Large Scale Laboratory Tests for Development of Dewatering System for Open Pit Mines Based on Horizontal Filter Wells Installed by Horizontal Directional Drilling

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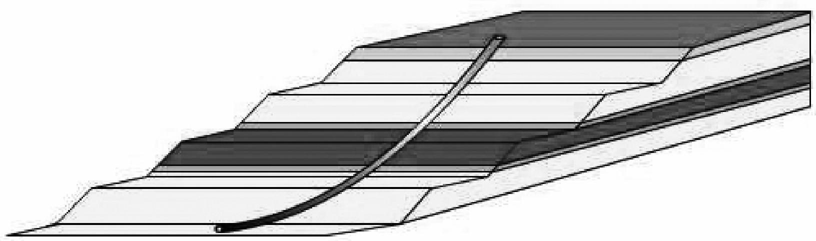
Abstract
Horizontal wells based on Horizontal Directional Drilling (HDD) are potentially more efficient in dewatering loose rock aquifers within mining or building projects compared with the commonly used vertical wells. To be able to use these horizontal wells as a primary dewatering method, deficiencies in calculation methods need to be eliminated. Therefore laboratory tests are conducted and field tests are planned, along with numerical simulation to precalculate test parameters, reproduce the test sequences, and implement the improved calculation methods, which is essential to provide reliable planning tools.

Key words: dewatering, horizontal wells, horizontal directional drilling, laboratory tests

Introduction
Many mining and underground engineering projects conducted in open pit mines and building pits require dewatering of aquifers to ensure safe and efficient excavation, transportation and dumping of loose rock material.
The current state of technology for dewatering projects in these cases is vertical wells. However, especially in thin aquifers vertical wells have a low pumping rate caused by short screen sections, and the active screen lengths are continuously reduced by the dewatering. To ensure the required rate of dewatering, a great many vertical wells need to be operated. All these wells have low-capacity pumps and therefore a lower efficiency, and all are separately provided with electrical equipment and penstock as well as with control and feedback control systems.
Horizontal well technology using the better horizontal wells installed by Horizontal Directional Drilling (HDD-wells) makes it possible to dewater the aquifers (at least partly) by using the free gradient along the wells (Figure 1). The water flows to the open pit, collected in drainage sumps, and from there pumped out of the pit with bigger pumps and a higher degree of efficiency. Because horizontal wells have long screen sections it is possible for one horizontal well to duplicate the pumping rate of several vertical wells, leading to savings in material and energy.

Figure 1 *Example of a simple HDD-well for dewatering in open pit mines*



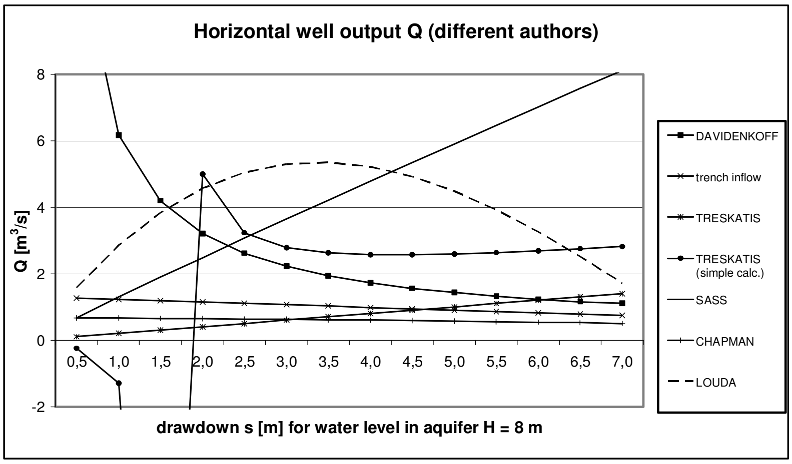
Horizontal Directional Drilling (HDD) technology is approved in many trenchless pipe-laying operations. The technology and the possible fields of application are described in Fengler (1998). Because the technology is widely known, details are not discussed here.

Several projects in German lignite mines have showed that as well as technological problems there are also deficiencies in calculation and numerical simulation.
To obtain better simulation methods on which to base better planning tools, laboratory tests as well as field tests are found necessary.

Methods
Numerical software to calculate horizontal wells is based on empirical or analytical equations. Empirical solutions mostly are obtained in one special case considering special boundary conditions, which often can not be passed to other cases.
The analytical solutions are applied to ideal conditions like complete flow or rotational symmetric flow, which cannot be assumed when using horizontal wells for dewatering. The conditions which are valid for HDD-wells for mine dewatering can be described thus:

(1) the filter screen is located next to the bottom of the aquifer;
(2) with continued dewatering, the ground water level decreases (theoretically no steady state will be obtained);
(3) during the final stage of dewatering, the ground water table next to the filter screen is lowered to the screen level, causing incomplete incident flow;
(4) with continued dewatering, the effective filter screen length in inclined horizontal wells decreases;
(5) conditions change from confined potentiometric levels to a free water table.

