

To: DPLG:Public Submissions

From: Edward Cranswick

Cc: Minister Holloway;

Sent: Friday, 7 August 2009 5:01:48 PM

Subject: Response to Draft Environmental Impact Statement

Stop THE OLYMPIC DAM MINE Expansion

Submission on proposed expansion of the Olympic Dam mine
Response to Draft Environmental Impact Statement

Email: <>

Postal address: Assessment Branch

Dept. of Planning and Local Govt

RE: Proposed Olympic Dam Expansion

GPO Box 1815, Adelaide SA 5001.

SA Planning Minister Paul Holloway <>

Federal Environment Minister Peter Garrett <>

I oppose the proposed expansion of the Olympic Dam mine for the following reasons:

FAILURE TO CORRECTLY ASSESS SEISMIC HAZARD/RISK

Please find my submission on the subject "Seismicity anticipated to be stimulated by BHPs proposed open pit mine at Olympic Dam" in the attached MS-Word-compatible file <SeismicityAnticipatedOlympicDam20090807.doc>

Yours sincerely,

Edward Cranswick

07AUG2009

Seismicity anticipated to be stimulated by BHP's proposed open pit mine at Olympic Dam

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07AUG2009

Abstract

The proposed excavation of one of the largest open pit mines on Earth, 4.1 km long, 3.5 km wide, 1 km deep, and the associated perturbation of the local groundwater pore pressures in a region of horizontal compressive stress would most likely stimulate local seismicity. The removal of 1 km of rock would reduce the vertical stress by about 30 MPa, increase the deviatoric stress, and facilitate thrust-type faulting in the vicinity of the quarry. Other studies suggest the intermittent reactivation of significant faulting has occurred in the Quaternary on structures in the region that are difficult to recognize, and they surmise that variations in pore pressures may trigger this activity. Even small, local seismic and ground-fracturing events could have a hazardous impact on mining infrastructure and the associated large tailings ponds filled with radioactive and other toxic liquids whose disruption could contaminate regional ground and surface waters. Though the BHP Environmental Impact Study does not mention stimulated seismicity, it is important to assess the maximum hazard & risk posed by the seismicity anticipated to be stimulated by the planned open pit mine, to monitor current and future seismicity with a local seismograph network, and to make this information available the public.

Introduction

Broken Hill Proprietary (BHP) currently owns and operates the existing underground copper-uranium-gold-silver Olympic Dam mine 10 km north of Roxby Downs in SA, Australia, and as presented in their Olympic Dam Expansion Draft Environmental Impact Statement 2009 (Draft EIS), the company has proposed to expand the mining operation and create an open pit mine 4.1 km long, 3.5 km wide, 1 km deep (Draft EIS, Executive Summary) – this would make it one of the largest open pit mines on Earth. The excavation of this open pit mine and the associated perturbation of the local groundwater pore pressures would most likely stimulate (i.e., either trigger or induce – the distinction will be later discussed) seismicity in the vicinity of the mine that would pose a seismic hazard to the mine. In this paper, I critique the Draft EIS with respect to the seismological implications and possible consequences of the proposed open pit mine.

Consideration of Earthquake/Seismic Hazard in the Draft EIS

The substantive presentation of earthquake or seismic hazard/risk in the *Main Report* of the Draft EIS is perfunctory – it is limited to less than one page (pp. 240 and 242) in section 8.4.1 *Seismic Activity* (8.4 *Natural Hazards*, Chapter 8 *Meteorological*

Environment and Climate). It begins with the argument that small earthquakes are not damaging, and it states “Earthquakes that measure 5.5 to 6.1 may cause slight building damage” – this could be disputed by the citizens of Newcastle, NSW, 13 of whom were killed by the magnitude 5.6 1989 Newcastle earthquake (McCue et al. 1990) that caused AUD\$4 billion damage <http://en.wikipedia.org/wiki/1989_Newcastle_earthquake>. It is followed by a discussion of the earthquake catalogue of South Australia that emphasises recent, small earthquakes but does not mention the damaging magnitude 5.4 1954 Adelaide earthquake that resulted in more than 30,000 insurance damage claims (Sinadinovski et al. 2006). The key issue here is that relatively small earthquakes that are close can be damaging – *particularly those that are immediately below the site of interest*.

