LESSONS LEARNT FROM DEWATERING CHALLENGES IN CHRISTCHURCH

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ABSTRACT

Foundation and infrastructure construction in Christchurch often involves groundwater management which is executed as dewatering. By virtue of these works being temporary the design responsibility often falls to the contractor, and on many occasions for smaller projects dewatering systems are specified and installed without input from experienced engineers or personnel, and without close oversight from designers. This practice evolved due to the varying plant and equipment that contractors have available, and uncertainties involved in specifying dewatering systems. Depending on the chosen dewatering method and the quality of installation and operation, dewatering can pose significant risks to the surrounding buildings and infrastructure.

This paper outlines typical dewatering methods for horizontal and vertical infrastructure construction in Christchurch. Based on the author's experience as a designer and while undertaking construction observations the common issues with dewatering will be discussed through two case studies, where improper dewatering installation led to ground subsidence and instability, and caused significant damage to adjacent infrastructure.

A review of each case study indicated that each share common organisational contributions and construction issues, which in turn have led to the poor performance. The paper will specifically discuss the timing of the dewatering drawdown period and the knowledge and background of the persons typically responsible for dewatering. Lessons learned are drawn for engineers designing and supervising projects involving dewatering. These lessons include appropriate limitations on dewatering for specifications, and the key stages of dewatering setup where site supervision is required.

1 INTRODUCTION

The science and engineering aspects of dewatering are well understood, and detailed guidance is available on suitable dewatering methods for Christchurch soils, such as the Christchurch City Council (CCC) Dewatering Guidelines. However, for smaller projects the specification and installation of dewatering is often not undertaken by engineering professionals and is the responsibility of the contractor. Depending on the size and experience of the contractor, they may not be sufficiently knowledgeable to identify suitable dewatering methods, or to troubleshoot these methods if they are found to be inadequate.

This paper will outline the key methods of dewatering in Christchurch soils. Two project examples are then presented where errors in dewatering construction led to significant delays and damage to adjacent infrastructure and the environment, resulting in cost implications for the subcontractors involved. Common aspects of these two examples are discussed, and then recommendations are made for the supervision of projects involving dewatering.

2 DEWATERING METHODS

Christchurch is a low-lying, coastal city which geologically comprises alluvial outwash sediments, dune deposits, and estuarine or swamp deposits (Brown and Weeber (1992)). Ground conditions can comprise gravel, silts, sands and organic soils, and groundwater levels are typically shallow, at 0.5m to 3m depth throughout the city. Due to the geological setting, the groundwater regime can be complex comprising sub-artesian and flowing artesian conditions, with numerous springs. Groundwater management can be further complicated due to highly variable soil permeability and groundwater flow rates. Low plasticity silts and fine sands are also common and are prone to piping, and gravel layers can have highly varying groundwater flow rates if lenses of clean gravel or underground streams are encountered.

Suitable dewatering methods have been developed for Christchurch soil conditions by local contractors through extensive historical, often bitter, experience. Dewatering methods typically used for infrastructure projects and their suitability can be broadly characterised as follows.

2.1 SUMP PUMPING

Pumping directly from a sump within or adjacent to the excavation, where water enters the excavation and flows on the base of the excavation or through a drainage layer to the sump. This can be effective where a minimal drawdown is required in gravel, or where cohesive soils are present. This method is generally unsuitable in soils prone to piping, or where a dewatering drawdown of more that 1m is required, particularly if the excavation will be open for a significant period of time.

2.2 WELL POINTING

A vacuum pump and header pipe is connected to closely spaced well points or dewatering ‘spears’ which may be driven, augered or jetted into the ground depending on the soil conditions. The spears typically have a slotted filter at the intake and can be installed with a surrounding filter material of sand or fine gravel, although in clean sand a surrounding filter medium is not always required. The filter medium can be installed around jetted wells by using the jetting process to create a void at the base of the well, then reducing the flow rate to just maintain an annulus around the well. Filter material is then added around the well at the ground surface where it can settle to the base of the well. Well pointing is most effective in clean sands, or in silty sand with appropriate filter mediums surrounding the wells, and may achieve a drawdown of 4-5m if installed effectively and with close horizontal spacings.

