Mine Closure 2026 – AB Fourie, G Boggs, J Heyes & M Tibbett (eds)

doi:10.36487/ACG_repo/2615_136

From risk to relinquishment: adaptive pathways for the Hazelwood mine

Angus McKenzie-McHarg [a,*], Rachel Chong [a], Jonathan Missen [b]

[a] *GHD, Australia*

[b] *Hazelwood mine, ENGIE, Australia*

Abstract

Planning for the rehabilitation of the Hazelwood mine required a rigorous and transparent risk-assessment approach to support the site's transition to a safe, stable and sustainable final landform. The risk assessment process is fundamental to achieving ENGIE's aspirations for the future use of the site while meeting statutory mine closure obligations. The work was undertaken by GHD, a global engineering and advisory firm, in collaboration with ENGIE, an international energy company and asset owner responsible for the site. GHD supported ENGIE to update the 2025 Hazelwood Risk Assessment and Management Plan (ENGIE 2025a) for the proposed rehabilitation and the aftercare period. In doing so GHD has utilised a range of risk assessment techniques to consider rehabilitation planning, technical understanding, stakeholder expectations, the regulatory environment and long-term relinquishment outcomes.

Adaptive pathway planning (APP) (ENGIE 2025b) is a relatively common tool in other industries including healthcare, financial services and industrial manufacturing but has not been widely adopted in the mine closure context. APP can provide a dynamic and flexible approach to risk designed to support decision-making in uncertainty and particularly useful for evaluating long-term scenarios and risk mitigation strategies.

APP was essential to the risk assessment process, incorporating long-term uncertainty associated with components such as water sourcing, the geotechnical behaviour of mine batters, compliance and regulation. APP enabled the Hazelwood mine to demonstrate how risks will be managed to meet regulatory obligations and maintain community and stakeholder objectives. The APP process assessed 3 alternate closure pathways – namely, the preferred, the contingency and the non-preferred – which included a range of triggers and mitigation measures.

To ensure a reasonably broad scope of risks, the assessment actively utilised internal specialists, independent reviewers and regulatory authorities. Critical controls for key risks were identified (International Council on Mining and Metals 2015), including the definition of performance standards essential for demonstrating that critical controls remained effective and were periodically reviewed.

APP is intended to demonstrate how risks are managed under alternate rehabilitation scenarios and, in turn, increase positive community and stakeholder sentiment. This provides a defensible, stakeholder-aligned, statutorily-considered pathway towards relinquishment.

Keywords: *adaptive pathway planning; mine closure, risk assessment, rehabilitation*

1 Introduction

In Victoria, Australia, the regulatory landscape around mine closure and relinquishment continues to evolve with changing economic, environmental and social expectations. As a result, there is a growing emphasis on

* Corresponding author.

understanding how risks change and emerge over time, an integral component of the mine closure and relinquishment planning.

Mining operations typically have a strong understanding of the risks required to implement an effective closure plan under a 'typical' closure pathway. However, current risk management frameworks (International Standards Organisation 2018) do not consistently or effectively communicate how new or changing risks will be identified, managed and governed over time. A particular challenge is clearly articulating how risks associated with relinquishment will evolve, and how operations will respond to the emergence of new risks as site conditions, land use and stakeholder expectations change.

The purpose of this paper is to outline the adaptive pathway planning (APP) approach that was undertaken at ENGIE's Hazelwood rehabilitation project and demonstrate how this approach can be adopted by similar operations. This approach provides a structured and transparent framework for communicating how risks are expected to evolve along the relinquished pathway and how closure objectives for a safe, stable and non-polluting landform can be achieved for a successful relinquishment of the site.

This paper presents the context of the current regulatory framework, identifies key gaps in existing approaches, and describes the methodology applied by GHD and ENGIE to address these gaps. The outcomes of the study are intended to improve transparency and confidence between operators, regulators and the broader community in relation to long-term closure and relinquishment outcomes.

2 Context

The approach to risk management at Hazelwood has evolved significantly over the past decade, based on mining incidents, increasing regulatory expectations, greater community scrutiny, and the long-term complexity associated with mine closure and rehabilitation.

Generally, risks are assessed under static conditions; a point in time assessment that may be relevant to specific stages of the mining life cycle. Recently, risks associated with the Hazelwood mine have been assessed across the 3 following phases:

- Phase 1: active rehabilitation
- Phase 2: passive rehabilitation
- Phase 3: post-closure.

