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

Orica Botany GTP Operation Ecological Monitoring Program Report No. 2

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 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.

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 Progress report to be issued in November 2006. 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 second progress report (of four reports in total) and details the sampling undertaken to date and discussion of the results of the first three 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****	***June 2006***
Round 4 (October 2006) Monitoring	Progress Report	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, the second monitoring round was undertaken in October 2005 and a third monitoring round was undertaken in April 2006. Further monitoring will be undertaken in October 2006 and 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 and three were conducted in August 2005, October 2005 and April 2006 respectively. Future monitoring will continue in October 2006 and 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 assessment of groundwater, the assessment of dune vegetation involves:

- survey of plots in the vegetation community; and
- assessment of changes in vegetation cover using aerial photographs.

Vegetation Survey

Five vegetation monitoring plots (20 m x 20 m) were established in the sand dunes north of Penrhyn Estuary (Figure 3). Four plots were 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.

Baseline vegetation surveys were performed in August and October 2005 and April 2006. Surveys will continue to be performed each April and October for the duration of the monitoring program. Vegetation surveys utilised a random meander technique. Vegetation structure was described according to the nomenclature of Specht (1972). Projective foliage cover, height and stem diameter were recorded for the dominant stratum (tree or tall shrub layers) and height and density recorded for sub strata (shrub and groundcover layers). All taxa present within each plot were identified and recorded. During the April 2006 survey each species present was assigned a "cover abundance value" based on the modified Braun Blanquet scale. The number and relative abundance of age classes present was noted. Physiographic attributes were also recorded for each plot including soil type, landform, vegetation health, degree of disturbance and degree of weed infestation. Reproductive processes, such as flowering, fruiting and seeding were also noted and described.

Subsequent surveys will provide an indication of changes to the vegetation in the study area during the period of commissioning of the GTP. The timing of further surveys will be focused towards peak growth and reproductive periods of vegetation communities in temperate south-eastern Australia, primarily in April and October.

Aerial Photo Interpretation

In addition to the vegetation monitoring conducted in August and October 2005, aerial photographs were examined using a geographical information system (GIS) and a raster pixel classification tool. Review of the aerial photos revealed distinct differences in the colour of vegetated areas and areas of bare sand. The GIS and raster pixel classification tool identifies and classifies each polygon as being either sand or vegetation and then calculates a total area occupied by each ground cover type. The area occupied by each ground cover type can then be compared for successive years. This was presented in the Progress Report 1, issued in December 2005.

Aerial photos were obtained for 2001 and 2005. The area of the dunes covered by vegetation or by bare space was analysed and recorded (Figures 4 and 5) (Section 3). If suitable aerial photographs are available in 2006 and 2007, then analysis of these will also be completed and compared to photographs from 2001 and 2005.

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.

Unfortunately, prior to the third round of monitoring in March 2006, the monument for the bundle piezometers BP108 was vandalised and a sample could not be collected from the 4.0 m port, whilst the 2.25 m port was blocked.

The salinity of the BP109 and BP115 was highly variable and no trends with respect to time were identified. There was no change in either pH or redox condition of the groundwater.

Overall, there is an apparent trend of a slight drop in the SWL in each of the bundle piezometers, however, the SWL is variable due to the influence of the tides and may also be attributable to the background drought conditions. There was no trend of increasing salinity of the groundwater and the pH varied from 7.0 to 7.5, indicating that this is influenced by rain water infiltration.

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). Water quality parameters were measured one week after installation by inserting a water quality probe into the well to measure standing water at the top of the well. Water quality probes were lowered to assess the water quality at the base of the well 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 2d.

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, for example GW01, GW04, GW05 at low tide and GW05 at high tide in Round 2. In most of these wells, except GW01, the shallower water also has a high pH (7.8) and a relatively high dissolved oxygen content (5.0 - 7.0 mg/L) indicating that the source is likely to be rain and not groundwater.

For the purposes of the discussion below, a difference between the shallow and deeper groundwater present in the ten monitoring wells was defined as being greater than 10,000 µS/cm, for example, if the conductivity of the water in the upper portion of the monitoring well was 30,000 µS/cm and the conductivity of the water in the deeper part of the monitoring well was 45,000 µS/cm. In the first monitoring round, a difference was only observed at monitoring well GW03 at low tide. In the second monitoring round, differences in the conductivity of the shallow groundwater and deeper groundwater was observed at monitoring wells GW01, GW02, GW03, GW04 and GW05 at both high and low tides. In the interim monitoring round undertaken in December 2005, differences were observed in the conductivity in GW02 at high tide and GW02 and GW09 at low tide.

