

***Identification and preliminary risk assessment
of prime development zones in the greater
Melbourne area for recycled water use***

prepared by

Department of Natural Resources and Environment

Centre for Land Protection Research, Bendigo



Report Contributors

Project Management

Martin Bluml

Land Capability Assessment

Nathan Robinson

David Rees

Hydrogeological Assessment

Mayavan Pillai

Peter Hekmeijer

Environmental Assessment

Geoff Savage

User Note:

This preliminary risk assessment is essentially a desk top study utilising existing information with limited field checking. Therefore, this study is not a comprehensive evaluation of each Prime Development Zone (PDZ), but rather a preliminary investigation to highlight the risks associated with new irrigation development.

It is recommended that the risk category assigned to each PDZ remain preliminary until detailed investigations are completed.

This study is primarily concerned with irrigated agriculture within the PDZs. It should not be assumed that other forms of recycled water use are inappropriate or should be restricted within the study area. In addition, this study does not consider the social, economic or regulatory situations that may influence the siting and development of irrigated agriculture in the region.

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Executive Summary

This report has been prepared by NRE research staff as input for a scoping study on reuse of water in the Melbourne region. Existing literature has been reviewed and available soil, land and water datasets have been analysed. Specifically, this background report identifies land capable of utilising recycled water for irrigated agriculture, and provides a preliminary hydrogeological and environmental risk assessment.

The report was commissioned in December 2001 by the Metropolitan Water Recycling Committee who oversee the implementation of Melbourne's Water Recycling Strategy. A 20% water recycling target has been set by Melbourne Water and the strategy requires preparation of a preliminary scoping study to address three key areas:

1. Developing markets for recycled water and pricing recycled water.
2. Identification of land capable of supporting high-value irrigated crops (utilising recycled water), and a preliminary assessment of the hydrogeological and environmental risks associated with any new irrigation development.
3. Infrastructure requirements for recycling, associated transport, planning, and urban/rural development.

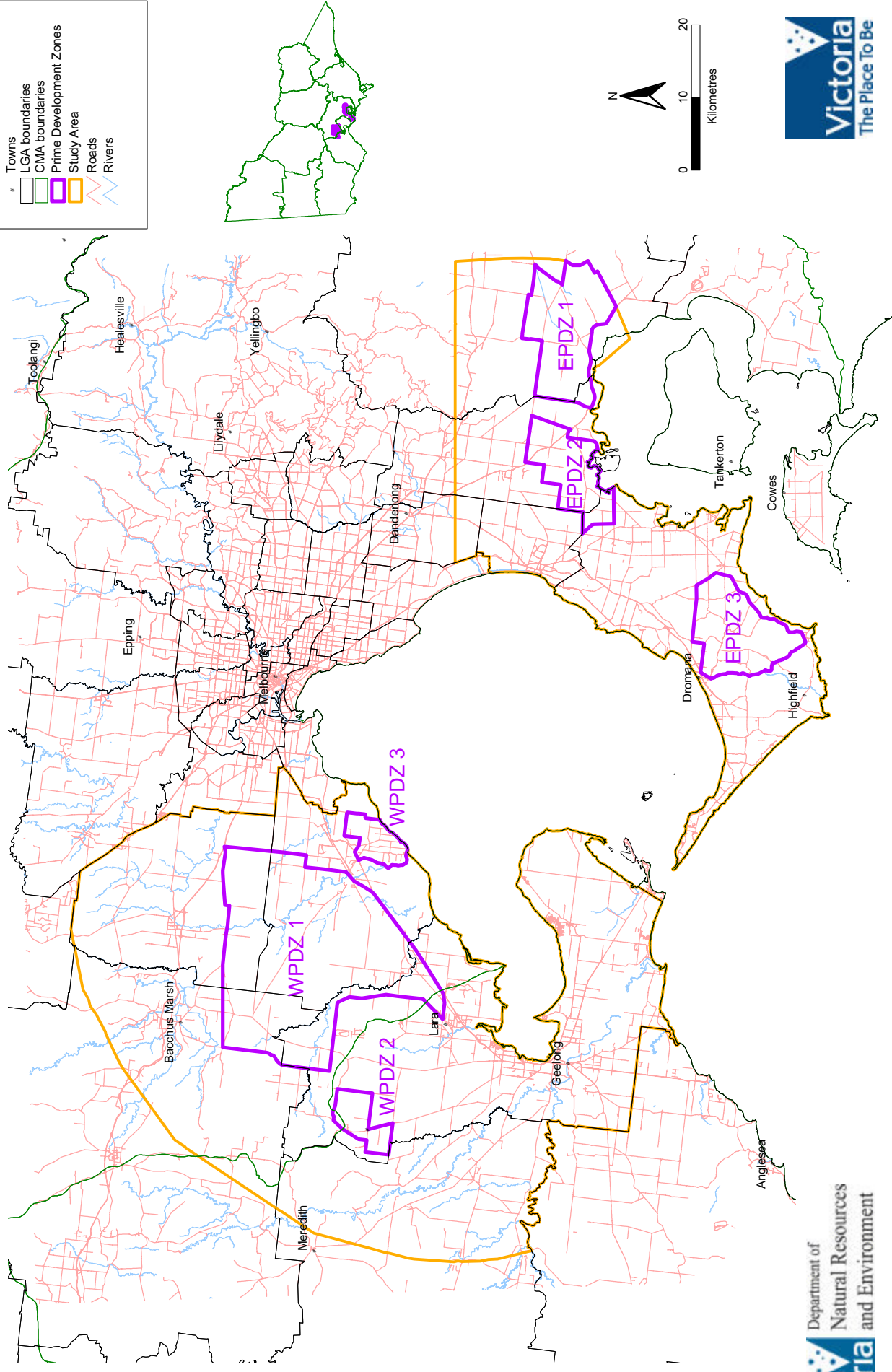
This report addresses point 2 above.

The sources of recycled water are the Eastern and Western treatment plants managed by Melbourne Water. The plants produce approximately 350 000 ML of effluent per annum. The effluent is currently discharged into Port Phillip Bay and the marine environment.

The objective of this study is to identify Prime Development Zones (PDZs) for irrigated agriculture. A systematic method has been applied to eliminate inappropriate areas from development, apply land capability assessment to available areas, and evaluate the environmental risks associated with irrigation development. Six PDZs have been delineated; three to be supplied with water from the Western Treatment Plant, and three from the Eastern Treatment Plant. Although six PDZs have been delineated, other land exists with the potential to support irrigated agriculture in the study area. In particular, the Bellarine Peninsula may warrant further investigation.

The PDZs include existing irrigation areas at Werribee, Cranbourne and Koo Wee Rup (refer to Map 1). Production risks are considered low in all of the PDZs if best management practices are applied and development is concentrated on the most favourable soil types.

Map 1 Location of Prime Development Zones



From a hydrogeological perspective, PDZs at most risk are those adjacent to Port Phillip Bay (EPDZ 1) and Westernport Bay (WPDZ3). These areas are of high to moderate risk and require further investigation to manage and prevent groundwater problems.

Environmental risks reflect the diverse ecosystems present in the study area and the range of threats presented by new irrigation development. In general, most PDZs are considered a moderate risk as they contain environmental assets of greater than regional significance. However appropriate planning, siting, and the use of buffers can address these issues. An exception is EPDZ 1, this PDZ is considered high risk due to drainage and water quality issues associated with Westernport Bay.

The total area of land capable of supporting irrigated agriculture within the PDZs is approximately 76 000 ha. This is sufficient to meet the 20% recycling target of 70 000 ML per annum. The minimum area of land required will depend upon the mix of irrigation enterprises that adopt recycled water. However, the recycling target could be met by utilising 20% of the total land delineated within the PDZs.

When prioritising PDZs for development, the class of recycled water available, the capability of the land, and the land available for agriculture are considered important. In general, the western PDZs have a moderate capability for irrigated agriculture and access to Class B recycled water. In comparison, the eastern PDZs have very high to moderate capability and will have access to Class A recycled water in 2004. Therefore, the eastern PDZs appear better suited to a diverse range of horticultural enterprises, while water quality in the west may restrict the range of irrigated crops established. Conversely, the area of land available in the western PDZs (54 200 ha) will provide greater opportunity for future irrigation expansion than in the east (22 200 ha). The pressures exerted in the east by urban encroachment may also restrict future irrigation development. Therefore, both eastern and western PDZs have specific advantages for development.

The evaluation of land for delineation of PDZs was a desktop study using available published data on land and soil quality. Most of the existing map information has insufficient detail to be used for property based irrigation planning, therefore expert judgement has been applied largely as an exercise in interpretation and extrapolation. As the spatial variability of soils in the PDZs is inherently high, the PDZs will contain land of mixed capability for irrigated agriculture. The boundaries of the PDZs are simple, following in most cases obvious topographic features such as roads that run near or adjacent to mapped soil boundaries. Detailed soil survey for irrigation suitability will be needed in order to progress and advocate specific irrigation development within the PDZs.

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List of Abbreviations

BVT	Broad Vegetation Classes
CMA	Catchment Management Authority
CCMA	Corangamite Catchment Management Authority
ETP	Eastern Treatment Plant
EVC	Ecological Vegetation Class
FFG	Flora and Fauna Guarantee
GMA	Groundwater Management Area
IBRA	Interim Biogeographical Regionalisation of Australia
MAR	Managed Aquifer Recharge
PDZ	Prime Development Zone
PPWCALP	Port Phillip and Westernport Catchment and Land Protection Board
TDS	Total Dissolved Salts
VMU	Vegetation Management Units
VROTS	Victorian Rare or Threatened Species
WTP	Western Treatment Plant

1 Introduction

The Metropolitan Water Recycling Committee has been established to oversee and implement Melbourne's Water Recycling Strategy. The strategy will include the preparation of a Preliminary Scoping Study that will address the following key issues:

1. Developing markets for recycled water and pricing recycled water.
2. Assessing land capability for high-value irrigated crops and other land uses, investigating groundwater and salinity risks, and ensuring protection for areas of high environmental value including Port Phillip Bay and RAMSAR listed wetlands.
3. Infrastructure requirements for recycling, associated transport, planning, and urban/rural development.

The scoping study will provide a preliminary evaluation of a series of strategic regional and sub-regional projects, using a triple bottom line assessment of the costs and benefits of each.

In the greater Melbourne region, Melbourne Water has a target to recycle 20% of effluent from the Eastern and Western Treatment Plants by 2010. Meeting this 20% recycling target can be achieved by two principal means:

- recycling treated effluent from the Western and Eastern treatment plants; or
- intercepting sewage before it reaches the treatment plants. Options include constructing local treatment plants in areas with high recycling potential, such as Melbourne's outer growth areas, or 'mining' sewage from the mains and treating it locally for reuse.

In the outer Eastern and Western metropolitan areas, development opportunities may be limited due to a lack of water for industry and agriculture. By utilising recycled water, increased water availability can lead to greater regional development and job growth in areas close to Melbourne with links to appropriate transport and other infrastructure.

This background report is primarily concerned with the second key issue identified for the scoping study. This includes the identification of sustainable PDZs for irrigated agriculture in the greater Melbourne region, and the assessment of potential on-site and off-site environmental impacts associated with new development.

1.1 Identification and preliminary risk assessment of Prime Development Zones in the greater Melbourne region

This background report was undertaken in two stages. Stage 1 includes the identification of PDZs for irrigated agriculture within the nominated study area. Stage 2 involves the specific assessment of hydrogeological and environmental risks associated with irrigation development in these PDZs.

The identification of PDZs was confined to land within a 40 km radius of the Western Treatment Plant (including the Bellarine Peninsula), and land within a 30 km radius from the Eastern Treatment Plant (refer to Map 1).

In developing the methodology for this study, the following assumptions have been made in relation to irrigated agriculture and recycled water use:

- any irrigation development must be capable of operating for a minimum 50 years without resulting in unacceptable land or water degradation;
- recycled water quality from both treatment plants will be of Class C standard; and
- current government water policy and Environmental Protection Authority (EPA) guidelines will continue to be implemented.

This study has provided information at a suitable scale to support the Preliminary Scoping Study. It is however recommended that detailed PDZ investigations are completed. The minimum requirements for detailed PDZ investigation have been outlined in Section 8.

It is also important to note that this study is primarily concerned with biophysical constraints associated with irrigated agriculture, and has not evaluated the social, economic or regulatory situations that may further influence the siting and development of PDZs.

2 Methodology

2.1 Stage 1: Identification of Prime Development Zones

The selection of land capable of supporting irrigated agriculture involved the development of two separate map overlays:

1. land availability for agriculture within the study area, and
2. an assessment of soil-landform types capable of supporting irrigation development (land capability assessment).

When combined using a Geographic Information System (GIS) these map overlays can be used to delineate PDZs for irrigated agriculture.

The development of these overlays required the identification of relevant datasets, GIS layers and map-based products for the study area. Utilising the available information, key evaluation criteria were then developed to support the construction of the two map overlays.

The evaluation criteria and datasets used to produce the overlays are presented in the following tables. Table 2.1 and 2.2 were used in identifying land that is available for agricultural use, while Table 2.3 is used in assessing the capability of the land to support irrigated agriculture.

2.1.1 Evaluation criteria for the identification of Prime Development Zones

The primary exclusion criteria highlight where irrigated agriculture is considered an incompatible land use. These exclusions are based upon land tenure, zoning and other regulatory arrangements. The exclusions are considered non-negotiable, they are therefore excluded from development within the study area or PDZs.

Table 2.1 Primary exclusion criteria - GIS and relevant datasets used in the identification of PDZs

Primary exclusion criteria	GIS layer used
Commonwealth land	PLMMT100
Victorian public lands	PLMMT100
VPP Zones other than RZ, ERZ, RLZ	DOI RURAL OVERLAYS
Water catchment areas (CALP Act)	PWSC100
RAMSAR listed wetlands	RAMSAR100
Areas listed under CAMBA/JAMBA agreements	Draft Port Philip and Westernport Native Vegetation Plan (PPWCALP 2000)
Areas >20% slope	DEM25

The secondary evaluation criteria in Table 2.2, highlight where irrigated agriculture is not regarded as an incompatible land use, however development may impact upon sites of environmental significance, or be restricted by salinity or flooding risk. It is considered that appropriate planning, management and use of buffer zones can overcome these limitations.

Table 2.2 Secondary evaluation criteria - GIS and relevant datasets used in the identification of PDZs

Secondary evaluation criteria	GIS layer used
Very high priority for native vegetation retention	Draft Port Philip and Westernport Native Vegetation Plan
Bioregional Conservation Status of EVCs	Draft Corangamite Native Vegetation Plan
Habitat for Victorian Rare or Threatened flora	Draft Port Philip and Westernport Native Vegetation Plan
Habitat for FFG listed flora species	Draft Port Philip and Westernport Native Vegetation Plan
Habitat for Victorian Threatened fauna	Draft Port Philip and Westernport Native Vegetation Plan
Habitat for FFG listed fauna species	Draft Port Philip and Westernport Native Vegetation Plan
Bonn habitat	Draft Port Philip and Westernport Native Vegetation Plan
Existing salinity discharge areas	SOILSAL25
Flooding risk	FLOODWAY25

The tertiary evaluation criteria in Table 2.3 specifically highlight soil-landform types that will support irrigated agriculture (land capability analysis). This has been broadly assessed using existing soil-landform information collated for the greater Melbourne region, in conjunction with a modified land capability assessment table for irrigated agriculture (Appendix A, Table 9.1).

The modified table was needed to overcome the variability and scale of soil-landform information across the study area. The information available was not sufficient to fully consider soil hydraulic properties, soil chemistry and long-term water quality issues associated with recycled water use. Consequently, a simplified set of soil-landform criteria were used to evaluate basic soil hydraulic properties needed for irrigation, irrespective of water quality. Where gaps in soil-landform information existed, soil properties were estimated by regional experts.

Table 2.3 Tertiary evaluation criteria - GIS and relevant datasets used in the identification of PDZs

Tertiary evaluation criteria	GIS layer used
Soil type (Principal Profile Form)	Victorian soil sites database & GM-SOILS
Topsoil texture	Victorian soil sites database & GM-SOILS
Stone content	Victorian soil sites database & GM-SOILS
Gravel content	Victorian soil sites database & GM-SOILS
Slope	DEM25
Topsoil sodicity	Victorian soil sites database & GM-SOILS
Subsoil sodicity	Victorian soil sites database & GM-SOILS

2.2 Stage 2: Preliminary risk assessment of Prime Development Zones

The preliminary risk assessment for PDZs involved both hydrogeological and environmental risk assessments.

Each PDZ has been assigned a high, moderate or low risk for the hydrogeological and environmental risk components (refer to section 6). The risk classifications are intended to distinguish between PDZs where risks can be minimised by appropriate siting and land management, and those high risk areas where current irrigation technology and land management practices will not control environmental degradation.

2.2.1 Hydrogeological and salinity risk assessment

In determining the hydrogeological and salinity risk of the PDZs, it was necessary to identify and assess the following individual risk factors:

- risk to existing beneficial groundwater quality;
- risk of elevated watertable levels;
- risk of waterlogging and seasonally perched watertables; and
- risk due to inherent hydrogeological setting of the area.

The latter three categories relate to soil salinity risk whilst the former relates to the risk to the underlying groundwater resource. The risk factors are classified according to the criteria contained in Tables 2.4 to 2.7.

Table 2.4 Criteria used in the analysis of risk to beneficial groundwater quality

Risk category	Criteria
Low	PDZ area mostly > 2500 mg/L TDS groundwater (equivalent stock & domestic quality)
Moderate	PDZ area mostly between 1000 & 2500 mg/L TDS groundwater (equivalent good quality irrigation supply)
High	PDZ area mostly < 1000 mg/L TDS groundwater (potential potable supply)

Note: This table is based on Leonard (1992) and Victorian Groundwater Beneficial Use Map Series (DCNR 1995).

Table 2.5 Criteria used in the analysis of risk of elevated watertable

Risk category	Criteria
Low	PDZ area contains watertable mostly > 5 m depth
Moderate	PDZ area contains watertable broadly in the range 0-10m depth
High	PDZ area contains mostly watertable < 5m depth

Note: This table is based on assessment of 1998 Port Phillip region watertable depth surface, SKM (1999).

Table 2.6 Criteria used in the analysis of risk of seasonally perched watertables and/or waterlogging

Risk category	Criteria
Low	Mostly non-duplex soils & substantial relief
Moderate	Significant duplex soils & low relief landscapes
High	Mostly duplex soils & low relief landscapes

Note: This table is based on assessment of soil texture (presence of duplex soils) and landform (whether this is amenable to drainage or otherwise).

Table 2.7 Criteria used in the assessment of inherent hydrogeological risk conducive to groundwater discharge

Criteria
Assignment of risk category is dependent upon assessment of the following hydrogeological parameters: aquifer characteristics (storage, permeability, horizontal gradients) nature of groundwater flow system (local or regional system) landform & position in landscape (top or bottom of catchment) influence from other adjoining aquifer systems (vertical gradients)

Note: This table is based on various sources of expert knowledge.

The risk category (low, moderate, high) was judged for each PDZ using available field, analytical and conceptual modelling data. As an example, end members of the risk category spectrum may exhibit the following characteristics:

- Low risk can be expected to be characterised by upper catchment location, substantial slope, high permeability, no upward groundwater contribution from underlying aquifers.
- High risk can be expected to be characterised by lower catchment location (eg. landlocked by ocean), subdued slope, low permeability, significant upward groundwater contribution from underlying aquifers.

2.2.2 Environmental risk and threats to biodiversity

In determining environmental risk, the threat to biodiversity posed by each of the PDZs was considered most important. The threat to biodiversity is considered highest where environmental assets of regional or state significance are threatened. These threats may include clearing, waterlogging, salinity, spray drift and weed encroachment.

To enable the risk to be determined, the relevant conservation significance of all environmental assets present in the PDZs were identified. A subjective risk assessment was then applied by comparing the significance of the asset with the opportunity to minimise the threatening processes posed by the establishment and management of irrigated agriculture (refer to Table 2.8).

Table 2.8 Environmental risk classes and definitions

Environmental risk	Asset description	Definition
Low	Unacceptable threat to sites of high environmental significance or biodiversity	Presence in PDZ of environmental assets of regional or higher significance, with no reasonable opportunity to reduce the threat from development
Moderate*	Manageable threats to sites of high environmental significance or biodiversity	Presence in PDZ or surrounds of environmental assets of regional or higher significance, but threats can be reduced through appropriate siting and management
High	Minor or no threat to sites of high environmental significance or biodiversity	No known environmental assets of regional or higher significance in or surrounding the PDZ

* Note: Appropriate management could include the establishment of buffers between the PDZ and environmental asset, or the application of best management practices to ensure that environmental threats are controlled.

3 Land capability for irrigated agriculture in the study area

To adequately identify PDZs for irrigated agriculture, it is necessary to have a good understanding of soil drainage and the quality of water to be applied. In addition, it is necessary to know where agriculture can take place, as not all land is available for agricultural use.

Soil drainage is influenced by position in the landscape, soil texture, soil structure and soil chemistry. Between them, these components will determine the long-term structural stability and drainage characteristics of the soil profile under irrigation. This in turn will dictate irrigation management practice on-farm.

Water quality will also influence irrigation management on-farm as recycled water is frequently higher in salinity, nutrients and organic materials than potable water. These properties commonly result in a reduction in soil drainage capacity through a breakdown in soil structure and clogging of soil pores.

Therefore, prior to the establishment of irrigation infrastructure, it is important to understand the complex relationship between the quality of recycled water to be used and the soil hydraulic and chemical properties.

This high level of investigation was not possible within the scope of this study. A simplified approach assessing the basic soil hydraulic properties has been used as a surrogate measure for the capability of land to support irrigation, irrespective of water quality.

Existing soil-landform studies have provided the basic soil texture and structure information required for the land capability assessment. Table 3.1 describes the soil-landform studies used to collate the soil-landform information for the study area, while Map 3.1 shows the extent of the digital soil-landform mapping available.

3.1 *Soil and landforms of the study area*

The area immediately west of the Western Treatment Plant (WTP) is dominated by the volcanic (basalt) plains with other geological features such as the sedimentary hills to the north. The treatment plant is sited on the alluvial plain of the Werribee River where irrigated agriculture is already well established.

The Eastern Treatment Plant (ETP) is situated in a low lying area (Carrum Swamp) that divides the sandy undulating plain to the north and east, with the uplifted hills of the Mornington Peninsula to the south. The dune/sandsheet terrain is utilised for irrigated agriculture at Five Ways and Cranbourne. The uplifted hills contain older basalt outcrops, sedimentary rises, occasional granitic hills (Mt Martha, Arthurs Seat) and basalt hills to the south-east (Red Hill). Sand sheets and old beach ridges are superimposed on the older sedimentary rocks, particularly just south of Carrum Downs. Lower-lying unconsolidated calcareous sediments also occur to the south-west, these include the Boneo irrigation area.

