1 Introduction

Groundwater Dependent Ecosystems (GDEs) are generally defined as ecosystems that use groundwater either at some stage of their life cycle or by one generation which is critical to the existence of that species. Demonstration of groundwater *use* does not necessarily equate to groundwater *dependence*. By dependence it is meant that the ecosystem would be significantly altered and even irreversibly degraded if groundwater availability was altered beyond its 'normal' range of fluctuation (Colvin et al. 2003). In addition to identifying the dependence on groundwater, it is important to understand the sensitivity of ecosystems to different stresses. GDE sensitivity includes impacts of changes to water levels, chemistry, recharge, or discharge volume. GDEs may be altered by indirect or direct effects of climate change, changes in surface water management, groundwater pumping for water supply, changes in water quality, or land use changes.

Some GDEs will be more resilient to perturbations than others. Sensitivity is intimately linked to the likely degree of change and the probability of changes occurring. For example, wetland species may depend on groundwater to maintain inundation but a species able to tolerate greater water level decline or decline for a longer period would be less sensitive than one less able to tolerate the change. Similarly, it is important to identify whether postulated changes to the environment are likely to occur and to focus on sensitivity to plausible risks.

1.1 Project Outcome

The main outcomes sought from the project are:-

1) Valued new knowledge to assist development and refinement of State and regional policies on GDE management and water management in areas of resource competition (including regional Sustainable Water Strategies);

2) Valued new knowledge to assist targeting and management of high-value wetlands/streams and groundwater management areas;

3) Provision of a sound basis for targeting detailed investigations of GDEs;

4) Reduction in the impact of farming systems on GDEs at risk of disturbance through land use practices, including groundwater pumping and drainage diversion.

1.2 Project Background

An outcome of the 1994 Council of Australian Government's Water reform framework was that water allocation planning is required to protect ecosystems, including Groundwater Dependent Ecosystems (GDEs) that have an important function or conservation value. The unprecedented dry conditions over the last twelve years have highlighted the significant role groundwater plays in maintaining many natural systems. This period has also seen an increase in groundwater use for both agricultural and domestic purposes. This project will focus on determining which agricultural systems pose a risk to the groundwater of landscapes that contain GDEs, which GDEs are most sensitive to groundwater system changes and which ones are at greatest risk. It will also aim to determine possible ranges of groundwater volumes used by terrestrial groundwater dependant ecosystems.

Previous research by DPI (CMI 102552) has developed the first Victoria-wide map of landscapes that potentially contain groundwater dependent ecosystems. The map provides a spatial understanding of the extent and landscape setting of a range of groundwater dependent ecosystems. In delivering the project, it became clear that the maps provide key information to a wide range of organisations that manage groundwater (incl. DSE, EPA and RWAs) or manage natural ecosystems, such as DSE and CMAs. The project group is working closely with DSE (Groundwater Reform Group) in using the new GDE maps to develop guidelines for Environmental Water Allocations for Groundwater Management Areas (GMAs). Both Goulburn

Murray Water and DSE have shown strong interest in becoming partners in further development of the GDE maps.

This project will deliver a transparent assessment of the impact of major agricultural practices on groundwater dependent ecosystems and provide a spatial map of where GDEs are currently at risk. It will improve our understanding of the impact of agriculture on high value biodiversity assets and increase our understanding of the role that groundwater plays on securing our natural heritage. The project will contribute to the Key Project FF104 output of 'Reliable and defensible approaches to measuring and monitoring natural resources and agriculture sustainability, the AFG 4 Year Strategy Outcome 1 'Farming and resource management that sustains the natural resource base', and Future Farming Strategy Action 4 ' Strengthening land and water management. Successful completion will lead to more sustainable resource management through improved accounting, land use planning, site selection, and farm system design. The project aligns with 'Our Water Our Future' water accounting and management priorities '. It will also directly benefit the National Research Priority 1: An Environmentally Sustainable Australia.

1.3 Project Objectives

The initially recorded project objectives were to: (i) identify threatened high-value GDEs in Victorian National Action Plan (NAP) regions (i.e. Goulburn-Broken CMA, North Central CMA, Wimmera CMA, Mallee CMA, Glenelg Hopkins CMA and Corangamite CMA), (ii) assess their groundwater dependency (nature and degree), and (iii) identify the threats to these GDEs, their susceptibility to these threats and likely consequences.

