cape jaffa anchorage

environmental impact statement february 2005

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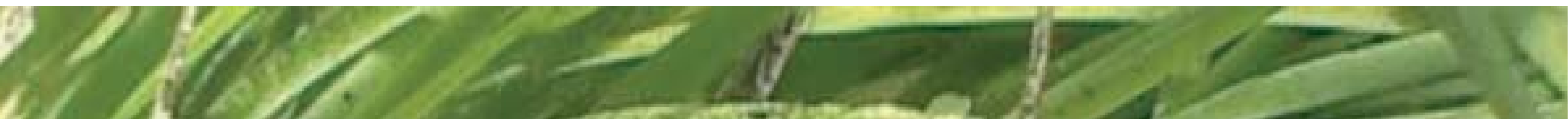
cape JAFFA ANCHORAGE



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cape jaffa anchorage

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prepared for

Kingston District Council

and

Cape Jaffa Development Company Pty Ltd

by

Masterplan SA Pty Ltd

and

Tonkin Consulting

Also see Authors & Contributors

This book was designed and produced by
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33 Carrington Street
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APPENDIX 1

Cape Jaffa Development Company Pty Ltd/Urban and commercial new development/Cape Jaffa/ SA/Cape Jaffa anchorage marina and residences (EPBC #2004/1816), Australian Government Department of Environment & Heritage, 4th November 2004

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Cape Jaffa Information Sheet and Questionnaire

CAPE JAFFA ANCHORAGE

SEA
SAND
SECLUSION
and SAFETY
at Cape Jaffa

The Kingston District Council is investigating the possible future development of Cape Jaffa including associated infrastructure and facilities to meet the needs of the professional fishing industry, aquaculture industry, recreational boating users, residents and visitors.

A draft Development Concept has been prepared to indicate the general form of development which could satisfy some of the needs identified.

If you have any other queries, please contact Stephen Rufus at Kingston District Council on (08) 8767 2033or by email to srufus@kingstondc.sa.gov.au

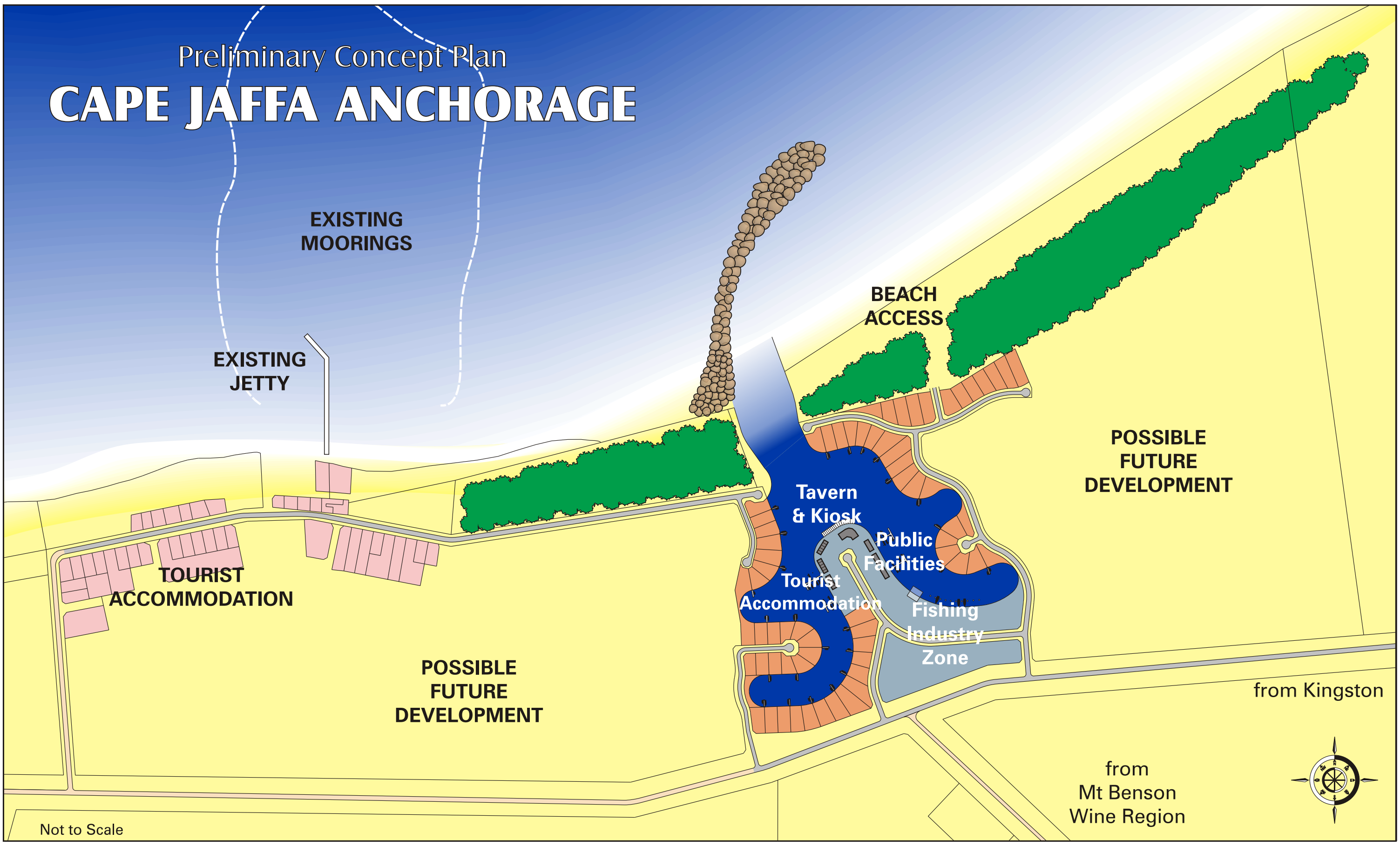
The questionnaire can be faxed to Council on (08) 8767 2937 or sent to :

Kingston District Council
PO Box 321
KINGSTON SE SA 5275

Or delivered to the Council office at :

29 Holland Street, Kingston SE

KINGSTON DISTRICT COUNCIL
Gateway to the South East Coast



Councillor Evan Flint, Chairman of the Kingston District Council stated :

"that with the legislative framework being established for aquaculture within South Australia and the development planning process nearing completion for marine based aquaculture at Cape Jaffa, the Council has begun investigating development and infrastructure requirements to support this industry. In addition, the infrastructure currently provided for the professional fisherman is ageing and proving to be inadequate with recreational facilities in the area sub standard and in desperate need of upgrading."

Investigations

The investigations being undertaken will assist Council and other relevant authorities to identify issues and ultimately determine the suitability, form and nature of any future development or growth at Cape Jaffa.

In the meantime, Council is wishing to inform the community about their intentions, and to seek information and input from anybody interested in any aspect of the project.

The accompanying form is designed to assist in this information gathering process and your input is valued.

A range of facilities are being contemplated including:

- Fish receival, processing and holding stores;
- Fuel, waste and pump out facilities;
- Fish weighing facilities area;
- Boat and service ramp(s):
  - public, and
  - commercial/industrial;
- Storage - secure hard stand and shed storage;
- Public marina berths (long and short term);
- Commercial fishing vessel berths;
- Fishing industry and aquaculture service and industrial area;
- Apartment, holiday house, motel and cabin accommodation;
- Chandlery and boat brokerage;
- Manager's office and residence;
- General store/kiosk;
- Tavern/cafe/restaurant;
- Motor repair station - marine servicing;
- Recreation facilities and open space;
- Beach access;
- Protected seaway access to Lacepede Bay; and
- Residential allotments with private marina berths.

Other service infrastructure requirements include:

- Effluent treatment and Woodlot area;
- Stormwater management facilities;
- Water supply; and
- Power and telecoms reticulation.

Allotments for residential purposes may include:

- Water views and water access;
- Sea views, water views and water access; and
- Sea views.

It is also possible to set aside a large area of coastal dune native vegetation which currently forms part of existing privately owned grazing land.

There is also beach in private ownership that could be transferred to public ownership.

KINGSTON DISTRICT COUNCIL

Gateway to the South East Coast

CAPE JAFFA QUESTIONAIRE

Name:			
Address:			
Home or Business Phone:	Mobile Phone:		
Age Group	18-24 / 25-34 / 35-44 / 45-54 / 55-64 / 65+		
Are you a resident of this area?		YES	NO
If you are visiting Cape Jaffa is it ………………………	your first time	YES	NO
	one of several visits	YES	NO
When do you normally visit the area? eg. school holidays, summer, winter etc.			
How long do you normally spend at Cape Jaffa or your chosen South East destination?			
What is your preferred accommodation?	Motel	YES	NO
	Hotel	YES	NO
	Cabin	YES	NO
	Caravan	YES	NO
	Tent	YES	NO
	Friends Residence	YES	NO
What recreational activities do you seek in the area?	Fishing	YES	NO
	Swimming	YES	NO
	Wine tasting	YES	NO
	Beachside holiday	YES	NO
	Other activity		
Do you trail a boat on your visits?		YES	NO
If so what size is the boat and what facilities would suit your needs?			
What type of boat do you have?	Power	YES	NO
	Sail	YES	NO
If facilities like those shown on the concept plan were available would you use them?		YES	NO
If there are other facilities you would like provided please list them.			
Would you consider investing at Cape Jaffa either for residential purposes, business purposes or both?	Residential	YES	NO
	Business	YES	NO
	Both	YES	NO
Would you like to register your interest in land or other opportunities at Cape Jaffa?		YES	NO
I would like to register my interest in…			
What issues or concerns do you have about the possible development of Cape Jaffa?			

Any other comments or suggestions would be greatly appreciated.

Would you like to receive further information about possible development at Cape Jaffa?

If you have any other queries please contact Stephen Rufus at Kingston District Council on (08) 8767-2033

This questionnaire can be Faxed to Council on (08) 8767-2937 or sent to:

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Cape Jaffa Anchorage information pamphlet, distributed at 2004 Seafood & Wine Festival

cape JAFFA ANCHORAGE

INTRODUCTION Cape Jaffa has been identified over a number of years and through various studies as being strategically well located to accommodate fishing, aquaculture and tourist activities. In January 2000 Kingston District Council established a committee to investigate the future development requirements for Cape Jaffa. Through the extensive processes of a Section 30 Review and a Plan Amendment Report under the Development Act, Council formally identified Cape Jaffa as a suitable location for expansion of the existing settlement.

To enhance the quality of facilities, services and environmental management, a comprehensive development of the locality is required. To that end, the Kingston District Council and the Cape Jaffa Development Company have entered into an agreement to facilitate the proper development of Cape Jaffa. This information sheet provides an update on the progress of the proposal and its investigations.

THE PROPOSAL The Cape Jaffa Anchorage Project involves the development of a safe haven and moorings to accommodate fishing vessels and activities, together with areas for recreational boating facilities, hard stand areas and tourist and residential accommodation.

FEATURES OF THE PROPOSED DEVELOPMENT INCLUDE

- Safe Boat Haven
- Dredged channel and groynes to provide a protected seaway access
- Main basin area and residential waterway
- Public boat ramp
- Commercial areas to support the fishing and aquaculture industries
- Public/recreational and private marina berths
- Commercial Fishing vessel berths
- Residential Allotments
- Apartment, motel and cabin accommodation
- General Store/Kiosk/Tavern
- Recreation areas and open space
- Beach Access
- Reticulated mains water supply
- Effluent treatment and stormwater management facilities
- Reticulated power and telecommunications
- Predominately allotments of $750m^2$ or greater with average widths of 20m

APPLICATION STATUS On the 19th January 2002, following preliminary investigations and discussions with the Kingston District Council and the Cape Jaffa Development Company, the project was declared by the Government as a Major Project under Section 46 of the Development Act. This requires investigations into the environmental, economic and social impacts of the proposal, which are set out in Guidelines issued by the Government following input from the public and Government Agencies.

The key issues being investigated include
- Visual effects on the coast and locality
- Water sustainability
- Effects of the development on groundwater
- Native Vegetation
- Management requirements
- Effects on communities
- Native Title and Aboriginal Heritage
- Construction and operation effects
- Infrastructure requirements

The required investigations are extensive and are nearing completion. These investigations will be documented in an Environmental Impact Statement (E.I.S.) that will be submitted to the Government in February or March 2004. Shortly thereafter the E.I.S. will be placed on public exhibition providing the opportunity for comment and formal submissions.

A public hearing will also be held and thereafter a response to any submissions will be prepared. After receiving the response, the Government will assess the E.I.S.

CONSULTATION During the early investigations for the project, several meetings were held with members of the public to consider the views and needs of the community. This assisted in developing early concepts for the Cape Jaffa Anchorage.

Further public consultation has been undertaken to advance the proponents' understanding of the needs of the community. The scientific investigations to research the key issues as part of the E.I.S. have also assisted in significant improvements to the concept for the Cape Jaffa Anchorage.

Further opportunity for comment on the proposal will be available when the E.I.S. is placed on public exhibition.

CONTACTS A number of people have previously provided feedback to Council and many have registered an interest in the proposal.

If you have any queries about the proposal, wish to make any comments, register your interest or confirm your interest, please contact Robert Gabb of the Cape Jaffa Development Company on (08) 8298 6723 or on email rgabb@tne.net.au or write to R Gabb, Cape Jaffa Development Company ℅ PO Box 150, Brighton SA 5048.

Alternatively, you may wish to speak with Stephen Rufus at Kingston District Council on (08) 8767 2033.

cape JAFFA ANCHORAGE


1 STREETSCAPE


2 OPEN SPACE RESERVE


3 WATERFRONT RESERVE


4 MOORINGS


5 WATERFRONT TAVERN


6 BOAT RAMP


7 FISHERMANS WHARF


8 COASTAL WALKWAY


9 FISH PROCESSING


10 WATERFRONT LIVING

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ARCHAEOLOGICAL INVESTIGATION OF CAPE JAFFA ANCHORAGE MARINA, CAPE JAFFA, SOUTH AUSTRALIA

PREPARED FOR CAPE JAFFA DEVELOPMENT COMPANY

September 2004

By Keryn Walshe and Jude Bonell
TimeMap Pty Ltd
Heritage Consultants
Adelaide, South Australia

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ABSTRACT

Archaeological investigations were carried out across the proposed Cape Jaffa Anchorage Marina Site by TimeMap Pty. Ltd. in liaison with representatives from Kungari Inc., MasterPlan Pty. Ltd. and Cape Jaffa Development Co., on behalf of the proponents for the development.

A series of different investigative techniques were used to determine the distribution and nature of archaeological sites, if any, within the proposed marina area. The investigations included a ground surface survey, test pits and sub-surface inspection.

Three discrete archaeological sites and two locations each with two cultural finds were recorded. The sites are located between 150m and 750m from the foreshore. The type of sites recorded in the proposed marina area are consistent with previous recordings and are representative of the numerous middens and stone tool scatters in this region, particularly the middens previously recorded in the Bernouilli Conservation Reserve, south of Cape Jaffa (Wood 1995).

The highest density site is situated on a dune crest where active wind deflation has revealed a scatter of flint tools and shell. Test pits nearby indicate that there is no sub surface deposit and all sites are unstratified.

All three archaeological sites were found to be highly disturbed and poor integrity with remnant scatters of stone tools and some faunal material. Low densities were found for all sites (less than one or equivalent to one artefact per square meter). Sites varied from approximately 30m in width to less than 10m.

All Indigenous heritage sites are automatically protected under the *South Australian Aboriginal Heritage Act*, 1988.

SECTION ONE

1.1 Study Area

The proposed Cape Jaffa Anchorage Marina site is situated approximately 300km by road from Adelaide. Cape Jaffa is a modest seaside town located on the southern headland of Lacepede Bay and has a strong emphasis on fishing and aquaculture. Natural features such as the Margaret Brock reef and adjacent coastal strips have been given conservation status.
The proposed development area has been under pastoral use for over 100 years resulting in significant modification to the pre-contact landscape. A few remnant stands of mature bulloaks are noticeable amidst the low ground cover of mostly introduced grasses and weeds. Intact, geologically recent dune systems run parallel to the coast and soils are principally sandy-loam over limestone/calcrete layers that extend out to the ocean. Dune heights are low, reflecting the robust on shore winds. In the extreme east and extreme west of the site, water collects in inter-dunal, lower lying areas.

1.2 Native Title Issues

There are no Native Title Claims or Indigenous Land Use Agreements over the proposed marina area. Consultation and all field investigations have been carried out with Kungari Inc. (Chair, Ms. Leonie Casey).

1.3 Indigenous Archaeology of the South-East Region

A number of archaeological investigations have been undertaken in the south east of South Australia over the last 60 years (Campbell & Noone 1943, Campbell *et al* 1946, Egloff *et al* 1989, Frankel 1986, Luebbers 1978, 1980, 1982, 1983 and 1984, Rhoads 1982 and 1983, Tindale 1957 and Wood 1995). The most relevant to this study is that by Wood (1995), a National Estate funded program aimed at compiling prior recordings with new investigations. This study provides information on 10 midden and artefact sites recorded within 15km north and 8 km south of the study area, along the coastal foreshore. These sites are characterised by predominantly flint flakes and cores and little faunal material. The degree of integrity is described as varying from poor to moderate. This description confirms the general site pattern for the south east of South Australia generally, as indicated by previous investigations. The lack of previous site recordings within the proposed marina area itself probably reflects limited access and low ground surface visibility.

Inland areas have received less attention with a specific focus on caves such as Mount Burr near Millicent (Campbell et al 1946). Luebbers (1978, 1980, 1982, 1983 and 1984) has carried out extensive surveys along Younghusand Peninusula, the Coorong, to the north of Kingston S.E and the entire coast from Cape Buffon at Southend to Canunda Rock and spot checks from Canunda Rock to Cape Banks, near Carpenter Rocks. Rhoads (1983) recorded 37 sites with the richest areas being lagoon environments between the southern end of Lake Frome at Southend and the northern end of Lake Bonney, a distance of approximately 17 kilometers. This confirmed earlier reports by Luebbers (1978, 1980, 1982, 1983) and added to the original documentation by Campbell and Noone (1943) and Campbell et al (1946). Generally in this region the degree of visibility and in turn success for site location, is intrinsically linked to deflation activity or erosion of exposed calcrete beds.

Other archaeological investigations in this region (Campbell & Noone 1943, Campbell et al 1946, Egloff et al 1989, Frankel 1986, Luebbers 1978, 1980, 1982, 1983 and 1984, Rhoads 1982, Tindale 1957) have revealed a similar site pattern described as:

- high density of midden sites (residue of occupation and reflective of coastal resource use);
- stone tool scatters (most commonly chert and flint with lower quantities of quartz, quartzites and silcretes);
- grinding tools present;
- deflation reveals surface scatter sites;
- occupation sites linked to fresh water sources;
- burial sites closely linked to sand dunes and shelves.

Interestingly, exceptionally rare finds such as wooden artefacts have also been recovered from the broader region, such as around Wyrie Swamp, near Millicent. A number of boomerangs were recovered, some of which are currently on display in the South Australian Museum. These have been dated to around 9,000 years old (Jones 1996) and their remarkable state of preservation is entirely due to the anaerobic qualities of the peaty burial environment.

A chronological context for archaeological site patterning in the study region is provided by two excavations carried out in the 1980's (Egloff et al 1989, Frankel 1986). Frankel (1986) excavated three caves (Malangine, Koongine and Piccaninnie) located along the coast toward the South Australian/ Victorian border, south of Mt. Gambier. Koongine Cave yielded an occupation span commencing at about 9,500 years ago and continuing to 700 years ago. Intense occupation appears to have occurred between 9,000 and 7,000 years ago. Piccaninnie Cave, near Port McDonnell yielded a single date of about 5,500 years old. Charcoal samples were also collected from the 'Finger Point' midden sites located in the dune field near Port McDonnell (Egloff et al 1989) yielding a series of dates between 800 to 3,000 years ago.

SECTION 2

2.1 Field Survey Methods

The archaeological investigation aimed to identify surface sites and determine the potential for sub-surface material. Previous investigations in the same region have clearly established that middens are closely connected to foreshore areas but have been unable to predict the potential for finding middens or other site types inland.
Three field trips took place and a different investigative technique was employed each time:

- Ground surface survey
- Trench excavation
- Rotary hoeing of the upper 30cm of soil

The initial ground surface survey was significantly inhibited by low visibility due to grass and weed cover across the proposed marina area. An active deflation bowl in the proposed marina area offered 100% visibility and revealed an artefact scatter. The remaining sandy rises, covered by grass and weeds, held an unknown potential for yielding other sites. In order to provide some means of predicting the distribution, types and density of surface sites and the potential for sub-surface deposits a backhoe for shallow trenching and a rotary hoe for removing the top surface. The results of the investigative methods are given in the following sections.

2.2 Pedestrian and Vehicle Survey and Results

On the 22 July, 2003 a field inspection of the proposed development area was carried out by Noelene Casey (senior elder, Kungari Inc), Leonie Casey (Chairperson, Kungari Inc.), Simon Tonkin (Master Plan), Robert Gabb (Cape Jaffa Development Company), archaeologist Keryn Walshe and field assistant Jude Bonell. The weather was cold with intermittent heavy rain showers and dense cloud cover. Due to the weather conditions and the nature of the terrain it was decided to inspect the area by vehicle, with pedestrian survey taking place in selected areas. Selected areas included deflation bowls scoured out in the dune ridges by wind activity, the margins of wetlands and any other surfaces offering high visibility. Mature native trees were also inspected for evidence of cultural modification.

Ground surface visibility on the day was particularly poor due to extensive grass and weed cover and only two sites were recorded. One site has been revealed by wind deflation and one site by sand removal, vehicle disturbance and wind activity.

Cape Jaffa AS 1, 0384893 5911115

This site has been exposed by wind action on a high dune ridge that trends east to west and sits parallel to beach. The deflation measures approximately 30m by 30m and faces south west. Nestled in the upper surface of loose sand are numerous stone tools manufactured from grey flint. Tool types include tula chisels, flakes, scrapers and blades. The average size range of tools is 20x10mm and density averages one artefact per sq.m. Flint cortex (debitage) is also present suggesting tool manufacturing on site. Faunal material includes cockles, mussel and cuttlefish.

Cape Jaffa AS 2, 0382906 5910581

This site is situated on an informal vehicle track immediately behind the private residences fronting King's Drive. Removal of sand, presumably for building, followed by vehicle movement and wind activity from an east-west trending low dune has exposed stone tools, shell and hearth stones. The tools average 1 per sq. m. and include cores, scrapers and flakes all manufactured from grey flint. Some cortex debris is present and a discrete knapping area was identified. A thin, disturbed lens of mussel shell is eroding out from the upper 5cm of sandy soil adjacent to a scatter of burnt hearth stones. Other shell fragments identified include turbo and unidentified gastropod operculum.

Cape Jaffa AS 2; tools and shell remains

Cape Jaffa AS 3, 0383965 5910729

This site has been revealed by numerous ploughing events and the fragmented, highly disturbed material was exposed in a furrow. Scattered artefacts and shell were found along a fence line and it is impossible to determine the original site dimension, integrity or nature due to the highly disturbed nature of this remnant area. Burnt and unburnt fragments of cockle, mussel and abalone shell; fragments of sandstone; two broken flint scrapers and a flint flake and a weathered, spherical flat stone were recorded.

Flint Find

A fragment of flint and a shell were dredged from bore site number 6. A layer of marled flint was recently located during investigative geo technical works indicating that flint bands associated with calcrete/limestone layers are present at 5-6m below the surface. Mollusc shell is found throughout the area and represents ancient phases of marine inundation across the proposed development area.

2.3 Test Pits by Trench Digger

A series of test pits were excavated by backhoe on the 21st August 2003. Test pits were shallow and not undertaken on areas with cultural material present. The excavations were carefully observed and some of the excavated sand was sieved on site. Observes included Leonie Casey and Robert Casey (Kungari Inc), Simon Tonkin (MasterPlan), Keryn Walshe (archaeologist) and Jude Bonell (field assistant).

Test pits were carried out on both dune crests and lower lying wetlands, reflecting both proposed canal and housing areas. Test pits were essentially positioned to test influences such as the height above sea level, the key environment and proximity to the foreshore on site distribution. Each test pit measured approximately 2m by 2m and was excavated to a variable depth of 1.5m to 3m.

A total of nineteen test pits were excavated. The test pits consistently revealed a profile of shallow, loamy topsoil approximately 25-30cm deep overlying mobile yellow sands perched above a calcrete horizon of variable depth. One archaeological site was revealed but no sub-surface material was identified in any of the 19 excavations. The archaeological site was located within the upper 5cm of soil and is described below.

Cultural Artefact Finds, 0384669 5910532

A ground edge axe, a flint awl, a broken hearth stone and some charcoal were revealed by a single shallow excavation scrape across the surface. The axe is highly characteristic of the greenstone axes traded from Western Victoria into south-eastern South Australia along well established and very ancient trade routes. The flint awl is unusual with an upturned point and dentated margins. The mollusc shell is characteristic of beach formation over phases of marine inundation as discussed earlier and not considered to be cultural. The two artefacts were taken for safe keeping by Kungari Inc representatives, thus no site can be considered to exist at this location.

Ground edge axe and flint awl with natural marine shell.

Details of the test pits are summarised in Table 1 below.

Table 1: Test Pit Finds

No.	GPS co-ordinates	Depth (m) of excavation	Comments
1	0383371 5910336	3	Sieved. No finds.
2	0382936 5910343	2	Sieved. Few flint nodules from underlying calcrete horizon.
3	0383352 5910476	4	No finds.
4	0383647 5910513	4	No finds.
5	0384011 5910584	3.5	No finds.
6	0384068 5910723	2	Sieved. No finds.
7	0384280 5910749	2	No finds.
8	0384911 5911159	2	Sieved. No finds.
9	0384875 5911143	2	No finds.
10	0384896 5911170	2	No finds.
11	0384974 5911150	2	No finds.
12	0384447 5910577	2	No finds.
13	0384546 5910716	2.7	No finds.
14	0384669 5910532	0.5	Ground edge axe, flint awl. Hearthstone and charcoal.
15	0384915 5910829	2	No finds.
16	0384894 5910843	1	No finds.
17	0384395 5910975	1	No finds.
18	0384318 5910899	1	No finds.
19	0384352 5910861	1	No finds.

2.5 Tractor and Hoe, Surface Clearance

On the 23rd September 2003 a tractor was used to firstly slash the high grass and then a hoe used to turn over the first 20-30cm of topsoil. Visibility was thus increased from less than 15% to greater than 85% on average. The tractor cleared four strips, allowing a corridor of approximately 2m width and a combined length of 2330m. Excellent surface visibility was given for approximately 4.7 square kilometres.

Clearance of grass cover by rotary hoe

Stages 1 and 2 of the proposed development works program, between King's Drive and Limestone Coast Road were selected for its higher priority. Dune crests and ridges were targeted over lower lying areas as previous finds clearly indicated a higher potential for site material in sandy, elevated areas. Clearance by the hoe revealed a continuous low density scatter of shell representing earlier marine incursions and to a lesser extent wind transported material. Clearance also revealed two cultural finds.

Results of clearance by the hoe are summarised in Table 2 below.

Table 2: Results from Hoe

Track	Start	Finish	Finds	Comments
1	0384014 5910610	0383630 5910633	Broken hearth stone, sandstone nodule, cockle & mussel shell fragments	Thin scatter of shell
2	0383965 5910729	0383773 5910708	Weathered, flat spherical stone, cockle & mussel shell	Thin scatter of shell
3	0383471 5910540	0383419 5910547	Cortex debris	
4	0383621 5910286	0383283 5910293	Flint adze slug, cockle shell	

The above finds represent natural accumulations of shell debris and two cultural finds- a flat spherical stone and a flint adze slug. The shell associated with these finds is not cultural.

2.6 Summary of Results

The field investigations carried out by a combination of ground surface survey, backhoe excavation and surface clearance revealed three discrete archaeological sites and two other locations each containing two cultural finds. All three sites are located between 150m and 750m from the foreshore. The type of sites recorded in the proposed marina area are consistent with previous recordings and are representative of the numerous middens and stone tool scatters in this region, particularly the middens previously recorded in the Bernouillii Conservation Reserve, south of Cape Jaffa (Wood 1995.

SECTION 3

3.1 Discussion and Significance Assessment

The types of sites identified in the proposed development area are entirely consist with previous site recordings for the region. Middens and stone tool scatters comprise the bulk of known sites along the south east coast.
Flint cobbles can be found within close proximity along every beach and cliff from Cape Banks to the Victorian border (Wood 1995) and the presence of predominantly flint tools on the sites recorded during this investigation is unsurprising. Interestingly the flat spherical hand sized stones found associated with one site and as an isolated cultural find are provenanced to Biscuit Flat, about 30kms southeast of Cape Jaffa.
Food remains indicate an emphasis on marine foods, particularly shellfish. Sea grass beds characterise the immediate beach front, but reef formation extends further away to the south east and around the point.
Freshwater was not an impediment to making use of this rich resource area, as indicated in the permanent stand of freshwater in nearby Hog Lake and in ephemeral wetlands between the dune ridges.
The three recorded sites appear to lack sub-surface, stratified deposit. Numerous test pits did not reveal any evidence for sub-surface cultural material. Sites appear confined to the upper horizons of darker sandy soil. Underlying loose sand was found to be devoid of any evidence for occupation.
The site finds ranged from low density disaggregated stone tool scatters to discrete higher density clusters of shell and stone tools. However, all sites identified to date have been significantly disturbed by on going pastoral activity and site integrity is extremely low.
Certainly the region offered optimal and varied resources throughout most of the year. The presence of permanent stands of water, such as Hog Lake and semi-permanent and ephemeral sources such as the wetlands suggests an ideal environment for year with a range of seasonally available particular foods.

However it must also be acknowledged that patterns of movement within a landscape are not only dictated by the availability of food, water and shelter. Ceremonial and other obligations need to be fulfilled, generating a less obvious archaeological pattern.

The field investigations did not identify any evidence for burials and there are no formal records of burials in either the proposed development area or the broader region.

The three sites recorded here are discrete, highly disturbed sites lacking sub-surface deposits and exhibiting poor integrity. The four cultural finds from two separate locations are representative of the region. The find of a ground stone axe is rewarding but not unusual in this region. There is insufficient data on finds of stone axes as most were collected by property owners over the last 100 years. Stone axes are easily recognisable and in similar fashion to grinding stones and other 'iconic' objects were collected in vast numbers during pastoral development. The location of the stone axe and flint awl cannot be considered a site as these two cultural objects are no longer physically present in the landscape.

3.2 Issues for Site Protection, Avoidance or Disturbance

Under the South Australian Aboriginal Heritage Act, 1988, all Aboriginal sites are automatically protected and permission to disturb, salvage or destroy must be gained under Section 23 of the Act from the Minister for Aboriginal Affairs and Reconciliation.

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APPENDIX ONE: Protocols for Protecting Aboriginal Heritage Sites and Objects at Cape Jaffa Anchorage Marina

Responsibilities under the South Australian Aboriginal Heritage Act, 1988:

1. Under Section 23 of the Act, it is illegal to damage, disturb or interfere with a site without permission from the Minister for Aboriginal Affairs (Mr. Terry Roberts),
2. A site under the Act means an area of land that is of significance to Aboriginal tradition or to Aboriginal archaeology, anthropology or history,
3. An Aboriginal object under the Act, means an object that is of significance to Aboriginal tradition or to Aboriginal archaeology, anthropology or history,
4. The penalty for damaging, disturbing or interfering with a site or object without the Minister's approval is in the case of a body corporate $50,000 and $10,000 or 6 months imprisonment for others,
5. Under Section 20 of the Act, the owner, occupier or agent of the land must report the discovery of a site or to the Minister for Aboriginal Affairs as quickly as reasonably possible. Penalties for non-compliance apply.

The above points mean that all Aboriginal sites and objects are protected under the SA Aboriginal Heritage Act, 1988. If a site or object is found, it must be reported by the land owner or agent to the Minister for Aboriginal Affairs.

This raises a number of questions-

1. how do we recognise a site or object?
2. who reports the find?
3. who is the find reported to?
4. what happens then- are we allowed to keep working?
5. how do we ensure that the site is avoided?

Recognising a site or object

So far, four sites have been recorded in the proposed marina area. The most common and likely site at Cape Jaffa is a cluster of stone tools and shell debris scattered across the ground. These are the most likely type of site at Cape Jaffa - a midden. These represent camping places where Aboriginal people have left behind stone tools and food remains (shells and the bones of small animals). Sometimes these are very extensive both across the surface and below the surface. Middens have been recorded along the coastal foreshore. The most common raw materials for making stone tools from are blue-grey flint and limestone. Flint is associated with the formation of limestone.

Another site type is a burial. Many burials have been recorded along the Coorong, but not at Cape Jaffa. The potential for this is considered to be low on in view of the archaeological investigations to date.

Reporting a site or object

If a site or object is found during works at Cape Jaffa Anchorage Marina by a construction team or member of that team, it must first be reported to the site manager. The site manager reports to:

-archaeologist for the field investigation (0412356387)

-Kungari Inc representative (87672085)

Preliminary discussion will take place and the Department of Aboriginal Affairs and Reconciliation (0882268900) will then be contacted at the discretion of Kungari Inc.

The site or object will be recorded and a GPS location taken. Information on the site or object will be added to the archaeological report.

Getting back to work and site avoidance

The site or object must be avoided by the construction team. A new work plan must be produced with the GPS position for the site or object shown. The plan must be made available to all construction teams using heavy vehicles.

Permission to salvage the site or object must be gained from the Minister for Aboriginal Affairs and Reconciliation, Mr Terry Roberts. This will take some time after an application has been submitted to the Ministers Department (0882268900). It is generally preferable to avoid the site or object.

Any problems or queries

Generally minor problems and queries can be sorted by a phone call to the archaeologist involved in the field investigations. If the matter is of a more serious nature, the Department of Aboriginal Affairs and Reconciliation must be contacted for advice. At some point the relevant Indigenous heritage representatives need to be updated and given an opportunity for comment. This process relies on a balance of sensitivity to protecting Aboriginal sites and objects and a common sense attitude being maintained. There is rarely a need to panic and think the worst in terms of work and budget schedules.

APPENDIX 11

Cape Jaffa Anchorage Development Proposal Flora and Fauna Investigations, RMP Environmental Pty Ltd, Playfair R, October 2004

RMP Environmental Pty Ltd
PO Box 2 Daw Park SA 5041 Tel/Fax (08) 8276 9011 rmp@internode.on.net

CAPE JAFFA ANCHORAGE DEVELOPMENT PROPOSAL

FLORA AND FAUNA INVESTIGATIONS

OCTOBER 28, 2004

Prepared by R. Playfair

Terrestrial Flora and Fauna

Site inspections were undertaken in May 2003 by Bill Matheson, and in September 2004 by Roger Playfair, Mark deJong & Steve Milne. The habitat areas were inspected on foot and observations of fauna activity, vocalisations or scats, tracks and diggings were recorded. Assessment of the terrestrial flora and fauna of the site is based on information collected on site visits, database searches, anecdotal information and review of published information.

Regional Context

The majority of the project site has been used for cereal cropping and pastoralism. Most of the original vegetation has been cleared, however there is some remnant vegetated foredune of varying integrity and a small area of seasonally inundated paperbark swamp. Though not listed as a threatened plant community in the South East, paperbark swamp areas have been severely depleted in the region through altered ground water regimes and clearance for agriculture. Adjacent to the south western corner is Bernouilli Conservation Reserve, 200 ha of coastal heath vegetation type in relatively good condition.

Figure 1 Extent of vegetation types in relation to project area. Total project area is enclosed by red line. Vegetation types A and B enclosed by blue lines. Source of photography: Department for Environment, Heritage and Aboriginal Affairs, 1997.

Flora

On this site there are three generalised habitat/vegetation types:

- Foredune coastal heath (A) in three discrete patches between the beach and the development area. A narrow strip of this habitat type also lines the access road on the southern boundary of the site.
- Paperbark Swamp (B) in one small area near the south east corner of the site.
- Open Pasture (C) covering the majority of the site.

The extent of the proposed project area and areas covered by these habitat types are shown on Figure 1. Appendix 1 has more comprehensive plant lists for these habitat areas as well as similar areas nearby.

Foredune coastal heath (A)

Between the beach and the proposed anchorage basin there are some narrow strips of coastal vegetation that still remains on the foredune. These areas are quite dense shrubland dominated by *Leucopogon parviflorus* (coast beard heath), *Acacia longifolia* var. *sophorae* (coastal wattle), *Olearia axillaris* (coast daisy bush) over a ground layer consisting of *Isolepis nodosa* (knobby club rush), *Carpobrotis rossii* (pigface), *Lepidosperma gladiatum* (coast sword sedge) and *Tetragonia implexicoma* (brown spinach). Exotic grasses are common around the edges particularly in the smaller (western) patch and there are serious infestations of *Asparagus asparagoides* (bridal creeper) in both areas. Open areas are dominated by *Euphorbia paralias* (sea spurge) and *Euphorbia terracina* (false caper). A very narrow strip of degraded coastal heath habitat type also runs along Cape Jaffa Road on the southern boundary of the site.

Bernouilli Conservation Reserve, a 200 ha. area to the south west of the development site and Butcher Gap Conservation Park, 10 km north are both reasonably well-preserved examples of this vegetation type. Appendix 1 has more comprehensive plant lists for these reserve areas.

Photo 1 Western patch of coastal heath looking from King Drive. Note the exotic grasses and onion weed on the edge of the tall shrubland.

Photo 2 Inland edge of coastal heath. The larger patch to the east is very dense and bridal creeper infestation mainly around edges.

Paperbark Swamp (B)

A very small area of Paperbark Swamp exists in the south eastern corner of the site. This area is only inundated during the winter when the rainfall fills the soil profile and a temporary swamp is created. This creates an area of quite low biodiversity because many understorey plants do not tolerate swamp conditions. The fringes of this area are dominated by *Gahnia filum* (thatching grass), *Gahnia trifida* (cutting grass), *Isolepis nodosa* (knobby club rush), *Samolus repens* (creeping brookweed) and *Tetragonia implexicoma* (brown spinach), and the central part consists of *Melaleuca halmaturorum* (swamp paperbark) over mainly bare ground or shallow water (in winter). Pasture grasses also form a dense sward where the pasture meets the swamp.

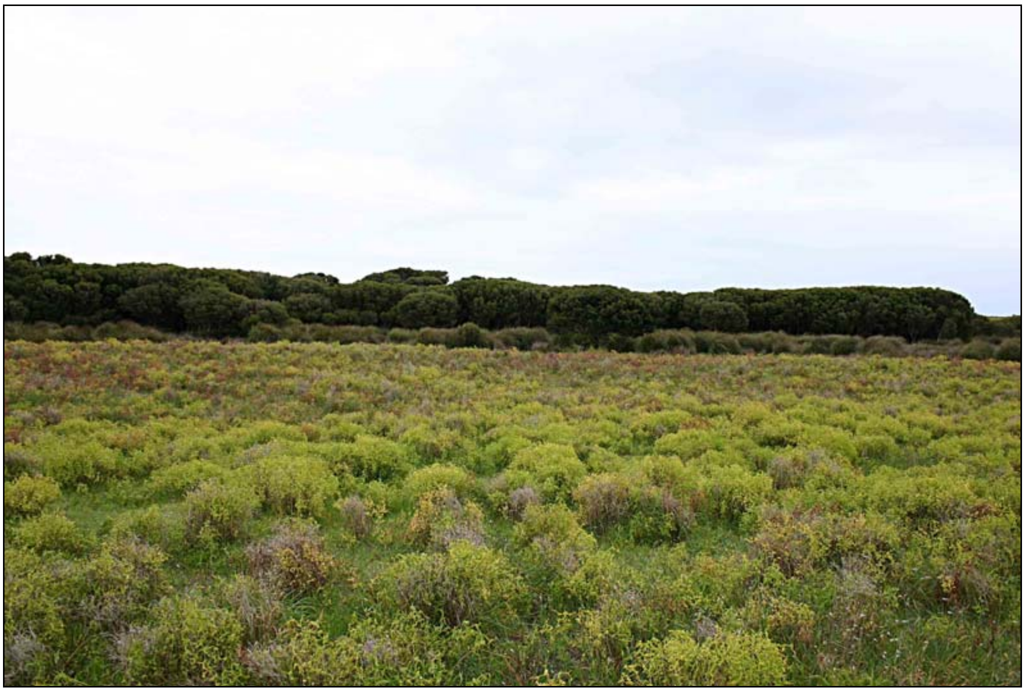

Photo 3 Swamp paperbark area with the fringe of thatching grass. Pasture habitat type in foreground.

Photo 4 Swamp paperbark area with some standing water and thatching grass and knobby club rush in the midground.

Open pasture (C)

Taking up approximately 90% of the site area is an open pasture vegetation type. Historically grazed and "improved by the use of pasture seed and fertiliser application. Dominated by exotic grasses, *Euphorbia terracina* (false caper) with some patches of *Marrubium vulgare* (horehound), this area is not used by most native fauna species due to its domination by exotic plants, often not attractive to them for breeding or feeding, and the low open nature provides little protection from predators.

Photo 5 Open pasture with very dense infestation of false caper.

Photo 6 Open pasture with moderate infestation of false caper.

Fauna

Mammals

There was limited evidence of mammal presence recorded at the site during the site assessment. Rabbit warrens were noted at several locations in the coastal dunes. However, few fresh rabbit tracks, scats or diggings were observed, indicating that rabbit population size and activity was generally low.

Mammal species recorded in SA Museum databases within 20 km of the coast and at coastal DEH biological survey sites in the Cape Jaffa region are listed in Table 1.

Table 1 – Mammals Recorded in the Region

Species	Common Name	Conservation Status SA (NPW Act)	Conservation Status Aus (EPBC Act)
Antechinus flavipes	Yellow-footed Antechinus		
Antechinus minimus	Swamp Antechinus	Endangered	
Cercartetus concinnus	Western Pygmy-possum		
Cercartetus lepidus	Little Pygmy-possum		
Cercartetus nanus	Eastern Pygmy-possum	Vulnerable	
Chalinolobus gouldii	Gould's Wattled Bat		
Chalinolobus morio	Chocolate Wattled Bat		
**Felis catus*	Cat		
Hydromys chrysogaster	Water-rat		
Isoodon obesulus obesulus	Southern Brown Bandicoot	Vulnerable	Vulnerable
Macropus fuliginosus	Western Grey Kangaroo		
Macropus giganteus	Eastern Grey Kangaroo	Rare	
Macropus greyi	Toolache Wallaby	Extinct	Extinct
Macropus rufogriseus	Red-necked Wallaby	Rare	
Miniopterus australis	Bentwing-bat		
Miniopterus schreibersii	Large Bentwing-bat		
Mormopterus planiceps	Southern Freetail-bat		
**Mus musculus*	House Mouse		
Nyctophilus geoffroyi	Lesser Long-eared Bat		
Pseudomys apodemoides	Silky Mouse		
Pteropus poliocephalus	Grey-headed Flying-fox		
Rattus fuscipes greyi	Bush Rat		
Rattus lutreolus	Swamp Rat		
**Rattus rattus*	Black Rat		

Species	Common Name	Conservation Status SA (NPW Act)	Aus (EPBC Act)
Sminthopsis crassicaudata	Fat-tailed Dunnart		
Tachyglossus aculeatus	Short-beaked Echidna		
Trichosurus vulpecula	Common Brushtail Possum		
Vespadelus darlingtoni	Large Forest Bat		
Vespadelus regulus	Southern Forest Bat		
Vespadelus vulturnus	Little Forest Bat		
Vombatus ursinus	Common Wombat	Rare	
**Vulpes vulpes*	Fox		

A number of these species are likely to occur in the coastal heath foredune habitat. The Common Wombat (*Vombatus ursinus*), which is considered "Rare" in South Australia, is known from coastal vegetation in nearby Bernouilli Conservation Reserve. Evidence of wombat activity was not observed in the project area, however its presence cannot be completely discounted. The Short-beaked Echidna (*Tachyglossus aculeatus*) has also been reported from nearby coastal areas (Foulkes *et al.* 2003a), but no evidence of its presence was noted. The Western Grey Kangaroo (*Macropus fuliginosus*) is expected in most habitats in the region and may occur at the site. The Red-necked Wallaby (*Macropus rufogriseus*) has been recorded in tall coastal shrubland (Foulkes *et al*. 2003a) although there are no database records in the vicinity of the site. Introduced species such as cats, foxes, house mice and black rats are also likely to be present at the site.

Mammal Species of Conservation Significance

Other species of conservation significance recorded in the region (Table 1) are not likely to be found in the habitat types present and are not expected at the site, as discussed below.

Swamp Antechinus (*Antechinus minimus*) is associated with Silky Teatree (*Leptospermum lanigerum*) tall shrubland and Cutting Grass *(Gahnia trifida*) sedgelend (Foulkes *et al.* 2003a), which are not present or not sufficient in size or quality to support this species.

Eastern Pygmy Possum (*Cercartetus nanus*) is an inhabitant of stringybark and manna gum open forest and woodland (Foulkes et al. 2003a), which are not present at or near the site.

Eastern Grey Kangaroo (*Macropus giganteus*) is a resident of open forest and woodland and has not been recorded in coastal habitats in the region (Foulkes *et al.* 2003a).

Reptiles and Amphibians

Although weather conditions during the site inspection in September 2004 were suitable for reptile activity, few reptiles were observed. Several Four-toed Earless Skinks (*Hemiergis peronii*) were found under debris in the paperbark swamp and would also occur in the coastal shrubland areas. A snake (possibly an Eastern Brown Snake, *Pseudonaja textilis*) was observed fleeing into dense vegetation in the coastal dunes. Large numbers of the Common Froglet (*Crinia signifera*) were heard calling in the paperbark swamp.

Table 2 – Reptiles and Amphibians Recorded in the Region

Species	Common Name	Conservation Status SA (NPW Act)	Aus (EPBC Act)
Reptiles			
Amphibolurus norrisi	Mallee Tree-dragon		
Aprasia striolata	Lined Worm-lizard		
Austrelaps superbus	Lowland Copperhead		
Bassiana duperreyi	Eastern Three-lined Skink		
Chelodina longicollis	Common Long-necked Tortoise		
Ctenotus orientalis	Eastern Spotted Ctenotus		
Ctenotus robustus	Eastern Striped Skink		
Drysdalia coronoides	White-lipped Snake		
Hemiergis peronii	Four-toed Earless Skink		
Lampropholis delicata	Delicate Skink		
Lampropholis guichenoti	Garden Skink		
Lerista bougainvillii	Bougainville's Skink		
Morethia adelaidensis	Adelaide Snake-eye		
Morethia obscura	Mallee Snake-eye		
Notechis scutatus	Eastern Tiger Snake		

Species	Common Name	Conservation Status SA (NPW Act)	Conservation Status Aus (EPBC Act)
Pogona barbata	Eastern Bearded Dragon		
Pseudemoia entrecasteauxii	Southern Grass Skink		
Pseudemoia rawlinsoni	Glossy Grass Skink	Endangered	
Pseudonaja textilis	Eastern Brown Snake		
Pygopus lepidopodus	Common Scaly-foot		
Tiliqua nigrolutea	Blotched Bluetongue		
Tiliqua rugosa	Sleepy Lizard		
Tiliqua scincoides	Eastern Bluetongue		
Varanus rosenbergi	Heath Goanna	Rare	
Amphibians			
Crinia signifera	Common Froglet		
Limnodynastes dumerilii	Bull Frog		
Limnodynastes peronii	Striped Marsh Frog		
Limnodynastes tasmaniensis	Spotted Grass Frog		
Litoria ewingii	Brown Tree Frog		
Litoria raniformis	Golden Bell Frog	Vulnerable	Vulnerable
Neobatrachus pictus	Painted Frog		
Neobatrachus sudelli	Sudell's Frog		
Pseudophryne bibronii	Brown Toadlet		
Pseudophryne semimarmorata	Marbled Toadlet		

Reptile and amphibian species recorded in SA Museum databases within 20 km of the coast and at coastal DEH biological survey sites in the Cape Jaffa region are listed in Table 2. Most of these species are relatively common and widespread, and a number are possible inhabitants of the coastal shrubland habitat. These include the Lined Worm-lizard (*Aprasia striolata*), Eastern Three-lined Skink (*Bassiana duperreyi*), Bougainville's Skink (*Lerista bougainvillii*), Southern Grass Skink (*Pseudemoia entrecasteauxii*), Eastern Tiger Snake (*Notechis scutatus*) and Bluetongue lizards (*Tiliqua* spp.). The Sleepy Lizard (*Tiliqua rugosa*) and Adelaide Snake-eye (*Morethia adelaidensis*) have been reported from sites in Bernouilli Conservation Reserve and may also occur in the coastal shrubland.

Several additional frog species including the three *Limnodynastes* species listed in Table 2, Brown Tree Frog (*Litoria ewingii*) and Painted Frog (*Neobatrachus pictus*) may also inhabit the paperbark swamp area at the northern edge of the site.

The open pasture areas are likely to support only those species capable of exploiting heavily disturbed areas (eg. Four Toed Earless Skink, Eastern Brown Snake) and are not expected to be used by the majority of other reptile and amphibian species.

Reptile and Amphibian Species of Conservation Significance

Three species of conservation significance have been recorded in the region (Table 2) but are not considered likely to inhabit the project area.

The **Glossy Grass Skink** (*Pseudemoia rawlinsoni*) is considered "Endangered" in SA and is a grassland/sedgeland specialist, often found on the edges of wetlands or lakes (Foulkes *et al.* 2003b). It has been recorded from sites dominated by cutting grass (*Gahnia* spp.) within the region, the closest being at Lake Hawdon South, approximately 35km to the south-east (Stewart *et al.* 2001, Milne 2004). Although cutting grass is present in the paperbark swamp area, compared to sites where the Glossy Grass Skink has been recorded it is more limited in extent and subject to much heavier grazing pressure and represents relatively poor quality habitat. The presence of this species cannot be completely discounted, but it is considered unlikely.

The **Southern Bell Frog** (*Litoria raniformis*) is considered "Vulnerable" both in SA and under the Commonwealth EPBC Act. Although its habitat requirements are not fully understood, it is most commonly found in or near permanent water bodies with dense fringing vegetation (Cogger 2000) and it is likely that it requires permanent or semi-permanent still water bodies for reproduction (Robertson 2000). The Southern Bell Frog is thought to have very similar biology to the closely related Green and Golden Bell Frog (*Litoria aurea*) (Pyke 2002) and studies of this species have reported that breeding is almost completely restricted still, relatively unshaded water bodies that are low in salinity (Pyke *et al.* 2002). Breeding ponds are generally small (<1000m^2) and shallow (<1m deep). Significant predictors for the presence of *L. aurea* include diversity of vegetation on the banks of water bodies, presence of emergent vegetation and potential shelter provided by nearby rocks or thick, low vegetation (Hamer *et al.* 2002; Pyke *et al.* 2002). The paperbark swamp area does not contain thick, low and diverse fringing vegetation, and does not represent suitable habitat. The presence of the Southern Bell Frog is considered unlikely.

The **Heath Goanna** (*Varanus rosenbergi*), considered “Rare” in SA has been rarely recorded in the South East. It prefers heath shrublands, eucalypt woodland and forest, and woodland with a heath understorey (Foulkes *et al.* 2003b). There are no database records at or near the project site, and its presence is unlikely.

Birds

Of the available habitat types on this site, the paperbark swamp whilst wet, supports a far more diverse bird population than the open pasture or the coastal heath. Though small in extent, the dense cover of the paperbarks, standing water, mud and surrounding thatching grass all provide for a wide range of birds needing fruits, seeds, insects, protection from predators or nesting sites. After the standing water dries, many of those birds that rely on shallow water or mud will move elsewhere to return in winter when the wetland refills.

The DEH vertebrate survey site in Bernouilli CR provided no bird data relevant to the project site. Table 3 lists the birds observed on separate visits in May, 2003 and September, 2004. They are presented as being in a particular habitat type, but not all are habitat specific.

Table 3 Birds recorded at project site, May 2003, Sept 2004.

Common Name	Scientific Name	Habitat#		
		PS	P	CF
Australasian Shoveler	*Anas rhynchotis*	+		
Australian Magpie	*Gymnorhina tibicen*		+	+
Australian Pelican	*Pelacanus conspicillatus*	+		
Australian Shelduck	*Tadorna tadornoides*	+		
Australian Spotted Crake	*Porzana fluminea*	+		
Beautiful Firetail	*Stagonopleura bella*	+		
Black-shouldered Kite	*Elanus axillaris*		+	+
Black-winged Stilt	*Himanotopus himantopus*	+		
Blue-winged Parrot	*Neophema chrysostoma*	+		
Brown Falcon	*Falco berigora*		+	+
Brown Thornbill	*Acanthiza pusilla*			+
Brush Bronzewing	*Phaps elegans*			+
Chestnut Teal	*Anas castanea*	+		
*Common Starling	*Sturnus vulgaris*		+	+
Crested Pigeon	*Ocyphaps lophotes*		+	+
*Eurasian Blackbird	*Turdus merula*	+		+
*Eurasian Skylark	*Alauda arvensis*		+	
*European Goldfinch	*Carduelis carduelis*	+		+
Grey Fantail	*Rhipidura albiscapa*	+		
Grey Shrike-thrush	*Colluricinchla harmonica*	+		+
*House Sparrow	*Passer domeesticus*			+
Little Pied Cormorant	*Phalacrocorax melanoleucos*			+
Little Raven	*Corvus mellori*		+	+
Magpie-lark	*Grallina cyanoleuca*	+		
Masked Lapwing	*Vanellus miles*	+	+	
Musk Duck (Rare in SA)	*Biziura lobata*	+		
Nankeen Kestrel	*Falco cenchroides*			+
Pacific Black Duck	*Anus superciliosa*	+		
Richard’s Pipit	*Anthus novaeseelandiae*		+	
Rufous Bristlebird (Vulnerable in SA)	*Dasyornis broadbenti*			+
Silver Gull	*Larus novaehollandiae*	+		
Silvereye	*Zosterops lateralis*	+		+
Singing Honeyeater	*Lichenostomas virescens*			+

Common Name	Scientific Name	Habitat#		
		PS	P	CF
Spiny cheeked Honeyeater	*Acanthagenys rufogularis*	+		+
*Spotted Turtledove	*Streptopelia chinensis*	+		+
Striated Fieldwren	*Calamanthus fuliginosus*	+		
Stubble Quail	*Coturnix pectoralis*		+	
Superb Fairy Wren	*Malurus cyaneus*	+	+	+
Welcome Swallow	*Hirundo neoxana*			+
Whiskered Tern	*Chlidonias hybridus*	+		
White-browed Babbler	*Pomatostomas superciliosus*			+
White-browed Scrubwren	*Sericornis frontalis*			+
White-fronted Chat	*Epthianura albifrons*	+		
Willie Wagtail	*Rhipidura leucophrys*	+		+

**PS** Paperbark swamp wetland, **P** pasture, **CF** Coastal foredune

Whilst not observed on either site visit, it is possible that the available habitat may support Brown Quail (*Coturnix ypsilophora*) (Vulnerable in SA) and Southern Emu-wren (*Stipiturus malachurus*) (Rare in SA).

Migratory Species
A range of petrels and albatrosses, pelagic feeders are expected to visit this coast periodically, staying mainly over the deep water, often following fishing vessels and larger ships and rarely making landfall. Australian Painted Snipe and White-bellied Sea-Eagles may also be occasional visitors.

Bird Species of Conservation Significance
The Biodiversity Plan for the South East of South Australia (DEHAA 1999) highlights a number of birds of conservation significance in the region (Table 4). Of these, the Orange-bellied Parrot, Southern Emu-Wren, Beautiful Firetail, and Hooded Plover are the only species that are recorded, or have any mapped or predicted habitat at Cape Jaffa or nearby. The Musk Duck (Rare in SA) was observed at the site even though habitat appears suboptimal. The "Vulnerable" Rufous Bristlebird was also observed in its preferred habitat of dense coastal heath.

Table 4 Threatened Bird Species with potential habitat at the site - from in the SE Biodiversity Plan

Species	Status A* & SA**	Distribution
Orange-bellied Parrot (*Neophema chrysogaster*)	A: Endangered SA: Endangered	Breeds in south-western Tas. Over-winters in southern Vic and SA (coastal SE, MM to Lake Alexandrina).
Southern Emu Wren (*Stipiturus malachurus*)	A: - SA: Vulnerable	Eastern, south-eastern from Qld, NSW, Tas, Vic, SA (SE, KI, EP, MLR) and south-western Australia.
Beautiful Firetail (*Stagonopleura bella*)	A: - SA: Vulnerable	South-eastern Australia from NSW, Vic. Tas, SA (SE, MLR, KI, Lower MM).
Hooded Plover (*Charadrius rubricollis*)	A: - SA: Vulnerable	Southern Australia from south-western WA, and ocean beaches of Vic, Tas, SA.

*A = Australian status under the Environment Protection and Biodiversity Conservation Act, 1999.

**SA = South Australian status under the Schedules 7,8,9 of the National Parks & Wildlife Act, 1972.

Orange-bellied Parrot – This species is listed as Endangered at both State and National level. The current total population is estimated at approximately 200 birds. They breed in south west Tasmania and migrate to the coastal salt marshes, samphire flats and dunes of south-eastern Australia over winter. Up to 70% of the entire population concentrates at three wintering sites around Port Phillip Bay and the Bellarine Peninsula in central southern Victoria. Carpenter Rocks (SW of Mount Gambier) is considered to be the most used site in South Australia, and Orange-bellied Parrots have been recorded at other locations along the South East coast (Orange-bellied Parrot Recovery Team 1998). In South Australia, 10 of the 15 important areas of habitat for the Orange-bellied Parrot identified by Gibbons (l984) are protected through a combination of reservation, heritage agreements, or planning regulations. Key feeding habitat in Victoria is considered to be sheltered coastal habitats (Higgins 1999), mainly low samphire herblands. Samphire habitats are also used in South Australia, though it is considered that birds also feed on the seeds of colonising strandline plants, especially sea rocket (Cakile maritima) on ocean beaches, dune frontages and adjacent dune systems and sheltered areas along rocky foreshores (Garnett and Crowley 2000, Higgins 1999). Two-horned sea-rocket grows in varying densities along the high water mark in the Cape Jaffa area and could be used by visiting Orange-bellied Parrots.

Southern Emu Wren - This species is found in tea-tree shrubland, sedgeland and heaths, much of which is grazed by stock that have fragmented the habitat. None were recorded on the site. A sedentary species, it is listed as vulnerable in South Australia. The main threats are habitat loss and predation by foxes and feral cats.

Beautiful Firetail – Found in coastal heath communities in Tasmania and south eastern Australia, Beautiful Firetails forage on or near the ground, feeding on grass seeds. Vulnerable in South Australia, a small group was observed in the paperbark swamp area at the western end of the site. The greatest threats are from wildfire, which could destroy small populations, and fox and cat predation.

Hooded Plover – Although this species has been removed from the federal Environment Protection and Biodiversity Conservation Act list, it is still considered vulnerable in South Australia. Population appears to be declining, and low breeding success is suspected. This species nests on beaches above the high water mark and its eggs and young are vulnerable to recreational activities such as off-road vehicles (Frith 1982). It has been observed in Bernouilli CR. Dogs, foxes and feral cats also pose threats to the Hooded Plover.

Musk Duck - This species is Rare in South Australia and usually associated with deep permanent lakes, swamps and dams, but is sighted occasionally at sea (Frith 1982). They have been recorded at Bernouilli Conservation Park, and were seen at the Cape Jaffa site in May, 2003 and September, 2004. Musk Duck usually nest in reed beds associated with permanent freshwater, none of which exist at this site.

Rufous Bristlebird – This is generally a shy, elusive species that inhabits dense coastal heath thickets. It is Vulnerable in South Australia but not listed in the South East Biodiversity Plan. Clearance of habitat is the major threat to this species. The linear coastal heath habitat is particularly susceptible to disturbance and fragmentation by development. Fox and feral cat predation is another serious threat, particularly near settlements (Hopton et al. 2003).

Other Flora and Fauna related questions

5.2.5 Detail the impact on land and native vegetation of the off-site depression of the watertable and outline the extent of groundwater depression and effect on farming and horticulture and other operations within the groundwater depression zone.

Extent of Groundwater Level Changes

The changes to groundwater levels in the vicinity of the development is discussed in detail in Section 5.2.3.

Effects of Watertable Depression on Land

The water regime of much of South Australia's South East has been significantly affected since the arrival of Europeans. The construction of a complex network of drains has dried out most of the former wetlands of the region. The State of the Environment Report for South Australia (1998) estimated that only 2% of pre-European wetlands now remain.

The South East has also undergone excessive clearance of deep rooted perennial native vegetation and replacement with shallow rooted annual crops and pasture, which has led to a significant increase in groundwater recharge rates. Consequently water tables have risen and this has caused problems such as dryland salinity and more saline higher volume surface flows. This scenario exists in the Upper South East and further inland. In the area immediately behind the foredunes south of Kingston, the seasonal inundation is a result more of poor drainage of surface water than rising watertable.

Extensive agriculture is the dominant land use in the area of potential groundwater level changes. The land is limited in its primary production capacity due to poor nutritional and structural characteristics of the soils and a propensity to inundation in low-lying areas. Other land uses in the region include forestry, viticulture, conservation and horticulture. Bernouilli Conservation Reserve is the densely vegetated area on the coast in the south west of Figure 5szadgf. There is an almond grove south of the Major Project Area, a number of wineries four kilometres south east, and pine forests approximately six kilometres south east.

The township area is predominantly residential. The caravan park provides tourist accommodation and the commercial activities (crayfish processors) are located immediately adjacent to the jetty.

East, west and immediately south of the site is generally low-lying and portions in the east and south are seasonally inundated.

To the south of the site, the land rises, increasing the depth below ground level to the watertable. In this area, the minor changes in groundwater elevation become progressively less further from the site.

The most significant effect of the reduced groundwater levels is expected to be the improved drainage in the seasonally inundated low-lying areas. As a result of periodic inundation or very shallow groundwater levels, some areas currently exhibit elevated groundwater salinity or elevated soil salinity. After the completion of the whole marina development, land currently subject to seasonal inundation within the groundwater depression zone is likely to be inundated less often, for a shorter period, or not at all. This may allow improved agricultural productivity and reduce soil salinity over time. In addition, low-lying areas within the groundwater depression zone will become more suitable for residential or commercial use.

Viticulture and forestry areas are well outside the zone of influence of the development and no effects are anticipated.

The horticultural activities are on the periphery of the zone of influence where water level changes are expected to be about 0.3 metres. This land is elevated (8-10 metres AHD) and the ground water level is generally less than 1.5 metres AHD, which corresponds to approximately 6.0 metres below ground level. Horticultural crops in these areas are generally shallow-rooted and unlikely to be dependant on the groundwater.

The potential impact on the urban activities at the Cape Jaffa settlement is expected to be minor, though poorly drained areas may benefit from reduced risk of inundation.

Potential Effects of Watertable Depression on Native Vegetation

In the Bernouilli Conservation Reserve, modelled groundwater level changes post-development are less than 0.4 metres. The modelled groundwater level changes in the vegetated coastal dunes are less than 0.2 metres west of the breakwaters and up to 0.4 metres east of the breakwaters.

The construction of the basins will result in the interception of the local groundwater flow to the coast. Within the waterways, groundwater will mix with the seawater that enters the marina via the channel through the coastal dunes. Salinity of the water in the basins will be approximately the same as seawater and there will be increased salinity of the groundwater beneath the coastal dunes.

The coastal dunes are of moderate relief (1-5 metres high and 40-60 metres wide) and are densely vegetated with a wide range of native species that are very well adapted to the coastal conditions.

The extent to which the native vegetation relies on groundwater for survival will determine what long-term effects there are likely to be. Beneath the coastal dune vegetation in Bernouilli CR and the foredunes at Cape Jaffa, depth from the ground surface to the water table, even with seasonal fluctuations of 0.5-1.0 metres is in excess of 2.0 metres, and it is unlikely that this vegetation would access the water table to survive. This vegetation type has adapted its water requirements well to surviving the salt-laden winds, high infiltration rate of the sands and the low natural rainfall, so it is not expected that there will be any effect on this coastal vegetation from either increased salinity or a lowering of the water table in this area.

The *Melaleuca halmaturorum* swamp is very reliant on a regime of flooding and drying for its survival. Populations of *M. halmaturorum*, found along the edge of wetlands, can live for 100 years. However, these populations are at risk from flooding if young seedlings are drowned. In studies at Bool Lagoon, it was found that recruitment of *M. halmaturorum* has been negatively affected by an increase in the permanence of the surface water (Denton and Ganf, 1994). Young seedlings are more likely to survive if the mature trees set and drop seed in spring as the water recedes. The young trees then have sufficient time to grow and establish themselves in the mud flats before the next winter rains. The removal of grazing animals also assists this recruitment process. The health of *M. halmaturorum* juveniles suffers where floods exceed six to nine weeks. Germination does occur, but seedlings fail to become established (Denton and Ganf, 1994).

Modelling suggests an overall depression after completion of the final stage of 0.6-0.8 metres from current levels in the area of the *M. halmaturorum* swamp.

Construction of waterways will take place over a number of stages, and it is expected that groundwater level changes will occur gradually over a ten to fifteen year period. The modelling used to estimate groundwater levels does not account for the seasonal fluctuations when winter rains recharge the shallow unconfined aquifer. These fluctuations are of the order of 0.5-1.0 metres.

The critical factor for the survival and regeneration of the *M. halmaturorum* is the period of seasonal inundation. Over recent years, depending on the amount of winter rainfall, the area east and north of the project site has standing water from about May to November. This is not expected to change significantly. It is possible that after completion of the final stage of the development (10-15 years), the draining of this area through the aquifer into the marina basin may bring drying on more quickly. This possible change may be offset through stormwater management involving a system of retention basins that will allow infiltration of stormwater into the groundwater and its redirection towards the swamp area.

Taking all these factors into account, it is not expected that the survival of the *M. halmaturorum* will be threatened. The removal of stock will aid regeneration. If any changes in vegetation structure do occur, it will be over an extended period and if seasonal drying of the swamp happens slightly more quickly than currently, conditions may favour the *Gahnia filum* (thatching grass). This successional shift is expected to have minimal effect on the habitat value of the swamp area.

As development progresses, the ground and surface water conditions in the swamp and surrounding areas will be monitored, and water regimes managed as required to ensure minimal effect on the native vegetation.

5.2.15 Outline the Effect of the Development on any Native Flora and Fauna, Including any Impact on Coastal and Marine Flora and Fauna

A. Coastal Native Vegetation

The most serious threats to the remnant native vegetation are from further fragmentation, exotic weed invasion and wildfire. The effect of potential changes in water table level is discussed in section 5.2.5.

Fragmentation

Construction of access tracks, either official or unofficial, and unauthorised clearing through and in high quality native vegetation allows access to weeds and garden escapes by facilitating seed dispersal and reducing competition for light and water. It is vital to maintain the integrity of the existing native vegetation and to restore any areas of degraded vegetation.

Exotic weed invasion

Some garden plants have the capacity to become environmental weeds because they adjust easily to low soil fertility, are prolific seed producers or are spread by birds, people or vehicles. At the western end of King Drive, bridal creeper, gazania spp., Marguerite daisy, soursob, black-eyed Susan and kikuyu grass have all invaded native vegetation. Golden cypress is also established in dense native vegetation near Cape Jaffa Road.

Lawn clippings disposed of inappropriately in the edges of native vegetation encourages the spread into native vegetation of grasses that reproduce vegetatively.

It is therefore appropriate that:

a. buffer zones be established to provide a separation between the vegetated dunes and residential allotments
b. dumping of garden refuse in native vegetation be prohibited
c. grass mowing extending into adjacent native vegetation encouraging the spread of Kikuyu, Couch and Buffalo grass be prohibited.

Wildfire

Unauthorised burning off and accidental fires all destroy habitat and can kill flora and fauna. Native flora and fauna are generally well adapted to fire and employ reproductive mechanisms that enable their survival. The vegetation on and around the site is not highly flammable and the risk if uncontrolled fire is very low.

The proposed 6.0 metre buffer zone between residential allotments and the coastal foredune vegetation will inhibit weed spread and reduce fire risk. A limited number of access tracks to the beach will be constructed and pedestrians prohibited access to the remaining areas. This will protect the overall health of the vegetation, minimise further weed spread and enhance the available habitats.

B. Coastal Native Fauna

With the increased population, there will inevitably come an increase in predatory pressure from domestic cats and dogs. These effects and possible habitat destruction through increased pressure from a variety of human activities are the main threats to native fauna.

Birds, Mammals, Reptiles and Amphibians

The proposal does not involve significant loss of habitat for terrestrial fauna resulting from native vegetation clearance. The main potential impacts to fauna are:

- fragmentation of available habitat by access tracks
- habitat degradation due to weed invasion, increased pedestrian use or fire
- increased predation by domestic dogs and domestic and feral cats

Although there are no terrestrial fauna of particular conservation significance thought to be present at the site, these impacts could reduce the diversity and abundance of those native mammal and reptile species that are present, particularly in the coastal dunes.

If the paperbark swamp area is fenced from stock grazing, the habitat quality for native fauna is likely to improve. However, this may be offset if there are significant changes to the water table as a result of its proximity to the planned marina channels.

The mitigation measures described to minimise impacts on native vegetation would also minimise impacts to fauna habitats. In addition, appropriate measures to mitigate impacts specific to fauna include:

- minimising the number and width of access paths through the dunes to minimise fragmentation effects
- installation of signage and fencing to prevent off-path access
- measures to ensure domestic dogs and cats are under control and do not access native vegetation areas.

A program to control foxes and feral cats in the region would be likely to have a beneficial impact on native fauna.

Migratory birds, including all the albatrosses and petrels may visit the area occasionally, but are unlikely to show any preference for this area over much of the rest of the South East coast. Many are unlikely to make landfall at all even if they are in the area. The proposed development is therefore unlikely to have any significant effect on any of these species.

The small numbers of orange-bellied parrots that may visit over the winter are unlikely to be affected by the slightly increased “people pressure” on 1-2 km of the South East coastline.

C. Marine Flora and Fauna (from SARDI 2004)

Construction Impacts

Impacts associated with the construction phase may be direct, such as habitat removal, or indirect such as turbidity. The major, although very localised, effect will be the direct loss of habitat from the breakwater and entrance channel. Both of these features will result in the removal or burial of approximately 3 ha of seagrass. This area is likely to be similar in extent to the area that has been lost around the current swing moorings, which will be removed and are expected to recolonise by *Amphibolis antarctica* rather than *Posidonia* sp., which can take several decades to recolonise.

The indirect impacts of construction include increased turbidity and sedimentation related to dredging, scouring of seagrasses around the breakwater and the potential propagation of ‘blowouts’ from the channel. Given the small volume of sediment to be excavated (4,000-5,000 m^3), the open well-flushed nature of the area, the short dredging duration (~2 weeks), and the relatively coarse sediments, it is very unlikely that increased turbidity will cause problems for the seagrasses in the vicinity. Construction sources of turbidity are expected be short-lived, with the seagrasses in the area likely to experience decreased light availability for less than 1 month in total.

Scouring of seagrasses around the base of the breakwater could occur if increased sand movement or suspended sediment concentrations occur in this region. Any direct increase in sediment concentrations will be short-lived, and are therefore unlikely to be significant. As part of the development, provisions will be made for bypassing sand around the breakwater.

The greatest concern associated with construction is the potential for the excavated entrance channel to form an erosion scarp that could then propagate away from the channel. ‘Blowouts’ are common along the southern Adelaide metropolitan coast, and form when wave energy erodes the sediment in a patch devoid of seagrass. There has been very little erosion around Maria Creek (Kingston boat ramp), where conditions are similar, and the same is expected at Cape Jaffa.

Runoff from the dredge spoil could potentially cause problems, through increasing turbidity or resuspension of contaminants. Using a series of settlement ponds for dewatering will ameliorate turbidity problems. These ponds will be located in the marina basin, isolated from the ocean during construction by a coffer dam. Low turbidity water will then be disposed of to sea. Given the relatively undeveloped nature of the site, it is unlikely that the sediments to be excavated will contain any significant levels of contamination. To ensure that this is the case, sediments will be sampled and tested for the main problem contaminants (heavy metals) prior to any dredging activity. Given the small volume, it is intended to dispose of all of spoil on land.

Operational Impacts

Impacts associated with the operational phase are related to groundwater/seawater interactions and the potential introduction of marine pest organisms.

There will be minimal inputs of groundwater into the marina, and any contaminants present will be heavily diluted and thus inconsequential. Thus, any water quality problems will be related to stormwater inputs, other discharges, or poor flushing of the marina basin. Stormwater will be diverted to a stormwater treatment facility, and so will not be an issue. Discharges from vessels will be minimised by providing the appropriate waste disposal facilities (for oil, bilge water, wastewater etc), and hardstands will be equipped with pollution traps. The flushing time of the marina is expected to be rapid (6-8 days), suggesting that water exchange will be sufficient to prevent serious water quality deterioration.

There are over 250 known introduced marine species in Australia. In terms of marine pests, the environmental impact of a coastal development such as a marina may be considered from three interrelated perspectives:

- introduction or enhancement of the distribution of a marine pest during construction
- provision of a large expanse of new habitat for colonisation by species that may not otherwise occur in the area due to dominance of seagrass
- ongoing potential for introduction of pest species from other infected areas through increased boating traffic

Disturbance created by construction of a marina is likely to favour opportunistic marine organisms. The only possible mitigation for this is to ensure that water quality is sufficient that local species are able to colonise, which appears likely to be the case at Cape Jaffa, although even then it is likely that the marina will soon support an assemblage of introduced species.

Pleasure craft are more likely vectors for marine pests than larger vessels, particularly for hull-fouling species. Fishing vessels can also be important agents for new introductions, particularly those that use easily contaminated bottom trawling or dredging gear. The risks will depend on the amount of traffic from other ports. Boats based in the marina which rarely travel to areas such as Port Adelaide and Port Phillip Bay are likely to be low risks, whereas visiting vessels from these ports will be higher risk. Similarly, local rock lobster vessels will be low risk, as they generally restrict their voyages to the southeast of South Australia. Visiting trawlers operating out on the shelf will be higher risk if they use the marina, which is unlikely.

5.2.16 Detail Measures to Protect Dunes and Beach During and After Construction, including Buffers

Construction vehicles, equipment and machinery will not traverse the beach or enter the dunes area at any time during construction. Necessary clearance of shrubs for beach access walkways will be undertaken using minimum disturbance methods and disturbance will be restricted to the width of the path only.

Construction of the canals will involve extensive excavation and spoil will be used to raise the land level for some of the residential allotments. During construction, the sandy spoil will be unstable in strong winds, especially where not protected by the vegetated foredunes (ie. >40m away). Spoil can be protected from wind erosion by sowing cereal rye with complete fertiliser after the opening rains of winter if necessary. Mulching of spoil may also be necessary to minimise dust nuisance from wind-blown sand.

A buffer zone of 6 metres will be maintained on the seaward side of the development adjacent to the coastal heath vegetation throughout the development. This buffer zone will not be used for vehicular traffic and will be maintained in a stable and weed-free state.

5.2.25 Visual Amenity and Landscape Quality

Inevitably the proposed development will change the visual amenity of the area with the construction of the marina and the development of up to 400 allotments. Much of this will be on the landward side of the foredune, emphasising the importance of maintaining the native vegetation on the dunes in good condition.

Currently, there are some amenity plantings along a 200 metre section of King Road just east of the township. However, some unsuitable species were planted with poor results. Further amenity plantings in accordance with a landscape plan will be undertaken using local provenance native plants that can tolerate high pH soils, low fertility, low moisture regimes and salt laden winds (see Appendix 2). Design guidelines for these plantings will take account of:

- Visual impact, both short and long term
- Ease of maintenance (ie. as sustainable as possible)
- Creation of litter
- Health and safety issues
- Habitat value for native birds

5.2.26 Potential for Exacerbation or Creation of Environmental Problems

Potential general environmental problems are weed spread, wind erosion and destruction of native vegetation. There is potential for a significant human impact on the native vegetation following the proposed development. For example, there is already a well-used track running through the middle of the dune that extends from the village to the existing public boat ramp. This track is currently used by walkers and cyclists, degrading the native vegetation and spreading weeds into the centre of the vegetated area. Through the development, access to this area will be restricted by fencing and signage to allow regeneration of native plants and habitat regeneration.

It is proposed to close the Cape Jaffa Road from the intersection with Limestone Coast Road and Rothalls Road, and the portion (500 metres) of King Drive from its eastern end to the existing township. There will be 27 allotments next to the foredune on the north side of King Drive.

To minimise the risk of garden plants escaping into the native vegetation from these allotments, a 6 metre buffer zone with a substantial impervious fence (eg. treated pine palings) will be established between the existing native vegetation and the northern boundary of the residential allotments to allow regular monitoring and maintenance. An all-weather access road (stabilised surface) will be provided to limit the movement of garden plant seed into the native vegetation and allow for maintenance.

Two 1.5 metre wide walkways are proposed to provide access across the foredune to the beach. These will be fenced and fitted with a board walkway to prevent erosion.

Currently there is trail bike and off-road vehicle activity along the beach. Pressure from such activities is likely to increase as allotments are taken up and the resident population increases. An integral part of the development involves the provision of vehicle access only to the beach north of the site. All commercial fishing activities currently using the beach will be relocated to within the marina.

Potential changes in water table levels are discussed in Sections 5.2.2-5.2.5

5.3.10 Describe the impact on local and regional land uses (eg viticulture, horticulture and other forms of primary production) from groundwater drawdown or contamination.

Extent of Groundwater Level Changes
The changes to groundwater levels in the vicinity of the development is discussed in detail in Sections 5.2.3 - 5.2.5.

Effects of Watertable Depression on Land Use
Extensive agriculture is the dominant land use in the area of potential groundwater level changes. The land is limited in its primary production capacity due to poor nutritional and structural characteristics of the soils and a propensity to inundation in low-lying areas. Other land uses in the region include forestry, viticulture, conservation and horticulture. Bernouilli Conservation Reserve is a densely vegetated area on the coast adjacent to the project area to the southeast. There is an almond grove south of the Major Project Area, a number of wineries four kilometres southeast, and pine forests approximately six kilometres southeast.

The township area is predominantly residential. The caravan park provides tourist accommodation and the commercial activities (crayfish processors) are located immediately adjacent to the jetty.

To the south of the site, the land rises, increasing the depth below ground level to the watertable. In this area, the minor changes in groundwater elevation become progressively less further from the site.

The most significant effect of the reduced groundwater levels is expected to be the improved drainage in the seasonally inundated low-lying areas. As a result of periodic inundation or very shallow groundwater levels, some areas currently exhibit elevated groundwater salinity or elevated soil salinity. After the completion of the whole marina development, land currently subject to seasonal inundation within the groundwater depression zone is likely to be inundated less often, for a shorter period, or not at all. This may allow improved agricultural productivity and reduce soil salinity over time. In addition, low-lying areas within the groundwater depression zone will become more suitable for residential or commercial use.

Viticulture and forestry areas are well outside the zone of influence of the development and no effects are anticipated.

The horticultural activities are on the periphery of the zone of influence where water level changes are expected to be about 0.3 metres. This land is elevated (8-10 metres AHD) and the ground water level is generally less than 1.5 metres AHD, which corresponds to approximately 6.0 metres below ground level. Horticultural crops in these areas are generally shallow-rooted and unlikely to be dependant on the groundwater.

The potential impact on the urban activities at the Cape Jaffa settlement is expected to be minor, though poorly drained areas may benefit from reduced risk of inundation.

As development progresses, the ground and surface water conditions in the swamp and surrounding areas will be monitored, and water regimes managed as required to ensure minimal effect on the native vegetation.

No significant effect on the dune vegetation is expected following the construction of the waterways as it is unlikely to be dependent on the groundwater.

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As part of the investigations, discussions were held with Malcolm Lankenau, pastoralist and previous owner of the project area.

Professionals consulted with regard to flora and fauna investigations:

- Bates, R. – Botanist (orchids), State Herbarium, Department for Environment and Heritage.
- Croft, T. - Biodiversity Assessment Services, Dept Water, Land and Biodiversity Conservation.
- DeJong, M. – Ornithologist, Dept of Water, Land & Biodiversity Conservation.
- Green, R. – Ornithologist, OBP winter count contributor, Mt Gambier.
- Haywood, B. - SA Orange-Bellied Parrot Working Group, Department for Env. & Heritage.

- Hutchinson, M. – Curator, Reptiles, South Australian Museum.
- Matheson, W. – Landcare consultant.
- Milne, S. - Herpetologist, Ecos Consulting.
- Natt, V. – Ornithologist, OBP winter count contributor, Kingston SE.
- Reardon, T. – Curator, Bats, SA Museum.
- Squire, E. – Biodiversity Assessment Services, Dept Water, Land and Biodiversity Conservation.
- Stark, J. – Birds Australia, OBP winter count coordinator

APPENDIX 12

Cape Jaffa Anchorage Development Proposal Preliminary Biodiversity Assessment, RMP Environmental Pty Ltd, Playfair R, September 2004

RMP Environmental Pty Ltd
PO Box 2 Daw Park SA 5041 Tel/Fax (08) 8276 9011 rmp@internode.on.net

CAPE JAFFA ANCHORAGE DEVELOPMENT PROPOSAL

PRELIMINARY BIODIVERSITY ASSESSMENT

SEPTEMBER 22, 2004

Prepared by R. Playfair

TABLE OF CONTENTS

INTRODUCTION

There are certain situations under which the provisions of the Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act) can be triggered by development proposals. These are when a development will, or is likely to have a significant effect on:

1. World Heritage areas (not relevant to this proposal)
2. Ramsar Wetland areas (not relevant to this proposal)
3. threatened species and communities
4. listed migratory species
5. Commonwealth marine areas (not relevant to this proposal)
6. nuclear actions (not relevant to this proposal)

In order to minimise duplication in processes, it is necessary to ascertain right at the beginning if the EPBC Act will be triggered or not. Due to the lack of a bilateral agreement between Federal and South Australian Governments, the extent of "dovetailing" between State and Federal environmental impact assessment processes is not yet finalised.

If an intensive biological survey discovers a threatened species during a later phase of the EIS under South Australian legislation, the EPBC Act may be triggered, requiring a separate EIS under that Legislation, leading to unnecessary duplication of assessment processes, along with added administrative and time overheads.

To avoid any duplication of processes, the two questions this initial work needs to answer are:

- Are there (or are there likely to be) any listed species or migratory species in the area of the development?
- If so, will the development have a "significant impact" on them?

This scoping study aims to collect sufficient background information to make an informed judgement about whether any listed threatened or migratory species depend on the development site for habitat critical to their survival.

This brief report aims to identify the availability of habitat for, or presence of, any species listed in the EPBC Act Schedules.

With reference to the preliminary investigations by Matheson, 2003 and interrogation of the EPBC Act on-line database, the following species were investigated for the potential of being affected by the proposal:

Threatened species

Amphibians

Litoria raniformis Southern Bell Frog, Growling Grass Frog – Vulnerable

Birds

Albatrosses and Petrels

Diomedea amsterdamensis Amsterdam Albatross – Endangered
Diomedea dabbenena Tristan Albatross – Endangered
Diomedea epomophora Southern Royal Albatross – Vulnerable
Diomedea exulans Wandering Albatross – Vulnerable
Diomedea gibsoni Gibson's Albatross – Vulnerable
Diomedea sanfordi Northern Royal Albatross – Endangered
Thalassarche bulleri Buller's Albatross – Vulnerable
Thalassarche cauta Shy Albatross – Vulnerable
Thalassarche chrysostoma Grey-headed Albatross – Vulnerable
Thalassarche impavida Campbell Albatross – Vulnerable
Thalassarche salvini Salvin's Albatross – Vulnerable
Halobaena caerulea Blue Petrel – Vulnerable
Macronectes giganteus Southern Giant-Petrel – Endangered
Macronectes halli Northern Giant-Petrel – Vulnerable
Pterodroma mollis Soft-plumaged Petrel – Vulnerable

Terrestrial Birds

Leipoa ocellata Malleefowl – Vulnerable
Neophema chrysogaster Orange-bellied Parrot – Endangered
Rostratula australis Australian Painted Snipe – Vulnerable
Lathamus discolor Swift Parrot – Endangered

Mammals

Bats

Miniopterus schreibersii bassanii Southern Bent-wing Bat – Conservation Dependent

Cetaceans (Whales)

Balaenoptera musculus Blue Whale – Endangered
Eubalaena australis Southern Right Whale – Endangered
Megaptera novaeangliae Humpback Whale – Vulnerable

Sharks

Carcharodon carcharias Great White Shark – Vulnerable

Plants

Pterostylis cucullata Leafy Greenhood – Vulnerable
Thelymitra epipactoides Metallic Sun-orchid – Endangered

Threatened Ecological Communities

In the proposed project area, there are no listed threatened ecological communities (Appendix A).

Terrestrial species covered by migratory provisions of the EPBC Act, 1999

Haliaeetus leucogaster White-bellied Sea-Eagle
Hirundapus caudacutus White-throated Needletail
Leipoa ocellata Malleefowl
Neophema chrysogaster Orange-bellied Parrot

Wetland species covered by migratory provisions of the EPBC Act, 1999

Gallinago hardwickii Latham's Snipe, Japanese Snipe
Rostratula benghalensis Painted Snipe
Arenaria interpres Ruddy Turnstone
Pluvialis fulva Pacific Golden Plover

Marine species covered by migratory provisions of the EPBC Act, 1999

Diomedea amsterdamensis Amsterdam Albatross
Diomedea dabbenena Tristan Albatross
Diomedea epomophora Southern Royal Albatross
Diomedea exulans Wandering Albatross
Diomedea gibsoni Gibson's Albatross
Diomedea sanfordi Northern Royal Albatross
Thalassarche bulleri Buller's Albatross
Thalassarche cauta Shy Albatross
Thalassarche chrysostoma Grey-headed Albatross
Thalassarche impavida Campbell Albatross
Thalassarche melanophris Black-browed Albatross
Thalassarche salvini Salvin's Albatross
Macronectes giganteus Southern Giant-Petrel
Macronectes halli Northern Giant-Petrel

Information collection processes

The information collection task comprises the following activities:

- Preliminary site investigation by Matheson, 2003
- Literature search through scientific research and historical data for relevant flora and fauna information,
- Access State Herbarium, SA Museum and SA Environmental Database for relevant flora and fauna records,
- Interview professionals with the high levels of knowledge of species under consideration,
- Directed search on site for presence of habitat and quality assessment.

SITE DESCRIPTION

The proposed project site is on the coast of Lacepede Bay (Figures 1 & 2), approximately 20 km southwest of the township of Kingston in the South East of South Australia, bounded to west and east by 382000 and 384000 respectively and south and north by 5910000 and 5912000 respectively (AMG Zone 54, GDA96).

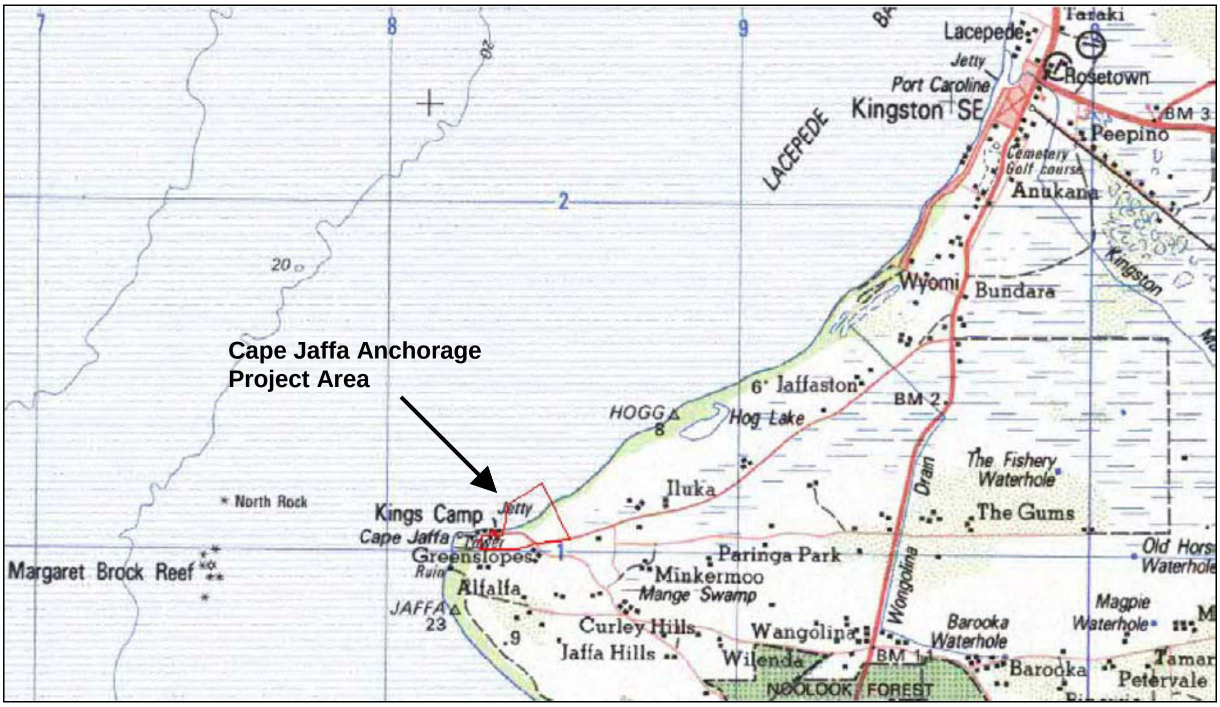

Figure 1 1:250,000 Topographic Map Extract (Source: Department for Environment, Heritage and Aboriginal Affairs, 1999)

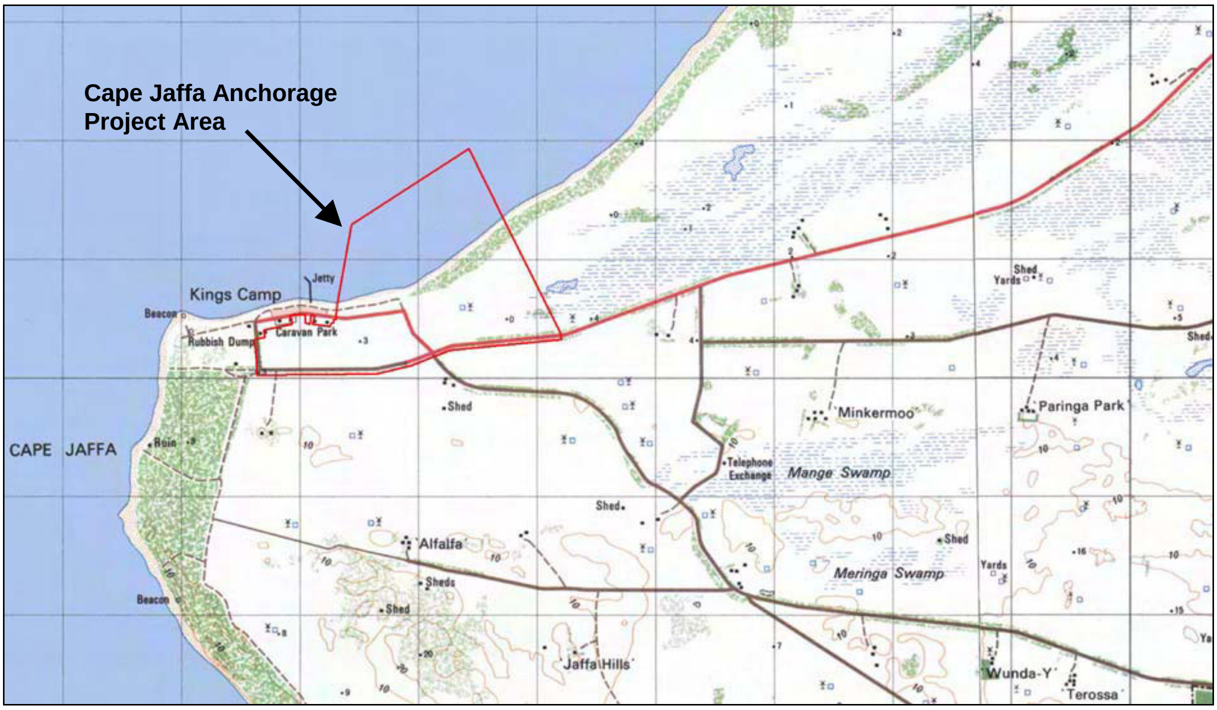

Figure 2 1:50,000 Topographic Map Extract (Source: Department for Environment, Heritage and Aboriginal Affairs, 1999)

AVAILABLE HABITATS

On this site there are three generalised habitat/vegetation types:

- Foredune heath (A) in three discrete patches between the beach and the development area. A narrow strip of this habitat type also lines the access road on the southern boundary of the site
- Paperbark Swamp (B) in one small area in south east corner of the site
- Open Pasture (C) covering the majority of the site

The extent of the proposed project area and areas covered by these habitat types are shown on Figure 3.

