz [silt + vf, clear, equant, ang.], vari conc; biotrbtn [infilled by clean vf sand] Biotrbn brnsh infill to lower part of interval	(BO)	frmbdl pyrite in Bioturbation. Diturpanoids?	
								N3/5YR8/1		Sand laminae / bioturbation distinct; clean qtz [vf] + mafics, within mud bands	BO – IP	pyrite	
60·65								N3		Mud, as above; minor sand-filled bioturbation [no mafics]			
										[Recovery, total 100% c drilling mud]			
62·23 62·8								5Y2/1 grdtnl mtl		Mud, plastic, sandy [qtz, vf – silt, equant], some biotrbn with clean sand infill increasing downwards; cm-sized horizontal burrows.	(Bo)		Bookpurnong Beds
								5Y5/1		Sand, qtz [vf, eq., clean], mafics [silt], por, sat, gradational upper, irreg. lower	BO IP		
								5Y2/1		Mud, Sandy upper; grdtnl to lower laminated Mud	Bo	pyrite frmbds in biotrbn infill	
62·65								5Y5/1 – 3/1 mtl.		Sand, bioturbation – mottled, qtz [f–vf, clean, eq., ang.], (mafics) [silt, < 0.5%]; subvertical burrows	BO IP		
										[Recovery 100%]			

MOURQUONG MEM 1



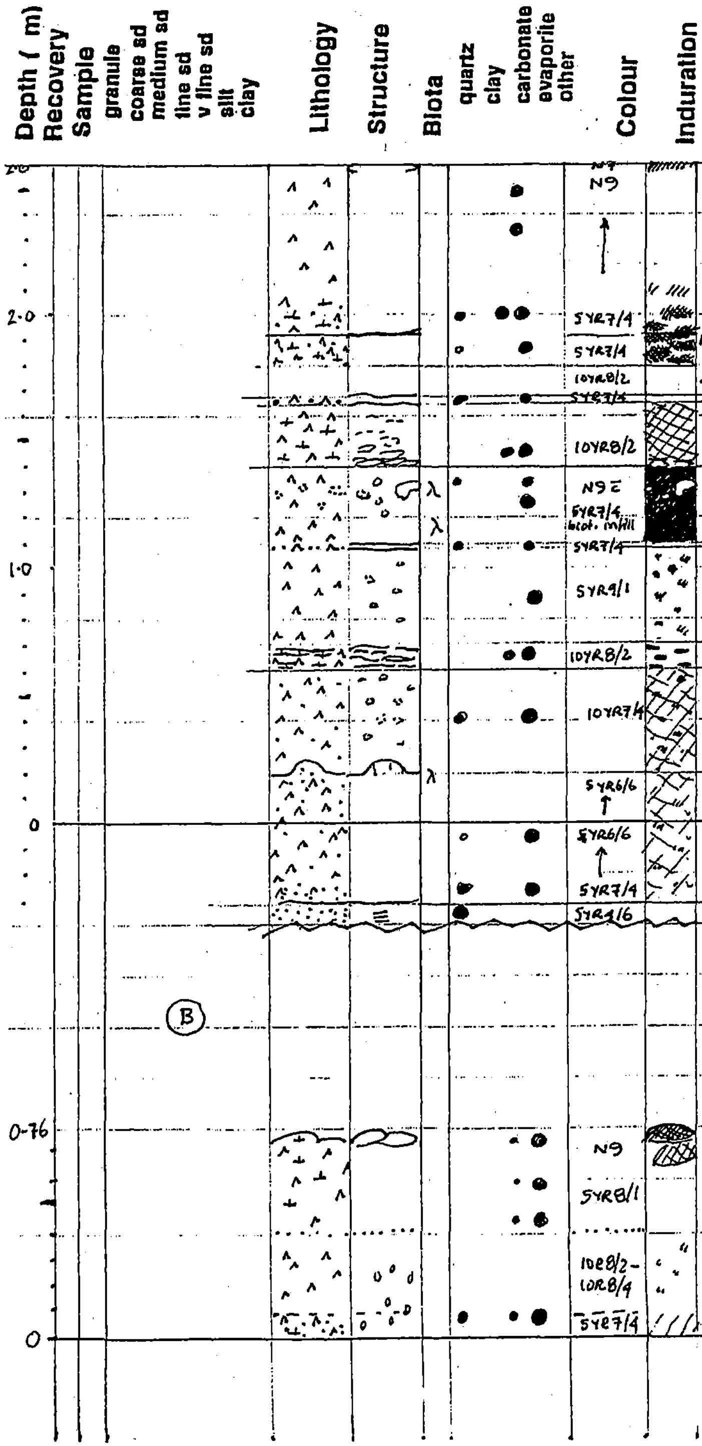
Depth (m)	Colour	Description	Porosity	Diagenetic features	Interpretation
62.8	Vari 5Y2/1-6/4 5YR4/6	Irreg banded, variegated float of cuttings	vari		Float
	5Y6/1	Sand, uniform, qtz [vf-(f), equant, ang?], mafics [silt, <0.5-1%], (musc) [m], porous, sft]; increasing matrix downwards	IP		? float ?? no
	5Y4/1 5Y3/1 ≡	Sand, laminated, clayey-(clayey), qtz [vf, equant, unif]; Increasing clay laminae Mud, sandy, ((laminated)) from sand content; minor biotrbtn tubes [infill by vf sand, frmbdl pyrite]; biotrbn [horiz, por.]	(IP) (IP) vari → to ((IP))	frmbdl pyrite In porous sands between clays pyrite in biotrbn	Bookpurnong Beds!
		Sand; vari, incr. lamination, biotrbn	IP		
63.45		[Recovery 87%] [actual 638]			
		9 October 1995			
68	5Y1/1 (5Y2/1)	Mud - Clay, olive black, clotted texture [&colour], partly obscuring faint colour lamination; Bioturbation [15-30%, horiz, vf sand infill, some frmbdl pyrite occlusion]	((BO))	frmbdl pyrite in BO porosity	Bookpurnong - Geera
		Sand; biotrbn increases sl. in mud, with f sand infill.	(BO)	arsenopyrite? + pyrite	
68.65		[Recovery 77%]			
74.0	5Y1/1 ((5Y2/1)) in mottling	Clay/mud, uniform ol. black; clotted colour texture from bioturbation [~15%, 2-3mm D, infill by muddy sand, pyrite in larger horizontal tubes, ~1cm D], minor lignitic lumps [rndd, m-c, vitreous]; Biotrbn not as frequent in lower 30cm; minor v thin sandy partings.	((BO)) ((BO))	frmbdl pyrite, to totally pyritized in larger cm-sized burrows.	Bookpurnong / Geera
74.65		[Recovery 94%]			
80.65	5Y7/1 ((5Y4/1)) mottling	Mud, sandy [vf, qtz], uniform olv. black; clotted texture; ~10-15% Biotrbn. [~2mm D] giving a faint lensoidal appearance. ← pellets [faecal] surface of infilling burrows [pyritized]. ← (flattened pyritic burrows)	((BO)) ((BO))	frmbdl pyrite replaces pellets in v lrg. burrows. (arsenopyrite)?	Bookpurnong / Geera
	5Y3/1	Mud, laminated with v thin dk clay laminae giving flazer appearance.			
[illegible]		[Recovery 45%]			
81-60					



Description	Porosity	Diagenetic features	Interpretation
Dol.?, sandy [gB, rndd. fn], foss [bivalve frags, gastropods, (ostracods)]	(FR)	phosphate, glauconite, pyr dolomite ; silic. vugs. - glauconite	
Mud, glauconitic [rndd, f-m, dk brown], clotted texture	((FR))		
Mud, uniform, frbl, pyritic f. traces impressions of fauna ; burrows [black with glauc. pellets & pyrite] fractured	((BO)) ((FR))	pyrite	

[RECOVERY 80%]

MOURQUONG PITFACE (MEM 1)

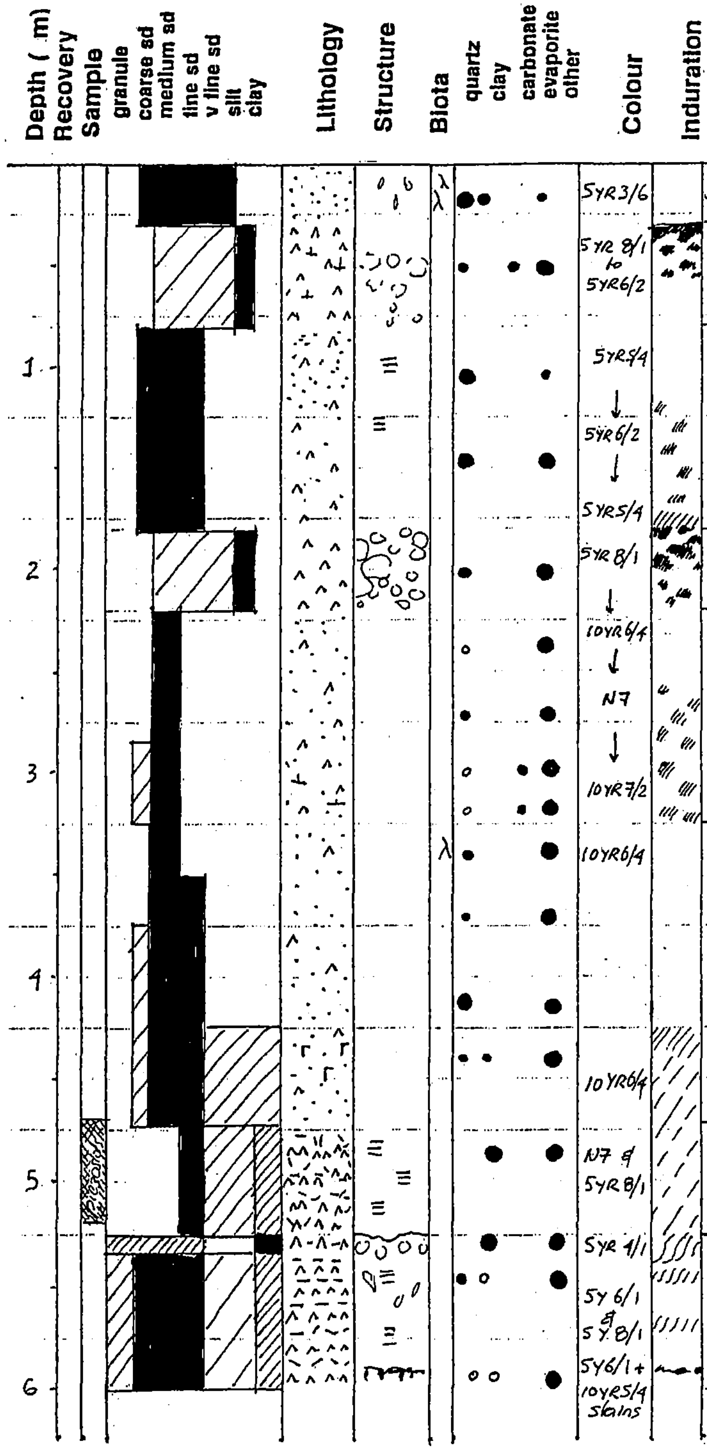


Depth (m)	Colour	Description	Porosity	Diagenetic features	Interpretation
					[illegible]
	N9	Kopi, flour	Ic	Kopi	
	↑	gradational colour change			
2.0	5YR7/4	vg nodules, partly induration	Ic	calcite gypsum, carbonate cement	
	5YR7/4	Kopi gypsum [sugary] firnst, sand [qtz, clean], uniform texture, calcareous			
	10YR8/2				
	5YR7/4	soft granular gypsum + qtz.			aeolian qtz event
	10YR8/2	Gypsum Granstone, calcareous cement bands subhorizontal, wavy, gradational margins fissile to base due to varying calcite cement.	Ic	calcite cement bands	
	N9 5YR7/4 biot. infill	Kopi, compact to v. indurated, uniform appearance with upper bioturbation [cm-sized, infilled by pinkish sand/gypsum mixture]	(Ic)	gypsum dias.	
	5YR7/4				
1.0	5YR9/1	Kopi flour, unconsolidated with scattered cm-sized indurated/compact lumps var. inducts	Ic		
	10YR8/2	Nodular calcareous, v porous gypsite with colloform carbonate	Ic	calcite cement bands	
	10YR7/4	Gypsite, qtz sand rich, clotted, compact appearance	Ic		
	5YR6/6 ↑				
0	5YR6/6 ↑	softer Gypsite with minor qtz sand. increased gypsum ↑	Ip Ic		
	5YR7/4	v sandy Gypsite, compact			
	5YR4/6	Sand, qtz [orange stained], slt uniform	Ip		Woorman Fm dune
0.76	N9	Gypsite lumps, partly induration with soft karst surface & upthrust teepee forms.	Ic	gypsum surface induration	teepee
	5YR8/1	Kopi, v soft powder, calcareous	Ic		kopi
		— colour change distinct			
	10YR8/2- 10YR8/4	Kopi, v-soft flour with cm-sized nodules	Ic		
0	5YR7/4	Brownish sandy gypsum	Ip		dune sand

This profile Ⓑ may be equivalent to top of Ⓐ separated 50m across crest of dune

MOURQUONG PITFACE (MEM 1)

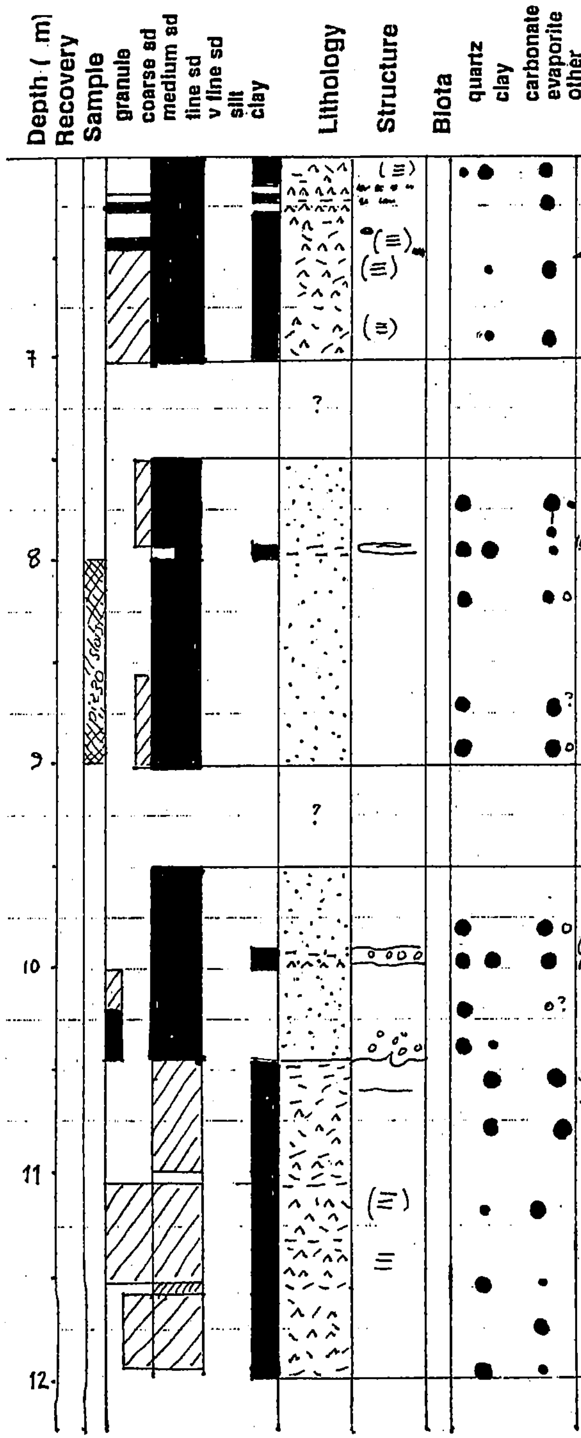
MOURQUONG MEM 2



Description	Porosity	Diagenetic features	Interpretation
Sand, unimodal, (srt), qtz [c, rndd. pol. → f/vf, stained], humic aggregates	IP		humus-rich soil
Kopi, unif. gypsite [vf] calc., incl. sand aggregates [qtz, fe stained f-c)]	IC	gypsum carbonate mobilisation	Kopi
Sand, unconsolidated, qtz [pink-yel, f-c], gypsum [m-c discoids], fragments [kopi, yel], (srt), por. ↓ increasing sorting faint lamination from variation in gypsum / qtz content of sand size	IP	etched gypsum crystals	aeolian gypsum dune YAMBA FORMATION
Kopi, unif, gypsum [silt, wh], qtz [f-m, rndd, subsph], lumpy, variably indurated ↓ ~~gradational~~	IC	remobilized gypsum	Kopi
Sand, gypsum [discoid frags. etched, yel, m-c], (qtz) [m-c, pol., rndd], vari content; porous, (srt) ← Kopi fragments in sand [vc-c], some carbonate;	IP IC / IP	(carbonate) oxidized pyrite framboids, silt size	aeolian gypsum sand
Sand, por, frbl, gypsif. [f-c, frags, disc., frosted, etched, yellow], (qtz) [m-c, pink] ↓ minor matrix of clay, halite	IP IP	some gypsum aggregate concretions	aeolian sand
Mud, gypsum [f, eq.], sucrosic texture; colour laminated; variable porosity & gypsum particle size. Varves [alt. clay / gypsum laminae)	IC	(pyritic brownstaining) gypsum	lacustrine hypersaline evaporitic.
Mud, clay, qtz [c, rndd], gypsum [f], irreg. patchy to crude lamination bands of predom. discoidal gypsum in clay.	IC IC (IC)	brownstaining; framboidal pyrite diagenetic gypsum — cm-sized aggregates [vf xl gypsum]	evaporitic hypersaline

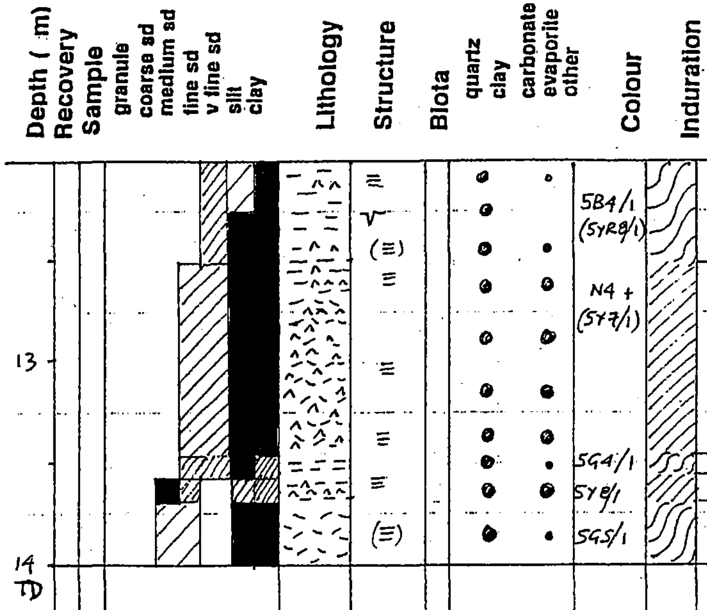
MOURQUONG MEM 2

MOURQUONG MEM 2



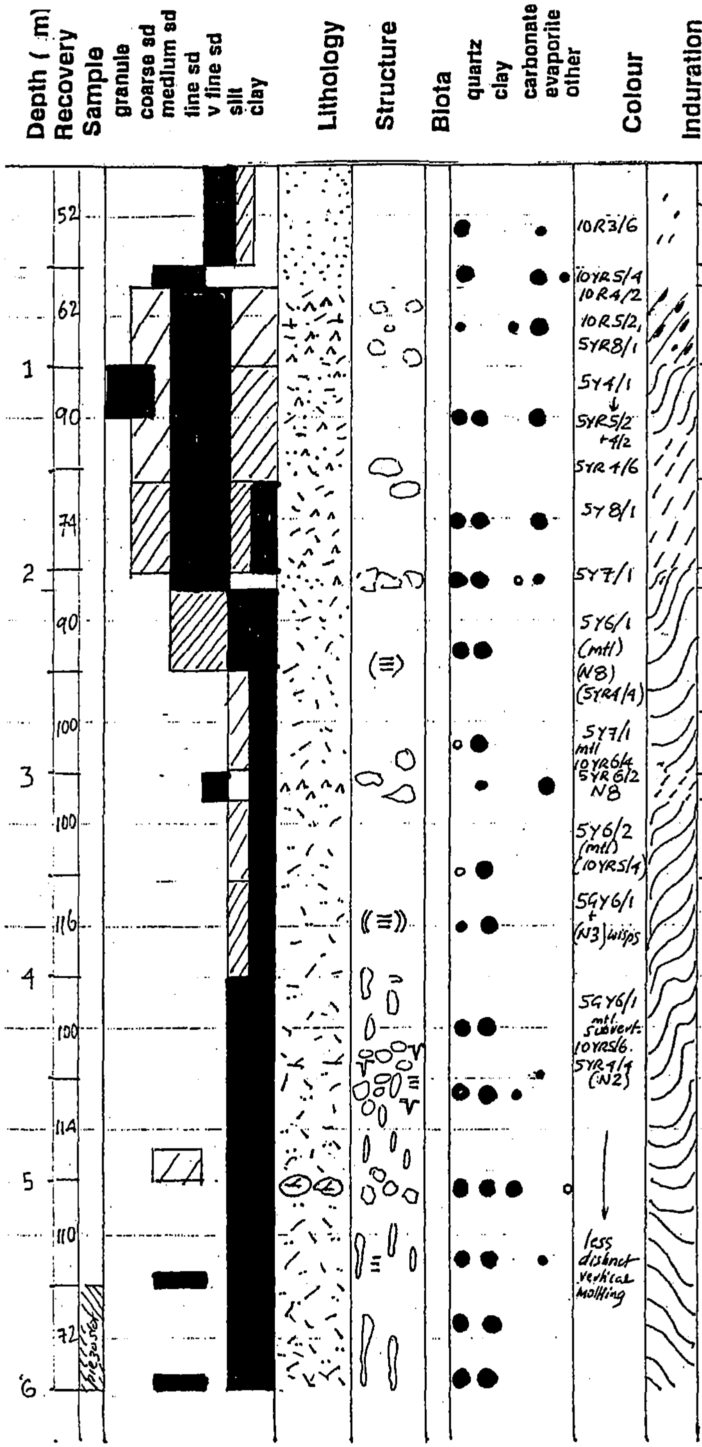
Colour	Induration	Description	Porosity	Diagenetic features	Interpretation
5Y6/1 ↓ 5Y8/1 ← stain 10YR5/6 5GY6/1 ↓ 5Y8/1		Mud, gypsif. [vari , f-m, discoids, vari-sized]; textural variations produce lamination	IC IC -IC	gypsum; clusters of discoidal crystals in oxidation stains. oxidation mottles	lacustrine YAMBA FORMATION
		?			?
10YR5/6		Sand, qtz [f-m , clear-yel, subrndd, subsph], gypsum [f-m, clear], musc [flakes]; (mafics)[vf ang.]; srt	IP		
10YR5/6-5YR5/6		Sand, muddy, (gypsum); colour oxidized	IP	Oxidized	
10YR5/6		Sand, qtz [f-m; clear-yel., rndd], gypsum? [f-m, yel, eu-anhedral], mafics [<<.05%, f]; (musc); srt, uniform darker colour; coarser fraction of quartz sand; no musc. or mafics	IP		fluvial sand IRYMPLE
					? SAND
10YR6/4		Sand, srt, qtz [ang-subang, clear-yel, f-m], gypsum [etched milky frags.], (mafics)[f-vf, rndd, sph.]; (musc) [m, flakes]; uniform some mud lumps towards base	IP		fluvial sand
(5B5/1) 10YR4/2		Sand, muddy, with small irreg. lumps of clay over gypsif [vf-f] mud.	(IP)		
10YR6/4		Sand, srt, qtz [f-m, clear-yel], gyps [f-m], (musc), mud lumps [mm - cm-sized blue clay]	IP		reworked Mud, fluvial
5B4/1 5G5/1 5G6/1		Mud, gypsum [f, xl, white], varying in laminae; c authigenic gypsum and diagenetic gypsum in laminae	— IC	Oxidation staining diag. gypsum in mud Jarosite staining discoidal crystals	lacustrine BLANCHETOWN CLAY
5G7/1 5G5/1 5G7/1 N4		Gypsite, clayey, diagenetic subhoriz discoidal framework: and laminar gypsiferous muds	IC IC		lacustrine