Each phase considers associated hazards and risks, and the potential impacts to the environment, any member of the public, land, property or infrastructure in the vicinity of the site.

Prior to 2014, the dominant risk assessment tool at Hazelwood was the bowtie[*], which was used to assess risks posed by the nominated major mining hazards (MMH)[†] in accordance with the *Occupational Health and Safety Act 2004* (Vic) (Government of Victoria 2004) and the mining specific provisions of the *Occupational Health and Safety Regulations 2017* (Vic) (Government of Victoria 2017), as administered by WorkSafe Victoria.

The Morwell Main Drain is a stormwater and groundwater management channel in the Latrobe Valley and was originally constructed by the State Electricity Commission of Victoria. It collects run-off from the town of Morwell, the Princes Freeway and industrial areas, and diverts it around the Hazelwood mine. In early 2011 ground movement due to heavy rainfall caused a sinkhole to open in the drain, leading to the collapse of a section of the Princes Freeway and a 7-month road closure.

[*] A bowtie risk assessment is a graphical method used to illustrate a hazard scenario by linking potential causes and consequences through prevention and mitigation control.

[†] Major mining hazards (MMH) are those prescribed under the *Occupational Health and Safety Act 2004 (*Vic) requiring formal identification and risk assessment due to their potential for high-consequence outcomes.

Following this incident the bowtie methodology was adapted to assess risk for each of the mine geotechnical domains and culminated in the initial ground control management plan (GCMP).

In February 2014 spot fires from nearby bushland ignited sections of exposed coal within the Hazelwood mine, which burned for approximately 45 days and led to an independent inquiry. The Hazelwood Mine Fire Inquiry Board (Government of Victoria 2016) made several recommendations for the site. Among these, Recommendation 15 was made to ENGIE, requiring it to 'Conduct, assisted by an independent consultant, a risk assessment of the likelihood and consequences of fire in the worked-out areas of the Hazelwood mine and an assessment of the most effective fire protection for the exposed coal surfaces.'

In May 2015, in response to the Inquiry recommendations, a collaborative risk assessment was undertaken involving mine operations personnel, industry specialists from other Latrobe Valley mining operations, and representatives from government agencies and emergency services. This process established the foundation for subsequent risk assessment management plans (RAMPs). Since then, additional risk assessments have been completed; providing a consistent body of reference material and supporting the ongoing development of risk assessment and management approaches.

As the risk management landscape has evolved, so has the risk assessment methodology. Initially, as had been the case for the MMH and the GCMP, bowtie analyses were the primary risk assessment tool; playing a central role in the identification, understanding and communication of risks and associated controls.

During the development of the rehabilitation and closure plan 2019, prepared as the basis for engagement with referral authorities and later superseded by the environmental effects statement (EES) process, bowtie analyses were supplemented to better demonstrate how risks evolve over the rehabilitation cycle and into closure. This was necessary as the traditional bowties tend to represent a point in time assessment of risk.

To address this limitation, the source-pathway-receptor (SPR) model was adopted. The SPR approach enabled key risks, particularly with respect to ground control and environmental impacts, to be presented in a manner that demonstrated how each individual risk reduced over time as rehabilitation work was completed. It is this SPR model which has been adopted in the declared mine rehabilitation plan (DMRP).

Under the current regulatory framework, RAMPs are designed to meet the requirements of the *Mineral Resources (Sustainable Development) (Mineral Industries) Regulations 2019* (Vic) (Government of Victoria 2019), and specifically Mining Licence Condition 1A (Risk Management) of MIN5004 for the Hazelwood mine, administered by the Department of Energy, Environment and Climate Action. These conditions require the licensee to identify and assess the likelihood and consequence of a risk and the potential impacts to the environment, any member of the public, land, property or infrastructure.

In response to regulatory concerns raised in 2024 and to better align with the requirement to demonstrate how risks evolve over time, particularly under conditions of uncertainty associated with rehabilitation and closure, an adaptive pathway planning (APP) approach has been adopted.

A timeline of the evolving risk management process for the Hazelwood mine is captured in Table 1.

