FLOODING OF THE SAAR-LORRAINE COAL MINES: COUPLING OF THE REGIONAL MODEL OF THE LOWER TRIASSIC SANDSTONES AQUIFER WITH A "BOX" MODEL OF THE MINING RESERVOIR

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ABSTRACT: Charbonnages de France (CdF) and Deutsche Steinkohle AG (DSK) has mandated the ANTEA/DMT working group to draw up a transborder groundwater / mining reservoir coupling model for the Center-East sector. This coupling makes it possible to calculate pumping flows, according to pressure losses between mines, in order to prevent brackish water intrusion from mines to the Lower Triassic Sandstones aquifer.

KEYWORDS: FLOODING, COUPLING MODEL, MINING RESERVOIR, LOWER TRIASSIC SANDSTONES AQUIFER.

RESUME: Les sociétés Charbonnages de France (CdF) et Deutsche Steinkohle AG (DSK) ont mandaté le groupe de travail ANTEA/DMT pour élaborer un modèle couplé nappe / réservoir minier transfrontalier sur le secteur Centre Est. Ce couplage permet de calculer en fonction des pertes de charge entre les mines, les débits à pomper de façon à empêcher les eaux minéralisées de la mine de remonter dans la nappe des grès du Trias inférieur.

MOTS-CLEFS: ENNOYAGE, MODELE COUPLE, RESERVOIR MINIER, NAPPE DES GRES DU TRIAS INFERIEUR.

1. Introduction

In agreement with the French company Charbonnages de France (CdF), Deutsche Steinkohle AG (DSK) has mandated the ANTEA/DMT working group to draw up a transborder model for dealing with groundwater in the main mining areas in Lorraine and Germany (cf. fig. 1) The aim of this modelling exercise is to couple the model of the Lower Triassic Sandstones (LTS) aquifer with the BOX model of the mining reservoir (Centre-East sector) so as to provide answers to the important hydrogeological issues arising as a result of the planned mine closures and the flooding that results from them.

The technical reason for this initiative is the fact that no uniform water level will be established in the mining reservoir. This implies that the behaviour of the flooding volume flows between the mining concessions is highly complex and can no longer be estimated by means of simple analytical evaluations.

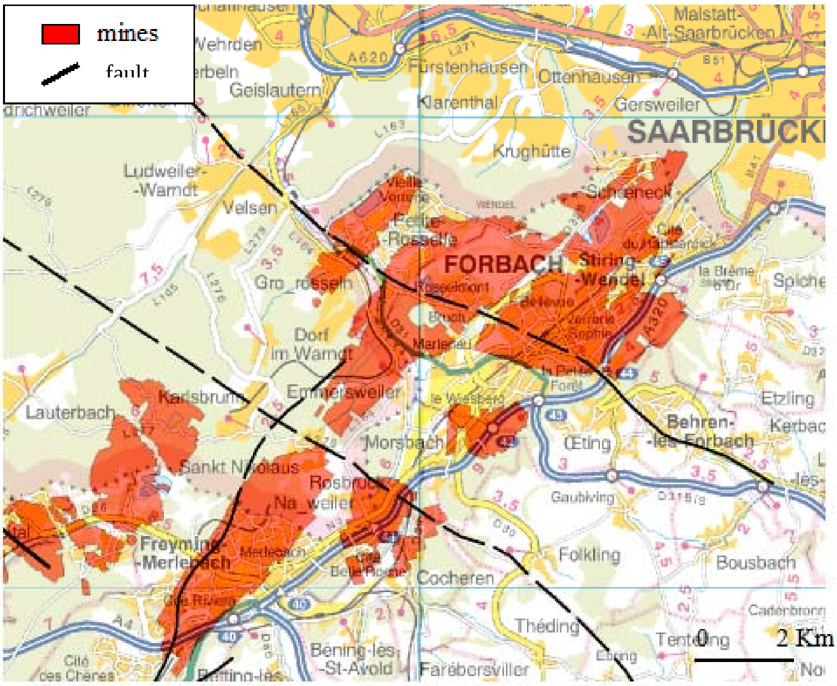

Figure 1: Saar-Lorraine coal mines (Centre East sector)

2. Coupling of the hydrogeological model of the LTS aquifer with the BOX model

ANTEA's VAL hydrogeological model and DMT's BOX model operate according to the so-called "volume evaluation" method. They use square meshing, which facilitates the production of a common grid. The advantage is that complicated couplings such as the transmission of volume flows between the models can be eliminated. It also allows calculations to be carried out in a transient state on the rise of the water level with interaction between the mines and the LTS aquifer.