MOURQUONG MEM 2



Description	Porosity	Diagenetic features	Interpretation
Clay, laminated with discoidal/ring gypsum [vf, unif] Mud, some gypsum in desiccn. fractures.	IC in ≡	Jarosite on pyritic gypsum in varves. (oxidation)	hypersaline lacustrine
	(IC)		Blanchetown Clay
Mud laminated with Gypsite [f, equant, sucrosic ~~texture~~]	(IC)		hypersaline varves
	IC		
	≈		lacustrine
	IC		hypersaline varves
Mud, laminated, wh; diagenetic gypsum th/out.	–	diagenetic gypsum discoidal ×6	

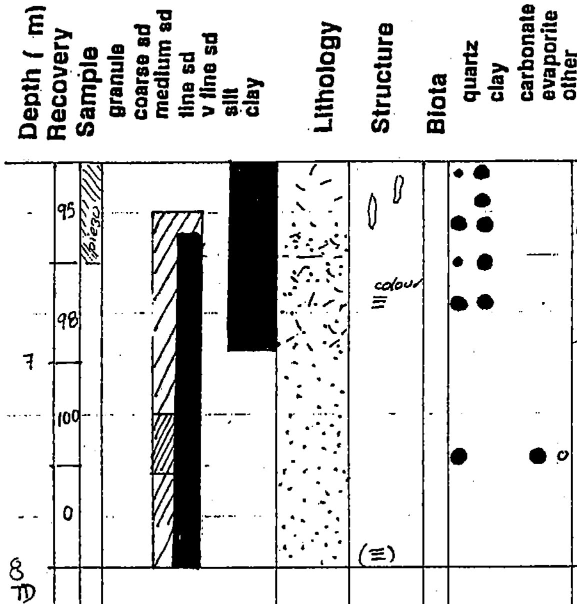
MOURQUONG MEM 3



Description	Porosity	Diagenetic features	Interpretation
Sandy, silty, friable, qz [vf-silt, Fe stained to opaque]	IP	red / oxidation	dune sand
Sand, qz, gypsum [yel] as for the basal sand, (musc) [f]	IP		reworked? IRYMPLE SAND?
Sand, gypsum [vf-m, wh, vari.], qz?; patchy cementation by gypsum crystals	IP	red / oxidation gypsum content	Kopi ? Top YAMBA lunette
Sand, gypsum [vf-m, discont. irreg.], qz?; oxidized, roselle nodules and lrg. discoidal crystals crumbled Mud alternations	IC	red / oxidation roselles, discoids irg. oxidation	hypersaline o/p on Blanchetown?
Mud, gypsiferous [authigenic?, equant to vf]	(IC)	reduction discoidal gypsum xls equant, clusters - roselles	hypersaline o/point on Blanchetown?
Sand vf qz? gypsum?, irregular patches	IP	gypsum? oxdn ↕ reduction	
Mud, unif to faintly laminated with vf sand; calcareous patches Clay [mottle-stained]	(FR)	carbonate [oxidation stained]	Blanchetown Clay
Clay, mottled stained, subvertical, irreg.; black fracture stains	FR	Fe/Mn stains in fracture	
gypsum [vf, semiconsolidated] replacement in clay	IC	vf soft sucrosic gypsum as nodules	
Clay, highly fractured to crumbly	(FR)	black stains on fractures. -Mn/Fe?	
Clay, vdense ↓ traces of lamination Mud	—	black Fe/Mn? wisps	Blanchetown Clay
Mud, [sandy bands), qz [m, rnd], uniform; colour staining on fractures	FR (FR	(Jarosite with gypsum) dolomite mud in fractures black stains [Mn/Fe]	(hypersaline lacustrine)
Mud with fractured dolomitic mud patches Mud with thin gypsum laminites Mud; sandy	(FR)	Dolomite, irreg. patches black stains in Fractures	hypersaline lacustrine
Mud - silty Clay, uniform with subvertical staining and scattered black flecks of ?pyrite Mud, sandy	—	polysulphide? pyrite? framboids	

MOURQUONG MEM 3

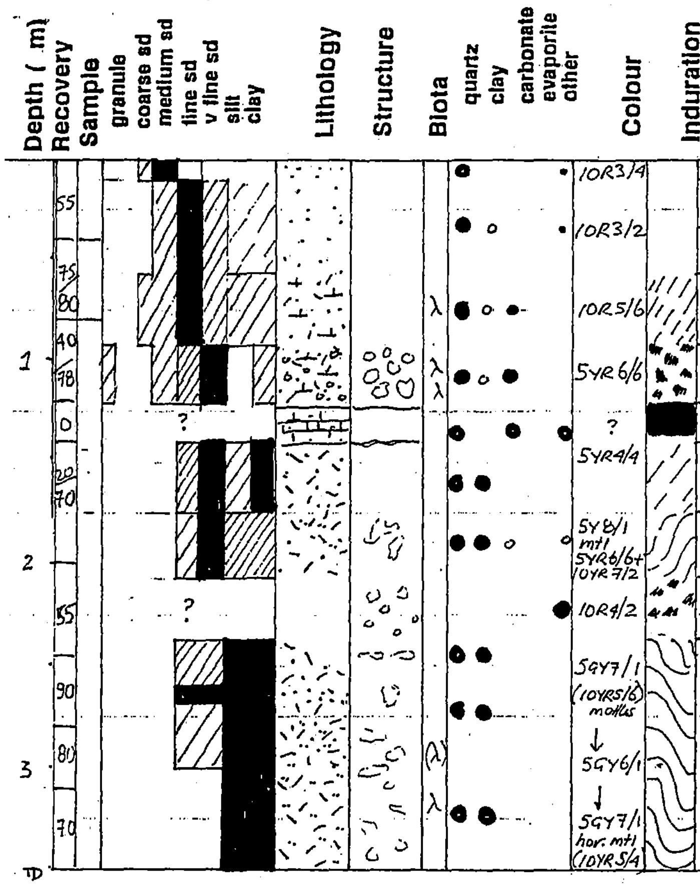
MOURQUONG MEM 3



Colour	Induration	Description	Porosity	Diagenetic features	Interpretation
5GY6/1 (mtl) (subhorz) 10YR6/4		Mud Clay, plastic, uniform; Subvertical irreg. orn. colour staining "Mud	—	oxidation/ reduction	Blanchetown Clay —
5GY6/1 horz. 10YR5/6 5YR5/6		Mud, sandy [Wckst]; mud to top Sand, muddy [Pckst], qtz [f-m], gypsum[m]; (mafics); slight variations in porosity horz: colour staining subtle	((IP))	oxidation in more porous patches	
10YR6/4 unif		Sand, srt, clean, unif, qtz [f-(m), clear, yel, rndd, subrndd - subsph], gypsum [elded, irreg to (rndd)]; mafics [f-vf, << .05%]	IP IP	oxidized oxidation staining	Parilla Sand?

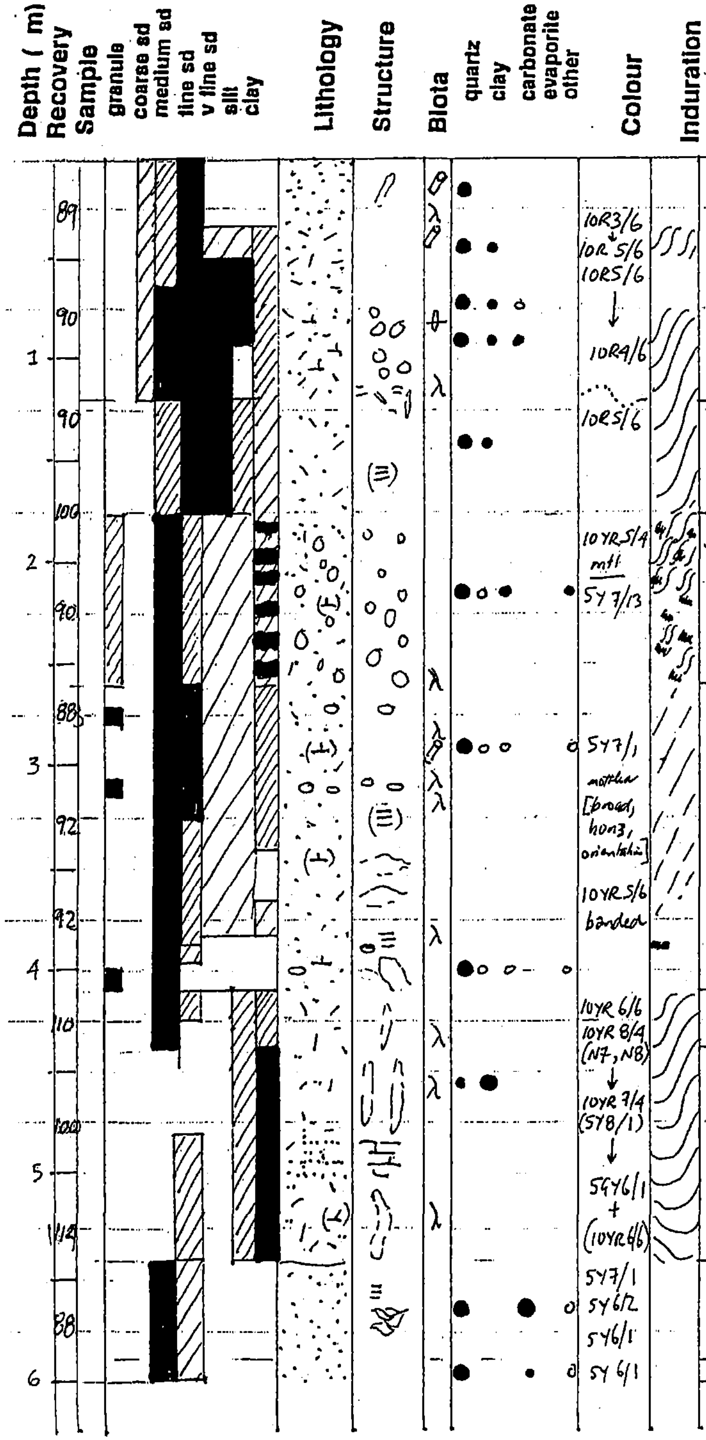
MOURQUONG MEM 3

MOURQUONG MSWM 2



Colour	Description	Porosity	Diagenetic features	Interpretation
10R3/4	Sand, srt, gb [m-f, ferrug, rndd-subrndd], lithic [ironstone lumps, m-c]	IP	oxidation zone	
10R3/2	Sand, (srt), gb [f-vf, (m), vari rndd-subrndd; ferrug. or frosted].	IP	oxidation zone	dune
10R5/6	Sand, clayey, [Grnst-Pckst], gb [f-m, rndd, subsph], matrix [orn. carbonate]; numerous vf-f root tubules in all orientations	(IP) BO	calcitic micrite matrix/cement	calcrete soil overprint
5YR 6/6	Sand/Gravel; patchy carbonate induration; irreg carbonate matrix nodules with surface black staining	(IP), BO	Calcrete nodules; anisotropic cementation; Mn? staining	calcrete soil o/print
?	Calcrete band; with surficial ferruginous banding	—	Ferruginisation; Calcrete formation	groundwater o/print
5YR4/4	Sand, clayey	—		float
5Y8/1 mtl 5YR6/6+ 10YR7/2	Sand, muddy, (srt), gb [f-vf; ?], (musc), (mafics) [vf]; light matrix (calcareous); black to dark small mm sized patches	((IP))	(Carbonate) Ferrug. nodular conc.	Irymple Sand
10R4/2		?		float?
5GY7/1 (10YR5/6) mottles ↓ 5GY6/1 ↓ 5GY7/1 hor. mtl (10YR5/4	Mud, (sandy) [gb, f-vf, rndd, clean], vari distribution in the mud; mm-sized black patches, ofn ochre patches; increasingly muddy Sand. ↓ Mud, (sandy), subhorizontal to vertical irreg. oxidized mottles; sand distribution irregular) ↓ Mud	— ((IP)) patches (FR)((BO)) (FR) (FR)	ferruginous sesquioxide precip. black/orn. oxide precip. in irreg patches, porosity controlled. iron staining	Blanchetown Clay

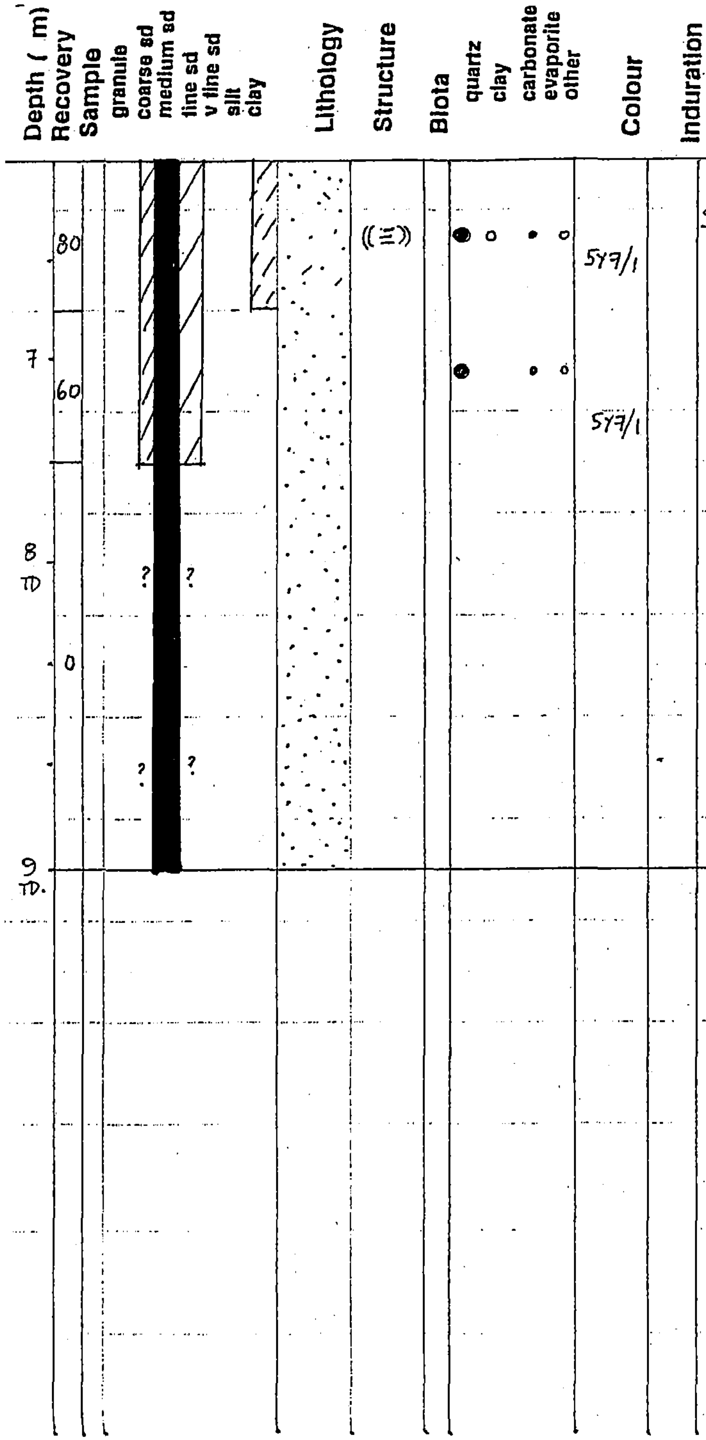
MOURQUONG MSWM 3



Description	Porosity	Diagenetic features	Interpretation
Sand, upper srt, por., unconsol., qz [f-m, ang-rndd, brn stained]; increasing clay matrix, more cohesive, (srt), por.	IP	oxidized	dune sand
Sand, uniform, (stratifica clay content) → horz. parting. Rhizoconcretions of carbonate [friable]	IP	(calcareous) rhizoconcretions	
Colour change irregular boundary		↕ oxidation change	
Sand, clayey, qz [vf-f, (silt)], gypsum [f, etched]; (srt) faint lamination from variable sorting	IP IP	Fe oxides in clay	water-saturated lacustri?
Sand, pebbly, (muddy); calcareous, qz [f-m, vari ang-pol.], musc, (mafics); colour ochreous; vari clay content of Sand to muddy Sand. Pebbles [rndd; subsph; ferug. gel] scattered in sand. ↓ increasingly srt sand	ID	pred. oxidizing; calcareous; irreg rndd ferug. pebbles [limonitic gel]; nodules forming in sand	lacustrine
Sand, qz [f-m, clean, clear, subsph, subang.], mafics [< .05%, rndd, vf-silt], (clay matrix); random rndd. concretionary pebbles. broad bands of limonitic cement.	IP ↓ IP	limonitic precip. as broad mottled bands, giving reduction of porosity & occasional nodule Ferruginous cement in bands.	Irymple Sand
pure white to orn. sand		Ferug. concretions	
Sand, clayey, qz [m-f, clear], (mafics); clay vari + ferug. concretionary patches	IP	(ferug precipitation)	
Clay, silty; uniform; fractured [conchoidal], greasy appearance; broad subvertical colour banding	(FR)		Blanchetown Clay lacustrine
Fractures in clay, infilled by sandy [f qz] clay, porosity occluded	—		
Mud, sandy to muddy Sand [qz, subang, subsph, f, clean], ((mafics)), clay/silt, minor dolomite; vari. composition in indistinct laminae	—	(dolomite), clay	
Sand, unif. srt, qz [m, subsph, subang. clear], gypsum [m, etched, subhedral], (musc) [m], mafics [f, rndd, < .05%]; faint lamination from colour and mafics content.	IP	small discoidal gypsum rosettes	Parilla Sand ?
↓ increasing Muscovite [m] flakes	IP		

MOURQUONG MSWM 3

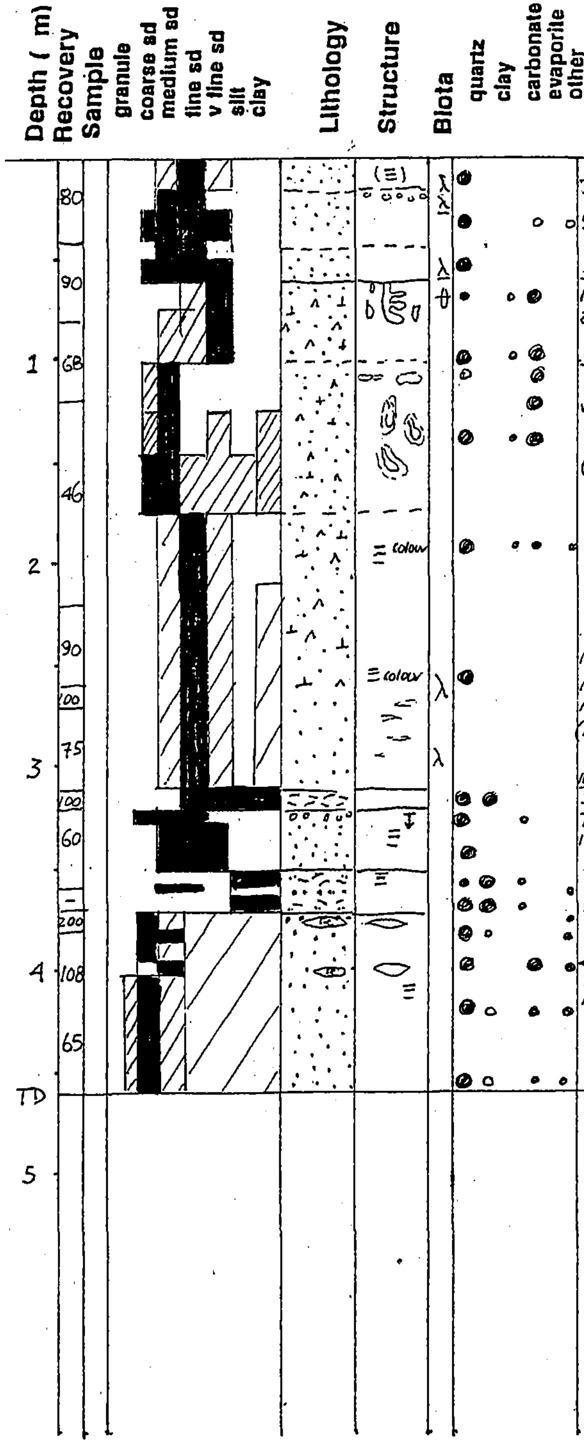
MOURQUONG MSWM 3



Description	Porosity	Diagenetic features	Interpretation
Sand, svt, unif, qtz [m, subsph, subrndd-(c) rndd, clear+ (wh), etched] (mafics) [f, rndd, ~0.5-1%], ; random gypsum fragments; matrix [<1 - 5%] variable, creating faint lamination ↓	IP	?gypsum	Irymple Sand? Parilla Sand ?
clean Sand, no matrix, mafics [m-f, subang to xlline], musc [flakes]	IP		Coastal ? ~~FLUVIAL~~ SANDS
	IP		
	IP		

