Improving Knowledge of Water-Dependent Assets and Receptors in the Gippsland Basin

DEPARTMENT OF ENVIRONMENT, LAND, WATER AND PLANNING

Part 2: Groundwater Dependent Ecosystem Prioritisation Framework

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Contents

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to present our approach to developing a database and prioritisation framework that identifies and prioritises Groundwater Dependent Ecosystems (GDEs) in the Gippsland region that have high values and that potential coal mining and coal seam gas (CSG) development is a potential hazard to in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

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1. Introduction

1.1 Project background

In response to community concerns regarding large scale coal and coal seam gas (CSG) activities, the Federal Government established the Independent Expert Scientific Committee (IESC) on coal seam gas (CSG) and large coal mining development in 2012. The IESC provides independent expert advice to governments to ensure that future decisions about the potential water-related impacts of CSG and large coal mining developments are better informed. The Bioregional Assessments are one of the key mechanisms to assist the IESC in developing this advice to ensure it is based on the best available science and independent expert knowledge. Six priority areas across Australia have been identified for Bioregional Assessment and the Gippsland region is one of these.

The Bioregional Assessment program for the Gippsland region is being managed by the Commonwealth Department for Environment (DoE) and the Victorian Department of Environment, Land, Water and Planning (DELWP), in partnership with the two Catchment Management Authorities (CMAs) in the Gippsland region; the East Gippsland and West Gippsland CMAs.

Victoria's existing gas energy demands are project to double by 2030 and Victoria's existing reserves are expected to be depleted by this time. There may be potential for unconventional gas, which includes CSG, to replace or supplement Victoria's declining conventional gas supply. While there are currently no CSG development proposals in Victoria, some companies are investing in CSG and other unconventional gas exploration. The Gippsland region has significant coal measures and is attracting the most interest for development, making it a priority for the Bioregional Assessment Program

A key part of the Bioregional Assessment program is developing a sound understanding of water assets, including those dependent on groundwater (for this project termed groundwater dependent ecosystems - GDEs), which have the potential to be impacted by activities associated with CSG and large coal mining developments. This will complement a recent report prepared for the East and West Gippsland CMAs which recommended improving conceptual understanding of all high value GDEs (Jacobs SKM, 2014).

Part 1 of the Improving Knowledge of Water-Dependent Assets and Receptors in the Gippsland region project collected data on five representative GDEs in the Gippsland region. The information collected was used to develop conceptual models that help visualise and communicate the potential relationships between large coal mining and CSG extraction activities and groundwater and surface water in the connected environments. The conceptual models also indicate how changes in groundwater and surface water levels and flows could impact on ecosystems dependent on the groundwater for all or some of their water needs.

This report forms Part 2 of the project which aims to develop a database and prioritisation framework that identifies and prioritises GDEs in the Gippsland region that have high values and that coal mining and CSG development may represent a potential hazard. The database and prioritisation framework will be critical to assist DELWP, the East Gippsland and West Gippsland CMAs and other stakeholders in understanding and responding to impacts and opportunities associated with CSG and large coal mining developments.

Although focused on potential CSG and large coal mining developments in the Gippsland region, the database and prioritisation framework developed in this project includes impacts associated with other potential hazards to the ecological functions of GDEs (e.g. climate change and groundwater extraction for irrigation).

1.2 GDE Database and Prioritisation Framework objectives

A GDE prioritisation framework is needed to be able to assess the values of ecological receptors within GDEs, the likelihood of impacts to those values from groundwater level changes (e.g. from groundwater extraction, coal mining and CSG developments), and options for managing potential hazards. Specifically, the database and framework are required to:

- Identify potential hazards to water assets associated with groundwater extraction
- Identify key information gaps
- Help focus attention on management for particular assets
- Allow for continual refinement
- Provide a framework for water assets for which there is currently no adequate information available to identify potential hazard.

1.3 Limitations and assumptions

This framework is an update of a GDE prioritisation framework developed for the Gippsland Region in 2014 (Jacobs SKM 2014). It uses the best data available at the time, however, new information is being generated all the time and it is important to note that for the framework to inform management in the future it will require regular updating as new information becomes available. This is particularly the case for new information that helps to better define impact pathways associated with groundwater drawdown due to potential CSG extraction.

Furthermore, the framework is based on landscape scale data to identify areas where GDEs sensitive to changes in groundwater could be susceptible to impacts from groundwater decline. It doesn't negate the need for local site-based assessments and investigation in order to further confirm GDE values and potential impacts.

Specific assumptions and limitations are provided at relevant locations throughout the report.

2. Existing prioritisation framework

In 2014, Jacobs SKM used the National Water Commission's GDE Toolbox framework (Richardson S, et al 2011) to establish a GDE (referred to as groundwater dependent water assets) prioritisation framework for the Gippsland region for the East and West Gippsland CMAs (Jacobs SKM, 2014). This existing database and prioritisation framework was adopted as a starting point for the current project. This section provides an overview of the current prioritisation/ potential hazard assessment framework. More detail can be found in Jacobs SKM (2014).

2.1 Definition and identification of a GDE

Jacobs SKM (2014) referred to GDEs as groundwater dependent water assets (GDWAs) and defined them as "*any surface ecosystems that has some form of dependency on groundwater*". This project looks at two sub sets of GDEs that define the broad groundwater processes associated with that ecosystem:

- **Surface water ecosystems dependent on groundwater,** which includes all surface water ecosystems with a groundwater component, such as rivers, wetlands, lakes, seeps, springs, estuaries and associated aquatic ecosystems. These ecosystems rely on groundwater that has been discharged to the surface, for example, as baseflow or spring flow (BoM, 2012).
- **Terrestrial vegetation ecosystems dependent on groundwater**, which includes all terrestrial vegetation ecosystems that access the water table below the natural surface. Note for the purposes of the 2014 project, these ecosystems were restricted to vegetation associated with floodplain and riparian zones and did not include all other terrestrial vegetation communities that could potentially access groundwater (see below).

GDEs that were excluded from the scope of works were cave and aquifer systems, coastal and marine systems and terrestrial vegetation generally not associated with a floodplain or wetland. This decision was in acknowledgement of the lack of information at the time regarding:

- The location and values of specific cave ecosystems
- The relationship and importance of groundwater to coastal and marine ecosystems
- The dependency and sensitivity of terrestrial vegetation not associated with floodplains/riparian zones/swamps and wetlands to groundwater. Furthermore, in the context of the definition of a GDWA in this project, a terrestrial vegetation ecosystem is not a "water asset", even though it may be dependent on groundwater.
- In consultation with the East and West Gippsland CMAs it was also decided that the presence of sub surface GDEs (floodplain and riparian vegetation) that are likely to be connected to groundwater will be captured as an attribute rather than an asset in their own right due to complexity of treating these as individual GDEs.

Existing spatial datasets pertaining to the location of GDEs were then used as the basis to identify GDEs in the Gippsland region. A base layer of GDEs for the Gippsland region was developed based on the application of the data summarised in Table 2.1.

Table 2.1 Base data layers

Dataset	Rule set*
Surface water ecosystems dependent on groundwater	
DEPI Wetlands 2013	All wetlands in the dataset excluding the following: • Any wetland with a *low potential for groundwater interaction* (defined in GDE Atlas) • Any man-made wetland (Wetland Origin in Wetlands 2013 dataset)
Vicmap Watercourse	All high and medium hierarchy watercourse (see below for a definition) in the dataset excluding the following: • Any river with a *low potential for groundwater interaction* (defined in GDE Atlas)
Terrestrial vegetation ecosystems dependent on groundwater	
GDE Atlas	The intersect/ overlay of a sub-surface surface expression of groundwater polygons in the GDE Atlas with the surface water ecosystems dependent on groundwater (wetland or river) asset identified above was used to identify those terrestrial vegetation ecosystems dependent on groundwater that represent floodplain and riparian vegetation only. These were not captured as an asset in their own right, but rather assigned to surface water ecosystem dependent on groundwater as an attribute in the spatial database.

* assumptions made to develop the rule sets are further detailed in Jacobs SKM (2014).

2.2 Area of interest (AOI)

Jacobs SKM (2014) focuses on identifying and locating all the GDEs which interact with the Gippsland region and have the potential to be directly or indirectly influenced by CSG and large coal mining developments. Two separate areas of interest (AOI) were defined (Figure 2-1):

- Gippsland region AOI based on hydrogeological basin and geomorphic unit (GMU) spatial data
- Extent of coal deposits AOI based on GMU boundaries and the following spatial data:
  - ***Brown coal deposits in the Latrobe Valley Group*** of the Morwell, Yallourn and Hazelwood Formations which are mined in the Latrobe Valley coal mines and extend almost as far east as Sale.
  - ***Brown coal deposits in the Latrobe Group (including the Traralgon Formation)*** which are targets for potential coal seam gas extraction. These sediments extend over most of the Gippsland region except for the far east.
  - ***Black coal deposits*** in the Wonthaggi/Korumburra region associated with Cretaceous aged sediments of the Korumburra Group.

Due to the project focusing on surface water ecosystems, the GMUs governed the line work (boundaries) of the AOI whilst taking into account the Gippsland region and coal deposit footprint. This allowed a change in landform to determine the AOI, rather than a hydrogeological basin or coal deposit boundary, which is more related to sub-surface features. This also provides a conservative approach for determining the AOI.

The application of the GMU dataset to govern the boundaries of the AOI ensures that the potential area of impact not only takes into account those GDEs impacted by potential CSG and large coal mining developments directly (e.g. the GDE is within the immediate impact zone of an open cut mine) but also those assets impacted indirectly (e.g. a surface feature impacted by the groundwater drawdown during dewatering) or via a downstream impact (e.g. a surface feature impacted by changes to a surface flow regime). In the case of these downstream impacts, potential CSG and large coal mining developments may be a potential hazard to GDEs that are not underlain by coal deposits and may be some distance away from the area of potential CSG and large coal mining developments.

It should be noted that the spatial extent of the coal deposit AOI extends beyond the jurisdictional boundary of the East and West Gippsland CMA (into the Port Phillip and Westernport CMA) as coal mining or CSG extraction in the Port Phillip and Westernport CMA has the potential to impact GDEs in the West Gippsland CMA area depending on the nature of groundwater connections across the catchment divide.

All assets included in the subset of GDEs were considered susceptible to potential CSG and large coal mining developments.

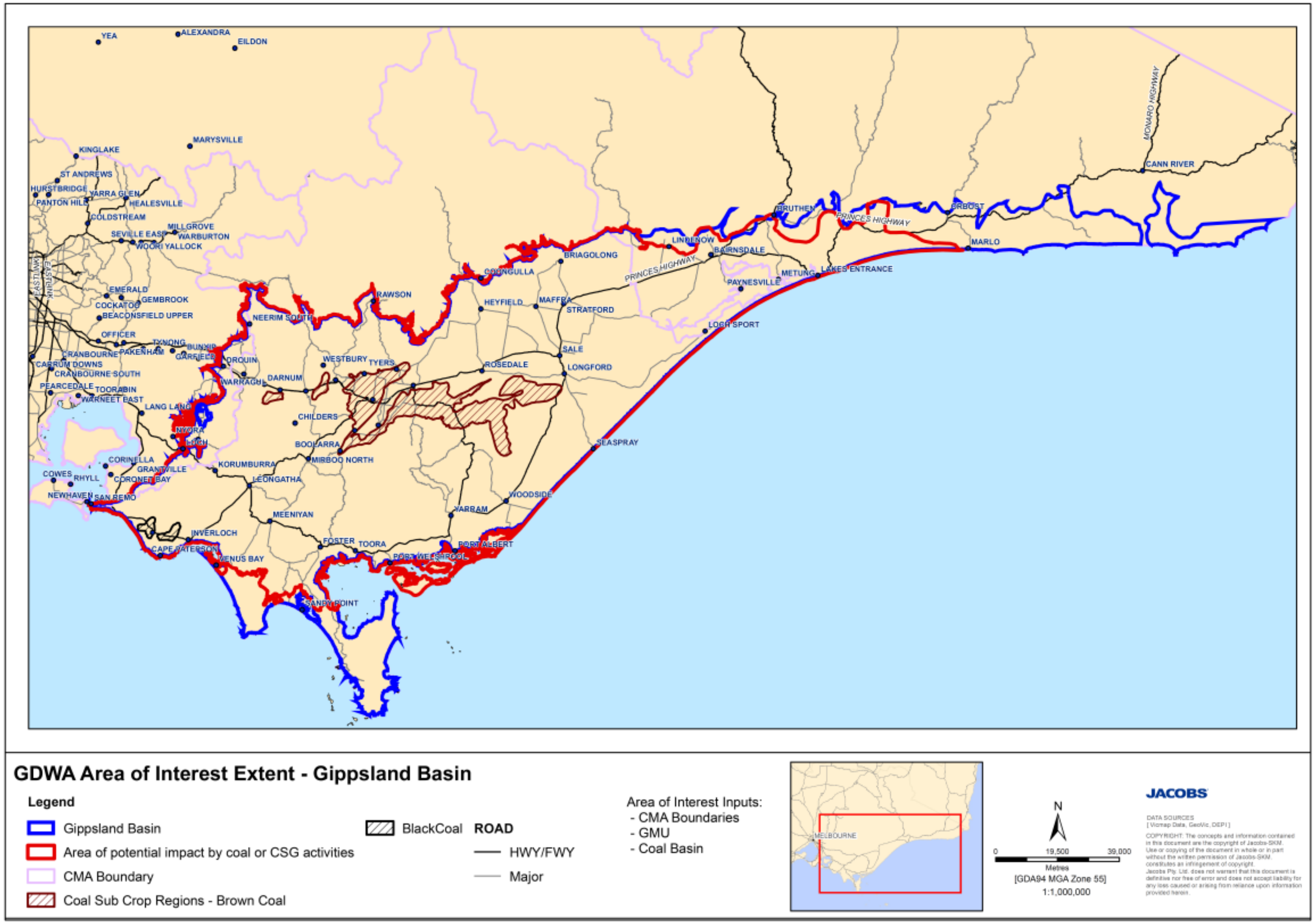

Figure 2-1 Area of interest

2.3 Threats to GDEs associated with CSG and large coal mining developments

GDEs in the Gippsland region could be affected by activities associated with the potential development of CSG or large coal mines, as these activities have the potential to change the water balance within both the groundwater and surface water system (SKM, 2012). CSG is held in the coal seams by water pressure. As water is pumped from the coal seams, the pressure is lowered and the gas is released (desorbed). As water pressure is reduced, CSG flow increases and water flow rates decrease from each well, typically to around a quarter to a third of the initial flow over a period of a few months depending on the hydrogeological conditions of the seam. This depressurisation process is targeted in the coal seams however, the surrounding aquifers can also be impacted (both vertically and laterally depending in the hydraulic properties of the aquifers and intervening layers). Depressurisation may also be required to lower the groundwater levels around coal mines, and large (deep) coal mines will obviously require large scale depressurisation / dewatering.

It should be noted that many of the threats are present at both exploration and development stage, however at the exploration stage impacts will be temporary and localised. During development, impacts are likely to be realised over larger areas and for longer durations. There are currently no CSG exploration or extraction activities being undertaken in the Gippsland region.

The activities associated with potential CSG and large coal mining developments and the threats they pose to GDEs are detailed in Table 2.2. In summary, GDEs in the Gippsland region have the potential to be affected by the following broad threats associated with potential CSG and large coal mining developments:

- Change in groundwater quantity (level and flux)
- Change in groundwater quality
- Change in surface water quantity (levels or flow)
- Change in surface water quality
- Surface disruption (open cut mining, well installation)

Table 2.2 Activity and associated nature of threat

Activity	Nature of threat arising from activity
Extraction of groundwater	Short and long term impacts from the extraction of groundwater (associated with depletion of groundwater pressures and falling groundwater levels) on existing users, groundwater-surface water interactions and GDEs.
Discharge of co-produced water	Co-produced water is defined as the water extracted from CSG wells during depressurisation and any water that is discharged from a large coal mine as part of the mine pit de-watering process. Altered surface water quality and flow regime may be experienced as a result of discharge of co-produced water to waterways.
Irrigation with co-produced water	Contamination of soils and shallow groundwater systems as a result of irrigation with CSG co-produced water through land salinisation, waterlogging or contaminants.
Storage of co-produced water	Contamination of surrounding environment (including GDEs, surface water, shallow groundwater) associated with above-ground storage of water/produced fluids (i.e. storage dams) as a result of leakage, dam wall collapse and salt crystallisation.
Re-injection of co-produced water	Regional contamination of groundwater as a result of direct re-injection of co-produced water into an aquifer, or leakage into surrounding aquifers, including geochemical changes.
Development of infrastructure (e.g. mine pits, transport, pipelines corridors etc)	Altered surface water flow patterns and habitat extent as a result of associated infrastructure requirements including mine pits, surface water diversions, changed drainage patterns, loss of key habitat or regional/ landscape habitat connectivity.
Well construction (exploration and development)	Localised hydraulic connectivity between isolated aquifers caused by poor drilling techniques, failed casing, poor cementing, general poor well construction and decommissioning.

Activity	Nature of threat arising from activity
	Contamination of local landscape, vegetation and surface waters as a result of drilling operations and drilling fluids (e.g. spills).
Hydraulic Fracturing	Well failure (casing or cement) causing increased hydraulic connectivity of aquifers and potential contamination of surrounding aquifers. Increased hydraulic connectivity of aquifers as a result of physical changes to aquifer due to over-pressurising the aquifer causing vertical fractures (increasing vertical hydraulic conductivity). Impact of chemicals used in hydraulic fracturing (at surface or in aquifers)

2.4 GDE prioritisation framework overview

In line with the National GDE Toolbox Framework (Richardson et al. 2011), a prioritisation framework/ potential hazard assessment was used to prioritise the GDEs in the Gippsland region. The prioritisation framework aimed to assess how sensitive GDEs were to change, with an emphasis on water regime changes (groundwater and surface water) from threats associated with potential CSG and large coal mining developments.

The prioritisation framework applied in Jacobs SKM (2014), is outlined in Figure 2-2 and has been applied by Jacobs in various risk-related projects (e.g. Melbourne Water GDE Risk Management Framework and Prioritisation). This prioritisation framework includes a traditional hazard assessment process (i.e. potential hazard = consequence x likelihood) and requires each component of the framework to be ranked high, medium or low.

The prioritisation framework has non-spatial and spatial components. The non-spatial components incorporate knowledge of the relationships between landscape and management (land use) processes and management. These relationships are developed in a series of tables as rules and ratings. The spatial component uses GIS to apply the rules and ratings and map their occurrences and outcomes at individual GDE sites/locations. This framework is consistent with the Australian Standard for risk assessment (AS/NZS ISO 31000:2009, Risk management - Principles and guidelines (http://infostore.saiglobal.com/store/Details.aspx?ProductID=1378670). The outputs of the potential hazard assessment are maps of the ranked overall potential hazard / priority GDEs (based on a likelihood and consequence analysis).

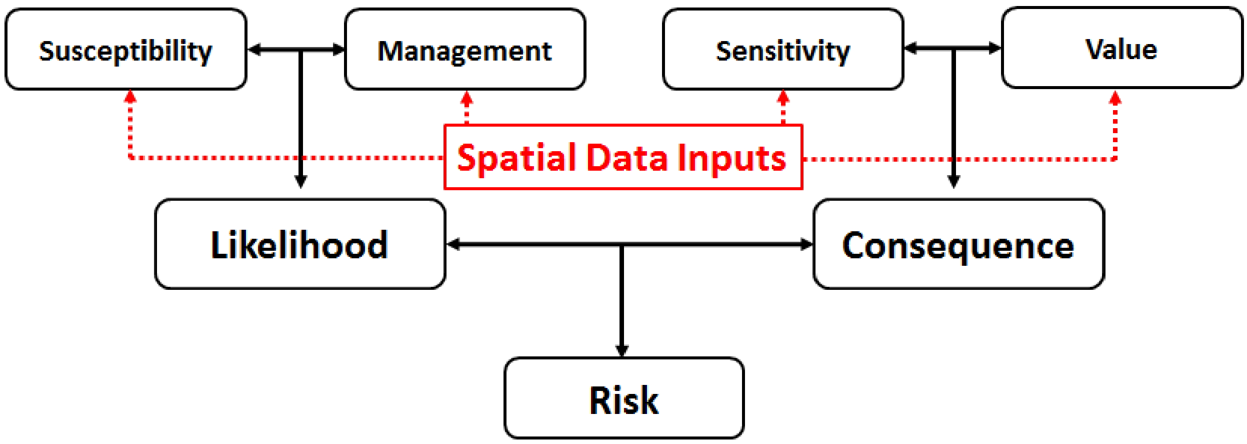

Figure 2-2 Potential hazard (risk) assessment approach for the prioritisation of GDEs in the Gippsland region

Each of the elements of the prioritisation framework presented in Figure 2-2 is described below.

Likelihood

Likelihood depends on the ***susceptibility*** of a GDE to impacts of current, proposed and future threats (i.e. groundwater level decline) and the moderating role that ***management*** has on the imposed threat.

The ***susceptibility*** is the chance a threatening process has on breaching a threshold on the characteristics of the GDE. The susceptibility of GDEs to groundwater level decline is determined through the current known locations where decline is happening, or possible, from activities such as extraction for irrigation and other consumptive uses, draw down due to coal mining activities and potential drawdown due to future gas development. The intersection of the current known extent of drawdown with GDEs in the Gippsland region identifies those GDEs susceptible to drawdown.

The ***management*** represents management actions that influence how susceptible a GDE is and is informed by existing management activities that impact positively on a GDE by mitigating or minimising the likely impact of groundwater decline (e.g. via management of causal factor in driving that decline, or via provision of an alternative water source). For example, a regulated river may have the option of supplementary flows if an extraction activity was to alter the surface water flow pattern.

Consequence

Consequence is the measure of how the threatening process impacts the GDE's capacity to cope with the threat ***(sensitivity)***, combined with the current ***value*** of the GDEs.

Sensitivity can be considered as the degree of resilience of a GDE has to any given threat, and the ***value*** is the worth of the environmental and social services provided by the GDE.

Sensitivity is derived from a set of rules based on a combination of spatial data and expert knowledge which provide an indication of the sensitivity of a GDE to a change in water regime (e.g. groundwater connection, water regime and alternate water source). These rules are discussed and presented in Section 2.4.2.

The ***value*** is a direct outcome of information compiled around the current ecological and social values associated with the GDE (e.g. threatened species, EPBC listing) and is rated high, medium or low.

Overall potential hazard

Potential hazard - the potential hazard is the product of the ***likelihood*** that degradation and/ or change will occur to a GDE and the ***consequence*** if that occurs.

Potential hazard = Likelihood x Consequence

The ***likelihood***, ***consequence*** and ***overall potential hazard*** is measured in terms of high, moderate and low.

2.4.1 Prioritisation approach

The GDE prioritisation approach involves developing a framework in which each of the four components of the potential hazard assessment (i.e. susceptibility, management, sensitivity and value) to be ranked. The framework aims to be simple, practical, multi-scaled, adaptive, updateable and is designed to:

- Increase the awareness of the connection between landscapes and groundwater, and the impact pathway that threatening processes (e.g. groundwater extraction, coal mining and potential CSG activities) have on groundwater level.
- Provide more meaningful analysis and description of the likely impacts of a range of threats on GDEs and be presented in a way that can be readily understood by local stakeholders including the community.
- Give the natural resource managers better capacity to provide advice and inform decision making around the likely impacts to GDEs from threatening activities in their management areas. It will provide the critical

spatial database, that when used in conjunction with sufficient literature would enable managers to efficiently respond to potential future threats to GDEs in their regions.

- Provide a critical source of information that will enable managers to better manage individual assets (wetlands, native vegetation etc.) in partnership with local land owners, managers and the community

Overall rankings for likelihood and consequence are used to develop an overall potential hazard assessment/ prioritisation ranking for each GDE site. Sites ranked high overall should be targeted for further work and consideration under a GDE potential hazard management framework.

The GDE prioritisation approach is more than just high level ecological value and likely threat from potential CSG and large coal mining developments, as it considers all aspects of the potential hazard assessment (susceptibility, management, sensitivity and value) to add depth to the prioritisation assessment. The approach is also designed to capitalise on the wealth of information held by DELWP and other state-wide agencies and the internal CMA data already gathered for a number of GDE sites.

Prioritisation frameworks are scale and data dependent. Data is often limited by inconsistent data collection across spatial scales, which affect the ability to apply rankings across entire jurisdictions in a uniform and equal manner. A standardised prioritisation process does not currently exist, however this is an approach that has been adopted by several government departments in Victoria to date. Using this framework, rules and criteria were developed to apply the prioritisation approach. The process of identifying criteria and rules was an iterative one, developed over a number of stages with consultation with the East and West Gippsland CMAs.

Specific criteria were assessed and ranked to form the basis of overall ranks for each aspect of the potential hazard assessment approach (susceptibility, management, sensitivity and value). A three category ranking system was used (i.e. high, moderate and low). It was recommended that:

- Sites with high value and sensitivity but low susceptibility and/or management hazard should be managed for conservation
- Sites with moderate to high value, sensitivity, susceptibility and management should be targeted for GDE management and investment
- Sites with low value/sensitivity and high susceptibility/management hazard should not become targets for GDE management.

Overall rankings for likelihood and consequence were used to develop an overall potential hazard assessment/prioritisation ranking for each GDE site. Sites ranked as having a high overall ranking should be targeted for further work and consideration under the GDE prioritisation framework.

The datasets and rules (criteria) applied to rank a GDE's value, sensitivity, susceptibility and management is provided in detail in Section 2.4.2.

2.4.2 Prioritisation rules

In order to assess the susceptibility, management, sensitivity and value associated with each GDE in the Gippsland region, rules were developed based on a combination of spatial data attributes and expert knowledge (in particular for identifying those GDE more sensitive to threats) to provide a measure of either high, moderate or low for each of the potential hazard assessment components. A summary of the datasets, criteria and rankings applied in the prioritisation approach to assess value, susceptibility and management, are detailed in Appendix B, Appendix C and Appendix D.

The rules developed and GIS analysis undertaken to determine the sensitivity of a GDE is more complex than the other components due to the large number of possible combinations of the spatial data attributes and the number of broad threat posed to GDE as a result of potential CSG and large coal mining developments (see Section 2.3).

The following section provides a more detailed description of the rules applied and the additional GIS analysis carried out to determine the sensitivity ranking of GDEs.

Sensitivity rules

Sensitivity rules were developed for each GDE type (rivers and wetlands) based on a combination of existing spatial data attributes and expert knowledge of the GDEs which are most sensitive to the following threats associated with potential CSG and large coal mining developments:

- Change in groundwater quantity (level and flux)
- Change in groundwater quality
- Change in surface water quantity (level and flow)
- Change in surface water quality
- Surface disruption (open cut mining) (see Section 2.3 for further details)

The attributes applied to determine sensitivity relate to either the water body or the dominant ecosystem type and consider both surface and sub-surface impacts to groundwater, therefore providing two levels of sensitivity. The sensitivity rules are designed to ensure each GDE has a potential hazard assessment completed.

Appendix E provides details of the sensitivity rules in a matrix form and Table 2.3 provides a summary of the attributes used to define sensitivity the rationale behind their application. As described in Section 2.1, within the sensitivity analyses the impact on changing water regimes to terrestrial vegetation GDEs is also provided by the development of a sub set of surface water GDEs, sorted by the likely occurrence of terrestrial vegetation dependent on groundwater. This makes it possible to identify wetlands and rivers that are highly sensitive to changes in water regimes that also contain terrestrial vegetation dependent on groundwater.