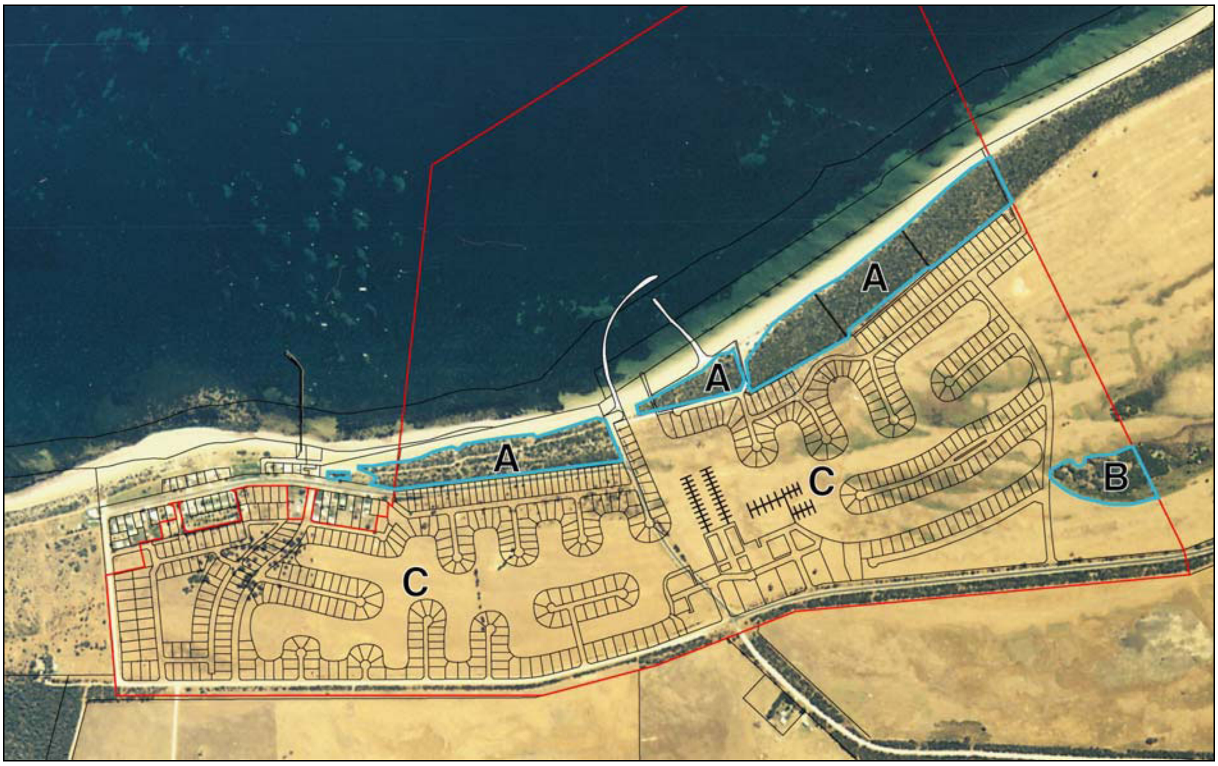

Figure 3 Extent of habitat types in relation to project area. Total project area is enclosd by red line. Habitat types A and B enclosed by bue lines.

Foredune heath (A)

Between the beach and the proposed anchorage basin there are some narrow strips of coastal vegetation that still remains on the foredune. These areas are quite dense shrubland dominated by *Leucopogon parviflorus* (coast beard heath), *Acacia longifolia* var. *sophorae* (coastal wattle), *Olearia axillaris* (coast daisy bush) over a ground layer consisting of *Isolepis nodosa* (knobby club rush), *Carpobrotis rossii* (pigface), *Lepidosperma gladiatum* (coast sword sedge) and *Tetragonia implexicoma* (brown spinach). Exotic grasses are common around the edges particularly in the smaller (western) patch and there are serious infestations of *Myrsiphyllum asparagoides* (bridal creeper) in both areas. Open areas are dominated by *Euphorbia paralias* (sea spurge) and *Euphorbia terracina* (false caper). A very narrow strip of degraded coastal heath habitat type also runs along the access road on the southern boundary of the site.

Bernouilli Conservation Reserve, to the south west of the development site is a reasonably well-preserved example of this vegetation type.

Photo 1 Western patch of coastal heath looking from King Drive. Note the exotic grasses and onion weed on the edge of the tall shrubland.

Photo 2 Inland edge of coastal heath. The larger patch to the east is very dense and bridal creeper infestation mainly around edges.

Paperbark Swamp (B)

A very small area of Paperbark Swamp exists in the south eastern corner of the site. This area is only inundated during the winter when the rainfall fills the soil profile and a temporary swamp is created. This creates an area of quite low biodiversity because many understorey plants do not tolerate swamp conditions. The fringes of this area are dominated by *Gahnia filum* (chaffy saw sedge) and *Samolus repens* (creeping brookweed) and *Tetragonia implexicoma* (brown spinach), and the central part consists of *Melaleuca halmaturorum* (swamp paperbark) over mainly bare ground or shallow water (in winter). Pasture grasses also form a dense sward where the pasture meets the swamp.

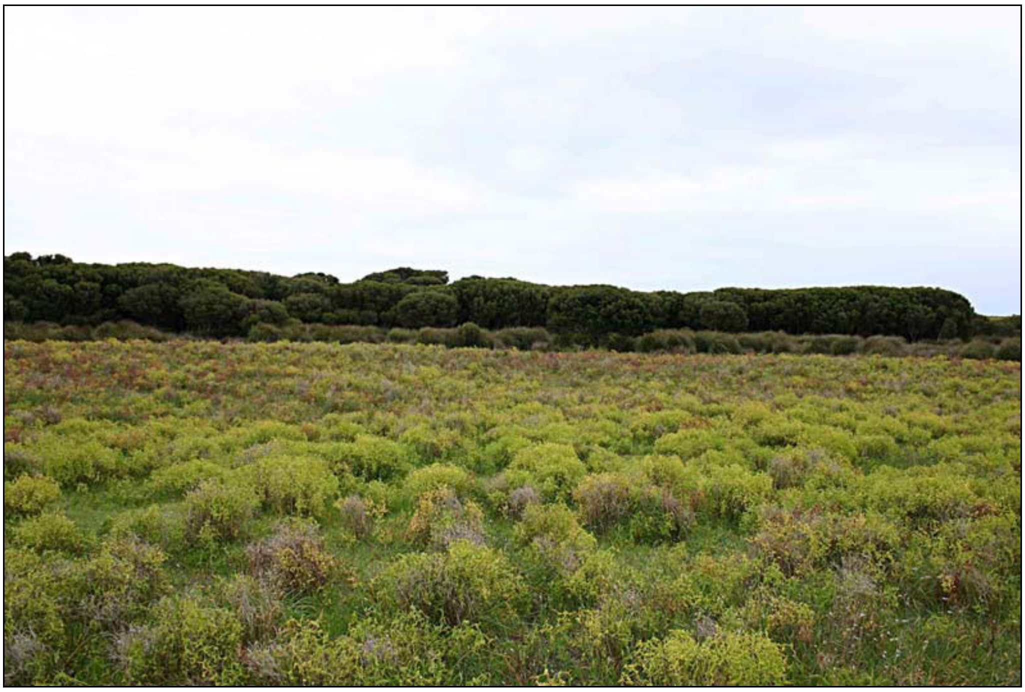

Photo 3 Swamp paperbark area with the fringe of chaffy saw sedge. Pasture habitat type in foreground.

Photo 4 Swamp paperbark area with some standing water and chaffy saw sedge in midground.

Open pasture (C)

Taking up approximately 90% of the site area is an open pasture vegetation type. Historically grazed and "improved by the use of pasture seed and fertiliser application. Dominated by exotic grasses, *Euphorbia terracina* (false caper) with some patches of *Marrubium vulgare* (horehound), this area is not used by most native fauna species due to its domination by exotic plants, often not attractive to them for breeding or feeding, and the low open nature provides little protection from predators.

Photo 5 Open pasture with very dense infestation of false caper.

Photo 6 Open pasture with moderate infestation of false caper.

SPECIES OF POSSIBLE CONCERN

AMPHIBIANS OF POSSIBLE CONCERN

Litoria raniformis (Southern Bell Frog) - Vulnerable

DESCRIPTION

Small to medium frog to 80 mm long, with dull olive to bright emerald green and large irregular patches of brown or golden-bronze above (Cogger, 2000).

DISTRIBUTION

In South Australia, the Southern Bell Frog is found along the River Murray and in the south-east of the State. It has also been recorded in the Adelaide Hills, although it is thought that this population may have been introduced (Tyler 1978). There are some records of the species from the lower River Murray and swamps adjacent Lake Alexandrina (Robinson *et al.* 2000, EPA 2002), but from Lake Albert and the Coorong. Eckert (2000) reports that it was known in the redgum swamps near Mosquito Creek (northern edge of Lake Alexandrina) and Langhorne Creek in the 1960s, and that it was abundant in reeds in Tolderol Game Reserve (northern edge of Lake Alexandrina) in early 1999. Currently (winter 2004), populations at Bool Lagoon are responding extremely well to the long wet winter and large amounts of standing water, and have reached levels far exceeding any recent records (pers comm. S. Milne, M. Hutchinson, 2004).

PREFERRED HABITAT

The habitat requirements of the Southern Bell Frog are not fully understood. It is most commonly found in or near permanent water bodies with dense fringing vegetation (Cogger 2000) and it is likely that it requires permanent or semi-permanent still waterbodies for reproduction (Robertson 2000).

The closely related Green and Golden Bell Frog (*Litoria aurea*) is thought to have very similar biology to the Southern Bell Frog (Pyke 2002). Studies of this species have reported that breeding is almost completely restricted to still, relatively unshaded waterbodies of low salinity (Pyke *et al.* 2002). Breeding ponds are generally small ($<1000m^2$) and shallow (<1m deep). Significant predictors for the presence of *L. aurea* include diversity of vegetation on the banks of waterbodies, presence of emergent vegetation and potential shelter provided by nearby rocks or thick, low vegetation (Hamer *et al.* 2002, Pyke *et al.* 2002). All of its known breeding sites are highly disturbed, either from human activities or flooding and other natural processes (Pyke et al. 2002).

Tadpoles of *L. aurea* can tolerate salinities of up to 4% seawater (1580 ppm) without apparent effect (Christy & Dickman 2002). Although salinities of 10-15% can be tolerated for up to three weeks before resulting in significant weight loss and eventual death, exposure to salinity above 5.5% seawater decreases growth rates, increases mortality and apparently prevents metamorphosis.

AVAILABLE HABITAT

The habitat present or nearby is not suitable for the Southern Bell Frog. There are no areas of still fresh water either on the development site or nearby.

DISCUSSION

The lack of suitable habitat for the Southern Bell Frog suggests that it is extremely unlikely to be present at this site and would not be impacted by the development.

PLANTS OF POSSIBLE CONCERN

Pterostylis cucullata (Leafy Greenhood) - Vulnerable

DESCRIPTION

The Leafy Greenhood (*Pterostylis cucullata*) is a ground-dwelling orchid. It produces a single flower that emerges from a bright green basal rosette comprising 5-7 oblong to elliptical leaves. Taxonomically still undescribed, there are thought to be two distinct forms, a tall inland hills form and a shorter coastal form (pers.comm. R. Bates).

DISTRIBUTION

Only five South Australian Herbarium records exist, all from the Mount Lofty Ranges and all probably the taller hills form (Appendix F). The shorter coastal form of *Pterostylis cucullata* is thought to be extinct in South Australia. Directed searches in coastal heath vegetation on the South East coast in recent years have been unsuccessful (pers.comm. R. Bates).

PREFERRED HABITAT

In the South East of South Australia, *P. cucullata* may be found growing in intact, ungrazed areas of open or closed coastal heath vegetation. It is very sensitive to disturbance, particularly by grazing animals.

AVAILABLE HABITAT

The parts of this site that potentially may have originally supported populations of *P. cucullata* are now either cleared of heathy vegetation, or have sustained some level of grazing pressure since European settlement.

THREATS

Grazing pressure and invasion by competitive exotic species are the main threats.

Thelymitra epipactoides (Metallic sun-orchid) - Endangered

DESCRIPTION

A robust herb to 60 cm high with distinctive iridescent grey-green flowers, that regenerates exclusively from seed (Jessop & Toelken 1986).

DISTRIBUTION

T. epipactoides is confined to south-eastern South Australia, lower Eyre Peninsula and south-western Victoria (Calder *et al.* 1989, Bates & Weber 1990). There have been 11 records of *T. epipactoides* in the South East region since 1963 mostly from Conservation Parks or Heritage Agreement areas inland from the coast (Appendix F).

PREFERRED HABITAT

In Victoria, *T. epipactoides* most commonly grows in sandy heaths and heathy woodlands, particularly open heathlands close to the coast (Calder *et al.* 1989). It occurs singly or in clumps mainly in fertile loams in scrubby heath (Bates & Weber 1990). *T. epipactoides* tends to prefer slightly acid sandy duplex soils (pH 5.6-7.5) and can tolerate some waterlogging during winter. There is a suggestion that *T. epipactoides* may favour disturbed habitats (particularly recently burnt) because of its frequent association with weed species and bare ground. This conflicts with other observations that existing populations are isolated remnants that survive in areas that retain near-natural plant communities (Calder *et al.* 1989). Records in South Australia over the last 40 years suggest that the less disturbed areas might be more favourable.

T. epipactoides appears to be highly palatable because stock grazing has adverse effects and it is well adapted to fire. Recommended management for the stimulation of *T. epipactoides* involves autumn fire to control overshrub density and removal of stock grazing pressure (Calder *et al.* 1989). An intensive search was undertaken in Messent Conservation Park (100 km north, inland from Salt Creek), where there have been historical records of *T. epipactoides* in October 2002 after a fire earlier that year. None were found, even though conditions and timing of the survey were thought to be optimal (E Squire pers. comm. 2002)

AVAILABLE HABITAT

Heavy and continuous long-term grazing and the historical clearance of native vegetation from the majority of the site has removed the entire original overstorey and replaced it with exotic grasses and weeds. Soil at this site is sand, and the heath that remains in a strip along the foredune is probably too dense to provide appropriate conditions to support a population of *T. epipactoides*.

THREATS

Stock grazing and destruction of heathlands through clearance for agricultural production are the main threats.

DISCUSSION

The available habitat for either of these species on the proposed site or the immediately adjacent areas is of dubious quality and is unlikely to be able to support populations of these plants.

The proposed development involves the excision of the coastal heath from the development and its ongoing management as a conservation and regeneration zone with people being excluded.

Given these environmental conditions, it is extremely unlikely that any development on this site will have a significant effect on any of the EPBC Act-listed plant species.

MAMMALS OF POSSIBLE CONCERN

BATS

Miniopterus shreibersii bassani Southern Bent-wing Bat – Conservation Dependant

DESCRIPTION

A small native bat, 13-17g in weight, blackish to reddish brown above and paler beneath, with a short muzzle and high crowned head.

DISTRIBUTION

South Australian distribution of this species is restricted to the near coastal South East. The "Bat Cave" at Naracoorte is the larger of only two known breeding sites for the Southern Bent-wing Bat (*Miniopterus schreibersii bassanii*) in southeastern Australia (the other being in western Victoria). Recent scientific evidence estimates the Naracoorte Bent-wing Bat population size at less than 50,000, and comparison with previous counts suggests numbers may be declining (pers. comm. T. Reardon, 2004).

PREFERRED HABITAT

Each night the bats leave their cave roosts and forage in forested areas for flying insects. They are capable of fast and level flying that is interrupted by quick, shallow dives to gather prey. Typically they forage in woodlands and can travel quite large distances during a night of feeding (pers. comm. T. Reardon, 2004).

THREATS

The major threat is degradation of nursery caves, loss of foraging habitat through native vegetation clearance, changing climatic conditions, human disturbance and the use of chemicals (pers. comm. T. Reardon, 2004).

AVAILABLE HABITAT

No appropriate habitat is available at the site for roosting, but individuals that roost in coastal caves near Robe or even from as far away as Naracoorte may visit the area at night.

DISCUSSION

Given the lack of habitat suitable for roosting, the proximity to residential areas that are havens for predators, and the low likelihood that the species will use the area for foraging, it is thought that the proposed development will have no effect on the population of this species.

CETACEANS (WHALES)

Balaenoptera musculus Blue Whale – Endangered

DISTRIBUTION

Distribution is oceanic and worldwide with extensive migrations between warm water (low latitude) breeding and cold water (high latitude) feeding grounds. Blue whale sightings have been recorded from all Australian states. Migration paths are widespread, not obviously following coastlines or oceanographic features. Exact breeding ground locations are unknown.

Southern hemisphere populations of 'true' blues drastically reduced through twentieth century overfishing, mainly in the Antarctic. Initial southern hemisphere population was estimated at 160,000–240,000, including 10,000 pygmy blues. Current population may be <1000 'true' blues, with some 6000 pygmy blues. Recent Antarctic surveys have found little or no evidence of increase in 'true' blue numbers since total protection in 1965 (Environment Australia, 1996).

Eubalaena australis Southern Right Whale – Endangered

DISTRIBUTION

The population using Australian coast is thought to number 600–800, though with three-year calving cycle and probably irregular movements of large proportion of the population (males, non-calving females, juveniles) only a percentage visits each year. Tendency for animals to remain close inshore for long periods can lead to repeat sightings and false belief that species is relatively common. As with all southern hemisphere right whales, gross exploitation, both shore-based and pelagic, particularly in the early 1800s, reduced numbers off Australia considerably. An increase has been observed off southern Western Australian coast since 1977, of some 10% per year. Off South Africa and South America, annual increases of about 7% have been observed. Numbers at the Head of Bight are fairly consistent from year to year (Environment Australia, 1996).

Megaptera novaeangliae Humpback Whale – Vulnerable

DISTRIBUTION

Distribution is worldwide, Antarctic pelagic in summer; temperate–subtropical/tropical coastal in winter. In winter and spring, sightings have been recorded from all states except Northern Territory. Annual migrations occur between the warm water breeding grounds (latitude 15–20°S), and summer colder water (Antarctic) feeding grounds (to 60–70°S). Northern and southern hemisphere populations are distinct, given temporal migration separation. There are at least six southern hemisphere populations. Off Australia, wintering animals are observed off both west and east coasts. Animals are sometimes seen in the eastern Great Australian Bight in early winter (Head of Bight and near Kangaroo Island).

As with all other humpback populations, numbers have been greatly reduced by commercial exploitation. Most recently since 1949, with whaling on the two Australian populations both from the coast and in the Antarctic, resulting in reduction to 5–6% of initial size by 1963. Despite international protection since then, recovery seems to have been delayed until mid-1970s, possibly mainly through continued illegal catches until about 1970 (Environment Australia, 1996).

THREATS

Direct disturbance is possible on migration path and in breeding/calving areas from:

- seismic operations
- collision with large vessels
- entanglement in fishing gear
- defence operations
- pollution, including increasing amounts of plastic debris at sea, oil spills and dumping of industrial wastes into waterways and the sea (Environment Australia, 1996).

DISCUSSION

Whilst some individuals may occasionally pass by in the relatively shallow waters off the development site during migration, they do not congregate in the area. The type of development proposed is very unlikely to increase the existing threats to any of these species significantly.

SHARKS OF POSSIBLE CONCERN

Carcharodon carcharias Great White Shark - Vulnerable

DESCRIPTION

Great white sharks have a moderately stout, torpedo-shaped body, are grey to grey-brown on the upper surface, white below; and have large serrated triangular teeth, a distinctive lateral keel along the body midline immediately before a crescent shaped tail. White sharks grow to at least six metres in length (NSW Fisheries, 1997; Last & Stevens, 1994).

DISTRIBUTION

The white shark is found throughout the world in temperate and subtropical oceans, with a preference for temperate waters (Environment Australia, 1996). The white shark is most frequently encountered off South Africa, southern Australia, northern California and the northeastern United States (Last & Stevens, 1994). In Australia, its range extends primarily from Moreton Bay in Southern Queensland, around the southern coastline to the North West Cape of Western Australia (Bruce, 1995).

PREFERRED HABITAT

White Sharks are uncommon but there are areas in Australian waters where encounters appear to be more frequent. These include waters in and around seal and sea lion colonies. White Sharks are normally found in inshore waters in the vicinity of rocky reefs and islands. They have been caught at varying depths to 1280m.

White Sharks of all sizes occur throughout their Australian range. However, there is a tendency for juveniles to occur in different areas from subadults and adults. Juveniles are most commonly encountered in inshore areas, often in the vicinity of the open coast beaches. The Great Australian Bight, Victor Harbour Coorong region (South Australia), areas off Portland and Ninety Mile Beach (Vic), Garie beach – Wattamolla and Port Stephens – Newcastle (New South Wales) and some areas off southern Queensland appear to be seasonally important for juvenile White Sharks (Bruce *et al.,* 2001). The areas where juveniles are mostly found are most likely pupping grounds (Environment Australia, 2002).

THREATS

Due to the transient feeding and breeding behaviour of white sharks, and their apparent ability to use a wide range of habitats, the destruction of marine habitats is not a serious concern for their survival. White sharks have few predators, and whilst not targeted by commercial or recreational fishers, they are sometimes caught as bycatch on long-lines, in nets and in aquaculture cages such as tuna farms. This is currently suspected to be the largest cause of mortality.

Shark control activities in parts of Australia include beach-meshing and drumlines, which usually kill the captured shark. These devices are not used in South Australia. Tourism does not pose a direct threat to white sharks but indirectly may limit the recovery of the population by altering their behaviour.

White sharks are particularly vulnerable to increased mortality due to their life history strategy. White sharks are naturally low in abundance, long-lived and have relatively low natural mortality. This means that white shark populations are poorly adapted to withstand increases in mortality from non-natural sources and, because of their low reproductive potential, would recover slowly if reduced in abundance (Environment Australia, 2002).

AVAILABLE HABITAT

It is possible that white sharks may occasionally visit the shallow water off the ocean beachs at Cape Jaffa.

DISCUSSION

Given the low probability that white sharks will be found in the waters near the proposed anchorage development, and the low level of human marine activities in these waters, it is unlikely that the development will have any significant impact on the white shark population.

BIRDS OF POSSIBLE CONCERN

ALBATROSSES AND PETRELS

Diomedea amsterdamensis **Amsterdam Albatross – Endangered (not in SA)**

Diomedea dabbenena **Tristan Albatross – Endangered (not in SA)**

Diomedea epomophora **Southern Royal Albatross - Vulnerable**

Diomedea exulans **Wandering Albatross - Vulnerable**

Diomedea gibsoni **Gibson's Albatross – Vulnerable (not in SA)**

Diomedea sanfordi **Northern Royal Albatross - Endangered**

Thalassarche bulleri **Buller's Albatross - Vulnerable**

Thalassarche cauta **Shy Albatross - Vulnerable**

Thalassarche chrysostoma **Grey-headed Albatross - Vulnerable**

Thalassarche impavida **Campbell Albatross – Vulnerable (not in SA)**

Thalassarche salvini **Salvin's Albatross – Vulnerable (not in SA)**

Halobaena caerulea **Blue Petrel - Vulnerable**

Macronectes giganteus **Southern Giant-Petrel - Endangered**

Macronectes halli **Northern Giant-Petrel - Vulnerable**

Pterodroma mollis **Soft-plumaged Petrel – Vulnerable (occasional visitor)**

DISTRIBUTION

Of these species suggested by the EPBC on-line database to be of potential concern in the area of the proposed development, five are not recorded in South Australia and one, the soft-plumaged petrel, is considered only an occasional visitor and not part of South Australia's established fauna (Robinson *et al*. 2000). All of these species are pelargic migratory birds that nest in the sub-Antarctic and undertake long flights roaming the southern oceans feeding, commonly following fishing boats for days. Birds are often seen scavenging scraps from fishing boats, but squid and fish are their preferred food. Galley refuse and floating waste also form part of their diet. They spend most of their life in flight, landing only to breed and feed (Marchant & Higgins 1993).

PREFERRED HABITAT

Oceanic deep water.

THREATS

The biggest threat is the interaction with fishing operations, particularly longlines. Albatross are common ship followers and strike at the baited hooks as they are being set and subsequently drowning. Albatross are slow to mature (some species take up to ten years before breeding) and they have a very low reproductive output of a single egg every one or two years, depending upon species. This means that even a slight increase in mortality may have serious consequences for the survival of a population.

DISCUSSION

Given the very rare appearance in the region of most of these species, and their preference to remain over deep water in flight for most of the time, it is very unlikely that any of the activities associated with the anchorage development will affect populations of any of these species.

TERRESTRIAL BIRDS

Leipoa ocellata (Malleefowl) - Vulnerable

DESCRIPTION

A large, quiet-moving native fowl (Pizzey and Knight 1997), with intricately barred plumage of subdued colours and a body length of approximately 60cm.

DISTRIBUTION

Fragmented occurrence in primarily mallee woodlands of Australia's temperate zone (Marchant & Higgins 1993, Pizzey & Knight 1997, Garnett & Crowley 2000).

PREFERRED HABITAT

Prefer long unburnt eucalypt mallee woodlands, or similar growth form semi-arid dry scrub and woodlands on sandy or loamy soils (Marchant & Higgins 1993, Garnett & Crowley 2000) or sandy and gravel soils (Pizzey & Knight 1997). They prefer mallee woodlands with a dense but discontinuous canopy layer to provide leaf litter, and a densely distributed variety of food shrubs and herbs, with some open ground to ease movement (Marchant and Higgins 1993, Pizzey & Knight 1997, Garnett & Crowley 2000) and occupy a 40-70ha home range (Schodde & Tidemann 1990). Birds are primarily graminivorous and favoured food plants include seed-producers Acacia, Senna and Beyeria, but invertebrates and herbaceous material also form part of diet (Marchant & Higgins 1993). Malleefowl do not normally breed in mallee within 20 years of being burnt (Marchant & Higgins 1993), and it has been reported that optimum fire frequency is likely to be every 60 years or more (Garnett & Crowley 2000).

THREATS

Clearance for agriculture has caused habitat fragmentation, and populations are forced to exist in sub-optimal habitats where they are susceptible to predation, fire and herbivore competition (Garnett & Crowley 2000).

AVAILABLE HABITAT

No mallee vegetation exists at the site. It is also isolated from any large patches of good quality mallee vegetation in the region that may support these birds. Despite the presence of possible food plants (acacias), the area is not considered suitable for Malleefowl.

Neophema chrysogaster Orange-bellied Parrot – Endangered

DESCRIPTION

A small slim 'grass parrot' with rich green upper and bright yellow lower plumage, and a distinctive orange patch surrounding the belly which gives rise to its name (Higgins 1997, Orange-bellied Parrot Recovery Team 1998, Pizzey & Knight 1997). Body size ranges from 22-25cm (Higgins 1997, Pizzey & Knight 1997) with a wingspan of about 31cm (Higgins 1997).

DISTRIBUTION

The Orange-bellied Parrot has a single breeding population of less than 200 mature adults in the wild, has steadily declined in abundance, and its range has contracted markedly since the 1920s, with all individuals now being in a single sub-population (Orange-bellied Parrot Recovery Team 1998).

Orange-bellied Parrots breed in Tasmania and migrate to the Australian mainland during winter (March to September). They were formerly widespread and abundant in central and southern parts of Tasmania and on the mainland in coastal areas from Yorke Peninsula in SA to Sydney in NSW (Higgins 1997, Orange-bellied Parrot Recovery Team 1998). Mainland range has reduced significantly, though individuals do move as far west as Lake Alexandina in SA and east to Gippsland in Victoria (Garnett and Crowley 2000, Higgins 1997). Up to 70% of the entire population concentrates at three wintering sites around Port Phillip Bay and the Bellarine Peninsula in central southern Victoria. Carpenter Rocks (SW of Mount Gambier) is considered to be the most used site in

South Australia, and it has been recorded at other locations along the South East coast at Canunda National Park, Lake Bonney, Bernouilli Conservation Reserve, Nora Creina, Robe, Butchers Gap, Blackford Drain, Woods Well, Magrath Flat and Lake Alexandrina. In South Australia, birds tend to spend less time and form smaller flocks than in the key sites around Port Phillip Bay (Orange-bellied Parrot Recovery Team 1998). Along the South Australian coast they are usually seen in groups of two or three, often in association with other *Neophema* spp. parrots. Anecdotal evidence suggests that they are gradually becoming harder to find, and the overall human pressure on coastal activities may be a factor (pers.comm. V. Natt).

The July 2004 count only recorded one individual in South Australia, and this was with one of the larger search efforts so far in terms of sites covered and included potential new areas (pers. comm. R. Green).

PREFERRED HABITAT

Key feeding habitat in Victoria is considered to be sheltered coastal habitats (Higgins 1997), mainly low samphire herblands. Samphire habitats are also used in South Australia, though it is considered that birds also feed on the seeds of colonising strandline plants, especially sea rocket (*Cakile maritima*) on ocean beaches, dune frontages and adjacent dune systems and sheltered areas along rocky foreshores (Garnett and Crowley 2000, Higgins 1997). In recent years, they have been observed in open pasture and coastal heath, and whilst data is limited, it appears that their habitat requirements may not be as narrow as originally thought (pers.comm. V. Natt).

THREATS

Fragmentation and degradation of over-wintering habitat by grazing, agriculture and urbanisation is thought to be the primary cause for decline in the species (Garnett and Crowley 2000). In the breeding areas in Tasmania, threats include changes to fire regimes, altered plant composition and competition for nesting hollows with the introduced common starling (Garnett and Crowley 2000, Higgins 1997).

In South Australia, 10 of the 15 important areas of habitat for the Orange-bellied Parrot identified by Gibbons (l984) are protected through a combination of reservation, heritage agreements, or planning regulations. Management Plans incorporating provisions for wintering habitat preservation have been prepared for the Canunda National Park (NPWS 1986), the Coorong National Park and Coorong Game Reserve (NPWS 1989), Beachport Conservation Park (Sutherland 1990), Bernouilli Conservation Reserve (NPW 2000) and Carpenter Rocks (Owers 1994).

Easily disturbed whilst feeding, Orange-bellied parrots can still be sighted near people. They seem to return to preferred feeding grounds and if general human disturbance levels increase, they may be feel threatened and move to other feeding areas (pers comm. V. Natt).

AVAILABLE HABITAT

There is no samphire habitat available at or near this site. There is limited and variable potential feeding habitat in the area along the seaward edge of the coastal heath where some strandline vegetation exists. It is very much dominated all year round by *Ammophila arenaria* (marram grass) (Photo 7), and the *Cakile maritima* (two-horned sea rocket) appears to be seasonal at this beach. In 2004, over the winter, very little *C. maritima* existed, and in September, germination of new plants began in the zone at the top of the beach, immediately in front of the marram grass (Photo 8). Storms and tides over the winter may be a determining factor in the quantity of *C. maritima* available for orange-bellied parrots at this site. The coastal heath on the foredune does provide roosting habitat, but it is unlikely to be used if there is no good feeding habitat nearby. Bernouilli Conservation Reserve, less than 1 km away also provides similar habitats, as does Butcher Gap Conservation Park, 10 km north.

Photo 7 Typical seaward edge of the coastal heath vegetation is dominated by a dense sward of marram grass (*Ammophila arenaria*) and extremely little sea rocket (*Cakile maritima*) in late August 2004.

Photo 8 Typical seaward edge of the coastal heath vegetation is dominated by a dense sward of marram grass (*Ammophila arenaria*) and newly germinated sea rocket (*Cakile maritima*) in late September 2004.

DISCUSSION

The literature suggests that orange-bellied parrots tend to avoid degraded areas and prefer samphire-dominated saltmarshes. Of the entire wild population, annually approximately 30% (40-50 birds) are thought to visit the South East coast of South Australia, and these will be spread quite widely over the samphire and strandline habitats along the coastal strip. These birds will visit during winter, a time of year when human activity is expected to be lower, even after the development is complete. It is unlikely that the available roosting habitat would be used if there is no feeding ground nearby. In South Australia it is considered that strandline plants (principally *Cakile maritima*) on beaches and dune complexes are important for feeding habitat, and there have been some sightings in recent years in open pasture situations (pers. comm. B. Haywood). The quantity and quality of the beach-fringing vegetation at this site is similar to that of much of the South East coastline, provides seasonally variable amounts of sea rocket for food, the foredune being dominated by marram grass, so it is unlikely that this area would be overly attractive for these visiting birds.

The census figures are gained from volunteer birdwatchers and available effort is variable from year to year. In 2004, the July count was very low with a high observer effort. The low number of sightings in recent years could be due to declining numbers coming to South Australia or birds feeding in different areas. Summer counts in the breeding grounds in Tasmania show the population overall is stable and not declining (pers. comm. R. Green).

Rostratula australis Australian Painted Snipe – Vulnerable

DESCRIPTION

The Australian Painted Snipe is a stocky wading bird around 220-250 mm long with a long pinkish bill. The adult female, more colourful than the male, has a chestnut-coloured head, with white around the eye and a white crown stripe, and metallic green back and wings, barred with black and chestnut. It is a cryptic bird that is hard to see, therefore often overlooked (DEH 2003).

DISTRIBUTION

Usually found in shallow inland wetlands, either freshwater or brackish, that are either permanently or temporarily filled. Usually only single birds are seen, though larger groups of up to 30 have been recorded. The species has a scattered distribution throughout many parts of Australia, with a single record from Tasmania. Though some individuals are apparently resident in some areas, other individuals appear to be nomadic, temporarily occupying areas where suitable habitat exists. The many records of this species from the Murray-Darling drainage system suggest that it may have been a key area for this species (DEH 2003).

PREFERRED HABITAT

Australian Painted Snipe nest and feed in shallow samphire or freshwater swamps. It nests on the ground amongst tall reed-like vegetation near water, and feeds near the water's edge and on mudflats, taking invertebrates, such as insects and worms, and seeds. The salt marshes are used more in southern Australia. Although the Australian Painted Snipe can occur across Australia, the areas of most sensitivity to the species are those wetlands where the birds frequently occur and are known to breed (DEH 2003).

THREATS

It is probable that the loss and alteration of wetland habitat since European settlement is a key factor in the species decline, particularly in the Murray-Darling Basin (DEH 2003).

AVAILABLE HABITAT

Wetland habitat on this site is extremely limited in extent and temporary.

DISCUSSION

The site is a long way from the Murray-Darling area, which is thought to be an original stronghold for this species, and the very small area of wetland habitat available suggests that development will have no effect on the survival of this species.

Lathamus discolor Swift Parrot – Endangered

DESCRIPTION

A small parrot 23-25 cm long, streamlined for rapid flight, it is green with red on the throat, chin and forehead. It also has red patches on its shoulders and under the wings. It has a blue crown and cheeks, blue on its wings and a long pointed tail (Frith 1982).

DISTRIBUTION

The swift parrot occurs in south-eastern Australia. It is migratory only breeding in Tasmania and over wintering on mainland Australia. The breeding range is largely restricted to the east of Tasmania within the range of the Tasmanian blue gum *Eucalyptus globulus*.

In February and March, after the breeding season, the entire population flies north, dispersing throughout Victoria and NSW. Like other migratory species, swift parrots form into large flocks sometimes comprising up to 500 birds before migrating (Frith 1982).

PREFERRED HABITAT

Woodlands and forests dominated by *Eucalyptus* sp.. The swift parrot's main food is pollen and nectar from eucalypts and they follow the blossoming of various species. They also feed extensively on insects, their larvae, seeds fruit and berries (Frith 1982).

THREATS

The main threat is loss of breeding and feeding habitat through native vegetation clearance.

AVAILABLE HABITAT

No suitable feeding habitat exists on or near the project site.

DISCUSSION

The eucalypt woodlands and forests preferred by swift parrots for feeding are not available at this site. They may occasionally be seen further inland where such vegetation types exist. Any development at this site will not have any effect on the population of swift parrots.

MIGRATORY TERRESTRIAL COASTAL BIRD SPECIES

Haliaeetus leucogaster White-bellied Sea-Eagle

DESCRIPTION

A very large white and grey eagle with a ~2m wingspan and 70-90cm body length (Pizzey & Knight 1997).

DISTRIBUTION

Throughout coastal Australia and large inland waterways, lakes and wetlands, including the River Murray and major tributaries (Schodde & Tidemann 1990). Absent from the South East of South Australia but occurs from the upper River Murray to the Coorong (Marchant & Higgins 1993).

THREATS

Human disturbance limits breeding or causes desertion of nest, clearance of tall vegetation near coast and inland waterways has reduced suitable breeding sites (Marchant & Higgins 1993).

EPBC STATUS

Protected under the Chinese-Australia Migratory Bird Agreement (CAMBA) and Japanese-Australia Migratory Bird Agreement (JAMBA).

PREFERRED HABITAT

Coastal surface waters and bays (Schodde & Tidemann 1990); islands, inlets and estuaries (Pizzey & Knight 1997); large open terrestrial wetlands and land adjacent to maritime and aquatic habitats (Schodde & Tidemann 1990, Marchant and Higgins 1993). The presence of shoreline aquatic vegetation is considered unimportant as long as open water remains (Marchant & Higgins 1993). They pair for life and are sedentary within their hunting range (Schodde & Tidemann 1990, Marchant & Higgins 1993) and breed near preferred habitats on islands, cliffs and in tall live trees up to 1km from water (Schodde & Tidemann 1990, Marchant & Higgins 1993, Pizzey & Knight 1997).

AVAILABLE HABITAT

None of the habitats at the site are considered important for the conservation of the White-bellied Sea-Eagle. There is no suitable breeding habitat at the site, and the area supports low-quality potential feeding areas.

THREATS

Human disturbance limits breeding or causes desertion of nests. Clearance of tall vegetation near coast and inland waterways has reduced suitable breeding sites (Marchant & Higgins 1993).

Hirundapus caudacutus White-throated Needletail

DESCRIPTION

Large, long-winged swallow-like bird with overall dark plumage and a white throat and undertail area. Wingspan ~50cm and body length~20cm (Pizzey & Knight 1997).

DISTRIBUTION

A non-breeding migrant from central and northern Asia, that is widespread in summer in east and south eastern Australia from north Queensland, along the east coast and ranges to Spencer Gulf in South Australia (Higgins 1999). Scattered records only in central, northern and western Australia (Higgins 1999).

EPBC STATUS

Protected under the Chinese-Australia Migratory Bird Agreement (CAMBA) and Japanese-Australia Migratory Bird Agreement (JAMBA).

PREFERRED HABITAT

Almost exclusively aerial over a variety of terrestrial habitats including forests, woodlands, agricultural land, urban areas, lakes and coasts (Pizzey & Knight 1997) but probably more often over forests and wooded areas (Higgins 1999). It is thought they roost at night amongst foliage of tall trees (Schodde & Tidemann 1990) though such occurrences are considered to be over-emphasised, as they probably roost aerially (Higgins 1999). Sometimes recorded in large flocks of 10,000-50,000 as they feed on insects at low or high altitudes, over a variety of landscapes. They are often observed during humid conditions prior to thunderstorms (Higgins 1999).

AVAILABLE HABITAT

The proposed project site provides no woodland habitat, and only a small amount of dense shrubland and coastal heath. There are quite large areas of these habitat types in the region. The white-throated Needletail does not appear to be very habitat specific in its needs, so it is thought that none of the habitats at the site are likely to be important for the conservation of the species.

THREATS

There are no references to any threatening processes.

Leipoa ocellata Malleefowl – see terrestrial birds of possible concern (p.15)

Neophema chrysogaster Orange-bellied Parrot - see terrestrial birds of possible concern (p.15)

MIGRATORY WETLAND BIRD SPECIES

Gallinago hardwickii Latham's Snipe, Japanese Snipe

A migratory wader that breeds in northern Japan and the east Asian mainland and migrates to Australia in summer (Higgins & Davies 1996, Pizzey & Knight 1997). Occurs in a variety of permanent and temporary wetlands, with a preference for open freshwater wetlands with nearby cover (Higgins & Davies 1996). Movement between wetlands can be unpredictable, and seemingly perfect habitat can go unused (Pringle 1987). Prefer to feed in mud and shallow water of freshwater wetlands, where they can probe for food in soft mud between vegetation (Higgins & Davies 1996).

Rostratula benghalensis Painted Snipe

Generally uncommon and mostly confined to wetlands in the south east and north east of Australia. Some patchy records in central, south western and northern Australia (Marchant & Higgins 1993, Pizzey & Knight 1997, Garnett & Crowley 2000). Inhabits shallow, vegetated freshwater (and sometimes brackish) temporary or infrequently-filled swamps (Marchant & Higgins 1993, Garnett & Crowley 2000), well vegetated fringes of wetlands, lakes and dams (Pizzey & Knight 1997) often with scattered clumps of lignum *Muehlenbeckia florulenta* (Marchant & Higgins 1993).

Arenaria interpres Ruddy Turnstone

Breeds in the Arctic and migrates to Australia (less common in southern Austrlia) from September to April. Feeds in shallow stony water and on seaweed covered beaches (Pizzey & Knight 1997, Frith 1982).

Pluvialis fulva Pacific Golden Plover

Breeds June-July in Siberia and western Alaska and migrates to Australian coasts and bayside tidal tidal shores, rocky outcrops running into the water, salt swamps and marshes. Favourite roosts are in debris-strewn beaches and exposed rocky areas in the water (Frith 1982).

PREFERRED HABITAT

All of these migratory species may visit the area occasionally to feed before moving on.

AVAILABLE HABITAT

The seaweed covered beach and the seasonal wetland in the south eastern part of the project site may provide feeding habitat for the occasional visitors. Neither of these habitats are particularly unique or specific for any of these species and the south east coast of South Australia has many other larger areas of similar or better habitat just as suitable for these itinerant foraging birds.

MIGRATORY COASTAL BIRD SPECIES

The following shorebirds and waterbirds, protected under the Chinese-Australia Migratory Bird Agreement (CAMBA) or the Japanese-Australia Migratory Bird Agreement (JAMBA) have been noted in the region, and potentially may be found occasionally in the seasonal wetland swampy are in the south-eastern part of the site.

Common Sandpiper	(*Actitis hypoleucos*)
Common Greenshank	(*Tringa nebularia*)
Marsh Sandpiper	(*Tringa stagnatilis*)
Black-tailed Godwit	(*Limosa limosa*)
Sharp-tailed Sandpiper	(*Calidris acuminata*)
Red-necked Stint	(*Calidris ruficollis*)
Curlew Sandpiper	(*Calidris ferruginea*)
Ruff	(*Philomachus pugnax*)
Double-banded Plover	*(Charadrius bicinctus)*

PREFERRED HABITAT

Migratory shorebirds generally inhabit tidal mudflats, estuaries, sandy and rocky beaches, saltfields, samphire swamps, sewage ponds and mangroves, though some species have preferential habitat types (Marchant & Higgins 1993, Pizzey & Knight 1997).

THREATS

Marchant & Higgins (1993) suggest that there are no immediate threats to their survival.

DISCUSSION

The overall quality of the pasture area as habitat for any native birds is poor. None of the birds under consideration are likely to be directly effected by any development in these areas. The pasture simply does not provide any food, cover or breeding habitat to support anything but the most common native birds of open plains. The White-throated Needletail would not be affected by any on-ground works given their aerial habits and preference for airspace over wooded areas, and the habitat is not considered suitable for the White-bellied Sea-Eagle, which also has a preference for wooded areas adjacent to waterways.

The absence of mallee habitat, close proximity to residential areas and associated noise disturbance, and the high probability of predation by domestic cats and dogs eliminates the likelihood of Malleefowl use of the area.

Painted Snipe and Latham's Snipe generally prefer good quality freshwater habitats that do not permanently exist at this site. There is only very limited seasonal wetland habitat providing shallow open water, flooded low vegetation and no open mud for use by waders.

Migratory species, including all the albatrosses and petrels may visit the area occasionally, but are unlikely to show any preference for this area ovr much of the restof the South East coast. Many are unlikely to make landfall at all even if they are in the area. The proposed development is therefore unlikely to have any significant effect on any of these species.

The small numbers of orange-bellied parrots that may visit over the winter

CONCLUSION

In terms of threatened species and migratory species listed by the *EPBC Act, 1999*, the proposed development on this site does not appear to involve any factors that are likely to significantly affect populations of any of the listed species (summary below).

Species	Likelihood of presence on site	Habitat available	Probable Impact
AMPHIBIANS			
Southern Bell Frog *Litoria raniformis*	Nil	Nil	Nil
PLANTS			
Leafy Greenhood *Pterostylis cucullata*	Extremely unlikely	Degraded	Nil
Metallic sun orchid *Thelymitra epeipactoides*	Nil	Degraded	Nil
MAMMALS			
Bats			
Southern Bent-wing Bat *Miniopterus shreibersii bassani*	Occasional nocturnal foraging	Nil roosting, limited foraging	Nil
Cetaceans(Whales)			
Blue Whale *Balaenoptera musculus*	Very occasional offshore	Offshore	Nil
Southern Right Whale *Eubalaena australis*	Very occasional offshore	Offshore	Nil
Humpback Whale *Megaptera novaeangliae*	Very occasional offshore	Offshore	Nil
SHARKS			
Great White Shark *Carcharodon carcharias*	Very occasional offshore	Offshore	Nil
Albatrosses & Petrels			
Various spp.	Very occasional overflying	Offshore	Nil
BIRDS Terrestrial Birds			
Malleefowl *Leipoa ocellata*	Nil	Nil	Nil
Orange-bellied Parrot *Neophema chrysogaster*	Not observed, possible occasionally in winter	Very limited foraging	Nil
Australian Painted Snipe *Rostratula australis*	Not observed, highly unlikely	Extremely limited foraging	Nil
Swift Parrot *Lathamus discolor*	Not observed, highly unlikely	Nil	Nil
White-bellied Sea-Eagle *Haliaeetus leucogaster*	Not observed, highly unlikely	Extremely limited foraging	Nil
White-throated Needletail *Hirundapus caudacutus*	Not observed, highly unlikely	Extremely limited foraging	Nil
Migratory Wetland Birds			
Latham's Snipe *Gallinago hardwickii*	Not observed, highly unlikely	Extremely small and seasonal	Nil
Painted Snipe *Rostratula benghalensis*	Not observed, highly unlikely	Extremely small and seasonal	Nil
Ruddy Turnstone *Arenaria interpres*	Not observed, highly unlikely	Extremely small and seasonal	Nil
Pacific Golden Plover *Pluvialis fulva*	Not observed, highly unlikely	Extremely small and seasonal	Nil

It may be that the removal of stock grazing in conjunction with some "conservation-oriented" management in the coastal heath areas may actually bring about an overall positive effect due to the removal of invasive weeds and exclusion of human traffic. The relocation of activities such as boat launching, vehicle and trailer parking and fishing equipment maintenance from the beach to the marina may also reduce the impacts along the beach edge of the coastal heath habitat areas.

This information must be viewed in the context of the fact that these species are "endangered" or "vulnerable", which means almost by definition, that their presence or absence is not easy to be 100% certain about. What is presented in this report is what we believe to be an informed assessment of the likelihood of significant negative effects on these species due to the proposed development.

The Proposed Meningie Canal Development and the possible effects on the Orange-bellied Parrot *Neophema chrysogaster*

Mark de Jong , June 2004

INTRODUCTION:
This short discussion considers a proposed development near Meningie, South Australia, and its possible effect on the population of the Orange-bellied Parrot. The proposal had been previously addressed in a referral under the EPBC Act 1999 submitted to Environment Australia (now the Department for Environment and Heritage) by PB Environmental in early 2003. The threatened species and ecosystems considered to be within range of the development area were investigated in that report, but didn't include the Orange-bellied Parrot, and as such the Department for Environment and Heritage have requested comment on the suitability of the habitat at the site for this species. The discussion was requested given the presence of a saltmarsh community both on and adjacent the site, a community that is recognised as key habitat of the Orange-bellied Parrot. This report will discuss the habitat requirements of the OBP, the population size and recent records in South Australia, and the suitability of habitat available on the site. From this an assessment of the likelihood of the occurrence of the bird at the site will be made, and comments on the effects of the proposed development on the population of the OBP will be provided.

BACKGROUND:

Neophema chrysogaster Orange-bellied Parrot

EPBC Status

Listed as Endangered. Current population thought to be <200 individuals (Higgins 1997), Garnett and Crowley (2000) suggest a population size of ~180 and a conservation status of Critically Endangered.

Description

A small slim 'grass parrot' with rich green upper and bright yellow lower plumage, and a distinctive orange patch surrounding the belly which gives rise to its name (Higgins 1997, Orange-bellied Parrot Recovery Team 1998, Pizzey & Knight 1997). Body sizes ranges from 22-25cm (Higgins 1997, Pizzey & Knight 1997) and it has a wingspan of *c.*31cm (Higgins 1997).

Distribution

Breed in Tasmania and migrate to the Australian mainland during winter. Formerly widespread and abundant in central and southern parts of Tasmania and on the mainland in coastal areas from Yorke Peninsula in SA to Sydney in NSW (Higgins 1997, Orange-bellied Parrot Recovery Team 1998). Mainland range has reduced significantly, and although individuals often move as far west as Lake Alexandina in SA and east to

Gippsland in Victoria (Garnett and Crowley 2000, Higgins 1997) up to 70% of the entire population concentrates at three wintering sites around Port Phillip Bay and the Bellarine Peninsula in Central Victoria (Orange-bellied Parrot Recovery Team 1998).

Carpenter Rocks (SW of Mount Gambier) is considered to be the most used site in SA (Orange-bellied Parrot Recovery Team 1998), and Higgins (1997) suggests they are found mainly near Carpenter Rocks, Kingston SE, and in the Coorong south of McGrath Flat. The Orange-bellied Parrot Recovery Plan (Orange-bellied Parrot Recovery Team 1998), notes that suitable winter habitat in South Australia exists at Canunda National Park, Lake Bonney, Nora Creina, Robe, Butchers Gap, Blackford Drain, Woods Well, Magrath Flat and Lake Alexandrina, *"where birds tend to spend less time and occur in smaller flocks than in the key sites in Port Phillip Bay"* (Orange-bellied Parrot Recovery Team 1998).

They are "*usually"* found within 10km of the coast on the mainland (Garnett and Crowley 2000, Orange-bellied Parrot Recovery Team 1998), and "*mostly"* within 3km of coast (Higgins 1997). The SA OBP Working Group recommends that count searches within 5km are adequate, and out to 10km from coast is unnecessary (SA OBP Working Group 2003) indicating that records beyond 5km from the coast in SA are unlikely. Breeding is currently restricted to a thin coastal strip in southwest Tasmania and birds then disperse to mainland Australia via King Island during autumn and return in Spring (Higgins 1997, Orange-bellied Parrot Recovery Team 1998). The northern migration is protracted and the return journey is rapid (Higgins 1997). In Tasmania Orange-bellied Parrots can be found within 30km of the coast.

Preferred Habitat

Breeding habitat is confined to SW Tasmania and nesting occurs in tree hollows in mature Smithton Peppermint *Eucalyptus nitida* and Swamp Gum *E. ovata* forests surrounded by buttongrass plains.

Wintering birds use a variety of habitats such as saltmarshes, coastal dunes, pastures and shrublands, estuaries, islands, beaches and moorlands (Orange-bellied Parrot Recovery Team 1998). It has become recently apparent that birds forage on weeds in additional habitats away from traditional saltmarsh and beach areas, such as farmland, clifftop vegetation, coastal scrub and wetlands (Stark 2004). Birds mostly feed on ground, and sometimes in shrubs up to height of 4m, but usually <1m above ground (Higgins 1997) where they feed on seeds and berries of a variety of plants (Higgins 1997, Orange-bellied Parrot Recovery Team 1998).

Key feeding habitat in Victoria is considered to be sheltered coastal habitats (Higgins 1997), mainly low samphire herbland dominated by beaded glasswort *Sarcocornia quinqueflora* and taller shrubland dominated by shrubby glasswort *Sclerostegia arbuscula* (Higgins 1997). Grassy or weedy pastures, including rough fairways on golfcourses are also used if near saltmarshes (Higgins 1997, Orange-bellied Parrot Recovery Team 1998). Saltmarsh habitat along the western shore of Port Phillip Bay at the Murtcaim Wildlife Area, Lake Connewarre and Swan Bay, including Swan Island in Central Victoria is considered to be critical (Orange-bellied Parrot Recovery Team 1998).

Samphire habitats are also used in South Australia, though it is considered that birds mostly feed on the seeds of colonizing strandline plants, especially Sea Rocket *Cakile maritima* on ocean beaches, dune frontages and adjacent dune systems and sheltered areas along rocky foreshores (Garnett and Crowley 2000, Higgins 1997). Strandline plants such as Sea Rocket are equally as important as saltmarsh in SA (Orange-bellied Parrot Recovery Team 1998). They sometimes use the edges of estuaries and coastal lagoons, pasture, open grassy areas and heath vegetation (Higgins 1997).

Mainland roosting habitat is mostly within 1km of feeding areas, often in dense clumps of Melaleuca, including Dryland tea-tree *Melaleuca lanceolata*, as well as Coastal Wattle *Acacia longifolia* ssp *sophorae*, Coast Beard Heath *Leucopogon parviflorus* and Coast Daisy-bush *Olearia axillaris* shrubs (Higgins 1997). Less optimal roosting sites have been used including dense weeds such as *Brassica* sp and dense native *Sclerostegia* shrublands (Higgins 1997).

Threats

Fragmentation and degradation of over-wintering habitat by gazing, agriculture and urbanisation thought to be the primary cause for decline in the species (Garnett and Crowley 2000). South Australian habitats have been adversely affected by drainage to establish agriculture and associated introduction of grazing, and some habitats may be compromised by growth of dense vegetation at feeding sites (Higgins 1997). Additional threats include 4wd activity on beaches in the se of SA damaging strandline vegetation, weed invasion of feeding habitats (Higgins 1997), a lack of availability of seeds of saltmarsh vegetation during winter and competition for seeds with other parrots and finches (Orange-bellied Parrot Recovery Team 1998). Threats to breeding include changes to fire regime altering plant composition and competition for nest hollows with the introduced common starling (Garnett and Crowley 2000, Higgins 1997).

Recent Records in SA

Higgins (1997) lists the results of winter counts in mainland Australia from 1979-1997, which show that small numbers in SA are common and numbers over 20 are rare, irregular and last occurred in 1989 (see table 1). Comments on the location of the records were not provided.

Table 1. National Orange-bellied Parrot Count data from South Australia 1979-1997

1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
7	7	4	27	22	18	13	8	0	18	28	18	0	0	5	2	2	3	0

(source Higgins 1997)

The results of searches in SA from the national count and opportunistic sightings in 2002, 2003 and May 2004 are also tabled (table 2) which have an advantage of providing general location details. Again small numbers are a feature.

Table 2. National Orange-bellied Parrot Count data from South Australia 2002-May 2004

	June 2002	June 2002	July 2002	July 2002	July 2003	May 2004
Number	2	2	4	3	2	2
Location	'Kingston SE'	'Pt MacDonnell'	'Salt Creek'	'The Coorong'	'Sthn Coorong	'Pt MacDonnell'

(source Bob Green, SA Orange-bellied Parrot Working Group - email distribution 2002, 2003 and 2004)

A noteworthy feature of the details in table 2 is that most of the records have occurred in areas remote from the Meningie district. Pt MacDonnell on the coast of the Lower South East is over 280km from Meningie, further if following the coastline; Kingston SE is 140km from Meningie; and Salt Creek 50km. No precise details on the locations of the records are given, and only the general locations were offered. The Southern Coorong is regarded as the lagoons south of Parnka Point (near McGrath Flat), which commences 25km south of Meningie and continues toward Kingston SE, 115km further south. The large geographical area of the Coorong makes precise interpretation of the location records difficult.

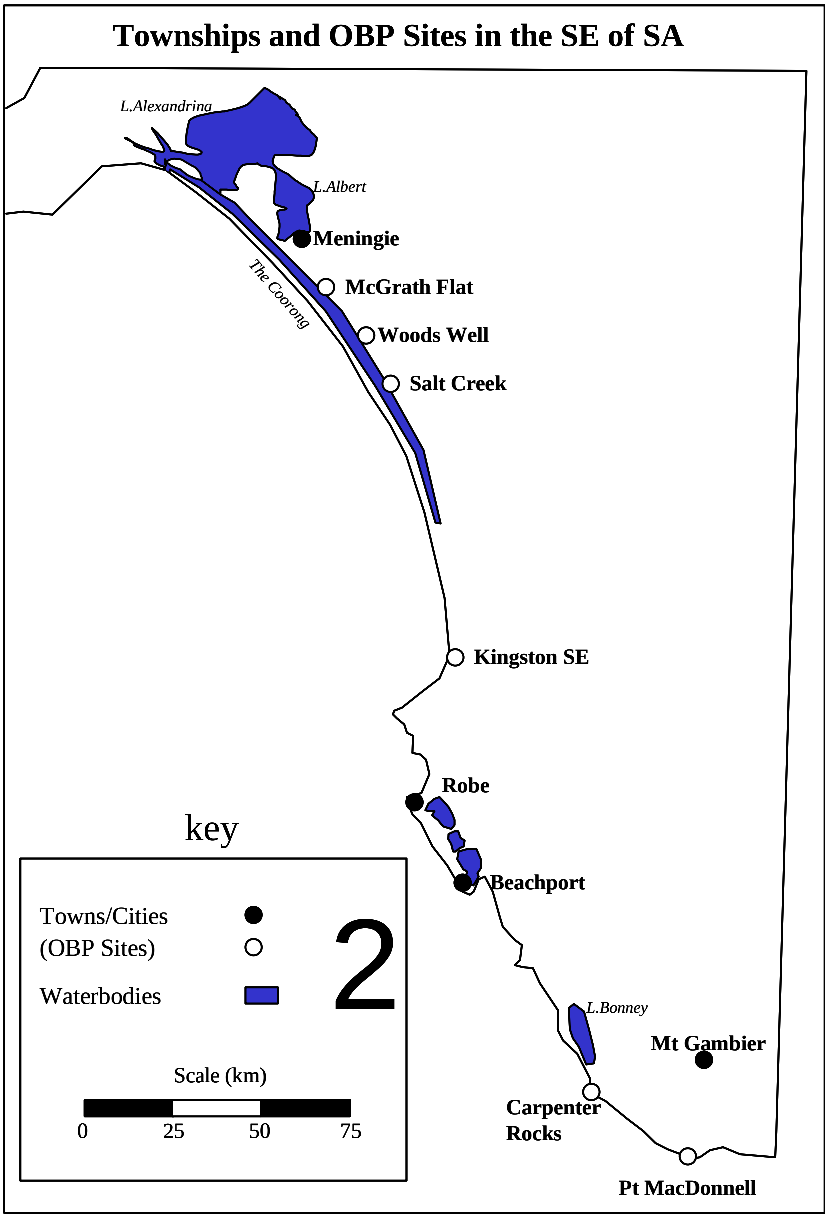

Figure 1. Map of the southeast of South Australia showing townships and sites recognised for the presence of Orange-bellied Parrots

DISCUSSION:

Available Habitat

There are two areas that potentially support habitat suitable for the Orange-bellied Parrot that could be influenced by the development. The first is within the development area, and consists of saline depressions inland from the edge of Lake Albert, and the second is adjacent the development area and consists of samphire dominated ponds and lagoons fringing the lake.

Figure 2. Plan of proposed development area (above). Boundary of development area transposed onto aerial photograph of the site (right).

Both habitats support Beaded Glasswort *Sarcocornia quinqueflora* and Samphire *Halosarcia* sp., native plants that are known to provide winter food (seeds) for the Orange-bellied Parrot in South Australia (Higgins 1997). Additionally it has been noted that saltmarsh habitat is used by Orange-bellied Parrots as a winter feeding habitat, and saltmarsh shrubland dominated by Beaded Glasswort *Sarcocornia quinqueflora* is regarded as critical winter habitat at sites in central Victoria (Orange-bellied Parrot Recovery Team 1998).

The saline depressions in the development area support degraded samphire vegetation that is sparse, low and provide very little cover for feeding birds. It is likely that the shallow saline groundwater table and damage by grazing has caused the degradation (background information can be found in the Preliminary Biodiversity Assessment). The water table rises in winter, creating areas of open water that cover the bulk of the saltmarsh vegetation. Higgins (1997) notes that Orange-bellied Parrots "*usually avoid feeding in flooded saltmarsh, though will feed in tops of taller Sclerostegia shrubs protruding above water*", and in low saltmarsh at Pt Wilson-Werribee, they feed within 4m of shrubs>0.5m high (Higgins 1997). The site supports low shrubs only that will be inundated in winter, rendering the saline depressions unsuitable for feeding during their winter migration. The vegetation fringing the saline depressions also supports samphire but is degraded by grazing, and again it has been noted that Orange-bellied Parrots "*do not usually feed in* *saltmarsh that has been heavily grazed by sheep*" (Higgins 1997). It is for these reasons that the saline depressions are not considered to provide habitat suitable for Orange-bellied Parrots.

The samphire-dominated lagoons on the fringe of Lake Albert provide habitat that is much less degraded than the habitat available in the saline depressions. The vegetation is denser, taller, healthier and less influenced by weeds, and is considered to be in good condition. The most obvious sign of degradation is localised damage by cattle on the fringes of the area. Most of the area (which is approximately 10ha in size) is permanently inundated given the stable pool level of Lake Albert created by management of the weir system into the Coorong. The healthy samphire may make the habitat suitable for the Orange-bellied Parrot, but given that they generally avoid wet areas (as mentioned before) it is difficult to suggest that they might use the area.

Location and regional context

The likelihood of the site supporting Orange-bellied Parrots is also dependant upon additional factors such as proximity to the coast and availability of better habitat in the district. The Meningie site is greater than 10km from the coast, and it has been noted that the birds are usually within 10km of the coast, and mostly within 3km. South Australian observers only search habitats within 5km of the coast. It is therefore possible that the habitats on the site are beyond the optimal range of the species.

The good quality habitat on the edge of Lake Albert represents a small example of a habitat that is common in the Upper South East and western Murraylands of South Australia. Stands of similar habitat, in a healthy, ungrazed condition, exist on the eastern shores of the Coorong covering 100's of hectares in close proximity to the coast. A large example of the saltmarsh habitat on the Coorong around McGrath Flat is in excess of 100ha.

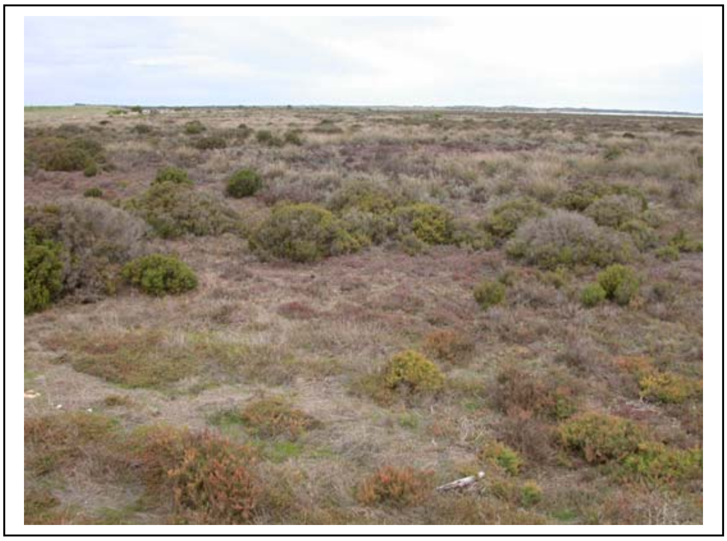

Plate 1. Saltmarsh habitat near McGrath Flat, in the Coorong National Park on the eastern shores of the Coorong.

It is assumed that Orange-bellied Parrots have been observed here, justifying the listing of McGrath Flat as a key site in South Australia. The samphire around Woods Well and Villa Dei Yumpa is similar. Extensive stands of this habitat exist along the Coorong, and beyond Kingston over 100km to the south. Also, the vegetation on the coastal side of Younghusband Peninsula (the dune system that separates the Coorong Lagoons from the Southern Ocean) supports sea rocket, an important food plant in South Australia.

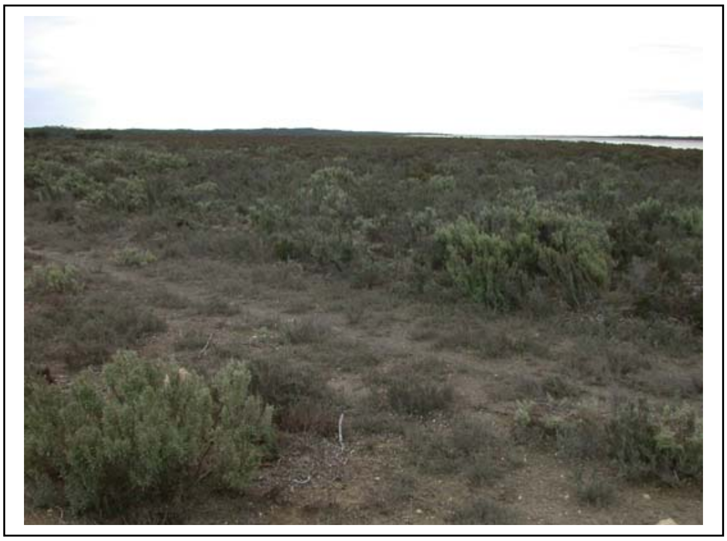

Plate 2. Saltmarsh habitat near Woods Well, also in the Coorong National Park on the eastern shores of the Coorong.

Plate 3. Saltmarsh habitat in the Coorong National Park at 42 Mile Crossing, between Salt Creek and Kingston SE. This habitat is common and extensive around the ephemeral lakes of the Coorong

Plate 4. Coastal trandline vegetation near the mouth of the Blackford Drain, 5km north of Kingston SE.

It is therefore considered that the Meningie site is outside the optimal range of the species, and significant habitat exists elsewhere in the district that is within the narrow coastal band that is preferred by the Orange-bellied Parrot.

CONCLUSION:

The Orange-bellied Parrot uses a variety of winter habitats to feed on seeds and berries. In South Australia as well as much of the mainland range of the species, their occurrence is confined to a narrow coastal strip most often no further than 3km inland. The literature suggests that they have a tendency to avoid degraded areas, and prefer to inhabit samphire-dominated saltmarshes. In South Australia it is considered that strandline plants (principally sea rocket) on beaches and dune complexes may be as important as saltmarsh habitat.

Two areas exist that support vegetation known to provide food for Orange-bellied Parrots on their winter migration to the mainland. Both areas are potentially affected by the proposed development, however the saline depressions are considered too degraded and too wet to support Orange-bellied Parrots. The samphire dominated lagoons are much healthier but are permanently wet, greater than 10km from the coast, and support a saltmarsh vegetation community that is extensive in the region, particularly along the shores of the Coorong National Park, and surrounding the ephemeral lagoons in the southern Coorong, within 4km of the coast. It is also noted that the lagoons are outside of the proposed development area and will not be damaged by the development. Given these circumstances it is not considered likely that the development of this site will adversely affect the species.

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APPENDIX 13

Cape Jaffa Anchorage Marina EIS Marine Studies, Tanner JE and Westphalen G, SARDI Aquatic Sciences, May 2004, Ref No. RD04/0059

Cape Jaffa Anchorage Marina EIS Marine Studies

Prepared for
Tonkin Consulting and Cape Jaffa Development Company

Jason Tanner and Grant Westphalen

South Australian Research and Development Institute,
Aquatic Sciences

May 2004

SARDI Aquatic Sciences Publication No. RD04/0059

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Table of contents

1. Executive Summary

This report details the potential marine environmental effects of the proposed Cape Jaffa Anchorage marina development, along with strategies for minimising these effects. Prospective monitoring requirements for the project are also outlined.

Video surveys of the area around the proposed development indicated that it was dominated by seagrasses in the genus *Posidonia* (54%), and *Amphibolis antarctica (*33%), with only a small amount of bare sand (9%). While *Posidonia* dominated inshore and *Amphibolis* was more abundant offshore, it was not possible to delineate different habitats within the area as the 2 genera were intermingled. There are some known areas of rocky reef nearby, but neither these, nor the rock lobster sanctuary at Cape Jaffa, are likely to be affected by the development.

On the basis of figures supplied by Tonkin Consulting that show that groundwater flow into the marine environment will not increase in the long-term as a result of the development, it can safely be concluded that alterations to groundwater flow will not have an adverse impact. In the short-term, there will be increased groundwater discharge during construction, but this should be rapidly diluted and not provide an environmental threat.

The impacts of the development on the marine flora and fauna will include the loss of some 3 ha of seagrass, although this will be offset over the longer term by the elimination of the existing boat moorings and recolonisation of the associated mooring scars. There may also be impacts associated with increased turbidity during construction, although a number of strategies will be put in place to reduce these. It is considered that the short duration of any increase in turbidity will not cause any problems for the seagrasses in the area. There may also be some scouring of seagrasses around the base of the breakwater, although experience at the nearby Maria Creek boat ramp suggests that if this does occur, it will be minimal. The entrance channel may also form the basis for an erosion scarp, which could then propagate along the coast, although this is considered unlikely given the sheltered nature of the location. Runoff from the dredge spoil could also cause problems, although again a number of strategies will be in place to minimise this possibility.

Strategies to reduce turbidity problems will include timing dredging events to coincide with periods of low water movement, use of a cutter-suction dredge to remove soft sediments, and possibly metal shields around the area being dredged.

Monitoring during construction will revolve around monitoring of turbidity to ensure that it remains below 10 NTU, as required by the Environment Protection (Water Quality) Policy 2003. After construction, the status of the channel will be monitored regularly to ensure that erosion does not become a problem. If erosion does start to occur, a variety of engineering solutions to halt it will be investigated.

Water quality will be protected by ensuring all stormwater is diverted to a treatment facility, and hardstands will be equipped with pollution traps. Discharges from vessels will be minimised by providing appropriate waste treatment facilities. Modelling indicates that the marina will have good flushing characteristics, further minimising the potential for problems with poor water quality. As a result, water quality monitoring will only be necessary if a problem, such as an algal bloom, is identified.

There is a high potential for the introduction of marine pests into the marina. It is almost certain that common species such as the Mediterranean fanworm will colonise. It may also be possible for species such as the Pacific Seastar and Japanese kelp, which are not currently in South Australia, to be introduced. To ensure any such introductions are detected early enough to control them, regular spot checks for key species will be conducted by the marina operators, and a community awareness campaign will be instituted.

2. Introduction

In June 2003, the South Australian Major Developments Panel released a document providing the required guidelines for the preparation of the EIS for the proposed Cape Jaffa Anchorage marina development. This development is a cooperative venture between the District Council of Kingston, and the Cape Jaffa Development Company. SARDI Aquatic Sciences was approached by Tonkin Consulting, on behalf of the consortium, to provide input into the EIS with respect to the likely impact of the development on the nearby marine system.

This document provides the results of field investigations carried out by SARDI Aquatic Sciences, as well as other input requested into the EIS. The areas covered are (numbers in brackets refer to points raised in the EIS guidelines):

a. Preparation of a habitat map of the benthic assemblages in the vicinity of the construction area
b. Likely effects of increased groundwater flow on marine assemblages (5.2.6)
c. Outline effect of removing swing moorings (5.2.14)
d. Outline effect of development on marine flora and fauna (5.2.15)
e. Outline strategies to minimise effects on the marine environment (5.5.1)
f. Detail proposed monitoring of impacts (5.5.12)
g. Outline measures to protect and monitor water quality (5.5.19)
h. Pest marine organisms (5.6.6)

3. Marine Habitats in the Vicinity of Cape Jaffa

In order to assess the potential implications of the Cape Jaffa Anchorage development on the marine environment, it was necessary to prepare a habitat map of the area. While some information is currently available on marine habitats around Cape Jaffa (Edyvane 1999, SKM 2001), the spatial and taxonomic resolution of these studies is too coarse to make a confident assessment of these implications. Thus additional video surveys were conducted to provide further details of the sessile marine macrofauna and flora present.

On November 25, 2003, a series of 15 remote video transects between 576 and 1000 m long were conducted using a digital video camera affixed to a sled towed behind a boat travelling at an approximately constant speed and direction. The beginning and end of each transect were marked using GPS, allowing the location of the transect to be plotted on a map (Figure 1). These videos were analysed in the laboratory, and assessed to determine the habitats present, and the location of any changes in habitat along the transect. In addition, all visible macrofauna, such as sponges and ascidians were recorded for each transect.

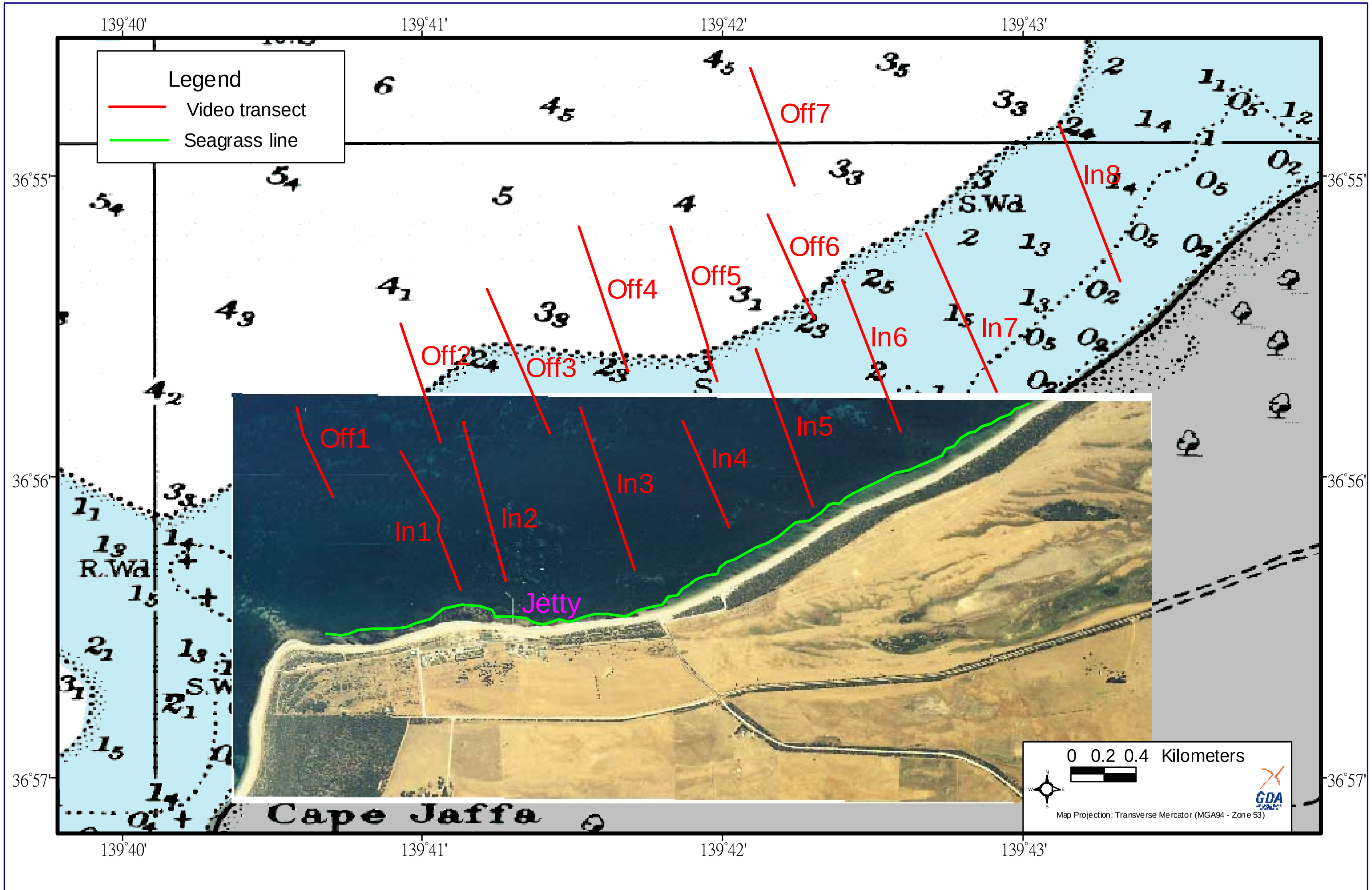

Figure 1: Locations of video transects surveyed at Cape Jaffa.
Sources: Marine Chart - PIRSA Spatial Information Services.
Aerial Photograph - DEH.
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All of the surveyed transects were dominated by seagrasses in the genus *Posidonia* and *Amphibolis antarctica*, with the former being more common along the inshore transects (Figure 2) and the latter along the offshore transects (Figure 3). Given the small scale heterogeneity seen along each transect, it is not possible to sub-divide the area into separate habitats. Instead, the entire study site is classified as mixed *Posidonia/Amphibolis* seagrass, with 54% cover of *Posidonia* and 33% cover of *Amphibolis*. This assemblage was present up to the inshore seagrass line marked on the aerial photograph (Figure 1). Inshore of the seagrass line was bare sand to the east of the jetty, and bare sand with some rocky reef to the west. The majority of the seagrass was very healthy, and formed dense beds, although the *Posidonia* did often have a relatively high epiphyte load. While the video footage could not be used to reliably identify beyond the level of genus, Bryars (2003) indicates that the area is dominated by *P. angustifolia* and *P. sinuosa* with some *P. coriacea*. Bare sand (9%) made up a relatively small proportion of the surveyed area, although there are some bare areas obvious as lighter patches in Figure 1. There were only a few small patches of macroalgae (predominantly *Ecklonia* and *Scaberia*, with some *Cystophora* and *Sargassum*) (see Figures 2 & 3). Very few macroinvertebrates were seen, with only 2 sponges and 2 ascidians recorded in total.

The mixed seagrass assemblage found off Cape Jaffa occurs extensively throughout Lacepede Bay to a depth of ~10m (Edyvane 1999, SKM 2001). Deeper waters are dominated by medium-dense macroalgae, predominantly *Carpoglossum*, *Cystophora* and *Seirococcus* (SKM 2001). Edyvane (1999), based primarily on the interpretation of satellite imagery, also suggests that there is an area of heavy limestone reef directly off Cape Jaffa itself, with some low profile platform reef also nearby (see Figure 4). Edyvane (1999) reported these areas as being dominated by macroalgae and most likely having a diverse sessile invertebrate assemblage.

It should be noted that the proposed development borders on a rock lobster sanctuary, with the western breakwater to be located just outside the eastern border of the sanctuary. Given the sanctuary is only for rock lobster, which occur on rocky reef rather than in seagrass habitats, it is very unlikely that the development will have an impact on the sanctuary's ability to achieve its objectives (protection of rock lobster). The nearest rocky reef is > 1 km from the marine sections of the development, and the boundary of the sanctuary was apparently set to coincide with easily observable marks on land rather than based on marine habitat boundaries relevant to rock lobster or their prey. While lobsters may move into seagrass areas to forage, it is unlikely that they will move this far, and the major prey species are also relatively sedentary (Jones & Morgan 2002). While lobsters are capable of migrations greater than 1 km, most animals restrict their movements to < 1 km, and remain within the vicinity of shelter (Ward et al. 2003). Longer distance migrations are to other areas with shelter, not to seagrass habitats. There could, however, be some flow-on effects associated with increased boating activity in the area, which may result in increased exposure to events such as pollution.

4. Likely effects of increased groundwater flow on marine assemblages

Tonkin Consulting (2003) has conducted a groundwater impact assessment of the proposed development, and suggests that there will be no long-term increase in the flow of groundwater into the marine environment. WBM Oceanics Australia (2004) combine this data with hydrodynamic models of tidal flushing, and show that any contaminants within the groundwater will be reduced to less than 0.3% of inflow concentrations at the entrance to the marina, and considerably less in the open ocean. From this, it can be safely concluded that under the scenarios modelled by Tonkin Consulting (2003) and WBM Oceanics Australia (2004) any existing groundwater contamination will have no detectable impact on the marine environment. So for example, while the maximum concentration of total organic carbon (TOC) detected in the groundwater is 78 mgL^{-1}, this will be diluted to 0.5 mgL^{-1} at the marina entrance, which is well below the trigger value set in the Environment Protection (Water Quality) Policy 2003 of 10 mgL^{-1}. Similarly for oxidised nitrogen, the maximum recorded value is 12.2 mgL^{-1}, which will be diluted to 0.08 mgL^{-1}, again well below the trigger value of 0.2 mgL^{-1}.

In the short term, it is expected that ~2500 m^3day^{-1} of groundwater will need to be pumped out of the site during construction. This water will be discharged to sea, and natural current and tidal movement should rapidly dilute it, so it is unlikely to have any detectable impact.

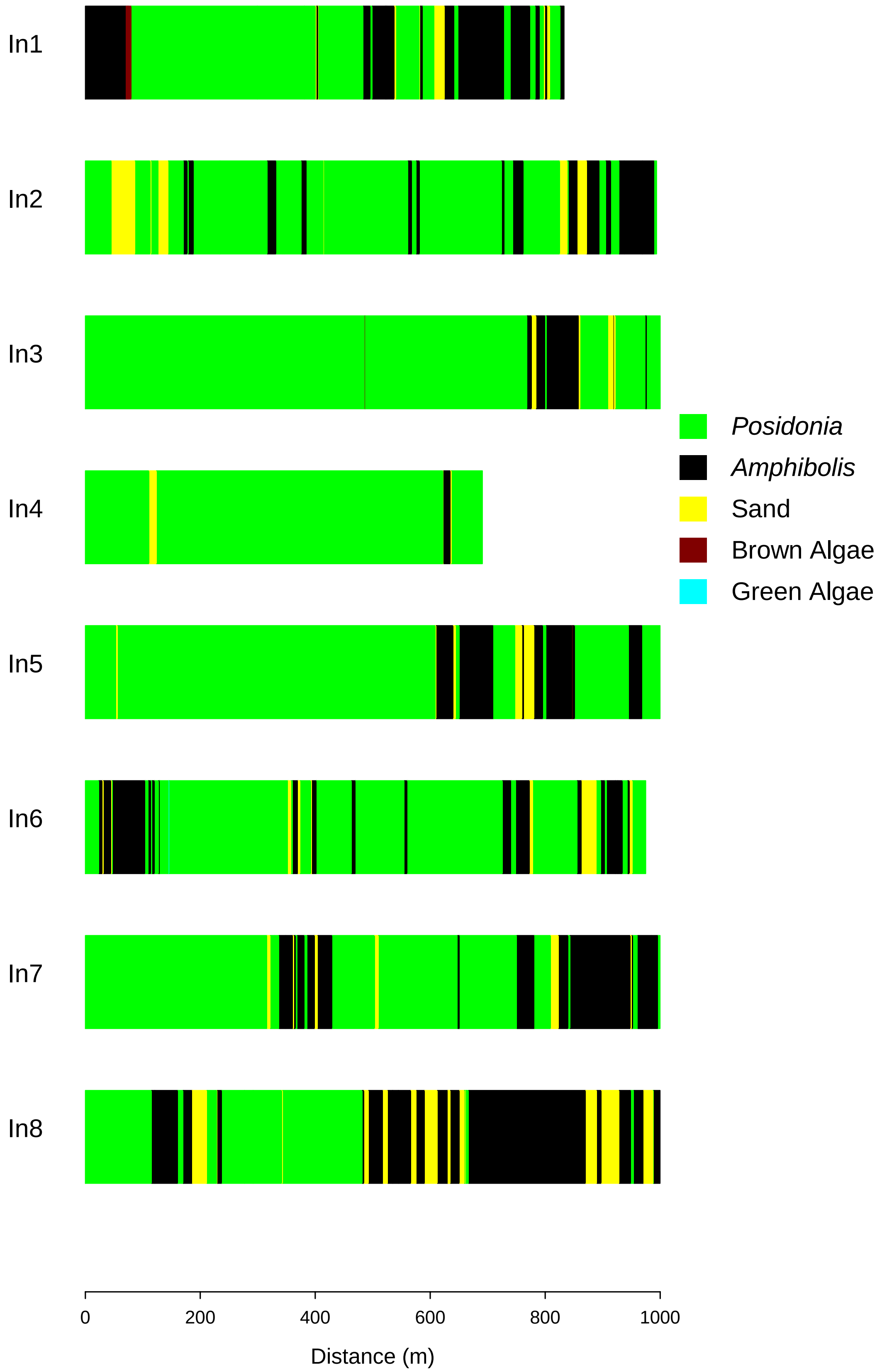

Figure 2: Spatial distribution of benthic assemblages along the inshore transects at Cape Jaffa. Zero m corresponds to the start of the transect in shallow water. See Figure 1 for transect locations.

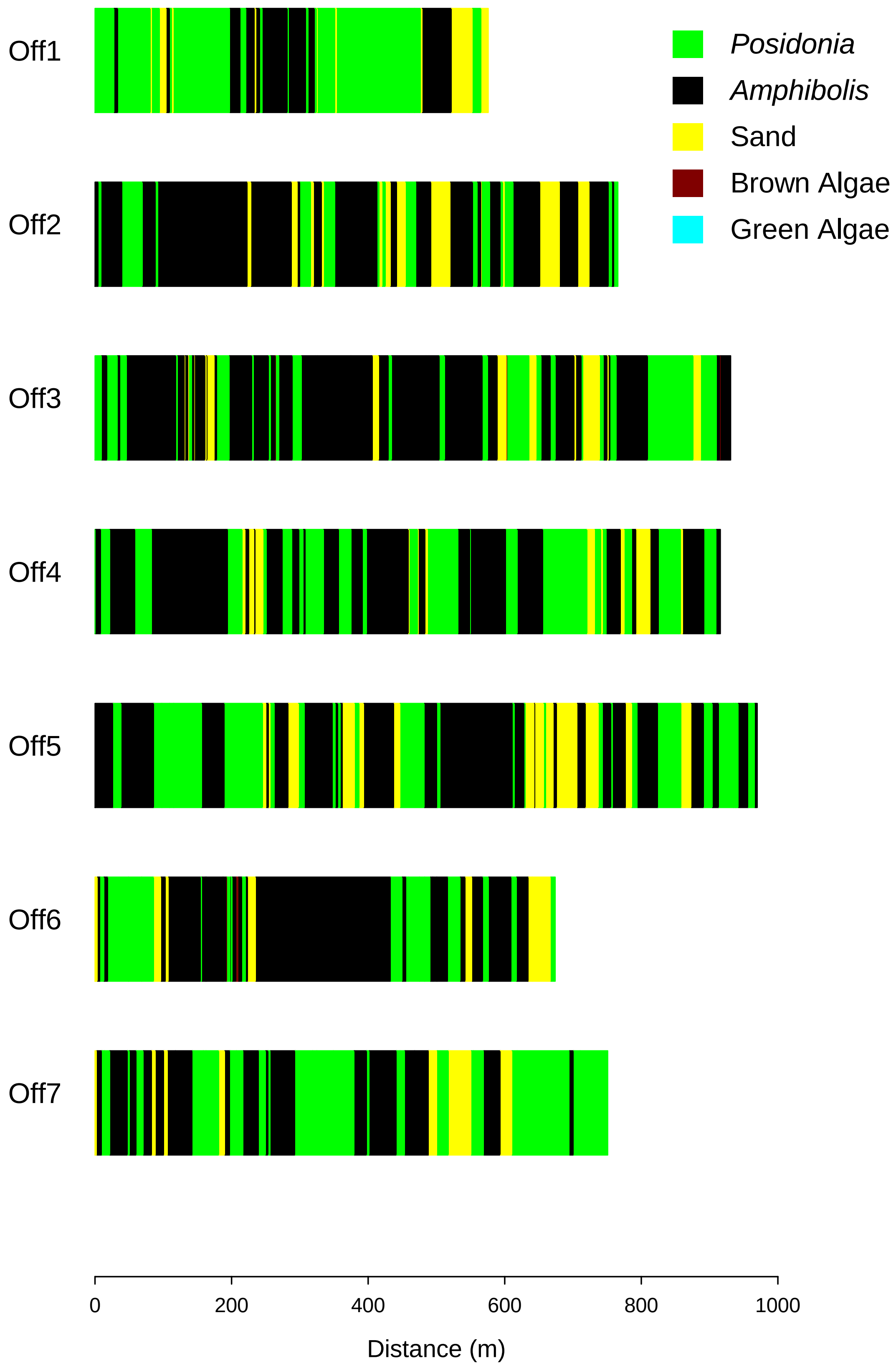

Figure 3: Spatial distribution of benthic assemblages along the offshore transects at Cape Jaffa. Zero m corresponds to the start of the transect in shallow water. See Figure 1 for transect locations.