MOURQUONG MSWM 3

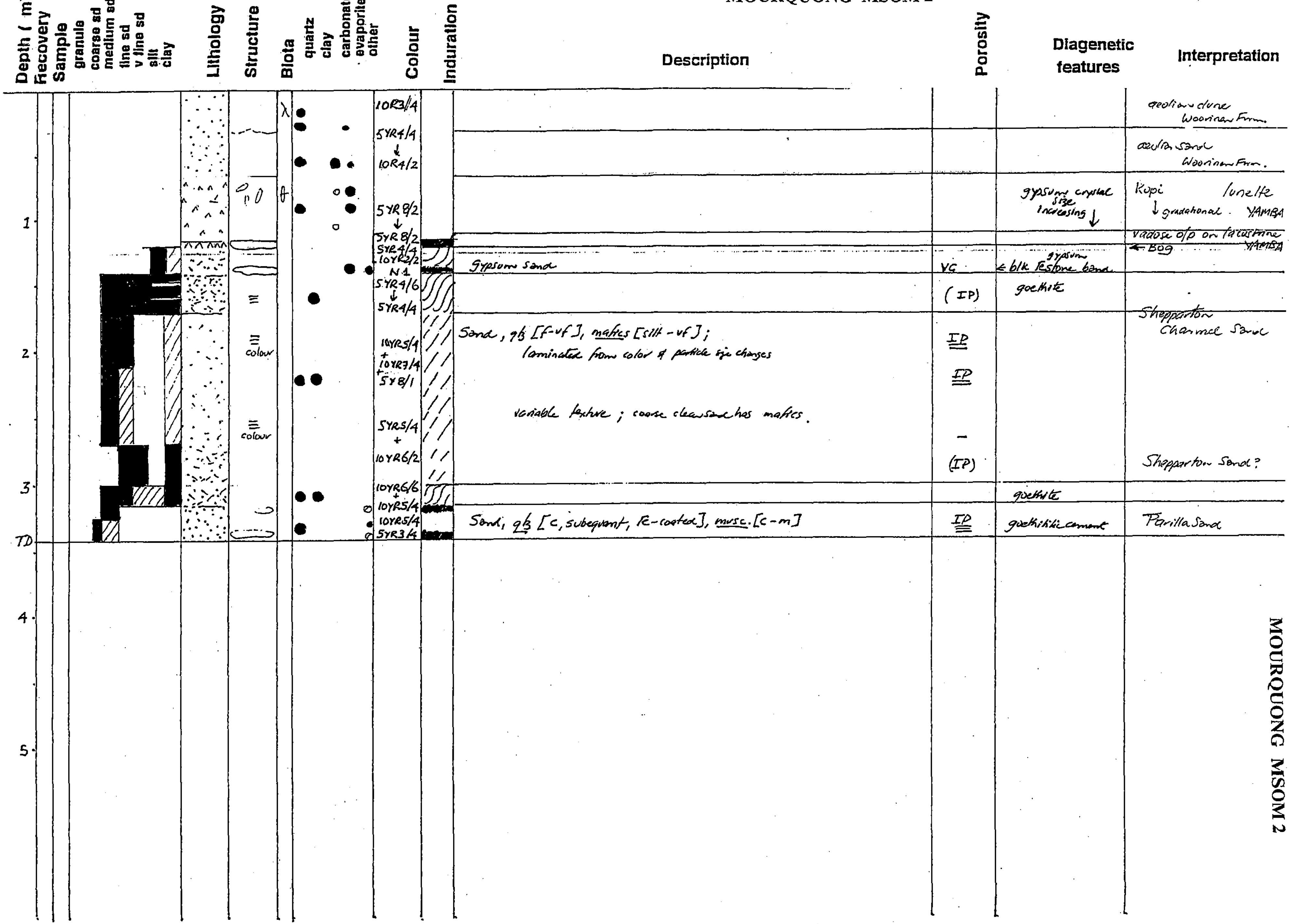
MOURQUONG MSOM 1



Colour	Description	Porosity	Diagenetic features	Interpretation
5YR4/4 5YR6/4	Sand, qtz [(vf)-f-(m), nonsph, rndd], (srt), faint colour lamination; horiz. roots	IP		post settlement layer
5YR4/6	Sand, (srt), qtz [m, srt, ferug, rndd, nonsph], vari srt., (mud) tubules?; gypsum ← srt	IP	μsph sugary gypsum	Dune sand, kopi profile
5YR6/6	Sand, as above			
10YR7/2 c̄ 5YR3/4 biotrbn ↓ 5YR6/4	Gypsite, gypsum [vf, wh], calcite [?mtx], (qtz) [vf]; increasing qtz content downwards; lrg biotrbn infilled by red qtz sand.	IP	gypsum & (carbonate)	Kopi with soil overprint.
variegated 5YR5/2 5YR 6/4 (10YR7/2)	Sand, gypsum [discoids, subhedral - euhedral, vm-c xls], qtz?; por patches of subvert. biotrbn? zoned c̄ wh gypsum [vf-vc, wh] in centres, surrounded by darker, clayier sand ↓ increasing qtz content.	IC IP	crystalline gypsum	lacustrine. Yamba Formation
5YR5/4	Sand, qtz [f-(m)-vf], (gypsum) [discoids]; lamination from goethite cementation.	IP	carbonate goethitic cement in laminae	Channel sands? of
colour lamination 10YR7/2 10YR6/4 (10R4/6) ↓ 10R6/4	Sand, colour-laminated, srt, qtz [m-f-vf, subsph, clear], calc., (gypsif.) [vc], mafics [vf, rndd, ~.05%]; matrix varies up to 5-10% with goethite.	IP	(calcareous) (vc gypsum discoids)	Shepparton Formation? low E fluvial.
5Y7/1	Mud, calc, (qtz) [vf-silt], vari sand content → ((lamination)	(IP)		
10R6/4 ≡ 10YR7/2 10R4/6	Sand, qtz [gran-m, rndd, sub-nonsph], mudlumps, rndd gypsum? dol. micrite Sand, qtz [vf-m], matrix [~5-10%]	IP	dolomite?	Blanchetown Clay
5Y8/1 (10R4/6)	Mud (sand) [qtz, f, rndd], ferrug.; musc. [silt flakes], (calc) colour mottled	≡(IP)	← ferrug. goethitic cement	
10R5/2 5R3/6 ←10R3/4 ≡10YR4/6 10YR7/2 5YR4/6 grdnl ↓ 10YR6/6	Sand, vc, por, qtz [c-(m), subsph, subang, clear, red, wh, opaq], musc [flakes], gypsum [etched, c], mafics [m-c, subang-sph, ~105%], matrix, vari ~5% ferrug cement; lamination and porosity varn. with Fe goethitic clay cements and ? silica and gypsum xl.	IP IP	← ferrug goethitic cement ← ferrug. goethite cement gypsum. silica (opal?) goethite.	Parilla Sand

MOURQUONG MSOM 1

MOURQUONG MSOM 2



aeolian dune Woorinen Frm.

aeolian sand Woorinen Frm.

gypsum crystal size increasing ↓

Kopi ↓ gradational lunette YAMBA

vadose o/p on lacustrine YAMBA

← Bog

Gypsum Sand

← blk gypsum festone band

goethite

Sand, qtz [f-vf], mafics [silt-vf]; laminated from color & particle size changes

variable texture ; coarse clean sand has mafics.

Shepparton Channel Sand

Shepparton Sand?

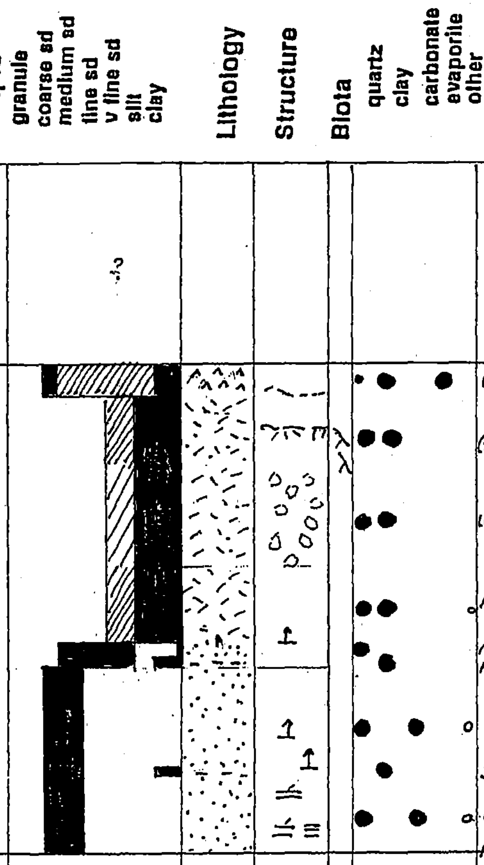
goethite

Sand, qtz [c, subequant, Fe-coated], musc. [c-m]

goethitic cement

Parilla Sand

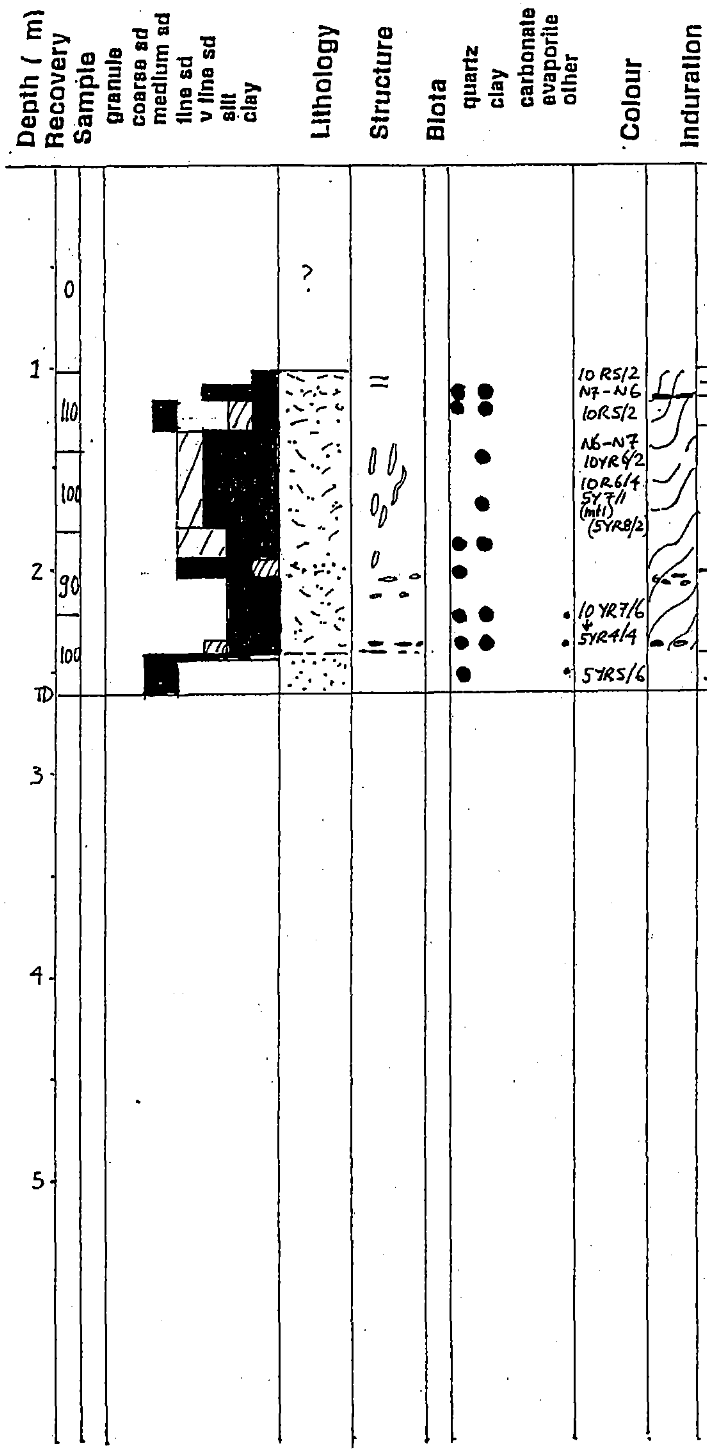
MOURQUONG MRT BM



Depth (m)	Recovery	Sample	Colour	Induration	Description	Porosity	Diagenetic features	Interpretation
	-				?			YAMBA
1			N5-N6		Mud, gypsiferous	(IC)	oxidized	YAMBA
	110		5B6/1 (10YR6/2) bands		Mud, sandy [gs vf]; rootlet haws and ped structure	–	rapid oxidation with coring – polysulphides?	lacustrine ? fluvial ← emergence d/p. Shepparton ?
2	75 92		N7/ 10YR6/4 mtl		Mud, sandy, [gs vf-silt], mottled	–	carbonate? magnesite or dol?	lacustrine? Shepparton Fmn
			10YR6/4		Mud, sandy [gs vf-silt] with mafics	((IP))		Shepparton Fmn.
	102		10YR6/4		Sand	IP		
			10YR6/4		~~Mud, sandy [gs m-vf], musc., mafics.~~			
3 TD	116 108		5YR4/6 ↓ 5YR5/6 ↓ 10YR7/2 ↓ 10YR7/4		Sand, unconsol. porous, gs [(m) -c -vc, eq., ang, clear], gypsum [c, clear], musc+phlog [booklets], mafics [rndd, vf -m]; lamination from fining up cycles	IP		fluvial ? or dune sand ? Parilla Sand or Shepparton Sand.
4								
5								

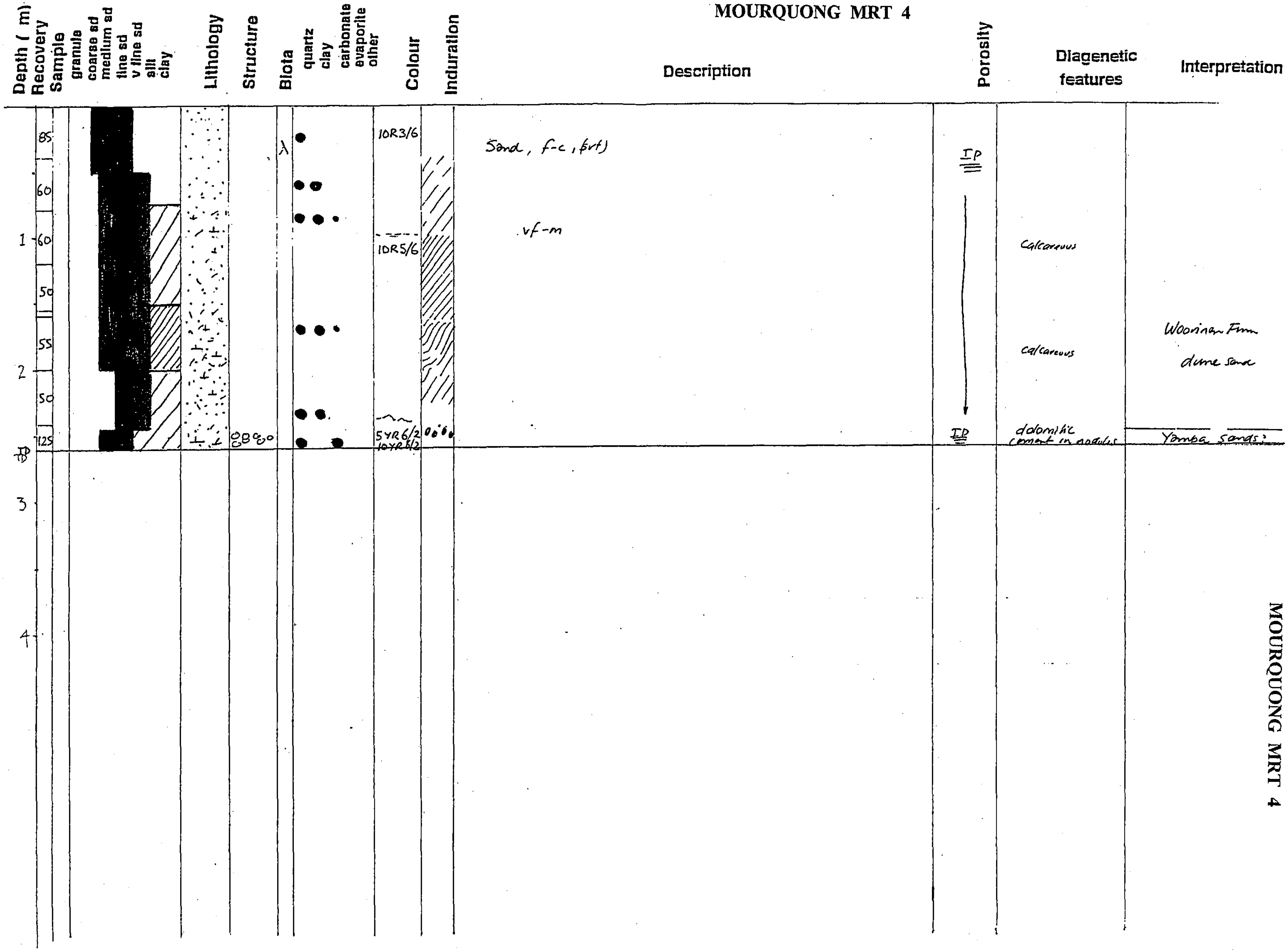
MOURQUONG MRT BM

MOURQUONG MRT 1



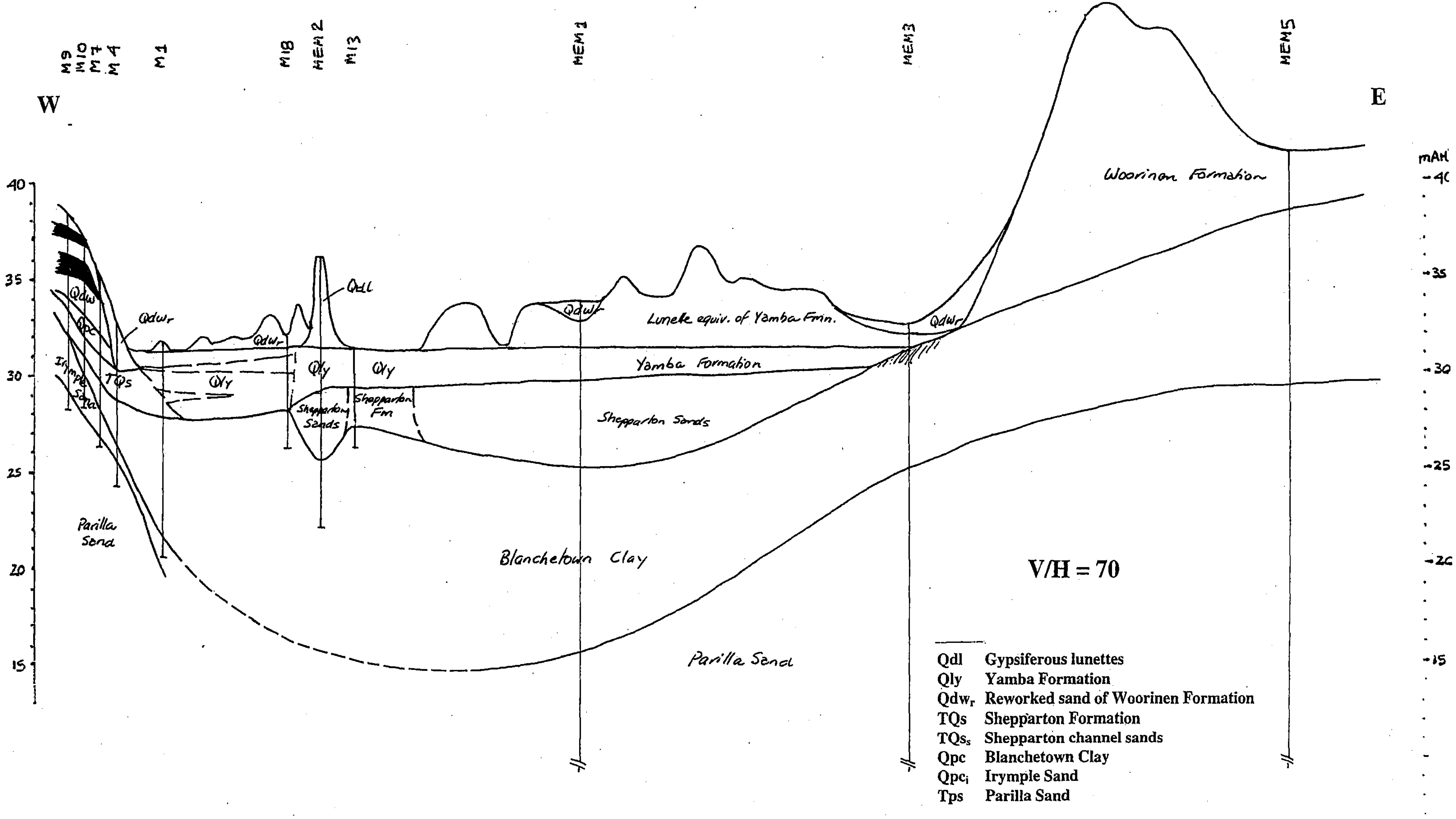
Colour	Description	Porosity	Diagenetic features	Interpretation
	?			Yamba mush ?
10 RS/2 N7-N6	Sand, muddy (srt) (q), qB [yel vf-silt] & black oxide stained zone	IP	oxidation	
10RS/2	Sand, clayey; qB [m]	—		
N6-N7 10YR6/2 10R6/4	Mud, sandy; equant mottling ↓ colour gradational	((IP))		Shepparton Formation ? clays
5Y7/1 (mtl) (5YR8/2)	Mud; sandy, (vertical mottling)	— (IP)		
10YR7/6 ↓	Mud, sandy, qB, (musc) [flakes, vf]; iron concretions	((Bo))		
5YR4/4	Mud, gradational↑ sandy [vf] with bands of concretions		goethitic concretions	
5YR5/6	Sand, srt., unconsol., qB [m-c, yel. stained, mdd, nonsph], (mafics) [m]	ID	light goethitic coating of sand particles	Parilla Sand ?