The overall model consists of 26 layers, the first section of which represents the LTS aquifer. The other sections in the model consist of 17 evaluation units corresponding to individualised mining reservoirs (BOXES). The coupling of the two models is shown in Figure 2.

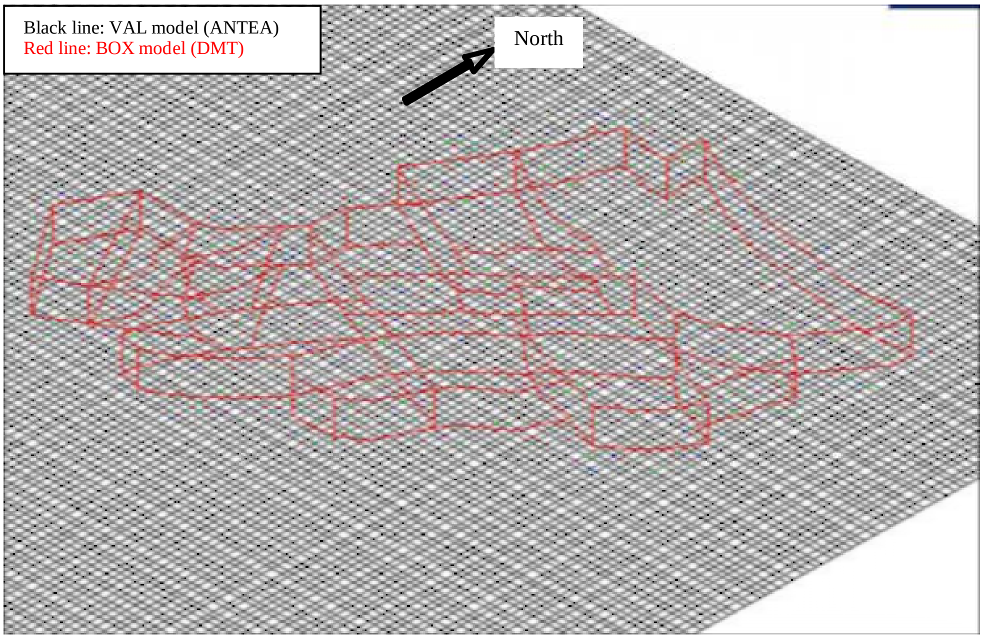

Figure 2: Coupling of the hydrogeological model of the LTS aquifer with the BOX model

3. Long-term future status forecasts of the overflow rate at the Gustave shaft

For reasons of security, simulations have been carried out with different hydraulic conductivities for the galleries. The variation in this parameter plays an important role in the water levels in the different mining areas (BOXES).

- "Optimistic" variant (hydraulic short-circuit between the galleries)

The differences in level which appear in relation to the discharge level at the Gustave shaft are negligible in all the BOXES due to the fact that the galleries are in a hydraulic short-circuit. The overflow rate at +192 m NGF (French datum level) at the Gustave shaft is very high: 12 m^3/min.

- "Realistic" variant (average hydraulic conductivity of the galleries)

In the case of this variant, differences of a few decimetres appear in the Forbach box to the East and in the Merlebach box to the South as well as differences of approximately 4 to 5 m between the Gustave shaft and the Forbach area, and 7 to 8 m between the Gustave shaft and the Merlebach area (cf. fig. 3). The overflow rate at +192 m NGF at the Gustave shaft is 8.4 m^3/min.

