17 Groundwater

Tables

Figures

17.1 OVERVIEW

This chapter provides an assessment of the potential groundwater impacts from construction and operation of the Mordialloc Bypass (Freeway) (the project), as outlined in Chapter 4: *EES assessment framework and approach*. It is based on the impact assessment prepared by WSP and presented in Appendix K: *Groundwater impact assessment*. Potential impacts to surface water are considered in Chapter 16: *Surface water and hydrology* and Appendix J: *Surface water impact assessment*.

Groundwater in the region is typically shallow with water levels just a few meters below ground level. Interactions between surface water and groundwater (termed groundwater–surface water interactions) occur at several surface water bodies within the study area and help maintain water levels within ecologically significant wetlands, such as the Ramsar listed Edithvale-Seaford Wetlands located about 700m west of the proposed alignment. Interfering with groundwater flows within the project area has the potential to adversely affect wetland water levels and ecological processes associated with surrounding wetlands, including the Edithvale Wetlands, part of the Edithvale-Seaford Wetlands.

Impacts to groundwater can be simplified into two categories: impact to *groundwater quality* and impacts to groundwater levels (*groundwater quantity*). Using a source – pathway – receptor approach, potential risks were identified and assessed as part of the impact assessment.

Construction of the project could affect groundwater availability through changes to groundwater levels, flows and recharge resulting from excavations and compression of soil. Construction of road embankments may result in soil compaction which has the potential to restrict groundwater flows. Compaction typically causes groundwater to become higher (mound) on the upstream side of the embankment (in relation to the groundwater flow direction) and to become lower (drawdown) on the downstream side. Whilst the driving of piles could impact flows between aquifer units by creating preferential flow pathways, the risk to groundwater is considered to be low. Aquifer units present at the proposed piling locations are already in hydraulic connection and the percussion driving of piles through the aquifer material compresses the near-pile material, self-sealing and preventing groundwater flow (NGCLC 2001). For the embankments, the impacts are predicted to be temporary and within the range of natural variability. Numerical groundwater flow modelling indicated a very low likelihood of project impacts extending beyond the project boundary. A detailed water balance also found there would be no impacts on the Edithvale Wetlands.

Groundwater quality could also be impacted by spills, stormwater runoff or from changes to groundwater flows, leading to activation and mobilisation of acid sulfate soils (ASS) or saltwater intrusion. Disturbance of acid sulfate soil and contaminated groundwater are addressed in Section 18.8 of Chapter 18: *Soils and contaminated land*. Standard controls covered in a Construction Environmental Management Plan (CEMP) will manage the risk of contaminants entering the groundwater system, however a Water Management and Monitoring Plan (WMMP) will also be developed to ensure any contamination to groundwater is identified and relevant contingency put in place.

17.2 EES OBJECTIVES AND REQUIREMENTS

The draft evaluation objectives for groundwater is defined in the *Scoping Requirements for Mordialloc Bypass Environment Effects Statement* (scoping requirements) (DELWP 2018).

Table 17.1 summarises the key issues relating to groundwater as identified in the scoping requirements. This chapter addresses requirements related to groundwater aspects, including the interaction between groundwater and surface waters. Groundwater contamination, including that within the former landfill site in the project's north, is addressed in Chapter 18: *Soils and contaminated land*. Impacts on biodiversity values of the wetlands are addressed in Chapter 10: *Biodiversity*. Cumulative groundwater impacts related to nearby Level Crossing Removal Authority (LXRA) projects are addressed in Chapter 21: *Cumulative impacts*.

DRAFT EVALUATION OBJECTIVE

To minimise adverse effects on groundwater, surface water and floodplain environments and minimise effects on water quality and beneficial uses, including the ecological character of the Edithvale-Seaford Wetlands Ramsar site.

Table 17.1 EES key issues – groundwater

Key issues
The potential for adverse effects on the functions, values and beneficial uses of groundwater due to the project, in particular on groundwater dependent ecosystems (GDEs) and the ecological character of the Edithvale-Seaford Wetlands due to changes in groundwater levels, behaviour or quality.
The potential for adverse effects on nearby and downstream water environments (including the Mordialloc Creek catchment and Edithvale-Seaford Wetlands) due to changed flow regimes, floodplain storage, run-off rates, water quality changes or other waterway conditions during construction and operation.

17.3 LEGISLATION AND POLICY

Commonwealth and State laws and policies relevant to assessing and managing environmental impacts on groundwater resources are outlined in Table 17.2.

Table 17.2 Legislation and policy – groundwater

Legislation / policy	Description
Commonwealth:	
Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC/ ARMCANZ 2000)	Provides guidelines for sustainable use of Australia's water resources by protecting and enhancing quality, while maintaining economic and social development. These guidelines are used as groundwater quality criteria for assessing beneficial uses outlined in the *State Environment Protection Policy* (SEPP) (Groundwaters of Victoria).
Australian Drinking Water Guidelines (NHMRC 2011)	Guide the Australian community and the water supply industry on what constitutes good quality drinking water. These guidelines are used as groundwater quality criteria for assessing beneficial uses outlined in the SEPP (Groundwaters of Victoria).
Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act)	Prescribes the Commonwealth's role in environmental assessment, biodiversity conservation, and managing protected areas and species, population and communities and heritage items. The Act is the Commonwealth's principal environmental protection and biodiversity conservation legislation. It provides for the conservation of biodiversity and the protection of the environment, particularly the nine Matters of National Environmental Significance (MNES), which including World Heritage Properties, National Heritage Places, Ramsar wetlands, nationally listed threatened species and ecological communities and listed migratory species. The Act states that 'controlled' actions, i.e. actions that are determined as likely to have a significant impact on a MNES, are subject to assessment and approval under the Act.
National Water Quality Management Strategy (NWQMS), 1994	NWQMS is the Australian and New Zealand governments joint approach to improving water quality in waterways. The objective of the NWQMS is to achieve sustainable use of water resources by protecting and enhancing their quality, while maintaining economic and social development. The NWQMS provides a framework for the community and government to develop and implement management plans for catchment, aquifer, coastal waters and other water bodies. The NWQMS includes guidelines covering water quality benchmarks, groundwater management, diffuse and point sources, sewerage systems, effluent management, and water recycling.

Legislation / policy	Description
State:	
Water Act 1989 (Vic)	The *Water Act 1989* provides the legal framework for water management and use in Victoria, including the issuing and allocation of water entitlements and the provision of water services by state-owned water corporations and catchment management authorities. The Act deals with the sustainable, efficient and equitable management and allocation of groundwater resources.
Environment Protection Act 1970 (Vic)	The *Environment Protection Act 1970* aims to prevent pollution and environmental damage by setting environmental quality objectives and establishing programs to meet them. The Act establishes the powers, duties and functions of the Environment Protection Authority (EPA). These include the administration of the Act and any regulations and orders made pursuant to it, recommending SEPPs, issuing works approvals, licences, permits, pollution abatement notices and implementing National Environment Protection Measures (NEPM).
State Environment Protection Policy (SEPP) (Groundwaters of Victoria)	The SEPP (Groundwaters of Victoria) is made under the *Environment Protection Act 1970* and aims to maintain and, where necessary, improve groundwater quality to a standard that protects existing and potential beneficial uses of groundwater. It sets a consistent approach to, and provides quality objectives for, groundwater protection throughout Victoria. This policy overrides all existing groundwater protection provisions in other SEPPs.
State Environment Protection Policy (SEPP) (Waters of Victoria)	The SEPP (Waters of Victoria) sets the framework for the protection of the uses and values of Victoria's surface water environments. The policy: • sets out the uses and values of water environments that communities want to protect (known as beneficial uses) • establishes objectives and indicators that describe the environmental quality required to protect beneficial uses (known as environmental quality objectives) • provides guidance to authorities, agencies, businesses and communities to protect and rehabilitate environmental water to levels to meet the environmental objectives (known as the attainment program).
Climate Change Act 2017 (Vic)	The *Climate Change Act 2017* establishes a long-term emission reduction target of net zero by 2050. The Act embeds the 2050 net zero emissions target and provides for the setting of five-yearly interim greenhouse gas emissions reduction targets, climate change strategies, and adaptation action plans to ensure the 2050 target is achieved and vulnerabilities to climate change impacts are reduced while potential opportunities are realised. Adaptation action plans will cover systems including the built environment and transport.

17.4 METHODOLOGY

The assessment methodology for groundwater investigations consisted of:

- an existing conditions assessment involving:
  - establishing a study area for investigating potential groundwater issues in the project area and an approximate 2km surrounding area
  - conducting a desktop review of publicly available information on the regional groundwater setting, and the relationship between groundwater and the functioning of wetlands near the project
  - a field investigation to establish site-specific conditions related to local and regional conditions identified in the desktop review. The intrusive investigations were designed to install a targeted monitoring network, gather water level data from key aquifers, collect and analyse groundwater and surface water samples for water quality parameters, measure the flow rates in the aquifers and set up monitoring bores for ongoing groundwater monitoring
- a risk assessment as described in detail in Chapter 4: *EES assessment framework and approach.*
- an impact assessment involving:
  - a preliminary assessment of embankment placement compaction effects, and
  - numerical model development to quantify potential impacts on groundwater
- development of environmental performance requirements (EPRs).

17.4.1 Field investigations

An intrusive field investigation program consisting of a multi-stage drilling program, sampling and aquifer tests was conducted. Initially, 19 groundwater monitoring bores were drilled within the project area. To inform the numerical groundwater modelling, a further 16 groundwater bores were drilled to increase the spatial area covered by the monitoring network (Figure 17.1). Of the 35 groundwater monitoring bores, 28 are in pairs as 'nested' locations. Nested locations are adjacent monitoring bores installed and screened in different aquifers. This allows for both the monitoring of groundwater levels at the same location and to assess the vertical flow gradient between aquifers.

Automated data loggers and groundwater level monitoring equipment were installed in 20 of the 35 bores. Groundwater level loggers record water levels at six-hourly intervals. Groundwater sampling and analysis was also undertaken on three occasions between August 2017 and March 2018, to capture seasonal variations in the aquifers and surrounding wetlands. Samples were taken from groundwater monitoring bores and from surface waterbodies, including Waterways Wetlands, Mordialloc Creek, Edithvale Wetlands (North and South) and Port Philip Bay at Edithvale. The purpose of the sampling was to obtain baseline water quality data and to compare chemical signatures of the water sampled to inform an understanding of connectivity across the surface water and groundwater bodies. Groundwater levels were also taken manually during each sampling event.

