

# PETROLEUM HYDROCARBON CONTAMINATION INCIDENT AT CHRISTCHURCH CITY COUNCIL GROUNDWATER PUMPING STATION

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## ABSTRACT

In March 2003 dissolved petroleum residues were noted by the general public within the Christchurch City Council's reticulated drinking water supply.

Initial investigations at the closest operating pumping station showed that the source of the petroleum residues had to have originated from either a leaking underground fuel supply line or from broken stormwater pipes that inadvertently received petroleum residues from cleaning activities within the pumping station.

Petroleum residues were noted floating on water present within the base of the well head chamber of one of the shallow supply wells. Petroleum residues had not contaminated the aquifer utilised by the well, but had entered the well via a faulty flange joint at the base of the well head chamber.

Excavations around the affected well head chamber and underground fuel line coupled with the installation of five monitoring wells indicated the presence of petroleum residues around the foundations of the pump house. A product recovery well was installed and around 35 L of fuel recovered.

All seals between the affected well and pumping station have been replaced and the system disinfected. Groundwater monitoring of the supply wells and monitoring wells following removal of the contaminant sources has shown attenuation of petroleum residues to non-detectable levels and as such the site has been recommissioned nine months after the initial contamination.

## KEYWORDS

**Groundwater contamination, petroleum hydrocarbons, reticulated water supply.**

## 1 INTRODUCTION

The urban area of Christchurch is supplied by a reticulated drinking water supply under the management and control of the Christchurch City Council (CCC). The water supply is sourced from groundwater obtained from a series of gravel aquifers, which lie beneath the city.

At times, for cost efficiency the CCC use on-site diesel run generators to power pumps that abstract groundwater from the underlying aquifers to supply the surrounding residential and commercial/industrial areas. As such, diesel fuel is typically stored in either aboveground or underground tanks. Due to the size constraints of some of the CCC pumping station sites the fuel storage is located in close proximity to the abstraction wells. Under these circumstances the possibility exists for contaminants, such as diesel fuel, to inadvertently enter the reticulated water supplies as a result of equipment failure or improper on-site maintenance and/or management procedures.

This paper describes such an incident whereby diesel fuel inadvertently entered the CCC reticulated drinking water supply system at one of their pumping stations within the north-west Christchurch catchment. The paper sets out the investigation procedures that occurred following notification by the general public of tainting of the

water supply. These procedures included excavation and removal of contaminated soil, installation and sampling of groundwater monitoring wells, sub-surface diesel recovery and improvements to the pumping station pipework and maintenance/management procedures.

## 2 SITE LAYOUT

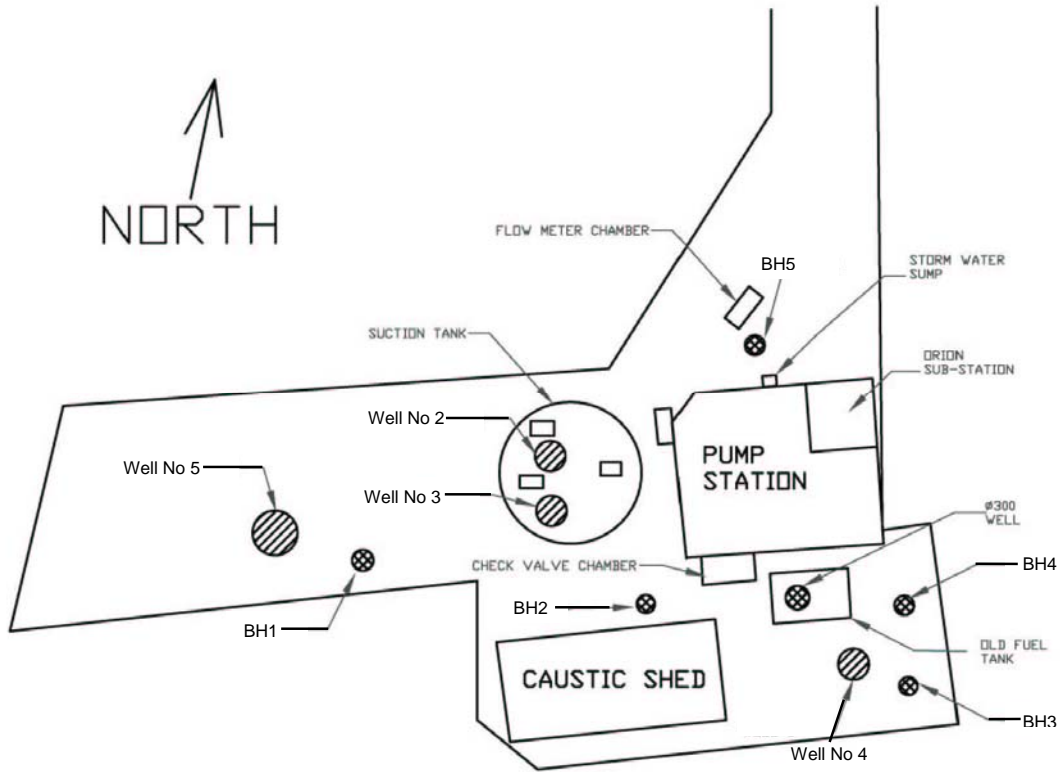
The CCC operated Auburn Ave pumping station is located on a rear section on the southern side of Auburn Ave in the western residential suburb of Riccarton, Christchurch. The site is bounded by residential properties on the northern, eastern and western boundaries and by Middleton Grange School playing fields to the south. The site, which is flat, comprises two buildings. A block building is centrally located along the eastern boundary and houses the pumping station and a garage/utility storage building is located along the southern boundary. The concrete floor of the pumping station is approximately 2.7 m below ground level.

The site surface comprises an asphalt sealed access-way from Auburn Ave whilst the southern and western areas are grassed. An underground concrete lined suction/storage tank (approximate dimensions of 7 m diameter and 7 m depth) is located immediately to the west of the pumping station beneath asphalt seal and is recharged by two flowing artesian wells (Well No. 2 and Well No. 3). Two concrete well head chambers, housing supply wells, are also located at the site, one on a grassed area to the south of the pumping station (Well No. 4) and the second on a grassed area to the west of the pumping station and suction tank (Well No. 5). Well No 5 also supplies the suction tank via a modulating valve to control levels within the tank. The four wells contribute to the CCC's reticulated water supply system in the area.