Table 3.2 presents a summary of the major landforms that are of interest for irrigated agriculture in the study area. Soil types may vary within these landscapes, therefore a brief description is provided to distinguish differences in soil structure, drainage characteristics, and capability to support irrigated agriculture. The land capability has been determined by comparing the existing soil-landform properties with those criteria listed in Table 9.1.

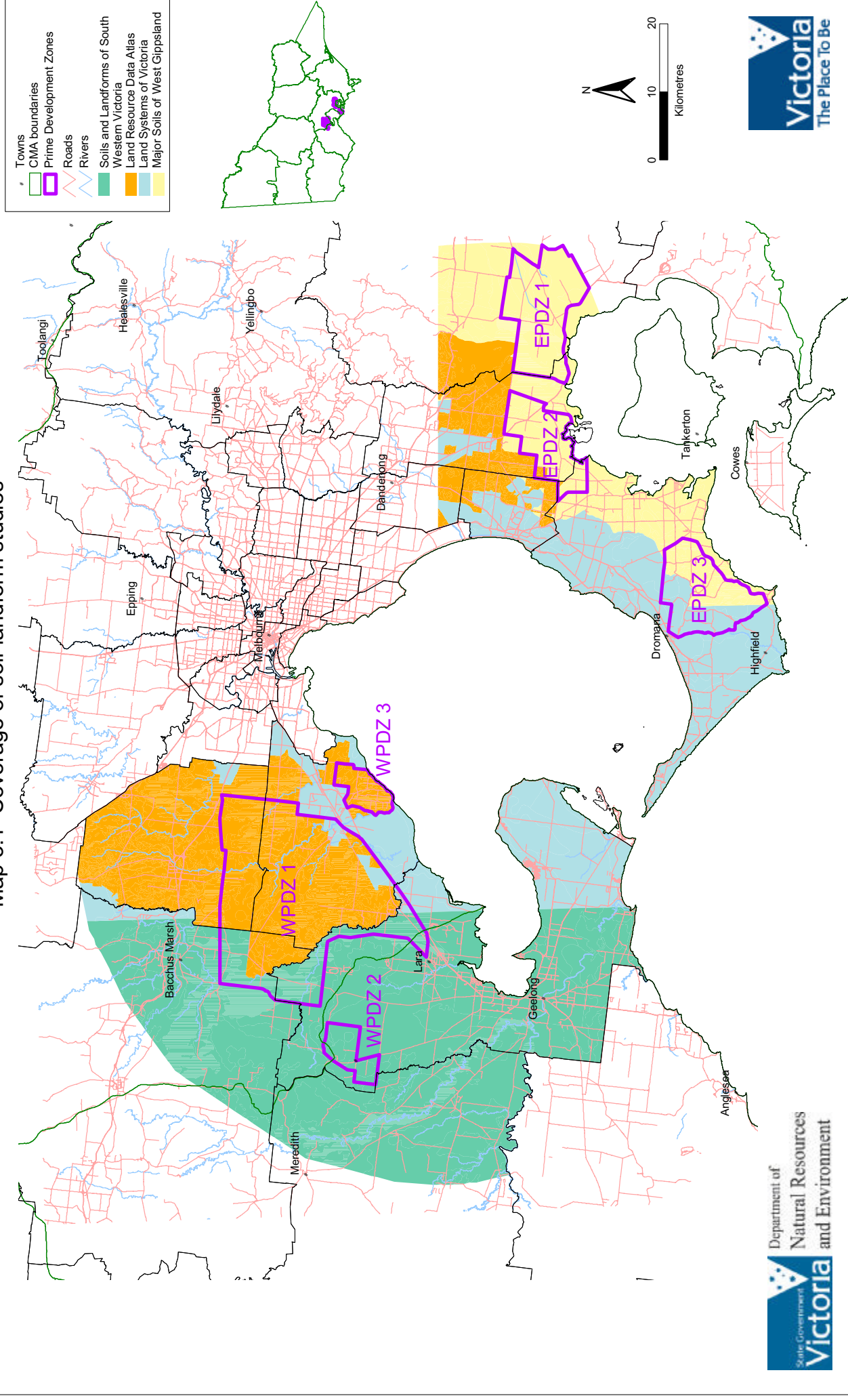
Table 3.1 Existing soil-landform studies in the greater Melbourne study area

Report	Comment	Scale
Soil and Landforms of South-Western Victoria (Maher & Martin 1987)	This report has described and mapped the major soil types and associated landforms. This included investigations of over 2.4 million hectares and 237 different soils.	1:100 000
Land Resource Data Atlas – Non Urban Areas (White & Kelynack 1985)	This study presents the location and extent of soil types across the Metropolitan area while also addressing the constraints and limitations to land capability.	1:25 000
Land Systems of Victoria (Rees 2000)	This report contains the only complete soil-landform mapping for the study area with basic classification of soils and landforms.	1:250 000
Major Soils of West Gippsland (Sargeant & Imhof in press)	This report is based on a previous study of the Westernport catchment (Sargeant, 1975) with revisions and extension eastward. The major output is soil landform mapping with descriptions of the major soil types.	1:100 000
A land capability study of the Cardinia Shire (MacMillan, Smith & Baxter, 1997)	This study presents the location and extent of soil types across this Shire while also addressing constraints and limitations to land capability.	1:25,000

Table 3.2 Major soil-landform units and soil properties for irrigated agriculture.

Major soil-landform units	Soil type Principal Profile Form (Northcote 1979)	Occurrence and management implications	Land capability class
Western volcanic plains – complex of volcanic cones, undulating and flat plain, open depressions and drainage lines	Gn4.13, Dr4.13, Dr5.13 Deep, well structured, alkaline red and reddish brown gradational and duplex soils, occasionally calcareous at depth.	Soils on the hill slopes of cones, undulating and flat plains, generally rock free and well drained with moderate to rapid permeability, but with slaking in the subsoil.	High to Moderate
	Db3.13, Db3.43, Gn4.3 Deep, brown basaltic clays or strongly structured duplex soils, with occasional A2 horizons and calcareous inclusions.	Soils on the undulating and flat plains, often rocky and poorly drained with moderate to slow permeability, moderate dispersion and rapid slaking present in the subsoil.	Low
	Db3.13, Db3.23, Dd3.1 Deep, well structured, friable duplex soils, with occasional A2 horizons and calcareous inclusions.	Soils in drainage lines, with very poor drainage, moderately permeable surface soils and very slow permeability in the subsoil, high risk of seasonal waterlogging or flooding.	Very Low
Sandy undulating plain	Uc2.32 Deep sandy soils with common hard pans or coffee rock at depth.	Soils as sand sheets of variable depth with excellent drainage and rapid permeability. Poor nutrient holding capacity and rooting depth may be affected by hard pans at a depth of 1 m.	High
Low volcanic hills	Gn3.11, Gn3.75, Deep, red brown, well structured gradational soil.	Soils on crests and moderate hill slopes, well drained with moderate to high permeability. High risk of sheet erosion and land slip on steeper slopes.	Very High
	Dy3.41, Dy3.31 Yellow, weak to moderately structured, mottled duplex soils.	Soils occur on undulating lower hills with gentle slopes, poorly drained with slow to imperfect subsoil permeability.	Low
Westernport alluvial plain	Uf6.22 Grey, strongly structured, organic peaty clay soils.	Soils occur within the drained Koo Wee Rup Swamp, with deep well drained topsoils and moderately permeable subsoils.	High
	Uf Grey, weak to moderately structured clay soils.	Soils occurring on the alluvial plain adjacent to the Koo Wee Rup Swamp, with deep, poorly drained topsoils and slowly permeable subsoils. Risk of seasonal waterlogging or surface ponding is high.	Very Low

Map 3.1 Coverage of soil-landform studies



The land capable of supporting irrigated agriculture is shown in Map 3.2. This map distinguishes land of varying capability for irrigated agriculture in the PDZs. Irrigated agriculture is best suited to land in class 1, 2 and 3, while land in class 4 and 5 is not considered capable of supporting irrigation. These classes are defined in Table 9.2 (Appendix B). As only land in class 1,2 and 3 are considered capable of supporting irrigated agriculture, a comparison of available land in each capability class is presented for each PDZ in Table 3.3.

Table 3.3 Area of land (hectares) available in each capability class for irrigated agriculture

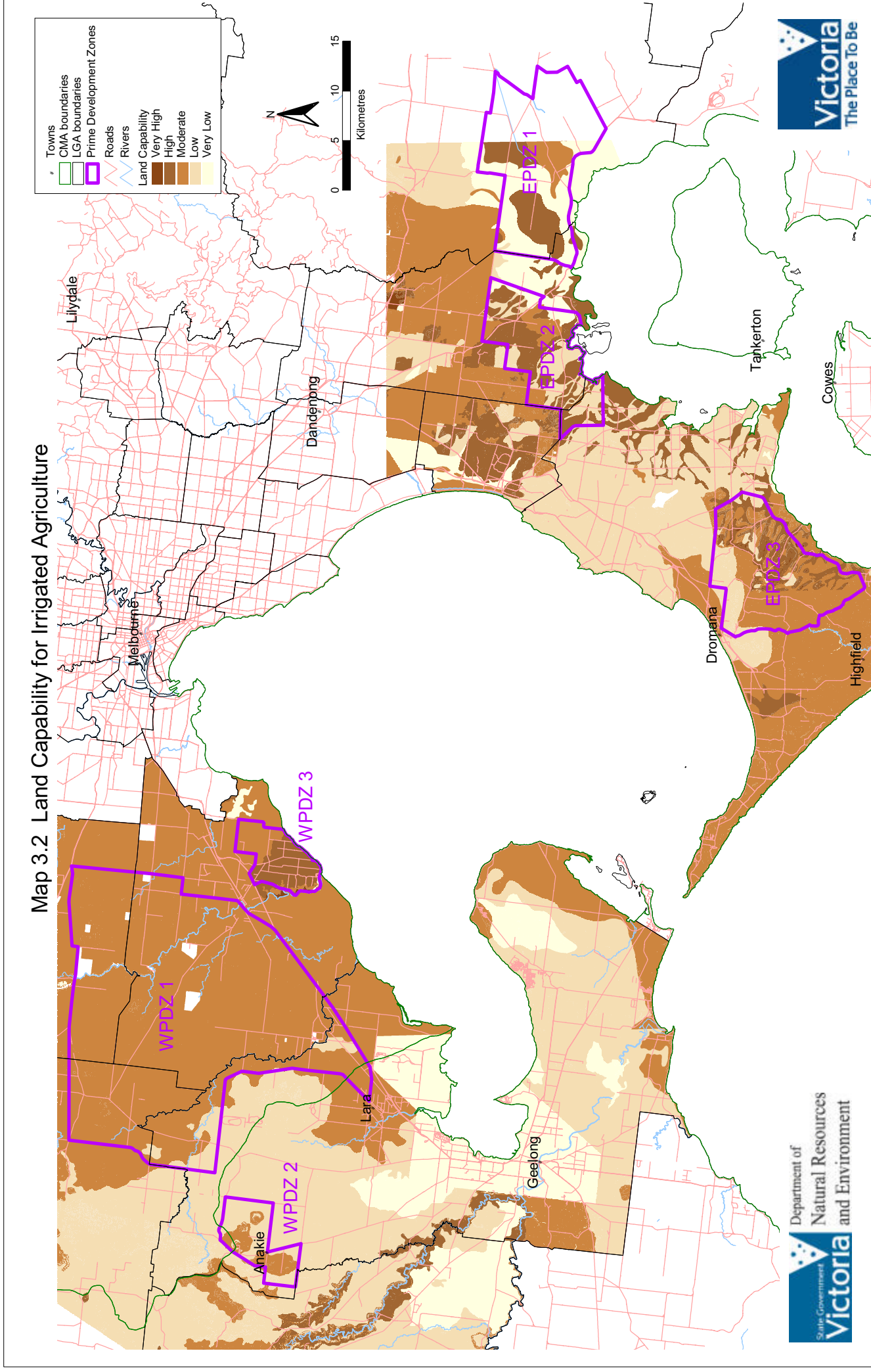
PDZ	Total area of PDZ	Excluded areas	Area of land available for irrigated agriculture	Area of land available in each land capability class				
				1	2	3	4	5
WPDZ1	59 073	8003	48 949	0	0	48 949	1997	0
WPDZ2	4046	397	1368	0	0	1368	2282	0
WPDZ3	3932	64	3844	51	2313	1480	0	23
EPDZ1	16 188	6210	6722	0	1702	5020	52	3202
EPDZ2	9863	1094	5567	0	4243	1324	2520	682
EPDZ3	13 333	1745	9983	166	3211	6606	1606	0
Total	106 435	17 513	76 433	218	11 469	64 746	8457	3907

This comparison has enabled PDZs with competitive advantages to be viewed. Ideally, those PDZs with the highest proportion of land in capability class 1 and 2 are generally preferred for new irrigation development, as this land will have lower management inputs and improved productivity. Under this scenario, EPDZ1, EPDZ2, EPDZ3 and WPDZ3 are favoured for irrigation development. However, when assessing the available area for irrigation development and the long-term potential for expansion, WPDZ1 is preferred above all PDZs.

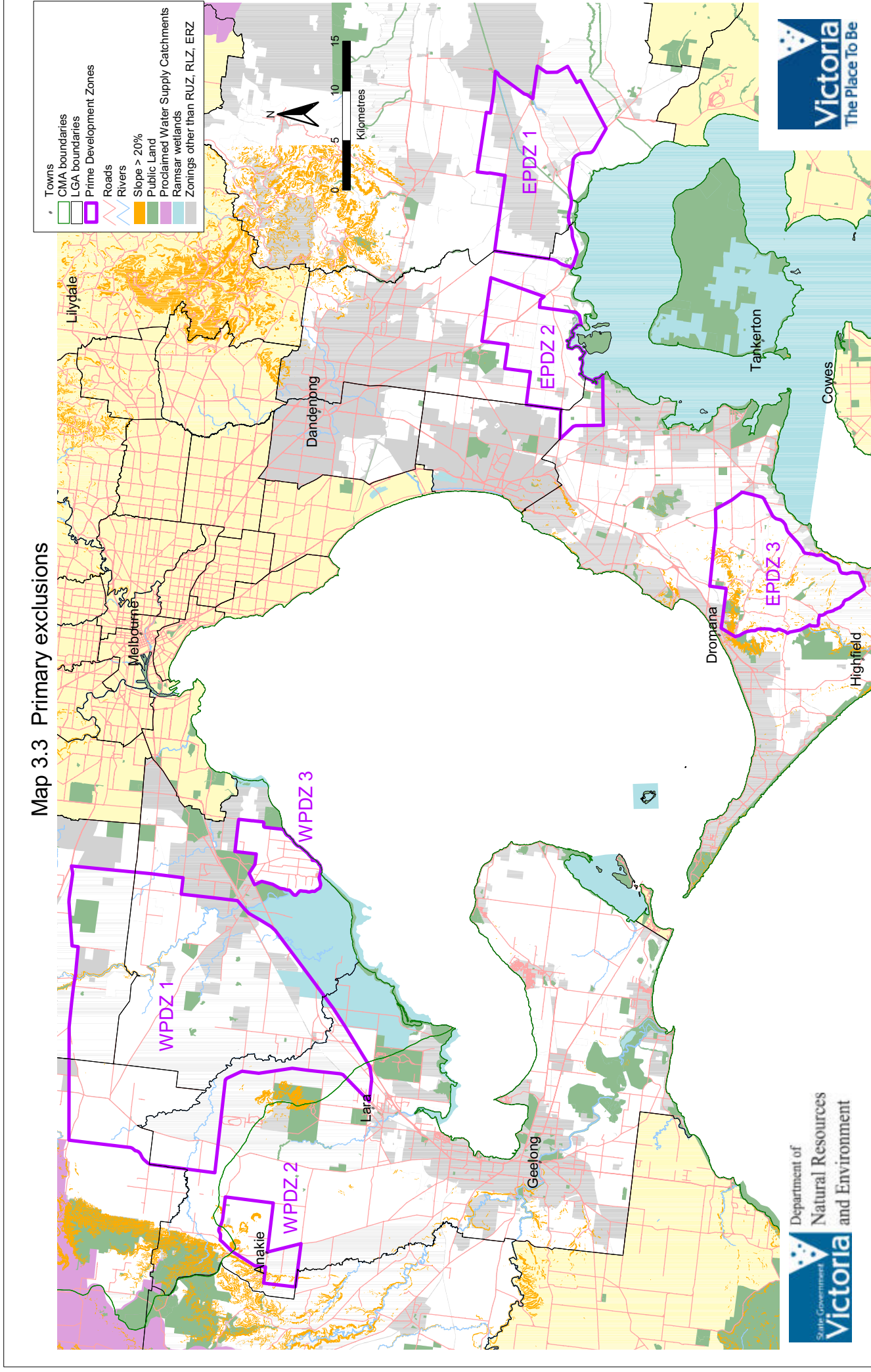
3.2 Other considerations for irrigation development

The land available for agriculture on the urban fringe of Melbourne is constrained by existing land tenure, zoning and other institutional factors such as legislative, statutory and policy controls. These factors exclude this land from future agricultural development (refer to Map 3.3). The proximity of PDZs to urban areas, utilities and sites of environmental significance also need careful consideration. The management of these issues will require buffer zones or some form of acceptable urban/rural interface that would minimise nutrient, pesticide and noise pollution. The use of relevant policy and zoning controls within municipal planning schemes can provide this level of protection, but will need support from local government and the Department of Infrastructure (DOI).

Map 3.2 Land Capability for Irrigated Agriculture



Map 3.3 Primary exclusions



4 Groundwater and salinity in the study area

Past experience with irrigation development in Victoria suggests that rises in groundwater level and salinity are common. This has resulted in widespread environmental degradation, particularly the deterioration of water quality in rivers, streams and wetlands. New irrigation developments must meet irrigation management guidelines that ensure efficient use of water and nutrients on-site, thereby minimising the need for rehabilitation activities. This will result in the development of sustainable and profitable irrigation developments. This is particularly important when considering the proximity of urban growth corridors to certain PDZs, and the potential damage to local and regional infrastructure.

The greater Melbourne study area has existing hydrogeological studies. However, the variability and scale of the information can provide only a coarse assessment of the PDZs. Existing studies used to prepare the hydrogeological and salinity risk assessment are summarised in Table 4.1.

Table 4.1 Existing hydrogeological studies in the greater Melbourne study area

Report	Comment
Port Phillip Region Groundwater Resources- Future Use and Management (Leonard 1992)	Report describing characteristics of groundwater systems, hydrogeology of the aquifers, groundwater resources and groundwater pollution.
Environmental Impact Statement (Tyco 2001)	Report assessing the soil, landform, geology, hydrogeology and groundwater modelling for the Westernport alluvial plain.
Melbourne Water WTP Preliminary Hydrogeological Review (Coffey Partners International Pty Ltd 1995)	Hydrogeology, groundwater modelling results for the Western Treatment Plant.
Land Disposal of Wastewater – Water and nutrient balance study Werribee Treatment Plant (SKM/NRE, 1996)	Geology, hydrogeology, soil nutrient balance study for the Western Treatment Plant.
1998 Watertable Surface for Port Phillip and Westernport (SKM 1999)	Modelling of depth to watertable, mapping prepared for the National Land and Water Audit.

In undertaking the assessment, the general hydrogeological framework for the study area, and the risks associated with existing salinity, high watertables, perched watertables and regional groundwater pressures have been evaluated. The opportunity to utilise aquifers for Managed Aquifer Recharge (MAR) or supplementary water supply was also examined. These issues are discussed below.

4.1 Conceptual hydrogeological framework for the study area

The hydrogeology in the region consists of ancient folded and fractured basement rocks that are in part covered by younger unconsolidated sediments and volcanics of Cainozoic age. The important yielding aquifers in the region are the sand, clay, gravel and limestone of the Werribee Formation, Batesford Limestone, Fyansford Formation-Brighton Group, and Bridgewater Formation. Older and Newer Volcanics occasionally support important aquifers. In the Westernport Basin the major aquifers include the extensive Tertiary Westernport Group aquifer system and localised aquifers in the surficial Quaternary sand and alluvial deposits. The collective network of Tertiary and Quaternary aquifers is interconnected in places and attains a total thickness of up to 250 metres onshore.

4.2 Current groundwater and soil salinity risk in the study area

Map 4.1 indicates the interpreted depth to watertable across the Port Phillip and Westernport catchments. This was generated using 1998 bore data from the statewide groundwater monitoring program, and is presented in terms of critical groundwater depth ranges.

Adjacent to the east and north-east perimeter of Port Phillip Bay, and the northern perimeter of Westernport Bay, watertables are shallow across coastal swamps, alluvial and basalt plains. These watertables are strongly controlled by sea level conditions. A delicate interaction exists between land management and the coastal hydrogeological environment. In general, the groundwater system has watertables within five metres of the surface. These watertables are strongly influenced by surface water management including drainage and irrigation management. Sea water intrusion impacts have been recognised in some areas where groundwater is pumped or drained.

Moving away from plains adjacent to the coast, watertable levels and salinity are less influenced by tidal movement and depth to watertable increases. On the basalt and alluvial plains, watertable depth and salinity is generally influenced by subtle variation in the landscape. On the basalt plains, incised streams are prone to receiving brackish to saline groundwater inflow. This is partly a natural condition, but is significantly exacerbated by land management change. Depressions in the landscape are also at risk where high watertables are found within capillary reach of the surface.

In the sand belt country to the south-east of Melbourne, salinity will generally be contained due to better system permeability.

In the uplands north of Melbourne, the Mornington Peninsula and the islands of Westernport Bay there are significant though localised areas of high watertable and salinity associated with fractured rock aquifer systems. Salinity characteristically develops at the break-of-slope and groundwater depth is strongly controlled by topography.

In terms of future irrigation development, watertable rise is likely to be area specific. This will mainly depend upon irrigation management practice, and local soil and groundwater conditions. Salinity is likely to occur where high watertables and irrigation development coincide.

Based on the available information, the overall groundwater and salinity risk has been summarised in Table 4.2. Factors that determine groundwater and soil salinity risk have been discussed and tabulated in section 2.2.1.

