P R O G R E S S R E P O R T

Orica Botany GTP Operation Ecological Monitoring Program Report No. 3

Prepared for

Orica Australia Pty Ltd

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1.1 Introduction

URS Australia Pty Ltd (URS) was commissioned by Orica Australia Pty Ltd (Orica) to undertake the ecological monitoring of receiving environments potentially affected by operation of the groundwater treatment plant (GTP) for the Botany Groundwater Cleanup (BGC) Project. The ecological monitoring has been undertaken in accordance with the requirements of the agreed Ecological Monitoring Plan for the Groundwater Treatment Plant and its Operations Final Workplan dated 13 October 2005 (URS, 2005).

The Workplan was prepared in accordance with the requirements of Orica's Environment Protection Licence and a Permit from NSW Fisheries (refer to Section 1.4). The Workplan was prepared in consultation with the Department of Environment and Conservation (DEC), NSW Health, Sydney Water Corporation, Sydney Ports Corporation, Botany Bay Council, the Department of Natural Resources (DNR) and NSW Maritime Authority. The first monitoring report was issued in December 2005.

1.2 Background

Groundwater contaminated with chlorinated hydrocarbons (CHCs) originating from the Orica Botany site have been migrating toward Botany Bay. To prevent the contaminant plumes from reaching the bay, the NSW DEC issued a Notice of Clean Up Action (NCUA No. 1030236) in 2003. This notice set a framework and timeframe for Orica to contain the contaminant plumes. Orica elected to use hydraulic containment established at several locations, including Foreshore Road (secondary containment line), north of Penrhyn Estuary and Botany Bay (Figure 1).

In common with most estuaries, groundwater currently discharges to Penrhyn Estuary and is controlled by tidal pumping. Fresh water mixes with saline water in the zone of diffusion in the intertidal zone at 2 m below the ground surface. Monitoring of groundwater over numerous events has confirmed that fresh groundwater is not discharged into Penrhyn Estuary (URS, 2005). The volume of saline groundwater discharged to the estuary will be reduced by the hydraulic containment, however, this is not considered likely to adversely impact the ecological receptors in the estuary.

Two stormwater drains, Springvale and Floodvale, discharge into Penrhyn Estuary. The estuary can be divided into the inner and outer estuary. The most sensitive ecological receptors (e.g. saltmarsh and seagrass) are present in the inner estuary and therefore, the monitoring program is focused on the inner estuary. At supratidal elevations in Penrhyn Estuary, the vegetation community is described as dune vegetation (Figure 1). At the upper limit of the intertidal zone in the inner estuary, saltmarsh species are present. Mangroves are also present at elevations immediately below that of the saltmarsh. Below the saltmarsh beds and mangroves are sandy mudflats. At isolated locations on the mudflats, seagrasses are present. These seagrasses are generally closer to the edges of the inner estuary and the central portion of the inner estuary is devoid of vegetation.

At the commencement of ecological monitoring, interim hydraulic containment, with extraction of approximately 1 ML/day, was already underway. Full scale hydraulic containment, with extraction of approximately 7.5 ML/day, was planned for early 2006. As indicated in the Workplan (URS, 2005a),

achievement of steady state water levels is dependent on the pumping regime, which will change over the life of the program to optimise the extraction of groundwater. To understand potential changes in ecological receptors and the relationship of the changes to the operation of the GTP it is essential to assess changes in the physico chemical characteristics of groundwater. Changes in water levels and quality will continue to be monitored during the operation of the project and in conjunction with the ecological monitoring to assess potential impacts to receptors in Penrhyn Estuary.

Groundwater extraction began in October 2004 with an extraction rate of between 0.6 and 1.0 ML/day until February 2006. Following commissioning of the GTP, the extraction rate for both Foreshore Road and Southlands reached a maximum of 2.0 ML/day in April 2006. This decreased to approximately 0.8 ML/day in May during maintenance shutdown of the GTP.

Over the period January - March 2006 the water table in monitoring well MWF15 located adjacent to the dune vegetation, dropped by 0.20 m from an average elevation of 0.40 m AHD in January to 0.20 m AHD in March. However, this elevation varies monthly, in the order of 0.15 m, and daily, in the order of 0.10 m, due to tidal fluctuations. It should also be noted that drought conditions were reported for the period January to March 2006 and in the absence of significant rainfall a drop of 0.20 m in groundwater elevation would be expected. Although the drought conditions persisted during the period March to September 2006, the decreased pumping rate on Foreshore Road led to an increase in the static water level of approximately 0.4 m.

1.3 Objectives

The objective of the ecological monitoring program is to assess whether impacts to the receiving environments occur following interception of groundwater and during operation of the GTP and full scale hydraulic containment. Specifically, the program will:

- review current physico chemical conditions and the potential for changes in physico chemical conditions in and near the estuary;
- review the conclusions of the EIS and review the likelihood of changes to physico chemical parameters and ecological receptors;
- monitor the physico chemical conditions in Penrhyn Estuary both before and during operation of the GTP and full scale hydraulic containment;
- monitor the key ecological receptors in Penrhyn Estuary both before and during operation of the GTP and full scale hydraulic containment; and
- review the requirements for long term monitoring of full scale hydraulic containment.

The monitoring program covers the period August 2005 to April 2007 which is planned to extend from interim containment to full scale hydraulic containment and the operation of the GTP.

Two identified mechanisms of potential impacts to the receiving ecosystems include the discharge of treated waters and the extraction of groundwater. The requirements for monitoring of discharge waters are included in the Workplan (URS, 2005), however, as significant volumes of water have not been discharged to date, no results are available for reporting. It is expected that Orica will include a summary of available results in the Annual Report to be issued in May 2007. Potential effects to biota as a result of extraction of groundwater are addressed in the following sections.

1.4 Licences and Approvals

A number of approvals are required for the BGC Project. Two of these approvals stipulate specific ecological monitoring requirements:

1. The special conditions in the revised Environment Protection Licence (EPL2148) – issued by DEC under the *Protection of the Environment Operations Act, 1997*; and
2. The Permit issued by the NSW Department of Primary Industries (specifically NSW Fisheries) under Part 7 of the Fisheries Management Act, 1994.

The ecological monitoring requirements of each of these licences was reviewed and agreed upon in the Monitoring Plan dated 13 October 2005.

1.5 Reporting Requirements

The following table summarises the monitoring and reporting schedule in the Workplan (URS, 2005). This is the third progress report (of four reports in total) and details the sampling undertaken to date and discussion of the results of the first four monitoring rounds.

Monitoring and Reporting Schedule

Activity	Report Type	Date
Round 1 (July 2005) Monitoring	Reported in Round 2 in December 2005	December 2005
Round 2 (October 2005) Monitoring	Initial/Progress Report	December 2005
Round 3 (April 2006) Monitoring	Progress Report* No. 2	June 2006
Round 4 (October 2006) Monitoring	***Progress Report No. 3***	***November 2006***
Round 5 (April 2007) Monitoring	Final Report	May/June 2007

**** denotes current report***

2.1 Monitored Parameters

This monitoring program is designed to assess changes in ecological receptors that are attributable only to the operation of the GTP. Changes observed to the ecological receptors will be assessed in the context of changes in physico chemical parameters as a result of the operation of the GTP that have the potential to impact the identified ecological receptors.

2.1.1 Physico Chemical Parameters

The monitoring workplan identified the need to establish and monitor the physico chemical parameters in the estuary prior to the operation of the GTP and after commencement of the operation of the GTP (URS, 2005). The key physico chemical parameters monitored include salinity (measured as electrical conductivity), dissolved oxygen, temperature, redox potential and pH. Sampling locations for physico chemical parameters are indicated in Figure 2. The monitoring program outlined the following requirements:

- compilation of existing data (September 2003 to June 2005); and
- measurement of key physico chemical parameters during the commissioning of the GTP for the next two years in the:
    - dune system;
    - saltmarsh community; and
    - intertidal mudflats (porewater only).

2.1.2 Ecological Receptors

The key ecological receptors identified for monitoring in Penrhyn Estuary included:

- seagrass;
- saltmarsh;
- mangroves;
- dune vegetation; and
- wading shorebirds.

