Solutions for large construction sites in groundwater-saturated subsoils at the large infrastructure projects in Central Berlin

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Abstract: The large construction sites in Berlin for the new public transportation system with its seven parallel tunnels up to 15 m below the water table in a high-permeable aquifer caused geotechnical and environmental challenges. Special focus will be given on an innovative groundwater management system for protection of vegetation and historical buildings.

Key words: groundwater management, groundwater modeling, large-scale construction project, watertight troughs.

Introduction

The decision to move the German Government from Bonn to the new federal capital Berlin had created many new tasks according to infrastructure. The regional traffic conditions in the central area of the city have to be updated. Therefore, since 1995 a large and complex tunnelling project including seven parallel tunnels to serve long distance trains, a subway line and a roadway had started. The total width of the tunnels is up to 80 m, the maximum excavation depth is 20 m over a length of almost 6 km. At the same time three new government buildings were constructed. Their building pits reached also a depth up to 15 m.
The legal regulations in Germany require for large-scale construction projects extensive environmental impact studies to access the existing situation and forecast the maximum possible impacts of the construction on the subjects of protection like groundwater, historical buildings and more.
The result of these impact studies led the authorities to the requirement of groundwater saving construction techniques. Another requirement was the implementation of a "groundwater management organisation" which has to control the groundwater level, the hydrochemical water quality and to manage the water volumes coming out of the construction pits to avoid groundwater lowering.

Geological and hydrogeological conditions

Construction in central Berlin is occurring in saturated soils of the glacial deposited quaternary stratum. In the Pleistocene stratum in this area, a part of the Warsaw-Berlin primary river valley, three different glacial periods and two interglacial periods can be

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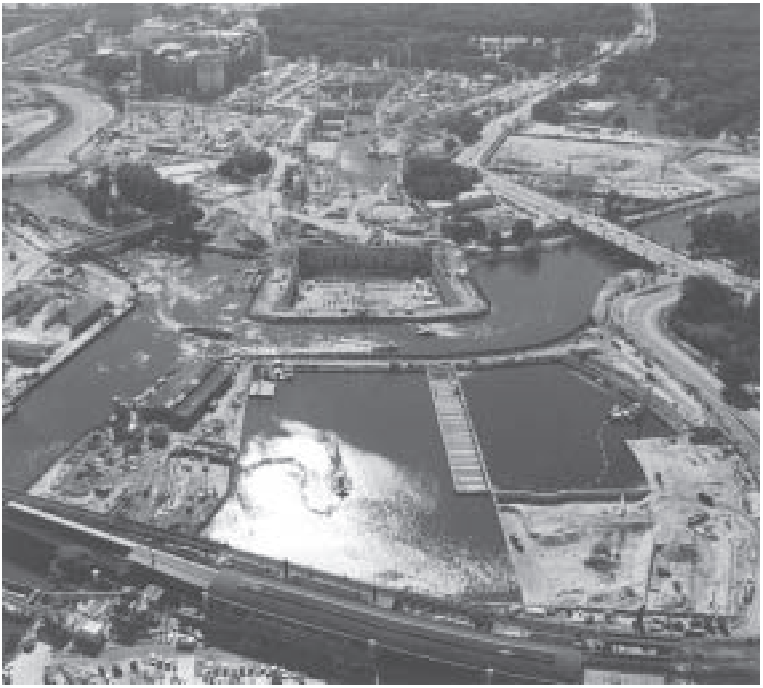

Figure 1. In front a construction pit with subaquatic concrete floor, in the back different construction levels of the troughs and in the upper area a part of the Tiergarten Park is visible.

identified. The glacial sediments are highly polymorphous in their lateral and vertical distribution. They also vary widely in their granulometric composition, which consists of tills, sands, gravel and banded clays. The total thickness of the Pleistocene sediments in the Berlin area usually is about 50 to 80 m and up to 250 m in the glacial erosion channels.

The till (ground moraine) consists mainly of a sandy, clayish marl with numerous boulders and much gravel. As a secondary process, the fine-grained matrix may have been washed out so that horizons enriched with boulders remain. The sand and gravel is mainly of glaciofluvial origin. In the Holocene period (postglacial) organic sediments were deposited in erosion pipes and basins.

Due to the history of the Center of Berlin a lot of backfill material, mainly in the form of building rubble covers the natural soil. Extensive construction work for tunnels, bunker and foundations of the 1933 to 1945 period was stopped at the end of World War II. Although there are existing old archive plans and aerial photos it was only possible to reconstruct the extent of all underground constructions after geophysical investigation.

The hydrogeological conditions are characterized by a high groundwater table (2-4 m below surface) and a high permeable pore aquifer with intercalated, low permeable residual moraine sediments.

