REINJECTION OF CONSTRUCTION DEWATERING WATER AT THE UNIVERSITY OF CANTERBURY

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ABSTRACT

The University of Canterbury is situated above a shallow semi-confined aquifer. Dewatering is required during construction of the basements of multi-storey buildings. Previously, dewatered water has been discharged to local waterways.

During the recent construction of the Biosciences building, concerns raised during the resource consent process meant it was not practicable to discharge all dewatering water to the local Okeover Stream. Alternative options evaluated included reinjecting the dewatering water to ground. The shallow aquifer is high yielding, which is a challenge for site dewatering due to the high pumping rates required, but also means reinjection can occur without raising groundwater levels excessively.

The results from testing of a trial bore indicated reinjection was feasible. Groundwater modelling was carried out to estimate where additional reinjection bores could be placed to minimise the mounding and the impact on the dewatering system.

Eight additional bores were drilled, tested and connected into a pipe network from the excavation site. The reinjection was successfully completed over the 6 month dewatering period while maintaining groundwater levels below ground level and minimising interference.

This paper discusses the investigations and the reinjection system, and illustrates the effectiveness of this solution through groundwater level monitoring data collected during construction.

KEYWORDS

Site Dewatering, Reinjection Bores, Aquifer Testing, Groundwater Modelling

1 INTRODUCTION

Dewatered groundwater from a construction site is usually discharged into a surface waterway or a stormwater sewer.

Groundwater levels at the University of Canterbury’s Ilam campus are shallow, which means that for construction of buildings which require basements, it is necessary to dewater the site to allow the basement, plus sufficient building structure, to be completed so that the building does not uplift out of the ground due to the groundwater pressure. Previously the University of Canterbury has used the option of discharging to one of the local waterways.

The University began construction of a new building to accommodate the Biosciences Department in 2008. The building included a basement and a lift shaft. The planned final floor elevation of the basement was 2.6 metres below ground level (mbgl) and the construction process involved working to a depth of 3.2 mbgl for the footings. Due to the shallow water table (between 0.9 and 2.2 mbgl), dewatering was required to reduce the water table elevation by between 1 and 2.3 m. The construction of the lift shaft required depression of groundwater levels to 5 mbgl for a period of around 48 hours.

The nearest surface waterways are the Okeover Stream and the Avon River. Both the Okeover and the Avon receive inflows from surface runoff during rainfall, groundwater recharge when the groundwater pressure is sufficiently high and discharges associated with activities at the University such as cooling water discharges.

The University applied for a consent to discharge all dewatering water into the Okeover at a rate of up to 300 L/s, based on preliminary estimates of the required dewatering rate.

During the processing of the application, some concerns were raised over the potential for the discharge to increase water levels in the Okeover downstream of the University during high rainfall events, and to result in flooding of neighbouring properties and increased risk of erosion. It would not have been possible to stop dewatering for several days during high flows in the Okeover, as inundation of the working area had the potential to result in irreversible damage to the building. To address these concerns, consideration was given to other discharge options. As a stormwater sewer was not available, the alternative of reinjecting the water into the same shallow aquifer from which it was abstracted was explored. It was proposed that this could either compliment the surface water discharge during high flows or be a stand alone method of discharge.

This paper describes the testing, analysis and subsequent assessments that were undertaken to determine the feasibility of discharging the dewatering water into a number of injection bores located several hundred metres to the south-east of the building site.

Figure 1: Location of Biosciences building and surface waterways at the University of Canterbury

Photograph 1: Okeover Stream

2 HYDROGEOLOGY

The first stage in the investigation to confirm the feasibility of the reinjection involved reviewing bore logs in the local area. This review indicated that a shallow aquifer exists beneath the site within a 5-10 m thick layer of permeable gravels and sandy gravels. This layer is overlain by 2-4 m of fine grained sediments that provide a low permeability cap over the shallow gravel aquifer. The bore logs also indicated the presence of low permeability sediments at the base of the permeable gravel layer. These sediments are expected to separate the shallow aquifer from the deeper aquifer, commonly referred to as Aquifer 1, that exists in the Riccarton Gravels. The bore logs indicate that in places there may be permeable gravel deposits that lie between this shallow aquifer and the deeper Riccarton gravels. The bore log information was used to define a target depth for a trial injection bore of between 7-14 m deep.