It was hypothesised in the EIS (URS, 2004) that potential changes in the shallow groundwater beneath the saltmarsh beds and discharges into the estuarine mudflats, could potentially lead to changes in the saltmarsh and seagrass communities. The mangroves are not considered likely to be affected by changes in the groundwater discharge regime as they tolerate fully saline conditions, however, it was noted that

their abundance in Penrhyn Estuary has been increasing in recent years and they are colonised both saltmarsh and seagrass habitats. Mangroves are being monitored only to determine if changes in the seagrass and saltmarsh communities are a result of invasion by mangroves, or other factors. Changes to the saltmarsh and seagrass communities will be assessed in the context of the physico chemical characteristics of the shallow groundwater and porewater.

It was also hypothesised in the EIS (URS, 2004) that the dune vegetation may be dependent upon groundwater beneath the dune system (Figure 3). The dune vegetation may be rainfall or groundwater dependent. If the dune vegetation was groundwater dependent and the groundwater was to become saline or drop in elevation, then the dune vegetation may decline in health or change in community structure. It is considered that the surficial groundwater beneath the dune system may be derived from rainfall percolation, which should remain unaffected by the operation of the GTP. This groundwater is being monitored for potential changes. Potential changes for the dune vegetation community will be assessed in the context of any changes observed in the groundwater.

It was hypothesised in the EIS (URS, 2005) that there may be adverse effects to the wading shorebirds by two indirect mechanisms, a potential change in food source if the benthic community on the mudflats changed or potential change in roosting areas if the saltmarsh community changed. It is widely acknowledged that there are numerous factors are currently causing wading shore bird numbers to decline globally, however, potential changes to the shorebird community will be assessed in the context if the operation of the GTP.

2.2 Monitoring Requirements

2.2.1 Physico Chemical Parameters

Potential changes in the identified ecological receptors in Penrhyn Estuary arising from hydraulic containment can only be assessed in the context of the physico chemical conditions in the estuary and surrounding habitats. To assess the potential for changes to the dune vegetation, seagrass and saltmarsh communities, the physico chemical parameters of groundwater are being monitored in the following three key areas:

- sand dunes (groundwater);
- saltmarsh beds (shallow groundwater);and
- seagrass beds on the intertidal mudflats (porewater).

To establish conditions prior to hydraulic containment and the commissioning and operation of the GTP, monitoring of these parameters commenced in September 2005. Pre-hydraulic containment conditions had already been established for porewater in Penrhyn Estuary by quarterly monitoring of six bundle piezometers since September 2003.

The groundwater beneath the dune vegetation is being monitored using bundle piezometers with sampling of depths varying from 2 to 5 m below ground surface. Shallow groundwater beneath the saltmarsh beds in the inner estuary is being monitored by ten shallow monitoring wells (approximately 1.0 m below ground surface). Seagrass on the intertidal mudflats is being monitored by the existing bundle piezometers. These bundle piezometers have sample ports at 0.1 m below the ground surface. A detailed description of the installed monitoring wells and piezometers is included in Section 3.

2.2.2 Saltmarsh

Saltmarsh is being monitored annually in April and October each year during the program. An initial monitoring round was undertaken in July 2005, with additional monitoring rounds undertaken in October 2005, April 2006 and October 2006. The final monitoring round will be undertaken in April 2007, with 5 monitoring rounds in total. Monitoring of saltmarsh is being undertaken by The Ecology Lab (TEL).

The saltmarsh communities are utilised by numerous species of shorebirds for roosting and feeding and are considered to have high conservation value (TEL, 2004 in URS, 2004). The saltmarsh community in Penrhyn Estuary is dominated by *Sarcocornia quinqueflora* and *Suaeda australis*. Saltmarsh are not considered to be groundwater dependent and water quality measurements obtained in the saltmarsh area suggests that the near-surface less saline groundwater is derived from rainfall.

It was hypothesised in the EIS (URS, 2004) that if the saltmarsh species were dependent on shallow groundwater and if groundwater levels were altered by the operation of the GTP then the dependent saltmarsh may be adversely affected. However, sampling of water quality parameters undertaken following the EIS during the development of the Workplan indicated that the presence of fresh water was not continuous and less saline shallow groundwater was most likely recharged by percolation of rainfall. As the saltmarsh beds represent a critical habitat, monitoring will continue to be undertaken.

If the saltmarsh community were adversely affected by a change in the availability of less saline shallow groundwater, then there may be a change in either the abundance, health or the community composition of the saltmarsh. The monitoring program assesses the percentage cover, species composition and condition of saltmarsh. Assessment is undertaken along three permanent transects at four sites within Penrhyn Estuary and two sites at each of the controls (total 24 transects). Transect began close to the shoreline and ran perpendicular to the shore to the top of the saltmarsh. The exception was at Woolooware Bay where transects stopped after 40 m as the saltmarsh habitat was too extensive to survey (~ 200 m). Four random (1 m^2) quadrats were sampled along each transect (total 96 quadrats). The abundance of epifaunal invertebrates, number of mangrove seedlings and pneumatophores and height of plants is also assessed in each quadrat.

The condition of saltmarsh plants was categorised using three “health” categorised as *good condition* (greater than 50% of the plant fleshy, growing tips), *poor condition* (less than 50% of the plant fleshy, growing tips) and *dead* (no growing tips on plant).

The monitoring program would establish conditions for the saltmarsh community prior to the commissioning of the GTP and then during the operation of the GTP. As noted in the workplan, saltmarsh

areas are generally being colonised by mangroves in Botany Bay and Port Jackson and mangroves have recently established in Penrhyn Estuary adjacent to the saltmarsh vegetation. Key saltmarsh habitat in Penrhyn Estuary has already been lost due to colonisation by mangrove species (URS, 2004).

If significant negative trends in the health of the saltmarsh community are identified during monitoring rounds, then DPI will be notified as required by Permit 05-030 issued under Part 7 of the Fisheries Management Act (1994).

2.2.3 Seagrass

Zostera capricorni is present on the intertidal mudflats of Penrhyn Estuary. Groundwater discharged to Penrhyn Estuary interacts with marine waters as a result of tidal pumping. As a result, no fresh groundwater is discharged to Penrhyn Estuary. Although freshwater is present at a depth of approximately 2.0 m, this is inaccessible to the seagrass community. It was hypothesised in the EIS (URS, 2004) that should the health of the seagrass in the estuary be dependent on discharge of groundwater, then cessation of groundwater may result in adverse effects to the seagrass community potential for effects and changes to seagrass community. Seagrasses are not dependent on freshwater and are found in full salinity estuarine and marine environments. The porewater, in this case, the interstitial water in the mudflats at a depth of 0.1 m has salinity similar to that of estuarine surface water present in the estuary (Tables 3a to 3c).

If the seagrass beds were adversely affected by a change in the groundwater discharge regime, then it would be expected that there would be a change in the abundance, distribution or health of the seagrass beds. The monitoring program records the extent of seagrass beds, seagrass density, leaf length and width and number of leaves per shoot during each round.

As is the case for saltmarsh, the habitat in Penrhyn Estuary is being colonised by mangroves. If significant negative trends in the health of the seagrass community are identified, then DPI will be notified as required by Permit 05-030 issued under Part 7 of the Fisheries Management Act (1994).

Monitoring rounds one, two, three and four were conducted in August 2005, October 2005, April 2006 and October 2006 respectively. The final monitoring round will be undertaken in April 2007. Monitoring of seagrass beds was undertaken by TEL.

2.2.4 Mangroves

Mangroves are present in the inner estuary and their abundance and distribution, as indicated from review of aerial photos, has increased. The community is dominated by the Grey Mangrove *Avicennia marina*, however, some individuals of *Aegiceras corniculatum* are present in the estuary. Mangroves have colonised saltmarsh habitat which provides valuable bird roosting habitat and the mangroves are considered to be of low conservation value (URS, 2004). The mangroves are not considered likely to be affected by hydraulic containment, however, they will be monitored to assess whether mangroves expand in distribution in seagrass and saltmarsh areas. This would assess whether a potential reduction in

saltmarsh species is due to a general loss of seagrass and saltmarsh communities or specifically due to mangrove invasion. Mangroves reside in saline environments and the health of mangroves is unrelated to the discharge of groundwater, therefore, there are no hypotheses relating groundwater discharge to mangrove health.

The distribution of the mangroves was measured in both surveys by mapping the extent of the mangrove community. The presence of mangrove seedlings in the saltmarsh beds was measured during the saltmarsh monitoring using the presence of mangroves in quadrats.