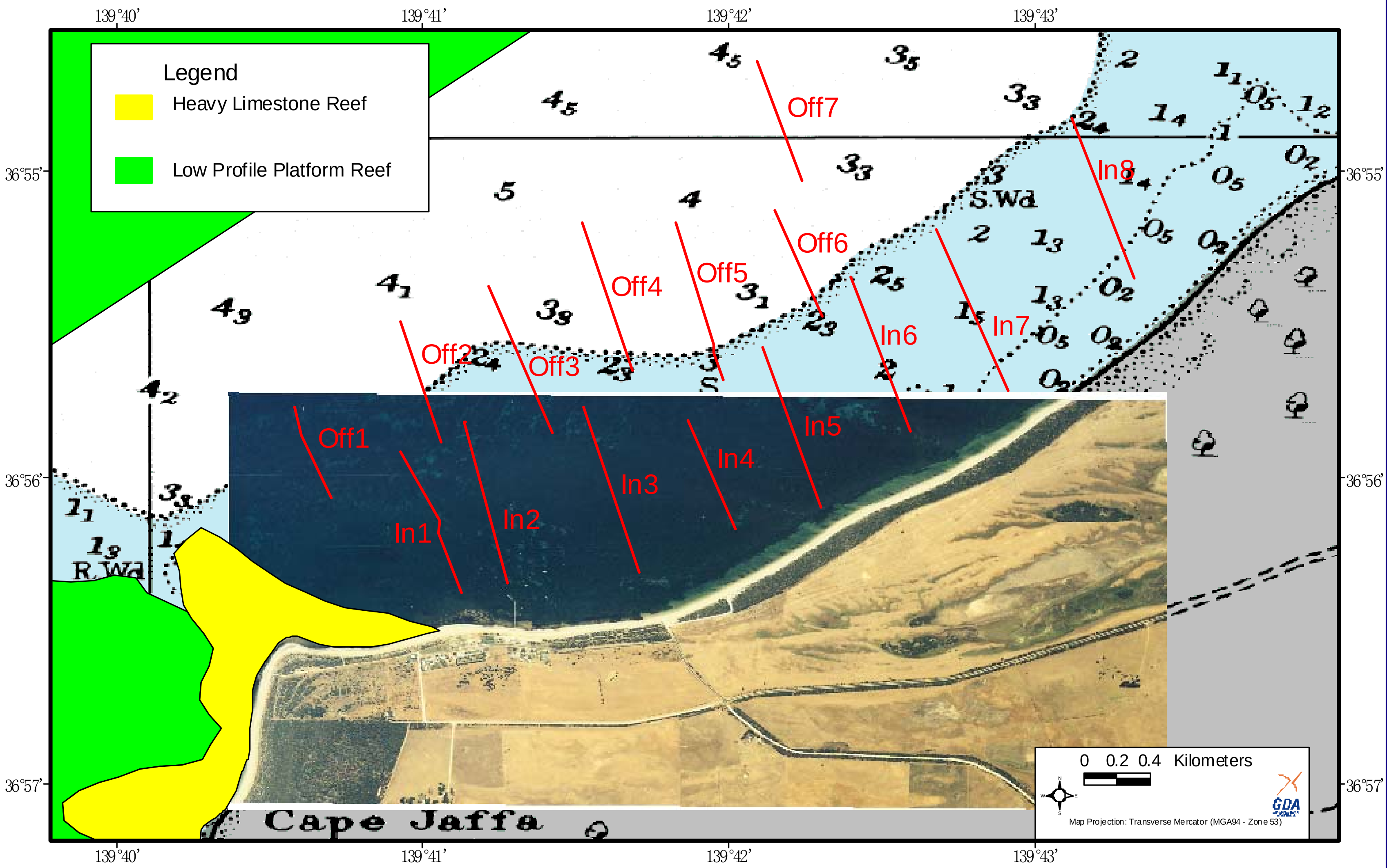

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Figure 4: Map of site showing putative areas of reef habitat.
Sources: Marine Chart - PIRSA Spatial Information Services.
Aerial Photograph - DEH.
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5. Potential effects of development on marine flora and fauna

The effects of the development on the marine flora and fauna can be divided into those related to construction and those related to continued operation of the marina.

Construction related impacts

The impacts associated with the construction of the marina can be further divided into the direct impacts of construction, such as habitat removal, and indirect impacts such as turbidity. The major, although very localised, effect will be the direct loss of habitat from the breakwater and entrance channel. Both of these features will result in the removal or burial of approximately 3 ha of seagrass. The area affected corresponds approximately to the inshore sections of transects In3 and In4, which Figure 2 indicates are primarily dense *Posidonia*. Judging from the aerial photography, this area is likely to be similar in extent to the area that has been lost around the current swing moorings, which will be removed and are expected to recolonise based on the information presented by Bryars (2003). The primary seagrass coloniser in the short and medium term is likely to be *Amphibolis antarctica* rather than *Posidonia*, which can take several decades to recolonise (Larkum et al. 1989).

The indirect impacts of construction include increased turbidity and sedimentation related to dredging, scouring of seagrasses around the breakwater and the potential propagation of 'blowouts' from the channel. While the majority of excavation will occur within the confines of a coffer dam, and will thus not directly result in elevated turbidity around the construction site, the entrance channel will need to be dredged as well. According to WBM Oceanics (2003) and SKM (2001), the surface sediments in the area are predominantly fine to medium sand (0.125 mm-0.5 mm in diameter), with only a few percent silt and clay. Given the small volume of sediment to be excavated (4000-5000 m^3), the open nature of the area with good flushing, the short duration of the dredging period (~ 2 weeks), and the relatively coarse nature of the sediment, it is very unlikely that increased turbidity will produce any substantial problems for the seagrasses in the vicinity. Depending on the nature of the sediments to be excavated from the marina basin itself, there may be a substantial pulse of highly turbid water when the coffer dam is first opened. This can be ameliorated by ensuring that a minimal amount of loose material is left in the excavated area when it is opened up to the ocean, and by slowly filling the basin. Both sources of turbidity will be short lived, with the seagrasses in the area likely to experience decreased light availability for less than 1 month in total. This short period of low light is well within the capability of both *Posidonia* and *Amphibolis* to withstand with no long-term negative effects (Clarke 1987, Greg Collings, SARDI, unpublished report). The third potential source of turbidity will be water from the dewatering operation. The dewatering ponds will be set up so that the discharge water has turbidity levels below those required by the Environment Protection (Water Quality) Policy 2003, and will be low enough to have minimal effect on seagrass for the short (~ 1 month) duration of the dredging and dewatering operation, so this will not be a problem.

Scouring of seagrasses around the base of the breakwater could occur if increased sand movement or suspended sediment concentrations occur in this region. Any direct increase in sediment concentrations will be short-lived, and thus unlikely to be significant. WBM Oceanics Australia (2003) also suggest that natural sand movement predominantly occurs inshore of the seagrass, and present suggestions for ameliorating the effects of any sand build-up/erosion due to the interruption of natural sand transport mechanisms. As part of the development, provisions will be made for bypassing sand around the breakwater. Thus problems with scouring are only likely to occur if erosion of the dredged channel or around the breakwater occurs. A similar setup to that proposed here is in place at the Maria Creek (Kingston) boatramp, which experiences higher water movement than is expected at Cape Jaffa Anchorage. There has been very little erosion around the breakwater at Maria Creek (J. Tyler, Tonkin Consulting, pers. com.), and the situation is expected to be the same at Cape Jaffa, so scouring of seagrasses is also unlikely.

The greatest concern associated with the construction of the marina is likely to be the potential for the excavated entrance channel to form an erosion scarp that could then propagate away from the channel. ‘Blowouts’ are common along the southern Adelaide metropolitan coast, and form when wave energy erodes the sediment in a patch devoid of seagrass. Blowouts have been documented at Cape Jaffa by Bryars (2003), although these are approximately 4 km from the proposed development site, in a more exposed area. Once a blowout forms, it tends to continue eroding,and increasing in size, and can result in significant seagrass loss. A similar situation has occurred at Beachport, where the loss of a substantial area of seagrass is now threatening the foreshore (Seddon et al. 2003). According to WBM Oceanics (2003), the coastline in the area is accretional rather than erosional, and has a much lower wave energy than either Adelaide or Beachport, which substantially reduces the risk of an erosion scarp forming. Again, the Maria Creek (Kingston) boat ramp is probably the best analogy for what is likely to occur at Cape Jaffa. As stated earlier, there has been very little erosion around Maria Creek, and the same is expected at Cape Jaffa. However, our understanding of when and where channels dredged through seagrass will erode rather than remain stable is insufficient to confidently state that erosion will not be a problem.

Finally, runoff from the dredge spoil could potentially cause problems, through either an increase in turbidity or a resuspension of contaminants. Using a properly designed series of settlement ponds for dewatering will ameliorate the former. These ponds will be located in the marina basin, which will be isolated from the ocean during construction by a coffer dam across the ends of the breakwaters. Low turbidity water will then be disposed of to sea. There are two options for this disposal. One is to pump the water off the end of the breakwater, ~ 200 m from the low tide mark. This is the preferred option under the Environment Protection (Water Quality) Policy 2003, but will result in the discharge being over seagrass. The alternative is to discharge it further inshore, which is a less sensitive environment being bare sand, but which has much more stringent restrictions on water quality which it may not be possible to meet. This situation will be discussed with the EPA prior to a final decision being made, as from a logistical and operational perspective there is little difference between the two options. Given the relatively undeveloped nature of the site, it is unlikely that the sediments to be excavated will contain any significant levels of contamination. To ensure that this is the case, sediments will be sampled and tested for the main problem contaminants (heavy metals) prior to any dredging activity. For dredging projects up to 10 000 m^3, it is required that 6 separate samples be taken and tested for contaminants (Environment Australia 2002). In previous dredging projects, the EPA has required testing for: copper, lead, zinc, chromium, nickel, cadmium, mercury, arsenic, silver, manganese, cobalt, vanadium, selenium and antimony. The levels of these metals should be compared against the NEPM guidelines (http://www.ephc.gov.au/nepms/cs/con_sites.html) to determine acceptable uses and management strategies for the spoil. Given the small volume, it is intended to dispose of all of the spoil on land.

Operation related impacts
The two main operation related impacts are likely to be associated with reduced water quality and the introduction of marine pests. Both of these issues are covered elsewhere in this report.

6. Strategies to minimise effects on the marine environment

While the direct loss of seagrass due to construction of the breakwater and entrance channel cannot be avoided, as stated earlier it is expected that the removal of the existing swing moorings once the marina is operational will result in recovery of the mooring scars, and thus over the longer term (~ 5-10 years) there is unlikely to be any net loss of seagrass habitat, although it may take considerably longer for *Posidonia* (potentially 50 years +) to recolonise the mooring scars. The recolonisation time for *Posidonia* will depend on whether the integrity of the rhizome mat has been maintained or not. Observations by Bryars (2003) suggest that the rhizome mat is still relatively intact, so recolonisation may occur more quickly.

Potential turbidity problems will be reduced by ensuring that dredging only occurs during periods of low water movement. Experience at Tumby Bay suggests that the greatest turbidity problems occur on spring tides, when the high water movement results in increased resuspension of loose material left by the dredging operation. Daily monitoring will show if turbidity is a problem, and dredging operations should be suspended if conditions result in turbidity exceeding the trigger values set in the Environment Protection (Water Quality) Policy 2003. It is intended to use a cutter/suction dredge to remove soft sediments from the dredge site, to minimise problems with turbidity at the dredge site. It does, however, leave the problem of what to do with the slurry, which has to go through a series of settling ponds for dewatering so that the water being returned to the ocean is low in turbidity. This will be done in the marina basin, which will be enclosed by a coffer dam across the ends of the breakwaters during construction. A barge mounted backhoe will be used to remove the more compacted limestone which occurs about 1m below the sediment surface. If needed, a metal shield will be placed around the section of channel being dredged, so that there is only a single pulse of turbidity when the shields are moved. This technique has recently been used successfully at Tumby Bay, albeit for maintenance of an existing channel. Given the coarse nature of the material to be removed, however, it may not be necessary to follow this procedure to maintain turbidity levels within the guidelines

If erosion of the entrance channel occurs, then several engineering solutions will be investigated, depending on the nature, extent and location of the erosion. These solutions could include extending the breakwater, and using geotextile mats to stabilise the edges of the channel. Any potential solutions will be informed by ongoing work at Beachport, where the Coast Protection Board is currently in the process of trying to slow foreshore erosion resulting from extensive seagrass loss.

7. Proposed monitoring of impacts

During construction

Apart from the direct loss of a small area of habitat, the only likely potential impact during construction will be associated with increased turbidity levels. Daily turbidity monitoring will be conducted while dredging is carried out. Turbidity levels will be monitored adjacent to the dredge site using a nephelometer, with a trigger value set at 10 NTU as per the EPA's water quality policy. A mixing zone of 50m will be allowed as per the EPA water quality policy for sites > 200m from the low water mark, meaning that turbidity will be measured 50 m from the dredge head each day. Turbidity will also be measured adjacent to the discharge pipe from the dewatering ponds. Prior to dredging, turbidity will be assessed over a period of 5 days at the dredging area and several other sites, to assess background turbidity levels. During dredging, turbidity will be monitored at the dredge site, as well as at a control site upcurrent of the dredge site. The control site will be used to ensure natural system-wide increases in turbidity are not blamed on the dredging operation. If turbidity exceeds 10 NTU, then dredging should be shut down until levels decrease and the procedure can be modified if the problem is not related to natural turbidity increase such as due to storms. Monitoring will occur 3 times daily, once at the start of the day's operations, once mid-way through, and once at the end. This may be modified depending on how close to the trigger level the turbidity is – for example if they only ever get to 50% of the trigger in the first 5 days of dredging the first monitoring episode of the day will be dropped.

After construction

Any longer term impacts that may occur are most likely to be associated with either reductions in water quality or marine pests (both discussed in other sections), or with continued erosion of the channel. Channel erosion will be visually obvious from the surface, and the marina operators will visually assess the condition of the channel sides and seagrasses along the channel edge to ensure that erosion is not occurring. This monitoring should occur weekly for the first 2-3 months, and then monthly thereafter if no problems are evident. The condition of the channel will similarly be assessed as soon as practically possible after any major storm activity.

8. Measures to protect and monitor water quality

As discussed above, there will be minimal inputs of groundwater into the marina, and any contaminants present will be heavily diluted and thus inconsequential. Thus, any water quality problems will be related to either stormwater inputs, other discharges, or poor flushing of the marina basin. Stormwater will be diverted to a stormwater treatment facility, and so will not be an issue. Discharges from vessels will be minimised by providing the appropriate waste disposal facilities (for oil, bilge water, wastewater etc), and hardstands will be equipped with pollution traps. The flushing time of the marina is also expected to be rapid (6-8 days WBM Oceanics Australia 2004), suggesting that water exchange will be sufficient to prevent a major deterioration in water quality.

As a result of these mitigation measures, it is considered that regular monitoring of water quality will not be needed. Instead, any monitoring will be targeted at specific problem events such as an algal bloom occurring in the marina, or seagrasses starting to die off around the marina entrance.

9. Pest marine organisms

There are over 250 known introduced marine species in Australia (Thresher 1999), although the actual number is likely to be much higher (Hayes and Sliwa 2003). Within the Outer Harbour area, in the Port River, Adelaide, Cohen *et al.* (2001) found 22 known exotic species, which included 17 exotic species in the nearby North Haven marina and 5 at the Royal South Australian Yacht Squadron (RSAYS), with a further 8 having been found previously (Cohen *et al.* 2001). The degree of marine pest infestation for the majority of South Australia's marina developments outside the Adelaide metropolitan area is largely unknown. While the vectors for most South Australian marine pest introductions are unknown, elsewhere in Australia recreational and fishing vessels are known to have resulted in both primary (new introduction to Australia) and secondary (spread to a new port within Australia) introductions. These include the black-striped mussel *Mytilopsis salei* in Darwin, the Asian Green Mussel in Cairns, and the Mediterranean fanworm *Sabella spallanzanii* in Eden (McEnnulty et al. 2001, Pollard & Rankin 2003).

In terms of marine pests, the environmental impact of a coastal development such as a marina may be considered from three interrelated perspectives.

1. There is the possibility of introducing or enhancing the distribution of a marine pest by the act of construction.
2. A new marina presents a large expanse of new habitat for colonisation by species that may not otherwise occur in the area due to dominance of seagrass. Invaders that may be local species from outside the general area, as well as introduced pest species, may be afforded a substantial opportunity.

3. There is the ongoing potential for introducing pest species from other infected areas by virtue of the increased boating traffic.

The act of construction itself may result in new introductions to an area if any dredges, barges or other craft are contaminated. Sediment remaining in barges/dredges from previous jobs can be an ideal place for exotic species to travel, and is of particular concern. Ballast/bilge water and hull fouling could also cause problems, especially as these craft tend to spend large amounts of time in major ports, which generally have large numbers of introduced species. Any construction vessels should be either cleaned and/or assessed for potential pest species before arrival if coming from such a high risk area. If the barge/dredge being used is based locally (ie in the south-east of SA), this cleaning is unlikely to be needed unless it is known to have spent time in an area with a marine pest problem.

The disturbance created by construction of a marina is likely to favour opportunistic marine organisms that tend to have high fecundity and rapid growth. Many of the most successful introduced species have these “weedy” properties and are thus likely to be successful in a disturbed habitat. Similarly the new substrates available after construction also favour taxa with these habits. The only possible mitigation for this is to ensure that water quality is sufficient that local species are able to colonise, which appears likely to be the case at Cape Jaffa, although even then it is likely that the marina will soon support an assemblage of introduced species.

Pleasure craft may be more likely vectors for marine pests than larger ships, particularly for those species that occur as hull fouling. Shipping operators spend substantial sums on antifouling mechanisms as any level of biofouling has a detrimental influence on the efficiency of a vessel’s movement and therefore the cost. Conversely, pleasure craft often accumulate substantial levels of fouling as they are often left at moorings for a protracted period without cleaning, and can accumulate substantial loads of fouling organisms. Fishing vessels can also be important agents of new introductions, particularly those that use easily contaminated bottom trawling or dredging gear. The risks associated with both of these agents will depend on the amount of vessel traffic from other ports. Boats based in the marina which rarely travel to areas such as Port Adelaide and Port Phillip Bay are likely to be low risks, whereas visiting vessels from these ports will be higher risk. Similarly, local rock lobster vessels will be low risk, as they generally restrict their voyages to the south-east of South Australia. Visiting trawlers operating out on the shelf will be high risk if they use the marina, although this is unlikely.

Invasions of species such as the European fanworm (*Sabella spallanzanii*) and the solitary ascidian (*Ciona intestinalis*), as well as other species already found in South Australia are likely to be unpreventable. Both species are well established along the metropolitan coast of Adelaide (Boxall and Westphalen 2003, NIMPIS 2003) and their further spread is sure to continue. A marina may also act as a point source for marine pest invasion of the surrounding community. Longer-term predictions as to the effect of a marina in terms of invasive species are difficult to make, as the biological consequences of such invasions are often unknown (McEnnulty *et al.* 2001). Most of these species are unlikely to invade the nearby seagrass meadows in problem numbers, as they have not become a problem in similar habitats in Gulf St Vincent. *Sabella spallanzanii*, along with several other species, may have the potential to invade nearby reefal habitats, although this has not yet been documented in the Adelaide region where it is more likely to occur due to higher population sizes and greater human disturbance. The only natural substrate on which *Sabella* has been found around Adelaide are *Pinna* (razorfish) shells, which do not occur around Cape Jaffa (Edgar 2000).

The taxa that are of greatest concern are those targeted for eradication in SA, namely *Caulerpa taxifolia*, and those species that are major problems elsewhere but do not yet occur in this state, such as the pacific seastar (*Asterias amurensis*) and the Japanese kelp (*Undaria pinnatifida*). Both are potentially disastrous to marine environments and associated industries in South Australia. The former is a major economic and environmental problem in Port Phillip Bay, while the latter only occurs in Tasmania to date, and is thus only an immediate risk if vessels move between Tasmania and Cape Jaffa. Those species on the Australian Ballast Water Management Advisory Council's marine target species list that are not currently present in Australia are unlikely to be primary introductions to Cape Jaffa as it will not receive international shipping, but may occur as secondary introductions if they become established elsewhere in Australia. Public awareness of marine pests and a mechanism of reporting potential sightings have been instigated as early detection is critical to the possibility of control (McEnnulty *et al.* 2001). However, prevention is far cheaper then remediation of marine pest issues (McEnnulty *et al.* 2001). As part of the management of marina facilities, these processes should be encouraged through signage with images of the most serious threats and contact numbers to report possible sightings (i.e. Fishwatch 1800 065 522). The local fishing and aquaculture community should be targeted with an awareness campaign, as they are the most likely to see something, and have the most to lose from any introduction.

Ideally, the marina should be fully surveyed for introduced pests every 2-3 years, as while it may be possible to control recent introductions, it will be impossible to control any introductions that have become firmly established and which have gained a foothold outside of the marina itself. For example, the recent outbreak of the black-striped mussel *Mytilopsis salei* in Darwin Harbour could only be eliminated because it was detected early. Such surveys are not currently required for other marinas, however, and their expense means that they could not be conducted on a sufficiently frequent basis to reliably detect new invasions at an early stage. An alternative would be for the marina operators to become familiar with the major species likely to invade and which are considered problematic, and to conduct more regular spot checks for these species. This alternative has the advantage of being low cost and increases the likelihood of early detection of the key problem species. If any of these species are found, then the relevant authorities in PIRSA should be advised and consulted for an appropriate response strategy. Such a strategy will vary depending on species and level of infestation (see NIMPIS 2003 and McEnnulty et al. 2001 for a list of potential control strategies for problem species), so it is not appropriate to document potential responses here in further detail.

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APPENDIX 14

Cape Jaffa Anchorage Marina Groundwater Impact Assessment Volume 1 – Desktop Study and Field Investigations, Tonkin Consulting, November 2003, Ref No. 20030318RA4

Cape Jaffa Anchorage Marina Groundwater Impact Assessment Volume 2 – Conceptual Hydrogeological Model, Tonkin Consulting, December 2003, Ref No. 20030318RA5

Cape Jaffa Anchorage Marina Groundwater Impact Assessment Volume 3 – Groundwater Flow Model, Tonkin Consulting, February 2004, Ref No. 20030318RA6

Cape Jaffa Anchorage Marina Groundwater Impact Assessment Volume 4 – Assessment and Management, Tonkin Consulting, December 2004, Ref No. 20030318RA7

Additional Groundwater Sampling, Tonkin Consulting , November 2004, Ref No 20030318LA4/ MCK/MCK

Kingston District Council and
Cape Jaffa Development Company

Cape Jaffa Anchorage Marina

Groundwater Impact Assessment

Volume 1 – Desktop Study and Field Investigations

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Document History and Status

Rev	Description	Author	Rev'd	App'd	Date
A	Draft for Client Review	MS/MK/ AD/GRP	MA	VAH	4/11/03
B	Revision 1	GRP	GRP	VAH	16/3/04
C	Revision with Final EIS edits	GRP	GRP	PJL	23/12/04
D	Revision following Planning SA comments	GRP	[signature]	[signature]	4/2/05

1. Introduction

1.1 Project Background

Cape Jaffa is located on the coast at the southern end of Lacepede Bay in the south-east of South Australia. This small township of 30 to 40 residents is between Kingston SE and Robe and supports an established fishing industry, mainly for Southern Rock Lobster. The existing township is concentrated near the jetty and includes a tourist park. The facilities for the fishing industry include storage facilities, waterfront weighing and holding facilities and accommodates approximately 33 fishing vessels on swing moorings. The location of the site is shown on Figure 1.1.

Kingston District Council and Cape Jaffa Development Company are proposing to develop a safe haven and moorings for existing and future fishing fleet, recreational boating facilities as well as tourist and residential development south-east of the existing township. The development, as detailed in the Development Proposal (Kingston District Council & Cape Jaffa Development Company, 2002), is proposed to include:

- Rock groyne, extending from the shore into the sea;
- Main basin and canal system;
- Commercial fishing births and public marina berths;
- Commercial and public boat ramps and associated facilities;
- Fish and aquaculture service industry, eg. fish receival, processing and holding, as well as dockside offices; and
- Residential allotments, private marina berths, tourist accommodation and services.

The proposed development is illustrated on Figure 1.2.

Cape Jaffa was chosen as suitable location due to its proximity to fishing areas, the potential for site development and safe waters.

Kingston District Council has requested that the development be treated as a Major Project to ensure a full and proper assessment is undertaken of this complex proposal.

Figure 1.1 Site Location Plan.

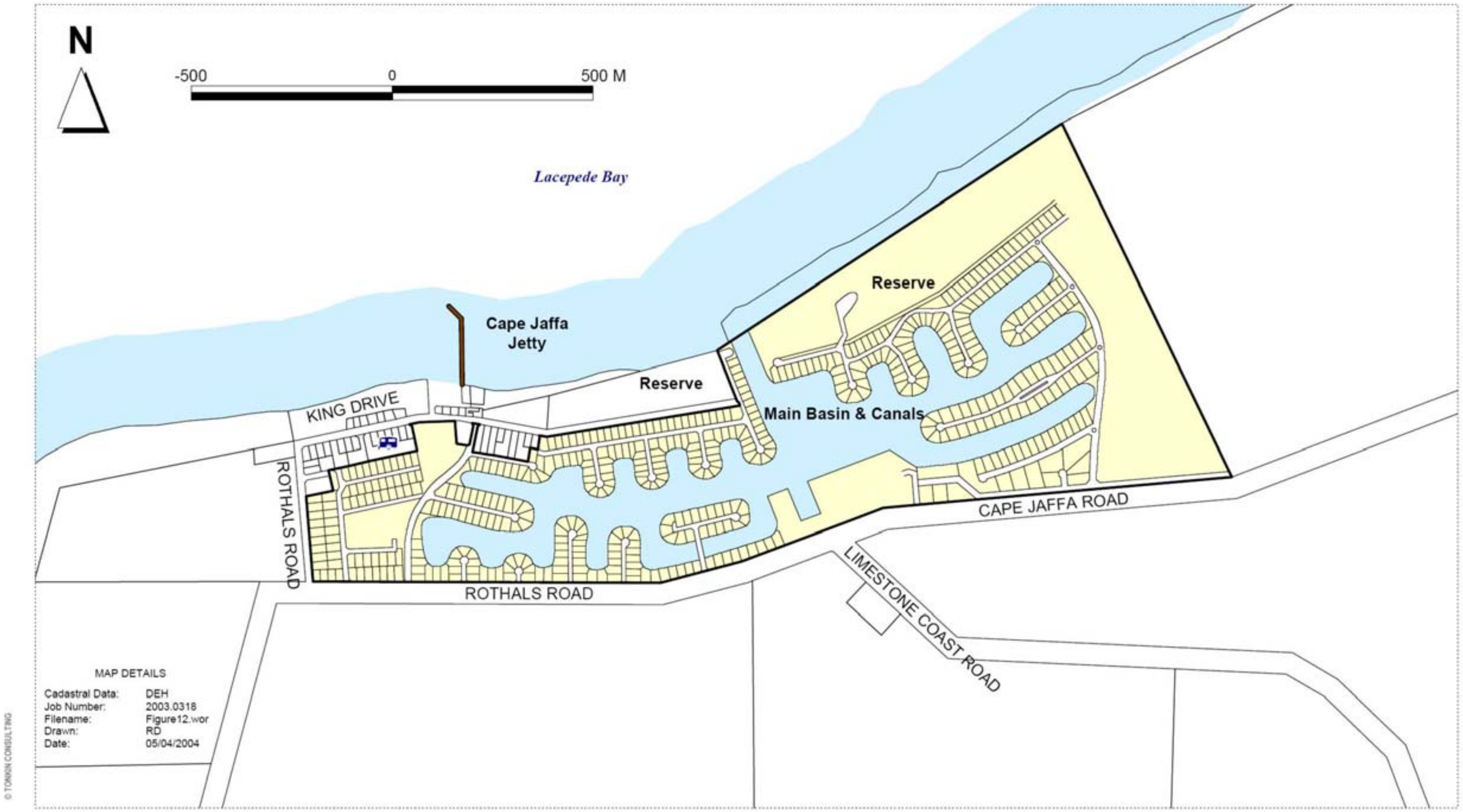

Figure 1.2 Proposed Development Plan.

1.2 The Study Area

The site incorporates:

- Allotment 123 in Deposit Plan 55486 (CT 5863/840);
- Part Section 92 of the Hundred of Mount Benson (CT 5560/348);
- Portion of King Drive;
- Portion of Cape Jaffa Road; and
- An area to sea in Lacepede Bay (Out of Hundreds)

in the area named Cape Jaffa.

The Major Projects Boundary is illustrated on Figure 1.3.

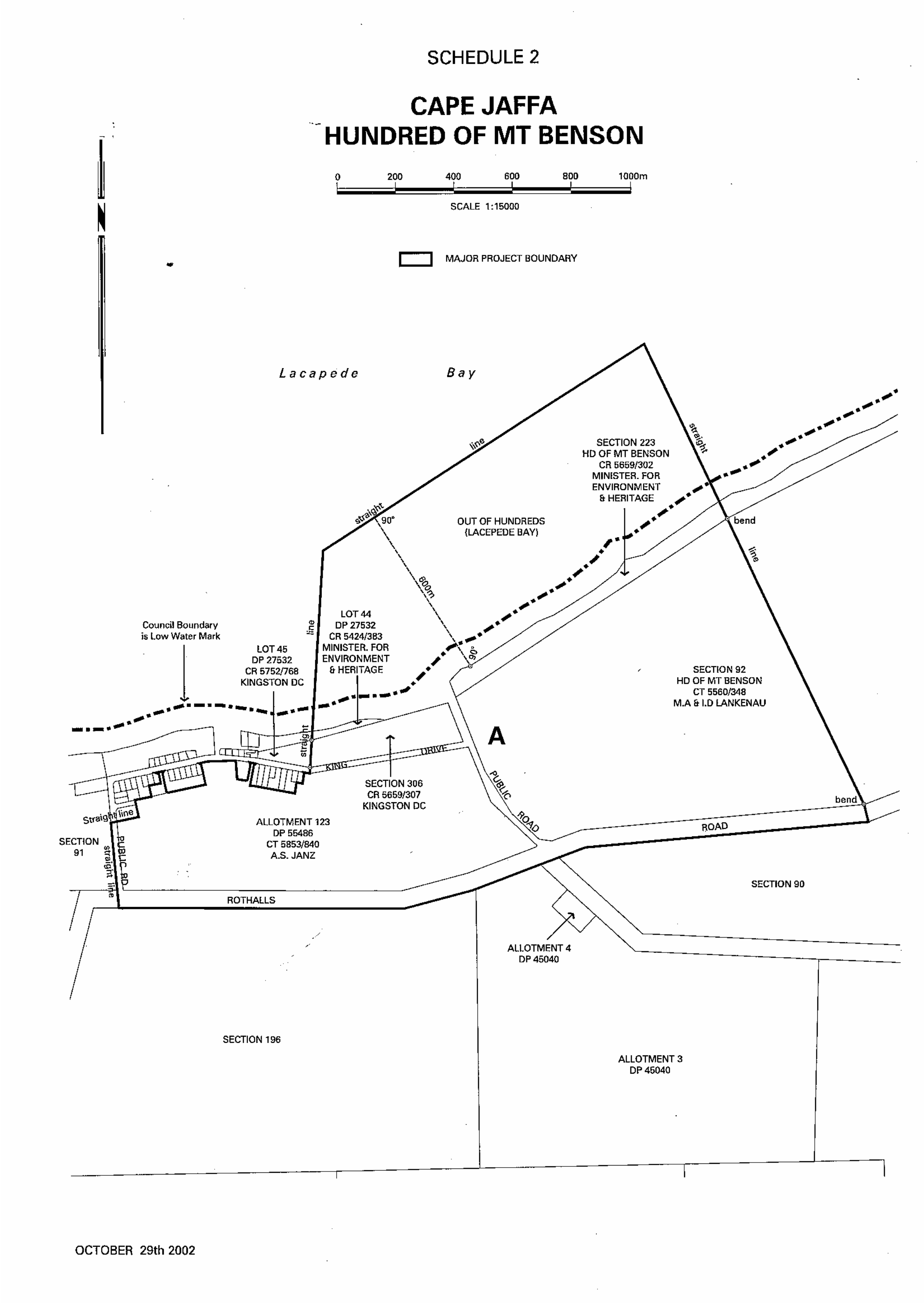

Figure 1.3 Major Projects Boundary as gazetted 29 October 2002.

1.3 Major Projects Legislative Requirements

Developments which are considered to be of a special or more complex nature than anticipated by the Development Plan may be declared as Major Developments, as allowed under Section 46 of the Development Act 1993.

The process for assessing and approving Major Developments or Projects involves:

1. Declaration by the Minister for Transport and Urban Planning.
2. Lodgement of a project proposal with the Major Development Panel to identify issues associated with the projects.
3. Preparation and release of an Issues paper for government and public comment prior to determination of the level of assessment required for the proposal.
4. Preparation of Guidelines by the Major Development Panel as a result of this review to enable the proponent to prepare an Environmental Impact Statement (EIS), Public Environmental Report (PER) or a Development Report (DR) for the proposal.
5. Assessment of the EIS, PER or DR by the Minister and release to the public for comment.
6. Forward of the Development Application to the Governor or relevant Minister and gazettal of decision in the Government Gazette.

Cape Jaffa was declared a major development by the Minister for Urban Development on 19 December 2002, i.e. it is of major environmental, social or economic importance. An Issues Paper was subsequently prepared by the Major Developments Panel (2003). Groundwater was identified in the paper as an environmental issue requiring further consideration by the Major Developments Panel.

Following public and government submissions on the proposed development, the Major Development Panel (MDP) has determined that the proposal will be subject to the processes and procedures of an Environmental Impact Statement (EIS). As a result, the Panel has prepared "Guidelines for the Preparation of an Environmental Impact Statement for the Cape Jaffa Anchorage Marina . Proposal by District Council of Kingston and the Cape Jaffa Development Company".

1.4 MDP Identified Groundwater Issues

The MDP has identified ten environmental issues related to groundwater. These issues are listed below, with numbers shown remaining consistent with those in the Guidelines (MDP, 2003).

5.2.1	Describe the known existing groundwater environmental conditions.
5.2.2	Detail any groundwater investigations and modelling undertaken on the site or in the locality of the site.
5.2.3	Describe the short and long term effects of establishing channels and basins on groundwater quantity and quality and movement, particularly watertable drawdown or contamination from salt water intrusion.
5.2.4	Describe stormwater and wastewater management and the potential impact on groundwater.
5.2.5	Detail the impact on land and native vegetation of the off-site depression of the water table and outline the extent of groundwater depression and effect on farming and horticulture and other operations within the groundwater depression zone.
5.2.6	Describe the likely effects on marine organisms, reef communities and seagrasses, given groundwater flow out to sea is likely to increase, potentially reducing the salinity and increasing nutrients and pollutants, particularly heavy metals.
5.2.7	Detail management systems to control the quality and quantity of outflow from the marina given that it is likely to become a sump for groundwater or high freshwater flows that may affect marine organisms.
5.2.8	Detail any seasonal variations of groundwater level and impact on marina design and off-site operations.
5.2.9	Describe the impact of housing and the commercial fishing base on groundwater quality.
5.2.10	Detail the measure to be taken to protect and monitor groundwater resources to ensure that the development does not have a deleterious effect on them.
5.2.20	Describe the impact of developing a wastewater treatment system to which the existing development can connect, including the impact of an irrigated woodlot on groundwater and the marine environment.
5.2.23	Described the effect of water table drawdown or contamination on local domestic water supplies, including that used for drinking and the watering of gardens.
5.2.29	Detail investigations to include in an environmental management plan.
5.3.10	Describe the impact of local and regional land uses (eg. Viticulture, horticulture and other forms of primary production) from groundwater drawdown or contamination.
5.3.17	Describe the impact of groundwater drawdown or contamination on the source and use of domestic water.
5.4.10	Describe how increased groundwater flows out to sea would be measured and whether such usage would be metered and charged for from the prescribed water

	resource.
5.4.11	Identify the economic implications for the rock lobster industry from increased groundwater flows and run-off out to sea.
5.4.12	Identify the economic implications for groundwater users from groundwater drawdown or contamination, particularly primary producers.
5.6.14	Identify the risk to proclaimed water resource (Lacepede-Kongorong Prescribed Wells Area).
5.6.15	Identify the risk to the marine environment and the rock lobster industry from increased discharges of groundwater that may potentially be contaminated by fertilisers.

1.5 Scope of Works

The Scope of Works to address the issues identified by the MDP and enable assessment of the potential risks to and impacts on groundwater from the Cape Jaffa Anchorage development will involve four stages, as outlined below.

STAGE 1: Desktop Review and Site Visit.

A review of available information to develop an initial understanding of the regional geology and hydrogeology based on available information. Information reviewed will include:

- Meteorological data;
- PIRSA data including registered groundwater users, geological and drillers logs;
- Regional geological and hydrogeological studies (including published geological and hydrogeological maps).

This review will address Issues 5.2.1 and 5.2.2 and part of Issue 5.2.8.

STAGE 2: Site Investigations.

Field investigation studies to determine and evaluate local geological and hydrogeological setting, including:

- Soil stratigraphy;
- Groundwater flow direction and gradient;
- Aquifer properties;
- Water level fluctuations;
- Hydraulic connection potential between shallow and deeper aquifer(s);
- Groundwater quality;
- Groundwater contamination status at the site;
- Tidal fluctuations and influence on groundwater levels.

This Stage will address Issue 5.2.8 and provide information to enable the development of the model.

The results of Stage 1 and Stage 2 are detailed in this report, “Volume 1 – Desktop Study and Field Investigations”.

STAGE 3: Model Development.

The findings from the Desktop Review and Field Investigations will be used to develop a conceptual hydrogeological understanding of the local environment. The Conceptual Hydrogeological Model will form the basis of the Numerical Hydrogeological Model. The numerical model will be used to:

- simulate current conditions; and
- predict changes to the system following development.

It is noted that the conceptual and numerical hydrogeological models may need to be refined as part of the Groundwater Management Plan when additional data becomes available.

This Stage will address Issue 5.2.3 and will enable the appropriate information to be provided to other disciplines for the evaluation of 5.2.5 and 5.2.6.

This stage will be documented in “Volume 2 – Conceptual Hydrogeological Model” and “Volume 3 – Numerical Hydrogeological Model”.

STAGE 4: Impact Assessment.

The outcomes of the above investigations and modelling will be used in assessing the impact of the development. In addition, the findings will be used to develop a groundwater management strategy for the site, which may include:

- Groundwater gauging program;
- Groundwater sampling program;
- Refinement of Conceptual Hydrogeological Model;
- Refinement of the Numerical Hydrogeological Model;
- Progress reporting.

The Stage will address Issues 5.2.4, 5.2.7, 5.2.9 and 5.2.10.

This stage will be documented in “Volume 4 – Assessment and Management”.

1.6 Authority Consultations

In undertaking this Groundwater Impact Assessment for the Cape Jaffa Anchorage Marina, discussions have been held with:

- Fred Stadter, Department of Water, Land and Biodiversity Conservation, Naracoorte
- Alex Eadie, Karen Ferguson, Lee Webb and Simon Wheaton, Planning SA, Adelaide
- Helen King, Environment Protection Authority, Mount Gambier
- Jennifer Schilling, South East Catchment Water Management Board, Mount Gambier.

2. Regional Environmental Setting

2.1 Climate

The climate at Cape Jaffa is a temperate, maritime climate consisting of warm, dry summers and cool, wet winters. The climate station at Robe (station no 28026) is south of Cape Jaffa and has been recording since 1860, resulting in 140 years of rainfall data and over 40 years of temperature data.

The mean daily summer temperature recorded at Robe is 13 to 23 ^{O}C with 18 to 28 mm/month mean monthly rainfall (Figure 2.1). During winter, the mean daily temperature is 8 to 15 ^{O}C with 85 to 105 mm/month mean monthly rainfall.

The mean average annual rainfall at Robe is 633 mm.

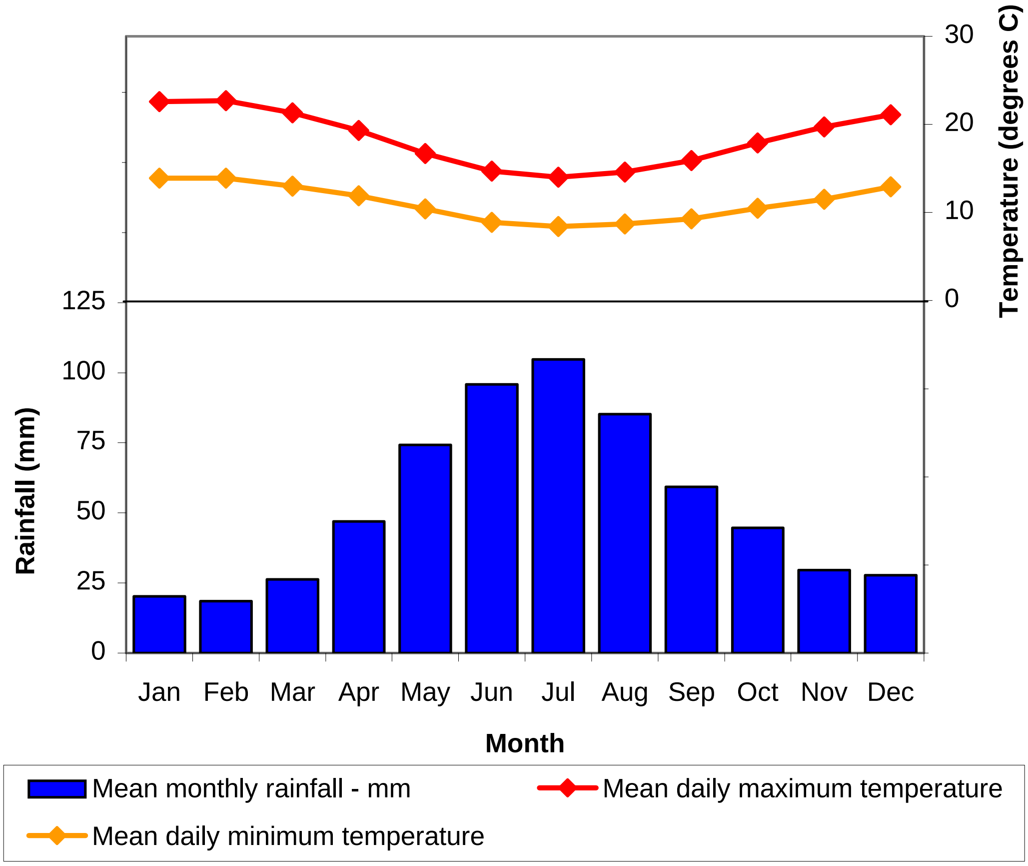

Figure 2.1 Mean monthly rainfall (mm) and daily temperatures (^{O}C) for Robe.

The lower temperatures and higher rainfall in winter may result in greater potential recharge of the aquifer.

Further information regarding climate issues are outlined in "Climatology of the Cape Jaffa Region. Winds, Waves, Tides and General Climate of the Cape Jaffa Region, SA." (Tonkin Consulting, 2003, Ref. 20010779RA1).

2.2 Physical Setting

Cape Jaffa is located at the cape that forms the southern end of Lacepede Bay.

The topography of the region is characterised by ridges of low sandy dunes and low lying swampy areas parallel to the coast of Lacepede Bay. Further to the south, the topography becomes more undulating and consists of limestone ridges that rise up to approximately 50 m AHD (Australian Height Datum) as indicated on the 1:50,000 Jaffa Topographic Map (Department for Environment, Heritage and Aboriginal Affairs, 1999).

The engineering survey for the study area indicates that the topographic relief of the site varies between approximately 1.5 and 4.5 m AHD.

Vegetation cover in the region is generally sparse and is predominantly grasses and cereal crops associated with agricultural uses. Taller tree species are generally associated with farm residences, the Cape Jaffa Caravan Park and dwellings within the Cape Jaffa township. Remnant native vegetation consisting of coastal shrubs and trees exist along the coastline and road corridors with a more substantial area of native vegetation located at the western end of the cape.

The study area typically consists of grasses and herbaceous weed species with sparse shrubby vegetation located west of Cape Jaffa Road. A band of remnant coastal vegetation exists along the coastline to the east of Cape Jaffa Road.

During prolonged periods of wet weather, the interdunal low lying areas flood. The region is crossed by several constructed drainage channels designed to drain some of these low lying areas to maintain agricultural land. The closest drain to the study area is the Wongolina Drain located approximately 10 km to the east.

2.3 Tide Levels

Due to the proximity of the proposed development site to the sea, the tidal levels for Cape Jaffa may influence the diurnal and seasonal groundwater depth, groundwater flow direction and/or flow rate as well as the groundwater quality.

Four years of continuous tidal data from 1980 to 1984 are available from Cape Jaffa. However, problems with the recording instrument are evident from this data. Tidal data for Kingston SE are published in the "Tidal Tables for South Australian Ports". Details on the tidal data have been previously reported for the Cape Jaffa Development Company by Tonkin Consulting in "Climatology of the Cape Jaffa

Region. Winds, Waves, Tides and General Climate of the Cape Jaffa Region, SA" (2003).

Tonkin Consulting (2003) notes that the tidal data from Cape Jaffa showed typical fortnightly neap to spring tide cycles and six monthly cycles in daily tidal ranges. The solstice daily tides (around June and December) range from 0.2 m (neaps) to 1.2 to 1.5 m (springs) while the equinox daily tides (around March and September) range from 0.5 m (neaps) to 0.9 m (springs).

Due to the difficulties in converting the Cape Jaffa data to AHD, the tide levels are not discussed here. However, similarities were noted by Tonkin Consulting (2003) between the Cape Jaffa and Kingston SE tide data.

The tidal patterns around Kingston SE have a fortnightly cycle between spring (large) and neap (small) tidal ranges (Table 2.1). The astronomical tidal range is generally less than 1 metre, though around the solstices and depending on meteorological conditions, the daily tidal range may be 1.2 to 1.5 m.

Table 2.1 Tidal data from Kingston SE (reported in Tonkin Consulting, 2003)

	Kingston Tide Data (m AHD)
Highest recorded water level	1.37
Springs	0.42
Mean high water neaps	0.22
Mean sea level	0.03
Lowest Astronomical Tide	-0.48
Lowest recorded water level	-1.04

Tonkin Consulting (2003) notes that actual tides in winter at Cape Jaffa may be higher than the predicted astronomical tide and lower in summer due to meteorological conditions at the site.

2.4 Surface Hydrology

The region is an undulating coastal plain sloping west/southwest towards the sea. Between Kingston and Beachport, a series of parallel dune ranges trend in a northwest direction, conforming approximately to the present coast. The dunes form a barrier to the seaward drainage of surface waters. Salt lakes and swamps have formed between the dunes.

The Glenelg River (Victoria) is the only perennial stream in the region. Watercourses have not developed because of the low topography, high permeability soils and coastal ridges, which act as a barrier to surface water flow. Surface water drains to swamps, lakes and sinkholes in the interdunal corridors (Love *et al*., 1992). An extensive network of man-made drains has been constructed to limit flooding of these low-lying areas.

2.5 Regional Geology

Geologically, the study area lies within the Gambier Embayment of the Otway Basin, which extends from Kingston SE to the Mornington Peninsula in Victoria. Basement highs outcrop in the northwest (Padthaway Ridge) and southeast (Dundas Plateau).

The section below provides a brief overview of the underlying geological sequence from oldest to youngest and is based on information given in:

- Department of Mines and Energy 1995, *Geology of the South-East, South Australia*, Second Edition, South Australia Geological Survey, Special Map 1:500,000;
- Department of Mines. 1951. *Geological Survey of SA, Kingston SE, 1 Mile Geological Series*, First Edition;

During the *Late Jurassic Period*, sequences of sand and silt were laid in an elongated depression now known as the Otway Basin.

Following the Jurassic Period, the *Cretaceous Period* was predominantly a fluvial environment with some marine incursion and resulted in the formation of the Otway Group, which are sedimentary rocks often-exhibiting interbedding between sandstones, siltstone, mudstone and claystone.

During the subsequent *Tertiary Period*, the Gambier Limestone was laid, unconformably over the Dilwyn Formation. The Dilwyn Formation is comprised of an interbedded sequence of sand, gravel and clay of fluvial (river) and deltaic (river delta) origin. The Gambier Limestone is a bryozoal limestone formed during open marine conditions and may also contain some marl, chert or dolomite. The limestone is noted as “dolomitized” (i.e. includes magnesium) along an inferred fault zone at Cape Jaffa (Dept of Mines, 1951).

The surface sediments in the southeast area were predominantly deposited during the *Quaternary Period* and are a record of sea level change. The Bridgewater Formation is the oldest Quaternary sedimentary deposit and is located to the south of Cape Jaffa. This formation is subtidal beach and aoelian (wind-blown) calcarenite (limestone) from stranded coastal ridges. The coastal strip around Cape Jaffa is predominantly Semaphore Sand of the St Kilda Formation, which is comprised of coastal barrier, beach ridge and dune sediments. To the east of this are the older lagoonal and lacustrine (lake) sediments and shell beds of the St Kilda Formation. Slightly older than these formations and further east is the Glanville Formation, which is comprised of lagoonal sediments and shell beds.

The surface geology of the area is shown on Figure 2.2.

2.6 Soils

The soil type series of the Cape Jaffa area is part of the Kingston Land System, which consists of low, parallel coastal dunes alternating with swamps. The dunes are predominantly vegetated and therefore currently stable and are comprised of deep shelly calcareous or calcareous siliceous sand (PIRSA, 2001b).

Swamps and lunettes are also found in the Cape Jaffa area. The swamps are moderately saline, dark cracking clay though calcareous clay on marl is also found. The lunettes are dark clay loam, often over dark clay on calcrete (PIRSA, 2001b). The salinity of the swamps and lunettes is predominantly induced by the saline groundwater.

2.7 Regional Hydrogeology

Within the Gambier Embayment, the two major aquifers of interest include:

- The unconfined Tertiary Limestone Aquifer (TLA); and
- The Tertiary Confined Sand Aquifer (TCSA).

2.7.1 Stratigraphic Sequence

The TLA is predominantly found within the Gambier Limestone though the aquifer may extend into the overlying Bridgewater and St Kilda Formations. The TLA consists mainly of calcareous sandstone and limestone deposits.

The TCSA is contained within the sand sequence of the Dilwyn Formation and is confined by the upper and lower clay sequences in the formation. This aquifer is in fact a multi-aquifer system, resulting from the interbedded sands, gravels and clays of the Dilwyn Formation. For simplicity, regionally it is treated as one aquifer. The upper clay sequence forms the aquitard between the TCSA and TLA.

Figure 2.3 presents a summary of the regional stratigraphic units (Love *et al.*, 2001).

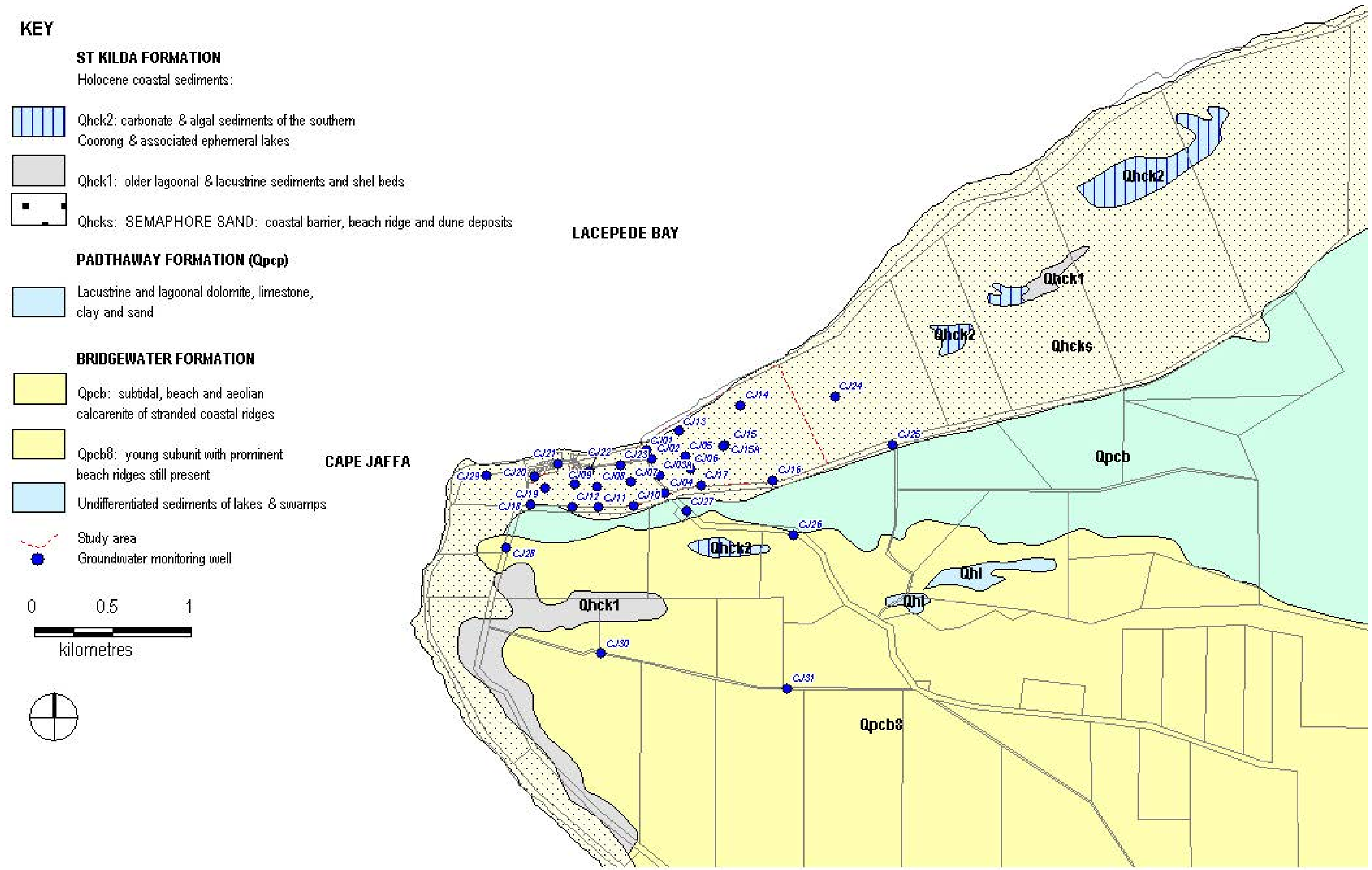

Figure 2.2 Surficial geology (DME, 1995).

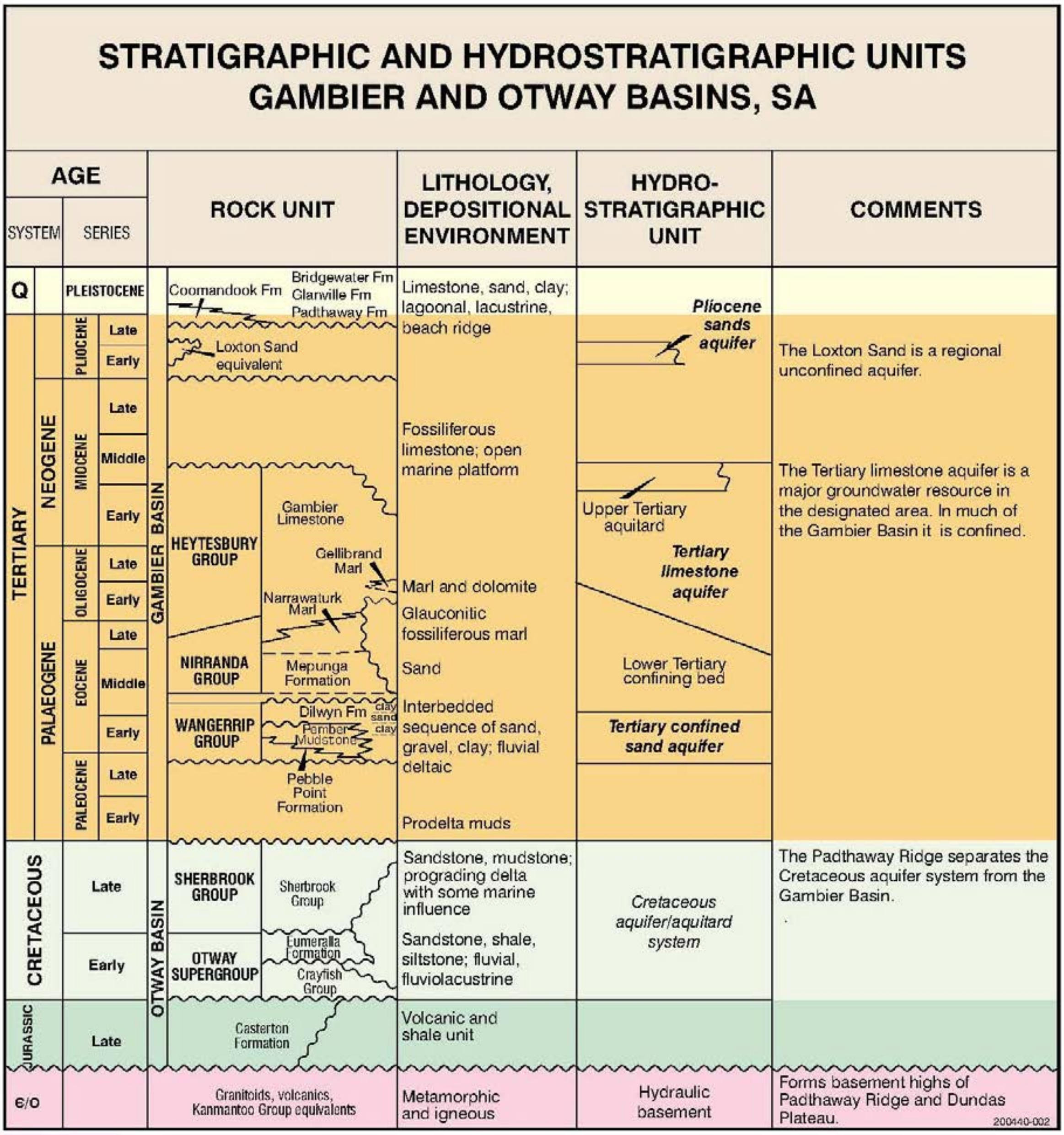

Figure 2.3 Regional stratigraphic profile (Love *et al.*, 2001).

2.7.2 Regional Groundwater Flow Direction and Aquifer Recharge

The groundwater flow in both the TLA and TCSA radiates from the Nangwarry-Tarpeena area towards the sea. Potentiometric surface contours for the TCSA aquifer is shown in Figure 2.4.

The aquifers are connected via fractures, faults or sinkholes allowing preferential flow. Recharge to the TCSA may occur in relatively small, localised areas (Brown *et al.*, 2001). Vertical recharge to the TCSA is via downward leakage from the TLA. This only occurs in the eastern portion of the Otway Basin, where there is a downward head gradient. In the west (near the study area) and south, however, the head gradient is reversed and there is potential for the TCSA to recharge the overlying TLA. The degree of connectivity between the two aquifers is poorly understood and is currently the subject of research.

A schematic cross section illustrating the two aquifers of interest, the aquitard and general groundwater flow direction is presented as Figure 2.5.

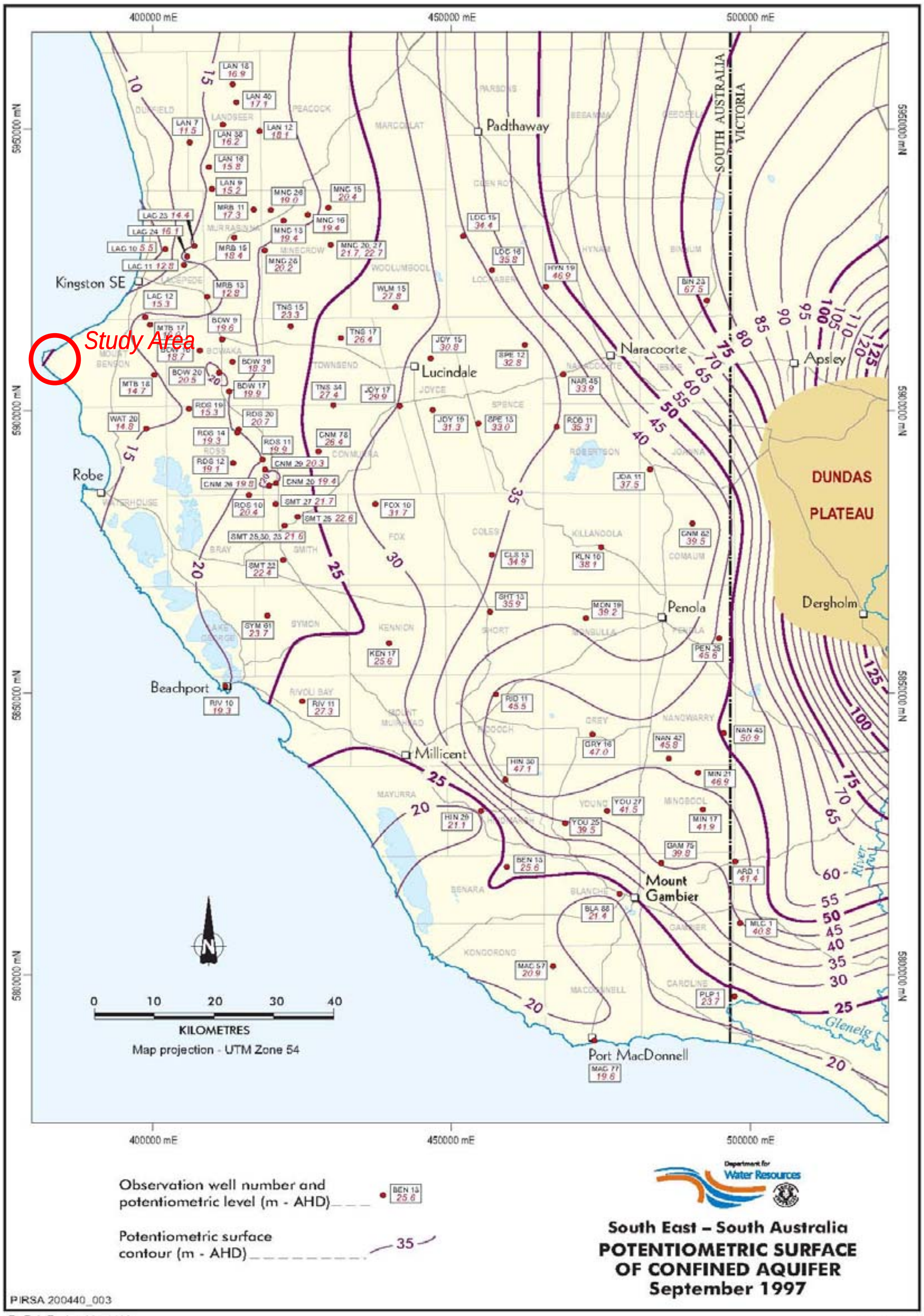

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Figure 3

Figure 2.4 Potentiometric surface of Confined Aquifer (TCSA) (Love *et al.*, 2001).

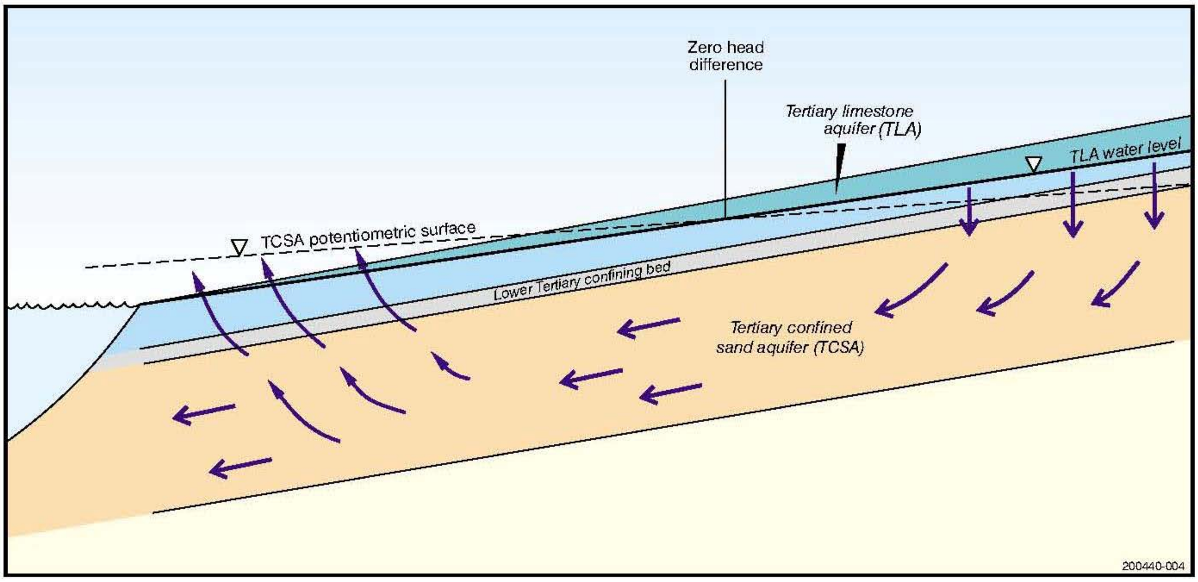


Figure 2.5 Schematic cross section of the aquifers of interest and groundwater flow direction (Love *et al.*, 2001).

2.7.3 Regional Aquifer Properties

Aquifer properties sourced from regional reports are summarised in Table 2.2.

Table 2.2 Aquifer Properties.

Property	Tertiary Limestone Aquifer (Unconfined)	Aquitard	Tertiary Confined Sand Aquifer	Reference
Flow rate	5-50 m/year	-	1-5 m/year	Love, Armstrong and Stadter (1992)
Thickness	10-20 m (Nangwarry-Tarpeena area)	5-40 m (Nangwarry-Tarpeena area)	Deepens near coast	Love, Armstrong and Stadter (1992)
	Increases west and south to >300 m along coast near Carpenter Rocks	20-40 m (except in northwest margin)		Cobb and Brown (2000)
Transmissivity	200 to >10,000 m^3/day/m	-	200 to 1,600 m^3/day/m	Love, Armstrong and Stadter (1992)
			40 to >4,500m^3/day/m	Cobb and Brown (2000)
Porosity	30-50% (estimated from logs) 50-60% (measured)	-	20-30%	Love, Armstrong and Stadter (1992)
Diffuse recharge	47 to 270 mm/yr in southern portion of Otway Basin 2 to 40 mm/yr northern	-	-	Love, Armstrong and Stadter (1992)
Vertical permeability	-	10^{-3}-10^{-7} m/day	-	Love, Armstrong and Stadter (1992)
Depth to water table	Near ground level west of interdunal flats to >40 m in Mt Burr Region	-	-	Cobb and Brown (2000)

2.7.4 Regional Groundwater Quality

Groundwater in the TCSA is approximately 25,000 years old and has low salinity, less than 1,000 mg/L Total Dissolved Solids (TDS) in the southeast region.

Beneath the dune ranges within the TLA, vertical permeability is high and groundwater quality is also good with TDS typically below 1,000 mg/L. The body of fresh groundwater in the TLA encompasses the Cape Jaffa and Mount Benson regions. Near surface interdunal saline water may rest on top of this body of fresh water (Nelson, 1972).

Salinity distributions in both aquifers are shown in Figure 2.6 and Figure 2.7.

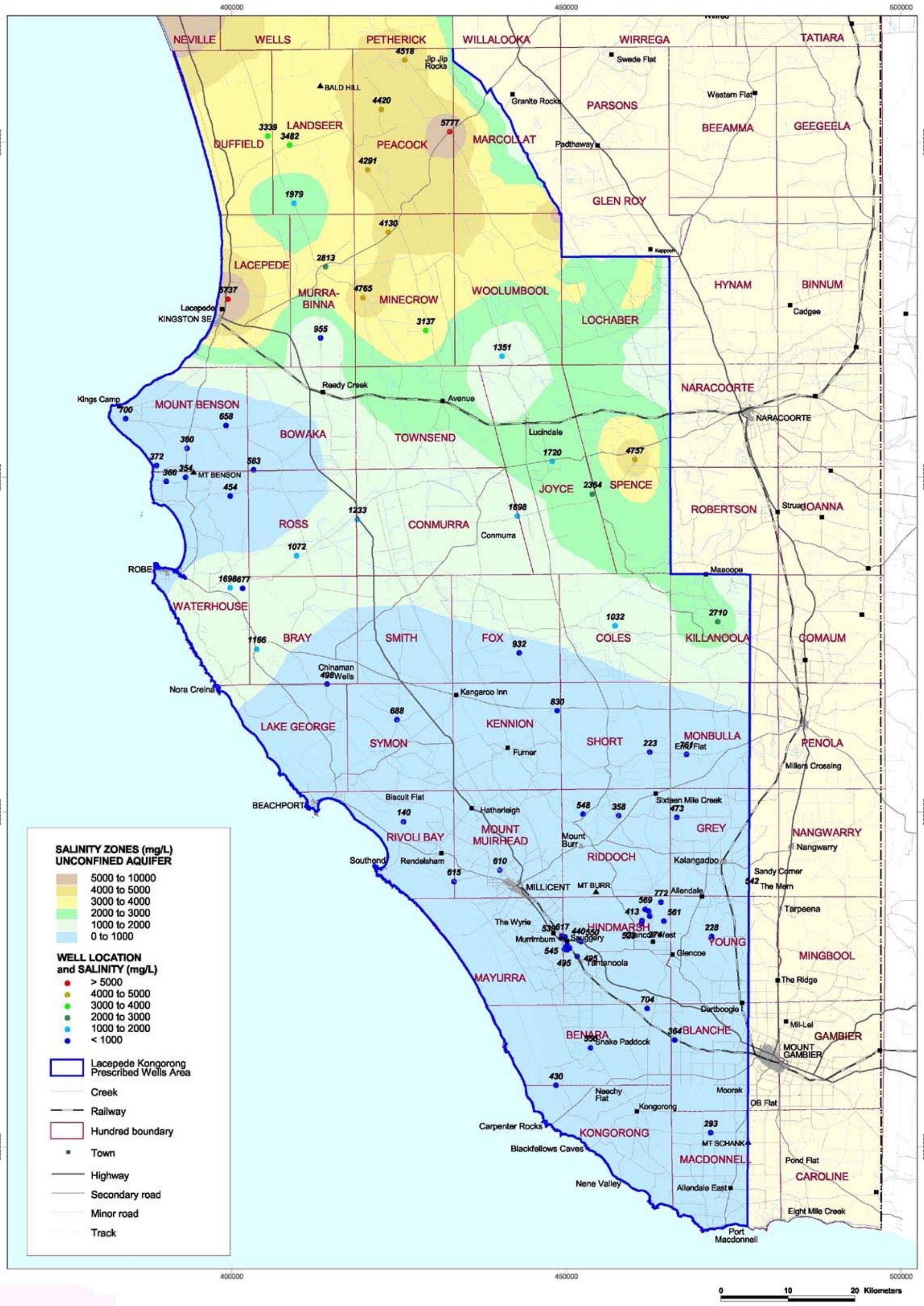


Figure 2.6 Generalised salinity distribution in Unconfined Aquifer (Walker *et al.*, 2001)

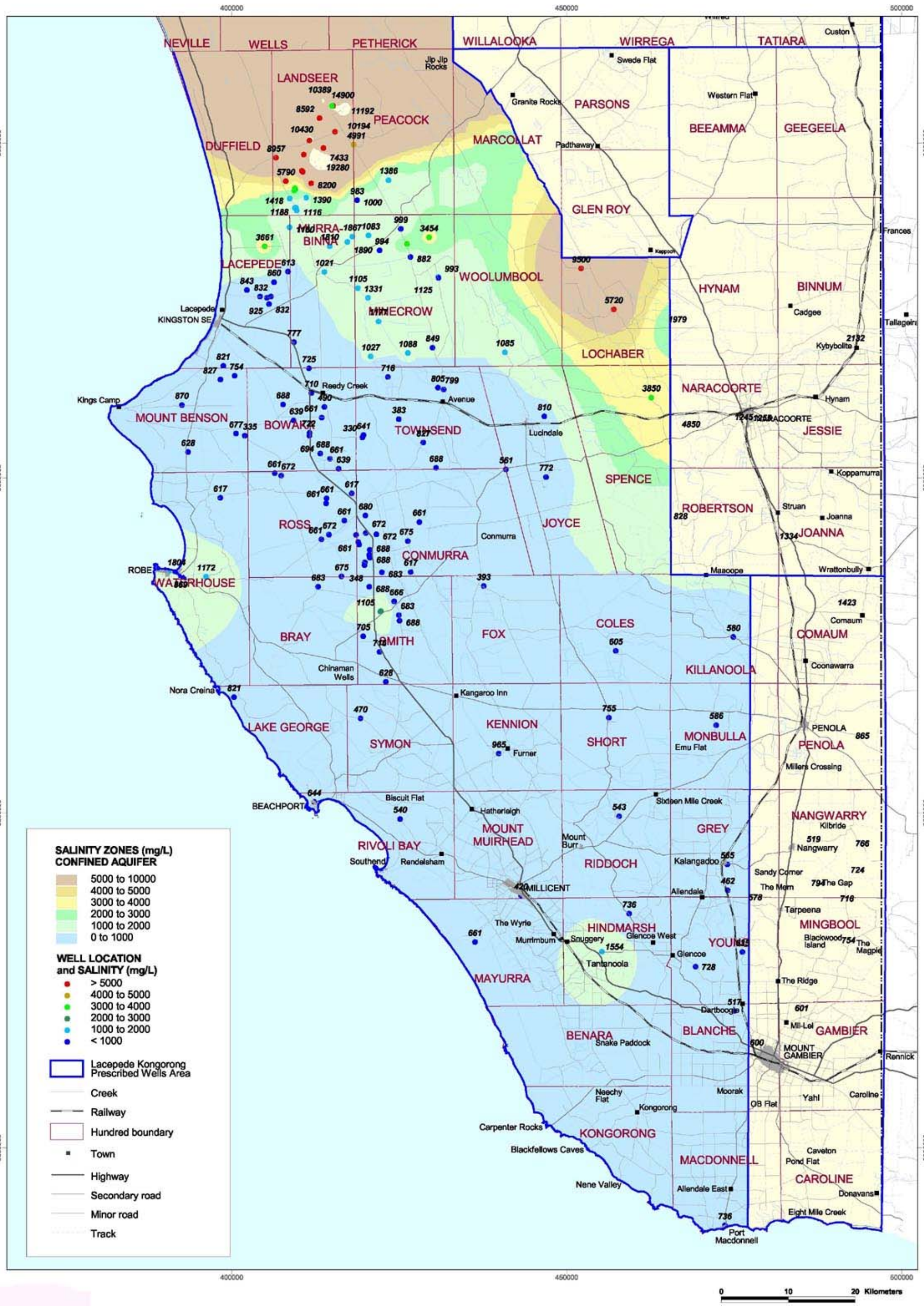


Figure 2.7 Generalised salinity distribution in Confined Aquifer (Walker *et al.*, 2001)

2.7.5 Regional Groundwater Use

As there are no significant surface water flows in the region, groundwater is used extensively. It is primarily used for irrigation, but is also used for stock watering, industrial and municipal uses.

Cape Jaffa is located within the Lacepede Kongorong Prescribed Wells Area (PWA). Groundwater allocations are described in the Water Allocation Plan (WAP) for the PWA, published by the South East Catchment Water Management Board (SECWMB, 2001).

For the TCSA, the Cape Jaffa is located in the Kingston Management Area. In this area, the WAP indicates that groundwater usage from TCSA is currently over-allocated and measures are being put into place to reduce groundwater usage from this aquifer. The extensive use of this aquifer is due to the relatively good quantity and quality of water available compared to (regionally) parts of the unconfined aquifer. In addition, many of the wells intersecting the confined aquifer are artesian and therefore pumping if often not required.

Groundwater use from the TCSA is extensively used for town water supplies and aquiculture in the Kingston Management Area. However, the predominant use is for irrigation purposes. Other uses include stock and domestic use particularly at locations where the salinity of the TLA is higher. Extensive leakage from the confined aquifer to the unconfined aquifer through poorly constructed or deteriorating wells has been identified in the region and a program is in place to replace, abandon or rehabilitate such wells.

It has been estimated that regionally, the total groundwater extraction from the TCSA for irrigation use during the 1996-1997 season was approximately 22,500 ML/yr (Walker *et al.*, 2001).

The TLA is used extensively for irrigation as well as minor use for stock and domestic purposes where the quality is good. The use of this aquifer for town water supply is significantly less than the TCSA due to the potential of contamination of water supplies from surface activities. At present, only the townships of Millicent and Mount Burr utilise the TLA as their main source of potable supply.

2.7.6 Registered Groundwater Users near the Study Area

Information of registered groundwater wells near the study area was provided by Primary Industries and Resources SA (PIRSA, July 2003). Figure 2.8 presents the location of registered groundwater wells and depth within approximately two kilometres from the study area.

Pertinent information relating to the registered wells and classified use is summarised below:

- The majority of the wells are classified as domestic wells, with a number of wells classified as industrial, stock, irrigation, observation and town water supply.
- The majority of the wells are drilled to depths less than ten metres below ground surface and hence are likely to be intersecting the unconfined TLA. The maximum depth of the registered wells near the study area is 35 m below ground level (bgl). It is noted that the majority of the wells within the study area were drilled recently for the purpose of this study.
- Available data on the groundwater quality, in terms of TDS (refer to Figure 2.9), suggests that the salinity is often less than 1,000 mg/L indicative of water suitable for potable supply as per NHMRC (1996).

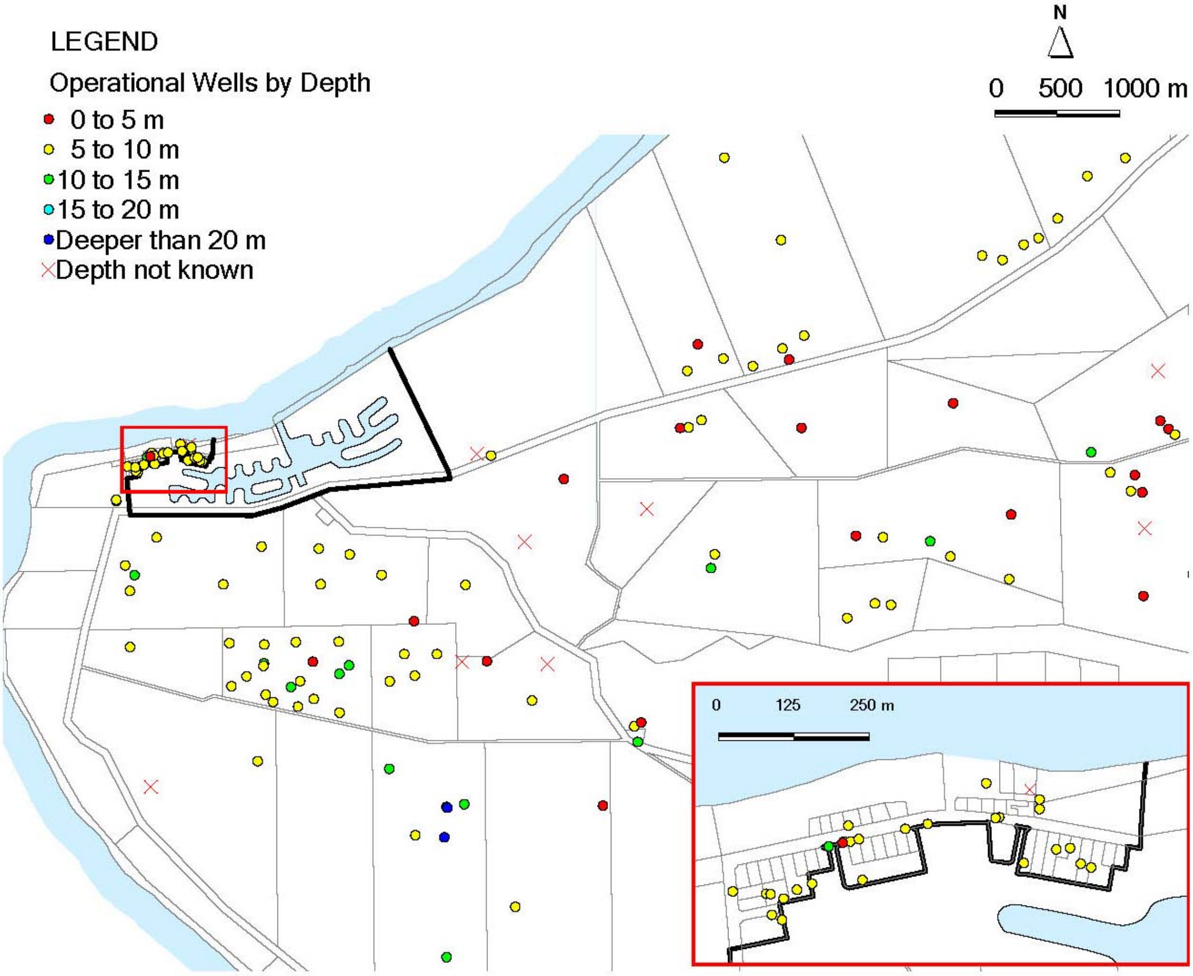


Figure 2.8 Registered groundwater wells near the study area indicating depth of well (PIRSA, July 2003).

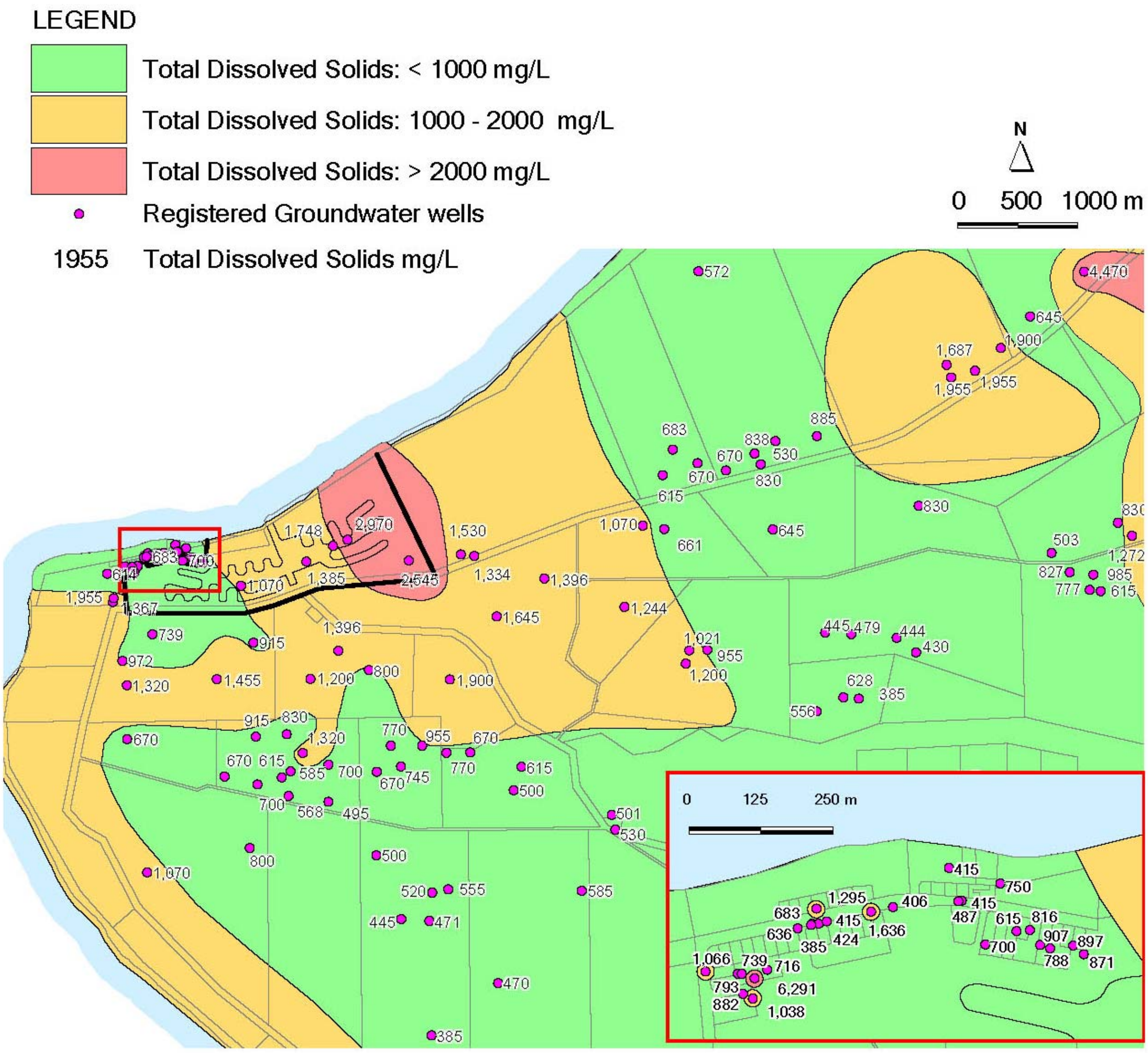


Figure 2.9 Inferred total dissolved solids distribution based on available TDS data (PIRSA, July 2003).

3. Field Investigations

This section presents the field investigations conducted for this study, including:

- The installation of a network of groundwater monitoring wells across the site and regionally;
- Groundwater level gauging;
- Investigation of the influence of tidal fluctuations on groundwater levels;
- Groundwater sampling and analysis; and
- Rising and falling head tests to establish aquifer properties.

3.1 Drilling Program

Drilling was carried out in June and July 2003 to establish a total of 34 groundwater monitoring wells. The purpose of the groundwater monitoring wells were to:

- Understand the underlying geological and hydrogeological conditions;
- Obtain information about the local hydrogeological environment;
- Evaluate spatial and temporal hydrogeological trends;
- Evaluate groundwater quality of shallow aquifer (St Kilda Formation and Tertiary Limestone Aquifer (TLA)).

The location rationale for each monitoring well is presented in Table 3.1. The location of the groundwater monitoring wells are shown on Figure 3.1.

Table 3.1 Rationale of the drilling program.

Well	Targeted Unit		Targeted Land Use / Contaminant Source			Hydrogeological Aspect		
	Sand	Limestone	Agricultural Pesticides / Fertilisers	Septic Effluent	Underground Storage Tanks (Fuel)	Marina Hydrogeology	Salt / Freshwater Interface	Regional Hydrogeology
CJ01		✓				✓	✓	
CJ02		✓	✓			✓		
CJ03		✓	✓			✓	✓	
CJ03A	✓		✓			✓		
CJ04		✓	✓			✓		
CJ05		✓	✓			✓		
CJ06		✓	✓			✓		
CJ07		✓	✓			✓		
CJ08		✓	✓			✓		
CJ09		✓	✓			✓		
CJ10		✓	✓			✓		
CJ11		✓	✓			✓		
CJ12		✓	✓			✓		
CJ13		✓				✓	✓	
CJ14		✓	✓			✓	✓	
CJ15		✓	✓			✓		
CJ15A	✓		✓			✓		
CJ16		✓				✓		
CJ17		✓				✓		
CJ18		✓				✓		
CJ19		✓				✓		
CJ20		✓		✓				
CJ21		✓	✓	✓	✓		✓	
CJ21A	✓		✓	✓	✓		✓	
CJ22		✓	✓	✓				
CJ23		✓	✓				✓	
CJ24		✓	✓					✓
CJ25		✓	✓					✓
CJ26		✓	✓					✓
CJ27		✓	✓					✓
CJ28		✓						✓
CJ29		✓						✓
CJ30		✓	✓					✓
CJ31		✓	✓					✓

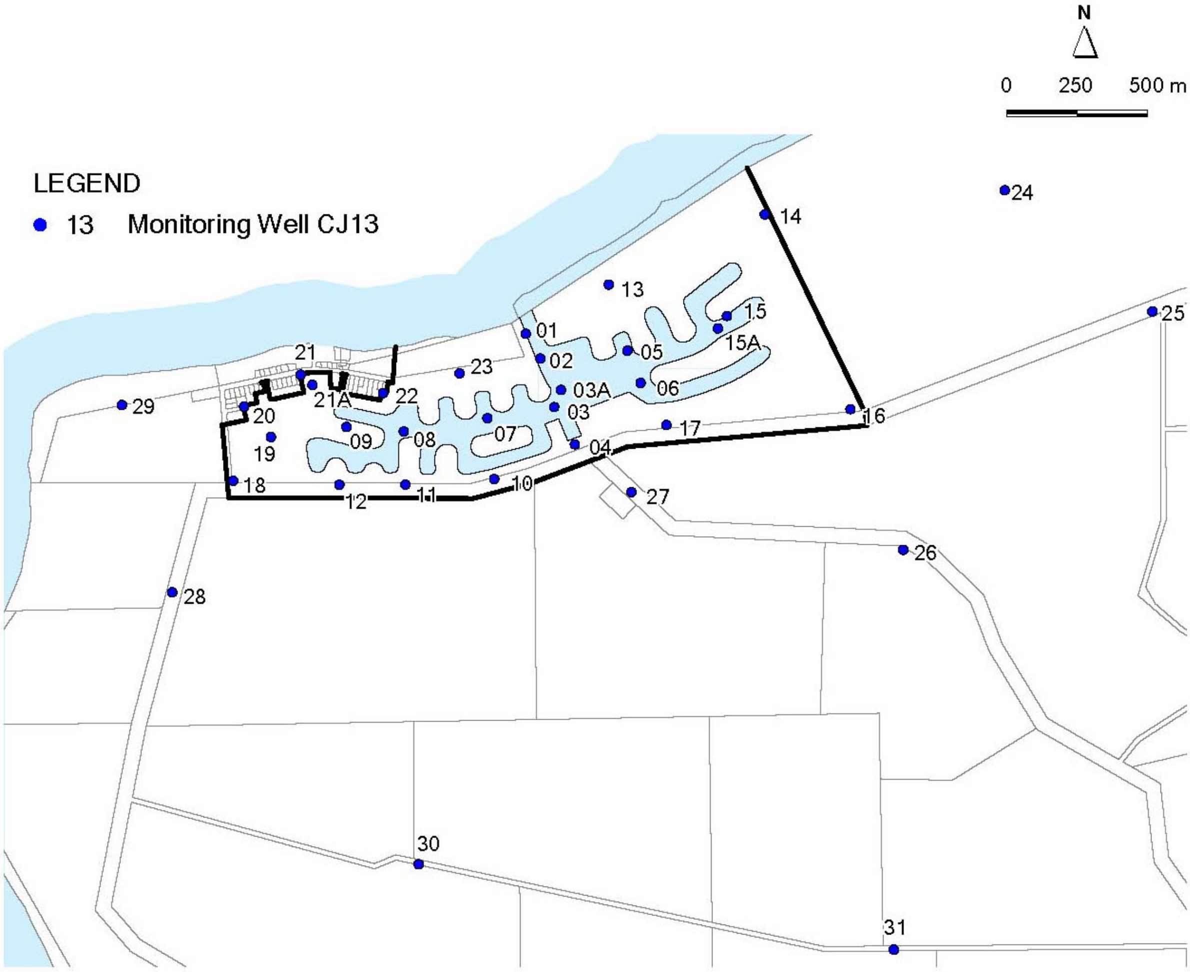


Figure 3.1 Groundwater well location plan.