2.3 WELLS

Isolated wells are drilled or driven into the ground and water is abstracted either with a vacuum pump, or with submersible pumps. Wells are typically installed with a large spacing between wells and to a greater depth than well points, and therefore require a high flow rate to achieve a similar groundwater drawdown. Where these are drilled, they can be installed with a surrounding filter medium. Isolated wells can be effective in permeable soils where a high flow rate to the well can be achieved, or where a layer of higher permeability in the soil strata can be targeted, such as a band of gravel.

It is common to install wells by driving a steel circular hollow section using a hydraulic breaker attachment on an excavator. Because this is a driven tube, it is not possible to install a filter medium around the well, and the wells typically have gas-cut slots to enable high water flow rates. These wells rely on the surrounding gravel self-filtering, once fines are extracted from close to the well. Once these wells are driven it is typical to develop the wells using compressed air at the base of the well to expel water and sediment from the surrounding gravels, before water is pumped from the well.

Common pitfalls with these dewatering methods are highlighted with two case studies of dewatering in Christchurch

3 CASE STUDY – DEEP SEWER INSTALLATION

This case study involved a sewer installation to a typical invert depth of 2.5 to 3.5m corresponding to a trench depth of up to approximately 3.0 to 4.0m, with the contractor relying on trench shields to safely excavate to this depth. The ground conditions comprised firm silt overlying silty sand and sand with a water table depth of approximately 1.0m as shown in Figure 1, although no ground investigations were undertaken prior to the contractor establishing on site.

The dewatering installation was attempted three times before a successful dewatering setup enabled efficient construction. Each attempt is described, with resulting observations and an interpretation of the mechanisms resulting in the performance of each setup.