*Photograph 1: Auburn Ave Pumping Station (viewed looking east)*



Figure 1: Plan view of Auburn Ave Pumping Station



### 3 DESCRIPTION OF SUBSURFACE SOIL, HYDROLOGY AND GROUNDWATER USE

The geological map of the Christchurch Urban Area (Brown & Weeber, 1992) shows that soils underlying the site comprise mainly of fine grained alluvial sand and silt deposits. This is confirmed by the logs from the on-site shallow monitoring wells, the logs of the four on-site public supply wells and from two wells located up to 350 m north of the site. The borehole logs have been obtained from Environment Canterbury's (ECan) well database.

The on-site monitoring well logs show low permeability silts and silty sands extending to depths of at least 8.5 m below ground level within the deepest monitoring borehole (BH1). The ECan logs of the four on-site public supply wells also show the underlying soils to comprise low permeability strata to depths of between 10 and 11.9 m below ground level. A summary of the well depth and screen data for the CCC supply wells is shown below:

Site Plan Reference	Screen Set Depth (m)
Well No. 2	19.5 - 27.1
Well No. 3	27.1 - 33.2
Well No. 4	29.2
Well No. 5	166-172

The strata logs of the two wells located between 85 m and 350 m north-west and north of the site, respectively, also show low permeability soils to depths of between 10 m and 17.6 m below ground level. The logs of the deeper wells generally show that the near surface low permeability soils are underlain by a sequence of gravel aquifers interspersed by lower permeability layers to depths of up to 190 m below ground level.

Based on the Christchurch Artesian Aquifers Report (North Canterbury Catchment Board, 1986) the low permeability, fine grained silty and sandy soils in the wider area are expected to extend to depths of around 16 m below ground level, beneath which are a series of gravel aquifers separated by fine grained layers. The first aquifer extends between 16 m to 40 m below ground level and has water pressures ranging between 2 and 9 m below ground level, whereas the second aquifer extends between 62 and 82 m below ground level and has water pressures ranging between 3 and 6 m below ground level. These aquifers form part of the Christchurch Artesian Aquifer System.

Groundwater has been observed in the on-site monitoring wells (BH1 to BH5), on 6 May 2003, at depths ranging between 2.144 m (BH3) to 2.635 m (BH1) below ground level. The water levels measured within BH1 to BH5 indicate quite variable groundwater elevations. It is likely that the presence of the large suction tank, the deep foundations of the pumping station and the variable permeability of soils within the backfilled excavation are influencing the local groundwater levels at these shallow monitoring wells. Within the underlying gravel aquifer, larger scale piezometric surveys throughout the city indicate a south-easterly direction of groundwater flow.

New Zealand guidelines have been developed that define whether the underlying aquifer is sensitive with respect to its potential use as a potable supply (Ministry for the Environment, 1999). Based on the geological profile of the soils beneath the site and within the surrounding area the underlying aquifer is not considered to be sensitive. The low permeability soils which underlie the site and surrounding area form part of the surface confining layer for the Christchurch confined aquifer system. In this area the shallow water table noted in the monitoring wells at the site is unlikely to be used for a potable supply. The site and surrounding properties are serviced by the Christchurch City Council's reticulated water supply sourced from groundwater wells abstracting water at not less than 19.5 m below ground level.

The nearest surface waterway is the Avon River, located approximately 1,000 m north-east of the site, which flows in a general easterly direction.

## **4 THE CONTAMINATION INCIDENT**

### **4.1 INITIAL OBSERVATIONS**

A resident of the north-west Christchurch suburb of Ilam was the first to note petroleum tainting of their reticulated water supply in the evening of 7 March 2003. The pumping station and the property that first reported the tainting is separated by approximately 1 km of reticulated pipework.

As an immediate consequence, that evening, CCC representatives inspected seven pumping stations within the north-west Christchurch reticulated catchment, which had on site petroleum hydrocarbon storage (typically diesel for the backup generator), to check for any obvious fuel losses. An additional five pumping stations within the catchment were also checked on the morning of 8 March. Nothing obvious was noted during the initial investigations, however, as a prudent approach Auburn Ave pumping station, which was the only operating station within the area at that time, was shut down at 10pm, 7 March. A total of 12 complaints regarding the quality of the reticulated water supply were recorded on the evening of 7 March.

### **4.2 INITIAL SITE INSPECTION**

#### **4.2.1 DETECTION OF PETROLEUM RESIDUES WITHIN WELL NO. 4**

An inspection by CCC representatives at the Auburn Ave pumping station on 10 March revealed the presence of separate phase diesel with a thickness of up to 0.3 m floating on water within a check valve chamber, located on the south-western corner of the pumping station.

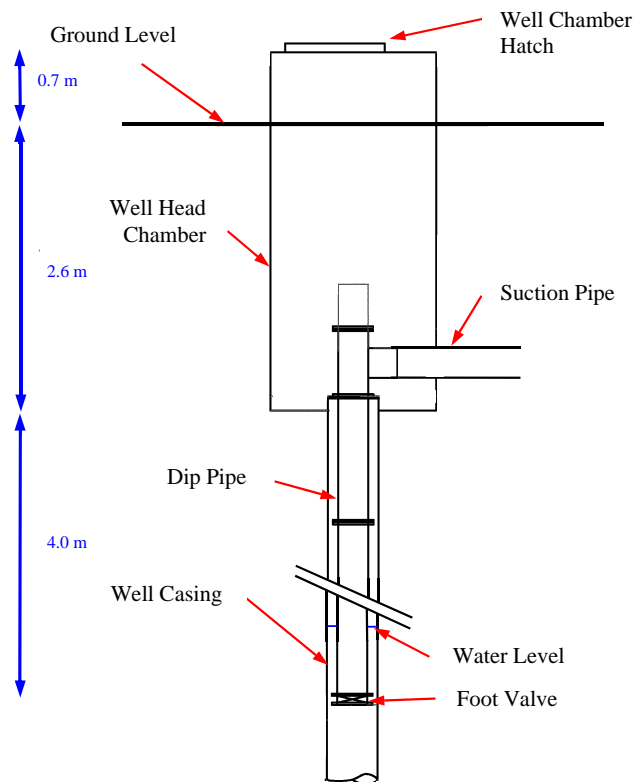
In addition, petroleum staining was noted on the walls of the concrete well head chamber of Well No. 4 to a height of around 0.3 m above the chamber base and a thin layer of diesel was noted floating on water present at

the base. The base of the well head chamber of Well No. 4 is around 2.6 m below the surrounding ground level. The well utilises a surface pump which is located within the pumping station. The well has a dip pipe (approximately 4 m long down the well casing) that has a foot valve located at its base. The CCC collected a sample of water from the dip pipe via an access port on the top of the well head and they reported that no obvious visual or odorous petroleum content was present. However, following the removal of the dip pipe from the well an oily film was noted within the annular space between the dip pipe and the well casing.