The section goes on to explain the quantification of earthquake hazard in terms of acceleration coefficients, and it cites the “Earthquake Hazard Map of Australia 1991” (McCue et al. 1993) as the source of acceleration coefficients that can be used to estimate the possibility of damaging strong ground motion that can be expected to occur at some given location over some given period of time.

A more comprehensive analysis of seismic risk/hazard done specifically for the Olympic Dam site is presented in section 7.2.1 *Earthquake Loading (7.2 Design Parameters, 7 Stability, Appendix F1 Tailings Storage Facility Design Report)* pp 68-70:

"During the stability review carried out in 2004, Environmental Systems and Services Pty Ltd ((ESS) incorporating the Seismological Research Centre) was commissioned to carry out a seismic assessment of the site (report contained in Knight Piesold 2004)"

Some of their assumptions underlying this assessment are explained below:

“The earthquakes considered in the ESS report are predominantly much larger distant events, with longer duration of strong ground motion – the type of earthquake that can cause damage to massive structures such as TSFs [Tailings Storage Facility]. In considering how various combinations of magnitude and distance contribute to ground motion, the ESS assessment found that in the case of Olympic Dam, the contribution to hazard from earthquakes closer than about 70 km is minimal, with most of the hazard being from larger distant events in the Flinders Ranges and its north westerly extension in the Denison seismo-tectonic zone (see Fig 7.2). Flinders Ranges is one of the more active areas within Australia. Assuming bedrock geology, the distance between the Flinders Ranges and Olympic Dam would allow seismic waves from the Flinders Ranges to be considerably attenuated before reaching the site.”

The critical shortcoming of this analysis is the assumption that there there could be no significant earthquakes near Olympic Dam itself. Relatively small earthquakes near or below the site could produce damage not only by strong ground shaking but also by

fracturing the ground surface, and these events could be stimulated by the mining operations.

Seismicity Triggered by Open pit Mining

Open pit mines have triggered significant earthquakes on at least three occasions: the magnitude 3.3 1974 earthquake at Wappingers Falls, New York, USA (Pomeroy et al., 1976); the magnitude 4.6 earthquake on 29 November 1980 at Belchatow, Poland (Gibowicz, 1982); and, the magnitude 4.6 earthquake at 1994 Cacoosing Valley, Pennsylvania, USA (Seeber et al. 1998). The abstracts of papers that describe these events are reproduced below:

Wappingers Falls – “On June 7, 1974, at 19:45:37 GMT, an earthquake of magnitude 3.3 (mb, Nuttli) occurred at Wappingers Falls, New York (41°37.75'N, 73°56.5'W). The maximum intensity was Modified Mercalli V' with a radius of perceptibility of 10km. This high intensity and rapid fall-off of intensity with distance late presumably associated with a shallow focal depth. Within 10 hr of the event, a portable array of microearthquake recording instruments was installed in the epicentral area. During the following 6-day period, over 100 aftershocks were recorded. Accurate locations could be made for 42. The aftershocks occurred within or beneath an allochthonous block of dolomitic limestone (Wappinger Group) which has been extensively quarried. Focal depths varied from zero to 1½ km. A composite fault-plane solution for the main shock and the well-located aftershocks indicates a thrusting mechanism with nodal planes striking N40°W and dipping 60 ° to the SW and 30 ° to the NE. This mechanism supports the north-northeast trending maximum compressive stress in eastern North America hypothesized by Sbar and Sykes (1973). The available evidence, including previous seismic history, locations, and the composite fault-plane solution indicate that this earthquake sequence and possibly past earthquakes in the same area may have been triggered by crustal unloading associated with quarrying operations in the presence of high horizontal compressive stress.” (Pomeroy et al.1976).

Belchatow – “On the 29th November 1980, an earthquake of magnitude 4.6 occurred in the brown coal mining area of Belchatow in Central Poland. This is by far the strongest manifestation of seismicity induced by surface mining. Although the removal of overburden and drainage of coal deposits by water withdrawal seem to be factors directly responsible for stress concentration, the pre-existing tectonic stress is probably the most important indirect factor responsible for originating the Belchatow event.” (Gibowicz, 1982).