3.1 FIRST DEWATERING ATTEMPT: WELL POINTING

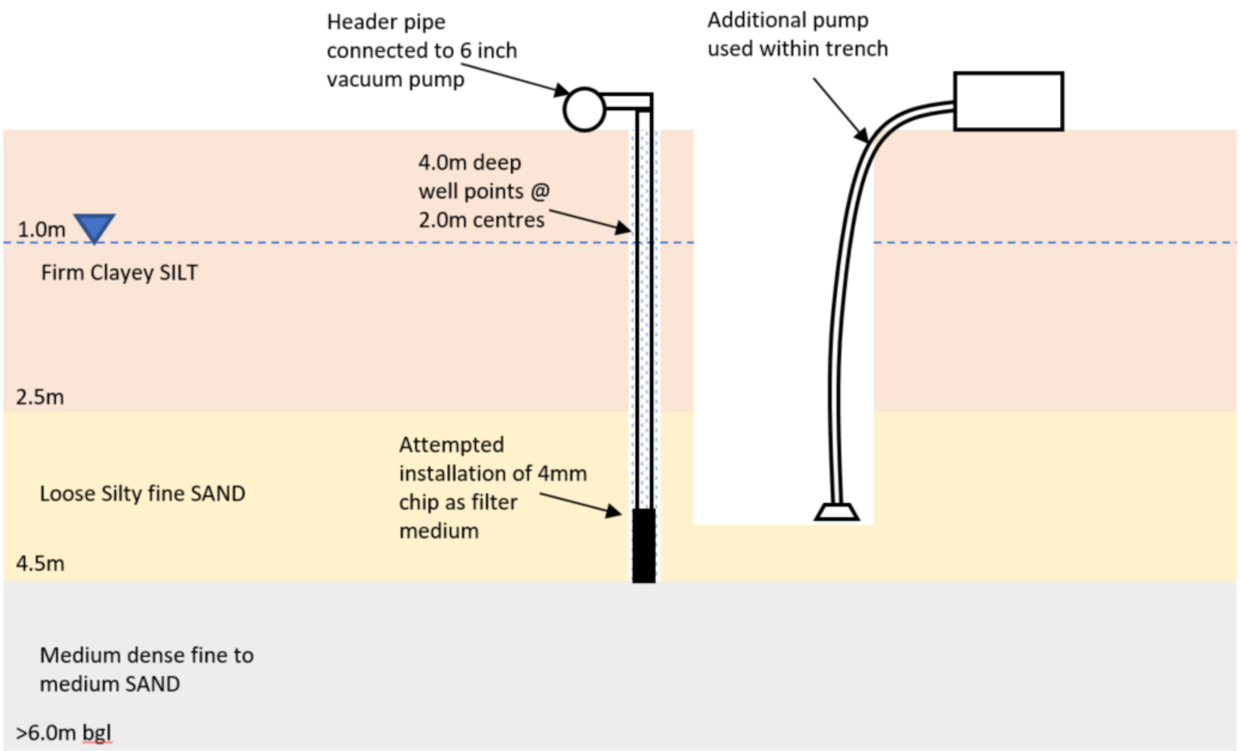

Figure 1: Dewatering with well-points

The contractor initially attempted dewatering through establishment of 4m deep well points, which were installed at 2m centres. The well points had stainless steel filters at the intake depth, and a surrounding filter medium of 4mm chip. This installation was not successful, and the following observations were made:

- The flow rate from the well-points was low, in the order of 2-5l/s for a line of 50m length and the trench was permanently under water, requiring the use of a flexi-pump within the excavation to attempt to lower the water level in the trench and enable pipe laying.
- Water was continuously cloudy, indicating a loss of fine silt from the surrounding soils.
- Some well points were occasionally drawing air into the header pipe, resulting in loss of vacuum in the header pipe and reducing the efficiency of the other well-points connected to the system.
- Heave within the trench was leading to extremely soft ground conditions, due to water flowing up through the trench base.

Considering the stratigraphy of the site, the well points were installed in a layer of lower permeability and so could not achieve a reasonable flow-rate to draw down the water table, while groundwater recharge into the trench was occurring through the deeper sand layer of higher permeability. In addition, the 4mm chip filter medium was ineffective at filtering the fine sand and silt, and the well screens were clogged with fine sand, further reducing the flow rate from the well points.

The quantity of water in the trench made pipe laying impractical, so an alternative dewatering system was established.

