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SEARLE PLANT, MORPETH

PROGRAMME OF REMEDIAL MEASURES TO REMOVE AND CONTAIN GOUNDWATER CONTAMINANTS IN CHEMICAL PLANT AREA

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MEASURES TO REMOVE AND CONTAIN GROUNDWATER CONTAMINANTS

Institute of Hydrology
Maclean Building
Crowmarsh Gifford
Wallingford
Oxon OX10 8BB
UK

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1. Introduction

1.1 General

A groundwater sampling survey was undertaken during February and April 1987 in the north-eastern area of the Searle Plant at Morpeth [1,2]. Contamination by volatile organic chemicals was identified in a saturated silt layer at about 3 m depth beneath and in the vicinity of Chemical Plants 1 and 2. There was also some evidence of contaminants in the mainly unsaturated foundation fill material beneath Chemical Plants 3 and 4. Leakage from the effluent drainage systems carrying wastewater from each chemical plant is considered to be the cause of the contamination.

The survey suggested that there was no immediate threat to the surrounding area. The extent of the contamination is restricted to the chemical plant area due to the low permeability of the till deposits underlying the site, whilst the depth of the drainage systems in relation to the more permeable parts of the sequence has largely determined the occurrence of contaminants beneath the chemical plants. Figure 1 indicates the inferred area of contamination in the fill material and in the silt layer based on a comparison of the depth of the drainage systems to these parts of the sequence.

The volume of leakage that has taken place cannot be estimated with the information available, although such leakage may have been occurring for up to 15 years in the Chemical Plant 1 and 2 area. The volume of groundwater in storage in the silt layer beneath this area is estimated to about 700 m^3, although about 450 m^3 of this is inferred as being contaminated. It is assumed that contaminants are distributed throughout this smaller volume.

The amount of leakage into the fill material beneath Chemical Plants 3 and 4 from the shallow effluent drain system is considered to be small since a saturated zone does not appear to have developed in the fill. These production plants were also built more recently and hence there has been a shorter time for contaminants to accumulate.

This report presents a programme of work together with details and designs for short and longer-term measures to remove contaminants from the area indicated as being polluted.

1.2 Scope of Work

The measures proposed for consideration in this study were as follows:

<u>Short-term</u>

Pumping from existing boreholes MP8, MP9, MP10, MP11 and MP13.

<u>Long-term</u>

(i) Install a larger diameter well near MP8 and, if required pump from MP9 (or well point near MP9).

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1 Searle Plant, Morpeth. Reconnaissance Survey Interim Results, February 1987

2 Searle Plant, Morpeth. Reconnaissance Survey Report on Phase I, May 1987

(ii) Develop remedial method(s) near boreholes MP10 and MP14 with consideration given to using MP10 or a new larger diameter well near MP10.

The details and designs for these proposed schemes should include recommendations and specifications for

- pumping rates

- whether any benefit would be derived from the early implementation of the short term measures

- whether the short and long term measures should be integrated

- zones of influence and rates of groundwater removal

- types, diameter, depths, screens and caps as applicable

- further recommendations or modifications that might result from undertaking the above

- recommendations for monitoring, including indicator parameters and frequency of sampling.

The scope of work specifically excludes trench drainage in the MP10-MP11 area. However, it would seem appropriate to consider the control of any pollutants not removed by the pump-out measures to provide long-term protection of the areas outside the plant.

The remedial measures are concerned mainly with removing contaminated groundwater from the silt layer in the vicinity of Chemical Plants 1 and 2, since the fill material is unsaturated. There are certain constraints regarding abstraction from this layer including:

• the low permeability of this layer, which has restricted the spread of the contaminants, will only suppport low abstraction rates prolonging the time required to remove the polluted groundwater (unless a larger number of abstraction points are installed)

• the high proportion of silts (about 40%) in the contaminated layer also limits the pumping rate if clogging of the filter is to be avoided or if the water being abstracted is to be free of fines. Under these circumstances, the area of the intake section should be as large as possible to allow water to enter the well under the minimum head change conditions

• the volume of water released by the silt layer will be only a proportion of the volume in storage

• if the layer is not naturally or artificially recharged such that the layer does become dewatered there may be a slight risk of compaction beneath the buildings

• the number of sites in which to locate new wells is limited by services and the buildings themselves.