Table 2.3 Sensitivity attributes and rationale

Attribute	Relevant GDWA	Attribute categories	Rule/ rationale for determining sensitivity
Wetland Type	Wetland	• Flooded river flats • Freshwater meadow • Sewage oxidation basin • Shallow freshwater marsh • Deep freshwater marsh • Permanent open freshwater • Semi-permanent saline • Permanent saline	Wetland types provide information on the general hydrology of the GDE; its preferred or existing hydrological state. Any change in surface water or groundwater quality and surface disturbance can change the preferred hydrological state of a GDE. It is assumed that GDEs are sensitive to any shift in their existing state (e.g. freshwater to saline, permanent to semi-permanent).
GW Connection	Wetland River	• High • Moderate • Low	Groundwater connection provides a physical sense of the current known reliance of the GDE and its ecosystems to groundwater. Changes in groundwater flow regimes will cause a greater shift in the water budget of GDE that have a high groundwater connection, compared to GDE that have a low level connection.

Attribute	Relevant GDWA	Attribute categories	Rule/ rationale for determining sensitivity
Salinity Regime	Wetland	• Fresh • Fresh-Hyposaline • Hyposaline • Hyposaline-Mesosaline • Mesosaline • Mesosaline-Hypersaline • Variably Salt Tolerant	Salinity regime provides information on the preferred salinity regime of the GDE. A change in surface water or groundwater quality can change the salinity regime, shifting it from its normal state and therefore making it sensitive to the impacts from potential CSG and large coal mining developments. For example, saline ecosystems would be negatively impacted if changes in hydrology caused an influx of fresh water.
Surface water regime	Wetland River	• Episodic • Intermittent • Intertidal • Permanent • Seasonal • Supratidal	Surface water regime provides a measure of resilience because it indicates an alternate source of water to groundwater. The impact of a change in the groundwater regime to a GDE depends to a degree on the surface water regime. If a GDE is permanently inundated from surface water it will have a level of resilience to changes in groundwater, as the GDE will remain inundated irrespective. However, if a GDE is episodically inundated with surface water, changes to the groundwater will have potentially a greater impact.
River regulation (environment al flow requirements, management plans)	River	• Regulated • Unregulated	River regulation provides an indication of the natural state of water regime of the GDE. The impact of a change in groundwater and surface water quality or quantity is diminished in regulated streams, therefore regulated GDEs are likely to be less sensitive to change that unregulated, as the water flow can be controlled and designed to provide water for instream ecosystems.
Additional Source of Water – River	Wetland	• Very low • Low • Moderate • High • Very High	Additional source of water (river) provides a measure of resilience because it indicates an alternate source of water to groundwater. GDE with a river as an additional water source (e.g. oxbow) will be more resilient to changes to groundwater quality or quantity. Alternatively, these GDEs will be highly sensitive to changes in surface water quality or quantity or surface disruption which may change the hydrology of its surface water (river) source.
Additional Source of Water – Tidal	Wetland River	• Tidal • Non-tidal	Additional source of water (tidal) provides a measure of resilience because it indicates an alternate source of water to groundwater. The sensitivity of a GDE which has a tidal component to their water source (e.g. estuaries) will vary depending on the situation. GDEs with tidal water as an additional water source (e.g. estuaries) can be more resilient to changes to groundwater or surface water quality or quantity. However, these GDEs may also be highly sensitive to changes, due to a reduction in groundwater baseflow causing the fresh water- saline interface to move further upstream resulting in saltwater intrusion in to the surface water and groundwater.

Attribute	Relevant GDWA	Attribute categories	Rule/ rationale for determining sensitivity
Additional Source of Water – Groundwater	Wetland	• Both surface and groundwater • Dominant groundwater	Additional source of water (groundwater) provides a measure of the current known reliance of the GDE and its ecosystems to groundwater. GDEs that have a dominate groundwater source will have a greater sensitivity to a change in groundwater (quality or quantity) than those GDEs that have both a surface and groundwater component to their water balance.
Water Source (Baseflow analysis)	River	• Dominant surface water • Both surface and groundwater • Dominant groundwater	Water source (baseflow) provides an indication of surface water and groundwater component of the water budget for the GDE. GDEs that have a dominant groundwater source will be more sensitive to impact associated with groundwater (e.g. change in groundwater quality and quantity) and GDEs that have a surface water source will be more sensitive to impacts associated with surface water (e.g. change in surface water quality and quantity and surface disruption).
Temporal nature of groundwater connection	Wetland River	• Ephemeral (Unpredictable, short term); • Intermittent (Irregular, Persists for Medium Term) • Permanent, Near Permanent • Seasonal (Annual, Regular)	The temporal nature of groundwater connection provides an indication of the permanence of groundwater as a source of water. GDEs that are permanently connection to groundwater will be more sensitive to changes in groundwater quality and quantity, than those GDEs with an ephemeral connection. GDEs with an ephemeral connection have evolved to not always require a source of groundwater and will therefore be more resilient.
Ecosystem Dependent on Groundwater (due to vegetation communities present)	Wetland River	• High • Moderate • Low	Ecosystems dependent on groundwater (vegetation) provide a link between a change in surface water and groundwater quality or quantity and surface disruption to the terrestrial ecosystems associated with the GDEs. These ecosystems reflect the sensitivity of GDEs that are semi-permanent/ ephemeral, and that when dry may still have a permanent connection to terrestrial ecosystems and are therefore sensitive to a change in water regime. This attribute ensures that impacts to both aquatic and terrestrial ecosystems are considered.
Instream Ecosystem (drought refuge mapping, low flow atlas)	River	• Present • Absent	Instream ecosystems are remnant pools sustained during dry/ cease to flow periods by groundwater discharge to rivers, providing refuge to aquatic flora and fauna. The presence of remnant pools are highly sensitive to changes in groundwater or surface water quality and quantity which may reduce inflows during low flow/ cease to flow periods causing a lower resistance to drying and cause changes in water quality that may result in loss of individuals and / or species.

There is a lack on concrete evidence regarding what is the most influential factor on the sensitivity of GDEs and therefore, it is not possible to develop a weighted multi criteria analyses to provide an overall sensitivity rating for each GDE. In addition to this, the complexity of the sensitivity rules applied would result in a large number of possible combinations of the attribute rankings (high, medium and low).

Therefore to simplify the results, the attribute ranking for each attribute was taken as an *average* by converting the rankings to integers according to:

- High sensitivity = 3
- Moderate sensitivity = 2
- Low sensitivity = 1

The *overall average* sensitivity of a GDWA for each of the sensitivity attributes/ rules was calculated using:

$$\frac{\text{(Sensitivity attributes 1) + (Sensitivity attributes 2) + (Sensitivity attributes 3) + (Sensitivity attributes 4).....}}{\text{Sum of total attributes}}$$

All attribute rankings were considered equally (i.e. weighting = 1) with the exception of the following attributes:

- Wetland groundwater quality and quantity were both given a higher weighting of 2 due to the significance role that groundwater plays in groundwater dependent wetlands
- Wetland surface water quality and quantity were both given a weighting of 0.5

The numerical ranges applied in the potential hazard assessment approach are detailed in Table 2.4 and the governing attributes and rules applied to determine these ranges are provided in Table 2.4.

Table 2.4 Numerical range of each overall sensitivity category

Criteria	Numerical Range – Wetland GDEs			Numerical Range – River GDEs		
Threat	**Low**	**Moderate**	**High**	**Low**	**Moderate**	**High**
Change in groundwater quantity	0 – 1.5	1.5 – 1.99	1.99 – 3.0	0 – 1.86	1.86 – 2.4	2.4 – 3.0
Change in groundwater quality	0 – 1.5	1.5 – 1.99	1.99 – 3.0	0 – 1.85	1.85 – 2.4	2.4 – 3.0
Change in surface water quantity	0 – 1.16	1.16 – 1.67	1.67 – 3.0	0 – 1.5	1.5 – 1.7	1.7 – 3.0
Change in surface quality	0 – 1.16	1.16 – 1.73	1.73 – 3.0	0 – 1.72	1.72 – 2.2	2.2 – 3.0

Surface disruption was not included in the analysis due to being assigned directly to value

3. Method to update existing prioritisation framework

As part of the development of the existing Gippsland GDE prioritisation framework (Jacobs SKM, 2014), key limitations and recommendations were idetified, particularly around the sensitivity of rivers, the inclusion of terrestrial vegetation as GDEs and the extent of CSG prospectivity areas.

Based on these limitations, updates to the existing Gippsland GDE prioritisation framework were identified in order to provide a more comprehensive prioritisation of GDEs and assessment of the likelihood of impacts to their values from a wider range of groundwater changes (i.e. not just from potential CSG and large coal mining developments) that may combine with potential CSG development to have impacts on GDEs in the future. These updates were discussed at a steering committee workshop in December 2014 and were developed further in a recommendations report provided to DEWLP in January 2015. Subsequently DEWLP provided approval to proceed with the prioritisation framework update. Specific updates include:

- Assessing overall potential hazard from potential CSG and large coal mining developments separately, therefore two overall potential hazard ranking outcomes are provided in the results. The existing prioritisation framework only provides one overall potential hazard assessment outcome; that is for potential CSG and large coal mining developments together.
- Further defining susceptibility of GDEs to groundwater change as a result of potential CSG developments by improving identification of potential hazard locations, including the application of updated prospectivity data. Susceptibility to large coal mining developments in the existing prioritisation framework (Jacobs SKM, 2014) remained unchanged.
- Improved definition of river sensitivity (e.g. in the way river reaches are assigned gaining and loosing characteristics and hence sensitivity to changes in groundwater level).
- Incorporation of terrestrial GDEs based on a broad scale assessment of the groundwater dependency of Ecological Vegetation Classes found in the study area.
- Identification of other threats (stressors) to GDEs (e.g. groundwater extraction, acid sulphate soils, land use change, coal mining, surface water regulation, climate change) in order to refine threat footprints so that groundwater and surface water impacts are not assumed to occur everywhere in the landscape. This will also allow for GDEs to be prioritised according to individual threats.

The following section provides further detail of the incorporation of these improvements in to the existing prioritisation framework.

3.1 Susceptibility of GDEs to potential CSG and large coal mining developments

The existing Gippsland GDE prioritisation framework (Jacobs SKM, 2014) captures the susceptibility of a GDE to potential CSG and large coal mining developments together; therefore the overall potential hazard is to both potential CSG and large coal mining developments combined. As part of the update of the existing prioritisation framework, the susceptibility of GDEs to potential CSG and large coal mining developments were treated separately and as such, there is now two overall potential hazard rakings which can be used to prioritise GDEs in the Gippsland region:

1. Overall potential hazard to GDEs from potential CSG developments
2. Overall potential hazard to GDEs from large coal mining developments

The existing Gippsland GDE prioritisation framework (Jacobs SKM, 2014) defines the susceptibility of a GDE to potential CSG development as the intersect of a GDE with the Lower Tertiary Aquifer (LTA). The LTA underlays a large proportion of the Gippsland Basin, however potential CSG extraction is likely to be limited to only certain area in the south east of basin. Using the LTA alone is a very precautionary approach in terms of identifying areas where there is a potential hazard from potential CSG extraction because the actual impact is likely to be a function of the hydraulic properties of the LTA, the lateral and vertical extent of potential groundwater drawdown with the aquifer and the depth of the LTA to the surface.

This precautionary approach was acknowledged in the original framework and the intent of the revised framework was to refine the area of potential impact based on outcomes from a regional scale numerical groundwater model being developed as part of the Bioregional Assessment process. This would more clearly define vertical and lateral pathways of potential groundwater drawdown from CSG extraction and relate this drawdown to changes in the water table level. This approach would have provided a refined area of impact that considered more explicitly the locations for potential CSG extraction, the hydraulic properties of the LTA and the spatial extent of potential water table drawdown.

Unfortunately the outcomes of the numerical model were not available in time for the current study, so an alternative approach was required.

Since the development of the original prioritisation framework, analysis of CSG prospectivity has been undertaken by Geoscience Victoria and *subregional scale* resource development boundaries have been developed defined by the depth to the top of Traralgon Formation of 400 to 800 m below the surface (Jacobs, 2015a) (Figure 3-1).

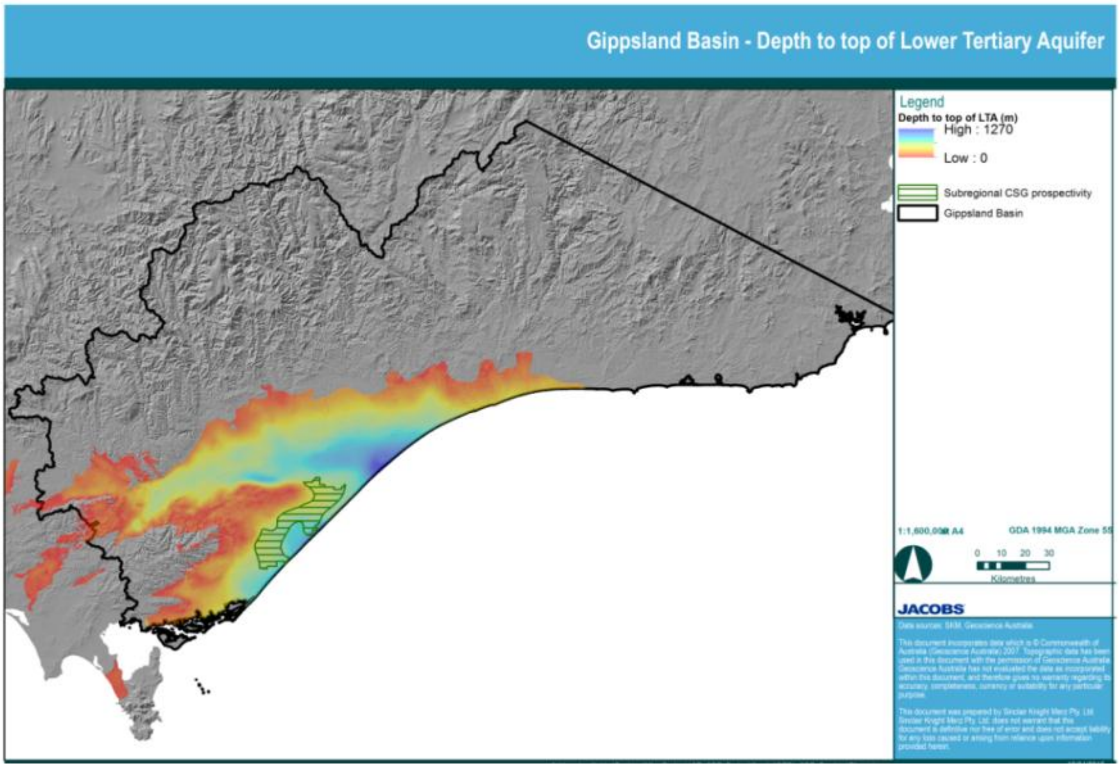

Figure 3-1 Extent of Lower Tertiary Aquifer compared with the sub-regional CSG area, showing that the extent of the LTA is much larger than the sub-regional prospectivity areas.

Based on feedback from DELWP the *subregional scale* resource development boundary was adopted as an indicator of the most likely areas for potential CSG developments and to reduce the current skew towards high priority / potential hazard across the whole extent of the LTA. However, it is acknowledged that this approach may underestimate the extent of potential impacts because it does not explicitly consider the potential lateral extent of impact associated with drawdown of LTA in the immediate area of potential CSG extraction. To overcome this, a buffer was applied to the *subregional scale* resource development boundary to determine the likely extent of high, medium and low potential hazard (Table 3.1).

Table 3.1 Ranking of susceptibility of GDEs to potential CSG developments

Threat	Threat ranking
Potential CSG Development	
GDEs located in the sub-regional scale boundary + 10 km buffer	High
GDEs located in the sub-regional scale boundary + 10 km – 30km buffer	Medium
GDEs located in all other areas	Low

3.2 River sensitivity

The existing Gippsland GDE prioritisation framework assigns river susceptibility to changes in groundwater based on whether the river is likely to be a losing, gaining or variable system. This attribution was based on work completed by GHD on assessing river baseflows, and on an evaluation of the geomorphic unit each river reach is associated with. The GHD data set was incomplete for the Gippsland Basin and the relationship between geomorphic unit and groundwater flow can be further developed.

A number of alternative methods were considered for assigning gaining or losing status to river reaches, for example, further baseflow analysis, assessment of seasonality of flow regimes, including timing and duration of cease-to-flow periods as an indicator of a losing system, further analysis of the geological and geomorphological settings of each river reach and depth to water table mapping.

Through the development of conceptual models describing the relationship between groundwater and associated GDEs (Part 1 of the current project), it become apparent that further analysis of river base flow regimes and cease-to-flow occurrences would not provide a sufficient landscape scale dataset from which to assign sensitivity. This is because there is few river flow gauges available for analysis, and of those, most are located on major river systems, which are also subject to river regulation, and may mask any groundwater dependency.

Through the conceptualisation process, we identified two river system types (alluvial and non-alluvial) and three levels of potential groundwater interaction based on depth to water table (<5m, 5-10 m and >10 m) that could be used to assign an overall level of susceptibility of river reaches to changes in groundwater water table level (Table 3.2).

River systems located on alluvial geology, and with depth to the groundwater table of less than 5 m, are likely to interact with groundwater and hence be gaining or variably gaining/loosing at various points in time. The specific susceptibility of these systems to groundwater change would vary depending on stream flow. For example, during seasonal high flow conditions and wet climate years with long durations of high flow, alluvial systems with generally shallow groundwater tables would have low susceptibility to groundwater change because surface water would dominate the water regime. However, during periods of low rainfall and low surface runoff these systems would become more susceptible to reductions in groundwater level. Even short periods of time when a river is susceptible to changes in groundwater level could result in a long-term impact on ecological values, particularly if a reduction in groundwater level resulted in an otherwise permanent river reach ceasing to flow for a period of time during a dry period. On this basis, these types of stream are assigned a high susceptibility to groundwater change.

Waterways located on alluvial geology but with depth to the groundwater table more than 5 m were most likely to exhibit loosing characteristics across the full range of flow conditions and hence have only a medium to low susceptibility to groundwater level change.

River systems located on non-alluvial geology are less likely to be susceptible to groundwater change, although in some non-alluvial systems, springs and local groundwater systems may still be important water sources to river systems at certain times, this is especially the case for headwater streams that may be spring fed. However, for the purposes of the current study we have assumed that local groundwater flow systems and spring systems in headwater reaches are unlikely to be impacted by regional scale changes in groundwater levels, so only medium to low susceptibility to changes in groundwater have been assigned to these river types.

Table 3.2 Rating table for assigning susceptibility of river systems to groundwater change

Geology	Potential for groundwater interaction	Susceptibility to groundwater change		
		Depth to water table <5m	Depth to water table 5-10m	Depth to water table >10m
Alluvial	High	high	medium	low
Non-alluvial	Med-low	medium	low	low

The susceptibility ratings provided in Table 3.2 are a broad, landscape scale assessment, and hence there is inherent uncertainty in the ratings. They could be further refined through examination of groundwater level data form bores in proximity to different river reach types. For example, for river systems where water table level drawdown is identified as a potential hazard, site specific investigations of groundwater level in local bores could be undertaken to refine areas of potential hazard.

3.3 Identification and prioritisation of terrestrial vegetation GDEs

The existing Gippsland GDE prioritisation framework does not capture terrestrial vegetation reliant on groundwater for all or some of its water supply as a GDE in its own right. To provide DELWP and the East and West Gippsland CMAs with a more complete GDE spatial dataset, terrestrial vegetation GDEs are included in the prioritisation framework for this project.

This project defines terrestrial vegetation GDEs as "*any terrestrial vegetation ecosystems that utilise the water table below the natural surface*" (Jacobs SKM, 2014). These ecosystems include terrestrial vegetation that depends on groundwater fully or on a seasonal or episodic basis in order to prevent water stress and generally avoid adverse impacts to their condition. Unlike the surface expression of groundwater (watercourse, wetlands and springs), groundwater is not visible from the earth surface (Richardson S, et al, 2011). Figure 3-2 illustrates the occurrence of surface and sub-surface expressions of groundwater in a regional context.

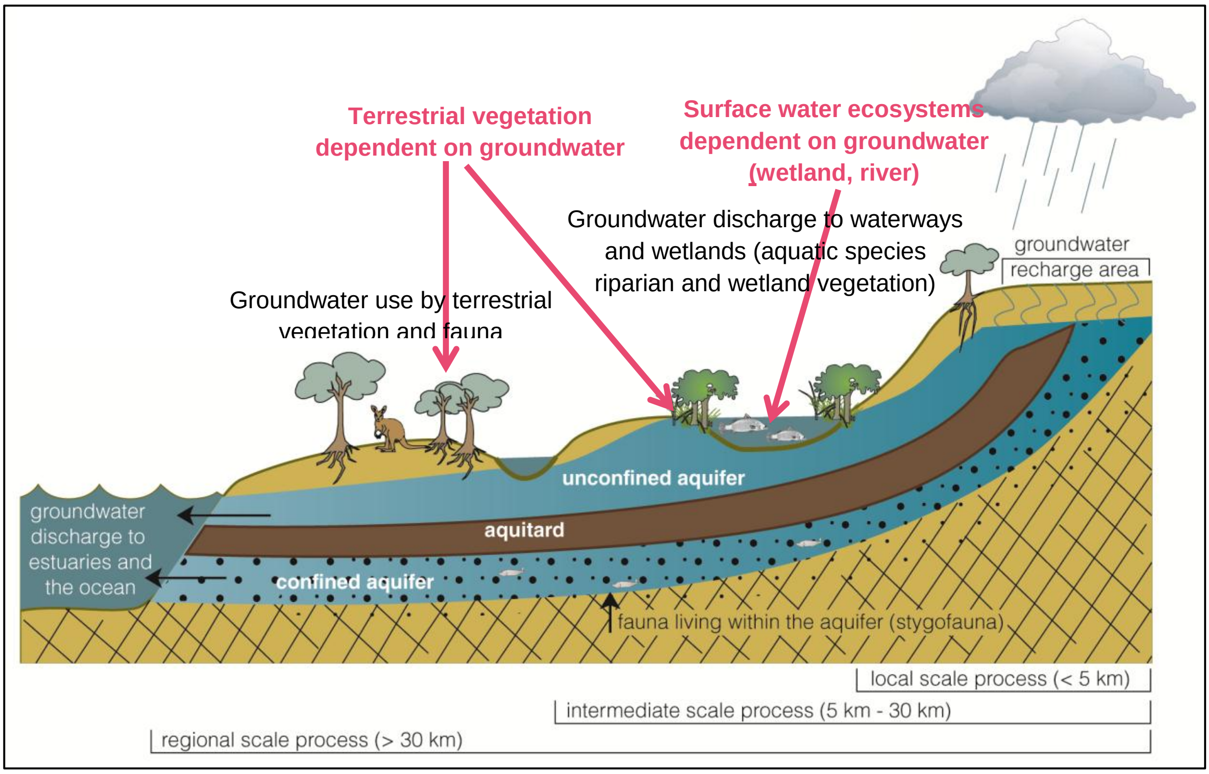

Figure 3-2 Ecosystems dependent on groundwater (Source: adapted from DEPI, 2011)

3.3.1 Identification of terrestrial vegetation GDEs

A base layer of terrestrial vegetation GDEs for the Gippsland region was developed based on the application of the rules summarised in Table 3.3.

Table 3.3 Identification of sub-surface GDEs

Dataset	Rule set
GDE Atlas (BoM, 2012)	All terrestrial vegetation GDEs (referred to as sub-surface GDEs in the GDE Atlas) in the dataset excluding the following: • Any GDE identified with a *low potential for groundwater interaction* Due to the GDE Atlas overestimating the location of terrestrial vegetation GDEs, a subset of terrestrial vegetation GDEs will also be made to exclude: • Any EVC selected as unlikely to be reliant on groundwater as proposed by expert review of the terrestrial vegetation GDEs in the GDE Atlas (see Appendix A)

3.3.2 Prioritisation rules

The prioritisation of sub-surface GDEs applied the same potential hazard assessment framework as the existing Gippsland GDE prioritisation framework (Jacobs, 2014) which included a traditional hazard assessment process (see Figure 2-2). In order to assess the susceptibility, management, sensitivity and value components of the potential hazard assessment for each terrestrial vegetation GDE in the Gippsland region, rules were developed based on a combination of spatial data attributes and expert knowledge (in particular for identifying those terrestrial vegetation GDEs more sensitive to threats) to provide a measure of either high, moderate or low for each component. A summary of the datasets, criteria and rankings applied in the prioritisation approach to assess value, susceptibility and management for the terrestrial vegetation GDEs and GDEs has been included with the existing Gippsland Prioritisation Framework datasets, criteria and rankings in Appendix B, Appendix C and Appendix D.

Similarly to the river, wetland and spring GDES, the rules developed and GIS analysis undertaken to determine the sensitivity of terrestrial vegetation GDEs are more complex than for the value component due to the large number of possible combinations of the spatial data attributes and the multiple water regime changes scenarios in which sensitivity is assessed. The sensitivity rules are designed to ensure that a sensitivity assessment can be completed for each water asset.

The sensitivity rules developed for terrestrial vegetation GDEs were based on a combination of existing spatial data attributes and expert knowledge of the terrestrial vegetation GDEs which are most sensitive to the following water regime changes associated with potential coal mining and CSG developments:

- Change in groundwater quantity (levels, flows) by way of a reduction or increase
- Change in surface water quantity (levels, flow regime).

The attributes applied to determine the sensitivity of terrestrial vegetation GDEs to a change in water regime relate to either the landscape conditions or water source associated with the terrestrial vegetation GDE. Appendix E, Table E-3 provides details of the sensitivity rules in a matrix form and Table 3.4 provides a summary of the attributes used to define sensitivity and the rationale behind their application.

Table 3.4 Sensitivity of sub-surface GDEs to a change in water regime

Attribute	Dataset	Attribute categories	Rule/ rationale for determining sensitivity
Vegetation Tolerance to Waterlogging	ARI Vegetation sensitivity layer	Waterlogging (Band 1) grid ranges converted to(based on natural break analysis) = • High (3,649 – 12,375 waterlogging grid range) • Medium (2,104 – 3,649 waterlogging grid range) • Low (0 – 2,104 waterlogging grid range)	Waterlogging provides an indication of the permanence of the water source to the terrestrial vegetation GDE. Based on expert advice, terrestrial vegetation GDEs with high waterlogging are assumed to be more sensitive to changes in surface water and groundwater regime.
Climate/ Landscape	GDE Atlas eco-hydrogeological zone mapping	EHZ converted to ranges = • High (Gippsland Plains) • Medium (South East Coastal Ranges) • Low (Northern Inland Slopes, Upper Slopes)	EHZ provides an indication of the interaction between groundwater and an ecosystem based on similar ecology, geology, climate and groundwater/ surface water connections. Based on expert advice, terrestrial vegetation GDEs in a higher rainfall areas and particular landscape settings (e.g. Highland areas) are less reliant on groundwater or surface water and therefore less sensitive to changes in groundwater. It is acknowledged that GDEs located in the headwaters areas may be impact by potential CSG developments where the target aquifer outcrops, however lateral and vertical connection data is currently not available to understand the extend of this impact and therefore has not been included in this sensitivity assessment.

