Fingerboards Mineral Sands Project Inquiry and Advisory Committee
Technical note

TN No: TN 037

Date: 25 June 2021

Subject: Further Climate Change Modelling Work

This technical note provides furthering climate change modelling work undertaken by EMM Consulting and Water Technology in response to question 8 of the IAC's third request for information dated 10 May 2021 (Tabled Document 294). This work updates the initial response to this question that was provided in TN 029 (Tabled Document 463).

MEMORANDUM

To	Kirsty Campbell
From	Tony McAlister
Date	25 June 2021
Subject	Kalbar/Fingerboards Climate Change Water Balance Assessments
Our ref	21020125_M05_V04_Climate change response.docx

EXECUTIVE SUMMARY

Water Technology and EMM have undertaken separate interrelated climate change investigations of water resource and water management elements of the proposed Fingerboards mineral sands project. Water Technology evaluated how relevant technical guidelines prepared by the Victorian Department of Environment, Land, Water and Planning (DELWP) could be applied to derive a range of future climate (rainfall and evaporation) scenarios and then used datasets produced using these guidelines to assess long-term future water resource availability ranges for the Mitchell River adjacent to the site of the proposed mine. EMM used the same climate data sets to assess how climate change may affect previous predictions of water supply usage and mine water management dam spills from the project site. Water Technology then used these predictions to assess how the new results affected previous evaluations of the potential effects of mine site operations on water resource and water quality characteristics of the Mitchell River downstream of the site. Key findings of the work that has been undertaken are as follows:

- All but 3 of the 14 climate scenarios evaluated saw reductions in potential surface water availability to the Fingerboards project from the Mitchell River at Glenaladale. Based on the 1,400 ML/day flow exceedance threshold before harvesting of water to the mine can occur, the current availability of 47% (that is, water can be supplied to the mine site for approximately half of the time) fell in 2040 (year 15 of the mine site, this being the last year when water extraction from the Mitchell River will be required) to a lowest value of 35.9% (that is, water can be supplied to the mine site for approximately one third of the time);
- With mostly reduced rainfall predictions, the average annual probability of a spill from the mine site to the Mitchell River will also reduce. Predictions using current climate data of a probability of a spill to the Mitchell River in any one year of the order of 3% typically reduce to around 1%;
- Given the potentially reduced magnitudes of surface water flow in the Mitchell River identified in the first point above, the availability of water for winter fill harvesting to supply water for mine operations could also reduce, and greater demands on groundwater could result. In the worst-case scenario in year 15, peak yearly groundwater demand could increase from around 1.7 GL per year using current climate data to a worst case of the order of 2.8 GL per year, an increase of approximately 65%. Regardless of this increase, there are more than sufficient groundwater reserves beneath and adjacent to the Fingerboards mine site to supply this potential increase in demand, with the groundwater assessment appendix to the EES described groundwater extraction rates of 3 GL/year for the full 15 years; and
- As there will be less winter fill harvesting from the Mitchell River if climate change cases occur, the impact of mine surface water extraction on downstream water availability will remain negligible. That is, even though there is less flow, there is also less harvesting able to be conducted due to the lower flow regime, meaning no effective change. From a water quality perspective, the lower flows in the river system as a whole are ‘balanced’ with lower likelihoods of spills from the mine site, meaning that there will be no change to previous predictions of no adverse impacts on water quality in the Mitchell River and Gippsland Lakes.

1 INTRODUCTION

Water Technology and EMM have respectively previously undertaken separate (though interrelated) regional and site-based water resource and water balance assessments in relation to Kalbar's proposed Fingerboards mineral sands project in Eastern Victoria. These assessments have all used historical rainfall and streamflow data as key forcing parameters for a range of contemporary water balance modelling assessments. These works were then used to inform Environmental Effects Statement (EES) documentation and reporting that has been the subject (along with other material) of an Inquiry and Advisory Committee (IAC) process.

In association with the hearings of the IAC, the subject of climate change and how this may relate to, and/or affect the viability of, or potential off-site impacts from, the project has been raised by the IAC. This technical memorandum documents the findings of climate change impact assessments that have been conducted by Water Technology and EMM in order to address this issue.

2 CLIMATE CHANGE ASSUMPTIONS

2.1 Climate change modelling methods applied by CSIRO and reported by DELWP

Water Technology and EMM have been asked by the IAC to use the Victorian Department of Environment, Land, Water and Planning (DELWP) 'Guidelines for Assessing the Impact of Climate Change on Water Availability in Victoria (2020)' (DELWP 2020). These Guidelines were developed such that there is a consistent approach across Victoria for applying climate change scenarios for temperature, potential evapotranspiration and rainfall analyses. Specifically, the Guidelines ensure that a range of possible climate scenarios is considered when assessing future water resource related project viability.

A description of climate change modelling is provided in the Guidelines and summarised here for reference.

CSIRO prepared the modelling used in the Guidelines, applying a multi-step process for developing estimates of changes in rainfall, evaporation and runoff at a river basin level (Figure 1). The main steps were:

- Obtain the results of the IPCC CMIP5 suite of global climate models (GCMs) (42 models) for two emissions scenarios:
  - RCP4.5, recommended in the Guidelines for testing robustness of planning outcomes
  - RCP8.5, recommended in the Guidelines for water supply planning
- 'Downscale' the global climate models to obtain results at a scale relevant to assessing river basins (typically 200 km by 200 km resolution)
  - this process provided rainfall and evaporation data for river basins
- Calibrate SIMHYD runoff models to 90 unregulated river catchments across Victoria using the period 1975-2014 to obtain runoff parameters broadly applicable to each river catchment across Victoria
- Apply the downscaled rainfall and evaporation to the SIMHYD models to develop estimates of runoff changes
- Results from the GCMs with 10th percentile, median and 90th percentile runoff responses to climate projections were selected and used to define 'low' 'medium', and 'high' climate change scenarios, with these names intended to refer to low, medium or high impact on water availability.
  - the 'low' results have more rainfall runoff and higher streamflows
  - the 'high' results have less rainfall runoff and lower streamflows
- The model data were reported by river basin

In addition to the climate projections developed from GCMs, a post-1997 step change climate scenario is described in Guidelines. This scenario is developed by scaling baseline climate data to have the (lower runoff) statistics of the post-1997 period, and is not developed from GCM outputs.

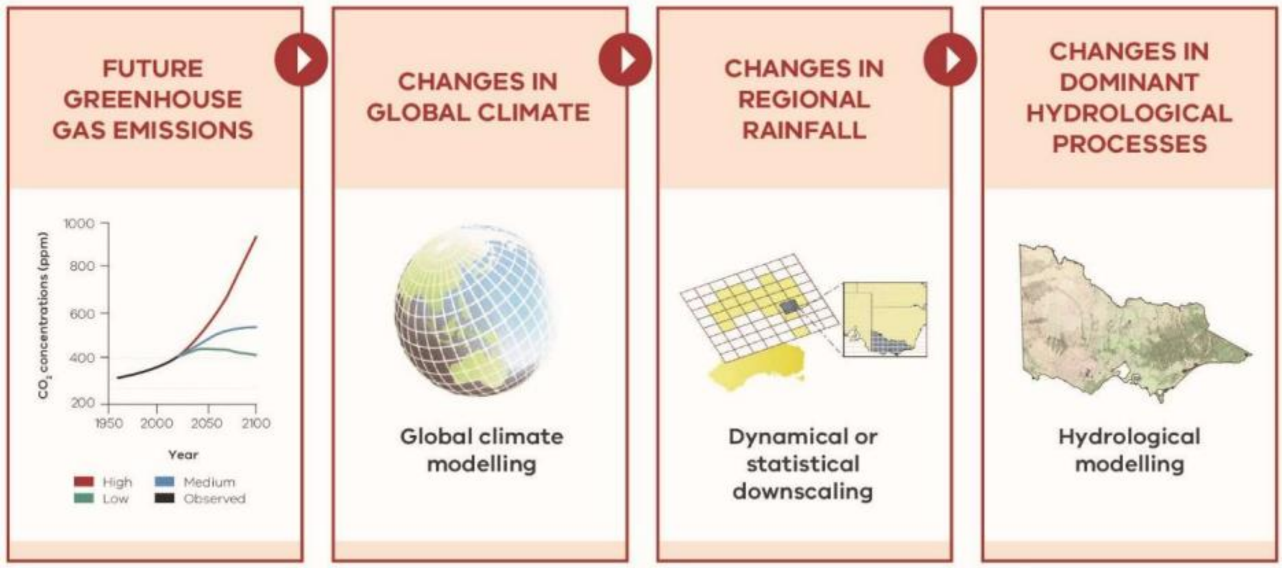


Figure 1 Overview of modelling process to derive climate change projections from global climate models (DELWP 2020)

2.2 Application of climate change to the Fingerboards project

Water Technology and EMM have been asked by the IAC to use the DELWP Guidelines in undertaking these assessments. A brief description is provided below of the scenarios that were tested in the modelling tools developed for this project, and importantly how these scenarios were parameterised in the models.

The IAC requested that Water Technology and EMM, on behalf of Kalbar, undertake relevant modelling assessments and provide technical advice regarding the following:

- Rainfall, run-off and spill predictions from the site, considering climate change impacts expected over the mine life, and for 20 years after mine closure;
- The above work should simulate rainfall and run-off in a manner that is consistent with the previously referenced DELWP guidelines; and
- Provide rainfall and run-off model results using the 1997 – present baseline period (i.e. a climate ‘step change’ scenario) in addition to the above.

In undertaking these assessments, we note that the DELWP Guidelines provide two methods of preparing potential future climate sequences, one using ‘flow duration curve decile scaling’ and the other using ‘stochastic data generation’ techniques. Given the relatively short timeframe that was available for these investigations and the availability of relevant hydroclimate transformation tools (as discussed in Section 3 below), the former of these two approaches was adopted. We believe that it is unlikely that adoption of the more complicated and time-consuming stochastic approach would necessarily change to any significant degree the overall findings of these investigations.