It is worth noting that Environment Canterbury, the Regional Council, had previously inspected this well head in November 2002, as part of a routine sampling programme, and no petroleum hydrocarbons were reportedly present. Therefore, it is assumed that the petroleum hydrocarbons entered the well head chamber after this point in time.

The CCC reported that further inspection of the flange joints between the dip pipe and the well casing at the base of Well No. 4 chamber revealed that a plastic sampling pipe was pinched between the flanges, thus preventing a water tight seal. According to the CCC the condition of the gasket between the two flange joints suggested that it was not able to provide an effective seal.

Figure 2: Schematic Diagram of Well No. 4



#### 4.2.2 EXCAVATION WORKS AT PUMPING STATION

An excavation was undertaken by CCC representatives at the rear of the pumping station and adjacent to the site's 2,250 L aboveground fuel storage tank (AST) containing diesel on 11 March 2003. During the excavation works the fuel line from the AST was exposed and diesel was noted seeping from the line, although the sand immediately surrounding the AST had no obvious petroleum odour. The tank and associated pipework were removed from the site.

The excavation extended between the rear of the pump building, the check valve chamber and Well No. 4. During the excavation works, under the supervision of PDP, petroleum affected soils were noted up to a depth of around 3 m below ground level. The suction pipe between Well No. 4 and the pumping station was exposed

with the invert depth of the pipe occurring at around 2.2 m below ground level (diameter 250 mm). The soils surrounding the pipe had a petroleum odour.

Black, degraded fuel was noted seeping from the base of the building foundations, at around 3 m depth, at the rear of the pumping station and into the base of the excavation. All petroleum affected soils from the excavation were carted to a Christchurch remediation facility. However, as indicated by the degraded fuel observed seeping from beneath the pumping station, petroleum hydrocarbon affected soils remain beneath the site, under the building foundations.

*Photograph 2: Excavation to Rear of Pumping Station*



A small submersible pump was placed into the base of the excavation and the fuel/groundwater mixture was removed into three 1,000 L tanks, which were interconnected with submerged outlets to operate as a simple oil/water separator. The discharge from the third tank entered the site's reticulated stormwater system. No obvious sheening or odour was noted on the discharge water entering the stormwater system, indicating that the oil-water separator was operating successfully. During a site inspection undertaken on 2 April 2003 a layer of black product with a thickness of around 30 mm was present within the first 1,000 L tank of the oil separator system. The product had an odour similar to that of diesel.

A sample of the product present within the first 1,000 L tank of the oil separator system (sample ref. 'IC1') was collected into a laboratory bottle for subsequent identification.

#### **4.2.3 PUMPING SUMP INSTALLATION**

Following the removal of petroleum affected soils from within the excavation to the rear of the pumping station a 400 mm diameter PVC pipe with overlapping diagonally cut slots was installed to a depth of around 3.9 m below ground level. The immediate area surrounding the slotted section of the pipe was backfilled with clean gravels which were underlain and overlain by filter cloth, whilst the remaining excavation was backfilled with sandy gravels.

It should be noted that as a prudent measure all seals along the suction pipe joints were replaced before the pipe was reconnected and the excavation backfilled.

The small submersible pump was placed into the base of the PVC casing and the pumped fuel/groundwater mixture was discharged into the three stage plastic tanks, prior to being disposed of into the reticulated stormwater system. Regular inspection of the discharge into the stormwater system showed no obvious signs of petroleum hydrocarbon residues or odour. A pumping discharge rate of approximately 0.015 L/s was required to hold the water level at the base of the sump (a drawdown of the original groundwater table of around 1.9 m). In

addition, regular inspections of the three 1,000 L separation tanks were undertaken to check for the accumulation of separate phase product.

#### 4.2.4 PETROLEUM HYDROCARBONS PRESENT WITHIN PUMPING STATION

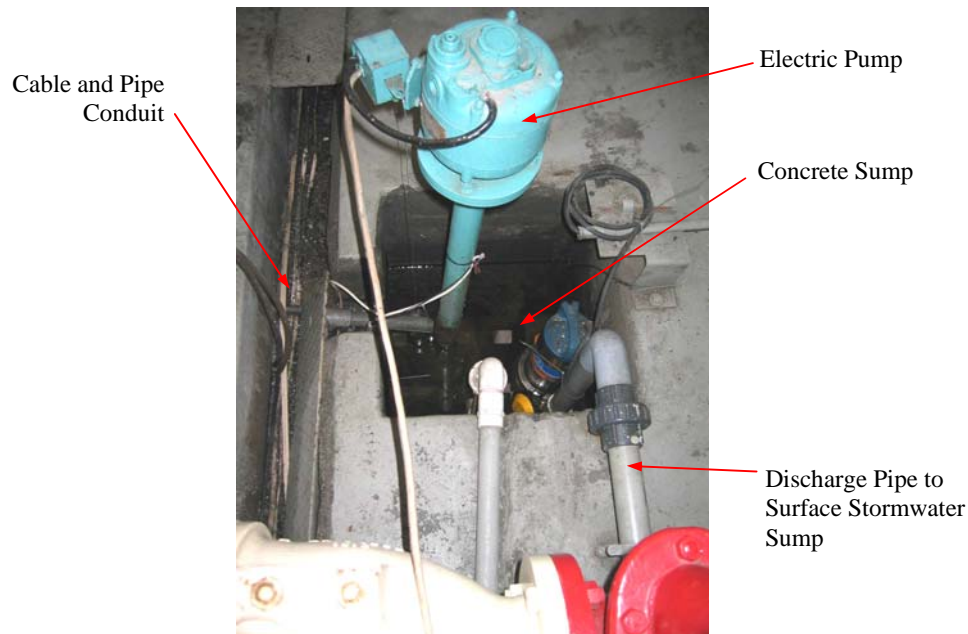
Clear separate phase product with a thickness of around 20 mm was observed within a small concrete sump located within the north-western corner of the pumping station. The CCC surmised that the source of the product might have been as a result recent maintenance and cleaning of a diesel engine within the building. A sample of the product (sample ref. 'Pump House Sump') was collected into a sample bottle for laboratory identification.

Any water that collects in the sump within the station gets pumped to a ground level sump at the front of the building and then is discharged to the reticulated stormwater system. The fuel noted in this station sump had been inadvertently pumped to the reticulated stormwater system, although it was not known over what time frame this had occurred. During the investigation works by CCC it was found that the stormwater pipes adjacent to the ground level sump were broken thus providing a route for hydrocarbon migration towards the water table.