Attribute	Dataset	Attribute categories	Rule/ rationale for determining sensitivity
Depth to water table	DEPI state wide depth to watertable mapping	Depth to watertable converted to ranges = • High (<5) • Medium (5-10) • Low (>10)	Terrestrial vegetation within areas of shallow water tables has less root development to cope with a shift in groundwater levels, and have evolved to have continual access to water. Therefore terrestrial vegetation GDEs in areas of shallow groundwater are generally more sensitive to changes in groundwater levels (assumption based on results in SKM, 2011b). Particular during prolonged dry seasons where access to alternate water supplies (e.g. surface water) is either reduced or ceased. Alternatively terrestrial vegetation GDEs that have access to permanent shallow water tables may be less sensitive to changes in surface water regime.
Vegetation type	Ecological vegetation classes (EVC)	Likelihood of groundwater connection determined for each EVC by expert review of the terrestrial vegetation GDEs in the GDE Atlas (see Appendix A)	Vegetation types provide information on general hydrological requirements of the terrestrial vegetation GDE. Particular ecological vegetation classes (EVC) require access to permanent water to maintain their ecological function. Based on expert advice, particular EVCs (e.g. riparian scrub, sand heathland, swamp scrub) have been assigned a rating (high, medium and low) of likely groundwater connection (provided in Appendix A)Terrestrial vegetation GDEs that have a high likelihood of groundwater connection will have a greater sensitivity to changes in groundwater and those with a low likelihood of groundwater connection will have greatest sensitivity to change in surface water patterns.
Additional source of water – surface water	Wetland current Low flow analysis - manual	Intersect of permanent wetland/ watercourse (with 25m buffer): • WTRREG (permanent assets) • Flow_Regim (permanent assets)	Additional source of water (surface water) provides a measure of resilience because it indicates an alternate source of water to groundwater. Based on expert advice, terrestrial vegetation GDEs with a wetland or watercourse as an additional water source (e.g. floodplain) will be more resilient to changes to groundwater quality or quantity. Alternatively, these terrestrial vegetation GDEs will be highly sensitive to changes in surface water quality or quantity or surface disruption which may change the hydrology of its surface water (watercourse or wetland) source.
Wetland and watercourse regulation	River regulation – manual entry Environmental Water Plan – manual entry	Intersect of regulated wetland/ watercourse (with 25m buffer): • Wetland_EW (EWP asset) • River_Reg (reg asset)	Watercourse or wetland regulation provides an indication of the reliability of the water source of terrestrial vegetation GDE asset within the vicinity of watercourses and wetlands. The impact of a change in groundwater and surface water quantity is diminished in regulated watercourses or wetlands, therefore terrestrial vegetation in the vicinity of regulated water assets are likely to be less sensitive to change than unregulated assets, as the water flow can be controlled and designed to provide water for instream ecosystems (assumption based on results in SKM, 2011b).

** Groundwater salinity was not incorporated in to the final sensitivity rules due to the salinity of groundwater in floodplain regions in Gippsland are generally mapped as >7,000 mg/l TDS (DELWP regional groundwater salinity mapping) which* *indicates that this groundwater is fresh to brackish and falls within the maintenance of ecosystems beneficial use segments A1 to C (0-13,000 mg/l TDS).*

There is insufficient evidence regarding what is the most influential factor on the sensitivity of terrestrial vegetation GDEs; therefore, it is not possible to develop a weighted multi criteria analysis to provide an overall sensitivity rating for each sub-surface GDE. In addition to this, the complexity of the sensitivity rules applied would result in a large number of possible combinations of the attribute rankings (high, medium and low).

To simplify the results, the same method adopted to calculate overall sensitivity for wetland, river and spring GDEs was undertaken (refer to Section 3.3.2). Overall sensitivity of terrestrial vegetation GDEs was taken as an *average* by converting the individual sensitivity attribute rankings (see Appendix E) to integers according to:

- High sensitivity = 3
- Moderate sensitivity = 2
- Low sensitivity = 1

The *overall average* sensitivity of a water asset for each change in water regime scenario was calculated using a simple spreadsheet tool (provided as an output of this project) with the following calculation imbedded:

$$\frac{\text{(Sensitivity attributes 1) + (Sensitivity attributes 2) + (Sensitivity attributes 3) + (Sensitivity attributes 4).....}}{\text{Sum of total attributes}}$$

All attribute rankings were considered equally (i.e. weighting = 1). The numerical ranges applied in the potential hazard assessment approach are detailed in Table 3.5. The governing attributes and rules applied to determine these ranges are provided in Appendix F.

Table 3.5 Numerical range of each overall sensitivity category

	Numerical Range – Sub surface GDE		
Threat	**Low**	**Medium**	**High**
Change in groundwater quantity	0 – 1.86	1.86 – 2.43	2.43 – 3.0
Change in surface water quantity	0 – 2.29	2.29 – 2.43	2.43 – 3.0

3.4 Threat types

Whilst the Bioregional Assessments are focussed on potential CSG and large coal mining developments and associated impacts on water assets, there are also a number of other threatening processes within the Gippsland region that are directly related to a change in water balance of the water asset (e.g. climate change, groundwater extraction for water supply). Therefore, this project provides a more detailed spatial analysis to identify locations across the Gippsland region where these additional threats to GDEs are more likely to occur and could exacerbate the overall impacts of any future CSG development. This will provide a more comprehensive assessment of the potential hazard from potential CSG development. These threats include (see Table 3.6 for a summary of ranking rules for each threat):

- Groundwater extraction – Groundwater extraction is managed through the development of Groundwater Management Plans and areas under threat are declared as Water Supply Protection Areas or Groundwater Management Areas (WSPAs). GDEs located in these areas may be currently at the greatest threat from groundwater extraction than GDEs in other, non-declared, areas. Although the opposite may also be the case in terms of the potential hazard associated with future groundwater extraction, due to the WSPAs generally having extraction managed and capped, whereas non-declared areas will be difficult to manage if significant groundwater extraction was to take place in these areas in the future.

- Acid sulfate soils (ASS) –The Atlas of Australian Acid Sulfate Soils shows areas where ASS is a potential hazard. ASS are a potential hazard to GDEs located in these areas as a reduction in soil moisture often associated with a reduction in groundwater and surface water quantity may expose these potential ASS.

- Surface water regulation – River regulation and alteration of flow regimes represents a potential hazard to GDEs. Rivers with reduced summer flow may be more reliant on groundwater inputs to maintain base flow and hence a reduction in groundwater levels could further impact on low flows. Furthermore, river regulation that results in a reduction on overbank flows may reduce recharge of alluvial groundwater sytems.

- Climate change – Climate change, namely, inundation of coastal areas from sea level rise, represents a potential hazard to GDEs located within the inundation zone. Coastal hazard mapping defines the potential zone of impact.

The inclusion of these additional threats does not provide a cumulative hazard assessment nor can the results be compared with the overall potential hazard assessment for CSG and large coal mining developments. The purpose of the inclusion of these threats is to provide managers a high level snap shot of some of the existing or futures stressors that may increase the impact of changes in water regime as a result of potential CSG and large coal mining developments. For example if a GDE is currently under stress from groundwater extraction, the impact of additional groundwater extraction associated with potential CSG development would likely to be more hazardous to this GDE than a GDE not facing any current or future stressors.

Table 3.6 Ranking of additional threats to GDEs

Threat	Threat ranking	Considerations
Groundwater extraction		
GDEs occurs in a Water Supply Protection Area	High	Further groundwater level decline as a result of potential CSG and large coal mining developments in these areas would further stress the aquifer.
GDEs located in a Groundwater Management Area	Medium	
GDEs located in all other areas	Medium	
Surface water regulation		
Regulated river	High	Regulated rivers are likely to be flow stressed, particularly during low flow periods. Any groundwater extraction in this period would further stress rivers with a groundwater dependency
Unregulated river	Low	
Coastal Acid Sulfate Soils (ASS)		
GDEs located in areas mapped as having potential coastal ASS	High	The lowering of the watertable beneath ASS could expose them if the saturation of these soils is dependent on groundwater.
GDEs located in areas mapped as not having potential coastal ASS	Low	
Climate change – sea level rise		
GDEs located in areas mapped as likely to be inundated by a 0.82 m rise in sea level (year 2100 prediction)	High	A complete change in water regime and source water supply will be a potential hazard for those GDEs located within the potential inundation areas.
GDEs located in areas mapped as unlikely to be inundated by a 0.82 m rise in sea level (year 2100 prediction)	Low	

This further spatial analysis would also enable GDEs to be prioritised by each identified threat, providing more comprehensive information for water managers to manage individual hazards to GDEs.

It should be noted that land use change as an additional threat was originally considered for inclusion in the prioritisation framework, however was excluded due to lack of information to help define areas susceptible to specific land use changes.

4. GDE prioritisation results

A total of 147,171 GDEs were identified in the Gippsland region which includes 4,061 wetlands, 6,162 river reaches and 136,948 terrestrial vegetation GDEs.

Table 4.1presents an overview of the prioritisation results for a change in groundwater quantity associated with potential coal mining and CSG developments in the Gippsland region. The maps provided in Figure 4-1 to Figure 4-22 also illustrate the overall potential hazard / priority and susceptibility for each GDE type (rivers, wetlands and terrestrial vegetation GDEs) to a change in groundwater quantity as a result of potential coal mining and CSG developments. These figures also show the result of the additional spatial analysis undertaken to determine those locations/ GDEs where there is also potential for additional hazards to occur (e.g. groundwater and surface water extraction) within the Gippsland region that are directly related to a change in water balance of the water asset (e.g. as a result of climate change, groundwater extraction).

Results for additional scenarios (e.g. change in groundwater quality, change in surface water quality and quantity and surface disruption) are available through interrogation of the spatial geodatabase provided as an output of this project.

Table 4.1 Number (count) of GDEs distributed across the potential hazard ranking categories for criteria pertinent to the prioritisation approach

Component	Wetland GDE Rankings			River GDE Rankings			Terrestrial vegetation GDE Rankings		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
GDE value	1,247	67	2,747	391	467	5,304	12,263	10,263	114,422
GDE sensitivity groundwater quantity*	1,748	1,292	1,021	101	3,800	2,261	57,255	78,057	1,636
GDE consequence groundwater quantity	993	1,032	2,036	3	888	5,271	8,218	57,630	71,100
GDE susceptibility – potential CSG development	656	1,673	1,732	5,182	810	170	82,738	32,899	21,311
GDE susceptibility – coal development	1,252	2,348	461	4,614	1,111	437	38,667	89,181	9,100
GDE management	512	1,603	1,946	2,407	1,042	2,650	18	5	136,925
GDE likelihood – potential CSG development	127	727	3,207	2,128	3,655	379	12	82,733	54,203
GDE likelihood – coal development	151	866	3,044	1,890	3,664	608	11	38,668	98,269
GDE hazard from potential CSG development	47	1,312	2,702	3	2,868	3,558	0	39,233	97,715
GDE hazard from coal mining development	46	1,698	2,317	3	2,601	3,558	0	25,596	111,352

** Note - the population of management, likelihood and overall hazard from potential CSG and large coal mining developments will not impact on the location of terrestrial vegetation GDEs as provided in the geospatial data base of Figure 4-1 to Figure 4-22, nor the value, sensitivity or susceptibility components of the potential hazard assessment.*

It is important to recognise that the potential hazard/priority results presented reflect an approach to superimpose the current state of knowledge across the Gippsland region. Within this there are untested assumptions that inform the final potential hazard and priority.

It is therefore strongly recommended that the information of the individual components (i.e. value, sensitivity, management and susceptibility) of the analyses that developed the potential hazard ratings are considered as important as the final outcome. It is also important to understand that there is a range of attributes pertaining to the water regime and ecosystem type for each GDE that have been used to develop the component rankings (see Appendix C and Appendix E).

This can be demonstrated by considering the case study locations adopted in Part 1 of this project; Groundwater Dependent Ecosystem Conceptual Modelling (Jacobs 2015b) (Table 4.2). Results show that the potential hazard to GDEs from potential CSG and coal mine development is high for the Latrobe River, Corner Inlet and Gippsland Lakes, and medium for the Mitchell River and Red Gum Plains. The potential hazard to Latrobe River, Corner inlet and the Gippsland Lakes is driven by proximity to prospectivity areas. Although the Mitchell River and Red Gum Plains are not as close to prospectivity areas, they still score a medium potential hazard because they have either high values or are within the footprint for potential deeper coal deposits.

Table 4.2 Potential hazard assessment results for a number of case study locations

Component	Latrobe River - Rosedale (River ID 231)	Mitchell River – Lindenow (River ID 1585)	Corner Inlet Wetland – within RAMSAR boundary (Wetland ID 80912)	Gippsland Lakes – Lake Wellington (Wetland ID 91188)	Red Gum Plains – (Sub-surface GDE ID 67542)
GDE value	H	H	H	H	L
GDE sensitivity groundwater quantity	H	M	H	H	M
GDE consequence groundwater quantity	H	H	H	H	M
GDE susceptibility – potential CSG development	M	L	H	H	L
GDE susceptibility – coal development	M	L	H	M	M
GDE management	L	L	L	L	H
GDE likelihood – potential CSG development	M	L	M	M	M
GDE likelihood – coal development	M	L	M	M	M
GDE potential hazard from CSG development	H	M	H	H	M
GDE potential hazard from coal mining development	H	M	H	H	M

Additional potential hazards to GDEs (Table 4.3) include additional groundwater extraction (for Mitchell River, Corner Inlet and Gippsland Lakes) and climate change and Acid Sulfate Soils for Corner Inlet and Gippsland Lakes GDEs. These potential hazards may increase the potential impacts associated with CSG and large coal mining due to current or future stress from other hazards.

Table 4.3 Additional hazards for a number of case study locations

Component	Latrobe River - Rosedale (River ID 231)	Mitchell River – Lindenow (River ID 1585)	Corner Inlet Wetland – within RAMSAR boundary (Wetland ID 80912)	Gippsland Lakes – Lake Wellington (Wetland ID 91188)	Red Gum Plains – (Sub-surface GDE ID 67542)
Additional potential hazard – climate change (sea level rise)	L	L	H	H	L

Additional potential hazard – river regulation (only for River GDEs)	H	L	N/A	N/A	N/A
Additional potential hazard – acid sulfate soils	L	L	H	H	L
Additional potential hazard – groundwater Extraction	M	H	H	H	L

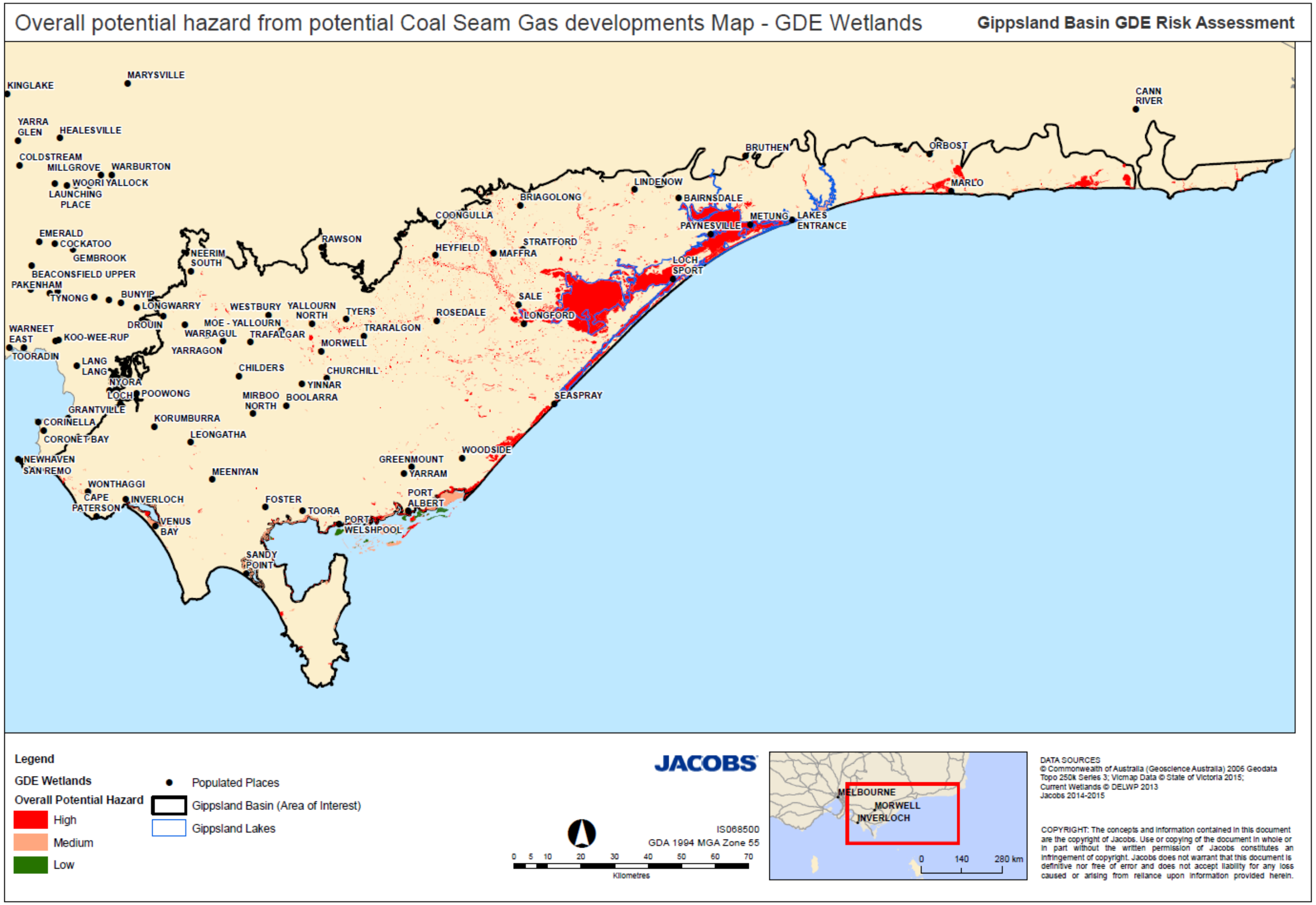

Figure 4-1 GDE wetlands – overall potential hazard from potential CSG developments to wetlands

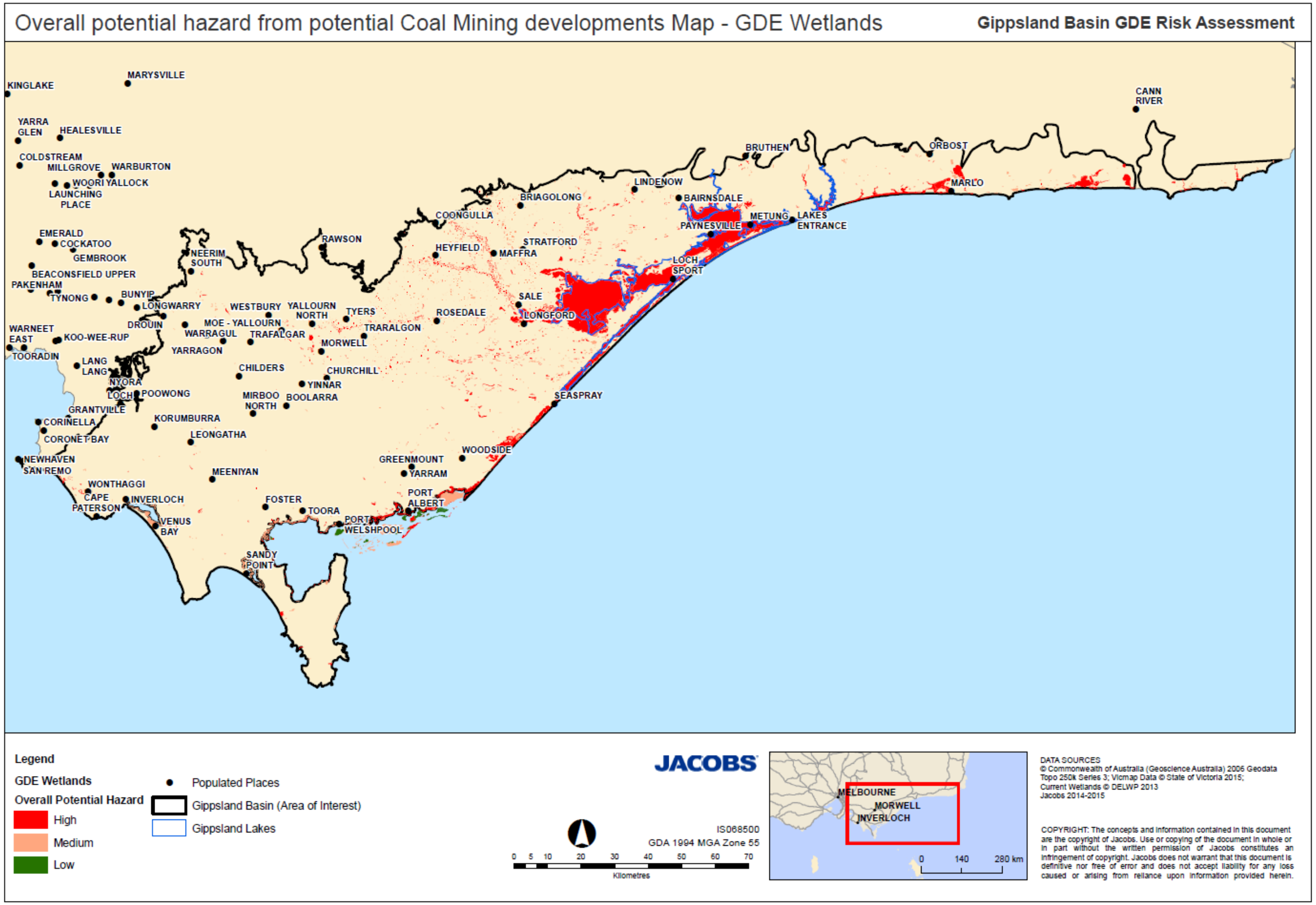

Figure 4-2 GDE wetlands – overall potential hazard from potential large coal mining developments to wetlands

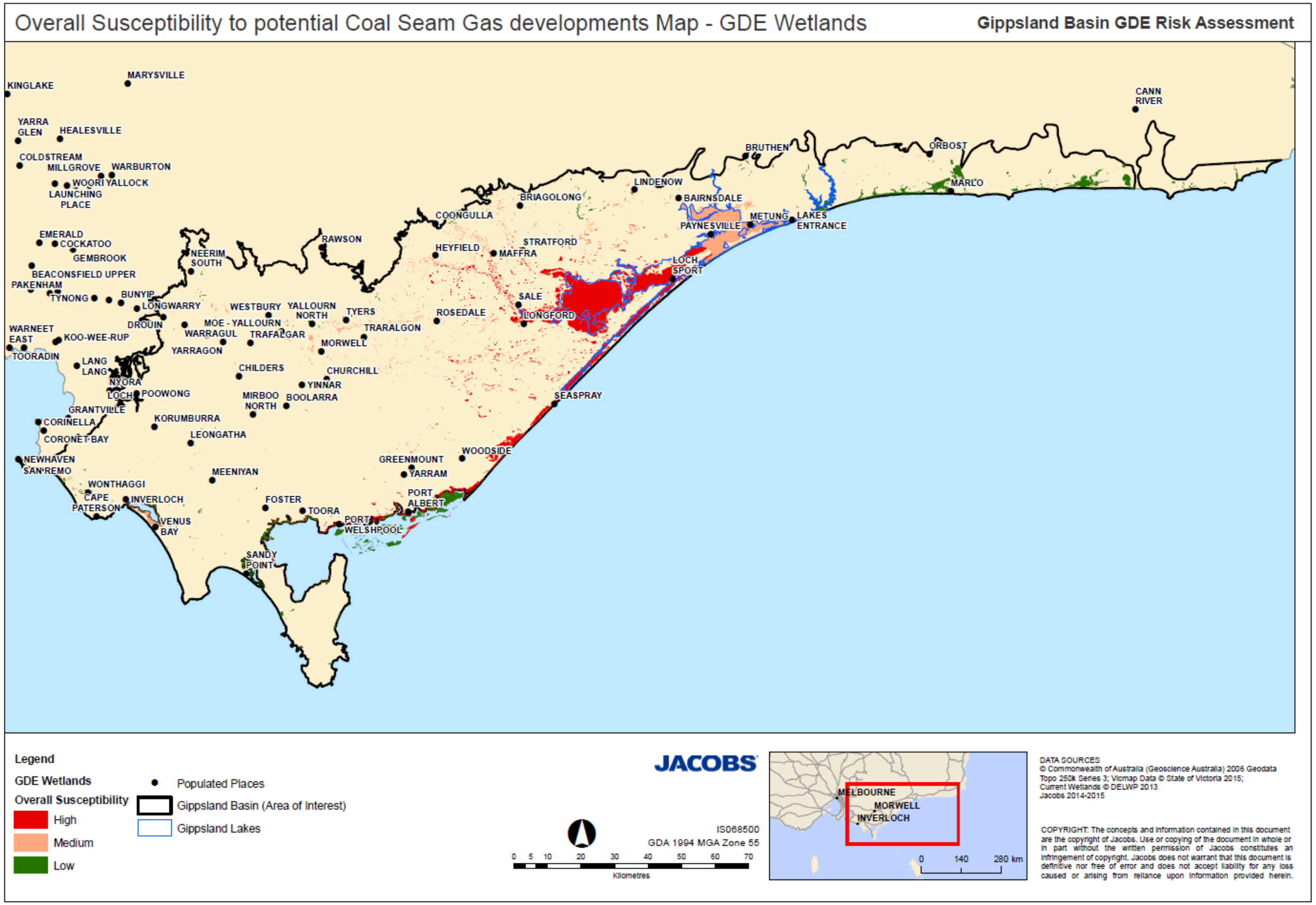

Figure 4-3 GDE wetlands – susceptibility of wetlands to potential CSG developments

