

FINAL REPORT

Orica Botany Environmental Survey Stage 4 – Remediation

Progress Report - Southern Plumes
DNAPL Source Area Delineation
Investigation, August 2005

Prepared for

Orica Australia Pty Ltd

1 Nicholson Street
MELBOURNE VIC 3000

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URS

Project Manager: URS Australia Pty Ltd
Michael Hayter
Principal Hydrogeologist
Level 3, 116 Miller Street
North Sydney, NSW 2060 Australia
Tel: 61 2 8925 5500
Fax: 61 2 8925 5555

Author: Date: 23 December 2005
(Optional) James Morrow
Environmental Engineer Reference: R031A_DNAPL_SOUTHERN
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URS Australia Pty Ltd (URS) was contracted by Orica Australia Pty Ltd (Orica) to undertake further delineation investigation of potential dense non-aqueous phase liquid (DNAPL) source areas located at both the Botany Industrial Park (BIP) and at Orica's Southlands (the site). This progress report presents the results of investigation works recommended in the URS 2005 DNAPL Source Area Delineation Investigation report (URS, 2005a).

At the time the 2005 DNAPL Source Area Delineation Investigation report (URS, 2005a) was prepared investigation works proposed within the Botany to Sydenham Goods Railway Corridor had not been undertaken due to delays obtaining access to the site from the land owner (RailCorp). Consequently, this progress report also presents the findings of soil and groundwater investigation works undertaken within the Botany to Sydenham Goods Railway Corridor as well as including preliminary investigation results that were presented in the 2005 DNAPL Source Area Delineation Investigation report (URS, 2005a).

DNAPL source area delineation investigations have been undertaken in an iterative manner since May 2004. The objective of the ongoing DNAPL source area delineation investigations is to obtain enough data to identify, characterise and delineate the source areas at the site. The aims of the delineation investigation works outlined in this progress report were to:

- Define the upgradient and lateral boundary of the S2 and S3 DNAPL source areas;
- Gain a better understanding of the vertical and horizontal distribution of DNAPL in the subsurface in the vicinity of the inferred DNAPL source areas of the S2 and S3 Plumes; and
- Better understand the distribution and characteristics of the various chemical compounds within the S2 and S3 DNAPL source areas.

Investigations undertaken prior to this assessment indicated that the source of the Southern Plumes was the historical manufacture of chlorinated solvents at the former Solvents Plant and former TCE Plant. Although it is possible that the DNAPL source areas overlap and the DNAPL sources are themselves likely to be composed of a spatial and temporal diversity of releases to the sub-surface, they have previously been referred to as the S2 and S3 source areas.

The S2 source area is inferred to lie beneath the former Solvents Plant, the Botany rail corridor and possibly Southlands Block 1. DNAPL was likely to have entered the subsurface as a result of leaks and spills at multiple locations at the former Solvents Plant including the former effluent collection pit (the 'Save All Pit'), former storage tanks for carbon tetrachloride (CTC) and tetrachloroethene (PCE) and an underground effluent collection system believed to be constructed of vitreous clay pipe. These releases could have occurred throughout the plant operating life.

Similarly, the S3 source area is inferred to lie beneath the former TCE Plant, the Botany rail corridor and possibly Southlands Block 1. DNAPL was likely to have entered the subsurface as a result of leaks and spills at multiple locations at the former TCE Plant including former storage tanks for trichloroethene (TCE) and PCE and an underground effluent collection system believed to be constructed of vitreous clay pipe.

A third DNAPL source area (S1) is inferred to lie beneath the northern portion of Southlands Block 1 and possibly the Botany Rail Corridor. Investigation works outlined in this report did not specifically target the inferred S1 DNAPL source area, however, given that the S1 source area may overlap with the inferred S2 source area it is possible that some of the findings are indicative of the S1 source area. Results of previous investigations of the inferred S1 source area are discussed where applicable to the results of the investigation works outlined in the report.

A summary of previous DNAPL source area investigations is provided in the 2004 DNAPL Source Area Investigation report (URS, 2004a) and the 2005 DNAPL Source Area Delineation Investigation report (URS, 2005a).

2.1 Operation and Layout of the Former Solvents Plant

The Solvents Plant operated from 1963 to 1991. The plant produced CTC and PCE using chlorine and propylene as feedstock when it commenced operation in 1963. The plant later used EDC wastes from the Vinyls Plant ('EDC Lights' and 'EDC Heavies') as supplementary feedstock for producing CTC and PCE. Propylene was formerly stored in the southern corner of the plant, adjacent to 1st Street. Chlorine was piped in from the Chlorine Plant. 'EDC Lights' were stored in the south-east corner of the plant between the Heavy Ends Treatment Plant and the Make Tanks. 'EDC Heavies' were also stored in this area, but were later moved to the western side of the plant (adjacent to 1st Street) to make way for the construction of the Heavy Ends Treatment Plant in the late 1970s.

By-products of CTC and PCE production included 'Heavy Ends' (primarily HCB, HCB_D, HCE and, post-1978, OCS) and hydrochloric acid (HCl). Prior to 1978 the 'Heavy Ends' were drummed at the plant before being transported to the northern part of the BIP for storage. 'Heavy Ends' were a solid-liquid mixture. In 1978 the 'Heavy Ends Treatment Plant (HETP)' was added to the Solvents Plant to reduce the amount of 'Heavy Ends' waste being produced. This separated the solid phase of Heavy Ends (HCB crystals) from the liquid components (HCB_D, HCE and OCS). The HCB crystal was drummed for storage and the liquid was recycled back into the plant as supplementary feedstock. This recycle caused the concentration of OCS to gradually increase from almost non-detectable to saturation (around 30% in Heavy Ends). Prior to the construction of the HETP, 'Heavy Ends' were drummed manually at the heavy ends accumulator. Heavy Ends wastes produced prior to the mid-1970s were stored at the current location of the Olefines II Plant. Heavy Ends wastes that were drummed after the mid-1970s were temporarily stored at the southern end of the soon to be, or newly, constructed HCB Drum Store until they were placed inside the shed. Further assessment of the former open area Heavy Ends drum storage area (near the Olefines II Plant) is provided in the Northern Plumes DNAPL investigation progress report.

A 1969 aerial view of the former Solvents Plant and surrounding areas is shown in Figure 2.1. The post 1978 layout of the former Solvents Plant is presented in Figure 2.2. The CTC and PCE manufacturing process was undertaken in the centre of the plant. The HETP was located in the southern corner of the plant. The CTC and PCE 'Make Tanks' were located along 2nd Street. These tanks were used to temporarily store newly made CTC and PCE whilst it was tested for quality. Once the CTC and PCE was considered suitable for sale it was transferred to the CTC and PCE Storage Tanks, located adjacent to 2nd Street in the northern corner of the plant. The CTC and PCE storage tanks were used throughout the life of the former Solvents Plant. The CTC and PCE tank farm was not bunded until approximately 1975.

During the period spanning 1970 to 1983 CTC and PCE were also stored at a tank farm located in the northern portion of the site, now occupied by the Alkatuff Plant. Both CTC and PCE were transported from the Solvents Plant to the tank farm by road tanker. Further discussion of this former CTC and PCE storage facility is detailed in the Northern Plumes DNAPL investigation progress report.

In 1983 three bulk storage tanks were constructed between the then Solvents Plant and former TCE Plant to store CTC and PCE. These tanks were used for CTC and PCE storage until the Solvents Plant was

decommissioned in 1991. The EDC Heavies tank was relocated to this bund too. These tanks are still present on the site and are currently used to store sodium hydroxide (NaOH).

CTC and PCE were transported from the site in road tankers. The tanker loading area was located on 6th Avenue on the southern side of the former TCE Plant. The tanker loading bay was fed by pipelines from the CTC and PCE storage tanks, which ran along 2nd Street on an overhead pipe gantry. Tankers may also have been loaded on 2nd Street adjacent to the CTC and PCE storage tanks, however there was no formal tanker loader infrastructure at this location. PCE was also drummed for sale. CTC may also have been drummed for sale prior to 1972. Drums were filled adjacent to the tanker loading facility on 6th Avenue. Drummed product was temporarily stored in a building on the corner of 6th Avenue and 2nd Street.

The floor of the Solvents Plant was constructed of concrete and featured a series of surface and underground drains. The underground drains were constructed of earthen pipes with push fit connections featuring rubber seals. Drainage from the former Solvents Plant was directed to the 'Save All' pit. The 'Save All' pit was noted to typically contain a quantity of free phase chlorinated solvent. During early operation of the plant solvent was periodically emptied from the Save All pit and recycled as feed back into the plant. During later operation of the plant solvent was automatically pumped from the pit on interface level control and recycled back into the plant. The aqueous phase was sent to the site effluent treatment system. A second pit, the 'Super Save All' pit was constructed around 1980 to provide back up storage for the 'Save All' pit.

Possible sources of solvent release to the former Solvents Plant drainage system include:

- Leaks from pipework, pumps and other plant equipment;
- Flushing of plant equipment prior to plant shutdowns;
- Purging (flushing) of solvent sample collection points prior to sample collection;
- Overflow of product storage tanks. It should be noted that the CTC and PCE storage tanks were not bunded until approximately 1975; and
- Spillage or overflow from road tankers during filling. Overflow or spillage within this area initially went to stormwater drains but was later captured by the effluent treatment system.

The former Solvents Plant experienced frequent shutdowns due to the aggressive nature of the process chemicals and process conditions to materials of construction, so there were typically two or three shut downs per week. Equipment requiring maintenance or repair was flushed out prior to works commencing. The former Solvents Plant also underwent a complete shutdown annually. During this period the entire plant was pulled apart and remnant solvent flushed into the plant drainage system.

2.2 Operation and Layout of the Former TCE Plant

The TCE Plant operated from 1948 to 1976. The plant produced both TCE and PCE using acetylene and chlorine as a feedstock. The acetylene was chlorinated to form both pentachloroethane, 1,1,2,2-tetrachloroethane. Pentachloroethane and tetrachloroethane were then dehydrochlorinated to form PCE and TCE respectively.

Figure 2.3 shows an oblique aerial view of the former TCE Plant circa 1962. Figure 2.1 shows an aerial view of the former TCE Plant and surrounding area in 1969. Manufacturing activities were located in the southern corner of the TCE Plant. TCE was stored in two tanks immediately north of the manufacturing building. A third storage tank in this area was used to store acetylene gas. Finished TCE product was drummed for sale and temporarily stored in a building in the eastern portion of the TCE Plant. This was the same building in which PCE and possibly CTC from the former Solvents Plant were drummed and temporarily stored. PCE manufactured in the former TCE Plant was stored with PCE produced in the former Solvents Plant.

The area immediately north-west of the manufacturing building was formerly used for ‘Tri Sludge’ treatment / storage. ‘Tri Sludge’ was a by-product of the former TCE plant. The sludge was placed into a concrete depression adjacent to the manufacturing building and the liquid component was allowed to evaporate. The composition of ‘Tri Sludge’ is not known.

The former TCE Plant is believed to have had a concrete floor. The floor is reported to have been in poor condition when the plant finished operations in 1976. The plant is believed to have had a drainage system similar to that of the former Solvents Plant, with a ‘Save All’ located in the western corner of the plant.

Aerial photographs taken at the time that the Solvents Plant was under construction (circa 1962) indicate that 1st Street only ran as far north as the former TCE Plant. The aerial photograph clearly shows evidence of surface drainage from the hardstand surface of 1st Street to the unsealed surface between the former Solvents Plant and the Botany rail corridor. The surface drain appears to head in a westerly direction from the north-west corner of the former Solvents Plant. The photograph also shows evidence of surface runoff from 1st Street to the area south-west of the TCE Plant.

2.3 Previous Investigations

Key findings of DNAPL source area delineation investigations reported in and prior to the April 2005 DNAPL Source Area Delineation Investigation Report (URS, 2005) are summarised in the table below. References for detailed findings are also provided in the table below. Figure 2.4 shows locations where key DNAPL investigation findings have been made.