Aquifer permeability was tested in 34 of the groundwater monitoring bores to estimate the groundwater flow rates in the relevant aquifers. The flow rates are used as an input to the numerical groundwater model.

The groundwater monitoring network is intended to remain in place for ongoing monitoring through the construction phase and for five years after the completion of construction.

Figure 17.1 Groundwater monitoring locations

17.4.2 Groundwater impact assessment methodology

Based on the outcomes of the risk assessment, the groundwater impact assessment involved:

- a preliminary assessment of embankment placement compaction effects
- numerical model development to quantify potential impacts on groundwater.

Embankment consolidation study

Due to the low-lying nature of the project area, the road level would mostly be raised on embankments. Embankment structures can create soil compaction and reduce permeability beneath the structures, constricting groundwater flow to down-gradient areas with the potential to impact on the ecological health of surrounding wetlands, including the Edithvale Wetlands.

The effect of reduced soil porosity on the permeability of subsoil layers was investigated based on laboratory test results. The assessment methodology is presented in Appendix C of Appendix K: *Groundwater impact assessment*.

Numerical model

To quantify the potential impacts identified during the preliminary desktop investigations and the risk assessment, a regional numerical model was developed using the groundwater flow simulation software MODFLOW-USG. The model area was designed to extend far enough to capture cumulative impacts from the Edithvale and Bonbeach level crossing removal projects, situated about 2.5km from the Mordialloc Bypass (Freeway) project. Figure 17.2 shows the model domain.

The regional numerical model was built for the project using data obtained through desktop investigations and field activities, including:

- topographical data
- aquifer data from the Victorian Aquifer Framework database
- climate data from the Bureau of Meteorology
- surface water drainage features
- groundwater entitlement data for nearby bores
- aquifer layer depth information obtained during the intrusive investigation program
- observed groundwater level and flow data from the sampling and analysis program.

The model was used to assess potential changes in groundwater flow associated with the proposed embankments, which could impact the adjacent wetlands, beneficial users such as registered bores and GDEs. The numerical model was run for a range of scenarios without the embankments, including steady state and transient conditions, to assess average and seasonal impacts on flows within the affected aquifers. To predict impacts of the embankment, the model was then run incorporating the reduced porosity resulting from differing embankment heights.

STEADY STATE VERSUS TRANSIENT CONDITIONS

Steady-state: A system is said to be in a steady state when the flow processes are (at least to a good approximation) constant with time. The inflows to and the outflows from the system are equal and, therefore, there is no change in storage within the aquifer. This also means that the water table elevation (mBGL) do not change with time.

Transient state: When the inflow term and outflow term differ, the total amount of water in the system under consideration changes. In this scenario, the heads and water table elevation change with time, and the system is in an unsteady, or transient, state.

Model calibration

Model calibration involves adjusting model parameter values within realistic bounds until the model outputs fit historical measurements, such that the model can be accepted as a reasonable representation of the actual system. The groundwater model was calibrated by running the model in steady state for the baseline period of 1995–2015 and varying key climate, hydrological and aquifer parameters to obtain a close match with observed groundwater levels from the groundwater monitoring bores. It was then run in transient state using current conditions for the groundwater monitoring period and a few years prior (January 2015 to February 2018). The parameters were further adjusted to improve the transient fit between the modelled and observed groundwater conditions from 166 observations from 43 sites for the period August 2017 to February 2018.

The calibration results showed a good correlation between simulated and observed groundwater levels.

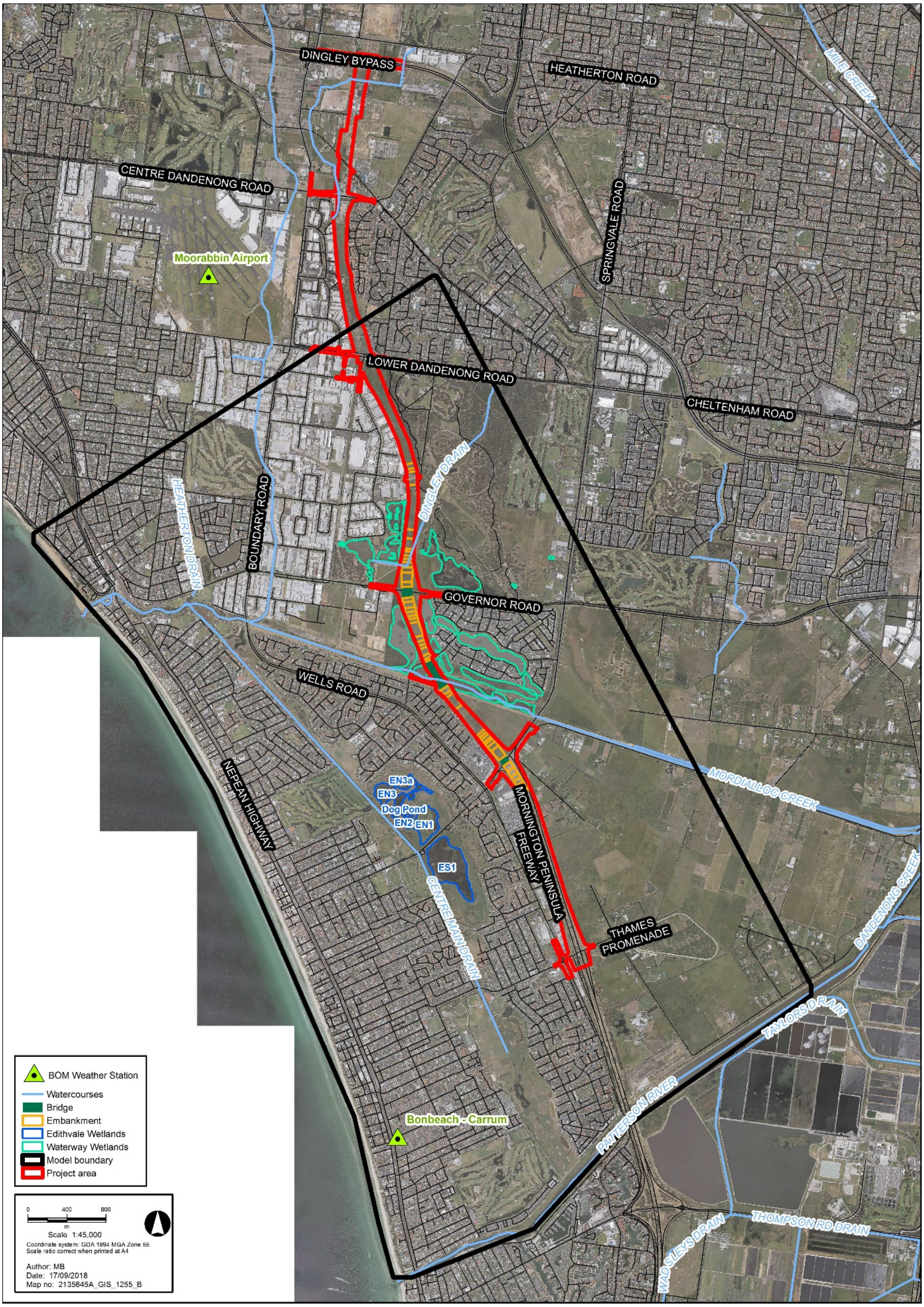

Figure 17.2 Model domain

Independent peer review

The groundwater modelling and assessment report was independently reviewed by a suitably qualified person as defined by the *Australian Groundwater Modelling Guidelines* (Barnett et al. 2012).

Water balance model

A water balance model was developed to include changes to surface runoff as a result of the project. This was used to model impacts on water levels within the wetlands due to changes in surface water and groundwater contributions.

Appendix D of Appendix K: *Groundwater impact assessment* contains a detailed description of the model development, calibration and predictions. It also contains the peer review response and Water Balance Modelling report.

17.5 STUDY AREA

The study area for the groundwater impact assessment includes the project area and an approximate 2km surrounding area extending to Port Philip Bay to the west, Patterson River to the south, Dingley Bypass in the north and 2km east of the project alignment. It incorporates the Edithvale Wetlands, Mordialloc Creek, Braeside Park wetlands, Woodlands Industrial Estate wetlands, Waterways Estate wetlands, Port Philip Bay and Patterson River. It also includes landfill sites at the alignment's northern end adjacent to the Dingley Bypass. The study area is depicted in Figure 17.3.