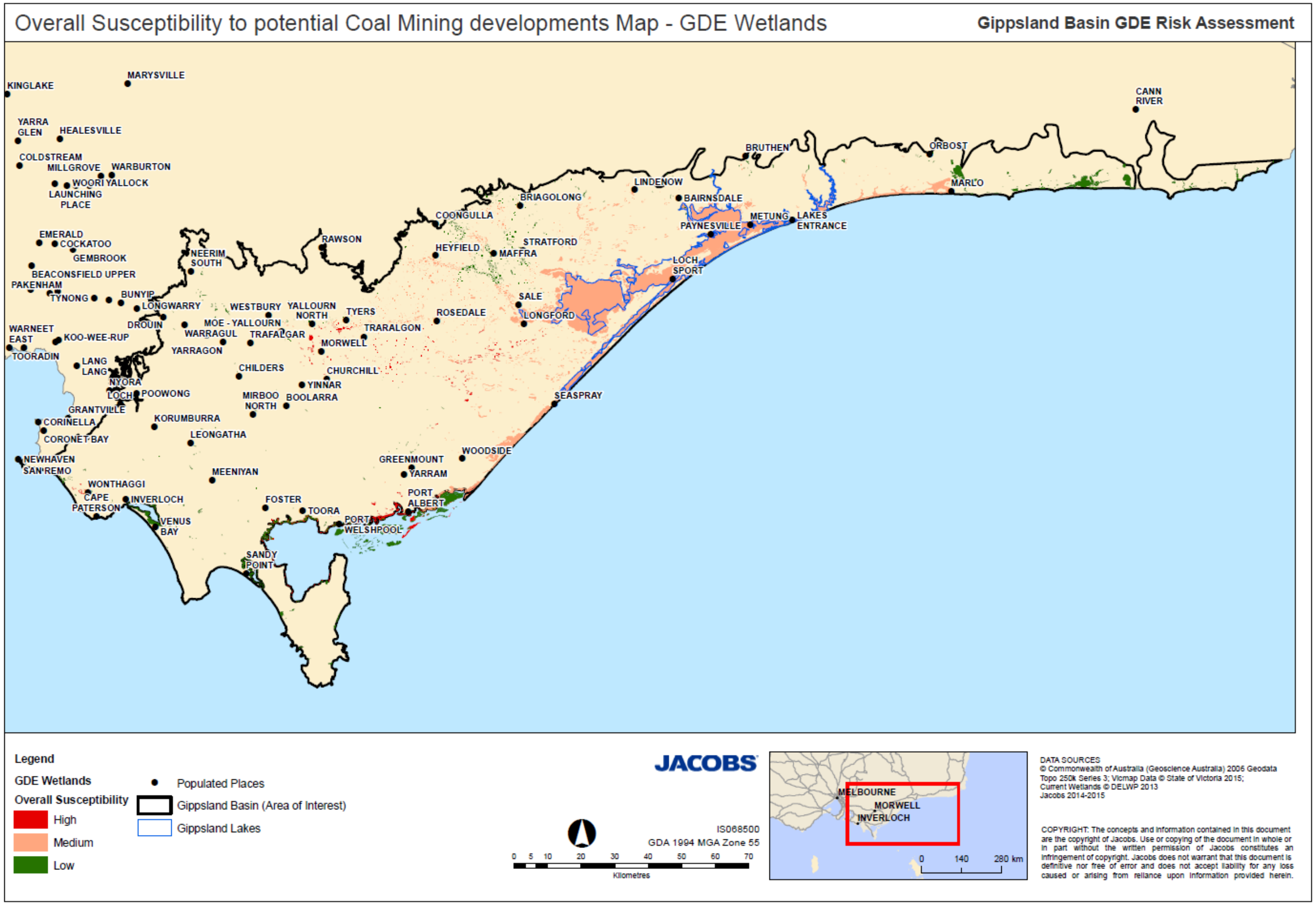

Figure 4-4 GDE wetlands – susceptibility of wetlands to potential large coal mining developments

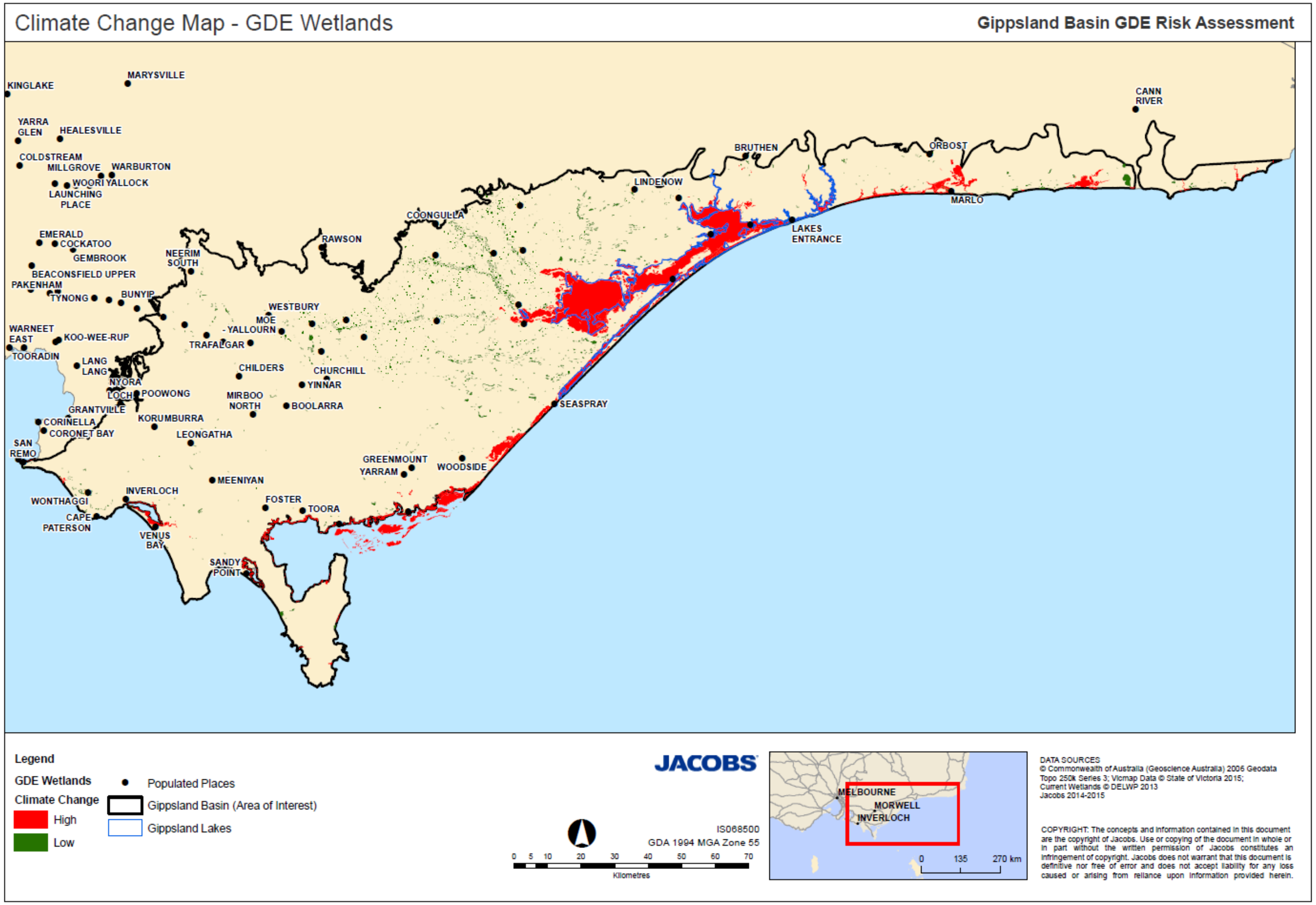

Figure 4-5 GDE wetlands – susceptibility of wetlands to climate change (sea level rise)

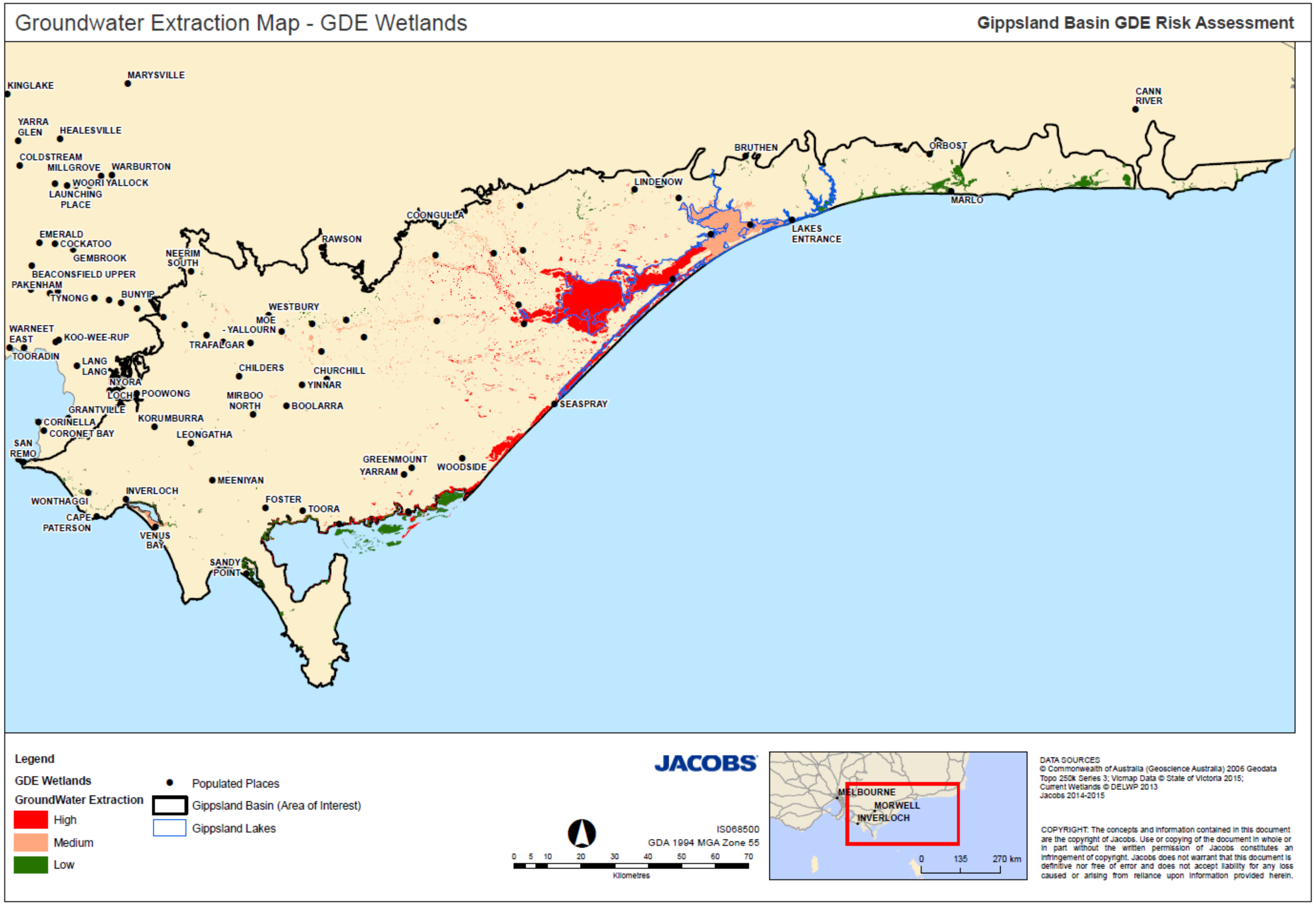

Figure 4-6 GDE wetlands – susceptibility of wetlands to groundwater extraction

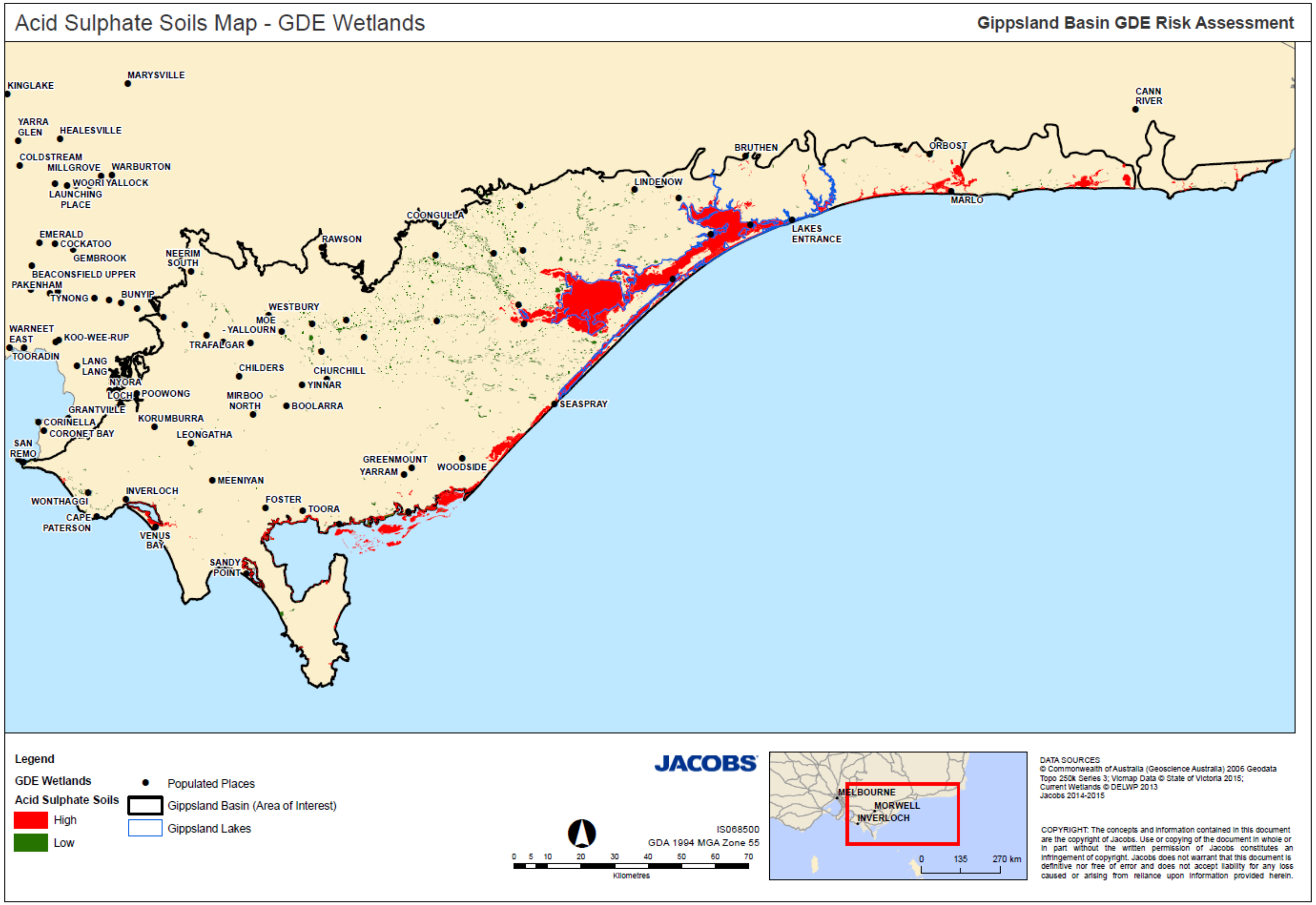

Figure 4-7 GDE wetlands– susceptibility of wetlands to potential acid sulfate soils

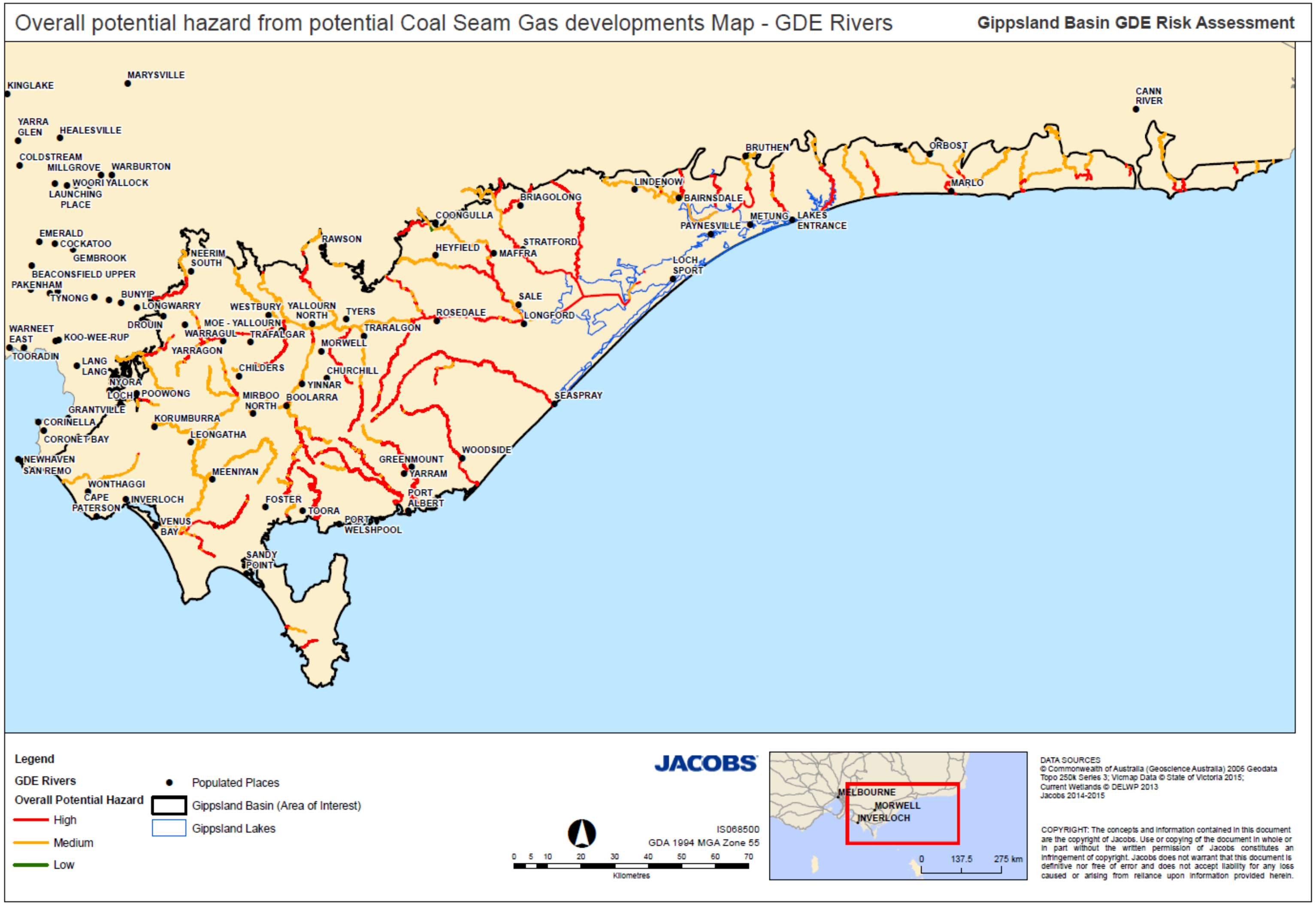

Figure 4-8 GDE rivers – overall potential hazard from potential CSG developments to rivers

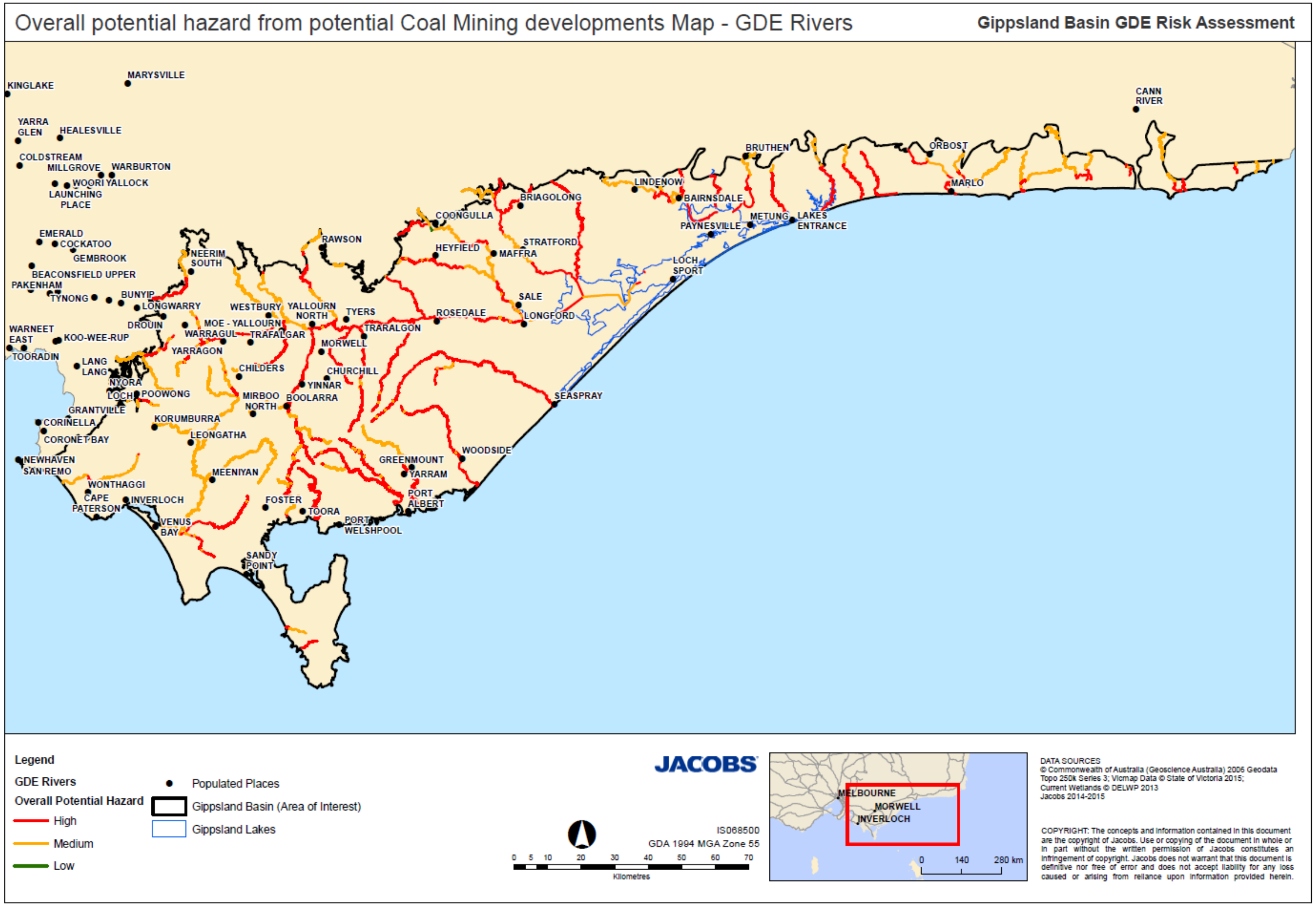

Figure 4-9 GDE rivers – overall potential hazard from potential large coal mining developments to rivers

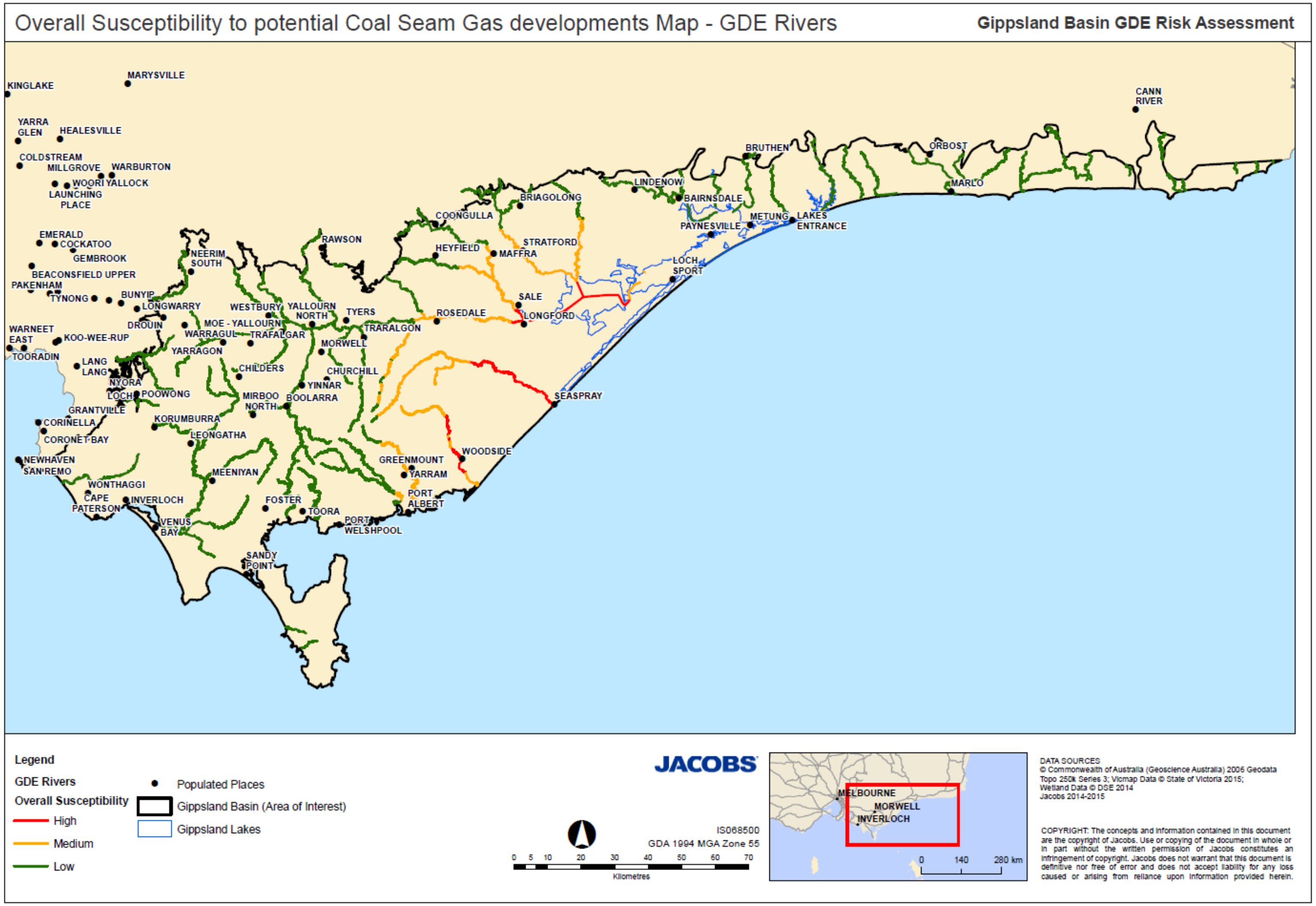

Figure 4-10 GDE rivers – susceptibility of rivers to potential CSG developments

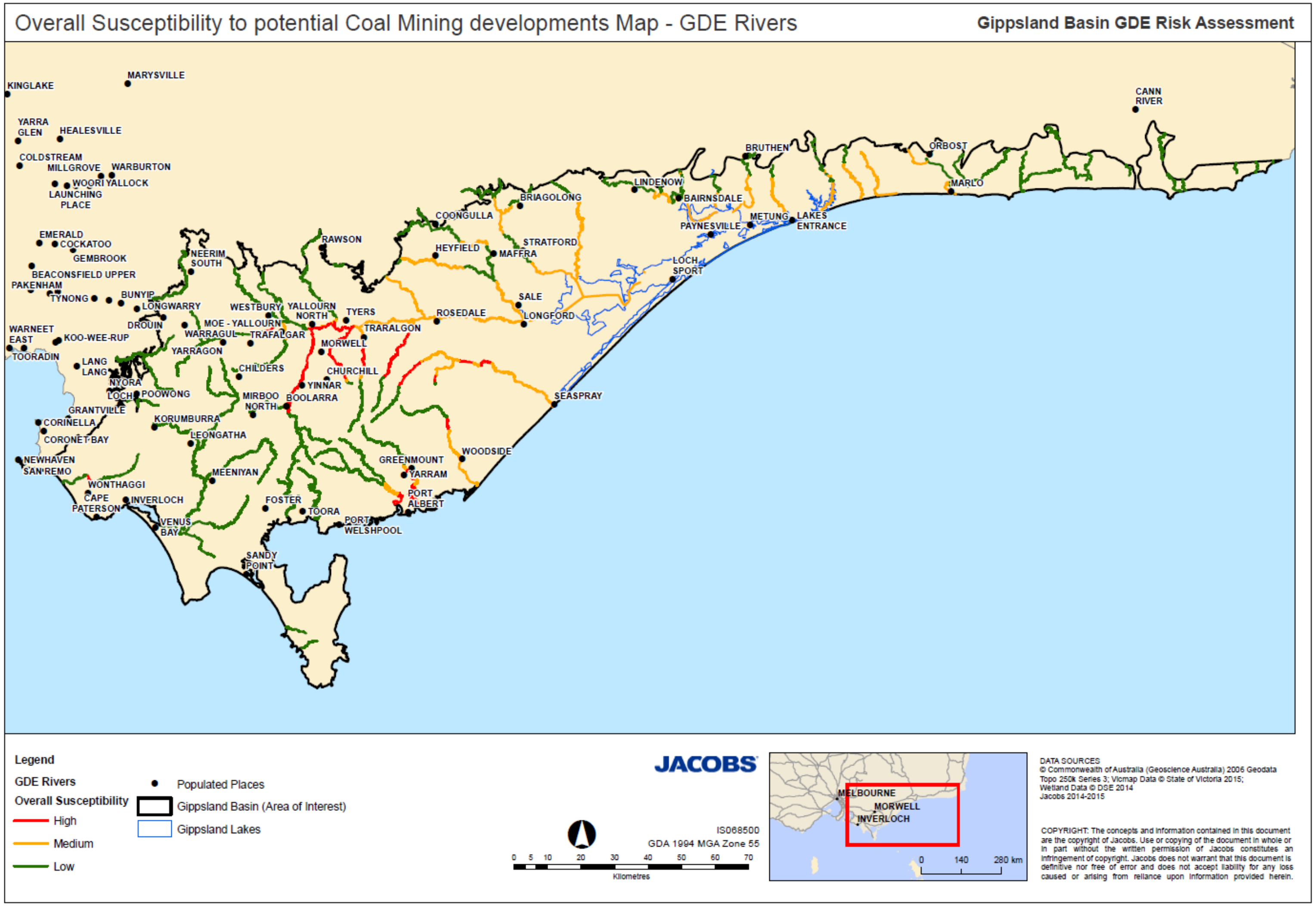

Figure 4-11 GDE rivers – susceptibility of rivers to potential large coal mining developments

