Flooding of the Königstein mine up to 80 m above sea level – Prediction and Reality

Jochen Schreyer[1], Udo Zimmermann[2], Ulf Jenk[1]

[1]WISMUT GmbH, Chemnitz, Germany
[2]WISMUT GmbH, Niederlassung Königstein, Germany

Abstract. Decommissioning of the Königstein mine is a special case in uranium mine flooding. This is related to the mine's location in the depths of four aquifers and to the fact that uranium mining was both by conventional methods and underground in-situ leaching using sulphuric acid. The area potentially affected by flooding of the mine workings is densely populated and the surrounding groundwater is an important drinking water resource. Following more than seven years of flooding experiment, the completion of numerous scientific, experimental and technical studies as well as of mining and engineering requirements, the competent authorities approved of the controlled flooding to start from January 2001. In a first step the mine was flooded up to a level of 50 m a.s.l. (above sea level) involving roughly 1.2 million m^3 of water. Between October 2001 and April 2002 the flooding level was raised to 80 m a.s.l., flooding ca. 2.7 million m^3 of mine voids. Flooding went trouble-free and provided satisfactory evidence of the technical controllability of the flood rise. Hydrochemical parameters of the flood water developed within predictions. The key issue of how drainage volume would develop could be answered as a result of flooding implementation. Prediction tools were validated and provide a valuable basis for further flood level rise and decision-making on final flooding stages.

Introduction

Remediation of the Königstein uranium mine south of Dresden/Saxony has some highly specific features. The uranium was extracted from the 4th sandstone aquifer initially using conventional mining methods and later an underground in situ leaching method using sulphuric acid. The mine is located in a ecologically sensitive and highly populated area (Fig. 1).

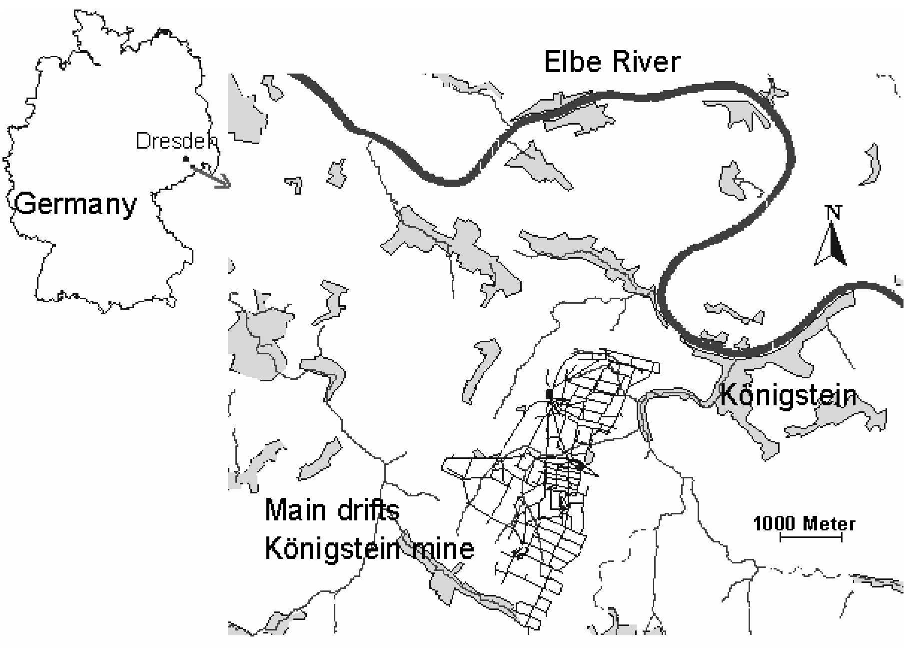

Fig. 1. Location of the Königstein mine

Experimental flooding of a small part of the mine was initiated in 1993 to gain hydrological, hydrogeological, geochemical, and rock mechanical data which will be used to predict conditions during the flooding process. The experimental area, being representative for the mine, is situated in its deepest parts and includes several former leaching blocks. Until October 1997 the experimental flooding level was at 33.4 m a.s.l., thereafter the level was raised to 40.0 m a.s.l. Quality of the flooding water is determined by the former leaching process and corresponding geochemical processes:

- pH 2 – 3, 10,000 mg/L solved substances
- 3,000 mg/L sulphate
- 500 mg/L iron
- 10 – 100 mg/L uranium.

WISMUT used the concept of controlled flooding (Schreyer and Zimmermann 1998), a major element of this approach being the control drift system which allows the collection of the draining flooding water. The controlled flooding will allow the reduction of pollutant concentrations to acceptable levels, to restore hydraulic conditions to nearly pre-mining conditions, and to prevent pollutant migration into the aquifer lying above and downstream of the mine. The flooding water, collected in the control drift system will be treated and then discharged to the Elbe river (Fig. 2). No relevant environmental impact is expected to occur with the control drift system and water treatment functioning.