Assessment of mangrove vegetation will be conducted annually in April and October for the period form August 2005 until April 2007 as part of this monitoring program. If significant negative trends in the health of the mangrove community are identified, then DPI will be notified as required by Permit 05-030 issued under Part 7 of the Fisheries Management Act (1994). The monitoring is being undertaken by TEL.

2.2.5 Dune Vegetation

It was hypothesised in the EIS (URS, 2004) that the dune vegetation may be groundwater dependent. It is unclear whether the dune vegetation is rainfall dependent or groundwater dependent. If the dune vegetation was groundwater dependent and if the groundwater become saline or dropped in height, then the dune vegetation may suffer or change in community structure. It is considered that the surficial groundwater beneath the dune system may be derived from rainfall percolation, which should remain unaffected by the operation of the GTP. The dependence of the vegetation on groundwater, the abundance, distribution and health of the vegetation community and the physico chemical parameters of the groundwater will be assessed during this monitoring program. Potential changes for the vegetation community will be assessed in the context of any changes observed in the groundwater.

The dune vegetation monitoring methodology was designed to assess changes in community species composition or health that could result from hydraulic containment and the experimental design will test the null hypothesis that hydraulic containment has no impact upon dune vegetation by altering the depth or physico chemical characteristics of groundwater. In addition to the monitoring of groundwater, the assessment of dune vegetation involves:

- survey of plots in the vegetation community;
- assessment of changes in vegetation cover using aerial photographs; and
- mapping and assessment of Banksias showing signs of senescence.

Vegetation Survey

Five vegetation monitoring plots (20 m x 20 m) were established in the sand dunes north of Penrhyn Estuary and along Foreshore Beach (Figure 3). Four plots are located downgradient of the hydraulic

containment whilst one control plot (Plot 5) was located further west, outside the area of influence of the secondary containment line.

The following data were collected for each plot:

- projective foliage cover, height and stem diameter of the dominant stratum (tree or tall shrub layers);
- vegetation structure according to the nomenclature of Specht (1972);
- height and density of sub strata (shrub and groundcover layers);
- all plant species present;
- a cover/abundance rating for each species present based on the modified Braun Blanquet scale;
- the number and relative abundance of age classes present;
- physiographic attributes including soil type, aspect, gradient and landform;
- degree of disturbance and degree of weed infestation;
- reproductive processes, such as flowering, fruiting and seeding; and
- signs of senescence, such as fallen and standing deadwood, dieback, leaf-yellowing or leaf fall.

The methodology has been progressively updated along with our understanding of site conditions. The recording of Braun Blanquet scores for each species was included in the October 2005 survey and all subsequent rounds. This system quantifies any significant changes in community structure that may occur such as a decline in the relative abundance of groundwater-dependent species or an increase in the degree of weed infestation.

A further refinement involved the targeted assessment of senescent Banksias observed on site, as recommended in the Stage 2 Report (Chapter 5.2, URS, 2005). This approach was initially triggered by the observation of numerous dead and stressed Banksias, particularly in the strip adjacent to Foreshore Rd. in the north of the Site. This area encompasses Plots 4 and 5 but a substantial area of vegetation containing Banksia dieback was observed in vegetation to the north of Plots 1 to 3. Accordingly the entire site was surveyed using a Random Meander technique and banksias showing signs of senescence were mapped using a hand-held GPS unit. This methodology allows greater flexibility than the Plot based survey and provides a record of both spatial and temporal variability in the extent of Banksia dieback.

The literature review did not suggest that Banksias are groundwater dependent (Stage 1 Report, URS 2005). Nonetheless they may be an appropriate indicator species for the overall health of the dune vegetation. Banksias are the tallest species in the Dune Vegetation and as the dominant strata they have the largest biomass and deepest tap root. Accordingly they may respond most rapidly to changes in the depth or salinity of groundwater.

Data on size, health and signs of stress were recorded. An initial Banksia survey was performed in July 2006 and a second survey performed along with the plot-based survey in October 2006.

Two years of baseline vegetation data has been collected through surveys performed in August and October 2005 and April, July (Banksias only) and October 2006. Surveys will continue to be performed each April and October for the duration of the monitoring program in order to coincide with peak growth and reproductive periods of vegetation communities in temperate south-eastern Australia.

Subsequent surveys will provide an indication of changes to the vegetation in the study area during the period of commissioning of the GTP.

2.2.6 Wading Shorebirds

Twenty-four species of resident and migratory shorebirds and seabirds, listed under the Threatened Species Conservation Act and/or the Environment Protection and Biodiversity Conservation Act, are known to occur, or have previously been recorded in Penrhyn Estuary (Avifauna Research & Services, 2004, in URS, 2004). The importance of Botany Bay for migratory shorebirds has been significantly reduced in recent decades due to habitat loss and disturbance throughout the bay. Although extensive bird habitats are still present in Botany Bay, these are generally located on the southern shoreline of the bay. The monitoring program would only assess impacts attributable to the GTP operation.

Potential changes to the shorebird population are being assessed by monitoring changes in the numbers of shorebirds visiting the estuary and also monitoring the health of the birds. Potential change to the community is being monitored by the presence or abundance of birds during feeding and roosting in Penrhyn Estuary. The program uses a system of transects to monitor the upper estuary, outer estuary, the outer sand spits, 'Port Beach', the derelict government jetty and Foreshore Beach. Bird counts are performed once a week at both high and low tides. The health of birds is monitored by using assessment of body condition by digital photography and is performed monthly (twelve sampling events per annum).

Bird counts commenced on 16 September 2005 and will continue until April 2007. Shorebird monitoring is being undertaken by Avifauna Research Services.

3.1 Physico Chemical Parameters

3.1.1 Installation of Bundle Piezometers in Dune Vegetation

It was originally proposed that only two bundle piezometers would be installed for the ecological monitoring program, however, three bundle piezometers were installed in the dune vegetation on the northern shoreline of Penrhyn Estuary (BP109, BP108 and BP115) (Figure 2). The piezometers are 25 mm ID tubes with a stainless steel drive point (Solinst™ Model 615 Piezometers). Drive points consist of a stainless steel cylindrical filter screen protected within a 20 mm stainless steel body. The construction details are summarised in the table below.

Bundle Piezometer Construction Details

BP108			
Nominal Depth	2.0 m	3.0 m	4.0 m
Depth Interval	1.90 – 2.20 m	2.85 – 3.15 m	3.85 – 4.10 m
BP109			
Nominal Depth	2.0 m	3.0 m	4.0 m
Depth Interval	1.85 – 2.15 m	2.85 – 3.15 m	3.90 – 4.20 m
BP115			
Nominal Depth	4.5	5.5	6.5
Depth Interval	4.25 – 4.50 m	5.25 – 5.5 m	6.50 – 6.75 m

Bundle piezometers were developed, purged and sampled for physico chemical parameters. Water quality parameters were measured for each piezometer (Tables 1a to 1d). The physico chemical parameters generally indicate that shallow groundwater has low conductivity (and salinity) and a pH of 8.0. In BP108 and BP109, the shallowest ports (2.0 m bgs), had low TDS (260 and 270 mg/L respectively), and a pH of approximately 8.0. The water quality parameters of the deeper water (5 m) in these bundle piezometers had a higher TDS of between 600 and 1,000 mg/L and pH of 7.3 to 7.7. These results suggest that the source of surficial groundwater is a result of percolation of rain water.

The standing water level (SWL) in each monitoring well dropped between monitoring rounds 1, 2 and 3 by approximately 0.20 m. Over the period January to March 2006 the water table in monitoring well MWF15 located adjacent to the dune vegetation, dropped by 0.20 m from an average elevation of 0.40 m AHD in January to 0.20 m AHD in March. However, this elevation varies monthly, in the order of 0.15 m, and daily, in the order of 0.10 m, due to tidal fluctuations. It should also be noted that drought

conditions were reported for the period January to March 2006 and in the absence of significant rainfall a drop of 0.20 m in groundwater elevation would be expected. In the period to June 2006, the SWL increased 0.4 m with the decreased pumping on Foreshore Road. The SWL in BP109 had previously dropped below the height of the 2.25 m piezometers, however, in the monitoring undertaken in June and September 2006, the SWL had increased and the 2.25 m port was no longer dry. The bundle piezometer BP108 (4.25 m), which was previously damaged by vandalism, was replaced for Round 4 monitoring.