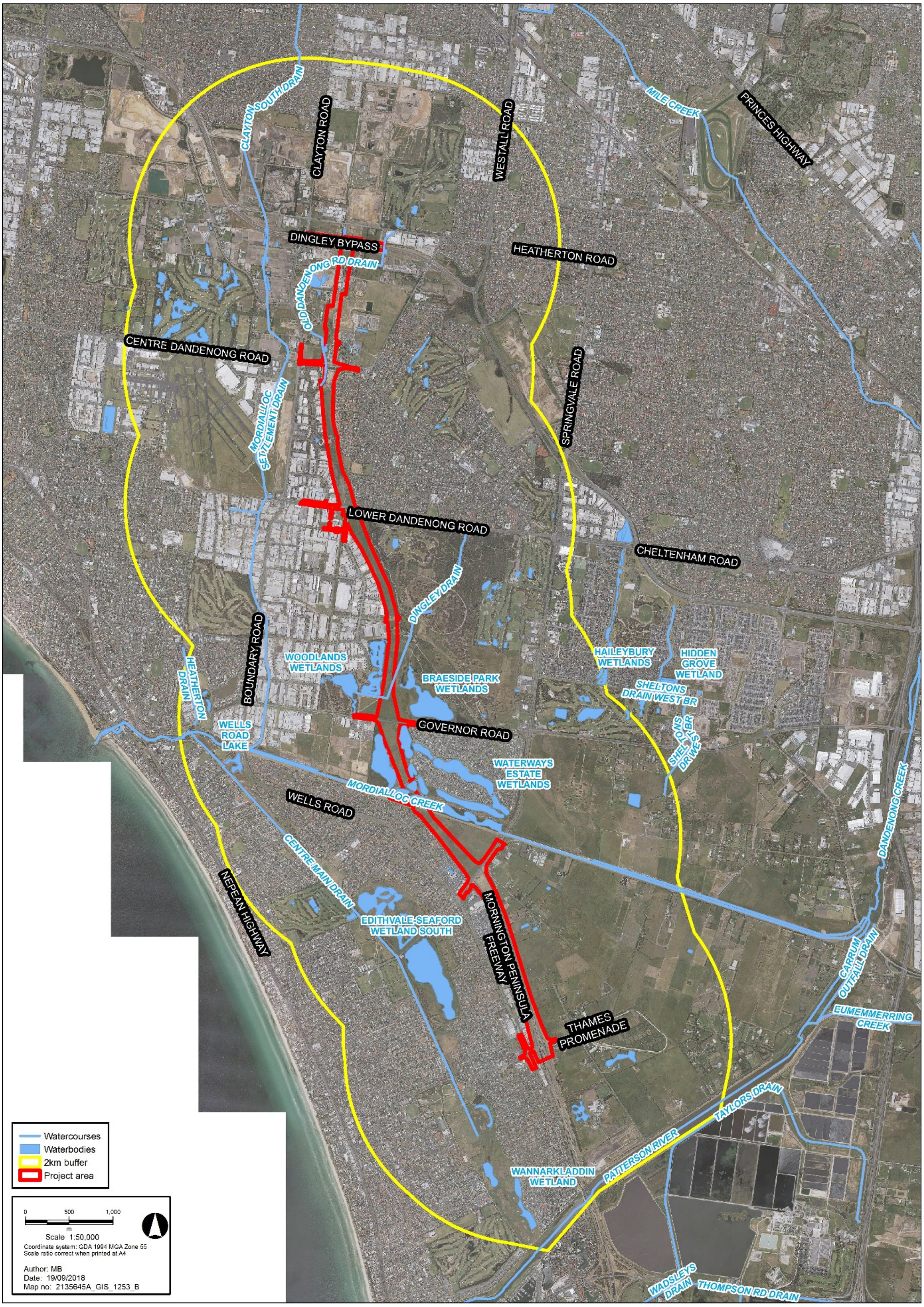

Figure 17.3 Groundwater study area

17.6 EXISTING CONDITIONS

17.6.1 Wetlands

Surface water overview

Prior to European settlement the Carrum Carrum Swamp was a freshwater wetland that drained to Port Phillip Bay via Kananook Creek. The swamp/wetlands have been significantly altered since European settlement. Swamp drains were excavated as of the late 1870s to drain the swamp to prevent flooding of Eumemmering Creek and to facilitate agriculture. The modified Edithvale-Seaford Wetlands are the last remnants of the Carrum Carrum Swamp.

These wetlands provide essential functions for receiving, retaining and diverting surface run-off and stormwater to protect surrounding and downstream properties from flooding and protect the water quality of Port Phillip Bay. The wetlands are also declared Wetlands of International Importance under the Ramsar Convention, protecting the ecological character of the wetlands.

Edithvale Wetlands

The Edithvale Wetlands lie to the southwest of the project area (Figure 17.4) and comprise two parts, north and south of Edithvale Road. These are referred to as Edithvale North Wetlands and Edithvale South Wetlands.

- *Edithvale South Wetlands* – the Edithvale South Wetlands is a single natural depression on the south side of Edithvale Road, which is predominantly fed by three drains from catchments to the east (cell ES1 in Figure 17.5). There is limited recharge from groundwater sources.
- *Edithvale North Wetlands* – the northern section of the wetlands comprises a series of constructed wetlands within the former floodplain on the north side of Edithvale Road (cells EN1, EN2, EN3, EN3a and Dog Pond in Figure 17.5). Groundwater recharge contributes to water inflows to cells EN2, EN3 and EN3a due to their hydraulic connection with the Brighton Sands aquifers.
- *Centre Main Drain* – the Centre Main Drain forms a discharge point for the Edithvale North and South Wetlands during wet periods.

Other wetlands

The project area is straddled by Waterways Estate Wetlands, Woodland Estate Wetlands and Braeside Park Wetlands. Like other wetlands within the former Carrum Carrum Swamp these were previously drained and cleared and have since been reinstated.

The wetlands at Woodland Estate and Braeside Park receive water from Melbourne Water drain reserve and the Dingley Drain. The Waterways Estate Wetlands are part of Melbourne Water's filtration system for Mordialloc Creek. These wetlands provide storage and flood protection for the City of Kingston.

Figure 17.4 Location of surface water features

Figure 17.5 Edithvale Wetlands – Location of wetland cells and indication of water sources

17.6.2 Aquifers

The key aquifers present along the project alignment relate to the geological characteristics and are identified as:

- Quaternary Aquifer – swamp sediments comprising of sand, gravel, clay and silt occurring at 0–3 metres below ground level (mBGL)
- Upper Tertiary Aquifer – sand, gravels and clays occurring at 3–16mBGL
- Upper-Middle Tertiary Aquitard – clay, silt, fractured rock and sand at 16–47mBGL.

The Quaternary Aquifer is largely associated with the remnants of the Carrum Carrum Swamp system and is found in the southern portion of the study area, approximately south of Governor Road. This is illustrated in Figure 17.6. It consists of an unconfined aquifer forming the water table aquifer.

The Upper Tertiary Aquifer is present under sections of the study area comprising of the Redbluff Sandstone which is the upper unit of the Brighton Group Sediments. This is illustrated in Figure 17.7. To the north of Governor Road, it outcrops to form an unconfined 25m thick aquifer. To the south, it is overlain by Quaternary Aquifer sediments to form a semi-confined aquifer between 6m and 20m deep. At some locations the Quaternary Aquifer and the Upper Tertiary Aquifer hydraulically connect, with groundwater transferring between each unit.

The Upper-Middle Tertiary aquitard underlies the Upper Tertiary Aquifer across the study area and is comprised of the Fyansford Formation which is also the lower unit of the Brighton Group.

AQUIFERS AND AQUITARDS

Aquifer: sediment or rock formation that is saturated with water and sufficiently permeable to allow the flow of usable quantities of water to wells or springs.

Aquitard: water-saturated geological unit that has low permeability and does not allow the flow of usable quantities of water. If completely impermeable, an aquitard is called an aquiclude.

Unconfined aquifer: those into which water seeps from the ground surface directly above the aquifer.

Confined aquifer: are permeable rock units that are usually deeper under the ground than unconfined aquifers. They are overlain by relatively impermeable rock or clay that limits groundwater movement into, or out of, the confined aquifer.

17.6.3 Groundwater levels

Groundwater monitoring indicates that groundwater levels across the study area are relatively close to the surface, with recorded water levels ranging from:

- 1.1 to 3.7mBGL within the Quaternary Aquifer
- 0.8 to 4.5mBGL within the Upper Tertiary Aquifer.

The assessment found that water levels in both aquifers reflected seasonal trends with groundwater levels typically higher (closer to the surface) during the wetter winter months and lower during summer months. Groundwater level contours in the Quaternary and Upper Tertiary aquifers are presented in Figure 17.6 and Figure 17.7, respectively.