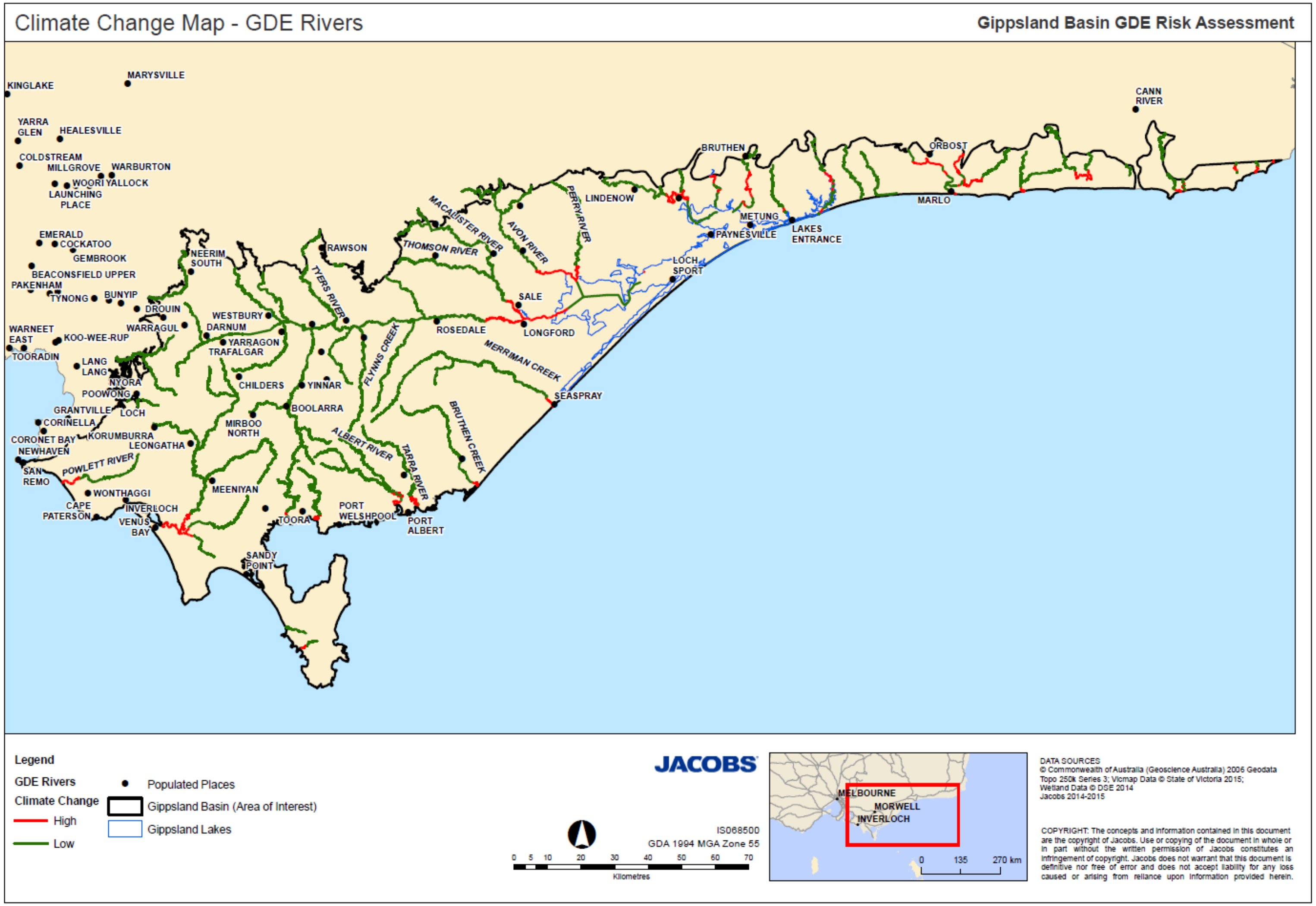

Figure 4-12 GDE rivers – susceptibility of rivers to climate change (sea level rise)

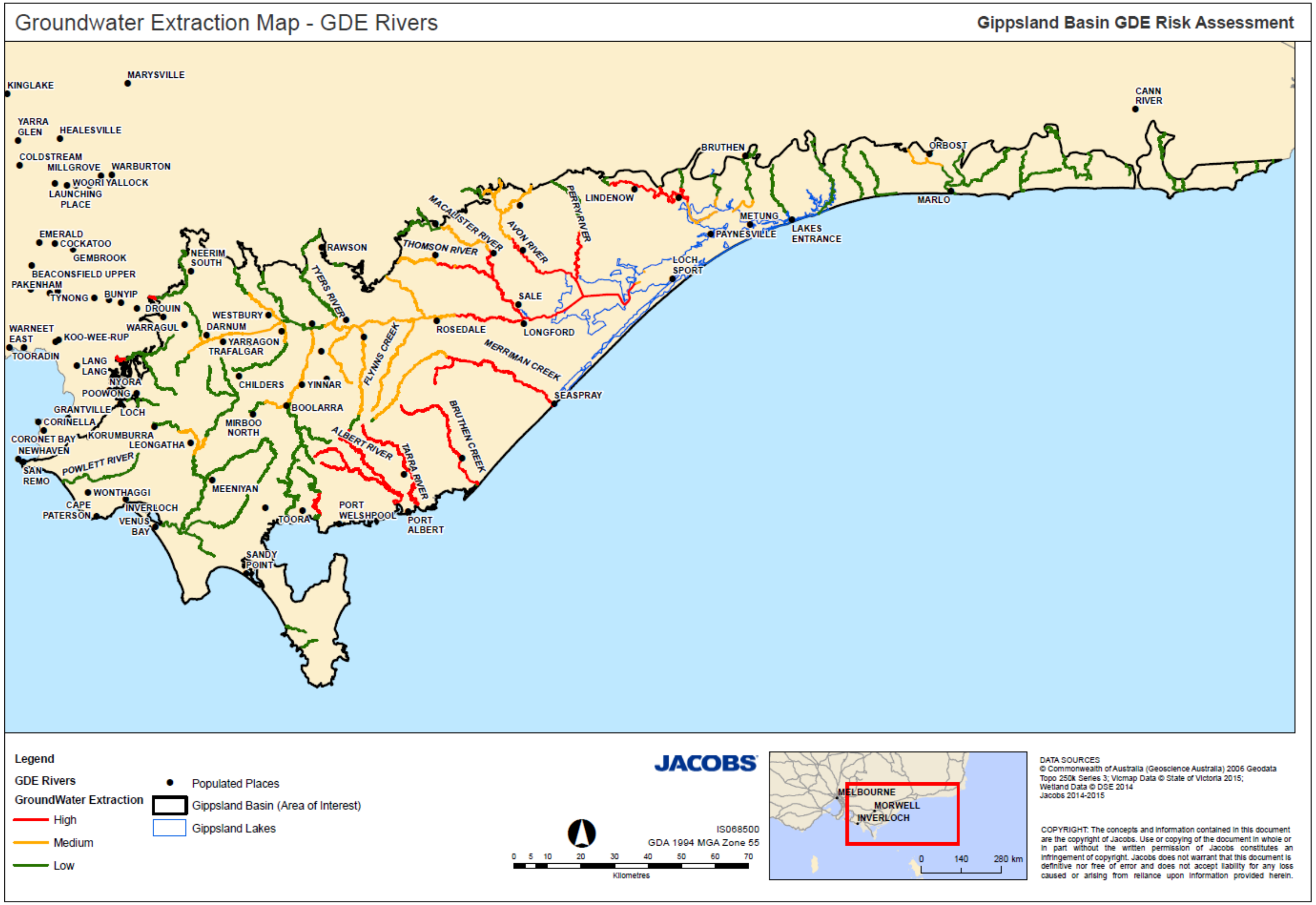

Figure 4-13 GDE rivers – susceptibility of rivers to groundwater extraction

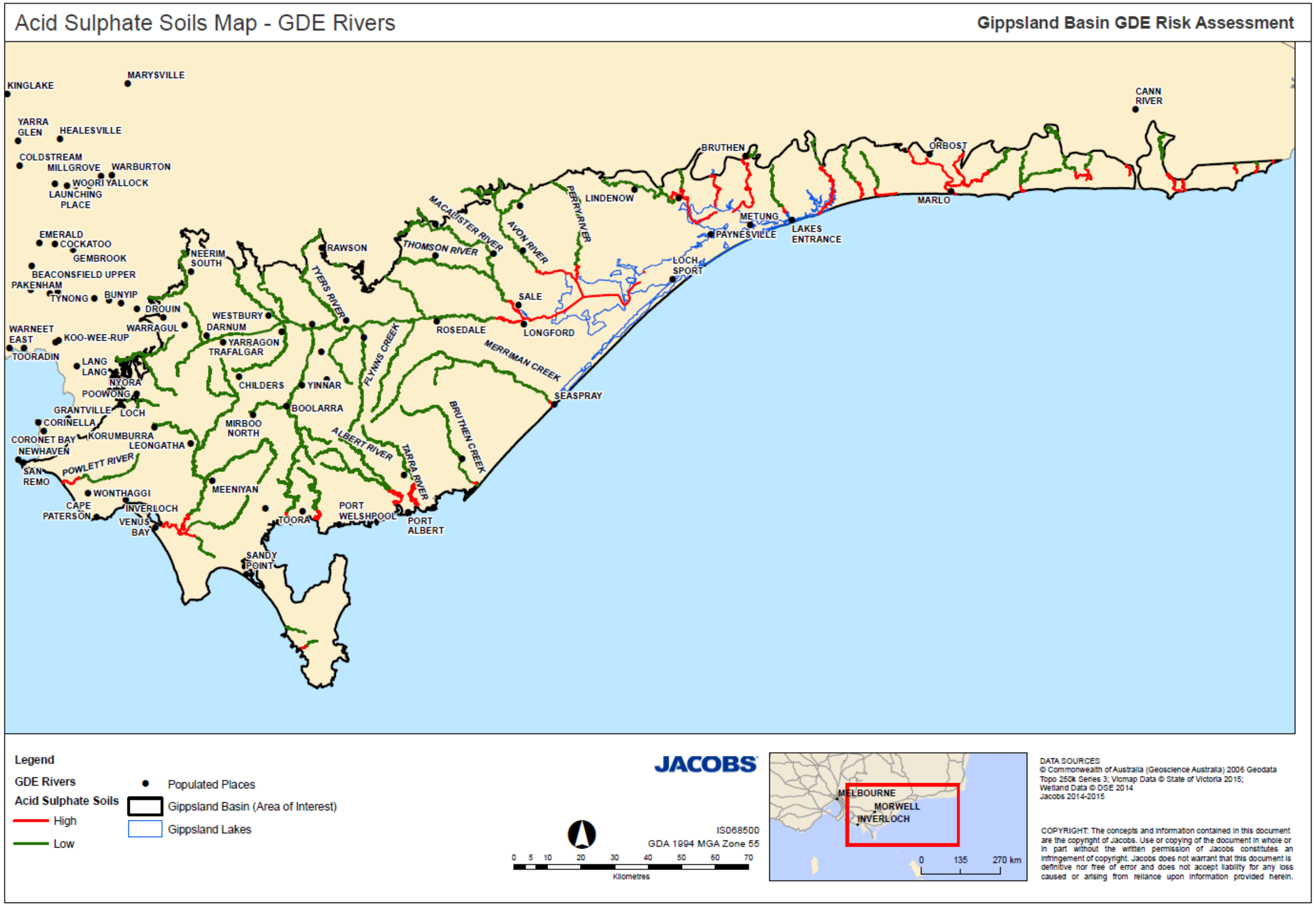

Figure 4-14 GDE rivers – susceptibility of rivers to potential acid sulfate soils

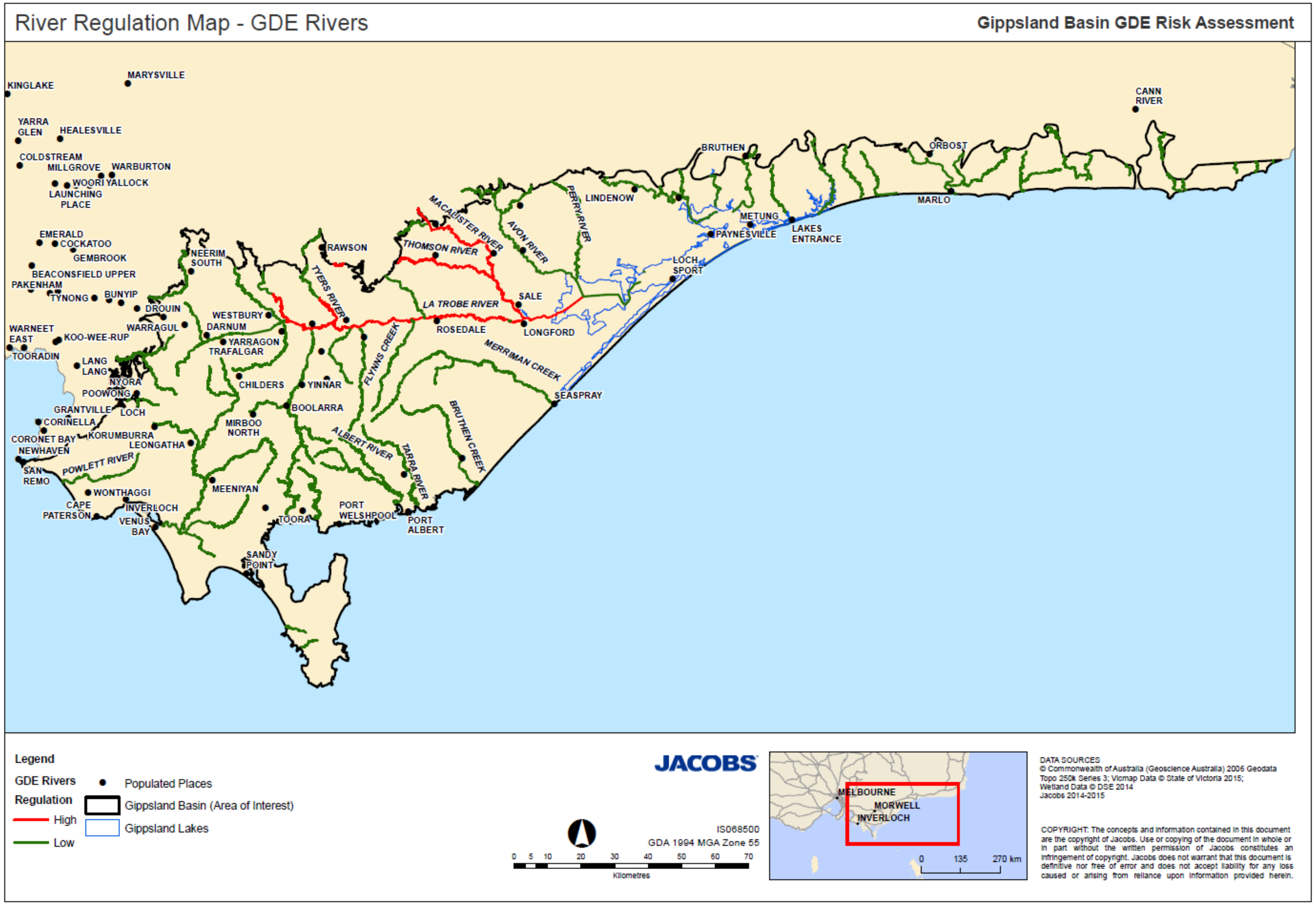

Figure 4-15 GDE rivers – susceptibility of rivers to the impacts of river regulation

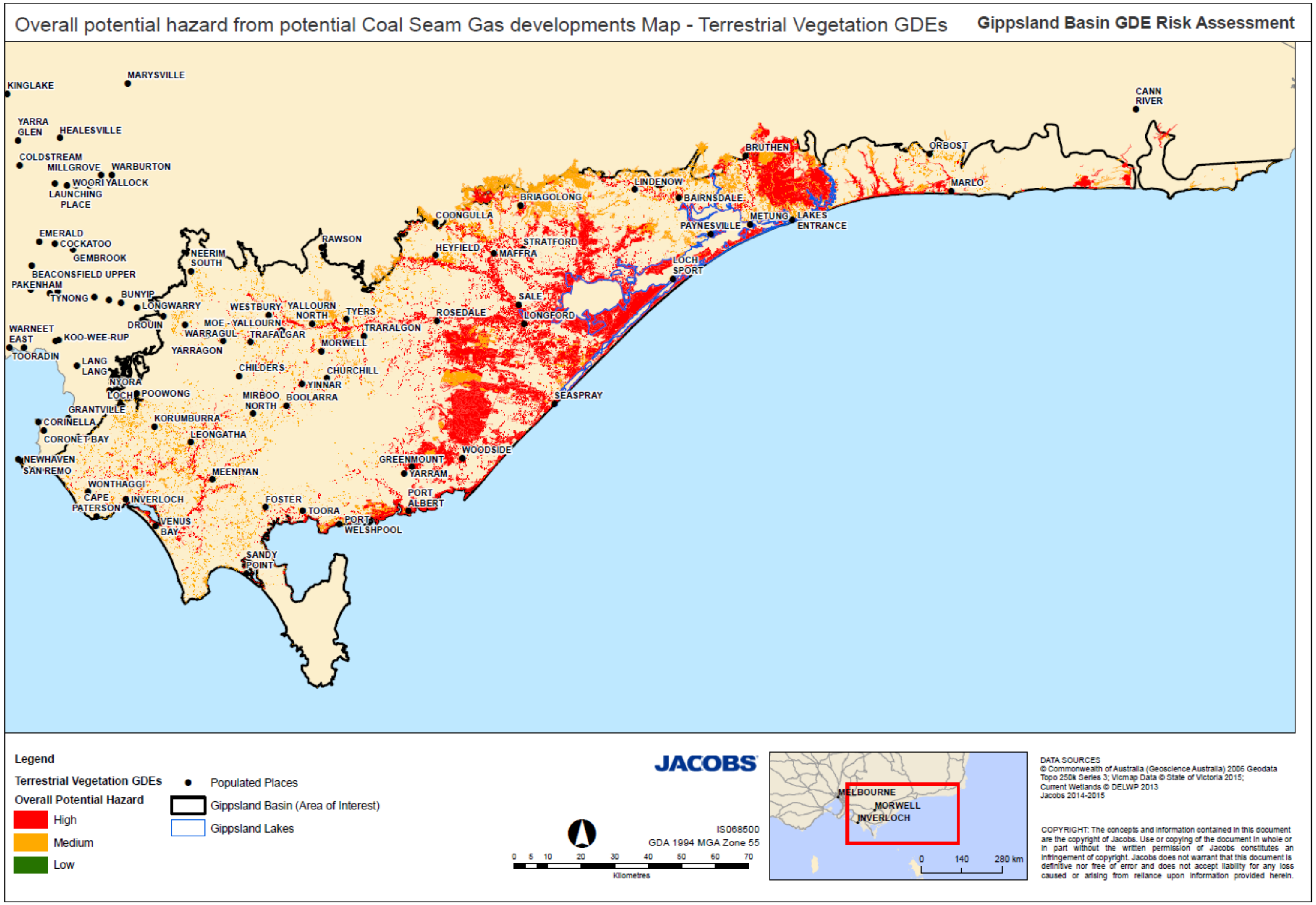

Figure 4-16 Terrestrial vegetation GDEs– overall potential hazard from potential CSG developments to terrestrial vegetation GDEs

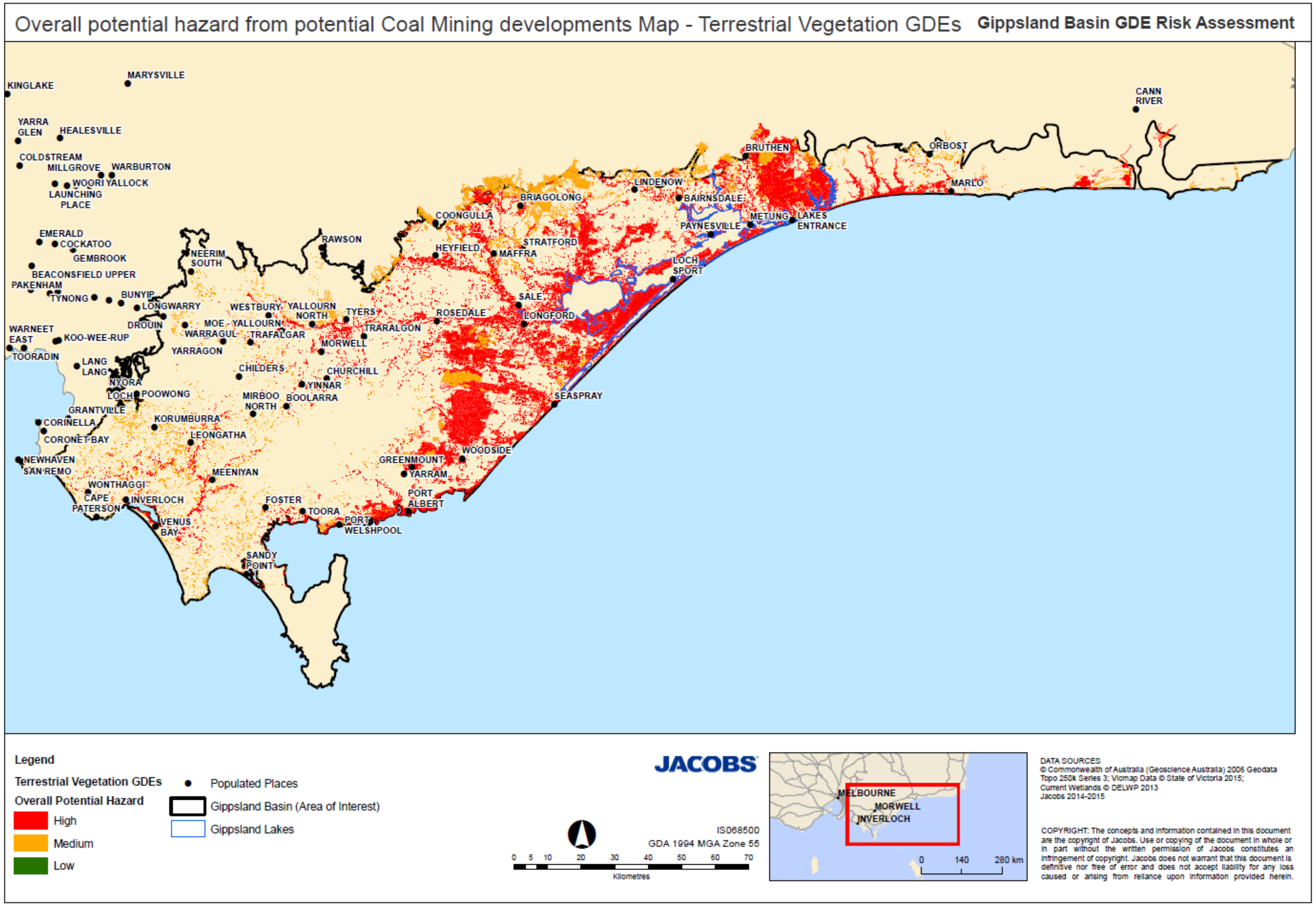

Figure 4-17 Terrestrial vegetation GDEs– overall potential hazard from potential large coal mining developments to terrestrial vegetation GDEs

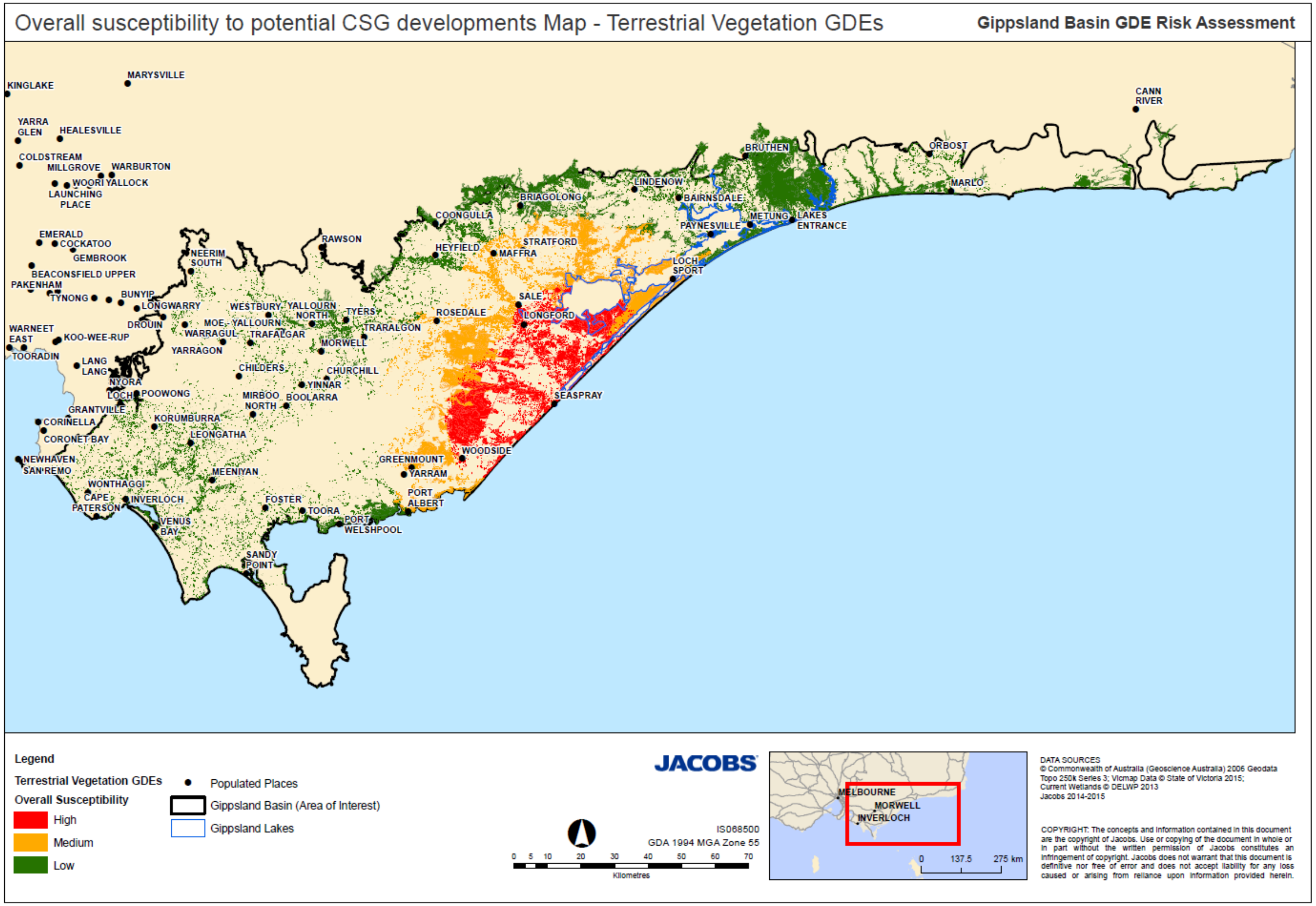

Figure 4-18 Terrestrial vegetation GDEs– susceptibility of terrestrial vegetation GDEs to potential CSG developments

