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In the course of the development of an enhanced geothermal reservoir at a depth of about 5 km underneath the city of Basel, a felt earthquake of magnitude $M_L = 3.4$ was triggered on December 8th, 2006. The operator's insurance paid out property damages of about 7 million CHF, which were attributed to the earthquake. The geothermal project has been suspended since.

The Kanton Basel-Stadt commissioned a study of the seismic risk resulting from continued development and subsequent operation of the geothermal system (SERIANEX study, <http://www.wsu.bs.ch/geothermie>). Besides seismicity triggered directly by the geothermal project, the study also considers the impact of the geothermal reservoir on natural seismic activity in the Basel region. The principal issue is to what extent the geothermal project may affect the occurrence of a large earthquake. Such an earthquake caused large damage to the city of Basel in the year 1356. To analyse the issue, a 3-dimensional geologic model of the subsurface of the Basel region has been developed. In the wider vicinity of the geothermal reservoir, eight relevant, natural fault zones were identified, each of them large enough to produce large earthquakes. We estimated the seismic activity of these faults, i.e. the time intervals when large earthquakes could be expected to occur on these faults. We found that the geothermal reservoir can have an impact on the recurrence time of these natural earthquakes by modifying subsurface stresses. But, numerical simulations demonstrate that these variations are very small and represent a negligible risk.

In addition, the development and operation of the project is expected to result in seismic activity in the immediate vicinity of the geothermal reservoir. We developed a numerical model to capture these processes, ran computational simulations and used empirical relations to investigate how future seismic activity might evolve. Given the local conditions, there is a high probability that earthquakes exceeding the strength of previous activity will occur during continued development and operation of the geothermal facility.

We expect the biggest event magnitude in the order of $M_L=5$. Further, we anticipate up to 30 felt earthquakes in the development phase, 9 of which might reach or exceed the intensity of the earthquake of December 8th, 2006. Within the operational period of 30 years, we expect 14 to 170 felt earthquakes. To estimate the associated property damage, we analyzed the vulnerability of the building stock within a radius of 12 km around the facility and we developed a seismic risk assessment using probabilistic modeling. Based on expert judgement, we expect no relevant property damages to infrastructural facilities resulting from the induced earthquakes. However, in all likelihood property damage of 40 million CHF is to be expected in case of continued development of the geothermal reservoir. This comprises minor structural damages, which we expect to occur in large numbers due to the high population density. There is a 15% probability, that damages will even exceed 600 million CHF in an extreme case. During the projected facility's operational period of 30 years, the most probable property damage is set at 6 million CHF per year. While the risk of the geothermal project to cause bodily harm is low, the property damage may be deemed as unacceptable according to risk criteria of the Swiss ordinance on major accidents. We reach the same conclusion also by comparing other technical risks in Switzerland, where in some cases potential cumulative damages are less. In light of the considerable property damage risk in Basel, we evaluated alternative concepts for developing the geothermal reservoir at its current location in the crystalline basement. We conclude that none of the concepts considered will completely rule out the occurrence of earthquakes. Therefore, alternative utilization concepts at this location will require a separate risk assessment. From a seismic risk perspective, the location of Basel is unfavourable for the exploitation of a deep geothermal reservoir in the crystalline basement. Other locations in Switzerland may offer a significantly lower seismic risk. A thorough evaluation of site-specific seismic risk should be required for future geothermal project developments in Switzerland. The findings of the Basel risk study constitute an important data point for future risk assessments. After analyses of the data acquired from the suspended project and after comparison with experiences made in other geothermal projects, we consider the Basel earthquakes caused by the geothermal project to have been exceptionally strong.