*Photograph 3: Inside Pumping Station*



*Photograph 4: Sump Inside Pumping Station*



### **4.3 LIKELY FUEL MIGRATION PATHWAY INTO WELL NO. 4**

According to the CCC the demand on Well No. 4 was reasonably high on Friday 7 March. The well was being pumped between 5:41am to 8:40pm on 7 March and contributed around 4,000 m<sup>3</sup> of a total 30,000 m<sup>3</sup> supply within the north-west catchment zone that day. A plausible scenario is that fuel had entered the Well No. 4 well head chamber, through cracks, etc, and was floating on water at the chamber base. The trench for the suction pipe from Well No. 4 to the pump station building could have provided a permeable pathway for the migration of petroleum hydrocarbons. The fuel/water mix was able to enter the well casing via the faulty flange joint at the chamber base and floated on the water surface in the annular space between the well casing and the dip pipe. Due to the heavy demand on the pumped well on 7 March the water table within the well was drawn down to a depth where dissolved petroleum hydrocarbons associated with the floating petroleum hydrocarbons could enter the dip pipe and thus petroleum affected groundwater entered the reticulated system.

## **5 GROUNDWATER MONITORING WELL INSTALLATION**

PDP supervised the drilling of five groundwater monitoring boreholes at the pumping station between 24 and 25 March (BH1 to BH3) and 2 and 3 May 2003 (BH4 and BH5). The wells were installed to further define the lateral extent and hence impact of the petroleum residues released into the surrounding ground. The locations of the installed groundwater monitoring wells are shown in Figure 1.

Each borehole was drilled to depths of between 5.5 m (BH4) and 8.5 m (BH1) below ground level to intercept the groundwater table at times of low water levels. Drilling was carried out utilising a truck mounted compressed air driven "Concentrix" 'down-hole-hammer' drilling rig. Each standpipe comprised a 50 mm diameter slotted uPVC pipe and screened between the base of each borehole installation and to a depth of up to 0.4 m below ground level (BH4). A plug of bentonite clay was installed above the screen packing material to prevent the inflow of stormwater. The surface of each borehole installation was finished with concrete and a lockable toby box set flush with the ground surface.

## **6 GROUNDWATER MONITORING WELL AND RETICULATED SUPPLY SAMPLING**

### **6.1 SAMPLING PROGRAMME**

Sampling of the on-site monitoring wells and/or of specific sections of the CCC's reticulated water supply (e.g. suction tank, Well No. 4 and reticulated piping) has been conducted on five separate occasions between 2 April and 26 November 2003.

The requirement for sampling was to ensure that the petroleum residues were reducing in concentration and to confirm that the water supply was safe to use again before recommissioning.

### **6.2 MONITORING WELL SAMPLING**

With regard to the groundwater monitoring well sampling rounds undertaken on 2 April and 6 May 2003 the same sampling methodology was carried out. On each occasion prior to sample collection, the depth to the water table below the rim of each monitoring well was measured, and the presence of separate phase product was checked using a clear plastic bailer to cut the surface of the water within each well casing. The wells were purged of at least three times the volume of water standing in the casing to ensure that representative groundwater that had not been exposed to the open environment was sampled. The water samples were collected using one-litre capacity dedicated bailers.

### **6.3 WELL NO. 4 SAMPLING**

A groundwater sample was collected from the CCC decommissioned Well No. 4 on 2 April 2003. Due to the well specifications and with the pump having been disconnected it was not feasible to purge the well of the equivalent of three well casings and as such a sample was collected directly from the dip pipe using a plastic one-litre dedicated bailer.

### **6.4 SUCTION TANK SAMPLING**

A sample of the groundwater that was present within the suction tank was collected on 16 May 2003. The sample was collected directly from the tank via the ground level manhole and using a plastic dedicated bailer.

### **6.5 MAIN DISCHARGE PUMP AND FIRE HYDRANT SAMPLING**

The suction tank was emptied to the Auburn Ave kerbside between 17 and 19 July 2003 using a submersible pump and direct aboveground hosing. During this time, water level measurements were taken in the suction tank and at on-site monitoring wells to determine if the shallow water table outside the tank was affected by the drop in water level inside the tank. The water levels in the monitoring wells remained relatively constant as the water level in the tank dropped from around 2 m to 7 m below ground level. This suggests that the suction tank is not receiving contaminated groundwater from the surrounding shallow water table.

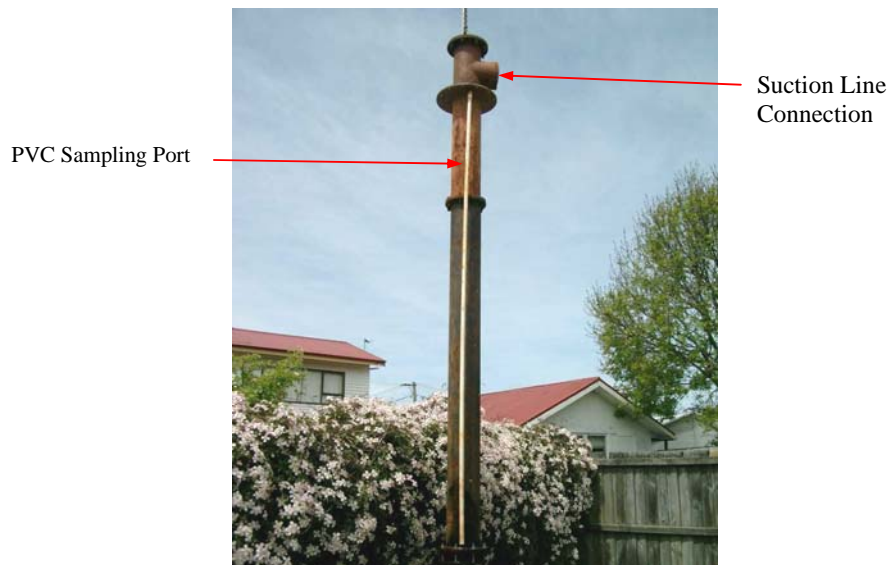
Whilst empty, the inside of the suction tank was cleaned with a high pressure hose and approximately 1 m<sup>3</sup> of sand that had entered the tank via Wells No. 2 and No. 3 was removed. Once the suction tank naturally refilled the water was chlorinated and allowed to stand for three hours before flushing of the reticulated system attached to the suction tank began.