Table 1 Evolving risk management process

Date	Definition
Prior	Risk registers/various
2012	Major mining hazards
2013	Ground control management plan (GCMP)
April 2015	Hazelwood mine fire preparedness support risk assessment
May 2015	Latrobe Valley mine fire risk assessment
February 2017	Risk assessment management plan (RAMP) 3.2
December 2019	RAMP 4.0
December 2019	GCMP 7.1
July 2023	GCMP 8.1
March 2025	Fire risk management plan
September 2025	Declared mines rehabilitation plan
July 2024 to October 2025	Technical studies supporting the environmental effects statement

3 Methodology

The adaptive pathways approach is a practical planning technique that has been developed in recent years in response to the need to plan for uncertain futures. It provides a structured way to demonstrate how management options can be implemented over time, how decisions may change as conditions evolve, and how actions can be taken to alter or influence outcomes in the face of uncertainty.

Key features of the approach are the linkage of pathways to scenarios and consideration of how these pathways change over time. As the site moves towards relinquishment, ENGIE may transition between scenarios or implement different management options within a scenario. This includes the identification of decision (trigger) points at which a decision is required to implement an alternative management option. Finally, it helps incorporate long-term vision and objectives in short-term decisions and actions.

Figure 1**Error! Reference source not found.** shows the adaptive pathway plan where trigger points are identified, which influence the change in the rehabilitation option pathway over time and how those decisions influence the rehabilitation option pathway selected.

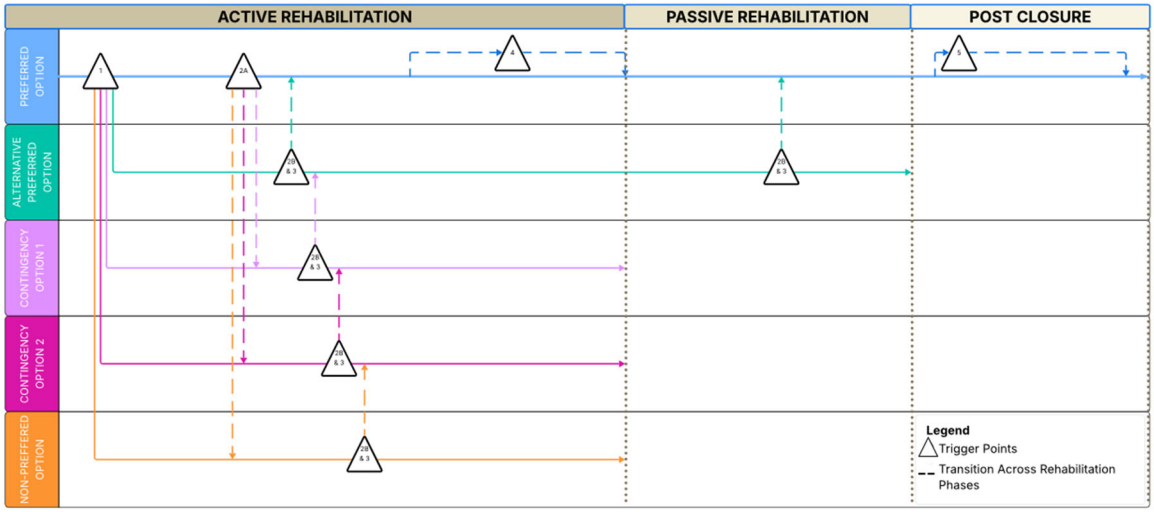

Figure 1 Sample: rehabilitation adaptive pathway plan

An APP process was adopted to structure the planning and decision-making framework used in this project. In summary, the process involved:

- structuring the problem, by defining the current and future states of the Hazelwood mine with particular focus on pit lake water sources
- exploring and characterising the feasible management options
- evaluating and defining pathways and implementation actions to manage key drivers of change and uncertainty.

Table 2 describes some of the key terms used within the adaptive planning and scenario planning context.

Table 2 Adaptive pathway planning key definitions

Term	Definition
Decision/trigger points	A point in time where progress needs to be reviewed and a choice made between alternate response options, thus determining which 'pathway' seems best to decision-makers at that point This includes an allowance for the lead time of an action and is used synonymously with trigger points
Scenarios	Problem-focused scenarios used to explore, 'What could happen in the future?' Scenarios that encapsulate both the problem definition and the solution and are used to answer the question, 'How can a specific target be met or future achieved?' This could be used for exploring at a high level both actions and/or pathways to meet certain objectives under different futures

3.1 Scenario identification

The preferred scenario assumes the pit void is filled to approximately RL +45 m, enabling achievement of the final landform criteria required for relinquishment. It relies on sufficient water availability, with water supplies sourced from Gippsland Water, groundwater from the M2 aquifer and the Hazelwood cooling pond (HCP). Under this scenario, aquifer pumping will cease and catchment run-off will be managed through the Morwell Main Drain. The resulting pit lake will submerge all exposed coal to reduce the risk of fire incidents and provide geotechnical stability, thereby achieving a safe, stable and non-polluting closure landform.