The electrical conductivity (EC) of the groundwater is considered to be an appropriate measure of the salinity of the groundwater and would be used to identify any saltwater intrusion in the groundwater beneath the dune system. The results of the monitoring do not suggest that there are any indicate significant trends in the EC of the groundwater. The EC is generally variable with the minimum observed 399µs/cm in Round 1 in BP108 (2.25m) and Round 4 in BP115 (3.25 m). The maximum EC was 30,500 µS/cm in BP108 (3.25m) in June 2006, this fell to 1,990 µS/cm in September 2006. Although the readings for EC were highly variable, approximately 85% of readings were within the range of 500 µS/cm to 3,000 µS/cm. No trend of increase in the salinity was identified in the groundwater beneath the dune vegetation.

3.1.2 Installation of Shallow Monitoring Wells in Saltmarsh Beds in Penrhyn Estuary

Ten monitoring wells to approximately 1.0 m depth were hand installed along two transects in the saltmarsh beds in the inner estuary (Figure 2). These were installed in order to measure the water quality parameters of the surficial ground water beneath the saltmarsh beds and to enable assessment of potential changes in water quality. Water quality probes were used to assess the water quality at the top and bottom of the wells to assess vertical stratification of water parameters in the monitoring wells, i.e. a lens of less saline water overlying the saline water. Water quality parameters for monitoring wells in the saltmarsh beds are summarised in Tables 2a to 2f.

Generally, there was little difference between the properties of shallow water and deeper water in the monitoring wells. Most samples reported estimated TDS values between 26,000 and 30,000 mg/L indicating estuarine or saline conditions. There were some monitoring wells where shallow water had a lower TDS than deeper water, however, these varied between monitoring rounds. In most of these wells, the shallower water had a higher pH (7.8) and a relatively high dissolved oxygen content (5.0 - 7.0 mg/L) than the deeper water indicating that the source is likely to be rain and not groundwater. No trends in surficial water beneath the saltmarsh beds were identified in the current monitoring.

These results generally support the hypothesis that a distinct lens of freshwater is not present beneath the saltmarsh and that the water is saline. Lower salinity water, where present, is likely to be derived from rainwater infiltration rather than groundwater. A consistent freshwater lens was not identified beneath the saltmarsh beds in Penrhyn Estuary. Therefore it is not likely that this would be observed to change. Additionally, what less saline water was observed was observed was likely to results from recent rainfall infiltration and would remain unaffected by the operation of the GTP.

3.1.3 Porewater in Penrhyn Estuary

Porewater data for Penrhyn Estuary from September 2003 (date of installation of bundle piezometers) until September 2006 (the most recent sampling round) has been collated (Table 3a to 3e). The water quality parameters generally indicate that the salinity of the porewater at a depth of 0.1 m (average of 25 900 ppt, n=176) is similar to the salinity commonly reported for surface water in Penrhyn Estuary. Such results confirm that there is little potential for a change in salinity as a result of the operation of the GTP. Data will continue to be collected for the porewater in Penrhyn Estuary and will be further evaluated in the subsequent reports. During the sampling undertaken in December 2005 (Table 3b) and March 2006 (Table 3c) water was only identified as being less saline at one port on one occasion. In the 0.1 m port of BP42 at low tide, the salinity was 19 mg/L compared with 31 mg/L at depth. However, this is situated at the top of the intertidal area in a zone of groundwater discharge. This result was only observed in March 2006 and may have been influenced by heavy rainfall (20 mm) approximately one week before the time of sampling. This will continue to be monitored and evaluated in the annual report to be issued in May 2007.

3.2 Saltmarsh

There saltmarsh beds located in the western portions of Penrhyn Estuary are dominated by *Sarcocornia quinqueflora and Suaeda australis*. The saltmarsh beds in the northern and eastern area of the estuary are dominated by *Sporobolus virginicus* and *Juncus spp.* The total area of these species was estimated by differential (DGPS) and a GIS. The area covered by saltmarsh is summarised in the table below.

Round 1	Round 2	Round 3	Round 4
643 m^2	6,558 m^2	6,479 m^2	7,846 m^2

The area covered by saltmarsh increased considerably between Rounds 1 and 2 as a result of the inclusion of saltmarsh stands at the eastern end of the estuary. The cover was generally consistent between Rounds 2 and 3 with a 20% increase during Round 4. This increase is likely to result from colonisation of the bare space between the access road and Springvale Drain at the eastern margin of the site. Potential differences between species composition and health will be analysed and discussed in detail in the Annual Report in April 2007.

3.3 Seagrass

In the Round 1 survey, one bed (total area of 865 m^2) of *Zostera* sp. was recorded on the southern shoreline of the inner estuary. During the Round 2 survey, two additional beds, located in the centre of the mudflats and on the northern side of the estuary were recorded (total area of 1,569 m^2). In Round 3, the area was recorded as 1,770 m^2. The area of seagrasses on mudflats increased from 572 m^2 to 1,306 m^2 in Round 2 and then 1,492 m^2 in Round 3. This is considered to represent a true increase in the area occupied by seagrass. The beds on the northern shoreline were absent in the most recent monitoring round. Given the absence of these patches in the first monitoring round, this may reflect the variable nature of these seagrass patches. The total area occupied by seagrass was only 369 m^2. This figure reflects

the lack of the patches on the northern shoreline and a slight decline in the area covered by the seagrass on the southern shoreline, being less than half of the area covered in the first monitoring round.

A large proportion of sediment along the southern shoreline occurs amongst the mangrove seedlings and pneumatophores (TEL, 2005). Extensive areas of the seagrass beds in Penrhyn Estuary at all locations are short and brown in colour. The base of these shoots are generally green in colour. There was a marginal increase in the area of seagrasses amongst the pneumatophores. This area increased from 293 m^2 to 332 m^2 over the three monitoring rounds.

3.4 Mangroves

The mangroves at Penrhyn Estuary were predominantly composed of the grey mangrove (*Avicennia marina)* with a few river mangroves (*Aegiceras corniculatum)* present. Mangroves, including mangrove seedlings, covered approximately 9,327 m^2 an increase of approximately 6% from the previous monitoring round (8,081 m^2). This represents an increase of approximately 20% from the first monitoring round in July 2005. Further detailed assessment will be provided in the Annual Report in May 2007. In the most recent survey, no recently dead mangroves (i.e. leaves were still attached, but dead) were recorded.

3.5 Dune Vegetation

The dune vegetation within the study area is classified "Planted Shrubland" and occurs on marine sands along Foreshore Beach and at Penrhyn Estuary (Figure 1). This community features a sparse to moderate tree stratum dominated by *Banksia integrifolia* to approximately 7 m in height, a sparse to moderately dense and wind-pruned native shrub stratum dominated by *Melaleuca ericifolia, Leptospermum laevigatum* and *Acacia longifolia var. sophorae* to 4 m in height, dense stands of the exotic shrub *Chrysanthemoides monilifera* , and a sparse groundcover of herbs and grasses to 0.5 m in height.

The dune vegetation is not classified as a Threatened Ecological Community (TEC) and is unlikely to support threatened plant species (Port Botany EIS, 2003). A review of available resources revealed the Eastern Suburbs Banksia Scrub in the Sydney Basin Bioregion (ESBS) is present in the local area and is listed as an endangered ecological community under both the TSC Act and the EPBC Act. However, the dune vegetation is not considered to constitute ESBS as per the NSW Scientific Committee Final Determination (2002) for this plant community. This conclusion is supported as the shrubland was planted in the 1980s and Foreshore Beach is not a remnant dune, but was formed from dredged marine material during previous development of Sydney Airport and the Port Botany.

The dune vegetation is therefore, of low to moderate conservation value. This community was planted, but some of the plantings are considered to be indigenous (characteristic of the remnant Coastal Dune Heath plant community) and thus the community would be expected to possess local conservation value as well as providing habitats for native fauna, particularly birds.

Four dune vegetation monitoring events have been completed: the initial survey in August 2005 and three scheduled surveys undertaken in October 2005, April 2006 and October 2006. An additional round of monitoring was conducted in July 2006 to establish the methodology for assessing senescence of banksias.