Key Findings of Previous Investigations

Location	Summary of Finding	Stage of Work
WG67D	DNAPL was identified (hydrophobic dye test) in drill cuttings collected from a depth of 9 m below ground level (bgl) during the installation of WG67D. A DNAPL sample was collected from WG67D (screened 18 – 21 m bgl). The DNAPL was comprised of 51% carbon tetrachloride (CTC) and 39% tetrachloroethene (PCE).	Stage 2 Survey (Woodward Clyde, 1996)
WG82D	DNAPL was identified (hydrophobic dye test) in drill cuttings collected from a depth of 12 m bgl during the installation of WG82D. A DNAPL sample was collected from WG82D (screened 20 – 23 m bgl). The DNAPL was comprised of 64% 1,1,2,2-tetrachloroethane (1,1,2,2-TeCA), 16% trichloroethene (TCE) and 16% PCE.	Stage 2 Survey (Woodward Clyde, 1996)
SB1	A DNAPL sample was collected from the 21 m sample port of SB1, a bundle piezometer installed by the Cooperative Research Centre – Integrated Mapping Technologies (CRC-IMT) group. The DNAPL was comprised of 53% PCE and 44% CTC.	Stage 2 Survey (Woodward Clyde, 1996)
SG3	DNAPL was identified in soil core collected from SG3 at a depth of 10 m bgl. The presence of DNAPL was confirmed with hydrophobic dye testing but a sample of DNAPL was not analysed.	Stage 2 Survey (Woodward Clyde, 1996)
CH06	DNAPL was identified (hydrophobic dye test) in soil core sample 2.5 – 5 m bgl. DNAPL was not collected. Analysis of soil did not confirm presence of DNAPL however elevated concentrations of TCE, PCE and 1,1,2,2-TeCA were detected in selected soil samples.	Former Solvents Plant and Former TCE Plant Investigation (URS, 2000)
CH07	DNAPL was identified (hydrophobic dye test) in soil core sample 2.5 – 4 m bgl. DNAPL was not collected. Analysis of soil did not confirm presence of DNAPL however elevated concentrations of TCE, PCE, 1,1,2,2-TeCA and HCB were detected in selected soil samples.	Former Solvents Plant and Former TCE Plant Investigation (URS, 2000)
CH09 (BP34)	<p>DNAPL was identified (hydrophobic dye test) in soil core sample 3 - 7 m bgl. DNAPL was not collected during the 2000 investigation and soil analytical results did not indicate DNAPL was present.</p> <p>Elevated concentrations of PCE, CTC, HCB, HCB were reported in groundwater samples collected from the upper 12 m of BP34 in 2000. Elevated HCB and HCB concentrations were reported in groundwater samples collected between 12 –20 m in 2000.</p> <p>BP34 was resampled in early 2005. DNAPL was observed in groundwater sampled from the 6 – 20 m sample ports. DNAPL samples were able to be collected from the 8 m, 12 m and 14 m sample ports. Groundwater analytical results were similar to those in 2000 with elevated PCE, CTC, HCB, HCB in groundwater samples collected from the upper 12 m and elevated HCB and HCB concentrations between 12 –20 m..</p> <p>DNAPL sampled from the 8 m port was comprised of 74% PCE, 12% HCB, 11% octachlorostyrene (OCS), 2% HCE and 1% HCB.</p>	<p>Former Solvents Plant and Former TCE Plant Investigation (URS, 2000)</p> <p>2005 DNAPL Source Area Delineation Investigation (URS, 2005)</p>

Background Information and Previous Investigations

SECTION 2

Location	Summary of Finding	Stage of Work
	<p>DNAPL sampled from the 12 m port was comprised of 45% HCBD, 32% OCS, 15% PCE, 6% HCE and 2% HCB.</p> <p>DNAPL sampled from the 14 m port was comprised of 50% HCBD, 45% OCS, 3% HCE, 2% HCB and 1% PCE.</p>	
CH10	<p>DNAPL was identified using hydrophobic dye testing in soil core sample 3 – 7 m bgl and 12 – 13 m bgl. DNAPL was not collected. Analysis of soil did not confirm presence of DNAPL however elevated concentrations of CTC, PCE, HCB and HCBD were detected in selected soil samples.</p>	<p>Former Solvents Plant and Former TCE Plant Investigation (URS, 2000)</p>
CH12	<p>Hydrophobic dye testing indicated DNAPL was present in soil core collected from 23.9-24.0m bgl. The soil sample was analysed and was found to contain elevated concentrations of TCE, PCE, 1,1,2,2-TeCA, Pentachloroethane, HCBD, HCE and HCB.</p>	<p>2004 DNAPL Source Area Investigation (URS, 2004)</p>
CH13	<p>Hydrophobic dye testing indicated DNAPL was present in soil core collected from 21.8 – 21.9m bgl. The soil sample was analysed and was found to contain elevated concentrations of HCBD and HCB.</p>	<p>2004 DNAPL Source Area Investigation (URS, 2004)</p>
CH17	<p>Soil analytical data from CH17 indicated that DNAPL may be present at several depths at this location. Calculated pore water concentrations indicate that DNAPL was potentially present at an approximate depths of 3 m bgl (PCE, CTC and HCBD), 8 m bgl (PCE, HCB), 20 m bgl (HCB, HCBD and HCE) and 21 m bgl (CTC, PCE, HCB and HCBD).</p>	<p>2005 DNAPL Source Area Delineation Investigation (URS, 2005)</p>
WG13	<p>DNAPL was sampled from WG13 (screened interval 5 – 7 m bgl) in early 2005. The DNAPL was comprised of 84% HCBD, 7% HCE, 5% OCS, 2% HCB and 2% PCE.</p>	<p>2005 DNAPL Source Area Delineation Investigation (URS, 2005)</p>

The scope of works detailed in this progress report is outlined below:

- Six core holes (CH18 to CH23) were advanced to bedrock within the Botany rail corridor. Where field observations indicated that DNAPL may be present, soil samples were analysed in the laboratory for volatile and semi-volatile chlorinated hydrocarbons (CHCs);
- Two of the core holes advanced within the Botany railway corridor were converted to bundle piezometers. BP95 was installed in CH20 and BP96 was installed in CH23. Groundwater samples were collected from each port of BP95 and BP96 and were analysed for volatile and semi-volatile CHCs;
- Six nested monitoring wells (WG204 - WG209) were installed in the vicinity of the former Solvents Plant and former TCE Plant to delineate the upgradient extent of the S2 and S3 source areas. Each location featured shallow, intermediate and deep 50 mm PVC monitoring wells. Groundwater samples were collected from each monitoring well and were analysed in the laboratory for volatile and semi-volatile CHCs; and
- A bundle piezometer (BP90) was installed to bedrock along 1st Street, downgradient of the former TCE Plant. Groundwater samples were collected from each port of BP90 and were analysed in the laboratory for volatile and semi-volatile CHCs.

Investigation works previously reported in the 2005 DNAPL Source Area Delineation Investigation report (URS, 2005) and re-included in this progress report are outlined below:

- One core hole (CH17) was advanced to bedrock through the concrete floor of the former Solvents Plant. Where field observations indicated that DNAPL may be present soil samples were analysed in the laboratory for volatile and semi-volatile CHC;
- Two core holes (CH24 and CH25) were advanced to bedrock at Southlands-Block 1, to the south-east of areas investigated during the 2004 DNAPL investigation works; and
- Groundwater samples were collected from BP34, WG62, WG65 and WG13, which are located downgradient of the former Solvents Plant along 1st Street. The samples were analysed in the laboratory for volatile CHCs. Where DNAPL samples could be obtained samples were sent for compositional analysis.

DNAPL investigation locations are presented in Figure 2.4.

4.1 Lithology and Geology

Soil borelogs and/or well construction logs are presented in Appendix B. Investigation locations are shown in Figure 2.4.

Figure 4.1 shows the location of several inferred lithological cross sections. The cross sections were constructed using available lithological data including core hole logs, well construction logs and CPT logs from the Stage 2 Survey (Woodward-Clyde, 1996). The location of the cross sections and details of their construction are summarised in the table below.

Summary of Inferred Lithological Cross Sections

Section ID	Figure Number	Section Description	Incorporated Construction Data
Transect A	Figure 4.2	Along 2 nd Street from 5 th Avenue to 8 th Avenue	WG204, WG205, WG206, WG207, WG208
Transect B	Figure 4.3	Along 1 st Street from 5 th Avenue to 8 th Avenue	CH06, BP90, CH07, WG13, CH08, WG62D, WG65S, CPT37, CH09, CH17, CH10, WG67D, WG204
Transect C	Figure 4.4	Along Botany Rail Corridor	CH18, CH19, CH20, CH21, CH22, CH23
Transect D	Figure 4.5	From the former Solvents Plant to the south-west corner of Southlands – Block 1	WG206, CH17, CH09, CPT38, CH20, CPT56, CH16, CPT69, CPT72, CPT82, CPT86
Transect E	Figure 4.6	From the former TCE Plant to the south-west corner of Southlands – Block 1	WG208, BP90, CPT41, CPT39, CH23, CPT60, CH25, CPT67, CPT71, CPT74, CPT75

The soil profile within the S2 and S3 source areas is dominated by well graded fine to medium grained sands. The inferred lithology presented in Figures 4.2 to 4.6 indicates that a fairly extensive low permeability layer exists at approximately 1 m AHD. This layer appears to extend from beneath the former Solvents Plant to the western side of Southlands-Block 1 (Springvale Drain). Soil core data collected from CH18 – CH23 indicates that the layer consists of approximately 0.1 m of peat overlying approximately 0.1 m of clay/sandy clay. A second extensive low permeability layer exists at approximately –15 m AHD. This layer is likely to extend across Southlands-Block 1 from the Botany rail corridor and appears to consist of peat, sandy peat and/or clayey peat. Other low permeability layers are present in the southern source areas but they appear to be less continuous than the layers at 1 m and – 15 m AHD.

CH17 was advanced through the concrete floor of the former Solvents Plant. Anecdotal information provided by Orica employees indicated that the former Solvents Plant area had been excavated to a depth of approximately 25 feet (7.5 m) bgl to remove peat layers to improve geotechnical stability prior to the building of the plant. The excavation was thought to have been backfilled with sand. Soil cores retrieved

from CH17 indicated that fill, which was fine to medium grained sand, was encountered to a depth of 7.6 m bgl. The fill resembled natural soil found at the site and is likely to have been the material that was originally excavated from beneath the plant during removal of the peat.

Bedrock was encountered at depths ranging from -7 to -20 m AHD within the inferred S2 and S3 source areas. Inferred bedrock elevation contours in the vicinity of the former Solvents Plant and former TCE Plant are presented in Figure 4.7. The contours show that bedrock beneath the former TCE Plant dips relatively steeply toward the west. Bedrock beneath the southern half of the former Solvents Plant also appears to dip towards the west. Bedrock beneath the northern part of the former Solvents Plant appears to dip toward the south-west. The inferred bedrock contours indicate that there is potential for a slight valley to exist in bedrock beneath the former Solvents Plant. Bedrock appears to be relatively flat beneath the north-eastern portion of Southlands-Block 1, then appears to dip relatively steeply toward the west beneath the western half of Southlands-Block 1.

Residual clay and sandy clay was encountered above the sandstone bedrock. The clay / clayey sand layer was typically approximately 1 m thick but was up to 3 m thick to the east of the former TCE Plant (at WG208 and WG209). The residual clay layer appears to have similar topography to the sandstone bedrock.

4.2 Hydrogeology

Water level data was collected from shallow and deep groundwater monitoring locations in the vicinity of the former Solvents Plant and former TCE Plant on 3 August 2005. The water level data was used to infer shallow and deep groundwater elevation contours in the vicinity of the S2 and S3 source areas.

Inferred shallow groundwater elevation contours in the vicinity of the S2 and S3 source areas are presented in Figure 4.8. Based on the inferred shallow groundwater contours, shallow groundwater in the vicinity of the S2 source area flows in a west south-westerly direction and shallow groundwater in the vicinity of the S3 source area flows in a south-westerly direction.

Inferred deep ground water elevation contours are presented in Figure 4.9. Based on the inferred deep groundwater contours, deep groundwater in the vicinity of the S2 and S3 source areas flows in a south-westerly direction.

Generalised groundwater elevation contours for the early 1940s, 1969, 1980, 1988 and 1989 were presented in the Stage 1 Investigation (A G Environmental Engineers et al, 1990) and are included as Appendix A. The contours indicate that groundwater flow regimes within the vicinity of the BIP were greatly affected by heavy extraction of groundwater for use by ICI and other nearby industry. With the exception of the 1942 plot, the historical groundwater elevation data indicates that groundwater flow in the southern source areas was typically toward the west and north-west.

4.3 Soil Investigation Results

Soil investigations works reported in this progress report were commenced in November 2004 and were completed in May 2005. The investigations commenced with the coring of CH24 and CH25 in November 2004. CH17 was cored in January 2005. The coring of CH18 – CH23 on the Botany rail corridor was delayed due to access requirements imposed by RailCorp and these works were not completed until May 2005 and the results of coring works could not be included in the 2005 DNAPL source area investigation report (URS, 2005a). For completion the results from CH17, CH24 and CH25 are also included within this report.

4.3.1 Field Observations

Field observations for CH17 – CH25 are summarised in the table below.

Summary of Field Observations – Southern Plumes Core Holes

Core Hole ID	Summary of Field Observations
CH17	<ul style="list-style-type: none"> • Strong CHC odours (unknown) noted throughout the upper 13 m. • Very strong CHC odour noted 7.4-7.8 m (unknown-possibly TCE or PCE) • Very strong odour noted 12.2-12.3 m (possibly CTC). • CHC odours relatively weak (13 – 19.9 m). • EDC like odour noted below 15m • Very strong heavy ends (HCBD like) odour 19.9-20.1 m. • Very strong heavy ends (HCBD like) odour 20.4-20.5 m. • Hydrophobic dye tests indicated that DNAPL was not present in tested samples.
CH18	<ul style="list-style-type: none"> • Very strong CHC odour (PCE/Heavy ends like) 5.4-6.6 m. • Very strong CHC odour (EDC like) at 10.5m. • Very strong CHC odour (unknown) 23-24 m. • Relatively weak CHC odour 17-22m. • Hydrophobic dye tests indicated that DNAPL was not present in tested samples.
CH19	<ul style="list-style-type: none"> • Petroleum hydrocarbon odour (diesel like) in upper 4 m. • Very strong CHC odour (PCE/Heavy Ends like) 5.5-6.4m. • Strong CHC odour (unknown) 22.1-23.0m. • Moderate CHC odours (EDC like) 12-22 m. • Hydrophobic dye tests indicated that DNAPL was not present in tested samples.