3 GROUNDWATER INVESTIGATIONS AND ANALYSIS

3.1 STEP INJECTION TEST AND CONSTANT RATE INJECTION TEST

The trial injection bore was drilled to a depth of 13 mbgl, with a 6 m screen extending from 7 m to 13 mbgl. Two observation bores were installed at 5 m and 15 m from the injection bore. These bores are screened between 8 m and 10 mbgl.

The first test carried out on the injection bore was a step injection test, the purpose of which was to determine a sustainable injection rate for the bore for a subsequent constant rate injection test. The step test involved injecting water into the bore at successively increasing injection rates. It was anticipated that as the rate of injection increased with each step, the water level in the bore would increase. However, an interesting phenomenon was observed whereby the water level during the third and fourth steps actually dropped lower than the static water level in the bore prior to testing.

Because of the unusual response, the step test could not be analysed with any standard analysis method. However, the minimal change in water levels in the injection bore during the test did demonstrate that the shallow aquifer is very permeable and suggested that it would be capable of receiving much higher rates of injection, without creating any significant mounding effects. The step test indicated that a 48 hour constant rate injection test could easily be carried out at an injection rate of 18 L/s.

Manual measurements of water levels in the two observation bores were also taken over the course of the step test. The small increases in water levels (<150 mm) observed in the observation bores were analysed using analytical drawdown solutions and the principle of superposition to account for the changes in the injection rate. The results were used to assess the likely changes during the constant rate test.

During the subsequent 48 hour constant rate injection test, the injection rate was generally maintained between 18 and 19 L/s.

The manually and automatically recorded drawdowns displayed a characteristic semi-confined aquifer response when plotted against time (semi-log scale), as expected from the background hydrogeological review, and confirmed that the Boulton (1973) solution was appropriate for the analysis. No observable effect on the interaction between groundwater and the Okeover or any other surface waterway was discernable in the water level data. Some background fluctuations in the water levels occurred, partly due to some fluctuations in the pumping rate and also as a result of pumping of other bores at the University.

Figures 2 and 3 show the measured and calculated drawdowns. The two parameter sets that resulted in the minimum and maximum predicted water level changes for longer term pumping are shown in Table 1. The storage coefficients obtained in the analysis are higher than expected for a semi-confined aquifer but had little bearing on the modelled scenarios.

Predictions made using the test results indicated that a sustainable injection rate as high as 50 L/s may be possible in the injection bore and similar injection rates could be expected in new injection bores intercepting the same strata and constructed in a similar way.

Table 1: Parameter sets resulting in maximum and minimum predicted water level changes

Scenario	**Bore**	**Transmissivity (T) (m^2/day)**	**Storage coefficient (S)**	**Aquitard conductance K'/B' (1/day)**	**Specific yield of material at water table (σ)**
Parameter set resulting in minimum predicted water level changes	5 m bore	4000	0.01	5	0.25
Parameter set resulting in maximum predicted water level changes	15 m bore	2500	0.005	1.4	0.25

