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Phone: +370 5 2745090; Fax.: +370 5 2744731; e-mail: ap2008@ap.vgtu.lt

INSUFFICIENT INITIAL DATA AS A CAUSE FOR BUILDING UNTRUE MODEL OF TCE – CONTAMINATED BERNAU PLACE, GERMANY

Aivars Spalvins, Janis Slangens, Romans Janbickis, Inta Lace

Environment Modelling Centre, Riga Technical University, 1/4 Meza Str., Riga, LV-1048, Latvia
E-mail: emc@egle.cs.rtu.lv

Abstract. The Bernau place (Germany) is heavily polluted by trichloretilene (TCE). In 2001, to remediate the place, a cleaning plant (CP) has been started. It occupies the original TCE spill area. Initially, it was believed that the nearby located TCE - contaminated pool was the natural sink for the original spill body. A hidrogeological model (HM) was built to simulate spatial migration of this dense pollutant. In 2005, it was found out that TCE from the spill area cannot reach the pool. The second, unknown before, TCE spill was detected in the vicinity of the pool. Therefore, the hydrogeological and contamination processes proved to be quite different from the ones assumed initially. It was necessary to reconsider the place remediation plans and to implement the new knowledge in HM. The case shows how incompleteness of initial data can result in building of wrong HM.

Keywords: Hydrogeological model, modelling of contaminant migration, initial data.

1. Introduction.

During 1935-1990, two overlaying aquifers of the Bernau place (30 km northeastward of Berlin) have been polluted with TCE. It is a dense non aqueous liquid, sinking in groundwater In 2001, the German company INGAAS GmbH has started CP that encloses an accumulator, which feeds a reactor where TCE gets dehalogeniated [1]. The accumulator occupies the original TCE spill area that is framed by a vertical wall (Fig. 1).

Rather complex hydrogeological models (HM) have been created (Fig. 1) for comparative regional and local modelling of tools (walls, drains, withdrawal of TCE through wells, etc.) that may be used for remediation of the place [2, 3, 4, 5, 6, 8, 9]. The Groundwater Vistas system [10] was used for creating of HM and modelling of the TCE migration.

Initially, it was believed that the Teufel pool was the main natural sink area that collected TCE emitted by the original spill. Both sand aquifers *L2* and *L3* were TCE – contaminated. In HM, they were divided in subaquifers, in order to simulate the spatial migration of this dense pollutant. The plane approximation steps h=10m and h=2.0m were applied for regional and local HM, accordingly.

The initial assumptions about the role of the Teufel pool were based on data collected in the vicinity of CP and on the fact that TCE was found in the pool. It seemed obvious that pollution of the pool was caused by the contaminant migration from the original spill area.

During the project, additional monitoring wells were installed. Data provided by these wells proved that the initial assumptions about the cause of the pool contamination were false.

In 2005, it was found out that TCE cannot reach the Teufel pool via the *L2* aquifer and the second TCE spill area was discovered nearby the pool. In this paper, the necessary corrections of HM are described. The reported case illustrates importance of complete initial data for building of HM.

2. Reasons causing corrections of HM

Principial corrections of HM were needed, due to the following new information presented:

- the second, not known before, source of TCE was discovered at the Teufel pool western side (Fig. 2);

in the *L2* aquifer, a peat body was found that prevented migration of TCE from the CP area