As far as possible these considerations have been taken into account in the proposed measures and designs.

2. Short term measures

The installation of pumps and level controls in boreholes MP8 to MP11 and MP13 (Figure 1) has been proposed to begin the process of removing contaminants from the chemical plant area. Varying concentrations of VOCs were found at MP8, MP11 and MP13, with traces recorded at MP10. Relevant information on the five boreholes is given in Table 2.1; full details can be found in the survey report of May 1987.

Each borehole was drilled at 200 mm diameter by the cable-percussion method. The lower part of each hole was left uncased and a 50 mm diameter galvanized steel pipe suspended from a well-cap arrangement was installed to monitor water quality and water levels (MP11 has two such pipes). Each pipe has a 0.5 m long tip with about 100 drilled holes of ¼" diameter wrapped in Terram 1000 or 700 grade, unwoven, synthetic filter secured by clips.

Simply pumping from the open drilled holes is very likely to lead to collapse of the hole. Similarly, pumping from the existing piezometer pipes, which were designed for monitoring purposes, has several disadvantages:

- the diameter may be insufficient to install the pump and level sensors
- pumping rates would be very small
- there is a limited sump in which to accumulate any fine material entering the screen

With the exception of MP13 simple recovery tests (Table 2.2) were made during the groundwater quality survey using the piezometer pipes, and a manually-operated vacuum pump arrangement. Pumping rates varied from 0.3 to 1.2 ℓ/min, averaging 0.7 ℓ/min, but in most cases this emptied the piezometer pipe within a few minutes. The volume removed during these tests represents about 6% in all cases of the volume of water in the drilled hole above the base of the piezometer. Some clogging of the Terram filter may have occurrred but it seems more likely that the small open area of the piezometer tip (3%) was further reduced by placing the Terram flush against the perforations. Whilst this is suitable for monitoring purposes the volume that can be removed by pumping from the existing piezometer designs is about 0.35 m^3/d (Tables 2.3 and 2.4).

Altering the Terram arrangement by using an inner layer to keep the Terram clear of the perforated section would improve the yield. However it would also be preferable to increase the open area as well. We propose, therefore, that the existing piezometer pipes are removed from MP8-MP11 and MP13 and replaced with 100 mm diameter PVC, prefabricated perforated pipe with at least 10% open area and incorporating a sump. The screen should be wrapped with an unwoven synthetic filter comprising three layers:

- inner layer to keep the unwoven fabric from contact with the perforations
- a middle layer of Terram 1000
- an outer protective mesh.

Basic costs for the screen and casing materials for this proposal would total approximately £500 for the five boreholes.

Suggested preliminary designs are given in Figure 2 with basic design data presented in Table 2.5. Figure 3 gives details of the well head construction. The final design may depend on the lengths of materials available from the manufacturers, but we would recommend that the manufacturer be asked to pre-assemble the casing and screen. The annulus should be back filled with a clean medium grained sand to support the formation.

The low pumping rates of the existing 2" diameter pipes are considered to be due, in part, to the small open area of the screen. The proposed design of the replacement 4" diameter pipe will provide a greater open area allowing higher pumping rates. Whilst this will provide better hydraulic connection with the well annulus, inflow will depend on the transmissivity of the silt layer and the head gradient induced by pumping: the permeability of this layer is low and the available drawdowns are very limited. Some 'trial-and-error' will be required to establish the pumping rates, but, in the meantime, we have assumed a rate of 0.3 ℓ/min per well. Screen entrance velocity criteria are exceeded at this rate and will cause some additional head losses.

Because of the low permeability of the silt and the small available drawdowns a discontinuous pumping regime will be needed. The extent of the cone(s) of influence cannot be estimated with such a regime; however, using the recovery data and a pump rate of 0.3ℓ/min for each well we have calculated that at least 2 m^3 of groundwater should be removed each day. However we feel that this figure could be an overestimate but it is based on the best available data that we have at present.

