Final Report

Assessment Tool to Determine Potential Risks of Urban Salinity

(Phase II)

Prepared for

Mildura Rural City Council

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Document Title

Final Report – Assessment Tool to Determine Potential Risks of Urban Salinity (Phase ll)

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Executive Summary

Resource & Environmental Management Pty Ltd (REM) was engaged by the Mildura Rural City Council (MRCC) to undertake Phase II of the Development of an Assessment Tool to Determine the Potential Risks of Urban Salinity Project. Phase II comprised the refinement of the assessment tool developed in Phase I. This report presents the refined Assessment Tool, details the methodology adopted in its development and application and presents selected potential options for managing the water budget in urban areas.

Following a review of existing data and a meeting with the MRCC and MCMA an intrusive field program, consisting of four additional nested groundwater monitoring wells and 54 soil bores, was completed to verify and refine the existing data sets. All new wells and one existing wells were subsequently gauged and sampled to determine groundwater depth and salinity respectively.

Groundwater investigations showed that the water table aquifer existed in the Blanchetown Clay overlying the Parilla Sands aquifer. The groundwater depth contours were revised accordingly using recent data from new and existing wells. The revised contours were consistent with all recent field measurements and provided a good estimation of the groundwater depth across the study area. The soil bores showed that a subsurface silty clay layer occurred extensively across the study area at an average depth of 2.1 m bgl that may act as an impediment to downward movement of water. Interpreted contours of depth to clay and clay elevation were subsequently developed.

Five levels of urban salinity risk were developed based on combinations of the soil and groundwater factors, grading from low to very high, and the associated actions required for development of land in each risk level were indicated. While most of the area proposed for development was assessed to be at moderate or higher risk of urban salinity due to the extensive presence of subsurface clays and areas of shallow groundwater, it is likely that development could still proceed in most areas if appropriate water management measures are adopted.

Where there is potential for perched groundwater to develop the installation of a subsurface drainage system to manage perched groundwater is an essential requirement of urban development. Other options to manage the water budget included efficient water use practices, effective stormwater management and increasing ground surface elevation. In all cases the proper design and verification of proposed salinity management strategies is essential to successful urban development in areas at risk of urban salinity.

Key recommendations arising from Phase II of the project were:

- Council should integrate the Urban Salinity Risk Assessment Tool into the urban development planning process, and use the Tool to

assess the level of risk and subsequent requirements from the developer on a case-by-case basis.

- Development in areas identified at a moderate or higher urban salinity risk should be subject to specific water management requirements.

- Development in areas at very high urban salinity risk should not proceed unless the developer meets rigorous water management requirements.

- The assessment tool should be regarded as a guide and, in cases where there is a high urban salinity risk, development requirements may include the installation groundwater monitoring wells for ongoing monitoring of regional and/or perched groundwater levels.

The forthcoming Draft Site Salinity Management Plan will detail the specific requirements to be met by developers to address the urban salinity risk where present. Council should integrate these requirements into the residential development planning process.

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1 INTRODUCTION

Resource & Environmental Management Pty Ltd (REM) was engaged by the Mildura Rural City Council (MRCC) to undertake Phase II of the project titled Development of an Assessment Tool to Determine the Potential Risks of Urban Salinity. Phase II comprised the refinement of the Assessment Tool developed in Phase I to provide a simple and cost effective means of determining the risk of occurrence of salinity within the Mildura urban area.

This report presents the refined Assessment Tool and details the methodology adopted in its development and application. A Draft Site Salinity Management Plan including potential options to manage the water budget in urban areas has been developed and is provided in a separate report.

1.1 Project Objective

The overall objective of the project was to provide the MRCC (and other stakeholders including the Mallee Catchment Management Authority (MCMA)) with a tool for use when re-zoning land to determine the potential risks of urban salinity from shallow regional or perched groundwater.

The specific objective of the Phase II component of the project was to refine and verify the data sets developed in Phase I (REM, 2004), and produce the Draft Site Salinity Management Plan for use in areas at risk of urban salinity.

1.2 Background

The City of Mildura is located in the north west region of Victoria (Figure 1) on the southern side of the River Murray and has a mean annual rainfall and potential evaporation of approximately 290 mm and 2150 mm respectively. Urban development in Mildura has occurred at a rate of about 40 ha per year for the past 10 years, making it one the fastest growing regional centres in Victoria. This development has largely occurred on areas previously used for irrigation and dryland farming purposes.

Development is predominantly occurring to the south west of the existing Mildura urban area, however, the study area for this project also incorporated the Irymple and Nichols Point areas. Future development is planned to occur mainly to the southwest of the existing Mildura urban area. The extent of expected expansion to the year 2030 is illustrated in Figure 2.

The MRCC is concerned by the rapid urban development into areas previously used for horticultural purposes and has identified the need for information regarding groundwater levels and salinity trends. Cases of salinity impacting on urban development have already been reported.

In Phase I of this project a tool was developed to assess the potential risk of urban salinisation in areas proposed for development using existing soil and groundwater data. Two potential processes were identified that may result in the development of urban salinisation in areas of Mildura where future urban expansion is proposed:

i) Areas where the regional watertable approximates 2.0 m below ground level (bgl) (4 m bgl was recommended as a conservative measure); and

ii) Areas where a perched watertable may develop on top of a subsurface clay layer, where the depth to clay was less than 4 m bgl).

The assessment tool therefore consisted of plans showing the depth to groundwater and potential for perched groundwater development, which when combined allowed the identification of urban salinity risk areas. In this subsequent investigation (Phase II) additional data was obtained that has enabled the verification and refinement of the preliminary assessment tool and the development of a salinity risk plan.

1.3 Scope of Works

The agreed scope of works for Phase II specifically comprised:

- A review of literature (eg. Thorne *et al*., 1990) on the presence and elevation of the clay layer to determine if any additional data exists to assist in the refinement of the data set.

- Drilling of 50 soil bores to a depth of 4.0 m below ground level to assist in the identification of the presence and therefore lateral extent of the subsurface clay layer.

- Preparation of detailed soil logs for all soil bores and new wells to assist in the identification of the clay layer;

- Installation of four additional nested groundwater monitoring wells where data gaps exist in the area proposed for urban development;

- The survey of all soil bores and new wells into Australian Height Datum and GDA coordinates;

- Measurement of groundwater depth and salinity in all new and existing groundwater monitoring wells in the vicinity of the area proposed for urban development;

- Integration of all new and existing soil and groundwater data to produce refined plans of the clay layer, groundwater depth and salinity risk based on the combination of both factors.

- Preparation of a report detailing the methodology and outcome of the program of works described above, including the development of the salinity risk overlay plan from depth to the regional groundwater and perched groundwater potential and also accounting for the presence of salinity indicator plant species.

- Conduct a workshop with stakeholders to present the application of the salinity overlay plan and its use in the planning process to minimise the potential impacts of urban salinity; and

- Preparation of a Draft Site Salinity Management Plan to be used for developments where the site has been identified to be at risk of urban salinity.

2 DATA REVIEW AND SITE INSPECTION

2.1 Review of Existing Data

The hydrogeology of the Mildura area (described in the Phase I report) comprises a regional groundwater system in the Parilla Sands aquifer and, in some areas, a perched groundwater system in the overlying Woorinen Formation. The semi-confining Blanchetown Clay unit separates the two aquifers and in some areas may also contain appreciable groundwater.

The two potential causes of urban salinisation identified in the Phase I report, shallow regional groundwater and perched groundwater, are associated with the watertable aquifer and the presence of subsurface low permeability (silty) clay respectively. The occurrence of shallow regional groundwater is largely determined by topography, with low-lying areas having the highest potential for salinisation. The occurrence of perched groundwater, however, is less predictable and requires the accurate delineation of the presence of subsurface clay.

