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ORICA BOTANY GROUNDWATER REMEDIATION PROJECT

ANNUAL REPORT TO THE NSW ENVIRONMENT PROTECTION AUTHORITY

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1 INTRODUCTION

This Annual Report updates progress on the remediation activities for the Orica Botany Groundwater Project.

The remediation program commenced in 1996, at the time of release of the comprehensive Botany Groundwater Stage 2 Survey in August 1996.

On 8 November 1996, Orica (then ICI Australia) issued a proposed Stage 3 Remediation Plan (The Five-Year Remediation Plan) to the NSW Environment Protection Authority (NSW EPA). The Plan was consistent with the proposed remediation strategy described in the Stage 2 Survey Report and addressed key issues identified by the NSW EPA when they reviewed the Stage 2 Report in May 1996. The Remediation Plan was based on a pollution reduction strategy.

In February 2000, Orica Australia Limited entered a Voluntary Investigation and Remediation Agreement (VRA3) with the NSW EPA under the Contaminated Land Management Act 1997 (Sections 19 and 26). The VRA3 formalised the principal features of the remediation program including target dates, reporting requirements and communication processes.

The VRA3 covered the works associated with The Five Year Remediation Plan with the aim of completion by December 2001. The VRA3 then required a further agreement to be then considered to cover a Stage 4 Remediation Plan. Following discussions with the NSW EPA, Orica submitted a set of documents to be included in a new Voluntary Remediation Agreement (VRA4) in December 2001.

VRA4 was issued by NSW EPA in May 2002.

Orica has retained a project team that comprises Australian and international experts. The project team continues to seek out the best technological advancements in land remediation for application at the Botany site. Orica continues to use expert consultants in North America to provide specialist technology and to peer review the work by Australian consultants.

Research programs have been conducted at the University of Toronto and the University of Waterloo in Canada, and Orica has access to emerging and innovative technology from the Remediation Technologies Development Forum (RTDF), a US Government-led program working to develop and trial more effective technologies for remediation of soil and groundwater.

This report describes progress of the project in 2003.

Significant developments during 2003 included:

- a) a strategy review conducted by Orica in the first half of 2003. This review developed an amended strategy that was presented to NSW EPA in June 2003. EPA accepted the amended strategy in July 2003.
- b) following detection of increased concentrations of chlorinated hydrocarbons (CHCs) in City of Botany Bay's Herford Street production bore, NSW EPA issued a Notice of Clean Up Action (NCUA) in relation to all CHC contamination arising from Botany Industrial Park (BIP). The Notice was issued in late September 2003, and a Groundwater Cleanup Plan (GCP)

issued by Orica to NSW EPA for its consideration on 31 October 2003. Orica was authorised to implement this GCP on 17 February 2004.

The NCUA and GCP have considerable duplication of the activities covered under the current VRA, primarily in areas of groundwater and surface water monitoring, remediation and reporting. However there are aspects of the current VRA that fall outside the scope of NCUA and GCP. The NSW EPA have foreshadowed that the VRA will be renegotiated in response to issue of the NCUA and GCP. This is essential to ensure that administrative burdens won't distract resources from the investigation, research and remediation actions.

In any event, VRA4 expires in December 2004 and will require renegotiation in advance of this date.

2 INVESTIGATIONS

2.1 Monitoring

In 2003 monitoring programs were developed and implemented in the following media:

- Marine biota
- Air emissions;
- Surface water; and
- Shallow and deep groundwater.

Orica's consultant URS Australia Pty Ltd (URS) conducted the work, and have prepared a summary report of the work undertaken (see Appendix 2). The main features are described briefly below.

2.1.1 Marine Biota

Marine biota monitoring was last conducted in 1998. Following that last round of monitoring it was concluded (Toxikos 2001, Appendix 2 of Orica 2001) that:

- Results for mercury and hexachlorobenzene (HCB) were variable, but without increasing trends;
- The number of species and number of fish within each fish species caught was highly variable and could not be controlled;
- Continued biota monitoring at a frequency of 12-18 months was unlikely to yield information that could be adequately interpreted; and
- The levels of mercury and HCB detected in fish in the 1998 survey did not pose a health risk to humans.

It was consequently recommended that biota monitoring be performed every 3-5 years.

Apart from being used as an input for the calculation of potential risks to human health, biota monitoring is also a useful indicator of remediation impacts. The

remediation and restoration of the Orica Southlands section of Springvale Drain was completed in December 2001 (reported in Orica 2002a). Thus in September 2003 Orica requested that URS prepare a proposal for further marine biota monitoring. The scope of this work included the collection and analysis of oysters, fish and sediments from Penrhyn Estuary.

URS collected samples of oysters (pre-spawning) and adjacent sediments in December 2003. Additional sampling is proposed to occur in March 2004 (post-spawning) to assess temporal/seasonal and biological variations. The results of the December sampling have not yet been reported; they will be included with the March results in next year's Annual Report.

During discussions with NSW EPA regarding the NCUA, Orica learnt that NSW EPA had coincidentally conducted sampling and analysis of wild oysters in Penrhyn Estuary. NSW EPA forwarded the data to Orica in late November 2003. Sediment samples were not collected. The NSW EPA investigations included metals that are not included in Orica's list of chemicals of concern (listed in VRA4 and the NCUA). Their results showed that HCB, mercury, lead and zinc were detected at levels higher than background. Lead and zinc are not included in Orica's list of chemicals of concern.