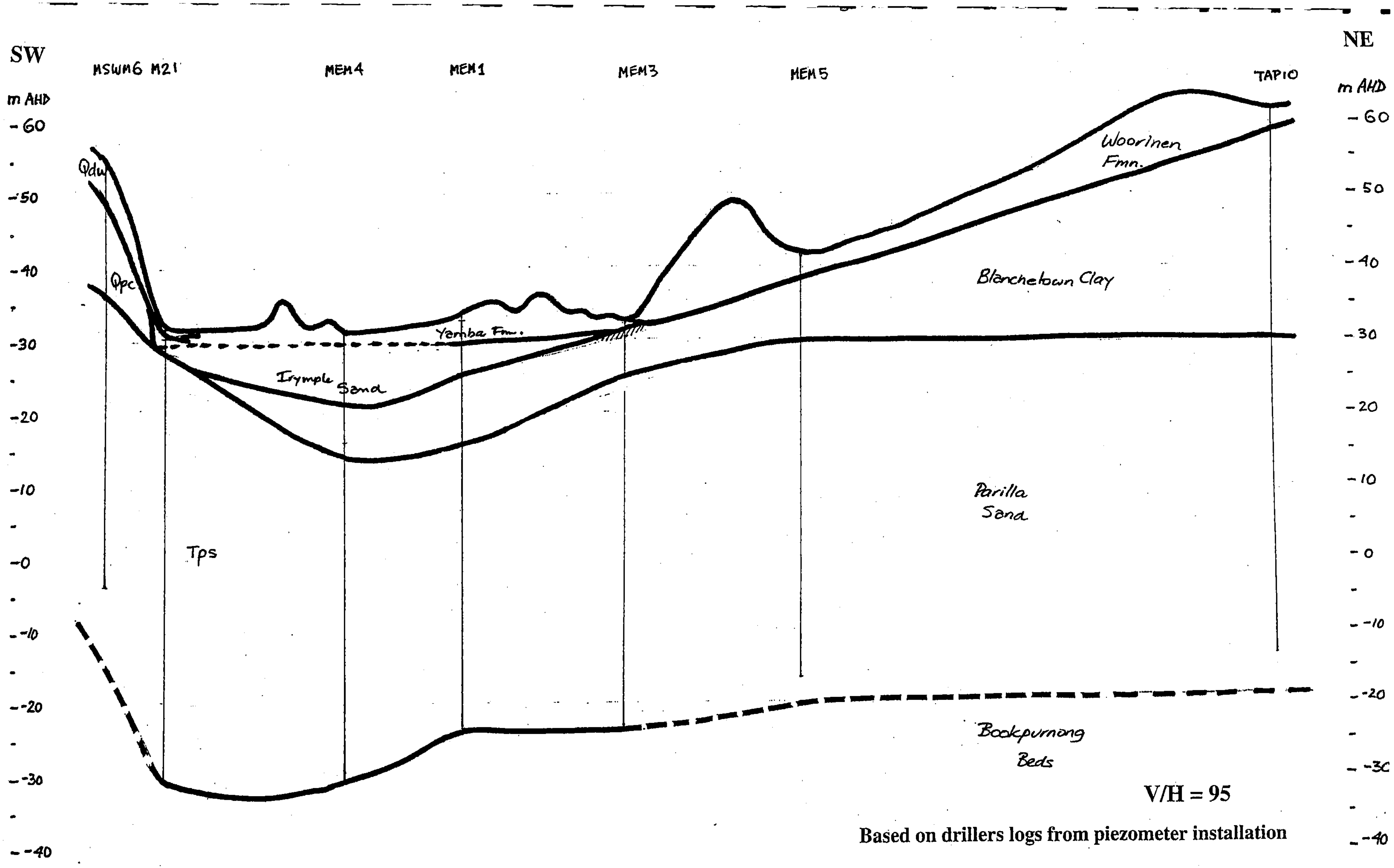
MOURQUONG MRT 4



Stratigraphy

MOURQUONG MWM - MEM TRANSECT





V/H = 95

Based on drillers logs from piezometer installation

Stratigraphy

MOURQUONG MSWM - MEM TRANSECT

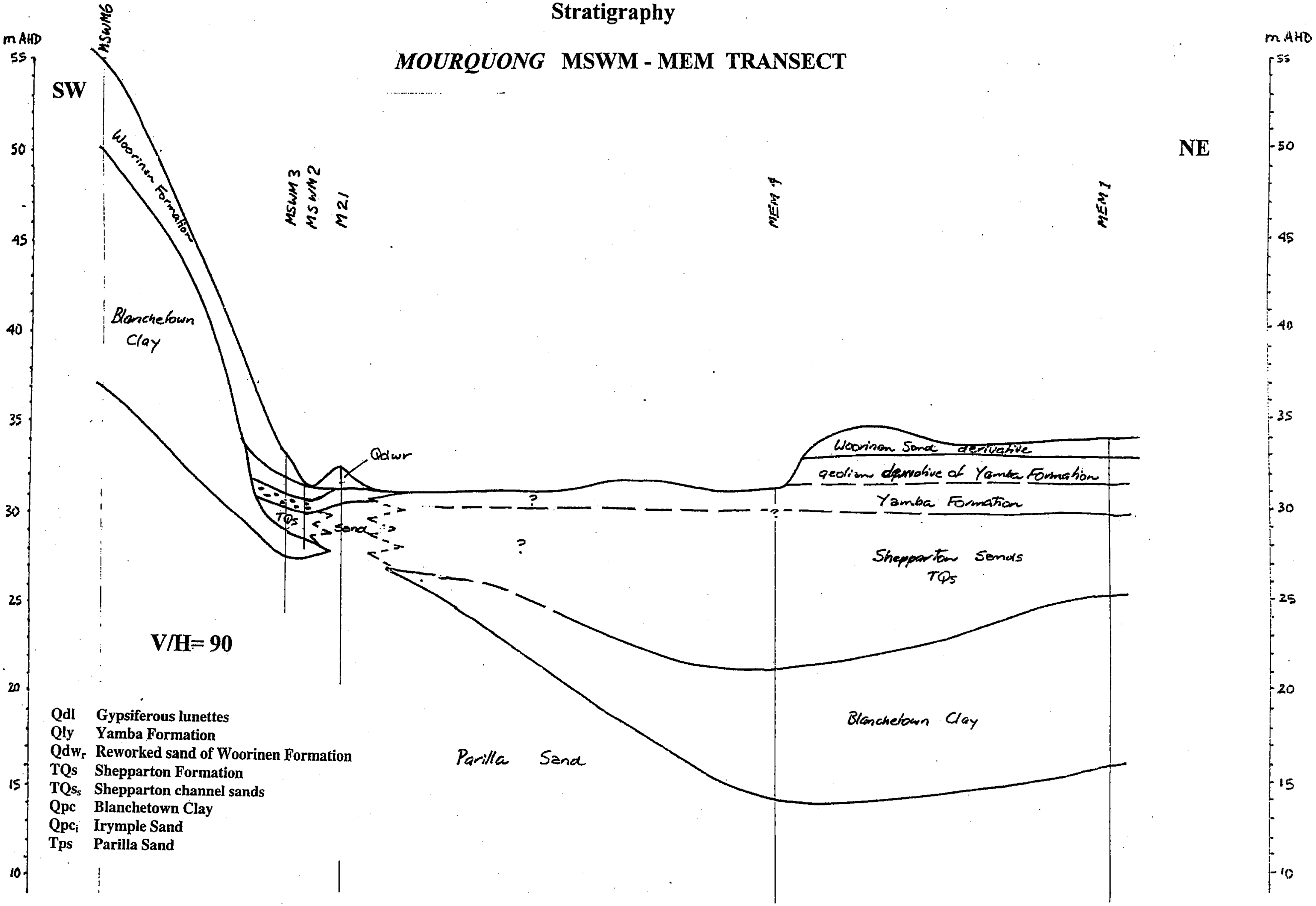


Table A9. Chemistry of Surface Water - Ratios to Br; Mourquong Disposal Basin

Description	*Elevation mAHD*	*Salinity mg/L*	*Lab. reference*	*Salinity/Br*	*Ca/Br*	*Mg/Br*	*Na/Br*	*K/Br*	*Cl/Br*	*SO4/Br*
OUT-1 CSIRO March 95		35000	950278	822	8.9	37.3	242	2.49	418	71.4
TRAN-1 CSIRO March 95		34000	950279	837	8.6	36.9	236	2.51	411	69.2
TRAN-2 CSIRO March 95		36000	950280	851	8.7	35.5	232	2.36	404	68.8
TRAN-3 CSIRO March 95		35000	950281	664	8.8	36.2	233	1.95	408	70.8
TRAN-4 CSIRO March 95		35000	950282	850	9.0	36.7	237	2.48	403	69.2
TRAN-5 CSIRO March 95		35000	950283	862	9.4	36.9	241	2.46	406	71.4
TRAN-6 CSIRO March 95		45000	950284	875	9.7	38.5	253	2.92	430	77.6
TRAN-7 CSIRO March 95		155000	950285	1069	3.2	35.9	248	1.45	434	64.3
TRAN-8 CSIRO March 95		124000	950286	886	4.5	32.1	229	1.36	471	19.6
TRAN-9 CSIRO March 95		196000	950278	1026	3.0	34.6	257	1.57	450	58.1
MQG01 CSIRO March 95		158000	950272	929	4.4	39.4	258	2.53	465	82.4
MQG02 CSIRO March 95		170000	950273	983	4.0	42.2	274	2.60	475	78.0
MQG04 CSIRO March 95		212000	950274	1071	3.0	46.5	288	2.22	535	71.2
MQGO5 CSIRO March 95		204000?	950275	#VALUE!	2.3	40.1	242	1.70	418	57.8
MQGO6 CSIRO March 95		216000	950276	831	2.3	40.4	250	2.08	458	67.3

Table A10. Chemistry of Surface Water - Ratios to Mg; Mourquong Disposal Basin

Description	*Elevation mAH*	*Salinity mg/L*	*Lab. reference*	*Salinity/Mg*	*Ca/Mg*	*Na/Mg*	*K/Mg*	*Cl/Mg*	*SO4/Mg*	*Ca/SO4*
OUT-1 CSIRO March 95		35000	950278	22.0	0.239	6.48	0.067	11.2	1.91	0.125
TRAN-1 CSIRO March 95		34000	950279	22.7	0.233	6.40	0.068	11.1	1.87	0.125
TRAN-2 CSIRO March 95		36000	950280	24.0	0.247	6.53	0.067	11.4	1.94	0.127
TRAN-3 CSIRO March 95		35000	950281	18.3	0.242	6.44	0.054	11.3	1.95	0.124
TRAN-4 CSIRO March 95		35000	950282	23.2	0.245	6.46	0.068	11.0	1.89	0.130
TRAN-5 CSIRO March 95		35000	950283	23.3	0.253	6.53	0.067	11.0	1.93	0.131
TRAN-6 CSIRO March 95		45000	950284	22.7	0.253	6.57	0.076	11.2	2.02	0.125
TRAN-7 CSIRO March 95		155000	950285	29.8	0.090	6.92	0.040	12.1	1.79	0.050
TRAN-8 CSIRO March 95		124000	950286	27.6	0.140	7.11	0.042	14.6	0.61	0.229
TRAN-9 CSIRO March 95		196000	950278	29.7	0.086	7.42	0.045	13.0	1.68	0.051
MQG01 CSIRO March 95		158000	950272	23.6	0.110	6.54	0.064	11.8	2.09	0.053
MQG02 CSIRO March 95		170000	950273	23.3	0.096	6.49	0.062	11.3	1.85	0.052
MQG04 CSIRO March 95		212000	950274	23.0	0.065	6.21	0.048	11.5	1.53	0.043
MQGO5 CSIRO March 95		204000?	950275	#VALUE!	0.058	6.03	0.042	10.4	1.44	0.040
MQGO6 CSIRO March 95		216000	950276	20.6	0.057	6.18	0.051	11.3	1.67	0.034

APPENDIX II

LITHOSTRATIGRAPHIC LOGS

Lithostratigraphy of the Mourquong Groundwater Discharge Complex

(based on AGSO Drilling, 1992)

by

Bruce Radke
Consultant

18 Hartley Street
Turner ACT 2601

1 December, 1992

Prepared as a contribution to the CSIRO-AGSO project:
Groundwater dynamics of evaporative brines and their
application to saline wastewater disposal

CONTENTS

INTRODUCTION

This study provides an interpretation of the lithostratigraphy of the Mourquong groundwater discharge complex, based on logging of drillcore recovered by AGSO, in conjunction with airphoto interpretation.
The lithostratigraphic model is compared with that developed for the Nulla discharge complex by Radke (1992).

Mourquong discharge complex lies due north of Mildura, in New South Wales between 4 and 8 kilometres north of the Murray River. It is adjacent to and directly north of the Stanley Wines vineyards on the Buronga-Dareton highway (Figure 1).

STRATIGRAPHY OF THE MOURQUONG DISCHARGE COMPLEX

Lithostratigraphic data is presented in the detailed lithological logs of Appendix I. This information is summarized in cross-sections of the complex along west-east and south-north sections (Figures 2,3). Interpretation of this sequence is presented in Figures 4 and 5.

Parilla Sand

The Parilla Sand was intercepted in the bottom 2 metres of Mourquong drillholes 4,7, and 9, and comprises semiconsolidated light olive grey, variably sorted to bimodal, quartz sand. Large colour mottling (reddish brown, yellowish grey and light grey) intensifies upwards with increasing clay-matrix content, down-filtered from the overlying Blanchetown clay, and with apparent bioturbation. The Parilla Sand is regionally continuous and extends beneath the Mourquong discharge complex (Scott et al., 1991; Rural Water Commission, 1991).

Stratigraphic Relationships: The upper Parilla Sand has a porosity-modified transition into Blanchetown Clay from the erosion, reworking, of its unconsolidated sands, and from infiltered clay.

Blanchetown Clay

The Blanchetown Clay is continuous beneath the discharge complex, apparently draping gently over the former Parilla topography. This, as well as superimposed differential subsidence, is generally echoed in the present land surface. Within the west-east and south-north transects, the Blanchetown Clay ranges from 3 to in excess of 8 metres thickness in Mourquong 1, at the lake centre. The unit thins to the west, towards and beyond the lake margin, and northwards along the axis of the lake to Morquong 3 and 14.

The lower 1.2 metre interval is an intermixture of underlying Parilla Sand and Blanchetown mud as thin-bedded sand-mud alternations. Where unweathered, the Blanchetown is predominantly bluish-grey mud and clay with stratiform gypseous mud facies and thin interbedded carbonates. The gypseous mud facies occurs in three separate lenses which are progressively thicker upsection from 0.75m to 3.5m thick at the top of the unit. This gypseous facies is apparently restricted to the central axis of the existing lake (Mourquong 1 and 3), however there is no subsurface data under an extensive area to the east which is interpreted as having a spatial and stratigraphic admixture of saline lacustrine and lunette deposits (Figure 1). Both the lenses of gypseous facies and stratigraphic thickness between carbonate horizons indicate a uniform thickening of the whole unit eastwards. Northwards the thinning is only apparent in the upper gypseous facies and an erosional hiatus is interpreted at the top of the Blanchetown Clay in Mourquong 3 and 14, on the upper erosional surface of a magnesitic micrite band within weathered mud.

Thin dolomicrite bands (laminae to thin beds) and horizons of indistinct to discrete dolomicrite nodules occur within the lowerpart of the unit, some having associated evidence of exposure and weathering, or erosion.

Fine framboidal pyrite is ubiquitous, imparting darker-coloured wisps and lamination. One horizon has distinctive varve-like lamination emphasized by the pyrite and has been used as a marker horizon identified throughout the unit except in Mourquong 14. In Morquong 9, a dense limonitic ochre within oxidation-mottled sediments is interpreted as the same horizon.

On the raised sloping section west of the lake margin, additional mixed sands, sandy muds and muddy sands constitute a middle sandy facies which overlies and is overlain by "typical" Blanchetown muds. This facies implies intermixture of Parilla Sands and therefore exposed Parilla nearby.

Stratigraphic Relationships: Blanchetown Clay overlies the Parilla Sand with a partially reworked zone of the underlying Parilla. The unit has an apparent conformable junction with the overlying Yamba Formation under Mourquong lake. Towards the western lake margin it is incised and covered by Woorinen sand derivative. Westwards beyond this erosional "nick", the Blanchetown has a weathered and oxidized upper surface over bright red dense puggy clay.

Woorinen Formation

These dune sands are recognized in Mourquong 7, 9 and 10. Semiconsolidated and calcareous dark reddish-brown quartz sands of the Woorinen Formation are distinctive, with sesquioxide staining on the quartz, calcrete profiles, bioturbation, and root traces. The sands range from 4m in Mourquong 9 to 2.5m in Mourquong 7 and are completely eroded off by Mourquong 5. The unit is variably indurated with calcrete carbonate. Two profiles, 0.5 to 1.5m thick, are recognized in Mourquong 9 and 10. The upper thinner and denser calcrete probably crops out between Mourquong 10 and 7.

Stratigraphic Relationships: The Woorinen Formation unconformably overlies a weathered and oxidized Blanchetown surface. It is eroded and partly covered on the slope down to Mourquong lake by the Woorinen sand derivative.

Younger, remobilized reddish quartz sands contrast the Woorinen in their absence of induration and are interpreted as a reworked dune sand, synchronous with and post-Yamba in deposition. This is referred to as the Woorinen sand derivative.

Yamba Formation (Brown and Stephenson, 1991)

The sequence overlying the Blanchetown Clay has a contrasting high clastic gypsum sand content as beds and laminae, interlaminated with clays and muds. These lake deposits also thicken eastwards into the discharge complex. On the south-north section the unit thickens slightly to Mourquong 3, and then thins considerably towards Mourquong 14 with a corresponding increase in thickness of interbedded quartz-sand bodies.
These brown gypseous quartz-sand intervals are interpreted as Woorinen sand derivative, and form two thin (0.5 metre) but extensive sheets which thicken suddenly in Mourquong 14. They are apparent aeolian equivalents of the lake deposits, and are transitional with gypsum-rich lunettes which have been delineated on aerial photography (Figure 1). In the cross-sections, these lunettes have been differentiated (Qdl) from the host Yamba Formation. No lithostratigraphic information is available on these lunettes.

The Woorinen sand derivatives probably indicate deflation events within the current discharge history and are probably equivalent chronostratigraphically with the deflation events proposed for the Nulla discharge complex (Radke, 1992).

Stratigraphic Relationships: The Yamba Formation overlies the Blanchetown Clay with apparent conformity under Mourquong Lake except at the northern end where a hiatus is inferred in Mourquong 3 and 14. On the western margin of the lake it lenses out under the Woorinen sand derivative. At least two intervals of the Woorinen sand derivative intertongue with the unit and, within the area of section lines, appear to extend over the whole area. Because of the type of lake accumulation, there are numerous breaks and micro-deflation events within the Yamba Formation.

DIAGENESIS

Carbonate

Bands and horizons of concretions of chalky white micritic carbonate occur within the Blanchetown Clay. Most occurrences are chalky dolomicrite but to the northern end of the transect, the upper eroded surface of the unit in Mourquong 14 and 3 appears to be magnesite (no effervescence in 10% hyrochloric acid).

Generally the Woorinen Formation is slightly calcareous. Calcrete profiles of varying maturity occur in the middle and upper Woorinen Formation. Where fully developed, the profile has a distinct and indurated upper boundary, mottled calcite-rich pinkish matrix in the host sand, scattered pisolites and reworked calcrete fragments. Extra cementation may occur in root traces. Two calcrete profiles are recognized, the upper one apparently eroded on the western slope between Mourquong 7 and 10.

Gypsum

Gypsum is present in the Blanchetown Clay as scattered laminae of clastic sands within muds and clays. This gypseous facies is only present under Mourquong lake, but is apparently absent laterally to the west into sandier Blanchetown facies beyond the lake. In the overlying Yamba Formation, gypsum is prolific as laminae and thin beds of primary clastic sands. These indicate seasonal or regular episodic origin. At a few upper horizons, hardpan layers of variable continuity and induration, indicate static groundwater levels when the lake was dry.

Pyrite

Within the Blanchetown Clay, much of the lamination within the predominantly blue-grey mud sequence is colour-enhanced by fine black framboidal pyrite which appears restricted to fine interparticle porosity in thin silty or sandy interbeds within gypseous facies. This suggests sulphate reduction occurred where organic matter and iron-rich porewaters were closely associated in porous gypseous laminae.

Discussion

Syndepositional diagenesis has been predominant in the sequence. Significant early diagenetic overprints occur in the Yamba Formation in gypsum hardpans where the lake has been dry, and groundwater levels have left indurated gypsum crystal crusts within the sequence. Pedogenic processes in the sands of the Woorinen Formation have also remobilized wind-blown carbonate into calcrete horizons.

POROSITY

General Statement

Lateral permeability within the complex is significant within the Parilla Sand, Woorinen Formation, Woorinen Formation derivative, and the lowermost and uppermost intervals of the Yamba Formation.

There are no impermeable aquitards except in the central area of Mourquong within the Blanchetown Clay. Porosity within the Blanchetown increases laterally towards and beyond the lake margin, in an apparent association with a thinner sandier sequence

which is contained within thin, relatively impermeable clays.
Porosity is predominantly the interparticle type in sorted sands. Less abundant porosity in the sequence comprises minor intercrystalline porosity in the carbonates, and some fenestral porosity in bioturbated horizons.

Porosity distribution in the Mourquong sequence is summarized in Figures 6 and 7. Details of porosity type and distribution is shown in the lithological logs of Appendix I.

Parilla Sand

Porosity is generally good, with uniform high interparticle porosity, but decreases gradually up to the Blanchetown contact. This reduction is a direct result of mud from the Blanchetown Clay.

Blanchetown Clay

This unit has extremely variable interparticle porosity, corresponding to the presence of thin interbedded sands, especially in the lower transitional interval with the Parilla Sand, as well as to the west beyond the lake margin where sands, sand interbeds, and muddy sands lie between less permeable Blanchetown muds.
Carbonate horizons, and the very pyritic laminae are both relatively porous, with intercrystalline porosity predominant.

Woorinen Formation

Medium interparticle porosity in the slightly clayey sands, is reduced within the calcrete profiles, corresponding to variable occlusion by micritic calcite cement. Fenestral and bioturbation porosity which is more erratic in distribution, becomes relatively abundant in these intervals.

Yamba Formation

Interparticle porosity has a predominantly stratiform distribution in thin flaser-like interbeds of lake muds and relatively porous clastic gypsum sands. Extensive quartz-dominant aeolian sand stringers and sheets, forming two intervals within this formation, are even higher in interparticle porosity.

REGIONAL STRUCTURE

Published regional studies (Rural Water Commission, 1991) indicate that the Mourquong complex is a topographic depression overlying the Koorlong Trough which has a western faulted margin along the Danyo Fault, separating it from the Merbein Ridge immediately to the west. The location of this fault is placed further east of the active lake under the Mourquong Swamp by Scott et al.(1991) although their stratigraphic cross-section enigmatically contradicts this position. Dislocation on the Danyo fault is only only below the Tertiary sequence and subsidence in the trough is implied throughout the Tertiary (Rural Water Commission, 1991). The present physiographic features of Mourquong are also an expression of this subsidence in the Koorlong Trough. More detailed geophysical delineation of the fault would be desirable to clarify this issue. Thicknesses of both the Blanchetown Clay and Yamba Formation confirm subsidence in the limited area investigated. Airphoto interpretation indicates a further extension of these deposits to the east, within a north-south elongate area of active accumulation (Figure 1).

HISTORY OF MOURQUONG AS A DISCHARGE COMPLEX

Present-day physiography reflects differential subsidence of the Tertiary sequence, controlled by pre-Tertiary structure. The Mourquong Discharge Complex is a swampy depression which overlies part of the western side of the Koorlong Trough. This depression has been existent throughout Blanchetown Clay and Yamba deposition, with the depocentre located at or further east of Mourquong 13.
Blanchetown deposition was initially and predominantly under lower salinities with intermixture of muds with sand derived from surrounding exposed Parilla Sand. Intermittent dolomite precipitation occurred in this earlier period of generally lower salinities. Three phases of higher salinities contributed minor gypsum to the lake muds. The last phase produced the thickest and uppermost gypseous facies.
These protracted phases of higher salinity fluctuations were restricted to the central depocentre.
Additional introduction of sands from the west occurred intermittently on the western margin and probably relates to initial Woorinen sand mobilization. A transition to Yamba deposition resulted from repeatedly higher salinity producing alternating laminae of lake gypsum and lacustrine muds. These alternations were very regular and probably seasonal.

At least two periods of lake drying, probable deflation, and resultant thin accumulation of quartz dune sands occurred. These are tentatively correlated with the B and C sequences at Nulla Discharge Complex. High, now eroded, remnant lunettes of gypseous sediment accumulated on the eastern margin of deflation areas. The deflation pattern appears quite complex on the eastern side, with lunettes accumulating against any former relief such as Woorinen dunes and even earlier lunettes. During one or more of these deflation events, the western lake margin was eroded back into the marginal slope (Figure 2). Commencement of Woorinen dune formation probably preceded this event. The Woorinen deposits on the western margin, with calcrete development occurred over at least two periods, with subsequent erosion and redeposition

COMPARISON OF MOURQUONG AND NULLA DISCHARGE COMPLEXES

Both Mourquong and Nulla discharge complexes have comparable lake deposits in a continuum through Blanchetown Clay to recent deposits. Radke (1992) presented three stratigraphic models for the Nulla sequence and favoured the absence of Blanchetown Clay below Nulla Spring Lake. Following this study of the Mourquong sequence, and the transitions within the Blanchetown Clay away from the lake, his third model (Radke, 1992, fig.18b) is now seen as a more viable model.

The major difference between the discharge complexes is in the structural and tectonic setting. At Mourquong, the subsidence and resultant lake deposition has its depocentre centrally or possibly to the eastern side of the complex. At Nulla, initially deposition was within a complex terrain resulting from differential erosion within a former Parilla dunefield. In the southwestern margin, around Nulla Spring Lake, there is greater lateral differentiation of lacustrine to the west and aeolian facies to the east.

Given the asymmetry of both complexes resulting from wind transport and therefore lunette accumulation predominantly on the eastern side, then we see the significant difference in the sequence facies geometry arising from different tectonism. At Mourquong, deflation of aeolian sands and clays on the western margin causes admixture with authigenic lake gypsum accumulating centrally as lake deposits. Lunette deposits accumulate to the east and then prograde westwards. However, with subsequent reflooding of the lake, and subsidence to the east, lacustrine deposits accumulate over the entire area, including between former lunette deposits and the overall spatial facies distribution is highly entropic over the whole area.
In contrast, Nulla Spring Lake has its depocentre of accumulation on the western margin. Lunette deposits are always on the raised eastern side and are subject to more deflation than at Morquong. At Nulla, successive deflation and flooding events tend to be more restricted to the western margin and at lower levels. This pattern may also indicate either lower gypsum precipitation rates, or more effective deflation of sediment out of the complex.

SUMMARY AND CONCLUSIONS

1. Mourquong groundwater discharge complex occurs on the western margin of the Koorlong Trough, adjacent to the pre-Tertiary Danyo Fault. The complex has been the subsiding and consequently has been a depocentre since at least the Pleistocene. Regional patterns suggest gentle subsidence may have been continuous throughout the Tertiary.

2. The AGSO drilling has defined the western margin and north-south variations within the complex. However the eastern area has a possibly significant and thicker lacustrine sequence which remains uninvestigated.

3. The observed sequence is consistent with that of Scott et al.(1991); Parilla Sand with significant lateral relief, over-draping of Blanchetown Clay, and overlying saline lacustrine deposits of the Yanba Formation. A small erosional bench has been incised into the Blanchetown Clay on the western margin, but did not significantly penetrate the formation. Although there is no window into the Parilla sand, lateral facies and porosity variations in the Blanchetown Clay, sandier and more permeable to the west, would allow lateral fluid migration.

4. Aside from the highly porous Parilla Sand and Woorinen Formation, the lacustrine Yamba Formation has highly porous sand horizons, especially basally and in the upper section. Blanchetown clay has modest but isolated sandy porous intervals under the lake. However, laterally to the west away from the lake margin, porosity increases in the Blanchetown Clay with increasingly mixed and interbedded sands in the unit. The dominant porosity is interparticle porosity in sands

5. Mourquong evolved into a saline evaporative basin gradually. During Blanchetown deposition, the central facies was intermittent and moderately gypseous. During and/or following Woorinen development, salinities were much higher, with predominant primary gypsum deposition in seasonal? or recurring events (Yamba Formation). Gypseous lunette remnants in the central-eastern part of the complex indicate several phases of significant deflation which is also evident from extensive thin sheets of quartz dune sand (Woorinen sand derivative) and thin gypseous hardpans within the Yamba Formation.

