Mine Health and Safety Council
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Project Title: Fluid-Induced Seismicity in the Central Basin Area: Ground Motion Prediction and the Development of an Early Warning System for Risk Reduction

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Related Projects: -

Category: -

Applied Research -

Summary

Background of the Study
The last active mine in the Central Rand Basin (CRB) area (50 km x 15 km), ceased operations in 2008. This resulted in the closure of the pumping stations, which previously maintained the underground water level in the mining voids. As a direct consequence of the water being allowed to flood the mine voids, seismic activity has increased directly beneath the populated area of Johannesburg.

Methodology
The proposed project addresses the problem of the risks posed by fluid-induced seismicity in the greater Johannesburg area by focusing on accurate quantification of the most important factors that contribute to the estimation of this hazard.

Results of the study
The level of seismicity in the CRB is not showing signs of decreasing with time since the number of strong events with moment (Mw) magnitudes above 1.4 is still as high as it was when monitoring began over five years ago. (see Figure 1)

Most events are located within historical mine boundaries. The seismicity pattern shows a strong relationship between the presence of the mining void and high levels of seismicity; no seismicity migration patterns were observed outside the areas of old mining. 3D modeling showed that residual mining induced stresses are being exploited by the water and also confirmed that the mined out reef is controlling seismicity. Strong lineaments in the seismicity pattern were observed that supported the result of the modeling.

Probabilistic seismic hazard analysis showed a maximum expected magnitude of 5.13 and a maximum value of peak ground acceleration of 0.15g. The highest levels of acceleration were observed in the eastern parts of the CRB. This was expected, since this area produces most of the seismic activity. Low rise buildings with unreinforced masonry, load-bearing walls are the most vulnerable to damage with an expected damage percentage ranging from 5 to 7%. The estimated expected damage is small when compared to the damage experienced in more seismically active areas.

Over the last five years, the total cumulative seismic moment released in the CRB was 9.0x10^{14} Nm. This is equivalent to a single earthquake of magnitude Mw 3.9, which is significantly less than the largest earthquake experienced during mining times.

The temporal evolution of the inter-event time confirms that the fluid-induced seismicity follows a clustering pattern and is not random.

Static stress drop heavily influences ground motion characteristics, which, in urban areas, affects the risk assessment. The observed static stress drop varied from 0.05MPa to 10MPa. It was found that large static stress drops could be associated with both small and large events.

Conclusions:
The nature of seismic events triggered by mine flooding, as well as the damage potential of surface ground motions associated with such events, needs to be monitored and investigated.

Recommendation:
Temporal and spatial changes in the rock mass of the Central Rand Basin imposed by fluid related seismicity should be evaluated continuously for the next few years. Characterization of the dynamic processes in the rock mass is mainly achieved by estimating the values of the spectral parameters of the seismic source. The methodology described in the report should be implemented in all areas where fluid-induced seismicity is observed and a seismograph network on the surface is available.

Figure 1. Bar chart of the seismicity rate over a period of 62 months for events with magnitudes larger than 1.4. The seismicity rate does not show signs of decreasing when examining the numbers of events recorded over the last five years. Instead, a variation in the level of seismicity was observed.