The species recorded at the site and their conservation statuses are listed in the table below. The dune vegetation is highly disturbed and subject to ongoing impacts from pedestrian traffic and rubbish, particularly adjacent to Foreshore Road and in the narrow stretch along Foreshore Beach (western margin of the study area). The community is subject to erosion at the high water mark and along drainage lines. Most of the area is heavily infested with the exotic shrub Bitou Bush (*Chrysanthemoides monilifera*). In places there are also moderate to dense infestations of herbaceous weeds such as Mother of Millions *(Bryophyllum delagoense),* Cape Ivy (*Delairea odorata*) and Bridal Creeper (*Asparagus asparagoides*).

Presence absence results from Rounds 1 to 4 are presented in Table 4 with the Braun Blanquet Values for Rounds 2, 3 and 4 presented in Table 5. Plant species present in the dune vegetation are presented in the following table:

Species Present in Dune Vegetation Sample Plots

Common Name	Scientific Name	Conservation Status
	Vulpia muralis	Exotic/common
Australian Stonecrop	*Crassula sieberiana*	Unprotected
Cud weed	*Gamochaeta pennsylvanica*	Exotic/common
Sydney Golden Wattle	*Acacia longifolia longifolia*	Unprotected / Common
	Acacia longifolia var sophorae	Unprotected
She Oak	*Allocasuarina distylla*	Probably adequate
Berry Saltbush	*Atriplex semibaccata*	Probably adequate
Coastal Banksia	*Banksia integrifolia*	Common
Old Man Banksia	*Banksia serrata*	Common
Carex	*Carex spp.*	Common
Pig Face	*Carpobrotus glaucescens*	Common
Plume Grass	*Dichelachne crinita*	Common
Knobby Club Rush	*Isolepsis nodosa*	Unprotected
Coastal Tea-tree	*Leptospermum laevigatum*	Common
Swamp Paperbark	*Melaleuca ericifolia*	Common
Native Geranium	*Pelargonium australe*	
Poa	*Poa poiformis*	Unprotected / Common
Hairy Spinifex	*Spinifex sericeus*	
NZ Spinach	*Tetragona tetragonioides*	Common
Sand Couch	*Zoysia macrantha*	Common

Common Name	Scientific Name	Conservation Status
Golden Wreath Wattle	*Acacia saligna**	Unprotected / Weed
Asparagus Fern	*Asparagus aethipicum*	Noxious weed
Bridal Creeper	*Asparagus asparagoides*	Noxious weed
Mother-of-millions	*Bryophyllum delagoense*	Noxious weed
Sea Rocket	*Cakile edentulata* var *edentulata*	Exotic/common
Green Cestrum	*Cestrum parqui*	Noxious weed
Bitou Bush	*Chrysanthemoides monilifera*	Weed of National Significance
Cape Ivy	*Delairea odorata*	Noxious weed
African Lovegrass	*Eragrostis curvulata*	Noxious weed
	Hydrocotyle bonariensis	Exotic/common
Lantana	*Lantana camera*	Weed of National Significance
Kikuyu	*Pennisetum clandestinum*	Exotic/common
Dock	*Rumex sp.*	Exotic/common
Fireweed	*Senecio madagascariensis*	Exotic/common

10 species were recorded in Plots for the first time in October 2006, including 7 new species (Table 4). New species include:

- the native, annual herb *Crassula sieberiana*;
- the exotic annuals *Vulpia muralis, Gamochaeta pensylvanica, Rumex sp. Senecio madagascariensis,* and *Cakile edentulata;* and
- the exotic perennial Noxious weed *Cestrum parqui.*

The appearance of these species probably represents colonisation of the Plots since the last survey round. This is not surprising since the species in question are grasses, annuals and noxious weeds respectively. These types of species have dynamic populations and spread, and colonise new areas when conditions are favourable.

The native species *Carprobobotus glaucescens* (Plot 4) and *Leptospermum laevigatum* (Plot 2) were present in April 2006 but absent in October 2006.

Species diversity is too low for quantitative assessment of the significance of any changes in the overall number of species present at the site. However the seven point Braun Blanquet index allows for quantitative assessment of the significance of changes in species abundance. These results are presented

in Table 5. A one point change in the Braun Blanquet rating for a species between survey rounds is considered significant and is highlighted in the table.

The data regarding presence and relative abundance infers the dominance of *Chrysanthemoides monilifera* (Bitou Bush) which was recorded in all five plots in all four surveys with Braun Blanquet ratings of between 4 and 5 in Plots 1, 2, 3 and 4 recorded in October 2006. This indicates that Bitou Bush currently makes up 30-90% of all individual plants present in each of these plots. This dominance has been consistent throughout the survey period (Table 5). The significant decrease in this species observed in control Plot 5 between October 2005 and April 2006 was maintained - a decline from 4 (25-50%) to 2 (5-10% of all individuals).

The invasive weed *Lantana camara* (Lantana) was observed in all plots. Lantana was not present in Plot 1 in April 2006, suggesting seedlings had recolonised by October 2006. Lantana is less dominant than Bitou Bush and makes up between 5-10% of individuals in each plot.

The most abundant native species occupying the large shrub/small tree stratum differed from plot to plot but generally consisted of *Melaleuca ericifolia, Leptospermum laevigatum* and *A. longifolia var sophora.* Abundances ranged from 2 to 4 between species and between Plots. In each Plot at least one of these species approached Bitou Bush in dominance demonstrating that overall there is a significant biomass of native species on site, despite the infestation by exotic weeds.

No significant change in the abundance of *Acacia longifolia var sophorae* was recorded from April 2006 to October 2006. *Acacia longifolia longifolia* was present in Plot 5 in October 2005 and *Acacia saligna* was recorded as present in August 2005 in Plot 3. However both were absent in April 2006 and again in the October 2006 survey.

The native shrub *Leptospermum laevigatum* declined in abundance in Plot 3 and declined from a rating of 1 to absence in Plot 2.

Groundcover species recorded over the survey period comprised of native grasses such as Hairy Spinifex (*Spinifex sericeus*), Plume Grass (*Dichelachne sp.),* the native herbs Pig Face (*Carpobrotus glaucescens),* and Native Geranium *(Pelargonium australe),* Knobby Club Rush *(Isolepsis nodosa)* and exotic weeds such as Mother of Millions *(Bryophyllum delagoense),* Cape Ivy (*Delairea odorata*) and Bridal Creeper (Asparagus asparagoides). The presence and abundance of these species has varied throughout the survey period. African Lovegrass (*Eragrostis curvulata*), Knobby Club Rush (*Isolepsis nodosa*), Sand Couch (*Zoysia macrantha*) and Hairy Spinifex (*Spinifex sericeus*) were recorded as absent in some plots in April 2006 in comparison to October 2005. However *Cakile edentulata var edentulata, Senecio madagascariensis, Rumex sp., Dichelachne crinita, Vulpia muralis, Eragrostis curvulata* and *Crassula sieberiana* were recorded for the first time in the October 2006 survey. Also *Pennisetum clandestinum* (Kikuyu) was subdominant in Plot 5 in October 2005, absent in April 2006, but was abundant (10-25% of all individuals) in Plots 4 and 5 in October 2006. It should be noted that Kikuyu was probably present as rhizomes throughout this period and was not detected because its leaves had died back. The variation observed over the four survey rounds suggests that populations of herbs and grasses fluctuate significantly within this community.

The native sedge *Carex sp.* declined significantly in abundance (from 3 to 1) in Plot 5 between April and October 2006. It has not been recorded in the other Plots.

Vegetation plots in Penrhyn Estuary are generally described as being low species diversity, low groundcover and moderate shrub density. Groundcover density increased in Plots 4 and 5 in October 2006 compared to the previous 3 rounds. This reflected an increase in the overall abundance and diversity of herbs and grasses but was dominated by cover of the exotic grass Kikuyu.

The canopy and understorey in all plots were disturbed and there is moderate to high density of tracks in the vicinity of all Plots. It is likely that species composition and abundance is affected by ongoing human influences as well as environmental factors.

A large amount of woody debris, the majority of which was recorded on *Melaleuca ericifolia* and *Bitou Bush*, was noted all plots during monitoring Rounds 1 to 3 and the October 2006 survey. Woody debris was also noted on *Leptospermum laevigatum, Lantana camera, Isolepsis nodosa, Acacia longifolia* and *Banksia integrifolia*.