3.2 SECOND DEWATERING ATTEMPT: SUMP PUMPING

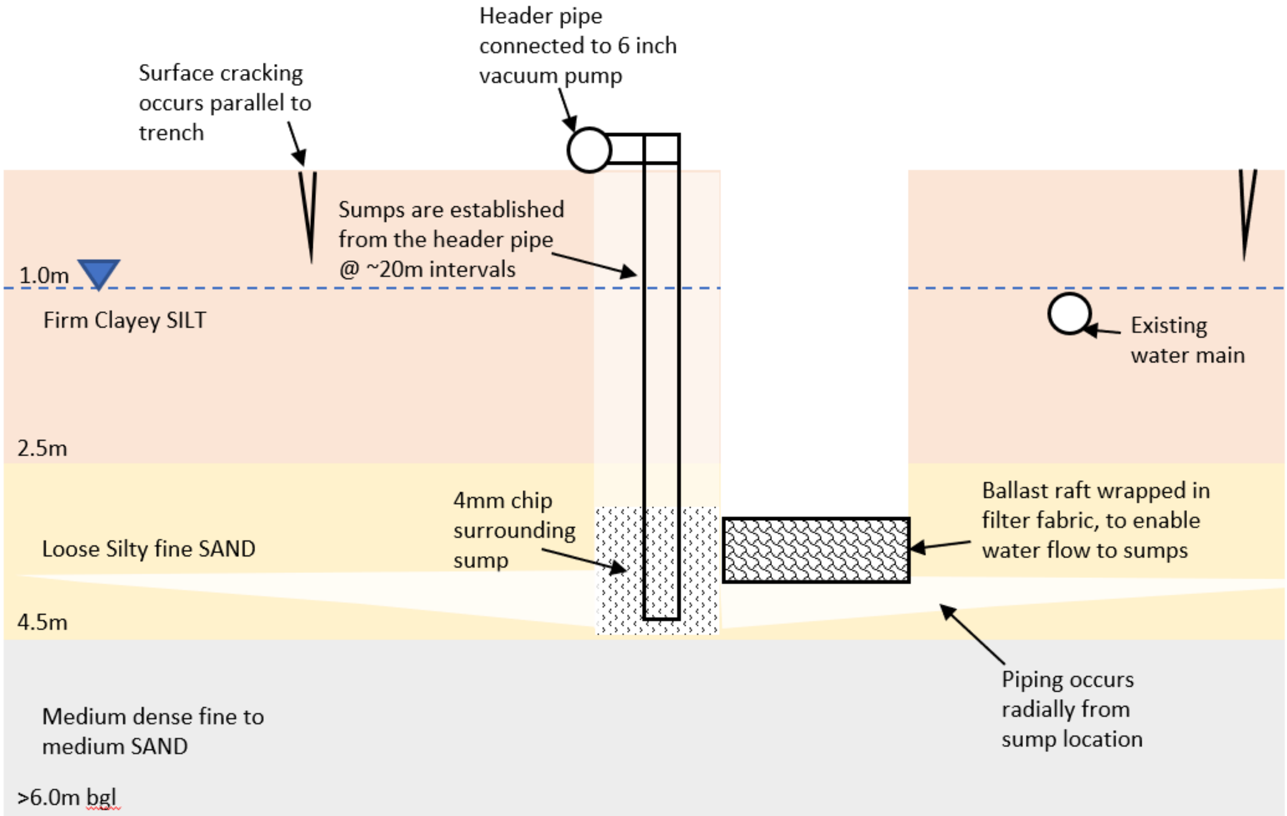

Figure 2: Dewatering with sump-pumping

Following the unsuccessful attempt at well-pointing, the contractor excavated dewatering sumps at roughly 20m intervals, and pumping began on Friday evening to enable groundwater to draw down over the weekend. The main sumps were placed adjacent to the trench, and the trench base was filled with railway ballast to type gravel to enable water to flow along the trench to the sump locations.

Based on soil volumes in the sediment tank,at least 18m^3 of fine sand and silt was extracted from the sump over the first night of pumping, resulting in a depression occurring around the sump location. More sediment is likely to have been discharged downstream. The loss of soil volume caused severe settlement adjacent to the trench, sufficient to break an adjacent council water main and further flood the excavation.

The depression developed for several weeks after pumping ceased from this well, resulting in settlement of both kerblines of the road, with an eventual diameter of approximately 15m to the edges of the depression. In addition, the pipe and manholes that the contractor had already laid dropped significantly, requiring re-laying.

Instability was evident in the trench sidewalls. The trench was shored with trench shields to prevent collapse, but the lateral instability resulted in cracks appearing parallel to the trench as the trench shields were loaded by ground failure on either side.

3.3 THIRD DEWATERING ATTEMPT: EXTENDED WELL POINTS

Following the unsuccessful attempt at sump pumping and the ensuing damage, the subcontractor sought advice from a local contractor with extensive experience on establishing an effective dewatering system. Following a deep trial pit excavation and observing the local geology, the well points were re-established with an extension on each well point, enabling them to target the deeper layer of sand. The successful dewatering setup is shown in Figure 3.