Table 4.2 Hydrogeological and salinity risk ratings for all PDZs

PDZ	Groundwater risk		Soil salinity risk		Overall risk
	Risk to beneficial groundwater quality	Elevated watertable risk	Perched watertable risk	Inherent hydrogeological risk	
WPDZ1	Low	Moderate	Moderate	Moderate	Moderate
WPDZ2	Low	Moderate	Moderate	Low	Moderate
WPDZ3	Moderate	Moderate	Low	Moderate	Moderate
EPDZ1	High	High	Moderate	High	High
EPDZ2	Moderate	High	Low	Moderate	Moderate
EPDZ3	Moderate	Low	Low	Low	Low

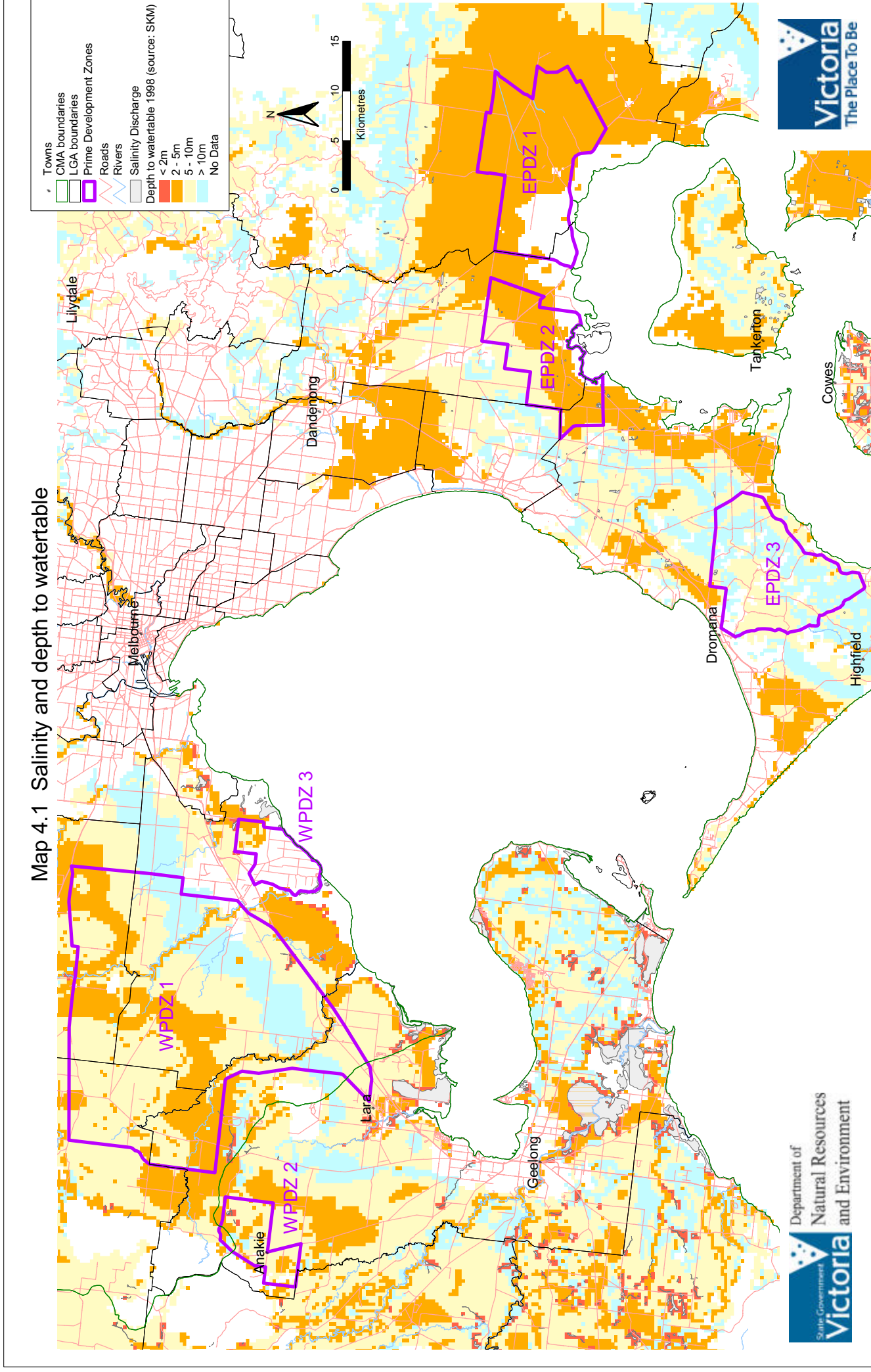
4.3 Potential groundwater resources in the study area

Groundwater quality and bore yields vary considerably in the study area. Useable groundwater occurs in the highly fractured and/or deeply weathered rocks in Kinglake, Monbulk and Silvan, the Bridgewater Formation on the Nepean Peninsula, and in the Groundwater Management Areas (GMAs) of Dalmore and Lang Lang in the Westernport catchment. Authorised extraction for irrigation water is licensed and managed by Southern Rural Water.

The demand for groundwater is generally highest in low rainfall areas (less than 750 mm per annum), particularly in the west where marginal to poor quality groundwater is most common. A summary of the groundwater resources of the study area is contained in Table 9.4, Appendix D.

Aquifer recharge is mainly through direct infiltration of rainfall into unconfined aquifers or into the outcrop areas of confined aquifers. Groundwater discharge primarily occurs offshore into the bays, or onshore into streams that drain the various catchments, low-lying swamps and coastal wetlands.

Map 4.1 Salinity and depth to watertable



4.4 Potential for Managed Aquifer Recharge in the study area

Managed Aquifer Recharge (MAR) is the artificial replenishment of groundwater aquifers with either stormwater or effluent water. MAR may provide an alternative to direct application of recycled water to land.

In Victoria, there are no MAR systems currently operating although there have been several feasibility studies carried out (Thompson 1972; Carrillo-Rivera 1976; Lakey 1978). The Carrillo-Rivera (1976) study describes recharge trials at the Eastern Treatment Plant and showed that treated sewerage can be injected into the confined Older Volcanics. Johnston (1990) summarised the processes controlling infiltration from a basin at Barwon Downs near Geelong, with results indicating that variation in stratigraphic profile is the major controlling factor for infiltration.

MAR is achieved via surface infiltration basins or direct pumping (also called injection) into purpose drilled bores. MAR is used worldwide (Dillon & Pavelic, 1996) as a water conservation, storage and quality improvement technique. Injection wells have advantages over infiltration basins in that recharge is directly into the aquifer. Therefore, resource losses due to evaporation and economic losses from submerging land are minimised. Where aquifers are confined or semi-confined by overlying clays, infiltration basins and recharge channels may be ineffective. In these cases injection wells may provide economic recharge rates (Dillon & Pavelic 1996).

The use of MAR as a water treatment tool is well established (Bouwer 1996), particularly with infiltration basins, whilst research into the advantages and disadvantages of injection recharge continues. In South Australia, MAR currently provides temporary storage of sewerage effluent for irrigated horticulture in Virginia, while a trial to supply the viticulture industry in Maclaren Vale is also underway.

The Werribee Formation aquifer holds the greatest potential as a reservoir for recycled water storage in the study area. The aquifer has favourable hydraulic properties with bore yields of up to 50 L/sec. Although salinities of up to 5000 mg/L TDS have been recorded, it has been shown that good quality water can be maintained close to the injection bore where mixing between injected water and groundwater occurs at the margin of the injection plume.

4.5 Constraints to future agricultural development

The interaction between irrigation water and groundwater condition is physically and chemically complex. Irrigation water may increase or decrease salt concentrations in the underlying groundwater depending upon irrigation management and maintenance of leaching fractions. With recycled water, the additional salt and nutrient concentration must be considered and managed appropriately.

The maintenance of a leaching fraction to control soil salinity will result in increased recharge to the groundwater system. Poor irrigation management may lead to the development of perched watertables on duplex soils, or rising watertables in unconfined aquifers. This can be exacerbated by the selection of land with sodic soils and poor drainage.

Engineering options such as sub-surface drainage systems or active groundwater pumping can effectively manage salinity and take advantage of excess water, but extensive hydrological investigation is required to determine their long-term viability.

When evaluating the need for drainage, the true economic and environmental cost of drainage disposal should be considered as the long-term costs may exceed the value of production from the irrigation scheme. Therefore, irrigation design and layout should aim to effectively control all water and nutrient input on-site thereby eliminating the need for drainage and the potential for off-site environmental damage.

5 Sites of environmental significance and threats to the biodiversity in the study area

The greater Melbourne study area contains many sites of regional and statewide conservation significance. However, large-scale intensive horticultural development may result in the incremental loss of environmental quality within the study area. This may occur through the clearance of native vegetation, disposal of drainage water, chemical spray drift or weed encroachment. Therefore, it is important to understand what environmental assets exist and undertake planning to conserve them.

The environmental assets and the policies and legislation protecting these assets are reviewed in a number of reports. This information has been used in the determination of environmental risk. The reports are summarised in Table 5.1

Table 5.1 Environmental reports used in the study

Report	Comment
Draft Port Phillip and Westernport Native Vegetation Plan (PPWCALP 2000)	Main source of flora and fauna data and strategies for managing these assets. Used to determine secondary exclusion zones (environmental).
Draft Corangamite Native Vegetation Plan (CCMA 2000)	Used for vegetation within the Corangamite CMA region, to ensure consistency with the region's vegetation management strategy. Used to determine secondary exclusion zones.
Werribee Catchment Action Program (PPWCALP 1999)	Used as background for catchment management priorities in the western study area.
Westernport Catchment Action Program (PPWCALP 1999)	Used as background for catchment management priorities in the eastern study area.
State Environmental Protection Policy, Waters of Victoria (EPA 1988)	Used to ensure compliance with water quality protection legislation in siting of PDZs.
Protecting the Waters of Western Port and Catchment, Schedule F8 to State Environmental Protection Policy, Waters of Victoria (EPA 2000)	Used to ensure compliance with Western Port catchment water quality protection legislation in siting of PDZs.
Guidelines for Wastewater Irrigation (EPA 1991)	Used to ensure compliance with wastewater irrigation standards in siting of PDZs.
Port Phillip & Westernport CALP Annual Report 2000/01 (PPWCALP 2001)	Used for stream condition data.
Flora and Fauna Guarantee Strategy (DCE 1992)	Provided Victorian rare and threatened species policy.
Victoria's Biodiversity Strategy (NRE 1997)	Provided Victorian biodiversity policy.

The entire eastern study area and the majority of the western study area is under the management of the Port Phillip and Westernport Catchment and Land Protection Board (PPWCALP). The main policy relevant to native vegetation in this region is the *Draft Port Phillip and Westernport Native Vegetation Plan* (PPWCALP 2000). The remaining area to

the far west is under the management of the Corangamite Catchment Management Authority (CCMA), this area has a native vegetation management policy outlined in the *Draft Corangamite Native Vegetation Plan* (CCMA 2000).

The goals of the *Draft Port Phillip and Westernport Native Vegetation Plan* are:

1. To maintain the extent and quality of indigenous vegetation in the region at 2001 levels, leading to a net gain in the future.
2. To ensure areas of priority vegetation in the region are maintained, enhanced and protected in the long-term.
3. To achieve comprehensive and representative cover of indigenous vegetation across the region.
4. To enhance the connectivity of native vegetation across the region to maintain ecological processes.
5. To protect land, air and water resources through strategic revegetation.

The goals developed under the plan provide a strategic framework for managing native vegetation in the Port Phillip and Westernport region. The goals of the adjacent *Draft Corangamite Native Vegetation Plan* are generally consistent with those of the Port Phillip plan.

Supporting the draft native vegetation plans are *Victoria's Biodiversity Strategy* (1997) and the following state legislation:

- *Planning and Environment Act 1987* (Vic)
- *Flora and Fauna Guarantee Act 1988* (Vic)

5.1 Sites of environmental significance in the study area

Since European settlement, much of the study area has been cleared and drained for agricultural, industrial and residential development. However, the study area still supports a diverse, but fragmented range of vegetation and wetland communities. These remaining communities are of high conservation value.

The landscape of the study area has been classified into bio-geographic regions (bioregions) at both a national and state level. Bioregions reflect the underlying environmental features and ecological patterns of the landscape. Under the Victorian classification, which forms part of the national IBRA framework (Interim Biogeographic Regionalisation of Australia), the western study area falls predominantly within the Victorian Volcanic Plains bioregion, but includes some parts of the Otway Plain and Central Victorian Uplands bioregions. The eastern study area falls within the Gippsland Plain bioregion.

The following is a discussion of the environmental assets of the study area.

5.1.1 Native vegetation

Vegetation mapping in Victoria has been undertaken at a range of scales, including the coarser-scale Broad Vegetation Type (BVT) mapping, and the finer-scale Ecological Vegetation Class (EVC) mapping. Due to incomplete EVC mapping of the Port Phillip and Westernport region, the *Draft Port Phillip and Westernport Native Vegetation Plan* used BVTs and Vegetation Management Units (VMU) consisting of proximal BVT fragments as the basis for its management strategy. In contrast, the *Draft Corangamite Native Vegetation Plan* was based on EVC mapping that has been completed for the CCMA region.

The study area contains a number of BVTs that are significantly depleted at a regional and state level. The BVTs have been assigned a very high priority for retention under the *Draft Port Phillip and Westernport Native Vegetation Plan*, and as such, clearing of these BVTs should be avoided. Table 5.2 lists important BVTs in the study area. The areas shown are for the Port Phillip and Westernport CALP region only.

Table 5.2 Broad Vegetation Types with very high priority for native vegetation retention

BVT	Original vegetation (ha)	Existing vegetation (ha)	Percentage remaining (%)
Grassland	204 724	6137	3
Plains Grassy Woodland	176 091	8351	5
Swamp Scrub	26 696	1456	5
Lowland Forest	93 973	7150	8
Coastal Scrubs and Grassland	35 154	4436	13
Heathy Woodland	44 017	13 578	31
Heath	26 213	8123	31
Herb-rich Woodland	6688	3334	50

Source: PPWCALP (2000)

Map 5.1 indicates the priorities for native vegetation retention in the study area, reproduced from the *Draft Port Phillip and Westernport Native Vegetation Plan*. Vegetation retention priorities in the Corangamite CMA region have been derived using EVC Bioregional Conservation Status mapping from the *Draft Corangamite Native Vegetation Plan*. As shown in Map 5.1, almost all of the remaining native vegetation within the study area has been assigned a very high priority for retention. These communities should therefore be protected from inappropriate development.

For native vegetation with a lower priority rating, the *Draft Port Phillip and Westernport Native Vegetation Plan* has described a framework for guiding decision making. Under this framework, consideration is given to the value of the vegetation as habitat for threatened or

migratory species (or other species-related attributes), the contributions to existing or proposed corridors, and the value to wetlands. For the purposes of this study, where native vegetation provides habitat for Victorian Rare or Threatened Species (VROTS) or Flora and Fauna Guarantee (FFG) listed flora and fauna species, the conservation significance is regarded as very high. Habitat maps for threatened flora from the *Draft Port Phillip and Westernport Native Vegetation Plan* have been reproduced in Map 5.2.

An appropriate buffer should be used for development adjacent to native vegetation to ensure that vegetation is protected from off-site effects such as chemical spray drift and weed infestation. Buffer widths need to be designed to suit the individual requirements of each area of vegetation, but as a minimum the *Draft Port Phillip and Westernport Native Vegetation Plan* has recommended a buffer width of 10 m for vegetation remnants. Generally, the greater the conservation significance, the wider the buffer should be made.

As an alternative, the buffer widths provided in Table 5.3 (Higgins 2000) are specifically designed to protect native vegetation adjacent to horticultural development.

Table 5.3 Proposed buffer widths based on regional conservation significance

Conservation significance of adjacent vegetation	Proposed buffer width (m)
Very High	50
High	40
Medium	30
Low	20

Source: Higgins (2000)

5.1.2 Fauna

The study area provides habitat for a large number of rare and threatened fauna species, including species protected under international agreements. Within the Port Phillip and Westernport CALP region, there are approximately 120 species of threatened wildlife, with some vegetation communities such as the Grassland BVT of the western plains, home to over 20 threatened species.

The main legislation and policies relevant to fauna in this region are:

- *Flora and Fauna Guarantee Act 1988* (Vic)
- *Victoria's Biodiversity Strategy* (NRE 1997)
- *Japan-Australia Migratory Bird Agreement* (JAMBA)

- *China-Australia Migratory Bird Agreement (CAMBA)*
- *The Bonn Convention of Migratory Species of Wild Animals*

Only vertebrate fauna data are considered in this study, as invertebrate data are limited. Records of fauna sightings across the state are kept in the *Wildlife Atlas of Victoria* maintained by NRE. Together with the recorded sightings of each species, the Atlas contains information on the species' threatened status and the FFG listing status.

The extent of threatened and listed fauna is closely linked to remnant native vegetation in the study area (refer to Map 5.2). This is supported by additional mapping contained in the *Draft Port Phillip and Westernport Native Vegetation Plan*. The plan also details those areas of vegetation provide habitat for birds migrating from China and Japan (CAMBA and JAMBA) and species listed under the Bonn Convention.

Where an area of native vegetation provides habitat for species listed under the FFG Act, CAMBA/JAMBA or the Bonn Convention, there is an obligation to consider the impact of development on the survival of threatened species. This is particularly important given the current level of clearing and fragmentation within the study area. It is therefore recommended that native vegetation is retained and protected where species are at risk from development.

In addition to the habitat value provided by existing vegetation, the *Draft Port Phillip and Westernport Native Vegetation Plan* has mapped proposed wildlife corridors. The creation of wildlife corridors aims to provide links between different populations of wildlife, ensuring evolutionary processes and habitat range are protected. This may be achieved through revegetation and complementary land management activities on public and private land. The regional corridor network proposed under the *Draft Port Phillip and Westernport Native Vegetation Plan* utilises road, rail and riparian corridors where possible to connect fragments of remnant vegetation. Where possible, the proposed regional corridor network should be recognised and implemented within the PDZs.

5.1.3 Rivers, streams and wetlands

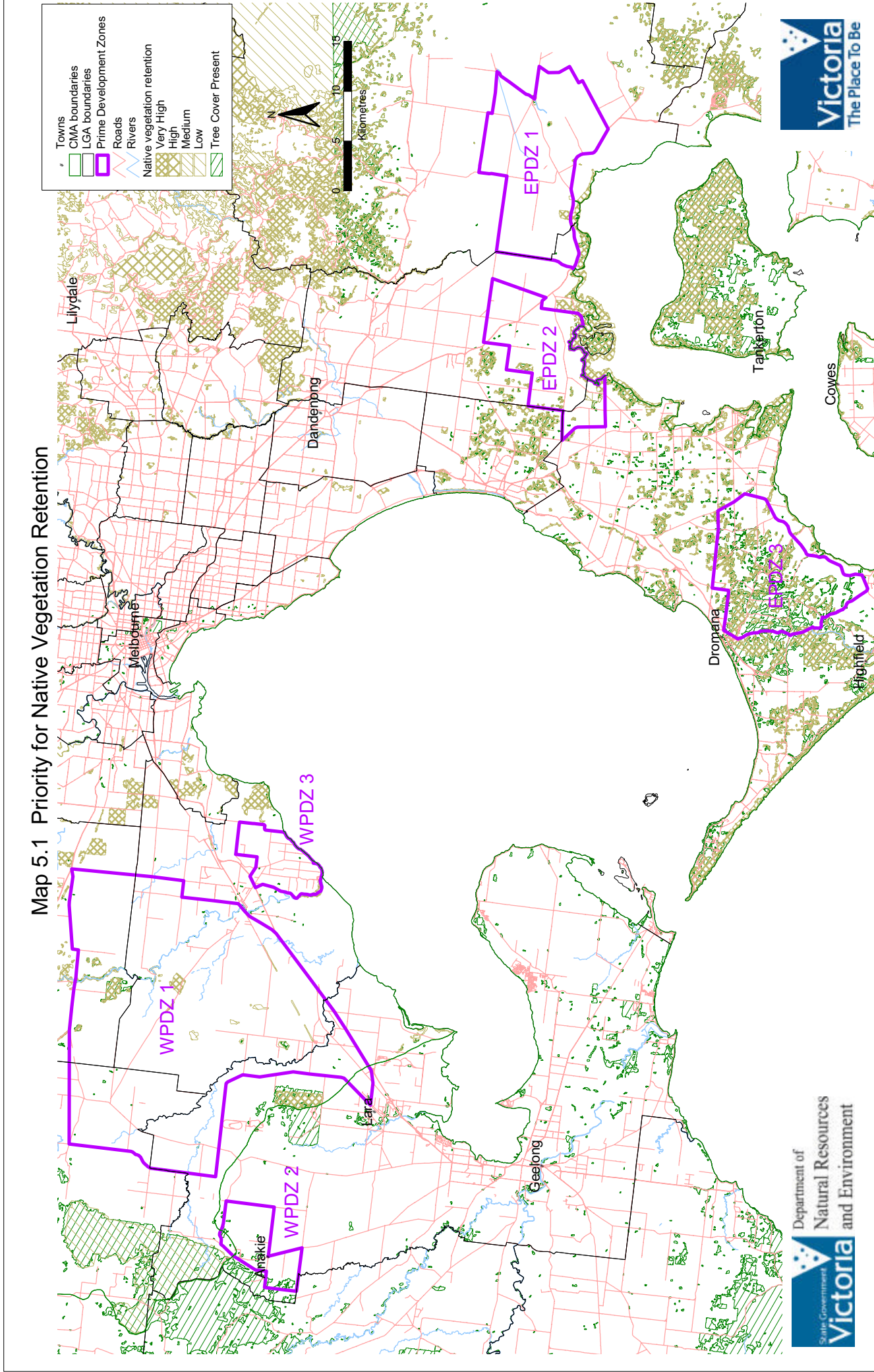
With respect to PDZ selection, the main legislation and policy relevant to streams, rivers and wetlands in the study area are:

- *State Environment Protection Policy - Waters of Victoria* (EPA 1988)
- *Guidelines for Wastewater Irrigation* (EPA 1991)
- RAMSAR/JAMBA/CAMBA/Bonn Convention

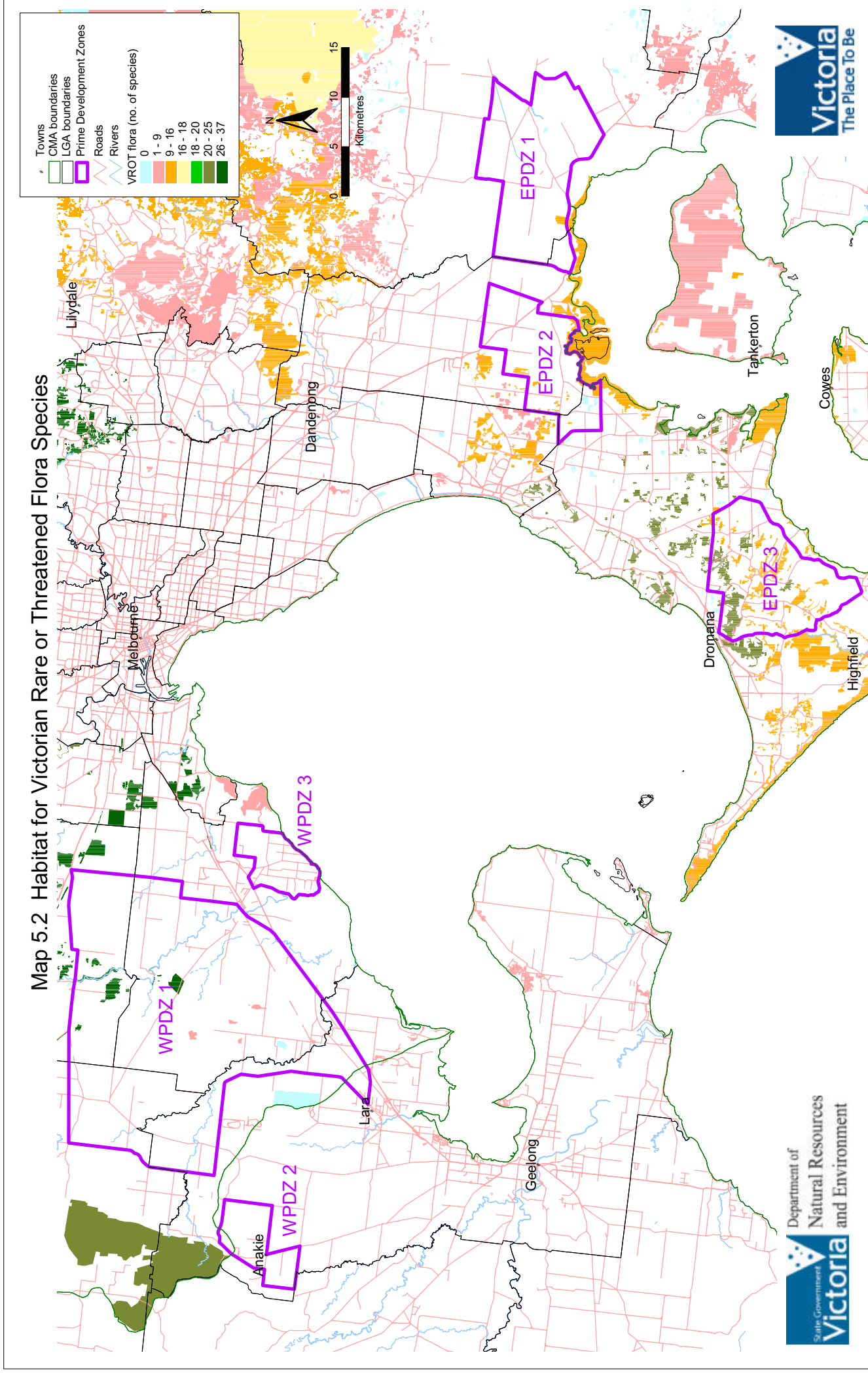
The waterways of the study area are generally degraded, with most streams in the study area having an Index of Stream Condition rating of moderate to very poor (PPWCALP, 2001).