Core Hole ID	Summary of Field Observations
CH20 / BP95	<ul style="list-style-type: none"> Moderate CHC odour throughout core hole (sweet odour - CTC/PCE like). Strong CHC odour 5.3-5.5m and 21.3-22.1m (sweet odour - CTC/PCE like). Hydrophobic dye tests indicated that DNAPL was not present in tested samples.
CH21	<ul style="list-style-type: none"> Petroleum hydrocarbon odour (diesel like) in upper 4 m. Moderate CHC odour (unknown) 4 – 13m. Weak CHC odour (unknown) 13 – 21m. Moderate CHC odours (unknown) 21.0 – 21.6m. Hydrophobic dye tests indicated that DNAPL was not present in tested samples.
CH22	<ul style="list-style-type: none"> Petroleum hydrocarbon odour (diesel like) 3 – 5m. Strong CHC odour (unknown) 4.5 – 6.0m. Moderate CHC odour (unknown) 6.0-13.0m. Moderate to strong CHC odour (unknown) 17 – 18m and 21 – 22m. Hydrophobic dye tests indicated that DNAPL was not present in tested samples.
CH23 / BP96	<ul style="list-style-type: none"> Moderate CHC odour (EDC like) 5 – 22m. Hydrophobic dye tests indicated that DNAPL was not present in tested samples.
CH24	<ul style="list-style-type: none"> Chlorinated solvent odours noted throughout core hole. Strongest odour at 4.7 m, 18.6 m and 21.0 m. (unknown). Strongest odours were not considered indicative of DNAPL presence. Hydrophobic dye tests indicated that DNAPL was not present in tested samples.
CH25	<ul style="list-style-type: none"> Chlorinated solvent odours noted throughout core hole. Strongest odour at 4.1 m, 14.5 m and 20.7 m (unknown). Strongest odours were not considered indicative of DNAPL presence. Hydrophobic dye tests indicated that DNAPL was not present in tested samples.

Strong CHC odours were typically noted within, or in close proximity to, low permeability layers within the soil strata. These observations are well reflected by the PID results presented below. Soil samples collected from CH18 – CH25 were screened in the field using a PID. The PID was used to screen sample headspace in a plastic snaplock bag. PID screening results are summarised in the following table.

As shown, elevated PID readings were typically encountered above the low permeability layer at a depth of approximately 1 m AHD and above the low permeability layers at depths between –15 and –18 m AHD. The PID screening results were generally consistent with field observations.

Summary of PID Field Screening Results (ppm Benzene Equivalence)*

Depth Interval (m AHD)									
	CH18	CH19	CH20	CH21	CH22	CH23	CH24	CH25	
6 to 5m	-	-	-	-	-	-	-	-	
5 to 4m	-	-	-	-	-	-	-	-	
4 to 3m	-	6	0	-	-	-	-	-	
3 to 2m	0	7	-	180	25	230	-	45	
2 to 1m	-	-	115	100	240	438	-	44	
1 to 0m	1526	121	183	-	1233	389	4	4	
0 to -1m	58	89	15	110	101	8	-	9	
-1 to -2m	-	-	65	30	57	61	-	7	
-2 to -3m	60	24	171	280	-	20	-	7	
-3 to -4m	-	-	53	290	45	25	-	6	
-4 to -5m	118	15	86	-	-	24	-	25	
-5 to -6m	-	0	109	80	-	31	-	60	
-6 to -7m	-	-	76	80	-	16	-	54	
-7 to -8m	101	-	73	170	28	-	-	34	
-8 to -9m	-	13	31	-	57	20	-	82	
-9 to -10m	16	-	1	8	37	69	-	9.3	
-10 to -11m	8	11	-	5	30	29	-	44	
-11 to -12m	0	-	181	2	470	57	-	36	
-12 to -13m	0	6	48	10			-	117	
-13 to -14m	0	-	108	128	36	16	60	23	
-14 to -15m	-	-	-	20		11	-	137	
-15 to -16m	-	-	968	570	72	11	-	89	
-16 to -17m	76	684	229	170	*****	6	121	*****	
-17 to -18m	1326	12	*****	*****	*****	*****	-	*****	

* - CH17 no PID data available due to instrument malfunction.

***** - Core hole reached bedrock above this depth.

Although strong CHC odours and elevated PID readings (in excess of 1000 ppm) were noted in some core holes, DNAPL was not positively identified in any of the soil cores using visual observation and hydrophobic dye testing in the field.

4.3.2 Soil Analytical Results

A minimum of three soil samples were collected from each core hole (CH17 – CH25) and were analysed in the laboratory for volatile CHCs, semi-volatile CHCs and total organic carbon (TOC). Soil analytical results are presented in Tables 4.1 and 4.2.

Compounds typically detected in soil samples included CTC, PCE, TCE, 1,1,2-TCA, 1,1,2,2,-TeCA, HCB, HCBd and HCE. These compounds are indicative of manufacturing activities at the former Solvents Plant and former TCE Plant. CTC and PCE were formerly made at the Solvents Plant using propylene and chlorine as raw products. EDC wastes ('EDC Lights' and 'EDC Heavies') generated from the former Vinyls Plant were also used as feedstock for the production of CTC. Heavy Ends (HCB, HCBd, HCE and, post-1978, OCS) were generated as a waste byproduct of CTC manufacturing.

TCE and PCE were formerly manufactured at the TCE Plant. The initial stage of the process involved using acetylene as a raw material to make 1,1,2,2-TeCA and pentachloroethane. These compounds were dehydrochlorinated to form TCE and PCE respectively. 1,1,2-TCA is a breakdown product of 1,1,2,2-TeCA and may have also been produced as a byproduct during the manufacture of TCE.

Relatively low concentrations of EDC, pentachloroethane, CFM, cis-1,2-DCE and trans-1,2-DCE were also reported in some soil samples. The detection of EDC in some soil samples is may be related to the use of EDC wastes as feedstocks for the former Solvents Plant or could be present as a result of 1,1,2-TCA degradation. Pentachloroethane was an intermediate product of the former TCE Plant. CFM is likely to be related to the degradation of CTC and cis-1,2-DCE and trans-1,2-DCE are likely to be related to the breakdown of PCE and TCE.

A method detailed by Feenstra et al (1991) was used to estimate the concentrations of CHCs in the pore water of soil samples analysed in the laboratory. The degree of partitioning between pore water and soil solids (K_d - the distribution coefficient) was determined using the known organic carbon water partition co-efficient (K_{oc}) and the fraction of organic carbon in the soil sample (f_{oc}). K_{oc} values were obtained from the Pennsylvania Department of Environmental Protection website (<http://www.dep.state.pa.us>) which provides chemical properties data from several resources. f_{oc} values were reported by the analytical laboratory. In order to calculate the theoretical pore water concentrations in soil samples URS assumed a soil density of 1860 kg/m³ and soil porosity of 0.3. The calculated theoretical pore water concentrations are presented in Table 4.3 and are presented on Figure 4.10 to Figure 4.49.

Soil samples with calculated pore water concentrations in excess of 10% of the pure phase solubility are summarised in the following table. Calculated pore water concentrations of PCE, CTC, HCB, HCB and HCE were consistently greater than 10% of their respective pure aqueous phase solubility limits in CH17, CH18 and CH19. PCE and TCE were greater than 10% of their respective pure aqueous phase solubility limits in CH20, CH21, CH22, CH24 and CH25. The calculated pore water concentration of HCB exceeded 10% in CH21 and CH23.

Summary of Calculated Pore Water Concentrations – CH17 – CH25

Core Hole ID	Depth	Major Compound	Calculated Pore Water Concentration (mg/L)	% of Pure Phase Solubility	Total Percentage Solubility (All Compounds)
CH17	2.7 – 2.8m	PCE	45	30%	33%
		PCE	19	13%	
	7.6 – 7.7m	HCB	0.055	>100%	>100%
		PCE	39	26%	
	12.2 – 12.3m	HCB	15	>100%	>100%
		HCB	57	>100%	
		HCE	181	>100%	
	19.9 – 20.0m	CTC	276	33%	>100%
		PCE	541	>100%	
		HCB	8.6	>100%	
HCB		6.6	>100%		
HCE		6.8	14%		
20.4 – 20.5m	HCB	15	>100%	>100%	
	HCB	57	>100%		
	HCE	181	>100%		
	HCB	8.6	>100%		
	HCB	6.6	>100%		

Core Hole ID	Depth	Major Compound	Calculated Pore Water Concentration (mg/L)	% of Pure Phase Solubility	Total Percentage Solubility (All Compounds)
CH18	5.35 – 5.55m	PCE	101	67%	>100%
		HCB	22	>100%	
		HCBD	36	>100%	
		HCE	23	46%	
	22.1 – 22.5m	PCE	50	33%	35%
	23.1 – 23.5m	CTC	736	89%	>100%
		PCE	2119	>100%	
		HCB	5.4	>100%	
HCBD		12	>100%		
CH19	6.2 – 6.4m	HCB	0.157	>100%	>100%
		HCBD	1.674	52%	
	16.7 – 16.9m	HCB	1.07	>100%	>100%
		HCBD	18	>100%	
	22.1 – 22.3m	CTC	146	18%	>100%
		PCE	149	99%	
		HCB	0.341	>100%	
HCBD		1.76	54%		
CH20	17.4 – 17.6m	PCE	29	19%	21%
	21.5 – 21.7m	PCE	37	24%	34%
CH21	5.2 – 5.4m	HCBD	0.609	19%	20%
	21.2 – 21.3m	PCE	23	15%	30%
		TCE	124	11%	
CH22	5.0 – 5.2m	PCE	178	>100%	>100%
		TCE	211	19%	
CH23	21.0 – 21.1m	HCBD	0.334	10%	14%
CH24	21.0 – 21.2m	TCE	176	16%	21%
CH25	4.0 – 4.2m	PCE	23	11%	15%

Where the total percentage solubility was in excess of 100%, DNAPL might have been present in the soil sample. The table below summarises the compounds that may exist as a pure component or mixed DNAPL in CH17 – CH25 based on calculated pore water concentrations in soil. It should be noted that HCB and HCE are solids at 25⁰C so they are not technically DNAPLs. However, it is possible that HCB and/or HCE could be suspended or dissolved into a DNAPL mixture. HCB and/or HCE may remain in the aquifer where the more volatile and/or soluble components of the carrier DNAPL have volatilised in the vadose zone or dissolved into groundwater.

Compounds That May Be Present as DNAPL – CH17 – CH25

Sample ID	Compounds Possibly Present as DNAPL or Major Component of DNAPL Mixture
CH17 (7.6-7.7m)	HCB, PCE
CH17 (19.9-20.0m)	HCB, HCB, HCB, HCB, HCE
CH17 (20.4-20.5m)	CTC, PCE, HCB, HCB, HCE
CH18 (5.35 – 5.55m)	PCE, HCB, HCB, HCE
CH18 (23.1 – 23.5m)	CTC, PCE, HCB, HCB, HCE
CH19 (6.2 – 6.4m)	HCB, HCB
CH19 (16.7 - 16.9m)	HCB, HCB
CH19 (22.1 – 22.3m)	CTC, PCE, HCB, HCB
CH22 (5.0 - 5.2m)	PCE, TCE

4.4 Groundwater Investigation Results

4.4.1 Field Observations and Parameters

BP90 and monitoring wells WG204 to WG209 were installed in May and June 2005. Soil samples were not collected during their installation but drilling cuttings were observed regularly throughout each borehole. Borehole and well construction logs are presented in Appendix B. Observations made during the installation of groundwater monitoring locations are summarised in the table below.

Summary of Well Installation Observations

Monitoring Location	Observation
WG204	CHC odours noted throughout. Strong CHC noted in well development water. Hydrocarbon sheen observed on bottom of the mud tank at the completion of drilling.
WG205	CHC odours not noted in drill cuttings. Strong CHC odour present in well development water.
WG206	CHC odours noted throughout. Strong CHC noted in well development water. Hydrocarbon sheen observed on bottom of the mud tank at the completion of drilling.
WG207	Strong CHC odour present in upper 3 m. CHC odours not noted below 3 m. Small beads of NAPL observed in mud tank (ie. in drill cuttings)
WG208	Moderate CHC odour at approximately 12 m bgl. No CHCs odours throughout the rest of the borehole.
WG209	Weak CHC odour throughout borehole.
BP90	Strong CHC odours (HCB/PCE like) in upper 10 m of borehole. CHC becoming weak to moderate below 10 m.