This paper examined the main water sources at Hazelwood and assessed feasible options to support planning for the rehabilitation project. The scenarios selected are based on the mine inflows multicriteria assessment performed and include:

- reducing the fill rate by minimising water inflows from surface water, artesian water, and the M1 and M2 aquifers
- using alternative mine fire water sources from Gippsland Water, the HCP or mine void water
- pumping out of the mine void.

The information used to populate the adaptive pathway scenarios was based on a series of completed risk assessments regarding these water sources and pathways. Each pathway was subsequently examined through a detailed risk assessment that covers the potential impacts to public safety, the environment, land, property or infrastructure. A summary of the scenarios identified and their pathways is summarised in Table 3.

Table 3 Scenario identification

Scenario	Pathway
Reduce fill rate by minimising water inputs – surface water	**Preferred option** Continue retaining surface water (allow evaporation and infiltration to balance inflows)
	Contingency option Reroute internal catchments to the surrounding environment
	Non-preferred option Collect and pump all surface water entering the mine void and discharge it
Mine fire water source – mine void water	**Preferred option** Maintain current pumping into the mine void
	Contingency option Plan a staged increase in the number of mine void pumps
	Non-preferred option Earlier-than-planned staged increase in the number of mine void pumps
Pumping out	**Preferred option** Maintain current pumping into the mine void
	Non-preferred option Earlier-than-planned staged increase in the number of mine void pumps

3.2 Workshops

Each pathway was assessed in a workshop environment to validate the information gathered from existing risk assessments/reports and provide additional content where necessary. The workshop attendees were subject matter specialists from ENGIE, along with a GHD facilitator to assist in capturing the information using the APP methodology. A summary of the workshops can be seen in Table 4.

Table 4 Workshops

Workshop	Workshop date	Attendees
Reduce fill rate by minimising water inputs – surface water	19 November 2025	ENGIE subject matter specialists, facilitated by GHD
Mine fire water source – mine void water	20 November 2025	ENGIE subject matter specialists, facilitated by GHD
Pumping out	20 November 2025	ENGIE subject matter specialists, facilitated by GHD
Risk ranking	27 November 2025	ENGIE subject matter specialists, facilitated by GHD

4 Results

To demonstrate the impacts to public safety, the environment, land, property or infrastructure, each pathway has been risk assessed using Earth Resources Regulation (ERR) risk criteria. For preferred pathways representing business as usual (BAU), risk ratings are based on existing risk assessments as documented in

the relevant risk registers. These ratings draw on established risk assessments to ensure consistency with the current understanding of stability, fire risk and rehabilitation planning requirements (e.g. DMRP, EES). The following key risk assessment inputs have been considered:

- stability risk register
- environmental aspects and impact register
- DMRP risk assessment
- fire bowtie (MMH)07, developed in accordance with the *Occupational Health and Safety Act 2004* (Victoria).

For the alternative pathways, risk ratings were assigned during facilitated workshops to represent the combined consequence and likelihood associated with each pathway deviation. These ratings reflect the collective judgment of subject matter experts, based on the anticipated change in conditions relative to the preferred scenario. To provide additional context and transparency, the underlying assumptions rationale and key considerations informing each risk assessment are documented in Table 6.

A summary of the risk rankings is provided Table 5.

