# Drainage problems during construction operations within a burried valley gravel aquifer

ALISTAIR ALLEN, DEJAN MILENIC

Dept. of Geology, University College Cork, Cork, Ireland; E-mail: a.allen@ucc.ie

**Abstract:** Dewatering, to a depth of 5 m, of a 400 $m^2$ excavation in gravels ($k_f = 6.87 \times 10^{-3}$ $msec^{-1}$) in a buried valley ribbon aquifer in Cork, SW Ireland, during construction of a basement, has proved problematic. Drainage required operation of 16 submersible, sump and suction pumps, with a total stated capacity of 400,000 gals/hr (500 l/sec) pumping at maximum capacity.

**Key words:** Dewatering; Gravels; Buried Valley Aquifer; Basement Excavation

## INTRODUCTION

Hydrogeological conditions are rarely considered during the design and planning stages of buildings and other construction projects by architects and civil engineers, even in situations when indications would make it prudent to do so. This can have significant consequences, when construction begins and groundwater conditions turn out to be a problem, as it is usually too late to modify the design parameters of the construction once the planning procedure has been completed.

We describe here the drainage problems encountered in the construction of an Art Museum at University College Cork (UCC), Ireland, located on a riverside site in the floodplain of the River Lee, which flows through Cork city. The floodplain overlies a buried valley infilled with gravels with an extremely high hydraulic conductivity.

## THE CONSTRUCTION SITE

The construction site is in the lower grounds of UCC main campus, on the south bank of the South Channel of the west to east flowing River Lee a kilometre to the west of Cork city centre (Fig. 1). The Lee, consists of two distributary channels 400 m apart, which separate about a kilometre upstream of the site and reunite about 3 km downstream at the beginning of its estuary. It occupies a broad low-lying floodplain approximately half a kilometre wide at this point. The construction site is situated about 20 m from the base of a 30 m high limestone scarp, which marks the edge of the floodplain. The Lee is tidal within Cork city, and the construction site is at about the tidal limit in the South Channel, with a range of about 15 cm in groundwater levels.

The Lee floodplain overlies a buried valley, formed 15,000 years ago during the Pleistocene glaciation, when sea level fell to -130 m OD, and rivers cut down to the new base level (ALLEN ET AL., 1999). At the end of the glaciation approximately 10,000 years ago, when the ice receded and sea

*Scientific paper*

level rose again, rivers responded to the rapidly rising base level by infilling their valleys with sand and gravel. The Lee Buried Valley is at least 60 m deep and 0.5-0.75 km wide (ALLEN ET AL., 1999; MILENIC & ALLEN, 2002; ALLEN & MILENIC, 2003), its margins marked within Cork city by 20-30 m scarps. The buried valley consists of unstratified unsorted fluvial gravels, overlain by about 3 m of alluvium. In this area, direct recharge of the buried valley takes place, but elsewhere recharge takes place by vertical percolation through the overlying alluvium, plus bank infiltration from the Lee under high flow conditions.