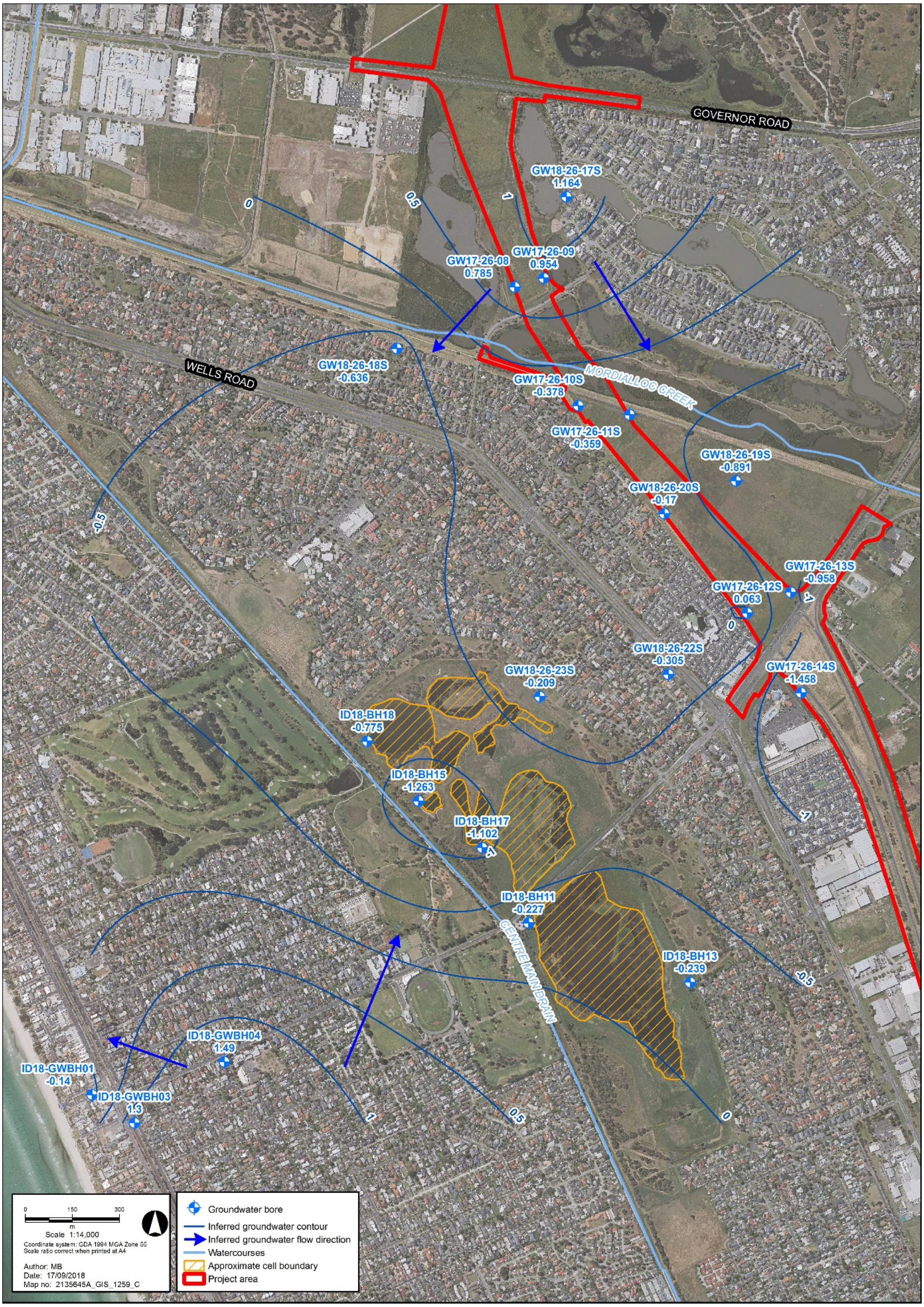

Figure 17.6 Groundwater level contours of Quaternary Aquifer

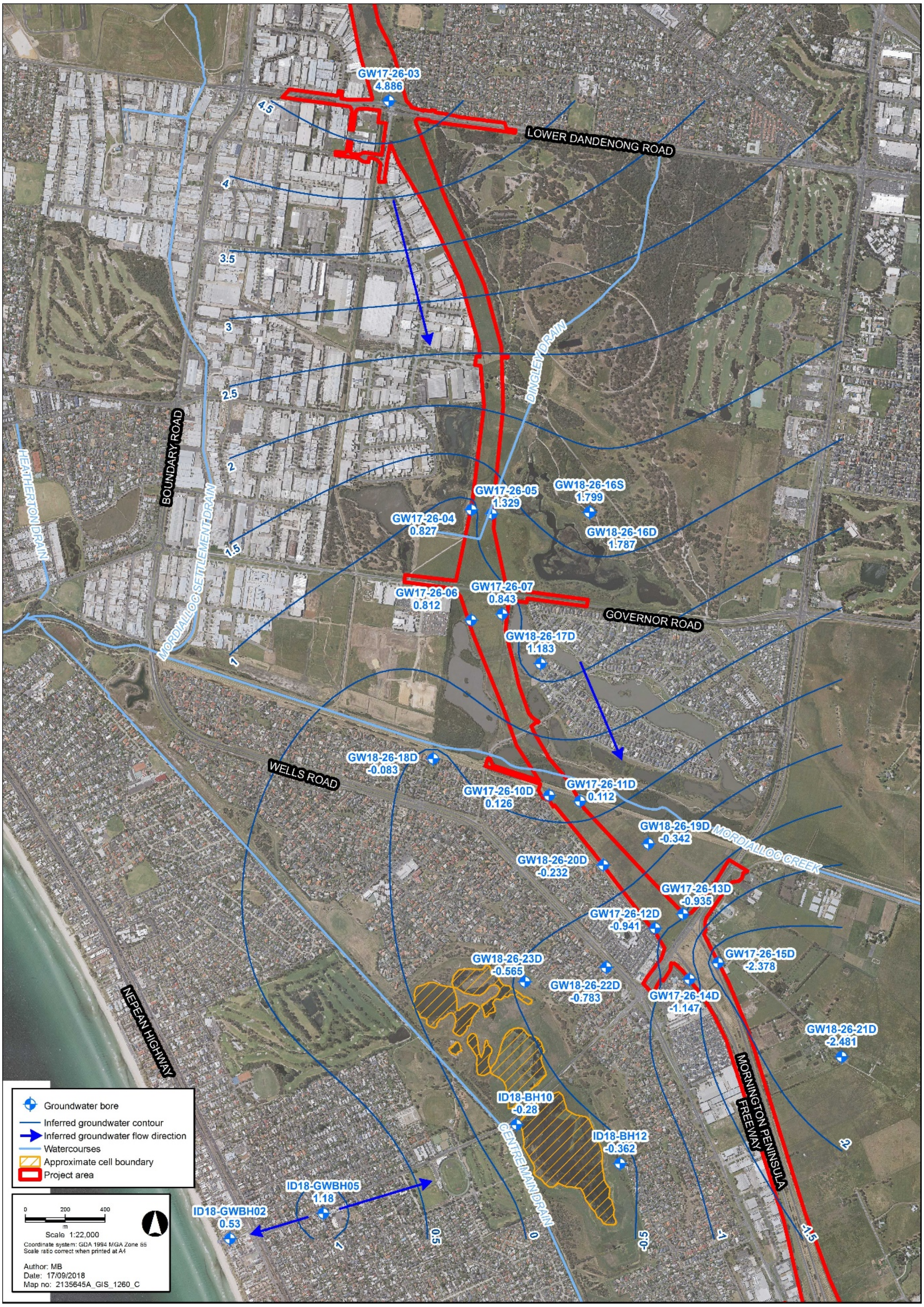

Figure 17.7 Groundwater level contours of the Upper Tertiary Aquifer

17.6.4 Groundwater flow

Groundwater flow direction

Monitoring indicates that groundwater flow directions in both aquifers are complex and influenced by topography, land use, connections to water bodies, groundwater use, proximity of Port Phillip Bay and the influence of the built environment and urban runoff management.

Monitoring results suggest that:

- groundwater within the Quaternary Aquifer moves south to south-west
- groundwater flow within the semi-confined Upper Tertiary Aquifer is in a south south-easterly direction towards discharge features such as Port Philip Bay, Patterson River and Edithvale Wetlands
- pumping from surface water bodies to maintain wetland cells during drier months can influence groundwater levels in the Quaternary Aquifer
- locally, the presence of a registered extraction bore towards the southern portion of the project area impacts groundwater levels and flow direction within the Upper Tertiary Aquifer with groundwater flow near Springvale Road directed south towards the extraction bore.

Groundwater flow rate

Groundwater flow rate is measured by its hydraulic conductivity, which is the rate of flow through porous soil or rock. Hydraulic testing was carried out at 34 groundwater monitoring bores. Flow rates measured in each aquifer were similar:

- Quaternary Aquifer – 0.05–0.80 metres per day (0.2 metres per day average)
- Upper Tertiary Aquifer – 0.13–0.70 metres per day (0.3 metres per day average).

17.6.5 Aquifer recharge and discharge

Regionally, water to the aquifers is recharged primarily from rainfall infiltration as observed in water level measurements. Recharge also occurs via leakage from surface water features in areas where the water table is below the stream and wetland levels. Locally, lower aquifers are recharged by vertical leakage from the upper aquifers in areas where they outcrop. However, groundwater flow direction between upper and lower aquifers depends on local pressure gradients and permeability.

Groundwater can discharge directly from shallow aquifers via seepage into creeks and surface drains. In lower aquifers, groundwater discharges into wetlands and surface streams, providing baseflow to streams, or to Port Phillip Bay and Westernport Bay. Where the water table is shallow and within the depth of plant roots, evapotranspiration can form a significant part of surface discharge. Water extraction by groundwater users is also considered a component of groundwater discharge.

17.6.6 Groundwater quality

The SEPP (Groundwaters of Victoria) evaluates the beneficial use of groundwater according to concentrations of specified Total Dissolved Solids (TDS). Segments A1 and A2 represent water with low TDS values (0–500 mg/L and 501–1000 mg/L). Segments with low TDS values have more beneficial uses, while those with higher TDS values (such as Segment D with 13000+ mg/L) have fewer beneficial uses.

Groundwater quality varies across the project alignment, and is influenced by surface water resources (including salinity), and water-rock interactions. The groundwater quality in the Quaternary Aquifer is fresh (Segment A2) near the Dingley Drain and ranges from brackish (Segment B) to saline (Segment D) elsewhere. The Upper Tertiary Aquifer shows similar groundwater quality, ranging from fresh (Segment A2) near the Dingley Drain, and brackish (Segment B) to saline (Segment D) elsewhere. Adopting a conservative approach, the aquifers would be classified as Segment A2.

Table 17.3 shows the potential beneficial uses of groundwater for the different segment classifications as defined in the SEPP (Groundwaters of Victoria). As shown, the beneficial uses protected for Segment A2 include potable water supply (acceptable) through to use on buildings and structures. It is noted, however, that the TDS values from the samples near Dingley Drain appear to be influenced by the adjacent surface water bodies, have considerably lower TDS levels than other groundwater samples from the aquifers and are not considered representative of regional aquifer conditions.

Table 17.3 Protected beneficial uses of the segments (Government of Victoria, 1997)

Beneficial uses	Segments (mg/L TDS)				
	A1 (0–500)	A2 (501–1,000)	B (1,001–3,500)	C (3,501–13,000)	D (>13,000)
Maintenance of ecosystems	✓	✓	✓	✓	✓
Potable water supply (desirable)	✓				
Potable water supply (acceptable)		✓			
Potable mineral water supply	✓	✓	✓		
Agriculture, parks and gardens	✓	✓	✓		
Stock watering	✓	✓	✓	✓	
Industrial water use	✓	✓	✓	✓	✓
Primary contact recreation	✓	✓	✓	✓	
Buildings and structures	✓	✓	✓	✓	✓

Analysis of the groundwater in the Upper Tertiary Aquifer indicates that groundwater quality and water quality in the Edithvale portion of the Edithvale-Seaford Wetlands is dominated by sodium and chloride ions, suggesting the wetland is connected to seawater flows into the system via the Upper Tertiary Aquifer. By contrast, the surface waters in the Waterways Wetland, Woodlands Industrial Estate Wetland and Braeside Park Wetland have a geochemical signature similar to that of rainfall, suggesting surface runoff as a major source of groundwater refill.

17.6.7 Sensitive receptors

Recharge sources to the Edithvale Wetlands

The water quality assessment concluded that there is a clear connection between the Upper Tertiary Aquifer and several wetland cells within the Edithvale Wetlands. Water quality in the wetland is reduced by groundwater from the Upper Tertiary Aquifer discharging to the wetland cells to replace water lost to evaporation. Surface water runoff from three stormwater drains also provides significant contributions to the wetland.

Groundwater dependent ecosystems (GDEs)

GDEs are communities of plants, animals and other organisms that depend on groundwater for survival.

The study area contains the following nine ecosystems that rely on the subsurface presence of groundwater:

- Coast Banksia Woodland
- Coastal Dune Scrub
- Creekline Grassy Woodland
- Damp Sand Herb-rich Woodland
- Grassy Woodland
- Heathy Woodland
- Plains Grassy Wetland
- Plains Grassy Woodland
- Swap Scrub (mosaic) (GDE Atlas, BOM, 2017b).

The GDE Atlas identifies five GDEs that rely on surface expression of groundwater:

- Clayton South Drain
- Seaford-Edithvale Wetlands (Ramsar Convention)
- Mordialloc Creek
- Mordialloc Settlement Drain
- Wannarkladdin Wetlands.

Figure 17.8 shows the GDEs relevant to the project.

Groundwater users

There are 402 registered groundwater bores within a 2km buffer of the project area, including a range of groundwater users.

Of these, 111 bores use groundwater for the following beneficial uses:

- stock and domestic (81)
- irrigation (30).

Twenty-one of these are located within 500m of the project site. Of the remaining bores, most are used for groundwater monitoring. The location of registered groundwater users is shown in Figure 17.9.