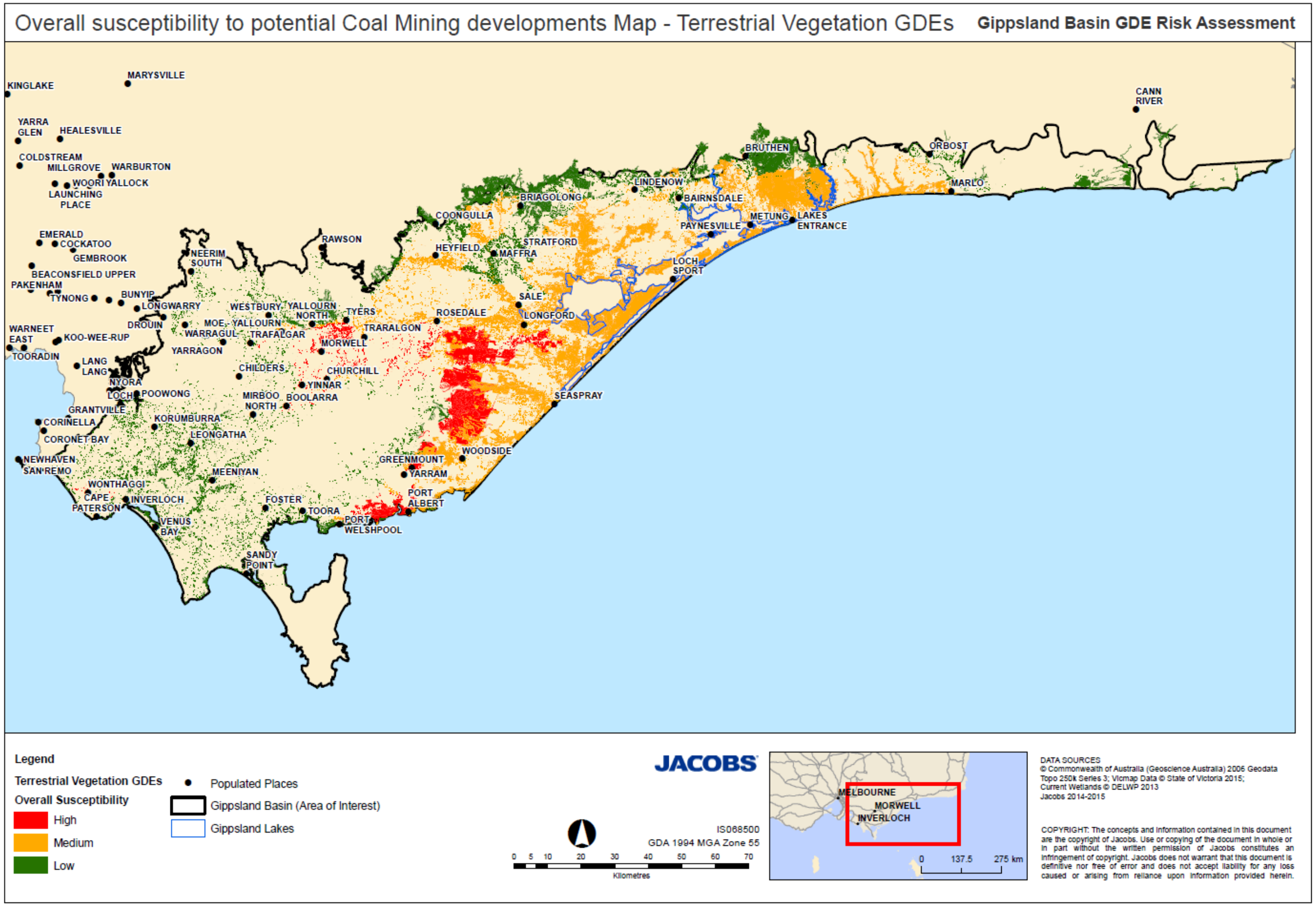

Figure 4-19 Terrestrial vegetation GDEs– susceptibility of terrestrial vegetation GDEs to potential large coal mining developments

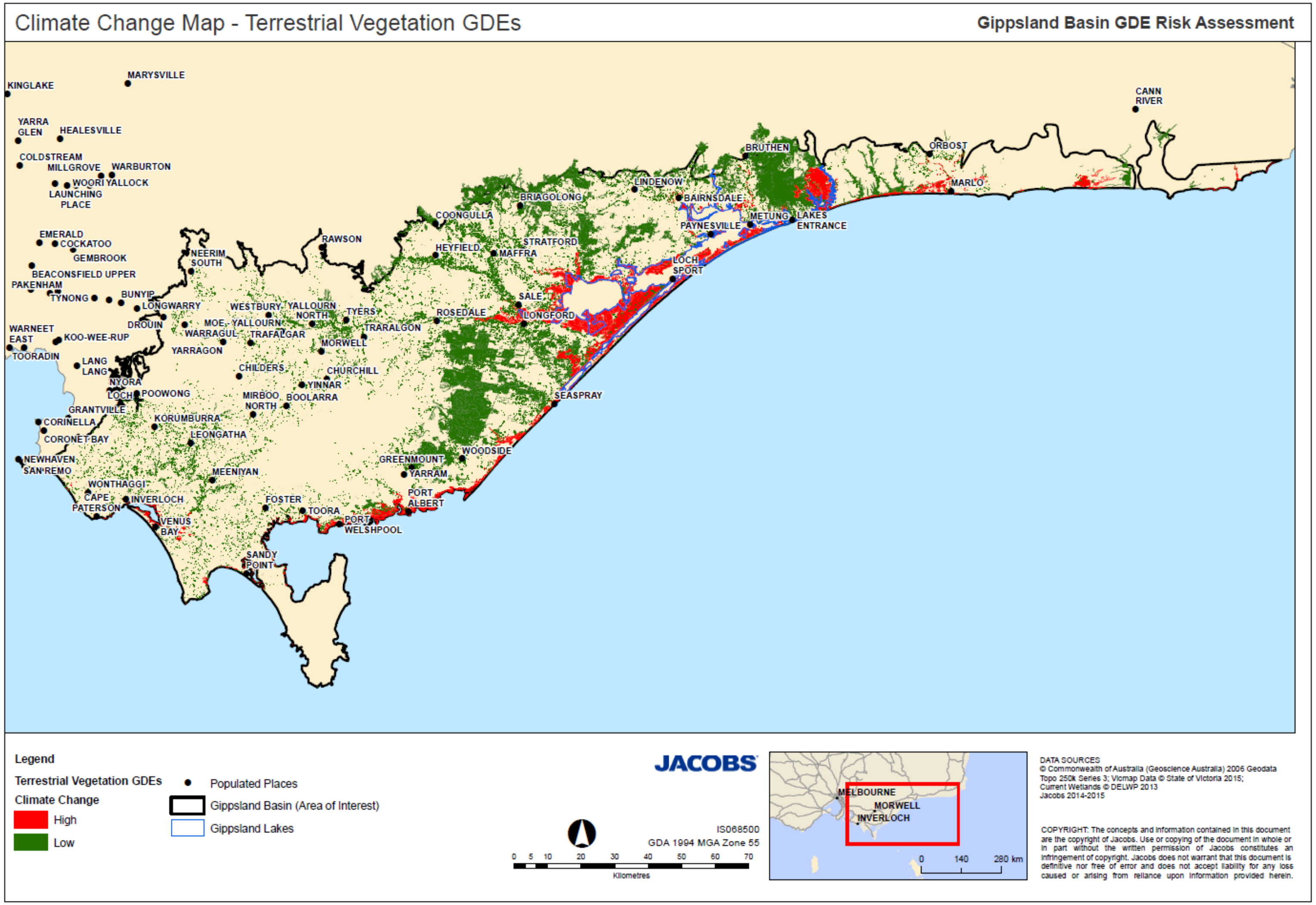

Figure 4-20 Terrestrial vegetation GDEs – susceptibility of terrestrial vegetation GDEs to climate change (sea level rise)

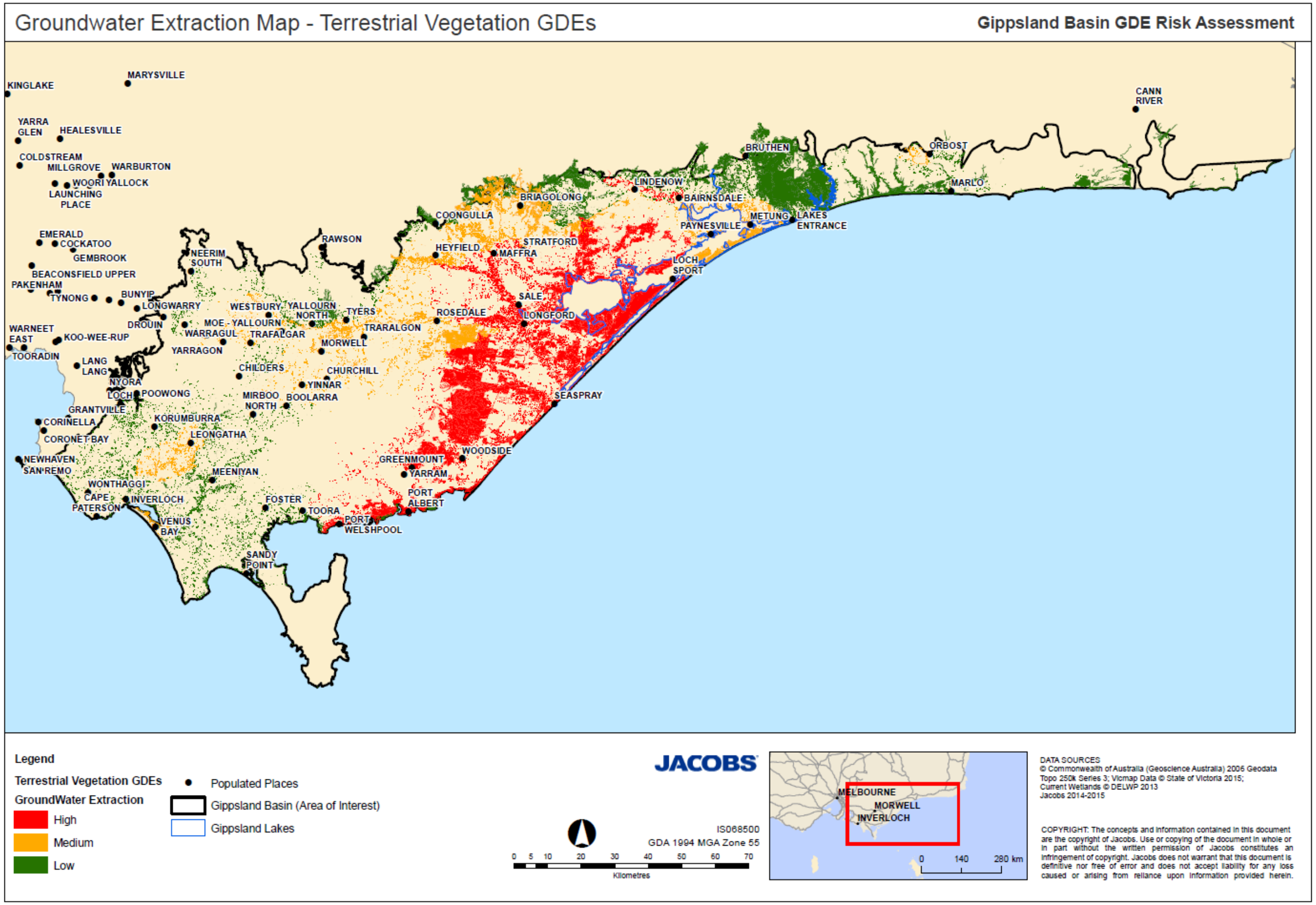

Figure 4-21 Terrestrial vegetation GDEs – susceptibility of terrestrial vegetation GDEs to groundwater extraction

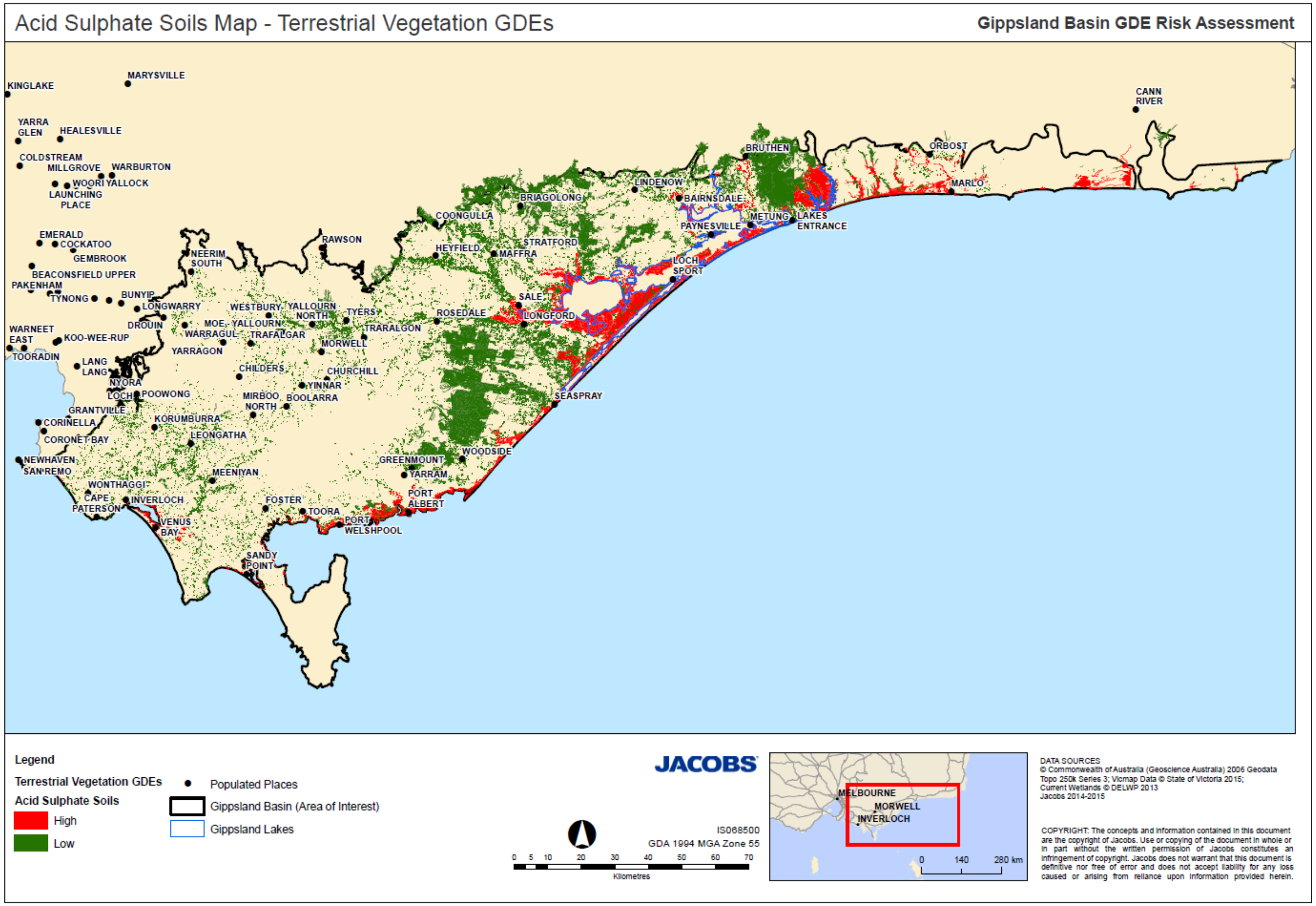

Figure 4-22 Terrestrial vegetation GDEs – susceptibility of terrestrial vegetation GDEs to acid sulfate soils

5. Framework limitations and future refinements

The current Gippsland GDE prioritisation framework provides a significant improvement on the previous framework through the addition of terrestrial GDEs and refinement of the way river reach susceptibility is assigned. However, limitations remain around the ranking of susceptibility to potential CSG development, particularly in how impact pathways are determined.

The previous framework based susceptibility to potential CSG development on the extent of the Lower Tertiary Aquifer (LTA) from which CSG is most likely to be extracted. The LTA underlays a large proportion of the Gippsland Basin, however potential CSG extraction is likely to be limited to an area in the south east of basin (termed the sub-regional prospectivity area. Using the LTA alone is a very precautionary approach in terms of identifying areas potentially of potential hazard from CSG extraction because the actual impact is likely to be a function of the hydraulic properties of the LTA, the lateral and vertical extent of potential groundwater drawdown with the aquifer and the depth of the LTA to the surface.

This precautionary approach was acknowledged in the original framework and the intent of the revised framework was to refine the area of potential impact based on outcomes from a regional scale numerical groundwater model. This would more clearly define vertical and lateral pathways of potential groundwater drawdown from CSG extraction and relate this drawdown to changes in the water table level. This approach would have provided a refined area of impact that considered the locations for potential CSG extraction, the hydraulic properties of the LTA and the spatial extent of potential water table drawdown.

Unfortunately the outcomes of the numerical model were not available in time for the current study, so the current framework adopted the sub-regional CSG prospectivity area to define the area of high susceptibility to groundwater level from potential CSG extraction. Buffers were adopted to acknowledge that the potential impacts could extend beyond the boundary of the mapped prospectivity area, however, this approach is likely to underestimate the extent of potential impacts because it doesn't consider the potential lateral impact associated with drawdown of LTA in the immediate area of CSG extraction. The areas mostly likely affected by this difference are GDEs in the Strzelecki Ranges where the LTA outcrops at the surface (Figure 5-1). This is because this area has already been shown to be impacted by groundwater drawdown from current on-shore and off-shore extraction activities through the development of the Yarram Water Supply Protection Area (Southern Rural Water 2010), so potential CSG extraction may further contribute to drawdown in this area.

When the outcomes of the numerical groundwater model become available the framework should be further updated to incorporate the modelled spatial extent of water table drawdown and the potential hazard areas redefined to generate a more accurate understanding of potential hazard areas.

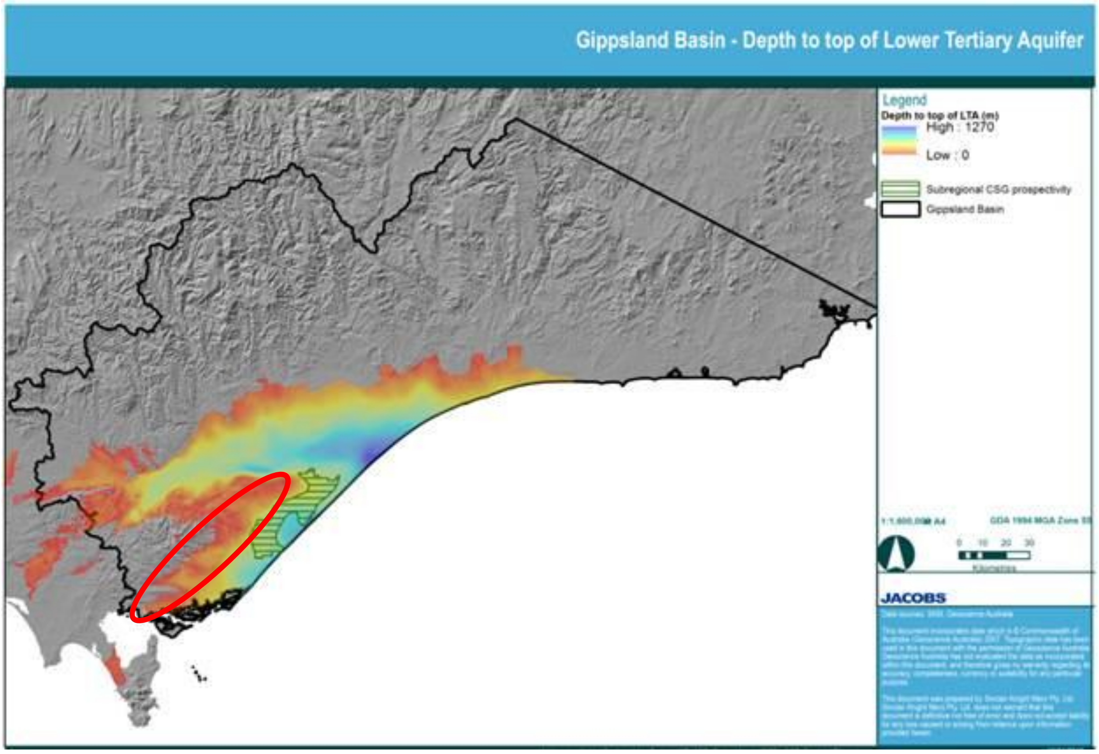

Figure 5-1 Depth to the Lower Tertiary Aquifer and the sub-regional CSG prospectively area. The red circled area indicates the area of the Strzelecki Ranges where the LTA outcrops at the surface and where current on-shore and off-shore groundwater drawdown is having an effect on water table levels.

6. Summary

The primary output of the Gippsland GDE prioritisation framework outlined in this report is a geospatial dataset. The dataset captures the location of the GDEs, including sub-surface GDEs, and information pertaining to the value, sensitivity, management and susceptibility of the water assets to potential coal mining and CSG developments in the Gippsland region, as well as a number of other threatening process that are directly related to a change in water balance of the water asset (e.g. climate change, groundwater extraction).

A combination of both existing spatial datasets and relevant literature, supplemented with expert knowledge of GDEs was used to bring together a range of attributes that describes the assets value, hydrology, groundwater service, landscape features and climate. This data was then used to inform the potential hazard assessment/ prioritisation.

The geospatial dataset is an updated version of the existing Gippsland GDE prioritisation framework to address some key knowledge gaps outlined in Jacobs SKM, 2014. Specific updates included:

- Assessing overall potential hazard from CSG and large coal mining developments separately, therefore two overall potential hazard ranking outcomes are provided in the results. Currently the existing prioritisation framework only provides one overall potential hazard assessment outcome; that is for CSG and large coal mining developments together.
- Further defining susceptibility of GDEs to groundwater change as a result of potential CSG developments by improving identification of potential hazard locations, including the application of updated prospectivity data and improved definition of river sensitivity (e.g. in the way river reaches are assigned gaining and loosing characteristics and hence sensitivity to changes in groundwater level).
- Incorporation of terrestrial GDEs based on a broad scale assessment of the groundwater dependency of Ecological Vegetation Classes found in the study area.
- Identification of other threats (stressors) to GDEs (e.g. groundwater extraction, acid sulphate soils, coal mining, surface water regulation, climate change).

The key benefit of this project is that the geospatial database, which identifies each GDE, describes its value and the current management regime can be updated when more information becomes available on either the location of potential CSG or large coal mining developments, or any other threat. The geospatial database can be used to determine which GDEs have the potential to be impacted. The database can also be refined over time and used as a basis for highlighting areas where further investment and investigation are required.

The updateable nature of the database is particularly important when considering that new information will become available through regional groundwater numerical modelling that will further refine the spatial extent of areas where the water table could decline due to potential CSG extraction. Once this information is available, the framework should be updated.

7. References

1. Bureau of Meteorology (BOM), 2012. *Groundwater Dependent Ecosystem Atlas* http://www.bom.gov.au/water/groundwater/gde/

2. Department of Sustainability and Environment (DEPI), 2011. *Western Region Sustainable Water Strategy*.

3. GHD, 2014. *Water Asset Identification Project State Report*. Report prepared for the Victorian Department of Environment and Primary Industries.

4. IESC, 2013. *Methodology for bioregional assessment of the impacts of coal seam gas and coal mining development on water resources*. Canberra.

5. Jacobs, 2014. *Identification of Groundwater Dependent Water Assets in the Gippsland Basin*. Report Prepared for the East and West Gippsland CMAs.

6. Jacobs, 2015a. *Victorian Water Studies - Baseline Monitoring Program for the Gippsland Basin.* Prepared for Department of Environment, Land, Water and Planning.

7. Jacobs 2015b. *Improving Knowledge of Water-Dependent Assets and Receptors in the Gippsland Basin: Groundwater Dependent Ecosystem Conceptual Modelling*. Prepared for Department of Environment, Land, Water and Planning.

8. Richardson S, et al, 2011. *Australian groundwater-dependent ecosystem toolbox part 1: assessment framework*, Waterlines report, National Water Commission, Canberra

9. SKM, 2012. *Conceptualisation of Key Groundwater Dependent Ecosystems in Melbourne Water Catchments: Phase 1 Proof of Concept*. Report for Melbourne Water.

10. SKM, 2011a. *Australian groundwater-dependent ecosystem toolbox part 2: assessment tools*. Waterlines report, National Water Commission. Canberra.