3 MODELLING APPROACH

In providing the assistance requested by the IAC, regional (eWater Source) and site-based (Goldsim) models previously developed by Water Technology and EMM were applied iteratively, as there is a degree of feedback between the models. The structure and logic of the eWater Source and Goldsim water balance models have been described in previous Water Technology and EMM reports and are not repeated here. The process that was followed is summarised below:

- Revised rainfall and evaporation data sets were derived for the Fingerboards site and for numerous sites across the catchments of the Mitchell and Perry rivers, as required to force the regional and site-based models, using the DELWP guidelines methodology as described below.
  - Historical daily rainfall and evaporation data was used as a basis for the climate change sensitivity analysis. The historical time series were adjusted to have similar exceedance properties to shorter reference periods and transformed to represent various climate change scenarios in accordance with the DELWP Guidelines. The climate change sensitivity assessment was focussed on the Mitchell River catchment as this was the primary source of potential external water supply to the project.
  - For consistency with the previous assessment, historical rainfall and evaporation data from 01/01/1900 was used to apply climate change transformations. The locations of the 13 gridded rainfall sites from SILO (SILO 2021) are shown in Figure 2. These are identical to the sites used in the Water Technology Regional Study (Water Technology 2020). Details of the rainfall locations are provided in Table 1.
  - The Hydroclimate Data Transformation Tool developed by DELWP and HARC (2020) was used to transform the historical time series. Pre-1975 rainfall and evaporation data was firstly adjusted to have identical exceedance properties to the post-1975 reference period. This was done for each site on a seasonal basis using exceedance percentiles (rather than on an annual basis or using decile statistics). The adjusted post-1975 reference period data was then transformed based on the projected change in average annual rainfall and potential evapotranspiration specified in the DELWP Guidelines (DELWP 2020). Projections were based on the Mitchell River basin parameters in the Guidelines and were performed for high, medium and low runoff scenarios for the years 2040 and 2065. The resulting adjusted rainfall and evaporation time series represent a range of possible future climate scenarios.
  - The rainfall dataset was adjusted to represent the climate change scenarios using the "peak and annual average factors" function in the Hydroclimate Data Transformation Tool. This function factors the intense rainfall data above a nominated threshold (the 1% AEP 24-hour IFD rainfall depth as specified in the DELWP Guidelines) and adjusts the remaining rainfall data to satisfy the projected annual average change in rainfall. The nominated threshold for each site is contained in Table 1. This detailed factorisation cannot be performed on evaporation data; therefore evaporation time series were projected based on annual factors only.
  - The analysis also considered the post-1997 reference period "step change" scenario. This transformation assumes that the post-1997 exceedance properties are representative of future climate change and are applied to the pre-1997 historical time series on a seasonal and percentile basis. No other climate transformations are applied to the resulting adjusted time series.
- Relevant rainfall and evaporation data for the period from 1900 – present were provided to EMM in order to enable simulation of the site water balance (Goldsim model) and related processes for the following periods:
  - 1975 – current;
  - 1997 – current (representing a potential step change climate case); and
  - 2040 and 2065 predictions of climate data with high, medium and low water availability, using both RCP 4.5 and RCP 8.5 climate predictions.
- Relevant rainfall and evaporation data were also used to inform the eWater Source model. This model was then executed with relevant climate series data in order to develop predictions of daily flow in the Mitchell River adjacent to the Fingerboards site. These predictions were then supplied to EMM in the form of daily flow sequences for each climate series at the Glenaladale stream gauging station for the period after 1955 (i.e. the period wherein the eWater Source model had been calibrated and there was some certainty as to water allocations in the catchment);

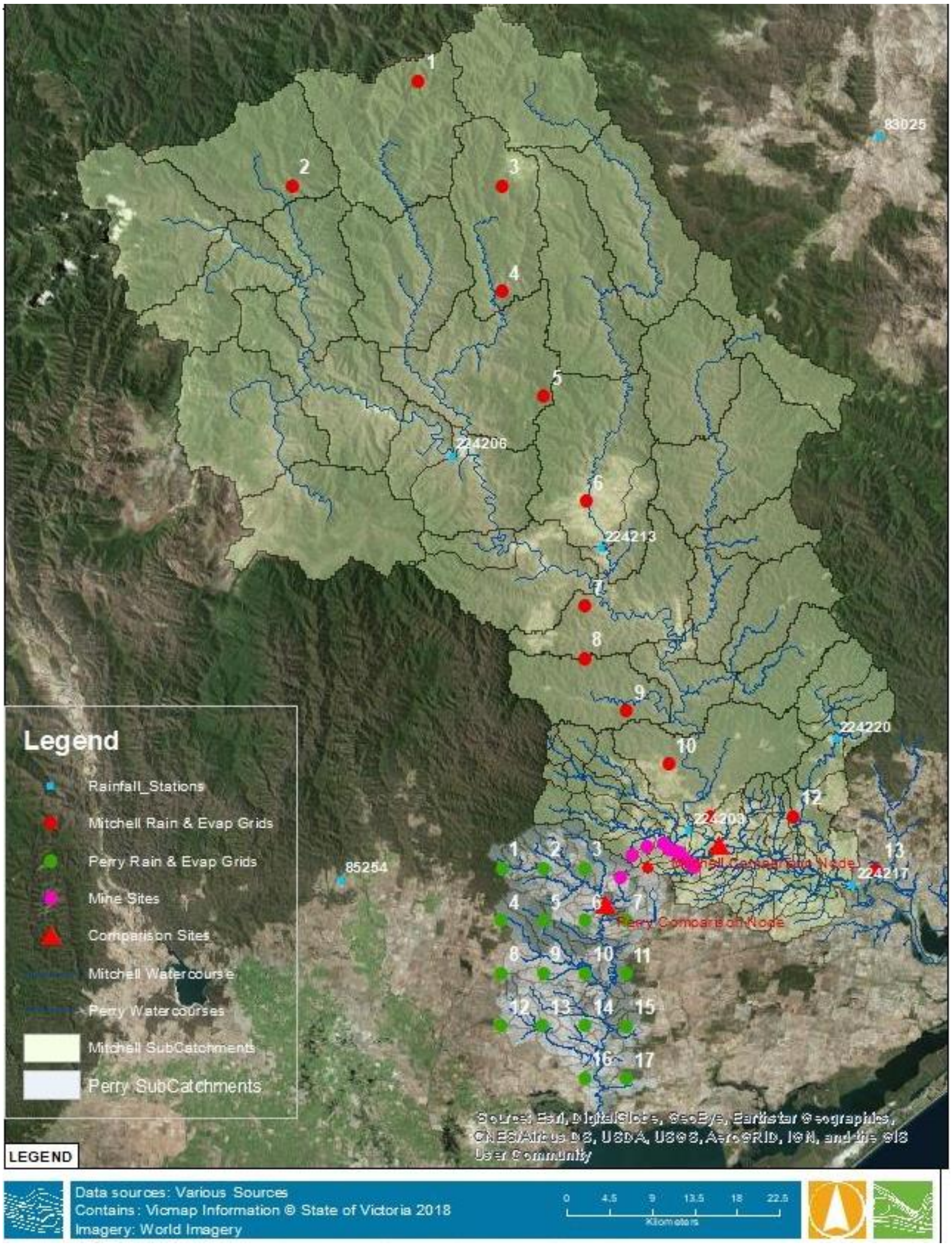


Figure 2 **Locations of grids where rainfall and evaporation data were downloaded from SILO, Red for Mitchell, magenta for Perry**

Table 1 Gridded Rainfall Location Summary

Gridded Rainfall Location	Co-ordinates	1% AEP 24 hr IFD Rainfall Depth Threshold
Site 1	-37.05, 147.05	88.4
Site 2	-37.15, 146.90	71.3
Site 3	-37.15, 147.15	94.6
Site 4	-37.25, 147.15	68.0
Site 5	-37.35, 147.20	74.8
Site 6	-37.45, 147.25	59.4
Site 7	-37.55, 147.25	63.2
Site 8	-37.60, 147.25	63.8
Site 9	-37.65, 147.30	66.2
Site 10	-37.70, 147.35	67.8
Site 11	-37.75, 147.40	68.8
Site 12	-37.75, 147.50	69.4
Site 13	-37.80, 147.60	67.1

- The Goldsim model was then run with each set of climate and streamflow data to produce estimates of run-off from the site to the Mitchell River for each of the potential site layouts included in the model (i.e., pre-mining, year 5, year 8, year 15 and post closure) for each climate sequence. We note that all these modelling works assumed that cyclones are applied on the site as has recently been proposed by Kalbar. Outflows from the site at each site outlet were collated for the period post 1955 for relevant combinations of climate and site layout and supplied to Water Technology for inclusion in the eWater Source model. The site-based water balance model itself was also run for the period 1900 – 2020 and results describing water movements on the mine site, including estimates of water management dam spills, were developed using the full model duration. Results describing pumping from the Mitchell River versus groundwater usage were developed for each climate scenario using only the post 1955 portion of the results, again, this being the period for which Water Technology believed that base case estimates of flow in the Mitchell River were reliable; and
- The eWater Source model was then run in a revised configuration with the new site flows derived by EMM and subsequently used to assess the implications of site works and the various climate scenarios on flow statistics downstream of the Fingerboards site.

A summary of the scenarios run is provided in Table 2.

Table 2 Scenario Summary

Scenario Number	Mine layout	Climate data
1	Pre mining	Baseline post 1975
2	Pre mining	Step change post 1997
3	Year 5	Baseline post 1975
4	Year 5	Step change post 1997
5	Year 8	Baseline post 1975
6	Year 8	Step change post 1997
7	Year 15	Baseline post 1975
8	Year 15	Step change post 1997
9	Year 15	RCP4.5 2040 Low
10	Year 15	RCP4.5 2040 Medium
11	Year 15	RCP4.5 2040 High
12	Year 15	RCP8.5 2040 Low
13	Year 15	RCP8.5 2040 Medium
14	Year 15	RCP8.5 2040 High
15	Post closure	Baseline post 1975
16	Post closure	Step change post 1997
17	Post closure	RCP4.5 2040 Low
18	Post closure	RCP4.5 2040 Medium
19	Post closure	RCP4.5 2040 High
20	Post closure	RCP8.5 2040 Low
21	Post closure	RCP8.5 2040 Medium
22	Post closure	RCP8.5 2040 High
23	Post closure	RCP4.5 2065 Low
24	Post closure	RCP4.5 2065 Medium
25	Post closure	RCP4.5 2065 High
26	Post closure	RCP8.5 2065 Low
27	Post closure	RCP8.5 2065 Medium
28	Post closure	RCP8.5 2065 High

4 SITE BASED ANALYSES

4.1 Spills from water management dams

The Goldsim modelling predicted that if rainfall similar to the **1978** climate sequence occurred again, it would cause water management dams in the Mitchell River catchment to spill, regardless of the mine layout at the time (Table 3). With the year 8 mine layout, the **1974** climate sequence would also cause water management dams to fill and spill.