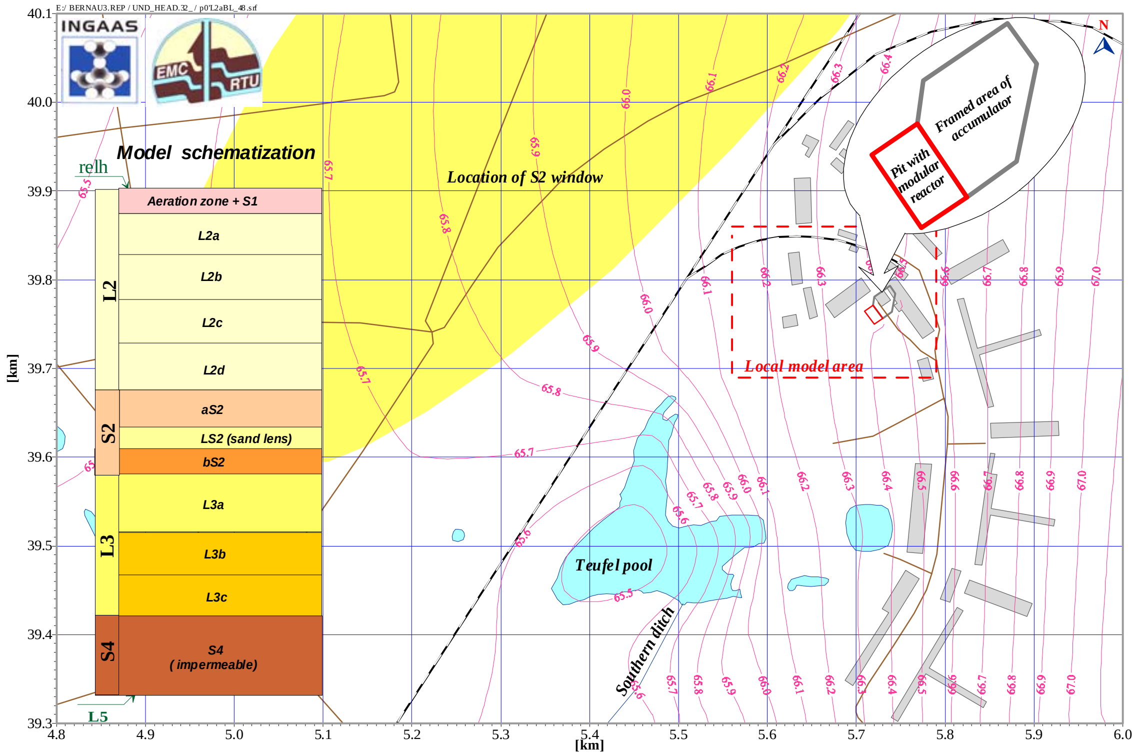

Fig 1: Original HM. Computed head [m asl] for the *L2* aquifer. Model schematization.The system of accumulator - reactor