11. SKM, 2011b. *GDE Triggers Project: Analysis of remotely-sensed evapotranspiration data to aid the management of groundwater dependent ecosystems.* Report prepared for Goulburn-Murray Water

12. Southern Rural Water 2010. *Groundwater Management Plan: Yarram Water Supply Protection Area*.

Appendix A. EVC type and reliance on groundwater

Table A 1 EVC type and reliance on groundwater

EVC Type	High	Medium	Low	Assessment Notes
Aquatic Herbland/Plains Sedgy Wetland Mosaic		✓		Qld WetlandInfo conceptual model
Banksia Woodland		✓		Qld WetlandInfo conceptual model
Billabong Wetland Aggregate		✓		
Blackthorn Scrub			✓	EVC description and position in landscape
Box Ironbark Forest			✓	
Clay Heathland	✓			NSW Office of Water (2012) Vol 3 Appendix 1
Clay Heathland/Wet Heathland/Riparian Scrub Mosaic	✓			NSW Office of Water (2012) Vol 3 Appendix 1
Coast Banksia Woodland	✓			Qld WetlandInfo conceptual model
Coast Banksia Woodland/Coastal Dune Scrub Mosaic	✓			Qld WetlandInfo conceptual model
Coast Banksia Woodland/Warm Temperate Rainforest Mosaic		✓		
Coastal Alkaline Scrub			✓	EVC description and position in landscape
Coastal Headland Scrub			✓	EVC description and position in landscape
Coastal Lagoon Wetland	✓			Qld WetlandInfo conceptual model
Coastal Saltmarsh		✓		Paper by Hickey (2008); see also review by Boon et al. (2011)
Coastal Vine-rich Forest		✓		
Creekline Herb-rich Woodland			✓	
Damp Forest			✓	EVC description
Damp Heathy Woodland		✓		
Damp Heathy Woodland/Lowland Forest Mosaic		✓		EVC description
Damp Sands Herb-rich Woodland			✓	
Damp Sands Herb-rich Woodland/Swamp Scrub Complex		✓		Commonwealth Dept Environment IW-45 GDEs
Damp Sands Herb-rich Woodland/Swamp Scrub Mosaic		✓		Commonwealth Dept Environment IW-45 GDEs
Deep Freshwater Marsh			✓	

EVC Type	High	Medium	Low	Assessment Notes
Dry Rainforest			✓	
Dry Rainforest/Warm Temperate Rainforest/Gallery Rainforest/Riparian Shrubland/Riverine Escarpment Scrub/Blackthorn Scrub Complex			✓	
Dry Valley Forest	✓			EVC description
Dry Valley Forest/Swamp Scrub/Warm Temperate Rainforest Mosaic	✓			As above
Dunes	✓			Qld WetlandInfo conceptual model
Estuarine Wetland	✓			Qld WetlandInfo conceptual model
Estuarine Wetland/Estuarine Swamp Scrub Mosaic	✓			Qld WetlandInfo conceptual model
Floodplain Reedbed		✓		Commonwealth Dept Environment IW-45 GDEs
Floodplain Riparian Woodland		✓		Qld WetlandInfo conceptual model
Floodplain Riparian Woodland/Billabong Wetland Mosaic		✓		Qld WetlandInfo conceptual model
Gallery Rainforest			✓	EVC description
Grassy Dry Forest			✓	
Grassy Forest			✓	EVC description
Grassy Woodland			✓	
Grassy Woodland/Swamp Scrub Mosaic		✓		
Heathy Woodland		✓		See EVC description plus groundwater dependency in other heathlands (e.g. NSW Office of Water 2012 Vol 3 Appendix 1).
Herb-rich Foothill Forest			✓	
Limestone Box Forest			✓	
Limestone Pomaderris Shrubland			✓	EVC description
Lowland Forest			✓	
Lowland Forest/Damp Sands Herb-rich Woodland Mosaic			✓	
Lowland Forest/Heathy Woodland Mosaic			✓	
Lowland Herb-rich Forest			✓	
Mangrove Shrubland		✓		Groundwater inputs shown to be important in NSW and QLD mangroves
Montane Riparian Thicket	✓			EVC description
Plains Grassy Forest			✓	

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EVC Type	High	Medium	Low	Assessment Notes
Plains Grassy Wetland			✓	Wetland component.
Plains Grassy Woodland			✓	
Plains Grassy Woodland/Gilgai Wetland Mosaic			✓	
Riparian Forest			✓	Higher rainfall (700-1000 mm) for this EVC 18 in Gippsland.
Riparian Forest/Warm Temperate Rainforest Mosaic		✓		
Riparian Scrub	✓			Groundwater dependency assumed because of alluvium substratum
Riparian Scrub/Swampy Riparian Woodland Complex	✓			Groundwater dependency assumed because of heath and Swamp Scrub components
Riparian Shrubland	✓			EVC description
Riverine Escarpment Scrub			✓	
Rocky Outcrop Shrubland/Rocky Outcrop Herbland Mosaic			✓	
Sand Heathland	✓			Qld WetlandInfo conceptual model
Sand Heathland/Wet Heathland Mosaic	✓			Qld WetlandInfo conceptual model
Sandy Flood Scrub	✓			Qld WetlandInfo conceptual model
Seasonally Inundated Shrubby Woodland			✓	Assessment based on similarity to Seasonal Herbaceous Wetlands, which have an episodic groundwater dependency
Sedge Wetland	✓			Qld WetlandInfo conceptual model
Shrubby Damp Forest			✓	
Shrubby Dry Forest			✓	
Shrubby Foothill Forest			✓	
Shrubby Foothill Forest/Damp Forest Complex			✓	
Spray-zone Coastal Shrubland		✓		
Swamp Scrub	✓			Commonwealth Dept Environment IW-45 GDEs
Swamp Scrub/Damp Sands Herb-rich Woodland/Wet Heathland Mosaic	✓			Commonwealth Dept Environment IW-45 GDEs
Swamp Scrub/Plains Grassy Forest Mosaic		✓		Commonwealth Dept Environment IW-45 GDEs
Swamp Scrub/Warm Temperate Rainforest/Billabong Wetland Mosaic	✓			Commonwealth Dept Environment IW-45 GDEs
Swamp Scrub/Wet Heathland Mosaic	✓			Commonwealth Dept Environment IW-45 GDEs
Swampy Riparian Complex	✓			

EVC Type	High	Medium	Low	Assessment Notes
Swampy Riparian Woodland	✓			
Swampy Riparian Woodland/Swamp Scrub Mosaic	✓			Commonwealth Dept Environment IW-45 GDEs
Valley Grassy Forest			✓	
Valley Grassy Forest/Swamp Scrub Mosaic			✓	
Valley Heathy Forest			✓	
Valley Slopes Dry Forest	✓			EVC description
Warm Temperate Rainforest			✓	
Water Body - estuary			✓	
Wet Forest			✓	Position in landscape and EVC description
Wet Heathland	✓			NSW Office of Water (2012) Vol 3 Appendix 1, plus Commonwealth Dept Environment IW-45 GDEs
Wet Heathland/Damp Heathland Mosaic	✓			NSW Office of Water (2012) Vol 3 Appendix 1, plus Commonwealth Dept Environment IW-45 GDEs
Wet Swale Herbland	✓			Qld WetlandInfo conceptual model
Wetland Formation		✓		Depends on position in landscape and wetland type

Appendix B. Final GDE Attributes

Table B 1 GDE geospatial dataset attributes

GDE Geospatial Dataset Attributes			
Field Group	**Dataset**	**Field Name**	**Short Description**
General	Manual	RIVER_ID	Unique number identifying each river
		WETLAND_ID	Unique number identifying each wetland
	Wetland 2013	WETLAND_NO	Unique number identifying each wetland
		NAME_MAIN	Main name given to the wetland
		NAME_ALT	Alternative name given to the wetland
		AQ_SYS	Wetland system class
		ORIGIN	Wetland origin class (natural, human-made)
		CMA	Responsible Catchment Management Authority
	DEPI VicMap Hydro	NAME	High and medium hierarchy rivers
		HIERARCHY	Unique number identifying each wetland
Landscape and Climate	GDE Atlas	LANDUSE	Broad landuse type
		GMA_DS	Groundwater management area
		LSCAPE_DS	Landscape assessment DEM analysis
		BIOREG_DS	Bioregionalisation
		GMORPH_DS	Geomorphological description
		EHZ_DS	Eco-hydrogeological zone name
	DPI GMU	GMU	Geomorphic units
		Lithology	lithology of sediments
	State-Wide Geology Mapping	Simpl_Geol	Simplified surface geological units
Ecosystem Type	Wetland 2013	DOM_VEG	Dominant vegetation class
		SAL_REGIME	Salinity regime class
	GDE Atlas	EHZ, EHZ_DS	Eco-hydrological Zone
		ECOTYPE_DS	Ecosystem type
		S_ETYPE_DS	Ecosystem type (vegetation type)
		ECOCL_DS	Groundwater dependent ecosystem class
		GWDEP_DS_1	Confidence of ecosystem being a sub surface GDE/ probability of groundwater connection
	CMA Stream Refuge	Catchment	Catchment in which the drought refuge is located – Thomson River Refuge ranking
		ScoreD	Drought refuge score – Thomson River
		C_Ecosystem	Catchment ecosystem in which the drought refuge is located – Macalister River priority reaches.
		Refuge	Discrete location along the Macalister Rivers identified as providing refuge to stream biota from drought, fire and flood impacts on stream flow and water quality.
		C_Ecosyt_1	Catchment ecosystem in which the drought refuge is located – Latrobe River priority reaches
		Fire	Fire refuge score – Latrobe River priority reaches
		Flood	Flood refuge score – Latrobe River priority reaches
		Drought	Drought refuge score – Latrobe River priority reaches
		Refuge_1	Discrete location along the Latrobe River identified as providing refuge to stream biota from drought.
	Victorian EVC Mapping	EVC_BC	The combination of EVC and bioregion is used to determine the bioregional conservation status (BCS) of an EVC
		EVCBCSDESC	Full description of the biodiversity conservation status.

GDE Geospatial Dataset Attributes			
Field Group	**Dataset**	**Field Name**	**Short Description**
Hydrology	Wetland 2013	CORR_CLASS	Victorian wetlands_1994 Corrick Classification
		WTRREG	Water regime class
		SRC_TIDE	Water source classification for tidal/non-tidal
		SRC_RVR	Water source classification for riverine flows. Expressed as the likelihood that the wetland receives water from riverine flows.
		SRC_GW	Water source classification for groundwater. Expressed as the likelihood that the wetland receives water from groundwater.
		SRC_ART	Water source classification for artificial / non-artificial
	GDE Atlas	DRBASIN	Drainage Basin
		GWDE	Confidence of ecosystem being a surface expression of groundwater GDE/ probability of groundwater connection
		PERMCON	Temporal nature of groundwater connectivity/ use
		GWFLOW_DS	Broad hydrogeological setting/ groundwater flow system
		DRBASIN_DS	Drainage Basin
		AQ_GEOL	Broad geology type of source aquifer
		AQ_SRCT	Source aquifer confinement (e.g. confined, unconfined)
	GHD Gaining and Losing	GHD_G_L	Spatial connectivity between GDE and groundwater (losing, gaining) derived from GHD report and intersection of remaining Rivers with GMU mapping to determine gaining or variable.
	CMA Stream Refuge	Catchment	Catchment ecosystem for Thomson River priority reaches
		ScoreD	Drought refuge score for Thomson River priority reaches
		C_Ecosytem	Catchment ecosystem for Macalister river priority reaches
		Refuge	Drought, fire and flood refuges for Macalister river priority reaches
		C_Ecosyt_1	Catchment ecosystem for Latrobe river priority reaches
		FIRE	Fire refuge score for Latrobe River priority reaches
		FLOOD	Flood refuge score for Latrobe River priority reaches
		DROUGHT	Drought refuge score for Latrobe River priority reaches
		Refuge_1	Drought refuge along Latrobe River priority reaches
	Manual Entries	RIVER_TIDA	
		RIVER_REG	Unregulated or regulated river
		WTR_REG	Season or permanent water regime
		REFUGE_ALL	All refuge datasets combine to indicate locations of drought refuges.
		WL_GDE	Waterlogging groundwater sensitivity
		GW_ALTWS_S	Indication of whether there is an alternate water source to groundwater (combination of SRC_TIDE and SRC_RVR)
		SW_ALTWS_S	Indication of whether there is an alternate water source to groundwater (combination of SRC_TIDE and SRC_GW)
	State-Wide depth to watertable mapping	DTW	Depth to water table groundwater sensitivity
GW Service	GDE Atlas	GW_REL_DS	Relative required of groundwater vs. other source (overall)
Value	AVIRA (aquatic Value Identification and Risk Assessment) – Rivers, wetlands and Estuary	WETLAND ID	AVIRA wetland ID
		AVIRA ID	Unique AVIRA ID
		WETLAND_NA	Wetland name
		NAME_12	River name
		BASIN	River basin number – AVIRA river
		System	River system – AVIRA estuary
		REACH	River reach number – AVIRA river
		Bas_Reac_1 ID	River basin and reach number combined – AVIRA river and estuary dataset

GDE Geospatial Dataset Attributes			
Field Group	**Dataset**	**Field Name**	**Short Description**
		Length	Length of river reach – AVIRA river
		BusinessID Business_1 Bas_Reach	River basin and reach number combined – AVIRA river, wetland and estuary
		Bas_Reach1 Bas_Reach_	River basin and reach number combined – AVIRA river and estuary
		Biosphere_ Biospehere1	Biosphere Reserve – AVIRA river, wetland and estuary
		Drought_Re	Drought Refuge – AVIRA river and wetland
		Heritage_R Heritage_1	Heritage River – AVIRA river and estuary
		Icon_River Icon_Riv_1	Icon River – AVIRA river and estuary
		Important_ Important_1	Important bird habitat – AVIRA river, wetland and estuary
		National_H National_1	National Heritage Site – AVIRA river and estuary (river dataset)
		National_1	National important wetland – AVIRA estuary (wetland dataset)
		Nationally	National important wetland – AVIRA wetland
		PreEuropea PreEurop_1	Pre European Indigenous Heritage site – AVIRA river and estuary
		Significan	Significant birds riparian site – AVIRA river
		Signific_1	Significant EVCs site – AVIRA wetland (wetland dataset)
		Signific_1 Signif_12	Significant birds Waterway – AVIRA river and estuary (river dataset)
		Signific_2 Signif_13	Significant EVCs site – AVIRA river and estuary (river dataset)
		Signific_2	Significant Fish – AVIRA wetland (wetland dataset)
		Signific_3	Significant fish migratory site – AVIRA river (river dataset)
		Signific_3	Significant flora wetland – AVIRA wetland (wetland dataset)
		Signific_4	Significant fish non migratory site – AVIRA river (river dataset)
		Signific_4	Significant invertebrate – AVIRA wetland (wetland dataset)
		Signific_5 Signif_16	Significant flora aquatic – AVIRA river and estuary (river dataset)
		Signific_5	Significant mammals – AVIRA wetland (wetland dataset)
		Signific_6 Signif_17	Significant flora terrestrial – AVIRA river and estuary (river dataset)
		Signific_6	Significant reptiles aquatic – AVIRA wetland (wetland dataset)
		Signific_7	Significant invertebrates aquatic – AVIRA river estuary (river dataset)
		Signific_7	Significant reptiles riparian – AVIRA wetland (wetland dataset)
		Signific_8	Significant invertebrates riparian – AVIRA river (river dataset)
		Signific_8	Significant birds – AVIRA estuary (wetland dataset)
		Signific_9	Significant mammals – AVIRA river (river dataset)
		Signifi_9	Significant EVCs – AVIRA estuary (wetland dataset)
		Signifi_10	Significant reptiles aquatic – AVIRA river (river dataset)
		Signifi_10	Significant fish dependent – AVIRA estuary (wetland dataset)
		Signifi_11	Significant reptiles riparian – AVIRA river (river dataset)
		Signifi_11	Significant fish resident – AVIRA estuary (wetland dataset)
		Signifi_12	Significant flora aquatic – AVIRA estuary (wetland dataset)
		Signifi_13	Significant flora terrestrial – AVIRA estuary (wetland dataset)
		Signif_14	Significant fish dependent – AVIRA estuary (river dataset)
		Signif_14	Significant reptiles – AVIRA estuary (wetland dataset)
		Signif_15	Significant fish resident – AVIRA estuary (river dataset)
		Signif_18	Significant reptiles – AVIRA estuary (river dataset)
		Wetland_Ve	Wetland vegetation condition – AVIRA wetland
		Victorian_ Victorian_1	Victorian heritage sites – AVIRA river, wetland and estuary
		Victorian1 Victorian_2	Victorian Parks and Reserves – AVIRA river wetland and estuary
		AVIRA_ECOL	Total ecological value from AVIRA

GDE Geospatial Dataset Attributes			
Field Group	**Dataset**	**Field Name**	**Short Description**
		AVIRA_SOCIAL	Total social value from AVIRA
	Victorian Biodiversity Atlas – Fauna 25 (first) and flora 25 (second)	SCI_NAME	Fauna species scientific name
		COMM_NAME	Fauna species common name
		FFG	Fauna FFG listing
		FFG_DESC	Fauna FFG listing full description
		VICADV	Fauna Victorian endangered species listing
		VICADV_DES	Fauna Victorian endangered species listing full description
		EPBC	Fauna EPBC listing
		EPBC_DESC	Fauna EPBC listing full description
		TREATY	Fauna treaty listing
		SCI_NAME_1	Flora species scientific name
		COMM_NAME_	Flora species common name
		FFG_1	Flora FFG listing
		FFG_DESC_1	Flora FFG listing full description
		VICADV_1	Flora Victorian endangered species listing
		VICADV_D_1	Flora Victorian endangered species listing full description
		EPBC_1	Flora EPBC listing
		EPBC_DESC_	Flora EPBC listing full description
		VBA_ALL	Total ecological value from VBA
	Victorian Heritage Sites	Heritage	Spatial intersect of any Victorian heritage site with a GDE. Includes Heritage Inventory 2014 and Heritage Register 2014.
	DEPI Vicmap Parks and Reserves	FEATURE_TY	Spatial intersect of any Victorian Park with a GDE.
		FEATURE_SU	Spatial intersect of any Victorian Reserve with a GDE.
		NAME_1	Name of Park or Reserve
	RAMSAR	RAMSAR	RAMSAR site number
		SITE_NAME	RAMSAR site name
		LAKE_NAME	RAMSAR lake name
		VERS_DATE	RAMSAR dataset version date
	Directory of Important Wetlands	FEAT_CODE	Type of wetland feature
		REFCODE	Reference code
		WNAME	Wetland name
		SOURCE	Source of information
		SUPPLY_BY	Data supplied by
		SPECIFIC_N	Specific name of wetland
Key Threats	Coal Inventory	GHD_Coal	Brown coal deposits – lower tertiary
		GHD_Coal	Brown coal deposits – mid tertiary
		GHD_Coal	Black coal deposits only
	Latrobe Valley Group Aquifer Mapping	VCG_Extent	Lower Mid-Tertiary Aquifer & Upper Tertiary Aquitard
	Geoscience prospectivity Mapping	CSG	Sub regional prospectivity GDE sensitivity ranking
	Manual Entries	Base_CM	All GDE not located in the footprint of Coal_Inv and VCG extent
	Manual Entries	RIVER_REG	All river GDEs that are impacted by river regulation
	Coastal Acid Sulfate Soils	AcidSul	All river GDEs located in the footprint of potential coastal acid sulfate soils
	Victorian Coastal Inundation Mapping – Seas Level Rise	Coatal_In or ClimateCh	All river GDEs located in the footprint of coastal inundation (sea level rise 82cm by 2100) impacts associated with climate change

GDE Geospatial Dataset Attributes			
Field Group	**Dataset**	**Field Name**	**Short Description**
	GMU and WSPA mapping	GW_use or GW_Extract	All river GDEs located in the footprint of groundwater extraction areas
Management	VLUIS2009	TENURE	Identifies if GDE is located on public or private land.
	Water Supply Protection Area	WSPA	Location of any Water Supply Protection Area
	Groundwater Management Area	GMA	Location of any Groundwater Management Area
	Biosite 100 and Biosite 250	Biosite	Spatial intersect of any Sites of Biological Significance with a GDE.
	Manual Entries	ENV_FLOW	Catchment for which environmental flow studies have been undertaken
		EG_WS	Rivers identified in the East Gippsland Draft Waterways Strategy as priority waterways
		WG_RHS	Rivers identified in the West Gippsland River Health Strategy (2005) as high priority
		REGIME_REQ	Wetlands connected to rivers that have an environmental water reserve
		Source_wet	Terrestrial vegetation that intersects wetlands (25m buffer)
		Source_rv	Terrestrial vegetation that intersects rivers (25m buffer)
		Wet_reg	Asset connected to wetland assets that are regulated
		Riv_reg	Asset connected to river assets that are regulated

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Appendix C. Final prioritisation approach

Table C 1 Prioritisation approach including criteria, datasets and ranking

Criteria	Application (GDE Type)	Description/justification of criteria and rules	Datasets	Options/attributes	Ranking		
					H	M	L
BASE LAYERS							
	Wetlands	The prioritisation analysis will focus on the wetland ecosystem types included in the Wetlands 2013 dataset that have a high or medium potential for groundwater interaction. The Corrick classification attribute in this data source will be applied in the wetland classification included in the base layer.	DEPI Wetlands 2013	WETLAND NO, WETLAND_MAIN, CORR_CLASS			
	Rivers	The prioritisation analysis will focus on the high and medium hierarchy water courses/ rivers (confirmed in consultation with CMA) included in the Vicmap Watercourse data set that have a high or medium potential for groundwater interaction.	Vicmap Watercourse	High and medium hierarchy watercourses, NAME			
	Terrestrial vegetation GDEs	The value and sensitivity assessment will focus on sub-surface GDEs capture in the GDE Atlas that have a high and medium potential for groundwater interaction.	GDE Atlas – sub surface	All high and medium groundwater dependent assets GWDEP_DS			
	All	The potential for groundwater interaction of wetlands and rivers and floodplain and riparian vegetation GDES from the GDE Atlas will be attributed in the base layer to filter out those assets with low potential for groundwater interaction. The probability of groundwater connection in this data source will also be applied in the wetland classification included in the base layer.	GDE Atlas – surface and subsurface	GWDEP_DS			
GDE VALUE							
Ecological value	Rivers	AVIRA provides environmental value of river reaches and information and the social values of waterways. The intersect of a number of values captured in the dataset (e.g biospheres and significant flora and fauna) with a GDE is used to infer ecological value within the GDE.	AVIRA (Biosphere_Reserves, Drought_Refuges, Icon_Rivers, Important_ Bird_Habitats, Nationally _Important_Wetlands, Significant_EVC, Significant_Birds, Significant_Fish, Significant_Flora, Significant_Flora, Significant_Reptiles, Significant _Invertebrates, Singificant_Mammals, Wetland_Vegetation_Condition)	Yes No 5 3 1	✓ ✓ 	 ✓ 	 ✓ ✓

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Criteria	Application (GDE Type)	Description/justification of criteria and rules	Datasets	Options/attributes	Ranking H	Ranking M	Ranking L
	Rivers	Drought refuges provide an important refuge for aquatic flora and fauna species during low flow or drought periods (cease to flow events), therefore are assumed as having high ecological value.	CMA drought refuge (REFUGE_ALL)	Yes	✓		
	Wetlands, sub surface GDEs	RAMSAR and DIWA sites are those wetlands that are representative, rare or unique or are important for conserving biological diversity, therefore any RAMSAR or DIWA site is assumed to have high ecological value.	Victoria RAMSAR and DIWA	Yes	✓		
	All	The Victorian Biodiversity Atlas manages information on wildlife in Victoria. This dataset encompasses vertebrate and invertebrate animals, vascular and non-vascular plants, and fungi from terrestrial and aquatic environments, including marine waters to the three nautical mile statutory limit. It includes both native and naturalised exotic species (including weeds and pests). The intersect of locations of threatened and endangered species (e.g. EPBC and FFG listed) with a GDE is used to infer ecological value for a GDE.	Victorian Biodiversity Atlas (EPBC, FFG, VICADV, TREATY)	Yes No	✓		 ✓
	All	The combination of EVC and bioregion is used to determine the bioregional conservation status (BCS) of an EVC. This is a measure of the current extent and quality for each EVC, when compared to it's original (pre-1750) extent and condition The bioregional conservation status provides an indication of ecological value of a GDE	Victorian EVC (EVCBCSDESC)	Endangered Vulnerable Depleted Rare Least Concern	✓ ✓	 ✓ ✓	 ✓
	All	Sites of Biological Significance provide the location of sites of conservation significance. These sites provide an indication of ecological value of a GDE.	BioSite	Yes	✓		
Social value	All	The identification of park and reserves which intercept a GDE provides an indication of social value.	VicMap Parks and Reserves (FEATURE_TY, FEATURE_SU)	Yes	✓		
	All	The identification of heritage sites which intercept a GDE provides an indication of social value.	Victorian Heritage Sites (Heritage)	Yes	✓		
	Rivers	AVIRA provides environmental value of river reaches and information and the social values of waterways. The intersect of a number of values captured in the dataset (e.g biospheres and significant flora and fauna) with a GDE is used to infer ecological value within the GDE.	AVIRA (PreEuropean_Indigenous_Heritage, Heritage_Rivers, National_Heritage_Sites, Victorian_Parks_and_Reserves, Victorian_Heritage_Sites)	Yes No 5 3 1	✓ ✓	 ✓	 ✓ ✓
Overall GDE Value Ranking	**All**	**The spread of rankings for ecological and social values will be assessed and used to assign an overall GDE value ranking for each GDE (see ranking matrices in Appendix D).**					

Criteria	Application (GDE Type)	Description/justification of criteria and rules	Datasets	Options/attributes	Ranking H M L
GDE SENSITIVITY					
GDE group	Wetlands	GDEs are sensitive to any shift in their existing state (e.g freshwater to saline, permanent to semi-permanent). The Corrick Classification provides an indication of the GDE's existing state.	Wetland 2013 (CORR_CLASS)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)
Groundwater connection	Wetlands, Rivers, sub surface GDEs	GDEs with high connection to groundwater are more sensitive due to changes in groundwater flow regimes causing a greater shift in the water budget of GDEs that have a high groundwater connection, compared to GDEs that have a low level connection.	GDE Atlas – surface and subsurface expression of groundwater (GWDEP_DS, GWDEP_DS_1)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)
Salinity Regime	Wetlands	GDEs are sensitive to any change in their existing salinity regime. A change in surface water or groundwater quality can change the salinity regime, shifting it from its normal state and therefore making it sensitive.	Wetland 2013 (SAL_REGIME)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)
Surface Water Regime	Wetlands	The impact of a change in the groundwater regime to a GDE depends to a degree on the surface water regime. GDEs are sensitivity to any change in their existing surface water regime.	Wetland 2013 (WTR_REG)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)
	Rivers	The impact of a change in the groundwater regime to a GDE depends to a degree on the surface water regime. GDEs are sensitivity to any change in their existing surface water regime. Manual entries include permanent or seasonal.	Manual entry (WTR_REG)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)
River Regulation	Rivers Sub surface GDEs	The impact of a change in groundwater and surface water quality or quantity is diminished in regulated streams, therefore regulated GDEs are likely to be less sensitive to change that unregulated, as the water flow can be controlled and designed to provide water for instream ecosystems.	Manual (RIVER_REG)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)
Connection to Surface Water (River)	Wetlands	GDEs are less sensitive to changes in groundwater if they have an alternate surface water source. Alternatively those GDEs with a surface water connection will more sensitive to changes in surface water regime.	Wetland 2013 (SRC_RVR)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)
	Sub-surface GDEs	Water assets are less sensitive to changes in groundwater if they have an alternate surface water source. Alternatively those water assets with a surface water connection will more sensitive to changes in surface water regime. Those sub-surface GDEs within a 25m buffer of a permanent watercourse were assumed as having an alternate surface water source	Manual (Source_Rv)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)