Cacoosing Valley – “A mb(Lg) 4.6 mainshock on January 16, 1994, in the Cacoosing Valley, 10 km west of Reading, southeastern Pennsylvania caused modified Mercalli VI-VII intensities and the highest earthquake damage (~\$2 million) in the eastern United States since 1944. Aftershock

hypocenters from a temporary local seismic network are confined to the upper 2.5 km of crust. They are clustered around the periphery of a tabular 3x3 km zone that is interpreted to outline the mainshock rupture. This zone matches the nodal plane with a reverse and left-lateral slip (strike 135 deg, dip 54 deg southwest, and rake 55 deg) of a focal mechanism obtained from aftershock first motions and from mainshock waveforms. This rupture does not correlate with any of the faults mapped in the epicentral area, but it is parallel to the most prominent fracture set, including joints and small faults. Maximum possible strike-slip accumulated on the causative fault is no more than several tenths of meters. A large carbonate rock quarry is centered above the rupture. We calculate a small, but significant (0.13 Mpa) Coulomb stress increase caused by the quarry on the shallow portion of the rupture. Most of this increase was caused by a pore pressure rise after the quarry was abandoned in December 1992 and flooded. Seismicity started on May 1993. We conclude that the 1993-1997 Cacoosing Valley sequence is probably triggered by the quarry. About 200 km northeast of Cacoosing, another quarry in early Paleozoic carbonate rocks triggered the 1974 mb(Lg) Wappingers Falls earthquake.” (Seeber et al. 1998).

All three accounts refer to the presence of a pre-existing tectonic stress and the effect of unloading the vertical stress by quarrying, and two of the accounts discuss the role of changing the pore pressure as part of the mining operation.

In Situ Stress and Tectonics of the Australian Crust

Although the continent of Australia (i.e., the Australian territory, not including the convergence margin to the north) is a wholly intraplate and is, therefore, less seismically active than regions near plate boundaries, it has one of the highest rates of intraplate seismicity (McCue et al. 2008). There have been the 11 historical earthquakes that have ruptured the ground surface in stable continental regions (SCR) world-wide, and 5 of these events have occurred in Australia since 1968 (Crone et al. 1997). Like most SCR, the Australian crust is characterised by a horizontal compressive stress, and the horizontal stress trajectories in the region around Olympic Dam trend approximately east-west (Hillis & Reynolds 2003).

Horizontal compressive stress, with a more NE-SW trend, is responsible for the surface-rupturing, thrust earthquakes that occurred roughly 500 km northwest and 1500 km north, respectively, of Olympic Dam: the magnitude 5.8 1986 Marryat Creek earthquake (McCue et al. 1987) and the three magnitude 6.3-6.7 1988 Tennant Creek earthquakes (Bowman 1992). Both epicentral areas had been essentially aseismic previously: “as at Marryat Creek, the historical and instrumental record of earthquakes offered no hint of potentially seismogenic faults in the Tennant Creek area” (Crone et al. 1997).

Crone et al. (2003) investigated the Roopena fault scarp near Whyalla, SA, roughly 300 km south of Olympic Dam, and the Hyden fault in WA, and they conclude:

“cratonic faults in stable continental regions (SCR) typically have a long-term behavior characterized by episodes of activity separated by quiescent intervals of at least 10,000 and commonly 100,000 years or more. Studies ... document multiple Quaternary surface-faulting events that are unevenly spaced in time. The episodic clustering of events on cratonic SCR faults may be related to temporal fluctuations of fault-zone fluid pore pressures in a volume of strained crust. The long-term slip rate on cratonic SCR faults is extremely low, so the geomorphic expression of many cratonic SCR faults is subtle, and scarps may be difficult to detect because they are poorly preserved. Both the Roopena and Hyden faults are in areas of limited or no significant seismicity; these and other faults that we have studied indicate that many potentially hazardous SCR faults cannot be recognized solely on the basis of instrumental data or historical earthquakes. Although cratonic SCR faults may appear to be nonhazardous because they have been historically aseismic, those that are favorably oriented for movement in the current stress field can and have produced unexpected damaging earthquakes.”

Potential for Stimulated Seismicity at Olympic Dam

Most open pit mines do not generate earthquakes, but, as documented above, some do. The extremely large dimension of the Olympic Dam expansion suggests that some part of the local Earth crustal rock/fluid system at some scale will be stressed beyond failure, producing seismicity. I will review here some of the mechanisms that maintain the stability of crust and, conversely, promote instability.