The CSIRO soil mapping data (Phase I Report, Figure 6, Penman *et al*., 1940) provided a preliminary delineation of areas where the soil profile contained subsurface clay across the majority of the proposed area for urban development. Hydrogeological data collected by the Rural Water Commission of Victoria (Thorne *et al.*, 1990) provided a broad scale appreciation for the extent and thickness of subsurface clays in the Mildura area. In particular, clay was present across most of the area, generally thinning out towards the Murray River, while the depth below the surface and thickness of the were spatially variable. The depth to clay was primarily governed by the thickness of the overlying Woorinen Formation dune system.

A lack of sufficient local detail in this data and the spatial variability of occurrence confirmed the need for verification and refinement of the existing soils data set.

2.2 Intrusive Investigation Plan and Drilling Locations

Following a review of existing data an intrusive field program, consisting of four additional nested groundwater monitoring wells and 50 soil bores, was designed to fill in the gaps in the existing data sets.

The locations of the four groundwater monitoring wells were chosen to fill in gaps in the existing well network focusing on areas where shallow regional groundwater appeared to occur. At each site a shallow well was designed to investigate the occurrence and duration of perched groundwater and a deeper well was designed to monitor groundwater depth in the watertable aquifer.

The locations of the 50 soil bores were chosen to provide an even coverage across the study area and, as far as possible, to verify areas where the 1940 CSIRO survey had identified subsurface clay. Four additional soil bores were drilled in the process of siting the groundwater monitoring wells, making a total of 54 completed soil bores.

2.3 Meeting with MRCC

A meeting was held with the MRCC and Mallee Catchment Management Authority (MCMA) the on Wednesday 17th of March 2004 and the proposed locations of the soil bores and groundwater monitoring wells were agreed upon.

The issue of existing tile drainage systems underlying the area proposed for development was discussed. Where these drains are damaged and/or blocked as a result of development there would be the potential for the development of localised perched groundwater mounds. The scope of this study, however, was limited to an assessment of the potential for perched groundwater as a result of the subsurface clay layer and regional groundwater only. Subsequent mapping, decommissioning and replacement of tile drains on a site-by-site basis may be an additional requirement on developers to ensure that the perched groundwater does not develop.

3 FIELD INVESTIGATION PROGRAM

3.1 Soil Bores

Drilling of the 54 soil bores was undertaken using a truck mounted environmental drilling rig utilising the push tube technique. Soil bores were extended to a maximum depth of 4.0m below ground level to identify the presence of a subsurface silty clay layer. The soil profile was logged in accordance with the Unified Soil Classification (USC) system and detailed logs for all soil bores are included in Appendix A. The location of each soil bore within the study area is illustrated in Figure 3.

Where clay was not encountered in the upper 4 m of the soil profile it was assumed that perched groundwater would not develop and become an issue. In the context of data interpretation, if clay was not encountered in the soil bore then either clay was absent from the soil profile or the depth to the top of the clay layer was greater than the 4 m depth of the soil bore.

3.2 Groundwater Monitoring Well Installation

Well permits were obtained for all new groundwater monitoring wells prior to the commencement of drilling (Appendix B), the locations of which are illustrated in Figure 3. An experienced REM hydrogeologist supervised and logged the installation of all new wells for which construction logs are included in Appendix C. A pre-collar was installed in the deeper wells to separate off any perched groundwater from the regional watertable aquifer.

The wells were installed using a combination of the hollow flight and solid auger methods. All materials used in the well construction were supplied by the drilling contractor and were new and undamaged. The wells were constructed using 50 mm, Class 18, threaded uPVC, with a screened interval from the base of the well of 3 m in the deeper wells and about 1.5 m in the shallower wells.

The annular space between the well screen and the borehole wall, to at least 1 m above the screen, was backfilled with clean, washed and well graded predominantly silica sand (filter material) of a size compatible with the geological unit monitored, ensuring that no significant loss of filter material occurred during well development.

A bentonite seal was placed above the filter material, extending to the soil surface in the shallower wells and, in the deeper wells, approximately 2 m above the sand filter material followed by cement slurry to the soil surface.

All wells were completed with lockable caps and gatic covers level with the soil surface. This method of completion minimises potential damage due to vehicle traffic and vandalism and ensures maximum lifetime of the wells.

3.3 Surveying

The locations of all soil bores and new wells were surveyed into Australian Height Datum and GDA coordinates by licensed surveyors Thomson and Singleton Pty Ltd of Mildura using a differential GPS unit. The survey data is included in Appendix D. This enabled the elevation of the subsurface clays to be accurately mapped, the development of groundwater depth contours and the assessment of groundwater flow directions.

3.4 Groundwater Sampling

Following the completion of the intrusive drilling program, all new wells and all available existing groundwater monitoring wells in the vicinity of the study area were gauged to determine the depth to groundwater. Due to recent urban development and other disruptive activities many existing monitoring wells in the study area appeared to have been destroyed or were no longer accessible. Groundwater depth was measured in one existing well located in the north west of Mildura. Subsequent consultation with the MRCC and MCMA resulted in the location and measurement of groundwater depth in an additional seven monitoring wells located in the study area to the south west of Mildura. The MRCC and Lower Murray Water provided recent groundwater depth data for eight additional wells in the study area.

Each of the new wells were purged of a minimum of three bore volumes of water with the field parameters including electrical conductivity, pH, redox potential and temperature measured after the removal of each bore volume. Purging continued until field chemical parameters had stabilised, or until the well was dry. Where a well purged dry it was left for a time and a sample was obtained when considerable recharge had occurred. Bores were only sampled after purging had confirmed that a representative groundwater sample was obtained. The salinity of the groundwater was recorded as the electrical conductivity (EC) reading obtained at the completion of the purging process. Purge sheets for all monitoring wells sampled are included in Appendix E.

4 REFINEMENT OF ASSESSMENT TOOL

4.1 Groundwater Salinity

Field measurements of electrical conductivity (EC) from the sampled wells occurred in two distinct groups according to the depth of the wells. As shown in Table 1 the two wells that were drilled to 9 – 11 m bgl, (MW01d and MW04d) had an EC of around 9 mS/cm while the two wells drilled to about 16 m bgl had an EC of about 70 – 80 mS/cm (for comparison, the EC of seawater is about 50 mS/cm).

This data illustrates mixing with depth between the saline regional groundwater and the low salinity perched groundwater originating from irrigation and/or rainfall. A rapid increase in salinity of infiltrating water would occur by a combination of dissolution of high salt storage in subsurface clay soils and mixing with the regional groundwater. The new wells drilled to about 16 m bgl showed that the saline regional groundwater system predominated at this depth, while the wells at 9 – 11 m bgl were influenced to a greater extent by infiltrating less saline water.

With such saline regional groundwater it is clear that in those areas where the capillary fringe zone[1] of the watertable intersects the ground surface, significant detrimental impacts would occur to housing, infrastructure and the health of vegetation.

4.2 Depth to Groundwater

The new regional groundwater monitoring wells were drilled to depths of between 9 and 16 m below ground level (bgl) and groundwater was encountered at between approximately 3.3 and 9.1 m bgl as shown in Table 1 (wells were completed with gatic covers so groundwater depth below ground level is about the same as from top of casing). In all cases the regional Parilla Sands aquifer was not encountered and the wells were installed within the Blanchetown Clay unit.

In the context of urban salinity the watertable aquifer of concern was defined as that existing in the Blanchetown Clay unit. The groundwater depth contours developed in Phase 1 of the project were revised to account for the new definition of the watertable aquifer, the additional data obtained from new and existing wells across the study area and

[1] The capillary fringe is the zone immediately above the watertable into which water may be drawn upward as a consequence of surface tension forces between the water and the soil particles, known as 'capillary action'. When the capillary zone intersects the soil surface water can move to the soil surface via the effects of surface evaporation and dissolved salts, which are not removed by evaporation, may become concentrated at the soil surface.

information arising from consultation with the MRCC and MCMA. The new contours (Figure 4) were based on recent data, collected since mid 2000, but mostly since mid 2003 (included in Table 2), and were generated by subtracting interpolated groundwater elevation from detailed surface topography. While it is acknowledged that the groundwater elevation data contoured was not all collected at the same time, given the fairly constant groundwater levels in Mildura, as shown in SKM (1999), the use of data within this 'time window' was considered most useful for the present purpose. The groundwater table is typically relatively flat compared to surface topography, therefore, by accounting for the shape of the land surface, this method minimises the error in calculating the depth to groundwater from relatively sparse field measurements across a large area. The revised groundwater depth contours were consistent with all recent field measurements and provided a good estimation of the depth to groundwater across the area proposed for development. However, it must be stressed that while this groundwater data is valid for 'the current situation', future changes to groundwater levels may occur that would require periodic updates to the data set.