2.1.2 Air Emissions

Air emission monitoring has been undertaken in Stages 3 and 4 on a 15-18 month cycle to assess seasonal variability. In 2002 URS conducted the monitoring in late November. Eight locations were sampled, targeting key receptor groups, including:

- Residents (both adult and children);
- Recreational users of the Botany golf course (both adult and children);
- Commercial workers in Discover Cove, Botany Road;
- SRA workers;
- Other industrial workers on the industrial areas above the plume; and
- On-site workers on the Botany Industrial Park (BIP).

The data collected in the November 2002 sampling event was generally consistent with previous results, with the exception of the flux emission rates measured at AS09 in the SRA area (which was attributed to the hot and dry weather at the time of sampling and the heat and dryness of the ground in this location exacerbated by the ballast and lack of vegetation). Comparison of the results obtained in the other sampling locations with previous data showed variability but no significant trends in the values. Overall, the 2002 results confirmed the measurement of consistently very low surface emission rates of the target chemicals at the residential locations.

In keeping with the 15-18 month sampling cycle, no air emission monitoring was conducted in 2003. It is scheduled for late February 2004.

2.1.3 Surface Water

Surface water monitoring is conducted to assess the impact of remedial activities and to monitor changes in environmental conditions arising from groundwater ingress.

There were two surface water sampling events in 2003 – March and September – in conjunction with monitoring of the Central EDC Plume (see Section 2.1.4). In both events samples were collected from Springvale Drain, Floodvale Drain and Penrhyn Estuary (at high and low tides). One new sampling location was introduced for these monitoring events: in the realignment channel parallel to Springvale Drain. All samples were analysed for volatile CHCs. Selected samples from Springvale Drain (including from two additional locations at the point where groundwater from the pilot-scale reactive iron barrier is thought to be intersected by Springvale Drain) were also analysed for dissolved iron and manganese (to assess the impact of the pilot-scale barrier).

Generally speaking, 2003 EDC¹ concentrations at all sampling locations were similar to those reported in 2002 (which showed a decrease relative to all sampling events in the previous 18 months), except at the point upstream of the Orica stormwater pipes' discharge into Springvale Drain (which appeared to be slightly higher than in 2002, but generally consistent with previous monitoring events). This particular location suggests an upstream source of EDC, perhaps associated with the Northern Plumes.

The concentrations of other volatile CHCs are low relative to EDC – EDC represents approximately 90% of the total volatile CHC mass. With the exception of EDC, no volatile CHCs were detected in the high tide sample collected from the new boat ramp in Penrhyn Estuary.

Results for all volatile CHCs from the new sampling location in the Springvale Drain realignment channel were higher than those reported for the point upstream of the Orica stormwater pipes' discharge into Springvale Drain. This indicates that the channel is intercepting the Central EDC Plume in the shallow part of the aquifer, and that the channel is not diluted by any other surface water other than incidental rainfall.

To investigate the possible discharge of dissolved iron and manganese from the pilot-scale barrier into Springvale Drain a seep sample at the estimated point of emergence and two surface water samples (up- and downstream of this point) were collected. The data indicated that there is a trend of increasing iron and manganese as Springvale Drain flows through Orica Southlands. However, the increase is not necessarily attributable to seepage from pilot-scale barrier – the highest concentrations were found at the McPherson Street crossing (the most downstream location tested for these metals). The increasing trend therefore more likely reflects the input of the naturally-occurring metals in the groundwater discharging into the drain. Ferrous iron was the predominant iron species in the seep sample, but was

¹ Ethylene dichloride or 1,2-dichloroethane; a compound formerly manufactured and stored on the operating site.

detected nowhere else, thus reflecting the reducing and anaerobic conditions of the aquifer.

2.1.4 Shallow and Deep Groundwater

The purpose of monitoring the shallow and deep groundwater is to assess the direction and rate of movement of the volatile CHC plumes in these aquifers, and to provide data for designing research and remediation activities. The plumes are broken up into 3 clusters: the Northern, Central EDC and Southern Plumes.

Because of its relative size and mobility, much of the groundwater monitoring tends to focus on the Central EDC Plume. However, samples were also collected and analysed from the Southern and Northern Plumes in 2003. In addition to Northern Plumes sampling, groundwater samples were also collected from residential bores to the west and southwest of the BIP (as part of the investigations related to the NCUA). Furthermore, sampling was conducted in relation to the design of the full-scale reactive iron barrier proposed for Block 1 of Southlands (see Section 3.3) and for filling data gaps required for the design of primary containment area (Southlands Block 2) project modules under the NCUA. The table below summarises the sampling program dates.

Sampling Event	Location/Purpose	Date
Northern Plumes	Herford Street bore, Nuplex site, Banksmeadow Public School	August
Northern Plumes	Residential bores	October
Central EDC Plume	Southlands Block 2, Exell Street, Foreshore Road	March
Central EDC Plume	BIP, Nant Street tank farm, Southlands Block 2, Exell Street, Foreshore Road, Botany Road (Botany Golf Course)	August
Central EDC Plume	Southlands Block 2 (primary containment area)	November/December
Southern Plumes	Southlands Block 1, Southlands Block 2, Botany Road, Foreshore Road, Penrhyn Estuary, Discovery Cove Industrial Park	August
Full-scale reactive iron barrier	Southlands Block 1 (geochemical and geotechnical design data)	November/December