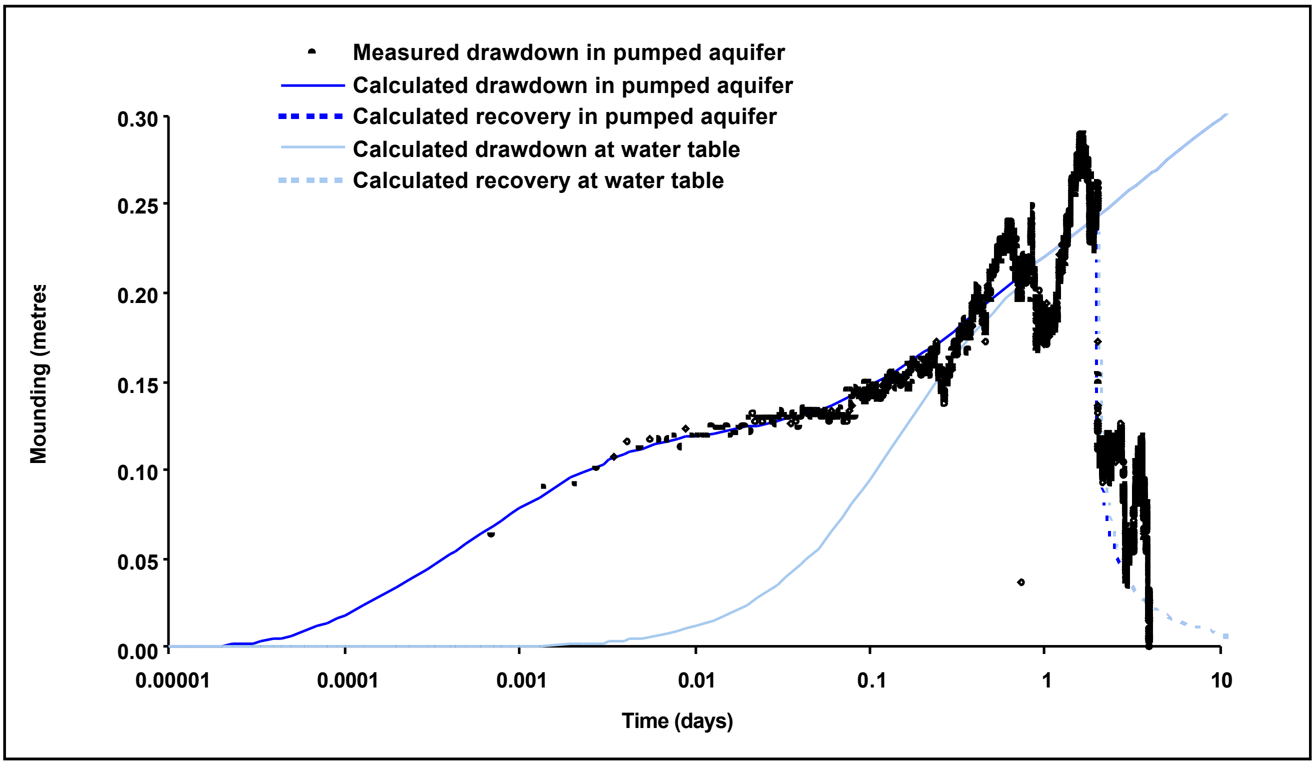

Figure 2: Measured and calculated drawdown in observation bore 5 m from injection bore