Table 5 Risk assessment summary

Scenario	Pathway	Risk rating
Reduce fill rate by minimising water inputs – surface water	**Preferred option** Continue retaining surface water (allow evaporation and infiltration to balance inflows)	Medium
	Contingency option Reroute internal catchments to the surrounding environment	Very high
	Non-preferred option Pump out	Very high
Mine fire water source – mine void water	**Preferred option** Maintain current pumping into the mine void	Medium
	Contingency option Planned staged increase in the number of mine void pumps	Medium
	Non-preferred option Earlier-than-planned staged increase in the number of mine void pumps	High
Pumping out	**Preferred option** Maintain current inflows into the mine void	Medium
	Non-preferred option Earlier-than-planned staged increase in the number of mine void pumps	Very high

Based on the assessment, 8 adaptive pathways were defined spanning preferred, contingency and non-preferred options across key scenarios. Preferred pathways were generally associated with medium risk outcomes, while contingency and non-preferred pathways showed higher risk ratings (up to very high), particularly where significant intervention was required or where impacts to environment, public safety and infrastructure increased. These higher risk pathways often require further controls, approvals or infrastructure to manage the associated risk. A detailed breakdown of each pathway, including triggers, impacts, actions and risk justification, can be seen in Table 6.

Table 6 Adaptive pathway risk assessment

Scenario	Triggers	Adapted pathway	Pathway description	Existing risk assessments	Pathway outcomes	Pathway actions required for implementation	Risk justification	Pathway risk rating
Reduce fill rate by minimising water inputs – surface water	Confirmation from the regulator to continue to retain surface water which is BAU EES outcome which can either confirm this approach or divert to another pathway that isn't covered in the adaptive planning process	**Preferred option** Continue retaining surface water run-off from the mine void catchment (inside mine crest) as BAU (allow evaporation and infiltration to balance inflows)	This is the existing system design currently in place at the mine void The forecasted water received on average is up to 7 GL with an evaporation rate of 6.8 GL. It is noted that climate changes/fluctuations could see a greater increase in evaporation or greater inflows from surface water Note: Further groundwater recharge has not been assessed and this could increase the losses due to groundwater recharge	Risk ID #5 Stability Risk Register	**The current impacts have been summarised:** **Geotechnical** As the water is retained in the mine void, the stability of the mine would increase as the water level rises Erosion from the discharges is minimal, based on the pipe and drainage discharge network Refer to Risk ID#5 of the Stability Risk Register for more details **Environmental** No expected onsite environmental impacts associated with retaining surface water; however, if the quality of the water in the void was to be contaminated, additional treatment would be needed prior to discharge and release to avoid negative environmental impacts The risk to the environment is known to be low and acceptable **Public safety** This is no change to the current risk known for public safety Risk is contained onsite and therefore there is no risk to members of the public **Infrastructure** No offsite infrastructure impacts from this scenario Impacts are already assessed within the Stability Risk Register #5.	BAU controls as per GCMP	Use Stability Risk #5 with a consequence of moderate and a likelihood of unlikely for the environmental category Noting the current stability risk assessment considers water level variations from paused to increasing	Medium
	Direction from RVRO to change from retaining surface water to diverting surface water Excessive fill rate, exceeding regulator expectation on fill rate or fill level	**Contingency option** Reroute internal catchments to surrounding environment	Rerouting of onsite flows will not ensure that surface water from construction activities will be captured, monitored and treated prior to discharge to nearby creeks and rivers The need for additional infrastructure for pumping will be needed as well as additional approvals from regulatory bodies SRW, EPA, CMA and ERR for discharging and impacts to other catchment areas	Project environmental aspects and impact register #ID 8	**The future impacts have been summarised as:** **Geotechnical** Increased risk of erosion to nearby catchments or by utilising previous dams, as retention holding reduces dam stability. **Environmental** Any deviation in the system performance would lead to untreated water entering Morwell River/Eel	Previous water discharge licencing assessments identified the following controls to assist with this pathway: Discharge licence/ agreement with EPA Additional water treatment system for discharge of water to the environment	Existing water management studies, risk assessments and regulatory engagement activities indicate that discharge of mine water to the receiving environment represents a less preferred management approach and is associated with increased environmental risk.	Very high