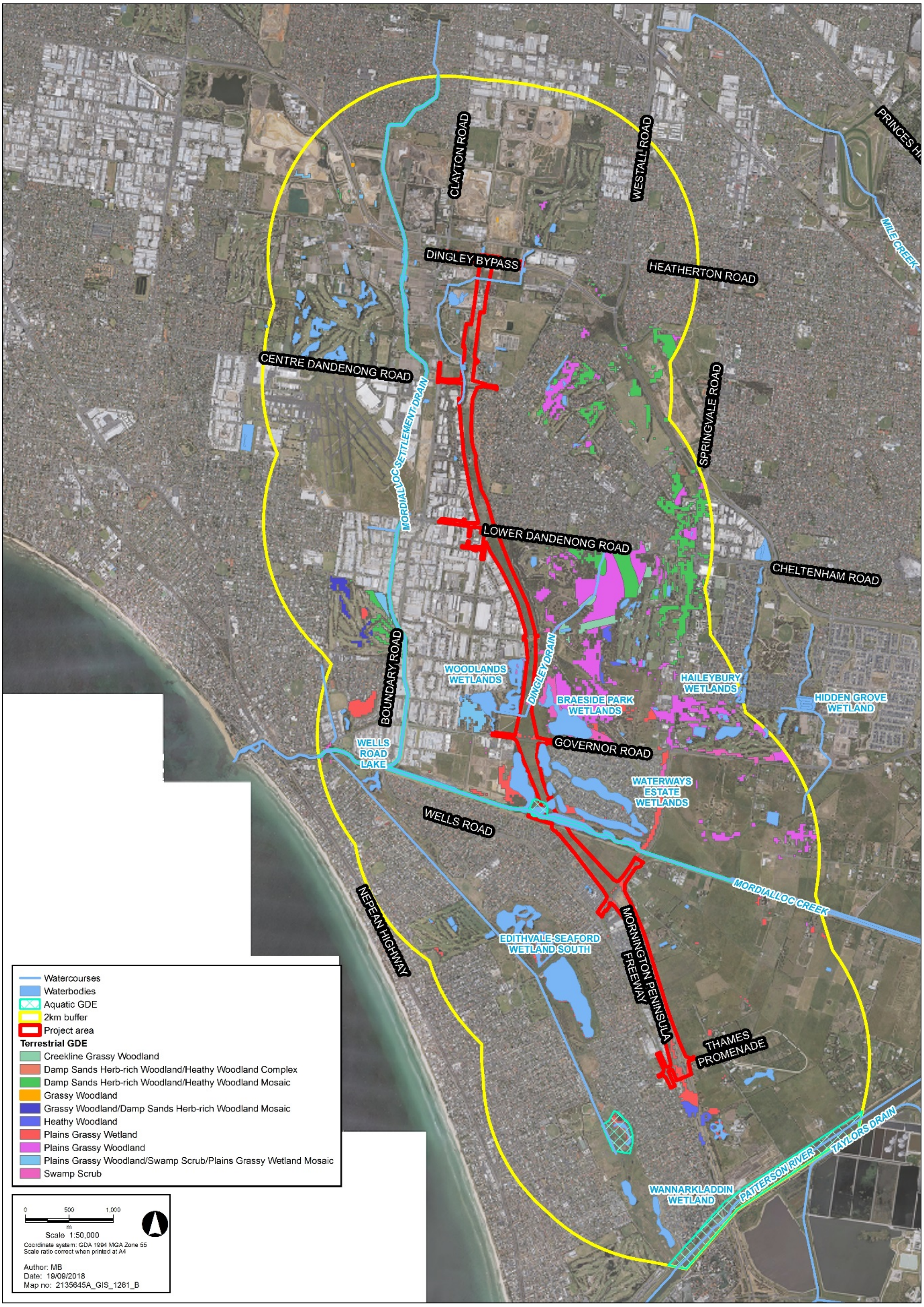

Figure 17.8 Groundwater dependent ecosystems (GDEs) within 2km of the project

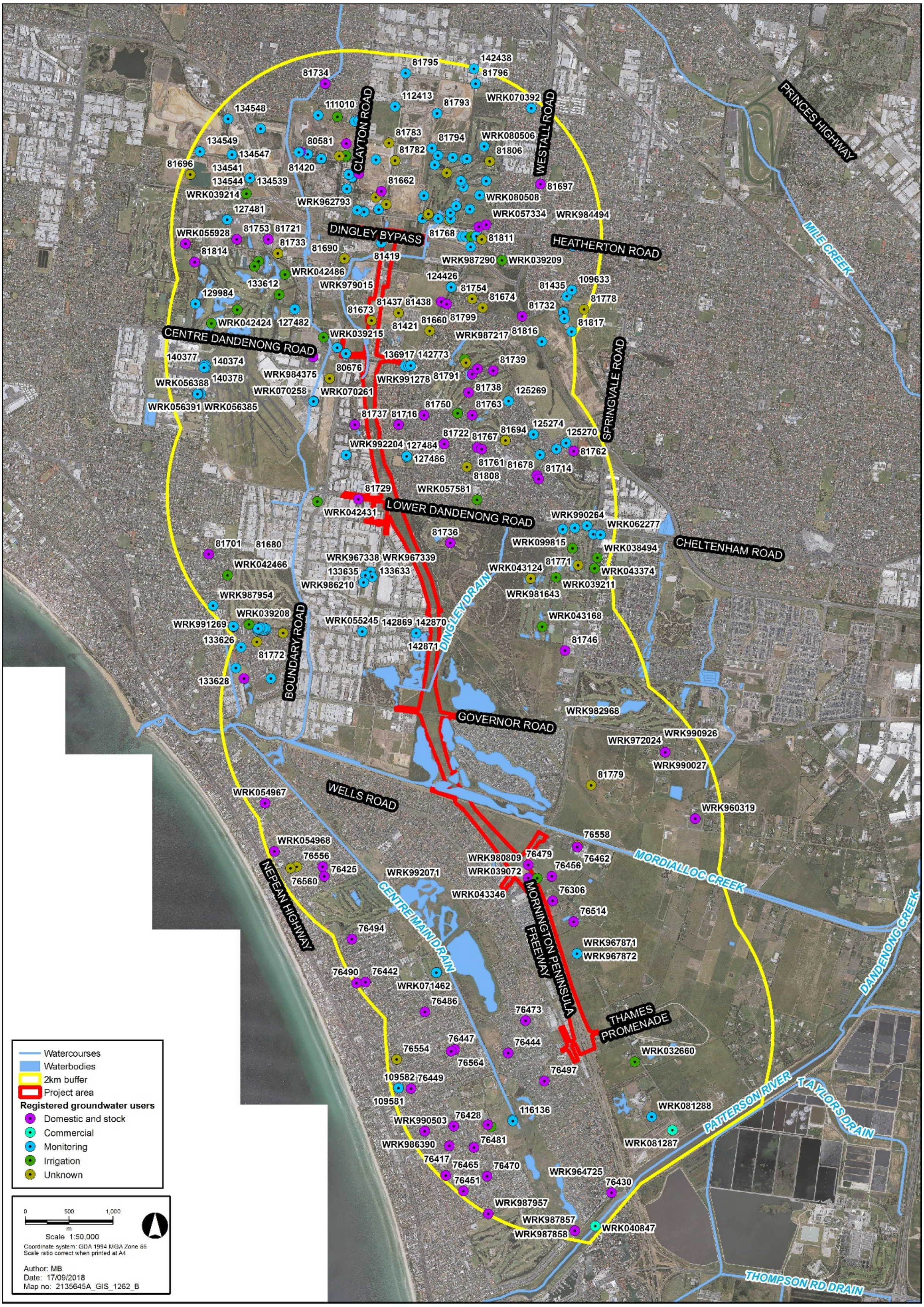

Figure 17.9 Registered groundwater users within 2km of Mordialloc Bypass (Freeway)

17.7 MODEL RESULTS

17.7.1 Conceptual groundwater model

Information gathered from the study was used to develop a conceptual hydrogeological model of the study area. Table 17.4 summarises the main points leading to the model's development. Figure 17.10 provides a north-south and an east-west cross section of the conceptual model of relevant regional groundwater flows.

Table 17.4 Summary of existing conditions

Existing conditions relevant to conceptual groundwater model	
Topography and drainage	• The study area is largely flat with elevations dipping from north to south with elevations close to or below sea level adjacent the Edithvale Wetlands and Centre Main Drain. • The study area's southern portion is within the former Carrum Carrum Swamp that was drained and cleared for agricultural settlement in the late 1800s. • Wetland cells in Edithvale Wetlands were deepened in 1987–88 leading to a direct connection between the wetland and the Upper Tertiary Aquifer. Thus, the wetland became a local groundwater sink with a decrease in water quality as the Upper Tertiary Aquifer discharges into the groundwater cells to replace losses through evaporation.
Water quality	• Salinity of groundwater in both aquifers is highly variable ranging from marginally saline to saline with salinity highest in the Upper Tertiary Aquifer near Port Phillip Bay. Water chemistry results for wetland cells (EN2 and Dog Pond) are associated with intrusion of sea water from Port Phillip Bay, which supports the understanding that the Edithvale Wetlands is connected to the Upper Tertiary Aquifer and acts as an evaporative groundwater sink.
Groundwater dependence	• The potential for groundwater/surface water interaction within the study area is likely due to the low-lying topography and geomorphology within the former Carrum Carrum Swamp. • Water quality sampling indicates that several wetland cells within Edithvale Wetlands (EN2, EN3, EN3a and Dog Pond) are hydraulically connected with the Upper Tertiary Aquifer. • Edithvale Wetlands also receives stormwater contributions, which can alter the volume of groundwater flowing to the wetland. Edithvale South Wetlands and Edithvale North Wetland cell EN1 appear to be entirely dependent on surface water.