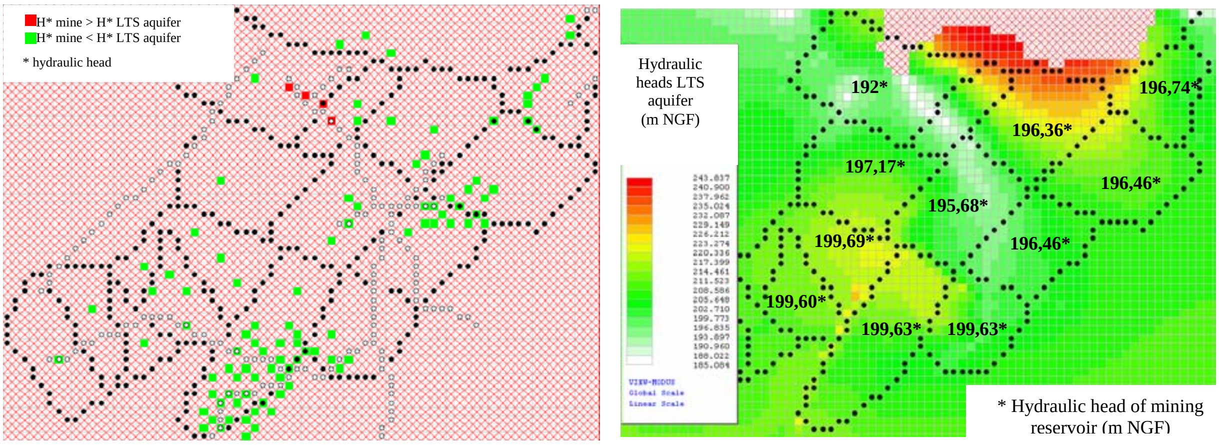

Figure 3: realistic variant

➢ "Pessimistic" variant (very limited hydraulic conductivity of the galleries)

The pressure losses induced by the low hydraulic conductivity of the galleries lead to increases in pressure in the mining reservoir in relation to the LTS aquifer in the Freyming-Merlebach and Forbach sectors (cf. fig. 4). This situation causes a risk of contamination of the LTS aquifer by the waters from the mining reservoir. On the other hand, the overflow rate at +192 m NGF at the Gustave shaft is now only 3.2 m^3/min.