The groundwater depth contours (Figure 4), indicated that areas of shallow groundwater of concern to urban development were located adjacent to Lakes Hawthorn and Ranfurly and across parts of the low lying land through the central, south west and south east part of the main area proposed for development. Regional Groundwater was within 4 m bgl in these areas, as verified by the measurements in MW01 (3.2 m bgl) and MW03 (3.4 m bgl) and also in the Deakin Avenue nested well (3.9 m bgl).

4.3 Perched Groundwater Potential

The soil bores showed that a subsurface clay layer occurred extensively across the study area at depths of less than 4 m bgl. This layer may act as an impediment to downward movement of water. Figure 5 presents interpreted contours approximating the depth to clay across the study area, indicating those areas where clay was not encountered in the upper 4 m of the soil profile. The widespread occurrence of subsurface clay indicated that there is also widespread potential for the development of shallow perched groundwater across the area proposed for development. The few sites where clay was not encountered in the upper 4 m of the soil profile were located in Irymple and Nichols Point and one on San Mateo Avenue south of Sixteenth Street.

The clay was generally described as a high plasticity grey silty clay and occurred at an average depth of 2.1 m bgl and as shallow as 0.7 m bgl. A histogram illustrating the distribution of depth to clay or absence of clay in the 54 soil bores is presented in Figure 6. Clay was encountered in 47 soil bores (87%) and was absent in 7 soil bores (13%), providing an indication of the probability that a given site within the study area will be underlain by subsurface clay.

Where perched groundwater was to develop, the slope of the clay layer would control the direction of perched groundwater flow. Contoured elevation of the subsurface clay layer (Figure 7) provides an indication of where perched groundwater could be expected to flow given that flow occurs down gradient from high to low elevation. Identifying the expected flow direction of perched groundwater is important because the impacts may well manifest some distance from the cause itself. In some cases this distance may transcend individual property boundaries and the issue of accountability for the resulting impacts would then arise. Understanding perched groundwater flow directions can therefore assist in identifying the cause for an observed salinity impact.

While the potential for perched groundwater to develop was identified across the majority of the study area, the absence of excess soil moisture in most of the soil bores and the absence of perched groundwater in the new shallow monitoring wells, indicated that perched groundwater was not prevalent under the current land use at that time of year (April – May). In a few cases, specific land use practices resulted in the development of perched groundwater. Isolated occurrences of perched groundwater occurred in heavily irrigated areas (SB01, SB50) and where a resident disposed of household grey water in a opened bottomed sump situated in a sandy lens overlying a confining clay layer (SB24 and SB24a). These examples illustrated the importance of the adoption of good water management practices in new urban developments.

All shallow wells installed by REM were dry on installation and remained dry at the time of sampling. While perched groundwater was not present at these locations, perched groundwater was observed at a depth of 1.99 m bgl in well number 115243 at Green Pine Park. Seasonal fluctuations in perched groundwater should be expected and, given that observations were made at the end of the summer, perched groundwater levels may well have been at a minimum. Monitoring of the shallow wells is important to determine the occurrence and timing of perched groundwater with respect to excess irrigation and/or rainfall infiltration and the seasonal timing of this occurrence.

4.4 Interpreted Risk of Urban Salinity

In the context of residential development, the relative risk of urban salinity was provided by the combination of groundwater depth in the regional watertable aquifer and the occurrence of subsurface clay in the upper 4 m of the soil profile. The approach adopted here categorised five levels of urban salinity risk on a scale grading from low to very high and the level of management response varied accordingly, as summarised in Table 3. In all cases the actions required by developers would require the completion of a limited number of soil bores in order to verify the risk level provided by the Assessment Tool. The logic behind the five risk levels, presented spatially in Figure 8, is summarised as:

Low: Groundwater is below the threshold level of 4 m bgl and a clay layer does not occur shallower than the 4 m bgl threshold for perched groundwater potential. The resulting risk of urban salinisation is low and this would be the land most suitable for development from an urban salinity perspective.

Moderate: Groundwater is below the threshold level of 4 m bgl and a clay layer is present in the upper 4 m of the soil profile. While regional groundwater is not a concern in these areas, there is potential for perched groundwater to develop on top of the clay layer, which presents a considerable hazard to urban development. These areas have been assigned a moderate risk level because the hazard is relatively easy to manage with the installation of a suitable drainage system. Shallow regional groundwater on the other hand is much more difficult to manage and is therefore assigned a high or very high level of risk.

High(a): Groundwater is 2 - 4 m bgl and the clay does not occur shallower than the 4 m bgl threshold for perched groundwater potential. In these areas groundwater is within the zone of concern for urban development and although not currently causing salinisation, poor water management could rapidly cause the onset of saline conditions.

High(b): Groundwater is 2 - 4 m bgl and there is potential for perched groundwater to develop on top of a clay layer in the upper 4 m of the soil profile. In addition to the hazard of perched groundwater, regional groundwater is within the zone of concern for urban development and although not currently causing salinisation, poor water management could rapidly cause the onset of saline conditions.

Very High: Groundwater is less than 2 m bgl. In these areas shallow saline groundwater is an immediate threat to urban development and some land may have already become salinised. The presence of salt tolerant plant species, although not specifically identified in the Assessment Tool, would automatically classify the affected land with a very high level of risk. If development were to proceed in such areas then the very high level of risk is an acknowledged liability and must require the most rigorous management approach.

5 WATER BUDGET MANAGEMENT

A land use change from agricultural (eg. vineyards) to urban (eg. residential) would result in change to the inflows and outflows that make up the water balance of the area affected. In general there would be a reduction in the amount of evaporation and evapo-transpiration, from the surface and plants respectively, due to a higher impervious area of roads and houses. Although the irrigation of crops would no longer occur, over watering of lawns and gardens may result in significant groundwater recharge. The effect of reduced evaporative outflow and sustained recharge from poor water management could cause perched groundwater to develop where subsurface clays are present.

While most of the area proposed for development was assessed to be at moderate or higher risk of urban salinity, it is likely that development could still proceed in most areas, providing that adequate salinity management measures are adopted.

In all cases the promotion of good water management practices such as efficient lawn and garden watering and appropriate disposal of stormwater and grey water should be encouraged. This would include stormwater management systems that ensure ponding and subsequent groundwater recharge do not occur in areas susceptible to perched or shallow groundwater. In the higher risk areas and particularly where shallow regional groundwater is a threat, efficient water use should be a requirement of development.

Where there is potential for perched groundwater to develop the installation of a subsurface drainage system is an essential requirement of urban development. The extensive tile drains installed under vineyard blocks that existed on the land previously removed up to 4 ML of water per hectare per year (N. Hayward, *pers. comm.*, 2004). This clearly illustrates the need for subsurface drainage to manage excess water and ensure the productive use of the land. Where urban development is to be located immediately down slope of an irrigated area (eg. vineyard) subsurface drainage would be particularly important to manage the additional inflow of perched groundwater.

In general, urban development should be avoided on land at very high risk of urban salinisation, particularly where the presence of salt tolerant vegetation indicates that the land is already salt affected. If development is to proceed in very high risk areas, where shallow regional groundwater is a threat, a detailed hydrogeological investigation should be undertaken, including groundwater modelling to assess the impact of development on groundwater levels. The regional nature of the groundwater system means that, unlike perched groundwater, shallow regional groundwater cannot be effectively managed on a local scale with subsurface drainage. Management strategies must therefore be concerned with maintaining groundwater at a safe depth below ground level and efficient water use practices to minimise groundwater recharge. For example, imported clean fill may be used to elevate the ground surface above the groundwater capillary fringe zone. However, the potential for disruption to groundwater flow up gradient of the development must be thoroughly investigated and addressed with suitable drainage prior to implementation.