Subjects of protection

On the one hand there is the complexity of the engineering works, on the other hand there are impacts on the environment especially on the groundwater budget caused by very large and deep troughs. Therefore the public authorities defined some boundary conditions. At first has to be mentioned the recreation area "Tiergarten" with its groundwater-dependent vegetation situated in the Center of Berlin very close to the construction sites. This ecosphere should not be negatively affected by the construction activities, i.e. by lowering of the groundwater table. Then there is the groundwater itself as a valuable subject of protection, as well as the surface water, whose quality must not be influenced by any construction works. Furthermore there are still historical buildings around the project area. There is e.g. the historical "Reichstag" which is founded on wooden piles or the "Brandenburger Tor". A lowering of the groundwater table around these historical buildings allows the access of oxygen on the wooden piles and could cause damage to the building structure.

Construction techniques

All these special conditions – large-scale construction project, high permeable aquifer, ecological considerations – approved the application of groundwater saving construction methods to minimize the impacts of groundwater lowering. The open excavations had to be designed as quasi watertight troughs mostly using diaphragm walls with tiebacks and underwater concrete base slabs with anchor piles. Also quite common are troughs with diaphragm walls and grouted sealing bottoms that counteract the uplift due to the selfweight of the soil above it. The bottoms can be jet-grouted using cement or grouted using silica gel, although the latter has lately been under suspicion to contaminate the groundwater.

During the construction of the open pits a large volume of groundwater flows towards the construction site as either excavation water, bilge water or residual water. Excavation water arises under construction of the subaquatic concrete floors and has to be pumped out of the excavation as bilge water (figure 1). Using the method of jet stream bases groundwater results from the soil because these excavations are made under dry conditions. After the troughs had been constructed small amounts of residual water can enter through cracks and joints of the bases or the walls. Although the troughs are watertight, and watertight means at maximum 1.5 l/s per 1000 m^2 of excavation area, this residual water also has to be pumped out.

Parts of the tunnels, where existing rivers, buildings or vegetation makes it necessary, had been constructed by using shield-type heading. The applied hydro shields had been driven through saturated sands with different stratas of ground moraine. The tunnels are up to 12 m below the groundwater level. The headwall of the tunnel was stabilized by using a bentonite suspension.

Ground-water Management

The environmental impact studies involving three-dimensional numerical groundwater modelling had led to the conclusion that these large scale constructions are possible, but only by using the groundwater saving techniques as described above. Because of the fact of planned 17 million mł of residual water (groundwater) the authorities permit includes the demand of implementation of an organisation, which cares about all questions of groundwater – the groundwater management organisation.

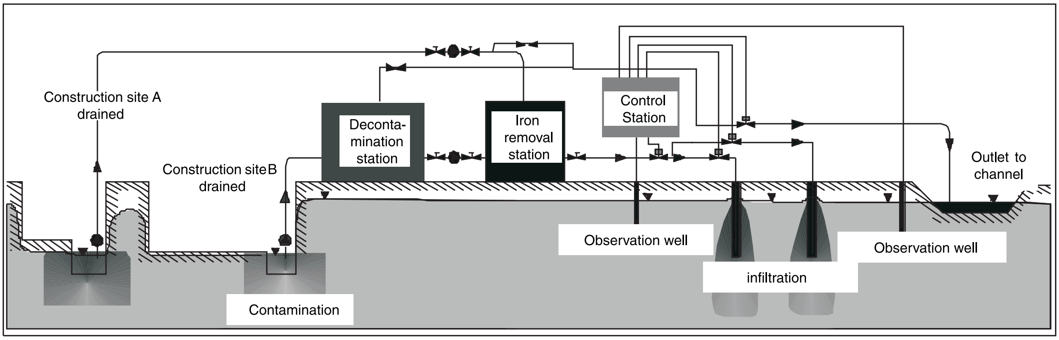

Figure 2. Principle sketch of the functionality of a part of the groundwater management system.

The main tasks of the groundwater management is the control and (hydrogeological) conservation of evidence of the groundwater table in a defined range, the hydrochemical quality and the water volumes coming out of the construction pits. For the realisation of this complex tasks the groundwater management organisation set up a system for conservation of evidence and handling the groundwater quantities (figure 2).
The drainage of seepage water into the excavation causes a lowering of the nearby groundwater table and the need to pump out of the trough. Depending on the water quality, it may have to be treated. The pumped water can be either re-infiltrated into the aquifer or led to a nearby channel. The decision about the way of the pumped water depends on the groundwater table at each time. The groundwater table is observed by at maximum 90 observation wells, which are equipped with automatically registering memory units. Periodical calculations with the calibrated groundwater model lead to an effective re-infiltration.

CONCLUSIONS

With the implementation of the innovative system of the groundwater management developed for an environmental protective construction technique within the ecological sensitive area in the Center of Berlin it is assured that the conditions of the authorities are executed. After more than seven years of groundwater management in the Center of Berlin it could be shown that large-scale construction is ecologically compatible possible. The protection of the “Tiergarten” e.g. was realized at every construction level, also during water inleakages in construction pits.