There are two RAMSAR-listed sites in the study area, one covering Westernport Bay, and the other extending over parts of western Port Phillip Bay and the Western Treatment Plant. The

Map 5.1 Priority for Native Vegetation Retention



Map 5.2 Habitat for Victorian Rare or Threatened Flora Species



Towns

- CMA boundaries
- LGA boundaries
- Prime Development Zones
- Roads
- Rivers
- VRoT flora (no. of species)

0
1 - 9
9 - 16
16 - 18
18 - 20
20 - 25
26 - 37



RAMSAR-listed wetlands within the study area have been included as a primary exclusion layer during the PDZ selection process.

The *State Environment Protection Policy - Waters of Victoria* (2000) prohibits the disposal of wastewater by irrigation within 100 m of surface waters. For the purposes of this study, a 100 m exclusion buffer should be applied around all surface waters within the study area. Where streams comprise part of the regional wildlife corridor network, a larger 500 m riparian corridor should be used where possible.

5.2 5.2 Constraints to future agricultural development

While the use of environmental overlays has been used to protect sites of conservation significance within the study area, it is important to acknowledge off-site impacts posed by any intensive agricultural/horticultural development. These threats may include salinity and waterlogging, drainage water disposal, nutrient runoff, chemical spray drift and weed infestation.

To limit the off-site environmental impacts related to irrigation, development within PDZs should aim to contain drainage water and nutrients on-site. The *Guidelines for Wastewater Irrigation* (EPA 1991) can provide assistance in relation to site selection, establishment and management.

All developments should also consider the use of environmental buffers and filter strips to contain surface runoff, chemical spray drift and weed infestation on-site.

6 Prime Development Zones – risk assessments

6.1 WPDZI

6.1.1 Land capability for irrigated agriculture

This PDZ is the largest in the study area. The terrain is generally flat to undulating volcanic plains with a sparse drainage network. There are occasional eruption points (generally low rises or low hills) that vary in elevation and rock outcrop. Average annual rainfall is approximately 450 to 500 mm.

There are three major soil types present in this landscape, however only one is considered appropriate for irrigation. The red texture contrast (duplex) soils with variable depth to rock are preferred. The soils are whole coloured and strongly structured in the subsoil. This implies good drainage despite the high clay content and significant sodicity in the subsoil. The surface soils are slightly acidic to neutral and lighter in texture.

These soils have a high to moderate capability for irrigation (refer to Map 6.1a).

6.1.2 Hydrogeological assessment and salinity risk

This PDZ has moderate overall groundwater and salinity risk rating.

Much of this PDZ is underlain by weathered multi-layered basalt (Newer Basalt Quaternary age). It is up to 100 m thick with localised groundwater flow cells (<2 km) superimposed upon a regional groundwater flow system (>25 km length). The subdued landscape and accompanying low groundwater gradients is conducive to sluggish groundwater flow albeit that moderate aquifer permeability exists.

Locally upward groundwater pressures within underlying aquifers may contribute to elevated watertable levels in the basalt plains. There are significant areas of watertable within 5 m of the surface, but mostly in the range 5 -10 m (refer to Map 6.1b). The predominantly duplex basaltic soils are susceptible to moderate waterlogging and/or seasonally perched watertables in the low-lying or flat areas.

The water quality in the underlying watertable aquifer is in the range of 2000 to 10000 mg/L TDS, thus risk of contamination by recycled effluent is assessed to be low.

6.1.3 Environmental risk and threats to biodiversity

Due to its large size, this PDZ covers an area with a number of significant environmental assets. Of particular concern are the remnant grasslands of the western plains. These grasslands have a very high priority for retention under the *Draft Port Phillip and Westernport Native Vegetation Plan* (PPWCALP 2000) and provide important habitat for flora and fauna protected under the FFG Act and the RAMSAR, JAMBA, CAMBA and

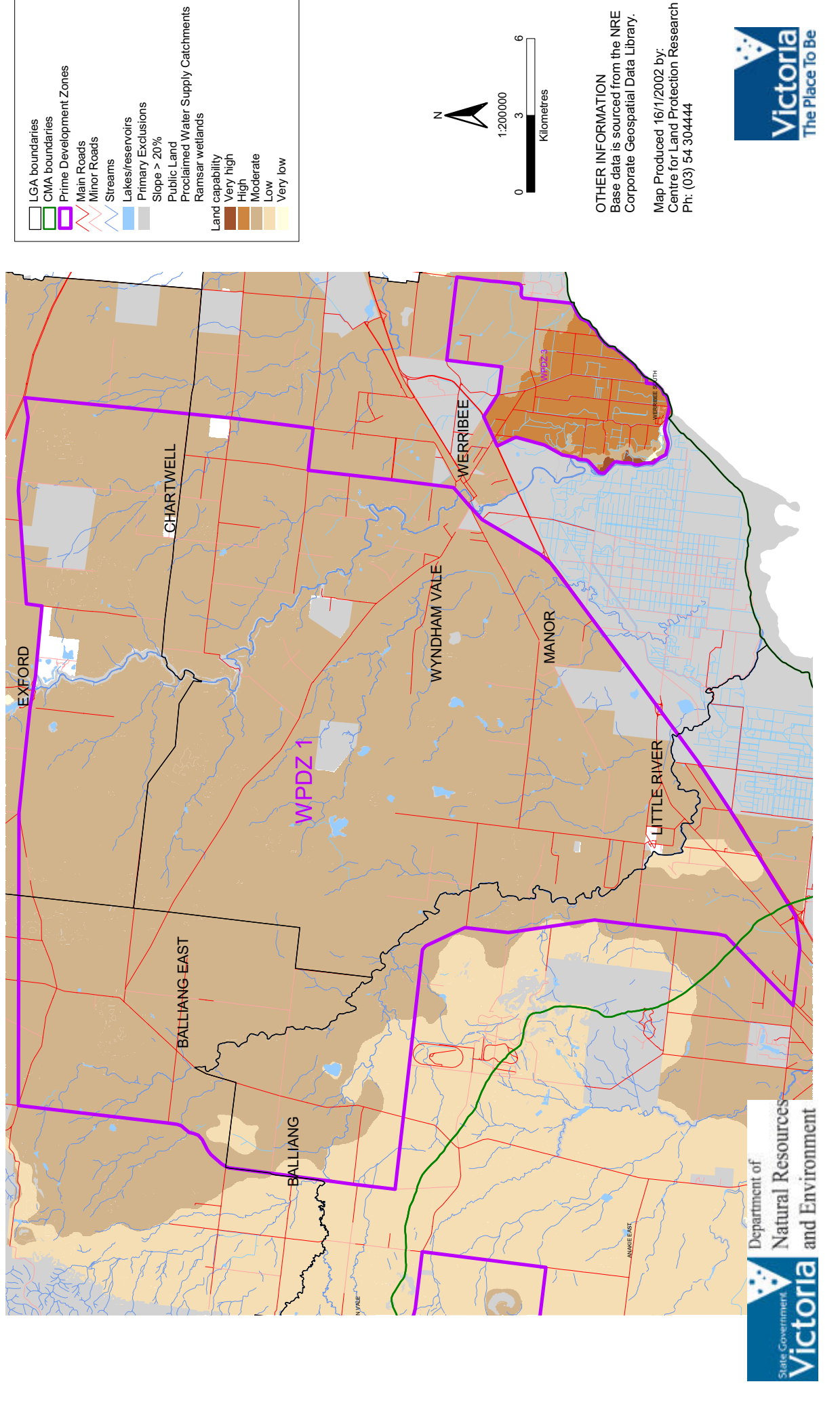
Bonn agreements. It is recommended that no development occur where these vegetation types are present. Any development adjacent to these remnants should incorporate a suitable buffer (refer Section 5). If possible, development should also avoid infringing upon the regional wildlife corridors linking these remnants, as proposed under the *Draft Port Phillip and Westernport Native Vegetation Plan* (PPWCALP 2000).

The rivers within this PDZ include the Werribee River and Little River. Given these waterways are already stressed within the extent of the PDZ, every effort should be made to ensure that development will not further degrade them.

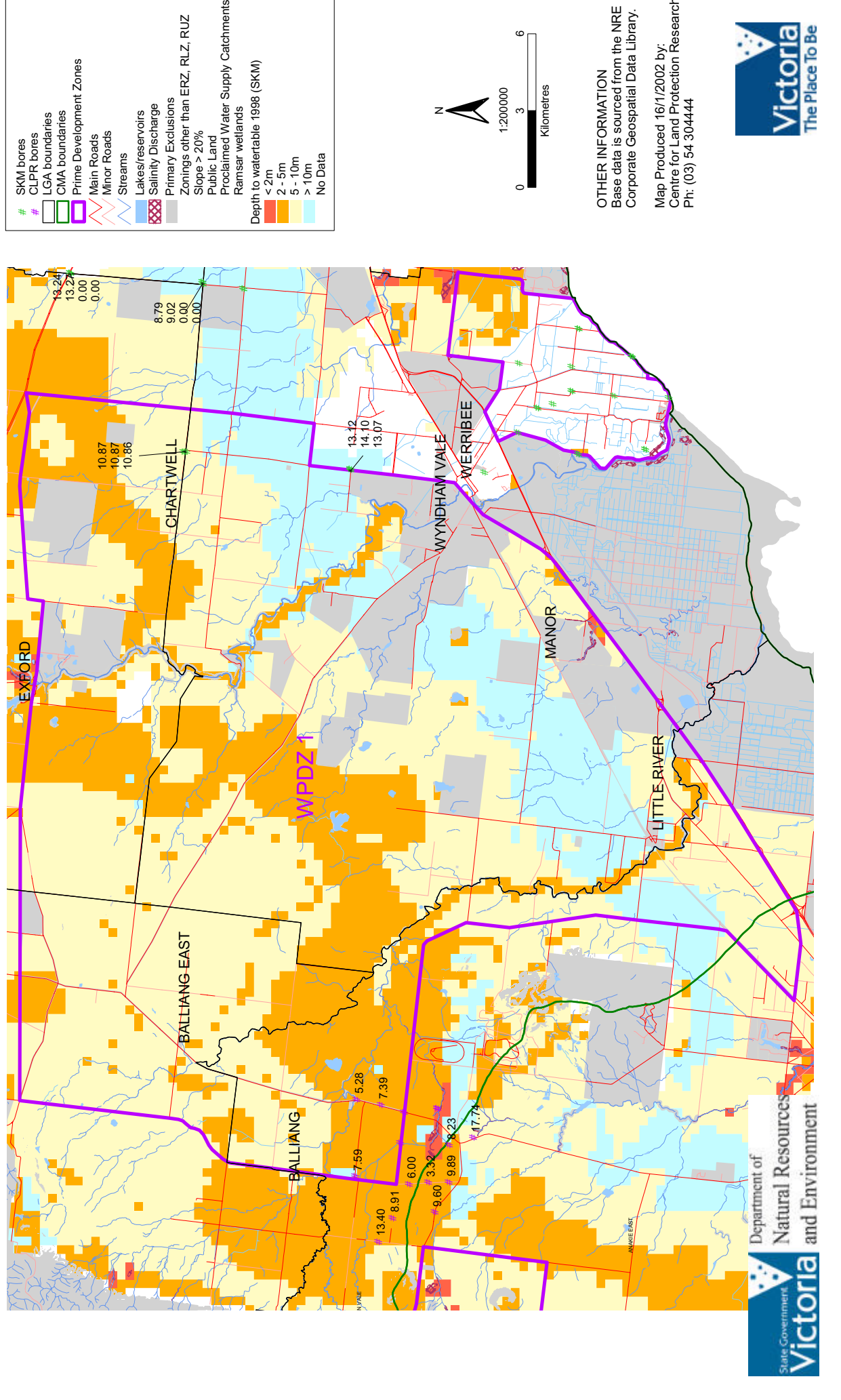
The *Draft Port Phillip and Westernport Native Vegetation Plan* recommends a minimum buffer width of 100 m for development adjacent to river and streams, while a 500 m buffer is recommended to support the regional wildlife corridor network.

A moderate environmental risk has been determined for this PDZ, primarily because there is a need to effectively plan and manage development adjacent to sites of high conservation significance (refer to Map 6.1c).

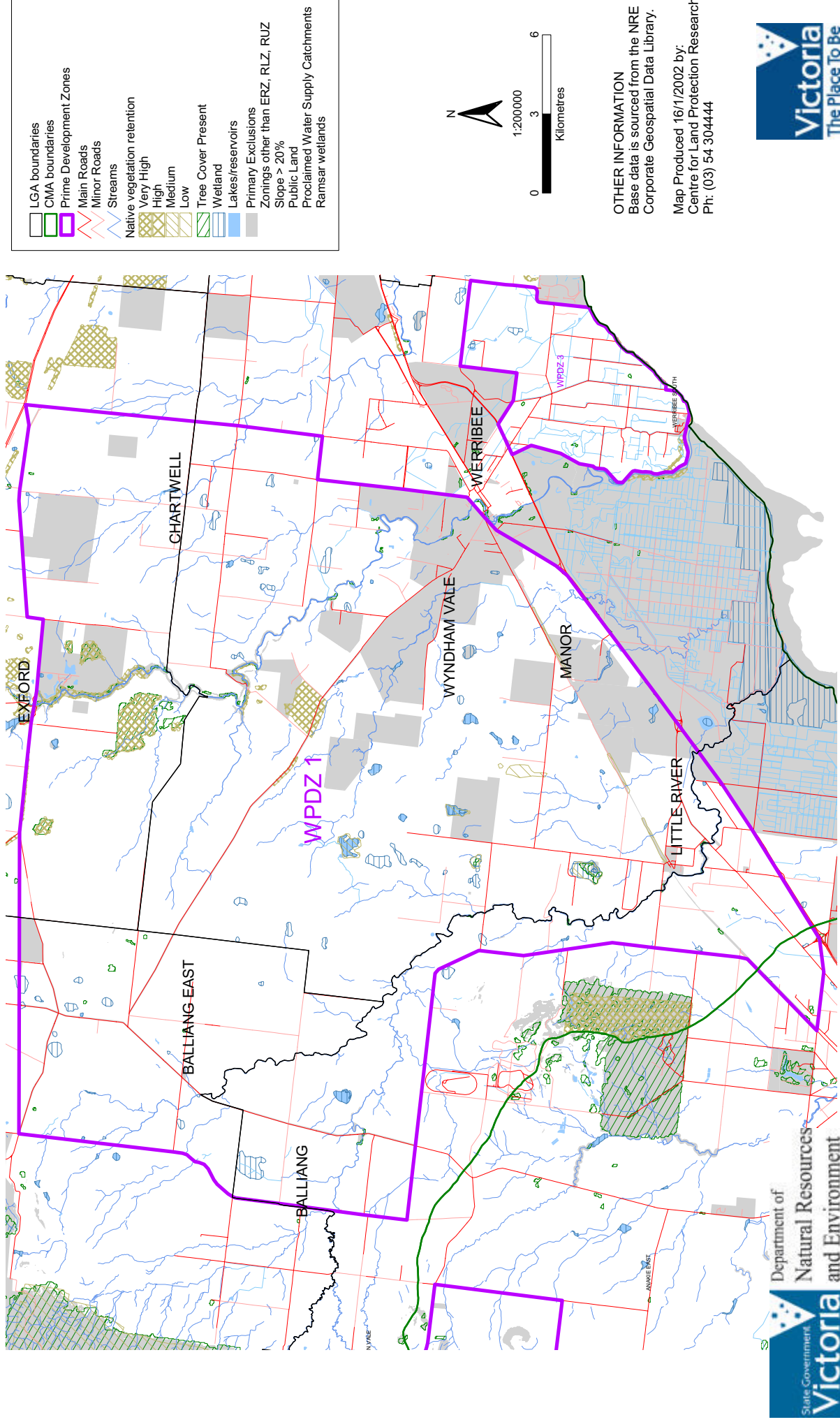
Map 6.1a WPDZ1 Land capability for irrigated agriculture



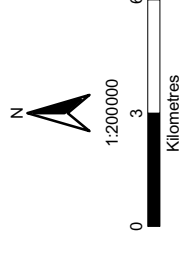
Map 6.1b WPDZ1 Salinity and depth to watertable



Map 6.1c WPDZ1 Priority for native vegetation retention



- LGA boundaries
- CMA boundaries
- Prime Development Zones
- Main Roads
- Minor Roads
- Streams
- Native vegetation retention
 - Very High
 - High
 - Medium
 - Low
- Tree Cover Present
- Wetland
- Lakes/reservoirs
- Primary Exclusions
- Zonings other than ERZ, RLZ, RUZ
- Slope > 20%
- Public Land
- Proclaimed Water Supply Catchments
- Ramsar wetlands



OTHER INFORMATION
 Base data is sourced from the NRE
 Corporate Geospatial Data Library.
 Map Produced 16/1/2002 by:
 Centre for Land Protection Research
 Ph: (03) 54 304444



6.2 *WPDZ2*

6.2.1 Land capability for irrigated agriculture

This PDZ contains volcanic rises (eruption points) and associated undulating plains with variable rock outcrop. The PDZ has a low average annual rainfall of approximately 500 mm.

Soil types include red texture contrast (duplex) and red gradational soils. The soils have variable depth of topsoil and subsoil. These soils are strongly structured in the subsoil and whole coloured. This implies reasonable drainage despite the high clay content and significant sodicity of the subsoil. The surface soils are slightly acidic to neutral and lighter in texture. These soils have a moderate capability for irrigation given slope, stone content and sodic subsoils (refer to Map 6.2a).

6.2.2 Hydrogeological assessment and salinity risk

An overall moderate risk has been determined for this PDZ (refer to Map 6.2b).

The basalt eruption points and rocky undulating plains facilitate high recharge, with groundwater discharge evident in some low-lying areas. The existence of steeper groundwater gradients and more permeable volcanic material near the head of the catchment results in a low inherent hydrogeological risk for this PDZ.