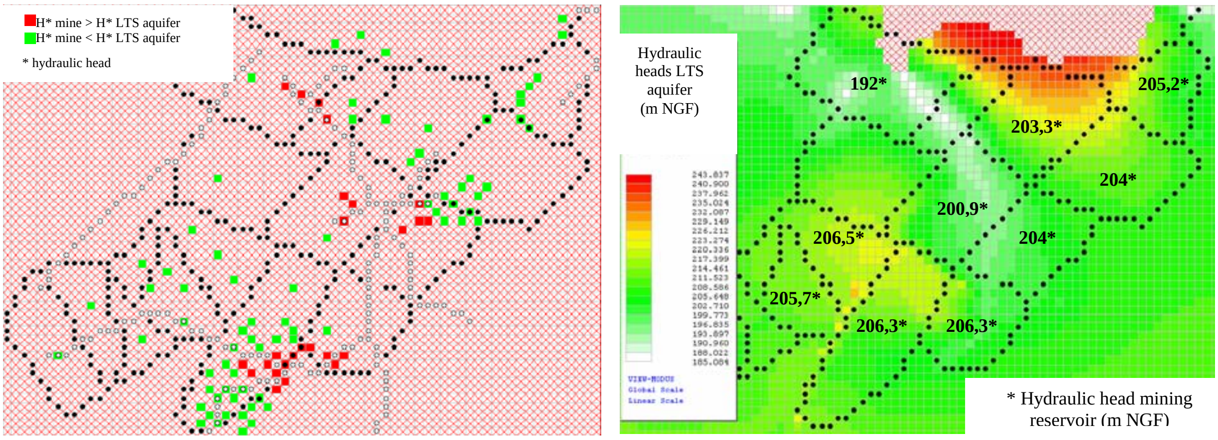

Figure 4: pessimistic variant

4. Behaviour over time of the final flooding phase

Due to the importance of the flows entering from the French side, the workings will be filled up in just a few years. The rate of rise of the water level, however, slows considerably when the level of the mine water in the workings comes close to that of the great piezometric depressions in the Lower Triassic Sandstones (cf. fig. 5). This rate of rise of the water level in the final phase depends to a great extent on the porosity of the Sandstones, in other words on its absorption capacity.
The BRGM estimates the absorption capacity of the Sandstones due to its porosity to be 10 %. This value was worked out on the basis of the interregional hydrogeological model. On the other hand, locally, the measures taken by the HBL on the boring samples of LTS give a porosity of approximately 5 % only. We must accept here that that laboratory studies do allow the fracture systems to be taken into account. The total absorption capacity due to porosity can only be judged

by means of observations in the evaluations of larger areas. As a result of these uncertainties, we will look at not only the 10% hypothesis, but also that of an absorption capacity of 5%.
The work of HEITELE argues in favour of the hypothesis of relatively high porosities. In this document, effective porosities varying between 5 and 15% have been determined on samples of Lower Triassic Sandstones. The document indicates on this subject that: "As Lower Triassic Sandstones contains a low proportion of binders coming from ferrous and clayey minerals with a homogenous granulation, which could be qualified as averagely to roughly clastic, this may explain the relatively high level of its porosity".

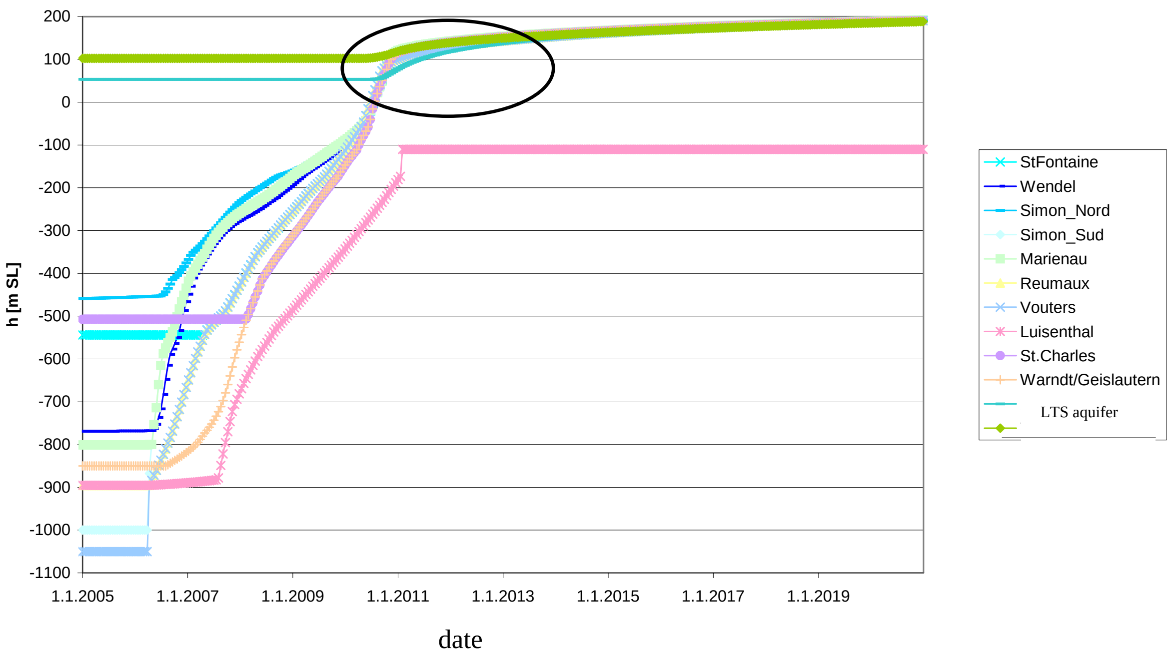

Figure 5: Flooding phase and final phase of the rise of groundwater (porosity 5%)

The next figure shows an extract from the first phase of the rise of water level in the Lower Triassic Sandstones:

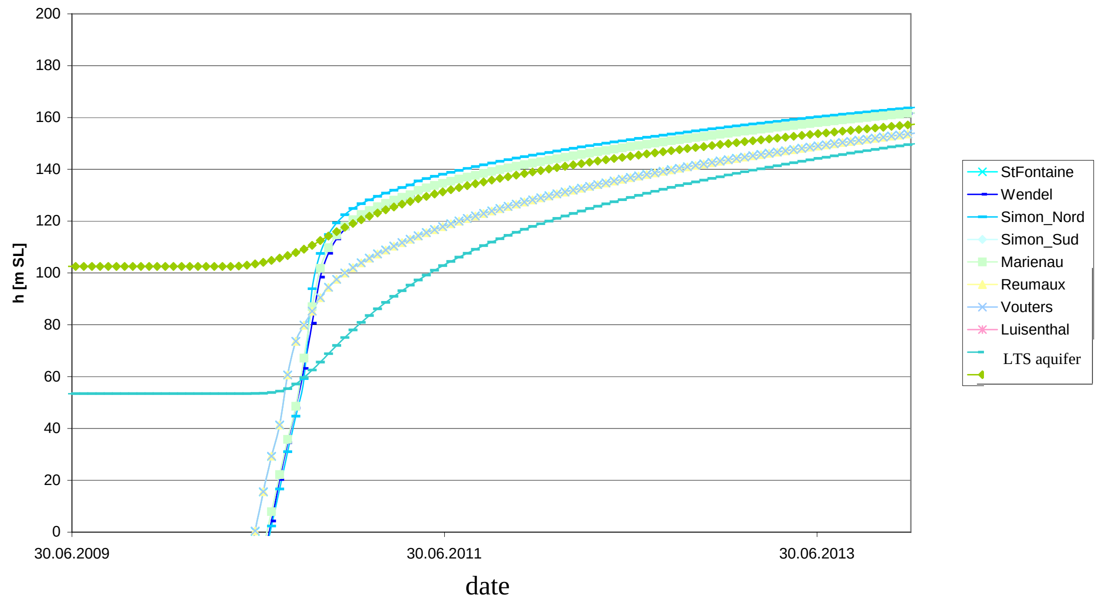

Figure 6: Extract from the flooding phase and the final rise of the groundwater (porosity 5%)

The following figure shows the rise in the final phase in the event of 10% LTS porosity. Furthermore, a small residual void has been integrated into the calculation which is likely to fill up, which leads to a slightly more rapid rise of the water level in the mining reservoir. As a result, the workings will also be flooded approximately six months earlier. This half-year is, however, negligible compared to the much longer total flooding period that we find with a 10 % porosity.