However, in Round 3 (March 2006), differences in the conductivity of shallow groundwater compared to deeper groundwater in wells GW01 to GW08 at both high and low tides. This is the only event where there was an observed difference between the shallow and deeper groundwater of the 4 monitoring events. This was approximately one week after a heavy rainfall (20 mm) event. The average pH of this water was 7.4. This suggests that the source of the intermittent freshwater lens is from rainfall and not groundwater (pH 5-6).

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 March 2006 (the most recent sampling round) has been collated (Table 3a). 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 Decmeber 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.

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 to be 5,967 m^2 (see table below). The areal cover was estimated by the use of a differential (DGPS) and a GIS.

Areal Cover of Saltmarsh Species Estimated from DGPS Mapped Area

Species Name	Areal Cover
Sarcocornia quinqueflora & Suaeda australis	4,112 m^2
Juncus spp.	1,135 m^2

Sporobolus virginicus	720 m^2

The percentage cover in the following table was derived from quadrats along transects in the saltmarsh beds. In these quadrats, the mean percent area of *S.quinqueflora* was approximately 10%, *S.australis* was approximately 44% *S.virginicus* was 14% and bare space was approximately 17%.

The saltmarsh were generally shorter than the saltmarsh species in reference areas, however, there was no change in this difference over time. There were no changes in the percentage cover of *S.quinqueflora* over time when compared to the control sites. There was no change in the condition of the plants at Penhryn Estuary or at the reference locations and nor was there a change in the spatial extent of saltmarsh in the three monitoring rounds over the period August 2005 to April 2006.

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 1770 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.

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 no change in the area of seagrasses amongst the pneumatophores. This area varied from 263 m^2 to 293 m^2 over the three monitoring rounds.

The density of *Zostera* at Penrhyn Estuary was within the range of densities observed at the controls and increased between surveys. In the second survey, the density of *Zostera* within Penrhyn Estuary varied considerably within and between study areas (TEL, 2005). The leaf length, leaf width and number of leaves per shoot varied little between surveys (TEL 2005). The blade length was observed to change seasonally, however, leaf width did not vary. The numbers of leaves per shoot was similar at Penrhyn Estuary to the Quibray Bay reference area.

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 8,081 m^2. In the second survey, several recently dead mangroves (i.e. leaves were still attached, but dead) were recorded.

In the saltmarsh transects and quadrats, the cover of mangroves was greater at Penrhyn Estuary than the controls. The number of pneumatophores recorded in quadrats was greater at Penrhyn Estuary in the second survey.

During the monitoring program, the area occupied by mangroves increased from 7,659 m^2 to 8,807 m^2, with the total increase in mangrove area attributable to the seaward migration of the mangrove stand. This trend in increase in mangrove abundance has been noted in each monitoring round and observed from aerial photographs of the area (URS, 2003). The numbers of pneumatophores in seagrass beds, which may indicate invasion of these beds by mangroves, was highly variable and no trends were identified.

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 shrub stratum dominated by *Melaleuca ericifolia, Leptospermum laevigatum* and *Acacia longifolia* to 4 m in height, 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 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.

Three dune vegetation monitoring events have been completed: the initial survey in August 2005 and two scheduled surveys undertaken in October 2005 and April 2006.

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 *Lantana camara* and typical roadside herbaceous weeds such as Mother of Millions *(Bryophyllum delagoense)*, Cape Ivy (*Delairea odorata*) and Bridal Creeper (Asparagus asparagoides).