6. Because of the continuous subsidence, greater in the central and possibly also in the eastern leeward area, a less interrupted depositional sequence is preserved with a generally stratiform geometry. The surface distribution of lunettes and lake deposits from overflooding is correspondingly complex (see Figure 1).

7. In contrast, Nulla Discharge complex has had little or no subsidence and is located among remnant islands of Blanchetown Clay. Locally at Nulla Spring Lake, the thickest sequence is on the western side and facies are laterally differentiated; lacustrine deposits predominate on the western side, and lunette deposits with interspersed erosional events predominate to the east. Major deflation events have sequentially incised the lake level
deeper on the western edge of the complex.

8. In summary, Mourquong complex, has had greater subsidence and consequent lower differentiation of facies, and minimal loss from deflation in comparison to Nulla.

ACKNOWLEDGEMENTS

Jim Ferguson initiated this study and provided the stimulus of searching questions throughout this study.
Bill Keeley gave assistance in core preparation necessary for the study. Thanks are extended to Gerry Jacobson for providing preliminary results of his geological mapping of the Mourquong area; and to Ross Brodie for his discussion on the regional pre-Tertiary structure.

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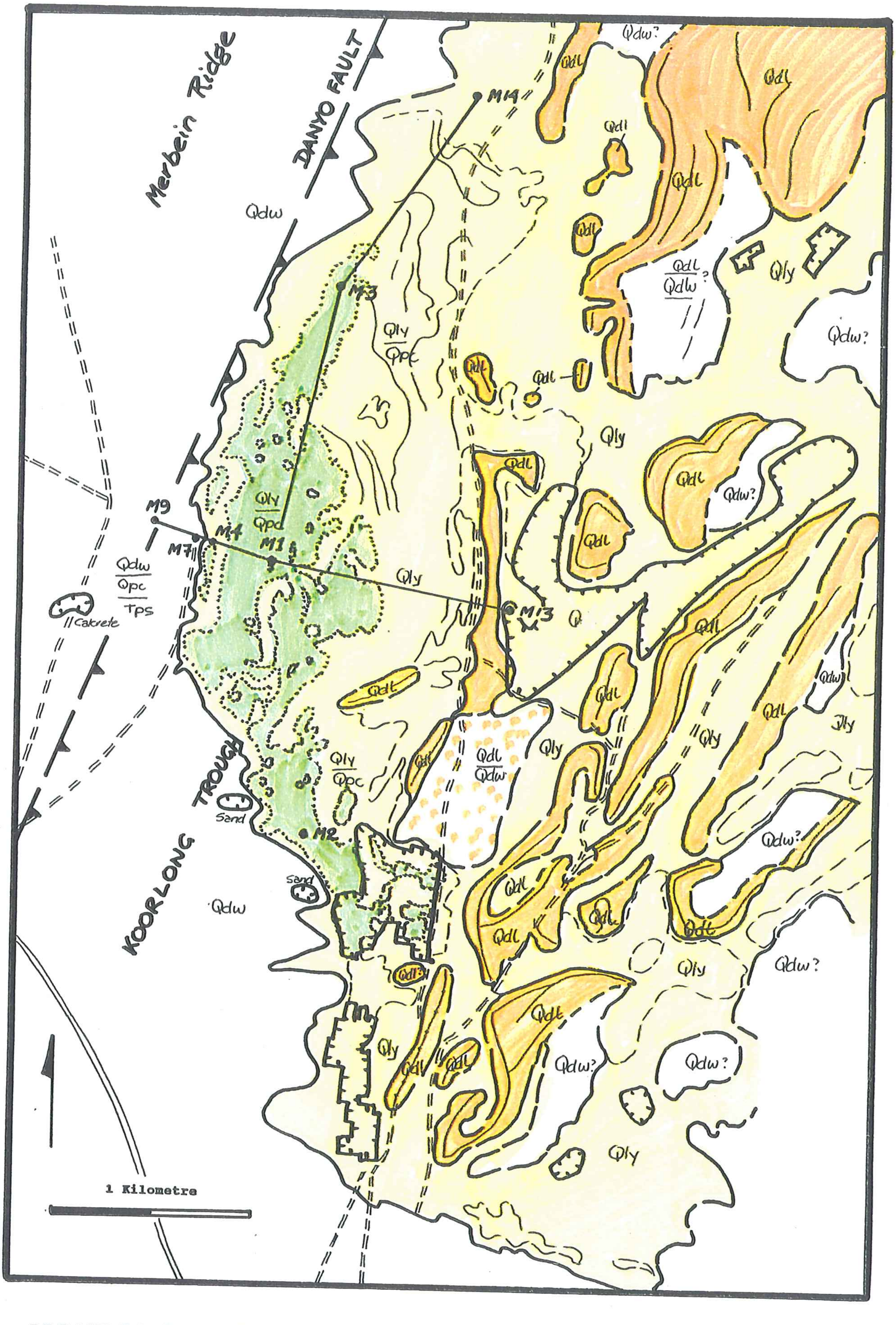

MOURQUONG DISCHARGE COMPLEX

LEGEND

●——●	drillholes and section line
═══	highway
═ ═ ═	track
⬭	quarry; mining pit
⋯⋯	lake margin as at 15/2/ 1982
——	lunette crest, trend
━━	stratigraphic boundary

STRATIGRAPHY

	Qdwr	active and reworked dune sand derived from Woorinen Formation
🟩	Qly	Yamba Formation
⬜	Qly_1	(probable equivalent of Nulla B sequence)
🟧	Qly_2	(probable equivalent of Nulla C sequence)
	Qdl	gypsite terraces and lunettes, 2 - 4 metres above lake level, (probable equivalent of Nulla B1 sequence)
	Qdw	Woorinen Formation red aeolian quartz sand with calcrete horizons
	Qpc	Blanchetown Clay
	Tps	Parilla Sand

Figure 1

MOURQUONG LITHOSTRATIGRAPHY

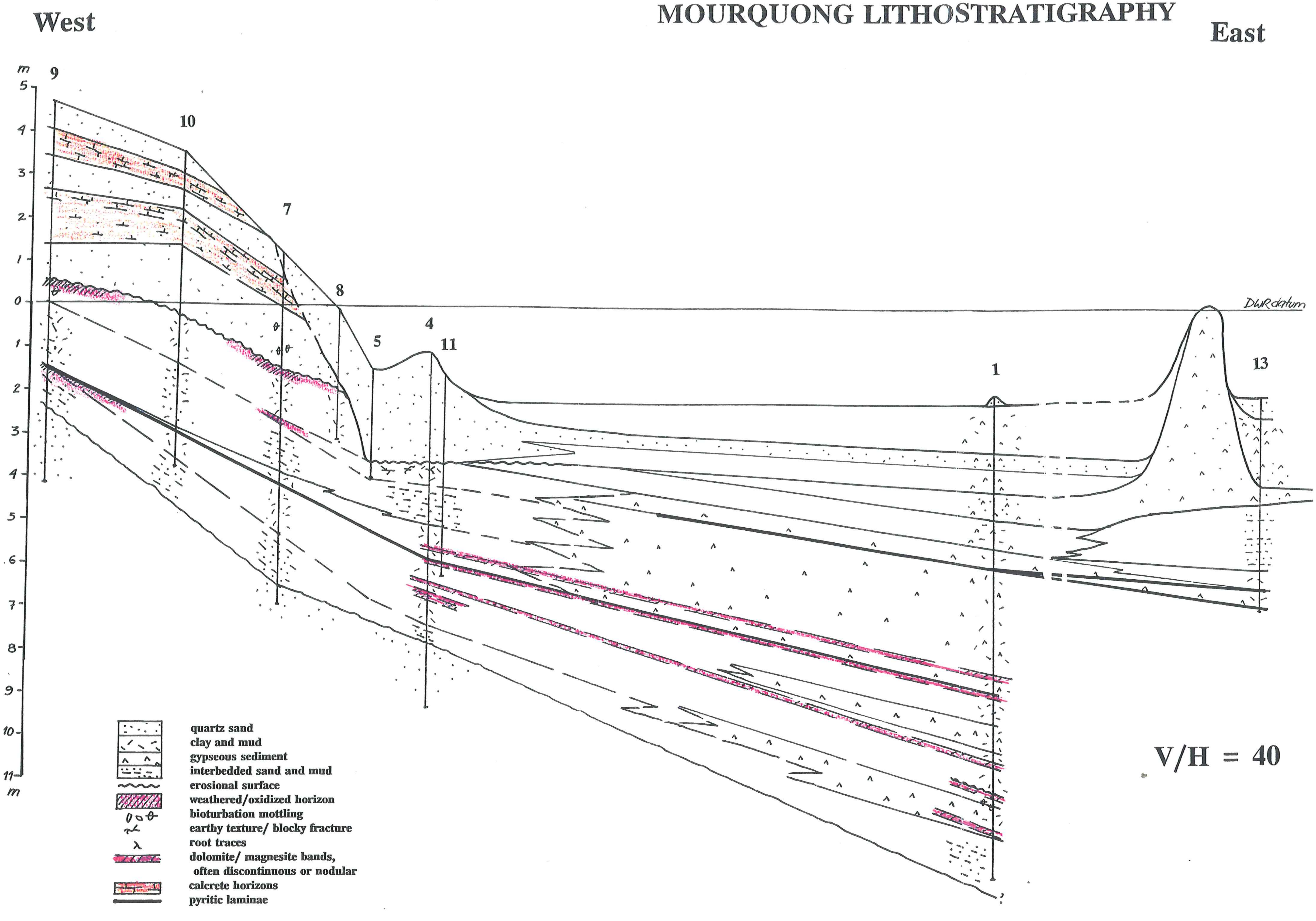

Figure 2

MOURQUONG LITHOSTRATIGRAPH

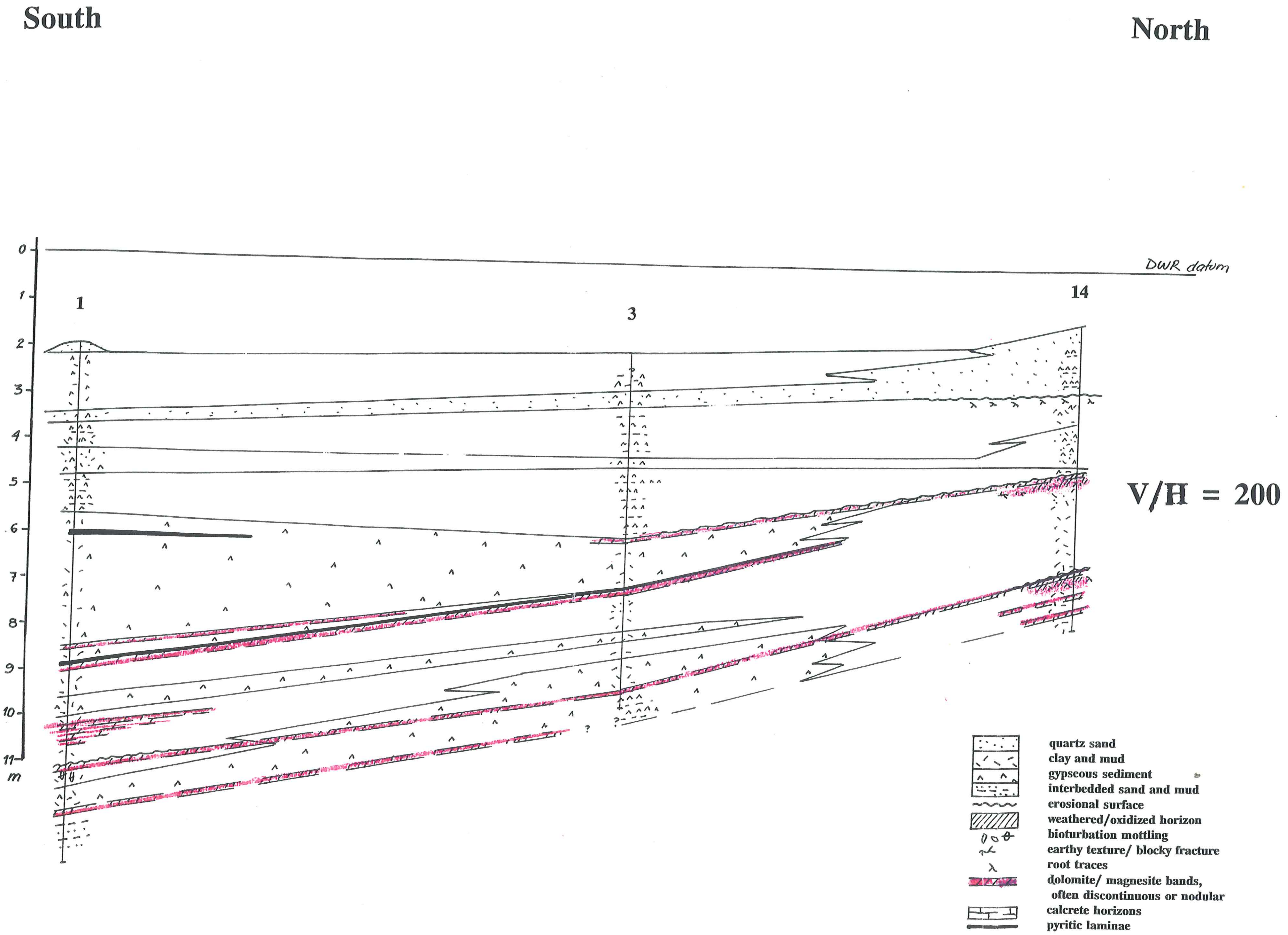

Figure 3

MOURQUONG STRATIGRAPHY

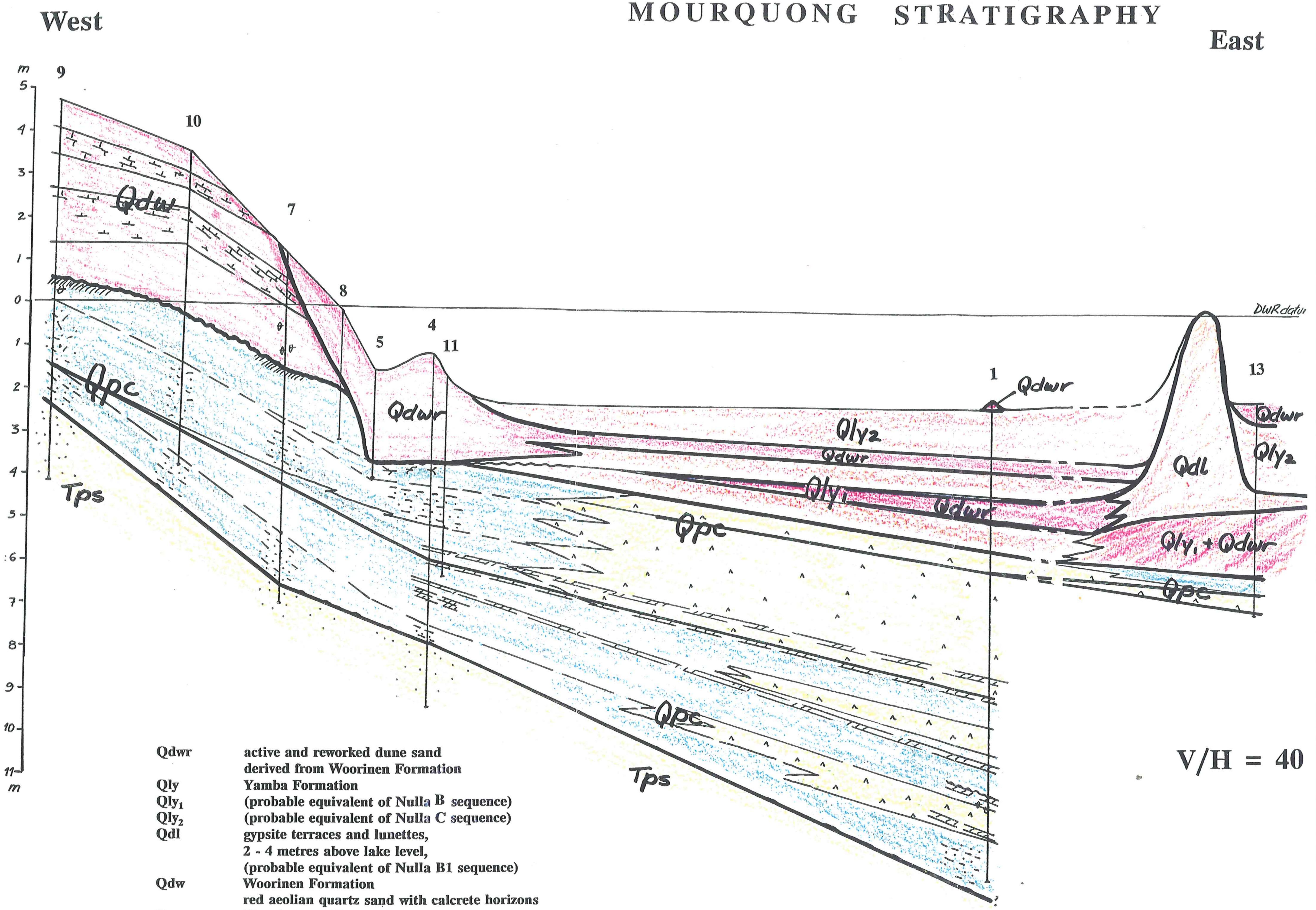

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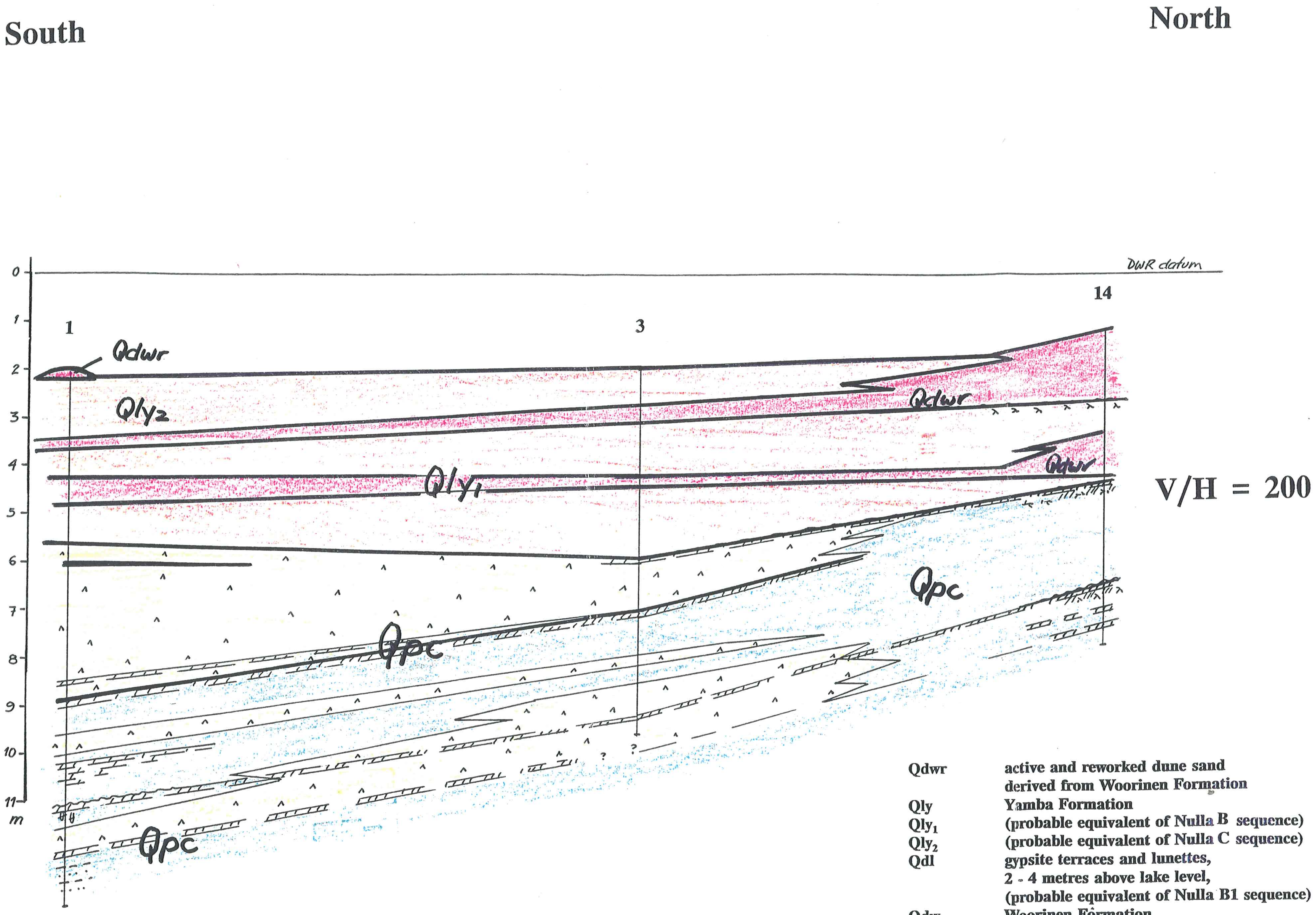
Figure 4

MOURQUONG STRATIGRAPHY



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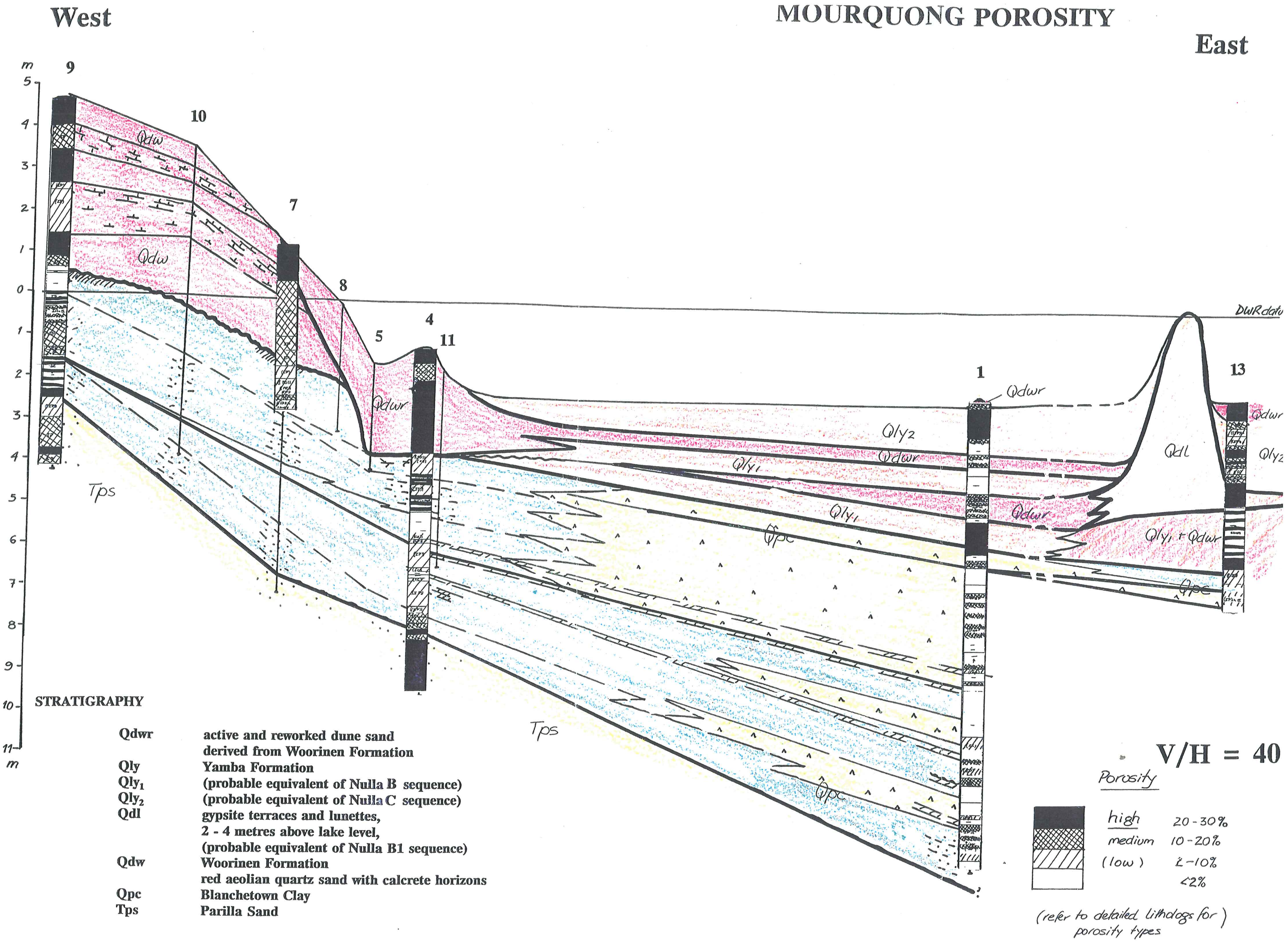
Qpc	Blanchetown Clay
Tps	Parilla Sand