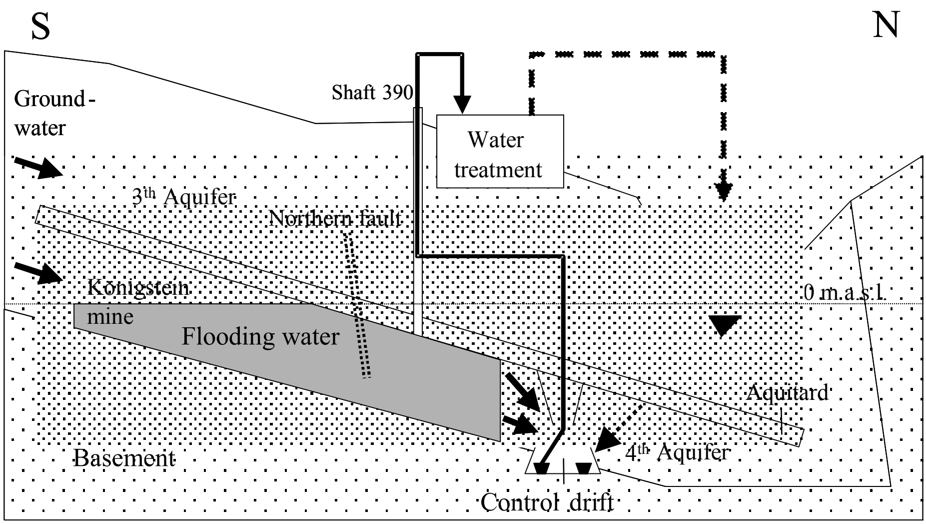

Fig. 2. Schematic cross section of the Königstein mine and the downstream region

Based on the experience gained from the flooding experiment and several scientific and engineering investigations the authorities permitted flooding of the Königstein mine to start in January 2001. Rise of the flooding water is limited to the level of 140 m a.s.l. to protect the groundwater aquifer. The results of the successful flooding are a good basis to make the decision on final flooding.

Results of the Flooding

Since flooding was initiated on January 29th 2001, ca. 3.7 million m³ of water were conducted into the flooding space by April 2002. Off that total, approximately 670,000 m³ drained from the flooding space into the control drift. 950,000 m³ were released via dams. Given that about 320,000 m³ of water (from the flooding experiment) were already stored in the flooding space when flooding of the mine was initiated, the water volume stored in the flooding space amounted to. 2.4 million m³ by the time the water level had risen to 80 m a.s.l. (Fig. 3).