Because this project was venturing into a new research field, it was allowed considerable flexibility to begin with. In the early stages of the project, it was recognised, with agreement from the project funders, that the initial project objectives (above) were too ambitious in the project timeframe and needed to be revised. The initial phase of the project used literature review of GDE studies and remote sensing methods to develop a geographic information system (GIS) layer for the location of potential terrestrial GDEs and to define attributes such as salinity and geomorphological unit for those locations (Dresel, et al., 2010). The second phase of the project, reported here, is to develop a methodology based on available data for assessing potential sensitivity of the GDEs to perturbation of the hydrologic system.

1.4 Status of Victoria GDE Mapping

Phase one of the project produced a series of GIS mapping layers for the state of Victoria, subdivided by Catchment Management Authority (CMA) region (Dresel, et al., 2010). Several remote sensing products were used to develop indicators of possible presence of GDEs across the landscape. Each remote sensing measure was classified to define regions where the presence of GDEs was indicated by using knowledge of the hydrogeology, vegetation mapping, visible imagery interpretation, and locations of known GDEs from literature review. Then these complimentary measures were combined into a map of potential GDEs. A groundwater interactive map – a generalized indication of expected depth to groundwater was developed, based on bore hydrograph, topography, geologic mapping, and geomorphological mapping. This map was used to divide the potential GDE areas into those expected to have generally shallow (~< 5m) vs. generally deep watertable. The groundwater interactive and other attributes assigned to the GDE locations are shown in Table 1.

Table 1. Attributes assigned to each potential terrestrial GDE location

Column Heading	Column Alias	Attribute Class Description	Symbols or Values	Symbol Description/Meaning
GWI_CODE	Groundwater interactive designation	Groundwater expected to be accessible by vegetation	8	Water table generally < 5m below surface
			9	Water table generally > 5m below surface
GW_TDS	GW Salinity Class	Groundwater Salinity Level in GDE Area	L	Low Salinity Class (Max <=1000 TDS)
			M	Moderate Salinity Class (Max 1001 to 19,999TDS)
			H	High Salinity Class (Max >=20,000 TDS)
SUR_GEOLGY	Surface Geology Type	Surface Rock Type (Geology) in GDE Area	S	Sedimentary (includes Newer Volcanics)
			I	Intrusive
			M	Metamorphic
			U	Unclassified (many are in water bodies)
GMU	GMU Class	Geomorphic Management Unit (GMU) in GDE Area	Various, all in the form X.X.X Where X is a #, 0 to 9	Each CMA includes a different array of GMU classes
DESCRIPTIO	GMU Class 'Description'	A written description of the GDE's 'GMU Class'	Various pieces of text	A description of the specific Geomorphic Management Unit (GMU) Class associated with each GDE.

It is important to note that the potential terrestrial GDE maps (Dresel, et al., 2010) are subject to considerable uncertainty. The mapping exercise was based on spectral characteristics expected to be shown by GDEs. No field verification of groundwater use or dependency was performed. Areas of potential GDE are likely over-classified in upland forests and other treed areas, steep terrain, and high precipitation regions. Some over-classification was considered desirable due to the sparse knowledge about GDEs in Victoria but it is probable that not all GDEs were identified. The maps provide the first cut prediction of where groundwater is predicted to support surface ecology. They also provide additional information to assist the development of management plans aiming to preserve key environment assets. The maps form a basis for more detailed catchment or local scale evaluation of the presence and sensitivity of potential GDEs. The remote sensing methodology can be optimized for particular catchments by more detailed analysis of aridity zones, vegetation characteristics (including tolerances), iterative adjustment of classification levels for the data sets, more detailed land-use analysis, and by development of training data from local field studies.

1.4.1 Enhancement to GDE Mapping

The sensitivity evaluation allows for more detailed assessment of GDE locations than possible for the State-wide mapping phase, but still without field validation. Several procedures were used to aid the sensitivity assessment.

The GDE map layers were overlain on air photo mosaics for the trial areas and surroundings. This helps identify areas of natural vegetation and assess the presence of trees or shrubs. Apparent differences in vegetation type then could be related to the data sets used in the analysis. This also aided in identification of most likely GDE areas out of the mapped polygons.

Morphologic features of the mapped potential GDE polygons were also used to identify the more likely GDE areas, combined with the air photo interpretation. Mapped areas that form cohesive areas in drainages appear more likely to represent distinctive ecosystems that may use groundwater. These features may occur along ephemeral streams or higher in the landscape where surface water is likely seldom present and can be seen by overlaying topographic contours or digital elevation models (Figure 1). Extensive upland forest areas and tree plantations could be excluded from the analysis this way. Some forest areas may still be groundwater dependent, but more detailed study is needed to determine and understand that dependency.