Northern Plumes

Investigation of the Northern Plumes began following detection of elevated concentrations of volatile CHCs (particularly EDC) in the City of Botany Bay's production bore in Herford Street, Banksmeadow (known as BMC-1) in July and

August. Nearby monitoring wells and bundle piezometers were also tested, as well as the pond on Botany Golf Course that BMC-1 pumped into. EDC in BMC-1 was significantly higher than had been detected in the previous monitoring event in 1996, although the sampling method employed in 1996 caused the sample to be significantly aerated (which would have reduced the concentrations of the volatile CHCs). Investigations of nearby monitoring points confirmed that the EDC – and the other volatile CHCs detected (in much lower concentrations) – was predominantly confined to the deeper aquifer. The resultant sampling of 30 residential bores (2 in initial round and 28 in later more extensive investigation) near the western margin failed to detect any Orica-sourced volatile CHCs². Orica will continue with regular monitoring of the residential bores pursuant to the NCUA.

Central EDC Plume

Monitoring of the Central EDC Plume, which is by far the largest and most dynamic of the plumes, occurred in March and August 2003. All samples were analysed for volatile CHCs. In March samples from one of the shallow wells at the northern end of Block 2 Southlands was also analysed for BTEX compounds³ to whether the upgradient Mobil facility could have any adverse impact on the passive bioremediation field trials in the shallow aquifer in Area A (see Section 4.2). The sample collected reported a slightly higher concentration than reported in 1996, but not high enough to be likely to adversely affect the trials.

Two long-screened monitoring wells were installed at the northern edge (Botany Road) of Botany Golf Course in August. Based on the volatile CHCs being detected in these wells, they appear to be located in the region where the Southern and Central EDC Plumes intersect.

The most significant changes in the distribution of EDC within the aquifer over the previous 12 months have occurred within the Central EDC Plume. The high concentration core (>5,000 mg/L) of the Central EDC Plume is continuing to migrate from the northern portion of Block 2 Southlands towards Botany Bay, and has most likely crossed the Southlands boundary. There has been a significant reduction in EDC concentrations near the inferred source zone (former EDC storages on the BIP) and Springvale Drain, suggesting significant dissolution of the DNAPL source has occurred.

Other volatile CHCs detected in the Central EDC Plume – comprising a small proportion in relation to the EDC – include CTC (at the intersection with the Southern Plumes), tetrachloroethylene (PCE), trichloroethylene (TCE) and vinyl chloride (VC). PCE concentrations are largely unchanged from 2002. TCE, on the other hand, has increased significantly near the inferred EDC source area since 1999. The increase is not believed to indicate a new source of contamination, but rather a progressive change in the DNAPL source composition through the dissolution of the more

² Chloroform was detected in a residential bore in Trevelyan Street, and 1,1-dichloroethane was detected in a bore in Tupia Street. The NSW EPA agreed with Orica's conclusion that these compounds were not associated with groundwater contamination from the Orica site.

³ Benzene, toluene, ethyl benzene and xylenes

soluble EDC in the DNAPL (i.e., as the groundwater becomes less saturated with EDC, the TCE has a greater opportunity to dissolve into the groundwater). However, such increases in TCE concentrations in areas where EDC concentrations are decreasing are not apparent further downgradient, indicating that the TCE is moving at a far slower rate (due to its higher rate of sorption onto soil particles) than the EDC.

The most significant change in the distribution of VC over the last 12 months occurred within the Central EDC Plume. A significant decrease in VC concentration was recorded between the inferred source zone and Springvale Drain. However VC concentrations have increased downgradient beneath Block 2 Southlands where the EDC concentrations continue to be elevated (>3,000 mg/L). This appears to be in a zone of lower permeability (i.e., where the plume travels slower). The elevated concentrations of VC suggest that VC is a source compound – not just a degradation compound.

Of the other volatile CHCs detected, chloroform has presented the most notable trend. In some of the bundle piezometers near the western margin of the Central EDC Plume appreciable concentrations of chloroform have been detected, although no carbon tetrachloride (CTC) -from which chloroform can be derived - has been detected. Chloroform, though, is fairly ubiquitous in the environment, and can be formed by the reaction of free chlorine (from the degradation of CHCs) with organic matter within the aquifer.

Southern Plumes

The Southern Plumes consist volatile CHCs – predominantly CTC, PCE and TCE – that arose from the former solvents manufacturing facilities located on the southern section of the BIP. These plumes underflow Southlands Block 1 and travel in a southwesterly direction towards Penrhyn Estuary. As part of the Southern Plumes monitoring program in 2003, two additional monitoring wells were installed between McPherson Street and Botany Road in the Discovery Cove Industrial Park to further characterise the distribution of volatile CHCs off-site.

The distribution of CTC was found to be largely unchanged from 2002, except in the deep groundwater in one of the bundle piezometers on Block 1 Southlands where an increase to 1999 concentrations was apparent. The new Discovery Cove well and one of the Foreshore Road bundle piezometers indicated that CTC concentrations are increasing at depth, but the bundle piezometer at Penrhyn Estuary still showed no signs of CTC.

PCE concentrations had also increased at Foreshore Road and Discovery Cove, as well as at Penrhyn Estuary. Concentrations on Block 1 Southlands were variable – some increases, some decreases – but there were also clear impacts from groundwater pumping activities by EnergyAustralia⁴ in the area. It appears that

⁴ EnergyAustralia has been undertaking repairs to the high voltage cables in their easement situated between Block 1 Southlands and the Sydenham to Botany railway line. Due to the shallow nature of the groundwater, the excavations required dewatering. The extracted groundwater was discharged onto the ground surface to the south of the excavations.

groundwater (presumably extracted from the shallow Central EDC Plume) discharged in the vicinity of one of the bundle piezometers and wells caused PCE concentrations at certain depths to decrease.