Spill events with a total volume of 5 Megalitres (ML) or less were predicted by the model for:

- The 1952 climate sequence when using the baseline climate and the year 8 mine layout;
- The 1974 climate sequence when using the step-change and 'low' effect 2040 climate change sequences with the year 15 mine layout; and
- The 2007 climate sequence when using the 'low' effect 2040 climate change sequences with the year 15 mine layout.

These spill events with 5 ML total volume or less are small enough that they are likely to be preventable through optimisation of onsite water management, and so have been listed in grey and italics in Table 3 to indicate that it may be appropriate to discount these events from further analysis. For example:

- 5 ML could be pumped in under 1 week (i.e. achievable during build-up of water over long wet periods) with a single 10 litre per second (L/s) skid mounted pump with water transferred to a pit sump if necessary for temporary storage. It is likely that several similar or larger pumps would be available on site to assist with water management; or
- 5 ML could be removed during build-up of water over long wet periods if the dissolved air flotation (DAF) plant were optimised to treat 25 ML/day rather than the nominal 24 ML/day.

Climate sequences which caused significant (>5 ML) spill volumes (e.g. 1978) are listed in Table 3 with standard black text.

Table 3 Climate sequences (years) which produced water management dams to over top in the Mitchell River catchment in the EMM site water balance model

Climate sequence	Mine year 5	Mine year 8	Mine year 15
Baseline (Post 1975 baseline)	1978	*1952*[1], 1974, 1978	1978
Step change (Post 1997 baseline)	1978	1974, 1978	*1974*, 1978
RCP4.5/RCP8.5 2040 Low[2]	Not modelled[3]	Not modelled	*1974*, 1978, *2007*
RCP4.5/RCP8.5 2040 Medium	Not modelled	Not modelled	1978
RCP4.5/RCP8.5 2040 High	Not modelled	Not modelled	1978

1: Years listed in italics represent spill events with small volumes (<=5 ML over the year) of water spilled.
2: RCP4.5 and RCP8.5 produced very similar results and have been grouped in this table
3: Year 5 and year 8 mine layouts were modelled only with baseline and step-change climate sequences. These mine years would be complete prior to 2040, so the 2040 climate change sequences were not used with these mine layouts.

As dewatering of the water management dams located in the Perry River catchment is prioritised in the model over dewatering of water management dams located in the Mitchell River catchment, fewer spills to the Perry River catchment were modelled. As seen in Table 4, the 1978 climate sequence caused the water management dams in the Perry River catchment to spill with the year 8 mine layout and the year 15 mine layout.

Table 4 Climate sequences (years) which produced water management dams to over top in the Perry River catchment in the EMM site water balance model

Climate sequence	Mine year 5	Mine year 8	Mine year 15
Baseline (Post 1975 baseline)	No spills	1978	1978
Step change (Post 1997 baseline)	No spills	1978	1978
RCP4.5/RCP8.5 2040 Low[1]	Not modelled[2]	Not modelled	1978
RCP4.5/RCP8.5 2040 Medium	Not modelled	Not modelled	1978
RCP4.5/RCP8.5 2040 High	Not modelled	Not modelled	No spills

1: RCP4.5 and RCP8.5 produced very similar results and have been grouped in this table
2: Year 5 and year 8 mine layouts were modelled only with baseline and step-change climate sequences. These mine years would be complete prior to 2040, so the 2040 climate change sequences were not used with these mine layouts.

The volumes associated with each modelled spill event are listed in Table 5 and Table 6. In general, the climate change scenarios produce less total spill volume than the baseline climate sequence, due to the climate change sequences being generally drier. However, the intense storms may become more intense, which affects the peak discharges in some scenarios, particularly the step change climate with the year 5 mine layout. The 'low' climate effect scenarios produced more runoff than the 'high' climate effect scenarios, as by definition the 'high' scenarios had a greater reduction in rainfall.

Table 5 Spill volumes for each modelled spill event (ML) – Mitchell River catchment

Climate sequence	Mine year 5	Mine year 8		Mine year 15	
Baseline (Post 1975)	1978: 21 ML	*1952: 3 ML* 1974: 109 ML 1978: 738 ML		1978: 90 ML	
Step change (Post 1997)	1978: 71 ML	1974: 105 ML 1978: 645 ML		*1974: 0.3 ML* 1978: 75 ML	
		RCP4.5	**RCP8.4**	**RCP4.5**	**RCP8.4**
2040 Low	Not modelled	Not modelled	Not modelled	*1974: 5 ML* 1978: 123 ML *2007: 2 ML*	*1974: 5 ML* 1978: 118 ML *2007: 0.7 ML*
2040 Medium	Not modelled	Not modelled	Not modelled	1978: 75 ML	1978: 75 ML
2040 High	Not modelled	Not modelled	Not modelled	1978: 40 ML	1978: 49 ML

Table 6 Spill volumes for each modelled spill event (ML) – Perry River catchment

Climate sequence	Mine year 5	Mine year 8		Mine year 15	
Baseline (Post 1975)	No spills	1978: 99 ML		1978: 99 ML	
Step change (Post 1997)	No spills	1978: 106 ML		1978: 106 ML	
		RCP4.5	**RCP8.4**	**RCP4.5**	**RCP8.4**
2040 Low	Not modelled	Not modelled	Not modelled	1978: 118 ML	1978: 131 ML
2040 Medium	Not modelled	Not modelled	Not modelled	1978: 96 ML	1978: 14 ML

Climate sequence	Mine year 5	Mine year 8		Mine year 15	
2040 High	Not modelled	Not modelled	Not modelled	No spills	No spills

As the 1978 climate sequence consistently produces spill events from the water balance model, hydrographs for that event have been produced in Figure 3 to Figure 8 for further analysis. From these plots, it is apparent that:

- The post 1997 step-change scenario creates marginally larger spill events than the baseline climate, due to an increase in storm intensity with climate change; and
- In the mine year 15 plots, the ‘low’ climate effect scenarios produced more runoff than the ‘high’ climate effect scenarios, as by definition the ‘high’ scenarios had a greater reduction in rainfall.

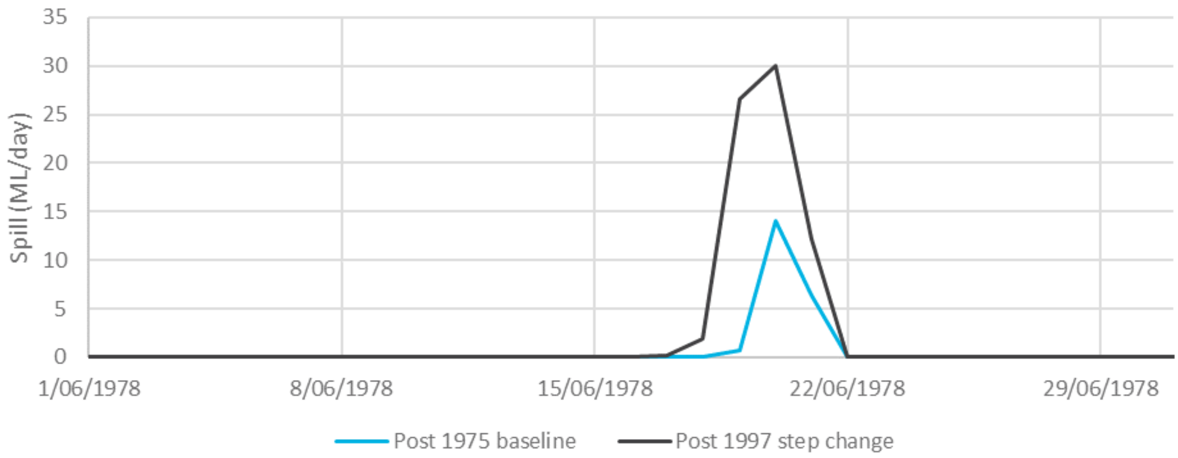


Figure 3 Hydrograph of water discharged to the Mitchell River, 1978 climate sequence, year 5 mine layout

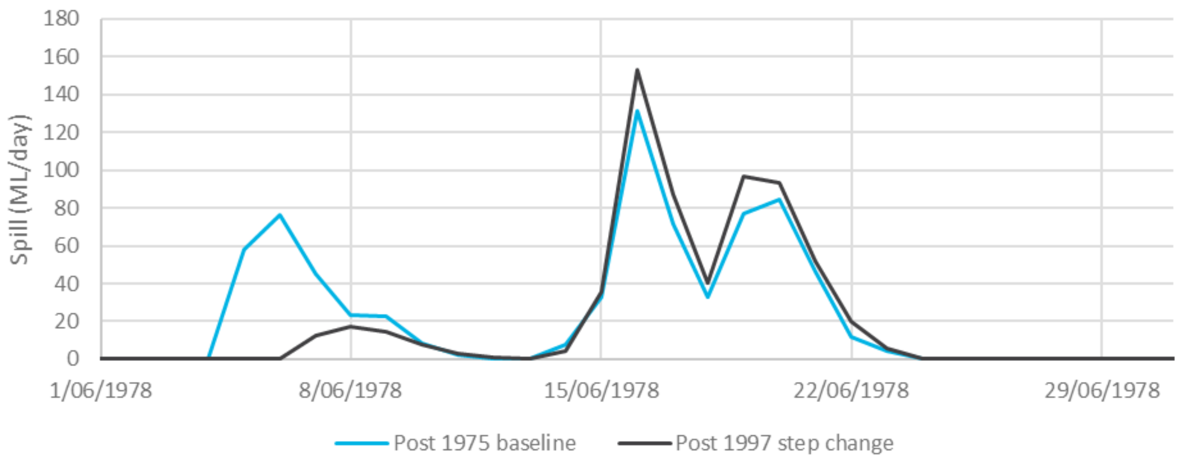


Figure 4 Hydrograph of water discharged to the Mitchell River, 1978 climate sequence, year 8 mine layout