Banksia survey

Banksias showing signs of senescence were surveyed and mapped in July 2006 and again in the Round 4 survey in October 2006. Data on species, size, health and signs of stress were recorded and are presented in Table 6.

Table 6. Dead and Stressed Banksias

Banksias	July 2006	October 2006
Dead	28	41
Dead due to dune erosion	5	9
Long dead	6	8
Total dead	39	**53**
Yellowing leaves	2	4
Defoliation	5	6
Dieback	9	10
Severe dieback	7	2
Total showing signs of stress	23	**20**

There are two species of Banksias present: *Banksia integrifolia* (Coastal Banksia) and *B. serrata* (Old Man Banksia). The majority of dead and stressed individuals were *B. integrifolia* (63 out of 73) however this species is much more numerous. Nine of the dead Banksias observed were located on the eroded southern edge of the dune and had probably been killed by sea water once the dune collapsed.

As can be seen from Table 6 the number of dead banksias increased between the July 06 and October 2006 surveys. There were 14 additional dead banksias. Of these 2 were long dead, and were missed in the

first survey, and 4 were dead due to dune erosion. 8 of the trees that were identified as showing signs of stress in the July survey were dead in October. This demonstrates that senescence of Banksias within the Dune Vegetation is ongoing. It also suggests that the methodology is sensitive to variation over time and may provide an effective indicator of change during the GTP operation phase of monitoring. The number of banksias showing signs of stress also increased by 4 over the period.

3.6 Wading Shorebirds

Shorebird monitoring commenced on 16 September 2005. All shore birds at Penrhyn Estuary and the immediate vicinity were counted on a weekly basis and digitally photographed with a high resolution camera monthly to determine whether the birds showed any signs of weight loss that may have resulted from ill health. Count data was entered onto a data set using Microsoft Excel spreadsheets and photographs were examined on a computer in order to profile the shape and condition of the birds. The study site was divided into seven areas; the creek, upper estuary, outer estuary, sand spit near Port Botany, beach next to Port Botany, the old government jetty (as a roost site) and Foreshore Beach (used as feeding habitat during spring low tides).

A total of 47 species of waterbirds were observed during the study from September 2005 to September 2006 (Table 1).

The bar tailed godwit is the most numerous arctic breeding migratory bird present in the estuary. The counts of this species have remained relatively constant over the past five years. The variable abundance during the year reflects the migratory nature of the birds. The red necked stint is also a migratory species that is present in Penrhyn Estuary. The results of monitoring from the past year were consistent with the previous five years.

The abundance of curlew sandpipers in the estuary has declined through the monitoring period, reflecting a trend that is evident across all of southeastern Australia. This species is generally found in the upper estuary. The remaining species are discussed in more detail in Appendix A.

The bar-tailed godwit was used as the indicator species for the assessment of bird body condition. The body fat rating is from 1 to 5, with 1 being the fat free weight of the bird and 5 being the maximum weight prior to migration. All birds were above the minimum value of 1, however, none had a value of 5, suggesting that Penrhyn Estuary is not the main launch site for migration to the Yellow Sea.

The study has revealed no signs of ill health by the birds using the area and no significant declines in the numbers of birds during this study period. The only species that has declined in abundance is the curlew sandpipers. However, this reflects a regional trend that is evident across all of southeastern Australia and not a result of site specific impacts.

Table 1: Birds recorded at Penrhyn Estuary September 2005 – September 2006

Scientific name	Common name	max count	Resident/migratory	Listing
Tringa nebularia	Common Greenshank	1	M	JC/EPBC
Actitis hypoleucos	Common Sandpiper	1	M	JC/EPBC
Arenaria interpres	Ruddy Turnstone	1	M	JC/EPBC
Calidris acuminata	***Sharp-tailed Sandpiper***	***22***	M	JC/EPBC
Calidris alba	Sanderling	3	M/Th	JC/EPBC
Calidris canutus	***Red Knot***	***18***	M	JC/EPBC
Calidris ferruginea	***Curlew Sandpiper***	***16***	M	JC/EPBC
Calidris melanotos	Pectoral Sandpiper	1	M	JC/EPBC
Calidris ruficollis	***Red-necked Stint***	***45***	M	JC/EPBC
Calidris tenuirostris	Great Knot	2	M/Th	JC/EPBC
Charadrius bicinctus	***Double-banded Plover***	***54***	M	EPBC
Charadrius ruficapillus	Red-capped Plover	8	R	
Elseyornis melanops	Black-fronted Dotterel	2	R	
Haematopus fuliginosus	Sooty Oystercatcher	1	R/Th	
Haematopus longirostris	Pied Oystercatcher	2	R/Th	
Heteroscelus brevipes	Grey-tailed Tattler	3	M	JC/EPBC
Himantopus himantopus	Black-winged Stilt	12	R	
Limosa lapponica	***Bar-tailed Godwit***	***162***	M	JC/EPBC
Pluvialis fulva	***Pacific Golden Plover***	***17***	M	JC/EPBC
Pluvialis squatarola	Grey Plover	1	M	JC/EPBC
Xenus terek	Terek Sandpiper	1	M/Th	JC/EPBC
Numenius madagascariensis	Eastern Curlew	1	M	JC/EPBC
Numenius phaeopus	Whimbrel	1	M	JC/EPBC
Vanellus miles	Masked Lapwing	2	R	
Other waterbirds				
Anas superciliosa	Pacific Black Duck	2	R	
Anas castanea	Chestnut Teal	6	R	
Anhinga melanogaster	Darter	1	R	
Ardea novaehollandiae	White-faced Heron	1	R	
Ardea ibis	Cattle Egret	4	M	JC/EPBC
Egretta alba	Great Egret	2	M	JC/EPBC
Egretta garzetta	Little Egret	1	R	
Butorides striatus	Striated Heron	1	R	
Threskiornis molucca	Australian White Ibis	16	R	
Pelecanus conspicillatus	Australian Pelican	12	R	
Phalacrocorax carbo	Great Cormorant	2	R	
Phalacrocorax melanoleucos	Little Pied Cormorant	4	R	
Phalacrocorax sulcirostris	Little Black Cormorant	50	R	
Phalacrocorax varius	Pied Cormorant	3	R	
Sterna nilotica	Gull-billed Tern	2	R	
Sterna albifrons	Little Tern	7	M/En	JC/EPBC
Sterna bergii	Crested Tern	24	R	
Sterna caspia	Caspian Tern	2	M	JC/EPBC
Sterna hirundo	Common Tern	130	M	JC/EPBC
Chlidonias leucopterus	White-winged Black Tern	1	M	JC/EPBC
Chlidonias hybridus	Whiskered Tern	1	R	
Larus dominicanus	Kelp Gull	2	R	
Larus novaehollandiae	Silver Gull	410	R	

En, Th = listed under the TSC Act as Endangered or Threatened
JC/EPBC = listed under JAMBA, CAMBA or EPBC Act as migratory species
M= migratory R= resident

3.7 Quality Control Elements

Data quality control elements for the project included the equipment used in fieldwork and the collation, investigation and interpretation of field data. Similar procedures were employed at URS, TEL and Avifauna Research Services.

All data generated were appropriately reduced and underwent validation prior to reporting. Records and numerical calculations were legible and sufficiently complete to permit reconstruction of the work by a qualified individual other than the originator.

The originating person reduced and validated the data package to ensure that:

- appropriate standard operating procedures have been followed;
- field sample results were correct and complete;
- QA check sample results were correct and complete; and
- documentation was complete.

Once data were input into the appropriate spreadsheet, a second hard copy was maintained with the file. The spreadsheet is then checked by a second operator. If the originating person found that the validity of data was in doubt due to non-conformance with the above checklist, then the data was flagged and appropriate corrective procedures were initiated. Once the originating person had validated the data package, it was then passed onto the project manager for independent review. In the event that errors were found, a greater percentage of results checking was required. These errors were to be flagged and to be brought to the attention of the originating person so that the cause of the errors could be addressed. A hard copy of all data and calculations, where appropriate was maintained on file for review should electronic data become corrupted or lost.

The field equipment used included quadrats for vegetation monitoring, water level probes and water quality meters. Before use, all equipment was visually inspected to ensure that it was in good repair, functional and accurate. Water quality meters were calibrated and checked daily before sample collection and measurement. Calibration of water quality meters was recorded on data sheets (Appendix B). Water quality parameters were recorded on monitoring well development and purging data sheets.