DNAPL was observed in groundwater sampled from several sampling locations in the vicinity of the former Solvents Plant and former TCE Plant. Consequently, groundwater parameters were not measured for monitoring wells in close proximity to the likely DNAPL sources (to avoid damage or contamination of the water quality meter). Groundwater parameters were measured in BP95 and BP96, located along the Botany rail corridor. Field parameters and field observations are presented in Table 4.4.

Groundwater samples from BP95 and BP96 were typically acidic, with pH ranging from 3.8 to 6.0. Recorded electrical conductivity ranged from 580 $\mu\text{S}/\text{cm}$ to 8120 $\mu\text{S}/\text{cm}$ and were typically in excess of 1000 $\mu\text{S}/\text{cm}$. The electrical conductivity readings are relatively high compared with groundwater at other parts of the BIP and may be indicative of impacts to groundwater from the salt stockpile located to the east of the S2 and S3 source areas. Recorded E_h ranged from 29 mV to 196 mV indicating reducing conditions within the aquifer. Recorded groundwater temperatures ranged between 18 and 23°C, however temperatures were measured ex-situ and are likely to be influenced by ambient air temperatures at the time of sampling.

Chlorinated hydrocarbon odours were noted in most samples collected during the investigation. Key observations made during the installation of monitoring wells and bundle piezometers groundwater sampling events are summarised in the table below.

Summary of Key Groundwater Field Observations – S2 and S3 Source Area

Sample ID	Observation
BP34 – 6m	Strong CHC odour. Minor amounts (<0.1 mm) of DNAPL visible as small surface slicks on purged groundwater.*
BP34 – 8m	Strong CHC odour. Approximately 2 mL of DNAPL visible as both small surface slicks and accumulations in purged groundwater. Approximately 1 mL of DNAPL collected in sample vial.
BP34 – 10m	Strong CHC odour. Minor amounts of DNAPL visible as small surface slicks on purged groundwater (<0.1 mm diameter).
BP34 – 12m	Strong CHC odour. Flakey solids present in groundwater with a tar-like texture (possibly DNAPL). Solids collected into sample vial.
BP34 – 14m	Strong CHC odour. Approximately 2 mL of DNAPL visible as both small surface slicks and accumulations in purged groundwater. Approximately 1 mL of DNAPL collected in sample vial.
BP34 – 16m, 18m and 20m	Strong CHC odour. Minor amounts of DNAPL visible as small surface slicks on purged groundwater (<0.1 mm diameter).
WG13	Strong CHC odour (HCBd like). Brown flaky solids suspended in purged groundwater with tar like texture (possibly DNAPL). Clear and colourless separate phase liquid with texture similar to melted wax (ie. more viscous than water) in bucket with purged groundwater (possibly DNAPL). Sample of flaky material and clear viscous liquid collected in sample vial.
WG205S and WG205I	Strong CHC odour (PCE like). Separate phase DNAPL identified in purged water (approximately 5 mL). Well was resampled using peristaltic pump with tubing pumping from the base of the well and approximately 200 mL of DNAPL was recovered.
BP90 – 16m, 18m and 19m	What appeared to be separate phase material was observed in sample tubing. The peristaltic pump appeared to have insufficient suction to bring the separate phase liquid to the sample bottle.

* - DNAPL tends to form a slick on the water surface when it is first introduced to a bucket. It is suspended until it can overcome the surface tension of the water by accumulating sufficient mass.

4.4.2 Groundwater Analytical Results

Groundwater samples were collected from all functioning sample ports of BP34, and from monitoring wells WG13, WG62D and WG65S in February 2005. Samples collected from these monitoring locations were analysed in the laboratory for volatile CHCs. Groundwater samples were collected from BP90,

BP95, BP96, and from monitoring wells WG204 to WG209 in May-June 2005. Samples collected from these monitoring locations were analysed in the laboratory for volatile and semi-volatile CHCs.

Groundwater analytical results for volatile and semi-volatile CHCs are presented in Tables 4.5 and 4.6. Analytical results are reported as a percentage of their respective pure phase aqueous solubilities in Table 4.7.

Analytical results and calculated percentage of pure phase solubility of compounds of concern along Transect A are presented on Figures 4.10 to 4.17. Analytical results and calculated percentage of pure phase solubility of compounds of concern along Transect B are presented on Figures 4.18 to 4.25. Analytical results and calculated percentage of pure phase solubility of compounds of concern along Transect C are presented on Figures 4.26 to 4.33. Analytical results and calculated percentage of pure phase solubility of compounds of concern along Transect D are presented on Figures 4.34 to 4.41. Analytical results and calculated percentage of pure phase solubility of compounds of concern along Transect E are presented on Figures 4.42 to 4.49. The locations of Transects A, B, C, D and E are shown on Figure 4.1.

As stated in the table above, samples containing free phase DNAPL (or suspected DNAPL) were collected from the 8, 12 and 14 m sample ports of BP34, and from monitoring wells WG13, WG205S and WG205I. These samples were sent to Leeder Laboratory for compositional analysis. The results reported by Leeder did not account for 100% of the mass of NAPL. For example, the mass of CHCs reported in the NAPL sample collected from WG205S accounted for 696 313 mg/kg (69.6% of the total mass). Leeder have indicated that this is likely to be associated with dilution of the NAPL sample prior to analysis. Consequently, the concentrations of CHCs reported in the NAPL samples were normalised to account for 100% of the mass. The normalised compositional data for the DNAPL samples is summarised in the table below. The laboratory was only able to provide estimations of the composition of the samples collected from BP34 (14 m) and WG13 as the mass of DNAPL in these samples was unable to be weighed.

Normalised Composition of DNAPL – S2 and S3 Source Areas (% wt)

Sample ID	PCE	CTC	HCBD	HCB	HCE	OCS	Others
BP34 - 8m	73.83	0.00	12.30	0.78	1.90	11.19	0.00
BP34 - 12m	14.83	0.00	45.13	2.00	5.80	32.24	0.00
BP34 - 14m	0.51	0.00	49.90	1.93	2.85	44.81	0.00
WG13	1.94	0.00	83.84	1.94	7.26	5.01	0.00
WG205S	93.35	5.89	0.29	0.11	0.36	0.00	0.00
WG205I	92.95	6.45	0.22	0.09	0.28	0.00	0.00

The NAPL samples collected from WG205S and WG205I have very similar compositions, with PCE accounting for approximately 93% and CTC accounting for approximately 6% of the DNAPL mass. The NAPL samples also contain minor 'Heavy Ends' components (ie. HCB, HCBD, HCE and OCS). The NAPL sample collected from WG13 is predominantly HCBD with minor components of the other heavy end compounds (HCB, HCE and OCS) as well as PCE. The NAPL samples collected from the 12 m and

14 m sample ports of BP34 are Heavy Ends components, predominantly HCBD and OCS, with minor components of HCB, HCE and PCE. The NAPL sample collected from the 8 m sample port of BP34 was predominantly PCE but had in excess of 20% 'Heavy End' compounds.

4.5 Quality Assurance and Quality Control

A qualitative assessment of all data reported in this report was undertaken by URS. Data validation summary reports are presented as Appendix C. The precision and accuracy of the data obtained was considered suitable enough for the data to be relied upon to make conclusions with respect to the main objective of this delineation investigation, which was to better characterise DNAPL source areas.

5.1 DNAPL Composition

5.1.1 Former Solvents Plant

Potential sources of DNAPL associated with the former Solvents Plant and potential DNAPL components are summarised in the table below.

Summary of Potential DNAPL Sources – Former Solvents Plant

Potential Source of DNAPL	Potential Major DNAPL Components
CTC Storage Tanks and Make Tanks	CTC
PCE Storage Tanks and Make Tanks	PCE
Manufacturing Process Infrastructure (eg Stripped Organics Tanks, Organics Recycle Tanks, Primary Decanter etc..)	CTC / PCE / HCB / HCBd / HCE / OCS / EDC
Effluent Collection System and ‘Save All’ pits	CTC / PCE / HCB / HCBd / HCE / OCS / EDC
Heavy Ends Treatment Plant and Redrumming Area	HCB / HCBd / HCE / OCS
EDC Lights and EDC Heavies Storages	EDC / CTC/ CFM / 1,1,2-TCA

As shown above there are several potential sources of DNAPL associated with the former Solvents Plant. DNAPL from the manufactured product storages is likely to be comprised of predominantly CTC or PCE with some impurities also present as a small component of the CHC mass. DNAPL from the Heavy Ends Drumming area or HETP is likely to be predominantly heavy ends (HCB, HCBd, HCE and, post-HETP startup, OCS) but may also contain minor components of PCE. DNAPL from the EDC Lights storages is likely to be predominantly EDC, with major components of CTC and CFM. DNAPL from the EDC Heavies storage is likely to be predominantly 1,1,2 TCA with other major component being EDC.

DNAPL associated with the effluent collection system is likely to have come from all parts of the former Solvents Plant and is likely to have been mixed while in the effluent collection drains and the ‘Save All’ pits. Consequently DNAPL from the effluent collection system is likely to have had a mixed and highly variable composition.

The highly variable composition of DNAPL within the source area means that the effective solubility of components within the NAPL mixtures is also highly variable and cannot accurately be predicted across the source area.

5.1.2 Former TCE Plant

Potential sources of DNAPL associated with the former TCE Plant and potential DNAPL components are summarised in the following table.

Summary of Potential DNAPL Sources – Former TCE Plant

Potential Source of DNAPL	Potential Major DNAPL Components
TCE Storage Tank	TCE
PCE Storage Tank	PCE
Manufacturing Process Infrastructure	TCE / PCE / Pentachloroethane / 1,1,2,2-TeCA
Effluent Collection System and ‘Save All’	TCE / PCE / 1,1,2,2-TeCA / Pentachloroethane / CTC
Tanker Loading Facility	PCE / CTC
Drum Filling and Storage	PCE / TCE / CTC
‘Tri Sludge’ evaporation pit	TCE / unknown CHCs

As shown above there are several potential sources of DNAPL located within the former TCE Plant. DNAPL from the manufactured product storages is likely to be comprised of predominantly TCE and PCE with some impurities also present as a small component of the CHC mass. DNAPL from the former Tanker Loading bay located on 6th Avenue may be comprised of either or both CTC and PCE. It should be noted that these compounds were piped to the loading bay from the former Solvents Plant. DNAPL associated with the filling and storage of drums may be comprised of TCE, PCE and CTC. It should be noted that PCE, and possibly CTC from the former Solvents Plant were drummed and temporarily stored at the former TCE Plant.

DNAPL from the manufacturing infrastructure may contain TCE, PCE, pentachloroethane and 1,1,2,2-TeCA. The exact composition of DNAPL from the manufacturing infrastructure would be dependant on what stage of the process the leak/spill occurred.

Similar to the former Solvents Plant, DNAPL associated with the effluent collection system is likely to have come from all parts of the former TCE Plant and is likely to have been mixed while in the effluent collection drains and the ‘Save All’. Consequently DNAPL from the effluent collection system is likely to have had a mixed and highly variable composition. Compounds that may be present in DNAPL from the effluent system include TCE, PCE, pentachloroethane and 1,1,2,2-TeCA.

The highly variable composition of DNAPL within the source area means that the effective solubility of components within the NAPL mixtures is also highly variable and cannot accurately be predicted across the source area.

The presence of TCE and 1,1,2,2-TeCA in NAPL samples or in the dissolved phase may differentiate DNAPL that has originated from a source associated from the former TCE Plant.

5.2 Assessment of Data

Characterisation of the Southern Plumes’ source areas to date has been largely based on the distribution of dissolved phase CHCs in groundwater. Collection and analysis of DNAPL samples within the Southern Plumes’ source areas has been limited to six locations. DNAPL compositions at these locations have been highly variable. The highly variable composition of DNAPL within the source areas means

that the effective solubility of components within the NAPL mixtures is also highly variable and cannot accurately be predicted across the source areas.

The total dissolved phase CHC concentrations from a DNAPL mixture vary significantly based on the pure phase solubility of the DNAPL components. Theoretically, the dissolved phase plume from a DNAPL with high molar fractions of compounds with low pure phase solubilities (eg. ‘Heavy Ends’) will contain less dissolved mass than a plume from a DNAPL with high molar fractions of compounds with relatively high pure phase solubility (eg. PCE, CTC and TCE). This is best illustrated using dissolved phase CHC data collected from BP34. Droplets of DNAPL were visible in groundwater sampled from both the 6 and 16 m sample ports of BP34. However, the total CHC concentration in the 6 m port was 171 mg/L compared with 3.7 mg/L in the 16 m port. The major component in the DNAPL observed at the 6 m sample port is likely to be PCE, while ‘Heavy Ends’ compounds are likely to be the major component of the NAPL observed in the 16 m sample port.

In order to provide additional insight to analytical data URS made an assessment based on the total percentage solubility (equivalent to the molar fraction). The concentrations of each compound detected in groundwater samples were converted into a percentage of the compounds’ pure phase solubility. The percentages for each CHC were added together to determine the ‘total percentage solubility’. The total percentage solubility was then used to assess the likely presence of DNAPL at or upgradient of the sample location. The benefit of assessing the data in this manner is that the composition of the DNAPL becomes irrelevant provided all of the components of the DNAPL are included in the analytical suite. If a groundwater sample is at saturation then the total percentage solubility will be 100% (or the molar fraction will be 1), irrespective of the composition of DNAPL.