The location of mapped wetlands was also correlated with potential GDEs. Caution was needed, however, because the various wetland map layers available use different definitions and may include areas subject to inundation without wetland vegetation.

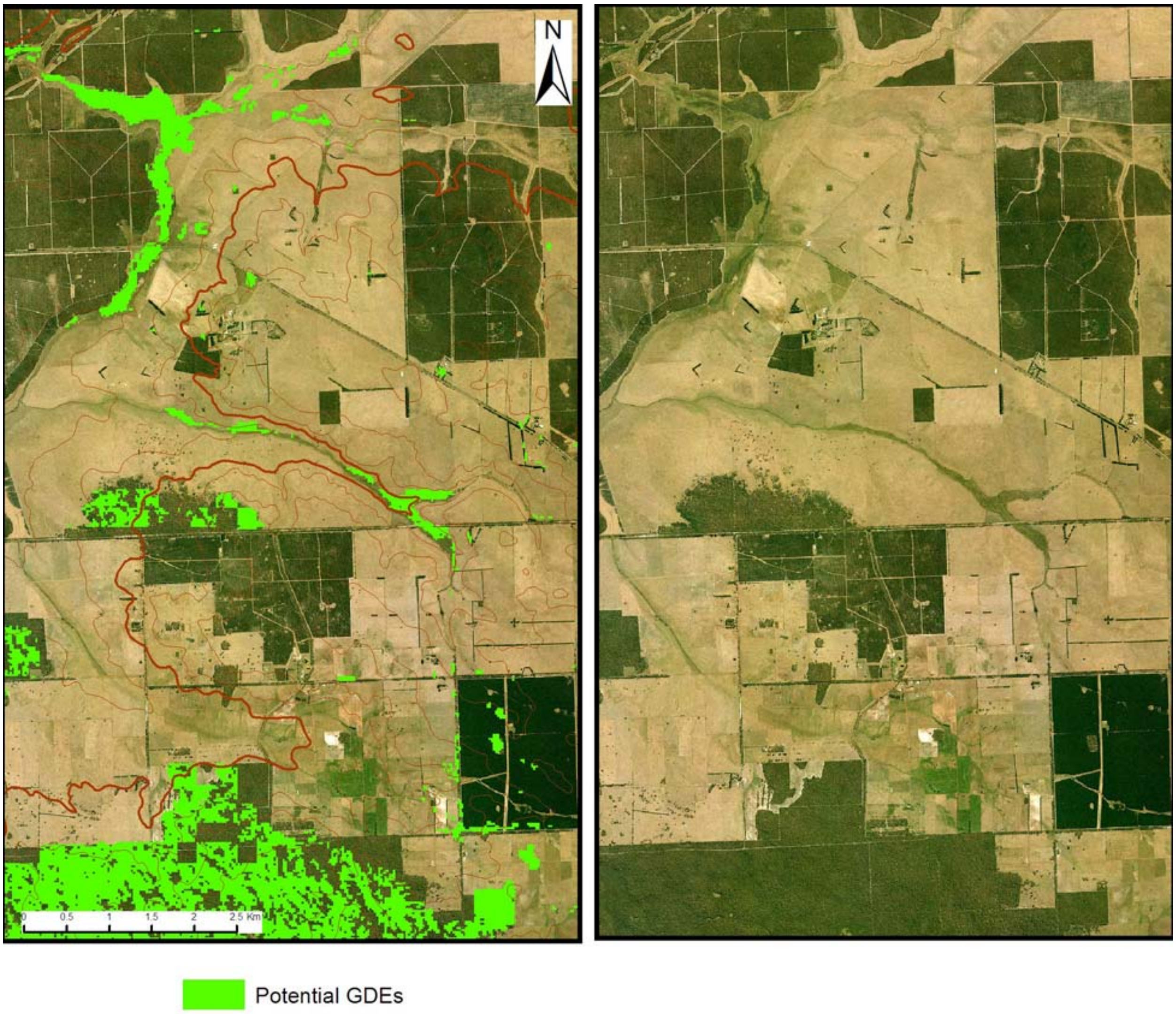

Figure 1 Potential GDE locations along the Crawford River showing more likely groundwater dependent vegetation along drainages and less likely forest vegetation not conforming to topography