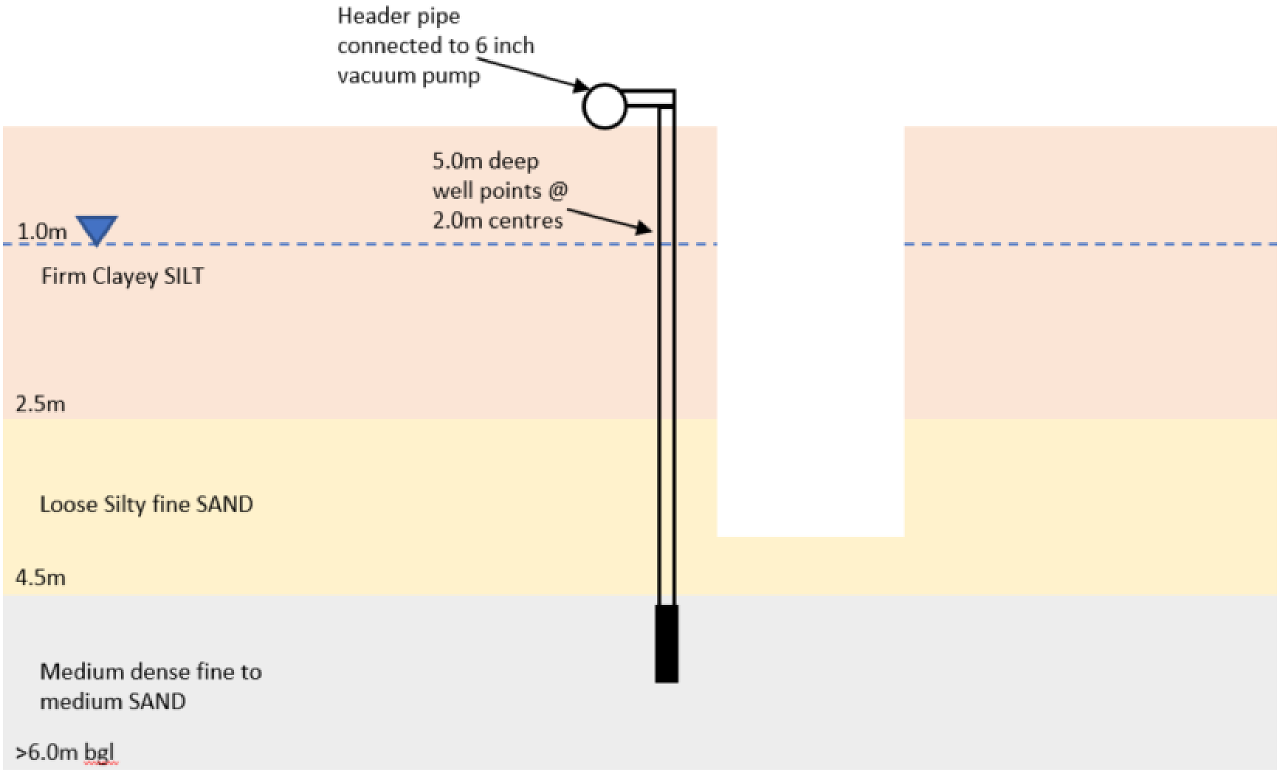

Figure 3: Well points are re-established 1m deeper, targeting the medium dense sand

The setup with the deeper well points was successful with clear water running at an increased rate of approximately 20l/s from the well points, creating a dry working environment within the trench and improving the strength of the trench foundation compared to previous setups. No further cracking was observed adjacent to the sidewalls of the trench, which was stable for the remainder of the job.

The deeper well points successfully targeted a layer of higher permeability, enabling an adequate dewatering drawdown to be achieved over the area of the excavation. As well as creating a dry working environment in the trench, the dewatering drawdown significantly improved the trench stability, leading to a reduced width of required road reinstatement. The extracted water was clean, and able to be discharged to the stormwater system without further treatment.

4 CASE STUDY – STRUCTURE EXTENSION

This case study involved extension of an existing underground concrete structure. The excavation was shored with sheet-piles and was dewatered using two deep wells driven by a vacuum pump, and two shallow sumps. The contractor had based their dewatering setup on ground investigation data supplied but the ground conditions were not verified during installation. The subsequently discovered variations in ground conditions had a significant impact on the dewatering set up. The site setup is shown in Figures 4 and 5.