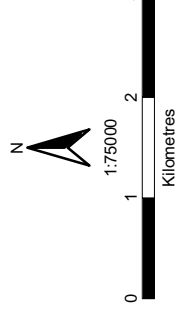
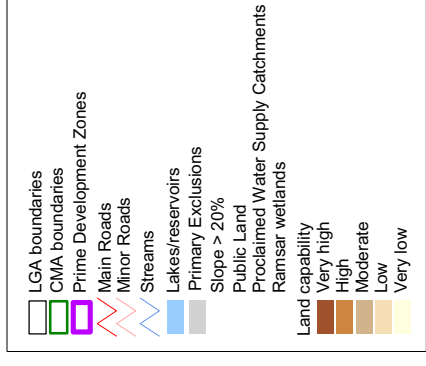
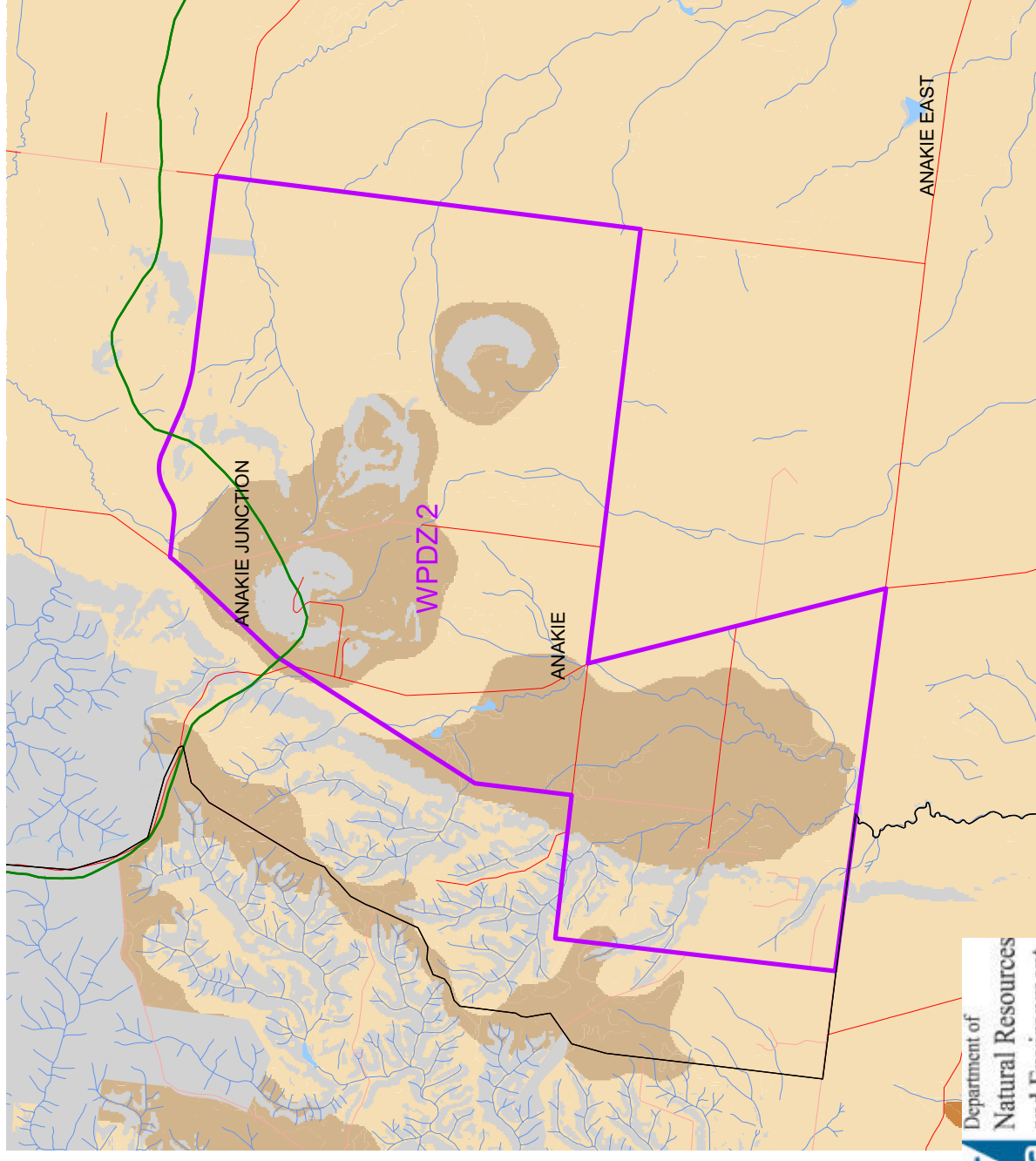
Elevated slopes have a low risk of waterlogging and/or seasonally perched watertables. In contrast, the heavier duplex soils of the plains and drainage depressions are of moderate to high risk. Within the undulating plains, a moderate risk of elevated watertables is present in low-lying depressions and wetlands.

The risk to groundwater quality is low in the undulating plains as existing groundwater quality is poor, but is potentially high on the volcanic cones where there are higher quality (potentially potable) pockets of groundwater.

6.2.3 Environmental risk and threats to biodiversity

This PDZ is located largely within the Corangamite CMA region. While the *Draft Corangamite Native Vegetation Plan* indicates EVCs with an Endangered status within the PDZ, they are located on public land and will not be directly threatened by development. The most significant community within this PDZ is the Plains Grassy Woodlands EVC. A low environmental risk has been determined for this PDZ (refer to Map 6.2c).

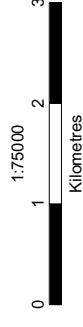
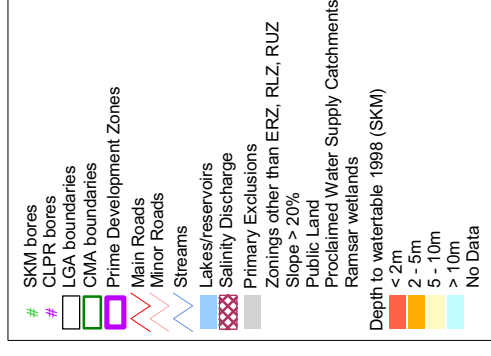
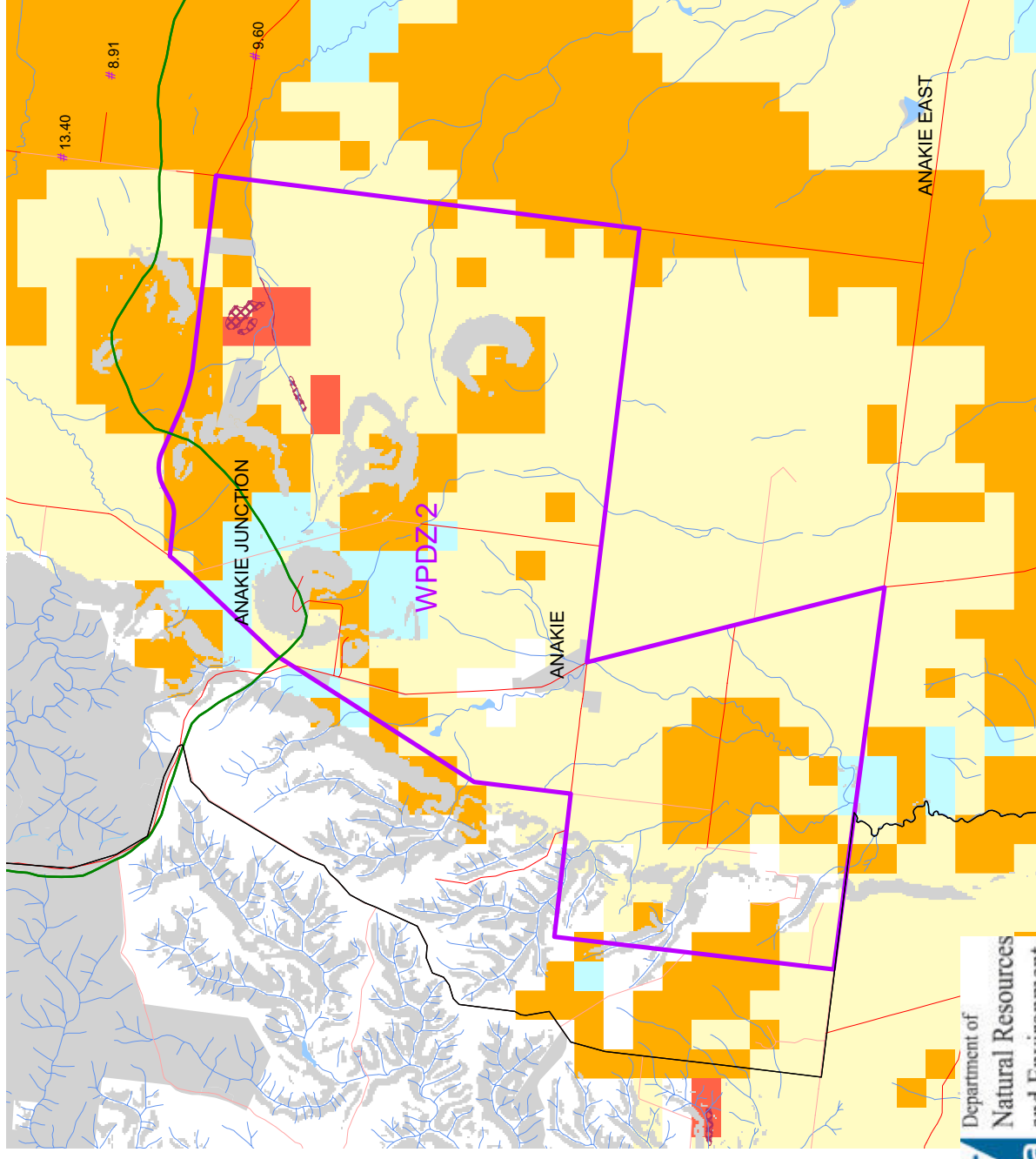
Map 6.2a WPDZ2 Land capability for irrigated agriculture



OTHER INFORMATION
Base data is sourced from the NRE
Corporate Geospatial Data Library.

Map Produced 16/2/2002 by:
Centre for Land Protection Research
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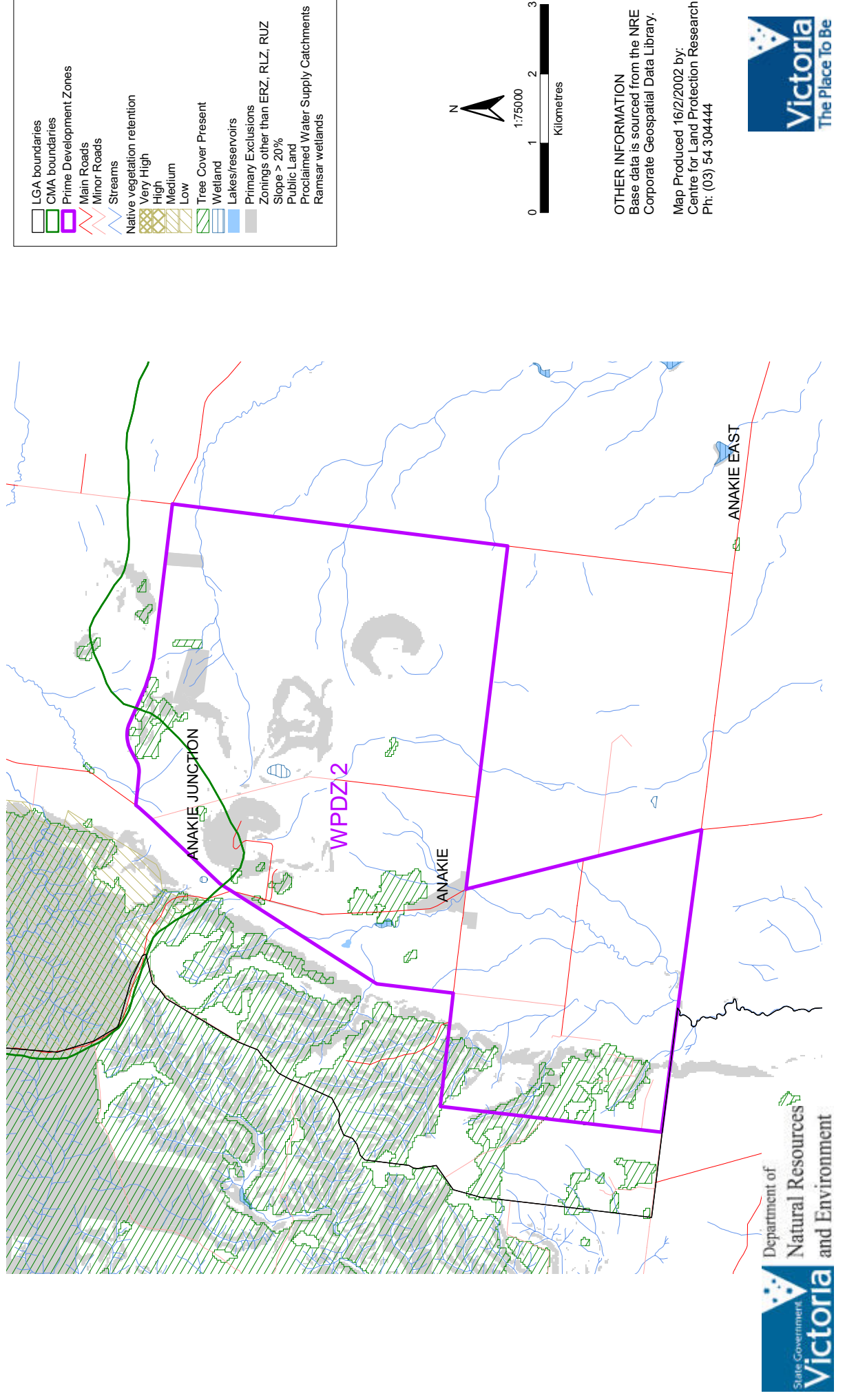
Map 6.2b WPDZ2 Salinity and depth to watertable



OTHER INFORMATION
Base data is sourced from the NRE
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Map 6.2c WPDZ2 Priority for native vegetation retention



6.3 WPDZ3

6.3.1 Land capability for irrigated agriculture

This PDZ is confined to Werribee River delta east of the Werribee River and the associated undulating volcanic plain to the north-east. The annual average rainfall for this area is approximately 500 mm.

The delta is a level plain that has been incised by the Werribee River. The plain has deep, red texture contrast (duplex) soils that are currently used for irrigated horticulture. The surface soils are moderately structured clay loams, while the subsoils are strongly structured, alkaline clays with little or no stone or gravel. These soils have a high capability for irrigated agriculture.

The basaltic soils on the undulating plain are also red texture contrast soils but have variable stone content and depth to rock, as well as alkaline and sodic subsoils. These characteristics restrict machinery operation and drainage. These soils have a moderate capability for irrigation (refer to Map 6.3a).

6.3.2 Hydrogeological assessment and salinity risk

The overall risk for this PDZ is moderate.

The PDZ is largely comprised of Werribee River deltaic sediments that range in thickness from 5 to 10 m and overlie basalt. The hydrogeological susceptibility of this landscape to soil salinity is assessed as moderate on the basis that it lies adjacent to Port Phillip Bay (i.e. bottom of catchment). Groundwater pressure in the underlying basalt will tend to impede downward vertical drainage from the sediments. This will in part be compensated by reasonable permeability in the deltaic sediments that will assist lateral drainage.

The waterlogging and/or seasonally perched watertable risk is rated low due to greater permeability in the soils of the deltaic sediments, however higher risk exists on basaltic soils where subsoil permeability is poor. The risk of soil salinity caused by elevated groundwater levels is significant, especially on the basalt plains and the coastal fringe, though effective leaching will limit this on the deltaic sediments (refer to Map 6.3b). Elevated watertables and/or groundwater perching in the coastal strip caused by leakage from the Western Treatment Plant lagoons is noted as a concern (AGC 1989).

As there are pockets of high quality groundwater within the deltaic sediments (that are elsewhere pumped for irrigated horticulture), there is a moderate risk to groundwater quality within this PDZ.

6.3.3 Environmental risk and threats to biodiversity

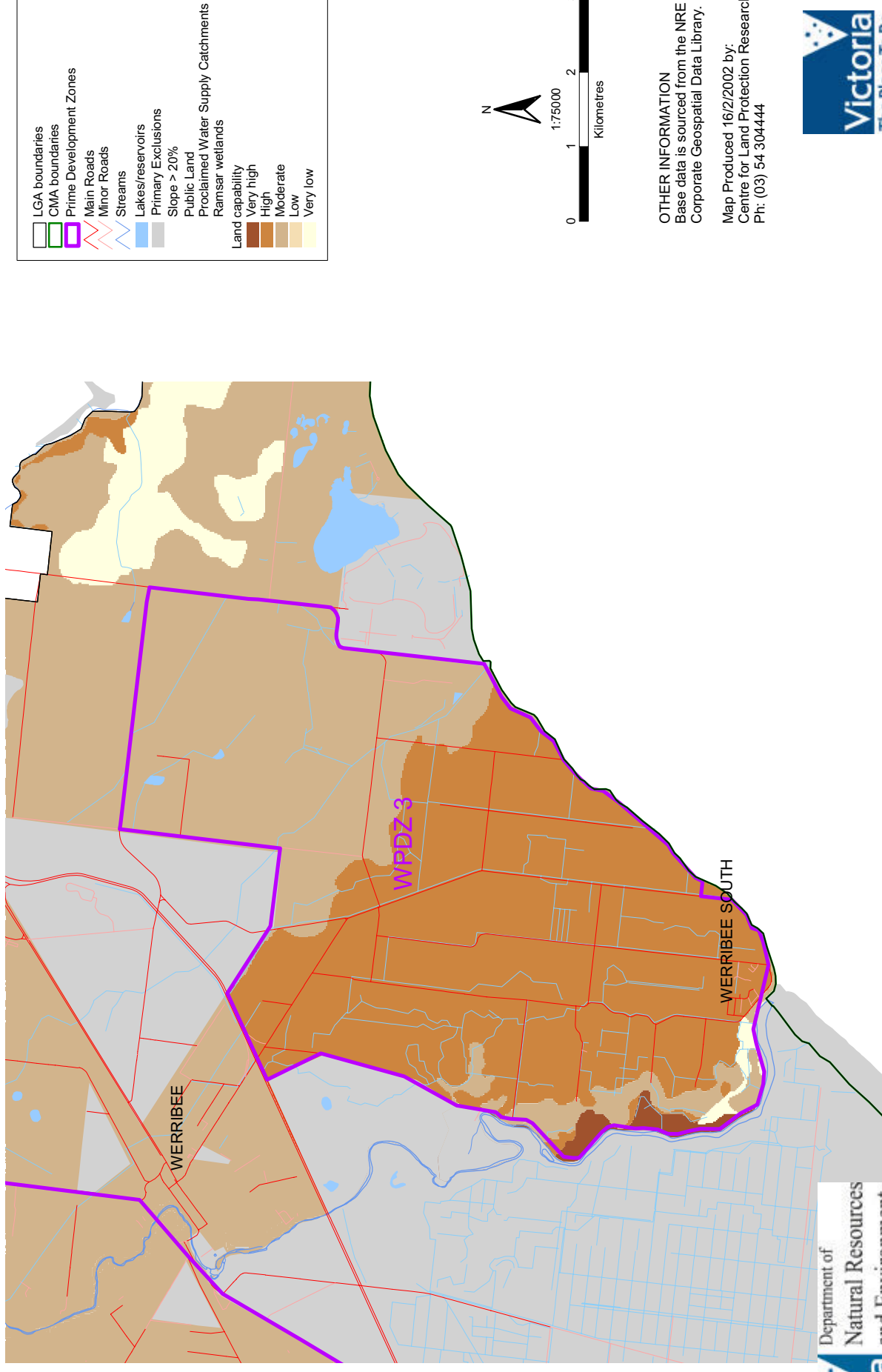
This PDZ contains few environmental assets. Of greatest concern is the RAMSAR-listed wetland, bordering the southern and western boundaries. While irrigation development is unlikely to directly impact upon native vegetation in the area, any development should ensure that the wetland communities are not subjected to excessive waterlogging, salinity or chemical spray drift.

The major waterway associated with this PDZ is the Werribee River. This has been assessed as having a very poor condition rating (PPWCALP 2001). As with WPDZ1, every effort should be made to ensure that development does not further degrade the condition of the river.

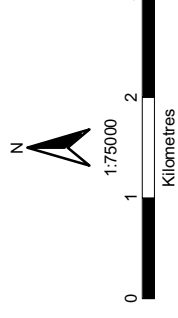
The *Draft Port Phillip and Westernport Native Vegetation Plan* (PPWCALP 2001) recommends a minimum buffer width of 100 m for adjacent development, while a 500 m buffer is recommended to support the regional wildlife corridor network.

A low environmental risk has been determined for this PDZ (refer to Map 6.3c).

Map 6.3a WPDZ3 Land capability for irrigated agriculture



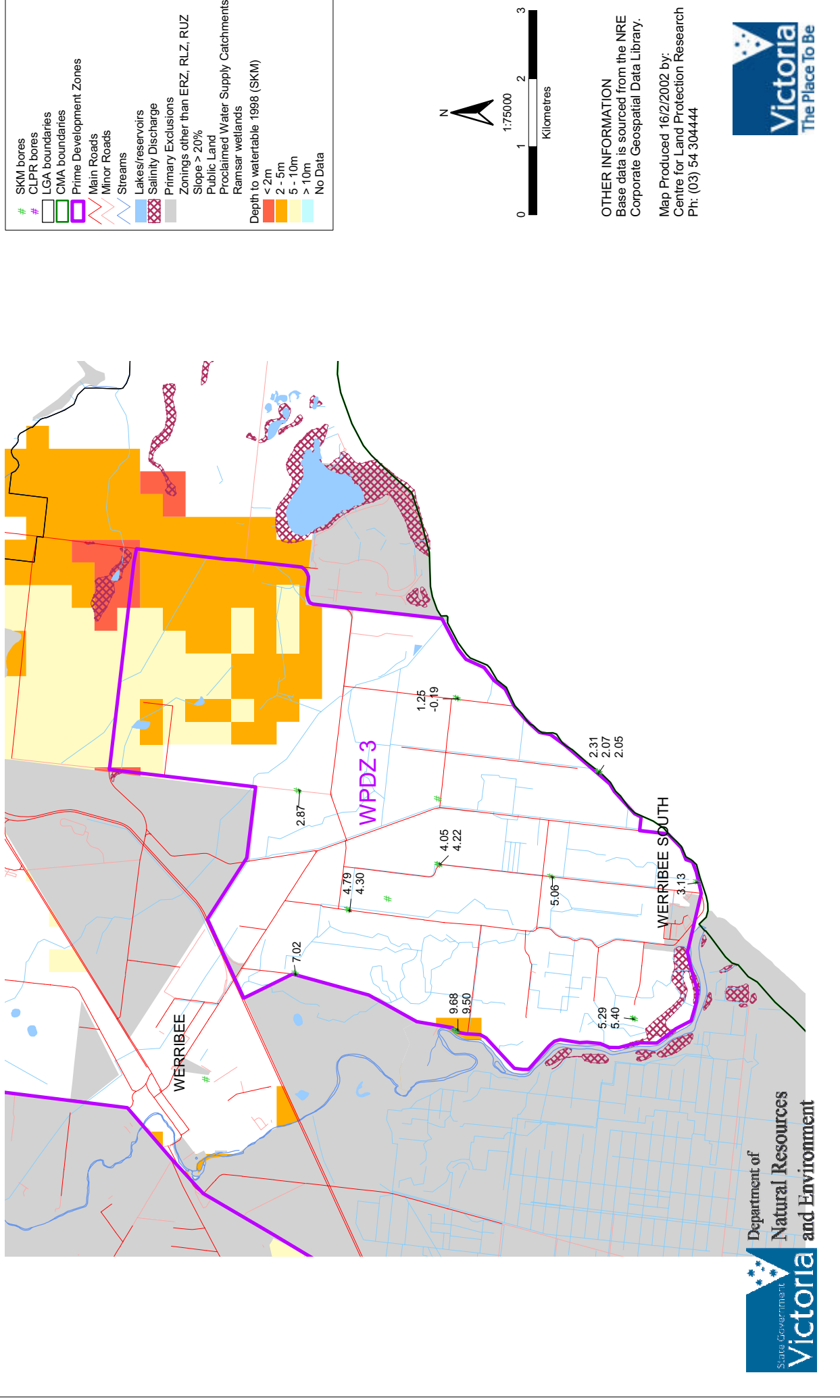
- LGA boundaries
- CMA boundaries
- Prime Development Zones
- Main Roads
- Minor Roads
- Streams
- Lakes/reservoirs
- Primary Exclusions
- Slope > 20%
- Public Land
- Proclaimed Water Supply Catchments
- Ramsar wetlands
- Land capability
 - Very high
 - High
 - Moderate
 - Low
 - Very low



