ENGIE Hazelwood

Hazelwood Cooling Pond Technical Assessment Report

October 2018

Executive summary

This study comprises a technical assessment of the Hazelwood Cooling Pond (HCP) embankments, i.e. the Eel Hole Creek (EHC) dam and the South Dam (SD) undertaken in accordance with the Australian National Committee on Large Dams (ANCOLD) guidelines. The study included:

- An engineering review of both embankments. This includes review of the seismic design performance of the HCP under the draft ANCOLD (2017) *Guidelines for Design of Dams and Appurtenant Structures for Earthquake*.
- Review and reassessment of the dam break consequences of the HCP under the ANCOLD (2012) *Guidelines for Consequence Categories for Dams.*
- Comprehensive risk assessment of the HCP under the ANCOLD (2003) *Guidelines for Risk Assessment* and the DELWP (2015) *Guidance Note on dam Safety Design Principles*.
- Risk mitigation options considered to achieve a tolerable risk position for the HCP.

Engineering review

The engineering design review was undertaken of both embankments that included:

- Assessment of embankment stability and acceptance criteria for static loading conditions, which found that both embankments pass the design acceptance criteria for steady state stability under normal and maximum flood loading conditions.
- A seismic assessment, including the liquefaction triggering potential in the foundation of both embankments, which determined that zones of potential liquefiable material are present within the embankment foundations. These materials are likely to liquefy under the magnitude 7 SEE earthquake (design earthquake with an annual recurrence interval of 1 in 2,000 years). Furthermore it was determined that some zones in the foundation may liquefy during a magnitude 6 earthquake.
- A post-seismic stability analysis using the limit equilibrium analysis, which indicated the post-earthquake stability of the EHC dam and the South Dam do not pass the acceptance criteria, with Factors of Safety of 0.74 and approximately 1.0 respectively, if the SEE event triggers liquefaction in some of the zones of the foundation.
- A post-seismic deformation analysis using finite element analysis to determine the likely extent of deformation of the EHC embankment as a result of slope instability. The deformation analysis showed a maximum horizontal displacement of 2.0 m and a maximum settlement of 0.8 m. These are assessed as very large for an embankment dam and are much more than the maximum acceptable deformation of 0.6 m proposed by FERC (2006) for a seismic event. It considered likely that under such large deformations the remaining embankment is likely to suffer significant cracking, which may result in a secondary piping failure.
- Identification of potential piping erosion failure mechanisms that were then assessed as part of the overall risk assessment. The key failure mechanisms, which were included in the risk assessment were piping through desiccation cracks in the crest of the embankments, piping through middle and lower parts of the embankments due to zones of poor quality earthfill material and post-earthquake piping failure due to cracking from large deformations.

Consequence assessment

A dam break model and consequence assessment was undertaken to assess the consequences of failure for the EHC and SD embankments after the power station closure and to re-assess the consequence category of the dams in accordance with ANCOLD (2012) *Guidelines on Consequence Categories for Dams*. The potential loss of life (PLL) assessment was revised for the consequence category re-assessment and as input into the risk assessment.

The consequence category re-assessment has confirmed consequence categories of **High C** for both embankments under sunny day failure conditions and **High C** and **Significant** consequence categories under flood failure conditions for the SD and EHC Embankment, respectively.

Risk assessment

The failure modes driving the current risk profile of the dam are:

- Piping in the crest of each embankment due to desiccation cracking.
- Post-seismic piping due to cracking from large deformations induced by an earthquake.

The ANCOLD guidelines on risk (2003) propose that, in any particular case, three guidelines regarding tolerability of life safety risk are to be satisfied; that is:

- The individual risk guideline: "For existing dams, an individual risk to the person or group that is most at risk, which is higher than 1 x 10^{-4} per annum is unacceptable, except in exceptional circumstances."
- The societal risk guideline; The cumulative societal risk plot (F-N curve) must plot below the ANCOLD (2003) limit of tolerability. Due to the uncertainty involved in the risk assessment process it is accepted industry practice to achieve a risk profile of at least an order of magnitude below the ANCOLD limit of tolerability. The ALARP principle must then be satisfied.
- The 'As Low As Reasonably Practicable' (ALARP) principle requires consideration of the possibilities of risk reduction. In order to satisfy the test, ANCOLD states (2003) that the dam owner needs to demonstrate gross disproportion between the money, time and trouble required to implement risk reduction measures; and the reduction in risk that would be achieved by those measures. The points that are relevant in making a judgement on whether risks are ALARP, based on industry practices, include the cost-to-save-a-statistical-life (CSSL), the level of existing risk, and societal concerns.