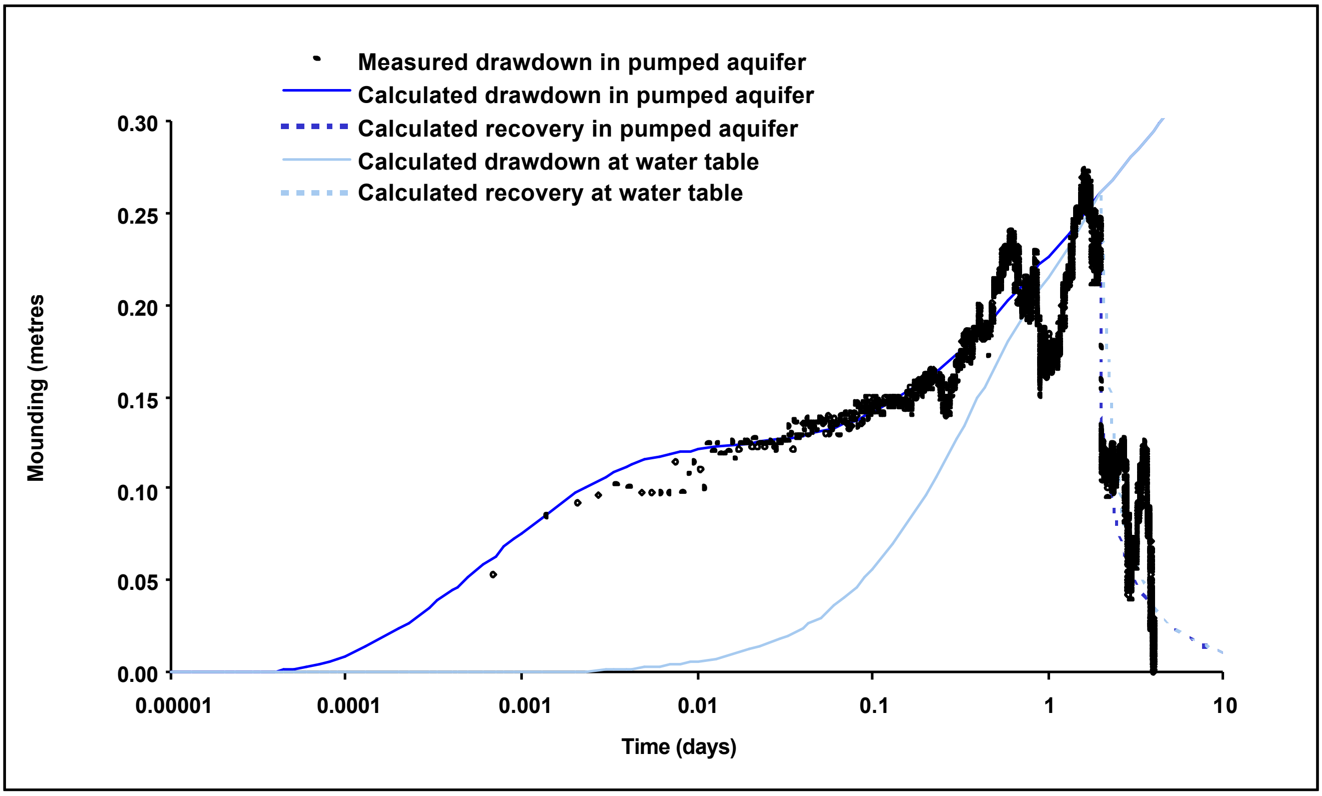

Figure 3: Measured and calculated drawdown in observation bore 15 m from injection bore

4 GROUNDWATER MODELLING

Modelling was carried out to assess the potential changes in groundwater levels for scenarios where the water abstracted from the dewatering area was reinjected into a number of bores. Iterative modelling was carried out to determine the required number of, and ideal locations for, the bores subject to constraints such as existing buildings and underground services.

It was important to carry out the modelling in a conservative manner as, if the reinjection system caused ground levels to rise higher than expected or even to ground level, it could have resulted in surface flooding, flooding of basements and damage to underground services and paved surfaces.

A number of different scenarios were modelled. Using the parameter set that resulted in the maximum predicted water level changes provided a conservative prediction of the increase in water levels around the injection bores. It was acknowledged that, while no interaction with surface waterways was observable over the 48 hour injection test, some interaction could occur with longer reinjection. It is expected that groundwater emerges in the Okeover Stream when groundwater levels are sufficiently high. However, by not accounting for any interaction, the predicted changes in groundwater levels would be conservatively high.

The available depth for mounding to occur was set based on the highest water level recorded in a 6.5 m deep bore with regular water level measurements available over a 5 year period, although it was recognised that there would be localised differences in the depth to groundwater across the site.

The modelling was carried out using the Boulton (1973) solution and the principle of well superposition to model reinjection into multiple bores.

Three scenarios were modelled with the set of parameters that predicted the maximum mounding. These were as follows:

1. Long-term reinjection of the dewatered water into groundwater at 200 L/s for 6 months. This value of 200 L/s was chosen as it represented the likely average rate of dewatering. This option represented the situation of reinjecting all dewatering water during construction.

