# Special features of the groundwater management in regard to large construction sites in Berlin, Germany

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## Introduction

As an exposed challenge to the development and reconstruction of the city of Berlin belongs especially the construction site Potsdamer Platz as the largest construction site in Europe within a downtown area. In scope of a city-agreeable construction site logistic concept, 6 million tons excavation material, 1.3 million tons ready-mixed concrete and 1.3 million tons packaged goods will be transacted during the construction period from 1993 to 2002 with a total investment volume of approx. DM 8 billion. The close spatial, structural and functional connection of individual construction projects with the simultaneous concentration of activities of five different investors requires an ingenious construction site logistics.

In this setting, a special aspect of the construction site logistics is the inclusion of groundwater handling as a part of the logistic concept.

It was expected and feared that through 6-8 years of continual construction activity and the accompanying dewatering measures a significant impact to the construction pits would take place as well as significant consequences to protected goods, like the big zoo, other parks and settlement-endangered buildings, because of the often coinciding, very large construction pits that are up to a hectare in size, 20 m deep and extend 16 m into the groundwater. According to initial projections the extraction of 12.5 million m³ residual groundwater plus approx. 1.5 million m³ bilge water was estimated for the dewatering of the construction pits. This prognosis is based on the observance of the maximum residual water leakage rate of 1.5 l/s per 1000 m² groundwater-moist construction pit surfaces.

Therefore, it is necessary to minimize the immense interference to the groundwater balance of approx. 320 m³/h over a period of approx. 5 years (!) and to avoid excessive groundwater fluctuations in the surrounding area.

## Orders from the water authorities

An interference to the groundwater balance due to construction requires a permit from the responsible water authorities. The tense situation of the groundwater balance and the expected impact to the environment prompted the Senate's Administration of City Development, Environmental Protection and Technology (Senatsverwaltung für Stadtentwicklung, Umweltschutz und Technologie SenSUT) to issue extremely restrictive and comprehensive orders in scope of the permits successively submitted to the developers in the years 1994-1996 from the water authorities for the engineering measures at Potsdamer Platz, among other things

- the use of groundwater-conserving construction methods (trough construction method, shield tunneling),
- the observance of the maximum residual water leakage rate of 1.5 l/s per 1000 m² groundwater-moist construction pit surface,

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- the observance of defined groundwater levels with a range of fluctuation of 1 m (between 30.0 and 31.0 m above mean sea level for the area of the big zoo) to secure the vegetation of the park areas,
- the reinfiltration of the residual groundwater accumulating in the construction pits according to need,

- the observance of extensive quality parameters for the drainage into a surface water or reinfiltration, if necessary.

In addition to this, each permit was completed by a new „unusual“ requirement: The three private (Daimler-Benz AG, SONY Berlin Ltd. and ABB/Terreno-Roland Ernst) and the two public developers of Potsdamer Platz (the State Government of Berlin and the Deutsche Bahn AG) must establish a common groundwater management.

**Organization framework**

Already in 1993 the firm Baustellenlogistik Potsdamer Platz (baulog) Ltd., whose technical management was supplied by the firm Emch+Berger Ltd., was founded by the five public and private investors of Potsdamer Platz with the goal to organize the entire supply and disposal of the large construction sites city-agreeably through railway and waterway shipping. A component of this task was also the handling of the occurring residual groundwater.

With the permission award from the water authorities to each investor and the therein required participation in a common groundwater management the legal basis was established, among others, for the proper realization and fulfillment of each individual requirement in scope of the collective total concept.

Based on a baulog-solicitation the contract for the groundwater management was awarded in 1994 to IMS Ingenieurgesellschaft Ltd. in cooperation with GCI Grundwasser Consulting Ingenieurgesellschaft Ltd. and for the groundwater handling the contractor combination (ARGE) Grundwasserverbringung Potsdamer Platz (see organization schema).