A similar impact was observed for TCE on Block 1. However the downgradient results were different to CTC and PCE, with no significant changes apparent at Foreshore Road. Indications are that TCE continues to migrate towards Penrhyn Estuary, albeit at a very slow rate.

EDC was observed to increase in the bundle piezometer affected by the EnergyAustralia pumping, confirming the conclusion that the groundwater originated from the Central EDC Plume. EDC was also observed at Discovery Cove at concentrations consistent with up- and downgradient concentrations previously observed. No significant changes were observed at Foreshore Road or Penrhyn Estuary.

Full-scale reactive iron barrier

In December 2003 URS undertook additional groundwater monitoring to provide design information for the construction of the full-scale reactive iron barrier on Block 1 Southlands (see Section 3.3). This work included the installation of additional monitoring points and the collection of core samples for geotechnical assessment along the preferred alignment for the barrier (adjacent to Nant Street and a short distance along McPherson Street). The groundwater results would then be used to determine the most appropriate locations to install yet more monitoring wells, which would be used for the collection of bulk groundwater samples for column trials⁵. The sampling, analysis and bulk sampling were completed in February 2004. The results will be consolidated and reported in 2004.

2.2 Human Health Risk Assessment

As no air emissions monitoring was conducted in 2003 (see Section 2.1.1), the Stage 2 human health risk assessment (Woodward-Clyde 1996) was not reviewed.

However, in light of the monitoring of the residential bores along the western margin, a revision of the western margin human health risk assessment was conducted to evaluate potential risks to the health of residents and users of Botany Golf Course. The groundwater and pond water data from the August sampling event were used for the assessment. Additional and more conservative exposure pathways were used than in the original 1996 assessment. URS concluded that the calculated risk values for both the residential and recreational (golf course) receptors do not pose an unacceptable risk to human health. This assessment is consistent with the findings of the Stage 2 risk assessment (Woodward-Clyde 1996).

⁵ Column trials will be conducted in Canada to assess new sources of iron (for the two barrier installation methodologies being considered: biopolymer slurry trenching and hydrofracturing) and the EHCTM product of Adventus Technologies (see Section 2.4).

2.3 Investigation of Potential Source Areas

No specific work has been done in 2003 to investigate potential source areas, although the full-scale reactive iron barrier sampling program in part helped to delineate the potential source areas by characterising the aquifer conditions downgradient of those areas.

Investigation of DNAPL source areas is a mandatory requirement of the NCUA, so more targeted investigations will be undertaken in 2004.

2.4 Review of Emerging Technologies

Over and above the research modules being undertaken (see Section 4), Orica also maintains a close watch on emerging environmental investigation and remediation technologies. For the most part this is achieved by exchanging issues and opportunities with a wide network of peers and experts in Australia and overseas, monitoring selected printed and electronic journals, monitoring selected websites (e.g., Remediation Technologies Development Forum (RTDF), Air Force Center for Environmental Excellence (AFCEE), Interstate Technology Review Council (ITRC) and US EPA), and participating in specialist environmental email discussion groups.

From time to time an Orica representative may also attend a high-gain international conference such as the International Conferences on Remediation of Chlorinated and Recalcitrant Compounds held in Monterey, California, in May of every even year. There was no such conference in 2003, however a member of the Botany Groundwater Project team will be attending the conference in 2004. The 2002 conference covered a number of emerging technologies that Orica has since looked into further:

- **Phytoremediation** developments – Orica co-sponsored a phytoremediation seminar tour of visiting experts from the USA in August 2003. A number of Orica site remediation specialists attended the seminars. The co-sponsorship also enabled Orica to meet with the visiting experts, including at the Southlands site. Orica representatives also met with Professor Alan Baker of Melbourne University to discuss options for research and implementation. Although proposals for further work have been presented to Orica, the Botany Groundwater Project team has deferred any of this work for the time being to ensure the focus on the core requirements of the VRA and NCUA is not distracted.
- Groundwater monitoring developments, including
 - **Membrane interface probes** – product literature and case studies have been reviewed by members of the Botany Groundwater Project team, but it was felt that the current state and availability of the technology in Australia is too limited to provide significant benefit to the project;
 - **Electromagnetic borehole flow meters** – unsuccessfully employed during the construction and early performance monitoring of the pilot-scale reactive iron barrier in 1999; not investigated further in 2003;

- **Passive diffusion bag sampler** – product literature and case studies have been reviewed by members of the Botany Groundwater Project team, and URS has proposed to trial this technology during groundwater monitoring events in 2003. Orica has decided against proceeding with trials of this technology because of problems arising from the use of long-screened wells (see below).

Orica was approached by an American company called Adventus Technologies (formerly part of Grace Bioremediation; the supplier of Daramend™ and Aquamend™ soil and sediments treatment technologies) to consider trials of a new product in their portfolio. The new product is called EHC™, which is used to form a **biologically-enhanced permeable reactive iron barrier**. It effectively combines the benefits of bioremediation with zero valent iron technology to broaden the range of treatable contaminants and to accelerate the treatment process. Orica met with representatives from Adventus Technologies in December 2003 and requested that they prepare a proposal for column trials using groundwater and soil sourced from Orica Southlands.