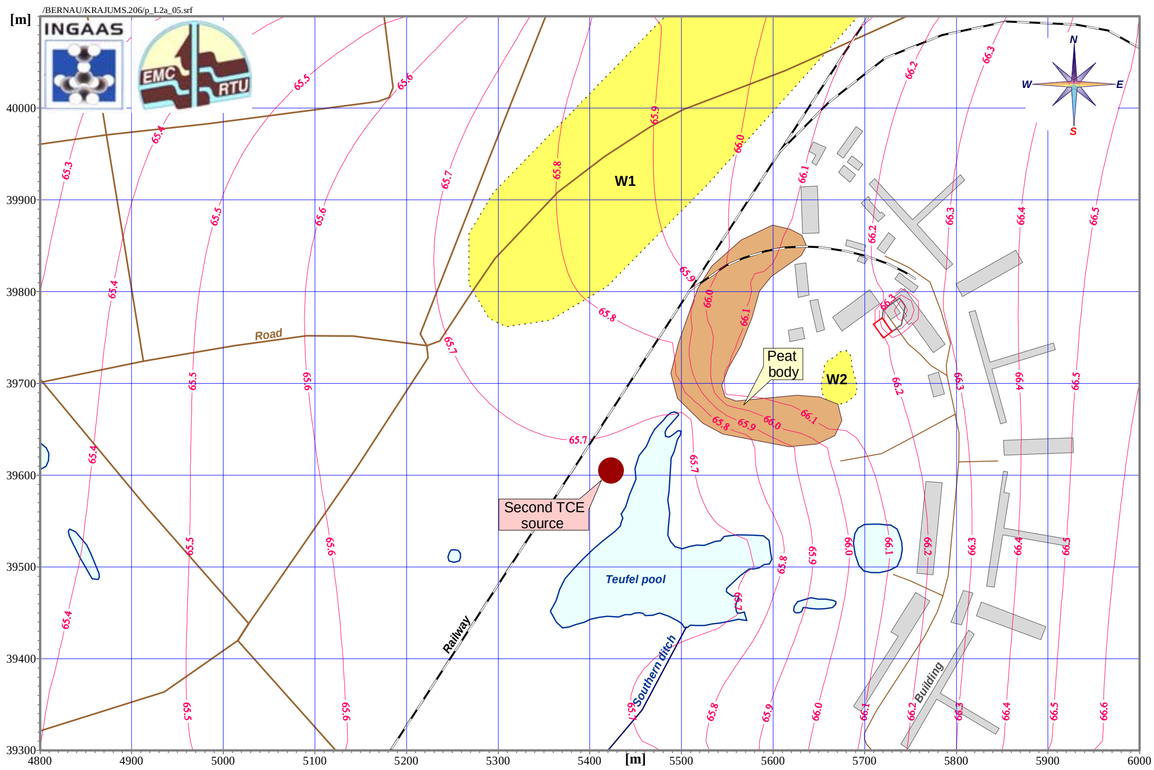

Fig 2. Corrected HM. Computed head [m asl] for the *L2* aquifer; W1, W2 windows of the *S2* aquitard

- (location of the first TCE source) towards the Teufel pool;

- in the *S2* aquitard, the area of the large hypothetical

- hydrogeological window W1 was considerably reduced and a new hydrogeological window W2 was arranged in the area where TCE from the *L2* aquifer may enter the *L3* one;

- in the *L3* aquifer, its SW-corner area of HM was turned impermeable.

The following minor changes have been made with respect to the original regional HM [2] that is used as a base for corrected HM:

- the boundary conditions of the *L2* and *L3* aquifers have been slightly changed to meet the principal corrections of HM;
- in the *L2a* subaquifer, to account for the Teufel pool depth, the volume beneath the pool surface has been turned into a body of the pool;
- for the recharge areas, more realistic variable infiltration flow distribution has been used instead of the constant one;
- to simplify forming of HM, no vertical anisotropy of aquifers has been accounted for;
- to simulate sinking of TCE in the *L3* aquifer, a descending flow through the *S4* aquitard is created by using the formal aquifer that is located beneath the *S4* aquitard.

Some corrections of HM (hydrogeological windows W1, W2; introducing the impermeable area of the *L3* aquifer) were accomplished by changing permeability of geologic layers. Temporarily, no changes of the original HM geometry were made.

To confirm the new understanding of how TCE migrates in the Bernau area, experiments on the TCE transport have been accomplished by applying corrected HM [7].

In Fig. 2, the computed head distribution for the *L2* aquifer of corrected HM is shown. It follows from comparison of the head distributions given by Fig. 1 and Fig. 2 that these distributions differ slightly even for their versions obtained by using HM. Due to a small hydraulic gradient of the *L2* aquifer, initially, it was practically impossible to detect the peat body by using monitored water levels of the pool and of the few wells that were located nearby the firstly detected TCE spill of the CP place. The Bernau case illustrates that sensible hydrogeological reasoning that is based on apparent data may be completely wrong. Unfortunately, no one is guarded against making false decisions when available information is not complete.

3. New hypothesis about the TCE migration

Contamination of the Bernau area is caused by two TCE sources located in the *L2* aquifer at CP and at the Teufel pool, accordingly.

TCE from the CP area migrates westward, sinks through the *S2* aquitard, especially, in the locus of the newly introduced hydrogeological window W2. When TCE has entered the *L3* aquifer, it migrates westward and also accumulates (due to TCE sinking) on the surface of the *S4* aquitard. No TCE from the CP area can reach directly the Teufel pool via the *L2* aquifer, because the eastern side of the pool is blocked by the massive peat body (Fig. 2).

In the *L2* aquifer, the Teufel pool is a sink for the groundwater flow. Normally, the pool level is lower than the heads in the *L2* and *L3* aquifers. Then TCE from the recently discovered spill area goes into the pool. The steady state corrected HM presents the case when the pool acts as the sink.