It must be stressed that proper design and verification of all proposed salinity management strategies is essential to successful urban development in areas at risk of urban salinity. The cost of a proper hydrogeological assessment prior to development would certainly be lower than that of the ongoing impact and remediation of salinisation.

The specific requirements that a developer must meet to gain approval for development on land identified to be at risk of urban salinity will be detailed in the subsequent Draft Site Salinity Management Plan document.

6 RECOMMENDATIONS

While most of the area proposed for development was assessed to be at moderate or higher risk of urban salinity, it is likely that development could still proceed in most areas if appropriate water management measures are adopted. The level of management and actions required of the developer would increase according to the identified level of risk. Management actions are designed to address the presence perched groundwater and the presence of shallow regional groundwater.

The recommendations arising from Phase II of the project are:

- Council should integrate the Urban Salinity Risk Assessment Tool into the urban development planning process and use the Tool to assess the level of risk and subsequent requirements from the developer on a case-by-case basis.

- Development in areas identified at a moderate or higher urban salinity risk should be subject to specific water management requirements.

- Development in areas at very high urban salinity risk should not proceed unless the developer meets rigorous water management requirements.

- Council should regard the Assessment Tool as a guide and, in cases where there is a high urban salinity risk, development requirements may include the installation of groundwater monitoring wells for ongoing monitoring of regional and perched groundwater levels.

The forthcoming Draft Site Salinity Management Plan will detail the specific requirements to be met by developers to address the urban salinity risk where present. Council should integrate these requirements into the residential development planning process.

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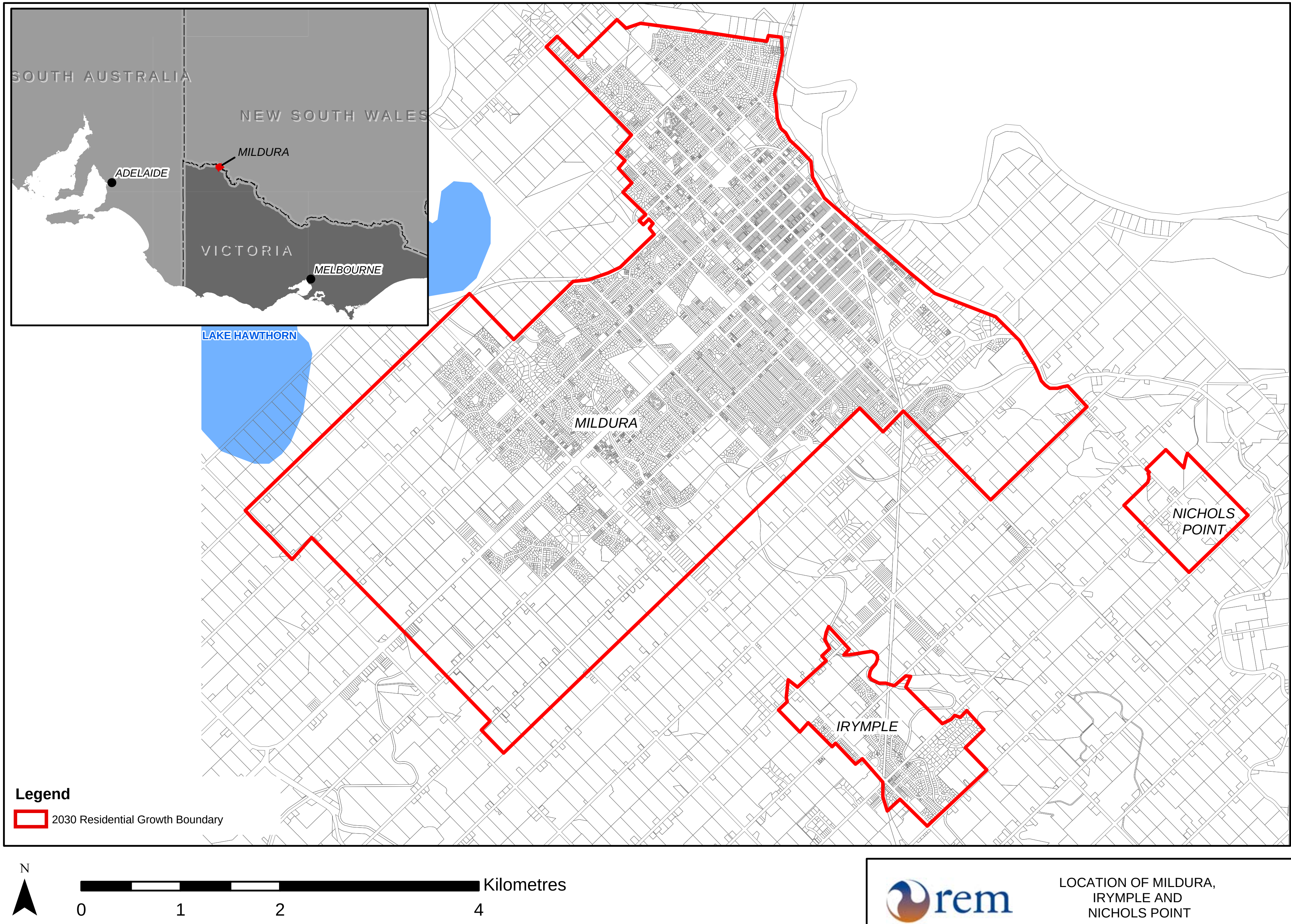
Figures



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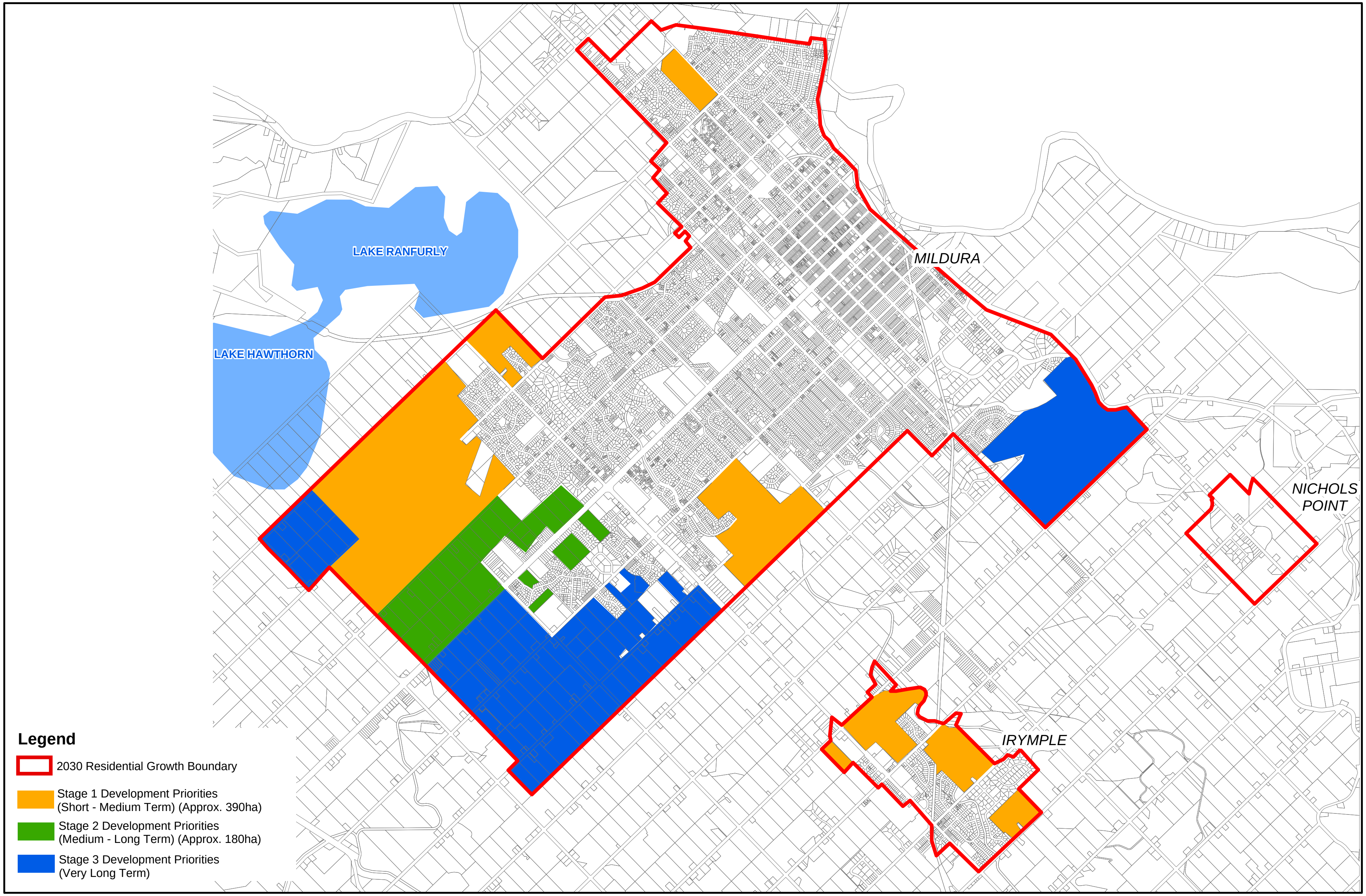
LOCATION OF MILDURA, IRYMPLE AND NICHOLS POINT