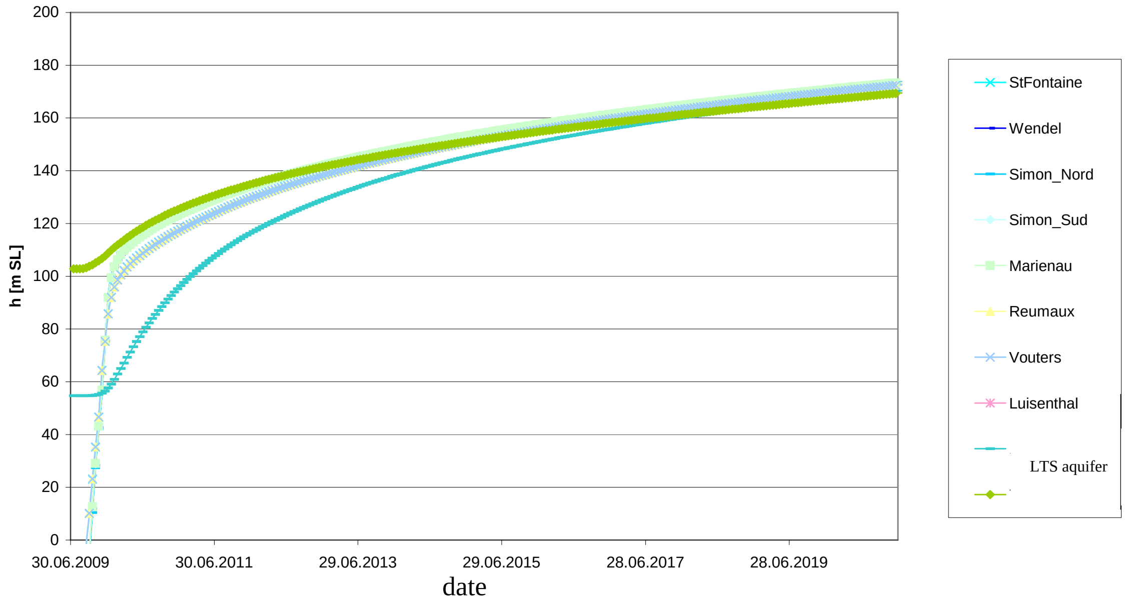

Figure 7: Flooding phase and final phase of the rise of the groundwater (porosity 10%)

An analysis of the rise curves clearly shows that over a period of time of 3 to 5 years, once the mining reservoir is almost full, there will temporarily be sectors where the water levels in the mining reservoir will be higher than in the LTS aquifer, which will create an upward flow. These are in particular the sectors where the piezometric funnels of Vouters and Marienau/Wendel are situated. This phenomenon can be explained by the fact that at other infiltration points away from the cone of depression, the flow of the water from the LTS aquifer continues downwards; this water, however, spreads inside the mine so as to form a relatively uniform water level, which may be higher locally than the water level in the LTS aquifer.

Due to the fact that the boundary conditions of the model for the status "drawdown – current situation" and "final phase" are specified separately depending on the problems that arise, a problem remains in calculating the total flooding until the final status. As far as the curves above are concerned, the model has been started from "the current status". In this way, we keep these boundary conditions for all the calculation, which leads to a lack of precision in the final phase of the calculation. Given the problems to be dealt with, the exact way in which the last stage of the final phase rolls out over time becomes of secondary importance, which makes it possible to tolerate these deviations at this stage.

5. Conclusions

The maximum overflow rate in the final flooding phase of the Gustave shaft is 12 m^3/min. This flow rate is calculated for an optimistic option in which the galleries retain all their hydraulic conductivity. In a rather more "realistic" option, the overflow rate is reduced to approximately 8.5 m^3/min, due to differences in level of approximately 4 to 5 m between the Gustave shaft and Forbach and approximately 7 to 8 m between the Gustave shaft and Merlebach, due to the deterioration in the conductivity in the galleries.

In the event of very poor hydraulic properties of the galleries (pessimistic variant), the water levels on the French side exceed the +200 m NGF mark in the mining reservoir. Consequently, the volume flow towards the Gustave shaft is reduced to approximately 3-4 m^3/min. This hypothesis leads us to fear a rise in the mine water level in the Lower Triassic Sandstones, in particular in the Rosselle valley area.

Before arriving at the long term future status, a very slow final phase of filling up the LTS aquifer should be expected after the very rapid filling up of the mining reservoir. The time needed to fill the LTS aquifer from a level of 100 m NGF up to the level of the Gustave shaft (+192 m NGF) will be at least 15 years (LTS porosity of 5%), but will probably be considerably longer (porosity of the Sandstones of 10%).

An analysis of the rise curves clearly shows that over a period of time of 3 to 5 years, once the mining reservoir has filled up first, there will temporarily be local sectors where the water levels in the mining reservoir will be higher than in the LTS aquifer, which will lead to an upward flow. These are in particular the cones of depression (Vouters and Marienau/Wendel).

To avoid the contamination of the Lower Triassic Sandstones aquifer by the intrusion of brackish mine water it will be necessary to dewater in different sectors of the mining reservoir in order to keep the hydraulic head of this reservoir lower than that of the Sandstones aquifer.

To avoid the risks (even in the pessimistic hypothesis), the method of management chosen by CdF is pumping at the Vouters and Simon 5 shafts (in France), maintaining a water level at about + 193 m NGF in the mining reservoir; the residual flow rate at the Gustave shaft will then be very low.

6. References

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