4.1 Physico Chemical Parameters

Physico chemical parameters measured in this study provide detailed information on water level and quality beneath the dune system, the saltmarsh beds and the porewater in the estuary. The original hypotheses regarding potential changes in the ecological communities presented in the EIS were based on the assumption that fresh groundwater is discharged to the estuary. This assumption was incorrect as groundwater discharge undergoes a complex interaction with tidal inundation and salinisation of the groundwater (discussed in Section 3 of the Workplan). The groundwater discharged to the estuary is therefore, higher in salinity than groundwater in the aquifer. This was corrected in the Representations Report (URS, 2004). The worst case scenarios are summarised for each of the regions below.

The hypothesis considered by Botany Bay Council was that groundwater beneath the dune system would drop in elevation and saline intrusion would increase pH and salinity of the water in the dune system and that groundwater dependent vegetation would be adversely affected. Groundwater beneath the dune system is generally between 2 and 3 m below the ground surface. This is deeper than the root system of the majority of shrubs identified in the vegetation sampling. The low conductivity and the relatively high pH indicate that the surficial water beneath the dunes is likely to be derived from infiltration of rainwater. Water recharged by rain is expected to remain unaffected by the operation of the GTP. Whilst a slight lowering of the water level in the dunes was reported, this is similar to the magnitude of tidal fluctuations in the dunes (0.20 m) and the lower levels may be a result of drought conditions. It is considered unlikely that significant changes to the groundwater and adverse effects to the vegetation have resulted from the operation of the GTP. The observed mortality of the Banksias is considered most likely to result from the sustained drought conditions in the region.

The EIS hypothesised that the saltmarsh vegetation may be dependent on fresh groundwater and as a result of changes in groundwater, saltmarsh communities may be adversely affected by the operation of the GTP. This prediction was revised in the Representation Report (URS, 2004) as the groundwater discharge was identified to be saline and the water accessible to the saltmarsh was identified as being derived from rainfall. Shallow monitoring wells installed in the saltmarsh beds indicate that the water beneath the saltmarsh beds is estuarine or saline, and freshwater lenses are generally absent. At some locations where shallow groundwater was slightly less saline, the pH and the dissolved oxygen content indicate that the water is likely derived from rainfall rather than groundwater sources.

Data from September 2003 to June 2005 indicates that the porewater in the mudflats of Penrhyn Estuary is generally saline. The process of salinisation of the groundwater prior to discharge in the estuary is a result of tidal pumping and has been noted since September 2003, when monitoring of the porewater commenced. Therefore, increased salinity in porewater following commencement of operation of the GTP and full scale hydraulic containment was considered unlikely and to date has not been observed. The porewater will continue to be monitored under the GCP. The ongoing monitoring of porewater confirms this observation.

Given that there is little potential for change in the physico-chemical parameters of the groundwater and porewater, there is considered to be little potential for change in ecological receptors to result from this.

4.2 Saltmarsh

The results of this monitoring program indicate that there are four main areas of saltmarsh present in Penrhyn Estuary. The saltmarsh habitats are dominated by mixed beds of *Sarcocornia quinqueflora* and *Suaeda australis* with additional areas of *Sporobolus virginicus*. The percentage cover of the species varied between the locations, however, each species was recorded at all locations. No significant changes were observed in the saltmarsh communities between the surveys.

The techniques currently employed for monitoring are considered suitable and will be used for the remainder of the monitoring program. The EIS (URS, 2004a) and Representations Report (URS, 2004b) suggested that there was the potential for increased abundance of salt tolerant species (*Sarcocornia quinqueflora*) as a result of the operation of the GTP. Monitoring of the saltmarsh stand has not identified any significant changes in the community structure or distribution. Under Fisheries Permit Number 05-030, issued under Part 7 of the Fisheries Management Act (1994), NSW Fisheries must be advised if vegetation is harmed. However, as no changes have been identified, URS considers that the saltmarsh has not been adversely affected by the operation of the GTP.

4.3 Seagrass

Two main seagrass beds were identified in the monitoring. The most northern bed was not identified during the first monitoring round, however, it has been observed in the past. The presence of the seagrasses in Penrhyn Estuary may be affected by the erosion of surface sediment in the estuary. The seagrasses in the estuary are generally short, sparsely foliated, brown and in poor condition. The seagrasses in the control areas were also observed to be in a similar poor condition. There are numerous factors which may affect the condition of seagrasses including tidal inundation, immersion in less saline waters or encroachment by mangroves. However, seagrasses were observed to increase in the spatial coverage during the first three monitoring rounds with a decline in the most recent monitoring round. This is most likely a reflection of the natural variability and dynamic nature of the intertidal seagrasses within Penrhyn Estuary. . Monitoring of seagrass beds will continue in Penrhyn Estuary.

The seagrass beds are not considered to be freshwater dependent and it was predicted that adverse effects to the seagrass would result from invasion by mangroves and not as a direct result of the operation of the GTP. As the spatial distribution of seagrass has not decreased over the monitoring period it is considered that it has not been adversely affected through invasion by mangroves. Under Fisheries Permit Number 05-030, issued under Part 7 of the Fisheries Management Act (1994), NSW Fisheries must be advised if vegetation is harmed. However, as potential increases in spatial have been identified, it is considered that the seagrass has not been harmed by the operation of the GTP.

4.4 Mangroves

Mangroves have been increasing in distribution in Penrhyn Estuary and represent the greatest area of species below the high tide mark. A baseline distribution has been recorded to allow comparison with future monitoring events. Some dead mangrove trees were observed during previous surveys, however,

the significance of this is unknown. Mangroves are not expected to be affected by the operation of the GTP and are primarily being monitored to determine if any changes to seagrass or saltmarsh distribution are concomitant with increases in mangrove distribution. The presence of mangrove pneumatophores in seagrass beds was highly variable and no trends were identified. The EIS (URS, 2004a) hypothesised that the abundance and distribution of mangroves may increase as a result of the operation of the GTP, and that mangroves may invade the seagrass community. The distribution of the mangroves has not changed and therefore, mangroves are not considered to have been affected by the operation of the GTP, nor influenced the distribution of seagrass within the estuary.

4.5 Dune Vegetation

The four vegetation surveys confirmed the classification of the dune vegetation as Planted Shrubland. The community is highly disturbed and features moderate to severe weed infestation, particularly by Bitou Bush. The dune vegetation has low species diversity but may have local conservation value due to the presence of plant species associated with the Coastal Dune Heath plant community and its value as habitat.

A general increase in the presence of dead wood on the large shrub/small tree stratum and was recorded in April 2006 in comparison to October 2005, probably as result of seasonal variations and drought conditions that were reported for the period January to March 2006. In the October 2006 period there was a decrease in the amount of dead wood with vigorous new growth of Bitou Bush and also the native shrub species *Acacia longifolia var sophorae* and *Melaleuca ericifolia*. Fruiting and flowering of Bitou Bush and native species was also observed in the October 2006 vegetation surveys.

The decline in groundcover health and density observed between October 2005 and April 2006 was also reversed with an increase in the density and diversity of groundcover species in October 2006. 7 groundcover species were recorded for the first time comprising a native annual herb, exotic grasses and annual herbs, and exotic, perennial noxious weeds. These are all typical coloniser-type species and so this may be an indicator of more favourable growing conditions over the last quarter than in previous survey periods.

Quantitative assessment of abundance through the Braun Blanquet index indicated considerable variation between the October 2005 and April 2006 survey rounds including changes within the control Plot 5. Some of this variation may be due to the re-configuration of Plots 1, 3, 4 and 5, which was undertaken during the April 2006 surveying event. However there was continued variation between the April 2006 and October 2006 surveys in all 5 Plots. The dominant trend was an increase in the abundance and diversity of groundcovers, dominated by exotic grasses and annuals. This may reflect the wetter than average months of August and September 2006 in comparison with harsher conditions between October 2005 and April 2006. Variation over the four sampling rounds shows that considerable fluctuation in the composition of the Dune Vegetation occurs both naturally and as a result of ongoing human disturbance.