Project: CT-01

Figure 1

May 2004



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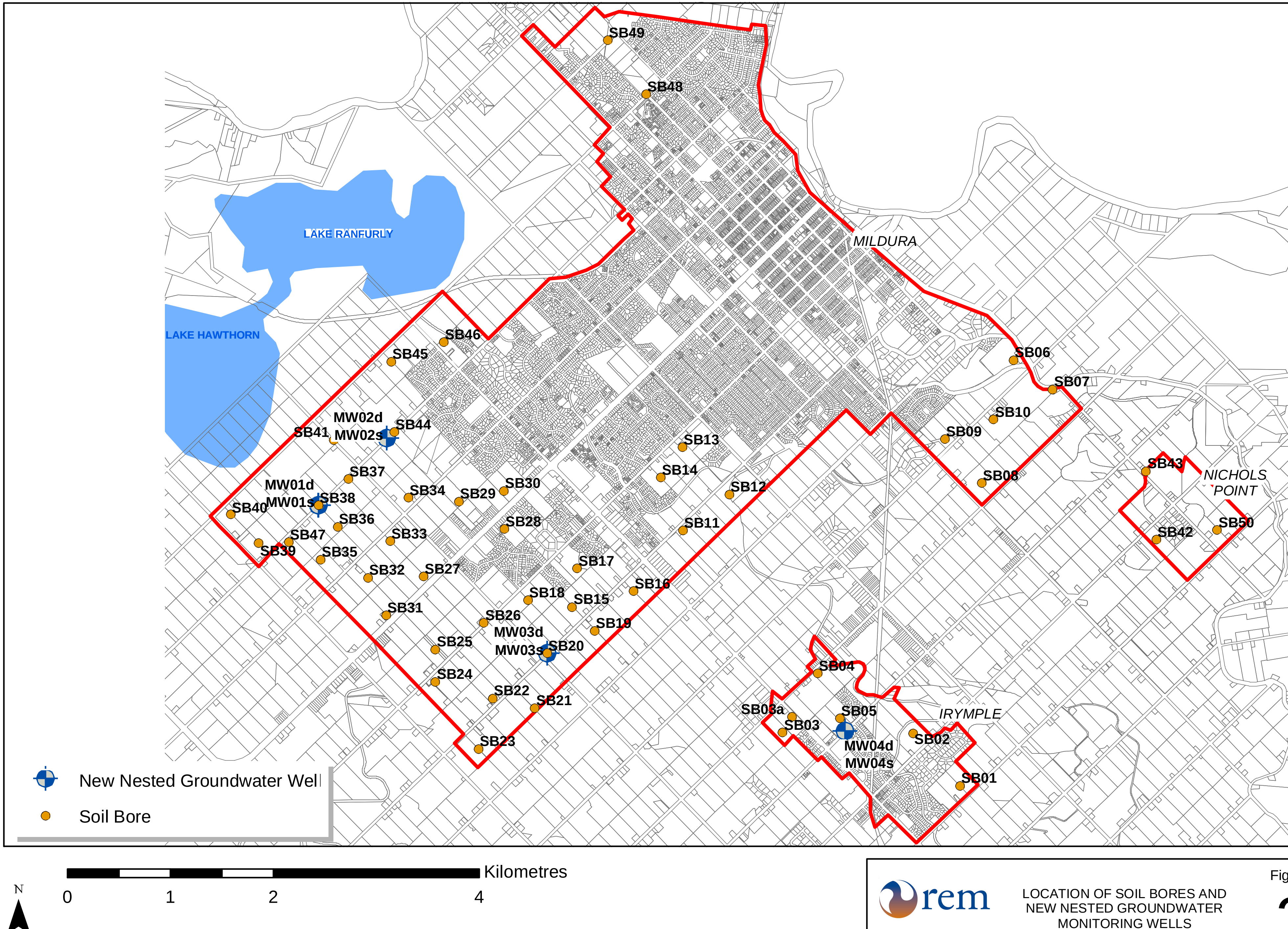
AREAS PROPOSED FOR URBAN DEVELOPMENT IN MILDURA, IRYMPLE AND NICHOLS POINT

Project: CT-01

Figure 2

May 2004



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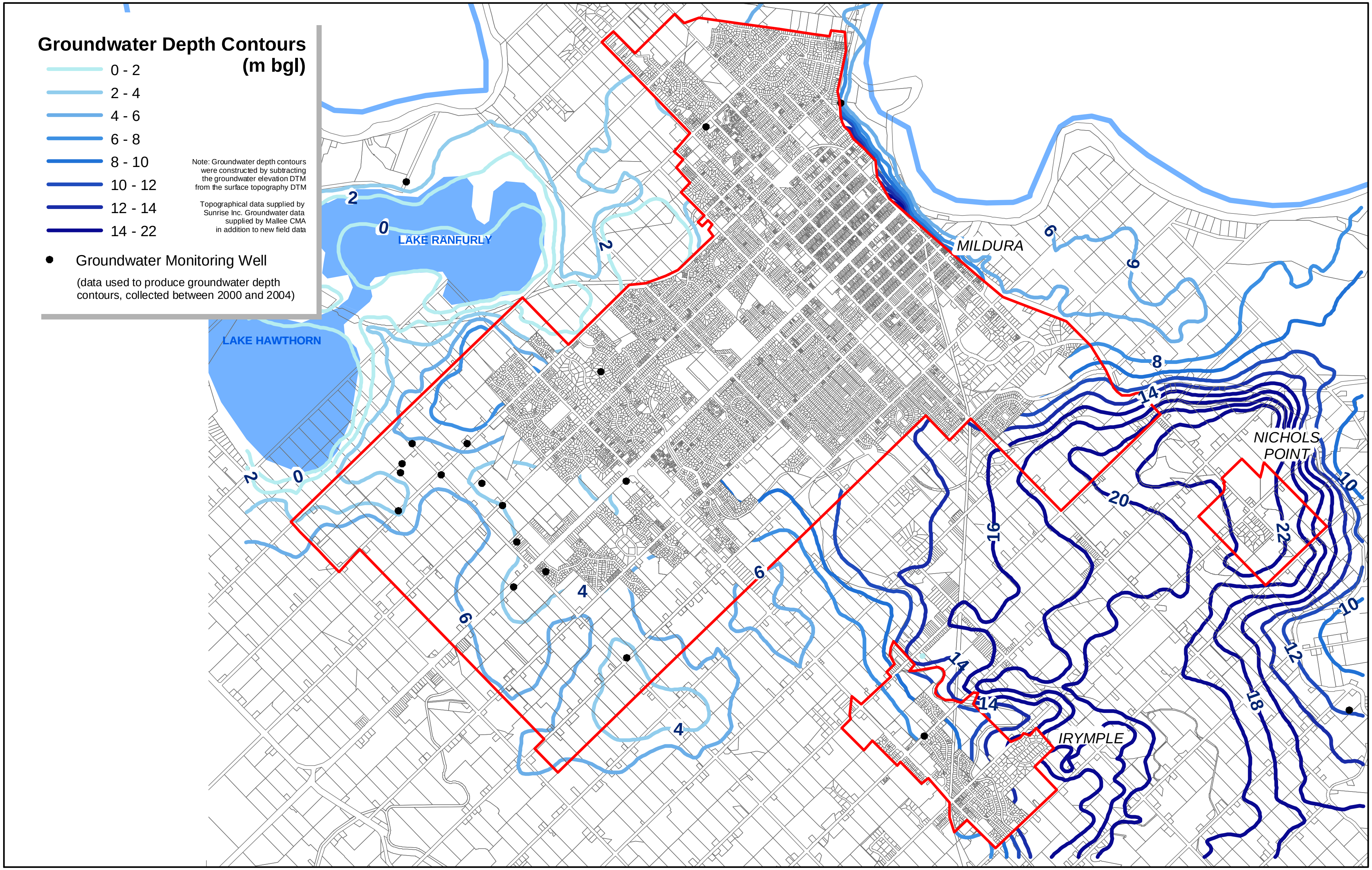
LOCATION OF SOIL BORES AND NEW NESTED GROUNDWATER MONITORING WELLS