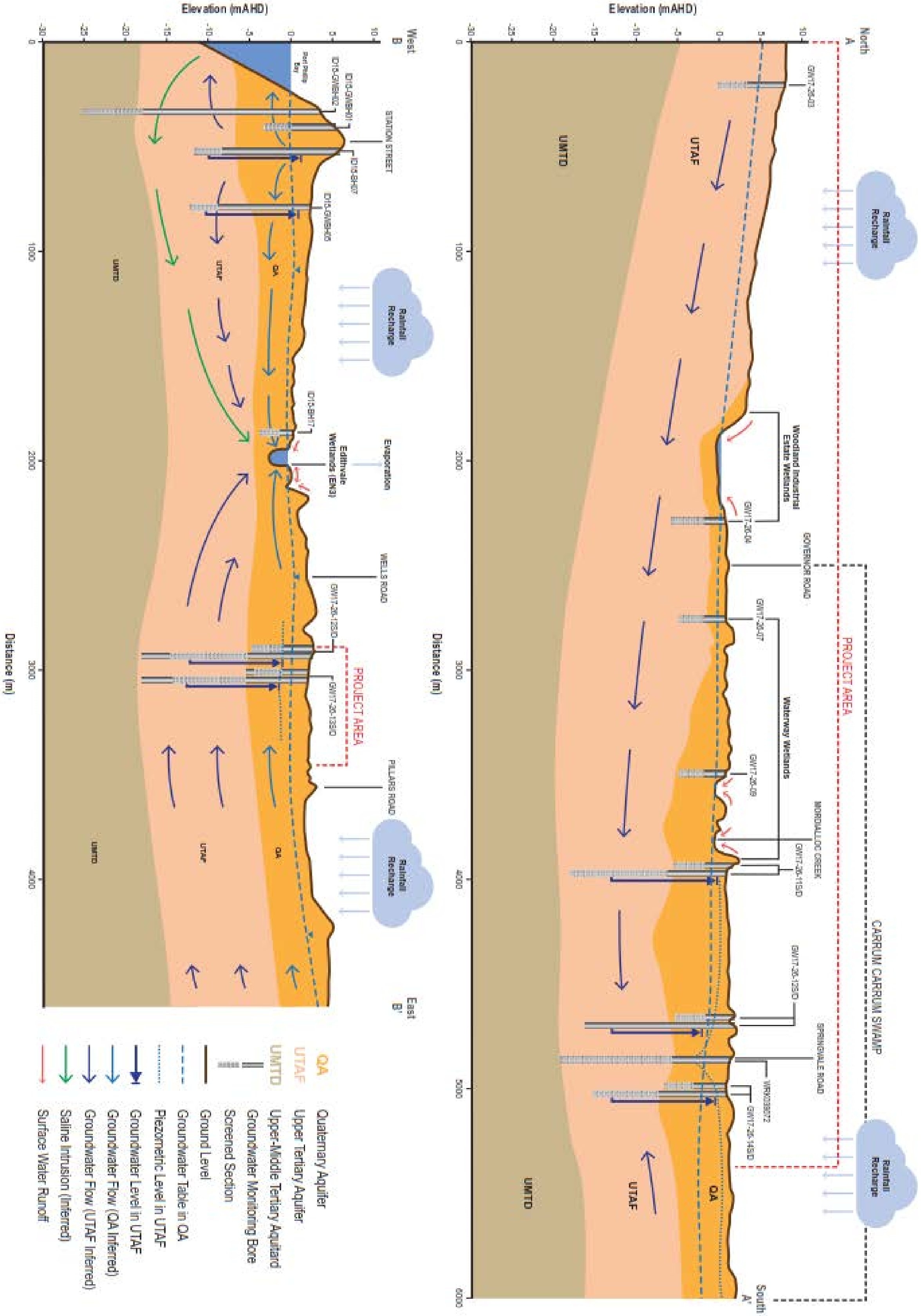

Figure 17.10 Conceptual model of regional groundwater flow setting between the project alignment and Edithvale Wetlands (note high vertical exaggeration)

17.7.2 Predicted water level changes

Road embankments could compress shallow unconsolidated alluvial material and reduce soil permeability, with the potential to alter the existing groundwater flow regime. These changes can lead to groundwater mounding up-gradient and reduced groundwater levels down-gradient of the embankments, with the potential for reduced availability for down-gradient users. As the groundwater flow is generally towards the coast, the impacts could result in mounding on the eastern side of the embankments and drawdown on the western side.

The numerical modelling described in Section 17.4.2 was used to quantify the potential impacts of road embankments on groundwater. Predictive modelling was carried out to assess both average and seasonal impacts.

The proposed embankments would vary in height across the project (Figure 17.11). The various embankment heights were used as an input to the model. The predicted groundwater table changes due to the embankments are described below.

Average impacts (steady-state conditions)

Under steady-state conditions, which assume constant recharge and discharge rates, the modelling predicted a maximum drawdown of 6cm at the Springvale Road embankment and a maximum water level rise of 11cm at the Governor Road embankment. The predicted changes only occur beneath the embankment itself with negligible changes predicted beyond the embankment footprint ranging from less than 5cm drawdown immediately adjacent to the embankment down to 1cm of drawdown approximately 500m west of the embankment towards the Edithvale Wetlands (Figure 17.12).

Seasonal impacts (transient conditions)

Factoring in differences in seasonal recharge rates, the results showed:

- At June 2020 (winter), which was used in the model as the year immediately following the embankments being put in place, the predicted maximum drawdown was 3.6cm at the southern embankment and the predicted maximum water level rise was 5.1cm at the northern embankment. Changes were only predicted to occur beneath the embankment itself (Figure 17.13).
- At December 2020 (summer), the maximum drawdown is 11cm at the southern embankment and maximum water level rise is 13cm at the northernmost embankment. Changes were predicted to be mostly beneath the embankment itself with changes of less than 5cm immediately adjacent to the embankment (Figure 17.14).

To understand the uncertainty inherent in the predictions, the model was run with changes made to the parameters, including the horizontal and vertical flow rates and aquifer recharge rates.

The results showed that predicted groundwater impacts are negligible under all modelled scenarios, providing additional confidence in the predictions.

17.7.3 Predicted changes groundwater inflows at Edithvale Wetlands

The groundwater model was used to predict changes in the groundwater component of the Edithvale Wetlands. The difference in groundwater discharge to the wetlands resulting from changes in groundwater flow near the embankments was predicted to be negligible (i.e. predicted changes to the flow rate of less than 10^{-3} millimetres per day) compared with natural variation from rainfall and evaporation.

A separate water balance model was created and the modelled groundwater component was used as verification. The water balance modelling results indicated water levels within the wetlands showed little sensitivity to reductions of groundwater baseflow into the wetland cells.

Cumulative surface water and groundwater effects on Edithvale Wetlands are discussed in Chapter 21: *Cumulative impacts.*

17.7.4 Summary of model predictions

The following conclusions were drawn from the modelling outputs:

- The modelled water table implies Edithvale Wetlands are a net groundwater discharge point, which is consistent with the chemistry of water quality samples.
- The bypass embankment effects on aquifer permeability are predicted to result in a very small change in groundwater level (10–15cm maximum).
- Most of the change is restricted to the embankment footprint with negligible groundwater level changes outside of the embankments.
- Construction of the embankment are not instantaneous therefore loading occurs progressively which is likely to allow for some equilibration of groundwater levels.
- The project is unlikely to have any measurable effect on groundwater levels adjacent to the Edithvale Wetlands or to groundwater flow contributions to the wetlands.
- The ecological character is not expected to be impacted as a result of the groundwater level or quality impacts from the project, as the water balance modelling indicated little sensitivity to groundwater change. This is further discussed in Chapter 10: *Biodiversity* and Chapter 22: *Matters of national environmental significance*.