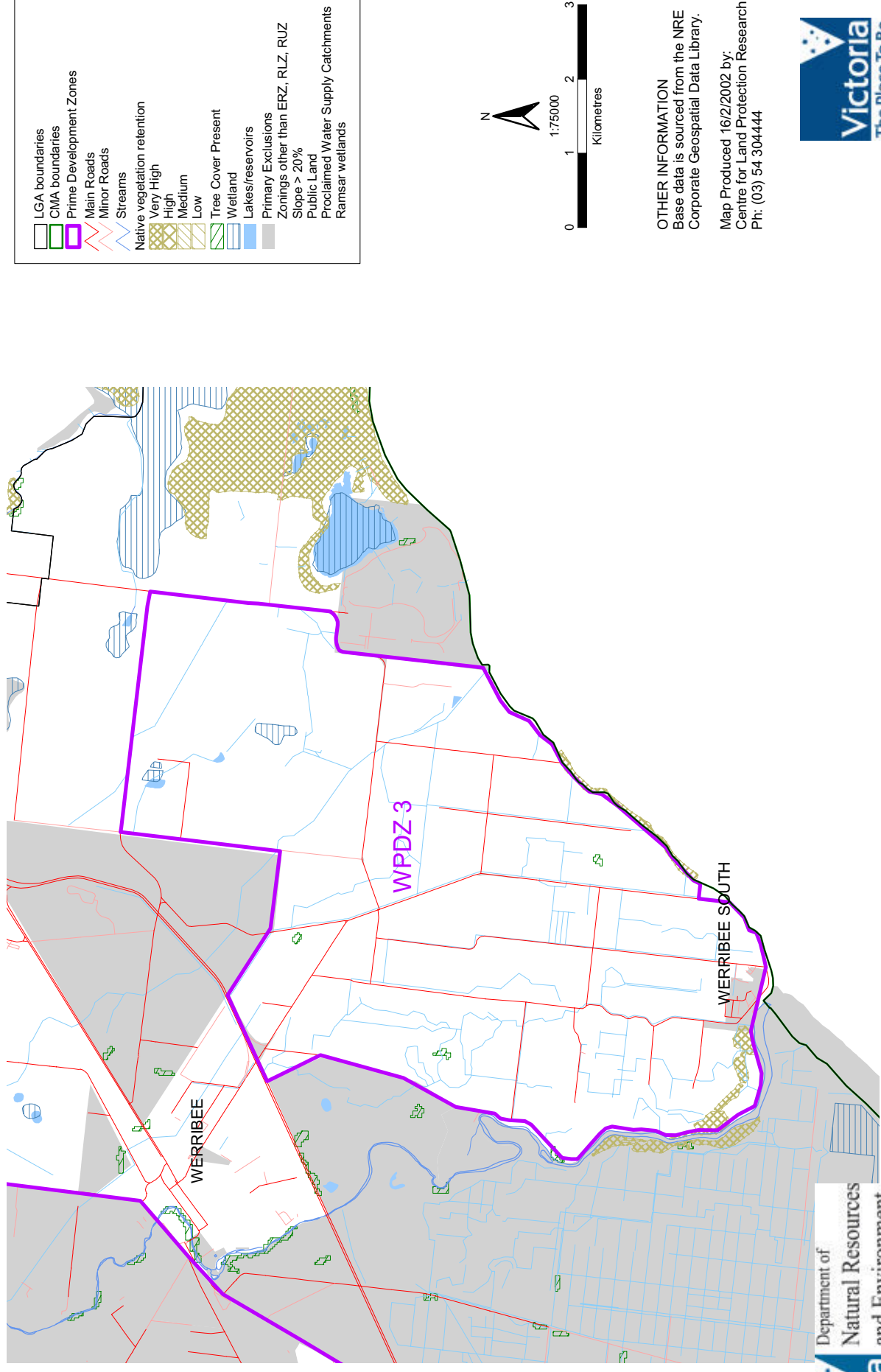
OTHER INFORMATION
 Base data is sourced from the NRE
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Map 6.3b WPDZ3 Salinity and depth to watertable



Map 6.3c WPDZ3 Priority for native vegetation retention



6.4 EPDZI

6.4.1 Land capability for irrigated agriculture

This PDZ is specific to the Westernport alluvial plain, consisting of low-level plains and minor occurrences of sandy plain or rises. The annual rainfall for the area is approximately 800 mm and this increases with elevation to the north.

The level plain has been drained to access soils that occur with low sandy rises to the north, east and west. The soils are dominated by heavy dark clays with a peaty variant of Dalmore clay (Sargeant 1975). This soil provides the major focus for horticultural activity. The peaty soils are friable (particularly in the topsoil) and deep with no rock, and despite sodicity and salinity issues, these soils are considered highly productive once drainage is established. The Dalmore peat areas are regarded as having high capability for irrigation, with some limitations related to subsoil drainage which can be a problem for deep-rooted vegetation.

The heavy clay soils surrounding the Dalmore peat are not considered capable of supporting irrigated agriculture, though some surfaces may be self-mulching and provide a reasonable growing medium for row crops in places. Sodicity is also high at depth, and together with drainage and nutrient-loading issues, may have negative off-site impacts (refer to Map 6.4a).

6.4.2 Hydrogeological assessment and salinity risk

This PDZ has a high hydrogeological and salinity risk rating.

This PDZ lies within a natural groundwater sink, surrounded by elevated recharge areas to the north, and a coastal boundary to the south. Effectively a closed hydrogeological system exists with limited capacity for groundwater storage in the aquifers beneath the plains.

Existing horticultural development relies heavily upon drainage to maintain perched and elevated groundwater levels. Where drainage infrastructure does not exist there is a moderate to high risk of waterlogging and/or seasonally perched watertables on the low permeability, peaty clay and clay soils of the coastal plains. Saline discharge areas are not uncommon on these soils. Map 6.4b indicates that most of the PDZ is underlain by watertables within 5 m of the surface.

Shallow groundwater of potable quality exists within the PDZ. In excess of 9500 ML/yr is extracted from the aquifer system. However gradual sea water intrusion into the onshore aquifers of the Westernport plains has been reported (SKM 1997), therefore exploitation of the aquifer needs to be carefully managed to avoid further sea water intrusion. In this sense, the substitution of groundwater pumping with recycled water can be effectively argued, although water quality may slowly deteriorate in the aquifer if the quality of recycled water used is poor.

6.4.3 Environmental risk and threats to biodiversity

The native vegetation within this PDZ has largely been cleared for agricultural and urban development. The vegetation of highest priority for retention is concentrated in the south along the coastline of Westernport Bay.

Westernport Bay and its unique seagrass, mangrove and saltmarsh ecosystem is a site of very high conservation significance. Westernport Bay is RAMSAR-listed, while the vegetation surrounding the bay provides habitat for species protected under the international CAMBA and JAMBA agreements, and the FFG Act. Any development in this PDZ will need to refer to *Protecting the Waters of Westernport and Catchment*, Schedule F8 of the State Environment Protection Policy (Waters of Victoria) (EPA 2000).

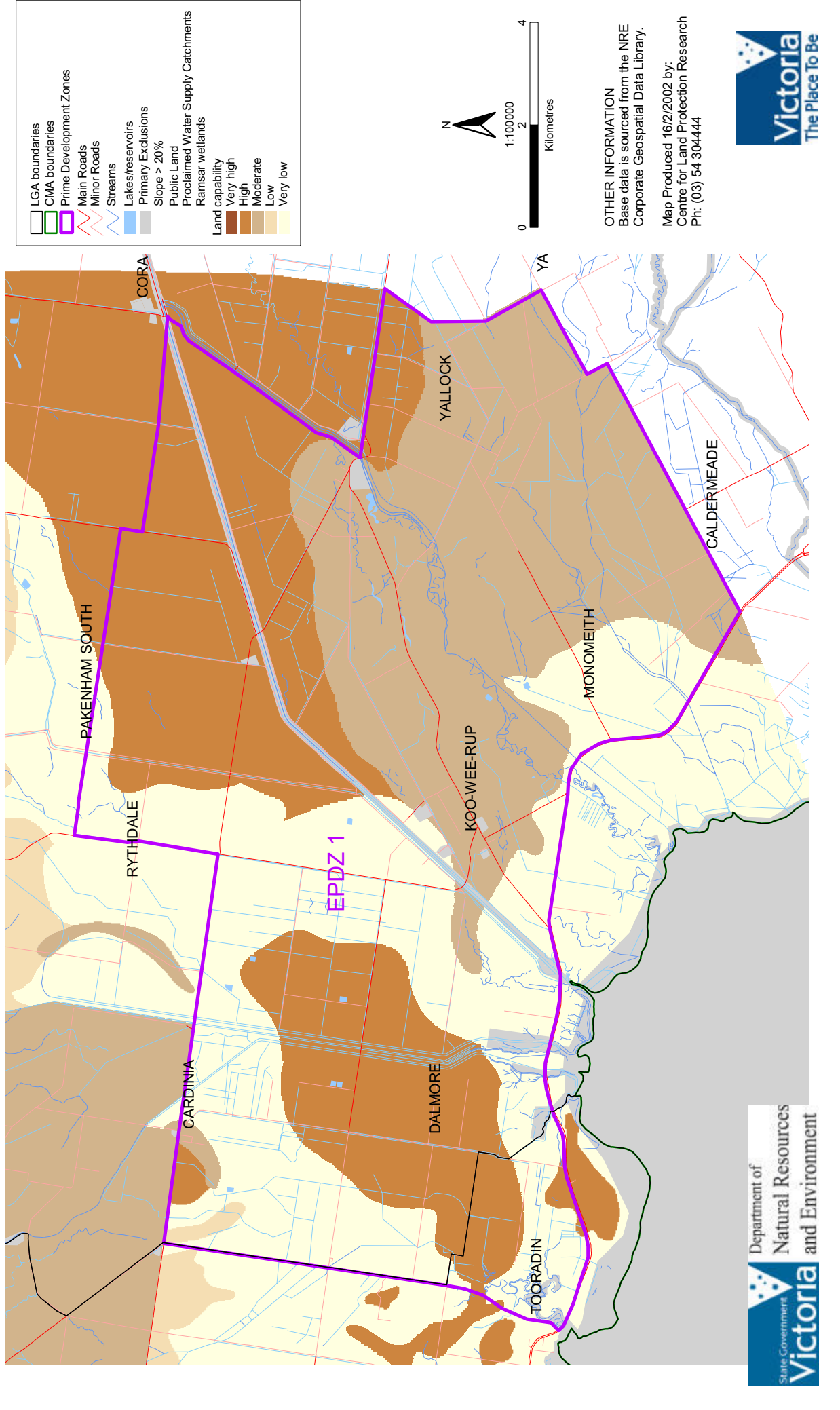
The main waterways within this PDZ are the Bunyip River and Cardinia Creek. These waterways are generally in poor condition (PPWCALP 2001). The nutrient and sediment loads transported by these streams are considered a major threat to seagrass communities in Westernport Bay.

As new irrigation development will require drainage, increased nutrient and sediment loads will increase where streams form part of the drainage network, particularly given the use of recycled water. This is considered an extremely high risk, given there has been continued decline in seagrass communities across Westernport Bay.

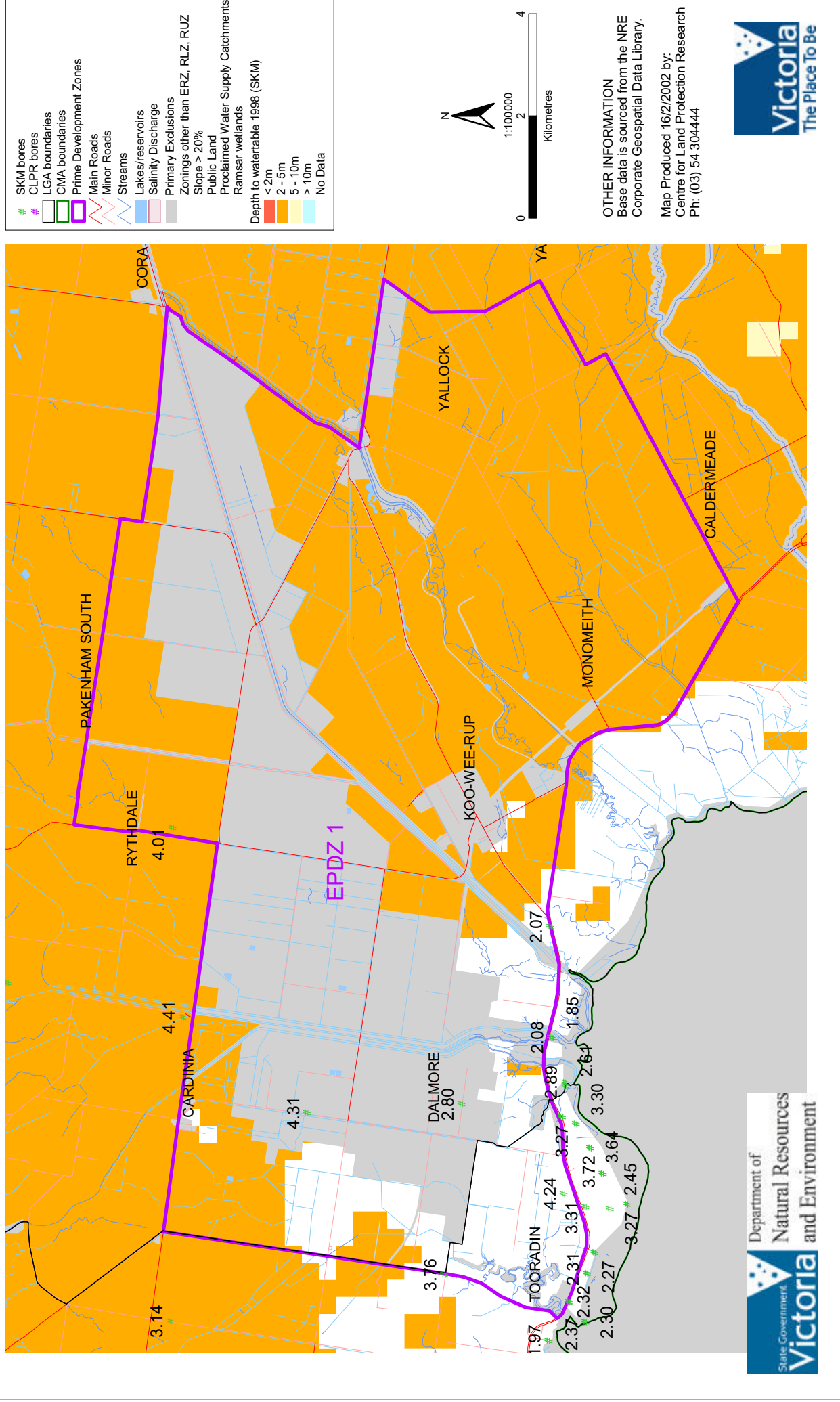
Unless drainage water and nutrients can be contained on-site, it is recommended that further irrigation development should not proceed. The use of buffers and filter strips will not be sufficient to manage nutrient and sediment input from the drainage network.

A high environmental risk has been determined for this PDZ, primarily due to the off-site risks associated with sediments and nutrients entering Westernport Bay (refer to Map 6.4c).

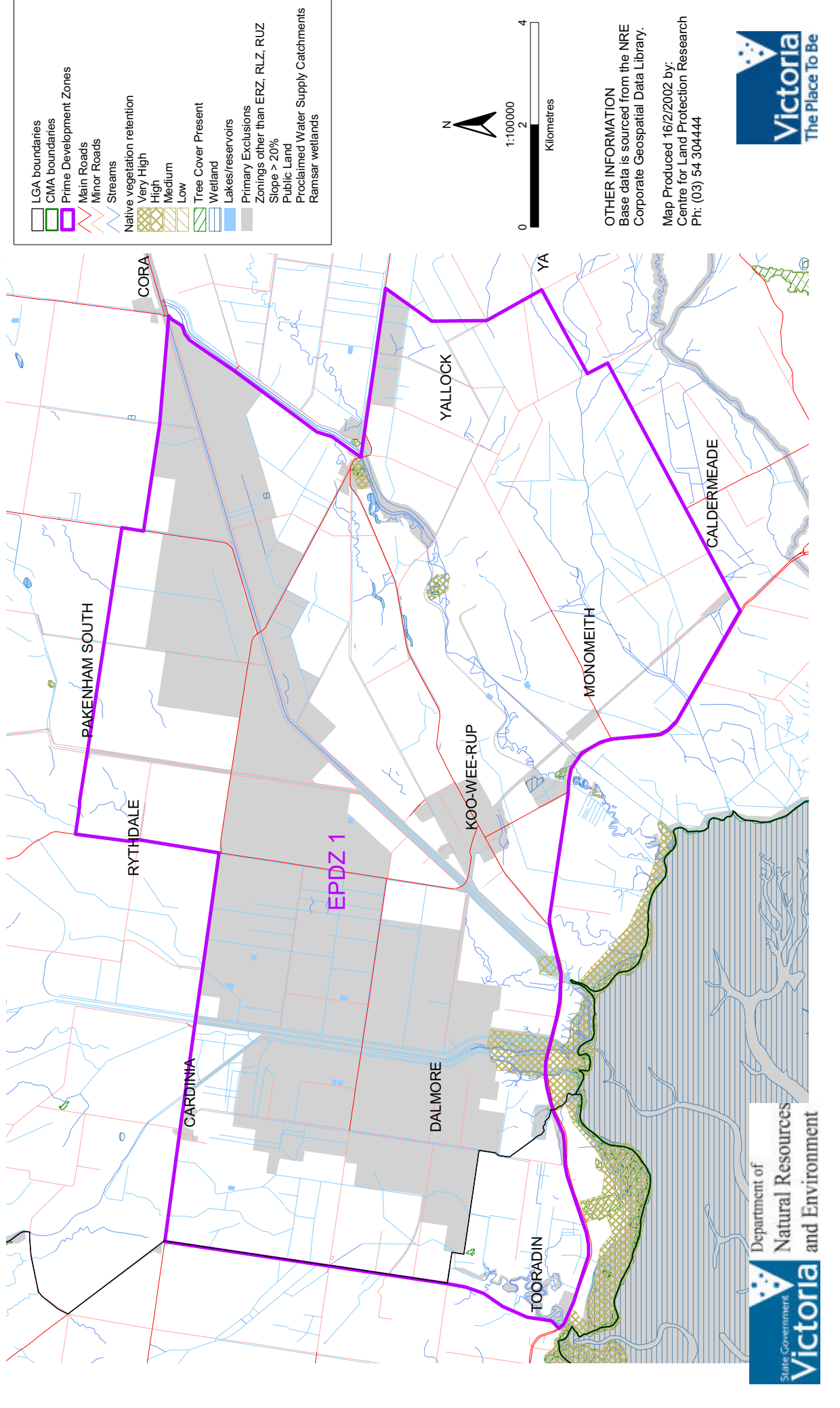
Map 6.4a EPDZ1 Land capability for irrigated agriculture



Map 6.4b EPDZ1 Salinity and depth to watertable



Map 6.4c EPDZ1 Priority for native vegetation retention



6.5 EPDZ2

6.5.1 Land capability for irrigated agriculture

This PDZ is dominated by sandy plains and rises, with low hills of the Mornington Peninsula in the south-west. Rainfall in the sandy rise terrain (Cranbourne to Narre Warren area) is relatively consistent but increases to the north. The average annual rainfall is between 700 and 900 mm.

The low, undulating terrain is dominated by dunes and sand sheets, but also includes low-lying areas of poorer drainage with limited dissection of the landscape. The most common soils are uniform sands of variable depth. A constricting layer either of clay or a cemented iron/organic pan may occur at depth. Where depth to clay is shallower, options for irrigation are reduced due to restricted drainage and rooting depth. Drainage is often rapid and water and nutrient holding capacity is low, therefore excess drainage from such an area may impact negatively upon local streams. These sandy soils have a high capability for irrigation with minor limitations where the clay base occurs at a depth less than 1.5-2 m (refer to Map 6.5a).

6.5.2 Hydrogeological assessment and salinity risk

This PDZ has a moderate risk rating for groundwater contamination and salinity.

This PDZ has significantly more relief and variability in land type (see above) than its neighbour, EPDZ1. These differences result in a moderate rather than high hydrogeological risk assessment. The variability across the PDZ means that some aquifer systems/landforms will have higher susceptibility, especially the lowlands adjacent to the coast.

The risk of salinity due to high watertables is regarded as high, as over 50% of the PDZ is interpreted to have watertables within 5 m of ground surface (refer to Map 6.5b). However, there is only minor surface expression of salinity in the PDZ.

The overall risk of salinity owing to waterlogging and/or seasonally perched watertable is regarded as low. This is based on the high permeability of the uniform sandy soils throughout most of the PDZ.

Groundwater quality is variable and ranges from 1000 to 6000 mg/L TDS depending upon location and depth. As some higher quality groundwater exists, the risk of contamination owing to recycled water is regarded as moderate.