Figure 2 *Horizontal well output, different authors, applied on a well at Schleenhain mine*



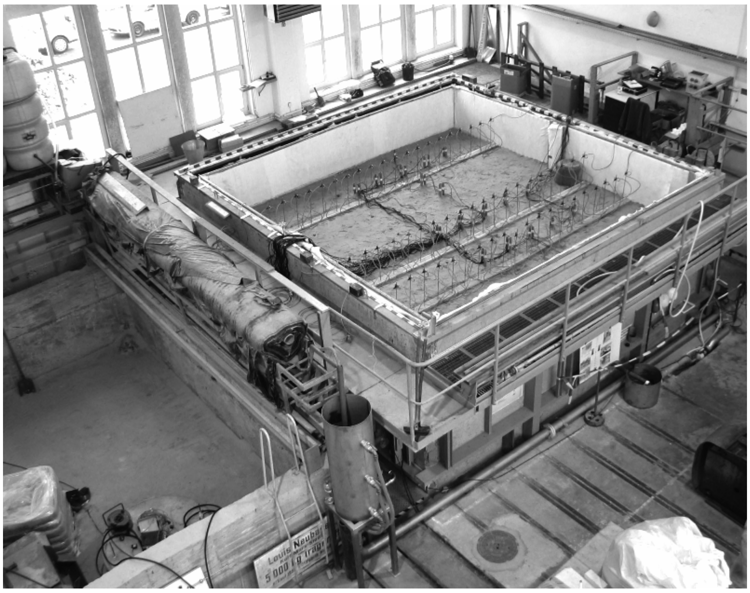
For the equations that are commonly used for horizontal wells and that are also implemented in numerical software, the attributes mentioned above are normally considered unsatisfactory.
Figure 2 shows a comparison of different calculation methods applied to an HDD-well that was operated at Schleenhain lignite mine (Germany) in 2002/03. Struzina (2003) compares the following methods published by:

- Chapman at Sass (1994): unconfined aquifer and non-ideal wells
- Damrath (1992): trench inflow, unconfined aquifer
- Davidenkoff at Herth (1994): Horizontal well assumed to be a building pit
- Louda at Lass (1975): based on single strand consideration on classic horizontal wells
- Sass (1994): valid only for confined aquifer
- Sass and Treskatis (2002): based on a quasi rectangular, rotational symmetric catchment area of HDD-wells

The comparison showed the problems of applying known calculation methods to HDD-dewatering wells and resulted in the preparation of laboratory tests that are currently being run.

The Institute for Mining at TU Bergakademie Freiberg possesses a test station for dewatering tests. The test station was adapted for horizontal well tests in 2007. The station has dimensions 6 m x 6 m x 2.5 m (length x width x height), and can be seen on Figure 3.

Figure 3 *Test station for horizontal dewatering tests at TU Bergakademie Freiberg*



Three sides of the test station are equipped with interspaces to define boundary conditions in the line to choose different water levels. On the fourth side, one eccentrically arranged horizontal filter screen dewaters the test station near its bottom. The water level is monitored by 50 observation wells, which are equipped with reading recorders. The flow rate of water towards the interspaces and the pumping rate of the horizontal filter screen are measured by two electromagnetic flow meters.

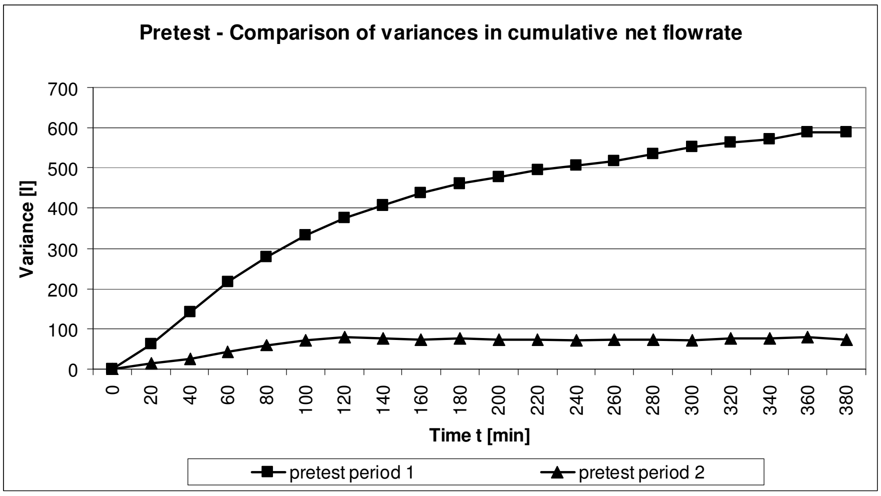
During the test period approximately 100 different tests will be conducted by varying the model material (2 materials, fine sand and fine gravel from Quaternary aquifers), the type of filter screen (slotted screen made of PVC and wire wrapped screen made of PVC), the diameter of filter screen (35 mm, 50 mm and 100 mm), attributes of the material in the annulus space around the screen (such as the model material, gravel around the screen, and volume disturbed by drilling), filter screen inclination and length, and the starting water level and rate of inflow to the test station.