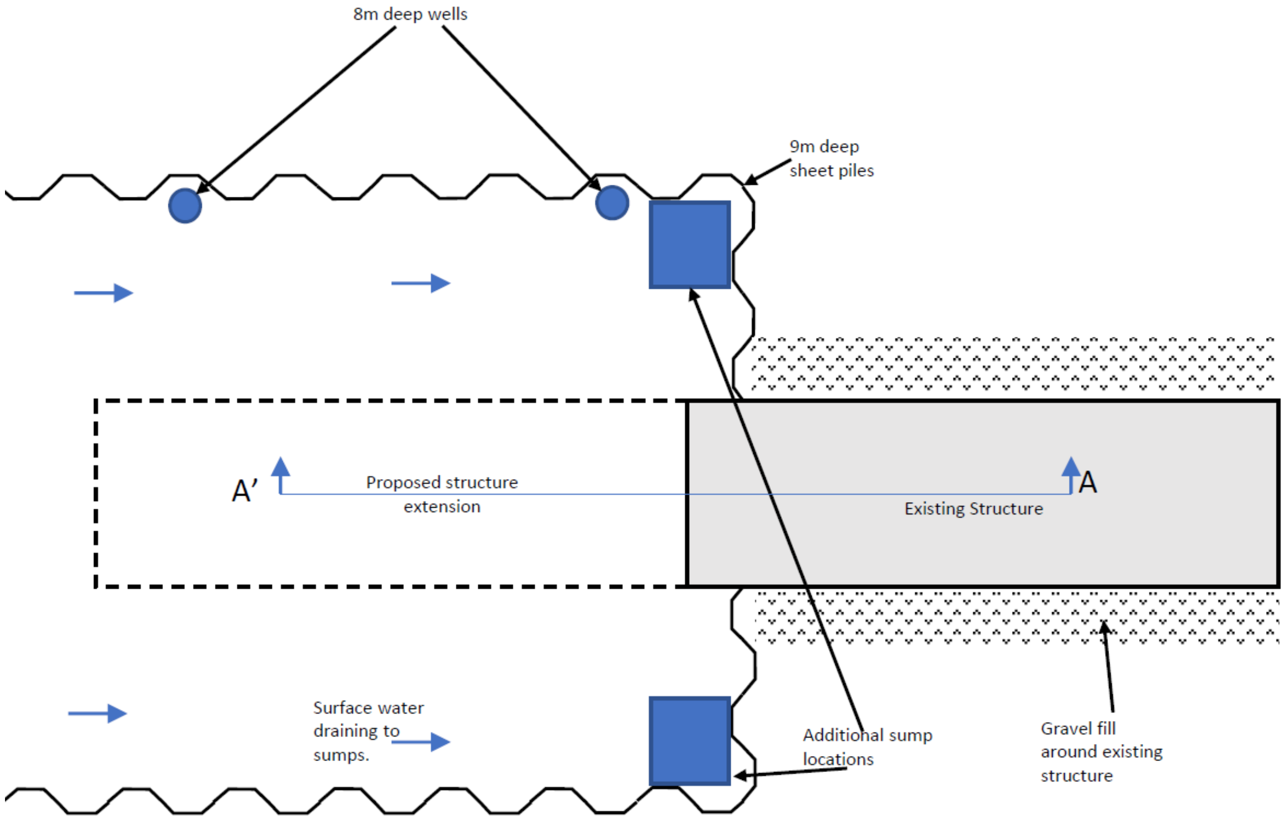

Figure 4: Plan view of structure extension

The excavation was shored with sheet piles to the side of the existing structure, with a gap in the sheet piles to enable a connection to the existing structure. Two deep wells were established on one side of the excavation, connected to a vacuum pump, with the intent of lowering the water table across the entire excavation. Both wells comprised driven steel tube sections installed using a breaker attachment on the excavator, with gas-cut slots to draw in water.