To confirm the absence of petroleum residues in the suction tank and reticulated pumping system at the Auburn Ave station, water samples were collected on 22 July 2003 from the main pump and from the fire hydrant located approximately 30 m west of the Auburn Ave pumping station driveway. A sample was collected from the fire hydrant to provide a representative sample of the water in the reticulated water supply being pumped from Auburn Ave pumping station. Prior to collecting the samples the pump had been operating for approximately four hours with two fire hydrants in Auburn Ave being used to draw the water from the reticulated system. The sample from the main pump was collected from the sampling tap at the side of the pump. The second sample was collected directly from the fire hydrant hose.

## 6.6 DISCHARGE PUMP FOLLOWING ISOLATION OF WELL NO. 4

During September, October and November 2003 the CCC undertook clean-up works of the affected Well No. 4 so that it could be brought back into service. The flange joint at the base of the well casing was cleaned and new seals fitted. The dip pipe and well head casing were cleaned with a steam cleaner. Following the reinstallation of the dip pipe the well and the suction line between the well head and pump station were chlorinated. Following a 24 hour period of chlorination a lay flat hose was connected to the recently installed pipework that allowed isolation of the groundwater abstracted from Well No. 4 following pumping.

*Photograph 5: Reinstallation of Dip Pipe into Well No. 4 Casing*



Groundwater was pumped from the well in isolation from the remaining station's water supply wells at a rate of approximately 80 L/s for a period of one hour before representative groundwater samples were collected. The depth to groundwater within the five monitoring wells (BH1-BH5) was measured at around 30 minutes following start up of the discharge pump and following around 60 minutes following start up. Following 30 minutes of pumping at around 80 L/s the depth to water within the monitoring wells increased between 11 mm (BH3) and 71 mm (BH2). No change in water level was measured in BH1, located furthest from Well No. 4.

## 6.7 SAMPLE HANDLING, STORAGE AND ANALYSIS REQUEST

On each occasion groundwater samples were collected into glass bottles supplied by the analytical laboratory. Following collection, all samples were stored in a chilly bin containing frozen ice packs before being transported via an express courier to RJ Hill Laboratories Ltd in Hamilton. The groundwater samples from the four separate sampling rounds were received the following day after collection.

All water samples were analysed for total petroleum hydrocarbons (TPH), benzene related compounds (BTEX) and poly-cyclic aromatic hydrocarbons (PAH). TPH analysis provides a general indicator of the level of petroleum contamination by a broad range of compounds within the sample. BTEX compounds only constitute a small percentage of the 500 or so different compounds present within diesel. For example, benzene only constitutes around 0.5% by weight of diesel fuel. However, BTEX compounds, and in particular benzene, are the most soluble of the petroleum hydrocarbons and hence the most mobile within a groundwater environment. In addition, benzene is a limiting carcinogenic compound with respect to the protection of human health. PAH compounds are typical of the more heavy fuels including diesel. They are less soluble than BTEX compounds, however, certain compounds (benzo[a]pyrene) are carcinogenic to humans.

## 7 GROUNDWATER SAMPLING RESULTS

### 7.1 SAMPLING UNDERTAKEN ON 2 APRIL 2003

At the time of sampling on 2 April 2003 three monitoring wells had been installed (BH1-BH3). No obvious petroleum hydrocarbon odour or sheening was noted on the water surface within the three monitoring wells (BH1 - BH3) prior to or during the purging process. With respect to Well No. 4 clear globules and a petroleum hydrocarbon sheen were noted on the water surface within the well standpipe casing.

The groundwater sampling results have been summarised below:

Well Ref	TPH	Benzene	Toluene	Ethyl Benzene	Total Xylenes	Benzo[a]pyrene	Naphthalene	Pyrene
BH1	<0.2	<0.0005	<0.001	<0.0005	<0.001	<0.000003	<0.00001	0.000026
BH2	<0.2	<0.0005	<0.001	<0.0005	<0.001	<0.000003	0.00008	0.000019
BH3	<0.9	<0.0005	<0.001	<0.0005	<0.001	<0.00003	<0.0001	0.00011
Well No. 4	19.8	<0.0005	<0.001	<0.0005	<0.001	<0.00003	0.0071	0.00738

Note – Detectable concentrations are shaded for identification

The gas chromatogram for the groundwater sample collected from Well No. 4 was similar to that of diesel.

### 7.2 SAMPLING UNDERTAKEN ON 6 MAY 2003

As with the sampling undertaken on 2 April, no obvious petroleum hydrocarbon odour or sheening was noted on the water surface within the five monitoring wells (BH1 - BH5) prior to or during the purging process.

The groundwater sampling results have been summarised below:

Well Ref	TPH	Benzene	Toluene	Ethyl Benzene	Total Xylenes	Benzo[a]pyrene	Naphthalene	Pyrene
BH1	<0.2	<0.0005	<0.001	<0.0005	<0.001	<0.000003	<0.00001	<0.000003
BH2	<0.2	<0.0005	<0.001	<0.0005	<0.001	<0.000003	<0.00001	0.000004
BH3	<0.2	<0.0005	<0.001	<0.0005	<0.001	<0.000003	<0.00001	0.000006
BH4	<0.2	0.0019	0.018	0.0016	0.0099	<0.000003	0.00100	0.000081
BH5	1.6	0.0298	0.007	0.0106	0.0973	<0.000003	0.0105	0.000067

Note – Detectable concentrations are shaded for identification

Possible identification of the detectable dissolved hydrocarbons in sample BH5 by gas chromatogram was not possible due to the low concentrations measured.

### 7.3 SAMPLING UNDERTAKEN ON 16 MAY 2003 – SUCTION TANK

TPH	Benzene	Toluene	Ethyl Benzene	Total Xylenes	Benzo[a]pyrene	Naphthalene	Pyrene
<0.2	<0.0005	<0.001	<0.0005	<0.001	<0.000003	<0.00001	0.000003

Note – Detectable concentrations are shaded for identification

### 7.4 SAMPLING UNDERTAKEN ON 22 JULY 2003 – DISCHARGE PUMP AND FIRE HYDRANT

TPH	Benzene	Toluene	Ethyl Benzene	Total Xylenes	Benzo[a]pyrene	Naphthalene	Pyrene
<0.2	<0.0005	<0.001	<0.0005	<0.001	<0.000005	<0.00003	<0.000005
<0.2	<0.0005	<0.001	<0.0005	<0.001	<0.000005	<0.00003	<0.000005

### 7.5 SAMPLING UNDERTAKEN ON 26 NOVEMBER 2003 – DISCHARGE PUMP

The groundwater sample was collected from the lay flat hose leading from the isolated Well No. 4.