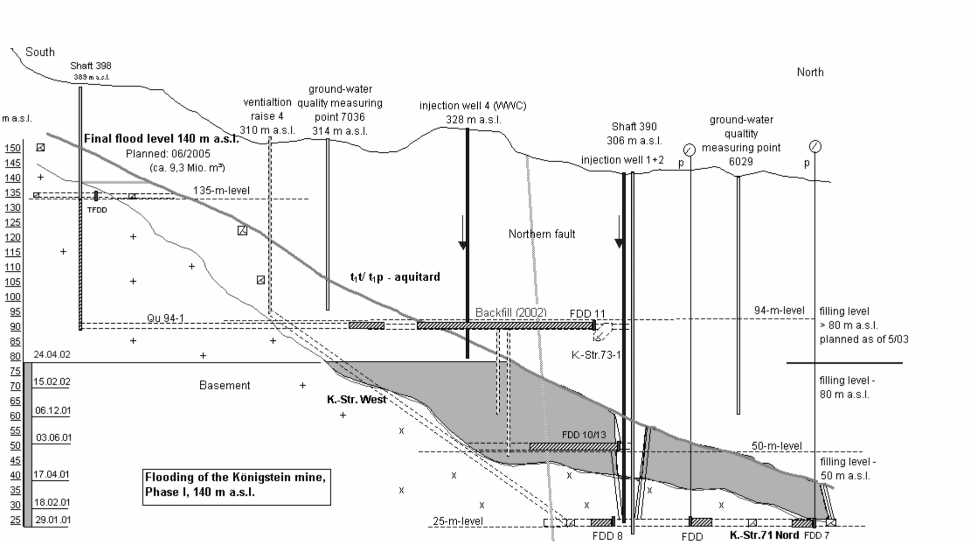

Fig. 3. Schematic diagram of the Königstein mine and flooding stages

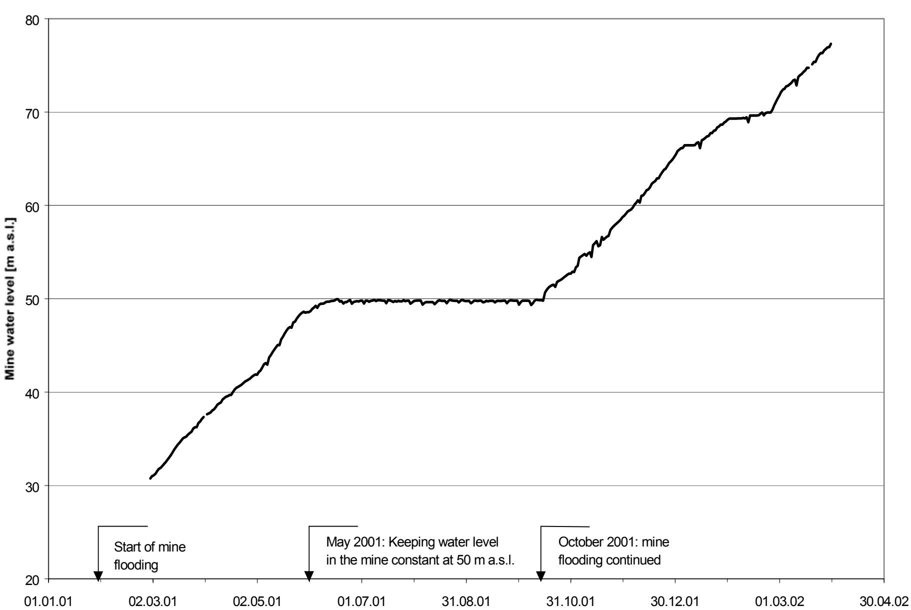

Fig. 4. Development of mine water level

As the flooding was proceeding, rise of the flood level was subject to active control by the controlled addition of groundwater and the release of flood water. Between May and October 2001, for example, the flood level was kept constant at 50 m a.s.l. This halt was conditioned by the necessity to finalize dam construction work at the 50 m level. Filling was resumed in October 2001 and the flood level allowed to rise to 80 m a.s.l. by April 2002 (Fig. 4).

The flood level will be kept at this elevation for about one year which will allow to implement construction work prior to flooding of the 94 m level (Fig. 5).

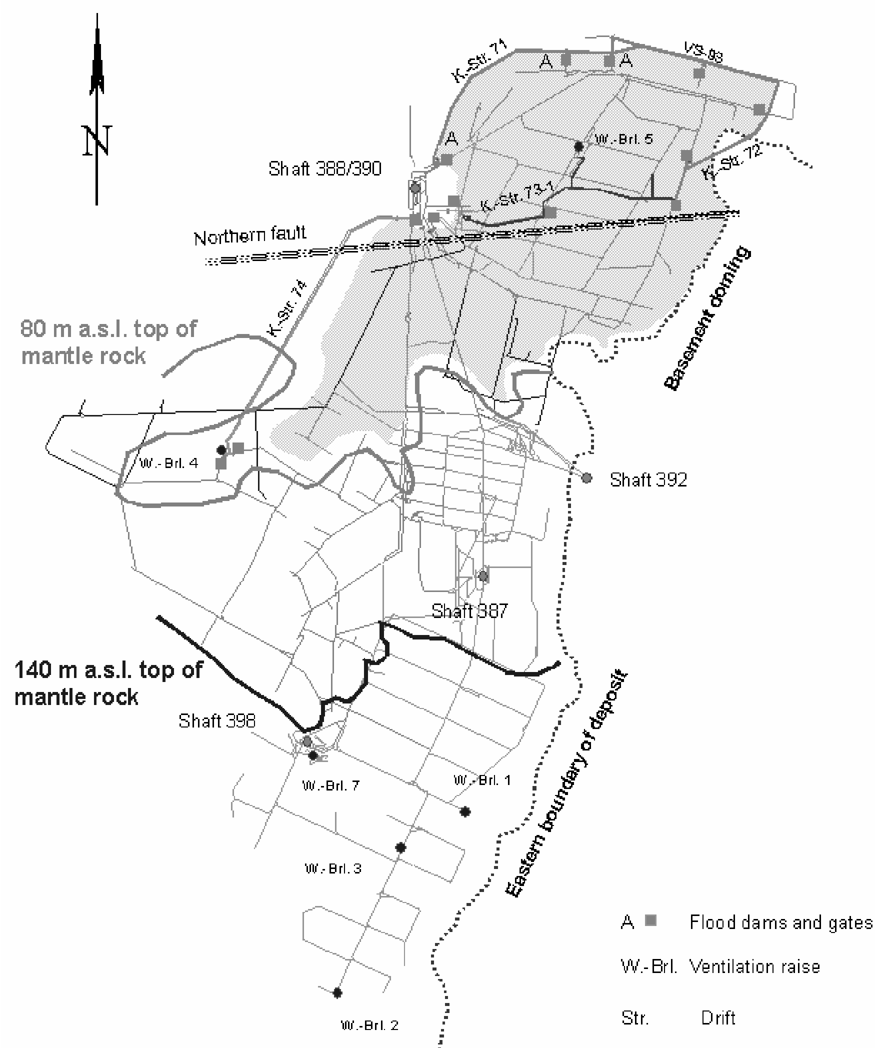

Fig. 5. Contour of flood water raise by April 2002, ca. 79 m a.s.l.