Figure

3

Project: CT-01

May 2004



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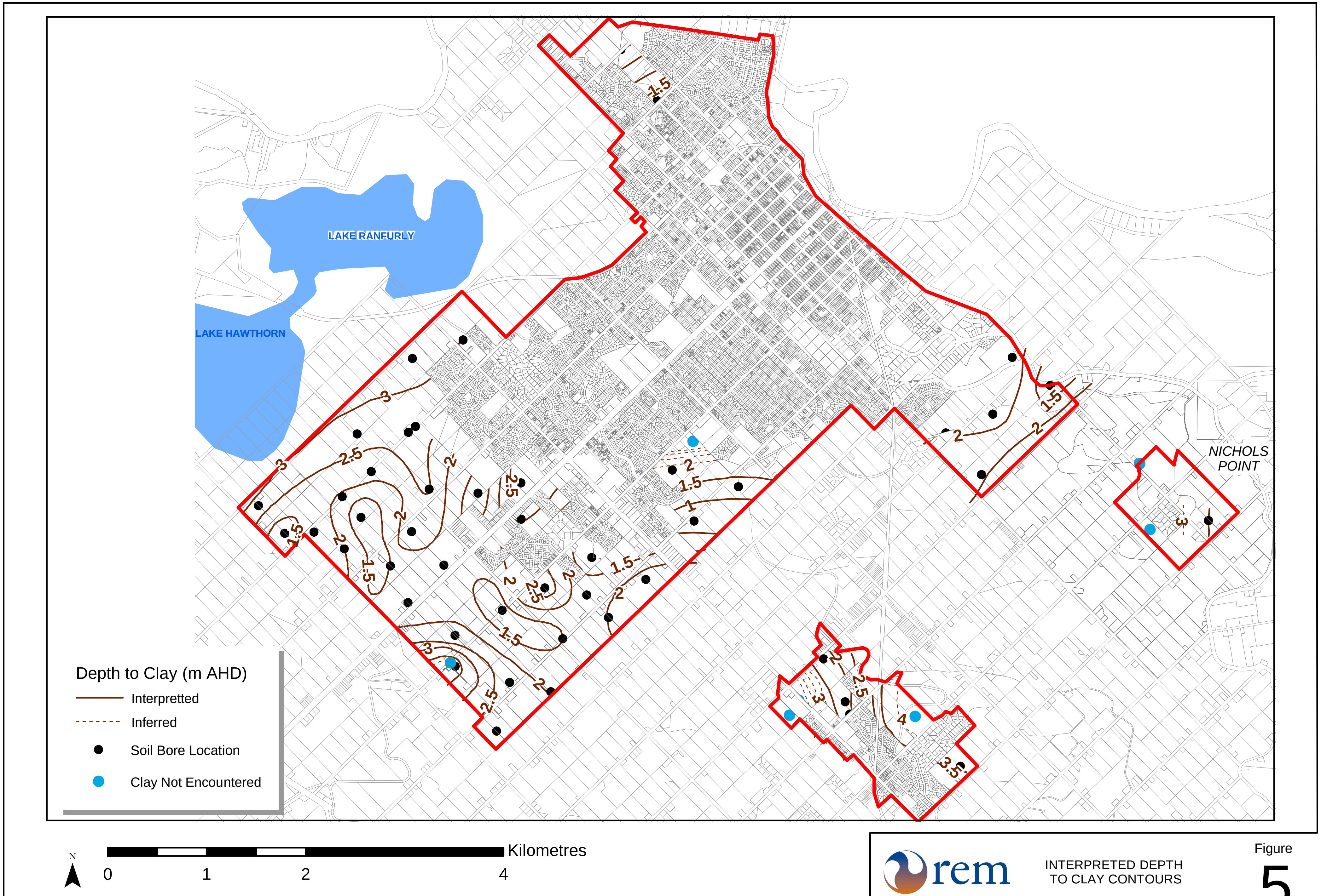
GROUNDWATER DEPTH IN THE WATER TABLE (BLANCHETOWN CLAY) AQUIFER

Project: CT-01

Figure 4

June 2004



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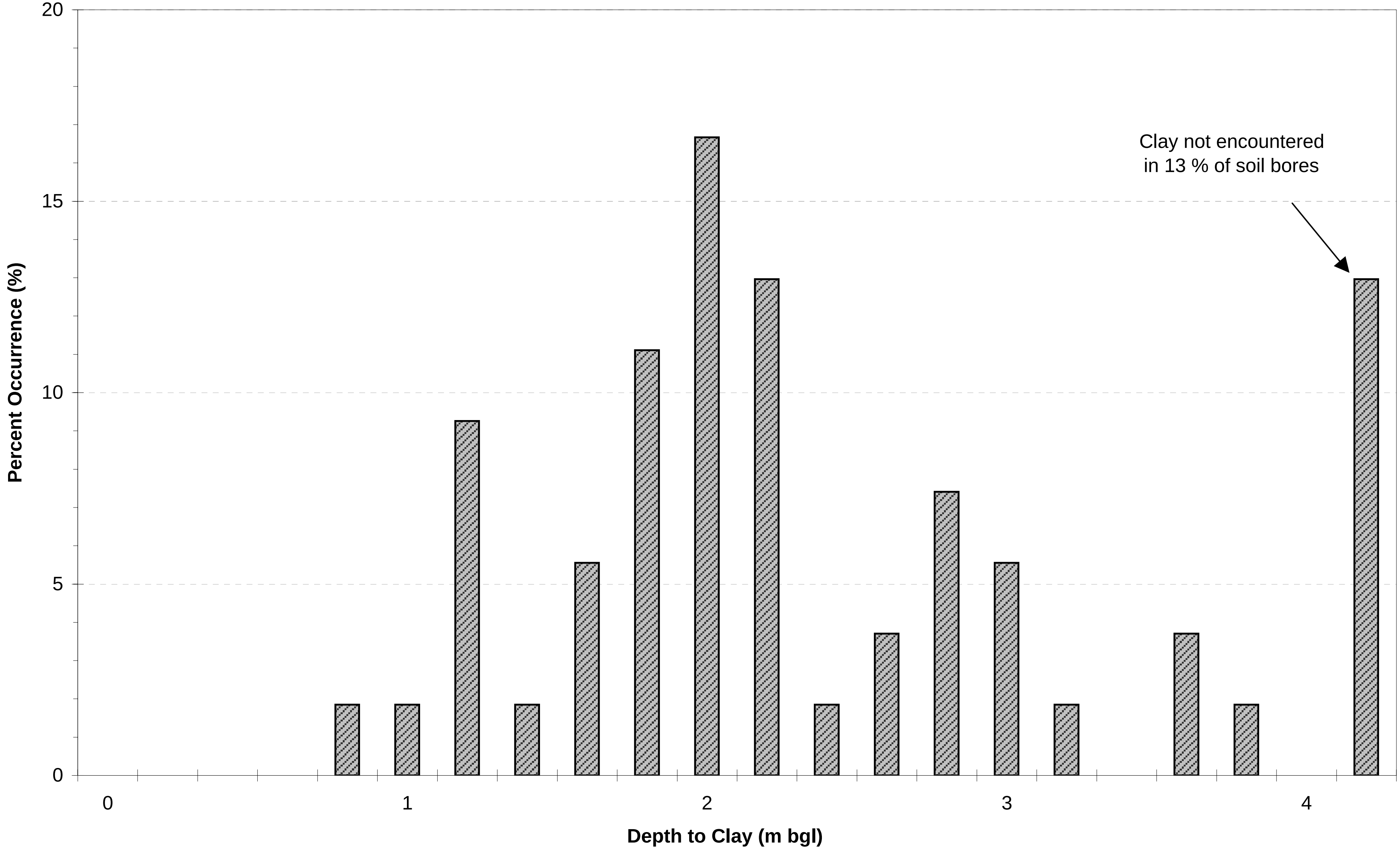
INTERPRETED DEPTH TO CLAY CONTOURS