Table 2.1

Short Term Measures : Summary of present construction details of MP8 to MP11, MP13 (m. bgl)

Well number	Total Depth (m)	200 mm casing	50 mm screen	Rest water level	Top of silt layer	Base of silt layer
MP8	3.9	0~2.3	3.15~3.65	2.8	3.0	(3.9)
MP9	4.6	0~1.7	3.15~3.65	2.7	2.3	(4.0)
MP10	5.4	0~1.7	4.4~4.9	3.9	4.6	(4.9)
MP11	4.0	0~1.75	1.7~2.3 } 2.9~3.4 }	1.3	1.5	3.4
MP13	3.6	0~1.7	2.4~2.9	1.5	1.9	2.7

Table 2.2

Recovery Test Summary

Well	Pumping rate used for recovery test (ℓ/min)	Drawdown 1 min after end of pumping (m)	Remaining available drawdown to top of screen after 1 min recovery (m)	Time taken to recover to within 0.1 m of rest water level (mins)
MP8	0.57	0.86	Nil	60
MP9	0.67	0.078	0.37	21
MP10	0.30	1.03	0.21	300
MP11	1.20	0.28	1.32	c.90
MP13	Not tested			

Table 2.3

Operating Conditions

Well	Rest water level April 1987 (m. bgl)	Pump cut-in level[1] (m. bgl)	Pump cut-out level [2] (m. bgl)
MP8	2.8	2.9	3.1
MP9	2.7	2.8	3.1
MP10	3.9	4.0	4.4
MP11	1.3	1.4	2.9
MP13	1.5	1.6	2.4

(1) Taken as 0.1 m below April 1987 rest water level. This may require adjustment for summer conditions or as dewatering occurs.

(2) Taken as approximately top of present piezometer screen position assuming pump intake is placed within screen.

Table 2.4

Pumping volumes[1] without modified design

Well	Volume in 2" pipe between cut-out levels[2] (ℓ)	Pumping duration (mins)	Non-pumping (mins)	Volume removed in 24 hours (ℓ)
MP8	0.4	1.5	≅ 30	≅ 20
MP9	0.6	2.0	≅ 2	≅ 200
MP10	0.8	≅ 2.5	≅ 150	≅ 10
MP11	3.0	10.0	45	100
MP13	1.6	≅ 5.5	(6)[3]	(≅ 20)[3]
				350

(1) Rate taken as 0.3 ℓ/min based on MP10 recovery test. Existing piezometer pipes. Same pumping rate at each well without any improvements due to modified or new designs

(2) 2ℓ per metre of pipe

(3) Assumed figures. No test information for this site

Table 2.5

Short Term Measures : Proposed construction details for modified design

Well	Depth to top of screen (m bgl)	Length of screen (m)	Length of sump (m)
MP8	3.1	0.5	0.3
MP9	3.0	1.0	0.6
MP10	4.6	0.5	0.3
MP11	1.5	2.1	0.4
MP13	1.9	1.0	0.7

3. Longer Term Measures

Since steps have already been taken to prevent any further leakage from the effluent drains, the immediate abstraction measures will begin the process of removing groundwater that has already been contaminated beneath the chemical plants. The longer term measures are intended to provide a better means of removing the contaminants and preventing any spread of the contaminated groundwater. As such they should be considered as supplementing the short-term measures by accelerating the removal of contaminants. The availability of suitable new sites for abstraction, however, particularly using well point systems or trenches, is rather restricted within the area of the chemical plants.

The limited available drawdown and low permeability of the silt layer sequence limit the use of single well points. Large diameter wells and trenches overcome this to some extent by allowing a larger seepage face for inflow from the silt layer whilst avoiding excessive drawdowns. Trenches, however, have been excluded as an option in the chemical plant area to intercept groundwater flow moving north-eastwards from the contaminated area.

We propose the following scheme for the long-term measures:

(i) Abstraction to continue from MP11, MP8 and MP13 within the contaminated area so as to continue the process of direct abstraction from the area.

(ii) Abstraction to continue from MP10, where only trace levels of contaminants have been found in the silt layer.