TPH	Benzene	Toluene	Ethyl Benzene	Total Xylenes	Benzo[a]pyrene	Naphthalene	Pyrene
<0.2	<0.0005	<0.001	<0.0005	<0.001	<0.0001	<0.0005	<0.0001

### 7.6 SEPARATE PHASE PRODUCT IDENTIFICATION

The two samples of separate phase product that were collected from the sump within the pumping station (sample ref. 'Pump House Sump') and from the first 1,000 L oil interceptor tank (sample ref. 'IC1') had gas chromatograms that were both similar to that of diesel. Incidentally, the gas chromatograms for these two samples are similar to that of the groundwater sample collected from Well No. 4 at the same time.

## 8 PUMPING TEST

On 8 May 2003 a trial pumping test was conducted on the pumping sump to find the optimum constant pumping rate which could be maintained for several hours during an actual pumping test before drawing the water table down to the intake of the sump pump. To determine the optimum pumping rate the pump rate was gradually increased while water levels were measured in two of the nearby groundwater monitoring wells (BH2 and BH4). The trial was conducted over a period of approximately 2 hours and a pumping rate of around 0.5 L/s was found to be the optimum rate.

A pumping test was conducted at the pumping sump, with water level measurements taken at the five monitoring wells (BH1 – BH5), Well No. 4 and the suction tank between 14 May and 18 May 2003. The pumping test was carried out to achieve two purposes:

- 1) to establish the effectiveness and extent of gaining hydraulic control of the shallow groundwater beneath the site by reversing the groundwater gradient towards the sump in the zone of groundwater affected by hydrocarbon residues. This would facilitate control of the petroleum hydrocarbon residues, both in dissolved and separate phase, and would prevent them spreading further from the site and allow the mobile fraction of the hydrocarbons to be drawn back towards the site for accumulation and subsequent recovery over an extended time period.

2) to remove mobile separate phase product and dissolved phase product that was present within the immediate vicinity of the pumping zone.

Several days prior to commencing the test the small submersible pump within the pumping sump was switched off so that the groundwater level within the immediate vicinity could recover to a static level. The three 1,000 L separator tanks were emptied and the contents disposed of at a suitable facility. In addition, the preceding three days to the start of the pumping test and throughout the pumping test were dry with no rainfall occurring in the local area.

In the hour prior to the start of the test the static water level was measured up to five times using an electronic water level probe at the respective monitoring points. Immediately after the test had started water level measurements were collected from the pumping sump, the five monitoring wells, Well No. 4 and the suction tank as quickly as possible (every few minutes) to get as many measurements of the initial drawdown response. Once the pump had been running for approximately one hour the water level measuring frequency reduced to between 5 and 10 minutes and as the test progressed this frequency further reduced to hourly measurements and then two hourly measurements, etc. The pumping test continued for approximately 100 hours before a final water level measurement round was undertaken.

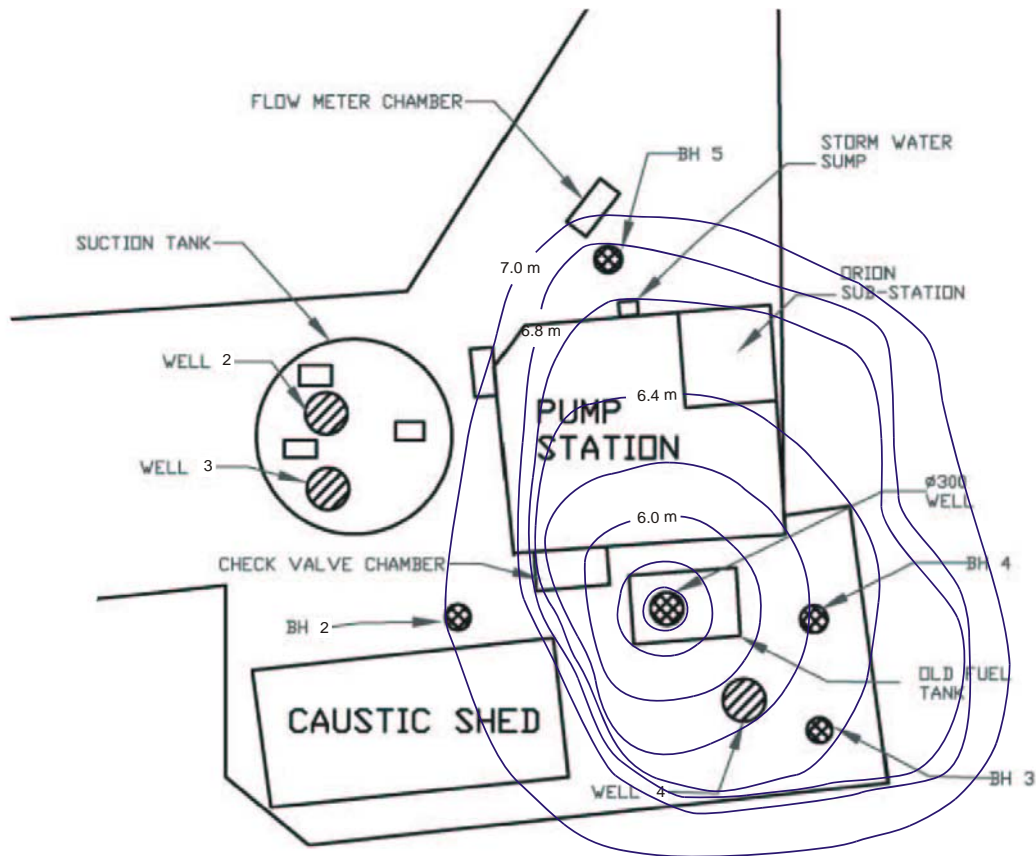
For the first 7.5 hours of the test the submersible pump was run at a relatively constant discharge rate of ~0.5 L/s. During this period the drawdown measured within the pumped well (1.843 m) and monitoring wells BH4 and BH5 (1.025 m and 0.736 m, respectively) was relatively high compared to monitoring wells BH1, BH2 and BH3 (0.01 m, 0.21 m and 0.176 m, respectively). The large drawdown in the pumping sump and well BH4 was due to the relatively permeable nature of the material within the surrounding excavation, whilst well BH5, located on the northern side of the pump house, is expected to be hydraulically connected to the building foundations and the excavation. Monitoring wells BH1, BH2 and BH3 were drilled into natural lower permeability soils and subsequently showed smaller water level draw downs.