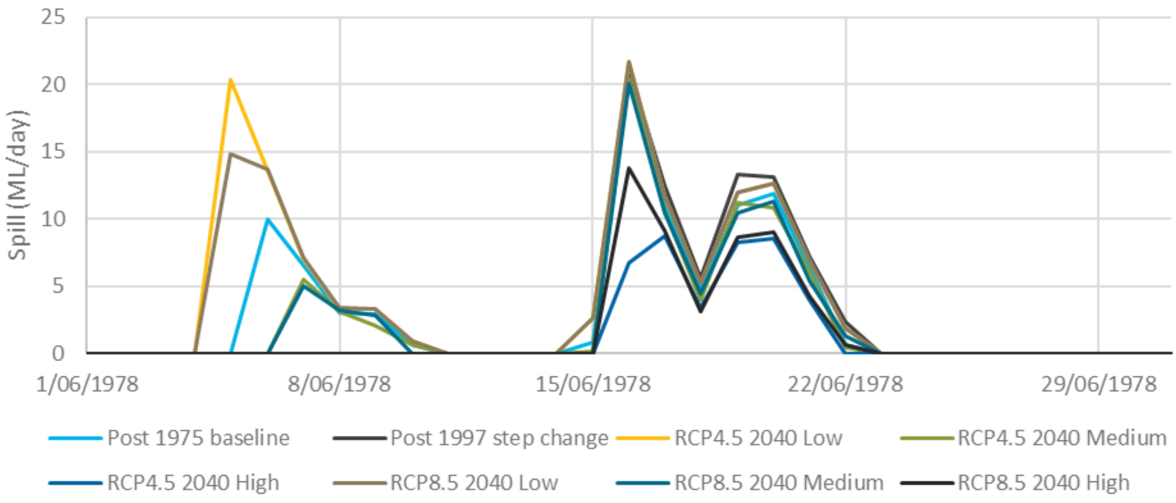
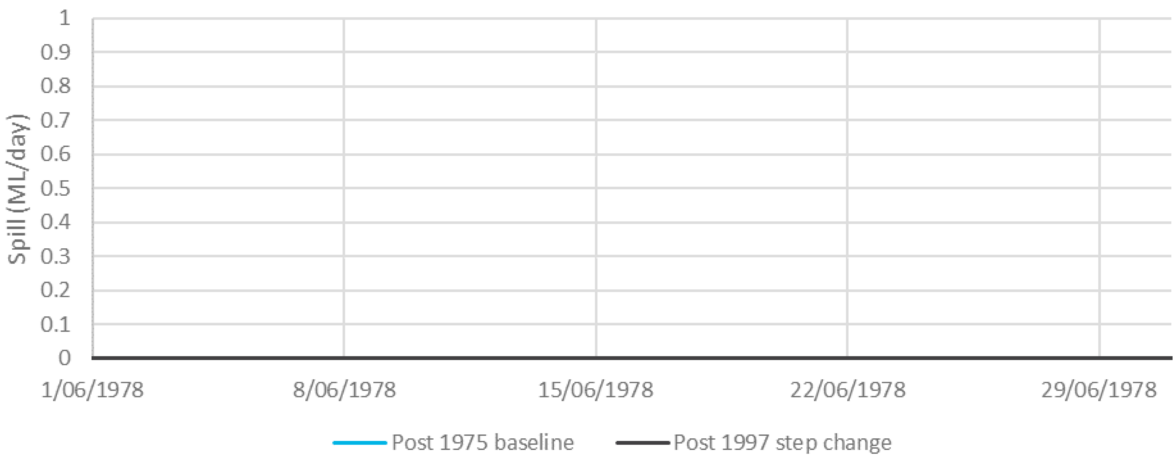


Figure 5 Hydrograph of water discharged to the Mitchell River, 1978 climate sequence, year 15 mine layout



Note: No spills were predicted to the Perry River catchment with the modelled climate sequences

Figure 6 Hydrograph of water discharged to the Perry River, 1978 climate sequence, year 5 mine layout

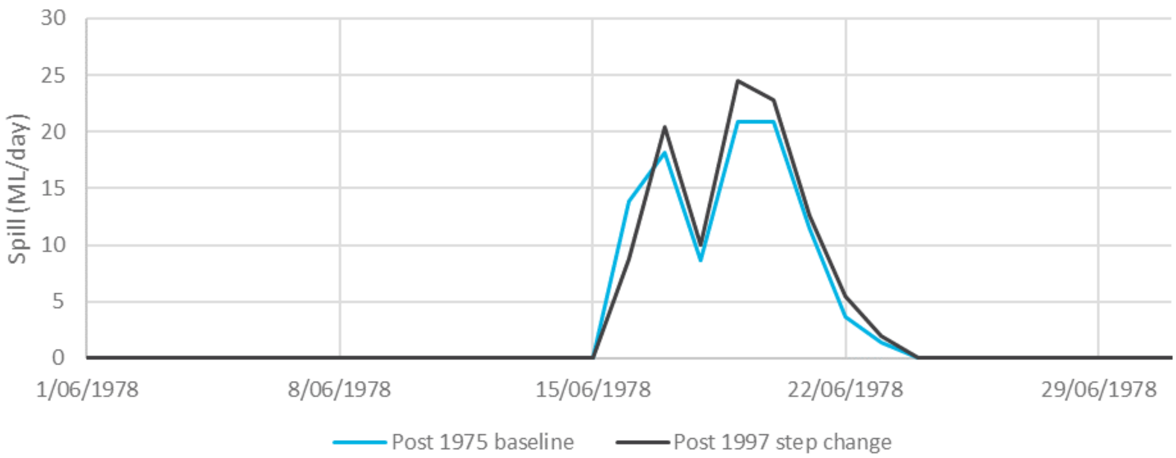


Figure 7 Hydrograph of water discharged to the Perry River, 1978 climate sequence, year 8 mine layout

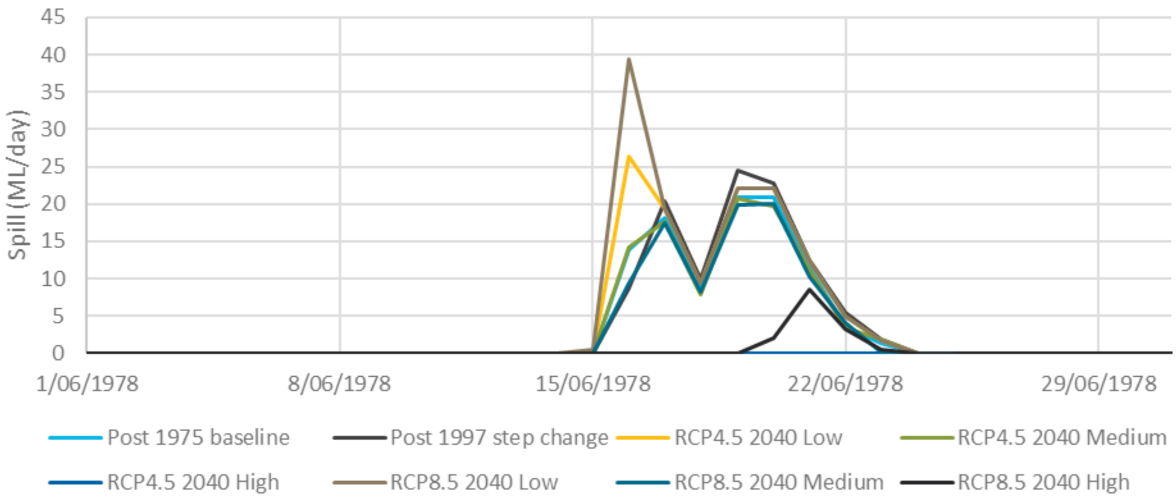


Figure 8 **Hydrograph of water discharged to the Perry River, 1978 climate sequence, year 15 mine layout**

The 1978 period was unusually wet, with more than 600 mm rain falling in the period March to July (Figure 9) and 240 mm in June alone. This exceeds the 90th percentile rainfall for each month over that period (Figure 10). This rainfall resulted in increased flows in the Mitchell River, with river height at Glenaladale reaching over 5 m, and flows of up to 60 GL/day (Figure 11). The model predicted water management dams spilling only during the peak flow periods, when dilutions of around 500:1 would have been achieved within the river (Figure 12).

With this context:

- greater than 90th percentile rainfall over consecutive months such as occurred in 1978 is expected to be extremely rare; and
- a release of stormwater from the site during an event such as the 1978 rainfall sequence is expected to have negligible effects due to the Mitchell River being swollen with runoff from its broader catchment.