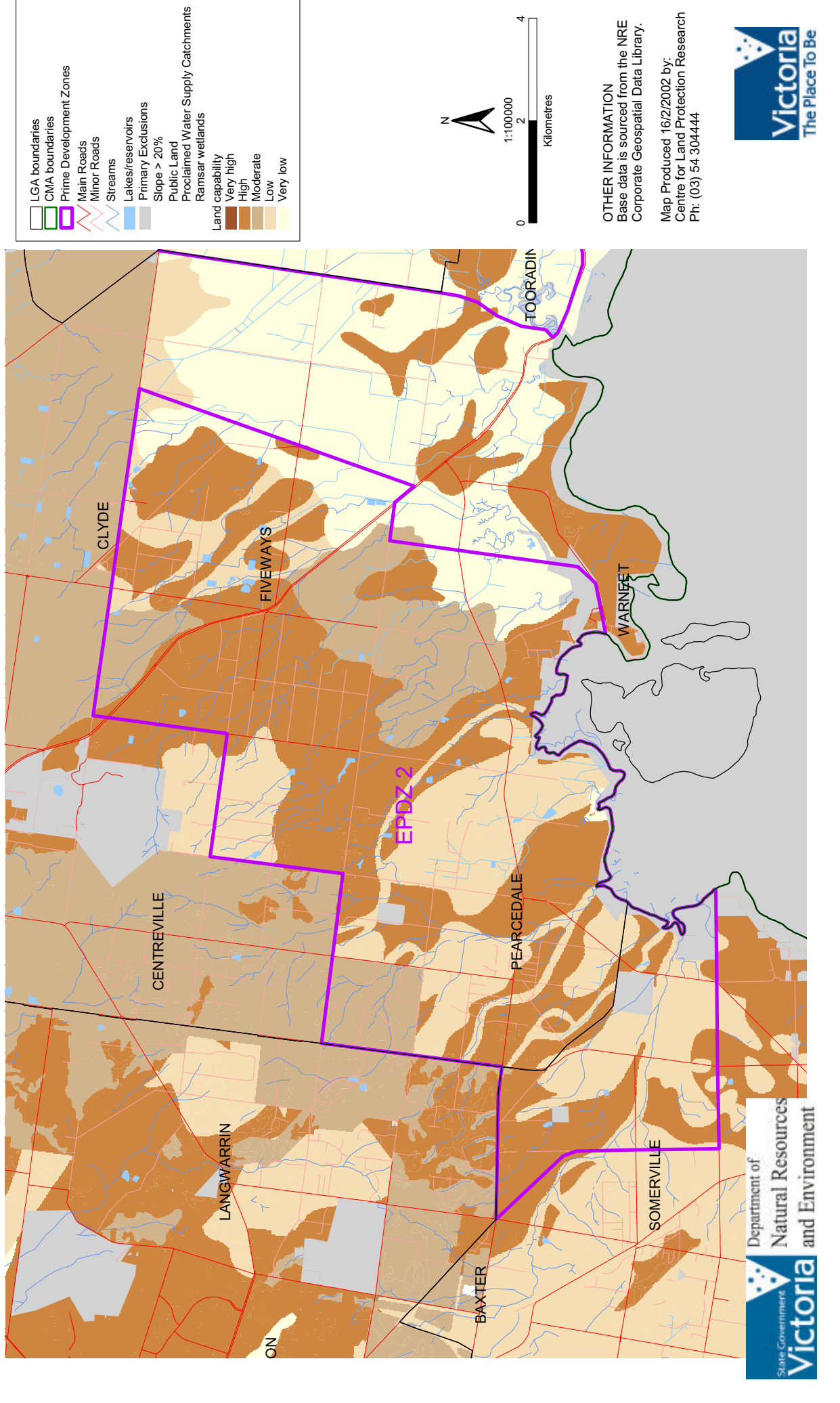
6.5.3 Environmental risk and threats to biodiversity

The native vegetation within this PDZ has largely been cleared for agricultural and urban development. Of greatest significance are the coastal vegetation communities associated with Westernport Bay in the south-east. Much of this vegetation provides habitat for species protected under the international JAMBA and CAMBA agreements, and the FFG Act. All development within this PDZ will need to consider the potential impacts of development on the Westernport Bay ecosystems, with reference to Schedule F8 of the *State Environment Protection Policy - Waters of Victoria* (EPA 1988).

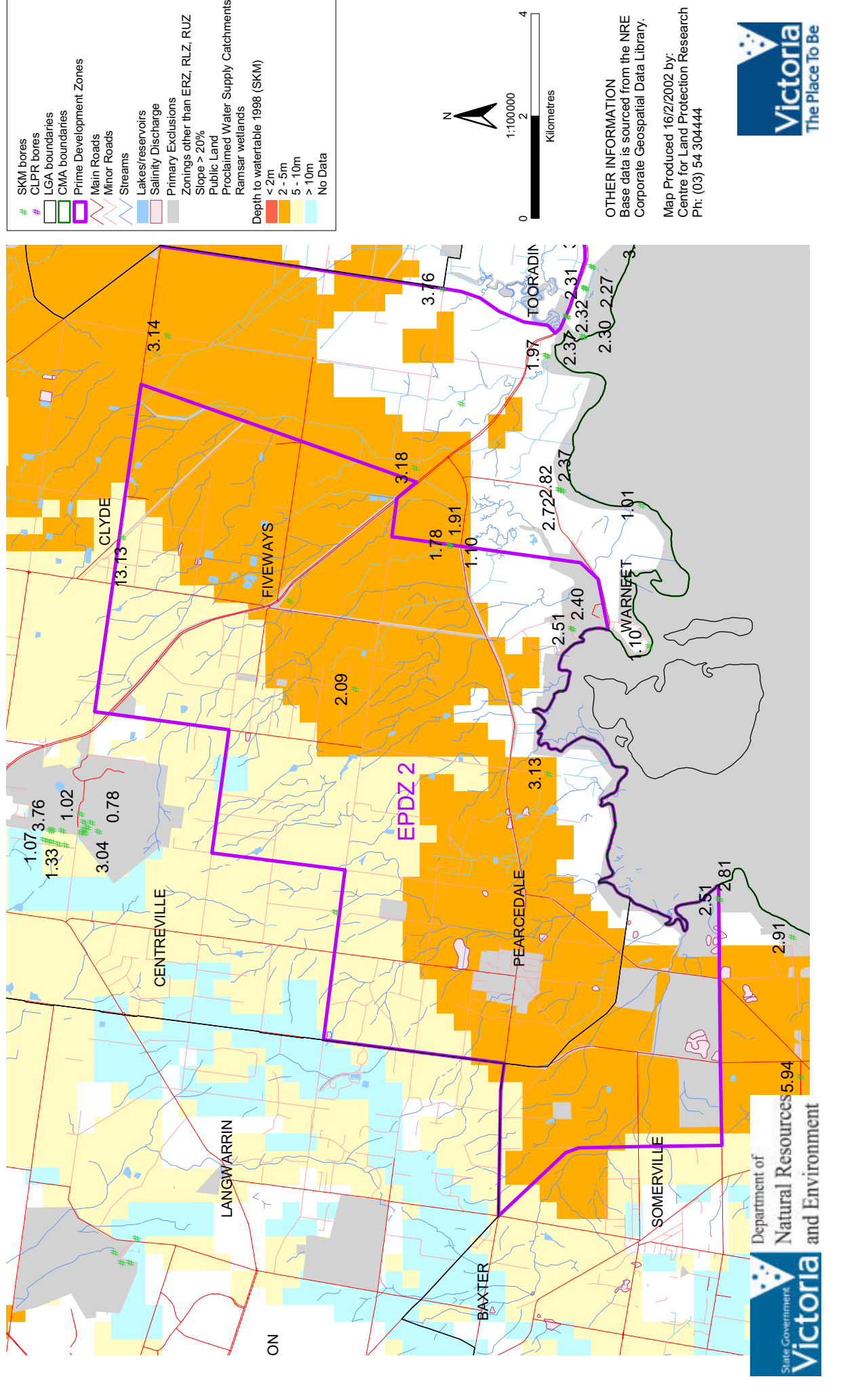
Smaller streams in the PDZ generally have a poor condition rating. Any development adjacent to these waterways should consider the use of a buffer.

A moderate environmental risk has been determined for this PDZ (refer to Map 6.5c).

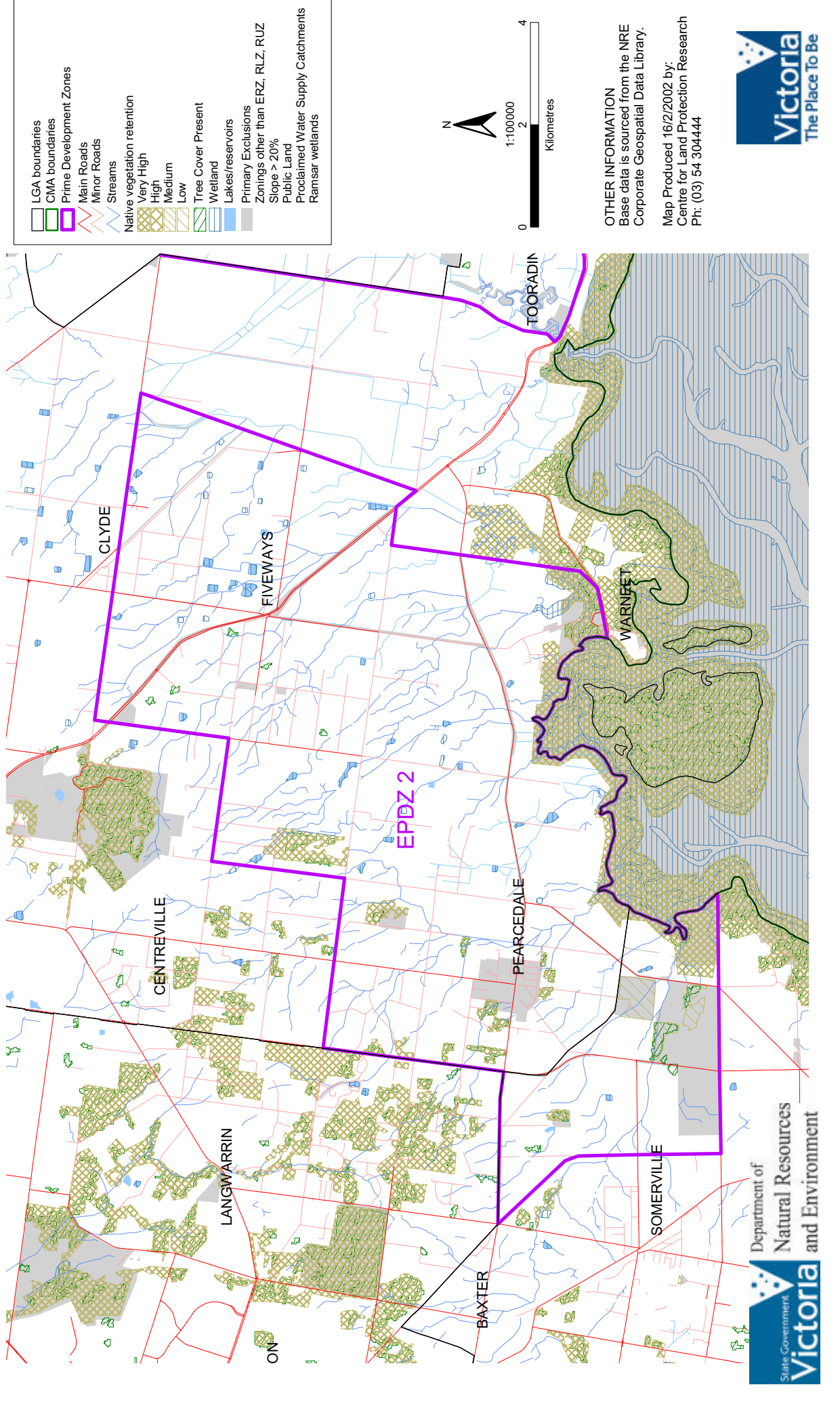
Map 6.5a EPDZ2 Land capability for irrigated agriculture



Map 6.5b EPDZ2 Salinity and depth to watertable



Map 6.5c EPDZ2 Priority for native vegetation retention



6.6 EPDZ3

6.6.1 Land capability for irrigated agriculture

This PDZ lies in the southern portion of the Mornington Peninsula where there are two landscapes capable of supporting irrigated agriculture. These include the elevated basaltic terrain around Red Hill, and the undulating calcareous dunefields at lower elevations closer to the Nepean Peninsula. The climate is dominated by maritime influences with higher rainfall at higher elevation. An annual average rainfall of about 1000 mm occurs in the Red Hill area decreasing to below 850 mm over the calcareous dunefields.

The elevated basaltic terrain consists of friable, well drained, red gradational soils while the calcareous dunefields have uniform sandy soils with excellent drainage. Both the friable red gradational soils and lighter calcareous sands are regarded as having high capability for irrigated agriculture.

Moderate slopes and the texture of the subsoils may be important management issues for the basaltic soils, while deep drainage and nutrient management are considered issues in the calcareous sands (refer to Map 6.6a).

6.6.2 Hydrogeological assessment and salinity risk

This PDZ mostly encompasses basalts of the Older Volcanic series as described above. Overall groundwater and salinity risk is concluded to be low.

The inherent hydrogeological risk is assessed as low, given the relative relief across the PDZ that is served by a well-defined surface drainage pattern. External groundwater influence is low. Due to its significant elevation above sea level, groundwater movement is not so restricted by sea water pressure. This is not to say saline discharge potential within the PDZ is negligible, rather it is most likely to be localised.

The interpreted watertable surface across the PDZ suggests that groundwater is in excess of 5 m depth across almost the entire area (refer to Map 6.6b) and the risk of salinity is considered low.

The risk of waterlogging and/or seasonally perched watertables is low on the elevated red basaltic soils where permeability is moderate to high. A higher risk can be locally attributed to the black basaltic soils at lower elevation.

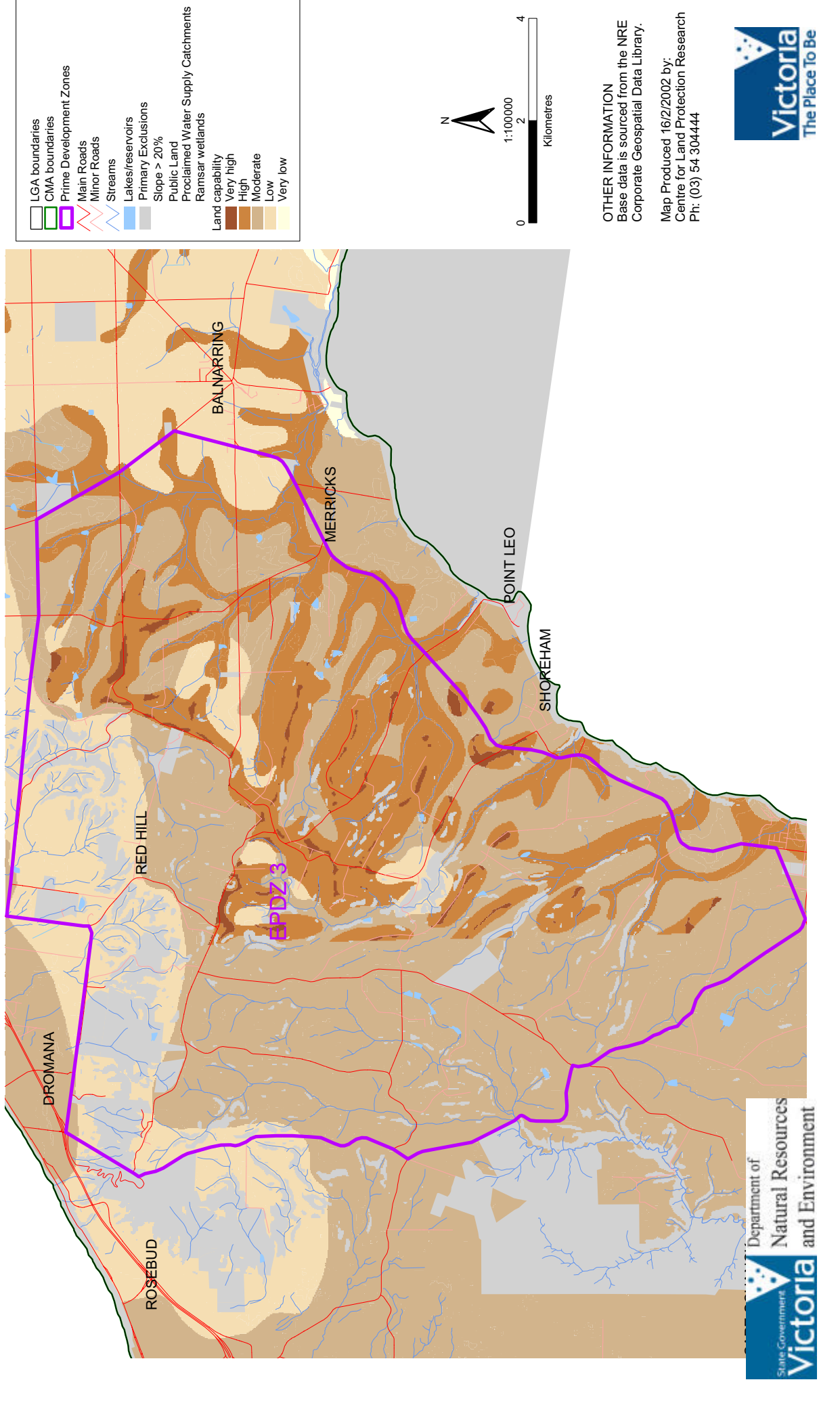
The risk to groundwater quality is regarded to be moderate owing to some higher quality groundwater likely to fall below the 2500 mg/L threshold.

6.6.3 Environmental risk and threats to biodiversity

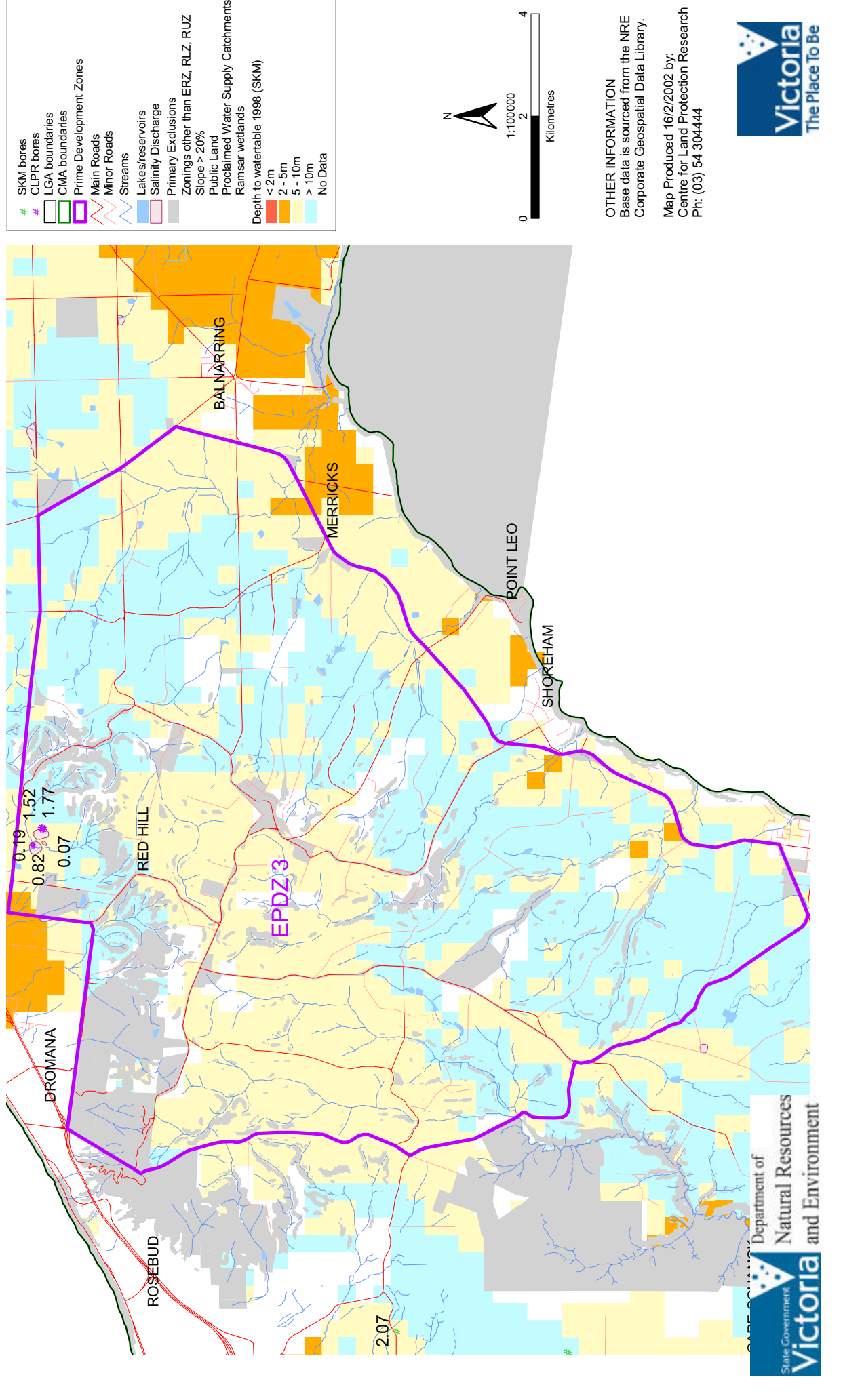
Located across this PDZ are fragments of coastal grassy woodland and lowland forest. These are a very high priority for retention under the *Draft Port Phillip and Westernport Native Vegetation Plan* (PPWCALP 2000). It is recommended that no irrigation development result in the loss or fragmentation of these vegetation types. As with the other PDZs, it is also preferred that no development infringes upon the proposed wildlife corridors linking important native vegetation within the region.

There are no major waterways within this PDZ, however minor streams are considered to be in good condition. This PDZ is assessed as having a moderate environmental risk (refer to Map 6.6c).