After 7.5 hours of relatively constant pumping the water level in the pumping sump was drawn down to the pump intake and as such the pumping rate started to slow down. This is the point at which all of the readily available water in the more permeable backfill of the excavation and foundations had been removed and the pumping rate was now representative of the natural lower permeability soils beneath the site. Approximately 15 minutes after the water level was drawn to the pump intake the flow rate had dropped from 0.5 L/s to around 0.04 L/s. After 24 hours the pump rate had decreased to around 0.016 L/s and at around 100 hours the pump rate had decreased to around 0.014 L/s.

Over the 100 hour pumping test the maximum measured drawdown recorded within the pumping sump was around 1.9 m, which reduced the water table within the sump to the intake on the submersible pump resting at the sump bottom, at around 3.9 m below ground level. All of the monitoring wells showed a drawdown as a consequence of pumping, between 1.035 m (BH4) located 6.75 m to the east and 0.048 m (BH1) located 20 m to the west of the pumping sump. Water level measurements collected from Well No. 4 and the suction tank showed a fluctuating water level over the measuring period.

After conducting the measured pump test over an approximate 100 hour period the pump remained switched on to continue to remove the water/product from the pumping sump whilst maintaining the cone of depression. A final measuring round was undertaken on 19 June 2003 when the pump was turned off. The water level within the pumping sump had reduced a further 16 mm, with further reductions also measured in BH2 (41 mm), BH3 (114 mm) and BH5 (4 mm). The water level within BH1 and BH4 had risen by 4 mm and 87 mm respectively. The water levels in Well No. 4 and the suction tank continued to show fluctuating water levels suggesting that they are not directly hydraulically connected to the surface unconfined water table.

Figure 3: Approximate Groundwater Level Contours After 100 Hours Pumping at Pumping Sump



**Note** – Elevation contours in relation to site datum (10 m at top of manhole of Well No. 4 well head chamber)

Throughout the pumping test the three 1,000 L tanks, in which the water was passed through prior to discharge to the reticulated stormwater system, were checked for the presence of separate phase product. An accumulation of product was noted in the first of the containers with a thickness of up to 8 mm after the 100 hour pumping test. No further accumulation was noted during the final water level monitoring round on 19 June 2003.

## 9 ASSESSMENT OF ENVIRONMENTAL RISK

The remedial works that have been carried out at this site and the associated sampling indicate that the Auburn Ave pumping station can recommence its contribution to the Christchurch City water supply. However, some hydrocarbon residues still remain within the shallow soils and groundwater at the site. This section discusses the risk posed by these residues.

### 9.1 POTENTIAL EXPOSURE PATHWAYS AND RECEPTORS

The main environmental and health issues, associated with petroleum hydrocarbons remaining beneath the site, relate to their potential direct impact upon the reticulated water supply and to a lesser effect to the underlying aquifer that is used for the reticulated supply in the area. A potential risk also exists for workers undertaking any future excavation or maintenance works at the site coming into contact with petroleum hydrocarbon affected soils and/or groundwater.

Exposure to petroleum vapours at the site is not expected to be a significant health issue due to the composition of diesel fuel, which generally has low volatility constituents (compared with products such as motor spirits) and employees only typically spending no more than a few hours working within the pumping station building.

Although the site is not considered to be underlain by a sensitive aquifer as defined by the Ministry for the Environment the groundwater sampling results were compared with New Zealand Tier 1 health based guidelines for a potable supply to provide a conservative assessment (Ministry for the Environment, 1999). In addition, the groundwater sampling results were compared with the MfE guidelines based on the potential health risk associated with the inhalation of petroleum vapour within the pumping station building.

## **9.2 GROUNDWATER SAMPLING ASSESSMENT**

With the exception of the groundwater sample collected from BH5 during the May 2003 round comparison of the groundwater monitoring well sampling results with the MfE Tier 1 drinking water criteria shows acceptable dissolved TPH, BTEX and PAH compound concentrations over the two sampling rounds.

The sample collected from BH5 recorded elevated TPH and benzene concentrations above MfE Tier 1 potable water criteria. The elevated petroleum concentrations detected in the groundwater sample collected from BH5 may be as a result of separate phase product entering the groundwater via the broken stormwater pipe leading from the sump within the pumping station.

The groundwater sample collected from Well No. 4 during the initial April 2003 sampling round also recorded elevated TPH concentrations above the MfE Tier 1 acceptance criteria.

The samples collected in May and July from the suction tank, the discharge pump and the fire hydrant recorded low to non-detectable dissolved petroleum hydrocarbon concentrations, which complied with the MfE Tier 1 drinking water criteria. In addition, the groundwater sample collected on 26 November 2003 from the discharge pipe connected to the isolated Well No. 4 supply recorded non-detectable TPH, BTEX and PAH compounds, following completion of the remedial works.

With regard to the risk of indoor inhalation from dissolved petroleum hydrocarbons, comparison with the MfE Tier 1 guidelines indicate that at the time of sampling acceptable residues were present in groundwater beneath the site and were considered not to pose a significant risk to users of the site or to adjacent residential properties.

## **9.3 UNDERGROUND SERVICES ASSESSMENT**

Due to the natural low permeability shallow soils at the site underground trenches for Telecom, power, stormwater and sewer services may serve as conduits for the accumulation and migration of petroleum residues. In addition, stormwater and sewer lines themselves may act as channels for product accumulation and migration. These services on-site are typically installed to depths of up to 1 m below ground level and are backfilled with gravelly strata. However, based on the measured depth to the water table at around 2.1 m to 2.8 m below ground level at the site these on-site trenches and associated services are unlikely to be significantly affected by any residual petroleum hydrocarbons. In addition, observations made at the monitoring wells installed by PDP at the site have shown no presence of separate phase product or product sheening. Due to the low volatility of diesel the accumulation of vapour within on-site stormwater and sewer lines is also expected to be low.

However, the reticulated water connection pipelines at this site do occur at depths greater than 1 m below ground level. In particular, it appears that the Well No. 4 suction pipeline and its backfilled trench have provided a conduit for floating petroleum hydrocarbons to migrate from the vicinity of the aboveground storage tank fuel line and the pumping station foundation area to Well No. 4.

## **9.4 ECOLOGICAL ASSESSMENT**

No ecologically important plants or habitats were identified on or adjacent to the site. The nearest surface waterway to the site is the Avon River, located approximately 1,000 m north-east of the site, which flows in a general easterly direction. Based on the separation distance to the Avon River it is unlikely to be adversely affected by any dissolved petroleum hydrocarbon residues that may be migrating from the site.