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

Species Present in Dune Vegetation Sample Plots

Common Name	Scientific Name	Conservation Status / Abundance
Sydney Golden Wattle	*Acacia longifolia longifolia*	Unprotected / Common
	Acacia longifolia var sophorae	Unprotected / Probably adequate
Golden Wreath Wattle	*Acacia saligna**	Unprotected / Weed
Coastal Banksia	*Banksia integrifolia*	Common
Old Man Banksia	*Banksia serrata*	Common
She Oak	*Allocasuarina distylla*	Probably adequate
Swamp Paperbark	*Melaleuca ericifolia*	Common
Bitou Bush	*Chrysanthemoides monilifera*	Weed of National Significance
Lantana	*Lantana camera*	Weed of National Significance
Coastal Tea-tree	*Leptospermum laevigatum*	Common
Asparagus Fern	*Asparagus sp.*	Noxious weed
Berry Saltbush	*Atriplex semibaccata*	Probably adequate
Pig Face	*Carpobrotus glaucescens*	Common
African Lovegrass	*Eragrostis curvulata*	Noxious weed
Hairy Spinifex	*Spinifex sericeus*	Probably adequate
NZ Spinach	*Tetragona tetragonioides*	Common
Cape Ivy	*Delairea odorata*	Noxious weed
Kikuyu	*Pennisetum clandestinum*	Exotic
Mother-of-millions	*Bryophyllum delagoense*	Noxious weed
Native Geranium	*Pelargonium australe*	Probably adequate
Poa	*Poa poiformis*	Unprotected / Common
Knobby Club Rush	*Isolepsis nodosa*	Unprotected
Plume Grass	*Dichelachne spp.*	Common
Carex	*Carex spp.*	Common
Sand Couch	*Zoysia macrantha*	Common
Bridal Creeper	*Asparagus asparagoides*	Noxious weed
	Hydrocotyle bonariensis	Exotic/common

Species diversity is too low for quantitative assessment of the significance of any changes in the 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. A 14% change in the rating (i.e. one Braun Blanquet rating) for a species from October 2005 to April 2006 has been assessed

A 14% decrease in a Braun Blanquet rating from October 2005 to April 2006 was recorded for the following species:

- *Chrysanthemoides monilifera* (Plots 1, 3 and 5);
- *Acacia longifolia longifolia* (Plots 2, 4 and 5);
- *Banksia integrifolia* (Plot 3);
- *Allocasuarina distyla* (Plot 4);
- *Isolepsis nodosa* (Plot 3);
- *Lantana camera* (Plot 5);
- *Leptospermum laevigatum* (Plots 2 and 5);
- *Spinifex sericeus* (Plot 5);
- *Dichelachne* spp. (Plot 1);
- *Poa poliformis* (Plot 5);
- *Pelargonium australe* (Plot 4);
- *Pennisetum clandestinum* (Plot 5);
- *Brypophyllum delagoense* (Plot 5); and
- *Delairea odorata* (Plot 5).

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

The invasive weed *Lantana camara* was observed in all but one plot in both August 2005 and April 2006 and in all plots in October 2005. *Lantana camara* however was not present in Plot 1 in April 2006. *Lantana camara* is less dominant than Bitou Bush andmakes up between 5-10% of individuals in each plot.

The most abundant native species occuping the large shrub/small tree stratum differed from plot to plot but generally consisted of *Melaleuca ericifolia, Leptospermum laevigatum, Acacia longifolia longifolia* and *A. longifolia var sophora.*

No significant change in the abundance of *Acacia longifolia var sophorae* was recorded from October 2005 to April 2006 however *Acacia longifolia longifolia* was rated 2 (5-10% of all individuals) in Plot 5 in October 2005 but was recorded as absent at this plot in April 2006. Further, *Acacia saligna* was recorded as present in August 2005 in Plot 3 but was recorded as absent during the October 2005 and April 2006 surveys.

Groundcover species recorded over the survey period comprised of grasses such as Hairy Spinifex (*Spinifex sericeus*), Pig Face (*Carpobrotus glaucescens),* Plume Grass (*Dichelachne sp.),* Native Geranium *(Pelargonium australe),* Sand Couch *(Zoysia macrantha),* Knobby Club Rush *(Isolepsis nodosa)* and roadside herbaceous weeds such as Mother of Millions *(Bryophyllum delagoense),* Cape Ivy (*Delairea odorata*) and Bridal Creeper (Asparagus asparagoides). The presence and abundance of these species were generally consistent across the survey period however it is noted that 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.