2. Short-term reinjection of the dewatered water into groundwater at 300 L/s for 5 days. This scenario represented the situation that could occur if, during construction of the lift shaft (greatest drawdown required), the discharge to the Okeover was restricted.

3. Short-term reinjection of the dewatered water into groundwater at 200 L/s for 2 days. This option represented the situation of the dewatering water being continually discharged to the Okeover Stream except for when the Okeover was above a certain stage height. During these times of restrictions the dewatering water would be reinjected into the aquifer. For this modelling, it was assumed that dewatering at the building site had been taking place prior to reinjection occurring. This was to incorporate the background drawdown caused by the dewatering that could be expected to exist prior to the short-term reinjection of the water.

The modelling indicated that the reinjection could be managed via the number and location of injection bores to ensure that aquifer pressures remained below ground level for both the short-term and long-term scenarios. It was identified that some variation in the injection rates between bores could be made to minimise the mounding. Figure 4 is an example of the model output. This shows the predicted drawdown around the construction site and mounding around the reinjection bores after 6 months of continuous dewatering and reinjection at a rate of 200 L/s, using the parameter set that resulted in the maximum change in groundwater levels.

While the level of mounding was shown to be acceptable, the modelling did indicate that the reinjection of water could create some interference with the dewatering by causing a mounding effect in the construction area.

Given the potential for the reinjection of dewatered water to result in a rise in groundwater levels in the dewatering area, further modelling was carried out using the set of parameters that resulted in the minimum change in groundwater levels in the excavation area. The purpose of this was to assess the minimum drawdown that could be achieved at the proposed dewatering rates. A dewatering system must achieve a sufficiently large drawdown in the excavation area. Using the set of parameters with a higher aquifer transmissivity provided the minimum change in groundwater level that could occur at the proposed dewatering rates, which is the worse case scenario for the dewatering process.

This modelling indicated that the proposed dewatering rates could depress groundwater levels to the required level, even with reinjection of the water occurring. Because of the potential for interference between the reinjection and the dewatering, the reinjection was considered more suitable for short term durations to minimise pumping costs, for example when discharge to the Okeover Stream was not possible due to high flows. However, the modelling indicated that both short-term and long-term reinjection was feasible.