## 9.5 AESTHETIC EFFECT ASSESSMENT

All excavations at the site have been backfilled with clean fill material. Any petroleum hydrocarbon residues that may be present at the site are now buried and would only be of aesthetic concern should further excavations be carried out at the site.

## 10 DISCUSSION

Based on the available information to date it appears that the source of the petroleum hydrocarbon contamination was one, or a combination of, a slow leak from the buried aboveground storage tank fuel line at the site and/or the discharge from the internal sump in the pumping station into a broken stormwater line. Both these sources of petroleum hydrocarbon discharges could have been operating at a low rate over a period of years and led to an accumulation of diesel in the gravel fill material around the pumping station building foundations and the trenches of the suction pipeline. The trench for the suction line to Well No. 4 appears to have provided a permeable pathway for floating separate phase diesel to enter the well head casing. It is likely that the petroleum residues entered the well itself via a faulty flange seal at the well head of Well No. 4. The petroleum residues were able to enter the water supply after the well was put under high demand, drawing dissolved petroleum hydrocarbons in through the dip pipe.

Piezometric levelling undertaken at the site does indicate that a downward hydraulic gradient exists from the water table to the first aquifer from which Well No. 4 abstracts, i.e. the underlying aquifer has a lower pressure than the water table and as such groundwater will tend to move downwards from the shallow water table to the underlying aquifer. The stratigraphic logs of the on-site abstraction wells show low permeability soils to depths of at least 10 m below ground level (10.6 m in the immediate vicinity of Well No. 4) and the water table has been measured within the on-site monitoring wells up to 2.9 m below ground level. Due to the downward hydraulic gradient, dissolved petroleum hydrocarbons could theoretically migrate from the lower permeability surface soils to the underlying gravel aquifer. However, there is no evidence of this occurring to date and the most likely pathway of petroleum hydrocarbons into the well has been via the well head, not the aquifer.

Under the current situation groundwater is abstracted from Well No. 4 via a surface operated pump located within the pumping station. As such, the maximum effective drawdown that can occur within this well would be equivalent to the base of the dip pipe, which is located at a depth of approximately 6.65 m below ground level. Similarly, Well Nos. 2 and 3 free flow into the suction tank which has an operating water level range of around 2 m to 7 m below ground level. As discussed above, the low permeability soils are present to a depth of up to 10.6 m below ground level within the vicinity of Well Nos. 2, 3 and 4. Provided the operating water levels in these three wells remain within the depth range of the near surface silty stratum there should be no mechanism that could allow separate phase petroleum residues to enter the gravel aquifer from which the wells abstract. Similarly, it is unlikely for dissolved phase petroleum hydrocarbons to significantly affect the reticulated water supply based on the screen depths of these three wells and the dilution provided by the surrounding groundwater within the first aquifer.

The risk to Well No. 5 is insignificant since it is screened at a depth of 166 to 172 m within the fifth confined aquifer.

The majority of the petroleum affected soils have been removed together with the removal of the former AST and associated pipework. In addition, mobile separate phase and dissolved phase product were removed from the water table over a period of at least six weeks following the installation of the pumping sump and during the subsequent pump test. All seals along the suction line and within the well head chamber have been replaced and the well head chamber and dip pipe has also been steam cleaned. In addition, the broken stormwater pipework located at the front of the pump station building has been replaced.

A new above ground fuel storage tank has been installed to the rear of the site. All fuel lines are contained within ducts that drain back to the inside of the pumping station building. In the unlikely event, any future leaks can be detected by routine site inspections.

The CCC is instigating a programme of introducing oil interceptors at pumping stations where the likelihood of contamination of stormwater systems and/or groundwater exists. In addition, regular pressure testing of fuel

tanks and associated fuel lines as well as regular well head inspections will be implemented by the CCC to further reduce of the possible reoccurrence of such an incident in the future.

## 11 CONCLUSIONS

Petroleum hydrocarbon residues were noted within the CCC reticulated drinking water system. Subsequent investigations revealed that the fuel line from the on-site aboveground diesel tank was leaking. Another possible source of the hydrocarbons could have been from the sump within the pumping station that contained separate phase product. It is possible that diesel inadvertently entered the sump during engine maintenance works. Usually water present within the sump is pumped to a ground level sump at the front of the building and then is discharged to the reticulated stormwater system. However, this reticulated pipework was noted to be broken thereby allowing a possible migration route to the water table for petroleum residues. The stormwater pipework has since been repaired.

Petroleum hydrocarbons were noted floating on water present within the base of the well head chamber of Well No. 4 and further examination showed that the flange joint at the chamber base was not water tight, thus allowing petroleum residues to enter the well casing and into the water supply. These pathways (leaking fuel line and/or broken stormwater pipe) could have been contributing petroleum residues to the underlying water table over a long period.

A suite of five groundwater monitoring wells were installed to assess the extent of residues in groundwater at the site. Sampling was undertaken at the monitoring wells, the affected supply well (Well No. 4) and from parts of the reticulated discharge system. The results showed that monitoring well BH5 and Well No. 4 had petroleum hydrocarbons above MfE Tier 1 groundwater acceptance criteria for a potable supply.

The results of a pump test showed that it was possible to gain hydraulic control of the separate and dissolved phase hydrocarbons at the site and as a result around 35 L of diesel was recovered during the process.

A downward hydraulic gradient exists from the water table to the first aquifer from which Wells No. 2 to 4 are screened. As such, dissolved petroleum hydrocarbon residues could leak into this aquifer, however, based on the screen depths and the dilution provided by the surrounding groundwater within this aquifer the reticulated water supply is unlikely to be adversely affected by any dissolved residues via this pathway. The pathway for this contamination incident was via the well head of Well No. 4.

A new aboveground fuel storage tank has been installed to the rear of the site. All fuel lines are contained within ducts that drain back to the inside of the pumping station building. In the unlikely event, any future leaks can be detected by routine site inspections.

All seals relating to Well No. 4 and between this well and the pumping station have been replaced and the well head chamber and dip pipe have been steam cleaned and disinfected. The CCC is instigating a programme of introducing oil interceptors at pumping stations where the likelihood of contamination of stormwater systems and/or groundwater exists. Recent sampling of groundwater from Well No. 4 and also from the remaining on-site supply wells has shown non-detectable concentrations of petroleum hydrocarbon concentrations and as such the site has been re-commissioned.

This incident emphasises the need for regular well head security assessments and inspections and demonstrates the ability to remediate petroleum hydrocarbon contaminated sites over relatively short time frames.

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