Since the Stage 2 Survey of the Orica Botany site and surrounds, innovative investigation methods have been employed for the purposes of site characterisation. For example, bundle piezometers have been used for discrete-level geochemical characterisation of the site. Whilst these have been very useful they have some limitations, specifically the inability to collect hydraulic data and collection of large sample volumes. More recently it was decided to install **long-screened monitoring wells** (up to 10 m) to enable the collection of both hydraulic and chemical data. Low flow sampling techniques were used to collect discrete-level samples from the long-screened wells. Should long-screened wells and low flow sampling prove successful in accurately defining vertical concentration profiles, it was anticipated that passive diffusion samplers could then be deployed. However, the monitoring data collected in August 2003 has indicated that long-screened wells may act as conduits for groundwater to move between the lower and upper part of the aquifer depending on the direction of the vertical gradient. Consequently, long-screened wells will no longer be used for monitoring and Orica will abandon or retrofit all existing long-screened monitoring wells to ensure that no vertical migration of groundwater occurs between different zones within the aquifer.

The installation of deep (>20 m) **bundle piezometers** in the latter part of 2003 in off-site locations presented problems for URS. The bundle piezometers were so long that they could not support their own weight when installed in the borehole. As a result, URS developed an innovative design using lighter-weight materials, which has been used successfully in 2003 in the new deep monitoring locations.

3 REMEDIATION

3.1 Remediation Strategy Review

Based on information and ideas gathered in an overseas mission in late 2002, a remediation strategy review was conducted in early 2003. The details of the review follow.

The remediation strategy in VRA4, which evolved in the period 1996-1998, has the following major elements:

- Installation of a permeable reactive barrier containing zero valent iron (Full-Scale Reactive Iron Barrier) in Block 1 Southlands to reduce the concentrations of chlorinated hydrocarbons entering Springvale Drain from the Southern Plumes, and consequent impact on Penrhyn Estuary/Botany Bay.
- Bioremediation field trials for the shallow and deep Central EDC Plume, which if successful would lead to full-scale bioremediation implementation.
- Ongoing monitoring of all plumes and re-assessment of human health risk assessment.

This strategy was developed at a time when the CHC concentration in Springvale Drain was dominated by contaminants derived from the shallow groundwater of the Southern Plumes. Subsequently, the arrival of the Central EDC Plume at Springvale Drain resulted in far higher concentrations of CHCs, dominated by EDC, in the drain's surface water. An analysis of surface water data in Springvale Drain showed that, whilst total CHC and EDC concentrations have now decreased significantly from their peak, EDC remains the dominant contribution to CHC contamination of Springvale Drain and hence Penrhyn Estuary.

In a strategy review paper presented to NSW EPA in June 2003, Orica therefore proposed that bioremediation of the Central Plume would have a more immediate impact on environmental improvement than the proposed shallow full-scale reactive iron barrier. It proposed a deferral of installation of the full-scale barrier to allow resolution of issues and opportunities identified with the full-scale barrier, namely:

- Investigation of potential environmental impact of high dissolved iron from the full-scale barrier, due to the abnormally low pH of the groundwater on Orica Southlands.
- Investigation of an alternative alignment to the diagonal alignment across Block 2, along Nant Street and McPherson Street. This alignment (whilst longer) increases the probability that the barrier will be downgradient of any dense non-aqueous phase (DNAPL) source areas.
- Investigation of the costs and environmental benefits of a deep full-scale barrier to maximise contaminant containment on Block 1, rather than treating only shallow groundwater.
- Investigation of the relative costs and technical practicability issues of biopolymer slurry trench and GeoSierra's Azimuth Controlled Vertical Hydraulic Fracturing (ACVHF or "hydrofrac") technologies.
- Preliminary investigation of Adventus Technologies biological permeable reactive barrier technology. This technology can potentially degrade EDC and dichlororomethane, the two CHCs not degraded by zero valent iron barriers, and increase the degradation rate of others by promoting biological degradation in addition to reductive dechlorination by iron. Laboratory-scale trials would give an indication of the applicability of this technology, potentially in conjunction with a conventional zero valent iron wall.

- Investigation of potential for enhanced in situ bioremediation applications on Block 1 of Southlands.

The strategy document also detailed the longer-term remediation strategy for the Central, Southern and Northern Plumes following completion of the bioremediation field trials.

NSW EPA accepted the revised strategy in July 2003 and granted a nominal six months to complete this work programme.

3.2 Springvale Drain Sediment Removal and Disposal

In November 2001 an estimated 1,100 m³ of contaminated sediments were excavated from Springvale Drain and placed into segmented sediment containment structures constructed adjacent to Nant Street pending assessment and disposal.

Three rounds of sampling were undertaken in 2002 and 2003 to characterise the waste and to delineate 'hot spots'. Two 'hot spots' were closely delineated and classified as Hazardous waste. The principal contaminants of concern were tetrachloroethylene (PCE) in one cell and hexachlorobenzene (HCB, a Scheduled Chemical⁶) in the other. The rest of the sediments were classified as Industrial waste.

Following authorisation by NSW EPA, the Industrial waste was sent to an appropriate landfill for disposal, and the 2 'hot spots' were placed into drums and transferred to one of Orica's licensed Hazardous waste depots on BIP pending treatment. A Project Completion Report for this work may be found in Appendix 5.