For example, assume there are two NAPL mixtures. NAPL 1 is composed of 10% HCBd and 90% PCE. NAPL 2 is composed 90% HCBd and 10% PCE. The theoretical effective solubilities of each of these NAPL mixtures are presented in the table below.

NAPL Mixture 1 and Effective Solubilities

Compound	Normalised Composition (%)	Molar Fraction	Pure Phase Solubility (mg/L)	Effective Solubility (mg/L)	% Pure Phase Solubility
HCBd	10	0.149	3.2	0.480	14.9%
PCE	90	0.851	150	128	85.1%

NAPL Mixture 2 and Effective Solubilities

Compound	Normalised Composition (%)	Molar Fraction	Pure Phase Solubility (mg/L)	Effective Solubility (mg/L)	% Pure Phase Solubility
HCBd	90	0.934	3.2	2.99	93.4%
PCE	10	0.066	150	9.90	6.6%

As shown above the expected dissolved phase concentrations of HCBd and PCE from the two NAPL mixtures varies significantly. However, the sum of the percentage solubilities is 100% in each case.

HCB was identified well in excess of its theoretical pure phase solubility in groundwater sampled at several locations during this investigation. The relatively high concentrations of HCB reported in analytical results may be indicative of HCB that has sorbed to particulate matter suspended in the groundwater samples. As such, HCB concentrations reported in some groundwater samples may not be indicative of dissolved phase HCB contamination. Therefore the inclusion of HCB in the calculation of total percentage solubility may be misleading.

There are other limitations of assessing the dissolved phase CHC data using ‘total percentage solubility’ within the Southern Plumes’ source areas. These are listed below:

- Raoult’s Law only applies for estimating dissolved phase contaminant concentrations for a single DNAPL mixture. Where multiple DNAPL sources with different DNAPL compositions exist it may be possible that the total percentage solubility exceeds 100% without DNAPL being present adjacent that that location. There are likely to be several DNAPL sources within each of the defined Southern Plumes’ source areas. The composition of DNAPL within each of the source areas is likely to be highly variable. DNAPL sources may overlap, be mixed together or have remained completely separated from each other;
- The calculation of total percentage solubility includes compounds that may be degradation products of CHCs within DNAPL mixtures;
- Raoult’s Law also assumes ideal component behaviour and this is not likely to be the case in the aquifer at the site; and,
- Calculation of total percentage solubility is based on literature values of pure phase solubility for individual CHCs. Literature values for pure phase solubility are typically measured in controlled conditions within a laboratory and may not adequately represent actual pure phase solubilities in groundwater at the site.

5.3 Distribution of DNAPL in the Subsurface

5.3.1 Source of DNAPL

Understanding how and where DNAPL entered the subsurface is an important factor in conceptualising the possible extent and distribution of DNAPL in the sub-surface. The composition of DNAPL samples collected during this and previous investigations of the Southern Plumes’ source areas can be used to assess likely sources of DNAPL within the source areas. Composition of DNAPL identified in the Southern Plumes source area to date are presented in the following table.

Normalised Composition of DNAPL Samples – Southern Plumes Source Areas (% wt)

Compound	WG205S	WG205I	BP34 8m	BP34 12m	BP34 14m	WG13	WG67D	WG82D	SB1
PCE	93.35	92.95	73.83	14.83	0.51	1.94	39.4	15.7	51.0
CTC	5.89	6.45	0.00	0.00	0.00	0.00	51.2	0.3	36.8
TCE	0.00	0.00	0.00	0.00	0.00	0.00	0.1	15.7	0.9
1,1,2,2-TeCA	0.00	0.00	0.00	0.00	0.00	0.00	0.0	64.4	2.0
HCB	0.11	0.09	0.78	2.00	1.93	1.94	1.4	0.4	1.1
HCBD	0.29	0.22	12.30	45.13	49.90	83.84	2.9	1.5	4.4
HCE	0.36	0.28	1.90	5.80	2.85	7.26	1.5	0.8	3.3
OCS	0.00	0.00	11.19	32.24	44.81	5.01	NA	NA	NA
Others	0.00	0.00	0.00	0.00	0.00	0.00	3.6	1.3	0.4

NA = Not Analysed

The DNAPL sampled from both WG205S and WG205I was predominantly PCE, with minor components of CTC and very minor component of Heavy Ends compounds. The composition of this NAPL is indicative of a source of pure PCE, or finished PCE product. The CTC and Heavy Ends components could be indicative of impurities within the product or partitioning of NAPL or dissolved phase contamination from other sources into the PCE-based NAPL. WG205 is located adjacent to the CTC and PCE finished product storage tanks. Information provided by an ICI employee indicated that road tankers may have been loaded along 2nd Street, adjacent to the former finished product tanks and WG205. Based on this information it could be inferred that the primary source of DNAPL at WG205 is leaks / spills from the former PCE finished product storage tanks.

DNAPL sampled from the 8 m sample port of BP34 was also predominantly PCE with components of Heavy Ends (primarily HCBD and OCS). DNAPL sampled from the 12 m sample port of BP34 was predominantly Heavy Ends (primarily HCBD and OCS) with component of PCE. DNAPL sampled from the 14 m sample port of BP34 was predominantly Heavy Ends (primarily HCBD and OCS) with very minor component of PCE (primarily HCBD and OCS). These results indicate that DNAPL identified in BP34 may be associated with two or more sources, each with different distributions. The abundance of OCS indicates that the DNAPL was created after the startup of the HETP in 1978. PCE-based DNAPL is present in the upper 10 m of the subsurface and Heavy Ends DNAPL is present throughout the soil profile. The distribution of PCE at BP34 seems consistent with the distribution at WG205 (ie. PCE DNAPL is present in the upper 10 m of the subsurface). CTC was not reported to be present in the BP34 (8 m) sample but was present in DNAPL sampled from WG205S and WG205I. Heavy Ends account for greater than 99% of the mass of CHCs in the DNAPL collected from the 14 m sample port of BP34. This (and the presence of OCS) indicates that this DNAPL is associated with the HETP (post 1978) of the former Solvents Plant (see Figure 2.2). The observable change in DNAPL composition in the vicinity of BP34 with depth is also evident in distribution of dissolved phase CHCs in the bundle piezometer.

Heavy Ends compounds account for over 98% of the CHC mass in DNAPL sampled from WG13. The DNAPL also contains less than 2% PCE. This composition is indicative of a source of Heavy Ends, possibly either the HETP (post 1978) or the Heavy Ends accumulation component (pre 1978) of the former Solvents Plant. The presence of OCS indicates that at least some of the DNAPL was created post-

1978. The presence of some PCE indicates a supplementary source of DNAPL, or could possibly be associated with partitioning of dissolved phase PCE into the DNAPL mixture.

DNAPL identified in WG67D and SB1 during the Stage 2 Survey (Woodward-Clyde, 1996) was primarily a mix of PCE and CTC, with a minor Heavy Ends component. It is not possible to determine how or where the DNAPL was mixed. The composition may indicate a source of mixed DNAPL (possibly the effluent collection system), or subsurface mixing of DNAPL from a pure PCE source and a pure CTC source. The Heavy Ends component may be indicative of impurities in finished products, surface mixing of DNAPL (ie. in the effluent collection system), or mixing of PCE / CTC based NAPL with Heavy Ends DNAPL from a separate source. The absence of OCS, however, cannot be used to suggest that the DNAPL pre-dated the HETP because OCS was not in the list of analytes for the Stage 2 Survey. However it can be concluded that the DNAPL collected from WG67D came from a source associated with the former Solvents Plant.

DNAPL identified in WG82D was predominantly 1,1,2,2-TeCA with minor components of PCE and TCE and traces of CTC and Heavy Ends compounds. This composition is indicative of contamination from a source located at the former TCE Plant. The presence of 1,1,2,2-TeCA, an intermediate product of TCE manufacture, indicates the DNAPL source may have been associated with the manufacturing process, the TCE Plant effluent collection system and/or effluent or spillage overflows to Southlands. The minor components of Heavy Ends and CTC in the NAPL are likely to be due to mixing with a supplementary DNAPL source from the former Solvents Plant.

EDC has not been identified in DNAPL samples collected from the Southern Plumes' source areas to date. In addition, the highest dissolved phase EDC concentrations reported in groundwater within the Southern Plumes represents a fraction of 1% of the EDC pure phase solubility. Based on the results of DNAPL analysis, the storage and use of EDC Lights and EDC Heavies wastes as feedstock is unlikely to be a significant source of DNAPL within the Southern Plumes' source areas.

5.3.2 Source Area Characteristics

URS calculated the 'total percentage solubility' for groundwater sampling locations relevant to the assessment of the Southern Plumes DNAPL source areas. URS also calculated the 'total percentage solubility' represented by the calculated theoretical pore water concentrations of CHCs in soil samples collected during this assessment and the 2000 former Solvents Plant and former TCE Plant investigation (URS, 2000). The total percentage solubility provides an indication of where DNAPL may exist within the subsurface at a location hydraulically upgradient of the sampled location. URS has also presented the concentrations of compounds of concern to provide an indication of which compounds may be present in DNAPL within the inferred source area.

The inferred lithology along Transect A, B, C, D and E are presented for comparison in Figure 5.1.

Transect A

As discussed in Section 4, Transect A runs along 2nd Street and is inferred to be located immediately upgradient of the former Solvents Plant and former TCE Plant. Total percentage solubilities along Transect A are presented in Figure 4.10. As shown, the total percentage solubility in WG205S, WG205I, WG206I and WG206D is greater than 100%, indicating that DNAPL may be located in close proximity to these monitoring wells. Figures 4.11 to 4.17 present the concentrations of PCE, CTC, TCE, 1,1,2,2-TeCA, 1,1,2-TCA, HCB and HCBd along Transect A. Figures 4.11 to 4.17 show that PCE and HCB are present at WG205S and WG205I in excess of their respective pure aqueous phase solubility. Other compounds with elevated concentrations (relative to their respective pure phase solubility limits) in WG205S and WG205I include HCBd and CTC. As discussed in Section 5.3.1, DNAPL was present in both WG205S and WG205I. Analysis of the DNAPL indicated that it was predominantly PCE with minor components of CTC and very minor component of Heavy Ends compounds. Figures 4.11 to 4.17 show that HCB was present in excess of its pure aqueous phase solubility in both WG206I and WG206D. HCBd was also reported in WG206I and WG206D at elevated concentrations with respect to its pure aqueous phase solubility. A hydrocarbon sheen was noted in the mud tank during the installation of WG206. The groundwater analytical data and field observations indicate that Heavy Ends DNAPL may be located at WG206. The total percentage solubility of CHCs in other wells along Transect A was less than 2%.

Small beads of DNAPL were observed to be suspended in the drilling mud tank during the installation of WG207. The total percentage solubilities for WG207S, WG207I and WG207D were all 0.1% which are not indicative of the presence of DNAPL. These results may indicate:

- That the substance observed in drilling mud was not a chlorinated DNAPL as noted during the monitoring well installation;
- Subsurface conditions adjacent to WG207 were still impacted by drilling fluids at the time groundwater samples were collected; or
- That WG207S, WG207I or WG207D were not screened across the potential DNAPL zone.

Transect B

As discussed in Section 4, Transect B runs along 1st Street and is inferred to be located immediately downgradient of the former Solvents Plant and former TCE Plant. Total percentage solubilities along Transect B are presented in Figure 4.18. As shown, the total percentage solubility in the majority of sample ports of BP34 and BP90 were greater than 100%. The total percentage solubility for WG13 was also greater than 100%. Total percentage solubility of calculated pore water concentrations for selected soil samples from CH10 and CH17 were also in excess of 100%. These results indicate that DNAPL may be present in the vicinity of BP34, BP90, WG13, CH10 and CH17 (it should be noted that DNAPL was collected from BP34 and WG13, and was observed at BP90). As discussed in Section 4.4.1, DNAPL was observed in groundwater sampled from all sample ports of BP34 located between 6 and 20 m bgl. DNAPL was also observed in WG13 and may have been observed in groundwater sampled from the 16, 18 and 19 m sample ports of BP90. Hydrophobic dye testing of soil samples during the 2000 former

Solvents Plant and former TCE Plant investigation (URS, 2000) indicated that DNAPL was present in the upper 3 m of CH06 and CH07, and the upper 6 m of CH10.

Figures 4.19 to 4.25 present the concentrations of PCE, CTC, TCE, 1,1,2,2-TeCA, 1,1,2-TCA, HCB and HCBD along Transect B. Figure 4.24 indicates that HCB concentrations in most sample ports of BP34 were greater than 100% of the pure aqueous phase solubility. Elevated concentrations of PCE relative to its pure aqueous phase solubility were also reported in the upper 10 m of BP34. Concentrations of CTC and HCBD reported in the upper 10 m of BP34 represented approximately 5% of their pure aqueous phase solubilities. HCBD concentrations reported in the lower 10 m of BP34 represented more than 35% of its pure aqueous phase solubility. Dissolved phase concentrations of CHCs in BP34 are indicative of the results of the analysis of DNAPL samples collected from the 8, 12 and 14 m sample ports. They indicated that PCE-dominant DNAPL was present in the upper 10 m of BP34 and Heavy Ends-dominant DNAPL was likely to be present throughout the piezometer.