Project: CT-01

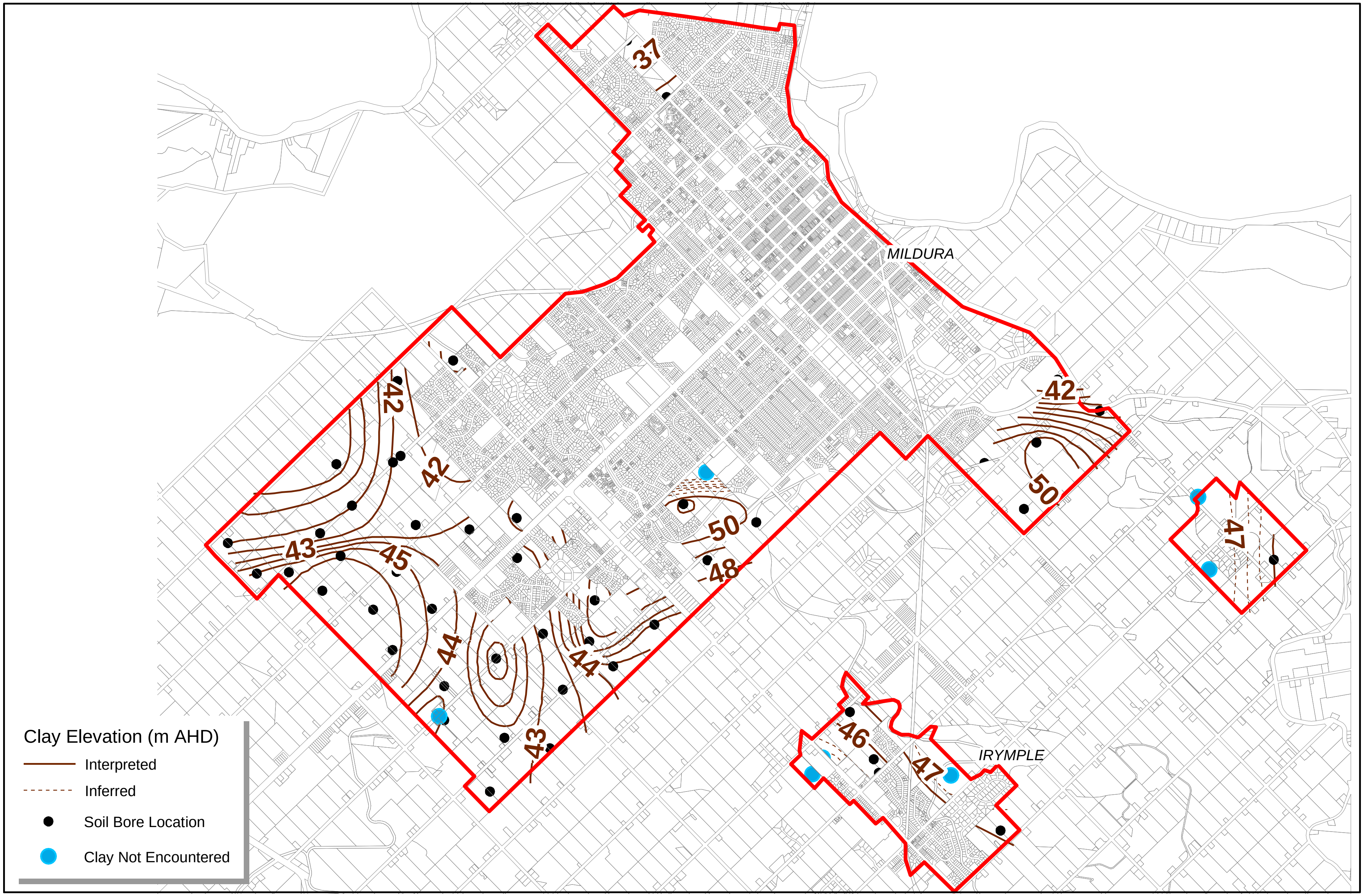
Figure 5

May 2004



HISTOGRAM SHOWING DISTRIBUTION OF DEPTH TO CLAY IN 54 SOIL BORES

FIGURE
6
May 2004



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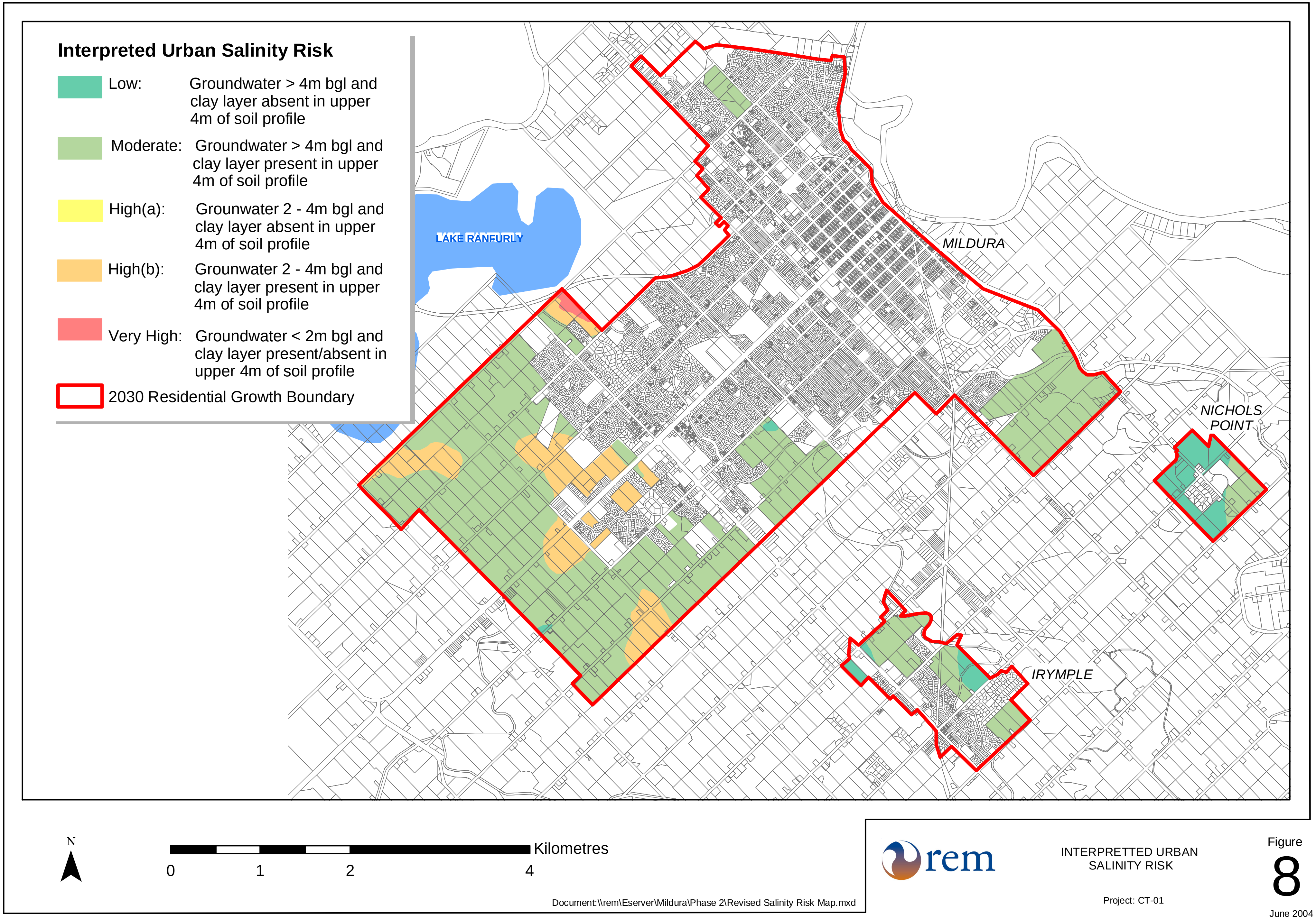
INTERPRETED CLAY
ELEVATION CONTOURS