3.3 Full-Scale Reaction Iron Barrier

The following activities occurred in relation to full-scale reactive iron barrier implementation in 2003, and should be read in conjunction with the report of activities by EnviroMetal Technologies Inc (ETI) in Appendix 3.

Implementation activity on the full-scale barrier was put on hold pending the outcome of the strategy review detailed in 3.1 above.

Following approval of the strategy review in July 2003, details of the various work modules were developed. The project modules were broken up as follows:

Module 1: Investigation of impacts of dissolved metals (ferrous and manganese) levels.

Module 2a: Collection of geochemical and geotechnical data for the proposed Nant Street/McPherson Street alignment. Based on this work, determine locations for collection of bulk samples for column trials.

Conduct column trials for new alignment using local iron and US-sourced iron (for biopolymer trench design) and US-sourced iron (for

⁶ As defined in the Scheduled Chemical Wastes Chemical Control Order (EPA 1994).

hydrofrac wall design).

Based on above results, prepare preliminary designs, cost estimates and technology evaluations for alternative alignments, barrier depths and alternative installation methods (biopolymer slurry trench and hydrofrac). Clear recommendation of installation proposed.

Module 2b: In parallel to column trials for Module 2a, parallel column trials for Adventus Technologies biological permeable reactive barrier.

Module 3: Desktop study of bioremediation potential for Southern Plumes on Block 1 Southlands.

Progress against these modules has been slowed down by the major workload created by the NCUA and GCP process.

Module 1 is essentially complete, with a draft report to be issued by URS in late February/early March 2004.

Module 2a and 2b works are well underway, with all geochemical and geotechnical data collected. Discussions with ETI, GeoSierra and Adventus have commenced to coordinate column trials and samples collection and despatch is imminent. A report of the field work (data gaps) is being finalised as a basis for design of the Nant Street/McPherson Street alignment. A briefing data package has been issued to GeoSierra.

Module 3 work has commenced with the assembly of all relevant geochemical data for consideration by GeoSyntec consultants.

Since commencement of the work programme, the NCUA and GCP process has necessarily changed the emphasis on some of this work. The NCUA requirement for contaminant containment around DNAPL source areas means that the original diagonal alignment across Block 1 will be abandoned, and a deep barrier wall must be installed. Hence the scope of work for Module 2a is reduced to biopolymer trench (Australian and US-sourced iron) and hydrofrac emplacement methods, for a deep barrier (bottom of Layer 2) along the Nant Street/McPherson Street alignment.

The completion of this work programme will be expedited in 2004 to enable:

- a) decision on basic implementation concept and design parameters
- b) allowance for downgradient dissolved metals treatment
- c) allowance for downgradient biological permeable reactive barrier for treatment of the full-scale barrier effluent groundwater (if required in practice).
- d) completion of full-scale barrier installation as early as practicable (consistent with NCUA and GCP requirements for containment of identified DNAPL source zones).

3.4 Containment of Contaminated Groundwater Plumes

In May 1999 Orica was directed by NSW EPA to undertake investigations to evaluate containment options for the EDC plume underflowing the Orica Southlands

area. Separate parallel investigation programs were undertaken for the shallow and deep EDC plume.

As reported in the previous Annual Report (Orica 2002a), neither Shallow or Deep EDC Plume Hydraulic Containment are remediation strategies considered by Orica to be the most effective at achieving remediation outcomes. The Principal Program Features of the Stage 4 Voluntary Remediation Agreement (see Appendix 1) states:

The shallow EDC Plume Hydraulic Containment system is *not* a preferred strategy. Orica's preferred strategy for remediation of the EDC Plume is bioremediation [see Section 4.2]. The possible use of hydraulic containment is subject to triggers such as unacceptable levels of EDC in surface waters...

Consequently, it was proposed in the 2002 Annual Report that this section would not be included in subsequent Annual Reports unless there was a need to resurrect these project modules.

Despite this, containment of contaminated groundwater plumes is a fundamental requirement of the NCUA process, with containment specified for:

- a) Primary containment area (Block 2 Southlands)
- b) Secondary containment area (upgradient of Penrhyn Estuary/Botany Bay for containment of contaminated groundwater that has passed the primary containment area)
- c) Identified DNAPL source zones

The NCUA mandates use of hydraulic containment methods for a), but not for b) and c) above.

Progress against these projects will be reported in quarterly reports submitted under the GCP rather than reported via the VRA Annual Reports to avoid unnecessarily duplication.

4 RESEARCH

4.1 Trial of Subsurface Reactive Iron Barrier Technology

No further performance monitoring of the pilot-scale reactive iron barrier for was undertaken in 2003. Investigations in 2003 were primarily focussed on developing the design of the full-scale reactive iron barrier in Section 3.3 (see also Section 2.1.4 for discussion of the groundwater monitoring).