HCB represents a significant proportion of the total percentage solubility presented for BP90. TCE concentrations reported in the 16, 18 and 19 m sample ports of BP90 represent greater than 50% of its pure aqueous phase solubility. PCE concentrations reported in these sample ports also represent up to 20% of its pure aqueous phase solubility. These results indicate that DNAPL that may have been observed in sample tubing of the 16, 18 and 19 m sample ports of BP90 may contain TCE, PCE and Heavy Ends compounds. This is indicative of contamination from both the former TCE Plant and the former Solvents Plant. Samples collected from the upper 10 m of BP90 reported elevated concentrations of HCB, HCBD, PCE and TCE relative to their respective pure aqueous phase solubilities.

Analysis of the aqueous phase sample collected from WG13 indicated that HCBD was present at a concentration greater than the pure aqueous phase solubility limit. Analysis of the DNAPL sample collected from WG13 indicated that DNAPL present at this location was predominantly HCBD, with minor components of other Heavy Ends compounds.

DNAPL was not observed in WG65S or WG62D. The total percentage solubility for these wells was 49% and 94%. Figure 4.24 shows that elevated concentrations of HCB relative to its pure aqueous phase solubility phase were reported in WG65S and WG62D.

Total percentage solubilities in soil samples CH17 (7.6 – 7.7m), CH17 (19.9 – 20.0m) and CH17 (20.4 – 20.5m) exceeded 100% indicating DNAPL may have been present in the soil samples. Calculated pore water concentrations for these samples indicate that if DNAPL was present in the CH17 (7.6-7.7m) sample it was likely to be comprised of HCB and PCE. If DNAPL was present in the CH17 (19.9 – 20.0m) sample it was likely to be comprised of HCB, HCBD and HCE. If DNAPL was present in the CH17 (20.4 – 20.5m) sample it was likely to be comprised of CTC, PCE, HCB, HCBD and HCE. The results of soil analysis from CH17 appear consistent with observed analytical results from BP34.

The total percentage solubility for soil sample CH10 (3.0m) exceeded 100%, indicating DNAPL may have been present in this soil sample. Calculated pore water concentrations for these samples indicated that if DNAPL was present in the CH10 (3.0m) sample, it was likely to be comprised of PCE, HCB and HCBD.

Transect C

As discussed in Section 4, Transect C runs along the Botany rail corridor and is inferred to be located downgradient of the former Solvents Plant and former TCE Plant.

Total percentage solubilities along Transect C are presented in Figure 4.26. Figures 4.27 to 4.33 present the concentrations of PCE, CTC, TCE, 1,1,2,2-TeCA, 1,1,2-TCA, HCB and HCBd along Transect C. As shown the total percentage solubility in soil samples collected from CH18, CH19 and CH22 were greater than 100% indicating that DNAPL may have been present in soil samples collected at these locations. Calculated theoretical pore water concentrations for soil sample CH18 (5.35-5.55m) indicate that if DNAPL was present in this sample it was likely to be composed of PCE, HCB and HCBd. Calculated theoretical pore water concentrations for soil sample CH18 (23.1-23.5m) indicate that if DNAPL was present in this sample it was likely to be composed of PCE, CTC, HCB and HCBd.

Calculated theoretical pore water concentrations for soil sample CH19 (6.2-6.4m) indicate that if DNAPL was present in this sample it was likely to be composed of PCE, HCB and HCBd. Calculated theoretical pore water concentrations for soil sample CH19 (16.7-16.9m) indicate that if DNAPL was present in this sample it was likely to be composed of HCB and HCBd. Calculated theoretical pore water concentrations for soil sample CH19 (22.1-22.3m) indicate that if DNAPL was present in this sample it was likely to be composed of PCE, CTC, HCB and HCBd.

The results of soil analysis from CH18 and CH19 appear very similar to those for CH17, with PCE and Heavy Ends contamination identified on a layer at a depth of approximately 1 m AHD and PCE, CTC, HCB and HCBd contamination identified above weathered sandstone.

Total percentage solubilities for groundwater samples collected from BP95 ranged from 3.4% to 66.6%. Elevated concentrations of PCE and CTC relative to their respective pure aqueous phase solubilities account for most of the total percentage solubility. Based on the inferred direction of groundwater flow in the vicinity of the former Solvents Plant, BP95 is approximately downgradient of BP34. The concentrations of PCE and CTC detected in the upper 10 m of BP95 are similar to those reported in the upper 10 m of BP34. The concentrations of PCE and CTC in deeper groundwater at BP95 are significantly higher than those in BP34. This possibly indicates a source of PCE and/or CTC downgradient of BP34 and upgradient of BP95. The concentrations of Heavy Ends compounds in BP95 are significantly less than those in BP34. Heavy Ends compounds have organic carbon partitioning coefficients (K_{oc}) an order of magnitude greater than other CHCs within the Southern Plumes. Therefore the dissolved phase Heavy Ends plume is unlikely to propagate as far downgradient as plumes of other CHCs within the Southern Plumes.

The relatively low Heavy Ends concentrations and absence of HCB in groundwater sampled from both BP95 and BP96 may indicate that Heavy Ends DNAPL is not present at these locations. Compositional analysis of DNAPL indicates that Heavy Ends are a component of all DNAPL samples collected within the Southern Plumes' source areas to date. Dissolved Heavy Ends concentrations in aqueous phase samples collected from wells with DNAPL present are consistently greater than 30% of their respective solubility limits. If DNAPL was present adjacent to BP95, elevated dissolved phase Heavy Ends concentrations would be expected. Although dissolved phase Heavy Ends are likely to be retarded much

more than other dissolved phase contaminants in the Southern Plumes, the rate of movement of all compounds in the non-aqueous phase (ie. a DNAPL mixture) is the same.

Total percentage solubilities for groundwater samples collected from BP96 ranged from 0.0% to 8.5%. Compounds detected in BP96 included PCE, TCE, 1,1,2,2-TeCA, HCB and HCBD, which are indicative of contaminants from both the former TCE Plant and the former Solvents Plant.

The total percentage solubility in soil sample CH22 (5.0-5.2m) was greater than 100%. This result indicates that DNAPL may have been present in this soil sample. Calculated theoretical pore water concentrations indicate that if DNAPL was present in the sample it may be comprised of PCE, TCE and 1,1,2,2-TeCA, indicative of DNAPL from a source at the former TCE Plant.

Transect D

As discussed in Section 4, Transect D runs in a south-westerly direction from the former Solvents Plant to the south-west corner of Southlands-Block 1. Transect D is intended to show trends at and downgradient of the former Solvents Plant. It should be noted that Transect D is unlikely to be perfectly parallel with the direction of groundwater flow and this should be considered when analysing the data discussed in this section.

Total percentage solubilities along Transect D are presented in Figure 4.34. Figures 4.35 to 4.41 present the concentrations of PCE, CTC, TCE, 1,1,2,2-TeCA, 1,1,2-TCA, HCB and HCBD along Transect D. The distribution and percentage solubilities of CHCs in BP95, BP34 and WG206 have been discussed above.

As shown in Figure 4.34 the total percentage solubility in the majority of sample ports of BP49 and BP23 are greater than 90% indicating these wells are located downgradient of a significant DNAPL source. Based on the distribution of dissolved phase contamination, the DNAPL is likely to be comprised of mostly CTC and PCE. The concentrations of CTC and PCE presented on Figures 4.35 and 4.36 appear to increase further downgradient of the former Solvents Plant. This is likely to be indicative of the actual groundwater flow direction not being parallel to Transect D. The elevated concentrations of CTC and PCE (relative to their respective pure aqueous phase solubility limits) reported in BP49 and BP23 are likely to be indicative of dissolved phase CHCs emanating from a DNAPL source located upgradient of BP23 (ie. to the north and west of BP95). This inference is supported by soil analytical data for CH18 and CH19. Soil and groundwater analytical results along Transect C indicate that a significant mass of DNAPL may be present in the vicinity of CH18 and CH19, located to the north of BP95.

The concentrations of PCE and CTC reported in BP23 and BP49 are significantly greater than those reported in BP34 and BP95. This is likely to be reflective of DNAPL with higher CTC and PCE effective solubilities, possibly due to a smaller proportion of Heavy Ends compounds in the NAPL. This may indicate that a PCE/CTC-based DNAPL may be present to the north of the area impacted by Heavy Ends DNAPL. The composition of DNAPL sampled from BP34 indicated that a PCE-based DNAPL may be mixing with Heavy Ends DNAPL beneath the former Solvents Plant.

Transect E

As discussed in Section 4, Transect E runs in a south-westerly direction from the former TCE Plant to the south-west corner of Southlands-Block1. Transect E is intended to show trends at and downgradient of the former TCE Plant. It should be noted that Transect E is unlikely to be perfectly parallel with the direction of groundwater flow and this should be considered when analysing the data discussed in this section.

Total percentage solubilities along Transect E are presented in Figure 4.42. Figures 4.43 to 4.49 present the concentrations of PCE, CTC, TCE, 1,1,2,2-TeCA, 1,1,2-TCA, HCB and HCBd along Transect E.

The relatively low total percentage solubilities reported in WG208 indicate that this sampling location is located close to the upgradient boundary of the DNAPL source area.

As shown in Figure 4.42, the total percentage solubility in 4, 8, 10, 16 and 19 m sample ports of BP90 were greater than 100%. These results indicate that DNAPL may be present at, or upgradient of, BP90. If DNAPL is present it is likely to be comprised of PCE/TCE from the former TCE Plant and Heavy Ends from the former Solvents Plant. The PCE concentrations reported in BP90 represent up to 30% of its pure aqueous phase solubility. The PCE concentrations reported in the downgradient bundle piezometer (BP96) represent up to 2.4% of its pure aqueous phase solubility.

The TCE concentrations reported in BP90 represent up to 92% of its pure aqueous phase solubility. The TCE concentrations reported in the downgradient bundle piezometer (BP96) represent only up to 2.9% of its pure aqueous phase solubility. These results may indicate that the dissolved phase plume of contamination identified at BP90 does not flow past BP96. It is possible that the core of the dissolved phase plume travels to the south or north of BP96. Based on the inferred direction of shallow and deep groundwater flow (see Figures 4.8 and 4.9) and results from BP24 and BP50 indicate that it is not likely to travel to the north of BP96.

The results may also indicate that the elevated concentrations of PCE and TCE identified in BP90 are the result of vertical mobilisation of a DNAPL pool during its installation. Field observations made during the installation of BP90 indicated that strong CHC odours were present in the upper 10 m of the borehole but only weak to moderate odours were noted in the lower 9 m of the borehole. DNAPL was not identified in the drilling cuttings during the installation of BP90.

The former TCE Plant ceased operation in 1976, approximately 30 years ago. It is possible that most of the residual DNAPL located within sandy layers of the aquifer has dissolved into the S3 Plume. Pooled DNAPL (if present) is likely to persist much longer than residual DNAPL existing as ganglia in sand, so too are compounds within the DNAPL that have sorbed onto or diffused into the soil matrix.

Concentrations of HCBd and HCB reported in some sample ports of BP90 represented greater than 100% of their respective pure aqueous phase solubility limits. HCB was not detected in BP96 and HCBd concentrations reported in BP96 represented less than 0.9% of its pure aqueous phase solubility. These trends are similar to those reported for BP34 and BP95 along Transect D. The apparent lack of dissolved phase Heavy Ends contamination at BP96 may indicate that groundwater flowing past BP90 travels to the

south of BP96. This inference is supported by the presence of HCBd at monitoring locations to the south of BP96 (ie. in BP36, BP40 and BP51) (URS, 2004c and URS, 2001). Similarly, the elevated PCE and TCE concentrations present in BP90 were also not evident in BP96 which also indicates that the core of the dissolved phase plume at BP90 may flow to the south of BP96.

Concentrations of TCE and PCE reported in the 6 m sample port of BP24 are high relative to concentrations of these compounds in adjacent sample ports. The concentration of TCE reported in the 6 m sample port of BP96 is also high relative to adjacent sample ports. These results may be indicative of DNAPL above or sorbed to a low permeability layer or capillary barrier at a similar elevation. The concentration of TCE appears to increase between BP96 and BP24. Similar to the distribution of CTC and PCE along Transect D, this is likely to be an indication that groundwater flow is not parallel to Transect E. Based on the inferred direction of shallow and deep groundwater flow in the vicinity of the former TCE Plant (see Figures 4.8 and 4.9), groundwater flowing past BP24 may come from the area to the north of BP96. Therefore it is possible that DNAPL with components of PCE and TCE is located to the north of BP96. The calculated theoretical pore water concentrations of PCE in soil sample CH22 (5.0-5.2m) represented 119% of the PCE pure aqueous phase solubility indicating that PCE may be present as DNAPL at this location. The calculated pore water concentration of TCE and 1,1,2,2-TeCA in the same sample represented 19.2% and 5.4% of their pure aqueous phase solubilities indicating these compounds were also likely to be present in DNAPL mixture (if it exists).