(iii) Construction of a large diameter well about midway between MP8 and MP14 close to the effluent drain.. A well in this location should prevent the escape of contaminants, from the MP8 area, between MP10 and MP9.

(iv) Replace MP9 by a second large diameter well to provide a more effective means of containing and removing contaminants from the area of Chemical Plant 2.

As part of the longer term measures we propose that a large diameter well is constructed close to MP9.

It will obviously not be worthwhile modifying the existing construction of MP9 if the proposed long-term measures are to be implemented either at the same time as or relatively quickly after the short-term measures.

A suggested design for the large diameter wells is shown in Figure 3 with the design data given in Table 3.1. These could be constructed by auger to a minimum diameter of 1.5 m. The artificial fill is sealed off by the upper casing. An overdrill to about 0.5 m into the grey clay will allow the silt layer to be dewatered to a greater extent. Assuming that the silt layer is about 0.9 m thick the well intake area is 4.2 m^2 (about 7.5 times that of the existing 200 mm diameter boreholes) and the volume of the well below water level, including the sump, is about 1.6 m^3. The maximum natural seepage rate into a well of this diameter is estimated to be not more than 2 ℓ/min. However, a pumping rate of 0.6 ℓ/min is recommended for continuous pumping, which should produce a cone of depression with a radius of about 30 m (transmissivity of 0.65 m^2/d, specific yield of 3% and time of 7 days). The pumping would be controlled by means of sensors.

The rising main should be suspended above the base of the well in case any fine material enters the well. However for maximum versatility it should be possible to lower the rising main to the bottom of the well. The grey clay should be sealed to prevent any contamination from having access to greater depth. The annulus of the hole should be back filled with a clean medium sand to support the sides of the hole.

Table 3.1

Longer Term Measures: Proposed construction details

Well	Depth of 3 m casing (mbgl)	Depth of screen (mbgl)	Total depth (mbgl)
MP15[1]	2.7	3.0 - 3.9	4.4
MP16[2]	2.2	3.3 - 4.3	4.8

[1] located between MP8 and MP14

[2] located close to MP9

The actual design of MP15 will depend on the actual depths to the base of of the fill and the depth of the silt layer.

4. Discussion

The contaminants that were measured during the reconnaissance survey should continue to be monitored on a regular basis during pumping. It is only necessary to measure the volatile organic compounds present in the discharge water. The first sample from each borehole, taken after half a days pumping to ensure that the water is representative of the silt layer, should be fully analysed to check whether there are any suitable marker chemical present in addition to methanol, acetone and tetra-hydrofuran (THF). If additional suitable VOCs are found then they should be included in the routine analysis.

The sampling and analysis should take place at weekly intervals but if after several weeks the results show little variation than the sampling interval can be increased to once a month. In addition to sampling the pumping boreholes samples should be taken for analysis at boreholes MP2 to MP7 at three monthly intervals. This is to check that no contamination has left the chemical plant area before remedial measures can be instigated. The depth of the water in each well should be measured at the same time as sampling.

Because of the uncertainties of the properties of the silt layer coupled with the small available drawdowns in the wells we consider that it will not be possible to operate a continuous pumping regime. It must be stressed that the calculations we have performed assume that the pumping rate is continuous and as such the abstraction rates could be optimistic. As these uncertainties exist the final pumping rates, together with the exact levels of the pump control sensors, must result from a period of 'trial and error'.

From the gradient of the groundwater surface and our estimate of transmissivity of the silt it is possible to calculate that there is a recharge of about 1 m^3/day into the chemical plant area. The effect of this recharge will be to maintain a flow into the wells for a longer period and also to slowly replace the water held in the formation and so flush out the remaining contamination.

The low permeability of the silt layer could mean that there may be local dewatering of the silt around the short term measure wells which could result in the complete interception of the contamination. Because of this we regard the large diameter wells of the long term measures to act as safety nets.

We recommend that the longer term measures should include the continued pumping of wells MP8, MP10-11 and MP13 in addition to the two large diameter wells. The only way of making sure that no contaminated groundwater leaves the site is to construct trenches along the eastern and northern sides which fully intercept the silt layer but we aware of the practical problems such a scheme would entail.