3.2 Construction of Groundwater Monitoring Wells

3.2.1 Groundwater Monitoring Wells Intersecting the St Kilda Formation

Three wells (CJ03A, CJ15A and CJ21A) were installed to intersect the surface dunal Semaphore Sands of the St Kilda Formation. These wells were located in proximity (i.e. within 5 to 20 m) of a corresponding deeper well targeting the TLA (CJ03, CJ15 and CJ21).

These shallow wells included at least 2 m of screened section and were installed to a total depth of at least 3 m. The design of the packing within the annulus of these wells included gravel to at least 0.5 m above the screened section with a bentonite plug of at least 0.5 m on top of the gravel extending to the surface.

Construction details of wells intersecting the St Kilda Formation are presented in Figure 3.2.

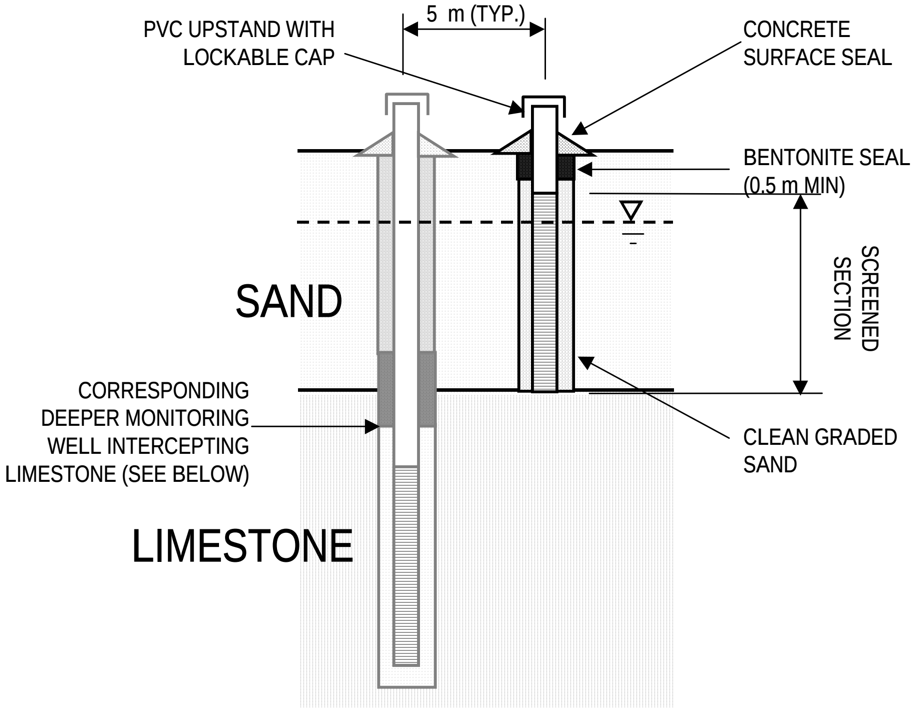


Figure 3.2 Typical construction details of wells intersecting the St Kilda Formation.

3.2.2 Groundwater Monitoring Wells Intersecting the Tertiary Limestone Aquifer

The majority of the groundwater monitoring wells have been designed to intersect the TLA underlying the St Kilda Formation. This unit was targeted as the depth of existing registered wells in proximity to the proposed development suggests that most of the existing users extract groundwater from this unit.

The construction of these wells were designed to penetrate at least 4 m into the limestone unit and included a 3 m screened section from the base of the well with gravel packing within the annulus of the well to at least 0.5 m above the screened section. A bentonite plug of at least 1 m in length above the gravel packing was installed over the sand/limestone interface.

Figure 3.3 illustrates the typical construction details of the wells intersecting the TLA.

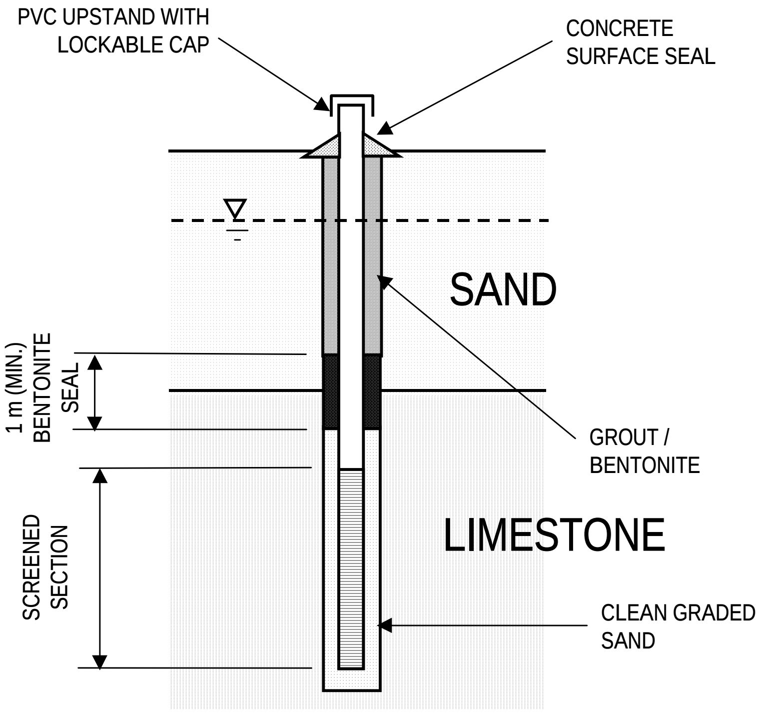


Figure 3.3 Typical construction details of wells intersecting the TLA.

3.2.3 Groundwater Monitoring Well Installation

Over the period of 19 June 2003 to 4 July 2003, 34 groundwater monitoring wells were installed at the site of the proposed Cape Jaffa Marina and within surrounding areas. The wells were installed by licensed drillers from Drilling Solutions under the full time supervision of Tonkin Consulting field personnel. Monitoring wells were installed using a variety of methods as stated on the lithological logs presented in Appendix A.

The initial wells were drilled using combinations of rotary air hammer and solid augering methods due to the anticipated difficulty associated with penetrating the limestone. However, the limestone was softer than expected and air drilling was not used after the second day of installations.

The sands encountered above the limestone were soft once water was encountered and collapsed when unsupported. This was overcome by placing a steel casing down the annulus of the hole during drilling. The PVC screen and casing were then placed within the casing which was gradually removed as the packing was added to the annulus.

The wells were logged by Tonkin Consulting field personnel to gain an appreciation of the soil stratigraphy as well as to determine appropriate well construction and packing details. Soil properties were logged from auger cuttings brought to the surface or from soils blown to the surface from the drill hole when air techniques were used. Subsequently, the depths of various soil units indicated on the logs should be considered as approximate. In some cases the drilling method made soil identification difficult due to the integrity of the samples retrieved.

The construction of each bore was determined once the limestone interface was encountered. Three wells were installed within the St Kilda Formation as depicted in Figure 3.2. 31 of the wells were then installed in accordance with the typical well construction presented in Figure 3.3 within the TLA. Well completion details are presented in Table 3.2.

In several of the wells the gravel and bentonite were initially over-poured or bridged, producing packing layers which exceeded the desired levels. When this occurred, the packing was removed from the well annulus by blasting compressed air or water down the outside of the PVC screen and casing. The water used in these instances was sourced from groundwater located within the base of an excavated pit located on site. Samples of this water were taken (refer Appendix B) to determine the potential for cross-contamination. In addition, extensive groundwater development was undertaken with the objective to remove water added during construction (refer Section 3.2.4).

The drilling rig was decontaminated between wells by high pressure water spray. Equipment rinsate samples were collected during installation of the wells to confirm the success of decontamination procedures, refer Appendix B.

Following construction, groundwater monitoring wells were surveyed by Allsurv on 7 July 2003 to the Australian Height Datum (AHD) and the Map Grid of Australia (MGA) coordinate system.

Table 3.2 Summary of well completion details.

Well	Construction Date	Easting (Zone 54)	Northing (Zone 54)	Drilled Depth (mBGL)	Measured Total Depth (mBGL)	Reduced Ground Level (mAHD)	Reduced Level, Top of Casing (mAHD)	Screen Details from (mBGL)	Screen Details to (mBGL)	Screened Unit
CJ01	30-Jun-03	383955.5	5910859.9	8.0	7.935	3.220	3.767	5.0	7.9	upper TLA
CJ02	28-Jun-03	384014.6	5910759.8	8.0	7.946	1.710	2.184	5.0	8.0	upper TLA
CJ03	27-Jun-03	384082.1	5910592.9	10.6	10.536	3.960	4.464	7.6	10.5	upper TLA
CJ03A	27-Jun-03	384089.9	5910595.0	4.5	4.416	4.190	4.702	1.5	4.4	Quaternary (St Kilda Frm)
CJ04	26-Jun-03	384151.9	5910416.5	10.0	9.932	3.430	3.898	7.0	9.9	upper TLA
CJ05	28-Jun-03	384362.9	5910791.9	8.1	7.882	2.160	2.660	5.1	7.9	upper TLA
CJ06	29-Jun-03	384415.9	5910662.2	10.0	10.108	4.480	4.917	7.0	10.1	upper TLA
CJ07	25-Jun-03	383801.6	5910520.6	9.0	9.044	3.340	3.901	6.0	9.0	upper TLA
CJ08	25-Jun-03	383466.4	5910467.5	12.3	11.879	3.110	3.566	9.3	11.9	upper TLA
CJ09	24-Jun-03	383236.5	5910486.6	7.2	7.027	3.310	3.738	4.2	7.0	upper TLA
CJ10	24-Jun-03	383828.8	5910277.1	7.2	7.075	3.070	3.535	4.2	7.1	upper TLA
CJ11	24-Jun-03	383472.8	5910255.4	8.7	8.020	3.030	4.460	5.7	8.0	upper TLA
CJ12	23-Jun-03	383208.1	5910253.8	10.2	7.146 *	3.710	4.264	7.2	10.2	upper TLA
CJ13	30-Jun-03	384288.1	5911056.5	8.0	7.622	3.260	3.756	5.0	7.6	upper TLA
CJ14	30-Jun-03	384913.7	5911337.7	8.5	8.441	3.570	4.044	5.5	8.4	upper TLA
CJ15	30-Jun-03	384754.2	5910917.1	7.1	7.000	1.560	2.000	4.1	7.0	upper TLA
CJ15A	30-Jun-03	384738.1	5910907.0	3.0	2.322	1.530	2.028	1.0	2.3	Quaternary (St Kilda Frm)
CJ16	29-Jun-03	385256.6	5910557.7	8.5	8.050	4.180	4.610	5.5	8.0	upper TLA
CJ17	29-Jun-03	384519.3	5910493.8	8.1	7.884	3.810	4.316	5.1	7.9	upper TLA
CJ18	19-Jun-03	382782.6	5910270.1	9.6	9.307	2.570	3.143	6.6	9.3	upper TLA
CJ19	24-Jun-03	382933.7	5910445.5	8.4	8.325	3.520	4.060	5.4	8.3	upper TLA
CJ20	20-Jun-03	382826.5	5910568.5	8.0	7.749	3.380	4.189	5.0	7.7	upper TLA
CJ21	20-Jun-03	383054.8	5910695.5	8.2	7.864	2.500	3.266	5.2	7.9	upper TLA
CJ21A	20-Jun-03	383054.8	5910695.5	3.0	3.493 **	3.110	3.573	1.0	3.0	Quaternary (St Kilda Frm)
CJ22	24-Jun-03	383378.8	5910622.7	9.0	7.463	2.960	4.232	6.0	7.5	upper TLA
CJ23	26-Jun-03	383690.0	5910700.3	7.0	6.894	2.140	2.599	4.0	6.9	upper TLA
CJ24	2-Jul-03	385874.8	5911434.2	9.0	8.760	4.590	5.470	6.0	8.8	upper TLA
CJ25	2-Jul-03	386466.9	5910948.3	5.0	4.470	2.640	3.330	2.0	4.5	upper TLA
CJ26	1-Jul-03	385468.5	5909993.9	8.5	8.390	5.940	6.650	5.5	8.4	upper TLA
CJ27	20-Jun-03	384379.0	5910225.0	8.6	8.350	3.060	3.600	5.6	8.4	upper TLA
CJ28	20-Jun-03	382538.2	5909823.2	17.0	16.675	4.520	5.100	14.0	16.7	upper TLA
CJ29	26-Jun-03	382336.8	5910574.0	9.0	8.866	4.460	5.010	6.0	8.9	upper TLA
CJ30	1-Jul-03	383526.1	5908734.3	11.0	10.925	7.390	8.150	8.0	10.9	upper TLA
CJ31	1-Jul-03	385430.8	5908391.9	9.0	8.955	7.260	7.820	6.0	9.0	Upper TLA

Notes
mBGL: metres below ground level
TLA: Tertiary Limestone Aquifer (upper sediments of TLA)
mAHD: metres Australian Height Datum
* measured total depth is less than the drilled depth due to blockage in well.
** measured total depth is greater than the drilled depth due to damage during development.

3.2.4 Development of Groundwater Monitoring Wells

On 4, 7 and 8 July 2003, the wells were developed using filtered compressed air. The purpose of well development was to remove fine particles and silts remaining within the well following construction and to attempt to purge possibly introduced water added during removal of over-poured materials. Wells were purged by Drilling Solutions. Volumes of water ranging from 110 L to 1100 L were removed, as presented in Table 3.3.

All wells were observed to have consistent rate of discharge during development with the exception of CJ21A, where well construction prevented development (refer Section 3.5.3). It was estimated that on average, 200 L of water was added to facilitate construction. Therefore, during development, the objective was to purge the well until at least 200 L of water was removed (where possible) and when the turbidity of the water visibly reduced.

Table 3.3 Well development volume.

Well	Volume of Water Purged (L)
CJ01	550
CJ02	900
CJ03	1100
CJ03A	650
CJ04	600
CJ05	650
CJ06	750
CJ07	330
CJ08	640
CJ09	600
CJ10	200
CJ11	600
CJ12	430
CJ13	185
CJ14	420
CJ15	800
CJ15A	110
CJ16	350
CJ17	650
CJ18	640
CJ19	600
CJ20	330
CJ21	650
CJ21A	0 *
CJ22	480
CJ23	650
CJ24	610
CJ25	340
CJ26	300
CJ27	600
CJ28	600
CJ29	600
CJ30	650
CJ31	200

* Well construction prevented development, refer Section 3.5.3.

3.3 Groundwater Gauging Investigations

To date, four groundwater gauging events have been carried out on:

- 7 to 9 July 2003 (all wells);
- 13 to 16 July 2003 (all wells);
- 28 October 2003 (all wells); and
- 11 November 2003 (selected wells).

Measurements were taken from the top of the casing to the water level using a dipmeter. The water levels from the top of casing were converted to relative levels using the survey levels of the wells. This data is presented in Table 4.2.

Continuous water level data was also undertaken in wells CJ01 and CJ04 using two Mini-troll data loggers. These wells were selected as they represent a groundwater flow path approximately perpendicular to the shoreline at the approximate location of the entry to the marina. CJ01 was located adjacent the shoreline, whilst CJ04 was located approximately 500 m inland and hydraulically up gradient.

The groundwater levels recorded in these wells has been compared to tide data collected from Cape Jaffa for the same period, as illustrated in Figure 4.1.

3.4 Aquifer Properties - Rising/Falling Head Tests

Rising and falling head tests (slug tests) were conducted on all wells during 7 to 9 July 2003 to estimate aquifer hydraulic conductivity.

The tests were performed by installing a Mini-troll logger in each well and displacing a known amount of water using a solid body. The water level was then logged every 0.5 seconds until the water level recovered to pre-test levels.

The rising head test involved monitoring and analysis the groundwater level response following insertion of the solid body, which resulted in a sudden rise in the groundwater level in the well prior to recovering to pre-test levels. The falling head test was performed when the solid body was removed, which resulted in a sudden drop in groundwater level in the well prior to recovering to pre-test levels.

3.5 Groundwater Sampling Program

3.5.1 Introduction

Groundwater sampling of all monitoring wells was conducted by Tonkin Consulting personnel from 13 to 16 July 2003, at least seven days after development. The depth to groundwater in each well was measured from the top of the casing using a dipmeter prior to disturbance from purging and sampling.

The groundwater wells were purged using the low-flow system (whale pump) to minimise disturbance to the water column and aquifer.

3.5.2 Groundwater Sampling Methodology

Throughout purging, field water quality parameters (TDS, dissolved oxygen (DO), pH, redox potential and temperature) were measured using a Troll 9000 water quality meter. The meter was positioned down the well below the well pump, except for the three shallow wells where field parameters were measured at the surface in the bucket due to the limited available water column for equipment.

Samples were taken when water quality parameters stabilised (where possible this included three consecutive readings of pH were within 0.1 units, TDS readings were within 5% and temperature within 0.2°C) and when at least three casing volumes of groundwater were removed from each well. Samples were placed into laboratory prepared and preserved bottles. Samples for dissolved metals analysis were filtered in the filed using 0.45 µm filters. Samples were placed in cool boxes with ice bricks and transported to the laboratory by overnight courier from Cape Jaffa.

Sampling equipment was decontaminated between each well using the three bucket method in accordance with the NEPM. Equipment rinsate samples were collected during sampling. For further information regarding decontamination procedures and rinsate analysis, refer Appendix B. Groundwater Monitoring Field Parameters Forms are included in Appendix C.

3.5.3 Field Observations

Groundwater field observations and field parameters are summarised in Table 3.4 and Table 4.4.

High turbidity and grey green colour of the groundwater sampled from CJ21A may indicate fragments limestone were present in the sample. Furthermore, when the groundwater was poured into the sulphuric acid preserved sampling container, a fizzing sound was noticed. The well was reported to have been installed to 3 m TOC on 21 June 2003. However, the depth of the well was recorded at 3.956 m TOC during water level measurements conducted on 8 July 2003. These observations suggest that the well may have been damaged during development. It is considered that the construction of the well is no longer able to effectively target groundwater within the sand unit above the limestone. However, the water levels recorded in this well were 3.045 m to 3.046 m, which is marginally below the reported construction depth of the well. Therefore if the well had remained as per its original construction, insufficient water is likely to have been available in the sand unit to produce an adequate sample.

Table 3.4 Summary of groundwater field observations.

Well	Colour	Turbidity	Odour
CJ01	Milky	Not recorded	None
CJ02	Clear	Very low	None
CJ03	White	Low	None
CJ03A	Clear	Low	None
CJ04	Pale brown changing to grey green	Medium	None
CJ05	Clear	Very low	None
CJ06	Cloudy changing to clear	Low	None
CJ07	Milky	Medium	None
CJ08	Clear	Very low	None
CJ09	Pale grey brown	Medium	None
CJ10	Pale grey brown	Medium	None
CJ11	Clear	Very low	None
CJ12	Pale grey	Medium	Slight pungent
CJ13	White	Medium	Sulfurous
CJ14	Pale grey changing to clear	Medium	Seaweed
CJ15	Light brown changing to white then clear	Low	None
CJ15A	Yellow changing to green	Low	Not recorded
CJ16	Pale grey changing to brown	Medium	Very slight pungent
CJ17	Pale grey changing to clear	Low	None
CJ18	Pale brown changing to clear	Low	None
CJ19	Clear	Very low	None
CJ20	Cream changing to clear	Medium	None
CJ21	Pale grey changing to clear	Low	Slight seaweed
CJ21A	Grey changing to white	High	Slight seaweed
CJ22	Clear	Very low	None
CJ23	Cloudy changing to clear	Low	Slight pungent
CJ24	Pale grey	Medium	Pungent
CJ25	Cloudy white	Medium	None
CJ26	Pale orange brown	Medium	None
CJ27	Clear	Very low	None
CJ28	Clear	Very low	None
CJ29	Clear	Very low	None
CJ30	Cloudy changing to clear	Low	None
CJ31	Pale orange brown	Low	None

3.5.4 Groundwater Analytical Program

A total of 38 groundwater samples were collected including four duplicate samples. Eight equipment rinsate samples were also collected (RA1-RA4 and RB1-RB4), refer Appendix B.

The primary laboratory selected for this project was Australian Laboratory Services (ALS). Amdel was selected as the secondary laboratory. Both Amdel and ALS are accredited by the National Association of Testing Authorities (NATA) for the analyses performed. Details regarding the field and laboratory QA/QC programs are provided in Appendix B.

Samples were submitted for combinations of three different suites of analyses:

Type I: (hydrochemistry and nutrients)

- pH
- Electrical Conductivity (EC)
- Total Dissolved Solids (TDS)
- Major cations (calcium, magnesium, sodium, potassium)
- Major anions (chloride, sulphate, carbonate, bicarbonate)
- Nutrients (Total Kjeldahl Nitrogen, nitrate, nitrite, reactive phosphorous)
- Total Organic Carbon (TOC)

Type II: (potential “contaminants of concern”)

- Organochlorine Pesticides and Organophosphate Pesticides (OCPs and OPPs)
- Heavy metals (arsenic, cadmium, chromium, copper, mercury, nickel, lead, zinc)

Type III (Extended Vic EPA Screen):

- Total Petroleum Hydrocarbons (TPH)
- Volatile Organic Compounds (VOCs)
- Polycyclic Aromatic Hydrocarbons (PAHs)
- Speciated Phenols
- Semi-volatile chlorinated compounds (SVCCs)
- OCPs and OPPs
- Heavy metals (antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, tin, vanadium, zinc)
- Cyanide
- Soluble fluoride

Samples collected from the nested shallow/deeper wells were submitted for more comprehensive analysis in order to compare groundwater chemistry between the sand and limestone units. Analysis details are presented in Table 3.5.

Table 3.5 Summary of groundwater analytical program.

Sample	Analysis		
	Type I	Type II	Type III
CJ01	✓	✓	
CJ02	✓		
CJ03	✓	✓	
CJ03A	✓	✓	
CJ04	✓		
CJ05	✓	✓	
CJ06	✓		
CJ07	✓	✓	
CJ08	✓		✓
CJ09	✓		
CJ10	✓		
CJ11	✓	✓	
CJ12	✓		
CJ13	✓	✓	
CJ14	✓		
CJ15	✓		✓
CJ15A	✓		✓
CJ16	✓		
CJ17	✓		
CJ18	✓		
CJ19	✓		
CJ20	✓	✓	
CJ21	✓		✓
CJ21A	✓		✓
CJ22	✓	✓	
CJ23	✓		
CJ24	✓		✓
CJ25	✓		
CJ26	✓		✓
CJ27	✓	✓	
CJ28	✓		
CJ29	✓	✓	
CJ30	✓		
CJ31	✓		

For Type I analysis, samples were collected in 2 bottles per sample including:

- 1 X 250 mL plastic unpreserved bottle for TDS, major cations and anions, alkalinity, conductivity, nitrate and nitrite, phosphorous and pH analysis; and
- 1 X 250 mL sulphuric acid preserved plastic bottle for TKN and TOC (or 1 X 1 L sulphuric acid preserved glass bottle where Type III analysis was also conducted).

For Type II analysis, samples were collected in 2 bottles per sample

- 1 X 250 mL nitric acid preserved plastic bottle for dissolved heavy metals (field filtered); and
- 1 X 1 L amber glass solvent washed bottle for OCP / OPP analysis.

For Type III analysis, samples were collected in 5 bottles per sample
Samples were collected in 5 bottles per sample including:

- 1 X 250 mL plastic unpreserved bottle for fluoride analysis (in addition to Type I analytes);
- 1 X 1 L sulphuric acid preserved glass bottle for ammonia and speciated phenol (in addition to Type I analytes);
- 1 X 250 mL nitric acid preserved plastic bottle for 16 dissolved heavy metals (field filtered);
- 1 X 250 mL sodium hydroxide and cadmium nitrate preserved bottle for cyanide analysis;
- 2 X 40 mL glass hydrochloric acid preserved vials with Teflon lined lids for VOC, BTEX and TPH (C_6 – C_{10}) analysis; and
- 1 X 1 L amber glass solvent washed bottle for speciated phenol, OCP / OPP, PAH, and TPH (C_{11} - C_{36}) analysis.

All samples were received in good order by the analysing laboratories with the exception of CJ11 where a breakage of a 1 X 1 L amber glass solvent washed bottle was reported on arrival. This breakage was able to be reported to field personnel prior to the completion of field work and a replacement sample CJ11B was able to be collected and submitted for analysis of OCP and OPP.

Analyses were undertaken within the recommended holding time with the exception of pH analysis. The holding time for pH is 6 hours, which could not be achieved given the remote location of the site and was therefore measured in the field as well during sampling.

4. Results

4.1 Local Soil and Geological Conditions

The soil profile observed during monitoring well installation was logged by Tonkin Consulting field personnel and is summarised in Table 4.1. The logs are presented in Appendix A.

Table 4.1 Generalised Soil Profile Encountered on Site.

Unit	depth to Top of Unit	Thickness of Unit	Location
Topsoil	0 m	0 – 0.5 m	All wells
Yellow brown to pale grey sands	0 – 0.5 m	2.4 – 7.6 m	All wells
Dark grey to green layer of clay of medium to high plasticity	2.4 – 5.0 m	0.2 – 2.2 m	CJ03, CJ04, CJ07, CJ10, CJ11, CJ12 and CJ22
Soft and wet limestone containing sand	2.4 – 7.6 m	Unknown	All wells

Soils described as having a 'seaweed odour' were recorded in sands observed in several monitoring wells (CJ01, CJ13, CJ14, CJ16, CJ17, CJ24, CJ26, CJ30 and CJ31). An odour described as 'decaying' was reported in clays observed in CJ04 and CJ11.

An animal effluent odour type was also recorded in soils observed during installation of monitoring wells CJ 15, CJ15A. The owner of this land reported that pig effluent had been disposed to this location in the past.

4.2 Groundwater Gauging Data

Groundwater level data collected during the gauging events is presented in Table 4.2. Data collected during continuous logging of wells CJ01 and CJ04 overlaid onto tidal data collected at Cape Jaffa jetty over the same period is illustrated in Figure 4.1.

Table 4.2 Groundwater gauging data.

Well	Groundwater Monitoring Event (07/07/03-09/07/03)		Groundwater Monitoring Event (13/07/03-16/07/03)		Groundwater Monitoring Event (28/10/03)		Groundwater Monitoring Event (11/11/03)	
	SWL mTOC	RWL mAHD	mTOC	mAHD	mTOC	mAHD	mTOC	mAHD
CJ01	3.124	0.643	3.016	0.751	3.335	0.432	3.350	0.417
CJ02	1.470	0.714	1.435	0.749	1.370	0.814		
CJ03	3.624	0.840	3.619	0.845	3.410	1.054	3.475	0.989
CJ03A	3.910	0.792	3.879	0.823	3.560	1.142	3.620	1.082
CJ04	2.965	0.933	2.945	0.953	2.780	1.118	2.850	1.048
CJ05	1.842	0.818	1.81	0.850	1.585	1.075		
CJ06	4.055	0.862	4.03	0.887	3.720	1.197		
CJ07	3.095	0.806	3.47	0.431	2.980	0.921		
CJ08	2.835	0.731	2.9	0.666	2.780	0.786		
CJ09	3.144	0.594	3.13	0.608	2.990	0.748		
CJ10	2.690	0.845	2.65	0.885	2.535	1.000		
CJ11	3.665	0.795	3.641	0.819	3.520	0.940		
CJ12	3.595	0.669	3.57	0.694	3.360	0.904		
CJ13	3.126	0.630	3.019	0.737	3.420	0.336		
CJ14	3.355	0.689	3.33	0.714	3.110	0.934		
CJ15	1.140	0.860	1.106	0.894	0.830	1.170	0.888	1.112
CJ15A	1.110	0.918	1.033	0.995	0.880	1.148	0.956	1.072
CJ16	3.335	1.275	3.305	1.305	3.040	1.570		
CJ17	3.36	0.956	3.335	0.981	3.040	1.276		
CJ18	2.517	0.626	2.5	0.643	2.260	0.883		
CJ19	3.448	0.612	3.425	0.635	3.205	0.855		
CJ20	3.613	0.576	3.582	0.607	3.450	0.739		
CJ21	2.774	0.492	2.735	0.531	2.780	0.486		
CJ21A	3.046	0.527	3.045	0.528	3.015	0.558		
CJ22	3.723	0.509	3.557	0.675	3.910	0.322		
CJ23	2.049	0.550	1.825	0.774	2.250	0.349		
CJ24	4.380	1.090	4.33	1.140	3.230 *	2.240		
CJ25	1.890	1.440	1.86	1.470	1.620	1.710		
CJ26	5.150	1.500	5.12	1.530	4.945	1.705		
CJ27	2.565	1.035	2.547	1.053	2.410	1.190		
CJ28	4.395	0.705	4.355	0.745	4.120	0.980		
CJ29	4.463	0.547	4.342	0.668	4.470	0.540		
CJ30	7.130	1.020	7.105	1.045	6.880	1.270		
CJ31	6.07	1.750	6.06	1.760	5.820	2.000		

mBGL metres below ground level
mTOC metres from Top of Casing
mAHD metres Australian Height Datum
SWL Standing Water Level
* Gauging data not reliable

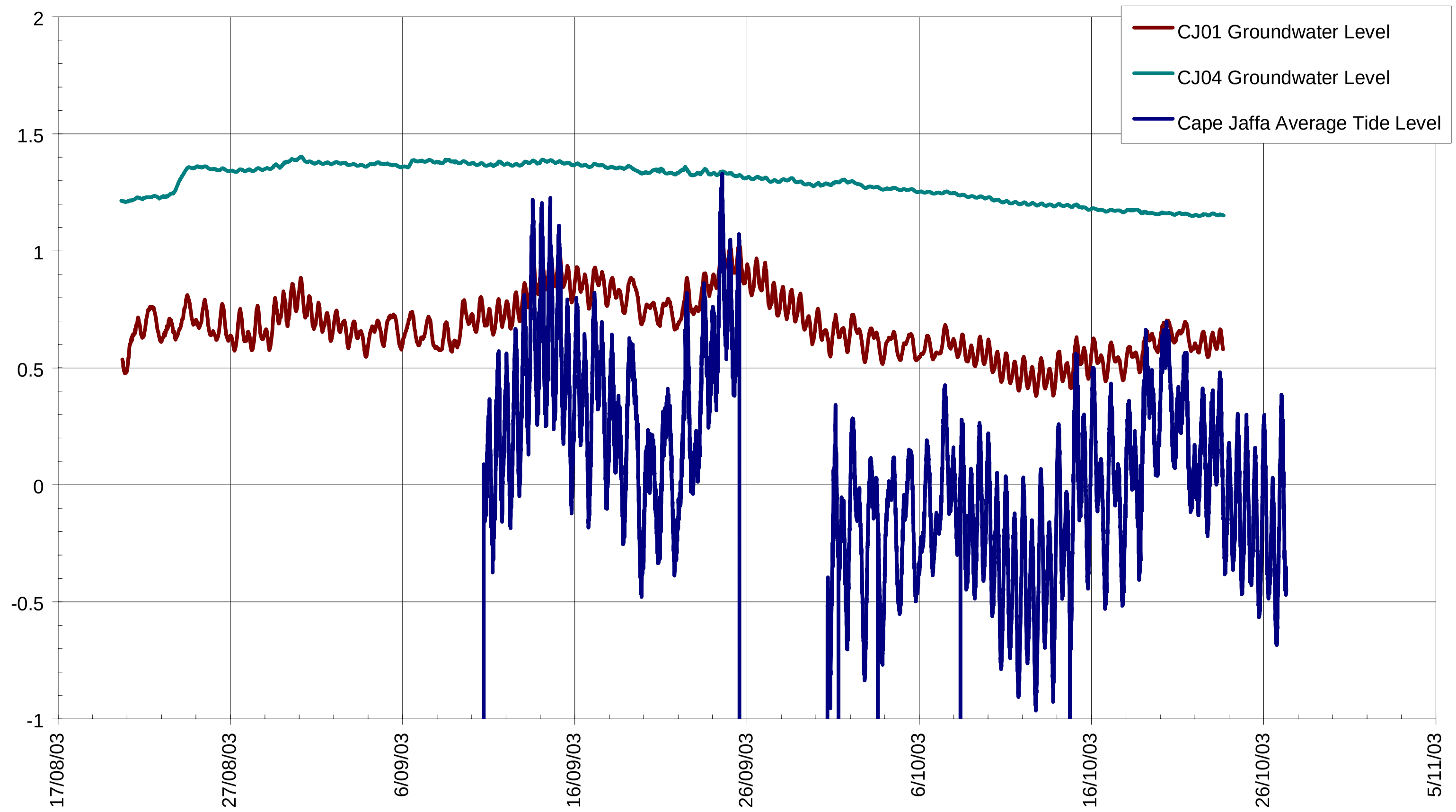


Figure 4.1 Continuous groundwater levels (CJ01 and CJ04) versus Average Tide Data for period 1/9/2003-24/10/2003.

4.3 Estimated Hydraulic Conductivity

Based on the falling and rising head curves obtained from each well, the aquifer hydraulic conductivity was estimated using the Hvorslev (1951) method for slug tests in unconfined aquifers (as cited in Freeze and Cherry, 1979).

A number of the wells exhibited water level oscillations following the falling/rising head recovery. Kruseman and Ridder (1990) indicate that water level oscillations may occur following an instantaneous change in water level due to inertia effects in highly permeable or deep wells. Given the relative shallow nature of wells at Cape Jaffa, it is considered more likely that this is an indication of a highly permeable aquifer, which is consistent with the known regional hydrogeology. There are methods for the determination of aquifer conductivity when oscillating water levels are observed for confined aquifers, but not unconfined aquifers. The hydraulic conductivity of these wells has been approximated using the Hvorslev method, however, the values for these wells should be used with caution.

The variation between the results for the rising and falling head tests is due to inherent error in the measurement procedure. In addition, higher variation is evident for higher hydraulic conductivities, which is due to less data being able to be captured during these tests as they occur over a shorter period than for lower hydraulic conductivities.

Table 4.3 Estimated hydraulic conductivity from rising and falling head tests.

	Hydraulic Conductivity K (m/s)	
Well No.	Falling Head	Rising Head
CJ01	2.5	1.4
CJ02	3.4	3.5
CJ03	3.9	7.5
CJ03A	2.9	5.9
CJ04 *	11.0	9.8
CJ05	2.1	3.9
CJ06	4.0	4.2
CJ07	1.7	2.4
CJ08 *	4.5	3.7
CJ09 *	27.7	4.5
CJ10	10.5	13.0
CJ11 *	7.2	13.9
CJ12	10.9	16.3
CJ13	5.4	12.7
CJ14	3.0	4.4
CJ15 *	6.5	6.5
CJ15A	3.1	7.7
CJ16	6.3	5.5
CJ17	5.2	7.1
CJ18 *	10.2	5.1
CJ19 *	7.2	6.0
CJ20	6.5	13.2
CJ21	4.7	3.5
CJ22	12.7	18.0
CJ23 *	11.8	7.7
CJ24	6.2	8.1
CJ25	6.7	11.8
CJ26	3.4	3.9
CJ27 *	6.8	8.7
CJ28	1.5	1.2
CJ29	3.2	2.9
CJ30 *	15.5	27.3
CJ31	4.9	5.7

*Oscillations observed during rising/falling head tests, permeabilities are approximate and should be used in this light.

4.4 Groundwater Analytical Results

4.4.1 Groundwater Assessment Guidelines and Criteria

Laboratory results have been compared to appropriate guidelines and criteria stated in:

- National Environment Protection (Assessment of Site Contamination) Measure Schedule B(1) Guideline on Investigation Levels for Soil and Groundwater, December 1999 (NEPM); and
- Environment Protection (Water Quality) Policy, 2003 South Australian Environment Protection Authority (WQ Policy).

For the assessment of potential human health risks, groundwater results have been compared to the following guidelines and criteria:

- NEPM Health – Investigation Levels for Drinking Water; and
- WQ Policy Criteria for Potable Supply.

For the assessment of potential ecological risks, groundwater analytical results have been compared to the following guidelines and criteria:

- NEPM Marine– Investigation Levels for Aquatic Ecosystems; and
- WQ Policy Criteria for Marine Aquatic Ecosystems.

For the assessment of potential risks to agriculture, results have been compared to the following guidelines and criteria:

- NEPM Irrigation – Investigation Levels for Irrigation Waters;
- NEPM Livestock – Investigation Levels for Livestock;
- WQ Policy Criteria for Irrigation Purposes; and
- WQ Policy Criteria for Livestock.

4.4.2 Field Parameters

Water quality parameters (TDS, DO, pH, redox and temperature) measured in the field are given in Table 4.4.

Table 4.4 Field and laboratory measurements of pH, TDS and EC and field measurements of temperature, redox potential, turbidity and DO.

Well	Temperature (°C)	Redox Potential (mV)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	pH		Electrical Conductivity µS/cm		Total Dissolved Solids (mg/L) [1]	
					Field	Laboratory	Field	Laboratory	Field	Laboratory
CJ01	17.11	-45	10	0.46	7.33	7.88	1,767	1,610	-	994
CJ02	17.38	-45	-	1.15	7.31	8.15	-	2,250	1,106	1,080
CJ03	17.67	9	0	0.56	7.23	7.64	3,298	2,860	-	1,760
CJ03A	17.10	181	90	2.87	7.49	7.5	1,170	1,500	-	806
CJ04	17.14	-4	-	1.02	7.13	7.52	-	3,380	2,511	2,060
CJ05	16.85	-12	1008	0.56	7.38	7.87	2,100	2,010	-	1,180
CJ06	17.79	-49	-	1.05	7.36	8.21	-	1,990	1,609	1,250
CJ07	17.74	-40	253	0.50	7.28	7.85	1,253	2,500	-	1,550
CJ08	17.13	88	-	1.05	7.27	7.52	-	2,160	1,600	1,360
CJ09	17.91	-93	-	1.02	7.29	7.69	-	1,620	1,275	1,050
CJ10	16.87	-24	-	1.07	7.57	7.93	-	2,070	1,586	1,220
CJ11	16.78	239	0	2.44	7.38	7.85	2,484	2,360	-	1,390
CJ12	17.13	-114	-	1.02	7.17	7.52	-	2,820	2,108	1,570
CJ13	16.24	-234	46	0.45	7.18	7.66	10,052	9,700	-	6,620
CJ14	17.63	-102	-	1.02	7.20	7.63	-	3,420	2,519	1,990
CJ15	16.12	-27	-	0.52	7.08	7.50	7,528	7,150	-	4,300
CJ15A	13.57	69	29	2.09	7.25	7.64	21,079	20,700	-	14,900
CJ16	17.48	-89	-	1.04	7.14	8.16	-	3,960	2,880	2,410
CJ17	17.69	32	-	1.43	7.17	7.65	-	1,660	1,258	5,150 [2]
CJ18	17.25	86	-	4.47	7.43	7.69	-	2,250	1,917	1,360
CJ19	17.53	-59	-	1.04	7.10	7.59	-	2,410	1,774	1,390
CJ20	17.69	17	-	0.97	7.36	7.88	2,371	1,900	-	1,140

Well	Temperature (^{o}C)	Redox Potential (mV)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	pH		Electrical Conductivity µS/cm		Total Dissolved Solids (mg/L) [1]	
					Field	Laboratory	Field	Laboratory	Field	Laboratory
CJ21	17.39	-33	-	0.98	7.36	7.71	-	2,240	1,660	1,550
CJ21A	16.77	69	-	4.72	7.59	7.38	-	676	-	439
CJ22	17.41	-	-	-	7.44	7.74	1,650	1,710	-	1,030
CJ23	17.72	-84	-	1.09	7.22	7.73	-	1,920	1,929	1,140
CJ24	16.69	-188	-	0.97	7.32	7.53	-	2,350	1,614	1,450
CJ25	16.63	-64	-	1.08	7.33	7.68	-	1,020	910	630
CJ26	16.82	75	-	10.19	7.36	7.62	-	1,460	1,229	898
CJ27	15.79	104	-	7.74	7.16	7.67	4,257	4,210	-	2,350
CJ28	17.30	125	-	11.96	7.39	7.80	-	3,240	3,172	2,000
CJ29	17.03	-36	5	0.67	7.27	7.80	2,026	1,420	-	864
CJ30	17.54	93	-	8.90	7.36	7.90	-	1,230	913	757
CJ31	17.16	59	-	7.21	7.49	7.89	-	786	541	516

Notes:

- \- Denotes that a value was not recorded.
1. TDS has been calculated from EC in the field, however a separate laboratory method has been used in the laboratory to measure TDS.
2. Laboratory measured TDS for CJ17 is considered to be unreliable (refer below).

4.4.3 Laboratory Results

The complete set of analytical results compared to the relevant assessment guidelines and criteria are contained in Appendix D. The original laboratory reports can be found in Appendix E.

4.4.3.1 pH

As indicated in Table 4.4, the pH recorded during field work ranged from 7.03 in CJ15 to 7.59 in CJ21A indicating that the water is neutral to slightly alkaline, and relatively consistent across the site. The pH values recorded by the analysing laboratory (7.30 to 8.21) were consistently marginally higher than the field recorded values. However, the recommended holding time (6 hours) was exceeded for the laboratory recorded values.

4.4.3.2 Salinity and Conductivity

Laboratory reported TDS concentrations ranged predominantly from 439 mg/L in CJ21A to 14,900 mg/L recorded for CJ15A.

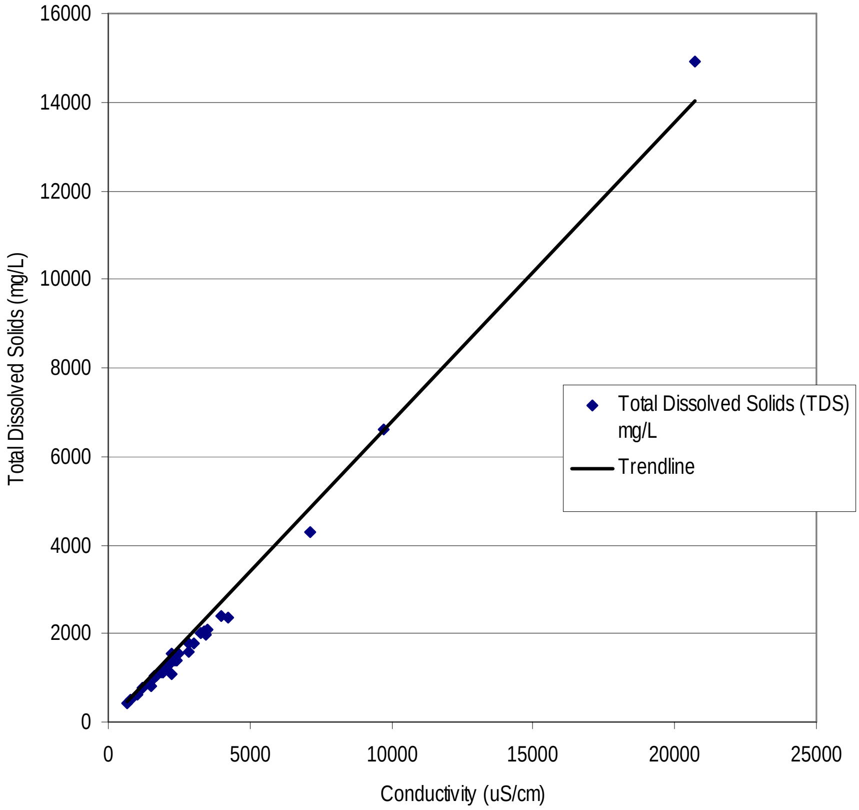
Laboratory reported values for EC ranged predominantly from 676 µS/cm in CJ21A to 20,700 µS/cm recorded for CJ15A.

With the exception of one sample, over the range of salinities encountered a good relationship between EC and TDS is observed, refer Figure 4.2. A regression of the data gives a line of best fit (with an R^2 of 0.9884) as follows:

TDS (mg/L) = 0.68 * EC (µS/cm)

The groundwater sample collected from well CJ17 was excluded from the data due to inconsistencies between the EC and TDS results given by the laboratory as well as between laboratory and field data.

Figure 4.2 Relationship and trendline between EC and TDS.



4.4.3.3 Organics and Nutrients

TOC ranged from 5 mg/L in CJ02 to 78 mg/L in CJ15A. Seven samples recorded concentrations of TOC equal to or in excess of the WQ Policy Marine criteria (10 mg/L) as presented in Table 4.5.

Table 4.5 Total Organic Carbon exceeding WQ Policy Marine criteria (10 mg/L).

Sample	Total Organic Carbon Concentration (mg/L)
CJ04	10
CJ13	12
CJ14	11*
CJ15	13
CJ15A	78
CJ21	31*
CJ21A	11

*Highest value of duplicate pair reported

For Type I analysis, **nitrate** and **nitrite** concentrations were reported separately and were below laboratory detection limits and / or the relevant assessment guidelines and criteria for the samples analysed. For Type II and Type III analysis, concentrations of nitrate and nitrite were reported as a combined concentration.

The combined nitrate and nitrate concentrations exceeded the WQ Policy Marine oxidised nitrogen criteria (0.2 mg/L) in eight samples, as summarised in Table 4.6.

The combined nitrate and nitrate concentrations exceeded the WQ Policy Potable criteria for nitrite (1 mg/L) in five samples, the NEPM Health guidelines (3 mg/L) in four samples and the WQ Policy Livestock criteria (10 mg/L) in one sample, as presented in Table 4.6. However, as the concentration of nitrite is generally less than that of nitrate, these levels may not represent actual exceedences.

Concentrations of total nitrate and nitrite in excess of WQ Policy Potable criteria for nitrate (10 mg/L) was reported in one sample as presented in Table 4.6. Since nitrate is likely to represent the majority of the nitrate and nitrite concentration, these levels may represent actual exceedences.

Table 4.6 Elevated Nitrate and Nitrite concentrations.

Sample	Sum of Nitrate and Nitrite Concentrations (as N) (mg/L)	
CJ03A	4.07	
CJ08	6.53	
CJ11	2.14	
CJ17	0.57	
CJ26	7.32	
CJ28	0.58	
CJ30	12.2	
CJ31	7.29	
Guideline /Criteria	**Oxidised Nitrogen Criteria (mg/L)**	
WQ Policy Marine	0.2	
Guideline /Criteria	**Nitrite Concentrations Guideline/Criteria (mg/L)**	**Nitrate Concentrations Guideline/Criteria (mg/L)**
NEPM Health	3	-
WQ Policy Potable	1	10
WQ Policy Livestock	10	-

Total Kjeldahl Nitrogen (TKN) ranged from below laboratory detection limits (0.1 mg/L) to a maximum of 4.2 mg/L in CJ31.

Total Nitrogen was estimated by adding nitrate, nitrate and TKN concentrations. The estimates of Total Nitrogen concentration ranged from the laboratory detection limit

(<0.11 mg/L) to 12.50 mg/L, and exceeded or was marginally below the WQ Policy Marine criteria (5 mg/L) in six samples as presented in Table 4.7.

Table 4.7 Total Nitrogen exceeding WQ Policy Marine criteria (5 mg/L).

Sample	Estimated Total Nitrogen (as N) Concentration (mg/L)
CJ03A	4.67
CJ08	7.03
CJ15A	4.90
CJ26	9.22
CJ30	12.50
CJ31	11.49

Phosphorous concentrations (reported as "Reactive Phosphorous as P") ranged from 7 to 1040 µg/L. Concentrations in excess of the WQ Policy Marine criteria for Soluble Phosphorous (100 µg/L) were recorded in samples retrieved from six monitoring wells as summarised in Table 4.8.

Table 4.8 Phosphorous exceeding WQ Policy Marine criteria (100 µg/L).

Sample	Reactive Phosphorous (as P) Concentration (µg/L)
CJ14	140
CJ15	120
CJ15A	870
CJ21A	100
CJ24	200
CJ31	1,040

Phenol concentrations were below laboratory detection limits (2 µg/L for the primary laboratory and 40 µg/L for the secondary laboratory) and below the WQ Policy Marine and NEPM Marine guidelines (both 50 µg/L). Speciated phenols were also all below laboratory detection limits (2 µg/L) and assessment guidelines and criteria considered.

Concentrations of **OCP**, **OPP**, **TPH**, **BTEX**, **PAH**, **VOC** and **SVCC** compounds were below laboratory detection limits and assessment guidelines and criteria considered.

4.4.3.4 Inorganics

Antimony concentrations ranged from below laboratory detection limits (1 µg/L for the primary laboratory and 5 µg/L for the secondary laboratory) to 4 µg/L in CJ24 and CJ26 which is in excess of the NEPM Health guidelines and WQ Policy Potable criterion (both 3 µg/L). Antimony in CJ08 equalled these guidelines and criterion. However, all values were less than the WQ Policy Marine criteria (500 µg/L).

Exceedences of the NEPM Health and WQ Policy Potable criteria for **arsenic** concentration (7 µg/L) were recorded in twelve of the eighteen samples analysed for arsenic, as presented in Table 4.9. The arsenic in sample CJ15A was recorded at concentration of 92 µg/L which is also in excess of the NEPM and WQ Policy Marine guidelines (50 µg/L).

Table 4.9 Elevated arsenic concentrations.

Sample	Arsenic Concentration (µg/L)
CJ01	14
CJ03	8
CJ03A	8
CJ05	13
CJ13	27
CJ15	31
CJ15A	92
CJ21	37*
CJ21A	8
CJ22	10
CJ24	14
CJ29	40
Guideline /Criteria	Arsenic Guideline/Criteria (µg/L)
NEPM Marine	50
WQ Policy Marine	50
WQ Policy Potable	7
NEPM Health	7

*Highest value of duplicate pair reported

Barium was detected in all samples analysed ranging from 3 µg/L in CJ21A to 32 µg/L in CJ15. These results are all less than the WQ Policy Potable criteria (70 µg/L).

Cadmium concentrations were at or below laboratory detection limits for the samples analysed (0.1 µg/L for the primary laboratory and 5 µg/L for the secondary laboratory) with the exception of the concentration recorded in sample CJ21 (2.8 µg/L) and CJ21A (0.4 µg/L). The concentration recorded in CJ21 is in excess of the NEPM Health and Marine guidelines and the WQ Policy criteria (all 2 µg/L).

Molybdenum was detected in all seven samples submitted for Type III analysis. Three of these samples recorded molybdenum concentrations in excess of the NEPM Livestock and Irrigation guidelines and WQ Policy Livestock and Irrigation criteria (all 10 µg/L). The concentration in CJ21 further exceeded the NEPM Health and WQ Policy Potable criteria (50 µg/L). These exceedences are presented in Table 4.10.

Table 4.10 Elevated molybdenum concentrations.

Sample	Molybdenum Concentration (µg/L)
CJ15A	40
CJ21	82*
CJ21A	21
Guideline /Criteria	**Molybdenum Guideline/Criteria (µg/L)**
NEPM Livestock and NEPM Irrigation	10
WQ Policy Livestock and WQ Policy Irrigation	10
NEPM Health	50
WQ Policy Potable	50

*Highest value of duplicate pair reported

Selenium concentrations were report as 10 µg/L in well CJ15A, which is equivalent to the NEPM Health guidelines and WQ Policy Potable criteria.

The concentrations of other metals analysed including **beryllium**, **chromium**, **cobalt**, **copper**, **lead**, **mercury**, **nickel**, **tin**, **vanadium** and **zinc** were below laboratory detection limits or the corresponding guidelines and criteria considered.

Cyanide in excess of the NEPM Marine (5 µg/L) was detected in five of the seven samples analysed. One sample (CJ15A) also recorded a concentration of cyanide in excess of NEPM Health and WQ Policy Potable criteria (80 µg/L). These exceedences are outlined in Table 4.11.

Table 4.11 Cyanide concentration rxceedences.

Sample	Cyanide Concentration (µg/L)
CJ15	26
CJ15A	265
CJ21	19
CJ21A	6
CJ24	34
Guideline /Criteria	**Cyanide Guideline/Criteria (µg/L)**
NEPM Marine	5
WQ Policy Potable	80
NEPM Health	80

*Highest value of duplicate pair reported

Fluoride ranged from 500 µg/L in CJ08 to 2,300 µg/L in CJ21A which was the only sample to exceed the NEPM Health and WQ Policy Potable (1,500 µg/L), NEPM Irrigation and WQ Policy Irrigation (1,000 µg/L) as well as NEPM Livestock and S EPA Livestock (2,000 µg/L) guidelines and criteria.

Concentrations of **chloride** in exceeded the NEPM Health (250 mg/L) and NEPM Irrigation (30 to 700 mg/L depending on irrigated crop) guidelines were recorded in eleven samples as presented in Table 4.12.

Table 4.12 Chloride exceedence of NEPM Health (250 mg/L) and NEPM Irrigation (30 to 700 mg/L).

Sample	Chloride Concentration (mg/L)
CJ03	800*
CJ04	929
CJ12	739
CJ13	3,430
CJ14	911*
CJ15	2,140
CJ15A	7,000
CJ16	1,120
CJ21	780*
CJ27	1,100
CJ28	919

*Highest value of duplicate pair reported

One concentration of **sulphate** in excess of the WQ Policy Potable (500 mg/L) and WQ Policy Irrigation criteria (1,000 mg/L) was recorded in CJ15A (1,760 mg/L). The other samples analysed had sulphate concentrations below both of these values.

4.4.3.5 Summary of Results

Groundwater analytical results exceeding the adopted guidelines and criteria are summarised in Table 4.13.

Table 4.13 Groundwater analytical results exceeding NEPM guidelines and Water Quality Policy.

Well	Potential Contaminant of Concern	Concentration	Water Quality Policy Exceedence				NEPM Exceedence			
			Potable	Marine	Irrigation	Livestock	Health	Marine	Irrigation	Livestock
CJ01	arsenic	14 µg/L	7	50	100	500	7	50	100	500
CJ02	-									
CJ03	chloride	800 mg/L					250		30-700	
	arsenic	8 µg/L	7	50	100	500	7	50	100	500
CJ03A	arsenic	8 µg/L	7	50	100	500	7	50	100	500
	Nitrate / nitrite	4.1 mg/L	10/1	0.2		30/10	50/3			30/10
	Total Nitrogen	4.7 mg/L		5						
CJ04	chloride	929 mg/L					250		30-700	
	TOC	10 mg/L		10						
CJ05	arsenic	13 µg/L	7	50	100	500	7	50	100	500
CJ06	-									
CJ07	-									
CJ08	Nitrate / nitrite	6.5 mg/L	10/1	0.2		30/10	50/3			30/10
	Total Nitrogen	7.0 mg/L		5						
	antimony	3 µg/L	3				3	500		
CJ09	-									
CJ10	-									
CJ11	Nitrate / nitrite	2.1 mg/L	10/1	0.2		30/10	50/3			30/10
CJ12	chloride	739 mg/L					250		30-700	
CJ13	chloride	3,430 mg/L					250		30-700	
	TOC	12 mg/L		10						
	arsenic	27 µg/L	7	50	100	500	7	50	100	500
CJ14	chloride	911 mg/L					250		30-700	
	TOC	11 mg/L		10						
	phosphorus	140 µg/L		100						
CJ15	chloride	2,140 mg/L					250		30-700	
	TOC	13 mg/L		10						
	arsenic	31 µg/L	7	50	100	500	7	50	100	500
	cyanide	26 µg/L	80				80	5		
	phosphorus	120 µg/L		100						

Table 4.13 Groundwater analytical results exceeding selected NEPM guidelines and Water Quality Policy (cont.).

Well	Potential Contaminant of Concern	Concentration	Water Quality Policy Exceedence				NEPM Exceedence			
			Potable	Marine	Irrigation	Livestock	Health	Marine	Irrigation	Livestock
CJ15A	chloride	7,000 mg/L					250		30-700	
	TOC	78 mg/L		10						
	sulphate	1,760 mg/L	500			1,000				
	phosphorus	870 µg/L		100						
	arsenic	92 µg/L	7	50	100	500	7	50	100	500
	molybdenum	40 µg/L	50		10	10	50		10	10
	cyanide	265 µg/L	80				80	5		
	selenium	10 µg/L	10	70	20	20	10	70	20	20
	Total Nitrogen	4.9 mg/L		5						
CJ16	chloride	1,120 mg/L					250		30-700	
CJ17	Nitrate / nitrite	0.6 mg/L	10/1	0.2		30/10	50/3			30/10
CJ18	-									
CJ19	-									
CJ20	-									
CJ21	chloride	780 mg/L					250		30-700	
	TOC	31 mg/L		10						
	arsenic	37 µg/L	7	50	100	500	7	50	100	500
	cadmium	2.8 µg/L	2	2	10	10	2	2	10	10
	molybdenum	82 µg/L	50		10	10	50		10	10
	cyanide	19 µg/L	80				80	5		
CJ21A	TOC	11 mg/L		10						
	Nitrate / nitrite	10 mg/L	10/1	0.2		30/10	50/3			30/10
	arsenic	8 µg/L	7	50	100	500	7	50	100	500
	molybdenum	21 µg/L	50		10	10	50		10	10
	cyanide	6 µg/L	80				80	5		
	fluoride	2.3 mg/L	1.5		1	2	1.5		1	2
	phosphorus	100 µg/L		100						
CJ22	arsenic	10 µg/L	7	50	100	500	7	50	100	500
CJ23	-									
CJ24	antimony	4 µg/L	3				3	500		
	arsenic	14 µg/L	7	50	100	500	7	50	100	500
	cyanide	34 µg/L	80				80	5		
	phosphorus	200 µg/L		100						

Table 4.13 Groundwater analytical results exceeding selected NEPM guidelines and Water Quality Policy (cont.).

Well	Potential Contaminant of Concern	Concentration	Water Quality Policy Exceedence				NEPM Exceedence			
			Potable	Marine	Irrigation	Livestock	Health	Marine	Irrigation	Livestock
CJ25	-									
CJ26	Nitrate / nitrite	7.3 mg/L	10/1	0.2		30/10	50/3			30/10
	Total Nitrogen	9.2 mg/L		5						
	antimony	4 µg/L	3				3	500		
CJ27	chloride	1,100 mg/L					250		30-700	
CJ28	chloride	919 mg/L					250		30-700	
	Nitrate / nitrite	0.6 mg/L	10/1	0.2		30/10	50/3			30/10
CJ29	arsenic	40 µg/L	7	50	100	500	7	50	100	500
CJ30	Nitrate / nitrite	12.2 mg/L	10/1	0.2		30/10	50/3			30/10
	Total Nitrogen	12.5 mg/L		5						
CJ31	Nitrate / nitrite	7.3 mg/L	10/1	0.2		30/10	50/3			30/10
	phosphorous	1,040 µg/L		100						
	Total Nitrogen	11.5 mg/L		5						

- No guideline exceedence.

5. Closure

The information obtained during the desktop study has been used to form an understanding of regional environmental and hydrogeology, in order to develop the scope of field investigations.

The data collected during the field investigations has been documented in this report (Volume 1) for the development of “Volume 2 – Conceptual Hydrogeological Model” and subsequently for “Volume 3 – Groundwater Flow Model”.

The impact of the development will be documented in “Volume 4 – Assessment and Management”.

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Kingston District Council and
Cape Jaffa Development Company

Cape Jaffa Anchorage Marina

Groundwater Impact Assessment

Volume 2 – Conceptual Hydrogeological Model

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Document History and Status

Rev	Description	Author	Rev'd	App'd	Date
A	Draft for comment	AD/GRP	AN	PJL	4/12/03
B	Revision 1	GRP	MS	PJL	16/3/04
C	Revision with Final EIS edits	GRP	PJL	PJL	23/12/04
D	Revision following Planning SA comments	GRP	[illegible]	[illegible]	4/2/05

1. Introduction

1.1 Background

Cape Jaffa is located on the coast at the southern end of Lacepede Bay, between Kingston SE and Robe, south-east of South Australia (Figure 1.1).

Kingston District Council and Cape Jaffa Development Company are proposing to develop a safe haven and moorings for existing and future fishing fleet, recreational boating facilities as well as tourist and residential development south-east of the existing settlement.

The project was declared a “Major Development” by the Minister for Urban Development on 19 December 2002 and subsequently following community consultation, the Major Development Panel (MDP) has determined that the proposal will be subject to the processes and procedures of an Environmental Impact Statement (EIS). As a result, the Panel has prepared “Guidelines for the Preparation of an Environmental Impact Statement for the Cape Jaffa Anchorage Marina. Proposal by District Council of Kingston and the Cape Jaffa Development Company” (the Guidelines).

The key groundwater assessment requirements identified in the guidelines include:

- Description of the existing groundwater environmental conditions;
- Evaluation of the impact that the proposed development will have on groundwater levels (drawdown) during and post construction;
- Evaluation of the influence of salt water intrusion;
- Impact assessment on existing groundwater users;
- Evaluation of the potential change in groundwater discharge to the marine environment; and
- Evaluation of groundwater contaminants entering the marine environment.

1.2 Study Area

The “study area” comprises the area defined as the Major Project Boundary as shown on Figure 1.2, which comprises:

- Allotment 123 in Deposit Plan 55486 (CT 5863/840);
- Part Section 92 of the Hundred of Mount Benson (CT 5560/348);

- Portion of King Drive;
- Portion of Cape Jaffa Road; and
- An area to sea in Lacepede Bay (Out of Hundreds)

in the area named Cape Jaffa.

The proposed development is shown on Figure 1.3.

The topography of the region is characterised by ridges of low sandy dunes and low-lying swampy areas parallel to the coast of Lacepede Bay. During prolonged periods of wet weather, the interdunal low-lying areas are prone to flooding. The region is crossed by several constructed drainage channels designed to drain some of these low-lying areas to maintain agricultural land. The Wongolina/Butchers Drain is the closest drain, located approximately 10 km to the east.

Figure 1.1 Location of Study Area

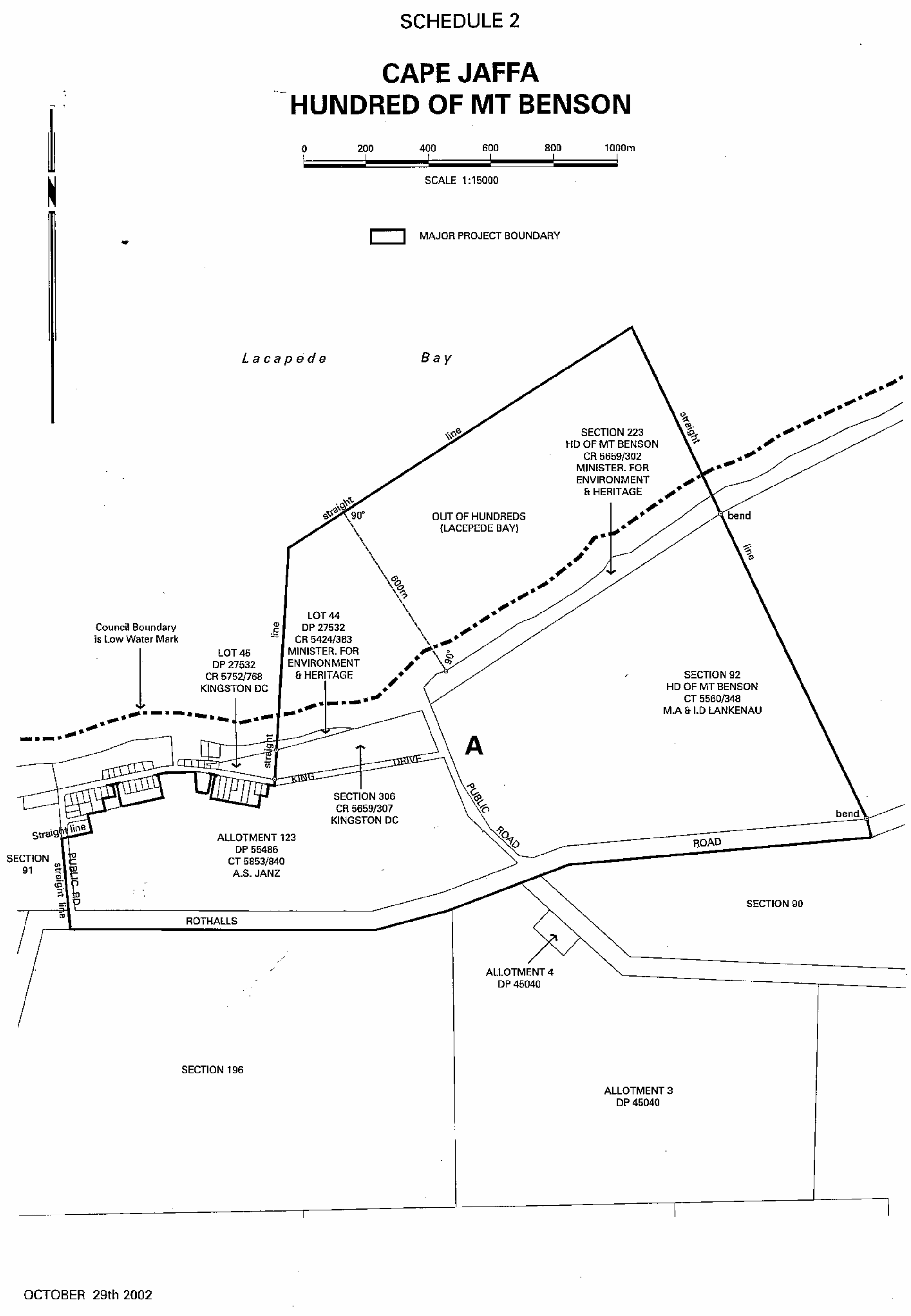


Figure 1.2 Major Projects Boundary as Gazetted 29 October 2002.

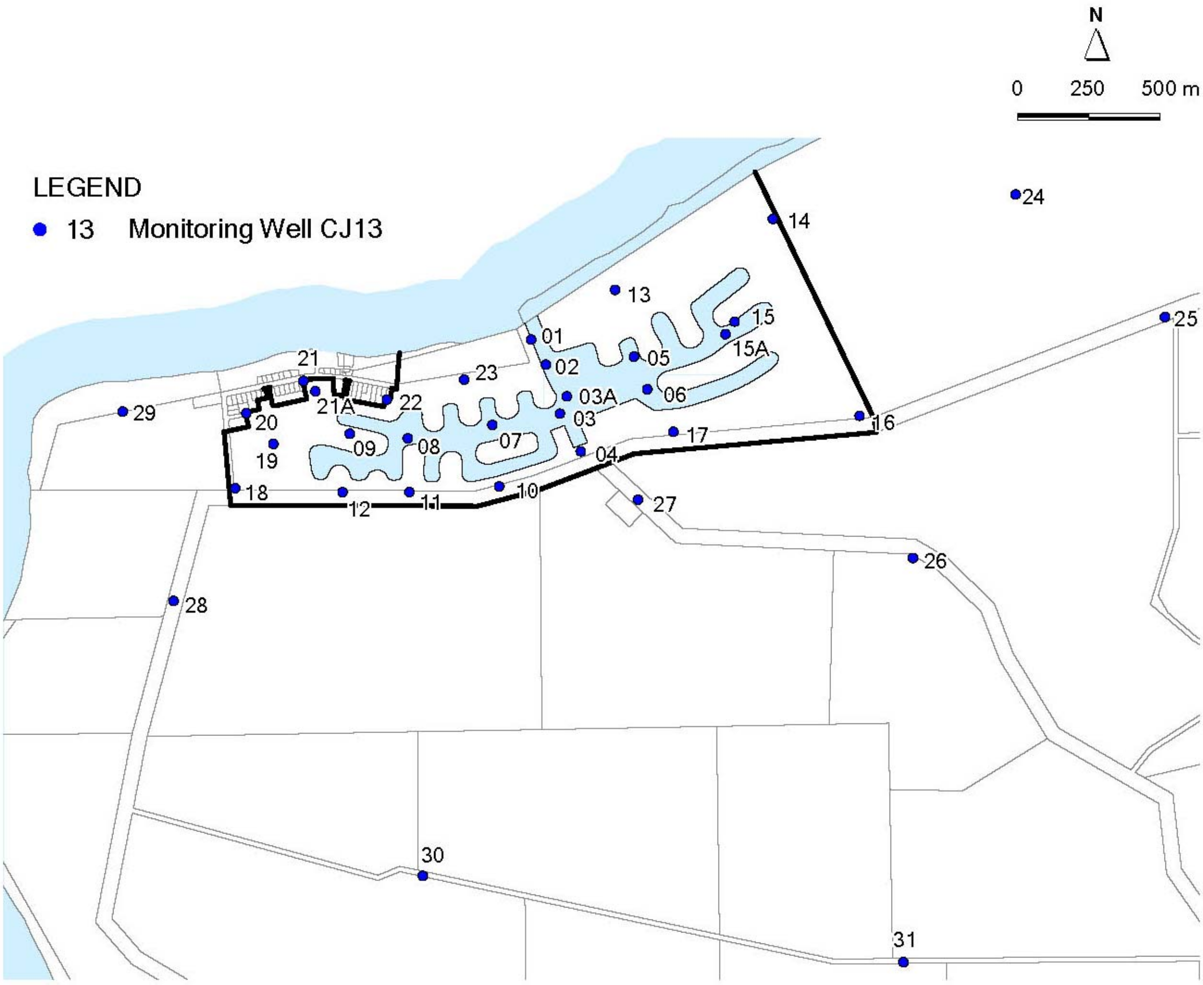


Figure 1.3 Development Concept and location of groundwater monitoring wells.

1.3 Context

Preceding this report, a desktop study and field investigations were undertaken to collect data relating to the regional and local hydrogeology, as documented in "Volume 1 – Desktop Study and Field Investigations" (ref: 20030318RA4).

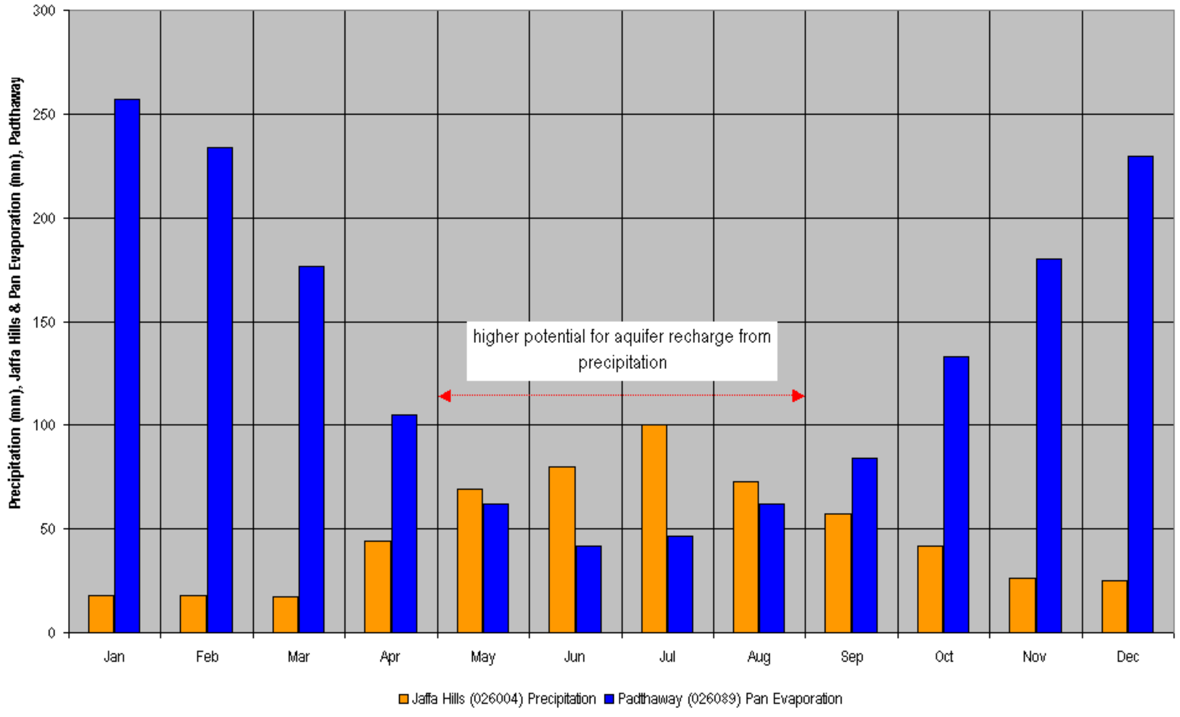
The objective of this report is to characterise the spatial and temporal hydrogeological conditions, using both regional and site specific groundwater information. Following on from the development of the conceptual hydrogeological model, the findings will be integrated into a numerical model to evaluate the likely impact of the proposed development on groundwater levels, influence on groundwater flow rates, directions and groundwater use.

The groundwater flow model will be documented as "Volume 3 – Numerical Groundwater Model" (ref: 20030318RA6). The assessment of the groundwater impacts as a result of the project and the proposed management plan will be documented in "Volume 4 – Assessment and Management" (ref: 20030318RA7).

2. Climate

The rainfall-evaporation relationship has implications for the groundwater in the study area with respect to the seasonal aquifer recharge potential. The climate at Cape Jaffa is a temperate, maritime climate consisting of warm, dry summers and cool, wet winters. The rainfall and evaporation records for the study area were obtained from the Jaffa Hills weather station (weather station 026004, precipitation data) and Padthaway (weather station 026089, evaporation data). Figure 2.1 presents the mean monthly rainfall and evaporation for these two climate stations.

Figure 2.1 Mean monthly rainfall and evaporation.



The mean annual rainfall is 559 mm, the majority falling typically from April to November. The mean annual pan evaporation is 1606 mm with mid-summer evaporation rates up to 250 mm/month and mid-winter rates of 50 mm/month. The high potential evaporation demand exceeds rainfall for most months, with the exception of May to August where the mean monthly rainfall is greater than evaporation. Further information regarding climate is provided in Volume 1, however, reference was made to rainfall data from the Robe weather station rather than the Jaffa Hills weather station which has been determined to be located closer to the site.

During the period of May to August, evaporation is on average less than rainfall and recharge is more likely to occur. However, recharge may also occur at other times during the year, particularly following intense summer rainfall events. This is due to the low topography of the site, lack of surface drainage features and permeable soils.

3. Geological Setting

A significant amount of work has been carried out on the characterisation of the regional geology with a detailed description documented in Bradley *et al* (1995). A brief summary is provided below and further detail is provided in Volume 1.

The study area lies within the Gambier Embayment of the Otway Basin, which extends from Kingston to the Mornington Peninsula in Victoria. Basement highs outcrop in the north-west (Padthaway Ridge) and south-east (Dundas Plateau).

The surficial geology is shown in Figure 3.1 (DME, 1995). The shallow geology near the study area is characterised by Holocene and Pleistocene sediments deposited during the Quaternary period. The St Kilda Formation (Holocene), including the Semaphore Sand, is found along the foreshore and consists of unconsolidated marine sediments, which comprise mainly dune deposits. The proposed development mainly overlies the St Kilda Formation (Figure 3.1). The Holocene shoreline envelops the Bridgewater Formation (Pleistocene).

The Holocene and Pleistocene marine sequence is approximately 10 m thick (DME, 1995) and these sediments overlie the Tertiary Formations, including the Gambier Limestone and Dilwyn Formation.

For the proposed development, a total of 34 soil bores were drilled (which were converted to groundwater monitoring wells). The location of the bores in relation to the surficial geology is shown in Figure 3.1. The majority of the bores were drilled through the Quaternary sediments and into the upper limestone unit, up to a depth of 12 m below ground level.

Figure 3.2 presents two geological cross sections, running north-east to south-west and south-east to north-west and are based on the lithological descriptions observed during the drilling investigation (July 2003). Typically the thickness of the Quaternary deposits ranged from approximately 5 to 10 m. A discontinuous clay layer, approximately 2.5 m thick was identified at some locations and was found to separate the Quaternary deposits from the upper limestone unit.

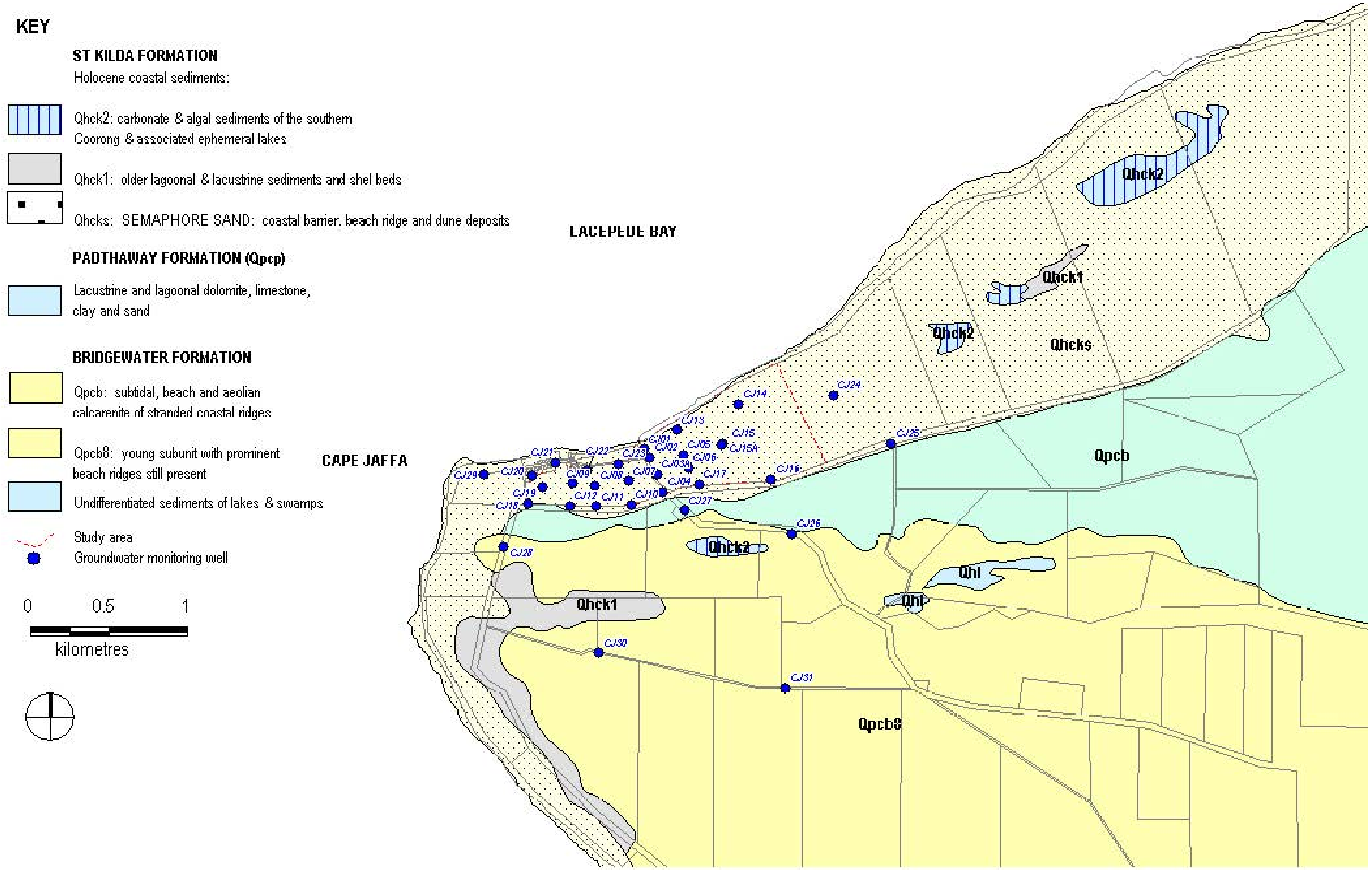


Figure 3.1 Surficial geology (DME, 1995)

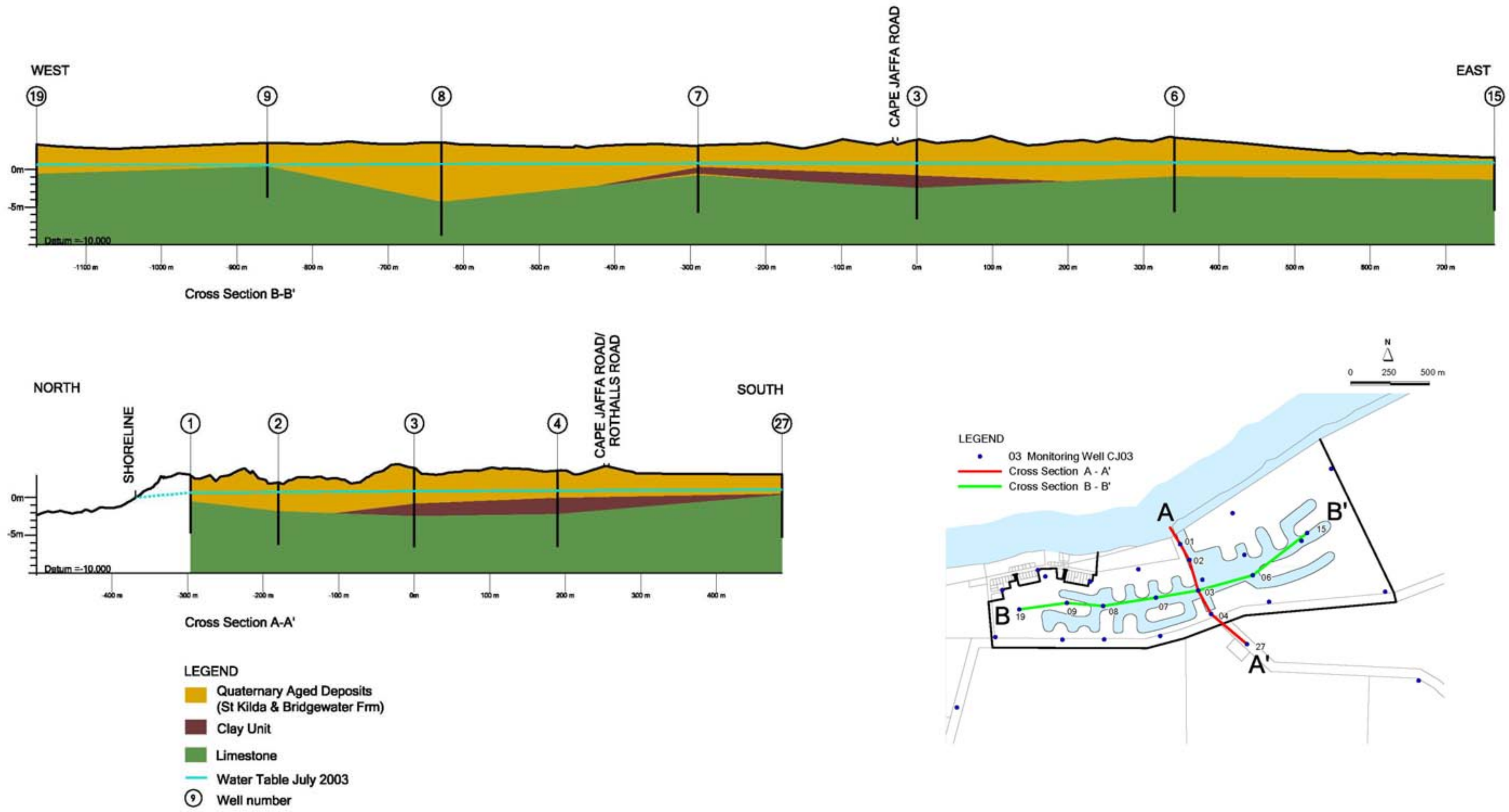


Figure 3.2 Lithological cross sections for the study area.

4. Hydrogeological Setting

4.1 Aquifers of Interest

The study area is located in the Gambier Embayment of the Otway Basin. The granitoids and volcanics of the Kanmantoo Group acts as an hydraulic basement, where two major aquifers exist, regionally referred to as:

- The upper unconfined Tertiary Limestone Aquifer (TLA); and
- The Tertiary Confined Sand Aquifer (TCSA).

The TLA is predominantly found within the Gambier Limestone though may extend into the overlying Bridgewater Formation and Semaphore Sands and consists mainly of calcareous sandstone and limestone deposits.

The TCSA is contained within the sand sequence of the Dilwyn Formation. This aquifer is a multi-aquifer system, resulting from the interbedded sands, gravels and clays of the Dilwyn Formation. For simplicity, it is treated as one aquifer.

The two aquifers are separated by a clay sequence, which forms the aquitard between the TCSA and TLA. Figure 4.1 presents a summary of the regional stratigraphic units (Love *et al*., 2001).

In June 2003, 34 groundwater monitoring wells were established. The majority of the wells were constructed to intersect the upper limestone unit. Three shallow wells were screened to intersect the Quaternary sediments. Well details and the lithological units that each well intersects is summarised in Table 4.1.

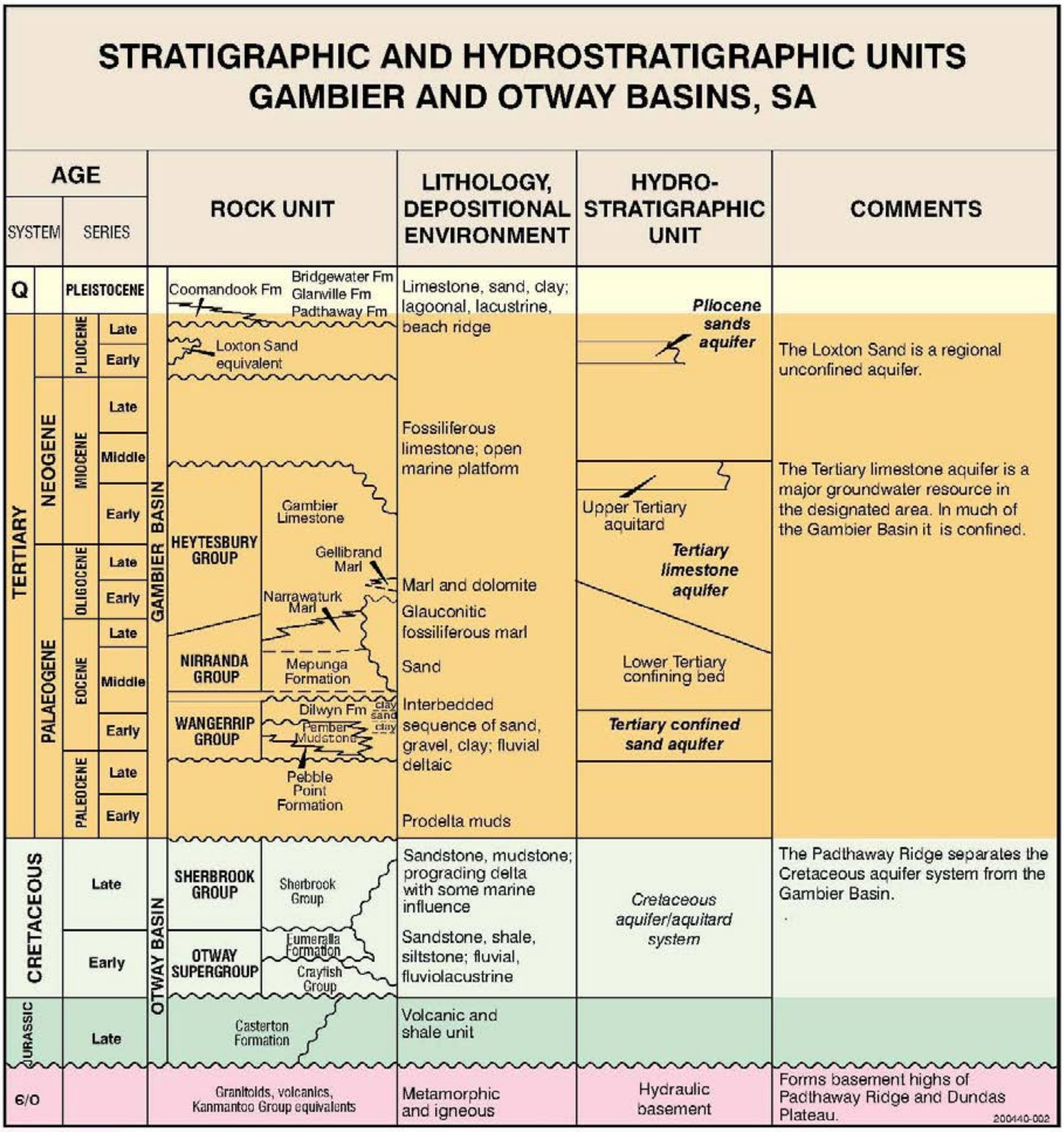


Figure 4.1 Regional stratigraphic profile (Love *et al*, 2001)

Table 4.1 Summary of well completion details

Well	Construction Date	Easting (Zone 54)	Northing (Zone 54)	Drilled Depth (mBGL)	Measured Total Depth (mBGL)	Reduced Ground Level (mAHD)	Reduced Level, Top of Casing (mAHD)	Screen Details		Screened Unit
								from (mBGL)	to (mBGL)	
CJ01	30-Jun-03	383955.5	5910859.9	8.0	7.935	3.220	3.767	5.0	7.9	upper TLA
CJ02	28-Jun-03	384014.6	5910759.8	8.0	7.946	1.710	2.184	5.0	8.0	upper TLA
CJ03	27-Jun-03	384082.1	5910592.9	10.6	10.536	3.960	4.464	7.6	10.5	upper TLA
CJ03A	27-Jun-03	384089.9	5910595.0	4.5	4.416	4.190	4.702	1.5	4.4	Quaternary (St Kilda Frm)
CJ04	26-Jun-03	384151.9	5910416.5	10.0	9.932	3.430	3.898	7.0	9.9	upper TLA
CJ05	28-Jun-03	384362.9	5910791.9	8.1	7.882	2.160	2.660	5.1	7.9	upper TLA
CJ06	29-Jun-03	384415.9	5910662.2	10.0	10.108	4.480	4.917	7.0	10.1	upper TLA
CJ07	25-Jun-03	383801.6	5910520.6	9.0	9.044	3.340	3.901	6.0	9.0	upper TLA
CJ08	25-Jun-03	383466.4	5910467.5	12.3	11.879	3.110	3.566	9.3	11.9	upper TLA
CJ09	24-Jun-03	383236.5	5910486.6	7.2	7.027	3.310	3.738	4.2	7.0	upper TLA
CJ10	24-Jun-03	383828.8	5910277.1	7.2	7.075	3.070	3.535	4.2	7.1	upper TLA
CJ11	24-Jun-03	383472.8	5910255.4	8.7	8.020	3.030	4.460	5.7	8.0	upper TLA
CJ12	23-Jun-03	383208.1	5910253.8	10.2	7.146 *	3.710	4.264	7.2	10.2	upper TLA
CJ13	30-Jun-03	384288.1	5911056.5	8.0	7.622	3.260	3.756	5.0	7.6	upper TLA
CJ14	30-Jun-03	384913.7	5911337.7	8.5	8.441	3.570	4.044	5.5	8.4	upper TLA
CJ15	30-Jun-03	384754.2	5910917.1	7.1	7.000	1.560	2.000	4.1	7.0	upper TLA
CJ15A	30-Jun-03	384738.1	5910907.0	3.0	2.322	1.530	2.028	1.0	2.3	Quaternary (St Kilda Frm)
CJ16	29-Jun-03	385256.6	5910557.7	8.5	8.050	4.180	4.610	5.5	8.0	upper TLA
CJ17	29-Jun-03	384519.3	5910493.8	8.1	7.884	3.810	4.316	5.1	7.9	upper TLA
CJ18	19-Jun-03	382782.6	5910270.1	9.6	9.307	2.570	3.143	6.6	9.3	upper TLA
CJ19	24-Jun-03	382933.7	5910445.5	8.4	8.325	3.520	4.060	5.4	8.3	upper TLA
CJ20	20-Jun-03	382826.5	5910568.5	8.0	7.749	3.380	4.189	5.0	7.7	upper TLA
CJ21	20-Jun-03	383054.8	5910695.5	8.2	7.864	2.500	3.266	5.2	7.9	upper TLA
CJ21A	20-Jun-03	383054.8	5910695.5	3.0	3.493 **	3.110	3.573	1.0	3.0	Quaternary (St Kilda Frm)
CJ22	24-Jun-03	383378.8	5910622.7	9.0	7.463	2.960	4.232	6.0	7.5	upper TLA
CJ23	26-Jun-03	383690.0	5910700.3	7.0	6.894	2.140	2.599	4.0	6.9	upper TLA
CJ24	2-Jul-03	385874.8	5911434.2	9.0	8.760	4.590	5.470	6.0	8.8	upper TLA
CJ25	2-Jul-03	386466.9	5910948.3	5.0	4.470	2.640	3.330	2.0	4.5	upper TLA
CJ26	1-Jul-03	385468.5	5909993.9	8.5	8.390	5.940	6.650	5.5	8.4	upper TLA
CJ27	20-Jun-03	384379.0	5910225.0	8.6	8.350	3.060	3.600	5.6	8.4	upper TLA
CJ28	20-Jun-03	382538.2	5909823.2	17.0	16.675	4.520	5.100	14.0	16.7	upper TLA
CJ29	26-Jun-03	382336.8	5910574.0	9.0	8.866	4.460	5.010	6.0	8.9	upper TLA
CJ30	1-Jul-03	383526.1	5908734.3	11.0	10.925	7.390	8.150	8.0	10.9	upper TLA
CJ31	1-Jul-03	385430.8	5908391.9	9.0	8.955	7.260	7.820	6.0	9.0	Upper TLA

Notes
mBGL: metres below ground level
TLA: Tertiary Limestone Aquifer (upper sediments of TLA)
mAHD: metres Australian Height Datum
* measured total depth is less than the drilled depth due to blockage in well.
** measured total depth is greater than the drilled depth due to damage during development.