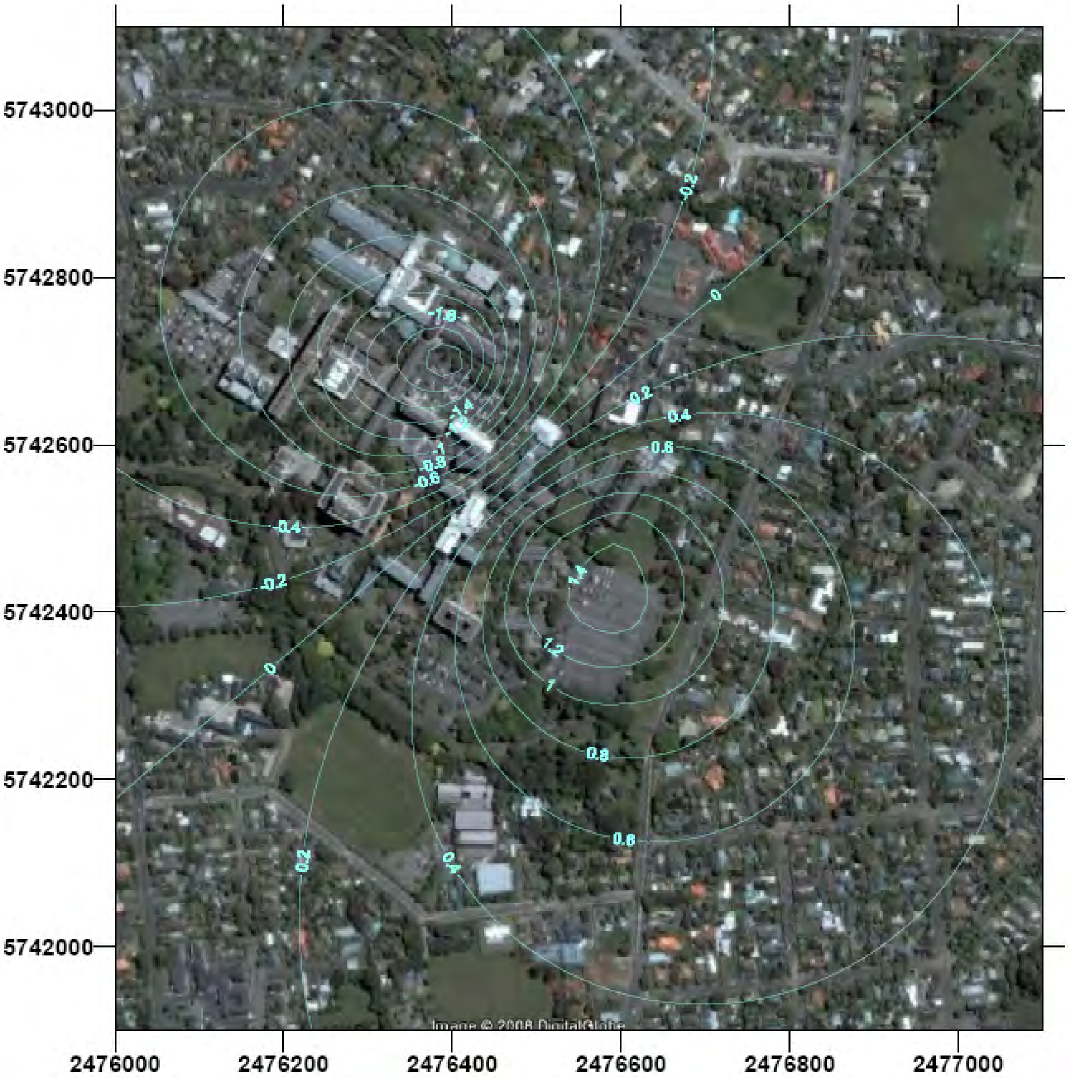

Figure 4: Drawdown at 6 months and 200 l/s continuous dewatering and reinjection using parameter set that resulted in maximum change in groundwater levels

5 RESOURCE CONSENTS

On the basis of the modelling results, bore permits were sought for a total of eight additional bores at the optimum locations determined through the modelling. Concurrently, consent applications were lodged for further testing of the bores and to discharge the dewatering water to the reinjection bores upon completion of the testing.

Consents were granted non-notified and the additional bores were drilled, tested and connected into a pipe network from the excavation site. A schematic of the scheme is shown in Figure 6. Also shown on Figure 6 are the locations of the six extraction bores for the dewatering located on the perimeter of the excavation site.

Consent conditions on the consent to reinject the dewatering water included the following requirements:

- Maximum discharge rate not to exceed rate of dewatering
- Maximum duration of 1 year
- Reinjection to reduce or cease if groundwater levels rise to within 0.5 mbgl on campus (measured at two piezometers)

The consent application to discharge to the Okeover proceeded to a hearing, and was subsequently granted. Consent conditions on the Okeover Stream discharge consent included the following requirements:

- Maximum discharge of 300 L/s for a maximum of one week during the lift shaft construction
- Maximum discharge of 200 L/s at all other times
- Minimum specified freeboard during dry weather (specified at particular property)
- Discharge to cease when water level exceeds set RL (specified at particular property)
- Maximum duration of 6 months

With the restrictions on the consent to discharge to the Okeover, it was necessary to have the reinjection system in place for periods of high flow in the Okeover.

6 RESULTS FROM THE DEWATERING PERIOD

Reinjection of the dewatering water was successfully completed during construction of the basement, the lift shaft and the first storey. The reinjection system proved to be a necessity as the dewatering rate required to allow construction was 275 L/s, while the consent to discharge to the stream only permitted 200 L/s. In addition, there was one day when restrictions were in place on the Okeover discharge consent, which meant all water had to be discharged to the reinjection system during this time to ensure that the construction site was not inundated.