Concentrations of PCE and TCE reported in the 18 m sample port of BP24 are also high relative to concentrations of these compounds in adjacent sample ports. These results may be indicative of DNAPL above or sorbed to a low permeability layer or capillary barrier at a similar elevation upgradient of BP24. The 18 m sample port of BP24 is at an elevation of approximately -12 m AHD. Concentrations of CHCs reported in BP90 indicate there may be DNAPL perched above the weathered sandstone at this location, which is at an elevation of approximately -11 m AHD. The relatively high concentrations of TCE and PCE identified in the 18 m sample port of BP24 may be indicative of DNAPL resting on or sorbed to weathered bedrock at an upgradient location.

5.3.3 Conceptual Model – DNAPL Entry and Fate

DNAPL is likely to have entered the subsurface at several locations across the former Solvents Plant. Possible DNAPL entry points are:

- Finished Product Storage Tanks (CTC and PCE);
- CTC and PCE Tanker Loading on 2nd Street
- Make Tanks (CTC and PCE);
- Solvents Plant Drainage System;
- Solvents Plant paved surface imperfections and joins;
- Solvents Plant 'Save All' Pit and Solvent Spillage Hold Tank;

-
- Effluent Treatment Plant; and
 - A grassed area along 1st Street.

DNAPL is likely to have entered the subsurface at several locations across the former TCE Plant. Possible DNAPL entry points are:

- Finished Product Storage Tanks (TCE);
- Finished Product Drum Filling and Storage (TCE, PCE and CTC);
- TCE Plant Drainage System;
- TCE Plant paved surface imperfections and joins;
- TCE Plant ‘Save All’ Pit;
- ‘Tri Sludge’ evaporation pit;
- CTC/PCE Tanker Loading Facility on 5th Avenue; and
- A grassed area along 1st Street.

Compositions of DNAPL entering the subsurface at the former Solvents Plant are likely to have been pure products (either PCE and CTC), intermediate process streams containing solvent and solvent/water mixtures, by-products (Heavy Ends) or a mixture of CTC, PCE and Heavy Ends. The composition of DNAPL from sources such as the Solvents Plant effluent collection system and ‘Save All’ pits is likely to be highly variable. Given the large differences between pure phase solubilities of Heavy Ends compounds and volatile CHCs, the effective solubilities of CHCs are likely to be highly variable across the source area.

Compositions of DNAPL entering the subsurface at the former TCE Plant are likely to have been pure products (TCE, PCE and possibly CTC), intermediate products (1,1,2,2-TeCA and pentachloroethane) or mixtures of intermediates and finished products. The composition of DNAPL from sources such as the TCE Plant effluent collection system and ‘Save All’ is likely to have been highly variable. Given the large differences between pure phase solubilities of TCE, PCE, pentachloroethane and 1,1,2,2-TeCA, the effective solubilities of CHCs are likely to be highly variable across the source area.

The results of DNAPL source area investigations undertaken to date have been fairly consistent with the conceptual understanding of likely DNAPL entry points. That is, contaminants associated with the former TCE Plant have typically been identified adjacent to the TCE Plant, whilst contaminants associated with the former Solvents Plant have typically been identified adjacent to the former Solvents Plant. However, Heavy Ends compounds have been identified at high concentrations relative to their respective solubilities along the entire length of Transect B, including BP90, which is located adjacent to the former TCE Plant. It is not known why Heavy Ends compounds are identified in BP90 but possible sources include the following:

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- The aerial photograph presented in Figure 2.1 shows objects lying on the grassed area along 1st Street in the vicinity of the former TCE Plant. Based on this photograph it is possible that plant equipment was temporarily stored in this area. The photograph shows an area of surface staining around one of the pieces of equipment and this may be indicative that DNAPL leaked/spilled from the stored equipment.
 - Soil excavated during the construction of a rail siding adjacent to the BIP produced excess spoil believed to be contaminated with CHCs including Heavy Ends. This spoil is stockpiled along the western boundary of the BIP in the vicinity of the former TCE Plant and the former Solvents Plant. It is possible (but unlikely) that DNAPL formerly located within this stockpile has migrated vertically from the stockpile.
 - It is possible that the grassed area along 1st Street was used to temporarily store drummed Heavy Ends from the former Solvents Plant. The grassed area is likely to have been the closest vacant area to the Heavy End drumming facility. Drums may have leaked or been accidentally spilled on the grassed area. However, newly drummed wastes are likely to have been placed in drums that were in relatively good condition so leakage is likely to have been minimal.
 - Part of the slab of the first PVC Plant (located at the south-west corner of the former Solvents Plant on the northern side of 6th Avenue across from the former TCE Plant 'Save All' pit) was used as a sludge dewatering pad for solids removed from site effluent and stormwater pits. These solids could have contained traces of Heavy Ends compounds (as well as other settleable compounds in the site effluent and stormwater systems). During their transportation to and from the dewatering pad, some of these solids could have been spilt onto unpaved or poorly sealed areas. The supernatant liquid was drained back into the former Solvents Plant effluent system.

The inferred lithology along Transect A, B, C, D and E are presented for comparison in Figure 5.1. The presence of DNAPL in WG205S and WG205I and its absence in WG205D indicates that vertical migration of DNAPL in this area is limited to approximately 12 m bgl (-6 m AHD) due to the presence of a low permeability layer at this depth. DNAPL is likely to have pooled above this layer and migrated laterally. The installation of WG205 has the potential to mobilise DNAPL into deeper parts of the aquifer.

Information provided by former ICI employees indicated that the area beneath the manufacturing component of the former Solvents Plant was excavated to a depth of approximately 25 feet (7.5 m) bgl prior to the construction of the plant. This was done to remove peaty layers which may have caused settlement and subsequent breakage of graphite and glass-lined pipework that was used at the plant. As a result, DNAPL that entered the subsurface through the plant's effluent collection system or joints/cracks in the plant's floor is not likely to have encountered any capillary barriers in the upper 7.5 m of the subsurface. Vertical migration of DNAPL from the effluent collection system may have been impeded by the presence of a low permeability layer at a depth of approximately 9 m bgl (1 m AHD). Lithological data obtained during this and previous assessments indicates that the low permeability layer at 1 m AHD is likely to play an important role in the distribution of DNAPL in the source area. Soil and groundwater analytical results along Transect B and Transect C indicate that DNAPL may be or have been pooled

above this layer. The fate of DNAPL resting on this layer is likely to be determined by the dip of the layer. Lithological data indicates that the layer is likely to be relatively flat. The distribution of CHCs in soil and groundwater samples collected along Transect C indicates that the layer may dip toward the west.

A second continuous low-permeability layer appears to be present at approximately –15 m AHD. It should be noted that weathered bedrock is encountered above this depth in parts of the inferred source area. The distribution of CHCs in soil and groundwater samples collected along Transect C, and the presence of DNAPL in WG67D, indicate that DNAPL may also be (or have been) collected as a pool (most likely shallow) above this layer.

Weathered sandstone within the inferred source area is encountered at depths ranging from –4 m AHD in the south-east corner of the former TCE Plant to –17 m AHD along the Botany railway corridor. The weathered sandstone appears to have a significant dip toward the west within the inferred source areas. The fate of DNAPL that reaches the weathered sandstone is likely to be determined by the localised topography of the sandstone. Based on analytical results for soil and groundwater samples collected along Transect C it can be concluded that the topography of the weathered sandstone layer significantly influences the fate of DNAPL. Weathered sandstone beneath the former TCE Plant is inferred to dip toward the west. Contaminants indicative of contamination from the former TCE Plant (TCE and 1,1,2,2-TeCA) were reported at elevated concentrations in the 23 m sample port of BP95, which was located within the weathered bedrock. In addition elevated concentrations of TCE and 1,1,2,2-TeCA were also reported in a soil sample collected close to weathered sandstone in CH21. BP95 and CH21 are located to the west of the former TCE Plant. The distribution of CHCs along Transect B indicated that TCE-based DNAPL was only identified immediately downgradient of the former TCE Plant (in BP90). Based on the inferred bedrock contours presented as Figure 4.7, BP90 is located up dip of BP95 and CH21. Similarly, compounds indicative of a DNAPL source from the former Solvents Plant are reported at elevated concentrations in soil samples collected near weathered sandstone at CH18 and CH19 relative to those reported in CH20. These results also indicate DNAPL migration in a westerly direction along the top of the weathered sandstone layer.

Based on data collected from CH18 to CH23, the low permeability layers above the weathered sandstone appear to be relatively flat in this transect. Any gradients in these layers are likely to be due to settlement of underlying sediments, and as a result may mirror those of bedrock at these locations, albeit at much smaller gradients. The inferred bedrock contours indicate that bedrock beneath the former Solvents Plant and former TCE Plant has gradients as steep as 1 in 10 toward the west. Based on these observations there is more potential for free phase DNAPL pooled above the weathered sandstone to travel further from the source compared to DNAPL pooled above other low permeability layers within the aquifer. However, it should be acknowledged that other factors play an important role in influencing the ability of DNAPL to migrate through the subsurface.

The TCE Plant ceased operation in 1976, approximately 30 years ago. Given the age of the source, it is possible that a significant proportion of the DNAPL mass that was present as residual ganglia in the highly permeable zones of the aquifer has dissolved into the S3 Plume. This may account for the low total percentage solubilities detected downgradient of the former TCE Plant relative to those downgradient of the former Solvents Plant. However, the presence of elevated total percentage

solubilities in some parts of BP90 indicates that DNAPL is likely still to be present in the subsurface in the vicinity of the former TCE Plant.

Observations made during this investigation and total percentage solubilities for groundwater downgradient of the former Solvents Plant indicate that significant mass of DNAPL is likely to exist both as residual and pooled DNAPL beneath the former Solvents Plant and possibly the Botany rail corridor.

Although it has not been discussed in any detail within this report DNAPL observed in the inferred S1 source area contains compounds from both the former Solvents Plant and former TCE Plant. The exact mechanism under which DNAPL reached this location is not known. Some possible scenarios are discussed below:

- Surface runoff and/or effluent from both the Solvents Plant and TCE Plant was mixed in open or subsurface drainage systems and entered the ground at a common point (possibly along a drain that travelled west from the BIP across the northern portion of Southlands-Block 1);
- Surface runoff and/or effluent was released from the Solvents Plant and TCE Plant on separate occasions but the effluent drained to a common point where DNAPL within the effluent/runoff entered the sub-surface; and/or
- DNAPL from both the Solvents Plant and TCE Plant entered the subsurface at different locations but have accumulated in similar locations due to topography of sub-surface capillary barriers and low permeability layers.

The compounds HCB and HCE were consistently identified in soil samples collected within CH17, CH18 and CH19. HCB and HCE are solids at 25⁰C so they are not technically DNAPLs. However, it is possible that HCB and/or HCE could be suspended or dissolved into a DNAPL mixture and be transported through the aquifer. Given the age of some of the DNAPL sources, it is possible that the more soluble and/or volatile components within the carrier DNAPL have volatilised in the vadose zone or dissolved into groundwater, leaving HCB and HCE behind.

5.3.4 Inferred DNAPL Source Area Boundary

Locations where DNAPL has been identified by field observation, or is inferred to exist based on calculated soil pore water concentrations are presented on a plan view in Figure 5.2. Locations where DNAPL is inferred to exist along Transects, A, B, C, D and E are presented on Figure 5.3. The inferred extent of the Southern Plumes' DNAPL source area is presented in Figure 5.4. It must be noted that this represents the locus of locations where DNAPL has been inferred at any depth, and does not represent presence of DNAPL throughout the aquifer profile. The extent of the S2 and S3 source areas have been inferred based on the following:

- The total percentage solubility for groundwater sampled from WG204S was 12.4%. The CHCs detected in groundwater sampled from WG204S were indicative of contamination from the former Solvents Plant. Based on this result it is not possible to assume that WG204 is located outside the DNAPL source area.

