Implications of Predicted Hydrologic Changes on Lake Senftenberg as Calculated Using Water and Reactive Mass Budgets

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Abstract. Lake Senftenberg, Germany, is a post-mining lake that was flooded 30 years ago. It is anticipated that the levels of the surrounding post-mining lakes will rise, and that this will lead to a reversal of groundwater flow and consequently to an increase of acidifying groundwater flux into the lake. A tool to predict the future water quality of Lake Senftenberg has been developed. Present and future groundwater fluxes were calculated using a 3D hydraulic model of the surrounding aquifers. Oscillating hydraulic fluxes within the saturated and the unsaturated zones of the island within the lake, caused by continuous lake level changes, were calculated using a 2D sub-model. Mass fluxes into the lake from the aquifers, from the island, and from the River Schwarze Elster were determined by sampling or by laboratory experiments and were coupled with the hydraulic fluxes. The fluxes of acidifying components from the island sediments and sulfide oxidation products from drained zones were determined in laboratory experiments. Sediment erosion due to rill and gully formation after significant lake level change was calculated. The amount of acidifying compounds released from the eroded sediments was determined by laboratory experiments. The input of alkalinity due to the sedimentation of biomass was estimated. Gaseous partial pressures and mineral phases were used to describe the geochemical boundary conditions of the resulting lake water.

Key words: Acid mine drainage, Niederlausitz post-mining area, sediment leaching, transport modeling, water management, water quality prediction

Introduction

The Niederlausitz mining district in eastern Germany is currently undergoing radical changes. In the 1980's, the area was part of one of the world’s largest lignite producing districts, but in 1990, most of the open-pit lignite mining activity was shut down, so that only five out of about 50 mines remained operating. Extensive mining had created a huge groundwater cone of depression (Figure 1). The water deficit for the Lausitz district in 1990 was estimated to be 9 billion m$^3$ of groundwater, including 4 billion m$^3$ of remaining open pit space that will form lakes.

Water management was centralized in the government-owned mining company and groundwater extraction measures of the individual mines were combined into a regional water management network. Groundwater flow modeling became necessary for decision making. The porosity and hydraulic conductivity parameters were defined for a large area model covering the entire Niederlausitz district, and local sub-models were refined with horizontal 500 x 500m and 125 x 125m grids using the finite volume simulation code GEOFIM (Both et al. 1990).

The mining administration agency Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft (LMBV) was formed to plan and conduct the remediation of the water deficit. Replenishment of the water deficit by natural groundwater recharge was estimated to be so slow that it would take around a century to re-establish natural steady-state flow. In most places, pre-mining groundwater levels could not be set as remediation goals, because urban development had occurred during the mining period in areas of formerly higher groundwater table. Therefore, a "near-natural, self-regulated water budget (hydrologic system)" approach was chosen. A total lake volume of 2.2*10$^9$ m$^3$ will be added by the flooding of 40-50 separate lakes. The distribution of the surface water and the interconnection of the lakes are key questions. Additionally, potential impacts of the hydrologic changes on water quality are not only a problem specific to Lake Senftenberg, as described in this paper, but also must be considered for most lakes in the area.

To achieve rehabilitation in a time period of decades and to minimize soil mechanics and water quality problems, it was decided that water from the rivers Spree, Schwarze Elster and Neiße would be used to eliminate the cone of depression and refill the pits.
Figure 1. Groundwater cone of depression in the Niederlausitz mining district located about 100 km south of Berlin, Germany. The approximate area shown is 70 x 60 km (LMBV 2001).

Most of the construction and grading to provide suitable shorelines has been completed during the past ten years, and a number of lakes are already being flooded. Most lakes will reach their final water levels before 2005, though some will not be filled until about 2015. However, problems are generated first, due to landslides occurring on the slopes of the overburden dumps during the rewetting of the sediments, and second, due to degradation of water quality from acid mine drainage.

The latter problem arises because the Tertiary (Miocene) lignite seam and its overburden contains pyrite and marcasite, and so acid-producing materials are present in the unsaturated overburden dumps. Leaching from runoff and from groundwater passing through these dumps transports ferrous iron and aluminum into the surface waters, where oxidation and precipitation cause the familiar effects of acid mine drainage. Flooding pits with surface water counters acidification by importing alkalinity and by cutting down groundwater inflow into the rising lakes. Whether this is a sustainable measure strongly depends on the local hydrogeologic setting, the interaction of the surface waters with ground water and the water management strategy. The local hydrogeological setting is controlled by a number of factors, of which the regional flow system and the geochemical material properties are the most important. Our objective was to provide a water management tool that takes into account regional groundwater and surface water flow as well as hydrochemical reactions, and that can be used in the decision making process during rehabilitation. The quantity of surface waters is limited, and therefore using them to flood mines potentially creates a conflict with other surface water users in the area. Therefore, the use of surface water to flood mines must be well justified.

In this study, all of the acid sources were added to determine the overall effect on the lake. First, the hydrologic budget was determined using a groundwater flow model. Second, the water quality of the ground and surface water fluxes was determined. Finally, further mass fluxes into the lake due to the leaching of bank sediments and to biological production were quantified.

Site description

Besides the large number of post-mining lakes that are in the process of being flooded, the Niederlausitz area also contains a smaller number that were flooded in the past. One of them is Lake Senftenberg (Figure 2), which was flooded 30 years ago using water from