Figure 5 shows the groundwater levels in two piezometers monitored on site over the dewatering period. Also plotted on this graph is the combined injection rate (total discharge flow rate across all reinjection bores) and the combined abstraction rate (total abstraction flow rate across all abstraction bores). The difference between these two lines represents the rate of discharge to the Okeover. Discharge to the Okeover commenced on 8 September 2008 and ceased on 29 January 2010. The peak abstraction rate was 280 L/s. The peak rate of discharge to the reinjection system was 233 L/s.

The Okeover stream stage is also plotted on Figure 5. There is a small increase in stream stage over the period where dewatering water was being discharged to the stream and subsequent decrease at the end of this period.

The groundwater level data for the piezometers in Figure 5 shows that the levels remained below the required 0.5 metre below ground level over the course of the reinjection. A decreasing trend can be seen in the water levels. This is likely to be a combination of a natural decline due to decreasing aquifer recharge over the summer months, and the net abstraction from the aquifer. More water was being abstracted from the dewatering bores than being discharged to the reinjection bores, with the difference being the discharge to the Okeover Stream.

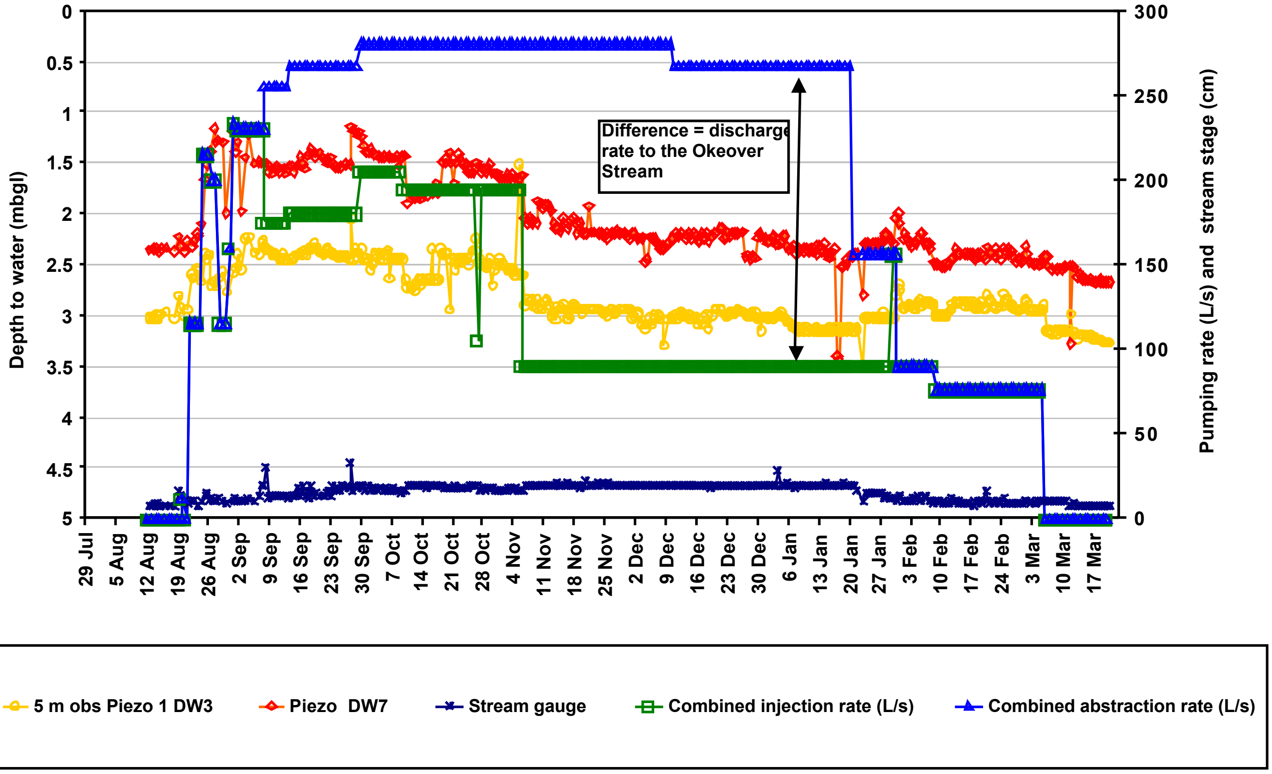

Figure 5: Monitoring results

7 CONCLUSIONS

The reinjection system was a successful solution to discharge the dewatering water that could not be discharged to the Okeover Stream.