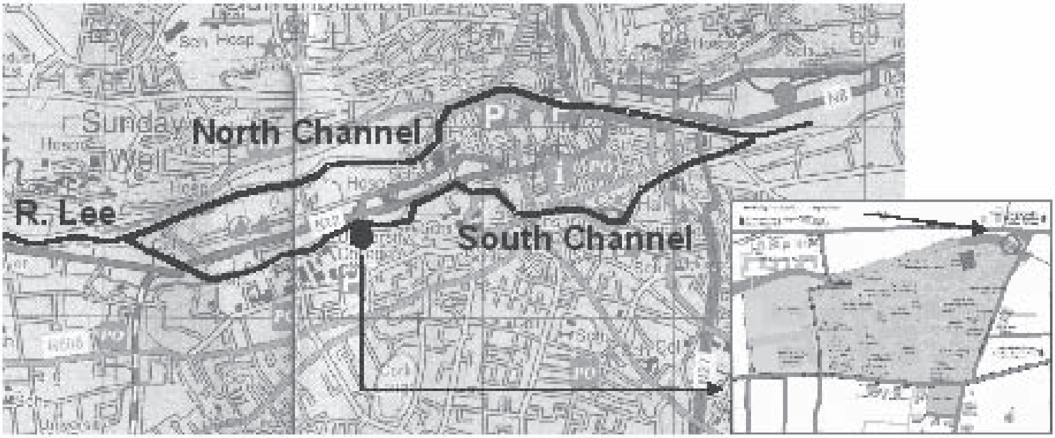


**Figure 1.** Map of floodplain of R. Lee in Cork city, showing location of Art Museum site. Inset shows detailed site location

At the construction site, 2.5-3.5 m of alluvium overlies at least 12 m of unstratified gravel in the deepest boreholes drilled during site investigations. Particle size distribution analyses were conducted on gravel samples collected from depths of 5m, 10m and 14m from one of these boreholes, to determine hydraulic conductivity by the USBR method. Hydraulic conductivities ($k_f$) of the order of 6.87 x $10^{-3}$ msec$^{-1}$, and showing little variation with depth, were calculated from the granulometric analyses (MILENIC & ALLEN, 2001). The site is at an average level of 5.5 m OD, and the maximum groundwater level recorded in wells is 4.6 m OD, indicating that the water table is only 0.9 m below the surface and that groundwater is semi-confined. The maximum high water level reached in the South Channel of the Lee adjacent to the site was 5.2 m OD. There is undoubted hydraulic connection between the river and the gravels beneath the site, yet all groundwater pumped from the wells was clear, even when the Lee was in spate and yellow gray with suspended sediment. However, groundwater being pumped from the gravels comes from depths of 7.5 m, so any recharge from the Lee when in spate, may only be identified at very shallow levels in the groundwater.

## Design Details

The proposed Art Museum was designed as a three-storey building 23.5 m high, with a footprint of 1000 m$^2$. A basement incorporated within the design, reaches a depth of 3 m with dimensions of 23.3 x 17.5 m (Fig. 4), giving a footprint of 360 m$^2$. In addition lift shafts and a sump required excavation to a further 2 m. The total volume of the hollow basement below the static water level is 1080 m$^3$. In order for this phase of the construction to proceed, continuous drainage to a depth of 5 m over a period of approximately 4.5 months from the beginning of December 2002 to mid-April 2003 was necessary. Under relatively wet winter conditions in Cork (mean rainfall for the period ~ 50 % of an annual mean rainfall total of 1200 mm), high recharge rates could be expected.

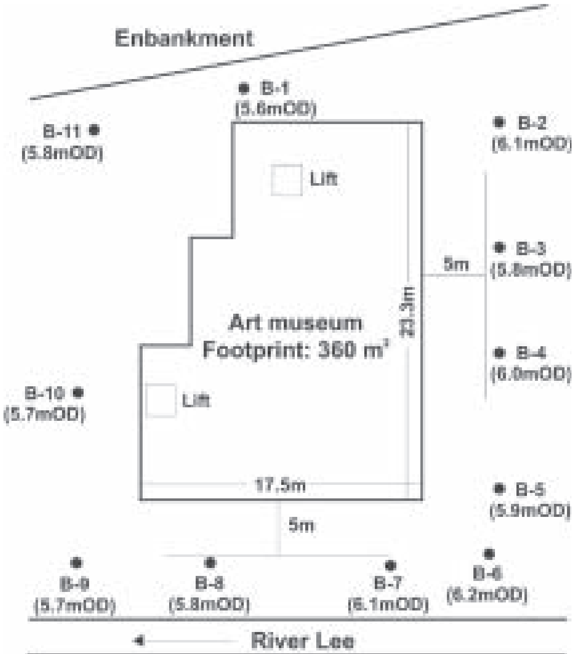


**Figure 2.** Plan of footprint of the Art Museum basement, showing location of the drainage wells (surface levels of wells in metres above ordinance datum [OD])