Vegetation plots in Penrhyn Estuary are generally described as being low species diversity, low groundcover and moderate shrub density. The canopy and understorey in all plots were disturbed. A large amount of woody debris, the majority of which was recorded on *Melaleuca ericifolia* and *Bitou Bush*, was noted in Plots 1, 2 and 3 during monitoring Round 2 and in all plots during monitoring Round 3. Woody debris was also noted on *Leptospermum laevigatum, Lantana camera, Isolepsis nodosa, Acacia longifolia* and *Banksia integrifolia* during monitoring Round 3.

Aerial photo interpretation

Ortho rectified aerial photos were obtained for the years 2001 and 2005 and interpreted. A GIS based raster pixel classification tool was used to identify different types of ground cover including bare sand and vegetation. Review of the aerial photos reveal distinct differences in the colour of vegetated areas and areas of bare sand. The GIS and raster pixel classification tool identifies and classifies each polygon as being either sand or vegetation and then calculates a total area occupied by each ground cover type. The area occupied by each ground cover type can then be compared between years. The area identified for analysis by this method was the same for in 2001 and 2005 (Figure 4). A detail of the same area of the 2001 and 2005 aerial photos is included for comparison in Figure 5. This analysis will be repeated in 2006 and/or 2007 if suitable aerial photos are available.

The table below summarises the results of the raster pixel analysis. The general percentage cover of vegetation is approximately 84% whilst bare sand is approximately 16%. The results indicate that there was less than 0.02% difference in the total area estimated between the two aerial photos. The area occupied by vegetation increased by 0.85 % between 2001 and 2005, which corresponded to a 4.76 % decrease in the area covered by bare sand. Qualitative interpretation of the aerial photo indicates that

although the percent cover of vegetation has increased, in the period 2001 to 2005, the vegetation appears to be thinned out and areas of infestation by Bitou Bush are evident.

Results from GIS based Raster Pixel Classification

Cover Type	2001 Area in m^2	2005 Area in m^2	Difference (m^2)	Change (%)
Vegetation	82813	83521	708	0.85
Sand	15614	14888	-726	-4.76
Total	**98426**	**98409**	**-18**	**-0.02**

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 (Figure 1 in Appendix A); 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 41 species of waterbirds were observed during the study (27 during the period 1 January to 1 March) as shown in Table 1. Some species of migratory waders decreased in numbers or were absent during this period, most likely as a result of migration to the Arctic. The Double-banded Plover, a winter migratory wader from New Zealand, was first observed on 1 March 2006.

In the period to 1 March 2006, the most numerically dominant species were the Silver Gull, Bar-Tailed Godwit and the common tern with counts of 230, 162 and 130 respectively. In the period to October 2005, the most numerically dominant species were Silver Gulls, Bar-tailed Godwits and Red-necked Stints with counts of 120, 95 and 44 respectively.

Most birds showed a preference for the upper reaches of the estuary at during most low tides. During spring low tides Bar-tailed Godwits moved along the intertidal zone of Foreshore Beach when the exceptionally low tides exposed an area of tidal mudflats. At other times the beach area at Foreshore Beach provided no suitable feeding habitat for shorebirds. Roost sites used by most shorebirds included the sand spits on both sides of the mouth of the estuary and were used at various times, depending on which sites were least disturbed by people and dogs. Most of the smaller shorebirds used a steep sand dune at the mouth of creek on the eastern side of the estuary as a roost when disturbance was high, except Bar-tailed Godwits which avoided this site and moved between the two sand spits when disturbed.

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.