The Teufel pool acts as the source for the *L2* and *L3* aquifers if a water level of the pool is higher than the heads of these aquifers. Such a situation has been monitored during January, 2005. Then in the *L2* aquifer, TCE migrates westward from the pool. When some amount of TCE has migrated far enough, TCE will continue slowly migrate westward even if the pool acts, as the sink. This fact has been confirmed by presence of TCE discovered there [7].

The Teufel pool collects surface runoff water from rather large area, because outputs of two stormwater sewage systems feed the pool. Due to this reason, the pool will act as the groundwater source if the precipitation rate is high and the level of the pool is not kept low by opening its water exit gate. Unfortunately, water of the pool is TCE polluted. Therefore, the gate of the pool cannot be opened permanently, in order to keep the pool in the sink regime.

It follows from the above considerations that the new hypothesis regarding contamination transport is much more complex than the initial one based on the assumption that only a single TCE source exists and the pool is contaminated due to TCE migration from this source.

4. Modelling of TCE migration

In order to confirm that corrected HM matches the new hypothesis, some tests on the TCE migration were performed for the both TCE sources. The MT3D type system was used [11] and the MOC (Method of characteristics) method was applied. The following transport parameters were used: the active porosity 0.25, time step 50 days, the dispersion coefficients: D_L = 0.2; D_T = 0.2; D_v = 0.1. The results were obtained for the elapsed time 5000 days.

Two concentration cells C_S = 100 mg/l modelled influence of the both TCE sources. One may also interpret the results as the relative ones, in percent. The cells were located in the *L2d* aquifer: the first and the second ones were placed in the W2 area, and in the locus of the second TCE source, accordingly.

The MT3D system cannot simulate properly migration of dense pollutants, like TCE. For this reason, a descending flow through the layer *S4* is artificially applied. It caused sinking of TCE in the *L3* aquifer and passing of TCE through the aquitard *S2* in the area W2.

In Fig. 3, the modelled concentration distributions caused by the first TCE cell are shown:

-TCE from the aquifer *L2d* sinks through the W2 window of the aquitard *S2* and enters the *L3* aquifer;

-in the *L3* aquifer, TCE migrates westward; the concentration in the *L3a* subaquifer is smaller than in the *L3b* and *L3c* ones; it confirms the sinking of TCE.

In Fig. 4, modelled concentrations caused by the second TCE source are shown, if the water level of the Teufel pool is 0.3 m higher than the average one. In this case, TCE migrates westward from the pool, as it should be, according to the TCE data monitored there.

When water level of the Teufel pool is normal, TCE from the second source migrates towards the pool and TCE enters into it. Therefore, water of the pool is TCE contaminated due to presence of the second minor TCE source that was found much later than the main TCE spill. Practically, no TCE enters the *L3* aquifer, if elapsed time is 5000 days.Emission rates of the two TCE cells applied for modelling were estimated:

- 245g/day and 20g/day, accordingly, for the first cell (W2 area) and the second one when the Teufel pool level was normal;
- 6g/day for the second cell when the Teufel pool level was 0.3m higher than the average one.

Therefore, the original main TCE spill area causes much larger contamination than the second one discovered later.

It follows from results of TCE migration modelling that corrected HM rightly simulates events discovered by latest field studies at the Bernau place.