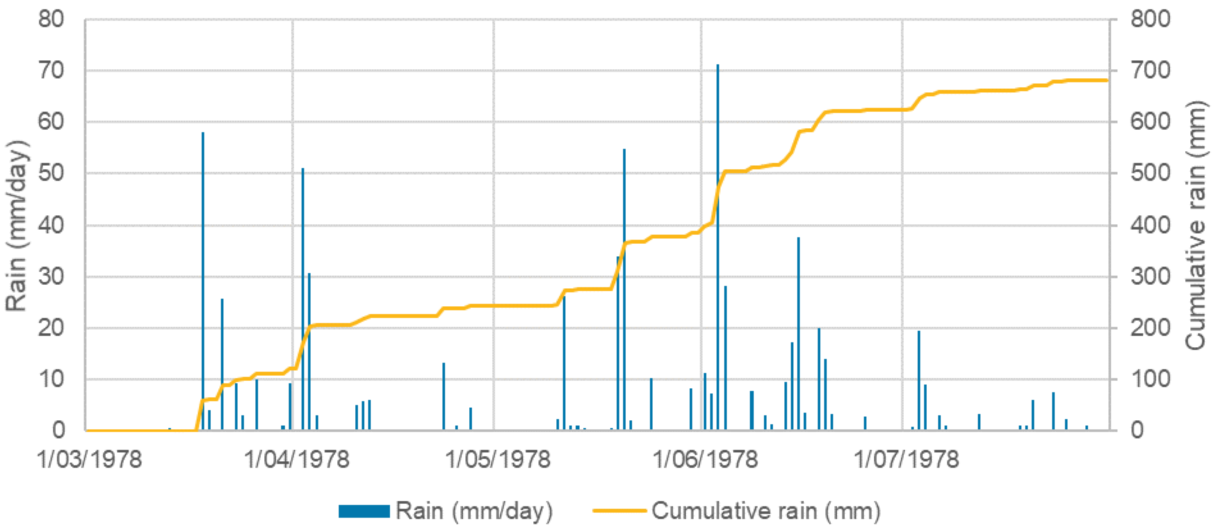


Figure 9 **1978 rainfall, daily and cumulative**

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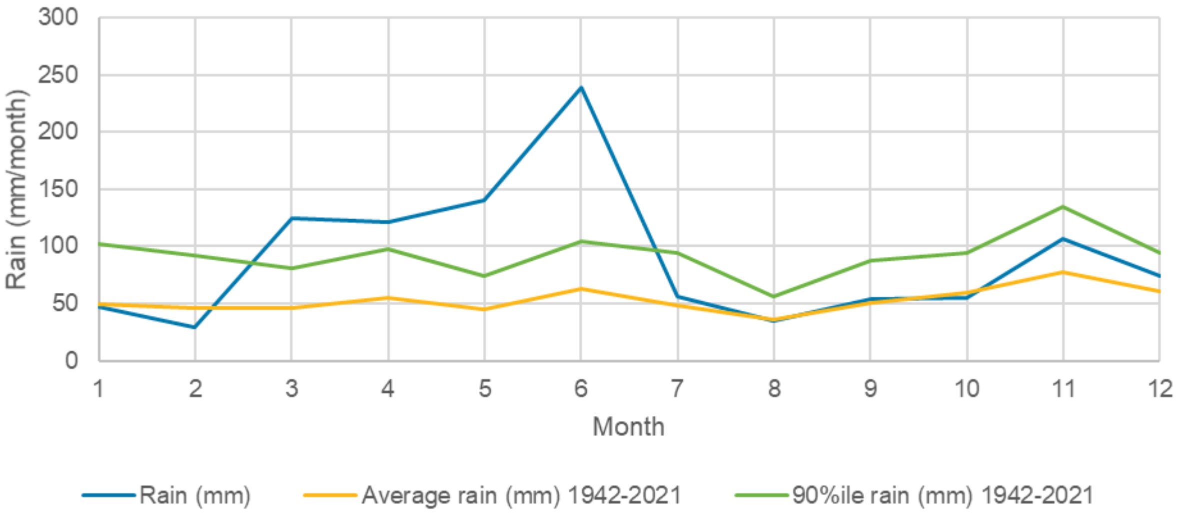

Figure 10 1978 rainfall, monthly

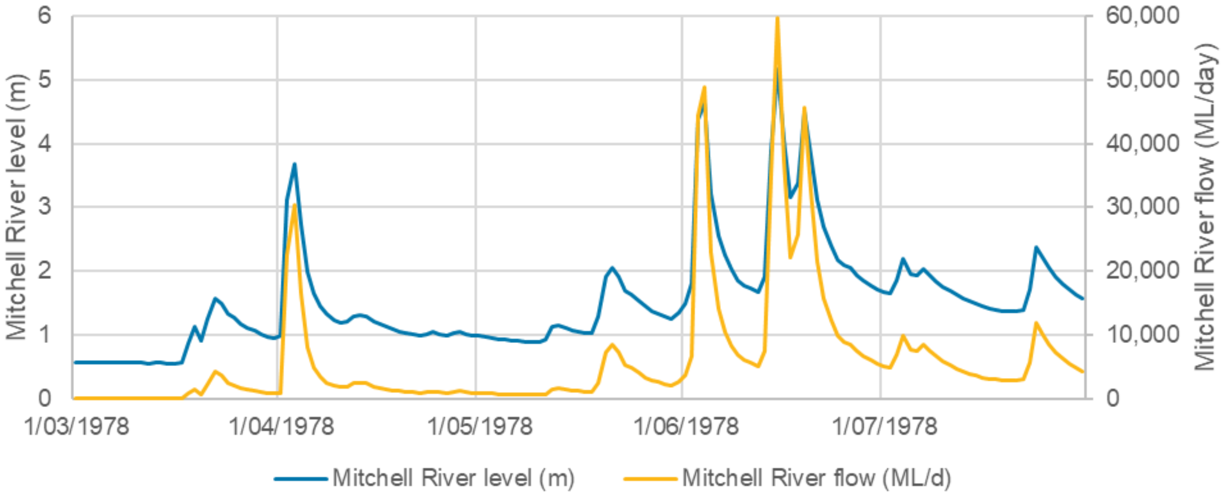

Figure 11 1978 Mitchell River flows

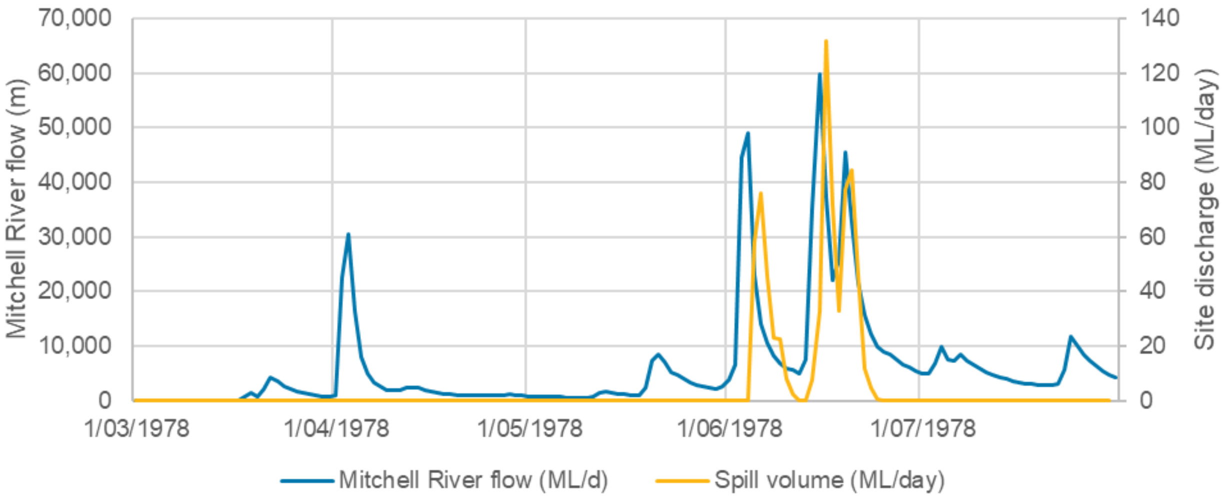

Figure 12 1978 Mitchell River flows and model spills

Using the data presented in Table 3 and Table 4:

- The average annual probability of climate conditions being such that a spill (greater than 5 ML) may occur would be around 1.05% p.a. in the Mitchell River catchment for all climate scenarios (Figure 13); and
- The average annual probability of water management dam spill to the Perry River catchment would be around 0.5% p.a. for all climate scenarios other than RCP4.5/RCP8.5 2040 High, for which the probability of spill would be 0% p.a. (Figure 13).

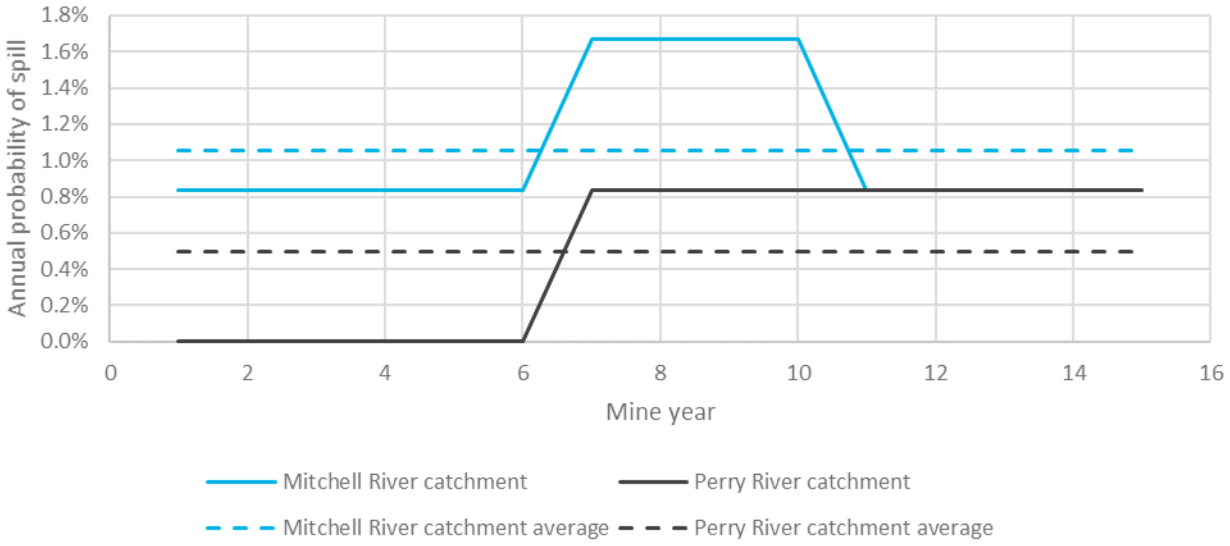

Figure 13 Annual probability of spill (modelled >5 ML spill volume), step change scenario

The main risk posed by spills from water management dams is to downstream water quality. The following text from EES Appendix A006AppE (Surface Water Assessment – Site Study) Section 7.2 remains current and provides context for interpreting the likely effect of spills:

- Water flowing through gullies will only be impacted when spillway flows occur – which is likely to happen only at rare intervals during the life of the mine. During all other times, gully flows will be at background surface runoff concentrations and there will be no water quality impacts.
- During a spillway flow event, TSS concentrations will be high. Due to their infrequent nature, there is not expected to be any significant siltation within gullies.
- Total nitrogen and phosphorus concentrations are estimated to decrease during mining; despite this phosphorus concentrations still exceed the aquatic ecosystem water quality objective.
- Background concentrations in undisturbed surface runoff (pre-mining) for aluminium and total phosphorus already exceed the relevant aquatic water quality objectives.
- The gully water quality modelling for the infrequent and short-term spillway flow events indicated that aluminium, total phosphorus and chromium concentrations may for short periods exceed aquatic water quality objectives. Comparing contaminant concentrations in short term gully flows to chronic toxicity values derived for generic freshwater ecosystems is not an appropriate application of the ANZECC guideline values as they rely on insufficient data to characterise the water quality requirements of ephemeral streams.
- The results indicate that all analyte concentrations in gully flows during the short-term spillway event will be suitable for use in agricultural irrigation water and livestock drinking water.