With respect to the distinction between triggered and induced earthquakes, I use the terminology of McGarr et al. (2002):

“the adjective 'induced' describes seismicity resulting from an activity that is comparable in magnitude to the ambient shear stress acting on a fault to cause slip, whereas 'triggered' is used if the stress change is only a small fraction of the ambient level ... By 'stimulated' we refer generally to seismicity either triggered or induced by human activities.”

and I will argue that both triggered and induced seismicity may be stimulated by the expansion of the Olympic Dam mine. The following analysis is taken from McGarr et al. (2002):

“*In situ* stress measurements made in a variety of tectonic settings, both active and inactive [i.e., SCR], indicate, almost invariably, that the ambient state of stress in the continental crust is quite close to the depth-dependent strength of the crust estimated from laboratory experiments ... Moreover, these same investigations reveal that the ambient pore pressure is nearly always close to hydrostatic. Laboratory estimates of crustal strength ... are based on stick-slip friction experiments as extrapolated to

conditions anticipated at depth in the crust. That is, if the upper seismogenic crust is pervasively faulted then frictional sliding across these faults ... will limit the strength of the crust.

The strength of a fault, or the shear stress τ required for failure, can be expressed as

$$\tau = \tau_0 + \mu(\sigma_n - p) \quad (1)$$

where τ_0 is the cohesion, μ is the coefficient of friction, σ_n is the normal stress across the fault and p is the pore pressure within the fault zone. Laboratory measurements of μ are generally in the range 0.6–1.0 ... Thus, for a given state of stress, the strength of a fault would depend upon its orientation, pore pressure, and cohesive strength. In estimating crustal strength it is often assumed that (1) faults exist in the crust that are optimally oriented for failure, (2) the water table is at the surface (hydrostatic pore pressure), and (3) the cohesive strength can be neglected.

...
Triggered or induced seismicity occurs when the mechanical state of the seismogenic crust is sufficiently perturbed to cause a fault to fail. As indicated by Eqn. (1), failure can occur either because the stress τ loading the fault increases or the strength of the fault is reduced due to a decrease in normal stress σ_n or an increase in the pore pressure p .

...
For a number of the case[s] ..., the stress changes required to trigger seismicity, as well as the corresponding stress seismic drops (of the order of 1 MPa), are small fractions of the shear stress acting to cause fault slip ... indeed, numerous studies ... lead to the conclusion that stress changes as small as 0.1 MPa [Eqn. (1)] may trigger earthquakes. This general observation is consistent with the idea that the crustal state of deviatoric stress tends to be nearly as high as the crustal strength ... The exception to this generalization is mining induced seismicity for which the stress changes causing the earthquakes are of the same order as the ambient crustal stresses loading the mine workings ...

McGarr et al. (2002,; see Figure 3 there) infer a logarithmic relation between the linear dimension of the causative engineering activity and the maximum magnitude of the earthquake that can be expected to be caused by that activity. The proposed Olympic Dam open pit has a linear dimension of 1-10 km, and they would predict a maximum possible earthquake in the range of magnitude 4-6 could occur as a result,

Possible Seismological Consequences of the Proposed Olympic Dam Expansion

The geological, tectonic, situ stress, and seismological data and mechanisms that I have presented suggest that some level of seismic activity can be anticipated to occur as a result of the proposed expansion of the Olympic Dam mine, possibly the

stimulation a significant earthquake on the Mashers Fault Zone that lies within the proposed open pit.

One of the most critical design criteria at Olympic Dam is to ensure the stability of the vast Tailing Storage Facility (TSF) that would contain the radioactive and otherwise toxic slurries and wastes produced by processing of the ore. The 1986 magnitude 5.8 Marryat Creek earthquake produced a 13-km long fault scarp with a maximum height of 0.9 m, and the three magnitude 6.3-6.7 1988 magnitude Tennant Creek earthquakes produced two fault scarps with a total length of 32 km and a maximum height of 1.8 m (Crone et al. 1997). Independent of any strong ground shaking that may be generated, the occurrence of earthquakes that produced comparable scarps, i.e., displacements of the ground surface, at Olympic Dam would probably seriously damage on the TSF, causing it to rupture and release its toxic materials into the environment.

Conclusions

The implication of the research reviewed in this paper is that most stable intraplate crust, i.e., the Australian continent, is on the brink of failure by earthquakes, waiting for the proverbial straw that breaks the camel's back – but in the case of the proposed Olympic Dam expansion, that straw is a gigaton of rock. The seismological concerns raised here need to be further investigated before we are prepared to load the camel of South Australia with such an enormous weight. On this basis, I oppose the planned expansion of the Olympic Dam as described in the Draft EIS.

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