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- DNAPL was identified in WG205S and WG205I. Therefore WG205 lies within the greater DNAPL source area.
 - Concentrations of Heavy Ends compounds were high relative to their respective pure aqueous phase solubility limits in groundwater sampled from WG206I and WG206D. Based on this result, WG206 can be inferred to lie within the DNAPL source area.
 - Total percentage solubilities for CHCs in WG207S, WG207I and WG207D were 0.1% indicating that WG207 is located close to the upgradient boundary of the DNAPL source area. However, DNAPL was observed in the drilling mud tank during the installation of WG207 so it is inferred to lie within the DNAPL source area.
 - Total percentage solubilities of CHCs in WG208S, WG208I and WG208D were less than 0.4%. These results indicate that WG208 is located close to the upgradient boundary of the DNAPL source area. CHCs detected in WG208 were indicative of contamination from either the former TCE Plant or former Solvents Plant and consequently it must be concluded that WG208 lies within the DNAPL source area.
 - The total percentage solubility for groundwater sampled from WG209S was 1.4%. The CHCs detected in groundwater sampled from WG209S were indicative of contamination from the former TCE Plant. Based on this result it is not possible to assume that WG209 is located outside the DNAPL source area.
 - Total percentage solubilities of CHCs reported in several sample ports of BP90 were greater than 100%. Field observations during groundwater sampling indicated that DNAPL may have been present in sample tubing for the lower three sample ports. Based on these results, BP90 may be inferred to lie within the DNAPL source area.
 - DNAPL was identified in WG13 so it is inferred to lie within the DNAPL source area.
 - The total percentage solubility of CHCs in groundwater sampled from WG62D and WG65S was up to 90%, mostly due to the presence of HCB. WG62D and WG65S are located in close proximity to WG13, where Heavy Ends-based DNAPL has been identified. Based on these results, WG62D and WG65S may be inferred to lie within or close to the DNAPL source area.
 - DNAPL was observed in groundwater sampled from several ports of BP34. This indicates that BP34 is located within the DNAPL source area.
 - Calculated theoretical pore water concentrations for soil samples in CH17 indicate that DNAPL may have been present in some samples. Based on these results, CH17 is inferred to lie within the DNAPL source area.
 - Hydrophobic dye testing undertaken during the 2000 investigation of the former Solvents Plant and former TCE Plant (URS, 2000) indicated that DNAPL may have been present in CH06, CH07,

CH09 (BP34) and CH10. Based on these results, these core hole locations are assumed to be located within the DNAPL source area.

- DNAPL was identified in WG67D during the Stage 2 Survey (Woodward-Clyde, 1996) and again during sampling in 2004. Based on these observations, WG67D is inferred to lie within the DNAPL source area.
- Calculated theoretical pore water concentrations of CHCs in soil samples collected from CH18 and CH19 indicate that DNAPL may have been present in some samples. Based on these results, and the proximity of the core holes to WG67D, these core holes are inferred to lie within the DNAPL source area.
- It is not possible to conclude whether BP95 and BP96 are located within the source area. The absence of elevated concentrations of CHCs (relative to their respective pure aqueous phase solubilities) in groundwater sampled from BP96 may indicate that the bundle piezometer is not located within the DNAPL source area.
- Calculated theoretical pore water concentrations of CHCs in soil samples collected from CH21 were relatively low compared to their respective pure aqueous phase solubility limits. Based on these results, this core hole is inferred to be located outside the DNAPL source area.
- Calculated theoretical pore water concentrations of CHCs in a soil samples collected from CH22 indicate that DNAPL may have been present in the sample. Based on these results, the core hole is inferred to lie within the DNAPL source area.
- Calculated theoretical pore water concentrations of CHCs in soil samples collected from CH24 and CH25 were relatively low compared to their respective pure aqueous phase solubility limits. Based on these results, these core holes are inferred to be located outside the DNAPL source area.
- DNAPL has been identified in WG82D, CH12, CH13, SB1 and SG3 located on Southlands-Block 1. DNAPL at these locations is indicative of the inferred S1 source. It is not known whether DNAPL in the S1 source overlaps with DNAPL in the inferred S2 source area.

It is not possible to accurately define the boundaries of the S2 and S3 DNAPL source areas based on data from the 2005 DNAPL source area delineation investigation. CHCs were detected in groundwater samples collected from the upgradient and lateral monitoring wells (WG204 – WG209). Unless contamination entered the subsurface in the dissolved phase, these results indicate there is DNAPL somewhere upgradient or adjacent to these monitoring wells. The relatively low concentrations of CHCs in WG208 and WG209 indicate that DNAPL may be sparsely distributed in the vicinity of these wells.

The upgradient and lateral boundaries of the source areas should be able to be determined accurately with further investigation using the distribution of dissolved phase CHCs. It will not be possible to accurately delineate the downgradient (western) boundary of the S2 and S3 DNAPL source area based on dissolved phase CHC concentrations in groundwater as elevated concentrations of volatile CHCs are known to persist a significant distance downgradient of the actual DNAPL source area due to the age of the source

areas. As shown in Figure 4.34, the total percentage solubility in BP49 is in excess of 100%, but this piezometer is likely to be located outside the DNAPL source area. However, Heavy Ends compounds (in particular HCB) may act as a useful marker in determining the downgradient boundary of the source. HCB is a solid crystal with a very low pure phase solubility and an organic carbon partitioning coefficient (K_{oc}) an order of magnitude greater than other CHCs within the Southern Plumes (resulting in high retardation of its dissolved phase plume). All DNAPL samples collected from the S2 and S3 source areas to date have had a component of HCB. Where DNAPL has been identified, the concentrations of dissolved phase HCB is high compared with its pure phase solubility. Although HCB is a solid it is possible that it is transported, either suspended or dissolved, in a DNAPL mixture. Whilst the presence of HCB may serve as a good marker for the downgradient boundary of the DNAPL source area it is possible that there are DNAPL mixtures within the Southern Plumes' source areas that do not contain HCB and in this case the assessment of data on this premise may prove misleading.

It should be noted that the inferred boundary of the S2 and S3 DNAPL source areas marks the area in which DNAPL may exist in some part of the aquifer. DNAPL is only likely to occupy a very small percentage of the available pore space within the marked source area, with a localised and potentially discontinuous distribution. This can be demonstrated by the following calculation.

Assuming the DNAPL source area is 200 m long, 200 m wide and 20 m thick, the volume of the source area is 800 000 m³. Assuming the porosity of the aquifer is 0.3, the total pore space within the source area is 240 000 m³. Assuming there is 100 tonnes of DNAPL in the source area with an average density of 1.6 tonnes/m³, the volume of DNAPL in the source area is 62.5 m³. This volume of DNAPL represents approximately 0.02% (2 in 10,000) of the total pore space.

6.1 Conclusions

The aims of the delineation investigation works outlined in this progress report were to:

- Define the upgradient and lateral boundary of the S2 and S3 DNAPL source areas;
- Gain a better understanding of the vertical and horizontal distribution of DNAPL in the subsurface in the vicinity of the inferred DNAPL source areas of the S2 and S3 Plumes; and
- Better understand the distribution and characteristics of the various chemical compounds within the S2 and S3 DNAPL source areas.

Based on the data from nested monitoring wells located to the north, east and south of the former Solvents Plant and former TCE Plants it is not possible to accurately define the upgradient and lateral boundaries of the S2 and S3 DNAPL source areas. CHCs were detected in groundwater samples collected from the upgradient and lateral monitoring wells (WG204 – WG209). Unless contamination entered the subsurface in the dissolved phase, these results indicate there is NAPL somewhere upgradient or adjacent to these monitoring wells. Investigation work further from the inferred sources of contamination will be required to identify the upgradient and lateral ‘clean edge’ of the DNAPL source areas.

Data obtained during the investigation has identified (or has potentially identified) DNAPL at several locations in the vicinity of the former Solvents Plant and former TCE Plant. The composition of DNAPL samples obtained during the investigation and distribution of dissolved phase contamination across and downgradient of the inferred source area indicate the following:

- The composition of DNAPL in the S2 and S3 source areas is highly variable. Potential DNAPL sources within the former Solvents Plant and former TCE Plants include pure finished products, by-products, intermediate products, and variable mixtures of all these compounds from subsurface effluent collection systems;
- Heavy Ends compounds are likely to be a major component of DNAPL mixtures located beneath the former Solvents Plant, in particular in the vicinity of the former HETP. Heavy Ends compounds also appear to be present in DNAPL that may be located along 1st Street, in the vicinity the former Solvents Plant and the former TCE Plant;
- PCE and CTC appear to be major components of DNAPL located at the northern end of the former Solvents Plant. PCE was the major component of DNAPL identified in WG205 and PCE and CTC were the major components in DNAPL identified at WG67D. The distribution of dissolved phase CHCs in BP49 also indicates that DNAPL located to the north of BP34 and BP95 is primarily composed of CTC and PCE. PCE and CTC are also likely to be a major component of DNAPL located beneath the former Solvents Plant; and
- Based on dissolved phase CHC concentrations in BP90, TCE and PCE are likely to be major components in DNAPL located beneath the former TCE Plant. Other compounds including 1,1,2,2-TeCA and Heavy Ends compounds are also likely to be a component of DNAPL at this location.

Lithological data obtained during this investigation have identified three layers within the subsurface that are likely to significantly influence the distribution of DNAPL. Extensive low permeability layers appear to be present at elevations of approximately 1 m AHD and -15 m AHD. The third significant layer is the weathered sandstone, which is encountered between -4 and -17 m bgl across the inferred S2 and S3 DNAPL source areas. The fate of DNAPL resting on these layers is likely to be determined by the dip of the layer. Lithological data indicates that the layers are likely to be relatively flat. The distribution of CHCs in soil and groundwater samples collected along Transect C indicates that the layers may have a slight dip toward the west. Sandstone bedrock beneath the former Solvents Plant and former TCE Plant generally dips toward the west. The slope of bedrock and low permeability layers is likely to significantly influence the distribution of DNAPL in the subsurface.

Elevated dissolved phase CHC contamination identified in BP90 was not identified in BP96, which is inferred to lie downgradient of BP90. The inferred deep groundwater contours indicate that dissolved phase contamination from a DNAPL source located close to BP90 may exist to the south of BP96.

6.2 Recommendations

URS recommend the following work to further assess and delineate the Southern Plumes' DNAPL source areas:

- A primary DNAPL recovery trial has been proposed for the former Solvents Plant. It has been proposed to routinely bale out a number of existing monitoring wells over the period of a month for the trial. This work should be undertaken to assess the potential for DNAPL to be recovered from the source area. Orica should attempt to recover DNAPL from existing monitoring wells (WG205S, WG205I and WG13) in the vicinity of the former Solvents Plant;
- Test pitting has been proposed within the former Solvents Plant. Eight test pits are to be excavated in targeted locations across the former Solvents Plant to assess potential DNAPL entry points. The data obtained should provide a better indication of where DNAPL has entered the subsurface and will therefore improve the conceptual understanding of the S2 DNAPL source area;
- If useful information is obtained during test pitting investigations at the former Solvents Plant, Orica should also consider undertaking a similar investigation at the former TCE Plant;
- WG204, WG206, WG207, WG208 and WG209 should be resampled. It is possible that the distribution of contaminants around some of these wells may have been affected by the mud rotary drilling methods used to install the wells. In particular, the analytical results for groundwater samples collected from WG207 did not reflect the visual observation of DNAPL in drilling cuttings at this location;
- An attempt should be made to recover a sample from the bottom of the PVC casing of BP90. Based on field observations during groundwater sampling and concentrations of CHCs in groundwater, DNAPL may be present above weathered sandstone at this location. The PVC bundle piezometer

housing was screened from 18 to 19 m bgl. It may be possible to collect a sample of DNAPL at this location (if it is present) through this screened interval;

- Existing CPT and borehole data for areas within and around the inferred Southern Plumes' DNAPL source areas should be used to define the topography of bedrock and other controlling layers for DNAPL migration. A better understanding of bedrock topography may assist in identifying further investigation locations, or identifying locations at which favourable conditions exist for trialling primary or secondary DNAPL source remediation; and
- Five bundle piezometers and 4 nested monitoring wells have been proposed for installation in the vicinity of the Southern Plumes' DNAPL source areas. The wells and bundle piezometers are to be installed to better delineate the Southern Plumes source areas. At the time this report was prepared the investigation works were in progress.

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- A G Environmental Engineers and Woodward-Clyde Consultants (1990). *ICI Botany Environmental Survey – Stage 1 Preliminary Investigations*, May 1990.
- URS (2001). Orica Botany Environmental Survey Stage 3 – Remediation *Full Scale Reactive Iron Barrier - Data Gap*, Document Number R035_D1, 14 May 2001.
- URS (2004a). Orica Botany Environmental Survey Stage 4 – Remediation *2004 DNAPL Source Area Investigation*, Document No R015, 12 August 2004.
- URS (2004b). Orica Botany Environmental Survey Stage 4 – Remediation *Preliminary Findings of Phase 2 DNAPL Source Area Investigation Works – Former EDC Storage Tank Area, Former Vinyls Plant and Former EDC Recovery Still*, Document Sequence No WCIE-4168_A, 17 November 2004.
- URS (2004c). Orica Botany Environmental Survey Stage 4 – Remediation *Full Scale Reactive Iron Barrier - Data Gaps – Module2a*, Document Number R010_A, 12 May 2004.
- URS (2005a). Orica Botany Environmental Survey Stage 4 – Remediation *2005 DNAPL Source Area Delineation Investigation*, Document No R023, 28 April 2005.
- URS (2005b). Orica Botany Environmental Survey Stage 4 – Remediation *Groundwater Cleanup Plan Quarterly Groundwater and Surface Water Monitoring Report – June 2005*, Document No R028, 15 August 2005.
- Woodward-Clyde (1996). *S2/C3 Water/Soil Phase 2. Stage 2 Groundwater Survey*. Report No. 3390R1-D, August 1996.
- Woodward-Clyde (1997). *Contamination Assessment – Vinyls Plant, ICI Botany*. Report No. RID3, May 1997.
- Woodward-Clyde (2000). *Orica Botany Environmental Survey, Stage 3 – EDC Source Area Investigation*. Report No. A8600436/55, February 2000.