In addition, the following proposed surface water impact mitigation measures included in Attachment H (Mitigation register) remain applicable:

- SW30 Appropriate outlet scour protection will be placed on all stormwater outlets, chutes, spillways and slope drains to dissipate flow energy and minimise risk of soil erosion.
- SW34 Ephemeral drainage gullies will be revegetated in areas downstream of future mining activities prior to operations commencing to increase landscape stability and specifically mitigate:
  - Effects of a moderate increased flow velocity downstream of the mine operations and the final landform.
  - Potential effects of tunnel erosion downstream of the mine void boundary where soil treatment is not planned.
  - Effects of sediment starvation by reducing sediment transport and encouraging deposition.

4.2 Water supply

It is Kalbar's intention that mine site water supply will be obtained from a combination of Mitchell River water via a winterfill license during the months of July-October when river flows exceed 1,400 ML/day, and groundwater. Mitchell River water will be stored in a freshwater dam for use through the year, while groundwater will be pumped to site to make up operating water volumes if/when the freshwater dam has been drained.

An assessment of the frequency of flows exceeding 1,400 ML/day at Glenaladale was completed by Water Technology for the climate scenarios described in Table 2, and results provided to EMM for use in the water balance model. Table 8 in the following section summarises the change in the frequency of flows exceeding 1,400 ML/day due to climate change. EMM used this data to simulate the availability of water to the mine, and the possible split between surface water and groundwater supply.

The Goldsim water balance model showed that during drought years, the Mitchell River may not contain sufficient flow to fully satisfy a winterfill license, and in these years the site will rely more heavily on groundwater. Figure 14 shows the frequency and magnitude of groundwater requirements through the modelled period when the site is in the Year 5 or Year 8 layout. Year 5 and Year 8 results are very similar as they use the same climate data and as site water demand remains relatively constant through the mine life, driven by a constant production rate.

Figure 15 shows the frequency and magnitude of groundwater requirements through the modelled period for the Year 15 mine layout, and shows that with climate change there would be a greater reliance on groundwater.

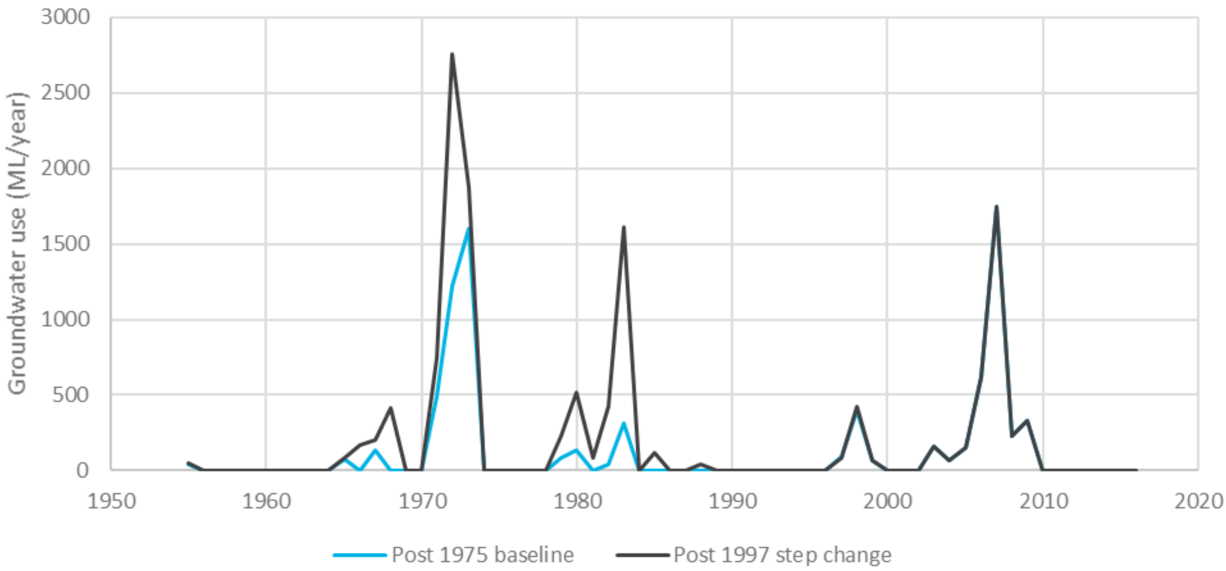

Figure 14 Groundwater requirements (mine year 5 and year 8 site layout)

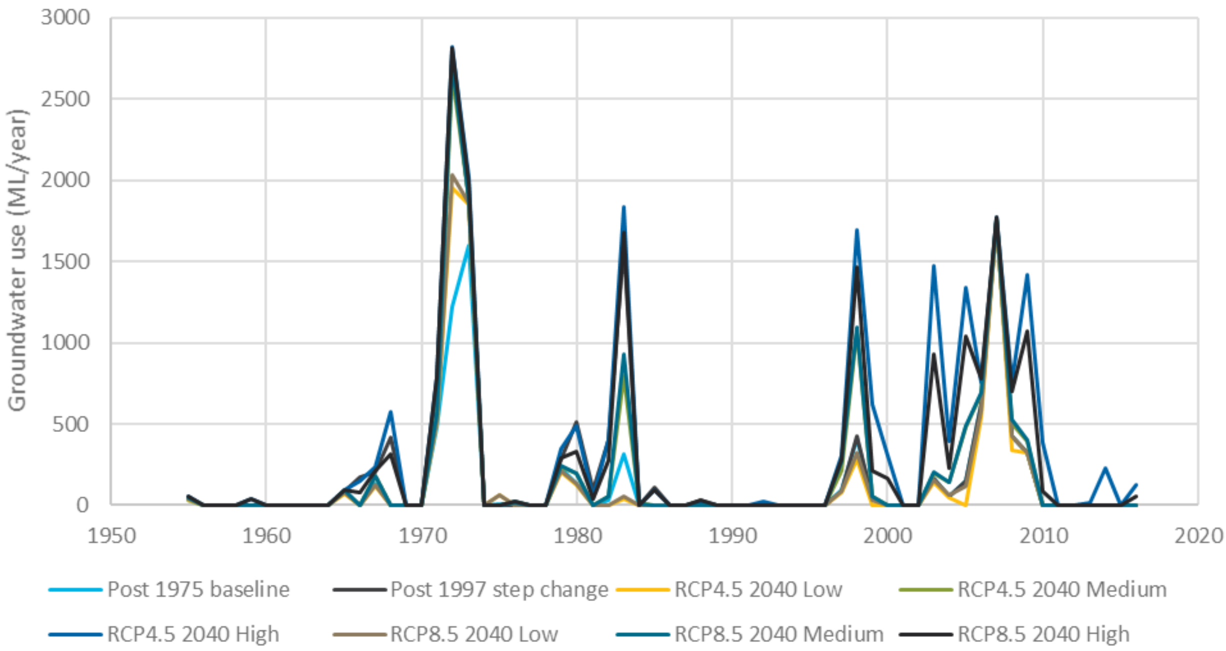

Figure 15 Groundwater requirements (mine year 15 site layout)

From the time series data presented in Figure 14 and Figure 15, groundwater requirement exceedance probabilities were calculated, and are shown in Figure 16 and Figure 17. This data shows that:

- In more than 50% of years, it can be expected that no groundwater would be required;
- In 10% of years, around 500 ML of groundwater may be required;
- In 5% of years, greater than 1,700 ML of groundwater may be required.

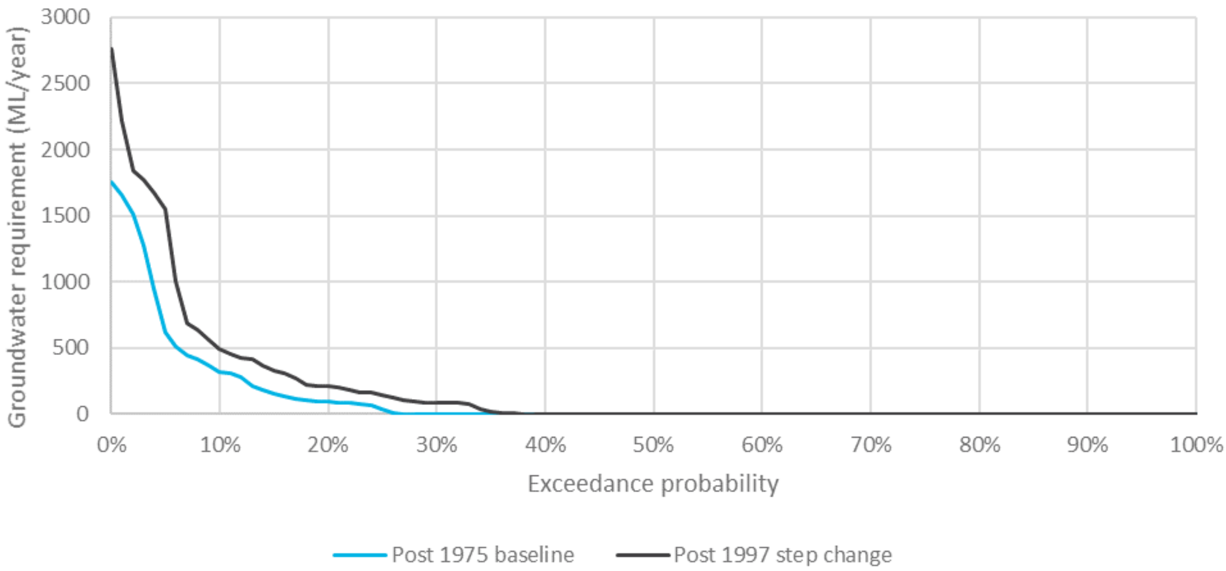

Figure 16 **Annual probability of groundwater requirements (mine year 5 and year 8 site layout)**