4.2 Investigation of Bioremediation Potential for Contaminated Groundwater

Based on the favourable outcomes of the laboratory microcosm studies performed at the University of Toronto, Canada, under the supervision of GeoSyntec Consultants in 2000 (reported previously (Orica 2001)), conceptual designs for field trials of enhanced bioremediation of the Central EDC Plume were developed in 2001. These trials have been designed to evaluate the feasibility of stimulating the existing

microorganisms in the shallow and deep aquifers to reductively dechlorinate the EDC and other volatile chlorinated hydrocarbons (CHCs):

- Area A is in the *shallow* aquifer at the northern end of Block 2 of Orica Southlands (i.e., hydraulically downgradient of Springvale Drain and upgradient of Floodvale Drain). This will involve simultaneous (side-by-side) trials of *passive* addition (i.e., slug injection) of two sparingly soluble (i.e., slow release) electron donors: emulsified edible *soybean oil*; and *calcium oleate* (injected as potassium oleate solution followed by calcium chloride solution to form calcium oleate).
- Area B is in the *deep* aquifer near the southwest corner of Block 2 of Orica Southlands. Three extraction wells will be used to extract deep (> 10 m) groundwater. Two wells will extract less contaminated groundwater from the inferred edges of the deep EDC plume; the third will extract more significantly contaminated groundwater from the inferred core of the plume. The extracted groundwater will be blended to achieve varying concentrations of EDC and other CHCs to evaluate their effect on the biological activity. The blended groundwater will then be reinjected in two locations. In one, emulsified *soybean oil* will have been *passively* added (by slug injection at the groundwater reinjection point). In the other, a soluble electron donor – *ethanol* – will be blended with the groundwater at a controlled rate prior to reinjection (i.e., *active* electron donor addition).

GeoSyntec's conceptual design was finalised in May 2003. GeoSyntec then commenced development of Standard Operating Guidelines for the trials.

In February 2002 Orica engaged Kellogg Brown & Root Pty Ltd (KBR) to produce the detailed engineering design for the trials' above-ground plant and equipment, and to procure and install this equipment.

At the same time, URS was engaged to design, procure and install the extraction, reinjection and monitoring wells for the trials. They were also requested to provide a costed proposal for the operation and maintenance of the active system in Area B and the sampling and analysis of both trial Areas.

Orica submitted a DA for the trials to the City of Botany Bay (Council) in August 2002 (which was subsequently revised in October 2002 to reflect revisions to the exact location of the aboveground infrastructure in Area B). Council approved the DA in March 2003.

During the course of 2002 and 2003 Orica has been working with a number of potential suppliers of the electron donors – particularly the emulsified soybean oil. Although an 'off-the-shelf' supplier of emulsified vegetable oil has been found in the USA, Orica would prefer to source the material from a local manufacturer. Commercial discussions between Orica, the American supplier and a local toll manufacture commenced in the last quarter of 2003.

Construction of the plant and equipment for the field trials began in October 2003. (Construction and subsequent commissioning were completed in February 2004.)

4.3 Co-operative Research Centre for Nano-Sized Zero Valent Iron

In late 2000 Orica was invited to participate in a Co-operative Research Centre (CRC) project for the development of nano-sized zero valent iron particles. These particles, measuring 100-200 nm (0.0001-0.0002 mm), have a number of potential advantages over conventionally sized ZVI particles (around 0.5 to 1 mm). They have much higher surface areas and therefore reactivity, and they may be placed more simply – and potentially cheaply – in aquifers using hydraulic or pneumatic fracturing and injection.

The project is being run by the CRC for Waste Management and Pollution Control out of the University of NSW. To date it has achieved:

- Development of a reliable bench-scale manufacturing technique, which is 3 orders of magnitude cheaper than any other known technique for producing iron nano-particles;
- Proving the ZVI particles' capabilities and effectiveness in destroying a wide number of target chemicals (particularly focussing on agricultural chemicals);
- Completed field trials in an agricultural setting; and
- Protected its intellectual property.

The next steps will be:

- Development of a bulk manufacturing process, including pilot-scale trials; and
- Remediation field trials in an industrial setting.

The project is expected to run through into 2005, subject to current program renewal discussions.

Orica is providing an in-kind contribution to the project, primarily providing advice based on its knowledge and experience with ZVI technology. NSW EPA is also a member of the project team.

4.4 In-well VOC Probe

In 2001 Orica was asked to assist in the trials and assessment of another CRC development: a probe that can continuously monitor concentrations of volatile organic compounds (VOCs) in a monitoring well. The probe had been trialed and demonstrated in Western Australia monitoring a BTEX (benzene, toluene, ethylbenzene and total xylenes) plume. The CRC for Waste Management and Pollution Control – through the University of NSW (UNSW) – wished to also trial and showcase it on the eastern seaboard monitoring a chlorinated hydrocarbon plume.

Due to further technology development of the probes, and limited resources at both UNSW and Orica, the trials have not yet proceeded. When they start, the trials are expected to be conducted over two years.

4.5 Phytoremediation

Work on phytoremediation in 2003 is discussed in the Section on Review of Emerging Technologies (Section 2.4). At this point in time, however, any plans to further investigate the feasibility of phytoremediation in the context of the Botany Groundwater Project have been put on hold. This is due to the greater focus on the investigation and remediation modules of the VRA and GCP, as well as the belief that phytoremediation is likely to have only limited application at this stage of the Botany Groundwater Project. Orica will be discussing this aspect with NSW EPA as part of the renegotiation of the VRA to take account of the implications of the NCUA/GCP workload.

5 COMMUNICATION

5.1 Community Liaison Committee

In 2003 there were 3 meetings of the Community Liaison Committee (CLC), all held at Botany Town Hall:

- Meeting 17 on 8 July 2003
- Meeting 18 on 23 October 2003
- Meeting 19 on 16 December 2003

The meeting scheduled for March 2003 was postponed, in consultation with the CLC Chair, because Orica was reviewing the Remediation Strategy for the Botany Groundwater.