Figure 5

MOURQUONG POROSITY



(refer to detailed lithologs for porosity types)

STRATIGRAPHY

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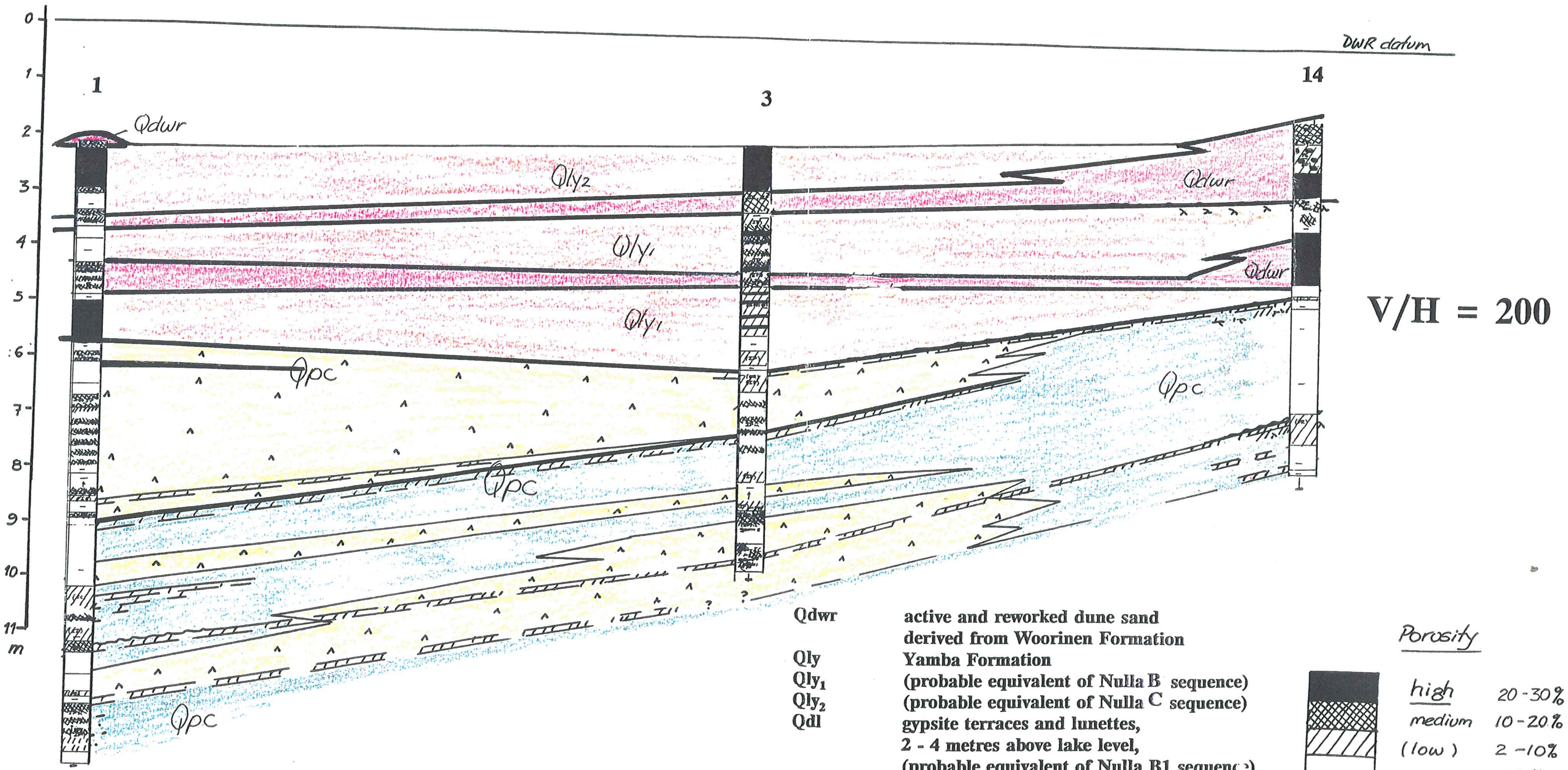
Figure 6

MOURQUONG POROSITY



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Qpc	Blanchetown Clay
Tps	Parilla Sand

Porosity

■	high	20-30%
▩	medium	10-20%
▨	(low)	2-10%
□		<2%

(refer to detailed lithologs for porosity types)

Figure 7

APPENDIX I

DETAILED LITHOLOGICAL LOGS OF CORED MOURQUONG DRILLHOLES

EXPLANATION AND LEGEND

Format

The purpose of this combined graphic and annotated log is to present information in categories which are readily utilized for analysis. Much of the information is repeated in different formats throughout the columnar documentation. All information is qualitative, being acquired by visual assessment. There are, however, systematic categories of abundance.
The stratigraphic log is arranged in 14 columns, being from left to right:

1. Depth below surface in centimetres
2. Core recovery
3. Sampled intervals
4. Particle size abundance
5. Graphic litholog
6. Sedimentary structures
7. Biota
8. Mineralogical composition
9. Colour
10. Degree of induration
11. Lithological description
12. Porosity
13. Diagenetic features
14. Interpretation of depositional environment

Scale

The scale on the left hand side indicates depth below surface in metres.

Core Recovery

Where documented, the core number is followed in parentheses by the recovery in %.

Samples

Sampled intervals are annotated as:

- P Petrographic
- X Mineralogic
- µP Palynologic

Particle size abundance

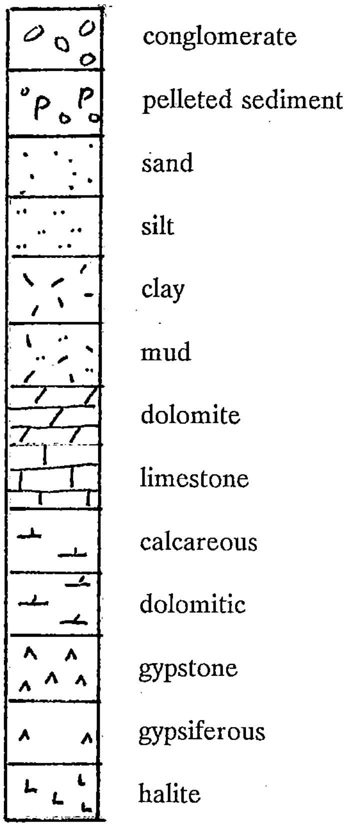
Particle sizes are documented in accordance with the classification of Wentworth (1922).

mm		
256 -----------		
	cbl	cobble
64 ------------		
	pbl	pebble
4 ------------		
	g	granule
2 -------------		
	vc	very coarse sand
1 -------------		
	c	coarse sand
0.5-----------		
	m	medium sand
0.25----------		
	f	fine sand
0.125-----------		
	vf	very fine sand
0. 0625---------		
	slt	silt
2 ----------		
	c	clay

These size categories equate with adjacent columns from left to right:
larger than granule; very coarse and coarse sand; medium sand; fine sand; verey fine sand; silt; and clay particles.

In some logs, relative abundance is indicated by the density of crosshatching up to black for major abundance.

Graphic Litholog



Gradational changes between lithologies have no line separating symbols as used for abrupt changes. Where the contrast is apparent but not abrupt, a dashed line is used for separation. Non-planar contacts are designated with relief and cross section comparable to their form.

Sedimentary Structure Log

Sedimentary structures are designated in graphic form in their relative orientation and abundance observed.

≚	cross-stratification
≡	lamination
≜	cross-lamination
↑≡	lamination with fining upwards of particle size
≡↓	lamination with coarsening upwards of particle size
∿	disturbed bedding
〰	erosional surface
∫	flaser structures
⊤	desiccation crack
⌇	slickenslided cellular structure
∽	erosional relief
ℰ	fractures
⬭	small lens
●	authigenic nodules
◢	authigenic gypsum crystals
★	gypsum rosettes
≋	argillans
ʃʃ	veining
θθ	bioturbation infill

Biota

P	Pellet
ϕ	Plant material
0	Wood fragment
λ	Rootlets
θ	Ostracods
8	Foraminifera
θ-	Bioturbation

Mineralogical Composition

Sediment mineralogy is categorized into 5 columns:
quartz, clays, carbonates, evaporites (predom. gypsum), and other.
Abundance estimates are qualitative and indicated as:
● major • minor ⊘ accessory ○ trace

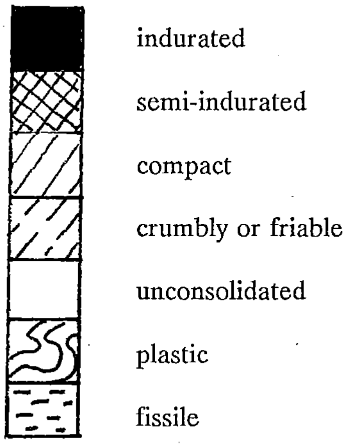
Colour

The colour of wet core is determined by visual comparison with the Geological Society of America Rock-Colour Chart, documented by the numerical designation in square parentheses. Where the rock is variegated owing to bioturbation, lamination or speckled by coloured particles, the colour variations are qualified accordingly, usually in parentheses.

mtl	mottled
intlmntd	interlaminated

Degree of Induration, Coherency

Graphic texture categories or combinations thereof are used to indicate the mechanical and textural properties of the wet core.



Lithological Description

The lithology is qualified by descriptive adjectives, indicating component particles, sedimentary structures, and their relative abundance (underlining - greater abundance, parenthesis - reduced abundance). Additional qualification of any component or structure is given in square brackets immediately following the feature to be qualified.

Where abbreviations are used, they are generally standardized BMR abbreviations. As a general rule of thumb, the abbreviation is derived by removing vowels. abbreviated nouns are indicated by upper case and abbreviated adjectives by lower case.

Abbreviations for Lithological Description

ang	angular
biot	biotitic
Biotrbn	bioturbation
calc	calcareous
Concrtn	concretion
Clay	clay
Cmnt	cement
cmpctd	compacted
desiccn	desiccation
discont	discontinuous
dissem	disseminated
dolmt	dolomitic
frctd	fractured
facetd	faceted
feldsp	feldspathic
Frgmnt	fragment
frmbdl	framboidal
horizntl	horizontal
incrsng	increasing
intbdd	interbedded
Intrclst	intraclast
intlmntd	interlaminated
lmntd	laminated
Lmntn	Lamination
Xlmntn	crosslamination
lrg	large
Lignt	lignite
ligntc	lignitic
Mud	mud
musc	muscovitic
Mtx	matrix
Mdst	mudstone
mic	micaceous
mtl	mottle
Nodl	nodule
Nucl	nucleus
Orgncs	organic material
Oxdzn	oxidation
oxdzd	oxidized
Ptchs	patches
pel	pelletal
pol	polished
por	porous
pyrt	pyritic
Pyrt	pyrite
pebbl	pebbly
qtz	quartzose
Qtz	Quartz
rndd	rounded
repl	replacing
Replmnt	replacement
Snd	sand
slt	silt
subang	subangular
subsph	subspherical

srt	sorted
spckld	speckled
slick	slickenslided
tn	thin
Text	texture
unif	uniform
vari	variably

Porosity

Porosity type follows the classification of Choquette and Pray (1970). Common porosity types in these sequences are:

IP	interparticle
BO	bioturbation
IC	intercrystalline
FR	fracture
FE	fenestral

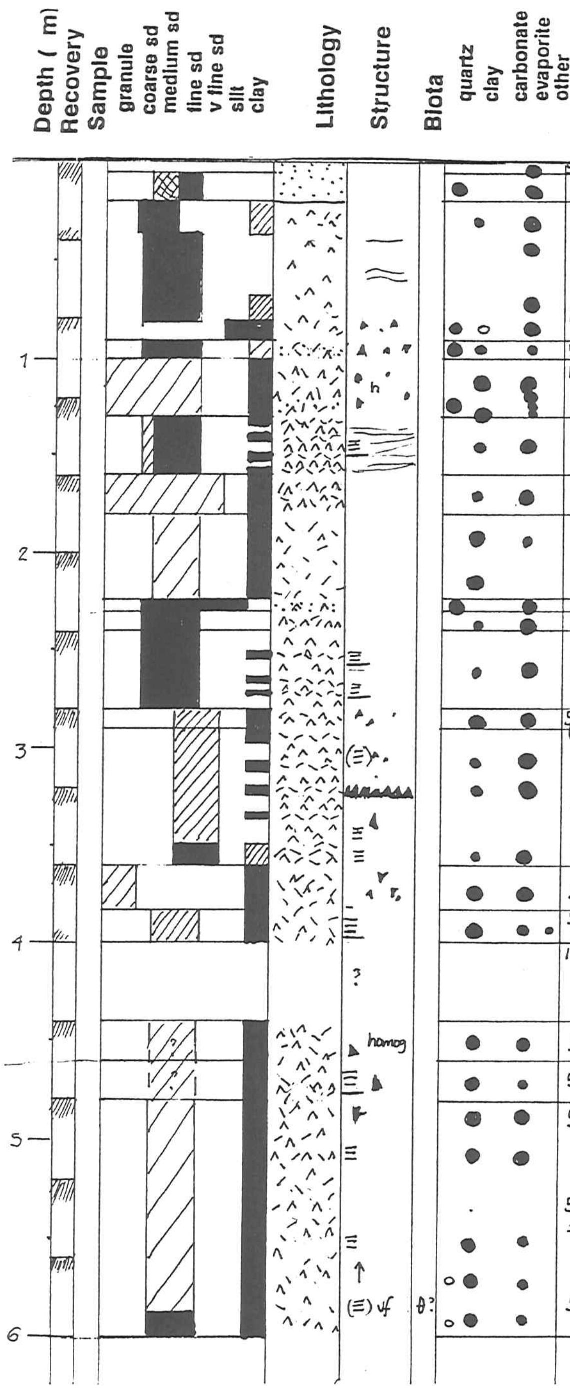
Qualitative abundance is indicated using:

IP	approx. 30-20%
IP	approx. 20-10%
(IP)	approx. 10- 2%
((IP))	approx. <2%

Diagenetic Features

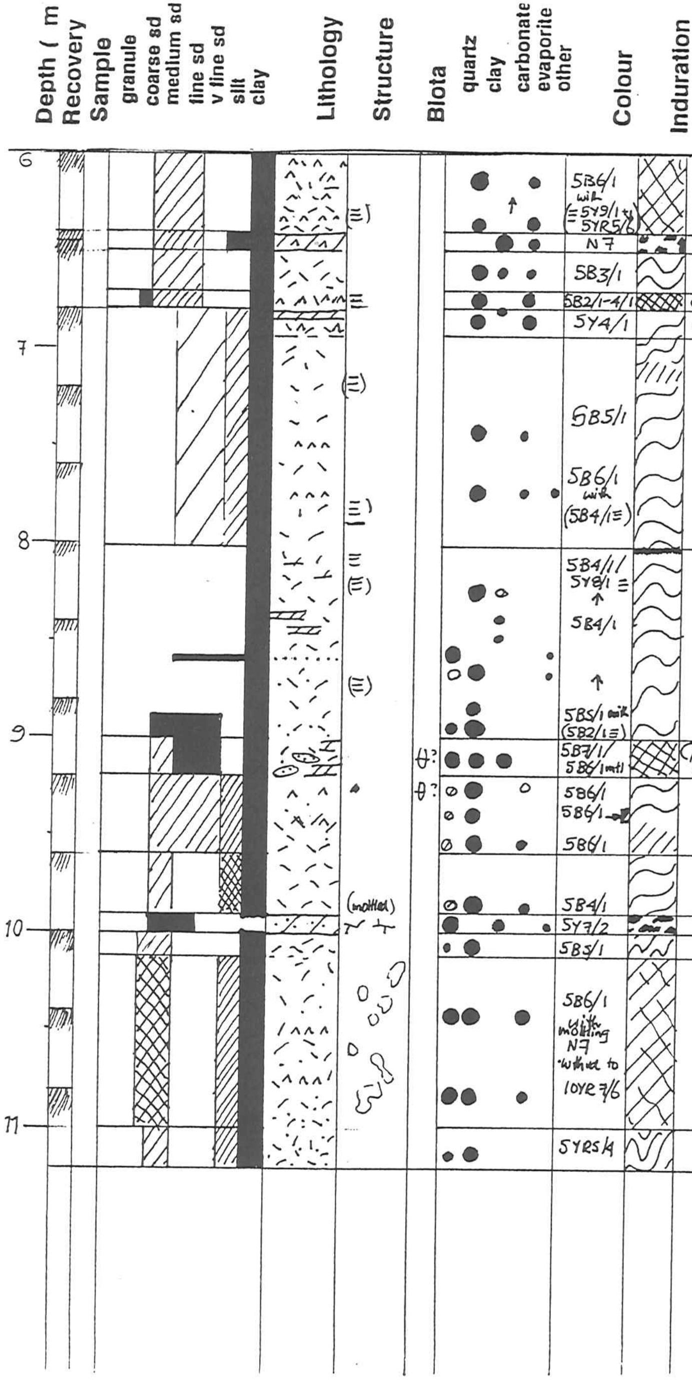
These are generally recorded in the last column but, where necessary, follow the lithological description separated by colon or full stop.

Mourquong 1



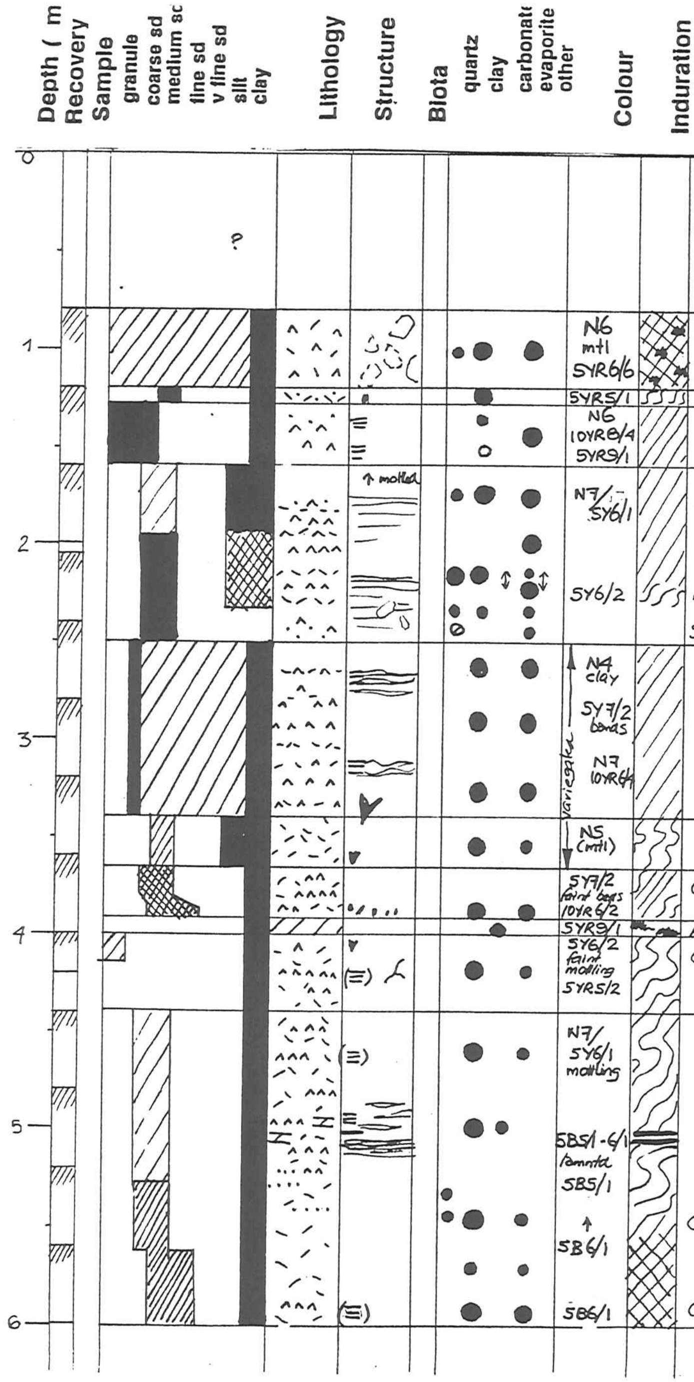
Colour	Description	Porosity	Diagenetic features	Interpretation
5Y4/1 +N2	Sand, v dark gy			
5YR3/1	Sand, qtz + gypsum, reddish	IP	late gypsum (subhedral)	aeolian sand, lake: o/p
10YR6/4 mtl (≡) 10YR3/2	Sand, gypsum, porous, silty Sand, gypsum ↑ Sand, clayey, qtz + gypsum, with upward increasing gypsum	IP	large gypsum xls.	Saline lacustrine
5YR4/1	Sand, qtz, gypsum (f-c)	IP	v lrg. gypsum xls	aeolian + / lacustrine
10YR5/2 5Y5/1	Mud, homogeneous, with large diag. gypsum.	—	lrg gypsum xls.	lacustrine + (aeolian), saline
N8 5Y5/1	Sandy mud, variegated, colour laminated: gypsum >, clay; laminae flaser-like to v regular	IP in sands		seasonal? salinity cycles; lacustrine
5Y5/1	Clay, homogenous with gypsum crystals, numerous growths/nodules		VC crystals gypsum	lacustrine
5Y6/2/ 5B6/1	Mud, homogenous, puggy with (gypsum crystals)	—	—	lacustrine with salinity o/p
5Y7/2	Sand, m-c, qtz, rndd, gypsum [silt - f]	IP		aeolian
5GY5/1	Sand, gypsum, srt [hemispheroids], porous, some clayey bands	IP		
5GY5/1 ≡5Y9/1	Sand, clean, srt to clayey; indistinct but v. well laminated wavy laminae; gypsum > clay weathered	IP in ≡	gypsum xls in gypsum sand	seasonal? salinity cycles lacustrine
5GY5/1+ (10YR6/4)	Mud	—		
5G4/1 5Y8/1 10YR6/4	Laminated Mud (clay) and gypsous sands: colour laminated variations. gypsum > clay; variably thick laminae	IP vari in sands	vc xlline hardpan (lrg gypsum xls)	← hardpan lacustrine seasonal? cycles
5G5/1	Mud, homogenous; gypsum crystals scattered	—	vc gypsum xls.	
5G4/1 ≡ 5Y8/1 - 10YR6/4	Mud, black, interlaminated gypsum sands [porous pyritic]	IP in sand	pyrite	lacustrine cycles *
	?			
5G2/1	Clay/Mud, (laminated) to homogenous		displ. lrg gypsum in clay	
5G6/1	Clay/Mud, distinctly laminated	— ⇔ IP		
5B7/1 5B4/1 ≡ =5Y8/1 5B5/1	Clay, v. finely laminated at top with gypsum sands [porous, srt] clays >> gypsum Clay with well-rounded gypsum sand homogenous; with white and rust-coloured gypsum sand bands. clay, mottled to homogenous (f-m, gran. gypsum sand disseminated)	IP ⇔ — — —	V lrg. gypsum xls (late diag, clear)	lacustrine, seasonal? sal. cycles

Mourquong 1



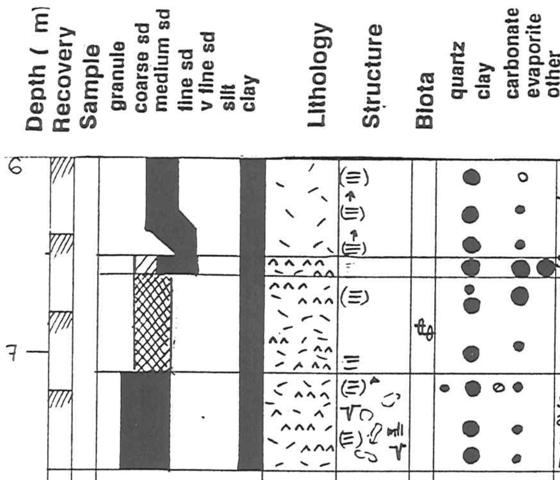
Colour	Description	Porosity	Diagenetic features	Interpretation
5B6/1 with (≡5Y9/1+/ 5YR5/6)		— ↑ IP	(dolomite) + gypsum	overprint of ? seasonal salinity
N7	Dolomicrite with gypsum crystals	(IC)	dolomite	
5B3/1	Clay, homogenous, with wisps of white carbonate & scattered gypsum	—	dolomite	
5B2/1-4/1	Clay, v.distinctive laminated c̄ black pyrite in porous gypseous sand laminae	IP in ≡	frmbdl pyrite	*
5Y4/1	Clay, fluid, gypseous [prismatic gypsum]			
5B5/1 5B6/1 with (5B4/1≡)	Clay, homog. blue grey with black wisps Clay with v fine pyritic & porous gypseous silts & minor sands [clayey, laminated] Clay - vf laminated, with v. thin pyritic bands. v.dark pyritic band	—	frmbd.pyrite	saline lacustrine
5B4/1/ 5Y8/1 ≡ ↑ 5B4/1 ↑ 5B5/1 with (5B2/1≡)	Clay, colour laminated, with lt gy indistinct dolomitic laminae (porous) ↓ uniform Clay with v thin silt-sand laminae; porous sands & silts are pyritic/black Clay, sandy, pyritic, laminated, c̄ c & clean sand c̄ pyritic framboids	(IC) IP in sand (IP) —	dolomite pyrite pyrite; disseminated + in porosity	fw lacustrine
5B7/1/ 5B6/1 mtl	Clay, sandy, dolomitic with biotrbn infilled by sand and replaced by dolomicrite horizontal biotrbn is silt & sand infilled	BP	dolomite	fw lacustrine
5B6/1 5B6/1 5B6/1	Mud, sandy, interbedded (indistinct) thin sands (light-coloured); faintly mottled impervious clay; upper horizon bioturbated with vf sand infil		gypsum	low-salinity lacustrine
5B4/1	Clay, faintly mottled; Mud, silty, sandy)			lacustrine
5Y7/2	Sand, fractured; irreg cemented with dolomicrite	(FR)	dolomite	
5B5/1	Clay, homogeneous, (sandy) [qtz, rndd]	—		Blanchetown Clay?
5B6/1 with mottling N7 ·whited to 10YR 7/6	Mud, mottled, with more distinct clay/sand differentiation upwards; cleaner quartz & gypseous sands. Sands are Pckst to Grnst, qtz [m-c, v rndd - ang.], claymatrix ~10% Alternation of sands and (sandy) muds.	IP in sands ↑ incr. (IP)		Parilla Sand? alternating with Blanchetown?
5YR5/4	Mud, homogeneous, reddish → sandy clay.			