Criteria	Application (GDE Type)	Description/justification of criteria and rules	Datasets	Options/attributes	Ranking H M L
Connection to surface water (wetland)	Sub-surface GDE	Water assets are less sensitive to changes in groundwater if they have an alternate surface water source. Alternatively those water assets with a surface water connection will more sensitive to changes in surface water regime. Those sub-surface GDEs within a 25m buffer of a permanent wetland were assumed as having an alternate surface water source	Manual (Source_Wet)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)
Connection to Tidal	Wetlands	GDEs are less sensitive to changes in groundwater if they have an alternate tidal water source. Alternatively those GDEs with a tidal water connection will be sensitive to changes in baseflow causing the salt water-fresh water interface to move further upstream.	Wetland 2013 (SRC_TIDE) Manual entry (RIVER_TIDA)	Yes(see Appendix E)	Differs for each threat/ activity (Appendix E)
Temporal Groundwater Connection	Wetlands, Rivers	GDEs that are permanently connection to groundwater will be more sensitive to change in groundwater quality and quantity, relative to GDEs with an ephemeral connection.	GDE Atlas – surface expression of groundwater (PERMCON_DS)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)
Water Source	Wetlands	GDEs that have a dominant groundwater source will have a greater sensitivity to a change in groundwater (quality or quantity) than those GDEs that have both a surface and groundwater component to their water balance.	GDE Atlas – surface and sub-surface expression of groundwater (GW_REL_DS)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)
	Rivers	GDEs that have a dominate groundwater source will have a greater sensitivity to a change in groundwater (quality or quantity) than those GDEs that have both a surface and groundwater component to their water balance. This will be derived from the spatial connectivity between GDEs and depth to watertable and geology mapping. Those GDEs that intersect shallow groundwater and are located in quaternary sediments are assumed to be more sensitive.	Manual entry (GW_Interact) Simplified Geology - intersect with quaternary sediments (Simpl_Geol) DTW - intersect with shallow DTW (DTW)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)
Instream ecosystems (river refuges)	Rivers	The presence of remnant pools are highly sensitive to changes in groundwater or surface water quality and quantity which may reduce inflows during low flow/ cease to flow periods	CMA drought refuge mapping (REFUGE_ALL)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)
Ecosystem type (due to vegetation communities present)	Wetlands, Rivers	GDEs with ecosystems (vegetation communities) dependant on groundwater are more sensitive to change in groundwater and surface water. This attribute ensures that both aquatic and terrestrial ecosystems are considered	GDE Atlas – subsurface expression of groundwater (GWDEP_DS_1)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)
Tolerance to waterlogging	Sub-surface GDE	Sub-surface GDEs that are prone to higher waterlogging are more sensitive to changes in groundwater and surface regime due to waterlogging providing an indication of the permanence of the water source to the GDE.	ARI Vegetation sensitivity layer (water logging) (WL)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)
Eco-hydrogeological zone	Sub-surface GDE	Sub-surface GDEs in a higher rainfall areas and particular landscape settings (e.g. Victorian Alps) are less reliant on groundwater or surface	GDE Atlas (EHZ mapping) (EHZ_ID)	Yes (see Appendix E)	Differs for each threat/

Criteria	Application (GDE Type)	Description/justification of criteria and rules	Datasets	Options/attributes	Ranking H	Ranking M	Ranking L
		water and therefore less sensitive to changes in groundwater.			activity (Appendix E)		
Depth to watertable	Sub-surface GDE	Sub-surface GDEs in areas of shallow water tables are more sensitive to changes in groundwater. Alternatively those sub-surface GDEs that have access to permanent shallow water tables may be less sensitive to changes in surface water.	DEPI state wide DTW mapping (DTW)	Yes (see Appendix E)	Differs for each threat/ activity (Appendix E)		
Overall GDE Sensitivity Ranking	**All**	**The spread of rankings for GDE sensitivity criteria will be assessed and used to assign an overall GDE sensitivity ranking for each GDE using an additional sensitivity analysis (see Appendix F).**					
GDE Consequence Ranking	**All**	**The overall rankings for GDE value and sensitivity will be assessed and used to assign a GDE consequence ranking for each GDE (see ranking matrices in Appendix D).**					
GDE SUSCEPTIBILITY							
Coal Mining	All	GDEs that intersect with black and brown coal deposits are assumed to be susceptible to coal mining.	Coal inventory	Yes	✓		
	All	GDEs that intersect with the Latrobe Valley coal (measures) are assumed to be susceptible to coal mining.	LCV extent	Yes		✓	
	All	All remaining GDEs that do not fall into one of the categories of criteria assessed above will be ranked as having low susceptibility to coal mining	Base layer – All GDEs	All other GDEs			✓
CSG Extraction	All	GDEs within the CSG subregional prospectivity boundary (based on work undertaken by Geoscience Victoria) are assumed to be susceptible to CSG activities.	Geoscience Victoria/ DELWP - sub regional coal seam gas prospectivity	Yes	✓		
	All	All remaining GDEs that do not fall into one of the categories of criteria assessed above will be ranked as having low susceptibility	Base layer – All GDEs	All other GDEs			✓
Coastal Acid Sulfate Soils	All	GDEs that intersect the mapped coastal potential acid sulfate soils are assumed to be susceptible to the impacts of acid sulfate soils.	DELWP Coastal Acid Sulfate Soils COASTAL_ACID_SULPHATE_SOILS/	Yes	✓		
River Regulation	Rivers	All river GDEs that are regulated are assumed to be susceptible to the impacts of river regulations	Manual – see sensitivity above	Yes	✓		

Criteria	Application (GDE Type)	Description/justification of criteria and rules	Datasets	Options/attributes	Ranking		
					H	M	L
Groundwater Extraction	All	GDEs that intersect a WSPA area assumed to have high susceptibility to groundwater extraction and those that intersect a GMA have medium susceptibility to groundwater extraction.	Located within a WSPA (WSPA_20130405\WSPA.shp) Located within a GMA (Vic_GMAs_GDA94)	Yes	✓ 	 ✓	
Climate Change	All	GDEs that intersect the mapped Victorian Coastal Inundation Sea Level Rise 2100 (0.82 cm) are assumed to be susceptible to the impacts of climate change.	Located within 2100 projected sea level rise boundary (SLR82CM_2100)	Yes	✓		
Overall GDE Susceptibility Ranking	**All**	**The spread of rankings for GDE susceptibility criteria will be assessed and used to assign an overall GDE susceptibility ranking for each GDE (see ranking matrices in Appendix D).**					
GDE MANAGEMENT							
River regulation	Surface expression of groundwater – Rivers	River regulation was considered as a management criterion with the assumption that storages which are able to pass flows/control releases are likely to provide environmental flows as part of this requirement.	Manual (RIVER_REG)	Yes			✓
Land management	All	Land management will affect MW's ability to manage GDEs. It is assumed this will be easiest to achieve on MW owned land, followed by public land and private sites	Land use layer (VLUIS2009). Null values indicate that there was no data available.	Private Public	✓ 	 ✓	
Environmental flow study	River refuges only	Catchment for which environmental flow studies have been undertaken and for which an environmental water reserve or stream flow management plan is available to enable priority flow recommendations to be delivered. The assumption is that River GDEs in these catchments are more likely to be better managed and achieve their environmental water requirements	Located within a catchment for which an environmental flow study has been undertaken. (Based on information provided by Simon Treadwell and attributed to SDL catchments - SDL_Catch_Vg94). Includes the following catchments: Latrobe River, Thomson River, Macalister River, Avon River Mitchel River, Lang Lang River, Bass River, Powlett River, Tarwin River, Tarra River. Preferred water regime is described in annual seasonal water plans prepared by the CMAs and endorsed by the Victorian Environmental Water	Yes			✓

Criteria	Application (GDE Type)	Description/justification of criteria and rules	Datasets	Options/attributes	Ranking H	Ranking M	Ranking L
			Holder.				
RAMSAR	Wetlands, sub surface GDEs	In designating a wetland a RAMSAR site, it is agreed to establish and oversea a management framework aimed at conserving the wertland and ensuring its wise use.	Victoria RAMSAR	Yes			✓
Wetland water regime requirements	Wetlands	Applies to wetlands connected to rivers that have an environmental water reserve that can be used to assist in the delivery of the preferred water regime to associated wetlands	Wetlands located in association with the Lower Latrobe River downstream of Sale. Includes: The Heart Morass, Dowd Morass, Sale Common. Preferred water regime is described in annual seasonal water plans prepared by the CMAs and endorsed by the Victorian Environmental Water Holder.	Yes			✓
West Gippsland River Health Strategy	Rivers	Rivers identified in the West Gippsland River Health Strategy (2005) as high priority (Management Program A - protection of highest environmental, social, economic value sub-catchments) will be targeted most for investments within the CMA.	WG_RHS Priority rivers include middle and lower Macalister River, Upper Thomson River, Lake Wellington, Morwell River, Trrtalgon Creek, Lower Latrobe River, Corner Inlet and Nooramunga, Fraklin River, Lower Agnes River, Wilsons Promontory, Waratah Bay, Tarwin River – lower west branch, Screw Creek, Pound Creek and Anderson Inlet.	Yes			✓
East Gippsland Draft Waterways Strategy 2014-2022	Rivers	Rivers identified in the East Gippsland Draft Waterways Strategy as priority waterways will be targeted most for investments within the CMA.	EG_WS Priority waterways include Mitchell Basin, Tambo Basin, Gippsland Lakes, Snowy Basin, Far East Basin	Yes			✓

Criteria	Application (GDE Type)	Description/justification of criteria and rules	Datasets	Options/attributes	Ranking H	Ranking M	Ranking L
Water Supply Protection Areas	All	An area declared under Section 27 of the *Water Act 1989* to protect the area's groundwater or surface water resources through the development of a management plan which aims for equitable management and long term sustainability. It is assumed that if a GDE occurs within a WSPA then it is subject to management principles/policies	Located within a WSPA (WSPA_20130405\WSPA.shp)	Yes			✓
Groundwater Management Areas	All	Victorian Groundwater Management Areas have groundwater allocation caps applied to them. It is assumed that a GDE is exposed to a moderate assessment of management in these areas (i.e. detailed management planning is not a requirement of GMAs as it is for WSPAs).	Located within a GMA (Vic_GMAs_GDA94)	Yes		✓	
	All	All remaining GDEs that do not fall into one of the categories of criteria assessed above will be ranked as having high management ranking	Base layer – All GDEs	All other GDEs	✓		
Overall GDE Management Ranking	**All**	**The spread of rankings for GDE management criteria will be assessed and used to assign an overall GDE management ranking for each GDE (see ranking matrices in Appendix D).**					
GDE Likelihood Ranking	**All**	**The overall rankings for GDE susceptibility and management will be assessed and used to assign a GDE likelihood ranking for each GDE (see ranking matrices in Appendix D).**					
GDE potential hazard ranking	**All**	**The rankings for GDE consequence and likelihood will be assessed and used to assign an overall GDE potential hazard ranking for each GDE (see ranking matrices Appendix D).**					

Appendix D. Ranking Matrices

Table D 1 Overall ranking classifications

Overall Ranking Classifications						
GDE Value						
Ecological Value AVIRA	H	M	L			
Biodiversity Atlas	H	L				
EVC (bioregional conservation status)	H	L				
BioSites	H	M	L			
Drought Refuges	H	L				
RAMSAR	H	L				
Social Value AVIRA	H	M	L			
Heritage Sites	H	L				
Parks and Reserves	H	L				
Overall Value Ranking						
High: Any GDE that has a high against any value attribute						
Medium: Any GDE that has either all mediums of a combination of mediums and lows for value attributes						
Low: Any GDE that has all lows for value attributes						
GDE Sensitivity (see appendix E for further breakdown)						
Sensitivity to change in groundwater quantity	H	M	L			
Sensitivity to change in groundwater quality	H	M	L			
Sensitivity to change in surface water quantity	H	M	L			
Sensitivity to surface disruption	H	M	L			
Overall Sensitivity Ranking						
See Appendix E for details and associated sensitivity analysis tool.						
GDE Consequence						
GDE Value	H	M	L			
GDE Sensitivity	H	L				
Possibilities	HH	HL	MH	ML	LH	LL
Overall Ranking	H	M	H	M	M	L
GDE Susceptibility						
Coal Mining	H	M	L			
CSG Extraction	H	L				
Overall Management Ranking						
High: Any GDE that has a high against any susceptibility attribute						
Medium: Any GDE that has either all mediums of a combination of mediums and lows for susceptibility attributes						
Low: Any GDE that has all lows for susceptibility attributes						
GDE Management						
River regulation	L					
Land management	H	M				
Environmental flows study	L					
Wetland water regime requirements	L					
West Gippsland River Health Strategy	L					
East Gippsland Draft Waterways Strategy	L					

Overall Ranking Classifications						
RAMSAR	L					
WSPA	L					
GMA	M					
Others	H					
Overall Management Ranking **Wetlands:** If water regime, RAMSAR, WG RHS, EG WS are L then management = L If WSPA is L and management not already L from the above rule then management = M All other GDEs management = H **Rivers:** If river regulation, env flow, WG RHS, EG WS are L then management = L If WSPA is L and management not already L from the above rule then management = M All other GDEs management = H						
GDE Likelihood						
GDE Susceptibility	H	M	L			
GDE Management	H	M	L			
Possibilities	HH	HM	HL	MM	ML	LL
Overall Ranking	H	H	M	M	M	L
GDE potential hazard						
GDE Consequence	H	M	L			
GDE Likelihood	H	M	L			
Possibilities	HH	HM	HL	MM	ML	LL
Overall Ranking	H	H	M	M	M	L

Appendix E. Final sensitivity rules

Table E 1 Sensitivity of wetland types to threats associated with large coal mines and CSG activity.

Threats	Wetland Group Type		GW Connection		Salinity Regime		Surface Water Regime		Temp Groundwater Connection		Ecosystem Type - GW dependent vegetation		Alternate Water Source to GW		Alternate Water Source to SW	
	CORR_CLASS		GWDEP_DS		SAL_REG		WTRREG		PERMCON_DS		GWDEP_DS_1		GW_ALTWS_SENS		SW_ALTWS_SENS	
Change in groundwater quantity	1 - Flooded river flats		High potential for GW interaction	H	Fresh		Episodic	L	Ephemeral (Unpredictable, Short-Term)	L	High potential for GW interaction	H	High	L	High	H
	2 - Freshwater meadow		Moderate potential for GW interaction	M	Fresh – Hyposaline		Intermittent	M	Intermittent (Irregular, Persists for Medium Term)	M	Moderate potential for GW interaction	M	Medium	M	Medium	M
	3 - Shallow freshwater marsh		Low potential for GW interaction	L	Hyposaline		Intertidal	L	Permanent, Near Permanent	H	Low potential for GW interaction	L	Low	H	Low	L
	4 - Deep freshwater marsh		Blank	L	Hyposaline – Mesosaline		Permanent	H	Seasonal (Annual, Regular)	H	blank	L				
	5 -Permanent open freshwater		Identified in previous study: fieldwork	H	Mesosaline		Seasonal	H	Blanks	L						
	6 - Semi-permanent saline				Mesosaline – Hypersaline		Supratidal	M								
	7 - Permanent saline				Variably salt tolerant		Unknown	L								
	99 - No category				No data											
					Unknown											
Change in groundwater quality	1 - Flooded river flats	L	High potential for GW interaction	H	Fresh	H	Episodic	L	Ephemeral (Unpredictable, Short-Term)	L	High potential for GW interaction	H	High	L	High	H
	2 - Freshwater meadow	H	Moderate potential for GW interaction	M	Fresh-Hyposaline	M	Intermittent	M	Intermittent (Irregular, Persists for Medium Term)	M	Moderate potential for GW interaction	M	Medium	M	Medium	M
	3 - Shallow freshwater marsh	H	Low potential for GW interaction	L	Hyposaline	M	Intertidal	L	Permanent, Near Permanent	H	Low potential for GW interaction	L	Low	H	Low	L
	4 - Deep freshwater marsh	H	Blank	L	Hyposaline – Mesosaline	M	Permanent	H	Seasonal (Annual, Regular)	H	blank	L				
	5 -Permanent open freshwater	H	Identified in previous study: fieldwork	H	Mesosaline	M	Seasonal	H	Blanks	L						
	6 - Semi-permanent saline	H			Mesosaline-Hypersaline	H	Supratidal	M								
	7 - Permanent saline	H			Variably Salt Tolerant	L	Unknown	L								
	99 - No category	L			No data	L										
					Unknown	L										
Change in surface water quantity	1 - Flooded river flats		High potential for GW interaction	L	Fresh		Episodic	H	Ephemeral (Unpredictable, Short-Term)	H	High potential for GW interaction	L	High	H	High	L
	2 - Freshwater meadow		Moderate potential for GW interaction	M	Fresh-Hyposaline		Intermittent	H	Intermittent (Irregular, Persists for Medium Term)	M	Moderate potential for GW interaction	M	Medium	M	Medium	M
	3 - Shallow freshwater marsh		Low potential for GW interaction	H	Hyposaline		Intertidal	L	Permanent, Near Permanent	L	Low potential for GW interaction	H	Low	L	Low	H
	4 - Deep freshwater marsh		Blank	H	Hyposaline – Mesosaline		Permanent	M	Seasonal (Annual, Regular)	L	blank	L				
	5 -Permanent open freshwater		Identified in previous study: fieldwork	L	Mesosaline		Seasonal	M	Blanks	L						
	6 - Semi-permanent saline				Mesosaline-Hypersaline		Supratidal	H								
	7 - Permanent saline				Variably Salt Tolerant		Unknown	L								
	99 - No category				No data											
					Unknown											

Threats	Wetland Group Type		GW Connection		Salinity Regime		Surface Water Regime		Temp Groundwater Connection		Ecosystem Type - GW dependent vegetation		Alternate Water Source to GW		Alternate Water Source to SW	
	CORR_CLASS		GWDEP_DS		SAL_REG		WTRREG		PERMCON_DS		GWDEP_DS_1		GW_ALTWS_SENS		SW_ALTWS_SENS	
Change in surface water quality	1 - Flooded river flats	H	High potential for GW interaction	L	Fresh	H	Episodic	H	Ephemeral (Unpredictable, Short-Term)	H	High potential for GW interaction	L	High	H	High	L
	2 - Freshwater meadow	H	Moderate potential for GW interaction	M	Fresh-Hyposaline	M	Intermittent	H	Intermittent (Irregular, Persists for Medium Term)	M	Moderate potential for GW interaction	M	Medium	M	Medium	M
	3 - Shallow freshwater marsh	H	Low potential for GW interaction	H	Hyposaline	M	Intertidal	L	Permanent, Near Permanent	L	Low potential for GW interaction	H	Low	L	Low	H
	4 - Deep freshwater marsh	M	Blank	H	Hyposaline – Mesosaline	M	Permanent	M	Seasonal (Annual, Regular)	L	blank	L				
	5 -Permanent open freshwater	H	Identified in previous study: fieldwork	L	Mesosaline	M	Seasonal	M	Blanks	L						
	6 - Semi-permanent saline	H			Mesosaline-Hypersaline	H	Supratidal	H								
	7 - Permanent saline	H			Variably Salt Tolerant	L	Unknown	L								
	99 - No category	L			No data	L										
					Unknown	L										
Surface Disruption	Sensitivity related directly to the value (not presented here) of the GDE															

Table E 2 Sensitivity of river types to threats associated with large coal mines and CSG activity.

Threats	River Regulation		GW Connection		Surface Water Regime		Water Source – River Groundwater Interaction (Geology and Depth to Watertable analysis)		Connected to Tidal		Ecosystem Type - GW dependent vegetation		Instream Ecosystem - Drought Refuge	
	RIVER_REG		GWDEP_DS		WTR_REG		GW_Interact		RIVER_TIDA		GWDEP_DS_1		REFUGE_ALL	
Change in gw quantity	Reg	L	High potential for GW interaction	H	Permanent	L	High	H	Yes	L	High potential for GW interaction	H	Blank	L
	Un-Reg	H	Moderate potential for GW interaction	M	Seasonal	H	Medium	M	No	H	Moderate potential for GW interaction	M	Yes	H
			Blank	L			Low	L			Low potential for GW interaction	L		
			Identified in previous study: desktop	H							Blank	L		
			Identified in previous study: fieldwork	H										
Change in gw quality	Reg	L	High potential for GW interaction	H	Permanent	L	High	H	Yes	L	High potential for GW interaction	H	Blank	L
	Un-Reg	H	Moderate potential for GW interaction	M	Seasonal	H	Medium	M	No	H	Moderate potential for GW interaction	M	Yes	H
			Blank	L			Low	L			Low potential for GW interaction	L		
			Identified in previous study: desktop	H							Blank	L		
			Identified in previous study: fieldwork	H										
Change in surface water quantity (increase through dewatering and discharge)	Reg	L	High potential for GW interaction	L	Permanent	L	High	L	Yes	L	High potential for GW interaction	L	Blank	L
	Un-Reg	H	Moderate potential for GW interaction	M	Seasonal	H	Medium	M	No	H	Moderate potential for GW interaction	M	Yes	H
			Blank	H			Low	H			Low potential for GW interaction	H		
			Identified in previous study: desktop	L							Blank	L		
			Identified in previous study: fieldwork	L										
Change in surface water quality (reduction)	Reg	M	High potential for GW interaction	M	Permanent	H	High	L	Yes	L	High potential for GW interaction	L	Blank	L
	Un-Reg	H	Moderate potential for GW interaction	M	Seasonal	H	Medium	M	No	H	Moderate potential for GW interaction	M	Yes	H
			Blank	H			Low	H			Low potential for GW interaction	H		
			Identified in previous study: desktop	M							Blank	L		
			Identified in previous study: fieldwork	M										
Surface Disruption	Sensitivity related directly to the value (not presented here) of the GDE													

Table E 3 Sensitivity of sub surface GDEs to threats associated with large coal mines and CSG activity.

Threats	Tolerance to Waterlogging		Eco-hydrogeological Zone		Depth to Watertable		Ecosystem Type - GW dependent vegetation		Additional Source of Water - Wetland		Additional Source of Water - River		Associated with regulated wetland		Associated with regulated river	
	WL_GDE_SENS		EHZ_DS		DTW		GWDEP_DS		SOURCE_WETL		SOURCE_RV		WET_REG		RIV_REG	
Change in groundwater quantity	H*	H	Gippsland Plain	H	H*	H	High potential for GW interaction	H	High	H	High	H	High	H	High	H
	M*	M	South East Coastal Ranges	M	M*	M	Moderate potential for GW interaction	M	Low (intersect)	L	Low (intersect)	L	Low (intersect)	L	Low (intersect)	L
	L*	L	Northern Inland Slopes, Upper Slopes	L	L*	L										
Change in surface water quantity	H*	H	Gippsland Plain	H	H*	L	High potential for GW interaction	L	High	L	High	L	High	L	High	L
	M*	M	South East Coastal Ranges	M	M*	M	Moderate potential for GW interaction	M	Low (intersect)	H	Low (intersect)	H	Low (intersect)	H	Low (intersect)	H
	L*	L	Northern Inland Slopes, Upper Slopes	L	L*	H										

Appendix F. Additional Sensitivity Analysis

Table F 1 Wetland GDE governing attributes and rules

Threat	Governing Attributes	Governing Rules
Change in Groundwater Quantity	Surface expression of groundwater interaction	High potential for groundwater interaction will always have high sensitivity
	Alternate water source to groundwater (tidal or surface water)	Medium potential for groundwater interaction will only be high if three or more other sensitivity attributes are high. Medium potential will never be low.
	Ecological community present (sub surface groundwater interaction)	Low potential for groundwater interaction will only be medium if there is a high potential for ecological communities (vegetation) to have a high potential for groundwater interaction or three or more other sensitivity attributes are high.
Change in Groundwater Quality	Surface expression of groundwater interaction	High potential for groundwater interaction will always have high sensitivity
	Alternate water source to groundwater (tidal or surface water)	Medium potential for groundwater interaction will only be high if three or more other sensitivity attributes are high. Medium potential will never be low.
	Ecological community present (sub surface groundwater interaction)	Low potential for groundwater interaction will only be medium if there is a high potential for ecological communities (vegetation) to have a high potential for groundwater interaction or three or more other sensitivity attributes are high.
Change in Surface Water Quality	Surface expression of groundwater interaction	Low potential for groundwater interaction will always have high sensitivity
	Alternate water source to surface water (tidal or groundwater)	Medium potential for groundwater interaction will only be high if three or more other sensitivity attributes are high Medium potential will never be low.
	Salinity regime	High potential for groundwater interaction will only be medium if the salinity regime is highly sensitive to changes in surface water quality or three or more other sensitivity attributes are high.
Change in Surface Water Quantity	Surface expression of groundwater interaction	Low potential for groundwater interaction will always have high sensitivity
	Alternate water source to surface water (tidal or groundwater)	Medium potential for groundwater interaction will only be high if three or more other sensitivity attributes are high Medium potential will never be low.
	Water regime	High potential for groundwater interaction will only be medium if the surface water regime is highly sensitive to changes in surface water quality or three or more other sensitivity attributes are high

Table F 2 River GDE governing attributes and rules

Threat	Governing Attributes	Governing Rules
Change in Groundwater Quantity	Surface expression of groundwater interaction	High potential for groundwater interaction and/ or the presence of a drought refuge will always have high sensitivity
	Drought refuge	Medium potential for groundwater interaction and the absence of a drought refuge will only be high if three or more other sensitivity attributes are high Medium potential will never be low.
	Water Source – gaining, losing, variable	Low potential for groundwater interaction and the absence of a drought refuge will only be medium if there is the presence of ecological communities (vegetation) that have a high potential for groundwater interaction and/ or the water source is highly sensitive to a change in groundwater quantity (gaining).
	Ecological community present (sub surface groundwater interaction)	
Change in Groundwater Quality	Surface expression of groundwater interaction	High potential for groundwater interaction and/ or the presence of a drought refuge will always have high sensitivity
	Drought refuge	Medium potential for groundwater interaction and the absence of a drought refuge will only be high if three or more other sensitivity attributes are high Medium potential will never be low.
	Water Source – gaining, losing, variable	Low potential for groundwater interaction and the absence of a drought refuge will only be medium if there is the presence of ecological communities (vegetation) that have a high potential for groundwater interaction and/ or the water source is highly sensitive to a change in groundwater quantity (gaining).
	Ecological community present (sub surface groundwater interaction)	
Change in Surface Water Quality	Surface expression of groundwater interaction	Low potential for groundwater interaction and/ or the presence of a drought refuge will always have high sensitivity
	Drought refuge	Medium potential for groundwater interaction and the absence of a drought refuge will only be high if three or more other sensitivity attributes are high Medium potential will never be low.
	Water Source – gaining, losing, variable	High potential for groundwater interaction and the absence of a drought refuge will only be medium if the water source is highly sensitive to a change in groundwater quantity (losing).
Change in Surface Water Quantity	Surface expression of groundwater interaction	Low potential for groundwater interaction and/ or the presence of a drought refuge will always have high sensitivity
	Drought refuge	Medium potential for groundwater interaction and the absence of a drought refuge will only be high if three or more other sensitivity attributes are high Medium potential will never be low.
	Water Source – gaining, losing, variable	High potential for groundwater interaction and the absence of a drought refuge will only be medium if the water source is highly sensitive to a change in groundwater quantity (losing).

Table F 3 Terrestrial vegetation GDE governing attributes and rules

Threat	Governing Attributes	Governing Rules
Change in Groundwater Quantity	Depth to watertable	Terrestrial vegetation GDEs assets that have a shallow depth to water table will have high sensitivity
	Groundwater Dependent vegetation	Terrestrial vegetation GDEs that have a high potential for groundwater interaction have high sensitivity Terrestrial vegetation GDEs that have a medium potential for groundwater interaction have medium or low sensitivity
	Tolerance to waterlogging	Terrestrial vegetation GDEs that have high waterlogging have high sensitivity
	Additional source of water – River or Wetland	Terrestrial vegetation GDEs that are connected, or receives a water source from a permanent river or wetland have low sensitivity
Change in Surface Water Quantity	Additional source of water – River or Wetland	Terrestrial vegetation GDEs that are connected, or receives a water source from a permanent river or wetland have high sensitivity All other water assets will have low sensitivity