The construction pit border was defined as a logistic interface in regard to the tasks and responsibilities of the groundwater management incl. handling and those of the individual construction companies. The construction companies responsible for the dewatering must treat and transmit the extracted water without pressure from the baulog handling system according to the quality requirements set by the authorities for drainage into a surface water or for reinfiltration. Therefore, in the contractor’s realm of responsibility lie clearly constructional caused groundwater relevant events, like accidents, leakage or contamination.

**Tasks and instruments of the groundwater management**

All hydraulic engineering measures should be controlled through a comprehensive groundwater management that is able to realize integral solutions for intricate and complex problems. In addition to the conceptional realization and monitoring of the requirements stated in the permit from the water authorities and the conservation of evidence, it was necessary to cost-effectively plan, control and monitor suitable facilities for the drainage and infiltration of the residual- and bilge waters.

The groundwater management that was conceived and realized by the companies IMS and GCI on behalf of baulog is based on three components:

1. Technical perfect control and conservation of evidence system, characterized through
   -high system transparency,

-permanent availability and operation
-high topicality of information
-access for all the participants to all specialized data
-data and falsification security.

2. Scientifically founded planning of the control of the water balance based on measured data and model prognoses with the aid of a
   -groundwater model that simulates the monitoring area,
      > at regular intervals immediate prognoses almost simultaneous to execution and
      > according to demand conceptional long-term planning allows
      > continuous updating of all relevant information on the hydrological and constructional conditions
      > and practically a real-time simulation system that is permanently operating.
3. Robust reliable facilities to control the groundwater balance with sufficient capacity with use of
   - well dimensioned infiltration wells with
      >high technical quality of support and duration,
   - an available distribution system with
   - securing the water quality.

A network of more than 100 groundwater gauging stations with automatic measuring probes and data loggers was established partially with radio transmission, whose hourly measurements are entered daily into a data base on the basis of the Groundwater Monitoring Software `GCI-GMS´, examined by means of an integrated evaluation program, documented and saved, if needed.

All information is accessible by the groundwater management, the developers and the technical authorities through computer stations that are connected to the telephone network. Daily more than 3000 data on the groundwater levels, amount of water and its quality are gathered and managed. In all components the installed system is operating already for 3 years steadily and reliably. The acceptance technically and in terms of the costs are excellent by the authorities and developers.

The three-dimensional groundwater model that was developed for the planning and controlling of the pipeline system, infiltration wells and the treatment facilities encompasses with 55 km² the entire central part of Berlin. It is based on the finite elements model FEFLOW and was designed in more than 140,000 elements with 8 model layers, whose boundaries are orientated to the hydrogeologic formations and the penetration depth of the construction measures. Thereby, the location of the construction sites, infiltration points and impermeable structures, like subway routes and old foundations were considered. The differentiated groundwater recharge rates were determined in small-scales and described dependent of the season as a locus-dependent condition. The external conditions were continuously updated and predicted as a function of time from the current measurements of the measurement network of the State of Berlin. Groundwater extraction by third parties in the area of evaluation are always pursued and recorded in the model. An own data processing project based on ARC VIEW as geographical information system was prepared for the registration, updating and model-fitting description of the internal condition caused from the construction. The calibration of the model that precedes the prognosis simulation is made more precise each month by means of the continuous model updating. The operative planning of the management is based on short- and middle-term prognosis calculations that are prepared each month covering a period of 3 to 4 months. An updating of the concept for each of the remaining total prognosis periods occurs in intervals of approx. 18 months.

The groundwater handling system was completely designed prior to commencement of the construction measures and analyzed in regard to its temporal necessity of disposition. Fundamental elements, like the central bilge- and residual water pipelines (3 DN 300 pipes) that are necessary for the duration of the entire construction period are arranged as main distribution pipelines between the construction measures, so that they most possibly do not require alterations. The pipelines are combined by valve connections, so that redundancy and capacity reserves for peak loads are available through the multitude of valve connections, in case alterations are necessary. Through numerous pressure increasing stations at the edge of the construction pits under the responsibility of the groundwater management the water is drained over a distance of maximum 2 km by means of primarily risen pipelines into the nearest receiving stream (Landwehr canal). All the temporarily needed pipelines leading to the construction pits and wells shall be installed shortly prior to their actual use. In the meantime, the total pipeline system has reached a length of approx. 8 km.