Wading Shorebirds Observed at Penrhyn Estuary in Rounds 1, 2 and 3

Common Name	Scientific Name	M=Migratory R=Resident	Max Count October 05	Max Count to March 05
Bar-tailed Godwit	*Limosa limosa*	M	95	162
Whimbrel	*Numenius phaeopus*	M	1	0
Grey-tailed Tattler	*Heteroscelus brevipes*	M	3	2
Ruddy Turnstone	*Arenaria interpres*	M	1	0
Red Knot	*Calidris canutus*	M	18	3
Sanderling	*Calidris alba*	M	1	0
Red-necked Stint	*Calidris ruficollis*	M	44	41
Sharp-tailed Sandpiper	*Calidris acuminata*	M	14	22
Curlew Sandpiper	*Calidris ferruginea*	M	16	3
Masked Lapwing	*Vanellus miles*	R	2	
Black-winged Stilt	*Himantopus himantopus*	R	4	
Pacific Golden Plover	*Pluvialis fulva*	M	16	18
Red-capped Plover	*Charadrius ruficapillus*	R	4	6
Double-banded Plover	*Charadrius bicinctus*	M	2	6
Silver Gull	*Larus novaehollandiae*	R	120	230
Little Tern	*Sterna alba*	M	7	0
Crested Tern	*Sterna bergii*	R	4	24
Common Tern	*Sterna hirundo*	M	20	130
White-winged Black Tern	*Chlidonias leucopterus*	M	1	0
Whiskered Tern	*Chlidonias hybrida*	R	1	0
White-faced Heron	*Ardea novaehollandiae*	R	1	1
Little Egret	*Egretta garzetta*	R	1	0
Great Egret	*Egretta alba*	R	1	1
Australian White Ibis	*Threskiornis molucca*	R	3	16
Australian Pelican	*Pelecanus conspicillatus*	R	12	4
Darter	*Anhinga melanogaster*	R	1	0
Pied Cormorant	*Phalacrocorax varius*	R	3	1
Little Black Cormorant	*Phalacrocorax sulcirostris*	R	12	50
Great Cormorant	*Phalacrocorax carbo*	R	2	0

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, which can be supplied if required. 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 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. The presence of lower salinity water in the shallow groundwater was identified in wells in Round 3, possibly as a result of a high rainfall event one week prior to the monitoring being undertaken.

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.

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 three monitoring rounds. 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 the 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 estaury.

4.5 Dune Vegetation

The August, October 2005 and April 2006 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.

Fruiting and flowering of native species was observed in the October 2005 vegetation surveys with seed capsules observed on these species in April 2006. A general increase in the presence of dead wood on the large shrub/small tree stratum and within groundcover species was recorded in April 2006 in comparison to October 2005, however this is likely to be a result of seasonal variations and drought conditions that were reported for the period January to March 2006. Future qualitative analysis of survey data will focus on any change in these parameters.

The seven point Braun Blanquet index allowed for quantitative assessment of the significance of changes in species abundance. This quantitative assessment indicated that a number of species including both overstorey and understorey species have decreased in abundance from October 2005 to April 2006. This assessment has also indicated that a number of both overstorey and understorey species have increased in abundance from October 2005 to April 2006, noting that changes in species abundance was also recorded within the control Plot 5.

Although the quantitative assessment has indicated that species abundance has changed over time, significant change in abundance is likely to be a result of the re-configuration of Plots 1, 3, 4 and 5, which was undertaken during the April 2006 surveying event. Re-configuration of these plots was required as markers were not clearly defined in the field or could not be located. This is likely to be a result of the markers disintegrating overtime or being removed by passers by.

The re-configuration of plots in April 2006 was undertaken before the planned increase in extraction rate to approximately 7.5 ML/day commences and is therefore, unlikely to have affected the integrity of this study. 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. The

increase in woody debris and senescence in *Chrysanthemoides monilifera* (Bitou Bush) across the study area is likely to be a result of Tip Moth damage which was recorded on this species in 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. 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.

It is recommended that permanent markers be placed immediately on all plots across the study area to prevent the loss of current plot boundaries and ensure consistency for future surveys.

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.

Anecdotal observation indicates that some Banksia trees in the dunes are in poor condition. The condition of individual trees will be monitored in future monitoring rounds.

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.

A distinct movement of migratory shorebirds was noted during September and October with changes in numbers of Red Knot and Red-necked Stint were consistent with previous years. These patterns will be compared with October 2006 bird counts as indicator of potential impacts of the BGC Project. In Monitoring Round 3 (April 2006) some species of migratory birds decreased in numbers or were absent during this period, most likely as a result of migration to the arctic.

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 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:

- Re-install new piezometers to replace blocked piezometers in the sand dunes;
- As an additional seagrass bed was identified in the estuary, the statistical design has become asymmetrical. Therefore, an additional site in the seagrass reference areas should be sampled in the next monitoring round;
- 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;
- Permanent markers have been placed at the vegetation plots in the dune system to prevent change in the quadrat location;
- 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 and 3. These Rounds have been completed and further monitoring will be undertaken in October 2006 and April 2007. The next report will be submitted in December 2006 following Round 4 in October 2006.

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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.

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