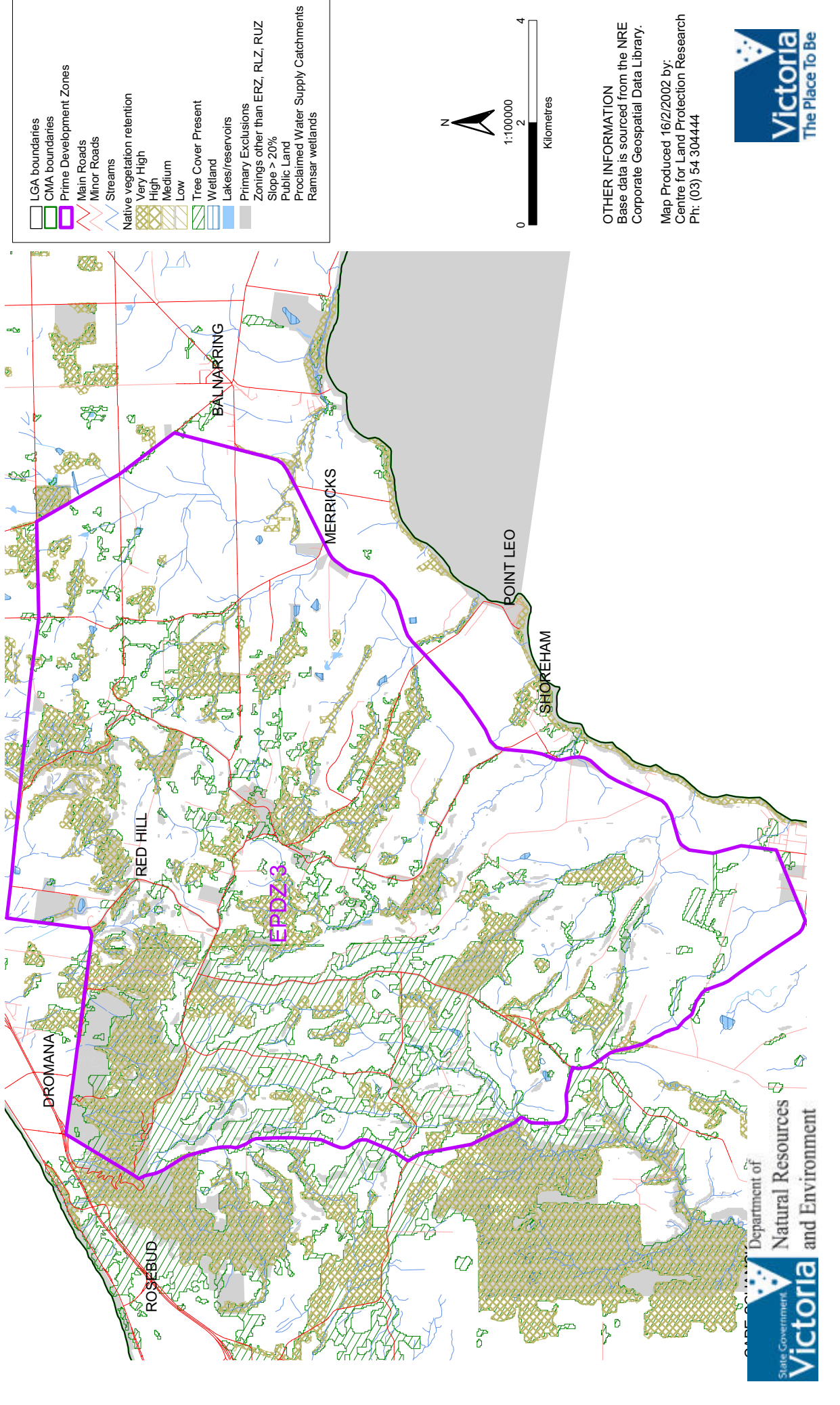
Map 6.6a EPDZ3 Land capability for irrigated agriculture



Map 6.6b EPDZ3 Salinity and depth to watertable



Map 6.6c EPDZ3 Priority for native vegetation retention



7 Discussion

The PDZs identified in this report represent land capable of supporting irrigated agriculture in the greater Melbourne study area. When combined, the total amount of land available for irrigated agriculture is approximately 76 000 ha, spread across six PDZs. There a number of important considerations relating to the development of the PDZs, and the use of recycled water. These include:

- the quality of recycled water.
- the seasonal usage of water for irrigating crops.
- the use of recycled water in existing irrigation areas.
- meeting the 20% water recycling target.
- the environmental impact of new irrigation development.

Recycled water is available from the Eastern and Western Treatment Plants managed by Melbourne Water. The quality of recycled water varies. The Eastern Treatment Plant will be upgraded to Class A¹ by 2004, while gradual improvement in water quality at the Western Treatment Plant has achieved Class B². This variation in water quality may influence both the type of enterprise, and the irrigation techniques and management employed. The application and use of recycled water is governed by the Guidelines for Wastewater Irrigation (EPA 1991), see Appendix C.

Class B water quality from the Western Treatment Plant may support a less diverse range of irrigation enterprises. The turbidity (NTU) and salt (TDS) levels present in the Class B water may impact upon less salt tolerant crops or restrict the use of sprinkler and microspray irrigation systems.

Irrespective of crop water requirements, seasonal demand will be an issue in both the eastern and western PDZs, as water application will generally occur between October and March. Issues regarding the storage of recycled water during periods of low demand will need to be addressed. Many of the existing vegetable growing areas are included within the PDZs. Therefore, options for substituting groundwater with recycled water use may exist. At present, irrigation areas at Werribee, Five Ways, Cranbourne, Koo Wee Rup and Boneo only have access to Class C recycled water that does not meet existing EPA guidelines. With the upgrade to Class A recycled water in the ETP, these restrictions will be overcome.

¹ Class A recycled water can be used to irrigate vegetable and other crops for human consumption

² Class B recycled water can be used to irrigate crops for human consumption only where they are peeled or shelled, or for use on tree and other crops for non human consumption

When aiming for the 20% water recycling target (70 000 ML per annum), the class of recycled water available, the varying capability of the land, and the land available for agriculture all become critical. The eastern PDZs are better suited to high value horticulture as they have a higher proportion of very high to moderately capable land with access to Class A recycled water. However in the east, less opportunity may exist for future expansion due to pressures exerted by urban encroachment. As more land exists in the western PDZs (approximately 54 200 ha) than in the eastern PDZs (approximately 22 200 ha), more irrigation development may ultimately occur in the less capable, but more extensive PDZs in the west.

Sufficient land exists to meet the 20% recycling target as calculations indicate in section 7.1, but competitive advantages and environmental considerations in each PDZ should be carefully considered when prioritising PDZs for development.

7.1 *Estimated recycled water use within PDZs*

The volume of recycled water required within the PDZs can be estimated using crop water use figures in conjunction with estimates of the area to be irrigated. The estimates can then be used to compare the contribution of each PDZ to meeting the 20% recycling target.

It is not possible to predict the type of crop, nor the area of land to be irrigated in a specific PDZ. Scenarios have therefore been developed for three crops and three levels of land uptake to provide a guide to the annual volume of recycled water use.

The crop types used in the calculations illustrate a range of irrigation requirements, including crops with both high and low water use. Crop irrigation requirements are based upon figures and methods provided in *Irrigation and Drainage Practice* (RWC 1988) that allow for climatic differences between the east and west of Melbourne. The crop types selected and their irrigation requirements are:

- Forestry 4.8 ML/ha (west) 2.3 ML/ha (east)
- Vegetables 6.7 ML/ha (west) 3.4 ML/ha (east)
- Viticulture 4.5 ML/ha (west) 2.4 ML/ha (east)

The irrigation development figures represent a low to moderate uptake of land for irrigation within the PDZs. These figures are likely to change as PDZs are further defined through detailed investigations. Land use scenarios for 10, 20 and 30 % uptake of land for irrigation are shown in Table 7.1.

Table 7.1 Estimated volume of recycled water use within Prime Development Zones.

PDZ	Area of land available for irrigated agriculture (ha)	Estimated annual recycled water use (ML)		
		Viticulture	Horticulture	Forestry
<u>10% uptake of recycled water</u>				
WPDZ1	48 949	23 200	34 300	24 300
WPDZ2	1368	1660	2400	1700
WPDZ3	3844	900	1300	900
EPDZ1	6722	2300	3400	2300
EPDZ2	5567	2100	2900	2100
EPDZ3	9983	2700	3900	2700
Estimated total water usage		32 860	48 200	34 000
<u>20% uptake of recycled water</u>				
WPDZ1	48 949	46 300	68 500	48 700
WPDZ2	1368	3300	4900	3500
WPDZ3	3844	1800	2600	1800
EPDZ1	6722	4700	6700	4700
EPDZ2	5567	4100	5900	4100
EPDZ3	9983	5500	7800	5400
Estimated total water usage		65 700	96 400	68 200
<u>30% uptake of recycled water</u>				
WPDZ1	48 949	69500	102 800	73 000
WPDZ2	1368	5000	7300	5200
WPDZ3	3844	2700	3900	2700
EPDZ1	6722	7000	10 100	7000
EPDZ2	5567	6200	8800	6200
EPDZ3	9983	8200	11 700	8100
Estimated total water usage		98 600	144 600	102 200

8 Further investigation of PDZs

Given the preliminary nature of this desktop study, it is recommended that more detailed investigations be undertaken for each PDZ. This should involve detailed field sampling and modelling as described below.

8.1 Detailed land capability analysis

Landform and detailed soils information is necessary to undertake a land capability analysis with a high degree of reliability, particularly where irrigation with recycled water is planned. As many of the PDZs do not have 1:25 000 scale soil-landform mapping available, this will require a strategic approach to both preliminary sampling and detailed laboratory analysis of soils.

It is recommended that where existing information cannot provide soil-landform units to at least 1:25 000 scale, field survey and detailed soil sampling be undertaken to provide reliable and accurate information on the distribution, physical and chemical properties of soils present.

It should be noted that most soil surveys undertaken for irrigation development in Victoria are presented at a scale of 1:10 000 scale or better, as this information is required for water balance assessment, irrigation layout and design, and scheduling of irrigation. However this next level of investigation should be funded by industry.

Land capability assessment tables for specific irrigated agricultural enterprises can then be used to determine the capability of the soil-landform unit to support the enterprise. Area statements and land capability maps can then be generated and used for comparative analyses within and between the PDZs.

The following steps are required.

- a) Utilising existing land system and soil mapping in conjunction with preliminary field sampling, identify key landform units and associated major soil types, map at the 1:25 000 scale.
- b) Using available information from existing studies and additional detailed soil sampling, provide landform and soil attribute data for each landform unit and major soil types, including saturated hydraulic conductivity and soil chemical parameters.
- c) Based on the most limiting factor (MLF) approach, develop land capability assessment tables to assess each landform unit for agricultural development using recycled water. Apply to landform units using the attribute data.
- d) Prepare overlay of PDZs and soil-landform unit boundaries, scan into GIS with appropriate base information (roads, streams, public/private land boundaries, water catchment boundaries, and contours).
- e) Prepare land capability maps identifying areas of high, moderate and low management input for irrigated agriculture using recycled water.

Study outputs required:

- Description and map of landform units and major soil types for moderate to low risk PDZs.
- An assessment of high, moderate and low management inputs required to support the agricultural enterprise within the PDZ.
- Area statements.
- Digital or hardcopy map products at the 1:25 000 scale showing land capability in the PDZs.

8.2 *Surface and sub-surface drainage assessment*

Lateral and vertical movement of water through the soil profile can potentially lead to the formation of perched watertables and saline discharge. Where landform and soil types vary, movement of water through the soil profile is expected to behave differently under irrigation than would be expected under broadacre pasture or cropping. Therefore, the need for surface and sub-surface drainage is considered of major importance to the long-term sustainability of PDZs. This drainage assessment would contribute to the hydrogeological analysis and would involve the following:

- a) Determination of the hydraulic performance of selected soil-landform units and associated soil types.
- b) Determination of the need for surface or sub-surface drainage infrastructure in each soil-landform unit of the PDZs.

Study output required:

- An assessment of the surface and sub-surface drainage requirements for specific soil-landform units in each PDZ.

8.3 *Hydrogeological impact and salinity risk assessment*

This component will identify potential changes to the local and regional groundwater systems associated with new irrigation development, and identify where irrigation development may result in on-site/off-site damage to land and water resources.

A degree of flexibility will be required in the methodology to accommodate data availability and the differing assessment requirements based on the risk status. In some PDZs, the lack of available bore data will require the establishment of monitoring bores. A level of confidence will be provided to indicate the reliability of the data provided. This assessment would involve the following:

- a) For all PDZ areas, approximately quantify recharge and define its distribution from an assessment of (i) current groundwater trends, (ii) irrigation data (including leaching fractions and soil water movement), (iii) infiltration measurements (if and where deemed absolutely necessary), and (iv) soil data (obtained from other components of the study and including, where appropriate, extrapolation of information from other irrigation areas in the region).
- b) Utilise existing maps of current (1998) and predicted (2020) watertable elevations and recent bore information to review depth to watertable under best practice irrigation (including perched watertables, if applicable) and considering proposed water allocations. Apply at a scale of 1:25 000 or as appropriate, depending on size of area and available data.
- c) Apply flow nets to the above and use simplified Darcy's Law analytical techniques to (i) quantify groundwater flows and salt loads, (ii) determine recharge-discharge relationships, and (iii) determine river or wetland interaction under current and proposed management.
- d) From the above, predict the on-site and off-site hydrogeological impacts of proposed horticultural development in all PDZ areas and determine (i) the sustainability of the proposed horticultural development, and (ii) the implications for surface and sub-surface drainage requirements.
- e) Preparation of hydrogeological impact assessment for each PDZ.

Study outputs required:

- Conceptual hydrogeological framework for each PDZ (regional and local processes).
- Current salinity risk status and groundwater impact status of each PDZ (including maps), and a detailed risk evaluation, where possible.
- Broad quantification and distribution of current and future recharge for all PDZs.
- Current and future projected groundwater trends for each PDZ as above, under existing and proposed management.
- Prediction of on-site and off-site hydrogeological impacts of proposed developments, and where applicable, the impacts of removal of water allocations from existing irrigation areas.
- Recommendations regarding development potential of PDZ areas.
- Recommendations for groundwater monitoring and other data requirements.

8.4 Environmental risks and threats to biodiversity.

This component will assess the potential on-site and off-site environmental impacts resulting from expanded horticultural development. The identification of existing wetlands, remnant native vegetation and rare and threatened flora/fauna will provide an important base to assess

the impact of drainage water disposal and clearing of native vegetation. The following steps are required:

- a) Identify the environmental significance of any ecosystems under threat.
- b) Determine the potential biodiversity impacts resulting from future irrigation development within the PDZs.
- c) Identify potential land management options to conserve or enhance biodiversity for the expanded irrigation areas.

Study outputs required:

- Digital or hardcopy map products at the 1:25 000 scale showing remnant vegetation and sites of environmental significance.
- Digital or hardcopy map products at the 1:25 000 scale showing areas at risk from drainage water disposal or saline groundwater discharge.
- An assessment of the potential loss and/or gains in biodiversity resulting from the development of drainage infrastructure, drainage disposal, salinity and waterlogging associated with new irrigation development.
- An assessment of potential land management options for conservation or enhancement of biodiversity within PDZs.

8.5 Comparative analysis of the Prime Development Zones

The comparative analysis will measure the comparative risk of expanded irrigation development both within and between PDZs. For each PDZ, the capacity to support irrigated agriculture, infrastructure development needs, and potential environmental impact will be considered.

Criteria will be established to assess the limitations and strategic advantages of each PDZ. These limitations and advantages will be identified using a simple qualitative description. This will enable areas of preferred development to be identified for each PDZ.

At a broader scale, the comparative analysis will indicate those PDZs that have a strategic advantage for horticultural development. This will allow a ranking of PDZs, or enable the PDZs to be prioritised for future development. This analysis requires the following:

- a) Develop key criteria to distinguish both limitations and strategic advantages for the comparative analysis of PDZs.
- b) Identify the limitations and/or strategic production and infrastructure advantages for PDZs.
- c) Identify the limitations and/or strategic environmental advantages for PDZs.

- d) Determine the comparative risks associated with development of irrigated agriculture in each of the PDZs, considering environmental aspects, land suitable for irrigation development, drainage water disposal, and hydrogeological implications of development.

Study outputs will include:

- Digital or hardcopy map products at the 1:25 000 scale identifying areas of preferred development within each PDZ, based upon environmental considerations, land suitable for irrigation, drainage disposal requirements, and hydrogeological implications.
- Digital or hardcopy map products at the 1:25 000 scale identifying areas that should be excluded from new irrigation development.
- A comparative assessment of PDZs, identifying areas of preferred development resulting from competitive advantages and environmental circumstances.

9 Appendixes

9.1 Appendix A Land capability assessment for irrigated agriculture

Table 9.1 Land capability assessment for irrigated agriculture

Land capability class	1	2	3	4	5
Principal Profile Form	Um1,5,6 Gn 2.1,3.1,4.1	Um 7 Gn3,4.3-4.4,2.2- 2.4	Um 2-4, Uf 1,5 Ug 5,6 Gn 1,3,5,4.5 Dr 1,2,3,5 Db 1,2,4 Dy 1,4,5 Dd 1,2,4 Uc 1	Uf 2,3,4 Ug 1-4 Dy 3 Dd 3 Gn 3.7-0	Dg Shallow saline soils Stony soils
Topsoil texture	SL,L	LS,S,LFS	ZL,CL	FSCL,ZCL	LC-HC
Stoniness (%)	0	1-10	10-20	20-50	>50
Gravel (%)	0	1-10	10-20	20-50	>50
Topsoil sodicity (%)	<6	<6	<6	6-15	>15
Subsoil sodicity (%)	<6	<6	6-15	15-25	>25
Slope (%)	0-4	0-4	4-20	20-32	>32

Note: The above table has been developed from regional data to provide a general assessment of land capability for irrigated agriculture. The assessment does not provide sufficient information for site specific evaluation. Additional site specific factors that would require consideration prior to development should emphasise soil hydraulic properties, soil chemistry, water quality issues, site size and layout issues.

9.2 Appendix B Definitions for land capability classes

Table 9.2 Definitions of capability classes for irrigated agriculture in the PDZs

Land capability class		Definition
1	Very high	High to very high productivity mostly on basaltic terrain, some floodplain. Suited to a wide variety of irrigated horticultural and cropping applications. Note: Flooding risk needs to be considered in floodplain areas as well as drainage in flood-prone areas and dissected terrain.
2	High	Moderate to high productivity on the alluvial and undulating plains and rises. Generally suited to irrigated horticulture, dairying and viticulture. Note: Waterlogging is an issue on adjacent terrain.
3	Moderate	Moderate to low productivity on variable stony plains and gentle to moderate slopes. Commonly suited to dairying, viticulture and tree crops. Note: Waterlogging may be an issue on adjacent terrain.
4	Low	Low to moderate productivity on rocky plains or steep to moderate slopes, or areas of poor drainage. Not capable of supporting irrigation. Typically utilised for forestry, dryland cropping and grazing.
5	Nil	Very low productivity or severe landform constraints exist (e.g. very steep slopes, rock outcrop). Not capable of supporting dryland agriculture and forestry.

9.3 Appendix C Permitted uses by class of water

Table 9.3 Permitted Uses by Class of Water

Class C	Class B	Class A
Secondary and pathogen reduction (including helminth reduction for cattle grazing)	Secondary and pathogen reduction (including helminth reduction)	Tertiary and pathogen reduction (including helminth reduction)
Urban (non potable)		Urban (non potable)
Municipal parks/sports grounds (controlled public access)		Residential uses, garden watering, toilet flushing, municipal parks (uncontrolled public access), fire protection
Agricultural	Agricultural	Agricultural
Cooked/processed human food crops not exposed to reclaimed water, grazing/ fodder for sheep cattle and horses (including grazing/fodder for dairy cows subject to five day withholding period after irrigation)	Dairy cattle grazing, dairy shed stockyard wash down, stock drinking (except pigs), and human food crops (e.g. peeled/shelled) not exposed to reclaimed water.	Raw human food crops exposed to reclaimed water
Industrial	Industrial	Industrial
Closed systems with no potential for human exposure	Livestock saleyard or abattoir stockyard wash down	Open systems with potential for worker exposure
All Class C and D uses (i.e. secondary treated effluent suitable only for non human food crops)	All Class C and D uses	All Class B,C and D uses

Source: Draft environmental guidelines for the use of recycled water (EPA 2001)

9.4 Appendix D Groundwater resources of the study area

Table 9.4 Groundwater resources of the greater Melbourne study area

Aquifer	Occurrence	Type and form	Area km ²	Hydraulic conductivity m d ⁻¹	Bore yield L s ⁻¹	Direct recharge ML y ⁻¹	Through -flow ML y ⁻¹	Total storage ML	1989 extraction ML y ⁻¹
<u>Western study area</u>									
Werribee Delta	Werribee South	Unconfined to semi- confined	117	1-15; 5	<5	3000	1400	160 000	4332
Bridgewater Formation	Geelong- Bellarine								92
Newer Volcanics	West of Melbourne	Unconfined to confined multi-layered fractured variable hydraulic parameters	2575	1-6	<1	15 450	700- 4250	1 180 000	2756
Brighton Group	West of Melbourne	Unconfined to confined sand & silt aquifer	1825	0.1-2	<3				2
Brighton Group	Geelong- Bellarine	Unconfined to confined sand, silt & limestone aquifer	340	0.1-2	<2				30
Batesford Limestone	Geelong- Bellarine	Confined by Fyansford Formation aquitard.	300	2-15	<30				
Werribee Formation	West of Melbourne	Confined to semi- confined by Altona coal seam and Fyansford Formation	1245	3-15	<50	3080	13 000	17 430 000	
Werribee Formation	Ballan- Graben Bacchus Marsh area	Outcrops or subcrops, more than 150 m thick beneath quaternary alluvium	385						1167
<u>Eastern study area</u>									
Bridgewater Formation	Nepean Peninsula	Unconfined sand clay aquifers	100	5-30; 10	<10	11 250	15 700	2 350 000	3954
Fyansford Formation- Brighton Group	South-east Melbourne- Northern Zone	Confined to unconfined sand, gravel & limestone aquifer system rests directly on Silurian basement	130	0.1-2	<18	2 300	2 000	420 000	1248
Fyansford Formation- Brighton Group	South-east Melbourne- Central Zone	Confined to unconfined sand, gravel & limestone aquifer system overlies basalts or Werribee Formation	325	0.4	<2	5 200	600	920 000	1312

Aquifer	Occurrence	Type and Form	Area km ²	Hydraulic Conductivity m d ⁻¹	Bore yield L s ⁻¹	Direct Recharge ML y ⁻¹	Through -flow ML y ⁻¹	Total Storage ML	1989 Extraction ML y ⁻¹
<u>Eastern study area (contd)</u>									
Fyansford Formation- Brighton Group	South-east Melbourne- Southern Zone	Confined to unconfined sand, gravel & limestone aquifer system overlies basalts or Werribee Formation	100			3 500	1 000	58 000	143
Fyansford Formation Brighton Group	South-east Melbourne- total	Confined to unconfined sand, gravel & limestone aquifer system rests directly on Palaeozoic basement	555			11 000	3600	1 390 000	2704
Older Volcanics	Cranbourne- Mordialloc	Outcrops at Cranbourne, elsewhere confined to semi- confined	125	5-10; 7.5	<15	500	820	26 160	2289
Older Volcanics	Mornington		45		<5				54
Older Volcanics	Silvan	Unconfined	70	<2	<32	4025	4000	56 000	1794
Werribee Formation	South-east Melbourne		200	5	10-20			641 000	677
Werribee Formation	Nepean Peninsula	Confined to semi- confined aquifer of sand and gravel	100		10-20				
Westernport Group- Baxter Formation	Westernport	Leaky-unconfined to confined aquifer of sand, clay, gravel	900	1-4	<25				
Westernport Group- Sherwood Formation	Westernport	Leaky-unconfined to confined aquifer of sand, clay, silt	900	1-8.5	<25				
Westernport Group- Yallock Formation	Westernport	Unconfined to confined aquifer of sand & gravel	900	3-4.8	<25				
Older Volcanics	Westernport	Semi-confined to confined aquifer of basalt	900	2.9-11.7	<15				
Childers Formation	Westernport	Semi-confined to confined aquifer of sand & gravel	900	3.0-3.7	2.5-25				

Source: Leonard (1979)

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