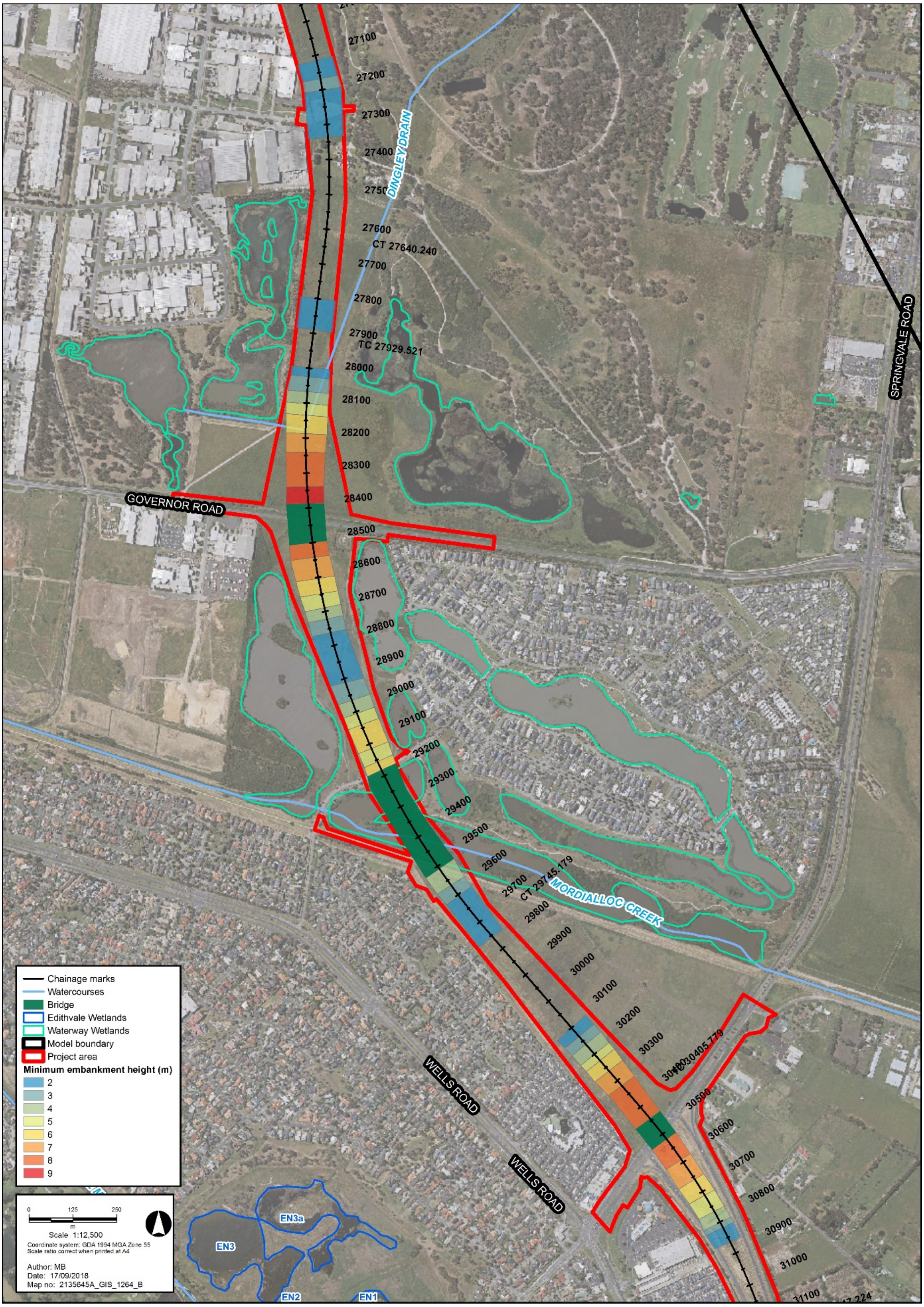

Figure 17.11 Embankment height

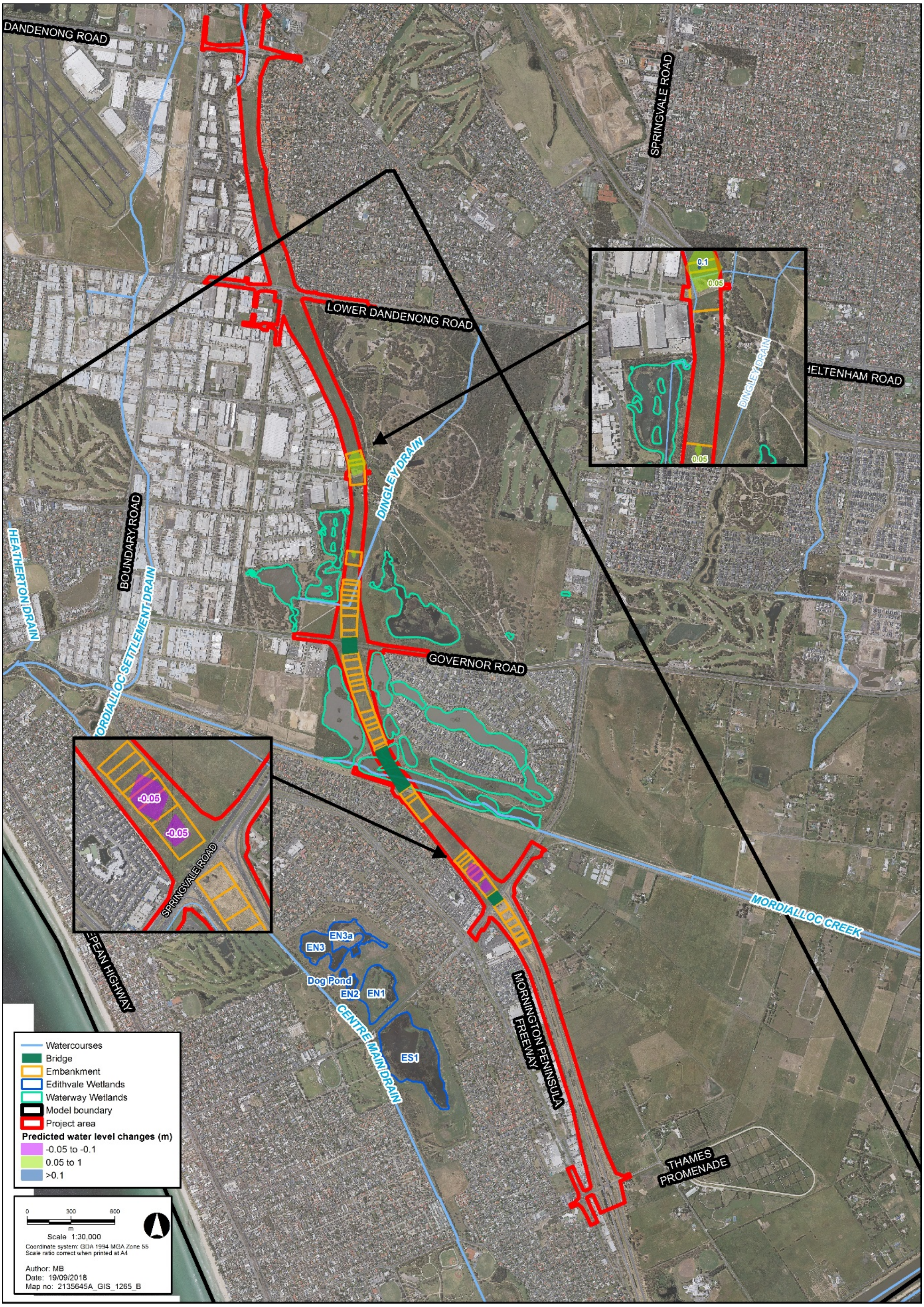

Figure 17.12 Predicted groundwater level changes (steady state)

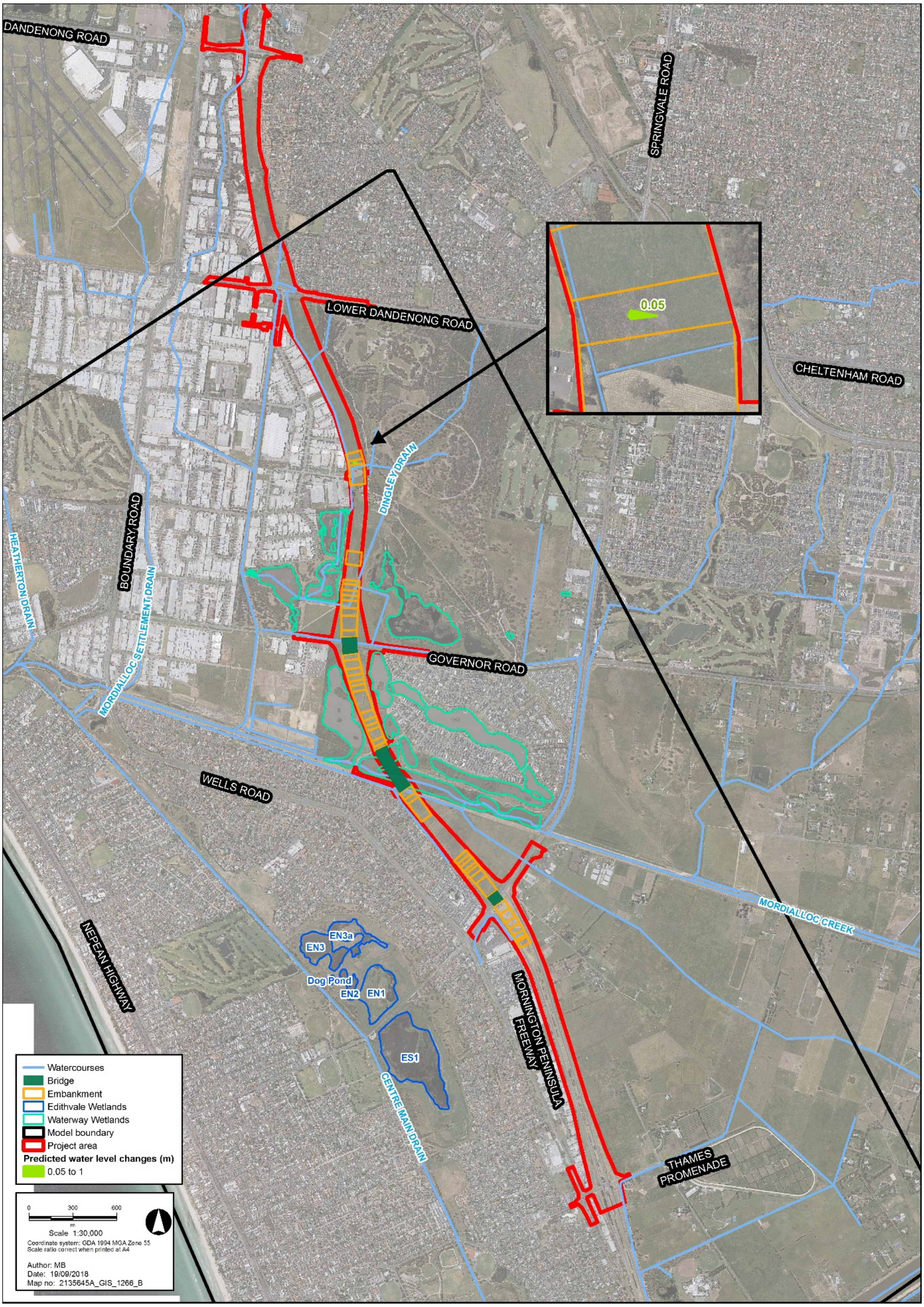

Figure 17.13 Predicted groundwater level changes (June 2020)

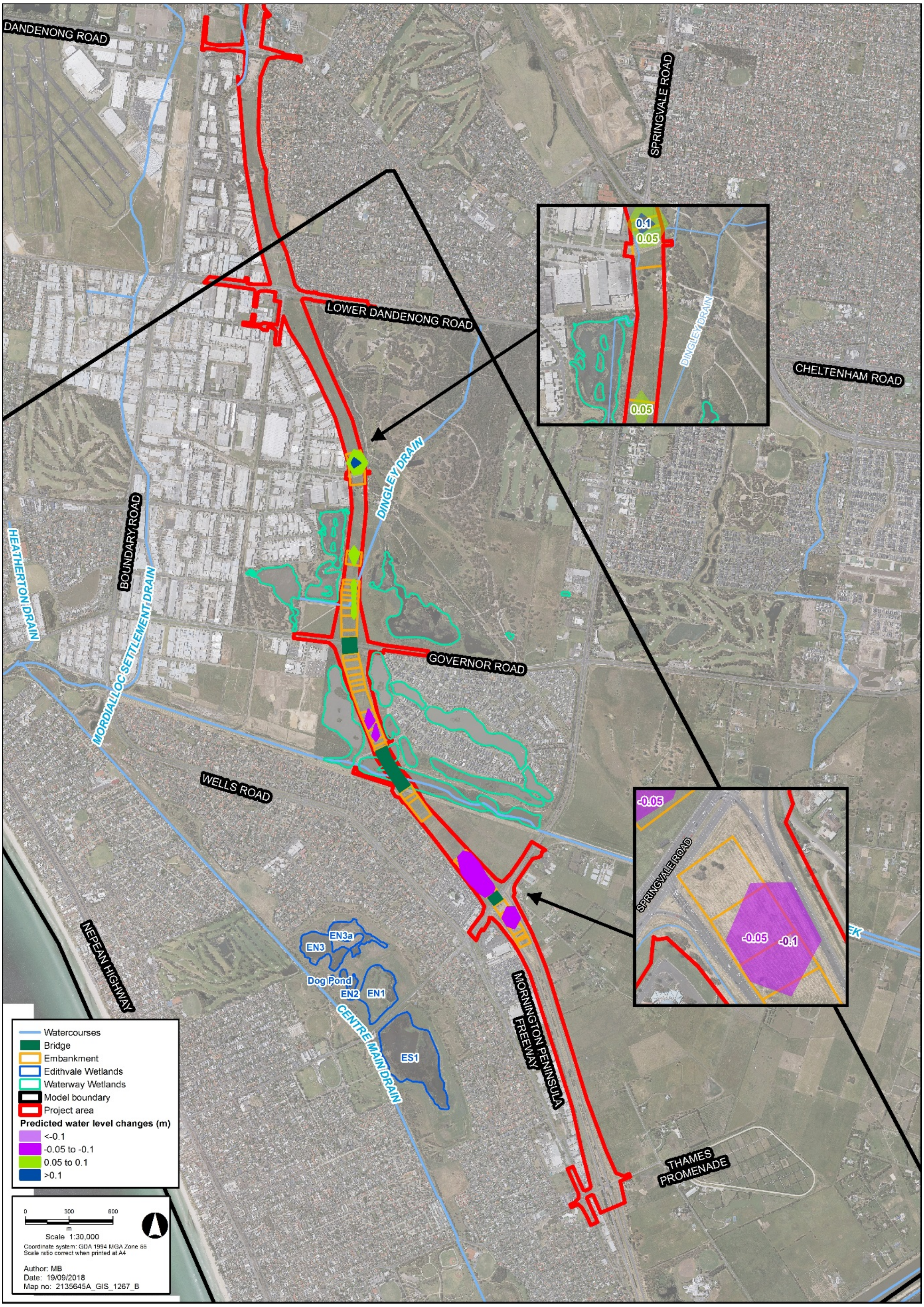

Figure 17.14 Predicted groundwater level changes (December 2020)