Scenario	Triggers	Adapted pathway	Pathway description	Existing risk assessments	Pathway outcomes	Pathway actions required for implementation	Risk justification	Pathway risk rating
			Construction water from rehabilitation activities needs to be considered as the mine void is being used as a sink in the preferred option Deferring from this by selecting the contingent option means going against EPA guidance The natural and mining topography have impacts on the catchment areas, which can report to the creeks and rivers or the mine void without major redesign and/or pumping infrastructure Additional studies will need to be undertaken on the erosion of the discharge points and added inflows to the environment Redesign of rehabilitation works areas to introduce redesign of catchments Monitoring of the changed surface water network at proposed locations needs to be monitored closely If water needs to be treated, additional reliance on a dosing system and additional pumps would decrease the reliability of the system and put added risks into maintaining it		Hole Creek/Bennetts Creek, with potential for EPA breaches Increased contribution of greenhouse gas emissions due to high energy consumption **Public safety** Increased flow impacting downstream users. Potential retention dam failures impacting public safety **Infrastructure** Additional pressure on external drainage systems and the need for ongoing maintenance and monitoring to ensure adequate performance to avoid the public being exposed to untreated water	Other actions needed include: Provision of water retention and transfer infrastructure Additional monitoring and TARPs for general operation and peak events	While water treatment systems can reduce potential impacts, implementation requirements, operational complexity and ongoing maintenance obligations mean that residual environmental risk may remain. As a result, this pathway is considered to increase environmental risk relative to the preferred option. The consequence rating increases from moderate to major and the likelihood rating increases from rare to likely, based on historical discharge events and current water quality monitoring data.	
	Direction from RVRO Excessive fill rate, exceeding regulator expectation on fill rate or fill level	**Non-preferred option** Pumping out equivalent volume of run-off water volume from the pit	Refer to pump out option					
Mine fire water source – mine void water	Confirmation from the regulatory body to proceed with this pathway	**Preferred option** Maintain the mine void pumps as a backup system for fire readiness/response (maintain the current mine void pumps BAU)	This option looks at maintaining 2 pumps in the mine void until the EES outcomes are known This would have little impact on the inflows of the mine void, even if used as a priority over other water sources	Fire risk management plan, incl MMH7 bowtie Stability Risk Register risk ID#5, 16 Environmental aspects register ID#8 & 13	**The current impacts have been summarised as:** **Geotechnical** No additional geotechnical risks as this is the current BAU process **Environmental** If the pumps are used, sprays or the overflow pipes need to be used in order to avoid discharge to the environment (via the HCP) without treatment) Reliance on the power and diesel system for pumping, which	Operation and monitoring as per BAU Implement and bring online fire tanks C & D overflow tank to the mine void to recirculate water and maintain fire service water in the mine void	Reference to fire bowtie where environment was assessed as major and rare, and public safety was rated as moderate and unlikely	Medium

Scenario	Triggers	Adapted pathway	Pathway description	Existing risk assessments	Pathway outcomes	Pathway actions required for implementation	Risk justification	Pathway risk rating
					contributes to greenhouse gas emissions **Public safety** No additional public safety risks as this is the current BAU process Reduced reliability for a water source into the fire readiness system (as using diesel pumps compared to a gravity supply system) **Infrastructure** Continue to maintain infrastructure			
	EES outcome Decommissioning of the HCP Unavailability of water sources from HCP or Gippsland Water Direction from the regulatory body to increase the number of mine void pumps	**Contingency option** Planned a staged increase in the number of mine void pumps (assuming there is adequate time for implementation)	A planned staged increase in the number of pumps in the mine void to supply recirculated water to the fire service network, assuming there is enough time to augment and test the system prior to bringing it online Assume that excess water will be returned to the mine void to avoid external discharge to the environment This option has a higher reliance on diesel pumps, resulting in higher maintenance and operational oversight requirements	Fire Risk Management Plan, incl MMH7 bowtie Stability Risk Register risk ID#5, 16 Environmental Aspects Register ID#8 & 13	**The future impacts have been summarised as:** **Geotechnical** No additional geotechnical risks as this is the current BAU process **Environmental** If the pumps are used, sprays or the overflow pipes need to be used in order to avoid discharge to the environment (via the HCP without treatment) Reliance on the power and diesel system for pumping, which contributes to greenhouse gas emissions **Public safety** During the addition of the new pumps, a risk assessment will need to be performed to assess the public safety risk. This will be included in the Fire Risk Management Plan (FRMP) process Reduced reliability for a water source in the fire readiness system (as using diesel pumps compared to a gravity supply system) **Infrastructure** Continue to maintain existing and additional infrastructure Testing of the new infrastructure needs to be performed prior to bringing it online	Hydraulic and pumping system assessments provided an outline of the proposed implementation and associated actions including: Implement and bring online Fire tanks C & D overflow tank to mine void to recirculate water and maintain fire service water in the mine void Continue the design and implementation of the staged increase of mine void pumps Revise operational, inspection, maintenance process Increase surveillance process or operational instructions to recirculate the water and avoid external water discharge (e.g. lock-out/tag-out system for valving) Update FRMP with the new operating model, with approval from the regulator Update fire related guideline to make sure it aligns with the new operating philosophy	The risk profile doesn't change from BAU but allows Hazelwood to stop relying on the HCP pumps as a water source	Medium
	Direction from the regulatory body to increase the	**Non-preferred option** Earlier-than-planned staged	Bring forward the schedule associated with the increased number of pumps in the mine void	Stability Risk Register risk ID#5, 16	**The future impacts have been summarised as:** **Geotechnical**	Hydraulic and pumping system assessments identified and proposed	If ENGIE was unable to complete the works in a planned approach, it would not have the	High