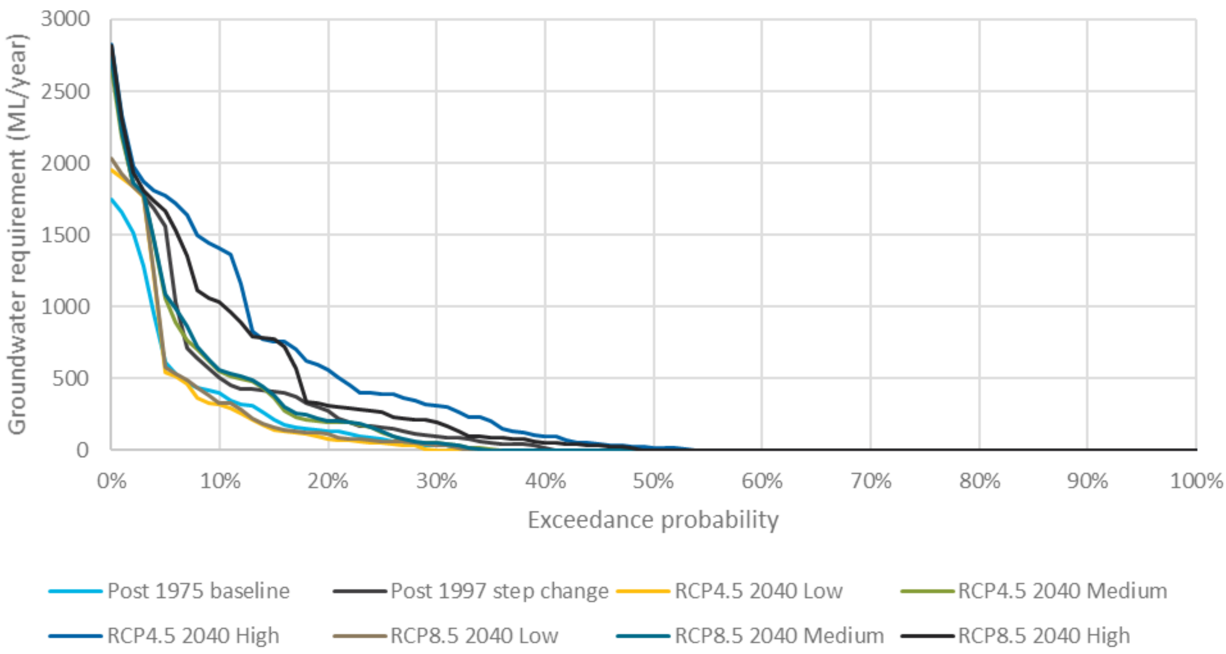

Figure 17 **Annual probability of groundwater requirements (mine year 15 site layout)**

Average yearly groundwater demands are illustrated in Figure 18. This data shows that the possible average draw from the aquifer (relevant to long term aquifer effects) could be between 100 ML/year to 350 ML/year depending on climate effects on river flows.

Peak yearly groundwater demands are illustrated in Figure 19. Peak groundwater use would occur in drought years when Mitchell River winterfill allocation is not available. It is likely that a drought would occur at least once during the 15-year mine life. Figure 19 shows that the peak groundwater requirement expected during drought is not expected to increase beyond 2,800 ML/year under any climate scenario, as this is the total site water demand.

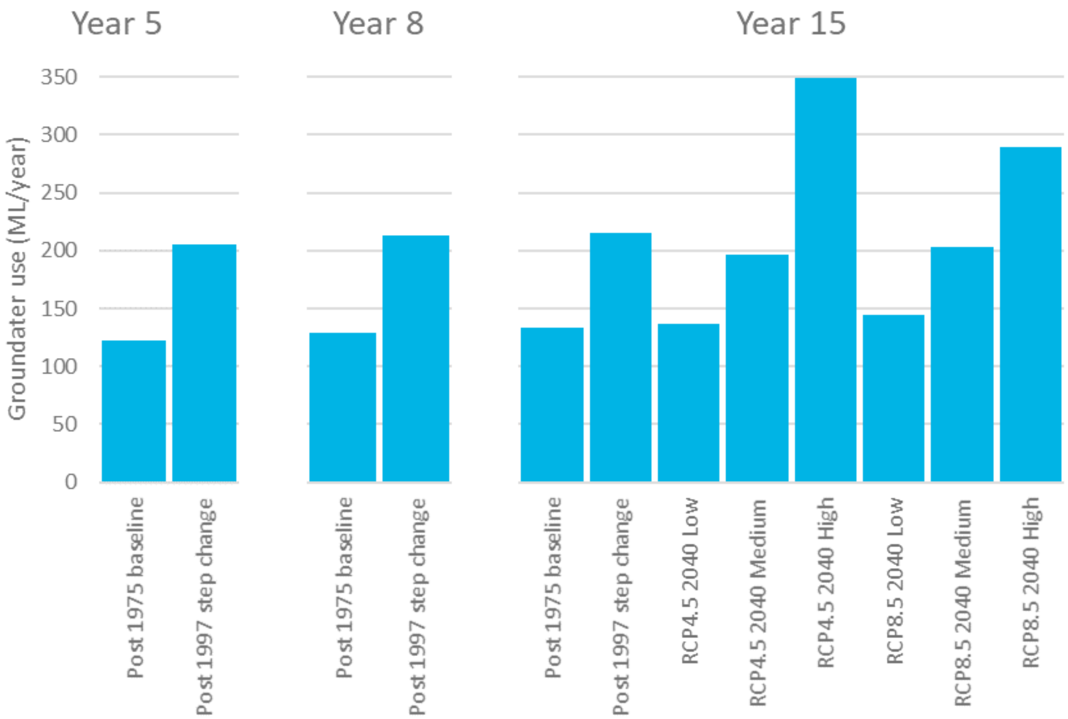

Figure 18 Estimated average groundwater requirement

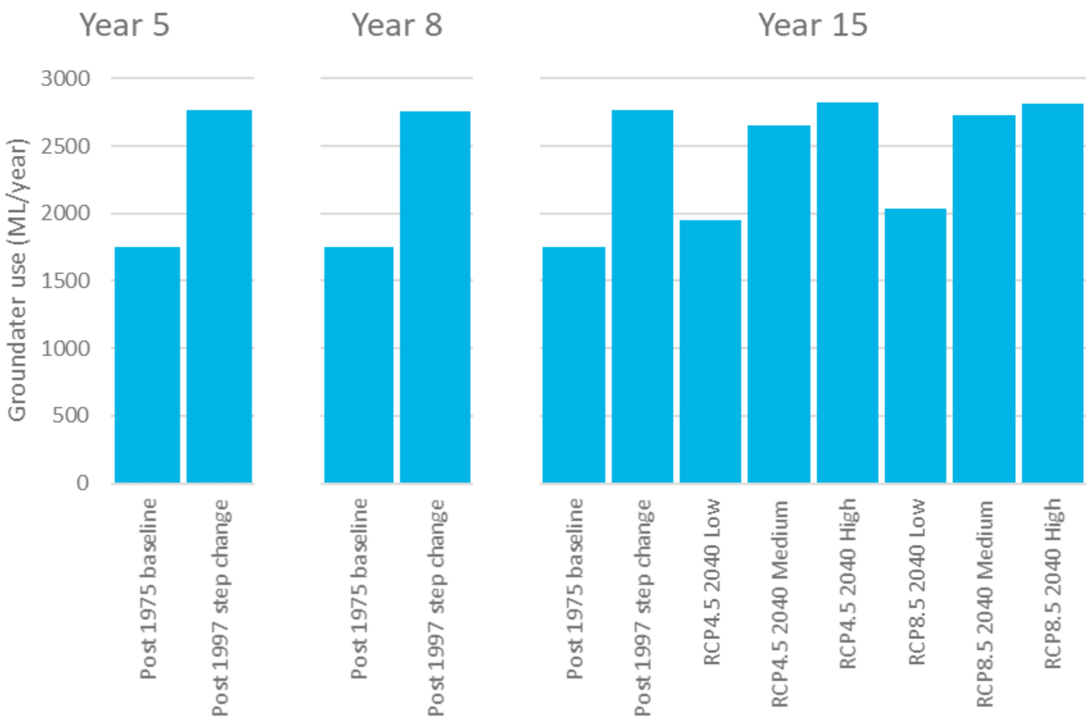

Figure 19 Estimated peak groundwater requirement

The groundwater modelling report Appendix A006AppB included data in Table 8.5 describing modelled rates of groundwater discharge to surface water features if the mine were to obtain a 3 GL/year water supply from groundwater for each year of the 15 year mine life. These results are summarised in Table 7.

Table 7 Modelled net groundwater discharges to surface water features when extracting 3 GL/year groundwater for 15 years (from Appendix A006AppB Table 8.5)

Receiving Feature	Current (ML/year)	Mining scenario (ML/year)	Change (ML/year)	Percent change
Mitchell River	14513	14553	+39	+0.27%
Perry River	533	529	-4	-0.75%
Gippsland Lakes	17688	17616	-72	-0.41%
Providence Ponds	210	209	-1	-0.35%

As the average groundwater extraction is predicted to be in the range 100 ML/year to 350 ML/year (Figure 18), much lower than the 3 GL/year modelled in the groundwater study, groundwater effects are likely to be around 10% of the magnitude reported in Appendix A006AppB. Given that the effects presented in Table 7 are already small volumes, it is likely that the groundwater effects will be negligible, with changes in discharge flow rates of <10 ML/year to each feature and with percentage changes of less than 0.1%

The groundwater model was not re-run to provide input to this climate change assessment, possible effects were estimated by scaling previously published results.

4.3 Summary

The key focus of this analysis has been on whether climate change may affect either the viability of the project (e.g., through their being insufficient flows in the Mitchell River) or see unacceptable off-site impacts (e.g., site operations causing unacceptable impacts on water quality or water resources).

From the perspective of the site-based analysis, it is apparent that:

- From a 'spill' perspective, while there are changes in the predicted discharges from site operations, some increases and some decreases, none of these changes are of sufficient magnitude to affect any of the previous findings and conclusions of the EMM and Water Technology EES investigations; and
- From a 'water resource' perspective, climate change may result in increased reliance on groundwater. The magnitude of this change is not of sufficient size to affect any of the previous findings and conclusions of the EMM and Water Technology EES investigations.

5 REGIONAL ANALYSES

As described earlier in this report, the regional eWater Source model was reconfigured and run for the wide range of scenarios listed in Table 2. Certain scenarios were also run both with and without the influence of the mine water extractions for the Fingerboards operation. In regard to these analyses, there are two separate, though interrelated areas of interest to the current investigations, these being:

- How climate change may affect flows in the Mitchell River system; and
- How operation of the mine, specifically water extraction for operations, may add to or affect these changes.