4.2 Registered Groundwater Users Near the Study Area

Information on the registered groundwater wells near the study area was provided by Primary Industries and Resources SA (PIRSA, July 2003). Figure 4.2 presents the location of registered groundwater wells and classified use within approximately 2 km of the study area. The depth of the wells is presented as Figure 4.3.

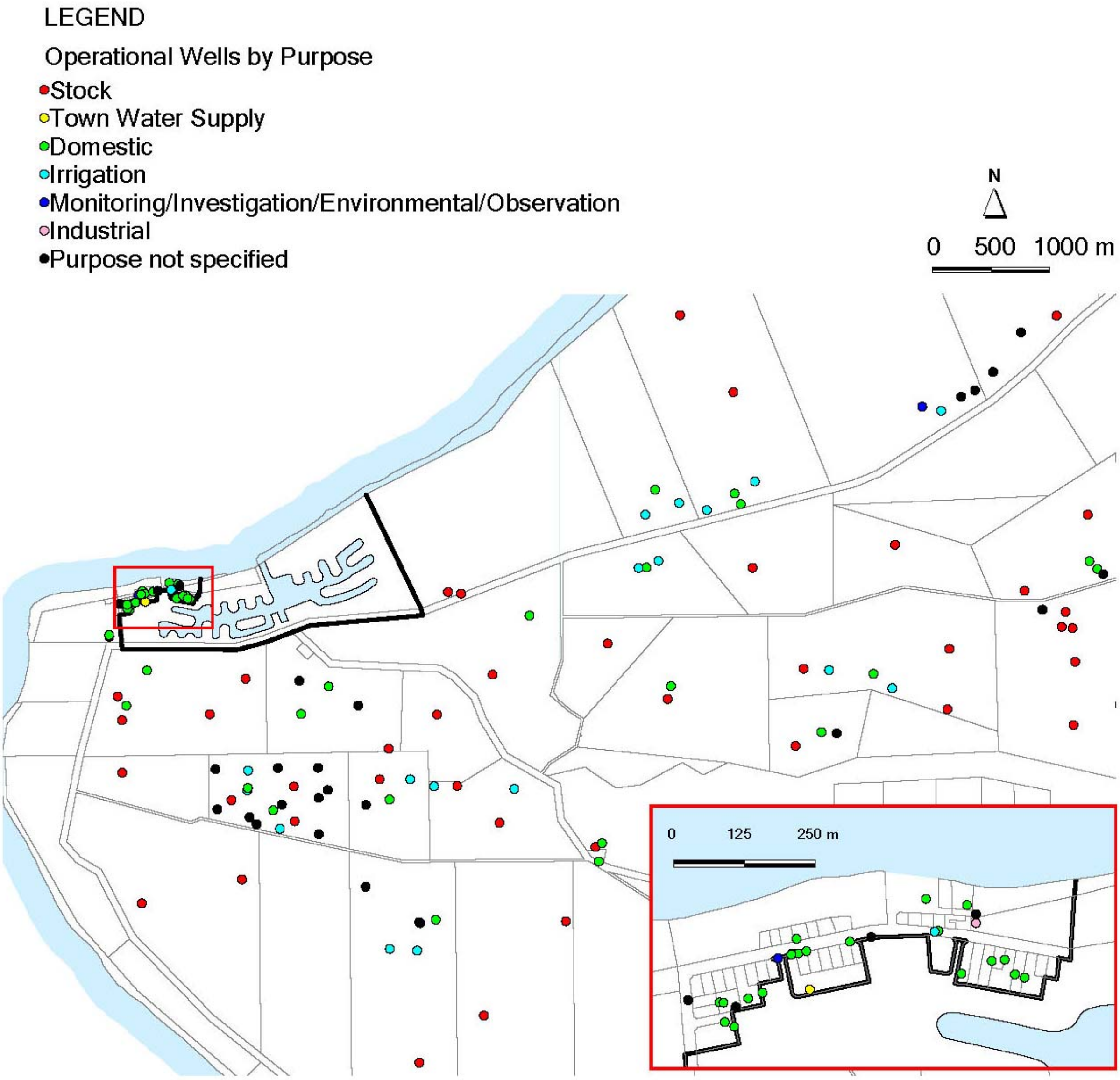


Figure 4.2 Registered groundwater wells near study area by purpose (PIRSA, July 2003)

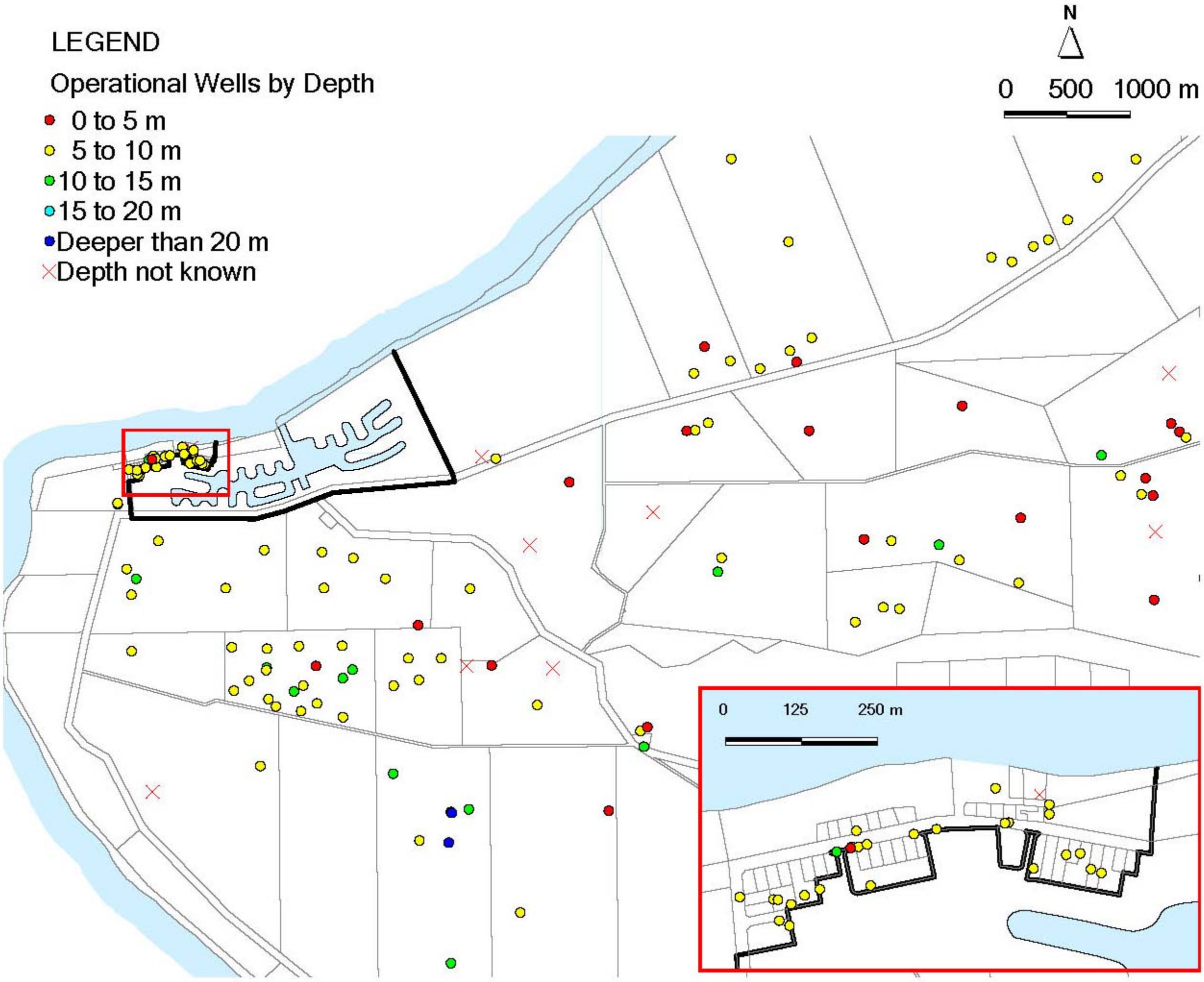


Figure 4.3 Registered groundwater wells near study area by depth (PIRSA, July 2003)

Pertinent information relating to the registered wells and classified use is summarised below:

- The majority of the wells are classified as stock/domestic wells and irrigation (Figure 4.4). One well within the two-kilometre study zone is classified as a town water supply well. The location of the town water supply well is shown in Figure 4.2 and 4.3. The town water supply well is drilled to a depth less than 10 m below ground level and likely to be extracting groundwater from the upper sediments of the TLA. This water supply is understood to be used for irrigation of coastal parks and gardens located at Cape Jaffa and not for potable supply.

- The depth of the wells have been divided into three groups:

- Wells with construction depths less than 5 m, likely to be intersecting the Quaternary sediments.
- Wells with construction depths between 5 to 10 m, likely to be intersecting either the Quaternary sediments or the top of the TLA; and
- Wells with construction depths between 10 to 20 m, likely to be intersecting the TLA.

The data suggest that all of the wells are intersecting either the Quaternary aquifer or the top of the TLA. Groundwater users in the immediate proximity of the proposed development are likely to be influenced by the development, the extent of which is investigated in "Volume 4 – Assessment and Management", ref: 20030318RA7.

Based on well depth, it is expected that none of the wells within approximately 5 km of the site are extracting groundwater from the confined TCSA. The registered wells that intersect the TCSA, within a 20 km radius of the site, are shown in Figure 4.5. Based on the location of the TCSA wells and the location and depth of existing users near Cape Jaffa, influence to neighbouring licensed users from any proposed future groundwater extraction (to service future requirements) of the development is unlikely to be significant. This is discussed further in Section 5.

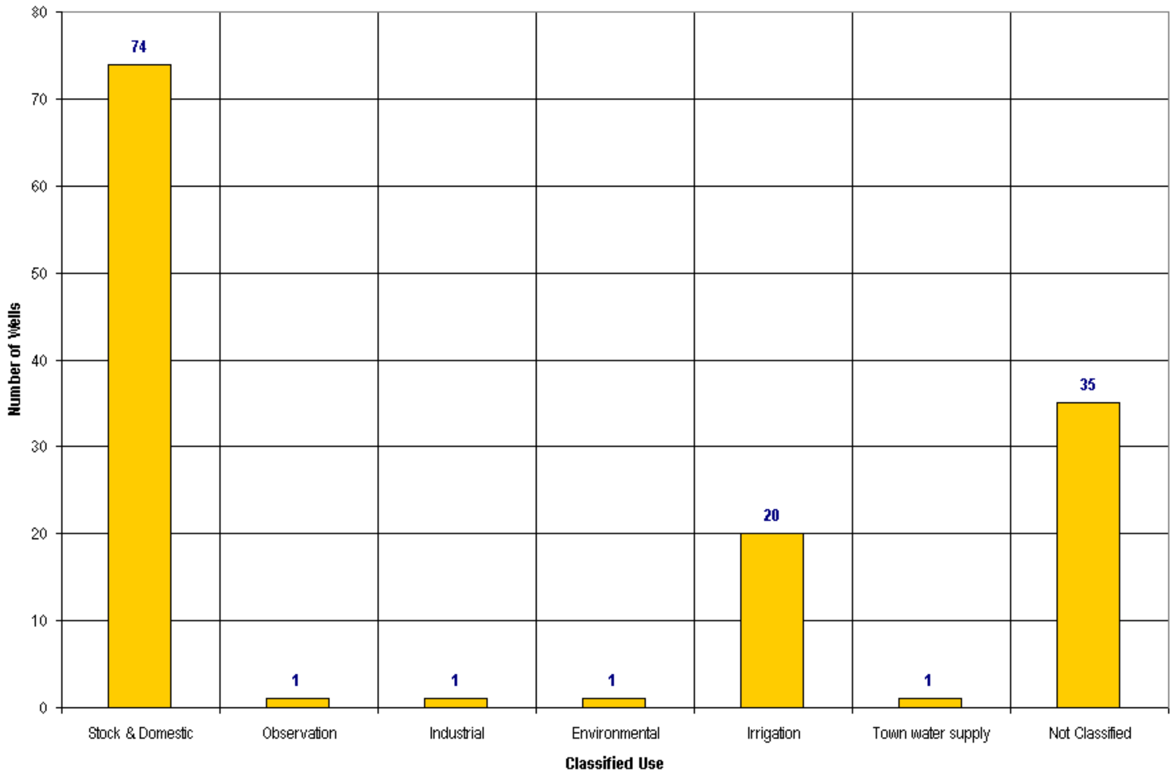


Figure 4.4 Frequency of purpose specified for registered groundwater wells within 5 km of study area (PIRSA, July 2003).

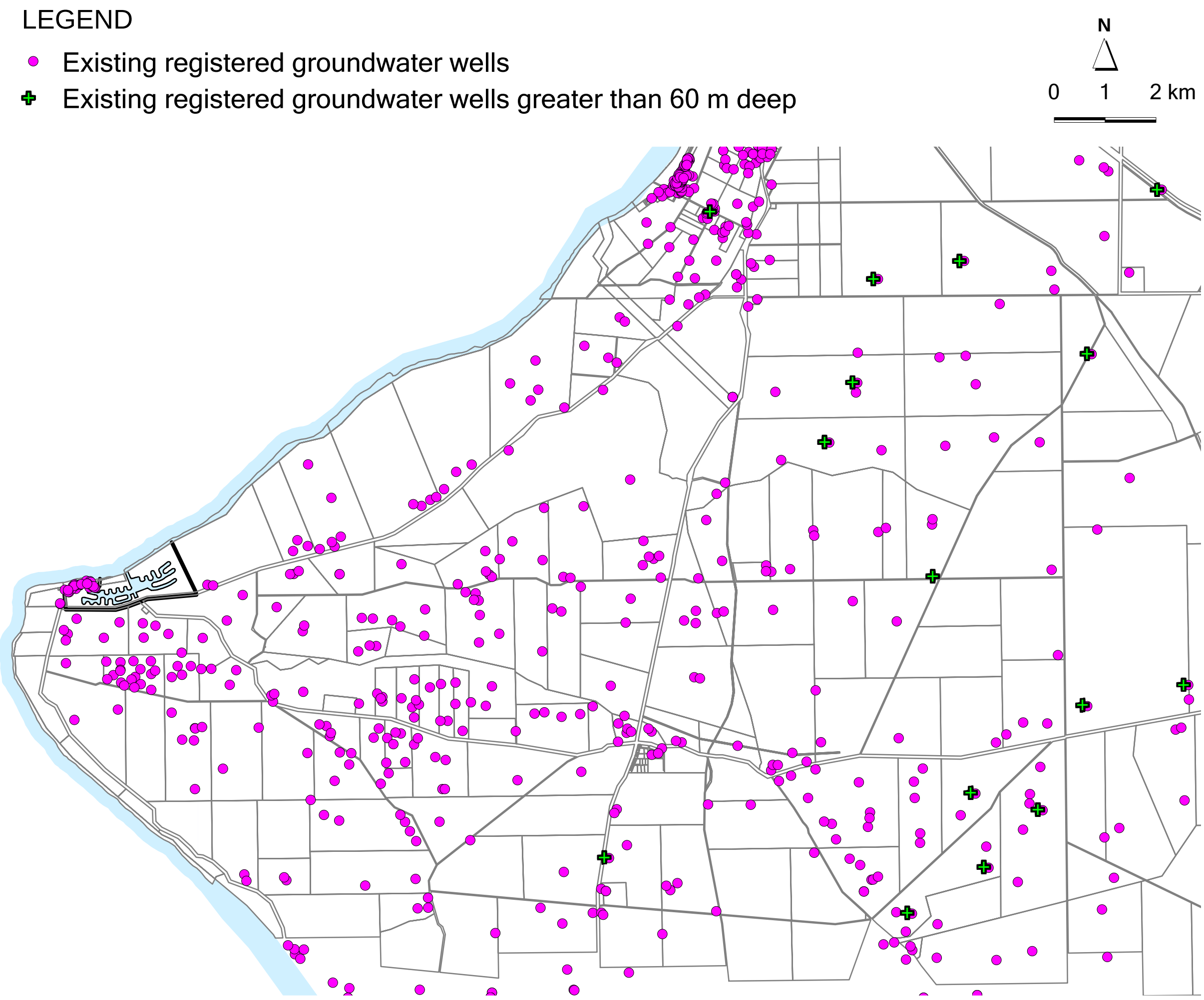


Figure 4.5 Registered groundwater wells in the region greater than 60 m deep (PIRSA, July 2003).

4.3 Groundwater Flow Direction

4.3.1 Regional Groundwater Flow Direction

Regionally, the groundwater flow in both the TLA and TCSA is towards the sea. Potentiometric surface contours for the TLA and TCSA for October 2001 are shown in Figure 4.6 and Figure 4.7. Based on the presented elevation contours the estimated hydraulic gradient for the TCSA is approximately 0.0002 in proximity to the study area.

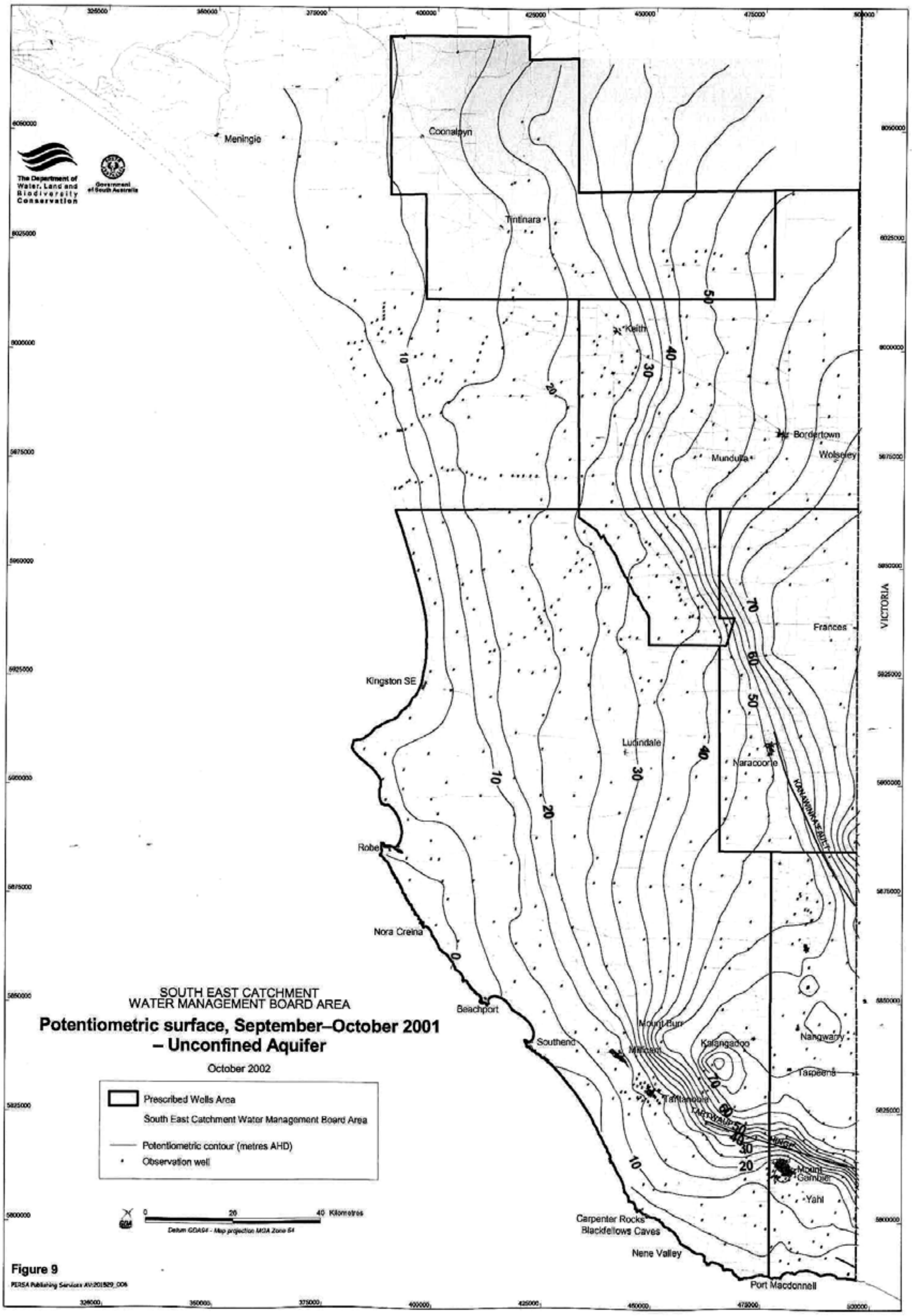


Figure 4.6 Potentiometric surface of Unconfined Aquifer (TLA), DWLBC (2002)

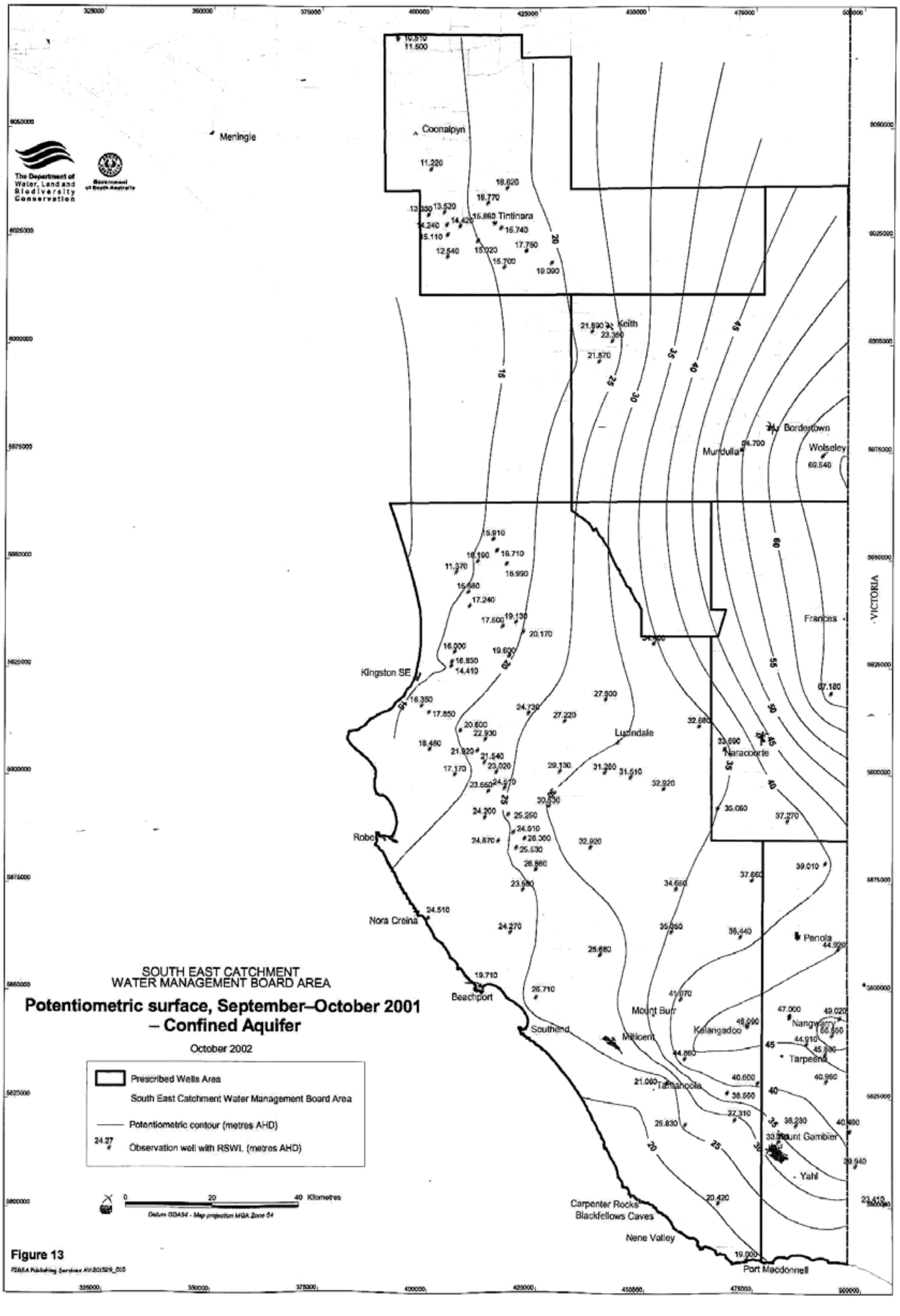


Figure 4.7 Potentiometric surface of Confined Aquifer (TCSA) – Ref Love *et al.* (2001).

4.3.2 Local Groundwater Flow Direction

A total of three groundwater-gauging events of all wells have been conducted at the site, between July and October 2003. Selected wells were gauged again in November 2003. The groundwater gauging data are summarised in Table 4.2.

Groundwater elevation contours for the TLA over the three main gauging events, are presented as Figure 4.8 and indicate flow towards the north-west.

The estimated hydraulic gradient is moderately consistent over the majority of the study area for all three gauging periods, however, a steeper hydraulic gradient was observed near the foreshore in October 2003. It is noted that October 2003 was the only gauging event were all the observations were taken during the same day. For both the July 2003 sets of data, water level observations were taken over a number of days and tidal level fluctuations may have influenced the observed levels during the gauging period and hence the groundwater elevation interpretations particularly near the foreshore.

Based on the three gauging events, the estimated hydraulic gradient was approximately 0.0004. A steeper gradient was observed along the foreshore, estimated to be approximately 0.0007.

The groundwater elevation contours for November 2003 indicate a groundwater mound around CJ24. This may be an indication of an erroneous data point at CJ24 and will be reviewed during future monitoring rounds.

Table 4.2 Summary of groundwater gauging data.

Well	Groundwater Monitoring Event							
	07/07/03-09/07/03		13/07/03-16/07/03		28/10/03		11/11/03	
	mTOC	mAHD	mTOC	mAHD	mTOC	mAHD	mTOC	mAHD
CJ01	3.124	0.643	3.016	0.751	3.335	0.432	3.350	0.417
CJ02	1.470	0.714	1.435	0.749	1.370	0.814		
CJ03	3.624	0.840	3.619	0.845	3.410	1.054	3.475	0.989
CJ03A	3.910	0.792	3.879	0.823	3.560	1.142	3.620	1.082
CJ04	2.965	0.933	2.945	0.953	2.780	1.118	2.850	1.048
CJ05	1.842	0.818	1.810	0.850	1.585	1.075		
CJ06	4.055	0.862	4.030	0.887	3.720	1.197		
CJ07	3.095	0.806	3.470 *	0.431	2.980	0.921		
CJ08	2.835	0.731	2.900	0.666	2.780	0.786		
CJ09	3.144	0.594	3.130	0.608	2.990	0.748		
CJ10	2.690	0.845	2.650	0.885	2.535	1.000		
CJ11	3.665	0.795	3.641	0.819	3.520	0.940		
CJ12	3.595	0.669	3.570	0.694	3.360	0.904		
CJ13	3.126	0.630	3.019	0.737	3.420	0.336		
CJ14	3.355	0.689	3.330	0.714	3.110	0.934		
CJ15	1.140	0.860	1.106	0.894	0.830	1.170	0.888	1.112
CJ15A	1.110	0.918	1.033	0.995	0.880	1.148	0.956	1.072
CJ16	3.335	1.275	3.305	1.305	3.040	1.570		
CJ17	3.36	0.956	3.335	0.981	3.040	1.276		
CJ18	2.517	0.626	2.500	0.643	2.260	0.883		
CJ19	3.448	0.612	3.425	0.635	3.205	0.855		
CJ20	3.613	0.576	3.582	0.607	3.450	0.739		
CJ21	2.774	0.492	2.735	0.531	2.780	0.486		
CJ21A	3.046	0.527	3.045	0.528	3.015	0.558		
CJ22	3.723	0.509	3.557	0.675	3.910	0.322		
CJ23	2.049	0.550	1.825	0.774	2.250	0.349		
CJ24	4.380	1.090	4.330	1.140	3.230 [1]	2.240		
CJ25	1.890	1.440	1.860	1.470	1.620	1.710		
CJ26	5.150	1.500	5.120	1.530	4.945	1.705		
CJ27	2.565	1.035	2.547	1.053	2.410	1.190		
CJ28	4.395	0.705	4.355	0.745	4.120	0.980		
CJ29	4.463	0.547	4.342	0.668	4.470	0.540		
CJ30	7.130	1.020	7.105	1.045	6.880	1.270		
CJ31	6.07	1.750	6.060	1.760	5.820	2.000		

mBGL metres below ground level
mTOC metres from Top of Casing
mAHD metres Australian Height Datum
SWL Standing Water Level
1. Gauging data potentially not reliable

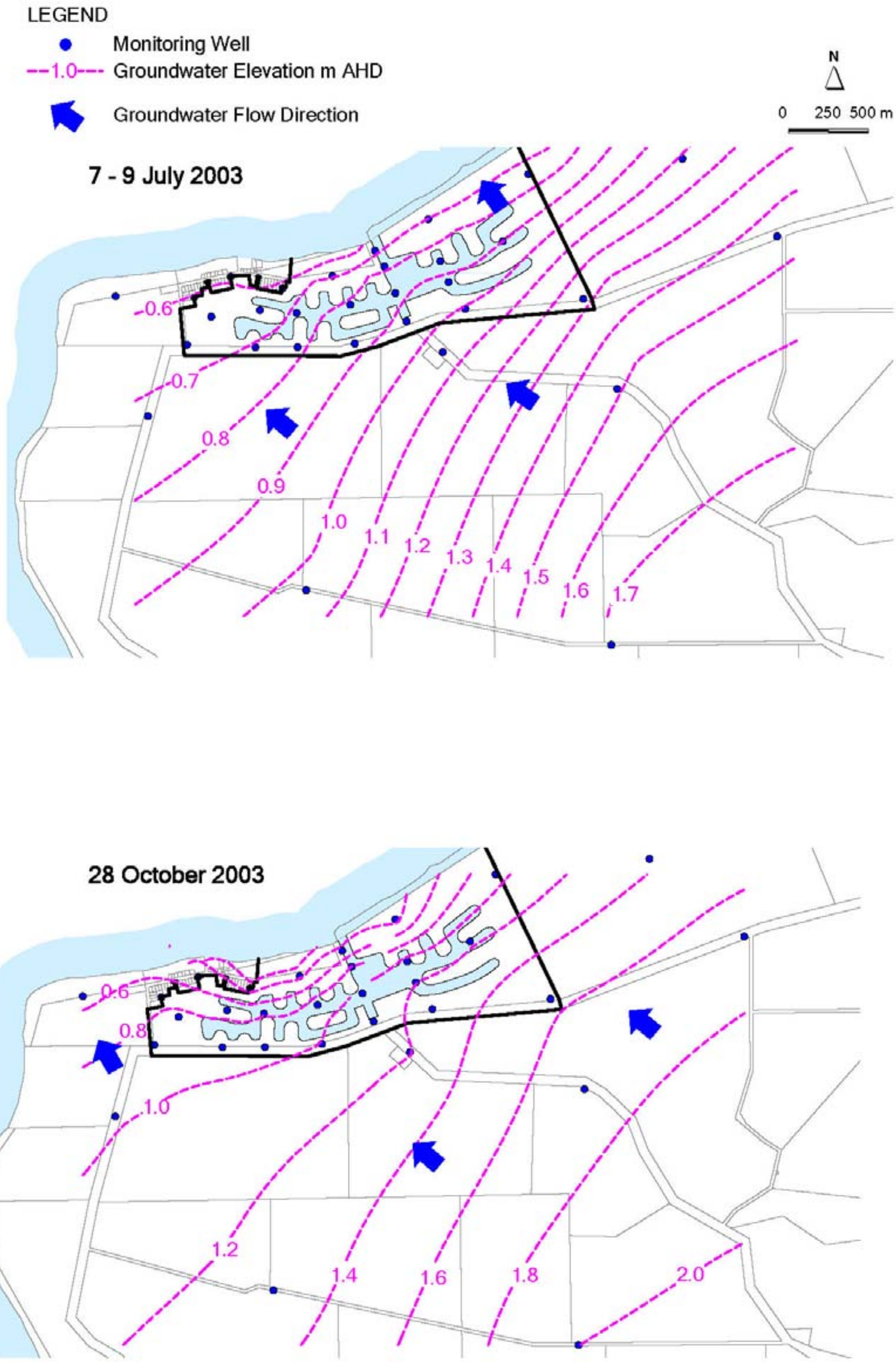


Figure 4.8 Water table contours and inferred groundwater flow direction in the TLA.

4.4 Groundwater Level Fluctuations

Temporal water level trends have been evaluated in order to consider external influences to the shallow aquifer system, including aquifer recharge from precipitation and seasonal water level trends. Hydrographs have been developed for a number of regional observational wells and selected newly constructed wells drilled within the study area (although the time series data available are limited).

4.4.1 Regional Groundwater Level Fluctuations

Due to the limited on-site water level data available, seasonal water level trends were evaluated using regional observation data near the study area of monitored aquifers. The location of the regional wells and the aquifer that the wells monitor is shown in Figure 4.9 and details are summarised in Table 4.3.

Table 4.3 Summary of regional groundwater wells.

Observation Well	Well Ref. No	NSL Elevation (m AHD)	Ref Elevation (m AHD)	Intersected Aquifer	Depth of Well (mBGL)	Easting	Northing	Construction Date
WAT020	6823-00523	8.35	8.99	TCSA	170.38	398256.69	5896993.8	1960
LAC012	6824-00238	2.01	2.4	TCSA	76.6	398692.68	5916696.7	1974
MTB007	6824-00323	-	11.42	Bridgewater Frm/TLA	12	389187.68	5907559.7	1996
MTB002	6824-00252	3.57	3.87	St Kilda Formation (Holocene)/TLA	6	389579.62	5912273.7	1970
MTB006	6824-00667	5.3	5.36	Bridgewater Frm/TLA	5.2	384440.63	5908626.8	1996

Notes
mBGL: Metres below ground level
mAHD: Metres Australian Height Datum
NSL: Natural surface level
TCSA: Tertiary Confined Sand Aquifer
TLA: Tertiary Limestone Aquifer

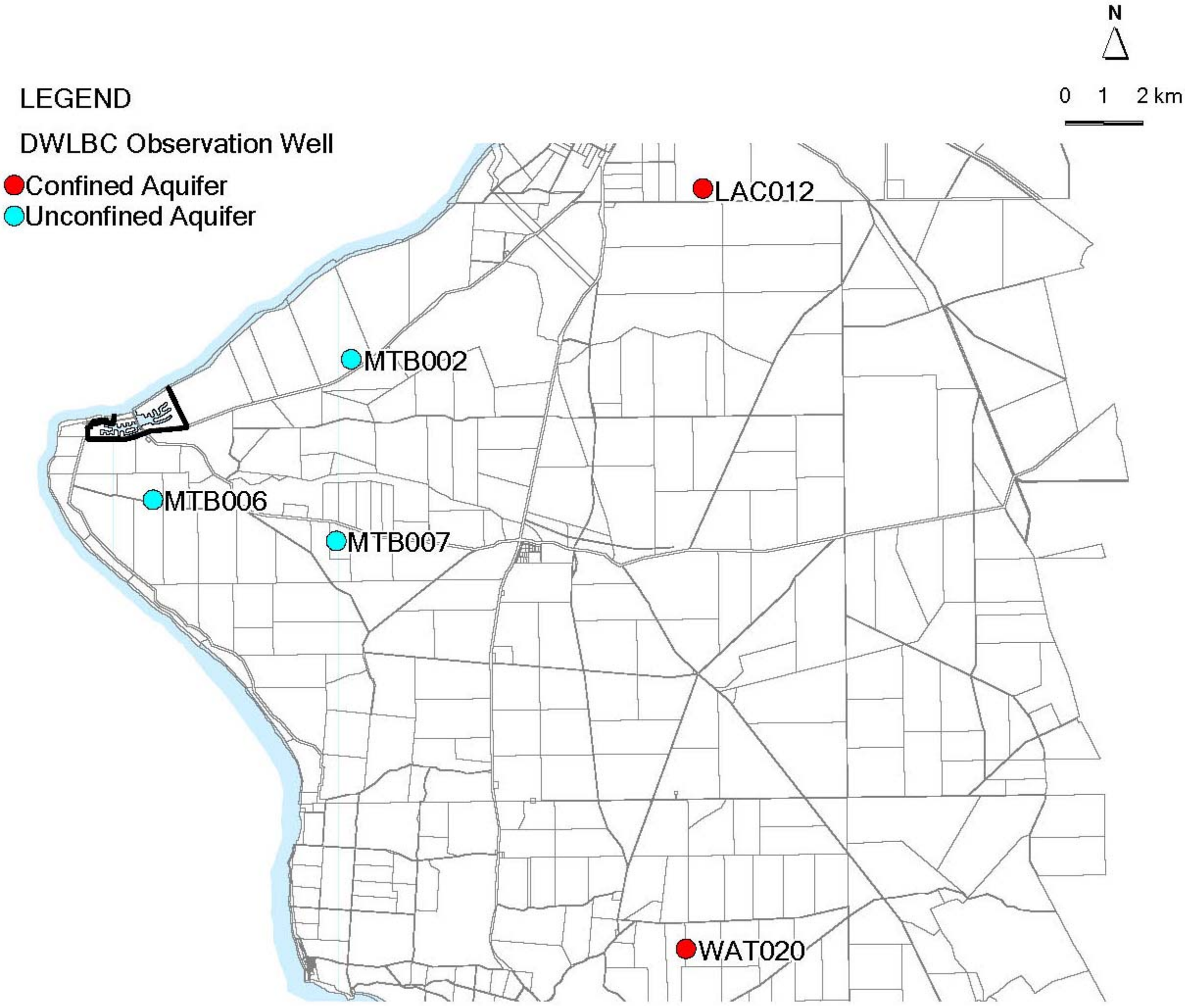
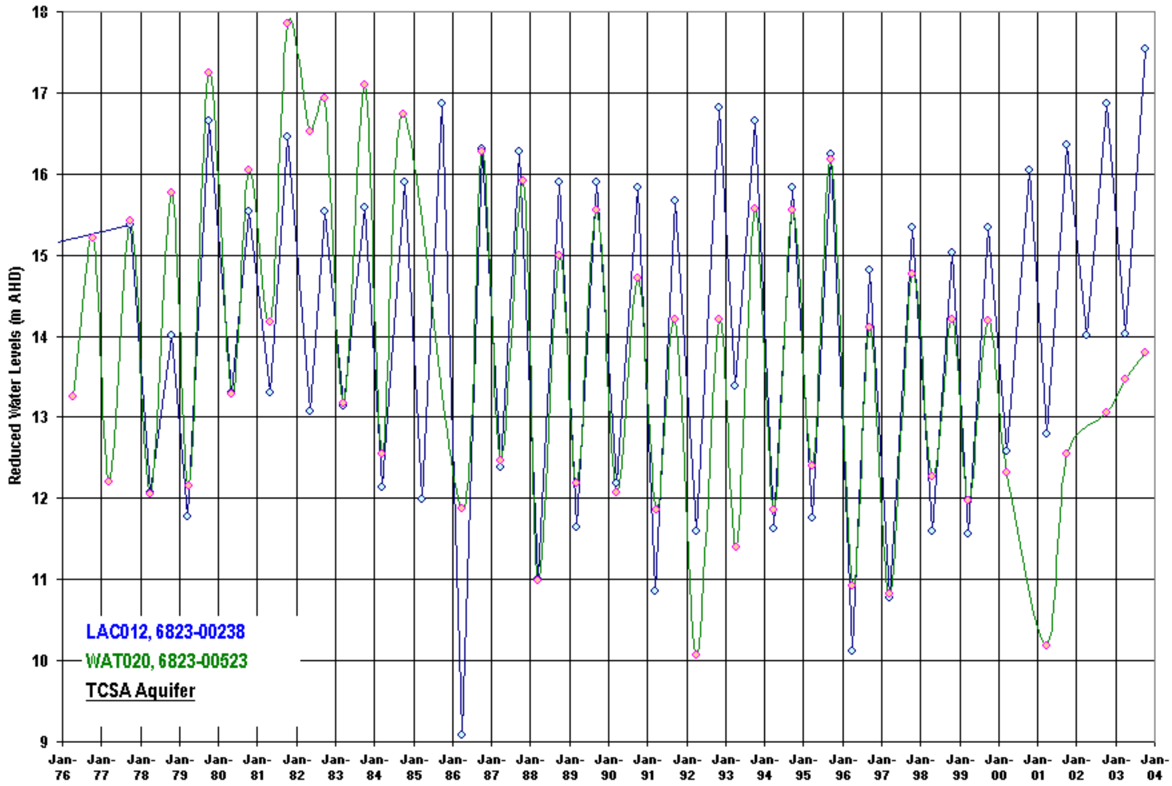


Figure 4.9 Location of regional groundwater observation wells.

Figure 4.10 presents the reduced water level fluctuations versus time for each observation well shown in Figure 4.9. The greatest water level fluctuations are observed within the deeper confined TCSA, with variations of up to 6 m recorded in the two local monitoring wells. Seasonal variation in these wells is typically between 2 to 4 m with groundwater levels higher following winter than summer.

Generally, water level fluctuations of between 0.5 to 1.0 m are observed within the unconfined TLA. The reduced water levels near the proposed development generally range between 0.5 to 2 m AHD for wells intersecting the TLA. Seasonal variation in TLA is less than TCSA and is typically between 0.2 to 0.8 m with groundwater levels higher following winter than summer.



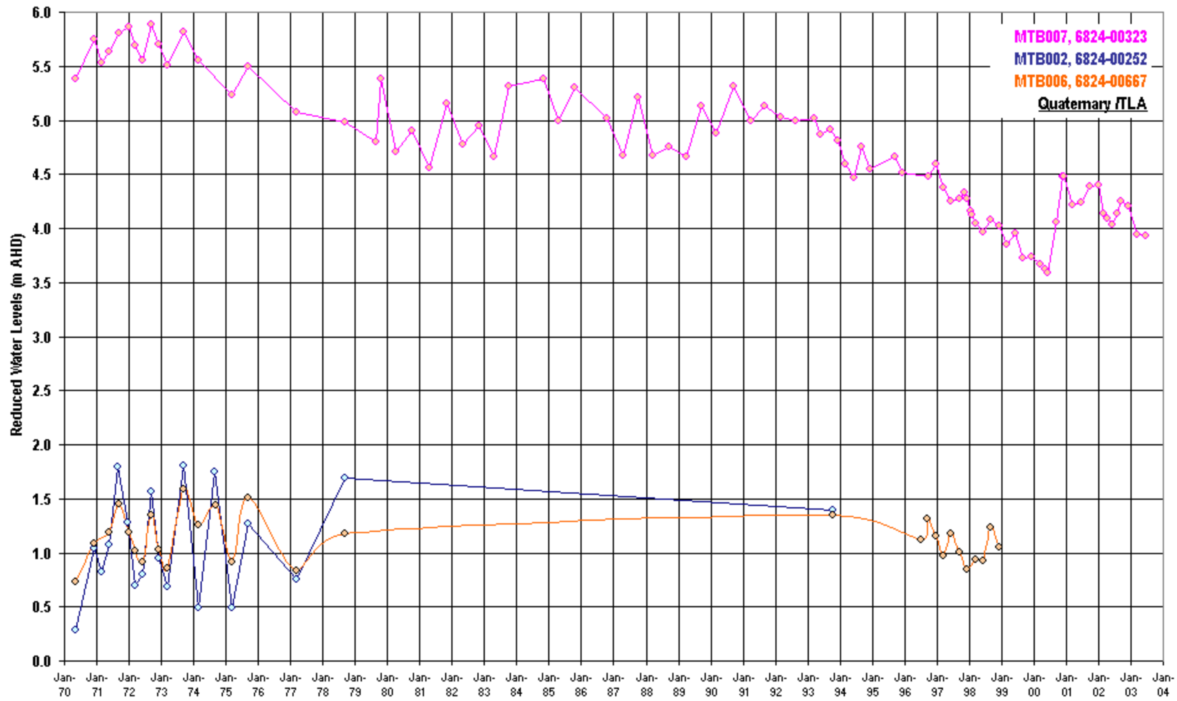


Figure 4.10 Groundwater Level Fluctuations of Regional Observation Wells (refer to Figure 4.8 for location of the wells)

4.4.2 Local Groundwater Level Fluctuations

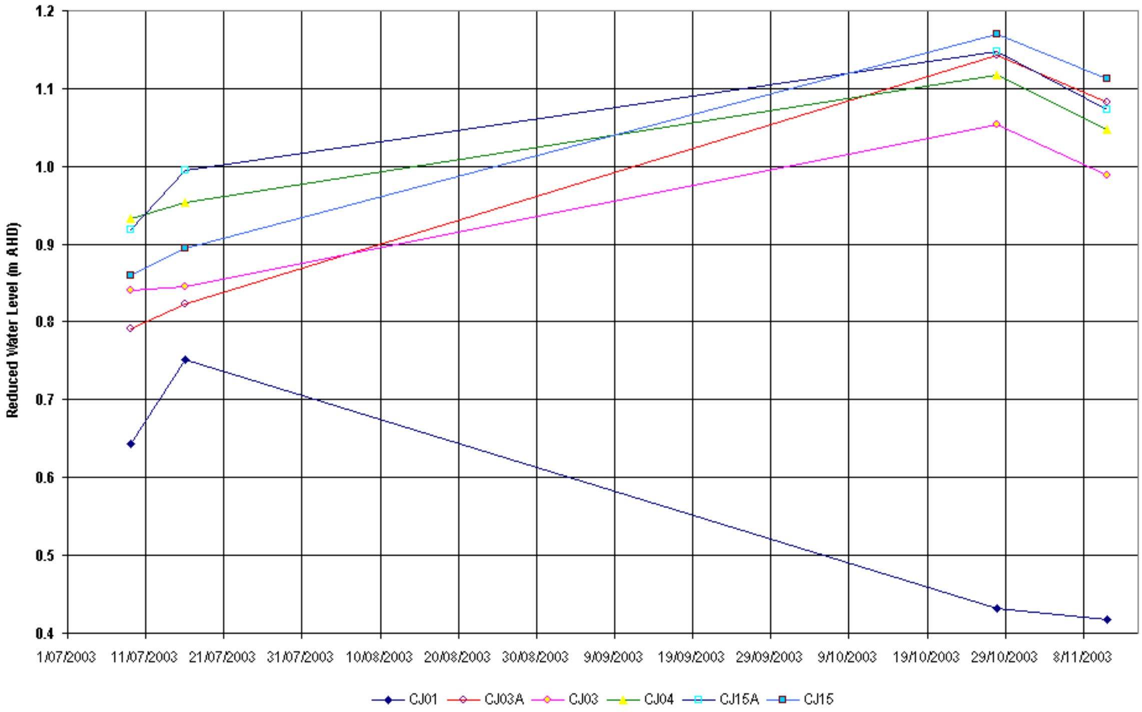
4.4.2.1 Groundwater Fluctuation in Local Groundwater Wells

Water level fluctuations for the study have been evaluated by undertaking gauging of the wells over a number of events and installing two data loggers at two locations CJ01 and CJ04. The routine gauging of all the wells is limited to three monitoring events of all wells and therefore difficult to establish long-term seasonal impacts.

Regional data has been be considered, particularly the historical water level information from observation well MTB006, which is located near the site and is assumed to intersect the TLA.

Figure 4.11 presents the hydrographs for all on-site monitoring wells (the first graph includes gauging records of four events, which were undertaken for some wells only). For most wells increasing water level trends were observed for the gauged periods of the wells between July and October 2003. Decreasing water levels were observed in November 2003 for the selected wells that were gauged. Generally, it is during May to August that precipitation exceeds evaporation and therefore more likely for aquifer recharge from precipitation to be relatively higher.

The trends for most wells appear to be similar. Different water level trends were however, noted for some wells, including CJ01, CJ13, CJ21, CJ22 and CJ29. These wells are located near the foreshore and are likely to be most influenced by tidal fluctuations (Figure 4.12).



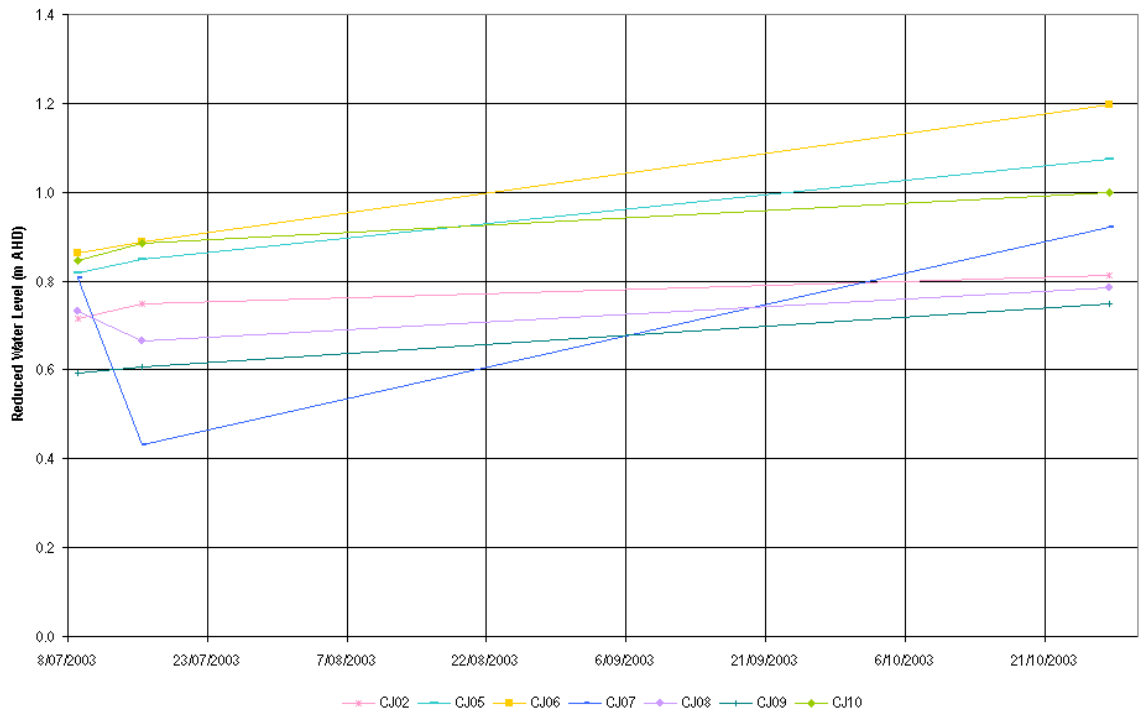
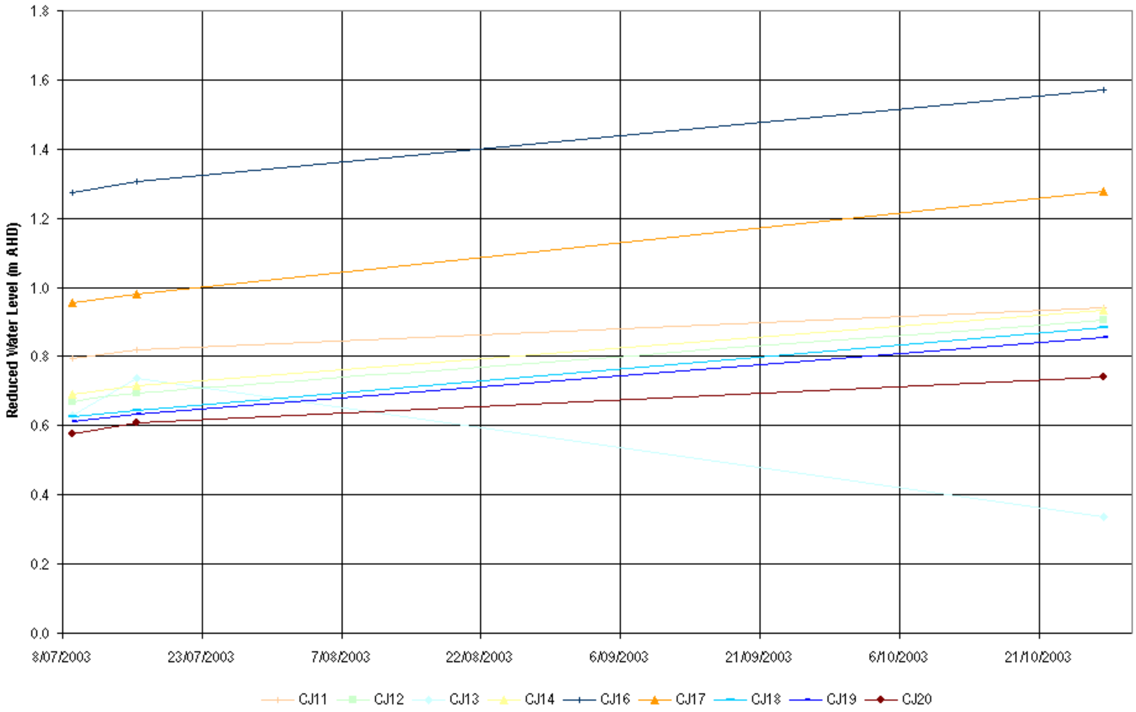


Figure 4.11 Hydrographs of wells with four gauging events.



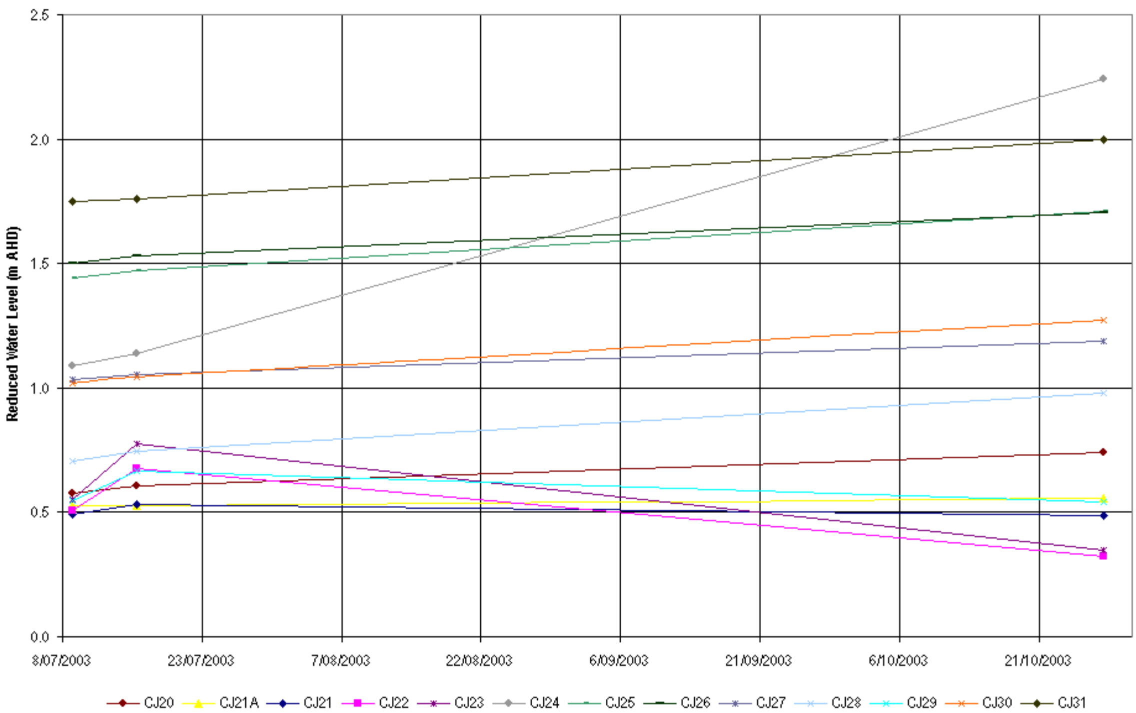


Figure 4.11 Hydrographs of wells with four gauging events (cont).

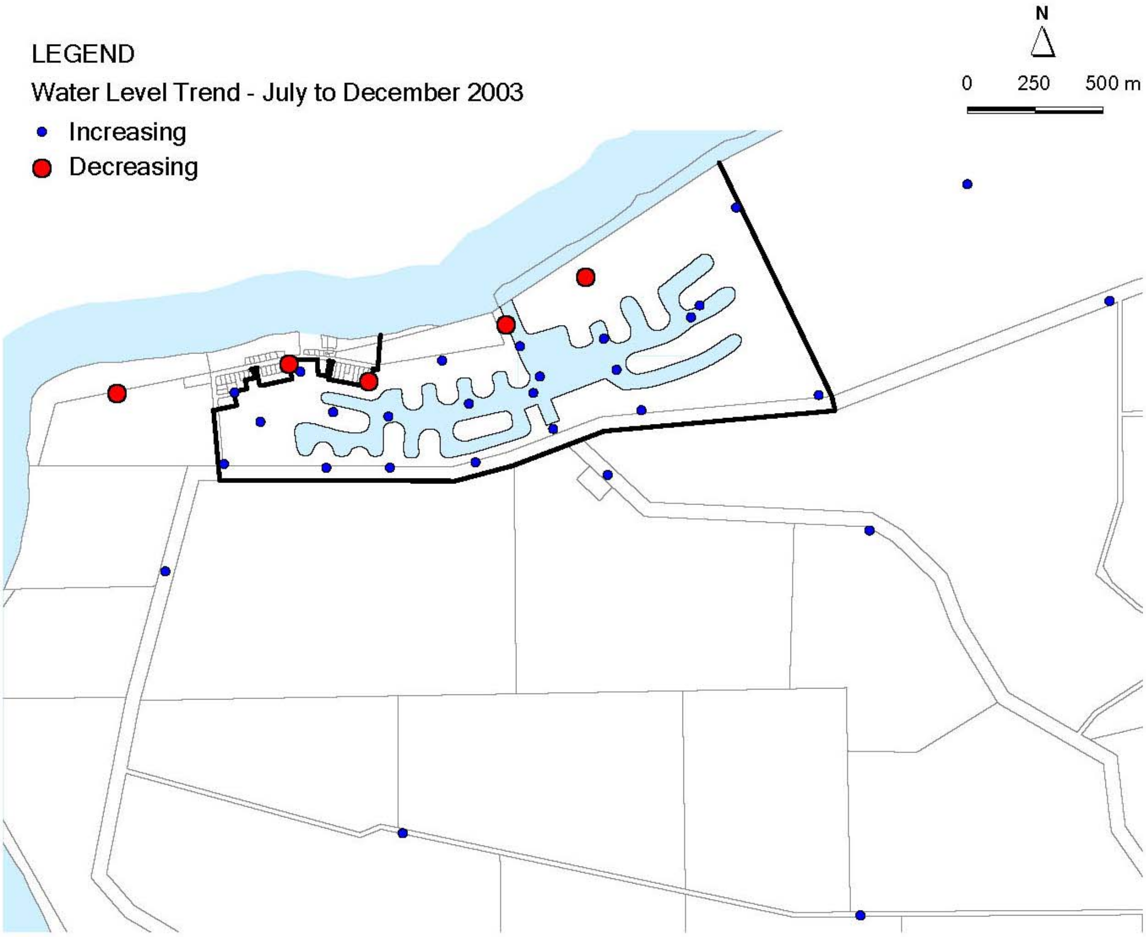


Figure 4.12 Location of wells with different water level trends (shown in red).

4.4.2.2 Groundwater Fluctuation and Tidal Level Fluctuation

An understanding of the relationship between groundwater movement and tidal influence is important for the conceptualisation of the groundwater system particularly when considering the discharge potential from the TLA to the marine environment.

The field investigation study has captured groundwater versus tide levels between August and November at monitoring locations CJ01 (along shoreline) and CJ04 (located approximately 500 m inland and hydraulically up gradient of CJ01). Based on the available groundwater gauging data and an understanding of the groundwater flow pattern, the two wells were considered to be located on a groundwater flow path approximately perpendicular to the shoreline.

The data loggers were set to record the groundwater level fluctuation at 30-minute intervals. Recorded data was downloaded from the data loggers at various stages.

The collected data was then used to compare the groundwater levels with measured tidal levels (by data logger installed at Cape Jaffa jetty) in order to assess the influence of the tides on the groundwater levels. The location of two bores along a flowline in the aquifer provides a mechanism by which to assess the retardation of the tidal effect as it penetrates further into the aquifer as well as an approximation of the change in hydraulic gradient over time.

A plot of the high frequency groundwater data and the tidal data for the monitored period is shown in Figure 4.13. To better illustrate the relative position of the groundwater and tidal levels a daily moving average of the data has been plotted. The plot indicates that the groundwater levels, at both locations, are at a greater relative level than the tide levels and hence the hydraulic gradient for the entire monitoring period, August to November 2003, is towards the marine environment.

The response to the tidal oscillation is more dampened in the distant bore, CJ04, which is located approximately 500 m inland compared to CJ01. Both wells appear to have a general trend of decreasing water level over the monitoring period.

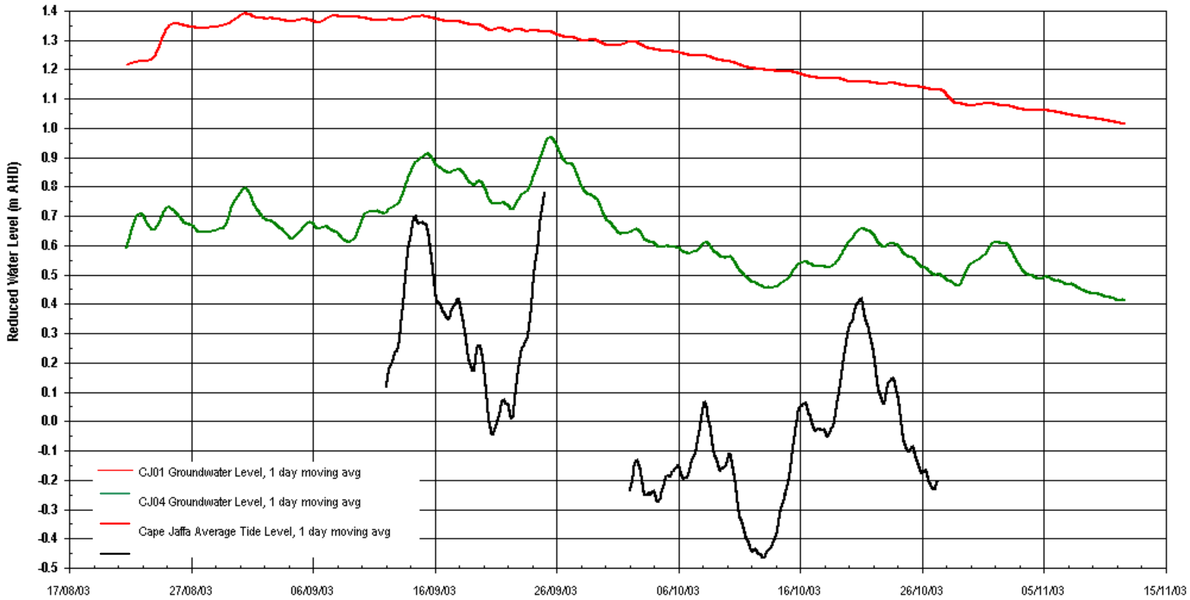


Figure 4.13 Reduced water levels for wells with data loggers and tidal level (daily moving average).

Figure 4.14 and 4.14 show hourly groundwater levels and the tidal level over a day interval (11 September 2003) to illustrate the phase shift between the tidal levels and corresponding wave pattern established in the groundwater at monitoring locations CJ01 and CJ04 respectively. The groundwater at CJ01 appears to be in phase with the tidal oscillation with little or no delay in the water level fluctuation response induced by the tide. It can be seen from Figure 4.15, that there is a lag time of approximately 1 to 2 hours for the more distant well (CJ04). As indicated in these figures, both wells appear to respond to relatively small (i.e. less than 50 mm) variations in sea level.

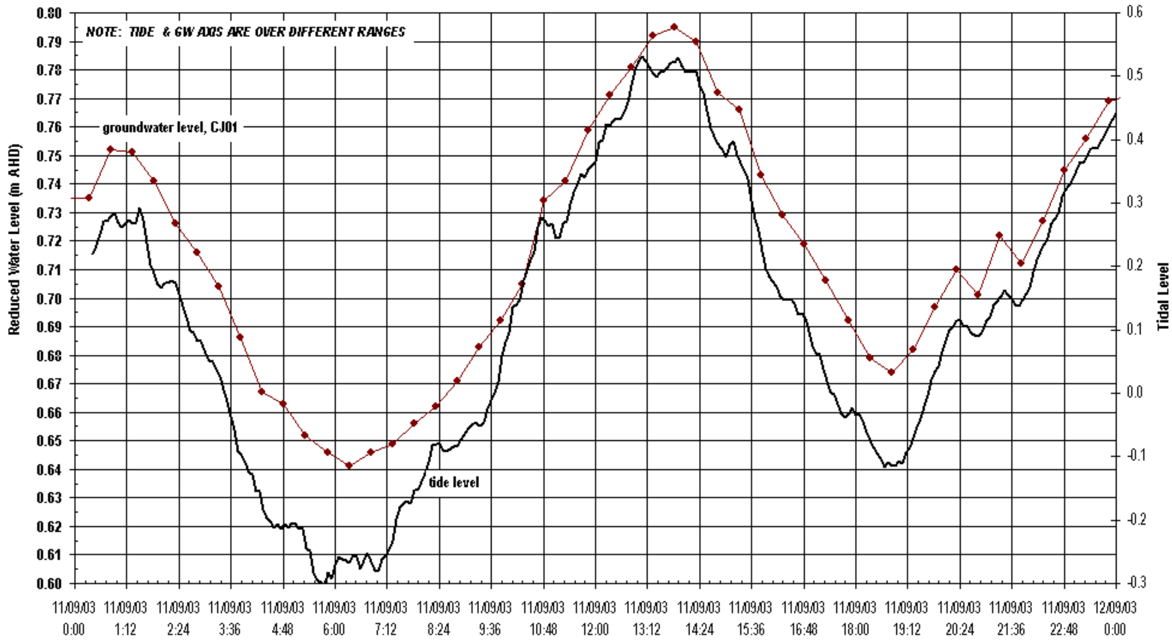


Figure 4.14 Comparison of reduced water levels, CJ01 over one tidal cycle.

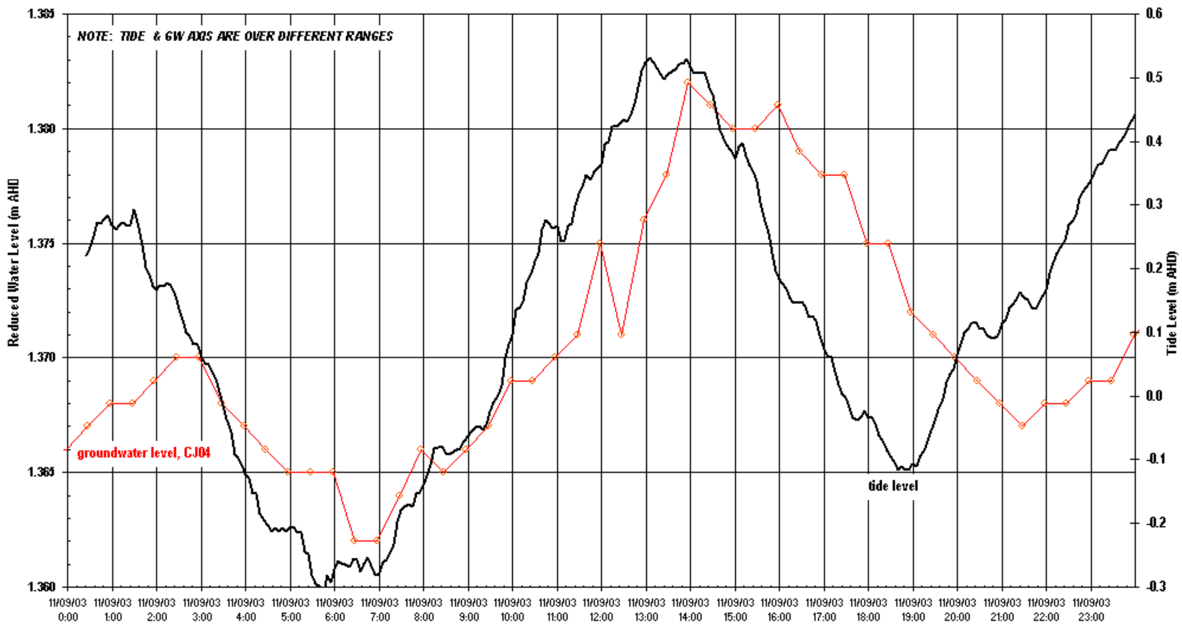


Figure 4.15 Comparison of reduced water levels, CJ04 over one tide cycle.

4.5 Aquifer Recharge

4.5.1 Regional Understanding of Aquifer Recharge

Recharge to the TCSA may occur in relatively small, localised areas (Brown *et al*, 2001) via downward leakage from the TLA in the eastern portion of the Otway Basin, where there is a downward head gradient. In the west (near the study area) and south, however, the head gradient is reversed and there is potential for the TCSA to recharge the overlying TLA. A schematic cross section of the aquifers of interest is presented in Figure 4.16. The degree of connectivity between the two aquifers is poorly understood and is currently the subject of research.

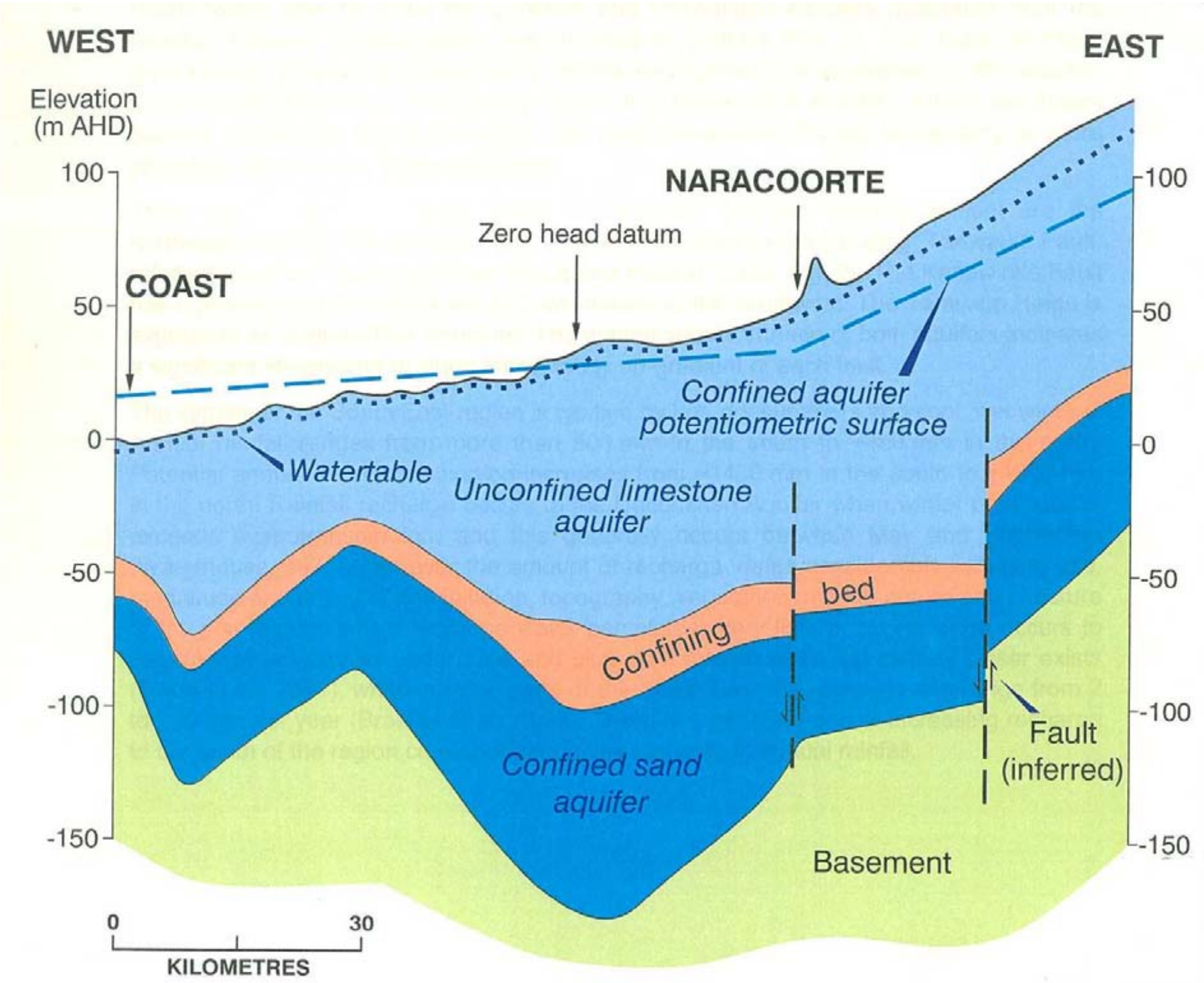


Figure 4.16 Schematic cross section of the aquifers of interest, DWLBC, 2002).

Within 5 km of the study area there are no wells that intersect the TCSA and hence a comparison of the water levels cannot be made confidently to confirm the notion of recharge of the shallow TLA from the TCSA. It is however noted that the potentiometric elevation contours of the TCSA (Figure 4.7) near Cape Jaffa is approximately 13 to 18 m AHD, as measured by DWLBC in the closest monitoring wells in September 2003. At the site, the gauged groundwater elevation contours ranged between 0.5 to 2.5 m AHD. A comparison of the regional TCSA and local water elevation levels supports the potential for the TCSA to be recharging the TLA. The presence of low salinity groundwater regionally in the TLA may also be an indication of recharge from the TCSA.

4.5.2 Local Aquifer Recharge

There are two sources of aquifer recharge: direct infiltration from precipitation and groundwater through-flow from hydraulically up-gradient sources. Aquifer recharge from precipitation is likely to be occurring on site due to high infiltration rates associated with sandy soils and lack of surface drainage features. Recharge is likely to be highest during months when precipitation exceeds evaporation (May to August) or during significant storm events.

Another source of Aquifer recharge to the shallow aquifer may be from the confined TCSA (as discussed in Section 4.5.1).

4.6 Aquifer Properties

4.6.1 Regional Aquifer Properties

Aquifer properties have been sourced from regional reports and are summarised in Table 4.4.

Table 4.4 Aquifer properties sourced from regional reports.

Property	Tertiary Limestone Aquifer (Unconfined)	Aquitard	Tertiary Confined Sand Aquifer	Reference
Flow rate	5-50 m/year		1-5 m/year	Love, Armstrong and Stadter (1992)
Thickness	10-20 m in Nangwarry-Tarpeena area Increases west and south to >300 m along coast near Carpenter Rocks	5-40 m 20-40 m except in northwest margin	Deepens near coast	Love, Armstrong and Stadter (1992) Cobb and Brown (2000)
Transmissivity	200->10000 m^3/day/m		200-1600 m^3/day/m 40->4500m^3/day/m	Love, Armstrong and Stadter (1992) Cobb and Brown (2000)
Porosity	30-50% (estimated from logs) 50-60% (measured)		20-30%	Love, Armstrong and Stadter (1992)
Diffuse recharge	47-270 mm/yr in southern portion of Otway Basin 2-40 mm/yr northern			Love, Armstrong and Stadter (1992)
Vertical permeability		10^{-3}-10^{-7} m/day		Love, Armstrong and Stadter (1992)

4.6.2 Local Aquifer Properties, Rising and Falling Head Hydraulic Conductivity Tests

In July 2003, aquifer tests (falling and rising head) were carried out on selected monitoring wells to estimate the hydraulic conductivity of the shallow aquifer. The estimated hydraulic conductivity at each location is presented in Figure 4.17 and Figure 4.18 and the data are summarised in Table 4.5.

The estimated hydraulic conductivities ranged between 1 to 30 m/day with an estimated geometric mean of approximately 5 m/day. An inferred zone of high conductivity appears to be present, running south-north, within the western portion of the study area for both falling and rising head analysis.

The variation between the results for the rising and falling head tests is due to inherent error in the measurement procedure. In addition, higher variation is evident for higher hydraulic conductivities, which is due to less data being able to be captured during these tests as they occur over a shorter period than for lower hydraulic conductivities.

Table 4.5 Estimated hydraulic conductivity (m/day) for study wells.

Well No	Falling Head (m/day)	Rising Head (m/day)
CJ01	2.5	1.4
CJ02	3.4	3.5
CJ03	3.9	7.5
CJ03A	2.9	5.9
CJ04	11.0	9.8
CJ05	2.1	3.9
CJ06	4.0	4.2
CJ07	1.7	2.4
CJ08	4.5	3.7
CJ09	27.7	4.5
CJ10	10.5	13.0
CJ11	7.2	13.9
CJ12	10.9	16.3
CJ13	5.4	12.7
CJ14	3.0	4.4
CJ15	6.5	6.5
CJ15A	3.1	7.7
CJ16	6.3	5.5
CJ17	5.2	7.1
CJ18	10.2	5.1
CJ19	7.2	6.0
CJ20	6.5	13.2
CJ21	4.7	3.5
CJ22	12.7	18.0
CJ23	11.8	7.7
CJ24	6.2	8.1
CJ25	6.7	11.8
CJ26	3.4	3.9
CJ27	6.8	8.7
CJ28	1.5	1.2
CJ29	3.2	2.9
CJ30	15.5	27.3
CJ31	4.9	5.7

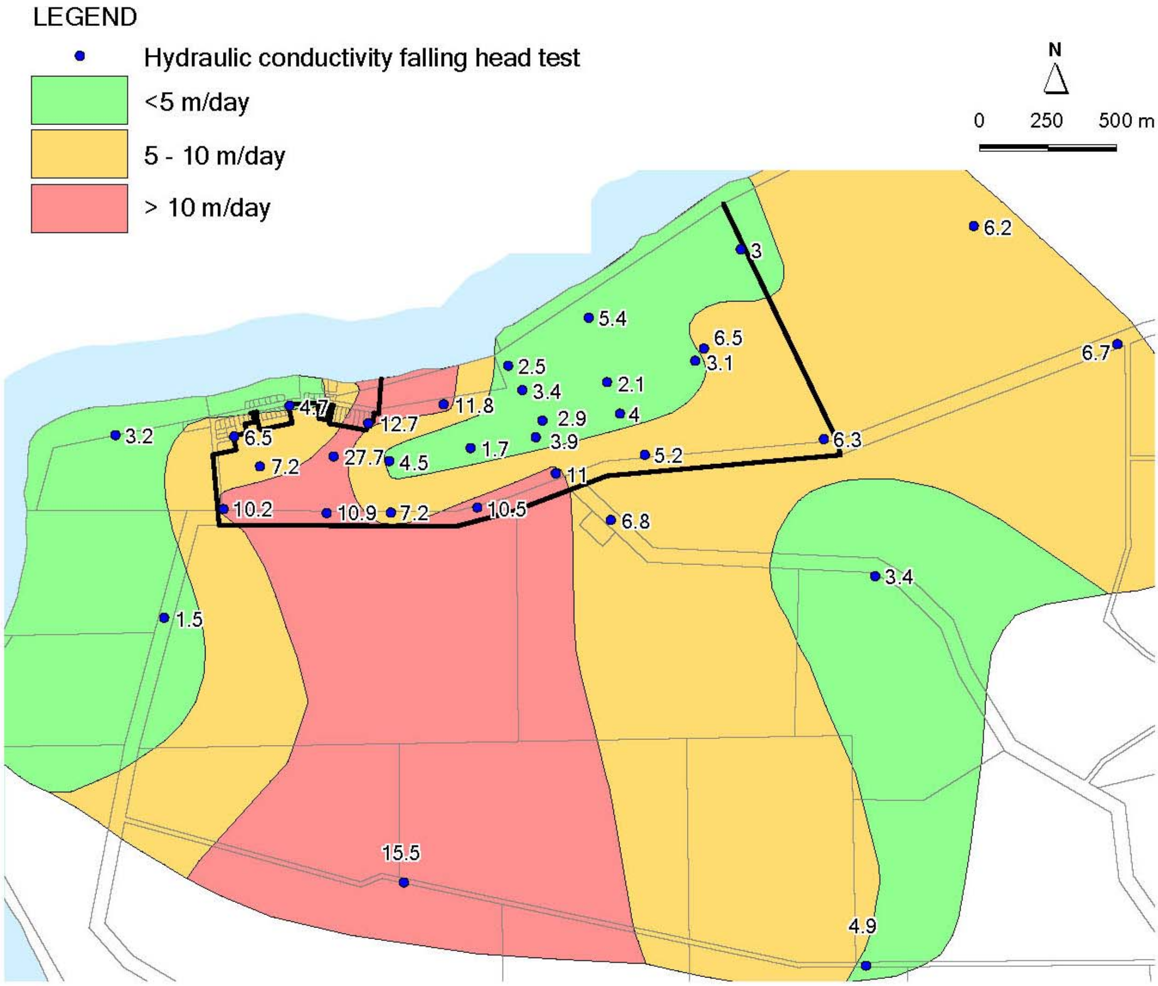


Figure 4.17 Inferred hydraulic conductivity zones – estimated from falling head tests (m/day).

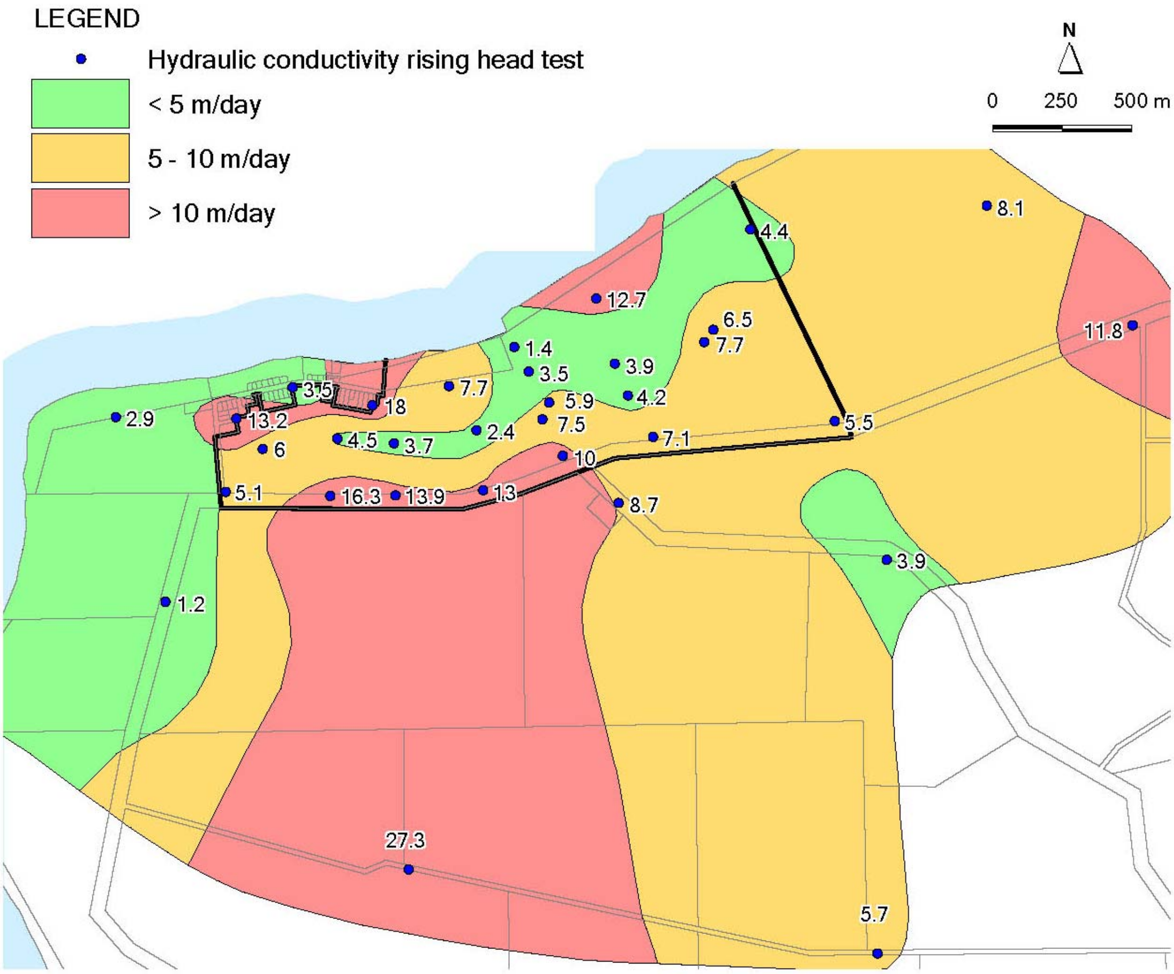


Figure 4.18 Inferred hydraulic conductivity zones – estimated from rising head tests (m/day).

4.7 Groundwater Salinity

4.7.1 Groundwater Salinity, Regional

Groundwater in the TCSA is about 25,000 years old and has very low salinity, below 1000 mg/L TDS in the southeast region. The salinity of groundwater within the TLA is also very good. Regional salinity distributions in both aquifers are shown in Figure 4.19 and Figure 4.20. The upward head gradient from the TCSA to the shallow TLA may explain the fresh groundwater quality observed near the Cape Jaffa region.

Figure 4.21 presents the inferred the TDS distribution zones based on available regional data sourced from PIRSA.