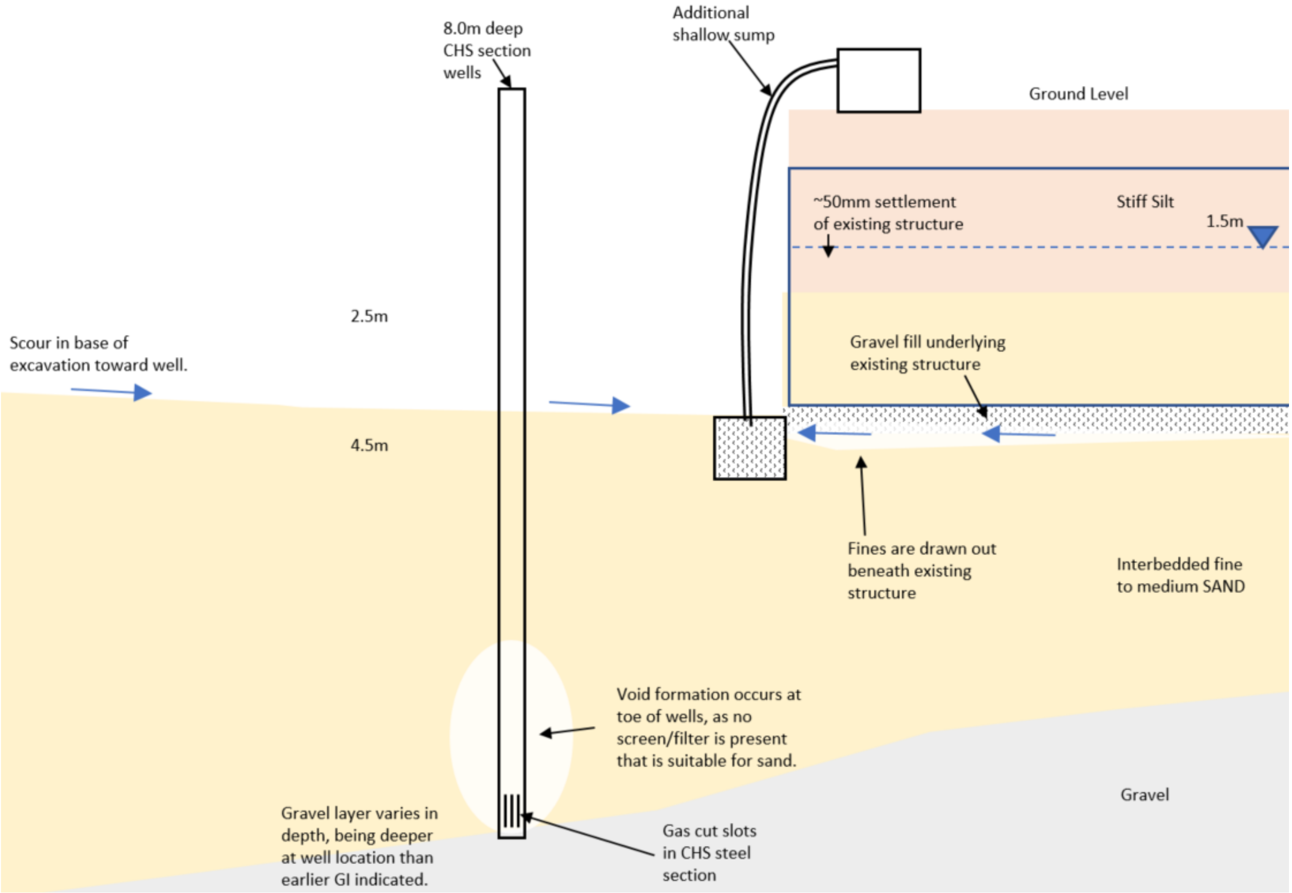

Figure 5: Section view showing dewatering setup and effects

The dewatering was established by the contractor and pumping began on Friday evening. By Saturday morning approximately 12 to 20m^3 of silt and fine sand had been drawn from the excavation, and had settled in an adjacent swale. Piping and extraction of sediment is expected to have occurred in three locations in the excavation as follows:

- The gravel backfill surrounding the existing structure allowed groundwater to flow freely along the structure to the shallow sumps, drawing silt and sand from adjacent to and beneath the structure. 50mm subsidence of the end of the structure occurred due to migration of fines.
- The deep wells were intended to be driven into a gravel layer, so were installed without any screen or filter medium. Due to the variation in depth to gravel, these wells were actually installed at the base of a fine sand layer. The fine sand was drawn into the wells, resulting in void formation at the base of the well.
- Groundwater infiltration into the excavation caused minor heave and scour on the base of the excavation.