Scenario	Triggers	Adapted pathway	Pathway description	Existing risk assessments	Pathway outcomes	Pathway actions required for implementation	Risk justification	Pathway risk rating
	number of mine void pumps earlier Inability to supply sufficient water for fire readiness/response from HCP and/or Gippsland Water due to water availability/supply system issues	increase in the number of mine void pumps	Reduction in water supply for fire readiness/response as the system is not optimised. Pumps might need to be refurbished and retrofitted to new water levels This option has a higher reliance on diesel pumps, resulting in higher maintenance and operational oversight requirements	Existing fire readiness planning documentation Technical mine fire guidance documentation Fire risk management plan, incl MMH7 bowtie	No additional geotechnical risks as this is the current BAU process **Environmental** If the pumps are used, sprays or the overflow pipes need to be used in order to avoid discharge to the environment (via the HCP without treatment) Reliance on the power and diesel system for pumping, which contributes to greenhouse gas emissions **Public safety** During the addition of the new pumps, a risk assessment will need to be performed to assess the public safety risk. This will be included in the FRMP process Reduced reliability for a water source in the fire readiness system (as using diesel pumps compared to a gravity supply system). **Infrastructure** Continue to maintain existing and additional infrastructure due to inadequate time for testing of the new infrastructure, resulting in potential infrastructure impacts Short-term pump selection is based on availability so may need to be redesigned at a later date to meet the design parameters of the system (i.e. head pressure reduced as water level rises)	the following implementation actions: Implement and bring online the C&D overflow tank into mine void to recirculate water and maintain fire service water in the mine void Accelerate the design and implementation of the increase of mine void pumps (design might be influenced by pump availability) Revise the operational, inspection and maintenance process Increase surveillance process or operational instructions to recirculate the water and avoid external water discharge (e.g. lock-out/tag-out system for valving) Update FRMP with the new operating model with approval from the regulator	potential coverage needed for fire readiness/ response and would be exposed during high fire risk periods The likelihood of the risk will increase For the environment, the likelihood would increase from rare to unlikely. The environment category gives the higher risk rating – therefore a high rating.	
Pumping out		**Preferred option** Maintain current inflows into the mine void (no pump out).	Refer to mine inflow scenarios					

Scenario	Triggers	Adapted pathway	Pathway description	Existing risk assessments	Pathway outcomes	Pathway actions required for implementation	Risk justification	Pathway risk rating
	EES outcome Instruction from RVRO and/or other regulatory authorities – subject to EPA approval	**Non-preferred option** Planned or unplanned stages of pumping out from the mine void	Pump out can be performed via the fire service system to spill into the HCP or to external waterway(s) via existing and/or new infrastructure/discharge systems until outcomes of the EES are known	Stability Risk Register Risk ID#5, 16 Environmental Aspects Register ID#8 & 13	**The future impacts have been summarised as:** **Geotechnical** Reduction in the water level in the mine void leading into variations in the groundwater table (refer to Stability Risk Register #5) Potential for erosion from prolonged wave action at a set level requires assessment If the water level lowers from pumping out, further risk assessments are needed to understand the geotechnical risk and exposure to various factors of safety Lowering the water level may expose saturated surcharge material, potentially resulting in instability or slumping and reducing their effectiveness **Environmental** Discharge of mine void water to the receiving environment may result in adverse environmental impacts if water quality criteria are not achieved. Additional water treatment, monitoring and discharge infrastructure would be required. Increased reliance on operational controls and compliance monitoring would be necessary to manage environmental risks **Public safety** Increased risk to the public of exposure to untreated mine void water **Infrastructure** Requirement for additional pumps and water treatment infrastructure (not yet designed or considered due to licensing requirements being unknown)	Existing water management studies Existing water discharge licencing assessments Existing geotechnical studies and hazard assessments Hydraulic and pumping system assessments Groundwater management studies EPA Discharge Licence(s) Develop and commence design and review process Implement the approved works, including water treatment plant(s), pumps and piping infrastructure Revise operational, inspection, maintenance process Increase surveillance process on external water discharge breaches	Existing water management studies, risk assessments and regulatory engagement activities indicate that discharge of mine water to the receiving environment is associated with an elevated environmental risk compared to the preferred pathway. While treatment systems and operational controls can reduce potential impacts, they require additional infrastructure, implementation effort and ongoing management, and may not fully eliminate the potential for environmental harm. Consequently, this pathway is considered to increase environmental risk relative to the preferred option. The consequence rating increases from moderate to major and the likelihood rating increases from rare to likely, based on historical discharge events and current water quality monitoring data.	Very high