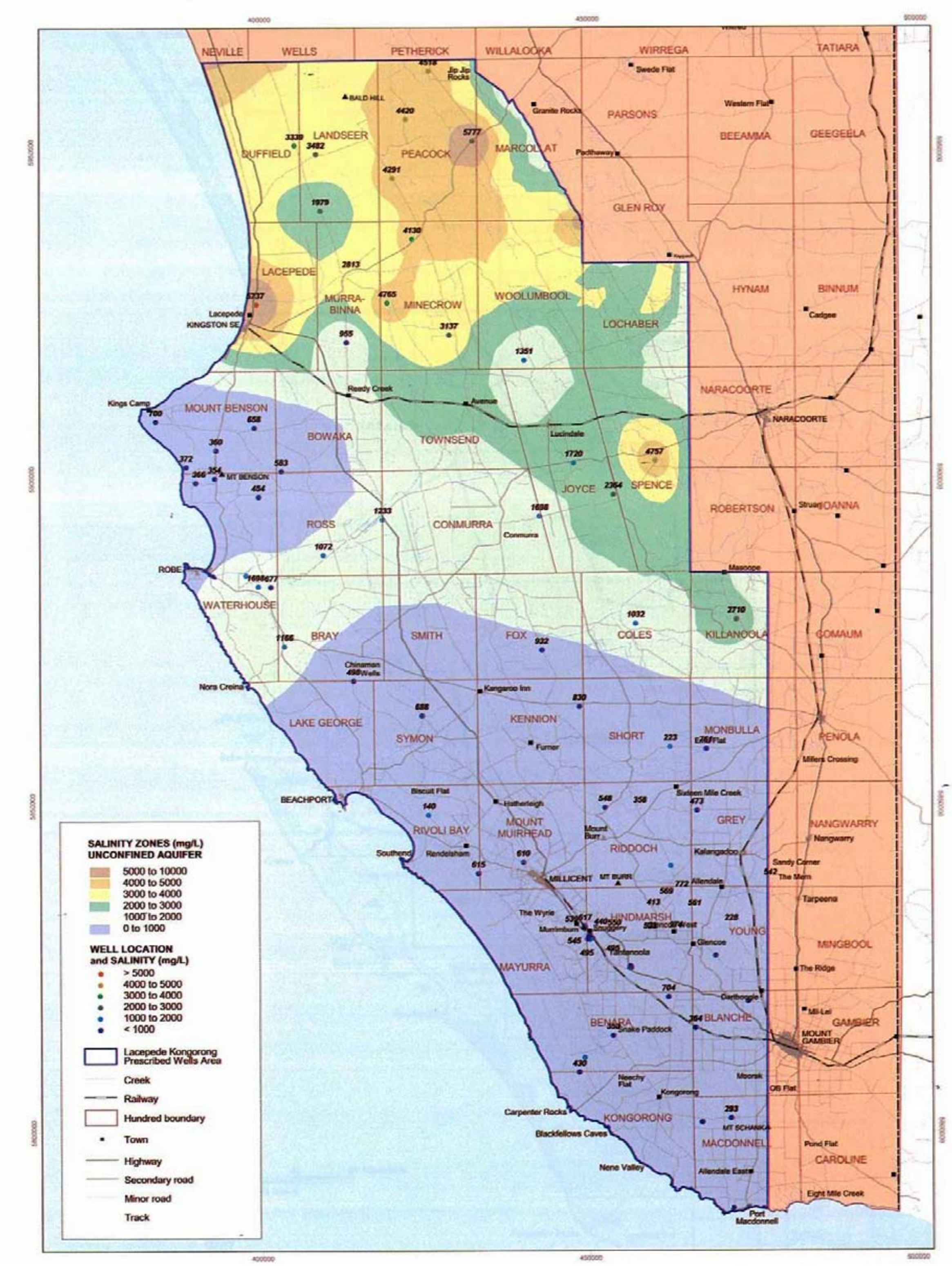


Figure 4.19 Generalised salinity distribution in the Unconfined Aquifer (SECWMB, 2001)

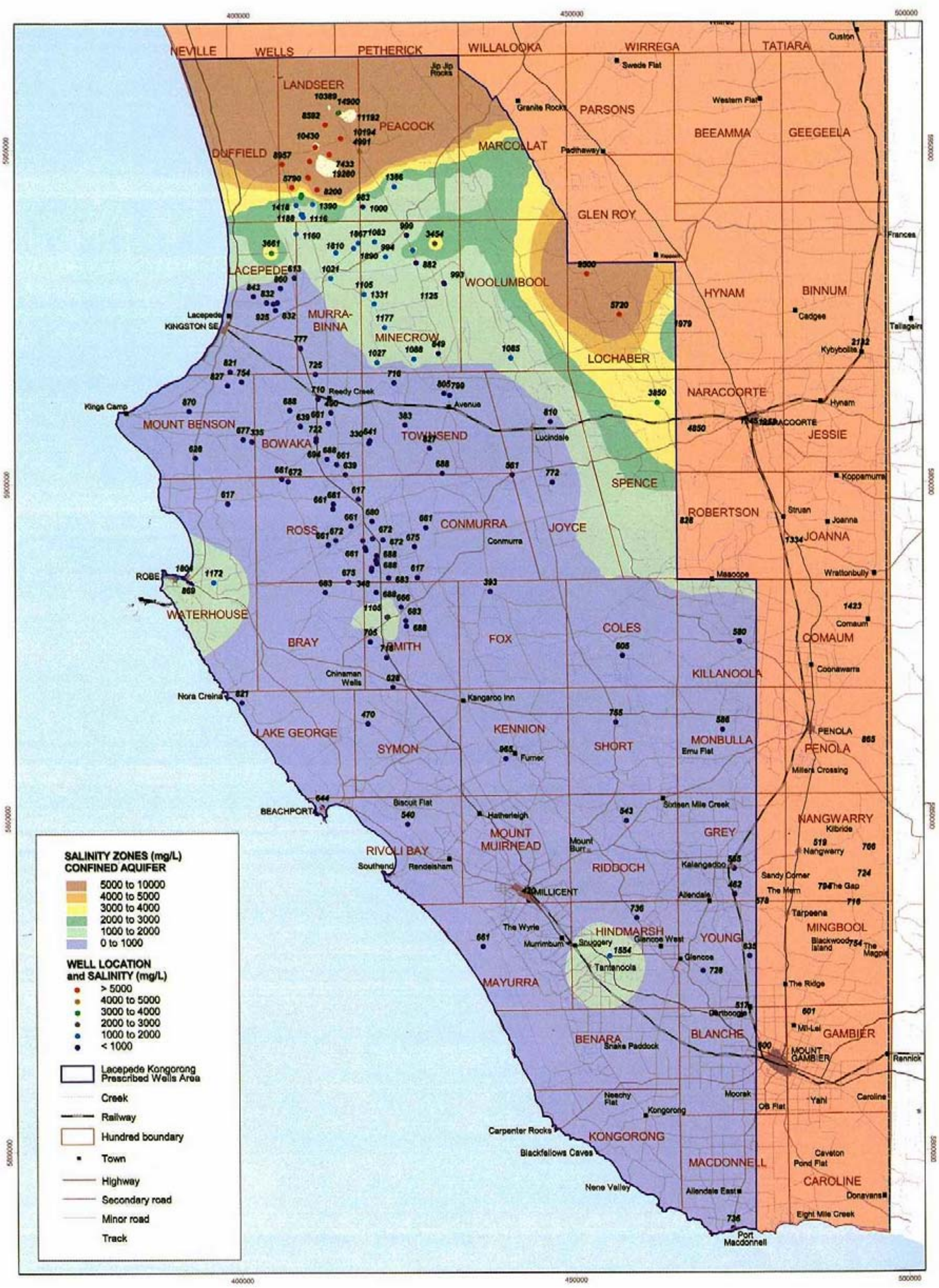


Figure 4.20 Generalised salinity distribution in the Confined Aquifer (SECWMB, 2001)

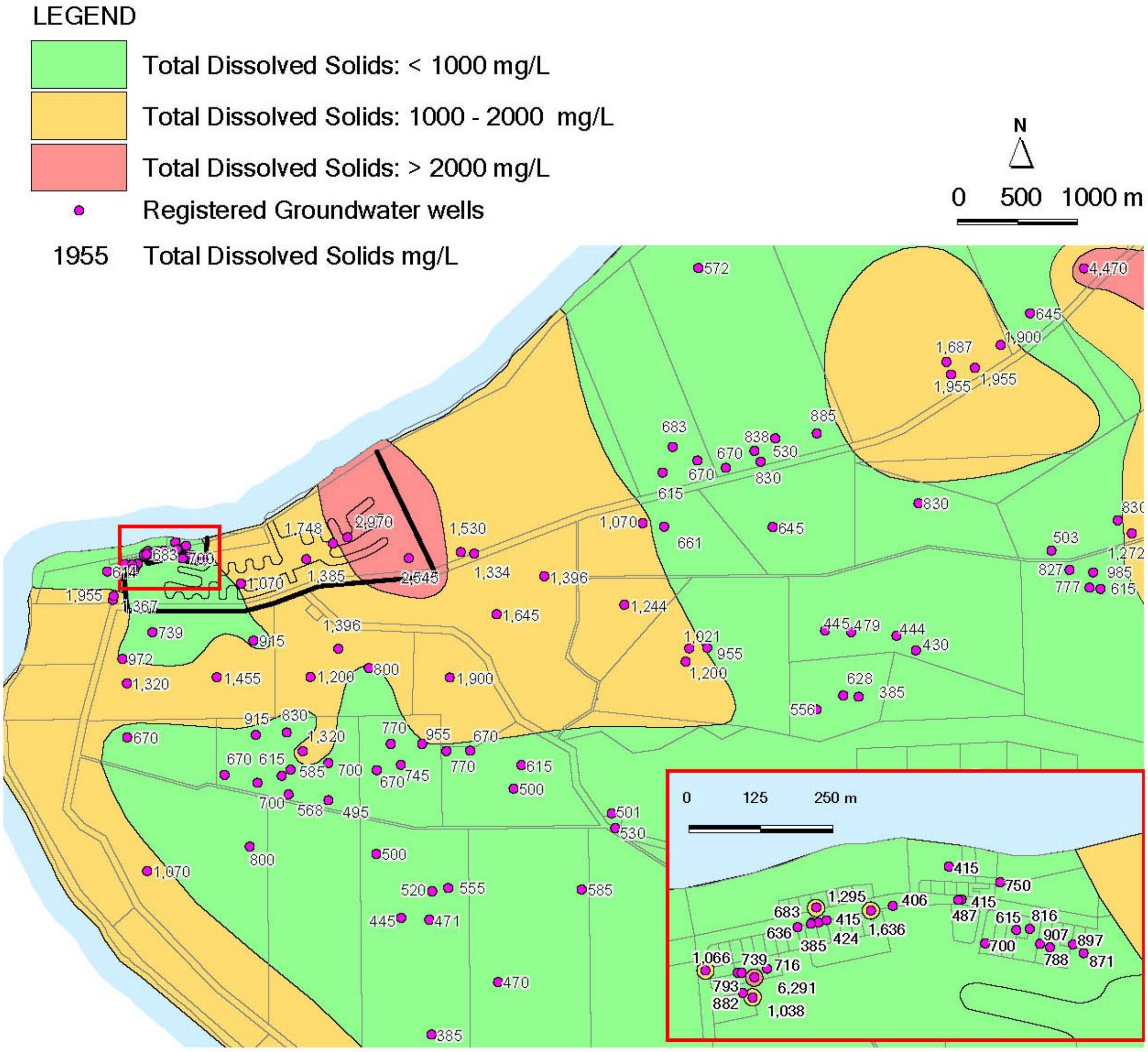


Figure 4.21 Inferred total dissolved solids (TDS) based on PIRSA data (PIRSA, July 2003).

4.7.2 Groundwater Salinity, Local

The spatial distribution of groundwater salinity, in terms of total dissolved solids (TDS), over the study area is presented as Figure 4.22.

Groundwater TDS measured during field investigations ranged between 439 mg/L to 14,900 mg/L. Generally, in low lying areas immediately to the south of the site, TDS was greater than 2,000 mg/L. Further to the south where the topography rises, TDS was typically less than 1,000 mg/L.

Higher TDS within the study area may be a result of:

- Shallow water table (i.e. less than 1 m below ground surface) where evaporation influences are likely to be higher;
- The application of piggery effluent contributing dissolved solids to groundwater; or
- Possible historical sea-water intrusion zones.

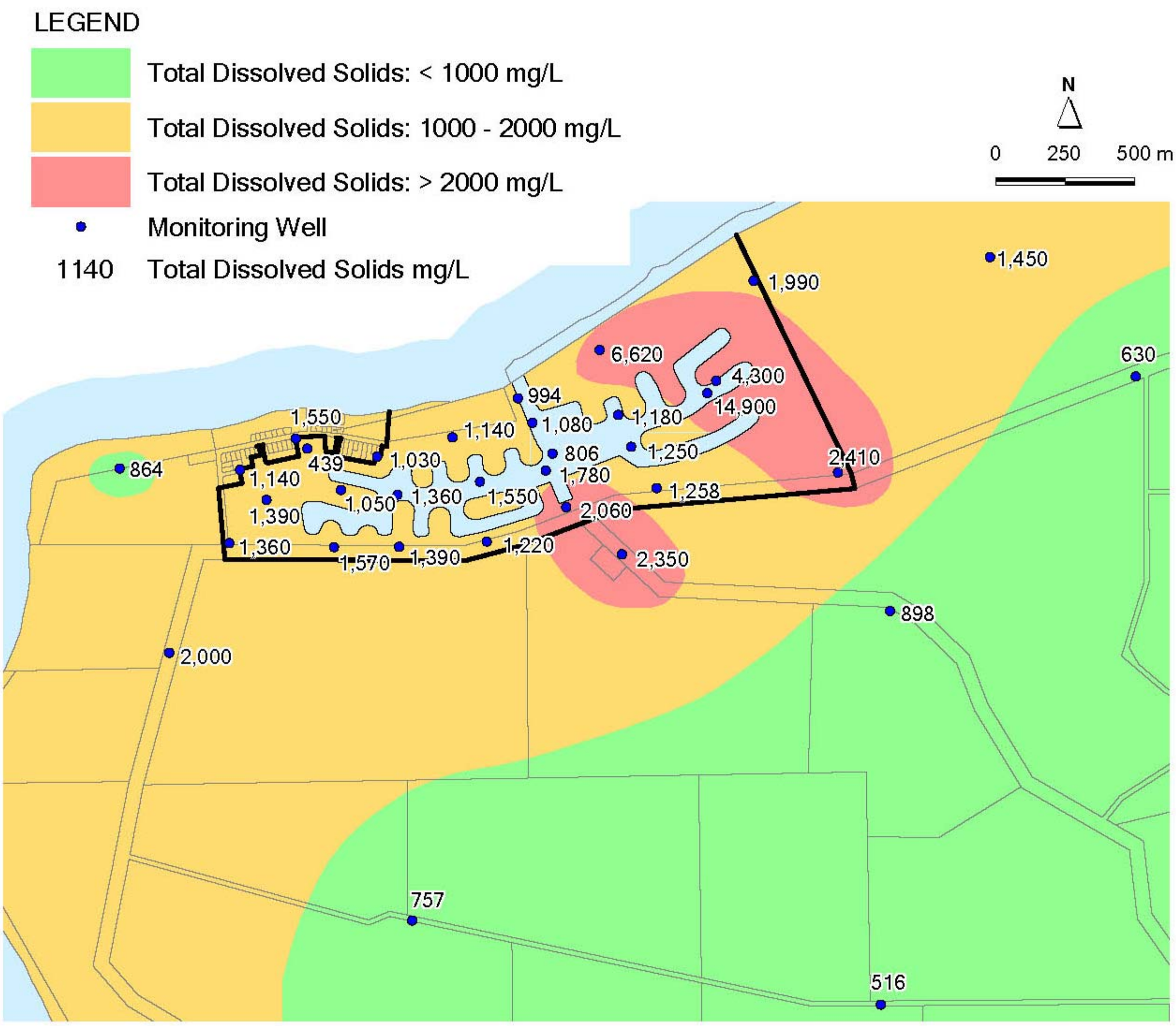


Figure 4.22 Inferred total dissolved solids (TDS) based on field investigation studies at the site (July 2003).

4.8 Local Groundwater Chemistry

In order to assess the chemical composition of local groundwater, the ratios of major ionic species for samples from the recently installed monitoring wells have been plotted on a trilinear diagram (Figure 4.23).

The results are generally grouped together, indicating similar hydrochemical composition, that the aquifer is continuous, and that groundwater within the sands of the St Kilda Formation and the underlying limestone are interconnected and can be considered as a single aquifer system. The diagram also indicates that the groundwater is dominated by ions of sodium, chloride, calcium and bicarbonate, with increasing dominance of sodium and chloride with salinity. This chemistry is typical of limestone aquifers.

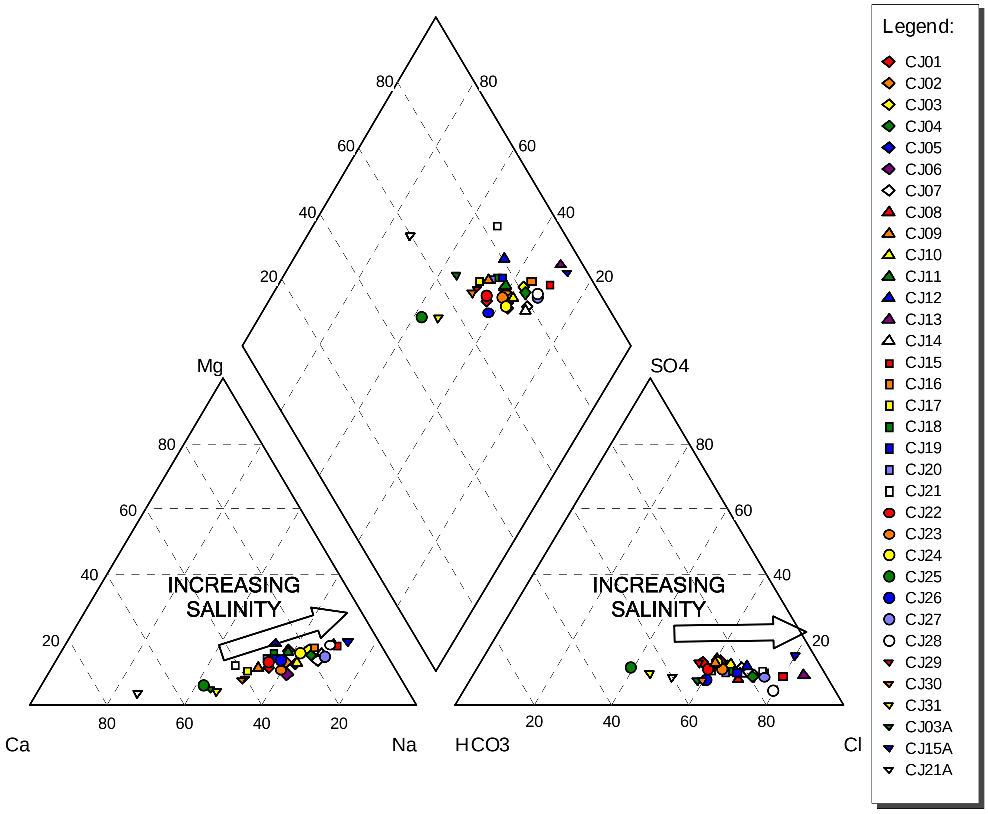


Figure 4.23 Trilinear plot.

4.9 Sea Water Interface

The seawater interface has not been encountered in any of the recently constructed monitoring wells or existing wells near the site, indicating that the seawater interface along the coast at Cape Jaffa is deeper within the unconfined aquifer below these wells. This is consistent with the behaviour of unconfined coastal aquifers within the region, as shallow domestic wells are found near the coast in many coastal towns in the South East of South Australia. At Cape Jaffa the salinity of wells near the coast is low, ie wells of about 1,000 mg/L have been recorded within 100 metres of the coast, thus the transition zone between fresh groundwater and seawater is expected to be narrow.

To assess the possible nature and location of the seawater interface, the Ghyben and Herzberg relationship has been applied to groundwater levels measured at the site. This relationship is that, due to the density difference between fresh groundwater and seawater, the minimum possible depth below sea level to the seawater interface is approximately forty times the elevation of the watertable above sea level (Freeze and Cherry, 1979).

This analysis is conservative as it assumes no groundwater flow to the coast and any flow to the coast, as exists at Cape Jaffa, acts to lower the interface. A sharp interface (ie a narrow transition zone) is assumed, consistent with site observations at Cape Jaffa.

In order to estimate a range of depths to the seawater interface at Cape Jaffa, the Ghyben/Herzberg relationship has been applied to the groundwater levels measured in July and October 2003. For the purpose of this analysis, sea level has been defined as 0 mAHD. Table 4.6 summarises the results of this assessment. Note that the depths are in metres below ground level (mBGL).

Table 4.6 Estimated Depth to Seawater Interface.

Location	Distance to Coast (metres)	July 2003 Interface Depth (mBGL)	Oct 2003 Interface Depth (mBGL)
Existing settlement	100 to 200 m	23 to 28 m	18 to 33 m
South-west corner of site	500 m	30 m	38 m
South-east corner of site	1,000 m	55 m	63 m

The table indicates that the expected trend of increased depth to the seawater interface further from the coast. The results also indicate that the seawater interface was deeper (closer to the coast) in October 2003 than in July 2003. This is due to the increased groundwater flow and level in October 2003 following winter rainfall recharge and also the effect of tide levels during the groundwater level gauging.

Other factors can result in local or temporary changes in the location of the interface. Tidal fluctuations, storm surges, seasonal groundwater level changes, excessive groundwater extraction or variations in aquifer properties near the coast can all influence the location of the interface. An example is seawater coning, which results from the interface rising locally due to a depression in the watertable around a well near a well during extraction.

4.10 Comparison of Semaphore Sands and Tertiary Limestone

As presented in 4.2, the depth of existing registered wells in proximity to the proposed development suggests that most of these wells are established into the Tertiary Limestone below the Quaternary Semaphore Sands. However, during field investigations, it was noted that groundwater extends through the shallow Quaternary Semaphore Sands and Tertiary Limestone. As the impact of the marina on registered groundwater users was the primary purpose of groundwater investigations, the upper limestone unit was targeted during the installation of groundwater monitoring wells. However, to assess interconnection and any differences between the sand and limestone units, several wells were established to target the sand layer in addition to those established in the limestone.

At a number of locations on site, a clay layer was observed below the water table between the sands and limestone units. The approximate extent and thickness of these clays is shown on Figure 3.2. This clay layer exists in varying thickness, generally within a zone between – 2.3 and 0.0 mAHD.

One of the wells targeting the sand unit was installed above the clay unit (CJ03A). To assess the differences between the sand unit and limestone unit above and below the clay, a continuous water level data logger was installed into this well and the adjacent well within the limestone (CJ03). Figure 4.13 shows the groundwater levels measured in these two wells. It also shows the tide levels for comparison. The plot generally confirms hydraulic connectivity between the units and shows larger tidal influence on the limestone aquifer than the shallow sands. The difference in groundwater levels between the two units shows a downward head gradient, which is typical of unconfined aquifers.

The unconfined aquifer in the shallow Quaternary Semaphore Sands has been found to behave very similarly to that within the Tertiary Limestones at locations where the clay layer was and was not present. The two units have similar chemical analysis exhibited from groundwater samples taken from the two stratigraphic units. In addition, the measured hydraulic conductivity in the two units is similar.

The marina will be excavated into the limestone to approximately – 3.5 mAHD and will extend below the sand unit and, where present, the clay layer. Due to the depth of excavation and the depth of existing registered wells, it is anticipated that the clay layer will have minimal influence in determining the effect to groundwater users as a result of the development. This hypothesis will be tested by the groundwater flow model by assuming a single aquifer system for the unconfined aquifer, extending through the limestone and into the overlying sands.

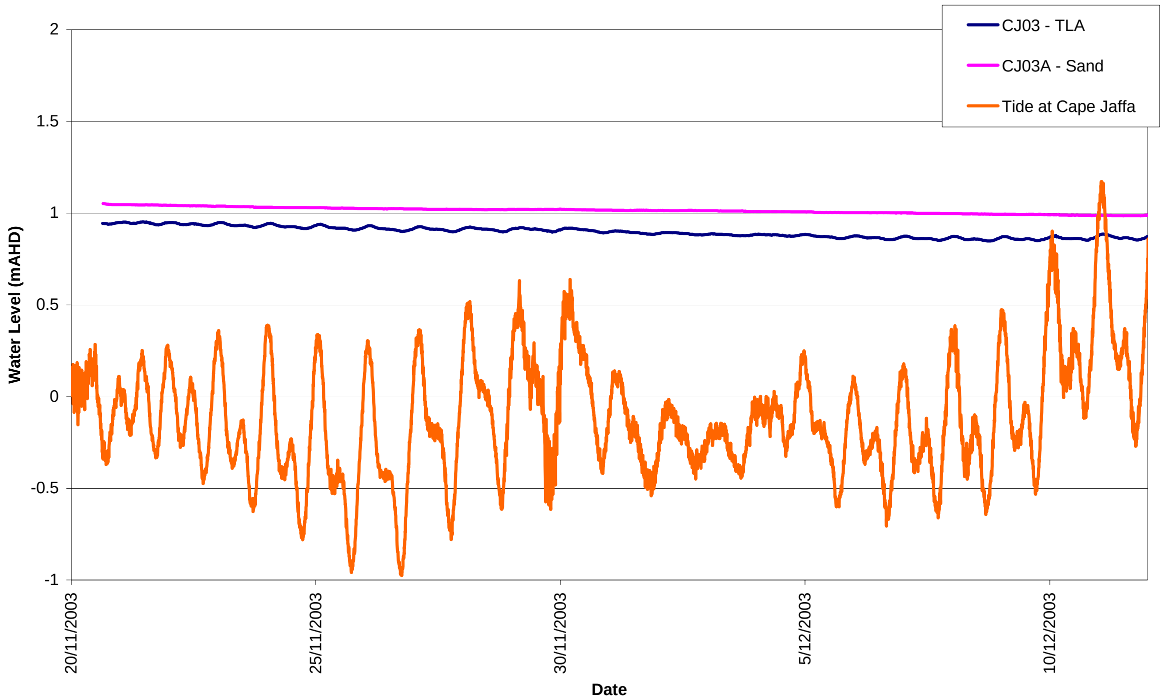


Figure 4.24 Reduced water level for tidal level (daily moving average) and nested wells CJ03 and CJ03A, targeting limestone and sand units.

5. Groundwater Contamination Status

5.1 Current and Historical Use

The site is currently used for cattle grazing and disposal of piggery effluent within Section 92 which forms the eastern part of the site. Allotment 123, which forms the western part of the site, is currently vacant and unused.

Inspection of the aerial photography from years 1958, 1975, 1981 and 2000 indicate that the predominant historical use of the site has been for agricultural purposes. Areas of native vegetation adjacent to the foreshore have been cleared over this period and the Cape Jaffa settlement has been developed, however, no other significant changes to the site were noted.

5.2 Potential Sources of Contamination

The use of the site for agricultural purposes may have been associated with the application of pesticides or fertilisers.

Anecdotal evidence and observations on site suggests that effluent resulting from the piggery located to the east of the site has been applied to the eastern part of the site (Section 92). The inferred area where this effluent has been applied is shown on Figure 5.1.

Other potential sources of groundwater contamination located within surrounding areas in proximity to the site include:

- Septic effluent from dwellings within the Cape Jaffa settlement;
- Fuel underground storage tanks (USTs) located at the Cape Jaffa caravan park;
- Boat refuelling facilitates located at the Cape Jaffa jetty; and
- Former minor landfilling within the area located to the west of Cape Jaffa settlement.

These activities and the potential contaminants of concern are identified in Table 5.1. The location of these activities is shown in Figure 5.1.

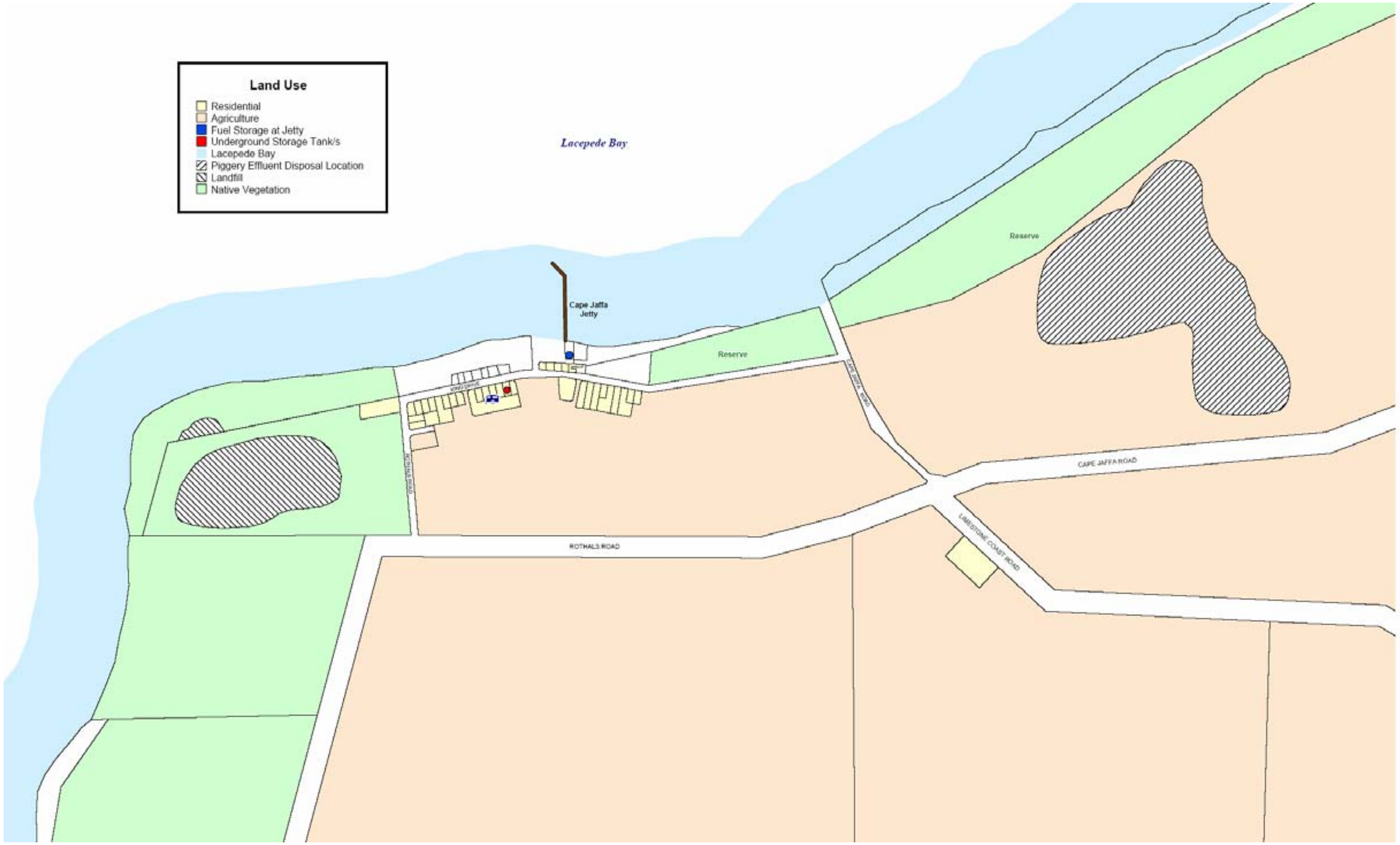


Figure 5.1 Existing land uses / potential groundwater contamination sources.

Table 5.1 Potentially contaminating activities and associate contaminants of concern.

Activity	Potential Contaminants of Concern
Pesticide use	Organochlorine Pesticides (OCPs) Organophosphate Pesticides (OPPs) Metal based pesticides
Fertiliser use	Macro-nutrients – nitrogen, phosphorus Micro-nutrients – heavy metals
Application of piggery effluent	Nutrients – nitrogen, phosphorus, TOC Sulphate, salts Biological Oxygen Demand (BOD) Heavy metals Pathogenic organisms
Septic effluent	Nutrients – nitrogen, phosphorus, TOC BOD Heavy metals Pathogenic organisms
Fuel USTs and refuelling facilities	Petroleum hydrocarbons Benzene, toluene, ethylbenzene, xylenes (BTEX) Lead
Landfilling	Heavy metals Polycyclic Aromatic Hydrocarbons (PAHs) Petroleum hydrocarbons BTEX OCPs/OPPs Nutrients

5.3 Groundwater Contamination Status

Thirty four groundwater monitoring wells located on and off site were sampled between 13 to 16 July 2003. Groundwater samples were analysed for a range of compounds to target the potential contaminants of concern identified above, with the exception of pathogenic organisms as samples could not be provided to the laboratory within the recommended holding time.

Details regarding the groundwater sampling event are documented in Volume 1 – Desktop Study and Field Investigations (ref: 20010318RA4). It is noted that the July 2003 groundwater sampling event provides a "snap shot" of the local groundwater contamination status.

Groundwater analytical results were compared to the guidelines contained in the *National Environment Protection (Assessment of Site Contamination) Measure* (NEPM) and the *Environment Protection (Water Quality) Policy 2003* (Water Quality Policy), refer Volume 1 – Desktop Study and Field Investigations. The relevant environmental values were selected based on the predominant use of groundwater in the region being human consumption, irrigation, livestock use and marine ecosystems. Concentrations of contaminants reported above the guidelines are summarised in Table 5.2.

Table 5.2 Groundwater analytical results exceeding NEPM guidelines and Water Quality Policy.

Well	Potential Contaminant of Concern	Concentration	Water Quality Policy Exceedence				NEPM Exceedence			
			Potable	Marine	Irrigation	Livestock	Health	Marine	Irrigation	Livestock
CJ01	arsenic	14 µg/L	7	50	100	500	7	50	100	500
CJ02	-									
CJ03	chloride	800 mg/L					250		30-700	
	arsenic	8 µg/L	7	50	100	500	7	50	100	500
CJ03A	arsenic	8 µg/L	7	50	100	500	7	50	100	500
	Nitrate / nitrite *	4.1 mg/L	10/1	0.2		30/10	50/3			30/10
	Total Nitrogen	4.7 mg/L		5						
CJ04	chloride	929 mg/L					250		30-700	
	TOC	10 mg/L		10						
CJ05	arsenic	13 µg/L	7	50	100	500	7	50	100	500
CJ06	-									
CJ07	-									
CJ08	Nitrate / nitrite *	6.5 mg/L	10/1	0.2		30/10	50/3			30/10
	Total Nitrogen	7.0 mg/L		5						
	antimony	3 µg/L	3				3	500		
CJ09	-									
CJ10	-									
CJ11	Nitrate / nitrite *	2.1 mg/L	10/1	0.2		30/10	50/3			30/10
CJ12	chloride	739 mg/L					250		30-700	
CJ13	chloride	3,430 mg/L					250		30-700	
	TOC	12 mg/L		10						
	arsenic	27 µg/L	7	50	100	500	7	50	100	500
CJ14	chloride	911 mg/L					250		30-700	
	TOC	11 mg/L		10						
	phosphorus	140 µg/L		100						
CJ15	chloride	2,140 mg/L					250		30-700	
	TOC	13 mg/L		10						
	arsenic	31 µg/L	7	50	100	500	7	50	100	500
	cyanide	26 µg/L	80				80	5		
	phosphorus	120 µg/L		100						

Table 5.2 Groundwater analytical results exceeding selected NEPM guidelines and Water Quality Policy (cont.).

Well	Potential Contaminant of Concern	Concentration	Water Quality Policy Exceedence				NEPM Exceedence			
			Potable	Marine	Irrigation	Livestock	Health	Marine	Irrigation	Livestock
CJ15A	chloride	7,000 mg/L					250		30-700	
	TOC	78 mg/L		10						
	sulphate	1,760 mg/L	500			1,000				
	phosphorus	870 µg/L		100						
	arsenic	92 µg/L	7	50	100	500	7	50	100	500
	molybdenum	40 µg/L	50		10	10	50		10	10
	cyanide	265 µg/L	80				80	5		
	selenium	10 µg/L	10	70	20	20	10	70	20	20
	Total Nitrogen	4.9 mg/L		5						
CJ16	chloride	1,120 mg/L					250		30-700	
CJ17	Nitrate / nitrite *	0.6 mg/L	10/1	0.2		30/10	50/3			30/10
CJ18	-									
CJ19	-									
CJ20	-									
CJ21	chloride	780 mg/L					250		30-700	
	TOC	31 mg/L		10						
	arsenic	37 µg/L	7	50	100	500	7	50	100	500
	cadmium	2.8 µg/L	2	2	10	10	2	2	10	10
	molybdenum	82 µg/L	50		10	10	50		10	10
	cyanide	19 µg/L	80				80	5		
CJ21A	TOC	11 mg/L		10						
	Nitrate / nitrite *	10 mg/L	10/1	0.2		30/10	50/3			30/10
	arsenic	8 µg/L	7	50	100	500	7	50	100	500
	molybdenum	21 µg/L	50		10	10	50		10	10
	cyanide	6 µg/L	80				80	5		
	fluoride	2.3 mg/L	1.5		1	2	1.5		1	2
	phosphorus	100 µg/L		100						
CJ22	arsenic	10 µg/L	7	50	100	500	7	50	100	500
CJ23	-									
CJ24	antimony	4 µg/L	3				3	500		
	arsenic	14 µg/L	7	50	100	500	7	50	100	500
	cyanide	34 µg/L	80				80	5		
	phosphorus	200 µg/L		100						

Table 5.2 Groundwater analytical results exceeding selected NEPM guidelines and Water Quality Policy (cont.).

Well	Potential Contaminant of Concern	Concentration	Water Quality Policy Exceedence				NEPM Exceedence			
			Potable	Marine	Irrigation	Livestock	Health	Marine	Irrigation	Livestock
CJ25	-									
CJ26	Nitrate / nitrite *	7.3 mg/L	10/1	0.2		30/10	50/3			30/10
	Total Nitrogen	9.2 mg/L		5						
	antimony	4 µg/L	3				3	500		
CJ27	chloride	1,100 mg/L					250		30-700	
CJ28	chloride	919 mg/L					250		30-700	
	Nitrate / nitrite *	0.6 mg/L	10/1	0.2		30/10	50/3			30/10
CJ29	arsenic	40 µg/L	7	50	100	500	7	50	100	500
CJ30	Nitrate / nitrite *	12.2 mg/L	10/1	0.2		30/10	50/3			30/10
	Total Nitrogen	12.5 mg/L		5						
CJ31	Nitrate / nitrite *	7.3 mg/L	10/1	0.2		30/10	50/3			30/10
	phosphorous	1,040 µg/L		100						
	Total Nitrogen	11.5 mg/L		5						

- No guideline exceedence.
* Nitrate and nitrite have been expressed as a combined concentration by the laboratory (refer Volume 1).

5.3.1 Organics and Nutrients

Phosphorous and Total Organic Carbon were in elevated concentrations within the western part of the site near the Cape Jaffa settlement, potentially associated with septic effluent discharge.

Total Nitrogen, phosphorous Total Organic Carbon and were also identified in proximity to the location where previous disposal of piggery effluent has occurred within the eastern part of the site. In addition, Total Nitrogen appears to be more concentrated within the shallow sand unit than in the underlying limestone.

Elevated concentrations of Oxidised Nitrogen and Total Nitrogen (as well as phosphorous at one location) were also identified regionally to the south of the site, outside of the development boundary. This may be related to the use of fertilisers associated with agricultural/horticultural activities near these locations.

Petroleum hydrocarbons, OCPs and OPPs were reported below the laboratory detection limit.

The location where nutrients and TOC was encountered is shown on Figure 5.2 to Figure 5.5.

Figure 5.2 Nitrate/Nitrite concentrations.

Figure 5.3 Phosphorous concentration.

Figure 5.4 Total Nitrogen concentration.

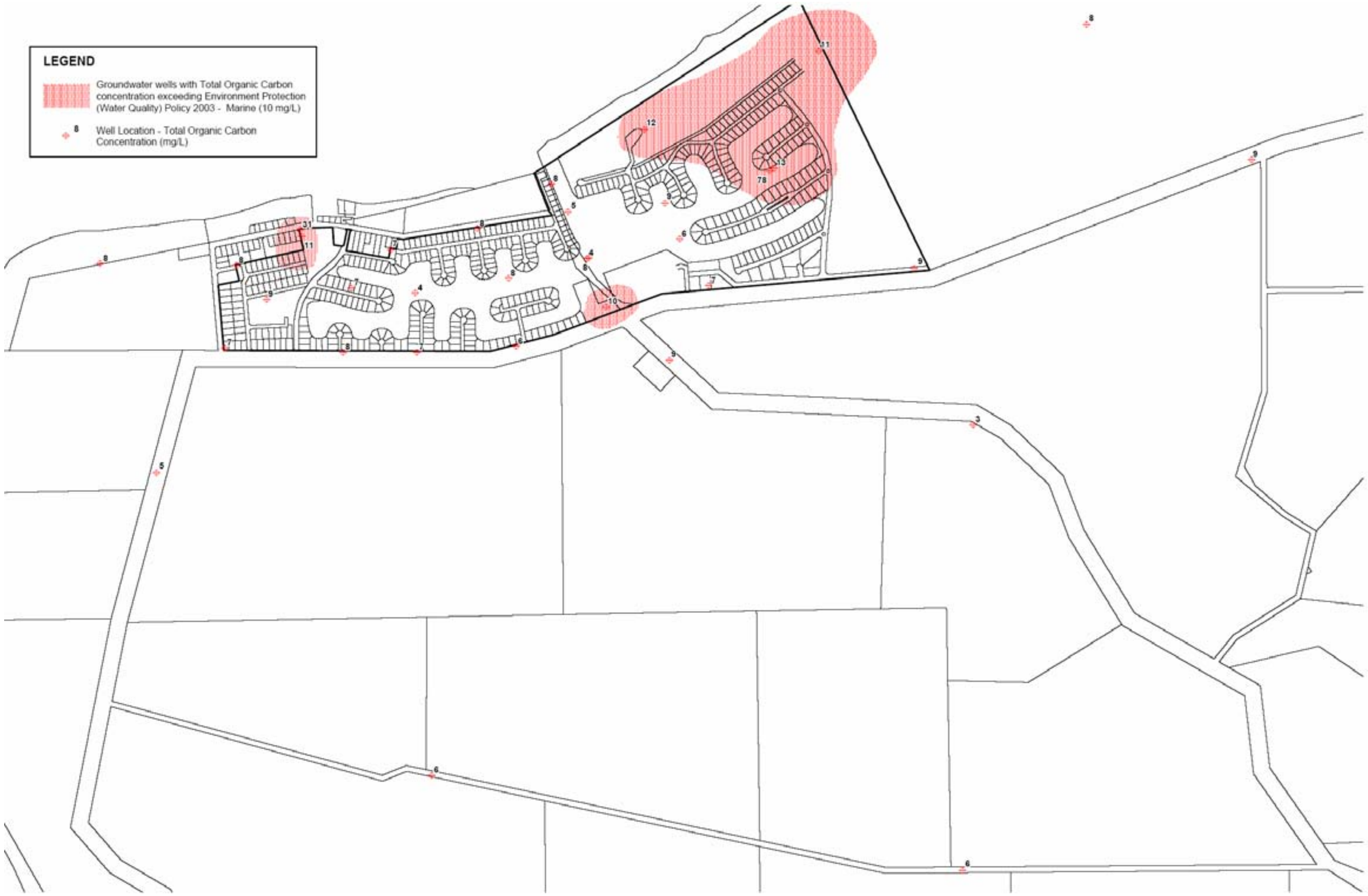


Figure 5.5 Total Organic Carbon concentration.

5.3.2 Inorganics

Elevated concentrations of chloride are predominantly located within the eastern section of the site and are associated with higher TDS concentrations. It is noted that the criterion listed in the Water Quality Policy is for chlorine and not chloride.

Arsenic, molybdenum, cyanide, sulphate and selenium were identified primarily within the eastern part of the site. Molybdenum and cyanide were analysed for a limited number of groundwater monitoring wells and therefore the extent of these contaminants is not certain.

These contaminants may have resulted from a number of sources. They are often related with pesticides (arsenic) and fertilisers (molybdenum, cadmium). Previous disposal of piggery effluent may have contributed to elevated selenium (feed supplement) and sulphate concentrations (Ayres and Hellier, 1998).

Arsenic and cyanide can be found naturally in the concentrations identified, with arsenic coming from some soil/rock minerals and cyanide from plant production or termite activity.

The location where these contaminants were encountered are shown Figure 5.6 to Figure 5.9.

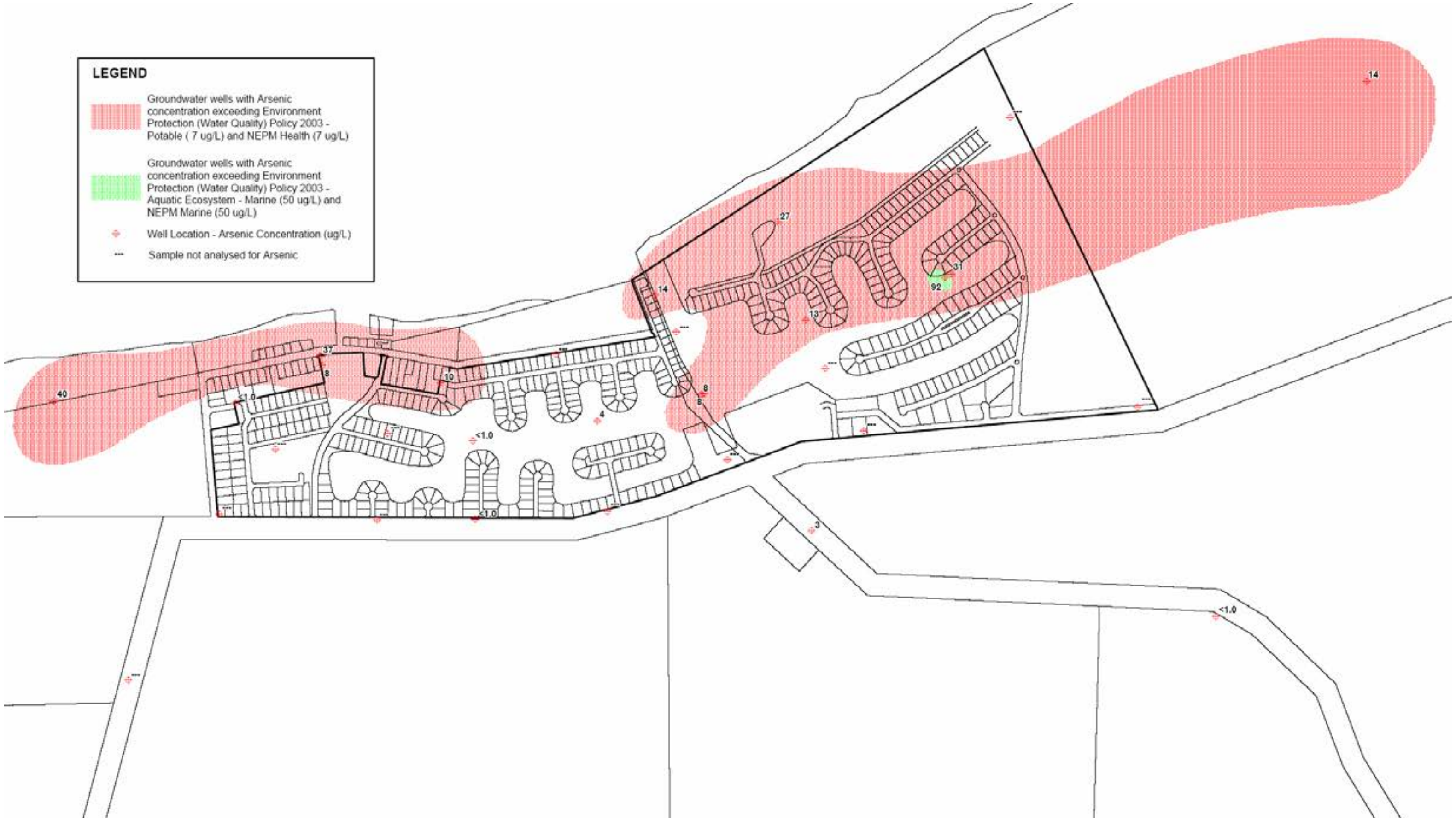


Figure 5.6 Arsenic concentrations.

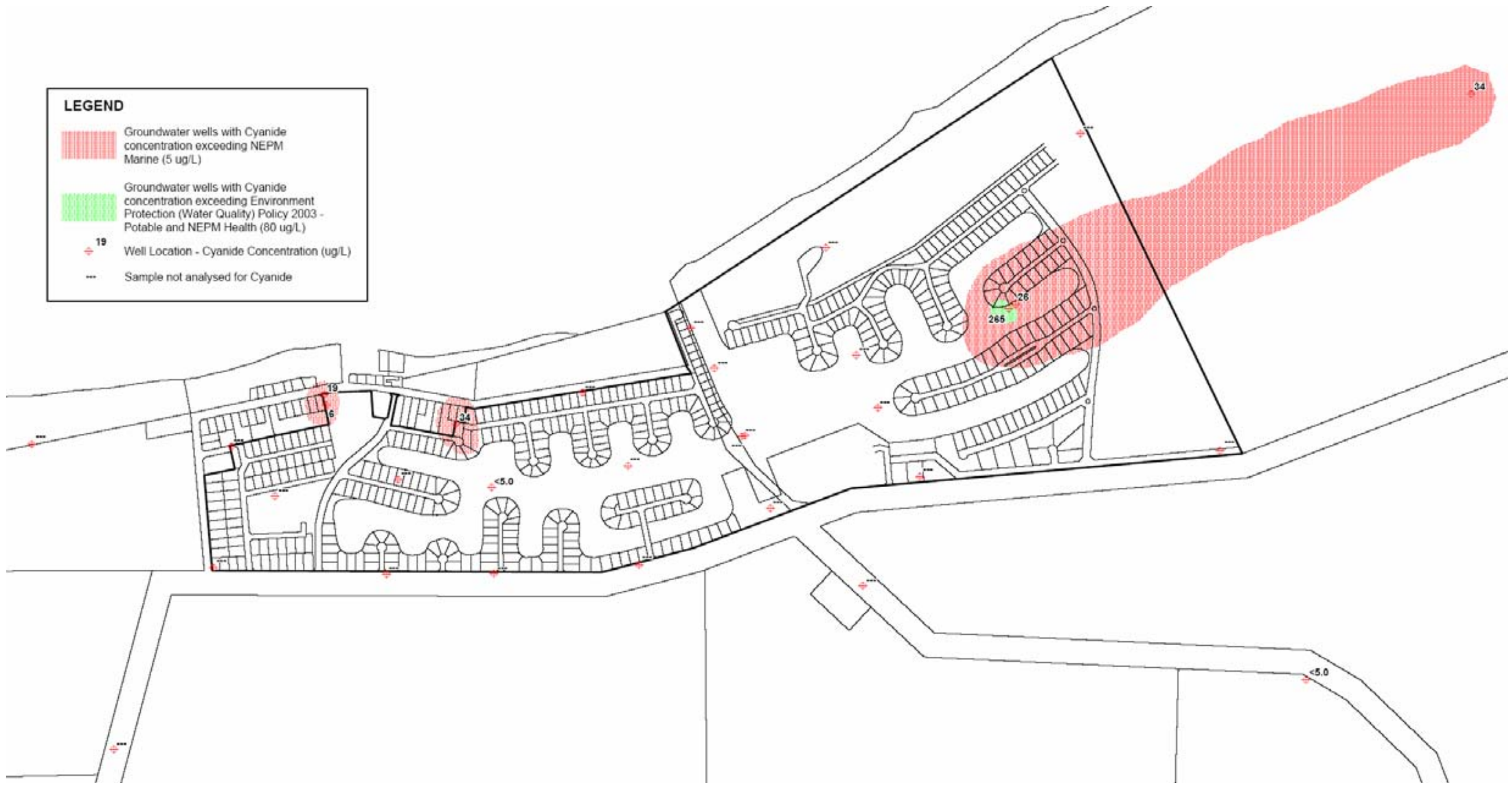


Figure 5.7 Cyanide concentrations.

Figure 5.8 Molybdenum concentrations.

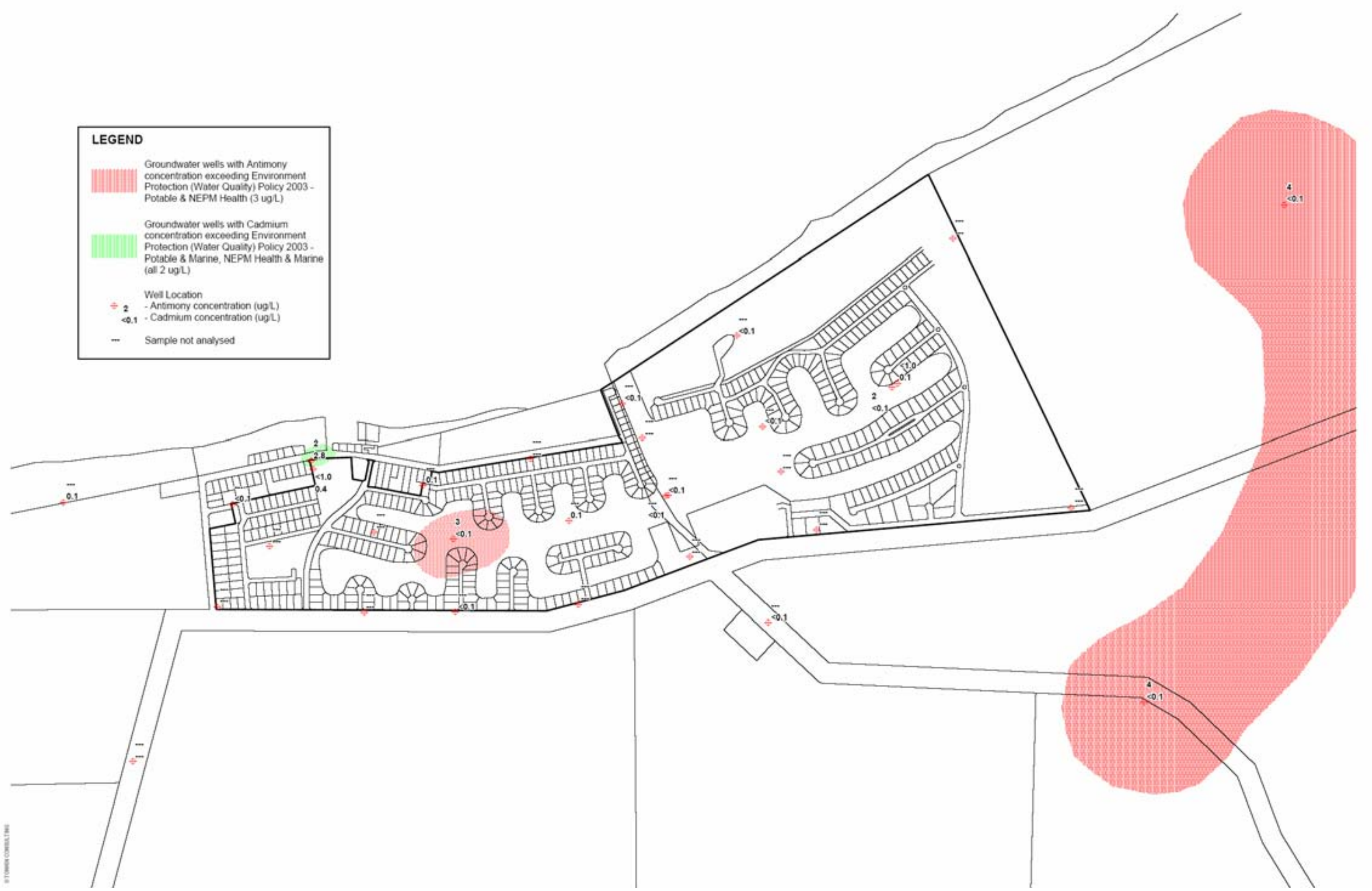


Figure 5.9 Antimony and cadmium concentrations.

5.4 Groundwater Contaminants of Concern

Based on the preliminary risk assessment, there are a number of contaminants within the groundwater located on and off site that may present a risk to:

- Marine environment;
- Human health;
- Livestock/irrigation uses.

The Cape Jaffa Anchorage Marina is likely to provide a pathway for groundwater and associated contaminants to enter the marine environment. The "contaminants of concern" relating to potential impacts on the marine environment identified during this assessment are summarised in Table 5.1.

Table 5.1 Contaminants of concern relating to potential marine impacts.

Contaminant of Concern	Location	Maximum Concentration
TOC	near the Cape Jaffa settlement & eastern part of site	78 mg/L (CJ15A)
Nitrate/nitrite	Southern part of site & regionally	12.2 mg/L (CJ30)
Total Nitrogen	Shallow groundwater on site& regionally	12.5 mg/L (CJ30)
Phosphorous	Eastern part of site & regionally	1,040 µg/L (CJ31)
Cyanide	Eastern part of site & adj. caravan park	265 µg/L (CJ15A)
Arsenic	Eastern part of site	92 µg/L (CJ15A)
Cadmium	Adjacent caravan park	2.8 µg/L (CJ21)

This information together with the changes to groundwater system as a result of the development will enable others to determine any potential impact on the marine environment.

6. References

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Kingston District Council and
Cape Jaffa Development Company

Cape Jaffa Anchorage Marina

Groundwater Impact Assessment

Volume 3 –Groundwater Flow Model

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1. Executive Summary

1.1 Introduction

Cape Jaffa is located on the coast at the southern end of Lacepede Bay, between Kingston SE and Robe, south-east of South Australia. Kingston District Council and Cape Jaffa Development Company are proposing to develop a boating safe haven adjacent the existing settlement.

A groundwater flow model for the Cape Jaffa marina was developed with the primary objective to assess the likely impacts of the proposed development on the shallow unconfined aquifer. The groundwater flow model, MODFLOW, was selected for the construction and simulation of groundwater flow at the site.

A detailed evaluation of the conceptual hydrogeological setting near the study area has been documented in “Cape Jaffa Development Corporation Conceptual Hydrogeological Model” (Tonkin, December 2003). The findings from this investigation form the basis of the design of the numerical model.

1.2 Model Design

The model grid was constructed in three layers to represent the confined aquifer, aquitard and unconfined aquifer. This was orientated to the principal direction of flow of the main aquifer of interest (unconfined aquifer), being northwest.

A steady state flow model was developed. For the unconfined aquifer, a constant head was assigned to the western boundary of the model to represent the shoreline. The constant head level was based on the average tide level at Cape Jaffa measured between July and September 2003. For the confined aquifer, a constant head for the western and eastern boundaries were assigned based on regional data. No boundaries were assigned for the aquitard as vertical flow between the confined and unconfined layer was considered to predominate.

The adopted aquifer properties for the unconfined aquifer were based initially on field investigations undertaken in July 2003. The hydraulic conductivities were then altered (within acceptable limits) during the calibration phase until the simulated results matched the observed water levels. Aquifer properties for the aquitard and confined aquifer were based on regional information.

Aquifer recharge from precipitation was applied to the unconfined aquifer. The removal of water from this aquifer from groundwater extraction in the area was assumed to be low.

1.3 Model Validation

The model was calibrated satisfactorily using October 2003 gauging data collected on site.

1.4 Model Simulations

Three key prediction scenarios were simulated. The outcomes of these simulations are summarised below:

Scenario 1 – Pre-Development Conditions

- The average groundwater discharge rate across the length of the site from the entire depth of the TLA is estimated to be approximately 750 m^3/day.
- The upward flow from the TCSA is expected to be low due to the low permeability of the confining layer separating the aquifers.

Scenario 2 – Stage 1 Dewatering Example

- The estimated area of drawdown as a result of the Stage 1 development during excavation and dewatering is unlikely to impact identified groundwater users in the area. The data collected during Stage 1 will be used to refine the management of subsequent stages as more knowledge about the groundwater system is gained.

Scenario 3 – Post-Development Conditions

- The change in water level following development is likely to range between 0.2 m and 0.6 m lower than existing conditions in the vicinity of the site. The resulting impact will be the equivalent (i.e. 0.2 – 0.6 m) loss of available head of water for extraction by the registered users.
- On a regional scale, the net groundwater flow to the marine environment will remain unchanged as there are no changes to the net water balance of the system.
- The estimated average groundwater discharge to the marina is estimated to be 900 m^3/day. WMB (2003) have identified that an estimated volume of at least 170,000 m^3/day of seawater will move through the basins and channels within a 24-hour period due to tidal exchange providing significant dispersion and mixing of groundwater discharge.

The results presented in this report are representative of a steady state flow model, as time series data regarding seasonal water level fluctuations was limited. In addition, details regarding the deeper units were sourced from regional studies.

The response of the system will be monitored through a Groundwater Management Plan during Stage 1 of the development. If considered necessary following Stage 1, the model will be revised and re-calibrated.

2. Introduction

2.1 Background

Cape Jaffa is located on the coast at the southern end of Lacepede Bay, between Kingston SE and Robe, south-east of South Australia (Figure 2.1).

Kingston District Council and Cape Jaffa Development Company are proposing to develop a safe haven and moorings for existing and future fishing fleet, recreational boating facilities as well as tourist and residential development south-east of the existing settlement.

The project was declared a "Major Development" by the Minister for Urban Development on 19 December 2002 and subsequently following community consultation, the Major Development Panel (MDP) has determined that the proposal will be subject to the processes and procedures of an Environmental Impact Statement (EIS). As a result, the Panel has prepared "Guidelines for the Preparation of an Environmental Impact Statement for the Cape Jaffa Anchorage Marina. Proposal by District Council of Kingston and the Cape Jaffa Development Company" (the Guidelines).

The key groundwater assessment requirements identified in the guidelines include:

- Description of the existing groundwater environmental conditions;
- Evaluation of the impact that the proposed development will have on groundwater levels (drawdown) during and post construction;
- Evaluation of the influence of salt water intrusion;
- Impact assessment on existing groundwater users;
- Evaluation of the potential groundwater outflow to the marine environment; and
- Evaluation of groundwater constituents entering the marine environment.

Based on the previous investigations referred to in Section 2.3, this report provides details pertaining to the developed groundwater flow model. The groundwater flow model was established to predict the likely impact of the development to the shallow Tertiary Limestone Aquifer (TLA).

Figure 2.1 Location of study area.

2.2 Study Area and Proposed Development

The "study area" comprises the area defined as the Major Project Boundary as shown on Figure 2.2, which comprises:

- Allotment 123 in Deposit Plan 55486 (CT 5863/840)
- Part Section 92 of the Hundred of Mount Benson (CT 5560/348)
- Portion of King Drive and
- Portion of Cape Jaffa Road

in the area named Cape Jaffa.

The proposed development is shown on Figure 2.3.

2.3 Previous Investigations

A considerable amount of work has been carried out on the characterisation of the regional geology and hydrogeology. A number of field investigations and site-specific studies have been completed. The findings from these investigations are documented in the following reports:

- Tonkin Consulting (November 2003), Cape Jaffa Anchorage Marina, Groundwater Impact Assessment, Volume 1 – Desktop Study and Field Investigations, ref. 20030318RA4.
- Tonkin Consulting (December 2003), Cape Jaffa Anchorage Marina, Groundwater Impact Assessment, Volume 2 – Conceptual Hydrogeological Model, ref. 20030318RA5.

The design of the groundwater flow model is largely based on the findings of the field investigations (Tonkin, November 2003) and developed conceptual hydrogeological model (Tonkin, December 2003).

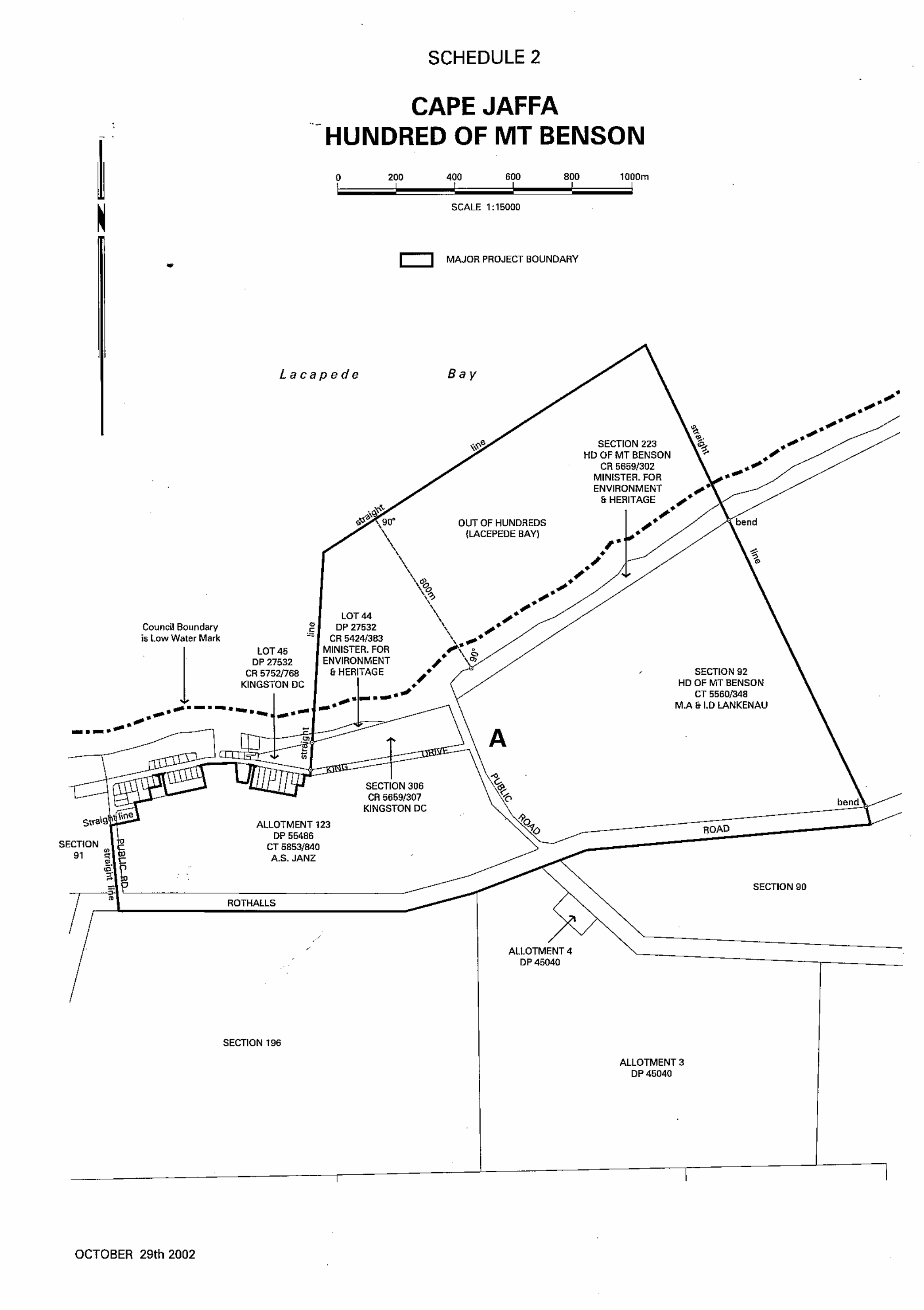


Figure 2.2 Major Projects Boundary as Gazetted 29 October 2002.

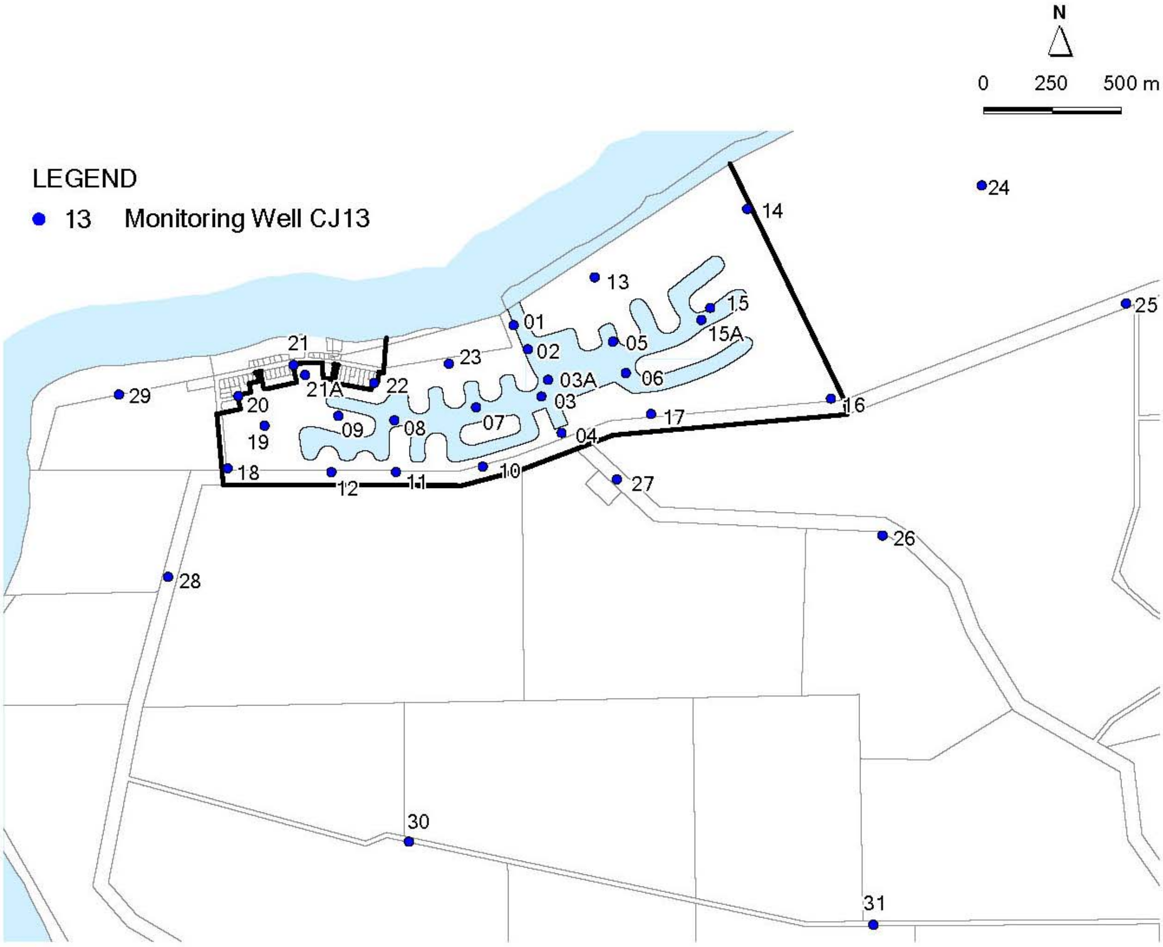


Figure 2.3 Development concept and monitoring well location.

3. Groundwater Flow Model

3.1 Objectives

The groundwater flow model for the Cape Jaffa marina was developed with the primary objective being to assess the likely impacts of the proposed development on the shallow unconfined aquifer, referred to as the Tertiary Limestone Aquifer (TLA).

3.2 Model Selection

The groundwater flow model, MODFLOW, was selected for the construction and simulation of groundwater flow at the site. MODFLOW is a three-dimensional finite difference groundwater flow model that is capable of modelling steady state and transient, multi-layered groundwater flow systems.

The model was developed by the US Geological Survey (McDonald and Harbagh, 1998). Details regarding the code and adopted governing equations can be sourced from the following reference: "A Modular Three Dimensional Finite Difference Groundwater Flow Model", (McDonald, M.G., and Harbaugh, A.W., 1988).

3.3 Summary of Conceptual Hydrogeological Understanding

A detailed evaluation of the conceptual hydrogeological setting near the study area has been documented in "Cape Jaffa Development Corporation Conceptual Hydrogeological Model" (Tonkin, December 2003). The findings from this investigation form the basis of the design of the numerical model.

In summary, based on the data collected during this study and collation of relevant information from regional reports, the key mechanisms influencing the system (or key characteristics of the conceptual hydrogeological system) are summarised below:

- Regionally, groundwater flows through two main systems, an upper unconfined aquifer referred to as the Tertiary Limestone Aquifer (TLA) and a deeper confined aquifer referred to as the Tertiary Confined Sand Aquifer (TCSA). The two aquifers are separated by a clay sequence forming an aquitard between the TLA and TCSA aquifers. Underlying the TCSA is a hydraulic basement, assumed to be representative of the vertical extent of the groundwater flow model.
- The groundwater flow direction from the TLA is towards the shoreline, with observed seasonal water level fluctuations. The water level fluctuations suggest that they are influenced from aquifer recharge via precipitation and tidal fluctuations.

- Groundwater flow in the TCSA is also expected to be in the direction of the shoreline, with discharge from this aquifer occurring some distance offshore. However, as there is no data in the immediate vicinity of the site to support this inference, regional data has been used.
- The water level differential between the TLA and TCSA aquifers suggests an upward potential of flow. However, as there are no wells intersecting the TCSA near the study area to confirm this inference, regional data has been used. For the design of the model it is assumed that an upward gradient from the TCSA to the shallow TLA exists.
- Groundwater in the region is the main source of water supply. Near the study area the main classified use of the registered groundwater users is for stock and domestic purposes. One well is classified as a town water supply well, although it is believed it is being used for the Cape Jaffa caravan. All registered wells near the study area are drilled to depths up to 20 m below ground level and are likely to be intersecting the TLA. No registered wells, near the study area, are likely to be extracting groundwater from the TCSA aquifer.
- Aquifer recharge to the shallow TLA aquifer is believed to be primarily by infiltration from precipitation.

A schematic cross section illustrating the regional understanding of the groundwater system is presented as Figure 3.1.

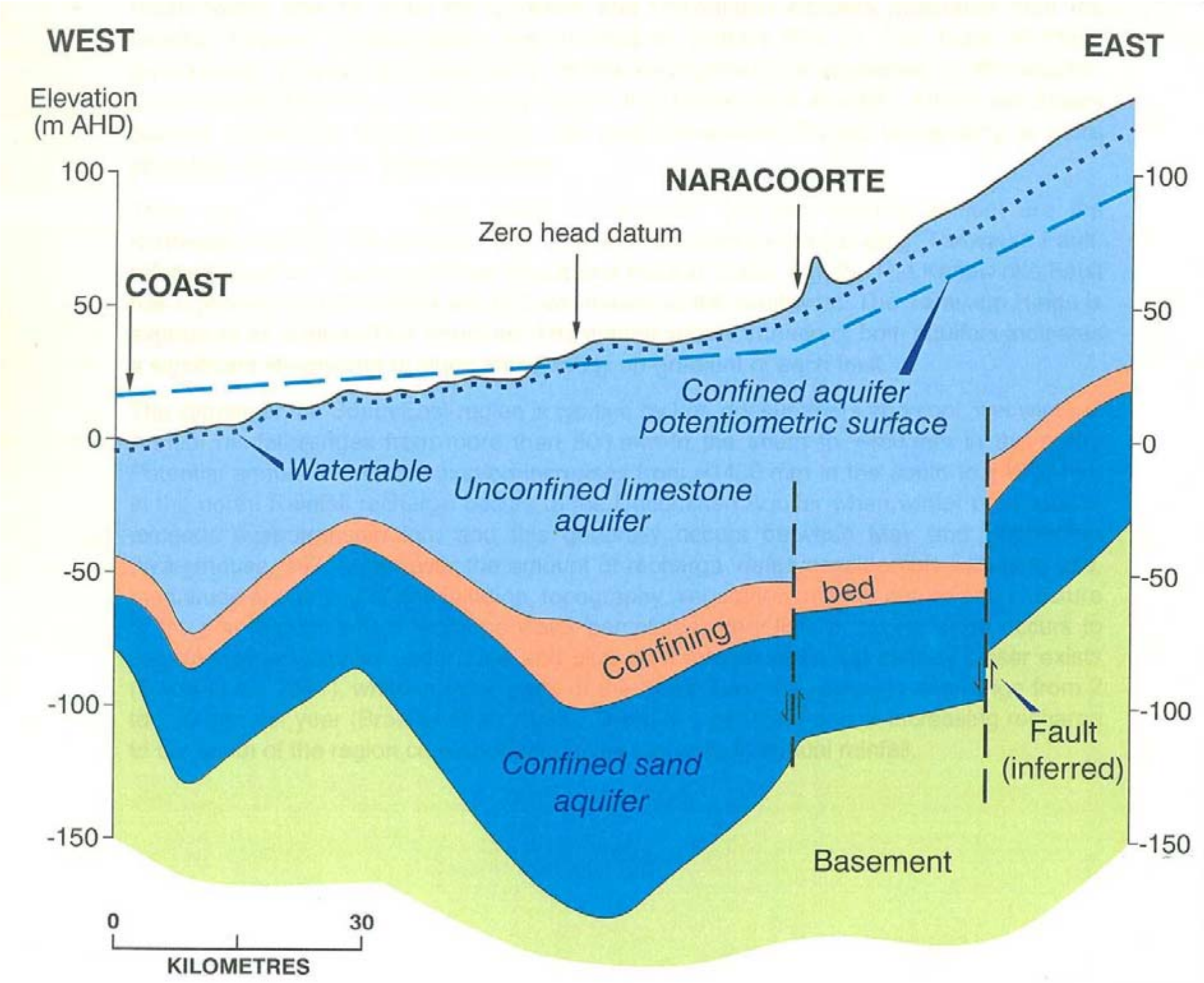


Figure 3.1 Schematic cross section of the aquifers of interest (DWLBC, 2002/10)

4. Groundwater Flow Model Design

4.1 Model Grid and Domain

The key stratigraphic units were discretised into three layers consisting of 124 by 124 cells, covering an area of 100 km^2. The spatial extent of the model domain is shown in Figure 4.1. The discretised model grid incorporates a finer grid within the study area (i.e. proposed development). The modelling grid was orientated to the principal direction of flow of the main aquifer of interest (TLA), being northwest.

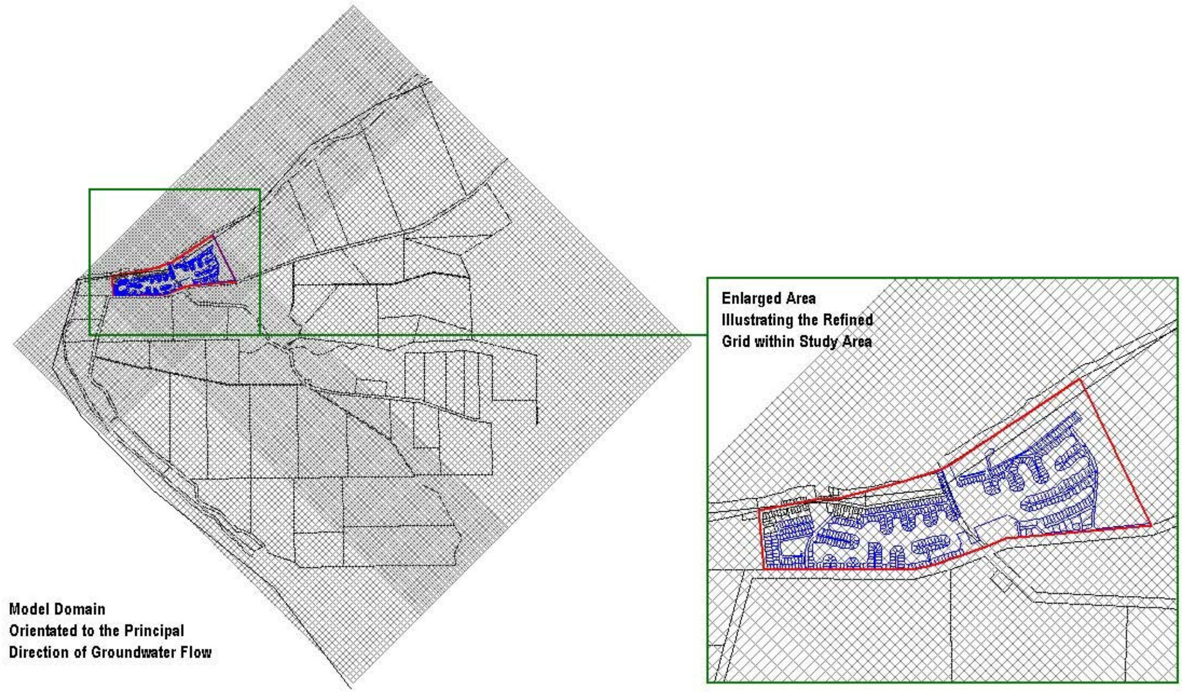


Figure 4.1 Modelling domain and discretised grid.

Vertically the model was discretised into the three main hydrostratigraphic units (Figure 4.2) including:

- **Layer 1** – representing the TLA aquifer assumed to be unconfined and approximately 50 m thick (from natural surface level to -40 m Australian Height Datum – AHD).
- **Layer 2** – the aquitard assumed a uniform thickness of 20 m (from -40 m AHD to -60 m AHD).

- **Layer 3** – the TCSA assumed to be confined and of uniform thickness of 15 m (from -60 m AHD to -75 m AHD).

As site wells do not penetrate the entire shallow aquifer (TLA) or deeper aquifer (TCSA), the vertical extent of each layer was based on regional studies (refer to Figure 4.2).

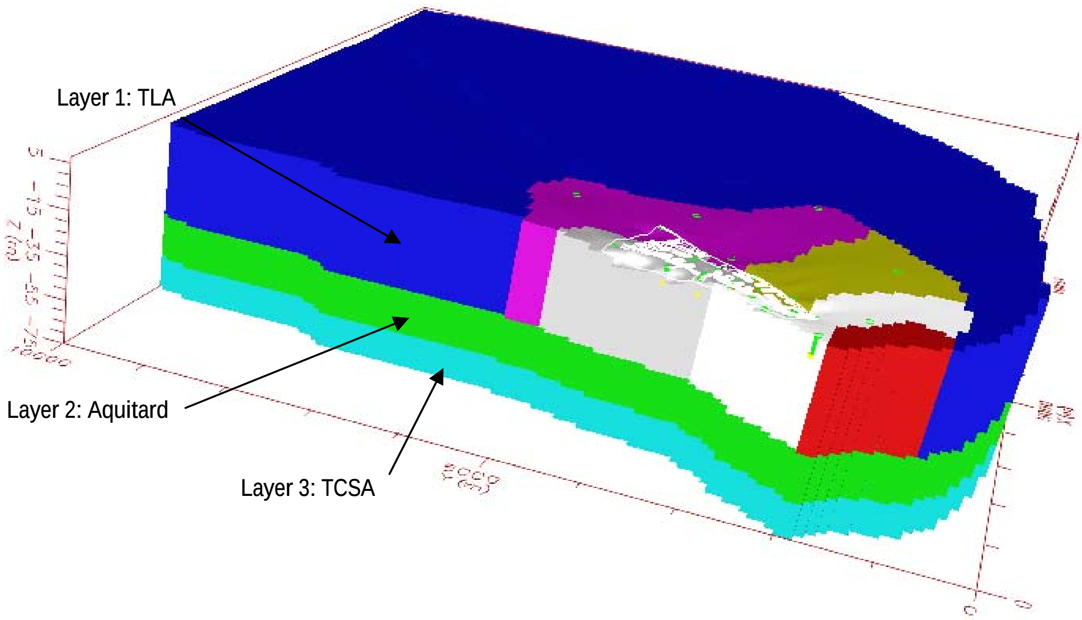


Figure 4.2 Vertical discretised model domain.

4.2 Time Discretisation

A groundwater flow model can be simulated as a steady state or transient flow model. A transient flow model considers the simulation of water levels that take into account seasonal influences such as aquifer recharge from precipitation and groundwater extraction. For the simulation of a transient flow model an understanding of the seasonal water level fluctuations needs to be available. At the site a total of three gauging events have been carried out between July and October 2003, which limits the ability to define a reliable transient model. Therefore for this assessment, a steady state flow model was developed.

The steady state model was calibrated using the October 2003 gauging event.

4.3 Boundary Conditions

In order to solve a groundwater flow equation boundary conditions need to be specified. The boundary conditions considered for this model are summarised below:

- Layer 1, TLA – given the complexity of tidal variation, the shoreline boundary was defined as having a constant head of 0.3 m AHD, which is representative of the average near shore groundwater levels at Cape Jaffa in October 2003, at the time of model calibration (Figure 4.3).

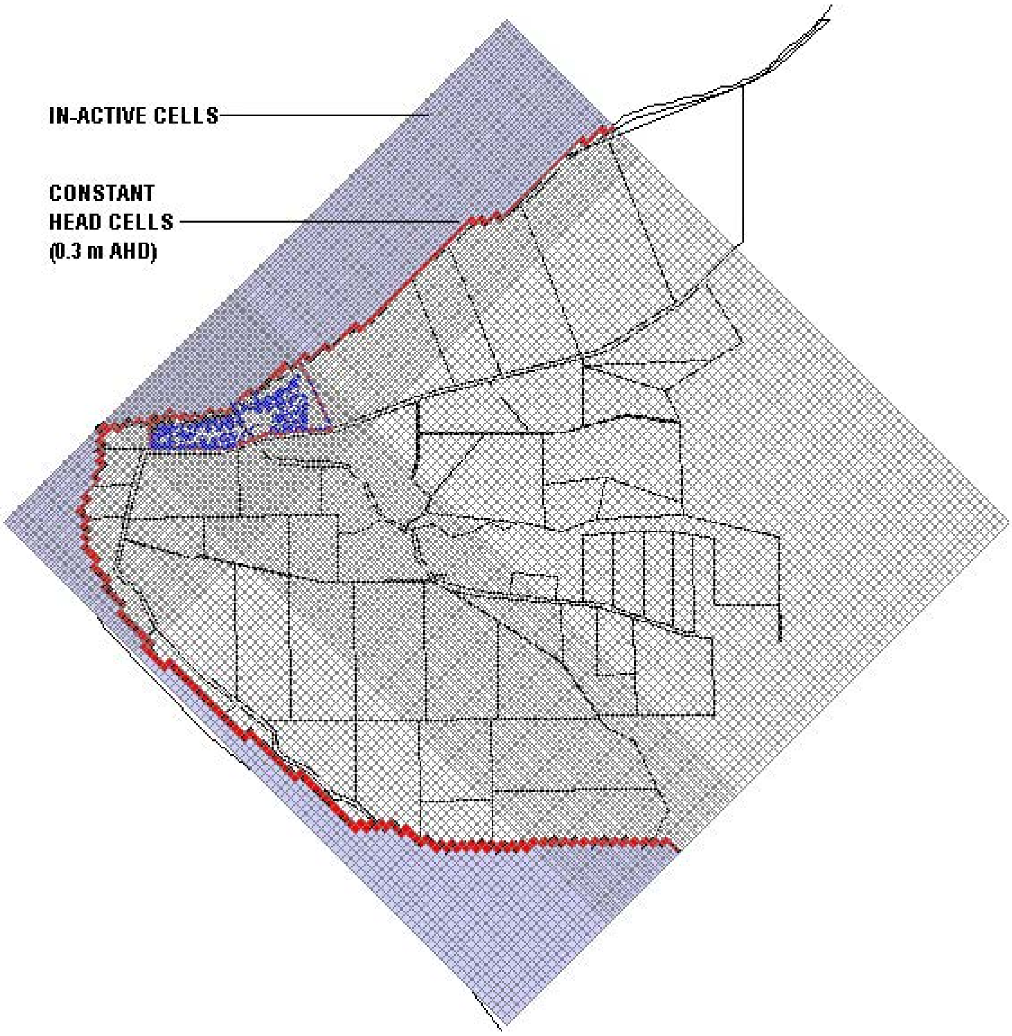


Figure 4.3 Boundary conditions for Layer 1, TLA.

- Layer 2, aquitard – no boundaries have been assigned to Layer 2; assuming that the hydraulic conductivity of this layer was lower than the Layer 1 and 3 and therefore vertical flow between the layers was considered to predominate (Figure 4.4).

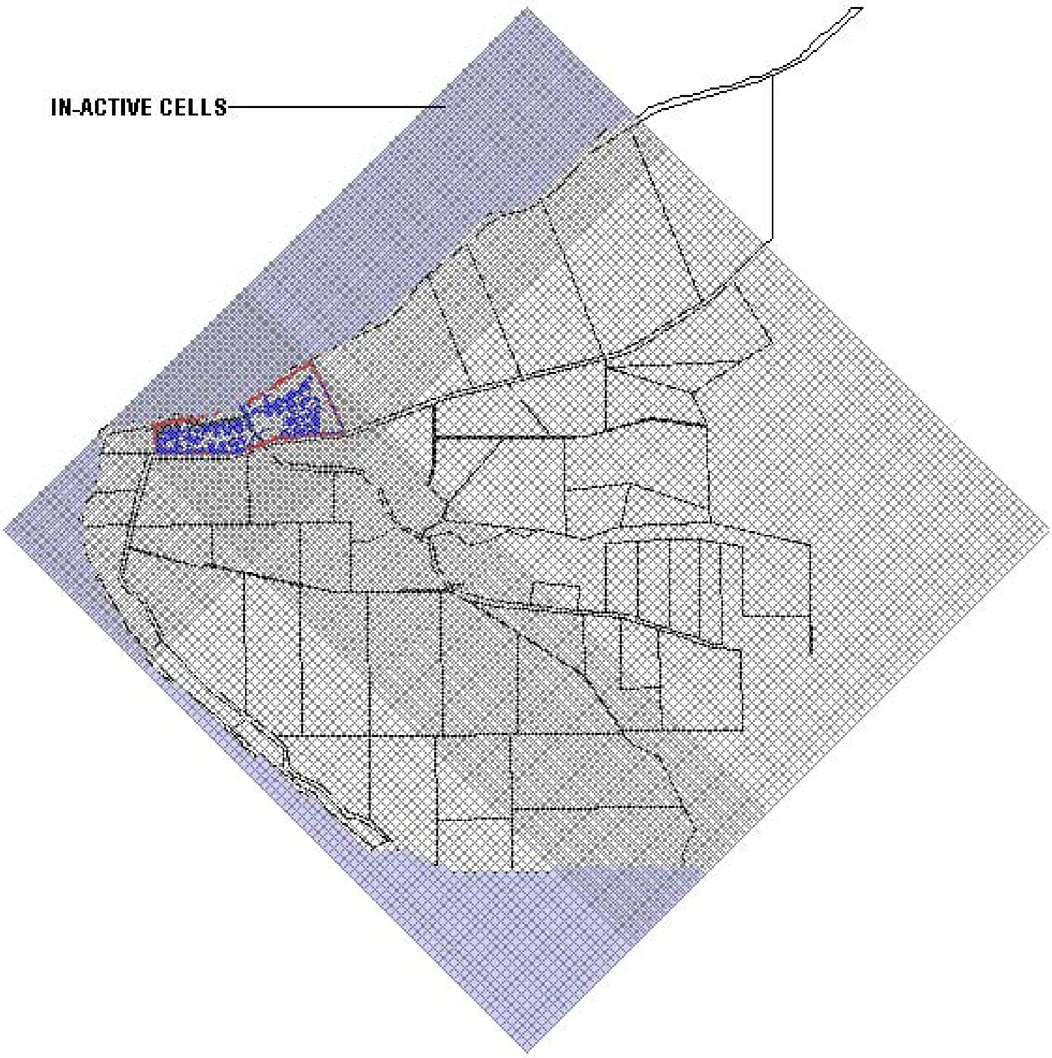
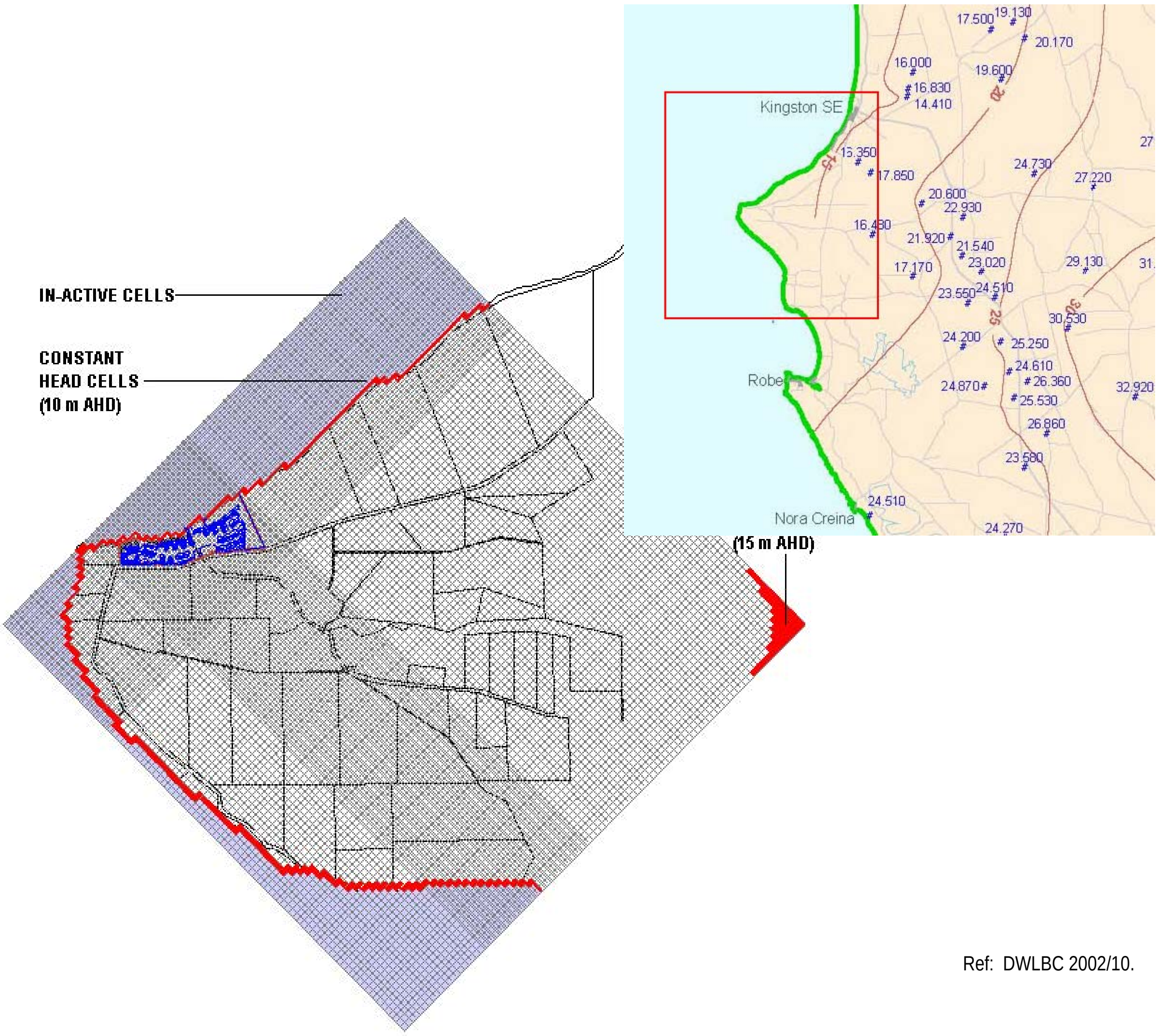


Figure 4.4 Boundary conditions for Layer 2, Aquitard.