It is difficult to isolate the contributions of these three sediment sources to the total volume of sediment discharge, however visible evidence of all three effects was present at the site. Sediment was observed discharging from the deep well, in addition to flowing from below the existing structure into the shallow sump.

5 COMMON FACTORS RESULTING IN POOR DEWATERING PERFORMANCE

Both projects suffered from several common factors, that caused or exacerbated the damage from their dewatering systems. These are considered as follows:

- The initial design of dewatering systems was undertaken without due consideration for the ground conditions, or for the risks posed if the ground conditions were not as expected. In Case Study 1, there was not sufficient information available to the contractor to enable a dewatering design, but they did not undertake investigations themselves until after their setup had failed. In Case Study 2 the contractor based their design on a single borehole without verifying the ground conditions during installation, although the presence of gravel at the toe of the well was critical to their setup.

- The site foremen did not have significant experience with dewatering. They did not understand the limitations of the dewatering systems they were installing, and did not understand the risks and consequences if the systems were not successful.
- Commercial pressures meant that the site foremen were reluctant to turn off and change their dewatering systems despite obvious damage.
- With both projects there was a rush to establish the dewatering system by the end of the week, to enable the water table to draw down over the weekend while the contractor was off-site. This lead to dewatering not being properly supervised when it was turned on to ensure that groundwater discharge was running clear and the system was well developed. The greatest damage at both locations occurred on a Friday night, with the dewatering having been established during the day and turned on as the contractors were about to leave site to enable drawdown over the weekend.

In both case studies presented, the contractor was responsible for the design and execution of temporary dewatering but in the authors' opinion did not have the knowledge or experience to successfully undertake this. The designer and principal had not specified any "Hold Points" or other restrictions on the dewatering process and were not aware of the deficiencies in the dewatering setups until significant damage had already been done. There was therefore no opportunity for the principal or designer to assist the contractor or mitigate the damage they caused. Given that there was no specification for dewatering as it was part of the temporary works, it was not possible to directly intervene or give contractual instructions.

6 RECOMMENDATIONS

For projects of this nature we believe it is the recommended approach for the contractor to develop the dewatering setup to suit their own available plant and equipment, and to fit with their overall construction methodology. This places responsibility for the performance of the system with the nominated contractor, reducing potential for claims resulting from dewatering not performing as expected and enabling the contractor to react quickly to changing conditions. Considering the examples presented, there are simple steps and limits that could be added to specifications to help the contractor avoid costly mistakes. The most relevant items to be added to specifications that would have been useful in these instances would be:

- Ensuring that a dewatering methodology is provided to the engineer for comment before dewatering establishment. This would enable the supervising engineers and the designer to assess the risk associated with the dewatering and see if there are any critical flaws in the plan considering the ground conditions and layout of the site.
- Placing a limit on the volume of sediment that can be drawn from any well while it is developed, before it stops drawing sediment. It is typical for freshly installed wells to draw silty water for a time, however there needs to be a limit to the volume of sediment extracted to ensure that unsuitable or incorrectly installed wells are abandoned before they cause damage.
- Having direct independent supervision of the site when pumping begins from a dewatering system, until the system stops drawing sediment. This would have enabled an independent party to assist the foremen to make the correct decision to turn off dewatering before damage occurs, as the site foremen will often be reluctant to make this decision due to the commercial pressures of their role.
- Request that contractors follow existing guidelines, in particular for Christchurch the Council dewatering guideline.

The above items would enable suitably experienced engineers to maintain oversight of the dewatering systems, without removing the contractor's ultimate responsibility for their performance. With these steps in place it may have been possible to aid the contractors in establishing a successful system, reducing the damage caused to surrounding infrastructure and the financial implications for these contractors.

7 REFERENCES

Brown, L.J., and Weeber, J.H. (1992). Geology of the Christchurch Urban Area. Scale 1:25 000. *Institute of Geological and Nuclear Sciences geological map,* 1 sheet + 104 p.