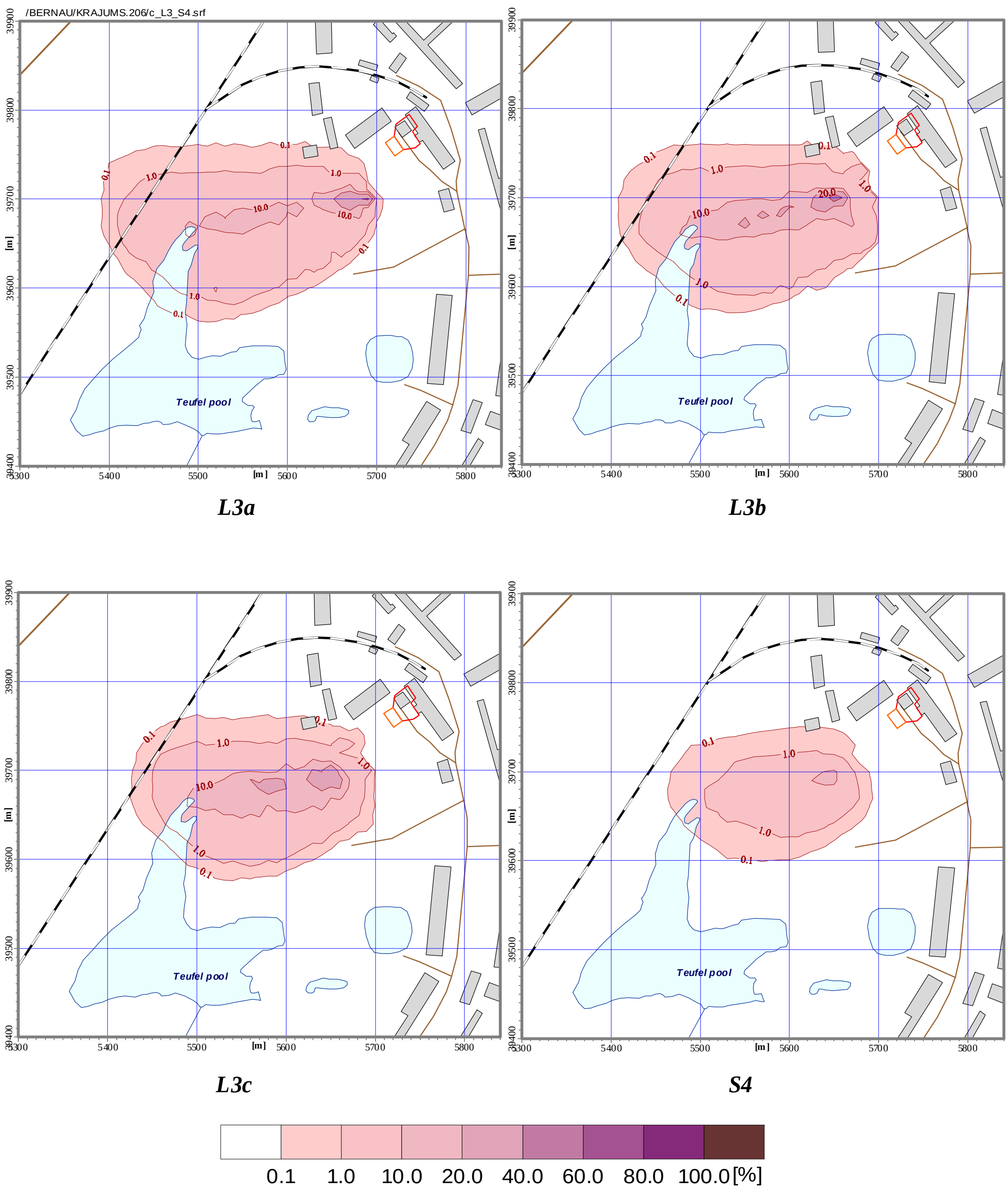

Fig 3. The first TCE source. Elapsed time 5000 days. Modelled TCE concentrations [mg/l] for the *L3a, L3b, L3c, S4* layers