- Layer 3, TCSA – a constant head has been assigned along the western and upper eastern boundary of the model. The constant head levels for this layer were based on the regional potentiometric surface elevations (Figure 4.5). The upper eastern boundary was assumed to be 15 m AHD, whilst the western boundary was assumed to be 10 m AHD.

- The hydraulic basement underlying the TCSA aquifer was assumed to be impermeable and assigned as a no-flow boundary conditions.
- Inactive cells were assigned beyond the western boundaries.



Ref: DWLBC 2002/10.

Figure 4.5 Boundary conditions for Layer 3, TCSA.

4.4 Aquifer Properties

The adopted aquifer properties were based initially on the findings of the raising/falling head tests conducted in July 2003 (Tonkin, December 2003). The hydraulic conductivity zones are presented (for comparison to the adopted zones) as Figure 4.6 (falling head) and Figure 4.7 (rising head). The aquifer properties were then modified during the model calibration phase, where the initially assigned hydraulic conductivities were altered (within acceptable ranges) until the simulated results matched the observed water levels. The spatial distribution of the assigned aquifer properties for layer 1 TLA is shown in Figure 4.8.

These properties were assumed to apply to the entire thickness of the unconfined aquifer, which is considered to be a valid assumption given that the model calibrated with the assigned hydraulic conductivities correlating well with measured conductivities and regional published data.

A single aquifer system was assumed for the unconfined aquifer within the groundwater model, extending through the limestone and into the overlying sands. This was considered appropriate given the similar hydraulic properties between the sand and limestone units and the thickness of the sand unit relative to the limestone unit. In addition, as existing registered wells target the limestone unit, the discontinuous clay layer identified between the sand and limestone units is likely to have minimal influence on determining the impact of the marina on groundwater users.

The fact that model calibration was achieved at locations where clay was and was not present indicates that the assumption of a continuous unconfined aquifer system within the sand and limestone units is appropriate for the purposes of the model and assessment of impact on groundwater users.

Figure 4.6 Inferred hydraulic conductivity zones estimated from falling head test, July 2003 (Tonkin, December 2003).

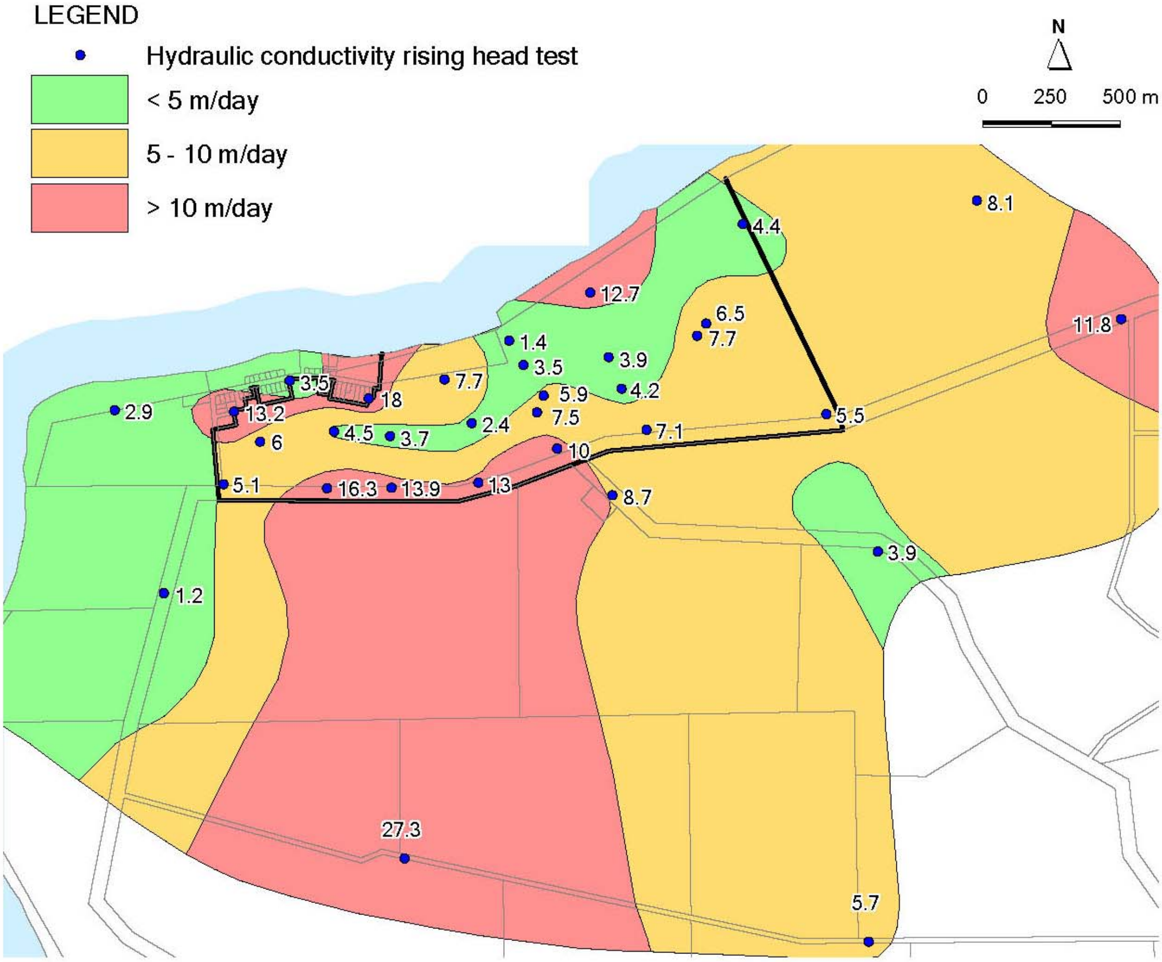


Figure 4.7 Inferred hydraulic conductivity zones estimated from rising head tests, July 2003 (Tonkin, December 2003).

Estimates of aquifer parameters for the aquitard and TCSAas well as the storage yield for the TLA, were derived from previous modelling exercises (PIRSA, May 2000) and regional aquifer ranges (Tonkin, December 2003). The adopted aquifer properties for these units are summarised below:

- Horizontal Conductivity for layer 2, aquitard, uniform over entire layer, 1 x 10^{-5} m/day;
- Horizontal Conductivity for layer 3, TCSA, uniform over entire layer: 15 m/day; and

- For transient simulations, the storage parameters for all layers were assumed to be uniform with a specific yield of 0.1 and specific storage of 1×10^{-6} /m, based on the findings of PIRSA (May 2000).

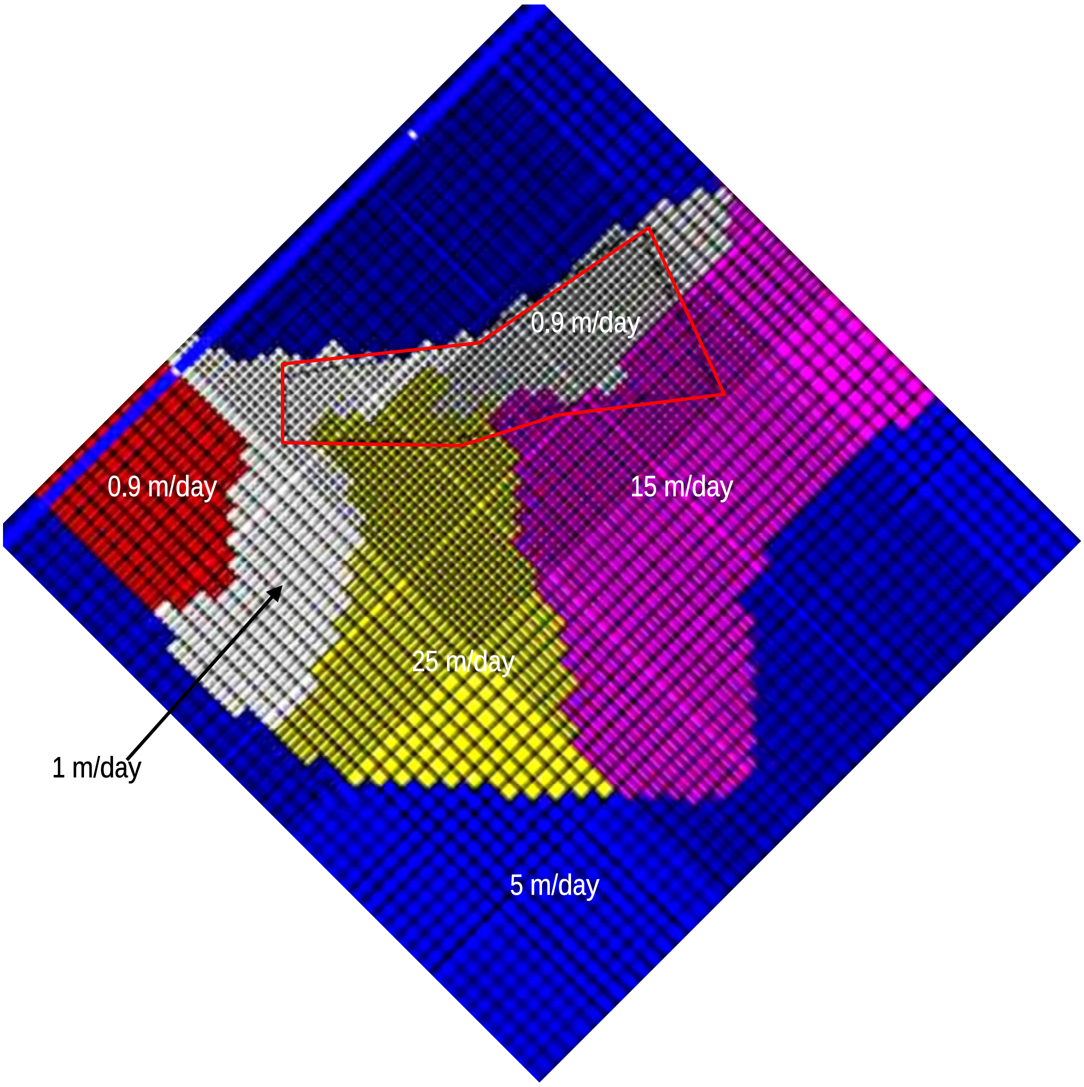


Figure 4.8 Spatial distribution of assigned horizontal conductivity for Layer 1 (TLA).

The assigned aquifer properties correlated well and were within the reported ranges of the data collected for this study (refer to permeability tests) and regional information (Tonkin, December 2002).

4.5 Sink and Source Considerations

Sink and source considerations relate to the external input or output of water from the aquifers from external sources, such as aquifer recharge from precipitation or extraction of groundwater. For the designed model the following sink and source terms were considered:

- Aquifer recharge from precipitation was applied to the uppermost aquifer layer (Layer 1, TLA) in the model. A recharge rate of between 10% to 15% of precipitation was uniformly applied across the modelling domain. Generally, monthly precipitation totals at Cape Jaffa range between 560 - 590 mm (40 years of data collected at Jaffa Hills, the closest station to the site). The adopted monthly recharge rates were derived based on the following and were adjusted within reasonable ranges, during model validation:
  - HELP model estimations (one dimensional model results of the infiltration of water from precipitation to the water table).
  - Review of available site data, including the influence of precipitation to water level fluctuations.
  - The adopted recharge rates.
- Removal of water from the uppermost aquifer, Layer 1, TLA from groundwater extraction in the area was assumed to be low and hence not considered.

5. Model Validation

5.1 Model Calibration

Tertiary Limestone Aquifer

Within the study area, the model was calibrated against the October 2003 groundwater elevation surface. Beyond the study area, groundwater level data was not available for this period.

Aquitard and Tertiary Confined Sand Aquifer

For the TCSA, the potentiometric elevation map for September-October 2001 was used to compare the predicted versus the simulated water levels.

The simulated versus observed water elevation contours (October 2003) for Layer 1, TLA, is shown in Figure 5.1.

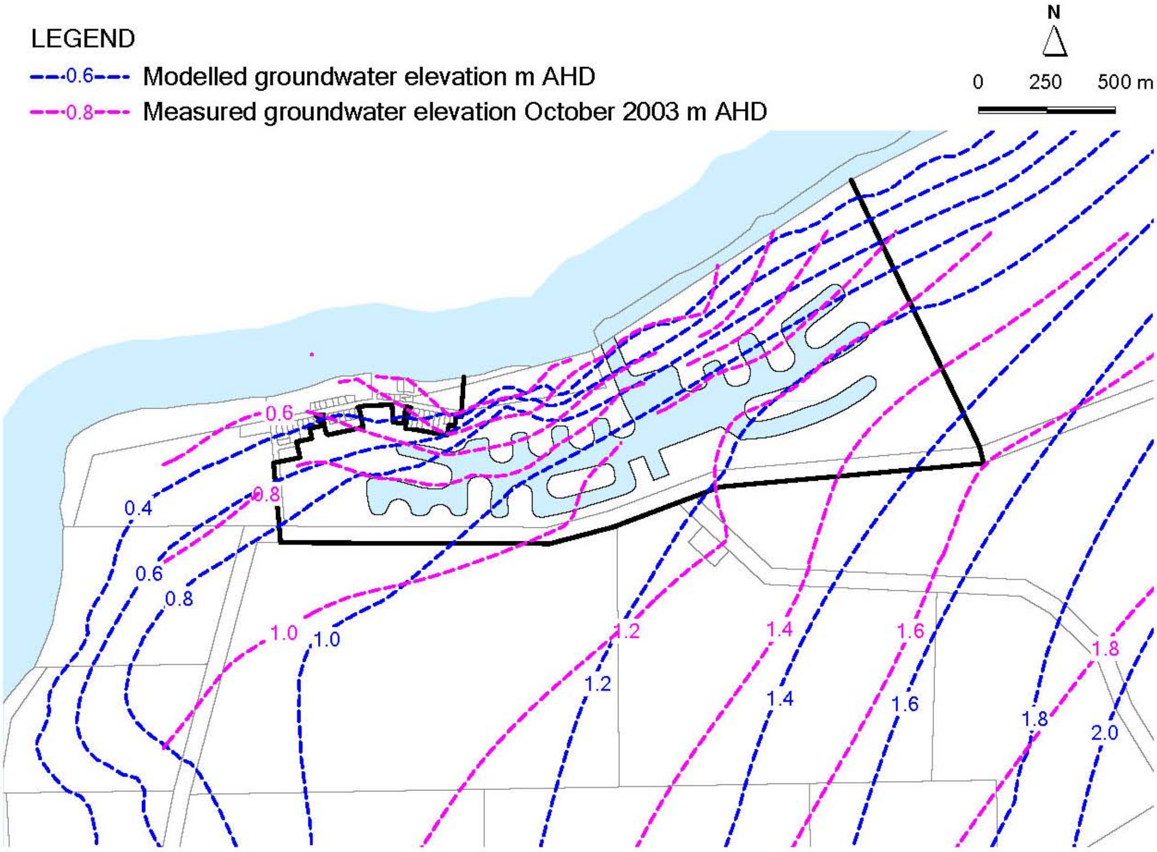


Figure 5.1 Observed versus calibrated groundwater elevations, TLA.

A scatter diagram of the observed (October 2003) versus simulated water levels is shown as Figure 4.2. Figure 4.2 illustrates the residual between the observed and simulated water levels at each gauged well in October 2003, with a satisfactory result for data lying on the 45-degree line. Although a satisfactory fit has been achieved (RMS < 10%) Figure 4.2 also illustrates that in general the model under predicts the simulated water levels. The maximum residual is approximately 0.2 and hence an error tolerance of up to 0.2 m should be implemented when considering the predicted results.

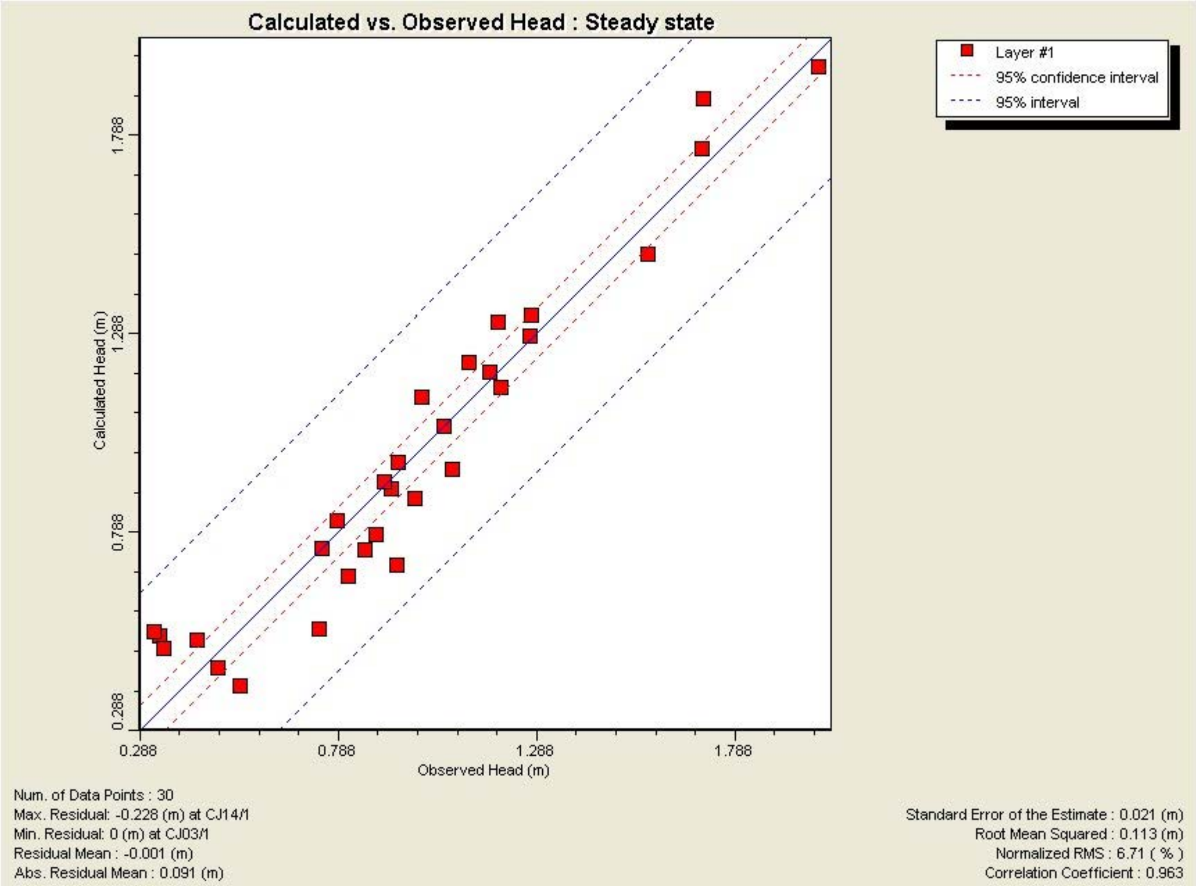


Figure 5.2 Model error analysis – scatter diagram.

5.2 Model Limitations and Assumptions

A number of limitations or assumptions have been adopted that impact the validity of the presented results. For most modelling studies, model limitations are inevitable as data gaps in the conceptual understanding of the behaviour of the system exists, spatially and over time. The following is a summary of the key limitations that assist in acknowledging the assumptions that have been adopted:

- The hydraulic connection between the aquifers is not well understood. Based on regional information, it was assumed that an upward hydraulic potential exists between the TSCA to the TLA.
- Aquifer properties and the geometry of the aquitard and TCLA layers were assumed to be uniform and based on regional studies.
- Due to the absence of seasonal time series data steady state conditions were considered.
- Groundwater extraction from the TLA was assumed to be insignificant.

- Aquifer recharge was assumed to be from precipitation. A value of 100 mm/year was applied uniformly across the model.
- The groundwater model was developed using MODFLOW, which assumes flow of water through a porous medium. MODFLOW does not consider the effect of density variation and hence assumes direct discharge to the marine environment.

6. Model Simulations

The calibrated and validated model was used to predict the impact of establishing the basins and channels on the existing groundwater environment. A total of three key scenarios were considered, including:

- Scenario 1 – Simulation of Pre-Development Conditions;
- Scenario 2 – Simulation of Stage 1, Dewatering Example; and
- Scenario 3 – Simulation of Post-Development Conditions.

6.1 Scenario 1 – Simulation of Pre-Development Conditions

The validated groundwater flow model was used to revise the conceptual hydrogeological understanding of the system, particularly the groundwater discharge potential from the TLA to the marine environment under current conditions. The findings are summarised below:

- Figure 5.1 in Section 5.1 presents the predicted groundwater elevation contours for the TLA, which compares well with the observed October 2003 conditions.
- The average groundwater discharge rate across the length of the site from the entire depth of the TLA (Figure 6.1) is estimated to be approximately 750 m^3/day.
- A review of the vertical flow patterns suggests an upward pressure from the TCSA to the overlying units, which are consistent with regional expectations. The estimated rate of leakage from the TCSA to the TLA is expected to be low due to the low permeability of the confining layer, which separates the two aquifers.

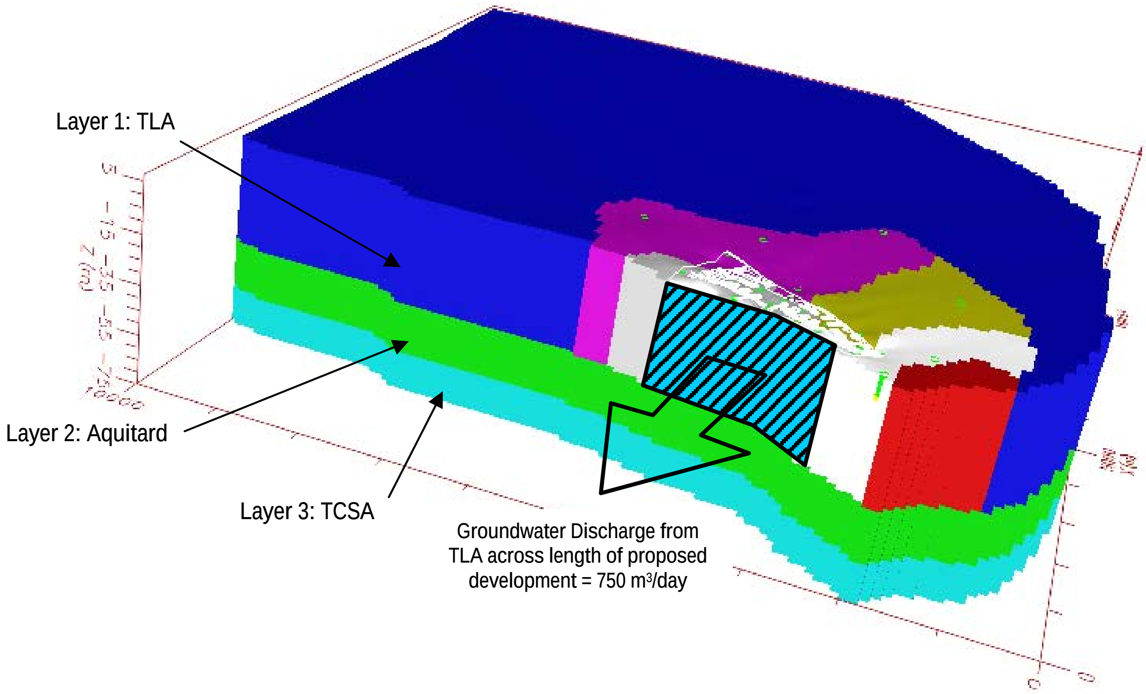


Figure 6.1 Average estimated groundwater discharge to Lacepede Bay from TLA.

6.2 Scenario 2 – Simulation of Stage 1, Dewatering Example

To limit the zone of influence caused by dewatering activities during construction and to obtain a field guide of the response of the system, the development will be staged. Stage 1 will be located away from existing groundwater users and located within a lower permeability zone which will minimise impact on the groundwater system until more knowledge is gained about the behaviour of the system in response to the works. Each stage, in accordance with the groundwater management plan, will include routine gauging and sampling of nominated wells to monitor the impact of the dewatering program. Scenario 2, involves the simulation of the change in the groundwater flow field, following the development of Stage 1 (Figure 6.2).

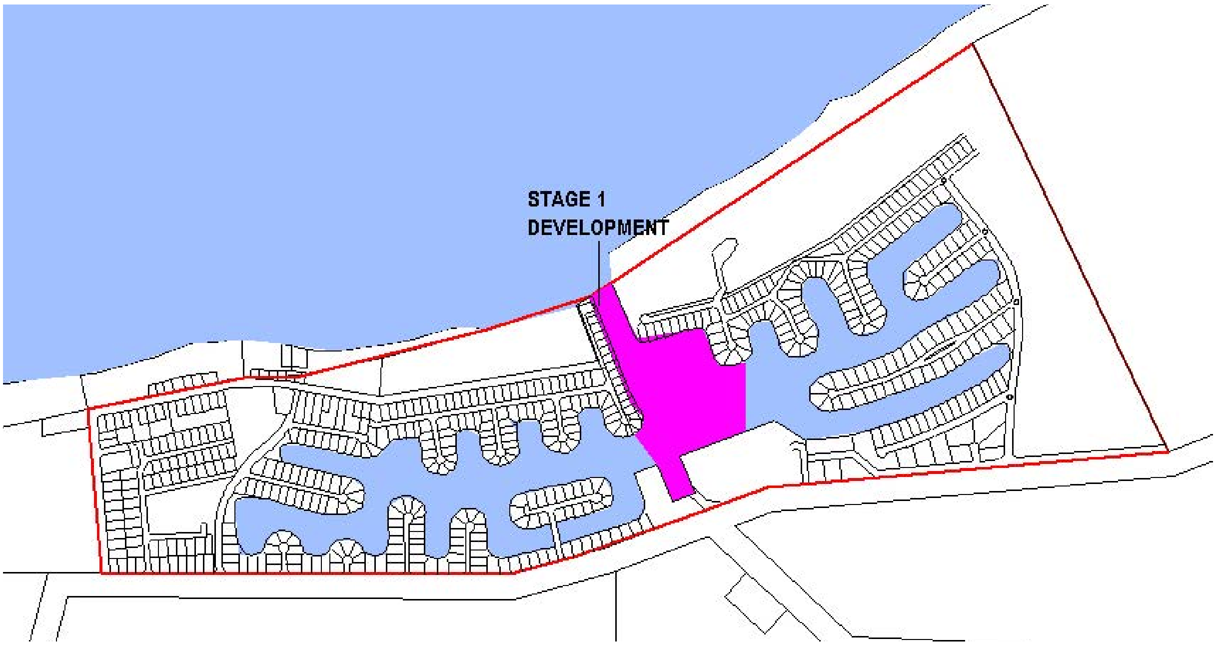


Figure 6.2 Extent of the Stage 1 development.

Dewatering activities associated with excavations below the water table are likely to result in significant groundwater inflows into the excavation. The rate of flow into the excavations will be dependent on the heterogeneity of the hydrogeological and geological environment, depth and size of the excavations and the aquifer properties.

Scenario 2 was broken up into a further two simulations, including:

- The initial simulation examined the drawdown influence during construction of the excavation to -1 m AHD. During the construction stage of the basins and channels, the greatest groundwater level impacts is anticipated, as water levels will be lowered below average tide levels .

  The estimated area of drawdown as a result of the Stage 1 development (during excavation and dewatering) and the location of existing registered wells are shown in Figure 6.3. It is noted that the estimated influence may be more pronounced should different hydrogeological or geological conditions be encountered or excavations be extended.

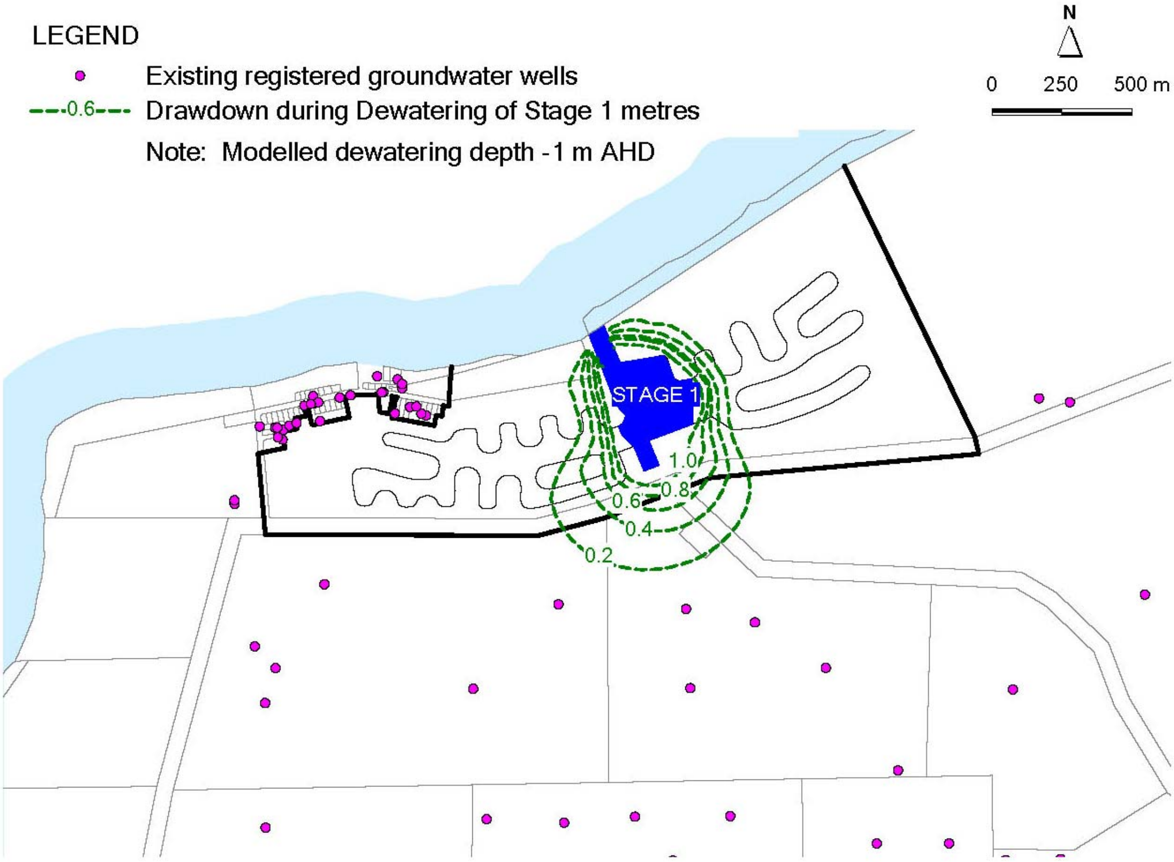


Figure 6.3 Stage 1 development, estimated area of drawdown (assumed excavation to top of limestone at approximately -1 m AHD)

- The second simulation, assumed steady state conditions and examined the change in water levels following completion of Stage 1, compared to pre-development conditions. Following construction, seawater ingress within the developed channel/basin will occur and raise the level at which groundwater discharges relative to the construction phase. Over time the aquifer system will reach a new equilibrium position.
- The predicted water levels following completion of Stage 1 and once the system has reached a revised equilibrium is shown in Figure 6.4. The highest water level change occurs in the vicinity of the Stage 1 construction area and progressively decreases away from this zone.

During Stage 1 of the development, it is proposed to monitor the response of the system through a Groundwater Management Plan to assess the accuracy of the model. If it is considered necessary following this assessment, the model will be revised and re-calibrated.

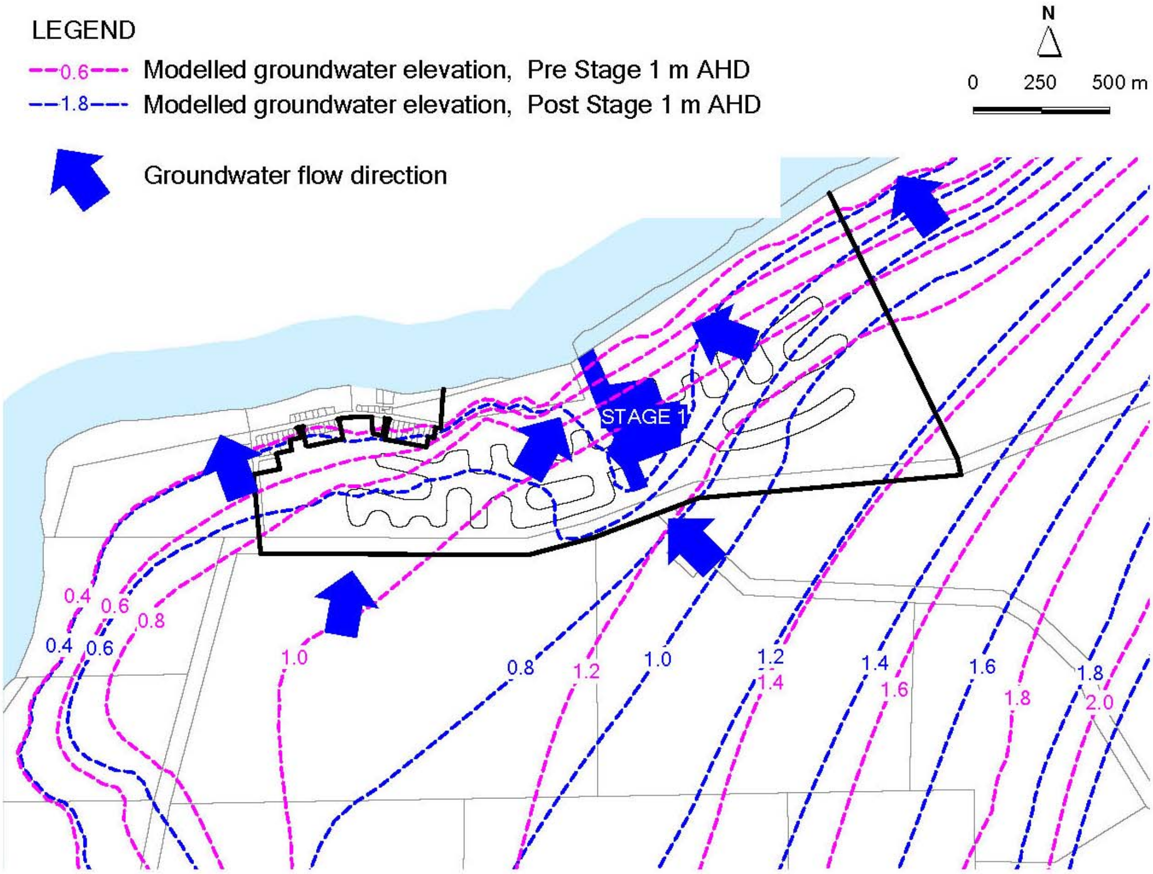


Figure 6.4 Stage 1 development, predicted TLA groundwater elevation contours following completion of Stage 1

6.3 Scenario 3 – Simulation of Post-Development Conditions

6.3.1 Simulated Water Level Change

Simulation 3, adopts the modelling conditions of the pre-development model (Scenario 1) with an altered shoreline, which reflects the location of the marina. The western boundary condition for the TLA was revised to include the proposed basins and channels as shown in Figure 6.5.

The predicted water levels for the TLA, pre- and post-development assuming steady state flow conditions is shown in Figure 6.6.

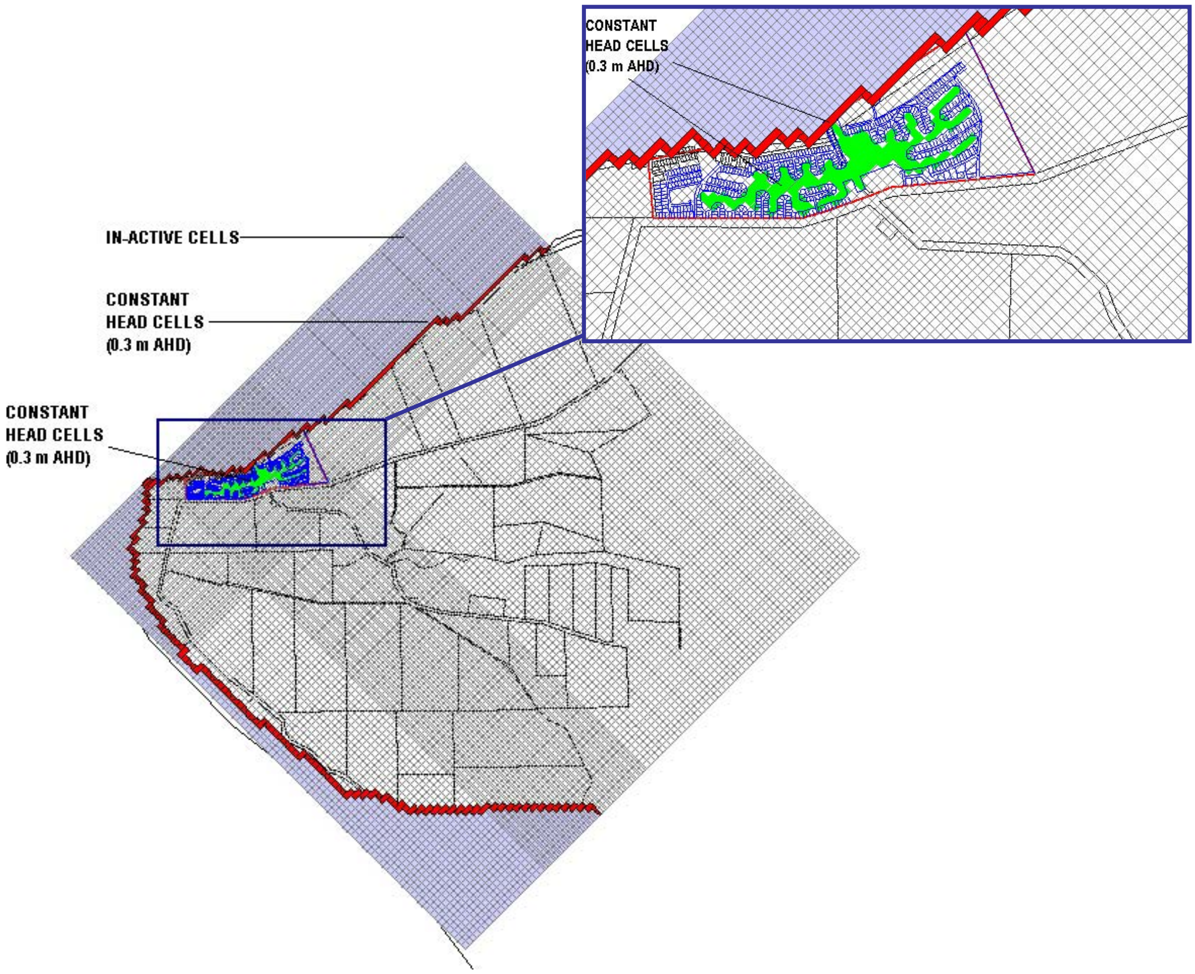


Figure 6.5 Revised boundary conditions – post development scenario.

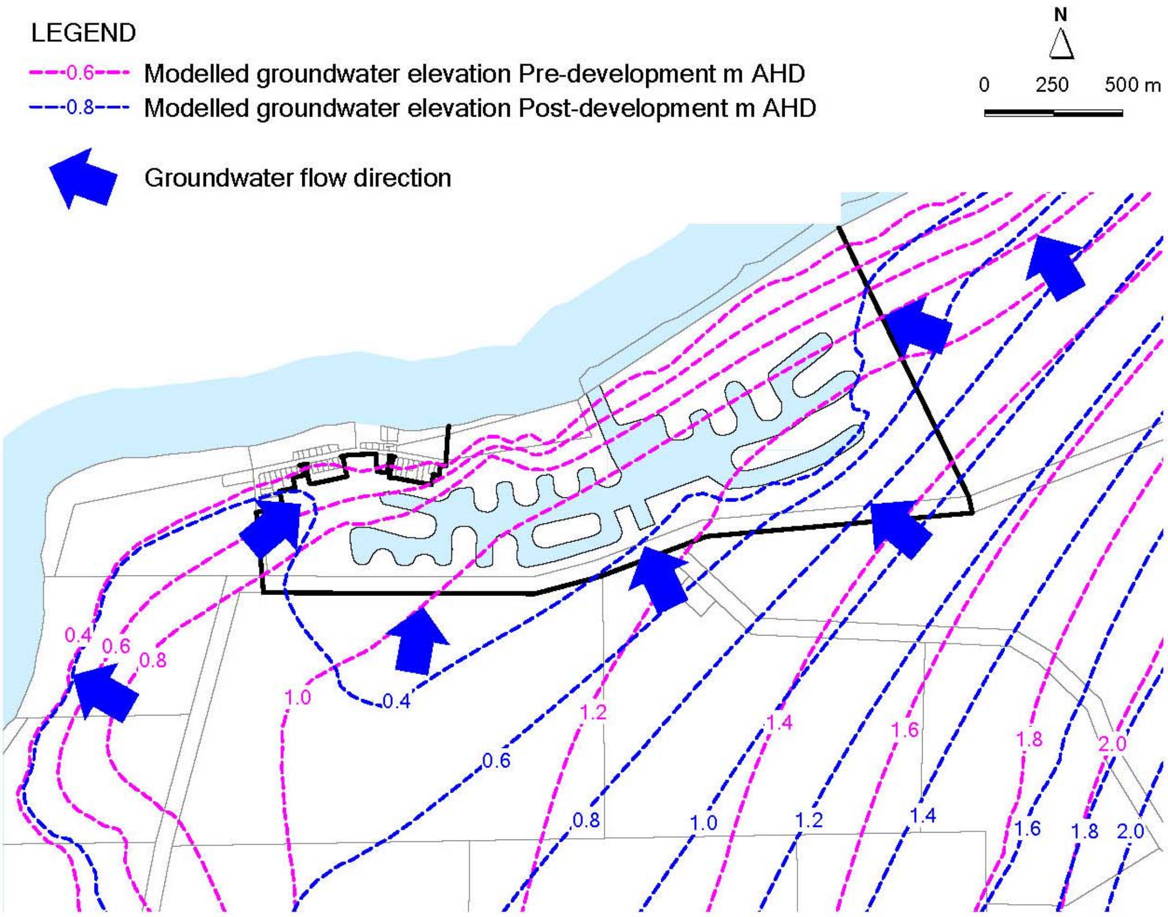


Figure 6.6 Predicted water levels, TLA – post development and pre-development.

The estimated change in water levels is shown in Figure 6.7, and incorporates the registered groundwater wells near the proposed development, including the depth of the well. The change in water level within this zone is estimated to range between approximately 0.2 m (southern extent) and 0.6 m (closer to the development) lower than existing conditions. Higher drawdowns may be experienced depending on the tidal range (for this simulation an average tide level of 0.3 m was assumed) and during excavation. It is further noted that when reviewing the areal extent of influence the error between observed versus simulated water levels should also be taken into consideration. An error tolerance of up to 0.2 m head difference exists between observed versus simulated results (refer to Section 5).

The resulting impact will be the loss of available head of water for extraction by the registered users. Based on the recent gauging results, the average depth to groundwater is approximately 3 m below ground level. The average depth of the registered wells is 8 m below ground level. The head of water available for extraction (assuming that the pump is located at the bottom of the well) is approximately 5 m, pre-development conditions. Therefore, as a result of the development, it is estimated that the general change in head of water available for extraction by existing users could be altered from approximately 5 m to approximately 4 – 4.5 m.

The model suggests that the cluster of registered wells near the Cape Jaffa Settlement appear not to be significantly impacted. A majority of these wells may experience a change in water level of approximately 0.2m and several located closer to the development may be impacted by approximately 0.4 m. This is likely to be due to these wells being located in proximity to the constant head boundary (i.e. the sea) in both the pre-development and post-development scenarios.

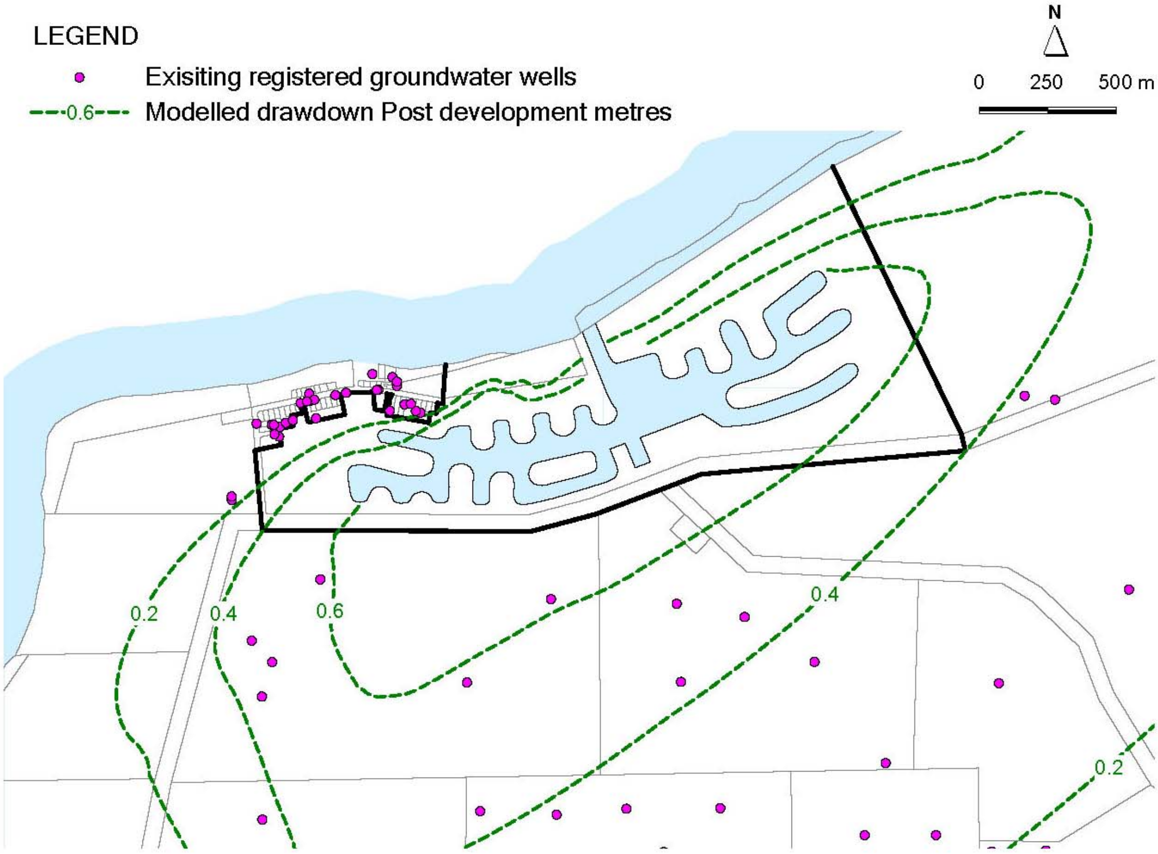


Figure 6.7 Predicted change in water level (pre-development to post development) in relation to registered groundwater wells.

6.3.2 Changes in Groundwater Flow Conditions

The construction of the marina will change local flow conditions. As the levels in the marina will be maintained at sea level, which is lower than existing groundwater levels, some of the groundwater flow surrounding the development will be re-directed towards the marina.

As there is no additional water added or removed from the unconfined aquifer system (other than during construction dewatering activities and for water supply), the net water balance is not disturbed, i.e. the regional total groundwater outlfow to the marine environment would not be changed. The groundwater level surrounding the channels and basins are however altered to the revised hydraulic boundary formed by the constructed basin. This revised hydraulic boundary is related to the level of water within the basins (or tide level). It is the revised boundary, which will yield a change in groundwater flow conditions.
The changes to groundwater flow conditions will be a re-distribution of flows. The marina will act as a conduit for groundwater flow and will create a concentrated outflow point through the entrance to the marina to the marine environment.

The above concepts are illustrated in Figure 6.8 and Figure 6.9.

As illustrated conceptually in Figure 6.8, for the pre-development situation, the flow to the marine environment is equal to the flow to the shoreline, i.e.:

$$A_{marine\ environment} = A_{shore}$$

Post-development the flow has is re-directed, as illustrated conceptually in Figure 6.9. For this situation, the flow to the marine environment is equal to the flow to the shore plus the flow to the marina, i.e.:

$$B_{marine\ environment.} = B_{shore} + B_{marina}$$

In addition, as there is no additional water added or removed from the system, the flow to the marine environment in the pre-development situation is equivalent to the post-development situation, i.e.:

$$A_{marine\ environment} = B_{marine\ environment}$$

PRE-DEVELOPMENT

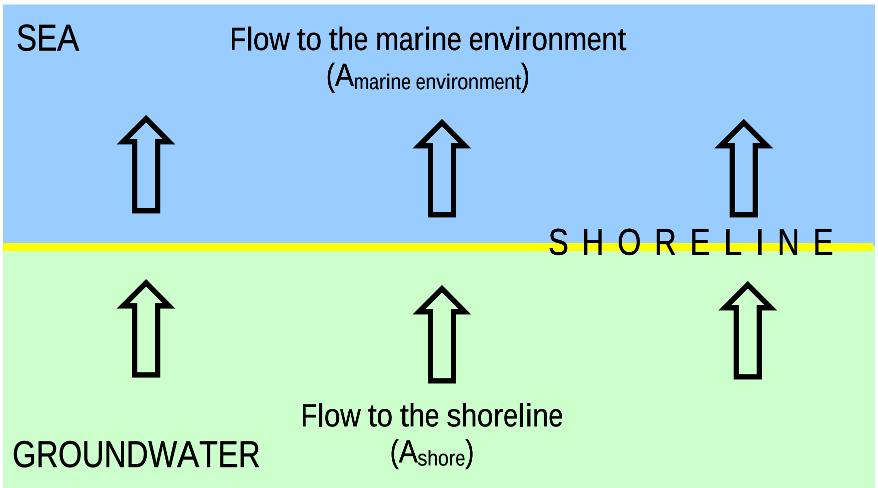


Figure 6.8 Conceptual groundwater flow in the unconfined aquifer – pre-development.

POST-DEVELOPMENT

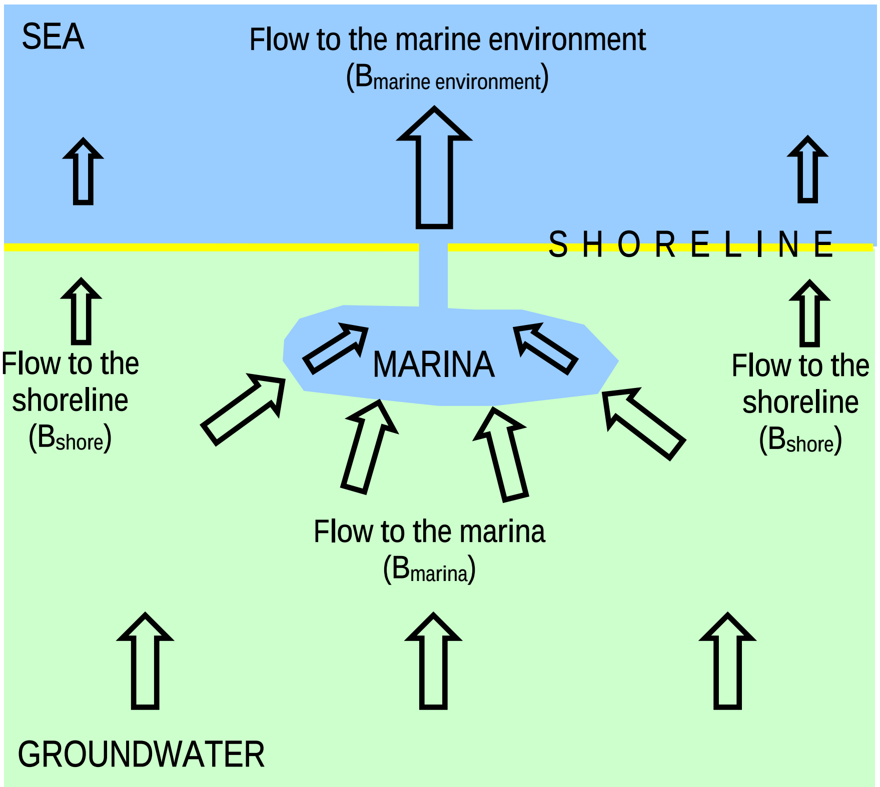


Figure 6.9 Conceptual groundwater flow in the unconfined aquifer – post-development.

The groundwater flow model was used to predict that the distribution of the average groundwater flows entering the marina basins and channels following completion of the development (B_{marina}) as being 900 m^3/day. This was undertaken by taking the difference in throughflow between pre-development and post-development steady state conditions for the TLA within the cells highlighted in Figure 6.10. As this difference in throughflow occurs due to the constant head boundary, it represents the flow into the marina basins and channels. This information has been used in assessing the impact of a concentrated groundwater outflow to the marine environment.

The distributed groundwater flow to the marine environment along the existing shoreline effectively reduces to zero due to the near zero hydraulic gradient between the basin and the shoreline, and is replaced by the modelled 900 m^3/day groundwater contribution to flow crossing the existing shoreline through the marina channel. The distribution of this flow is also illustrated in Figure 6.10.

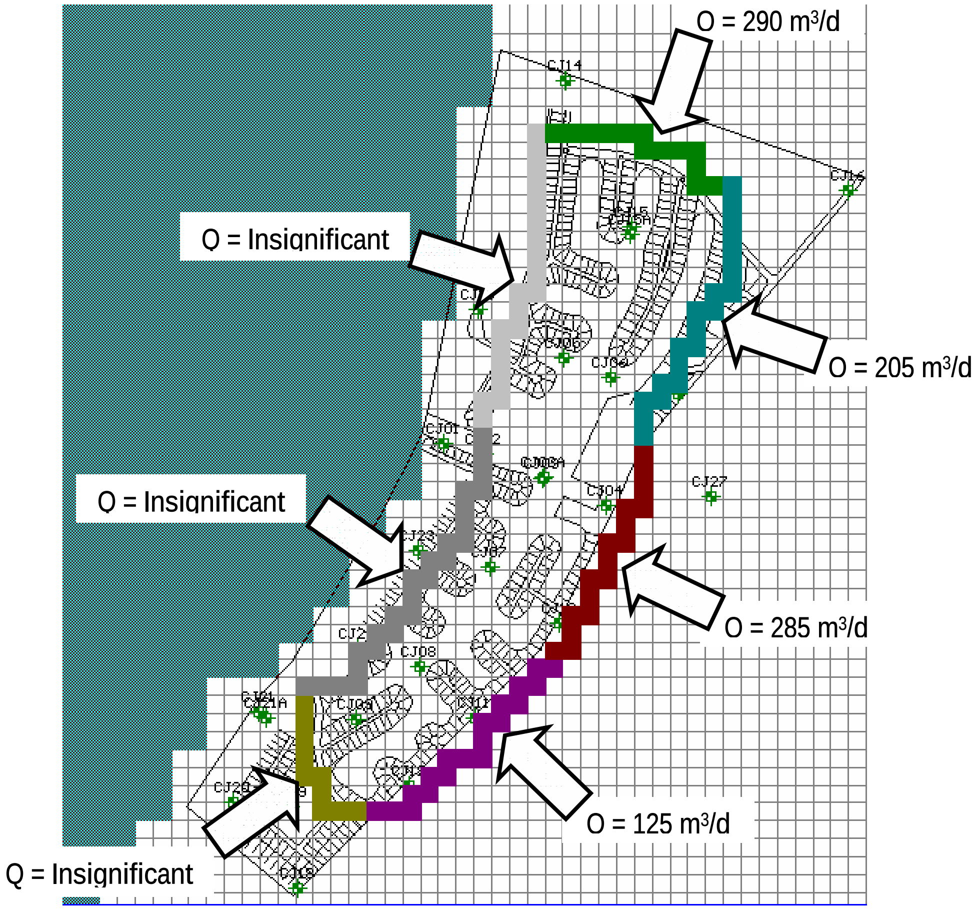


Figure 6.10 Predicted groundwater flow distribution into the marina – post-development.

A check of the above estimate was undertaken by using the model to calculate the change in through-flow between pre-development and post-development for the shoreline and marina basins and channels, represented by the highlighted cells in Figure 6.11. The change in through-flow using this method was estimated to be 700 m^3/day. This can be assumed to be the average discharge to the marina as no other changes were made to the model between pre and post-development. For the purpose of the impact assessment, the higher value of 900 m^3/day has been adopted.

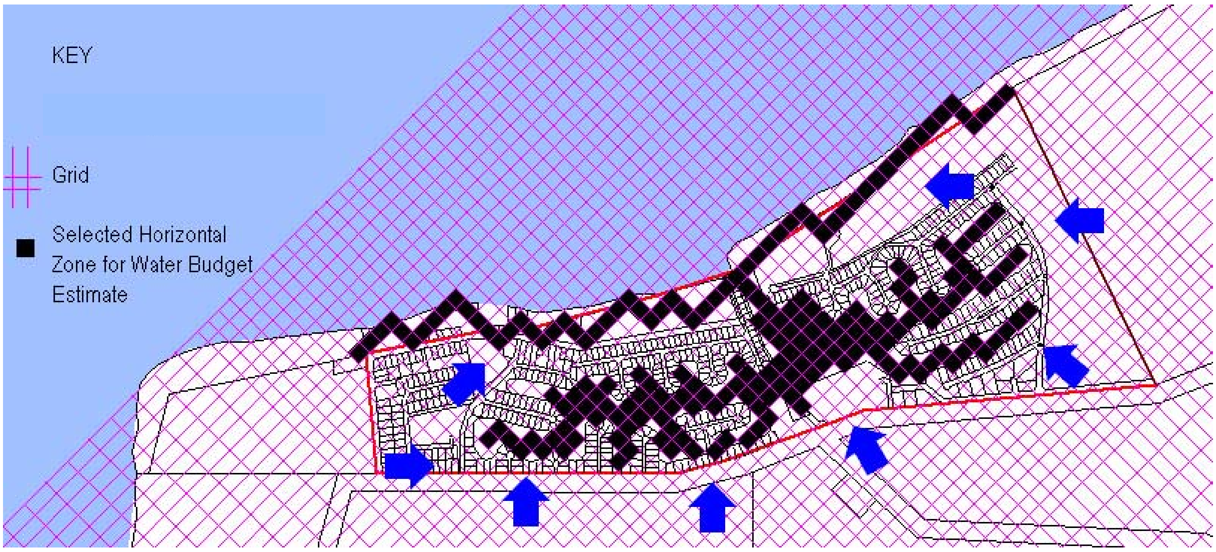


Figure 6.11 Model cells selected for estimating the change to the groundwater flow system from pre- to post-development.

The above discharge estimates are based on steady-state conditions for the model calibrated at October 2003 conditions. The actual groundwater discharge to the marina will vary from the above the estimate depending on tidal position and variations in the hydraulic conductivities surrounding the development.

WMB (2003) have identified that an estimated volume of at least 170,000 m^3/day of seawater will move through the basins and channels within a 24-hour period due to tidal effects (0.4 m tidal variation) providing significant dispersion and mixing of any groundwater discharge. The anticipated tidal flushing effect is significantly greater than the groundwater discharge to the basins and channels.

On a regional scale, the net groundwater flow to the marine environment will remain unchanged. The marina creates a re-distribution of the flows, with the model predicting approximately 900 m^3/day on average will enter the marina.

7. Conclusions

A three dimensional groundwater flow model was developed for the Cape Jaffa marina to evaluate the likely impacts of the proposed development on the shallow unconfined aquifer, referred to as the TLA.

The simulated results for the TLA were calibrated against the groundwater elevation contours for October 2003. Regional information was used to validate the simulation trends for the TCSA.

Three key prediction scenarios were simulated. The outcomes of these simulations are summarised below:

Scenario 1 – Pre-Development Conditions

- The average groundwater discharge rate across the length of the site from the entire depth of the TLA is estimated to be approximately 750 m^3/day.
- The upward flow from the TCSA is expected to be low as the head is reduced through the confining layer separating the aquifers due to its low permeability.

Scenario 2 – Stage 1 Dewatering Example

- The estimated area of drawdown as a result of the Stage 1 development during excavation and dewatering is unlikely to impact identified groundwater users in the area. The data collected during Stage 1 will be used to refine the management of subsequent stages as more knowledge about the groundwater system is gained, in accordance with a Groundwater Management Plan.

Scenario 3 – Post-Development Conditions

- The change in water level following development is likely to range between 0.2 m and 0.6 m lower than existing conditions in the vicinity of the site. The resulting impact will be the equivalent (i.e. 0.2 – 0.6 m) loss of available head of water for extraction by the registered users.
- On a regional scale, the net groundwater flow to the marine environment will remain unchanged as there are no changes to the net water balance of the system.
- The estimated average groundwater discharge to the marina is estimated to be 900 m^3/day. WMB (2003) have identified that an estimated volume of at least 170,000 m^3/day of seawater will move through the basins and channels within a 24-hour period due to tidal exchange (0.4 m tidal

variation) providing significant dispersion and mixing of groundwater discharge.

The results presented in this report are representative of a steady state flow model, as time series data regarding seasonal water level fluctuations was limited. In addition, details regarding the deeper units were sourced from regional studies. Continued gauging on site and observations during construction will ultimately further the conceptual hydrogeological understanding and hence may result in refinements to the developed groundwater flow model.

In order to assess whether any refinements are necessary, the response of the groundwater system will be monitored through a Groundwater Management Plan during Stage 1 of the development. If it is considered necessary following this assessment, the model will be revised and re-calibrated to the new data.

8. References

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Tonkin Consulting (November 2003), Cape Jaffa Anchorage Marina, Groundwater Impact Assessment, Volume 1 – Desktop Study and Field Investigations, ref. 20030318RA4.

Tonkin Consulting (December 2003), Cape Jaffa Anchorage Marina, Groundwater Impact Assessment, Volume 2 – Conceptual Hydrogeological Model, ref. 20030318RA5.

WBM Oceanics Australia (2003), Cape Jaffa Marina, Assessment of Tidal Flushing (draft report).

Kingston District Council and
Cape Jaffa Development Company

Cape Jaffa Anchorage Marina

Groundwater Impact Assessment

Volume 4 – Assessment and Management

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Cape Jaffa Anchorage Marina
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Document History and Status

Rev	Description	Author	Rev'd	App'd	Date
A	Draft for comment	AD/GRP	GRP	PJL	16/1/04
B	Revision 1	AD/GRP	PJL	PJL	16/3/04
C	Revision with Final EIS edits	GRP	GRP	PJL	23/12/04
D	Revision following Planning SA comment	GRP	[signature]	[signature]	4/2/05

1. Introduction

1.1 Background

Cape Jaffa is located on the coast at the southern end of Lacepede Bay, between Kingston SE and Robe, south-east of South Australia (Figure 1.1).

Kingston District Council and Cape Jaffa Development Company are proposing to develop a safe haven and moorings for existing and future fishing fleet, recreational boating facilities as well as tourist and residential development south-east of the existing settlement (Figure 1.3).

The project was declared a "Major Development" by the Minister for Urban Development on 19 December 2002 and subsequently following community consultation, the Major Development Panel (MDP) has determined that the proposal will be subject to the processes and procedures of an Environmental Impact Statement (EIS). As a result, the Panel has prepared "Guidelines for the Preparation of an Environmental Impact Statement for the Cape Jaffa Anchorage Marina. Proposal by District Council of Kingston and the Cape Jaffa Development Company" (the Guidelines).

The key groundwater assessment requirements identified in the guidelines include:

- Description of the existing groundwater environmental conditions;
- Evaluation of the impact that the proposed development will have on groundwater levels (drawdown) during and post construction;
- Evaluation of the influence of salt water intrusion;
- Impact assessment on existing groundwater users;
- Evaluation of the potential groundwater outflow to the marine environment; and
- Evaluation of groundwater quality parameters entering the marine environment.

Based on the previous investigations referred to in Section 1.3, this report provides assessment of the impacts relevant to groundwater issues by responding to the issues raised in the Guidelines. Where these issues are addressed in this document is summarised in Table 1.1.

Figure 1.1 Location of study area.

Table 1.1 Relevant issues identified in the Guidelines.

Issue ref.	Description	Section
5.2.1	Describe the known existing groundwater environmental conditions.	1
5.2.2	Detail any groundwater investigations and modelling undertaken on the site or in the locality of the site.	1.3
5.2.3	Describe the short and long term effects of establishing channels and basins on groundwater quantity and quality and movement, particularly watertable drawdown or contamination from salt water intrusion.	3, 4
5.2.5	Detail the impact on land and native vegetation of the off-site depression of the water table and outline the extent of groundwater depression and effect on farming and horticulture and other operations within the groundwater depression zone.	3
5.2.6	Describe the likely effects on marine organisms, reef communities and seagrasses, given groundwater flow out to sea is likely to increase, potentially reducing the salinity and increasing nutrients and pollutants, particularly heavy metals.	8
5.2.7	Detail management systems to control the quality and quantity of outflow from the marina given that it is likely to become a sump for groundwater or high freshwater flows that may affect marine organisms.	8
5.2.8	Detail any seasonal variations of groundwater level and impact on marina design and off-site operations.	1
5.2.10	Detail the measure to be taken to protect and monitor groundwater resources to ensure that the development does not have a deleterious effect on them.	9
5.2.23	Described the effect of water table drawdown or contamination on local domestic water supplies, including that used for drinking and the watering of gardens.	5
5.2.29	Detail investigations to include in an environmental management plan.	9
5.3.10	Describe the impact of local and regional land uses (eg. Viticulture, horticulture and other forms of primary production) from groundwater drawdown or contamination.	5
5.3.17	Describe the impact of groundwater drawdown or contamination on the source and use of domestic water.	5
5.4.10	Describe how increased groundwater flows out to sea would be measured and whether such usage would be metered and charged for from the prescribed water resource.	8

Issue ref.	Description	Section
5.4.11	Identify the economic implications for the rock lobster industry from increased groundwater flows and run-off out to sea.	8
5.4.12	Identify the economic implications for groundwater users from groundwater drawdown or contamination, particularly primary producers.	5
5.6.14	Identify the risk to proclaimed water resource (Lacepede-Kongorong Prescribed Wells Area).	5
5.6.15	Identify the risk to the marine environment and the rock lobster industry from increased discharges of groundwater that may potentially be contaminated by fertilisers.	8

1.2 Study Area and Proposed Development

The “study area” comprises the area defined as the Major Project Boundary as shown on Figure 1.2, which comprises:

- Allotment 123 in Deposit Plan 55486 (CT 5863/840);
- Part Section 92 of the Hundred of Mount Benson (CT 5560/348);
- Portion of King Drive;
- Portion of Cape Jaffa Road; and
- An area to sea in Lacepede Bay (out of Hundreds)

in the area named Cape Jaffa.

The proposed development plan assessed for the purpose of this report is shown in Figure 1.3. It should be noted that minor changes have occurred to the proposed development plan during the preparation of this report, however none of these changes have a material impact on the content of this report or its outcomes. The revised plan is shown in Figure 1.4 for comparison.

The topography of the region is characterised by ridges of low sandy dunes and low-lying swampy areas parallel to the coast of Lacepede Bay. During prolonged periods of wet weather, the interdunal low-lying areas are prone to flooding. The region is crossed by several constructed drainage channels designed to drain some of these low-lying areas to maintain agricultural land. The Wongolina/Butchers Drain is the closest drain, located approximately 10 km to the east.

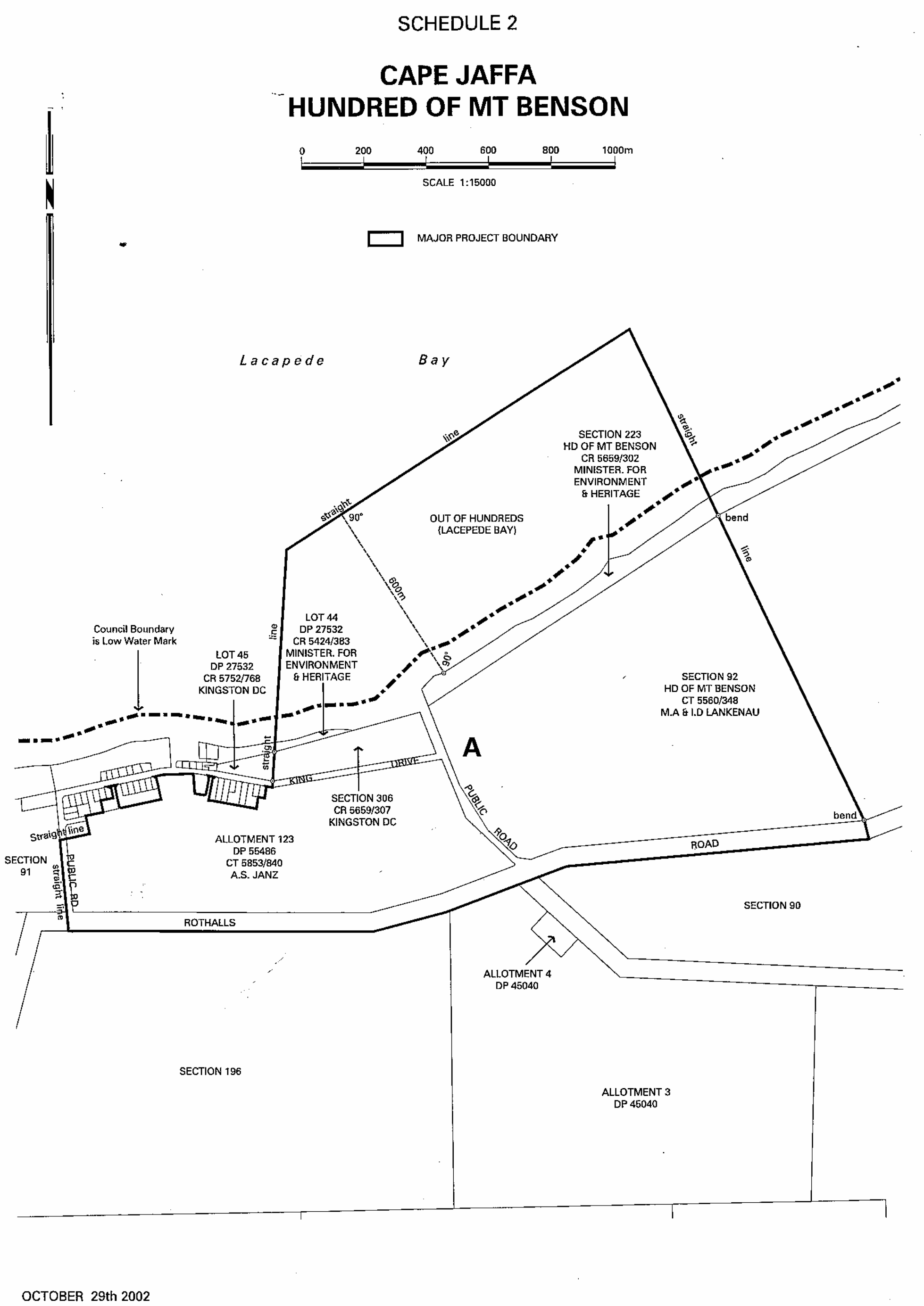


Figure 1.2 Major Projects boundary as gazetted 29 October 2002.

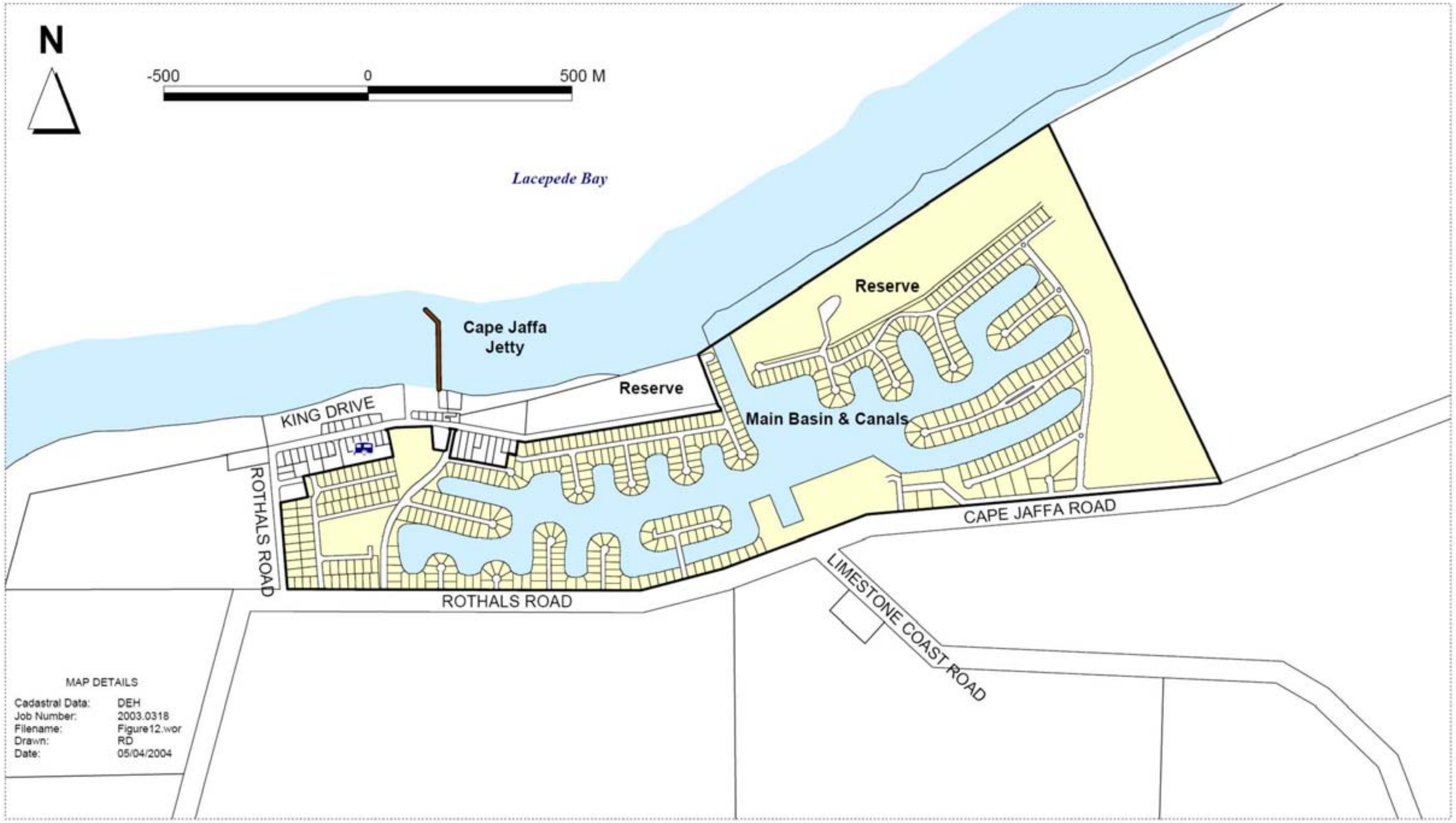


Figure 1.3 Development concept assessed for the purpose of this report.

Figure 1.4 Revised development concept.

1.3 Previous Investigations

> *5.2.2 Detail any groundwater investigations and modelling undertaken on the site or in the locality of the site.*

A considerable amount of work has been carried out on the characterisation of the regional geology and hydrogeology. A number of field investigations and site-specific studies have been completed, including:

- Tonkin Consulting (November 2003), *Cape Jaffa Anchorage Marina, Groundwater Impact Assessment, Volume 1 – Desktop Study and Field Investigations*, ref. 20030318RA4, which included:
  - Review of regional information including geology and soils, hydrogeology, groundwater levels and flow direction, aquifer properties, groundwater quality and usage, registered groundwater users, tidal level and climatic conditions.
  - Drilling of a total of 34 soil bores in June 2003, which were converted to groundwater monitoring wells. All the wells were screened to intersect the shallow unconfined aquifer. The location of these wells is shown on Figure 1.5.
  - A total of three gauging events with groundwater level data collected between June and November 2003.
  - Groundwater sampling and analysis for selected compounds in order to obtain a baseline understanding of the composition of groundwater near the study area.
  - Installation of data loggers within selected wells for the collection of high frequency water level data in order to evaluate the daily groundwater level fluctuation and influence of the tidal fluctuations.
  - Installation of a tidal station at the existing jetty for the collation of high frequency tidal level information that has been used and compared to the groundwater level information.
  - Aquifer tests including falling and rising head tests to determine the hydraulic conductivity of the shallow unconfined aquifer.
- Tonkin Consulting (December 2003), *Cape Jaffa Anchorage Marina, Groundwater Impact Assessment, Volume 2 – Conceptual Hydrogeological Model*, ref. 20030318RA5: Collation of all regional and local information for the development of a conceptual hydrogeological model, including:
  - Climate;
  - Geological information;
  - Identification of aquifers of interest;
  - Groundwater quality;
  - Identification of local groundwater users;
  - Description of known groundwater characteristics including:
    - flow direction
    - level fluctuations

  - aquifer recharge
  - aquifer properties
  - salt/fresh water interface.
- Tonkin Consulting (January 2004), *Cape Jaffa Anchorage Marina, Groundwater Impact Assessment, Volume 3 – Groundwater Flow Model*, ref. 20030318RA6: Development of a site-specific groundwater flow model to assess the impacts of the development on the groundwater system. The groundwater flow model, MODFLOW, was selected for the construction and simulation of groundwater flow at the site. MODFLOW is a three-dimensional finite difference groundwater flow model that is capable of modelling steady state and transient, multi-layered groundwater flow systems. The following conditions have been investigated by the model:
  - Modelling of existing pre-development conditions and calibration of the model against measure site data to determine the existing groundwater outflow to the marine environment over the site area.
  - Modelling of the impact on the groundwater environment during Stage 1 construction dewatering to determine water level changes and aerial extent of water level changes.
  - Modelling of the post-development impact on the groundwater environment to determine:
    - Water level changes and aerial extent of water level changes;
    - Water level impact on adjacent groundwater users; and
    - Groundwater outflow to the marina waterways and the marine environment.

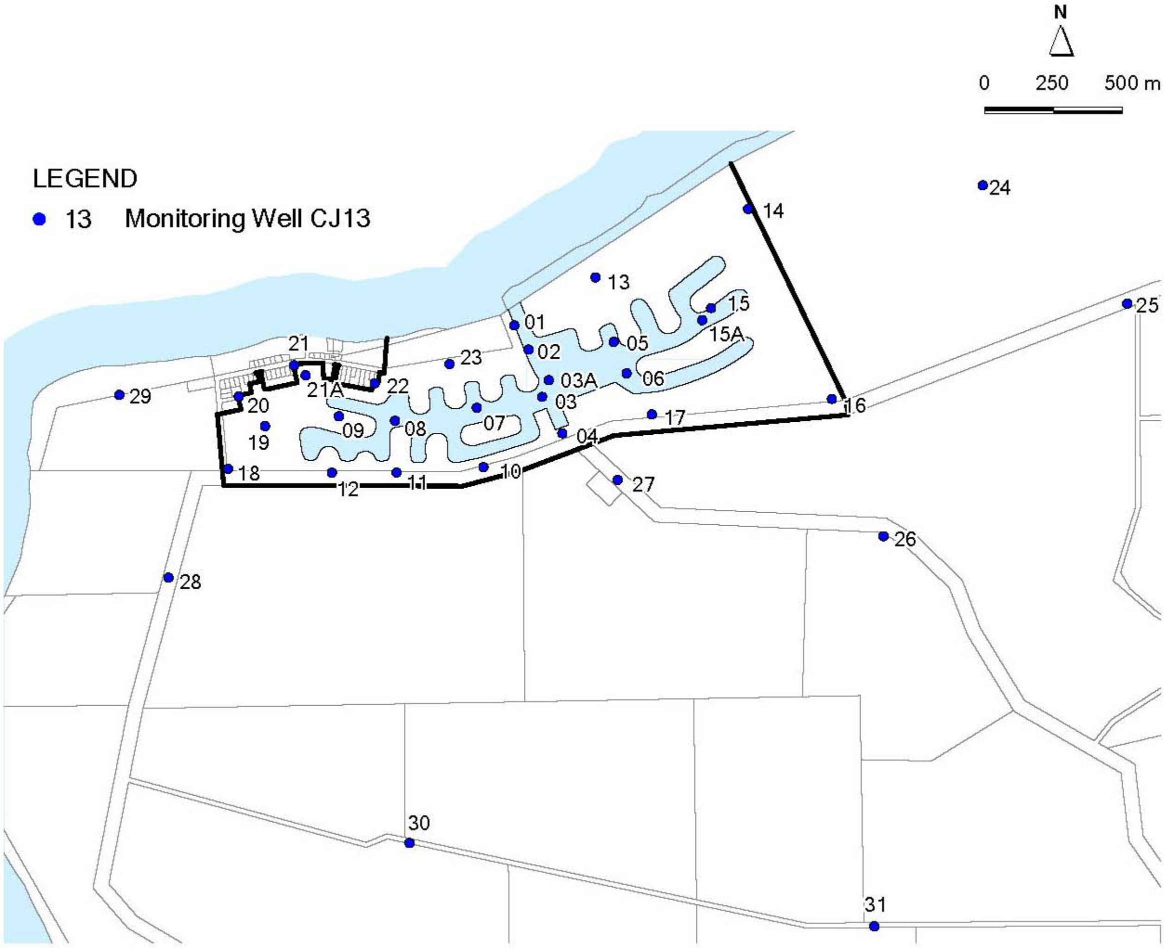


Figure 1.5 Groundwater well location plan.

2. Existing Groundwater Conditions

5.2.1 Describe the known existing groundwater environmental conditions.

5.2.8 Detail any seasonal variations of groundwater level and impact on marina design and off-site operations.

A detailed description of the existing groundwater environmental conditions has been documented in "Cape Jaffa Anchorage Marina, Groundwater Impact Assessment. Volume 2 - Conceptual Hydrogeological Model" (Tonkin, December 2003). The findings from this investigation form the basis of the groundwater impact assessment of the proposed development, including the basis of the design of the groundwater flow model.

A summary of the known existing groundwater environment conditions is presented below.

2.1 Aquifers of Interest

Groundwater flows through two main systems, an upper unconfined aquifer (also referred to as the Tertiary Limestone Aquifer) and a deeper confined aquifer (also referred to as the Tertiary Confined Sand Aquifer). The two aquifers are separated by a clay sequence, which forms the aquitard between the confined and unconfined aquifers.

A schematic diagram illustrating the aquifers of interest is presented as Figure 2.1.

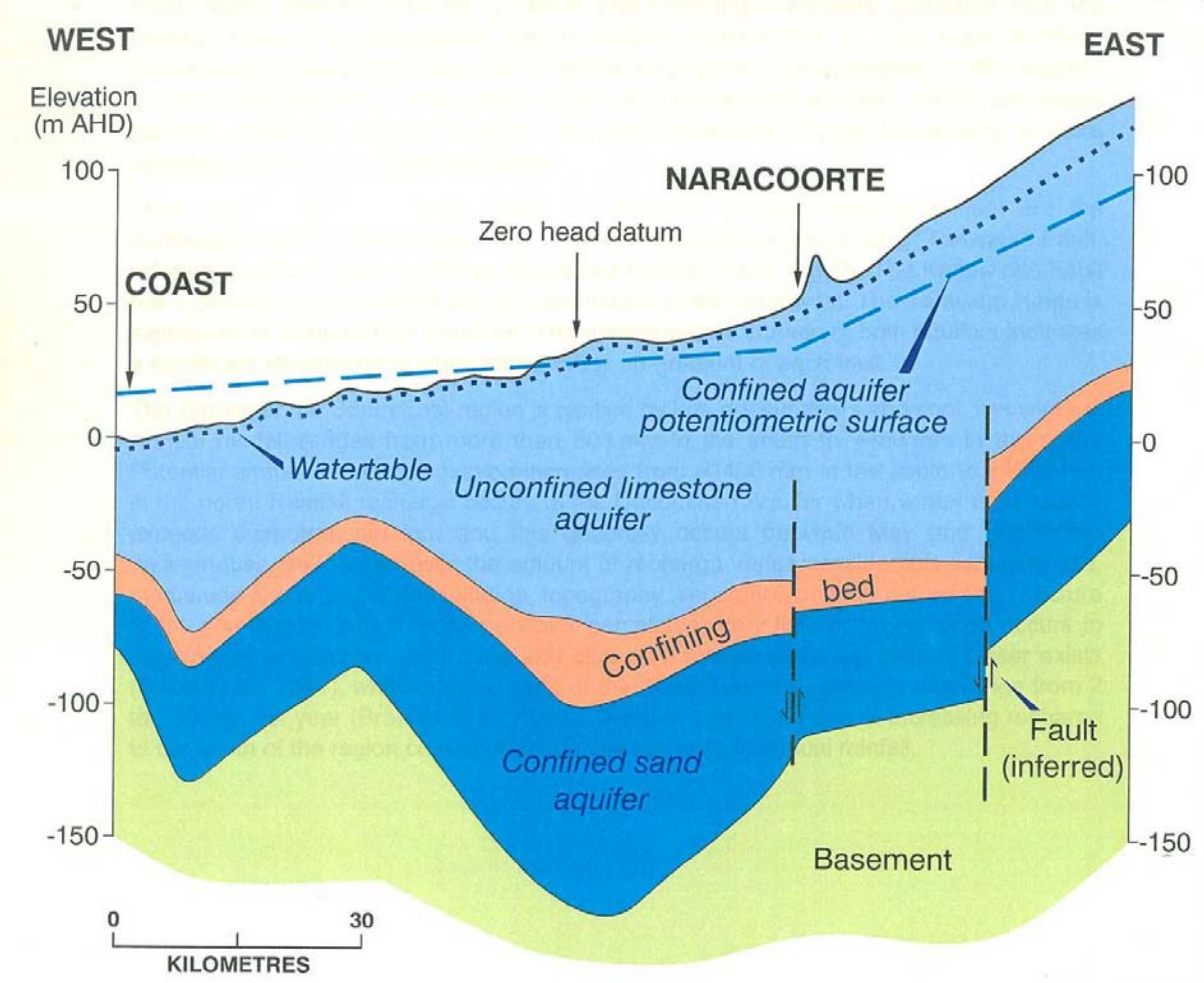


Figure 2.1 Schematic cross section of the Aquifers of Interest, Ref (DWLBC, 2002).

2.2 Existing Groundwater Use

Groundwater is a major source of water supply in the region. Near the study area, the main recorded use of the registered groundwater users is for stock and domestic purposes, as illustrated on Figure 2.2. One well is classified as a town water supply well although no town water supply exists for the Cape Jaffa settlement.

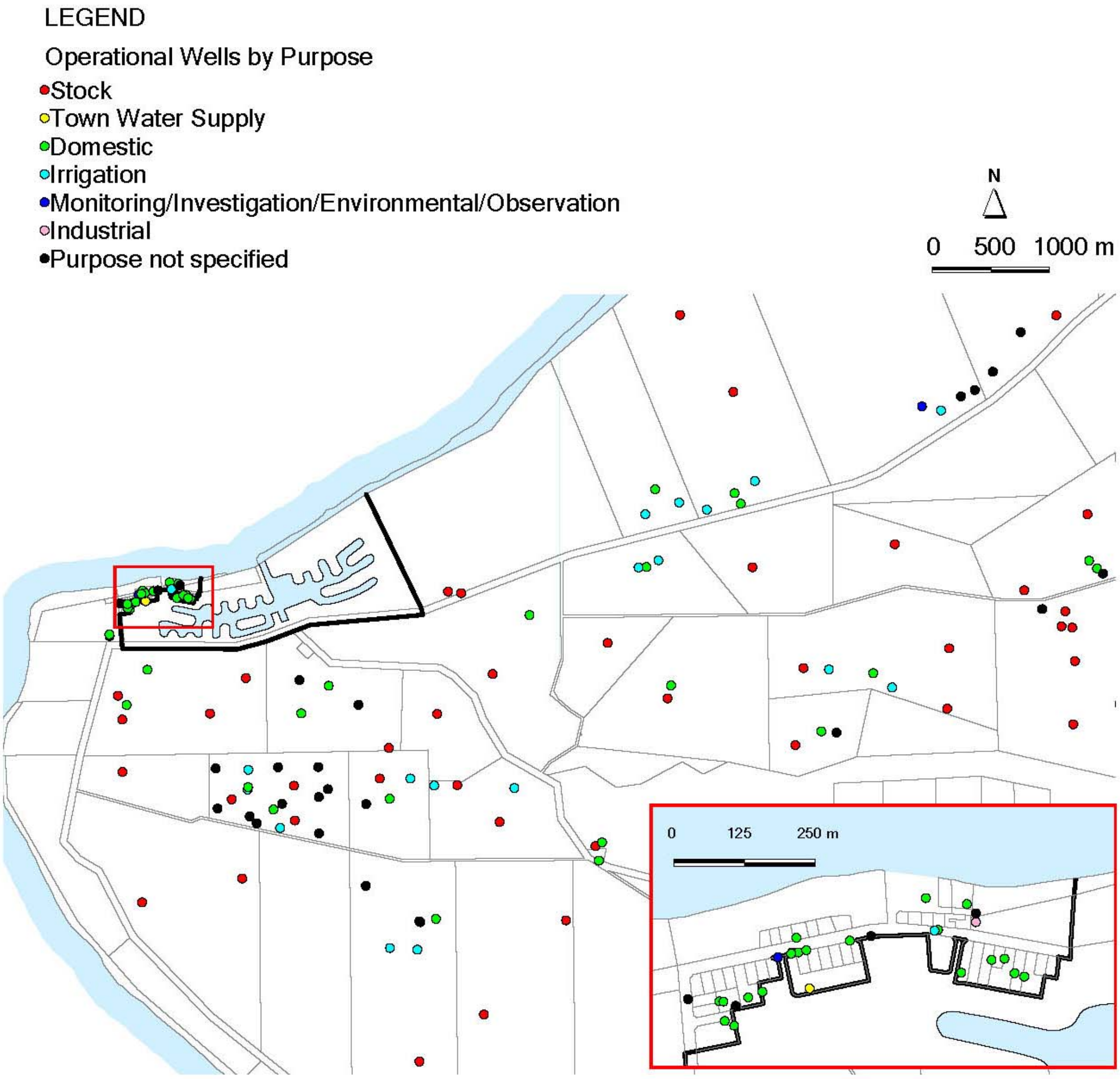


Figure 2.2 Registered groundwater wells and primary purpose near the proposed development site (PIRSA, July 2003).