Mourquong 3



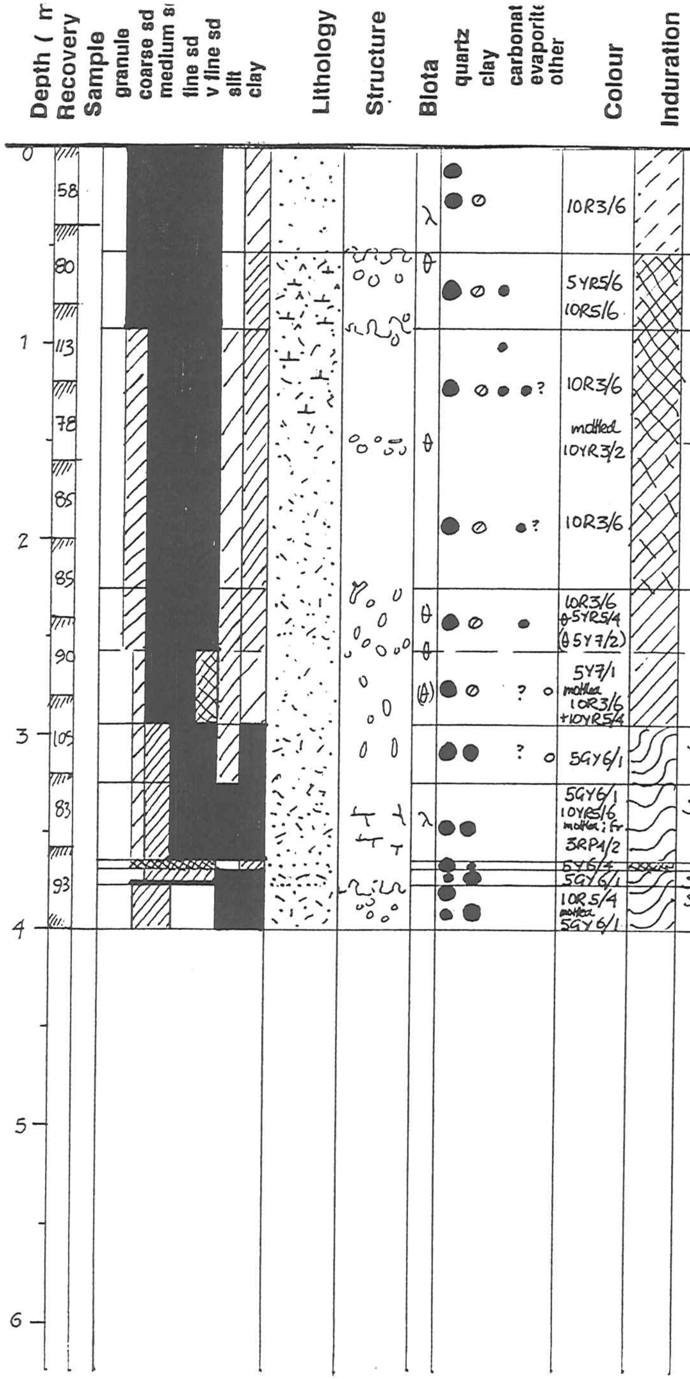
Colour	Description	Porosity	Diagenetic features	Interpretation
	?			
N6 mtl 5YR6/6	Sand, porous, gypseous with some dissolved gypsum cementation in clay matrix. some limonitic staining and flecks	IC, IP		lakeprecipitate; recemented
5YR5/1	Clay	—	faint colour banding	lakeprecip; oxidized
N6 10YR8/4 5YR9/1	Gypsum, silt sized to v.c.-granular [hemispheroids]; distinct changes; increasing clay to top	(IP) ↑ IP		lacustrine, saline deposits
N7/ 5Y6/1	Gypseous clay, homogenous; downward increasing lamination, but decreasing gypsum.	IP⇔(IP)		lacustrine deposits, precipitates.
5Y6/2	Mud, gritty [gypsum x/s], laminated with Gypsum sand [clear, c, a…] & f gypseous clay	IP IP⇔(IP) ((IP))		
	Sand, quartz [rndd, subrndd], gypsum [xl, water-eroded], saline, mudlumps; sorted	IP	halite	dune wash?
N4 clay 5Y7/2 bands N7 10YR6/4 variegated	Clay, gritty; alternating laminae of clay; lamination of yel & dkgy coloration alternating sorted to clayey gypsum sands and gritty clays; gypsum crystals [vc, hemispheroidal to silt], variably sorted; minor lamination of clay	((IP))⇒IP		lacustrine, seasonal salinity precipitates
N5 (mtl)	Mud, (gypsum), uniform; with laminae of gypsum sand	—	late?, large crystals of gypsum, twinned	
5Y7/2 faint bands 10YR6/2	Clay & Sand, gypseous [sand], (clayey), indurated; interbanded	(IP)	diagenetic bands of gyps.	← Mg rich waters
5YR9/1	Magnesite/Dolomite? vari chalky to clayey; silt fragments of anhydrite/gypsum?	—	gypsum/dolomite/Mag primary	
5Y6/2 faint mottling 5YR5/2	Clay, colour-mottled, reddish around porosity; v thin porous gypsum laminae, irregular diagonal fracture filled with gypsum crystals	(FR) (IP)	large diagenetic gypsum crystals	Oxidized upper sequence of clays
N7/ 5Y6/1 mottling	Oxidized upper clay with porous clean gypsum laminae; some fining-up in gypsum laminae			lacustrine; seasonal lamination from varied salinities. Magnesitic precipitation events ×2
5B5/1-6/1 laminated 5B5/1	Varved; very thin laminae of magnesite?; alternating with vf gypsum laminae; some Fe-stained	IP in gypseous ≡	Magnesitic laminae	
↑ 5B6/1	Clay with sand, gb [rndd, c, irreg.]		black pyritic stains	
5B6/1	Clay, gypseous; vf lamination, gradational margins.	(IP)	pyritic replacement of gypsum as striped x/s.	

Mourquong 3



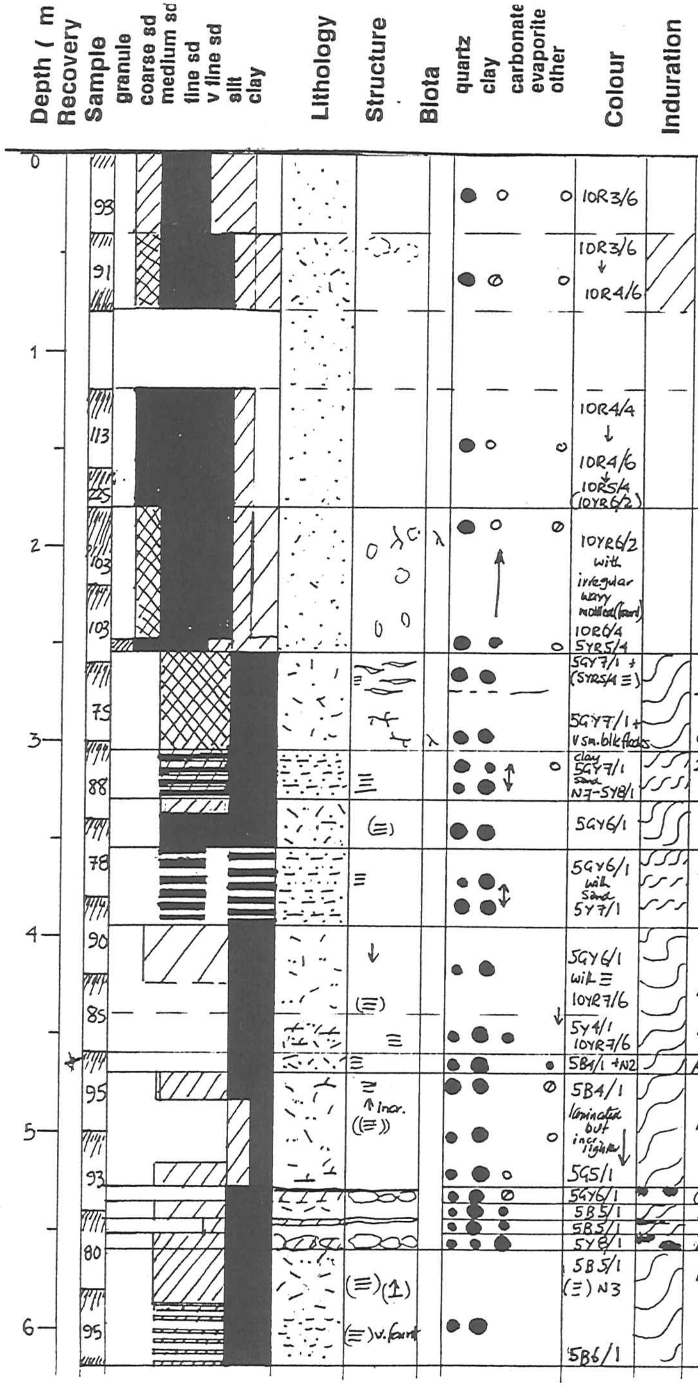
Colour	Induration	Description	Porosity	Diagenetic features	Interpretation
5B5/1 with traces		Clay with v thin laminae of clastic gypsum sand, decreasing down	— ↑ (IP) in gypsum	minor large gypsum x/s, minor frmbdl pyrite	upward decreasing hypersalinity, greater clay input Seasonal salinity
5B5/1 / N2-3		Varves of clay & gypsum sand laminits [f-m, srt, clastic]; ~16 laminae	IP in sand	pyrite in porous sand	lacustrine, seasonal lamination
N2-3/ 5B5/1 ↑ 5B5/1		Sand, gypsum [m-c], crudely laminated in Packstone-Grainstone variations. (laminated clay) with clastic gypsum [hemispheroidal] laminae	IP (IP) in gypsum ≡	blk frmbdl pyrite in gypsum clay	lacustrine, indistinct seasonal varns. ↑
5B6/1 ē mottling 5GY6/1 N8 crystals		Clay, plastic, blue gy - grn gy with indistinct to distinct inlamination of clastic gypsum sands, distinct base & fining up to muds/clays. Some desiccation features in clay bands	patchy IC in gypsum patches	authigenic early gypsum	lacustrine, hypersaline, seasonal variation. between gypsum precipn. & clay influx

Mourquong 7



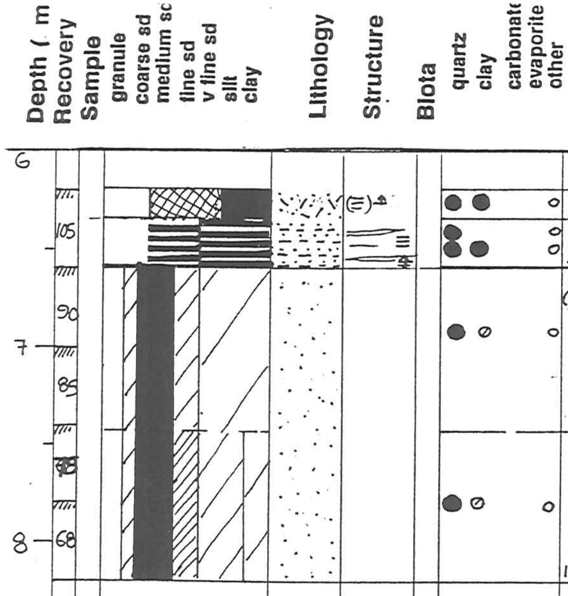
Colour	Description	Porosity	Diagenetic features	Interpretation
10R3/6	Sand, as below; unconsolidated upper 10cm, grading down to clayier sand. deep red-brown colour	IP		aeolian
5YR5/6 10R5/6	Sand, qtz [vc, rndd, irreg – f], clay, (opaques) [vf-silt]; matrix of calcitic micrite and ? gypsum mottled irregular lower boundary	IP	calcrete	aeolian; calcrete overprint
10R3/6 mottled 10YR3/2 10R3/6	Sand, (as below), calcareous – mottling in few small patches of black humic sand – – – – – – (bimodal ?) Sand, red, partially cemented by ?gypsum, salt? [not confirmed] uniform, occasional subvertical bioturbation	IP	calcrete gypsum cement	calcrete soil overprint on ◄ root tubules ? aeolian sand
10R3/6 θ 5YR5/4 (θ 5Y7/2)	Sand, very red, bioturbated, qtz [vc, etched, c – vf, ang]; gypsum [xlline to clastic] bioturbated junction	IP	v red gypsum	aeolian: sand
5Y7/1 mottled 10R3/6 +10YR5/4	Sand, (srt), qtz [rndd, c,– ang m–f – silt], (opaques) [vf-silt], (clay); mottling [subvertical, cm-wide bioturbation]	IP	oxidation in biotrbn porosity	Blanchetown Clay?
5GY6/1	Sand, muddy, qtz [(c), rndd; – f–vf, ang, clean], (opaques) [vf – silt], mud: minor mottling; diminishing mud/clay upwards	(IP)	minor oxidation of bioturbation	BC?
5GY6/1 10YR5/6 mottled; fr. 5RP4/2	Sand, mud/(muddy sand) – variable; blocky texture/color mottling/traces of purple rootlets; assoc. with patches of porous sand	((BO)) ((FR)) ((IP))	(oxidation) in porosity	soil o/print on BC?
5Y6/4	Sand, muddy	IP		
5GY6/1	Sand; sandy mud; variable sand [m → silt]	IP	purple FR stains – pyrite?	
10R5/4 mottled 5GY6/1	Sandy mud, (qtz) [m–c, rndd, clear]; some v sandy laminae; colour mottling to very strong red.	((IP)) in sand ≡	oxidation band?	BC?

Mourquong 4

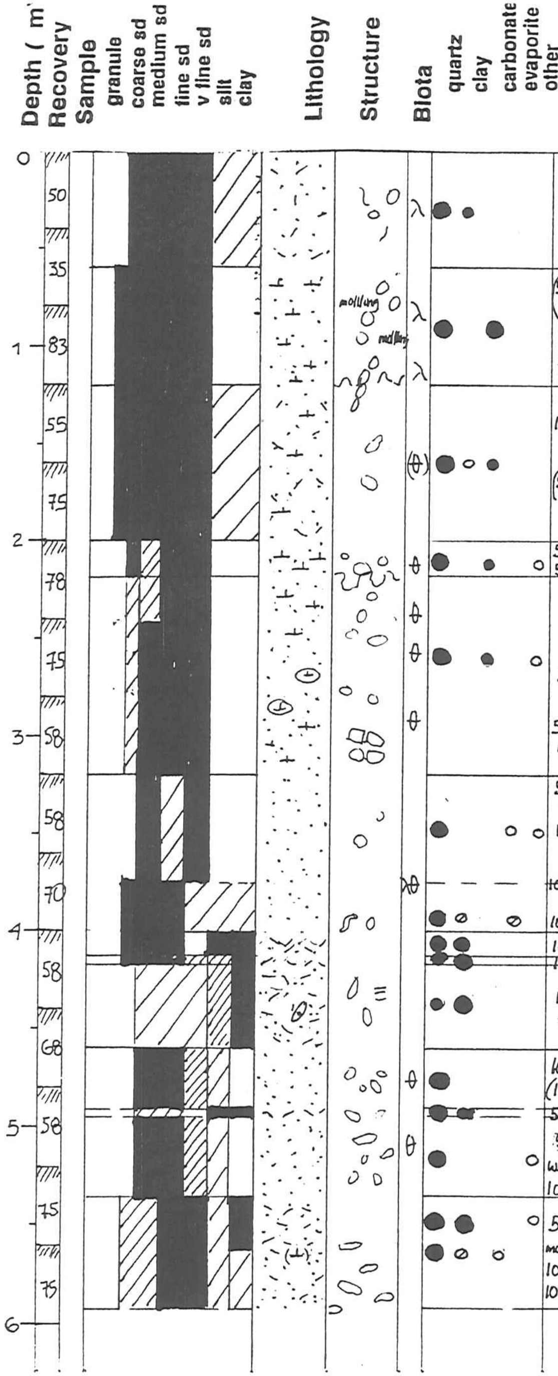


Colour	Description	Porosity	Diagenetic features	Interpretation
10R3/6	Sand, bimodal, qtz [rndd, c-vc; f-m, rnda]; surface staining v. strong; (opaques) [vf-silt]; humic patches	IP	—	aeolian sand
10R3/6 ↓ 10R4/6	Sand, (srt), qtz [vari rndd, vc-vf], matrix ~<5%	IP	Haematitic staining on sand	aeolian sand
		IP		aeolian sand
10R4/4 ↓ 10R4/6 ↓ 10R5/4 (10YR6/2)	↑ increasing iron staining on quartz grains Sand, qtz [vc, rndd, vari. stained, to vf], almost bimodal; very uniform	IP	Staing on sand	aeolian sand
10YR6/2 with irregular wavy mottled (band) 10R6/4 5YR5/4	Sand, qtz [vari. red stained], opaques [slt-vf] ↑ patches of dark humic material /stains Sand, qtz [granulees, rndd-vf, angular], opaques, [silt]	IP IP	pyrite? patchy with organics	aeolian dune sand
5GY7/1 + (5YR5/4 ≡) 5GY7/1 + v sm. blk flecks	(laminated) brown sand --- ↑ increasing sand content, some clean, laminated Clay, mud, (sandy), with root tubules & blocky fracture; variably blocky texture.	((IP)) (FR)		float. Blanchetown Clay with soil overprint
clay 5GY7/1 sand N7-5Y8/1	Interlaminated Sand, qtz [vf-f -m], (clay matrix); and Mud, sandy qtz; opaques [slt-vf]	IP in sand	—	Blanchetown Clay?
5GY6/1	Sand, muddy, variable (srt) - ((srt)), clayey to top.	((IP))	—	Blanchetown Clay
5GY6/1 with sand 5Y7/1	Interlaminated Mud, sandy; and Sand, variable matrix, qtz [f-c], clean, srt → (srt). Sand thickness and sorting increases to top.	IP in sand	—	Sand from Parilla Sand within Blanchetown Clay?
5GY6/1 with ≡ 10YR7/6	mainly sandy to top Mud, faintly laminated. Dolomicrite content & lamination increases down.	—	((dolomite))	B.C. /
5Y4/1 10YR7/6	Mud, laminated with orange dolomicrite	((FR))	dolomite	B.C.
5B4/1 + N2	Mud, pyritic lamination in more porous horizons?	((IP))	pyrite in porosity	B.C
5B4/1 laminated but incr. lighter ↓ 5G5/1	Mud, v. uniform, puggy, silty, subtle laminae; porosity coloured by pyrite. Mud with ((dolomite clast debris & sand))	((IP))	pyrite, vf frmbdl dissem. in laminae	B.C
5GY6/1	Concretionary dolomicrite, distinct upper contact; gradational lower	(IC)	surface dolomite concr.	
5B5/1	Dolomicrite, mud	=		
5B5/1	Sandy Cla			
5Y8/1	Dolomicrite, sandy, nodular, indurated to chalky	(IC)	dolomite	B.C
5B5/1 (≡) N3 5B6/1	Mud, clayey, puggy, uniformly coloured with v thin, indistinct lamination of sandy mud and ((sorted porous sandy laminae))	((IP))	—	B.C

Mourquong 4

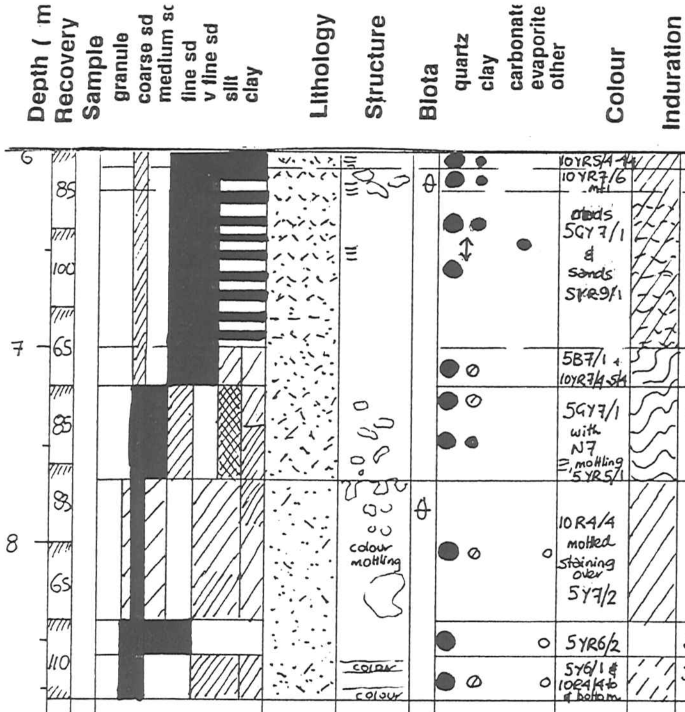


Colour	Induration	Description	Porosity	Diagenetic features	Interpretation
					Blanchetown Clay?
5B6/1		Interlaminated mud (sandy) & mudd sand . / Mud predominates	((IP))	—	Blanchetown Clay?
5B6/1 with some 5Y8/1-7/1		Interlaminated sandy Mud and Sand, [qtz [f-m, rndd] srt – (srt) v. distinct laminae ; some tend to fine-upwards	IPvari	—	Blanchetown Clay altern. with Parilla Sand
5B6/1 with (mtl 5Y6/4-10YR5-6) ↓ 5B6/1 ↓		↑ increasing clay content to ~10% Sand (as below) but with greenish colour ; opaques [rndd, ilmenite?]	IP ↑ IP IP	—	Parilla Sand with infiltrated Blanchetown Clay
		~~colour change~~			
10YR5/2 ↓ 10YR6/2		Sand, (silt), qtz [f-m-c-vc, rndd, varishaped], clay matrix [<5%], (opaques)	IP	—	Parilla Sand