The key outcomes of the risk assessment are:

- The current risk to the individual was calculated to be 9.7 x 10^{-5} per annum, which is less than 1 order of magnitude lower than the ANCOLD guideline for individual risk of 1 x 10^{-4} per annum.
- Considering the current societal risk profile, the cumulative probability of failure was estimated to be marginally below the ANCOLD limit of tolerability. Considering there are reasonable mitigation opportunities available, it is considered that the HCP does not meet the ALARP guideline in its current state.
- The failure modes driving the risk profile are:
  - Piping through the upper part of either embankment due to desiccation cracking of the crest.

– Piping of either embankment due to cracking from deformation induced by seismic liquefaction of the foundation.

Risk mitigation activities are therefore considered to be required for the HCP in consideration of the ALARP principle.

Risk mitigation

Risk mitigation options need to be considered to achieve a tolerable risk position for the continued operation of the HCP. The following mitigation options have been assessed:

- Mitigation A – lower the pond level approximately 2.7 m to RL 74.1 ie. to the bottom of the sluice gate valve.
- Mitigation B – construct a crest filter trench to prevent continuation of piping erosion in the upper part of the embankments and operate the pondage at the full operating level.
- A combination of both Mitigation A and Mitigation B.
- Mitigation C – a full height filter buttress, which will also serve the purpose of foundation improvement.

Both Mitigation Option A and Mitigation Option B will provide a risk reduction to around an order of magnitude below the limit of tolerability and Mitigation Option C three orders of magnitude.

- Mitigation Option A achieves the potential risk reduction without structural remedial work. This mitigation measure would result in a lowered pond level to RL 74.1 m, which would make it unsuitable for most recreational activities. Reducing the pond level to only 1 m below spillway level would not provide adequate risk reduction from piping.
- Mitigation Option B entails extensive structural remedial work and, although it would be effective in both reducing ongoing operational risk and maintaining the pond level, it would entail significant construction risk to workers operating construction equipment on the narrow embankment crests. There are other construction risks, such as instability of the trench and excessive seepage into the trench.
- There is little risk benefit in undertaking both Mitigation Option A and B together, ie. The incremental risk reduction of Mitigation Option B, once Mitigation Option A has been achieved, is negligible, and involves a risk to workers.
- Mitigation Option C would provide the greatest risk benefit, however is unlikely to be justifiable under the ALARP principle. This Mitigation Option C is in the “poor” ALARP justification zone based on CSSL and hence it is considered that the cost of this mitigation option is grossly disproportionate to the potential risk reduction.

Visual inspection and monitoring

It has been recommended to increase the frequency of visual inspections to daily and groundwater level monitoring to weekly. These monitoring frequencies can be reduced to twice weekly and fortnightly for visual inspection and groundwater monitoring respectively, when the lake water level drops more than a metre, i.e. below RL 75.8 m.

Conclusion

It is concluded that:

- The HCP does not meet risk the tolerability criteria as proposed by ANCOLD (2003) and hence risk mitigation activities are required if the pondage is to be retained.
- Both Mitigation Options A and B would achieve a tolerable risk position around an order of magnitude below the ANCOLD (2003) limit of tolerability. Mitigation Option A requires the lowering of the pond by approximately 2.7m. Mitigation Option B entails extensive remedial works with an unacceptable construction risk and at considerable cost but maintains the pond level.
- Mitigation Option C would provide the greatest risk benefit, however it is not justifiable under the ALARP principle.
- Therefore, based on this comprehensive risk assessment, if the HCP is to be retained then Mitigation Option A, ie lowering the pond by 2.7 metres below the spillway level, is the only option of those assessed which satisfies the ANCOLD criteria of tolerable risk while meeting the ALARP principles.

Peer Review

Engie appointed Golder to undertake an independent review of the technical assessment report. Golder confirmed the outcomes of the report, and concur that lowering the lake level by 2.7 m to RL 74.1 m is the most practical mitigation option.