All registered wells near the study area are drilled to depths less than 20 m below ground level and are expected to intersect the upper unconfined aquifer. There are no registered wells near the study area likely to be extracting groundwater from the confined aquifer. The closest registered operational well intersecting the confined aquifer is registered for stock and domestic proposes and is located approximately 12 km north-east of the study area. A monitoring well operated by the Department of Water, Land and Biodiversity Conservation (DWLBC) exists approximately 5 km east of the study area. Limited data regarding the confined aquifer is available in the immediate vicinity of the study area.

Regionally, the groundwater salinity of both the confined and unconfined aquifers is generally suitable for potable supply. However, the salinity of the unconfined aquifer at some locations is elevated.

Recent field investigation studies of the unconfined aquifer in the study area indicated that the groundwater salinity (measured as total dissolved solids) ranged between 400 and 15,000 mg/L. The distribution of salinity concentrations observed during these investigations is shown on Figure 2.3. In the low-lying areas immediately to the south and to the east of the site salinity was generally greater than 2,000 mg/L, which is likely to be attributable to salt being concentrated due to evaporation of shallow groundwater and little through-flow. Further to the south where the topography rises, salinity was typically less than 1,000 mg/L, therefore being potentially suitable for potable supply in terms of salinity in accordance with the Australian Drinking Water Guidelines (1996).

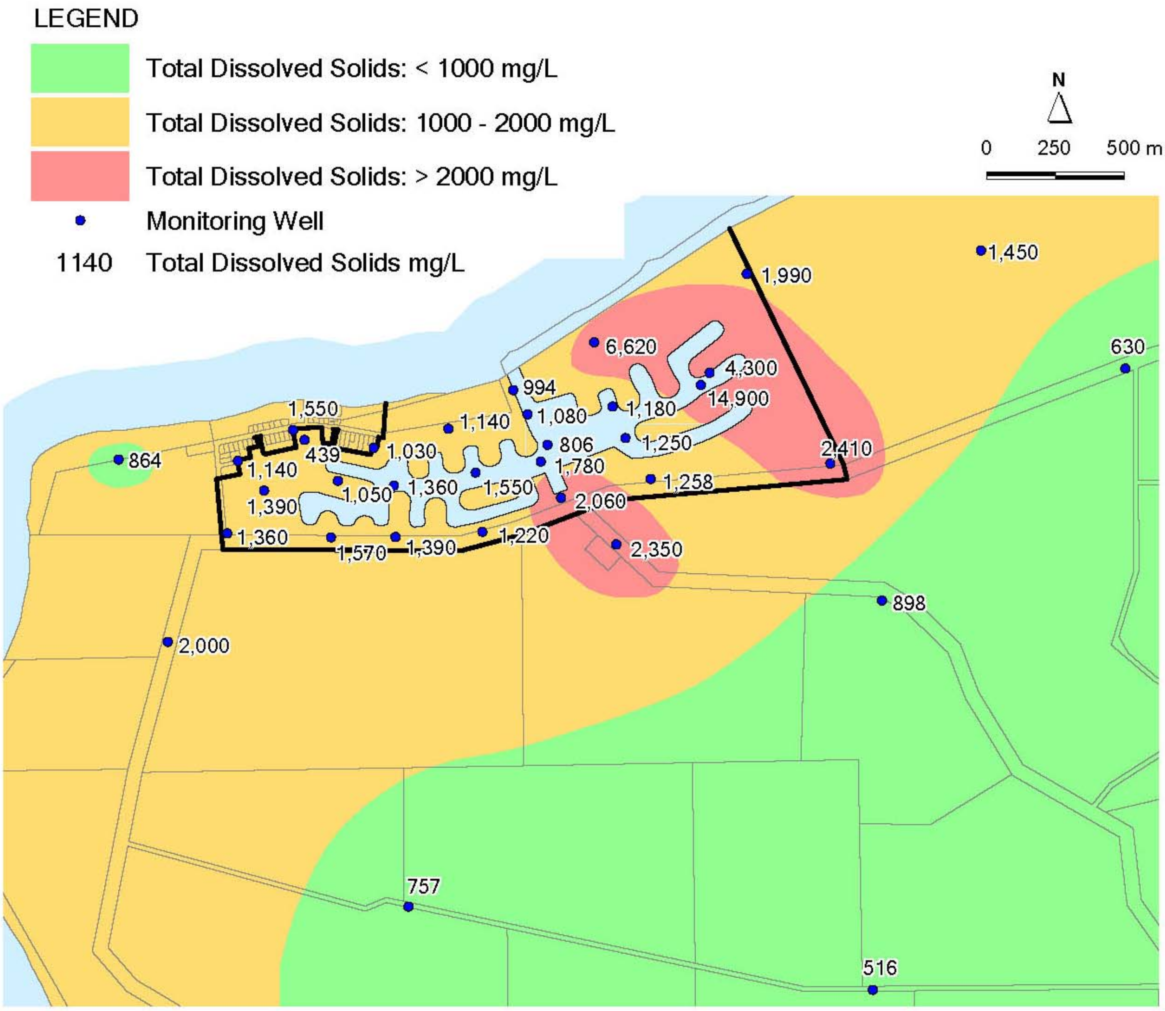


Figure 2.3 Salinity concentration (Total Dissolved Solids) based on field investigations undertaken July 2003.

2.3 Groundwater Flow Direction

The groundwater flow direction in the unconfined aquifer in the study area is towards the shoreline with the ultimate outflow being to the marine environment in Lacepede Bay. The groundwater flow direction encountered during the three gauging events undertaken between July 2003 and October 2003 are shown on Figure 2.4. Regionally, the groundwater flow direction in the confined aquifer is also generally towards to the coast.

2.4 Seasonal Groundwater Level Fluctuations

Groundwater monitoring data held by DWLBC indicates that there are seasonal groundwater level fluctuations in the unconfined aquifer that are generally between 0.5 to 1.0 m in proximity to the study area. This data indicates that the groundwater high generally occurs in early spring and the low in early autumn.

2.5 Tidal Groundwater and Seawater Level Fluctuations

Tidal/sea level variation is discussed in “Climatology of the Cape Jaffa Region. Winds, Waves, Tides and General Climate of the Cape Jaffa Region, SA” (Tonkin Consulting, August 2003). This report notes that there is limited data available in Cape Jaffa, and reference is made to four yeas of data collected from 1980 at Cape Jaffa, and data from the Kingston tide gauge.

Tonkin Consulting (2003) notes that the four years of tidal data from Cape Jaffa showed typical fortnightly neap to spring tide cycles and six monthly cycles in daily tidal ranges. The solstice daily tides (around June and December) range from 0.2 m (neaps) to 1.2 to 1.5 m (springs) while the equinox daily tides (around March and September) range from 0.5 m (neaps) to 0.9 m (springs).

The astronomical tidal range around Kingston SE is generally less than 1 m, though around the solstices and depending on meteorological conditions, the daily tidal range may be 1.2 to 1.5 m.

To assess the influence of tides on groundwater level, high frequency groundwater gauging stations were installed on site at two locations, CJ01 and CJ04 (refer Figure 1.5). A tide gauge was installed at the jetty to collect tidal data at Cape Jaffa.

Data collected between August and November 2003 indicate that the groundwater levels are higher than seawater levels. The hydraulic gradient and hence the direction of groundwater flow for the entire monitoring period is towards the marine environment. This is to be expected based on the regional understanding of groundwater flow.

These recent field investigation studies showed that groundwater levels near the shoreline are influenced by the tidal fluctuations of seawater levels. Groundwater level fluctuations due to tidal seawater oscillation was evident at both locations but the magnitude of the response was more dampened in the distant well (CJ04), which is located approximately 500 m inland compared to CJ01 (located closer to the shoreline).

The groundwater level oscillation induced by tidal variation near the shoreline (at CJ01) was in phase with the tidal seawater level oscillation with little or no delay. Approximately 500 m inland (at CJ04) there is a lag time of approximately 1 to 2 hours. This is consistent with the highly permeable sediments identified in the area.

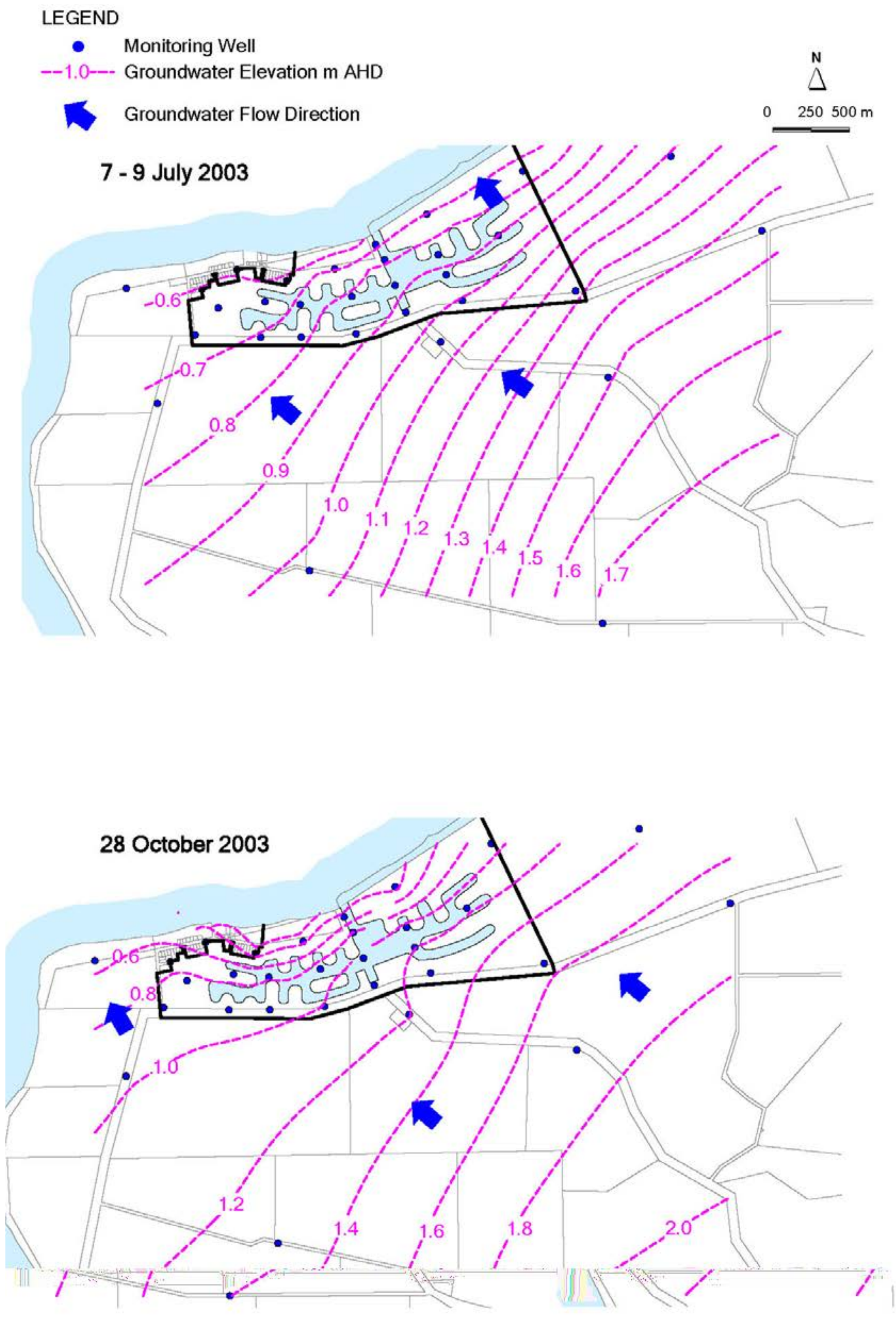


Figure 2.4 Groundwater elevation contours based on recent monitoring well gauging events.

2.6 Aquifer Recharge

There are two principal sources of aquifer recharge: direct infiltration from precipitation and groundwater through-flow from hydraulically up-gradient sources. Aquifer recharge from precipitation is likely to be occurring on site due to high infiltration rates associated with sandy soils and lack of surface drainage features. Recharge is likely to be highest during months when precipitation exceeds evaporation (May to August) or during significant storm events.

Vertical upward recharge from the underlying confined aquifer may be occurring, however, the groundwater flow model indicates that this contribution is likely to be minor. However, there is limited information regarding the confined aquifer near the study area to enable a more detailed analysis of the interrelationship between the confined and unconfined aquifers. Evidence that supports that some vertical upward recharge is occurring includes:

- Published potentiometric surface elevations of the confined aquifer indicate higher groundwater head contours compared to the observed levels of the shallow unconfined aquifer, indicating an upward hydraulic gradient. This is supported by the closest registered wells intersecting the confined aquifer being described as “flowing” wells, suggesting artesian conditions (or an aquifer under pressure).
- Low salinity groundwater within the unconfined aquifer exists near the shoreline, which may be due to recharge from the underlying confined aquifer, or alternatively as a result of sufficient through-flow occurring in the unconfined aquifer and/or aquifer recharge from precipitation.
- Regionally, upward migration from the confined to the unconfined aquifer has been observed due to leaking wells. A program to rehabilitate these wells is currently in place by DWLBC.

2.7 Aquifer Properties

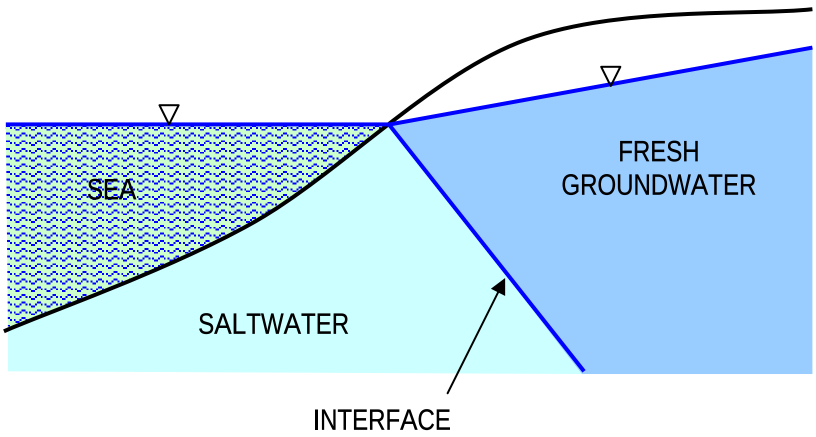
Within the study area, aquifer tests (both falling and rising head tests) were carried out on selected monitoring wells to evaluate the hydraulic conductivity of the shallow unconfined aquifer. The hydraulic conductivity ranged between approximately 1 to 30 m/day with a geometric mean of approximately 5 m/day. An inferred zone of high permeability sediments exists running north-south within the western portion of the study area.

Aquifer properties from regional reports were also sourced to supplement and confirm the data from the local field investigation studies.

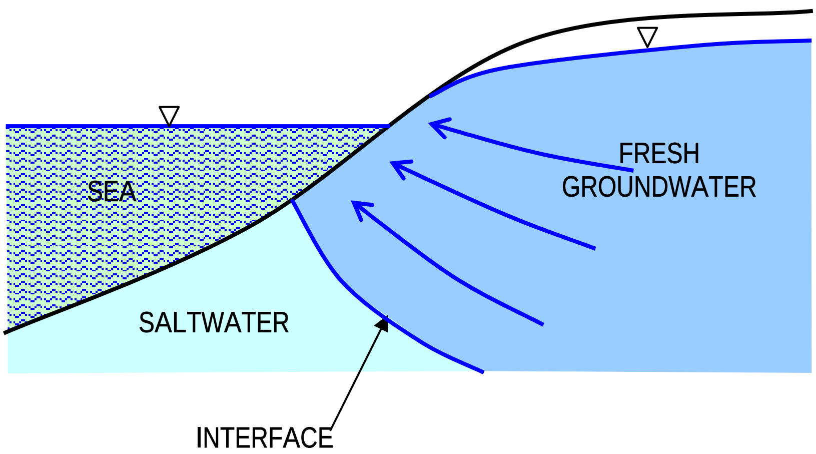
2.8 Freshwater-Seawater Interface

In unconfined coastal aquifers hydraulically connected to the sea, an interface between fresh groundwater and salt water is present. This interface occurs due to the density difference between salt water and fresh groundwater. As salt water is more dense than fresh groundwater, this interface usually projects inland into the aquifer (Freeze and Cherry, 1979). Figure 2.5 illustrates this concept for two situations:

- Under hydrostatic conditions (i.e. no flow); and
- Under conditions of steady-state seaward flow.



(a) Under hydrostatic conditions.



(b) Under conditions of steady state seaward flow.

Figure 2.5 Saltwater/freshwater interface in unconfined coastal aquifers.

This interface is not usually a sharp boundary and a mixing zone and a salinity gradient is often present. The flow conditions within the aquifer determine the location and configuration of the interface. A change in the flow conditions can alter the position of the interface. An example is excessive extraction of groundwater near the coastline which can draw the interface inland and hence impact the sustainability of the water supply.

In order to estimate a range of depths to the seawater interface at Cape Jaffa, the Ghyben/Herzberg relationship has been applied to the groundwater levels measured in July and October 2003. For the purpose of this analysis, sea level has been defined as 0 mAHD. Table 2.1 summarises the results of this assessment. Note that the depths are in metres below ground level (mBGL).

Table 2.1 Estimated Depth to Seawater Interface.

Location	Distance to Coast (metres)	July 2003 Interface Depth (mBGL)	Oct 2003 Interface Depth (mBGL)
Existing settlement	100 to 200 m	23 to 28 m	18 to 33 m
South-west corner of site	500 m	30 m	38 m
South-east corner of site	1,000 m	55 m	63 m

The seawater interface has not been encountered in any of the recently constructed monitoring wells or existing wells near the site, indicating that the seawater interface along the coast at Cape Jaffa is deeper within the unconfined aquifer below these wells. This is consistent with the behaviour of unconfined coastal aquifers within the region, as shallow domestic wells are found near the coast in many coastal towns in the South East of South Australia. At Cape Jaffa the salinity of wells near the coast is low, ie wells of about 1,000 mg/L have been recorded within 100 metres of the coast, thus the transition zone between fresh groundwater and seawater is expected to be narrow.

Based on the current knowledge of the regional hydrogeology and groundwater flow environment, it is expected that the interface in the unconfined aquifer at Cape Jaffa would resemble the situation in Figure 2.5b. The location of the interface will be influenced by the local groundwater extraction, the flow in the unconfined aquifer and the upward pressure from the confined aquifer.

2.9 Groundwater Quality

Thirty-four groundwater-monitoring wells located on and off site were sampled in July 2003. Groundwater samples were analysed for a range of compounds based on a review of historical land uses in the area, providing a “snap shot” of the local groundwater quality near the study area. The purpose of this investigation was to enable assessment of the impact of groundwater quality on the marine environment as a result of groundwater outflow into the marina (refer Section 8).

The results of this investigation indicated the presence of nutrients, in particular Total Nitrogen, Oxidised Nitrogen, Total Organic Carbon and Total Phosphorous, in the groundwater both on site and regionally. This is consistent with the use of fertilisers and the application of animal effluent likely to be associated with agricultural practices and intensive animal husbandry.

The presence of several inorganic compounds including Arsenic, Cadmium and Cyanide were also identified at some locations.

Further information regarding groundwater quality is given in Section 8.3.

3. Groundwater Level Changes

5.2.3 Describe the short and long term effects of establishing channels and basins on groundwater quantity and quality and movement, particularly watertable drawdown or contamination from salt water intrusion.

3.1 Introduction

During excavation of the basins and channels below the water table the associated dewatering activities are likely to result in significant groundwater and possibly seawater inflows into the excavation. The rate of flow into the excavations will be dependent on the heterogeneity of the hydrogeological and geological environment, depth of the excavations, aquifer properties and the rate at which groundwater is extracted during construction. These dewatering activities will cause groundwater drawdown in proximity to the development.

Following construction and introduction of seawater into the basins and channels, the groundwater level gradually reach a new steady state. As sea level is generally lower than existing groundwater levels (refer Section 2.5), the groundwater level for the new steady state condition will be lower than existing levels in proximity to the development.

The predicted effect of establishing the marina basins and channels has been evaluated using the groundwater flow model, which considers three key scenarios:

- Scenario 1: Pre-development conditions
- Scenario 2A: Stage 1 during excavation dewatering
- Scenario 2B: Post-completion of Stage 1
- Scenario 3: Post-development conditions

A detailed discussion on the developed conceptual and numerical hydrogeological model is documented in Tonkin Consulting (2003, Volume 2) and Tonkin Consulting (2004, Volume 3). It is noted that the established model adopts a number of assumptions, which are identified in the referenced reports and effort has been made in the groundwater management plan to address the relevant knowledge gaps (refer Section 9).

To minimise the zone of influence and obtain a field guide to the response of the system, the development will be staged. Stage 1 will be located away from existing groundwater users and located within a lower permeability zone which will minimise impact as more knowledge is gained about the behaviour of the system. The groundwater management plan will include the routine gauging and sampling of nominated wells to monitor the impact of the dewatering program.

3.2 Water Level Impacts of Stage 1 Dewatering

The modelling indicates that the greatest change to groundwater levels will be the temporary effect of the construction dewatering program. Following construction, the channels and basins will be maintained at sea level and the groundwater system will reach a revised equilibrium position over time.

The modelled drawdown influence on groundwater levels during Stage 1 construction dewatering and the location of existing registered wells are shown in Figure 3.1.

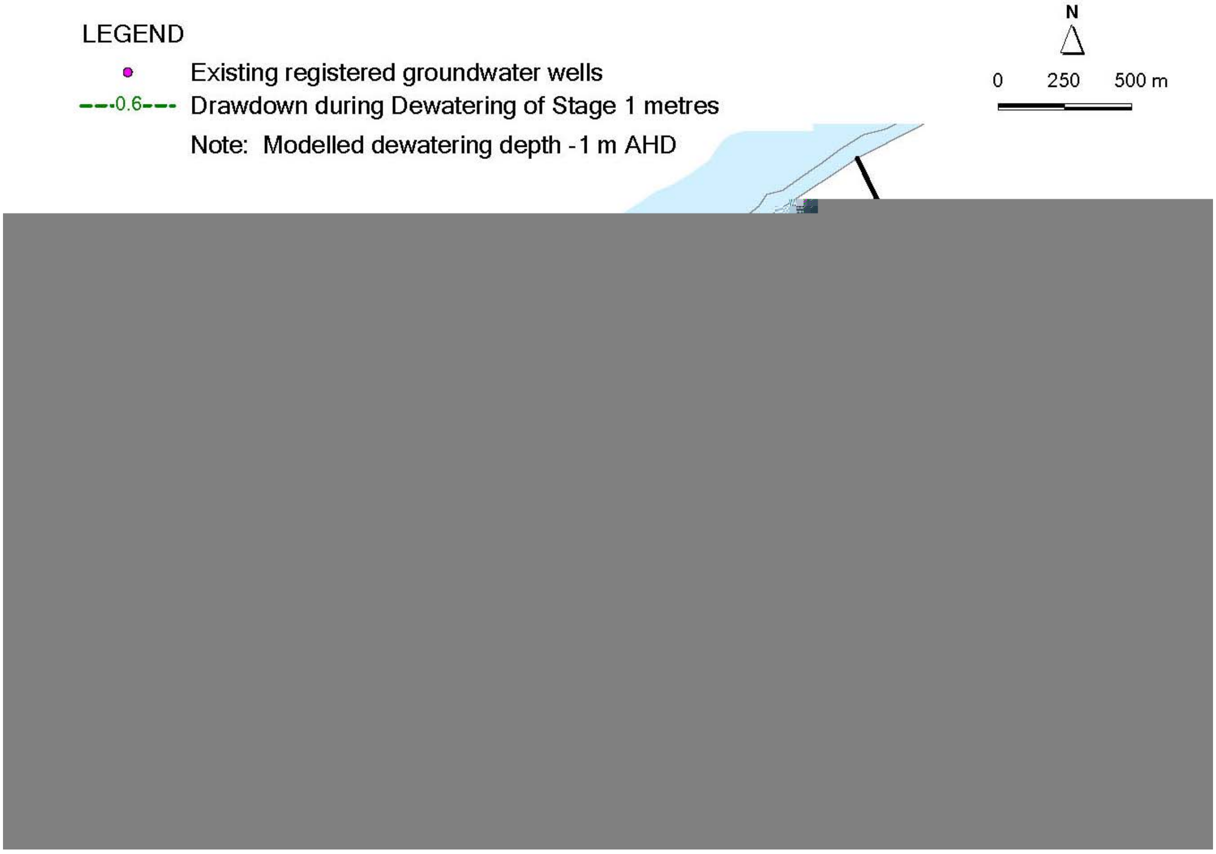


Figure 3.1 Stage 1 development, modelled area of drawdown (assumed dewatering to – 1 m AHD).

3.3 Water Level Impacts Post-Development

The modelled water level contours following construction of all stages of the development, assuming steady state conditions is presented in Figure 3.2. The change in water levels between pre- and post-development is presented in Figure 3.3, including the registered groundwater wells near the proposed development, including the depth of the well.

The model predicts in that water level post-development will be between approximately 0.2 – 0.6 m lower than existing conditions, as shown on Figure 3.3.

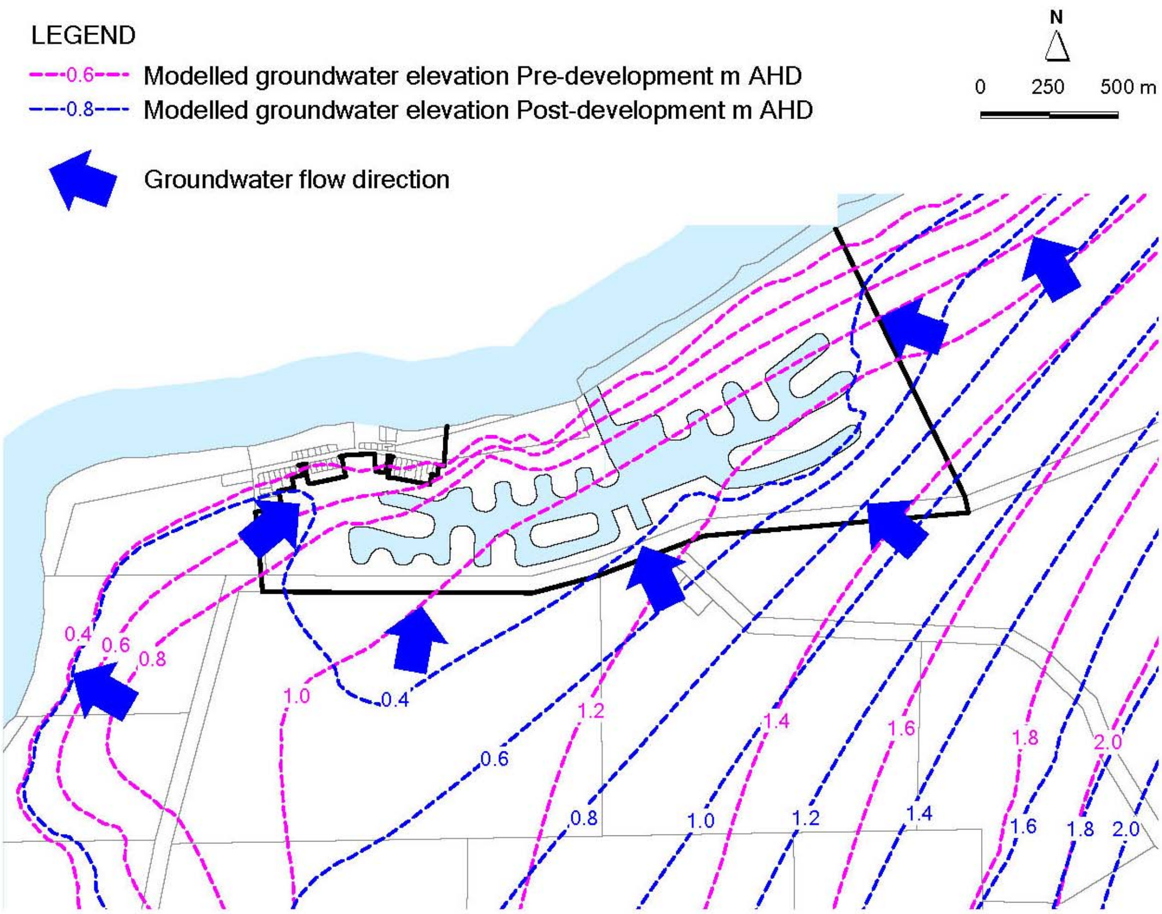


Figure 3.2 Predicted water levels in the unconfined aquifer, pre and post development.

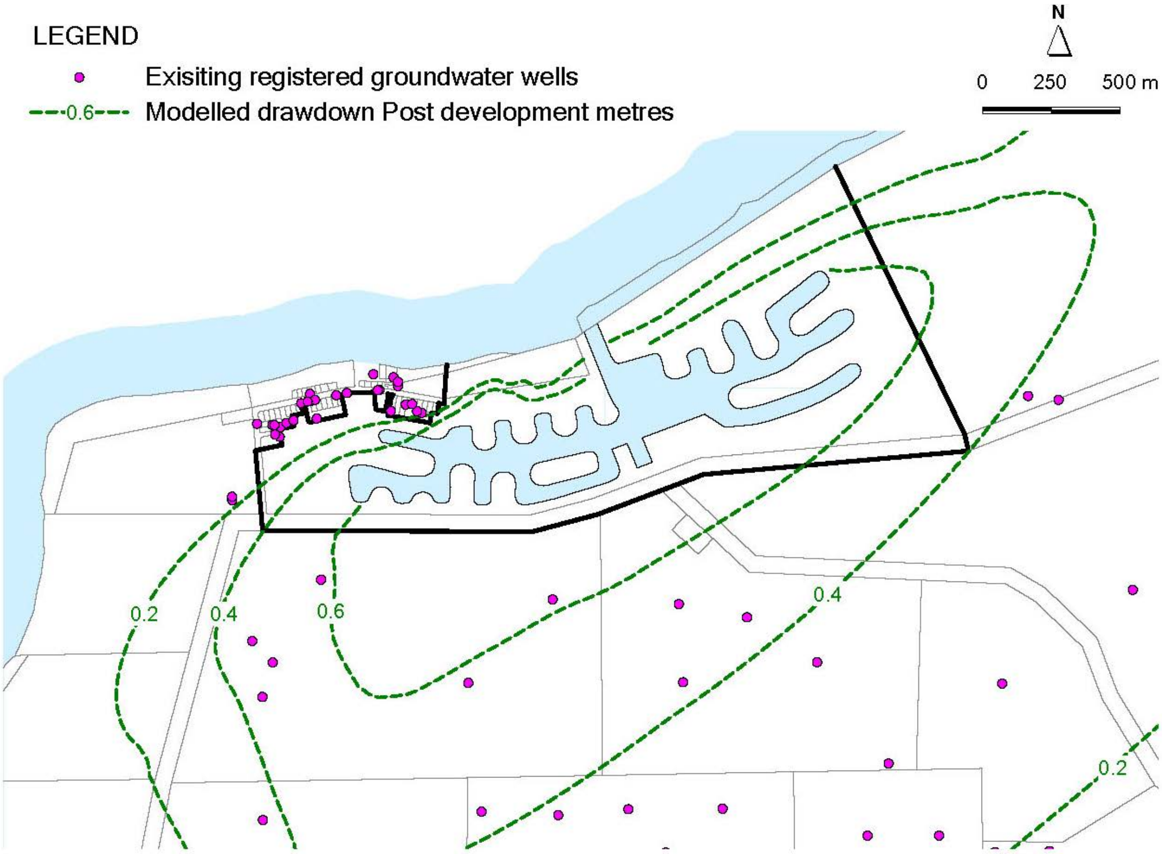


Figure 3.3 Predicted change in water level (pre-development to post development) in relation to registered groundwater wells.

4. Salt Water Intrusion

5.2.3 Describe the short and long term effects of establishing channels and basins on groundwater quantity and quality and movement, particularly watertable drawdown or contamination from salt water intrusion.

4.1 Salt Water/Fresh Water Interface Effects

As indicated in Section 2.8, the shape and position of the interface between salt water and fresh groundwater is a function of the flow conditions within the aquifer. Any action that changes the volume of fresh water outflow may result in a consequent change in the salt water/fresh water boundary. There is no evidence to suggest that current activities (groundwater extraction, aquifer recharge and tidal actions) are significantly adversely influencing the groundwater quality or that any significant salt water encroachment is occurring.

Salt water encroachment as a result of changes to the salt water/fresh water interface can either be active or passive (Fetter, 2001). Active salt water encroachment occurs when the natural hydraulic gradient is reversed and hence the natural flow direction toward the coast is reversed. In this situation groundwater flows inland which shifts the salt water/fresh water interface also inland. This can occur as a result of excessive or unsustainable groundwater extraction from an area.

Passive conditions occur when some local changes to the flow conditions occur but the hydraulic gradient remains towards the shoreline. In this case, the interface will slowly shift landward until it reaches a “revised” equilibrium position. Passive salt water encroachment is taking place today in many coastal aquifers where groundwater resources are being developed (Fetter, 2001) and is less severe as the boundary zone moves much more slowly compared to active salt water encroachment.

A variation of passive encroachment is seawater coning which occurs when groundwater is extracted from a well located above the seawater interface near the coast, particularly at high extraction rates. During extraction, the groundwater levels near the well are temporarily lowered and a cone of elevated seawater is formed. If the seawater cone is raised sufficiently to reach the well, then seawater will flow to the well and result in seawater intrusion.

4.2 Potential Seawater Intrusion at Cape Jaffa

None of the existing wells at Cape Jaffa or the wells drilled during the recent investigations exhibit elevated salinity levels consistent with seawater intrusion or encroachment, nor has the seawater interface been intersected by wells drilled during the recent investigations. The salinity of wells near to the coast is low compared to seawater (about 1,000 mg/L within 100 metres of the coast) and the interface is understood to exist seaward and below the influence of these wells. This is consistent with the behaviour of unconfined coastal aquifers within the region as shallow domestic wells are found near the coast in many coastal towns in the South East of South Australia. The existing location of the seawater interface is discussed in more detail in Section 2.8.

No active seawater intrusion occurs as a result of the waterways once they are established, as groundwater levels are not lowered below seawater level. In the short term, active seawater intrusion may occur temporarily during construction if dewatering of excavations is required to below sea level. The effects of active seawater intrusion will take some time to reach the dewatered zone and will only be observed on the seaward side of excavations. The effects are minimised by staging the construction of the waterways and reducing the duration, extent and depth of each dewatering event.

Once the waterways are established, the groundwater levels and flows in the vicinity of the waterways will change. Longer term effects could occur as a result of three factors:

- the groundwater of the peninsula between the waterways and the existing coastline will receive recharge from incident precipitation and only minimal groundwater through-flow. The recharge may not be sufficient to support viable long term groundwater extraction for potable use in this area;
- where groundwater flow to the coast is reduced, the interface will shift upward and extend landward beneath the fresh groundwater at a shallower angle (passive encroachment); and
- the edges of the waterways will effectively create new “coastline” inland of the existing coast and a seawater interface will be established around the waterways which will be closer to some of the existing wells.

These factors are discussed in relation to various areas adjacent to the waterways as set out below.

4.2.1 Eastern End of the Cape Jaffa Settlement

The eastern end of the Cape Jaffa settlement will be located on a peninsula between the waterways and the coast and groundwater extraction in this area is likely to be effected by seawater intrusion over time.

As discussed previously, the initial stages will not result in adverse effects as the development has been staged such that construction activities commence away from the existing settlement.

4.2.2 Western End of the Cape Jaffa Settlement

At the western end of the Cape Jaffa settlement it is expected that the groundwater flow to the coast will be reduced and the interface will shift upward such that it extends into the aquifer at a shallower angle (passive encroachment). Thus existing wells located above the seawater interface are subject to increased risk of seawater coning during extraction. The extent of increased risk is dependant upon the rate of groundwater extraction, the well's depth and the proximity of the well to the waterways and the coast. The potential effects progressively diminish to the west as the distance from the waterways increases.

Again, adverse effects of the initial stages are not expected as the development has been staged such that construction activities commence away from the existing settlement .

4.2.3 Adjacent to the Waterway (< 750m)

Areas within 750 metres of the waterways effectively become closer to the new "coastline" and consequently closer to the seawater interface. Despite being closer to the new coastline, the net flow of groundwater across this area does not change and availability of the groundwater resource will not be reduced.

The existing uses, such as domestic and stock watering, are unlikely to be effected by the changes to the location of the interface because the volume of groundwater extraction associated with these uses is generally low. Within this area there are no apparent major uses such as broad scale irrigation. Should any future major groundwater extraction be proposed in this area, it must have regard for the location of the seawater interface and be managed to prevent potential degradation of water quality. This type of management is typical of any major groundwater extraction regime in proximity to the coast, in order to avoid potential seawater intrusion.

4.2.4 Further from the Waterways (> 750m)

Areas beyond those adjacent to the waterways described above are unlikely to be effected. Within this area, the higher watertable elevation and greater distance from the waterways mitigates potential effects so that changes to the seawater interface are unlikely to cause any measurable effect.

The majority of existing registered wells located up to 3.0 kilometres south of the waterways are constructed to less than 15 metres below ground level. Based on the modelled post construction groundwater levels, at a distance of 1.4 to 2.0 kilometres south of the waterways, the minimum depth of the interface varies from 35 to 95 metres below ground level (estimated using the groundwater monitoring data from CJ30 and CJ31) and the depth of the interface increases towards the south east. Within the eastern part of this area the interface may be below the base of the aquifer and therefore the aquifer may consist entirely of fresh groundwater.

4.2.5 Town Water Supply

A change to the existing groundwater extraction regime may affect the position of the salt water interface, particularly if increased extraction occurs in areas immediately adjacent the proposed development.

It is anticipated, however, that the provision of a town water supply associated with the development is likely to result in a decrease in groundwater extraction in the areas immediately adjacent to the proposed waterways in the unconfined aquifer.

The possible sources of water for the proposed town water supply includes deeper sections of the unconfined aquifer or the confined aquifer unit. The selection of the most feasible option will consider the current location of the fresh water/salt water interface in both the unconfined and confined aquifers and the availability and sustainability of supply. In addition, the following will need to be considered in the selection of the most appropriate supply source:

- The competence of the aquitard between the confined and unconfined aquifers which will have an impact on each aquifer’s ability to provide a sustainable supply without salt water encroachment occurring.
- The zone of influence caused by groundwater extraction from the confined or unconfined aquifers in the vicinity of the fresh water/sea water interface.

To address the issues raised above, and confirm the assumptions made, the proposed groundwater management plan includes further field studies including hydrogeological investigation of the confined aquifer and its ability to provide and reliable and sustainable water supply.

These additional studies, including the established groundwater flow model, will assist in evaluating the most feasible groundwater supply option to minimise potential future salt water encroachment issues. A groundwater gauging and sampling program will also be incorporated into the groundwater management plan (refer Section 9), which will also assist in monitoring changes to the system.

4.3 Intertidal Mixing

As a result of the movement of water landward and seaward in response to tidal levels, an intertidal mixing zone between salt water and groundwater is likely to develop. This intertidal mixing zone would consist of a fringing area of variable water quality around the perimeter of marina waterways.

Salt water intrusion as a result of intertidal mixing is currently not significant along the shoreline, as illustrated by the fact that it has not been identified in recent field investigations undertaken along the coast. Therefore, the intertidal mixing zone as a result of the development is expected to be limited, potentially up to approximately 50 m in width fringing the perimeter of the marina waterways.

5. Impact on Existing Groundwater Users

5.2.23 Described the effect of water table drawdown or contamination on local domestic water supplies, including that used for drinking and the watering of gardens.

5.3.17 Describe the impact of groundwater drawdown or contamination on the source and use of domestic water.

5.4.12 Identify the economic implications for groundwater users from groundwater drawdown or contamination, particularly primary producers.

Existing groundwater users located near the development area extracting groundwater from the upper sections of the unconfined aquifer may be impacted by the proposed development by changes to groundwater levels or salt-water intrusion. These impacts are discussed below.

5.1 Groundwater Level Effects

As indicated in Section 3.3, the change in water level as a result of the development is estimated to be between approximately 0.2 – 0.6 m lower than existing conditions, based on the groundwater flow model.

The resulting impact on groundwater users would be the loss of available head of water for extraction. Based on the recent gauging results, the average depth to groundwater is approximately 3 m below ground level. The average depth of the registered wells is 8 m below ground level, as illustrated on Figure 5.1. The head of water available for extraction (assuming that the pump is located at the bottom of the well) is approximately 5 m, pre-development conditions. Therefore, as a result of the development, it is estimated that the general change in head of water available for extraction by existing users could be altered from approximately 5 m to approximately 4 – 4.5 m.

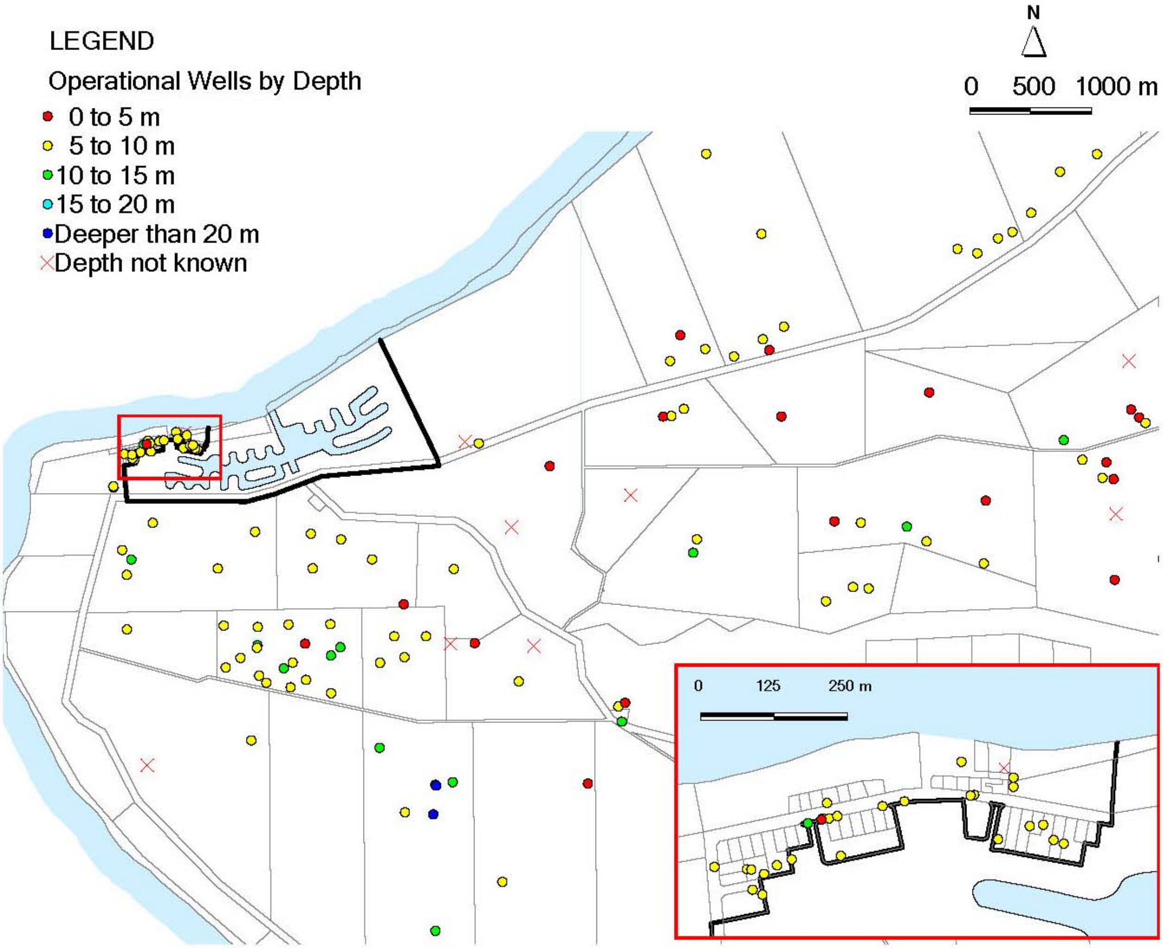


Figure 5.1 Registered groundwater wells by depth (m below ground level) near the proposed development site (PIRSA, July 2003).

The model predicts that the cluster of registered wells near the Cape Jaffa settlement would not be significantly impacted. A majority of these wells may experience a change in water level of approximately 0.2m and several wells located closer to the development may be impacted by approximately 0.4 m.

During the construction stage of the basins and channels, groundwater level change may be experienced due to dewatering operations, and this will be monitored and managed in accordance with a Groundwater Monitoring Plan (refer Section 9).

As indicated by tidal variation in the current groundwater environment, groundwater users located up to approximately 500 m from the marina development may also experience tidal fluctuations. However, the magnitude of this variation is likely to reduce significantly with distance, with fluctuations of approximately 0.3 m experienced 50 m from the marina as indicated by current conditions. It is expected that the majority of the existing groundwater users currently located similar distances (or closer) to the existing shoreline are currently experiencing tidal variations.

5.2 Salt Water Intrusion Effects

It is expected that the proposed development will result in changes to the existing seawater interface within the unconfined aquifer. The nature and location of the existing seawater interface is discussed in detail in Section 2.8, and the effects of establishing the waterways on the location of the seawater interface is discussed in detail in Section 5.2.3.

Active seawater intrusion is not expected to occur other than for short durations in localised areas during dewatering. This is not expected to adversely affect the groundwater nearby the development. The effects are minimised by staging the construction of the waterways to reduce the duration, extent and depth of each dewatering event.

The wells at the eastern end of the Cape Jaffa settlement will be located on a peninsula between the waterways and the coast and groundwater extraction in this area is likely to be effected by seawater intrusion over time. At the western end of the Cape Jaffa settlement, the seawater interface will shift upward to extend into the aquifer at a shallower angle. Existing wells at the western end of the Cape Jaffa settlement are subject to increased risk of seawater coning, depending on extraction rate, depth and location and the potential effects progressively diminish to the west as the distance from the waterways increases. Adverse effects of seawater intrusion on existing groundwater uses within the remainder of the locality are unlikely.

Ongoing monitoring and assessment will be undertaken during the first stages of the development prior to the later stages of construction of waterways.

The staged construction of the waterways minimises risks to the groundwater environment and nearby groundwater users as it minimises the zone of influence around each stage of the waterways and locates early stages away from the existing groundwater users. This allows additional investigations to be performed and greater understanding to be gained well before any risks to existing uses of the aquifer arise.

Further assessment and monitoring of the impact to groundwater users is proposed as part of the Groundwater Monitoring Plan (refer Section 9).

5.3 Groundwater Quality Effects

Based on the design principles proposed for the marina, the proposed development is unlikely to have a significant impact on groundwater quality, other than changes to salinity referred to above. Therefore, it is considered that there would be no notable change in groundwater quality as a result of the development.

5.4 Assessment of Impacts on Groundwater Users

The construction of the marina is anticipated to impact groundwater resources in the area immediately adjacent the site by causing localised changes to groundwater level (0.2 - 0.6 m lower than pre-development conditions), minor salt water intrusion fringing the basins and channels (up to approximately 50 m from the waterways) and local changes to the groundwater flow conditions and salt water/fresh water interface.

These changes may impact groundwater users in close proximity to the development area. These users, along with the Cape Jaffa settlement will have the opportunity to connect to an improved alternative water supply, that being the town water supply associated with the development.

6. Impact on Land Use

5.3.10 Describe the impact of local and regional land uses (eg. Viticulture, horticulture and other forms of primary production) from groundwater drawdown or contamination.

5.2.5 Detail the impact on land and native vegetation of the off-site depression of the water table and outline the extent of groundwater depression and effect on farming and horticulture and other operations within the groundwater depression zone.

As discussed in Section 3, a groundwater level change as a result of the development is estimate to be between approximately 0.2 and 0.6 m. Within the zone in which water level influence is expected as a result of the proposed development, the land is principally used for residential purposes within the Cape Jaffa settlement and for agricultural purposes.

Agricultural land in the area is principally used for grazing and it is considered unlikely that the changes to the groundwater system would have adverse impact on this land use. The lower lying area to the south of the proposed development may experience improved drainage as a result of a change to groundwater levels. This may be offset by issues relating to potential acid sulfate soils which may exist in this area which could influence agricultural productivity. Acid sulphate soils have been assessed separately.

Impacts to land and native vegetation have been assessed by others. These investigations have been based, in part, on the results of the groundwater investigations and modelling performed as part of this report.

7. Risks to the Prescribed Water Resource

5.6.14 Identify the risk to proclaimed water resource (Lacepede-Kongorong Prescribed Wells Area).

The impact of the overall development on the proclaimed water resource will be localised. As such, the impact on the Lacepede-Kongorong Prescribed Wells Area is expected to be negligible other than within the immediate vicinity of the marina site.

Impacts in proximity to the marina site may include localised changes to groundwater level, minor salt water intrusion fringing the waterways associated with the development and local changes to the groundwater flow conditions, as discussed in Section 5.

8. Groundwater Outflow to Marine Environment

5.2.6 Describe the likely effects on marine organisms, reef communities and seagrasses, given groundwater flow out to sea is likely to increase, potentially reducing the salinity and increasing nutrients and pollutants, particularly heavy metals.

5.2.7 Detail management systems to control the quality and quantity of outflow from the marina given that it is likely to become a sump for groundwater or high freshwater flows that may affect marine organisms.

5.4.10 Describe how increased groundwater flows out to sea would be measured and whether such usage would be metered and charged for from the prescribed water resource.

5.4.11 Identify the economic implications for the rock lobster industry from increased groundwater flows and run-off out to sea.

5.6.15 Identify the risk to the marine environment and the rock lobster industry from increased discharges of groundwater that may potentially be contaminated by fertilisers.

8.1 Groundwater Outflow

The construction of marina will change local flow conditions. As the levels in the marina will be maintained at sea level, which is lower than existing groundwater levels, some of the groundwater flow surrounding the development will be re-directed towards the marina in the unconfined.

As there is no additional water added or removed from the unconfined aquifer system as a result of the development, the regional total groundwater outflow to the marine environment would not be changed. The changes to groundwater flow conditions as a result of the development will be a re-distribution of flows. The marina will act as a conduit for groundwater flow and will create a concentrated outflow point through the entrance to the marina to the marine environment.

The above concepts are illustrated in Figure 8.1 and Figure 8.2.

PRE-DEVELOPMENT

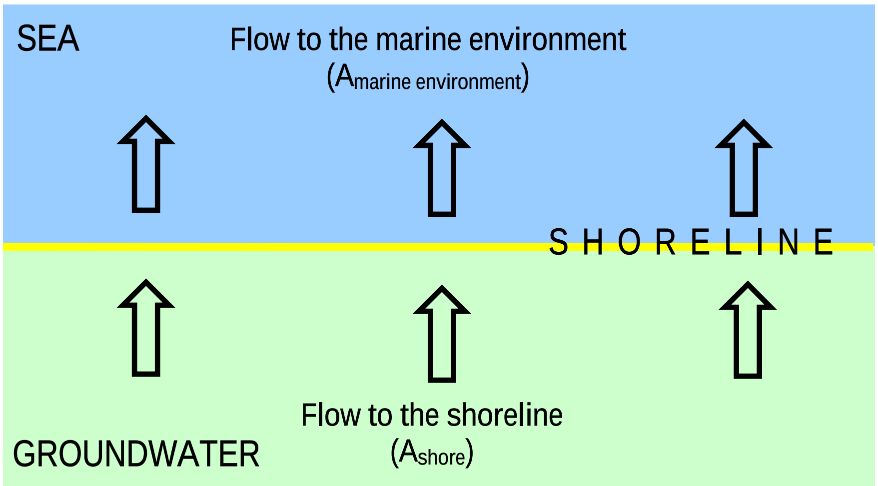


Figure 8.1 Conceptual groundwater flow in the unconfined aquifer – pre-development.

POST-DEVELOPMENT

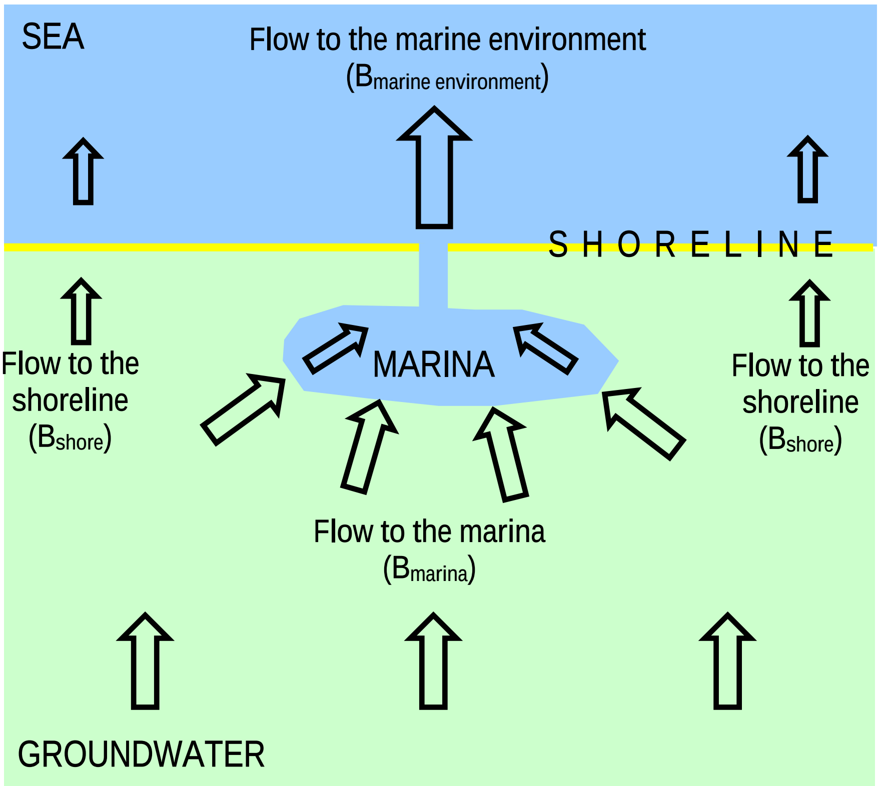


Figure 8.2 Conceptual groundwater flow in the unconfined aquifer – post-development.

As illustrated conceptually in Figure 8.1, for the pre-development situation, the flow to the marine environment is equal to the flow to the shoreline, i.e.:

$$A_{marine\ environment} = A_{shore}$$

Post-development the flow has is re-directed, as illustrated conceptually in Figure 8.2. For this situation, the flow to the marine environment is equal to the flow to the shore plus the flow to the marina, i.e.:

$$B_{marine\ environment.} = B_{shore} + B_{marina}$$

In addition, as there is no additional water added or removed from the system, the flow to the marine environment in the pre-development situation is equivalent to the post-development situation, i.e.:

$$A_{marine\ environment} = B_{marine\ environment}$$

The groundwater flow model predicts that the average groundwater flow that will be diverted into the marina following completion of the development (B_{marina}) will be approximately 900 m^3/day. This value has been used in assessing the impact of a concentrated groundwater outflow to the marine environment.

For comparison, WBM (2004) undertook modelling of the expected tidal exchange within the marina during various tidal conditions. During worst-case conditions (neap tide), the tidal exchange within the marina was estimated to be approximately 170,000 m^3/day.

8.2 Impact of Groundwater on Seawater Salinity

The tidal exchange within the marina predicted by WBM (2004) is several orders of magnitude higher than the predicted groundwater outflow to the marina post-development. Therefore the potential influence of groundwater outflow on salinity in the marine environment is considered to be negligible.

This assumes that the groundwater would be fully mixed with sea water within the marina. Given the small quantity of fresh groundwater compared to the tidal exchange (refer WBM, 2004) it is anticipated that any stratification due to density variations between fresh groundwater and seawater will be broken up by current, wave and wind action within the marina.

8.3 Impact of Groundwater Quality

Groundwater within the unconfined aquifer currently flows to the marine environment. Any pollutants that exist within this aquifer are likely to ultimately enter to the marine environment via this flow path. As indicated in Section 5.3, the proposed development is unlikely to have a significant impact on groundwater quality, however, the construction of the marina will create a conduit for groundwater flow which will enter the marine environment at a concentrated point (i.e. the marina entrance).

The following methodology has been used to assess the impact of groundwater quality on the marine environment as a result of construction of the marina:

- Sampling and analysis of groundwater wells;
- Comparison of results to published guidelines and criteria;
- Assessment of the dispersion and mixing effects due to tidal exchange within the marina;
- Assessment of the potential impacts to the marine environment (by others).

8.3.1 Existing Groundwater Quality

As indicated in Section 2.9, thirty-four groundwater-monitoring wells located on and off site were sampled in July 2003. Groundwater samples were analysed for a range of compounds based on a review of historical land uses in the area, providing a “snap shot” of the local groundwater quality near the study area.

Groundwater analytical results were compared to the *Environment Protection (Water Quality) Policy 2000*, Schedule 2 – Water Quality Criteria for Marine Aquatic Ecosystems (EPP Marine). Where the EPP Marine provides no criteria for a particular compound, reference was made to *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPC, 1999) for protection of marine ecosystems (NEPM Marine).

Concentrations of compounds reported above the EPP Marine are discussed in more detail in Volume 1 and 2 (Tonkin Consulting, 2003) with a summary presented below.

Organic Compounds

Samples were analysed for a range of organic compounds, all of which had concentrations below the detection limit of the laboratory. These compounds included:

- Speciated Phenols;
- Organochloride Pesticides/Organophosphate Pesticides;
- Total Petroleum Hydrocarbons;
- Benzene, Toluene, Ethylbenzene and Xylenes;
- Polycyclic Aromatic Hydrocarbons;
- Volatile Organic Compounds; and
- Semi-volatile Chlorinated Compounds.

Nutrients

The measured concentrations of Phosphorous, Total Organic Carbon, Total Nitrogen and Oxidised Nitrogen are higher than the EPP Marine at a number of locations both on site and regionally, as shown in Figure 8.3 to Figure 8.6.

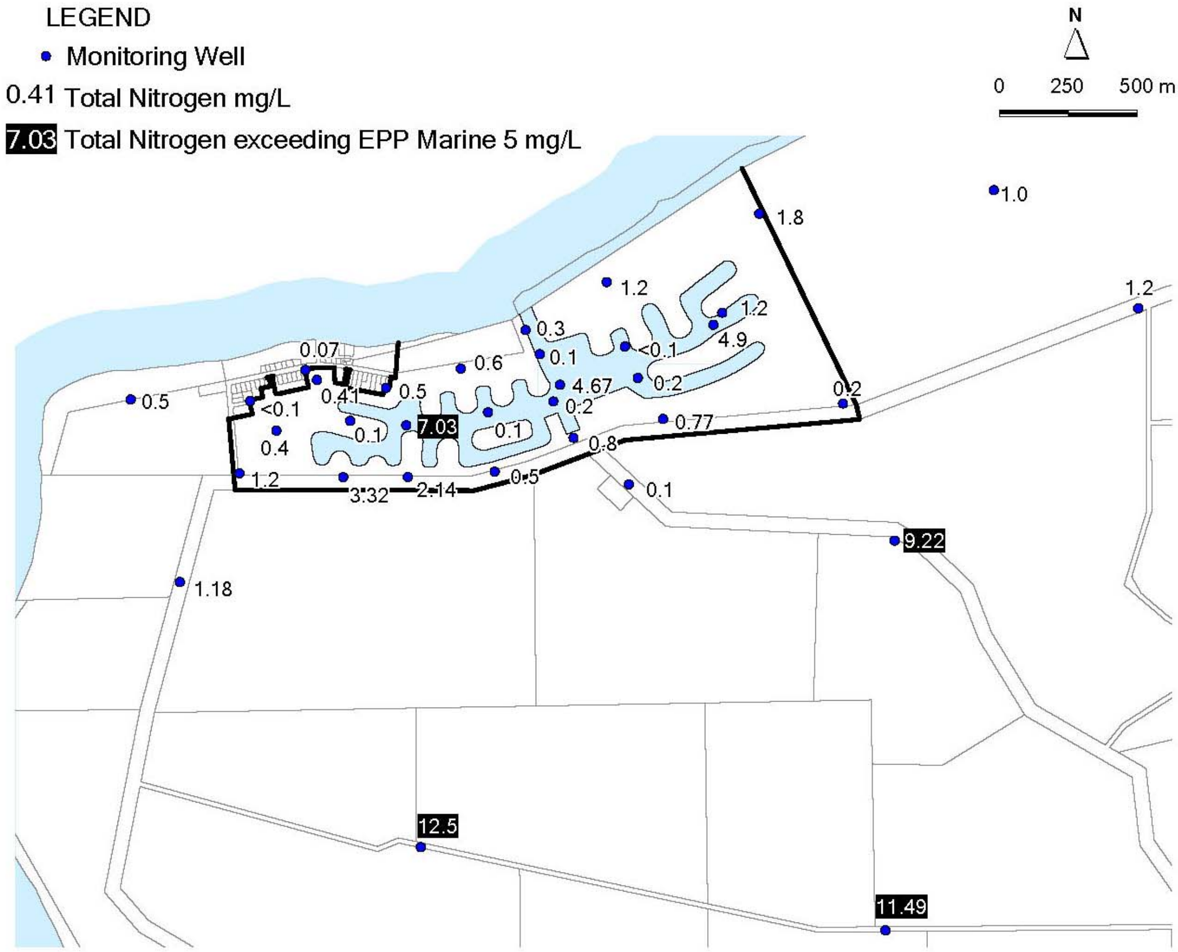


Figure 8.3 Concentration of Total Nitrogen in groundwater, July 2003.

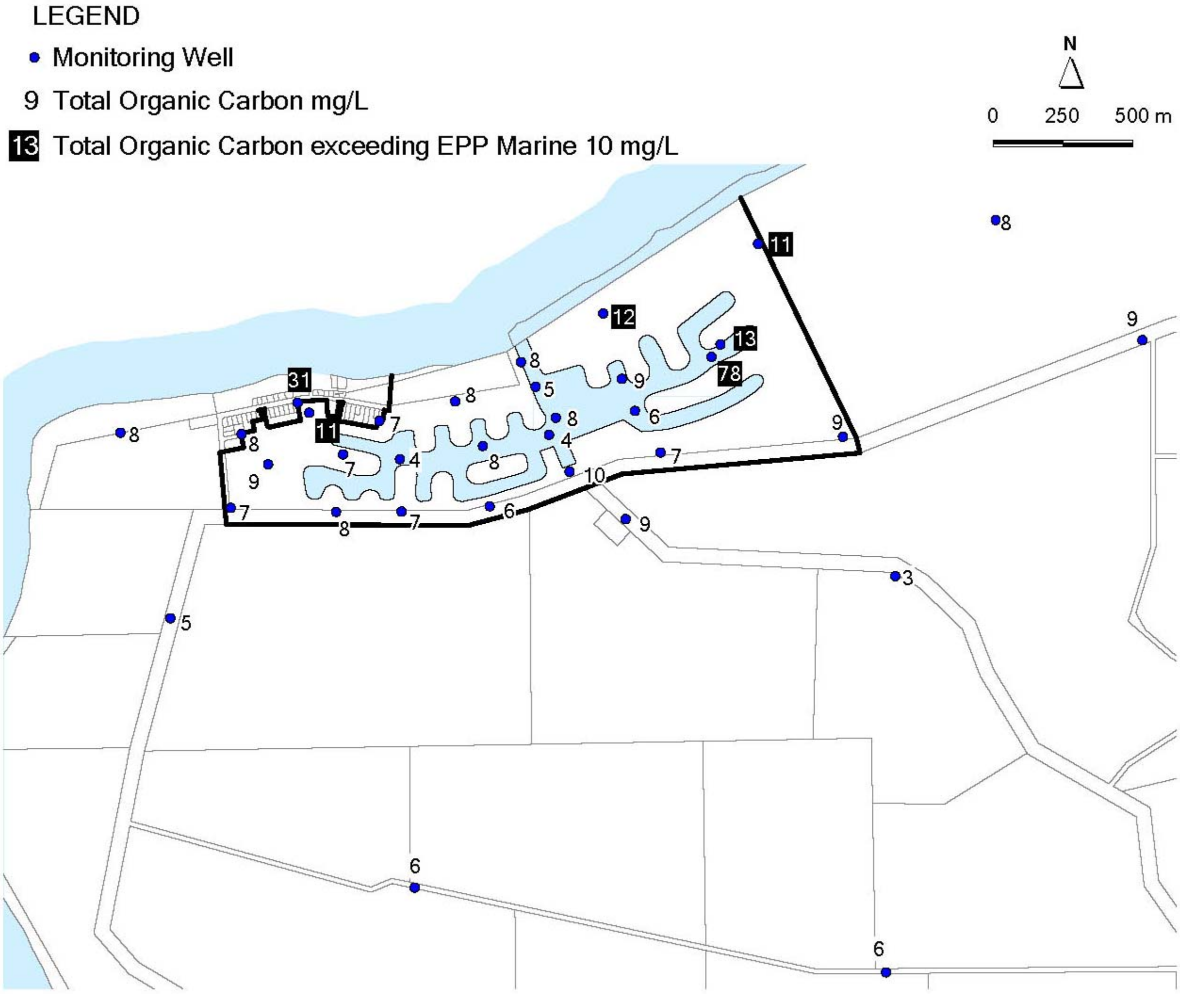


Figure 8.4 Concentration of Total Organic Carbon in groundwater, July 2003.

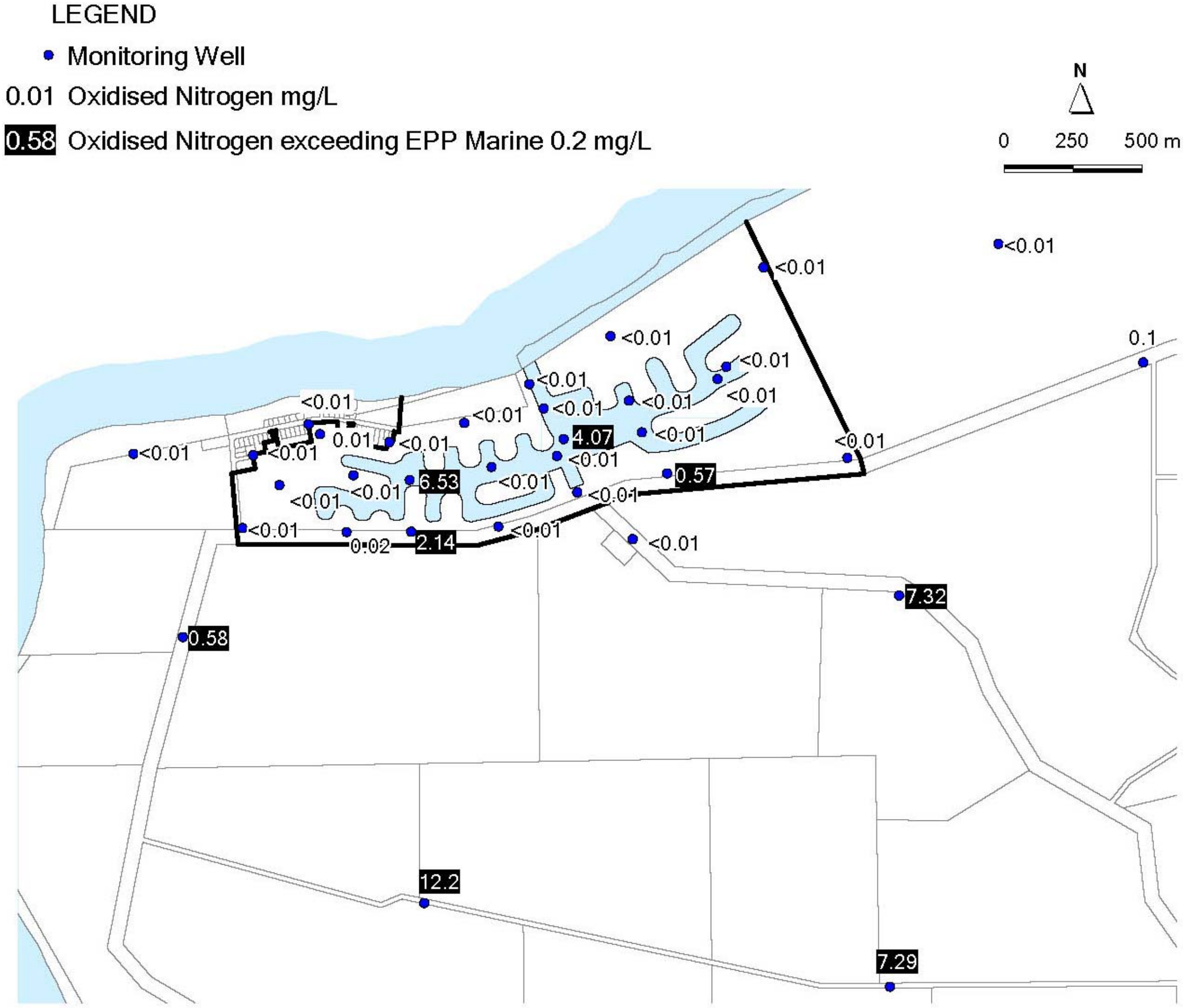


Figure 8.5 Concentration of Oxidised Nitrogen in groundwater, July 2003.

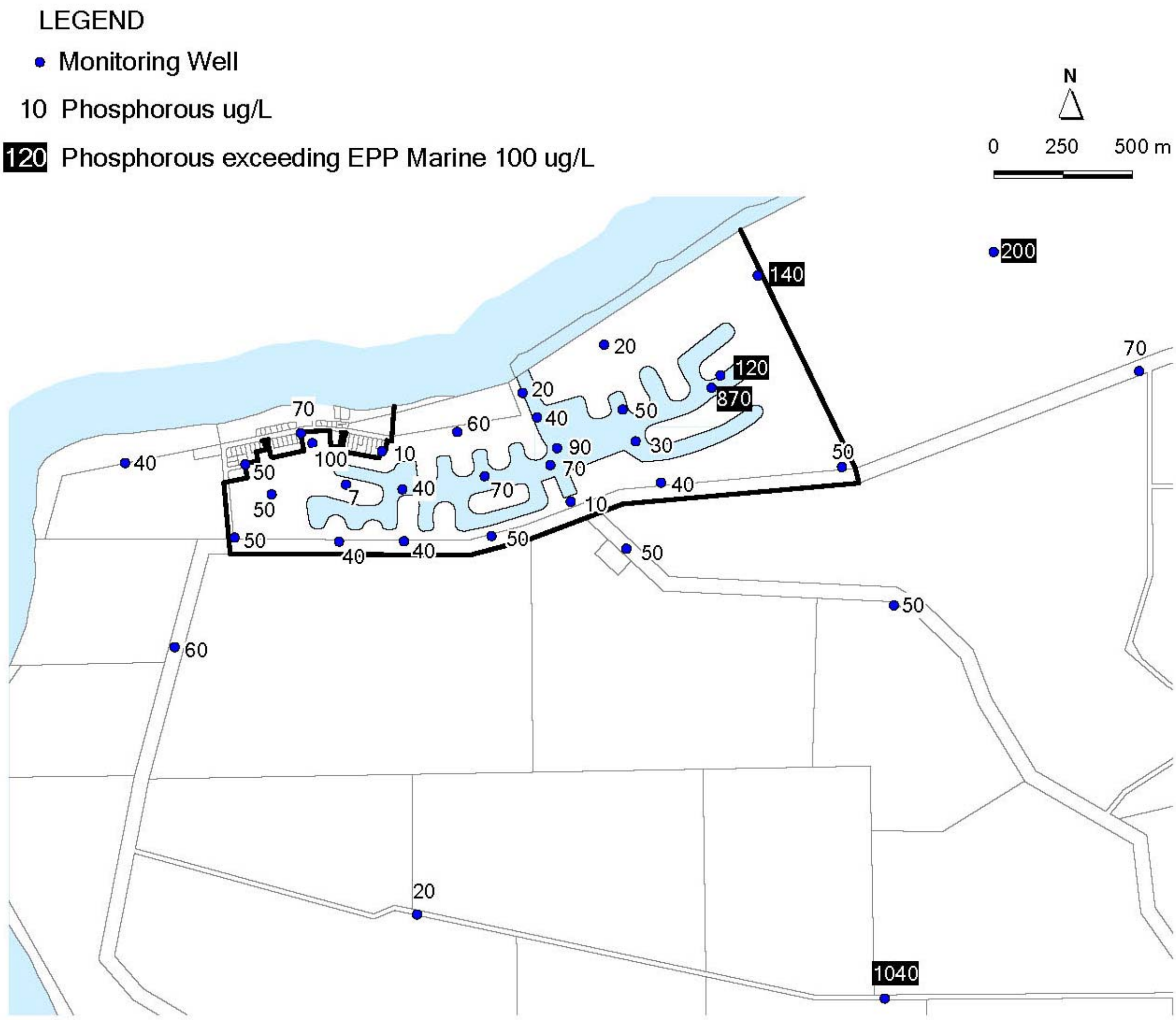


Figure 8.6 Concentration of Phosphorous in groundwater, July 2003.

Inorganic Compounds

Samples were also analysed for a range of inorganic compounds, including:

- Heavy metals (antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, tin, vanadium, zinc);
- Cyanide; and
- Soluble fluoride.

The concentrations of all inorganic compounds were below the EPP Marine criteria except for isolated concentrations of Arsenic and Cadmium. In addition, five of the seven samples analysed for Cyanide exceeded the NEPM Marine guideline. These are shown on Figure 8.7 to Figure 8.9.

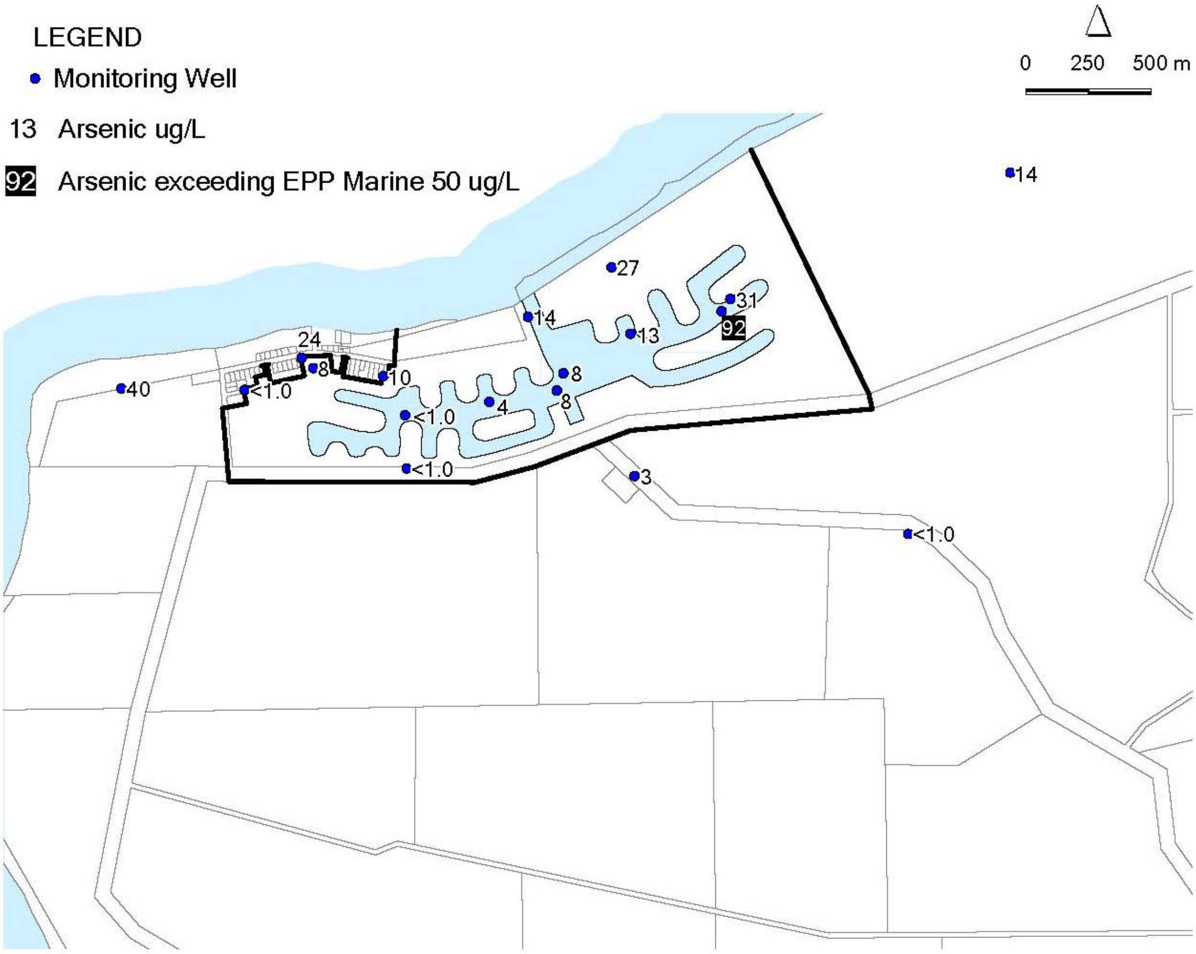


Figure 8.7 Concentration of Arsenic in groundwater, July 2003.

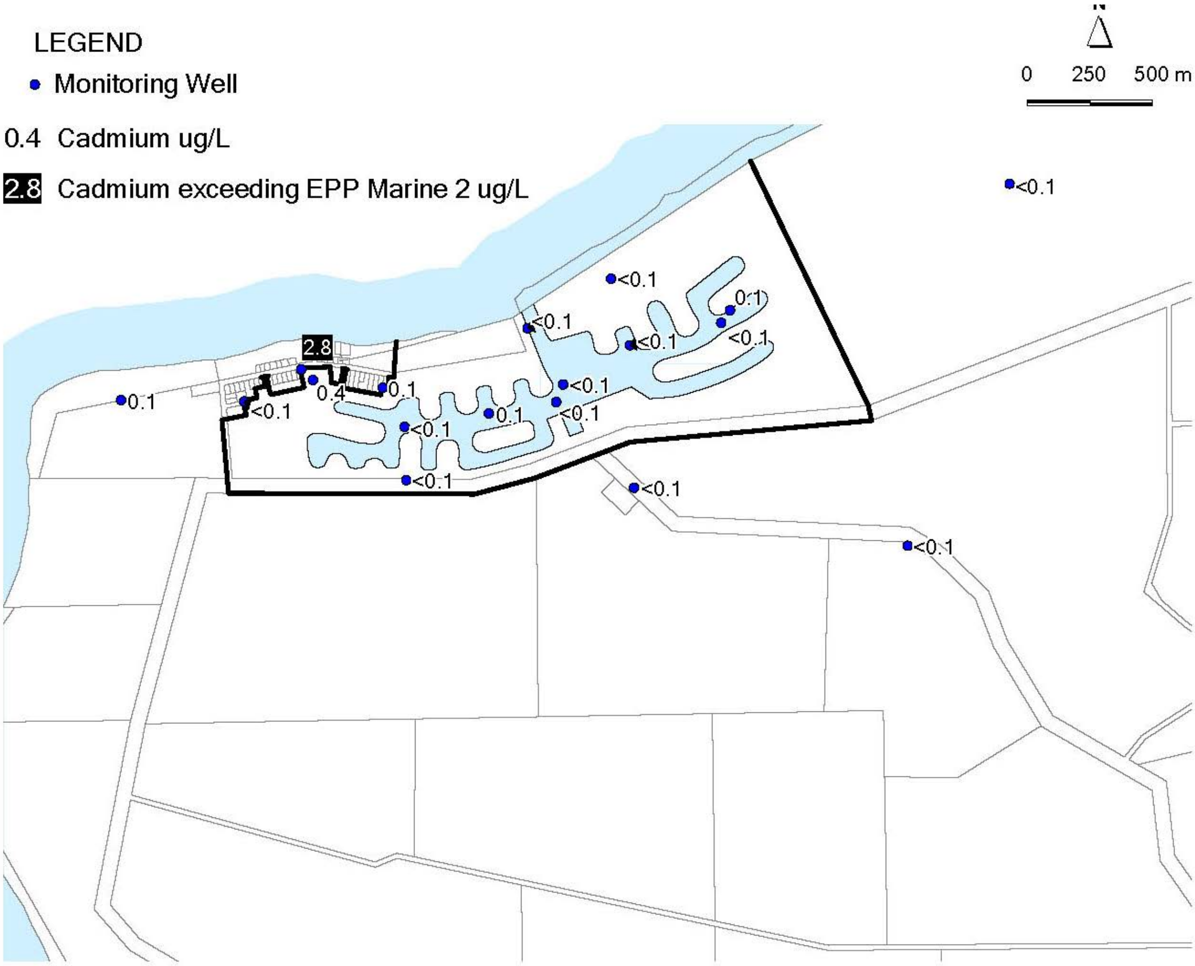


Figure 8.8 Concentration of Cadmium in groundwater, July 2003.

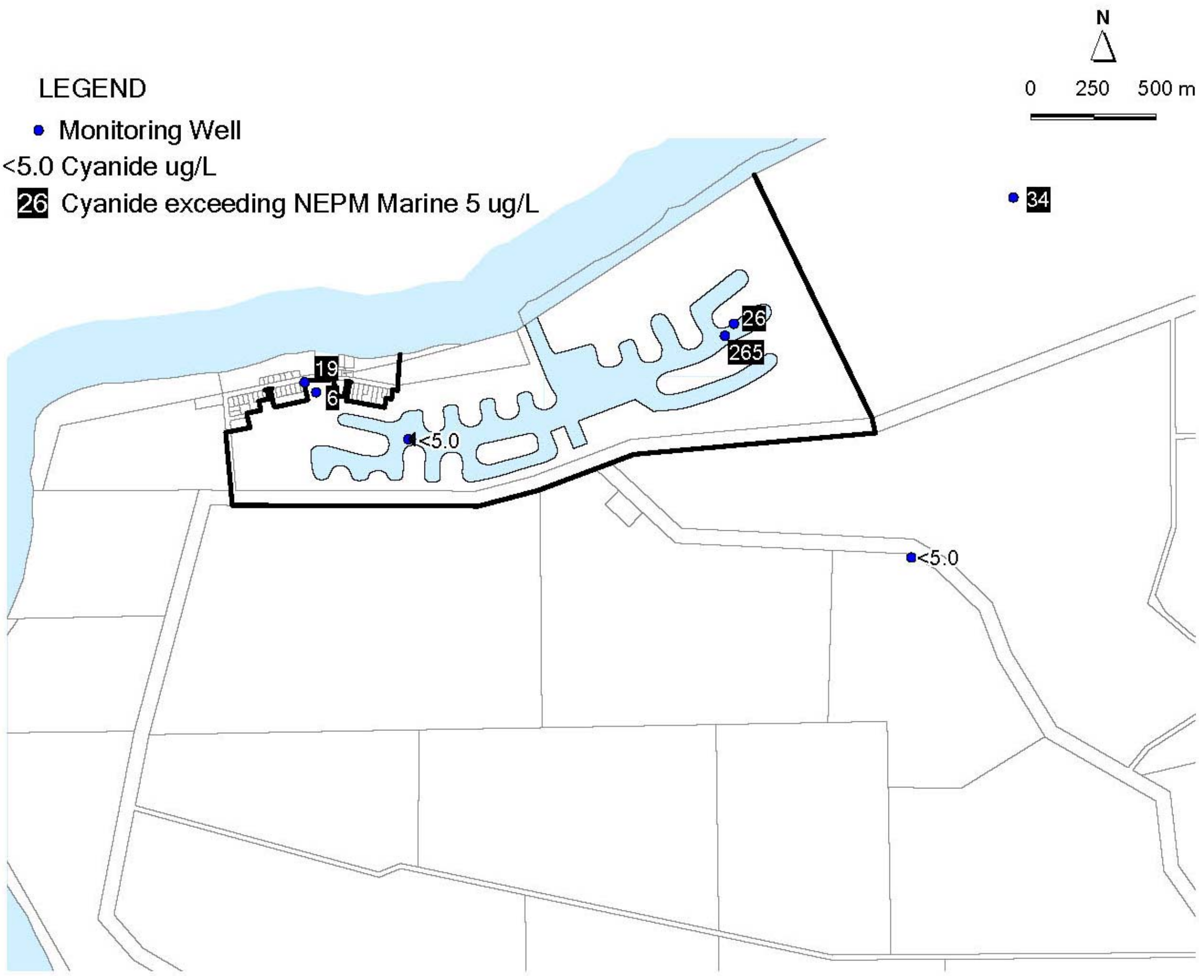


Figure 8.9 Concentration of Cyanide in groundwater, July 2003.

8.3.2 Dispersion and Mixing Effects

The model developed by WBM (2004) was used to assess dispersion and mixing of groundwater entering the marina due to tidal exchange. This information has been used to assess the impact of the groundwater/sea water mixture exiting the marina to the marine environment.

The model indicated that during worst case tidal conditions (neap tide), an analyte in groundwater entering the marina would be reduced to less than 0.66% of its initial concentration within the marina and 0.3% at the mouth of the marina due to tidal exchange and mixing with seawater. In order to obtain a conservative estimate of the potential impact of groundwater quality on the marine environment, the mixing factor has been applied to the highest concentration of groundwater analytes encountered both on and off site during the field investigations. This is summarised in Table 8.1.

Table 8.1 Maximum groundwater concentrations and effect of tidal exchange/mixing.

Analyte	Max. Groundwater Concentration Recorded On & Off Site (July 2003)	Effective Concentration due to Tidal Exchange & Mixing at Mouth of Marina	EPP – Aquatic Ecosystems – Marine Criteria
Total Organic Carbon (mg/L)	78	0.23	10
Oxidised Nitrogen (mg/L)	12.2	0.037	0.2
Total Nitrogen (mg/L)	12.5	0.038	5
Phosphorous (mg/L)	1.04	0.0031	0.1
Cyanide (mg/L)	0.27	0.00081	0.005 *
Arsenic (mg/L)	0.092	0.00028	0.05
Cadmium (mg/L)	0.0028	0.0000084	0.002

* NEPM Marine guideline – No value for EPP Marine.

As indicated in the table above, the predicted concentration of groundwater analytes entering the marine environment are expected to be significantly below the *Environment Protection (Water Quality) Policy 2003*, Schedule 2 – Water Quality Criteria for Aquatic Ecosystems – Marine.

A concentration gradient of these analytes may exist within the marina as groundwater disperses and mixes with sea water. As the marina basins and channels will be highly modified environments, they have not been afforded the same level of protection as the marine environment, and the impact of a concentration gradient is expected to be negligible. In addition, as the groundwater inflow to the marina is small compared to the volume of the marina waterways and the volume of tidal exchange occurring, it is reasonable to assume that mixing will be rapid and complete (WBM, 2004).

It should be noted that it has been assumed that the concentrations of the above analytes are negligible within the existing marine environment.

9. Outline of Groundwater Management Plan

5.2.10 Detail the measure to be taken to protect and monitor groundwater resources to ensure that the development does not have a deleterious effect on them.

5.2.29 Detail investigations to include in an environmental management plan.

The Cape Jaffa Development Company (CJDC) has invested significant effort into understanding current and post-development groundwater conditions in vicinity of the proposed Cape Jaffa Anchorage marina. CJDC are committed to continuing monitoring and assessment during the development phase.

CJDC will maintain a Groundwater Management Plan (GMP), prior, during and after construction of the marina in accordance with regulatory requirements. The purpose of the GMP is to:

- Confirm CJDC's commitment to the appropriate management of groundwater issues;
- Assign responsibility for the management of groundwater issues;
- Identify any further investigations;
- Commit to undertaking consultation and liaison with relevant statutory authorities and local groundwater users potentially impacted by the development;
- Define groundwater management requirements;
- Specify monitoring requirements to identify spatial and temporal changes to the groundwater system as a result of the marina development;
- Define environmental reporting requirements and make commitment to updating the conceptual hydrogeological understanding and numerical groundwater flow model if considered necessary as new information becomes available.

The GMP will include the following aspects:

- Details of further investigations, including hydrogeological investigation into the confined aquifer;
- Management of dewatering activities, including:
  - Managing dewatering disposal;
  - Developing of a dewatering trial; and
  - Managing impacts from dewatering.
- Management of the impact to groundwater users and the details of alternative water supply; and
- Groundwater Monitoring Program.

The Groundwater Monitoring Program will involve various components, including:

- Monitoring of wells developed by CJDC for the project to validate and update the conceptual and numerical models if considered necessary;
- Monitoring of nominated wells used by existing groundwater users to assess impact on groundwater supplies;
- Monitoring for disposal of water generated during dewatering activities; and
- Monitoring of water quality in the marina to assess groundwater outflow to the marine environment.

It is envisaged that Groundwater Monitoring Program would focus on the impact to salinity and water level.

Following completion of Stage 1 of the project, the monitoring program will be reviewed and a decision will be made as to whether the conceptual hydrogeological understanding and numerical groundwater flow model need to be revised.

10. References

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