Project: CT-01

Figure
7

May 2004



Document:\\rem\Eserver\Mildura\Phase 2\Revised Salinity Risk Map.mxd

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INTERPRETTED URBAN SALINITY RISK

Project: CT-01

Figure 8

June 2004

Tables

Well ID	Location		Elevation (m AHD)		Aquifer Monitored	Well Depth	DTW	RSWL	EC	Measurement Date
	Easting	Northing	Nat. Surf.	TOC		m TOC	m TOC	m AHD	mS/cm	
MW01d	602424.82	6213947.30	43.43	43.34	Blanchetown	8.920	3.175	40.165	9.14	11-May-04
MW01s	602424.22	6213946.71	43.44	43.33	Woorinen	2.580	dry	dry	dry	11-May-04
MW02d	603093.54	6214600.45	44.40	44.30	Blanchetown	16.030	6.790	37.510	82.60	11-May-04
MW02s	603092.61	6214599.25	44.38	44.33	Woorinen	2.500	dry	dry	dry	11-May-04
MW03d	604654.14	6212510.43	44.04	43.95	Blanchetown	16.235	3.385	40.565	70.50	11-May-04
MW03s	604652.91	6212509.18	44.07	43.98	Woorinen	1.950	dry	dry	dry	11-May-04
MW04d	607553.21	6211750.24	47.54	47.47	Blanchetown	10.830	9.121	38.349	9.04	11-May-04
MW04s	607552.40	6211749.47	47.54	47.44	Woorinen	2.025	dry	dry	dry	11-May-04

Note: AHD = Australian Height Datum; TOC = Top of Casing; DTW = Depth to Water; RSWL = Reduced Standing Water Level; EC = Electrical Conductivity

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SUMMARY DATA FROM NEW GOUNDWATER MONITORING WELLS IN THE PERCHED (WOORINEN FORMATION) AND REGIONAL WATERTABLE (BLANCHETOWN CLAY) AQUIFERS

TABLE

1

JUNE 2004

Well ID	Location		Aquifer Monitored	Well Depth m TOC	DTW m bgl	RSWL m AHD	Measurement Date	Source
	Easting	Northing						
MW01d	602425	6213947	Blanchetown	8.92	3.18	40.17	11-May-04	REM
MW02d	603094	6214600	Blanchetown	16.03	6.79	37.51	11-May-04	REM
MW03d	604654	6212510	Blanchetown	16.24	3.39	40.57	11-May-04	REM
MW04d	607553	6211750	Blanchetown	10.83	9.12	38.35	11-May-04	REM
??	602556	6214601		7.94	4.96		01-Apr-04	REM
7294	606740	6217921		12.79	10.51	32.63	11-May-04	MCMA
27013	603550	6213200		14.80	2.25	42.52	24-May-04	Trevor Clarke
27160	602815	6214321			6.06	36.65	26-May-04	Trevor Colpin
115239	604400	6215300	Blanchetown	10.00	5.55	36.43	26-May-04	Trevor Colpin
124771	604649	6214232	Blanchetown	10.00	3.91	46.68	26-May-04	Trevor Colpin
1	603865	6213350			3.85	40.20	23-Jun-03	MRCC
2	603577	6213640			2.59	41.42	23-Jun-03	MRCC
3	603440	6213997			3.15	40.53	23-Jun-03	MRCC
4	603237	6214214			2.61	41.19	23-Jun-03	MRCC
5	602843	6214294			4.37	38.56	23-Jun-03	MRCC
6	602459	6214402			4.66	36.61	23-Jun-03	MRCC
7	602444	6214315			4.36	36.51	23-Jun-03	MRCC
7092	600741	6217860	Blanchetown		2.53	30.51	22-Aug-02	MCMA
7093	600692	6217864	Blanchetown		2.51	30.48	22-Aug-02	MCMA
7183	600847	6217960	Blanchetown		5.47	30.50	22-Aug-02	MCMA
7195	605186	6219847	Blanchetown		2.57	31.00	23-Aug-02	MCMA
7219	601131	6217732	Blanchetown		4.46	31.09	26-Apr-00	MCMA
7366	605424	6217691	Blanchetown		4.37	36.35	23-Aug-02	MCMA
7711	605779	6219853	Blanchetown		2.53	32.65	23-Aug-02	MCMA
7957	612580	6212150	Blanchetown		2.64	34.02	22-Jul-02	MCMA
7961	611700	6212000	Blanchetown		10.60	34.82	22-Jul-02	MCMA
27036	602500	6217150	Blanchetown		4.59	31.65	23-Aug-02	MCMA

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ALL GROUNDWATER DATA COLLATED FOR THE WATERTABLE (BLANCHETOWN CLAY) AQUIFER FROM NEW AND EXISTING GROUNDWATER MONITORING WELLS

TABLE

2

JUNE 2004

Risk Level	Occurrence of Regional Groundwater	Clay Layer in Upper 4m of Soil Profile	Actions Required of Developer
Low	Deeper than 4 m bgl	Absent	Limited number of soil bores to verify absence of clay layer and regional groundwater at less than 4 m bgl
Moderate	Deeper than 4 m bgl	Present	Soil bores to verify extent of clay layer and regional groundwater deeper than 4 m bgl; drainage strategy to adequately address perched groundwater
High(a)	2 - 4 m bgl	Absent	Soil bores to verify absence of clay layer; groundwater wells for ongoing monitoring; strategy to address shallow groundwater and off site impacts
High(b)	2 - 4 m bgl	Present	Soil bores to verify extent of clay layer; groundwater wells for ongoing monitoring; strategy to address shallow reional and perched groundwater and off site impacts
Very High	Shallower than 2 m bgl	Present / Absent	Groundwater wells for ongoing monitoring; Detailed hydrogeological assessment including groundwater modelling to assess the impact of development on groundwater levels; Water management strategy to address regional groundwater and off site impacts

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LEVELS OF RISK OF URBAN SALINITY AND THE RECOMMENDED ACTIONS TO BE REQUIRED OF DEVELOPERS

TABLE

3

APRIL 2004

Appendix A:

Soil Bore Logs

Appendix B:

Well Construction Permit

Appendix C:

Groundwater Monitoring Well Construction Logs

Appendix D:

Location and Elevation Survey Data – Soil Bores and Monitoring Wells

Appendix E:

Groundwater Sampling Field Parameter Sheets