A total of 73 dead or stressed Banksias were recorded with a slight increase in the overall number between the July and October 2006 surveys. This demonstrates that senescence of Banksias within the Dune Vegetation is ongoing. It is unclear whether environmental factors (such as the record hot, dry

conditions during 2005) or natural senescence (ie. Banksias reaching the end of there natural lifespan) has caused the death of other Banksias in the Dune vegetation. However the two rounds of baseline data allow us to detect any change in the number or spatial distribution of dead or stressed Banksias once the GTP has commenced pumping.

The extraction rate for both Foreshore Road and Southlands was between 0.6 and 1.0 ML/day until February 2006 where it was increased to a maximum of 2.0 ML/day in April 2006. Over the period January - March 2006 the water table adjacent to the dune vegetation was recorded to have dropped by approximately 0.2 m however, this is within the range of tidal fluctuation and may result from drought conditions that were recorded for the period January to March 2006. Groundwater abstraction is therefore unlikely to have contributed to a change in species abundance from October 2005 to April 2006. Groundwater abstraction has decreased in 2006 due to ongoing maintenance of the GTP. As such the water levels have generally been maintained or risen slightly from the levels observed in monitoring rounds to April 2006.

The site is highly disturbed and any changes to the dune vegetation must be considered in the context of other impacts as well as the BGC Project. The literature review suggests that the Planted Shrubland community is probably not groundwater dependent, nor is there any specific indication that either *Banksia integrifolia* or *Banksia serrata* are groundwater dependent. However, the relationship between Australian terrestrial vegetation and groundwater is poorly understood. Some species present in the dune vegetation occur in other communities recognised as relying on groundwater and may be more susceptible to changes in the local groundwater regime.

The dune vegetation was not predicted to be adversely affected in the EIS (URS, 2004a), however, at the request of Botany Bay Council, assessment of the vegetation was included in the monitoring program. The hypothesis is that the groundwater pumping could alter the groundwater level beneath the dune vegetation and potentially alter the community. Only a slight decline (0.10 m drop in elevation) in groundwater level has been identified. This change may be related to the current drought conditions experienced in the Sydney Region. The vegetation is considered to be rainfall dependent and is not expected to be adversely affected by changes in the groundwater level.

4.6 Wading Shorebirds

The shorebird monitoring program has provided baseline bird count data that can be compared with ongoing bird counts throughout the operation of the BGC Project. It has also provided insights into the behaviour and feeding patterns of shorebirds. Notably, during spring high tides shorebirds were unable to feed until the tide receded beyond the seaward edge of the mangroves in the estuary. A reduction in feeding time compared with previous years was noted due to an increase in the area of mangroves. Any changes to the discharges of Springvale and Floodvale Drains as a result of the BGC Project may affect the area of mangroves and accordingly impact upon these shorebirds.

No changes in the abundances of migratory species have been observed in the past year of monitoring. The only species that has decreased in abundance is the curlew sandpiper, however, this is a reflection of long term regional trends and not a result of site specific impacts.

No evidence of poor health or body condition was observed amongst birds photographed during the study period. Although this does not necessarily indicate that 100% bird health is the normal condition for shorebird communities at the estuary, any evidence of poor health or body condition observed during ongoing monitoring will be noted. The EIS (URS, 2004a) hypothesised that if the benthic community in the estuary were drastically altered by a significant change in the salinity, then the food supply for wading shorebirds may decline and result in adverse effects to the abundance and health of shorebirds present in the estuary. However, the Representations Report (URS, 2004b) and the workplan (URS 2005) identified that porewater in the estuary is saline and would not measurably change in salinity as a result of the operation of the GTP. Therefore, significant changes to the benthic community or the food supply for the wading shorebirds are not expected. No changes to the wading shorebird community have been identified as a result of the operation of the GTP.

4.7 Integration of Biotic and Abiotic Data

The assessment of ecological receptors in Penrhyn Estuary and potential effects resulting from the operation of the GTP must be considered in the context of changes in the physico chemical parameters of the groundwater. If changes to the physico chemical parameters are absent, then changes that may be observed in the identified ecological receptors are likely to be due to factors other than the operation of the GTP. The following section discusses the integration of abiotic and biotic parameters. Further analysis of the changes in abiotic data will continue with the operation of the GTP and extraction of groundwater.

Water in the saltmarsh beds was predominantly saline. Where lower salinity water was present, the physico chemical parameters indicate that the source of the water is likely to be rainfall infiltration, rather than groundwater discharge. This indicates that there are unlikely to be changes observed in the shallow water as a result of the operation of the GTP. In addition, adverse effects to the saltmarsh vegetation are unlikely to result from the operation of the GTP.

Bundle piezometers in the dune vegetation indicated that the water table was between 2 and 3 m below the ground surface, i.e. deeper than the roots system of the majority of shrubs identified from the ecological monitoring. Fresh water was identified near the surface of the groundwater, however, the physico chemical parameters indicate that the source of the water is likely to be rain water infiltration and rather than a groundwater source. Although there was a lowering of the water table, this was within the range of tidal variation and may result from the current drought conditions. This indicates that there are unlikely to be changes observed in the surficial groundwater as a result of the operation of the GTP and further that adverse effects to the dune vegetation are unlikely to result from the operation of the GTP.

Available porewater data for the mudflats indicates that the porewater is saline, with salinity similar to surface waters in the estuary. The potential for a change in salinity to result from the operation of the GTP is therefore, considered limited. As a result, the potential for adverse effects to the seagrass beds to occur as a result of the operation of the GTP is also considered limited.

Two indirect mechanisms that could affect the wading shorebirds were identified. The first of this was a change in food source (i.e. the benthic community). Given that the salinity of the porewater has been shown to be estuarine (saline), then there is little potential for adverse effects to the benthic community.

Additionally, changes in composition of the benthic community are unlikely to affect the wading shorebirds as the total biomass of benthic organisms is not expected to change. The second mechanism capable of causing a decline in bird number is the loss of saltmarsh (roosting) habitat. This process is not limited to Penrhyn Estuary and is occurring throughout the Sydney Region. The colonisation of the saltmarsh vegetation by mangroves has previously been noted. The saltmarsh vegetation is unlikely to be adversely affected by the operation of the GTP, however, this will continue to be monitored.

Mangroves are not expected to be affected by the operation of the GTP, however, mangroves will be monitored to assess whether changes in seagrass of saltmarsh distribution is concomitant with an increase in the mangrove distribution. Increased mangrove abundance may also affect the distribution of several shorebird species.

The potential for adverse effects will be further evaluated in the next monitoring report, however, the data acquired to date represents a substantial baseline against which potential change can be assessed. The acquisition of both abiotic and biotic data means that causality and relationship of impacts to receptors can be assessed with respect to the operation of the GTP.

5.1 Conclusions

The conclusions following the third round of ecological monitoring in Penrhyn Estuary are summarised as follows:

- No significant changes in the physico chemical parameters of groundwater in dunes or porewater in the estuarine areas have been observed, the potential for changes to ecological receptors as a result, is therefore considered minimal;
- Negligible changes in groundwater levels in the dune system have been observed;
- No changes have been identified in the saltmarsh community;
- No decline in spatial coverage has been identified in the seagrass community;
- No changes have been identified in the mangrove community;
- No changes have been identified in the dune vegetation;
- No changes attributable to the operation of the GTP have been identified in the wading shorebird community;

No adverse effects to the ecological receptors have not been identified during the monitoring undertaken to date.

5.2 Recommendations

From review of the monitoring undertaken, the following actions are recommended:

- Observations made during the recent round of dune vegetation monitoring, indicated that some Banksia specimens may be in poor health. Therefore, it is recommended that individual Banksia trees be monitored in future rounds to determine if there are quantifiable changes in their health;
- Once Orica commences discharge of large volumes of treated water (>1 ML/day), the monitoring data should be incorporated into the monitoring reports. It is envisaged that suitable data will be available to include in the November monitoring report; and
- Monitoring and reporting of physico-chemical and ecological receptors should continue in accordance with the workplan, with the exception of the changes listed in these recommendations.

5.3 Further Monitoring and Reporting

This report is a progress report of Rounds 1, 2, 3 and 4. These Rounds have been completed and the final monitoring round will be undertaken in April 2007. The final monitoring report will be submitted in May/June 2007.

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The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 1 June 2006 and 18 January 2007 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

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Tables

Figures

Appendix A
Botany Groundwater Cleanup Project, Bird Monitoring Report

Appendix B
Water Quality Meters – Calibration Sheets