Approximately 5,000 newsletters were distributed to local residents and Botany Industrial Park employees following the October and December meetings.

A number of new members attended the committee meetings in 2003.

5.2 Communications Processes with Neighbours and the Wider Residential and Industrial Community

A series of events from July 2003 raised the public profile of the Botany groundwater contamination:

- Detection by the City of Botany Bay and NSW EPA of volatile CHCs in Council's Herford Street bore in Banksmeadow
- Media coverage of the issue raised wider community awareness and concern about the Central Plume of the contaminated groundwater
- Letters from NSW EPA and Orica were independently distributed to the local community explaining the status of the groundwater clean-up and a reminder not to use groundwater within the groundwater protection zones
- A public meeting was conducted by Save Botany Beach interest group on 10 September 2003 attended by approximately 200 local residents and interested parties. NSW EPA, Orica and DIPNR each presented to this meeting

- A Notice of Clean Up Action issued to Orica on 26 September 2003 by NSW EPA, which mandated Orica to clean up the groundwater within a much tighter timeframe than proposed in the Voluntary Remediation Agreement.

One of the key community concerns raised during this period was potential contamination of residential bores. To allay community concerns regarding this matter, on September 24 Orica wrote to approximately 550 local residents in the immediate vicinity of the groundwater plume offering URS to sample and test any groundwater bores on their properties. A total of 28 bores were tested, and of these URS advised that there were two bores where contaminants were detected but which were not considered to have originated from Orica. All of the owners of the bores have been advised of the results. In addition, further groundwater monitoring wells are being installed closer to the residential areas to ensure that if there are any changes to the groundwater conditions, they are identified early.

Efforts to improve community consultation are continuing.

Orica retained a community relations specialist in September to critically assess Orica's relationship with each of its stakeholders to help identify specific areas for communication improvement. This included a series of face-to-face interviews with CLC members to seek feedback on community perspectives about the project. Initiatives that have resulted from these discussions include:

- At least quarterly meetings of the CLC
- The current format and style of the Minutes are gradually being technically toned down so the content is easier to read and comprehend
- The style of the Newsletter will change to a more reader-friendly format
- The 5000 newsletters that are distributed to the homes in the Botany area are now being distributed in Orica envelopes
- Fixed distribution points of the newsletter will be introduced (i.e., Council notice boards, community notice boards, and through school newsletters)
- A draft Terms of Reference and draft Communication Guidelines were tabled at the December CLC meeting to help clarify aims and expectations of the CLC. Members have been asked to provide feedback so principles can be adopted at the next meeting
- A dedicated web site for the Botany Groundwater Project is being established to provide wider community access to information regarding the clean-up
- A regular column in the *Southern Courier* is being established to update the community on the implementation of the Groundwater Cleanup Plan
- Ongoing personal communication with potentially affected residents/industries downgradient of the groundwater plumes.

Orica has committed to a comprehensive communication program to help re-establish public confidence in its ability to address the groundwater clean-up. Orica will also monitor and evaluate the communication processes during 2004 to provide some measure of its effectiveness.

5.3 Annual Progress Report

The Voluntary Investigation and Remediation Agreement requires Orica to issue a written annual report of all facets of the remediation program.

Copies are issued NSW EPA, NSW Department of Infrastructure, Planning and Natural Resources (DIPNR), South Eastern Sydney Public Health Unit (NSW Department of Health), City of Botany Bay (for Council's library) and the CLC.

This is the fourth Annual Report under the Voluntary Agreement process, which has been issued as required. The first was issued in February 2001 (Orica 2001), the second in February 2002 (Orica 2002a) and the third in February 2003 (Orica 2003).

6 FORWARD PROGRAM

The Stage 4 Agreement is included in Appendix 1. It includes descriptions of the various monitoring, investigation, research remediation, and communication modules.

Key aspects planned for 2004 are:

- Monitoring program – ongoing monitoring of air emissions, surface water in Springvale and Floodvale Drains and Penrhyn Estuary, and shallow and deep groundwater. Completion of marine biota monitoring in Penrhyn Estuary in early 2004.
Groundwater and surface water monitoring will be in accordance with the schedule developed in the GCP, and will be reported at least quarterly as required by the NCUA.
- Monitoring program results will be reviewed against the Human Health Risk Assessment and, if necessary, the risk assessment will be revised.
- Ongoing evaluation of the potential of emerging technologies. For 2004, this will include:
 - attendance at the biannual internationally recognised Monterey conference on “Remediation of Chlorinated and Recalcitrant Compounds” in May.
 - evaluation of biological permeable reactive barrier technology
- Progress implementation of full-scale reactive iron barrier to earliest practicable completion consistent with NCUA requirements.
- Complete bioremediation field trials to enable decision on full-scale deployment of bioremediation as part of the GCP.
- Ongoing support of the CRC Research Project into nano-scale zero valent iron technology, dependent on current program renewal discussions.
- Ongoing community liaison in relation to the Botany Groundwater issue (under both the VRA and GCP)

7 REFERENCES

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APPENDIX 1 STAGE 4 VOLUNTARY AGREEMENT

APPENDIX 2 URS SUMMARY REPORT 2003

APPENDIX 3 ETI SUMMARY OF ACTIVITIES 2003

APPENDIX 4 GEOSYNTEC SUMMARY OF ACTIVITIES 2003

**APPENDIX 5 PROJECT COMPLETION REPORT FOR SPRINGVALE
DRAIN SEDIMENTS DISPOSAL**