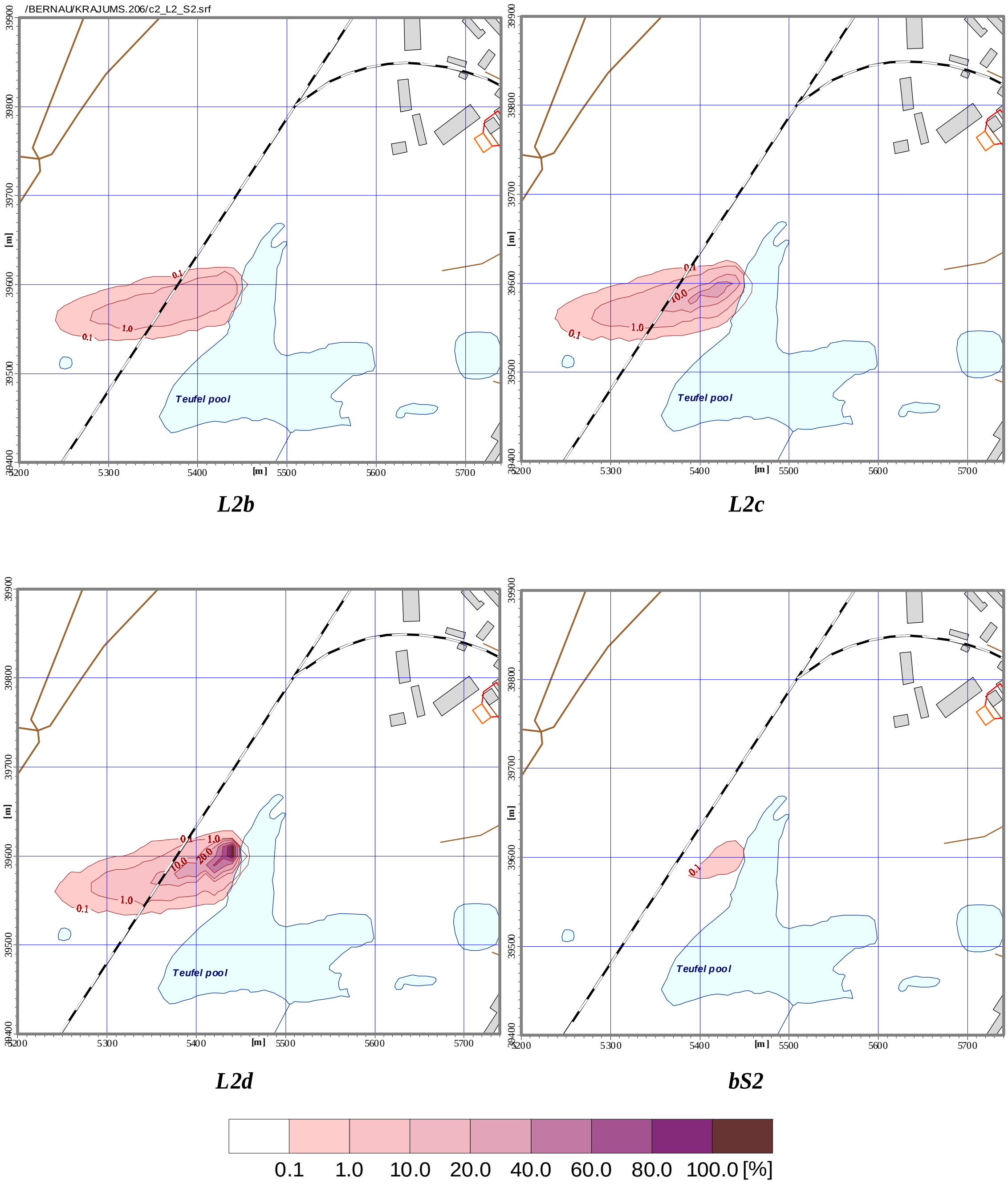

Fig 4. The water level of the Teufel pool is 0.3m higher than the average level. The second TCE source. Elapsed time 5000 days. Modelled TCE concentrations [mg/l] for the *L2b, L2c, L2d, bS2* layers

5. Conclusions

1. The reported Bernau case illustrates that incomplete initial data of the place hydrogeology and contamination concentrations may lead to a false interpretation of problems to be modelled. Such a mistake may result not only in a wrong model, but also in useless plans of sanitation for the contaminated place. Unfortunately, no one is guarded against making mistakes that are caused by apparent data misleading even experienced hydrogeologists.

2. Due to principal reasons that appeared recently, the hydrogeological model of the Bernau place area has been corrected and tested on matching the new hypothesis about the TCE migration for the Bernau area.

3. The corrected model may serve as the base for other forthcoming improvements and also for investigating possible remediation methods for the Bernau place.

4. Although the corrected model rightly performs main events of the TCE migration, the model is still rather far from perfection, because some principal unknown impacts may not be accounted for. Possibly, it is necessary to create a new model that rightly accounts not only for the TCE migration, but

also for changes of the model geometry that is founded on data provided by the new wells. They deliver information for much larger area than the initial one.

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