17.8 RISK ASSESSMENT

An environmental risk assessment (ERA) was undertaken to identify environmental risks associated with the construction and operation of the project. Where initial risks were rated as 'medium' or higher (with standard controls in place) these issues were further assessed and investigated in the Groundwater Impact Assessment Report (Appendix K). Where necessary, additional controls were identified as part of the Impact Assessment to reduce the identified risks to acceptable levels. These controls have been incorporated into the environmental performance requirements (EPRs) for the project. The initial risks were then re-assessed following application of the EPRs to derive the residual risk ratings. The methodology for the risk assessment has been described in Chapter 4: *EES assessment framework and approach*.

As previously mentioned, impacts to groundwater resources can be simplified into two categories: impacts to *groundwater quality* and impacts to groundwater levels (*groundwater quantity*). The risk assessment process used a source – pathway – receptor approach. Changes to groundwater resources can potentially impact both local and regional receptors.

Table 17.5 provides a summary of the key groundwater-related risk identified. During early project risk evaluations (prior to undertaking groundwater modelling) the only groundwater related risk that was seen to be potentially significant related to the potential effect of the road embankments on groundwater flows in the surficial aquifers with the receptors being beneficial users of groundwater, such as the Edithvale Wetlands. Whilst the development of the groundwater model was in consideration of the embankments, the model addresses several other identified risks such as impact to risk registered bores, wetlands and groundwater quality through interaction with acid sulphate soils,

The embankments are not expected to impact on the underlying aquifer systems. As discussed in detail in the *Impact Assessment* (Section 17.9), predictive modelling indicates with a high degree of certainty that potential impacts relating to this risk are low. The predictive modelling was incorporated in the formal risk assessment process, and this consequently rates as a low risk.

A range of other potential impacts were identified, all of which were assessed to be of negligible or low risk. These risks include the potential for reduced water quality from geotechnical investigations, the risks from driven piles, fuel and chemical spills, disturbance of existing contaminated soils and mobilisation of contaminated groundwater, and impacts to the water quality of wetlands due to groundwater regime changes (saline intrusion) from construction activities. Risks pertaining to contamination to groundwater and impacts of piling construction have been discussed in Section 18.8 of Chapter 18: *Soils and contaminated land.* As the reference design of the project does not require dewatering it is not considered a risk.

A full list of all groundwater related primary risks and further information on potential impacts determined to be low risk, are contained in Appendix K: *Groundwater impact assessment* and Attachment I: *Environmental risk assessment report*.

Table 17.5 Groundwater risk

Risk	Impact pathway	Primary impact	Project phase	Initial risk rating	EPR ref.	Residual risk rating
R-GW7	Construction impacts on groundwater quality	Compression of shallow unconsolidated aquifers from the loading weight of embankment structures changing groundwater levels and flow regime (choking off groundwater flow) and potential effects on existing users/sensitive receptors.	C	Low	N/A	Low

17.9 IMPACT ASSESSMENT AND MITIGATION

As previously mentioned in Section 17.4.2 the groundwater model was developed to assess the impact of the project on groundwater levels not only within the project boundary but also to beneficial users and sensitive receptors across a large area including the LXRA Edithvale – Bonbeach Project to assess for cumulative impacts. The modelled predictions to groundwater levels are summarised for both the construction and operational phases below.

17.9.1 Construction

Embankment structures (Risk R-GW7)

The loading weight of proposed embankment structures could result in compression of shallow unconsolidated aquifers changing groundwater levels and flow regime, with potential effects on existing groundwater users and sensitive receptors. Following the completion of groundwater modelling, the potential risk for environmental impacts from compression of shallow aquifers from the loading weight of embankment structures is considered low.

As discussed in Section 17.7.2 the construction of the embankment structures would reduce the permeability of the shallow unconsolidated aquifer, the numerical groundwater modelling indicated that impacts on groundwater would be minimal. The maximum predicted lowering of the water table is 11cm at the southern embankment at the Springvale Road bridge. The maximum predicted water level rise is 13cm at the Governor Road embankment. Groundwater modelling also predicted that most of the water level changes would occur below the embankment itself, with less than 5cm drawdown predicted immediately adjacent to the embankment. These predicted effects reduced to 1cm of drawdown approximately 500m west of the embankment towards the Edithvale Wetlands. These effects are much less than seasonal groundwater level variations, which range from 50cm to 1m.

An additional model sensitivity run was subsequently completed to investigate the impact on groundwater levels if the final design differs from the reference design which was modelled in detail. This task was outside of the initial scope, and it is not part of the Australia groundwater modelling guidelines 2012 and has therefore not been part of the independent review process. The model run approximated the impact of a 15m high embankment-type structure, wider than the existing roadway extending to the northern perimeter of the groundwater model, to model a ’fictitious’ worst case scenario that is unlikely to be constructed. The outcome of the model indicates that even with the overestimated embankment, impacts to groundwater level outside of the road footprint are predicted to be minimal, with effects predicted to be less than 5cm and well within the natural seasonal variation.

A water balance model was used to predict the impact that the embankments would have on groundwater inflows to the Edithvale Wetlands. The difference in groundwater discharge to the wetlands due to the embankments is predicted to be negligible (i.e. predicted changes to the flow rate of less than 10^{-3} millimetres per day) compared with the effects of surface water inputs, rainfall and evaporation.

In addition, given that the natural variation of groundwater is in the order of metres, the predicted water level changes are not expected to impact on any GDEs or existing extractive bore users described in Section 17.6.7. As such the minimal impact to the groundwater aquifers would not alter the current groundwater quality/salinity observed at Edithvale Wetlands or other locations.

The risk of contaminants entering the groundwater system because of construction activities is considered low. However, there is the potential for contamination to occur, and impact on sensitive receivers as outlined in Chapter 16: S*urface water and hydrology* and Chapter 18: *Soils and contaminated land.* A CEMP will manage the risk of contaminants entering the groundwater system, however a WMMP will also be developed to ensure any contamination to groundwater is identified and relevant contingency put in place (EPR W5).

Piling

During construction, piling will be required to establish the foundations for bridge structures such as where the road passes over the Waterways Estate Wetlands. Piling would be to a depth of less than 50m and therefore is expected to remain largely within the Quaternary and Upper to Upper-Middle Tertiary Aquifer levels. Geo-technical surveys to date have drilled to depths of approximately 50m without breaking through into the Upper-Middle Aquitard (below the Upper-Middle Tertiary Aquifer) in the project areas where piling is expected to take place. Piling for the Waterways bridge structure will involve singular piles, spaced at 25m intervals allowing for groundwater to flow between piles.

The risk assessment included a review of piling impacts on groundwater, which was considered to result in negligible impacts with the project as the separated piles will not form a barrier to groundwater flow (therefore not impacting on the Wetlands ecosystem). The likelihood of contamination of aquifers was negligible. Whilst the driving of piles could impact flows between aquifer units by creating preferential flow pathways (that could lead to contamination), the risk to groundwater is considered low as aquifer units present at the proposed piling locations are already in hydraulic connection and the percussion driving of piles through the aquifer material compresses the near pile material (self-sealing) preventing the vertical flow of groundwater and limiting the preferential pathway (NGCLC 2001).

17.9.2 Operation

The risk assessment rated all potential impacts during the operation of the road as being low risk. This included potential impacts on groundwater from road operations and potential fuel and chemical spills. A full list of all groundwater-related primary risks, and further information on potential impacts determined to be low risk, are contained in Appendix K: *Groundwater impact assessment*.

17.10 ENVIRONMENTAL PERFORMANCE REQUIREMENTS (EPRs)

As a result of the detailed investigation, additional environmental performance requirements (EPRs) are not required for the management of groundwater. The impact assessment has investigated potential impacts to groundwater levels at all GDEs and specifically at the Edithvale Wetlands, and the predicted water level changes as a result of the project are well within natural variation at the site and 1cm at 500m from the project.

As described above, Chapter 16: *Surface water and hydrology* describes the WMMP which includes monitoring groundwater for contamination (EPR W5) to ensure that the project causes no impact to groundwater quality. Details on the investigation into groundwater contamination is found in Chapter 18: *Soils and contaminated land.*

17.11 CONCLUSIONS

The ERA found that all the identified potential impacts on groundwater were negligible to low risk. The impact assessment found that construction of the project would result in minimal impact on groundwater and beneficial users of groundwater caused by the embankment structures.

Groundwater level changes would be primarily beneath the embankments and within the natural variability of each aquifer, with negligible impacts outside the embankment footprints. As the embankments have minimal impacts on regional groundwater flow or levels, negligible impacts are expected on groundwater contributions to the Edithvale Wetlands or other beneficial users of groundwater such as registered bores.

Piling is considered to have negligible impact on groundwater flows and quality with separated piles not limiting flow, whilst new pathways between aquifers are not a concern due to existing hydraulic connectivity between the quaternary and upper tertiary aquifer levels.

In addition, the water balance results showed that water levels within the wetlands had little sensitivity to changes considering groundwater baseflow into the wetland cells. Following the conclusion of predicted modelling, the groundwater risks associated with the embankment were assessed as being low.

Groundwater quality, contamination, impacts of piling and description of standard mitigation controls for spills and leaks is described in Chapter 18: *Soils and contaminated land* and will be managed through the development and implementation of a WMMP to satisfy the performance requirements specified in EPR W5. Through the implementation of this EPRs, the project would minimise adverse effects on groundwater and minimise effects on water quality and beneficial uses, including the ecological character of the Edithvale-Seaford Wetlands Ramsar site.