The laboratory tests currently running as well as planned field tests, are conducted along with PCGEOFIM® numerical simulations. The **P**rogram system for **C**omputing of **Geofi**ltration and **M**igration (PCGEOFIM®) is a hydrogeological simulation software (finite volume element model) designed specially for mine dewatering and mine flooding problems. PCGEOFIM® is used in the project for test planning, test pre- and re-calculation, and ultimately the implementation of the test results. Therefore the test station was modelled in PCGEOFIM® and discretized to volume elements of dimensions 0.1 m x 0.1 m x 0.1 m. Knowing that the equations currently implemented in the software are inexactl, the precalculation helped to plan several tests through:

- choice of the type and capacity of flow meters;
- determination of the number of observation wells needed;
- definition of installation location of the observation wells and
- planning of time needed.

To ensure that the test results are valid and reliable, an extensive pretest was made. The pretest period included 17 single tests. Because the principal interesting was in how to achieve the same test results by repeating one test, the same boundary conditions were adjusted in each test. The only parameters varied were the time between two tests and the technology to restore the water level after ending one test and before beginning the next. That was important, because the biggest problem was to ensure a constant and homogeneous saturation before each test. Comparing the first 10 tests (pretest period 1) to the last 7 (pretest period 2), the cumulative net flow rate differed up to 120 % and could be reduced to ca. 15%, as seen on Figure 4. Geoelectrical measurements helped to assess saturation and homogeneity of the model material in the test station.

***Figure 4** Comparison of variances in cumulative net flowrate of different pretest periods*



Conclusions

A dewatering system based on horizontal wells installed by HDD promises huge savings in the need for energy and materials compared with vertical wells, especially in thin aquifers.

Problems with the installation of those horizontal wells under mining conditions and deficiencies in calculation methods resulted in the planning of laboratory and field tests. The tests will clarify and verify improved calculation methods for horizontal wells operated under mining conditions. Those methods will be integrated in numerical simulations. The laboratory tests take place in a 6 m x 6 m x 2.5 m test station. The most important parameters that influence horizontal wells will be varied. The field tests will take place in lignite mines under the boundary conditions of an operating mine.

The laboratory tests are currently running while the field tests will start in the second half of 2008. It is expected to have achieved significant results by the end of the second quarter of 2009.

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References:

Damrath (1992) Wasserversorgung. ISBN 3-519-05249-0, Teubner, Stuttgart, 1992

Fengler (1998) Grundlagen der Horizontalbohrtechnik. Schriftenreihe aus dem Institut für Rohrleitungsbau an der Fachhochschule Oldenburg; Bd. 13, Vulkan-Verlag, Essen, 1998

Herth (1994) Theorie und Praxis der Grundwasserabsenkung. Ernst, Verlag für Architektur und technische Wissenschaften, ISBN 3-433-01285-7, Berlin, 1994

Lass (1975) Berechnung von Horizontalfilterbrunnen mit beliebig angeordneten Filterrohren. Inst. Hydraul. Hydrol., Techn. Ber. Inst. Wasserbau, TH Darmstadt, 1975

SASS (1994) Brunnen und Filter für die Sanierung von Untergrundkontaminationen. Schriftenreihe Angewandte Geologie, Lehrstuhl für angewandte Geologie der Universität Karlsruhe, ISSN 0933-2510, Karlsruhe, 1994

Sass and Treskatis (2002) Herstellungs- und Bemessungsgrundlagen für einen Trinkwasserbrunnen als Pilotversuch an einem Standort in Krefeld. In: Grundwasser 1/2002, p 24-34

Struzina (2003) Untersuchungen zum Einsatz von Horizontalfilterbrunnen zur Entwässerung und Entspannung von Mulden und Kesselstrukturen. Diplomarbeit, TU Bergakademie Freiberg, Fakultät für Geowissenschaften, Geotechnik und Bergbau, Institut für Bergbau, 1998, p 23-34