Note: Abbreviations used in Table 6: BAU = Business as Usual; EES = Environmental Effects Statement; RVRO = Resources Victoria Regulatory Operations; SRW = Southern Rural Water; EPA = Environment Protection Authority; CMA = Catchment Management Authority; ERR = Earth Resources Regulation; TARP = Trigger Action Response Plan; HCP = Hazelwood Cooling Pond; FRMP = Fire Risk Management Plan; MMH = Major Mining Hazard; GCMP = Ground Control Management Plan; DMRP = Declared Mine Rehabilitation Plan.

5 Conclusion

The adaptive pathway planning (APP) workshops and subsequent outcomes table were used to demonstrate ENGIE's processes for managing and mitigating all water sources entering the mine void. This assessment was incorporated into ENGIE's Risk Assessment and Management Plan and is intended to function as a live tool, continually being updated as mitigation measures are further developed and risks are reassessed as the Hazelwood rehabilitation project progresses.

The APP process enabled the Hazelwood mine to effectively identify potential triggers across the rehabilitation life cycle and define appropriate mitigation strategies that support a flexible and adaptive pathway towards relinquishment. This approach allows the rehabilitation strategy to respond to evolving regulatory, community and environmental conditions.

The workshops provided an appropriate environment and level of technical expertise to support open identification and evaluation of key risks. Overall, the APP process is an effective method for demonstrating how new risks may emerge or evolve over time and is expected to be an increasingly important regulatory requirement. It also demonstrates how operators can enhance their risk assessment capabilities in not only planning for the 'preferred' relinquishment scenario but also identifying and communicating controls or decision pathways for contingency and non-preferred relinquishment scenarios.

This paper demonstrates that while adaptive planning is often embedded within rehabilitation risk assessments, it is rarely undertaken in a formalised structure or communicated effectively to regulators or stakeholders; limiting its value in supporting transparent and defensible relinquishment decision-making.

Acknowledgments

The authors gratefully acknowledge the valuable intellectual guidance and technical expertise provided by James Faithful and Sarah Schuman (GHD). Their insights, constructive review and ongoing support contributed significantly to the development of the concepts and outcomes presented in this paper.

Use of artificial intelligence disclosure statement

In the preparation of this work, the authors used Microsoft Enterprise Copilot (powered by GPT-5) to review spelling, grammar, punctuation and readability. The authors have reviewed the content and edited it where required, and take full responsibility for said content.

References

ENGIE Hazelwood 2025a, *Hazelwood Rehabilitation Project Risk Assessment and Management Plan (RAMP)*, version 5.0, unpublished report.

ENGIE Hazelwood 2025b, *Mine Void Water Inflow Scenario Adaptive Pathways Planning – Hazelwood Rehabilitation Project*, prepared for ENGIE, unpublished report.

Government of Victoria 2004, *Occupational Health and Safety Act 2004 (Vic)*.

Government of Victoria 2016, *Hazelwood Mine Fire Inquiry – Implementation Plan,* Melbourne.

Government of Victoria 2017, *Occupational Health and Safety Regulations 2017 (Vic)*.

Government of Victoria 2019, *Mineral Resources (Sustainable Development) (Mineral Industries) Regulations 2019 (Vic)*.

International Council on Mining and Metals (ICMM) 2015, *Health and Safety Critical Control Management: Good Practice Guide*, London.

International Standards Organisation 2018, *ISO 31000:2018 Risk Management – Guidelines*.