The aquifer testing proved that the reinjection was feasible. It also provided critical information on the aquifer properties, which was required to determine the layout of the reinjection system through the groundwater modelling.

The groundwater modelling was a fundamental part of the design process. This ensured that the appropriate number of bores were installed at the optimal locations to prevent raising groundwater levels excessively. The modelling also minimised the costs of the bore installation and pipework by determining the critical number of bores required and the minimum spacing.

This project demonstrated that, with appropriate investigations and analysis, the reinjection of dewatering water can be a feasible alternative to surface water discharges.

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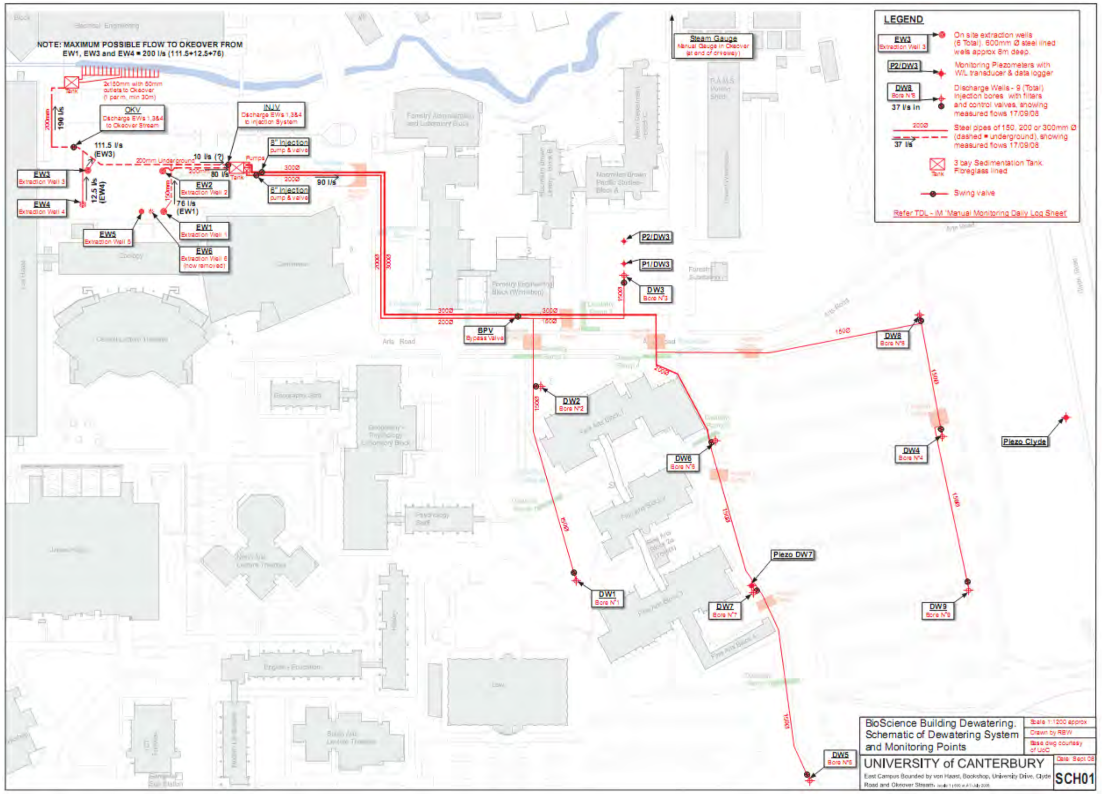

Figure 6: Abstraction and reinjection system