Flooding progress has established proof that the existing tools allow very flexible control of the flooding process. Rise of the flood level was regulated in a range of 0 m/d to ca. 40 cm/d. If need be, the flood level might also be lowered.
Comprehensive and sophisticated systems to monitor the flooding process function flawlessly, ensuring safety of the flooding process and preventing any environmental hazards.

The course which the flooding has taken until now indicates that the prognoses underlying the design and sizing of the technical systems were sufficiently accurate. But it demonstrated at the same time that prognoses made for the evolution of a natural system are afflicted with uncertainties and that local phenomena cannot in any case be readily predicted.

Selected Examples of Prognoses and Reality

Drainage volumes: one of the greatest difficulties in establishing prognoses for flooding the Königstein mine was to predict the drainage volumes which would accumulate in the control drift as a function of the flood level. Based on the findings from the flooding experiment, numerous detailed studies and in particular on the experience gained from many years of underground leaching it was possible to narrow down the probable range of pillar permeability. For the flood level rise to 140 m a.s.l. it was assumed that the available groundwater volume of about 450 m^3/h would suffice to reach the level of 140 m a.s.l., i.e. that the drainage would not exceed the flood water volume of 450 m^3/h. The capacity of water treatment installations was designed accordingly to handle 500 m^3/h.

When flooding was underway, there was noticeable drainage in the control drift as early as in March 2001. At a flood level of 50 m a.s.l. drainage rose to ca. 40 m^3/h. With the rise of the flood level from 50 m a.s.l. to 80 m a.s.l. the entire northern pillar in the control drift zone was submerged and drainage volumes rose. In April 2002, ca. 180 m^3/h drainage water were collected in the control drift and pumped for treatment. As this drained volume does not yet correspond to steady-state conditions, one has to anticipated a further increase with stationary flood water level. In the light of developments until now it is assumed that the design flood water level of 140 m a.s.l. may be reached with the available groundwater quantities. A more accurate assessment can only be made once steady-state conditions have established at a flood level of 80 m a.s.l. Uncertainties will nevertheless remain since the rise of the flood water level to 140 m a.s.l. will affect new pillar areas of unknown drainage behaviour.

Hydrochemistry of the flood water: Fundamental processes which determine the flood water composition and its development over time as the flooding proceeds could be established by the flooding experiment and accompanying studies (Jenk and Schreyer 2001).

During the flooding experiment it was already found that the obtained data would only allow summary assessments of the total system behaviour. A major shortcoming of the flooding experiment was the failure to establish by experiment or to narrow down the impact of the drainage pillar on flooding water composition. Therefore, there was no appropriate data for the calibration of prognosis tools.

With the flooding level reaching 140 m a.s.l. the prognosis predicted e.g. discharge with the flooding water of about 800 t uranium, up to 40,000 t sulphate and up to 10,000 t iron. With the flooding running for 15 months now and a flood water level at 80 m a.s.l., discharge up to now amounts to ca. 120 t uranium, 4,000 t sulphate and 1,000 t iron. This means that contaminant discharge on the whole is within the anticipated range. But it also turned out that some locations of the drainage pillar showed concentrations which strongly deviate from predictions. For instance, flood water draining from the pile at the location of the former main shafts showed uranium concentrations of up to 7 g/l und pH-values of below 1. This resulted in temporary uranium concentrations in the pumped off flooding water of about 250 mg/l. Anticipated average uranium concentrations were in the order of 60 mg/l.

Altogether, the flood water rise to 80 m a.s.l. showed sufficiently good matching with prognoses. On the other hand, it was obvious that a complex natural system like flooding of the Königstein mine is no obvious subject for detailed predictions. Presently available data does not allow to check prognoses for the temporal behaviour of the overall system.

Summary

The concept of controlled flooding was definitely confirmed by the course flooding has taken. On the other hand, there was no trend in the flood process outside the subjects/items covered by the predictions. Local deviations are readily detected by the underground monitoring system. In such case, flood control by means of the unflooded control drift allows appropriate intervention into the overall process and prevents that such local deviations might cause any environmental impact.

Establishment of stationary conditions with a flood water level at 80 m a.s.l. in late 2002 will provide a database that will allow to further hone the existing prediction tools. It will then become possible to provide verifiable prognoses for a number of flooding options beyond the level of 140 m a.s.l. Such prognoses will then serve as a decisive basis for decisions on the final flooding phase.

References

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