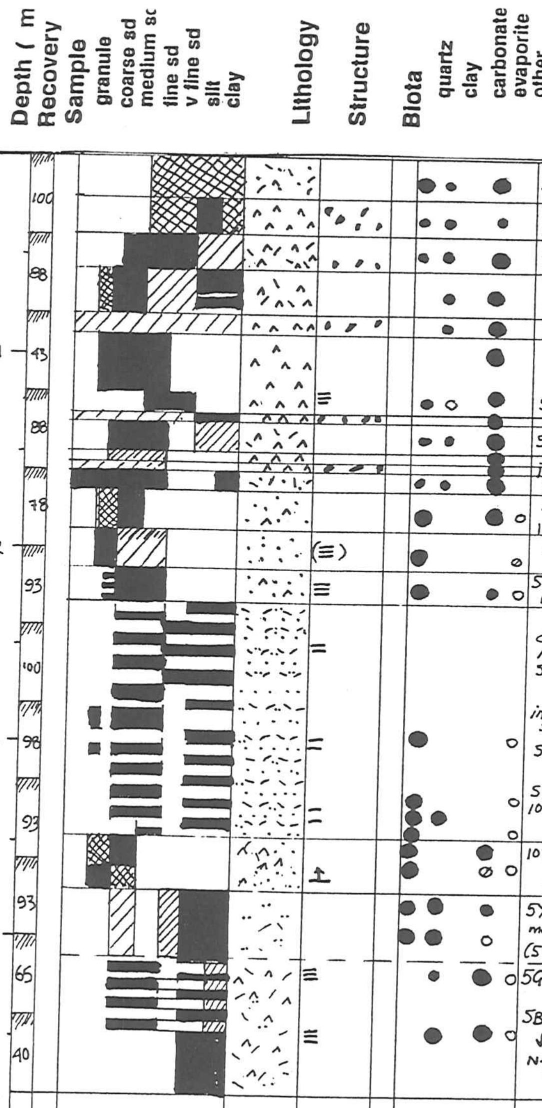
Colour	Description	Porosity	Diagenetic features	Interpretation
10R4/4	Sand, [vc – vf, rndd - ang] qB ; vari srt ; limonitic clay matrix ; not calc.; live rootlets and organic particles	IP		aeolian dune sand
(5YR4/6 - 10R4/4) with nodules 5YR8/4 + 5YR7/2	Sand (as below) with numerous calcrete nodules / clasts [subang, 10-12mm D], and fragmented tubes [15mm D], and disseminated calcitic matrix	IP	(calcrete) band, dissem. calcrete & nodules	aeolian sand; nodular calcrete overprint
10R5/4 & (5YR6/4) mottling	Sand, qB [vc - c, rndd; m - vf, ang, vari textured], micritic calcitic matrix; low but variable clay matrix.	IP	oxidation of clay matrix ; calcrete matrix.	aeolian sand
5YR4/6 5YR7/4	Sand, (bimodal), qB [c, f - vf], opaques); calc matrix varies 5–10%	(IP)	calcrete band	aeolian sand with distinct calcrete matrix
5YR4/6 + 5YR6/4 nodules	Sand, quartz (as below), calcareous ; with nodules of slightly more cohesion and higher calcrete calcitic matrix ; (but additional muscovite flakes and opaques) vague mottling ; calcrete nodules [equant to irreg., 7 - 10mm D]	(IP)	calcrete concretions, nodules (carbonate cement)	aeolian sand with calcrete profile o/p
5YR4/6 ↑ 10R4/4	Sand, vari from bimodal to (srt) ; qB [m + vf] to [m, rndd → vf, ang], gypsum ? [matrix], opaques ; ironstaining of sand ; bands of increased sorting	IP	oxidation of	aeolian sand
10YR3/2	horizon ~~of black humic stained~~ patches			
10R4/4	Sand, qB [c - m - f, alternating in ≡ , to vf, etched to angular], gypsum ? matrix ?; (black) mottling	IP	? vf gypsum cement	aeolian sand
10R4/4	Clay, puggy & intermixed, interbanded clayey sand of vari sorting.			
~~10R4/4~~	~~Sand, clayey, vari sized~~	–		~~Blanchetown ?~~
10R4/4 sl vari.	Clay, with silt / mud laminae [vf], trace ; clay is deep red, v puggy ; apparent boring is sand filled [as below]	–	oxidation of clay	Blanchetown ?
10YR7/4 (10YR5/2)	Sand [as below], mottle bioturbated ; sorted ; laminae of vari. grain size but generally sorted	IP ≡		lacustrine with Parilla input ?
5B7/1		–		
5Y/7/1 with mottling 10YR5/4	Sand, qB [srt, m - f , subangular , etched, clear ; vf silt], opaques [silt, white] uniform granulometry but strong colour mottling	IPin ≡	staining of quartz only	lacustrine with Parilla inp.
5GY7/1 mottled with 10YR7/4 10YR5/4	Sand, (laminated), vari sized, sorted ; predominantly sorted, qB [(c) - f - vf, ang, clean] ; matrix 0 - 10% ; mottled colour of matrix & colour - laminated ; clayey mud bands towards top	IP	oxidation of clays + ? pyrite	? : Parilla Sand

Mourquong 9



Colour	Description	Porosity	Diagenetic features	Interpretation
10YR5/4-4/4	v limonitic clayey ochre	IP	oxidation of pyrite ?	?
10YR7/6 mtl	Sands (as below) ; variable clay / limonitic matrix ; mottled colour	IP	oxidation of pyrite ?	.
clods 5GY7/1 & sands 5YR9/1	Sand (as below), unif colour but variable granulometry from lamina to lamina; interlaminated muddy sands and clay	IP ↕	—	? Parilla → Blanchetown
5B7/1 + 10YR7/4 stn	Sand, (srt), qtz [(c) - f - vf - slt, subang, clean]; stained clayey laminae	IP	variable oxidation in porous laminae	
5GY7/1 with N7 ≡, mottling 5YR5/1	Sand, muddy, qtz [c - f, subang], (opaques) [rutile]; matrix 10 - 30% of [clay + silt]	((IP))	—	Parilla Sand with Blanchetown infiltration
10R4/4 mottled staining over 5Y7/2	↑ matrix content increases to 10-15% to top ; intense red mottling to top Sand, silty, qtz [c, subang – m, slt]; clay matrix ~5% ; gngy or red staining in matrix : Sand granulometry unif.	IP	oxidation staining of sand in matrix clays	Parilla Sand
5YR6/2	Sand, srt, unconsol., qtz [vc - f, subang - (rndd), clean], srt, por. ; uniform	IP	homogonous mild oxdn.	Parilla Sand
5Y6/1 & 10R4/4 to bottom	Sand, bimodal ?, qtz [vc - c, rndd - subang ; vf - silt]; clay matrix 5 - 10% ; (opaques) [rutile]	IP	oxidation rim top & bottom in clay matrix	Parilla Sand

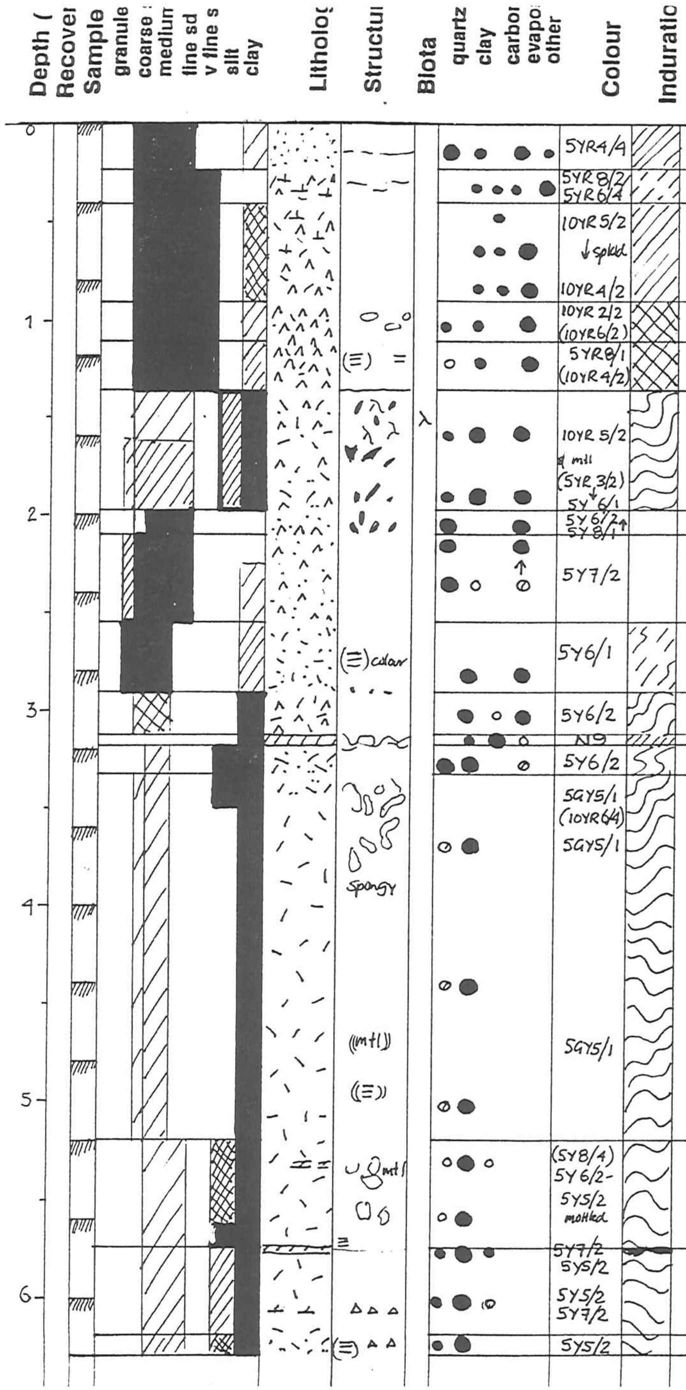
Mourquong 9



Colour	Induration	Description	Porosity	Diagenetic features	Interpretation
5YR5/2		Muddy sand, qtz, with numerous small gypsum flakes	IP	hemispheroidal gypsum	aeolian sands or lacustrine
5Y6/1 10YR6/2		Silt, qtz [silt-f, clean], (clayey), gypsum?	IP		aeolian
5YR4/2		Mud, gypsum [m - vf]; reddish silty mud matrix; qtz [vf-m]	((IP))	FR infill by sugary gypsum lrg diag. crystals gyps at base	↕ lacustrine with gypsum precipitation muddier
5Y5/1		Sand, muddy, gypseous [all crystalline, flakes, & cleaved]	((IP))	horiz lrg hemispheroidal gypsum	
5Y8/1		~~Bab~~indurated band of v lrg gypsum crystals	Ic	diag. gyps. overgrowths	Hardpan
N8/ 5Y8/1 ↓ 5Y6/1		Sand, porous, sorted, gypsum [crystals, ang. f-vc]; v clean	IP ↑		
		Laminae of vf, srt, gypseous Sand	IP		
5Y6/1		Lrg gypsum crystals	IP	late subhoriz lrg gypsum	Hardpan? in sd mud
5YR5/4		Muddy gypseous sand, (porous). (srt); gypsum [flat crystals to clastic]	(IP)		
5Y6/1 10YR6/2		Sand, clean, washed gypsum			
5Y6/1		Sand, clayey, qtz + gypsum crystals. Lrg. gypsum xls	IP IP		Hardpan?
5Y7/2 ↓ 10YR5/6		Sand, sorted, bimodal, qtz [m-vc, vari. rndd], gypsum [clean], (opaques)		gypsum crystals late	
5Y6/1		Sand, uniformly: por, srt, qtz [m-c, ang], opaques [rutile?]	IP	—	
5Y6/1 mtl 10YR5/4		Sand, por, srt, qtz [c-f, ang, clean], gypsum? [eq.], biotite	IP		
muds clays N7– 5Y6/2 inbedded sands 5Y7/1 ↓ 5YR5/6 10YR5/6		Interbedded muddy sands and muds, with sands of varying bimodality & sorting; generally v. porous: rust-coloured sands, high in opaques, adjacent to muds - muds, v. thin, gradational, fining upward sequences. - some sands have vf rutile abundant.	IP IP in sands	— oxidation to rust colour of some sands	↑ biotite muscovite detritus Parilla derived sands? or overbank fluvial crevasse splay deposits?
		Sands, micaceous, srt, qtz [ang, f], muscovite + biotite flakes			
10YR6/4 ↓ N7		Sand, srt, qtz [vc-m, rndd, polished, vari. coloured], rutile/tourmaline [m], (gypsum crystalline) [clastic, vari. rndd]; rust coloured at top	IP		↓ fluvial? lacustrine?
5Y6/2 mottled (5YR6/4)		Mud, massive, with thin laminae, rust-coloured sdn.- enhanced weathering	((FE))	oxidized porous laminae	Blanchetown Clay?
5G7/1 5B6/1 ↓ N4/N3		Muds, laminated; and Sands, gypseous [f-m, xlline, some clear, some with black lamination / striae in crystals]; v. subtle fining upward sequences in silts.	(IP) in ≡	vf pyrite, framboidal in porous laminae (some)	

Mourquong 1

Mourquong 14



Colour	Description	Porosity	Diagenetic features	Interpretation
5YR4/4	Sand, gß [f-c, vari. rndd, reddish colons], (gypsum), clay	IP	—	aeolian sand
5YR8/2 5YR6/4	V calcareous	FE		lunette
10YR5/2 ↓ spkld 10YR4/2	Gypseous clayey sand Sand, spongy, v. poorly sorted, diverse size range of gypsum crystals, fenestrae infilled by clear, sucrosic gypsum;	FE (IP)	fenestral infill	lunette? with soil overprint
10YR2/2 (10YR6/2)	Sand, gypseous, vari. sorted; humic rich	IP	diagenetic gypsum	lunette with soil overprint
5YR8/1 (10YR4/2)	Sand, clayey, gypseous [hemisph., (srt), humic-stained?]; interlaminated Sand, gß [srt, rndd, f-m-c]	IP		lacustrine/dune mix
10YR5/2 mtl (5YR3/2) ↓ 5Y6/1	Mud, gypseous [hemisph. x/s] rootlet moulds to top, lined with humic acids; spongy texture.	FE vari —	early diagenetic v large displacive gypsum crystals; patches of frmbdl pyrite	no reworking of lake gypsum
5Y6/2 5Y8/1 ↑	Sand, v. clean gß, gypsum; lrg gypsum nodules	IP	nodular gypsum	
5Y7/2	Sand, unconsol, gß [f-vc, clear, rndd → ang], (clay), (gypsum), (opaques)[ilmenite?]; variations in lamination; upward increase in sorting of sand.	IP	—	lunette ?
5Y6/1	Sand, muddy, gypseous [perfect small hemispheroids] ↑ gradational	IP	pyritic flecks in gypsum large crystals of gypsum	lunette?
5Y6/2	Mud, gypseous sandy			
N9	Magnesite, clayey with gypsum crystals [diag]	(IC)	pyritic specks; gypsum	?
5Y6/2	Mud, crumbly ((sandy)), ((gypseous))	—	weathered	weathered
5GY5/1 (10YR6/4) 5GY5/1 5GY5/1	Clay, mottled, spongy organic mottling Clay, v faintly oxd3d, mottled [broad & indistinct] at top	— —	weathered (framboidal pyrite traces) ((framboidal pyrite))	Blanchetown Clay?
(5Y8/4) 5Y6/2- 5Y5/2 mottled	Mud, (mottled), with slight slickensided fabric; discontinuous laminae of (dolomitic) clay	(FR)		weathered soil o/p? BC ?
5Y7/2	Dolomicrite, chalky: at base, grading to chalky clay		dolomite	
5Y5/2	Mud, ((sandy))			
5Y5/2 5Y7/2	Mud, fractured appearance with white chalky fragments.	—	dolomite precipn. in fractures	BC ?
5Y5/2	Mud, ((sand)) [f-m, dolzd].	—	dolomite↑?	

APPENDIX II

MORQUONG DRILLHOLE STATISTICS

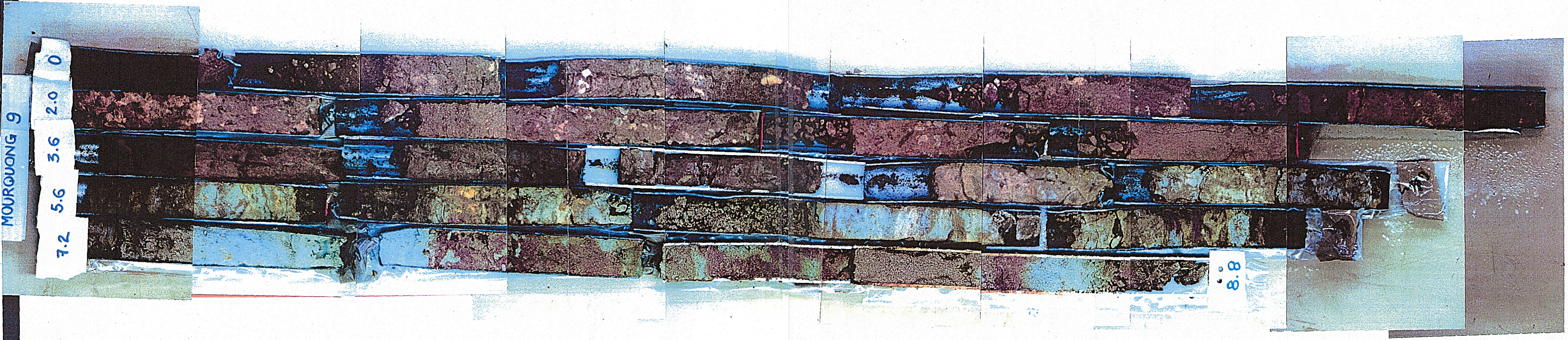
Drillhole	**Depth TD**	**Collar level (DWR 36908 as datum)**	**Comments**
1	**11.2m**	**-1.991m**	**yes**
2	2.1m	-1.75m	lost hole
3	**7.6m**	**-1.94m**	**yes**
4	**8.2m**	**-1.03m**	**yes**
5	2.5m	-1.43m	auger only
6	2.9m	1.0m	
7	**8.75m**	**1.12m**	**cored to 4m**
8	3.0m	0.075m	auger
9	**8.8m**	**4.64m**	**core**
10	7.21m	3.54m	auger
11	4.60m	-1.60m	auger
12	9.05m	6.30m	
13	**4.80m**	**-2.14m**	**core**
14	**6.50m**	**-1.20m**	**core**

APPENDIX III

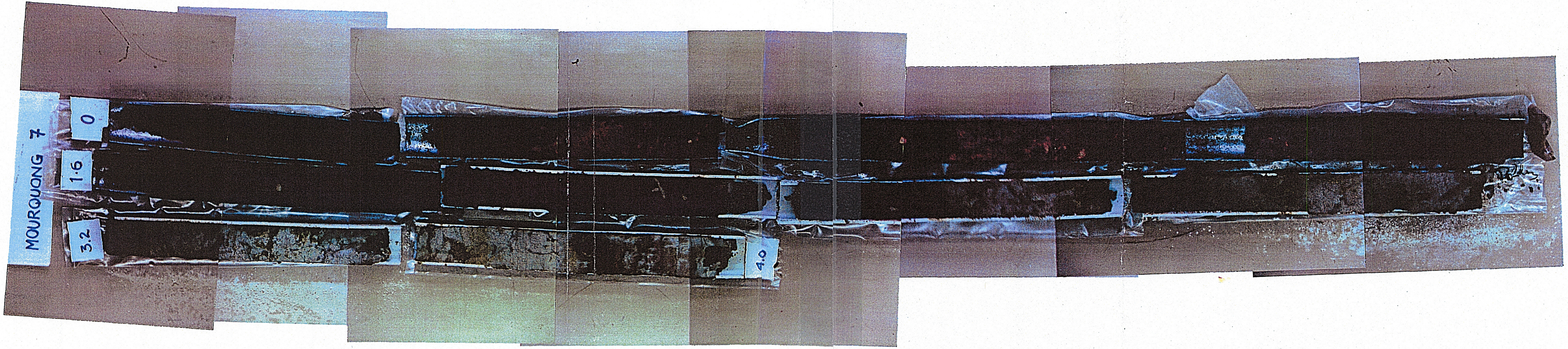
PHOTOGRAPHY OF DRILLCORES

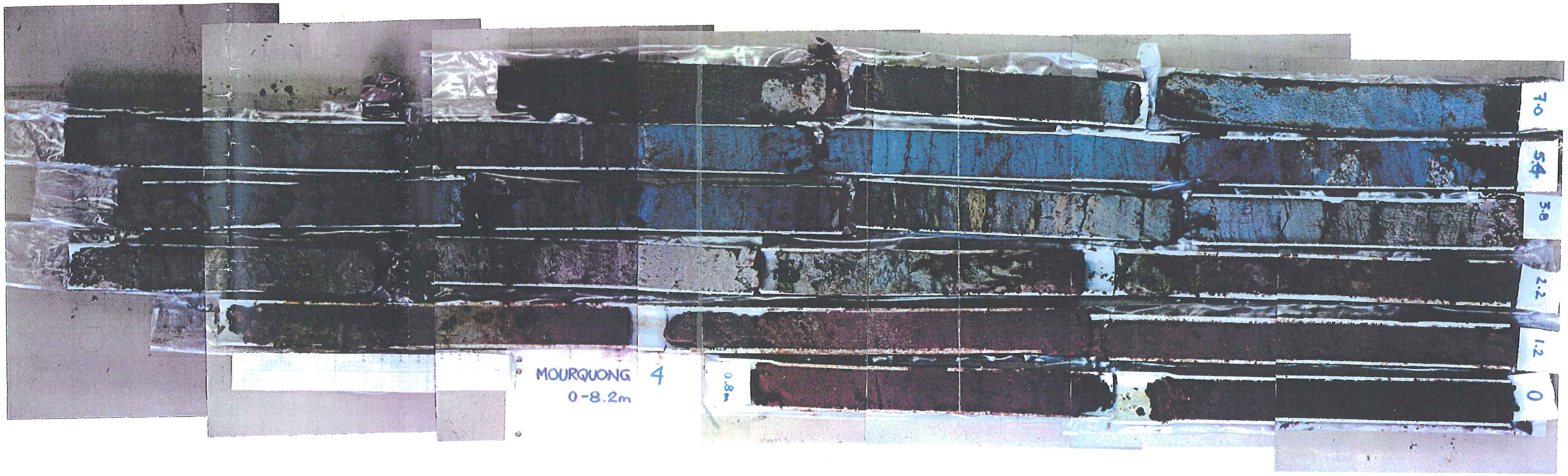
MOURQUONG 9,7,4, AND 13

1999/17



1997/17




MOURQUONG 4
0-8.2m
7.0
5.4
3.8
2.2
1.2
0
0.8m

1997/17