## Drainage Measures

In order to drain the basement area, twelve, 200 mm diameter, drainage wells were drilled mainly to depths of about 11.5 m around the perimeter of the excavation, about 8m apart and 5 m from the intended footprint of the basement (Fig. 2). These were lined with 160 mm casing, fully screened, into which 6" and 4" pumps were set at depths of 7.5 m. The purpose of these wells was to drain the perimeter and slopes of the excavation in order to stabilise the slopes. Although this has fulfilled its purpose, some parts of the excavation have needed, in addition, sheet piling to ensure stability.

The core of the excavation was drained by means of four 6” pumps, three submersible sump pumps placed in the two lift shafts and sump, and a suction pump. In all 16 pumps, pumping to maximum capacity were needed to reduce the water level by 5 m whilst the lift shafts and sump were excavated, and in order to maintain water levels at about 4 m depth, 12 pumps operated continuously from mid-December, 2002 to mid-April, 2003.

No measurements of flow rate or discharge were taken by the dewatering contractor, but on the basis of the pump manufacturers stated maximum flow rates for the various pumps, estimates of discharge from the site suggest that at the stage when the water table was being drawn down, close to 400,000 gals/hr (500 l/sec) were being pumped from the site. The drained water was dumped into the South Channel of the R. Lee. This value seems rather excessive, and it may be that the manufacturers claims for their pumps are slightly extravagant. At the end of March, 2003, for instance, estimates of flow rates based on pump capacities, in excess of 250,000 gals/hr (320 l/sec) were not completely consistent with the discharge entering the river, but the flow rates were probably only slightly lower than this level (10-20 %).

A further problem encountered in construction of the basement structure, was the buoyancy of the hollow concrete basement, which prevented the pumps being turned off until the concrete ground floor was poured and walls were constructed to first-floor level. Failure to do so could have resulted in the buoyant basement rising with the rapidly recovering water table when the pumping system was shut down, which could have destabilised the foundation piles, and significantly weakened them. This prolonged pumping operations and further increased construction costs.

## Conclusions

Constructions sited in low-lying, high-permeability, gravel aquifers with shallow water tables encounter major drainage problems, when significantly deep excavations are involved. The high hydraulic conductivities of the gravels give rise to very narrow cones of depression, so dewatering wells need to be sited very close together. If the excavation has a large footprint, perimeter wells will not have the capability of dewatering the core of the excavation, so some other form of dewatering technique will be required to fully dewater the excavation.

## References

Allen, A. R., McGovern, C., O’Brien, M., Leahy, K. L., Connor, B. P. (1999): Low enthalpy geothermal energy for space heating/cooling from shallow groundwater in glaciofluvial gravels, Cork, Ireland. In: Fendekova, M., Fendek, M. (Eds) *Hydrogeology and Land Use Management*. XXIX IAH Congress, Bratislava, Slovak Republic, IAH, Bratislava, pp 655-664.

Allen, A. R., Milenic, D. (2003): Low enthalpy geothermal resources from groundwater in fluvioglacial gravels of buried valleys, *Applied Energy*, 74, 9-19.

Milenic, D., Allen, A.R. (2001): *Investigations to determine the potential for utilisation of low enthalpy geothermal energy as a source of energy for space heating and cooling for the planned Art Museum at UCC tennis courts*. Dept. of Geology, UCC, Report. Series, 01/4, 6pp.

Milenic, D., Allen, A. R., (2002): Lee Buried Valley - A Significant Groundwater Resource, SW Ireland. In: Bocanegra, E., Martínez, D., Massone, H. (Eds.) *Groundwater and Human Development*, Proceedings XXXII IAH Congress, Mar del Plata, Argentina, ISBN 987-544-063-9, 8 pp.