A comprehensive network of measuring points that is installed in the handling system allows a detailed registration of the discharge rate from the construction pit. The discharge structure into the Landwehr canal possesses a capacity for peak discharge rates of approx. 2,700 m³/h.

For the purpose of maintaining the groundwater levels, especially in the area of the big zoo, groups of wells (approx. 30 wells) for the infiltration of residual water were established, whereas already a line of wells could be removed due to the northward shift of the construction activities.

The groundwater management concept for continuous control of the groundwater conditions, the planning and supervision of construction of the required handling facilities, the continuous prognoses of the change of the effected groundwater flow, controlling of the handling processes of the water pumped and the monitoring of the quality parameters were significantly effected by the unsharpness in terms of the design of the different construction measures at the beginning of the project and the modifications that occurred during the project, among others, change of the construction pit technology, linked with the change of the existing configuration of the construction pits, amount of water as well as the shift of the date for the planned extraction. This lead to a continuous revision and adaptation of the basic concept.

The concept´s ability to arrange itself and its module-like manufacturing allow a cost-saving realization of the total groundwater management.

**Documentation**

To keep the enormous input of data that result from the realization of the requirements stated in the permit from the water authorities clear and manageable and at the same time transparently organized as basis for controlling and decision making, it was agreed in coordination with the responsible technical authorities to prepare quarterly a comprehensive documentation for conservation of evidence with statements, among others, on the groundwater dynamics and -balance, observation of the hydrodynamic threshold values, on the water quality as well as on the technical modifications to the handling- and measurement system. Meanwhile, the 15$^{th}$ conservation of evidence report has been submitted to the water authorities.

This documentation in graphic form serves primarily the water authorities to monitor the observation of the their requirements in regard to the water laws as well as information to the interested public. Furthermore, these reports are instruments of the conservation of evidence for the investors and their technical experts to the interference in the groundwater balance that they caused and the resulting effects.

**Cooperation with third parties**

To detect and control influences to the controlling- and monitoring system by construction measures of third parties that do not belong to the investors of Potsdamer Platz , the responsible Senate committee required a close coordination with the baulog groundwater management in the permits issued to third parties by the water authorities that resulted with the repeated co-usage of the existing groundwater management monitoring system and/or of the baulog´s handling system.

**Results**

-Approx. 6.5 million m³ groundwater were pumped from October 1994 to the end of May 1998 from the construction pits at Potsdamer Platz. From this 0.5 million m³ were disposed by means of the combined sewage system due to its water quality.

-Due to the extremely impervious construction pits that were constructed under groundwater-conserving construction methods (wall-floor-construction with use of a underwater concrete floor or use of a soft gel floor) with a high cost expenditure for the investors, only a relatively small hydrodynamic influence to the surroundings occurred, especially in the area of the big zoo, so that by not falling below the threshold limit of 30.00 m above mean sea level (MSL) a reinfiltration of residual groundwater has not yet been necessary. Thereby, a significant requirement of the permit from the water authorities was fulfilled for the protection of the vegetation areas in the vicinity of the construction project Potsdamer Platz.

- With consideration of the local, technical, chronological and logistic aspects, concepts were developed and realized with close coordination of the technical authorities, the investors as well as the performing contractors and the groundwater management including the groundwater handling guaranteed the observation of the requirements in regard to water management with sufficient security and the smallest possible expenditure for the developers.

-The technically perfect control- and conservation of evidence system as well as the scientifically founded design and steering of required measures with the simultaneous use of innovative methods for the optimum realization of the goals have created the prerequisite to convincingly contradict the doubts raised publicly in the past in regard to the construction project Potsdamer Platz of an unacceptable endangerment of ecological and structural goods as well as the lack of environmental acceptability.

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