As such, these areas of interest are addressed separately below.

5.1 Climate change effects

In order to quantify this matter, the eWater Source model results were interpreted for 14 scenarios, these respectively including:

- Base case;
- Step change (post-1997);

- 2040 and 2065;
- Low, medium and high climate change; and
- RCP4.5 and RCP8.5.

The results of these analyses are presented in Figure 20 as a flow duration curve at Glenaladale and in Table 8 as the probability of exceedances at Glenaladale of the nominated Fingerboards mine water extraction threshold of 1,400 ML per day. Note that these cases exclude any extractions for the Fingerboards mine operation.

When the results presented in Figure 20 and Table 8 are reviewed, it is apparent that:

- For all 'low' climate change scenarios, flows in the system are actually predicted to increase;
- If the 'step change' climate change case is the 'new normal, then all 'medium' scenarios see minimal change; and
- For 'high' climate change scenarios, there are significant changes in flows in the system.

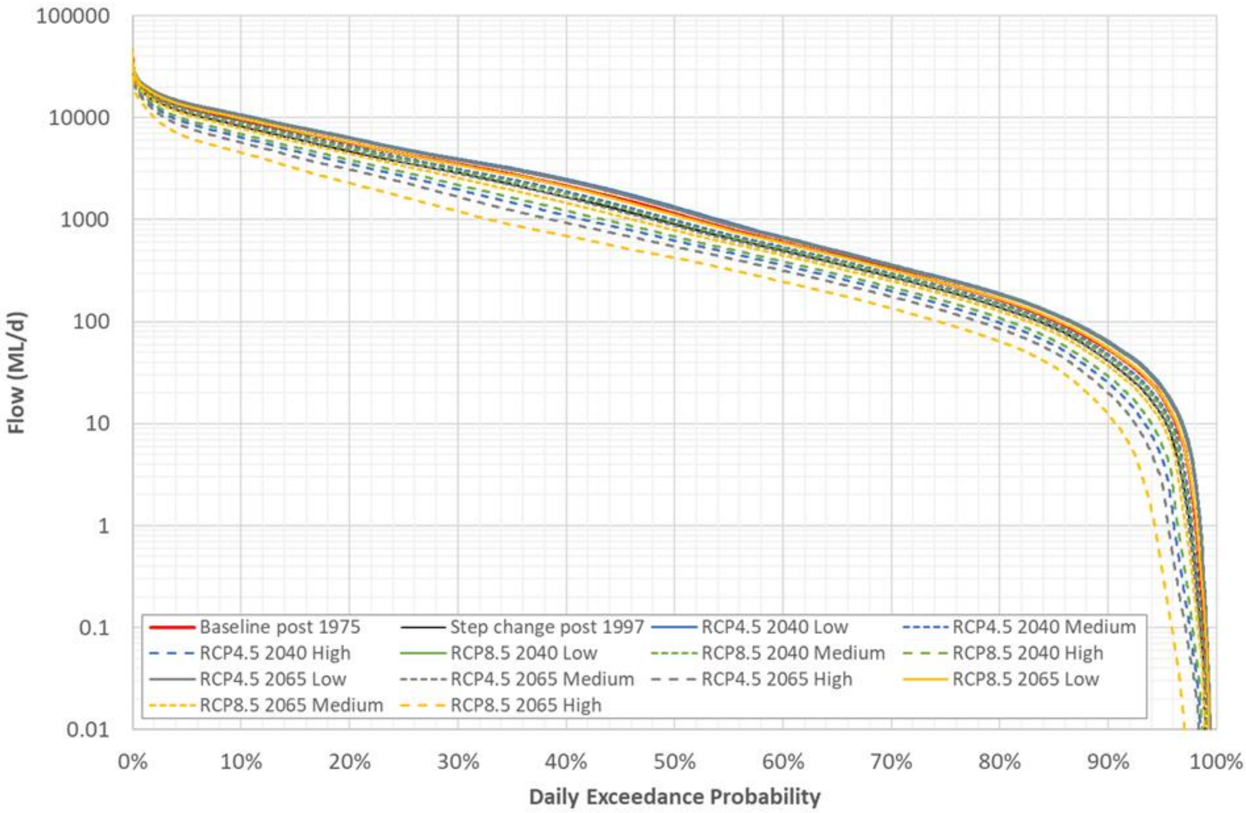

Figure 20 Glenaladale Flow Duration Curve – Climate Change Scenarios (no mine water extractions)

Table 8 Glenaladale 1,400 ML/day Exceedance Threshold Data – Climate Change Scenarios (no mine water extractions)

Scenario	1,400 ML/d Exceedance Probability
Baseline post 1975	47.03%
Step change post 1997	43.16%
RCP4.5 2040 Low	49.38%
RCP4.5 2040 Medium	44.79%

Scenario	1,400 ML/d Exceedance Probability
RCP4.5 2040 High	35.90%
RCP8.5 2040 Low	48.78%
RCP8.5 2040 Medium	43.95%
RCP8.5 2040 High	37.81%
RCP4.5 2065 Low	48.60%
RCP4.5 2065 Medium	42.59%
RCP4.5 2065 High	32.93%
RCP8.5 2065 Low	46.50%
RCP8.5 2065 Medium	40.72%
RCP8.5 2065 High	27.70%

5.2 Mine operation effects

It is noted that the mine life is relatively short (15 years) and as such any climate change impacts on its viability, or associated off-site effects of the operation, should be minimal. Regardless, in order to quantify this matter, analyses focused on the 2040/Year 15 mining scenarios - when such changes may become apparent, and when relevant 'forcing' data are available with which to inform analyses. As such, flow duration data at Glenaladale for the 2040 condition was the focus with the varying modified climate cases, with and without operation of the Fingerboards project (Figure 21 for 2040 and Figure 22 for 2065). Figure 23 and Figure 24 provide similar data only in this case as a 'typical year' time series with respective 'normal' and 'log scale' y axes. Similar to earlier analyses flow statistics have also been extracted for the same cases at the Glenaladale gauge site regarding exceedances of the nominated 1,400 ML per day threshold (Table 9).

When the results presented in Figure 21, Figure 22 and Table 9 are reviewed, it is apparent that regardless of what climate change case is looked at, the effects of mine operations on water resources in the Mitchell River are negligible. The maximum predicted change in percentage exceedance of the 1,400 ML/day threshold is 0.02% (of the order of 2 hours per year…), for the RCP4.5 2040 High case.

5.3 Summary

The key focus of this analysis has been on whether climate change may affect either the viability of the project (e.g., through their being insufficient flows in the Mitchell River) or see unacceptable off-site impacts (e.g., site operations causing unacceptable impacts on either water quality or water resources).

From the perspective of the regional analysis, it is apparent that:

- Climate change will modify the patterns of flow in the Mitchell River, however there will still be appreciable flows in the system; and
- From a 'water resource' perspective, the worst-case scenario indicates that operation of the mine will have minimal impact on the overall flow duration curve for a site downstream of the mine, regardless of which climate change case does eventuate.

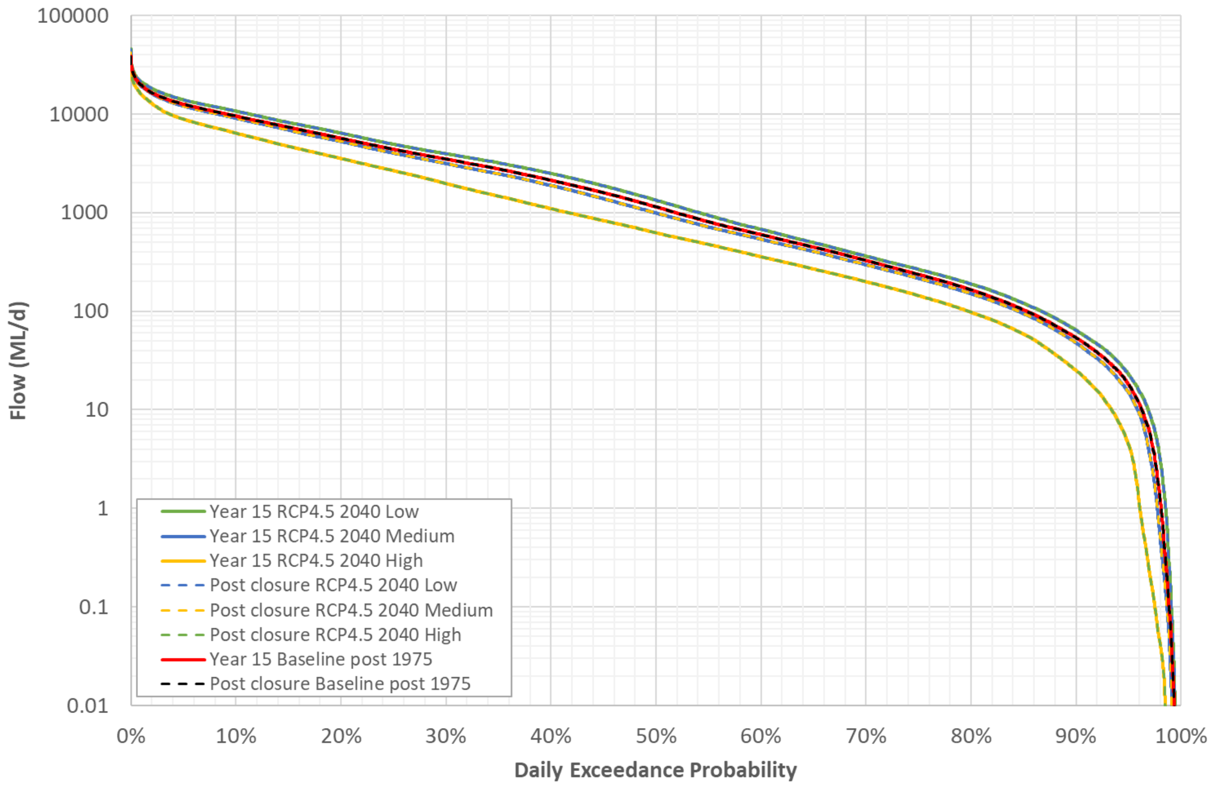

Figure 21 Glenaladale Flow Duration Curve – Base Case and RCP 4.5 2040 Climate Change Scenarios (with mine water extractions)

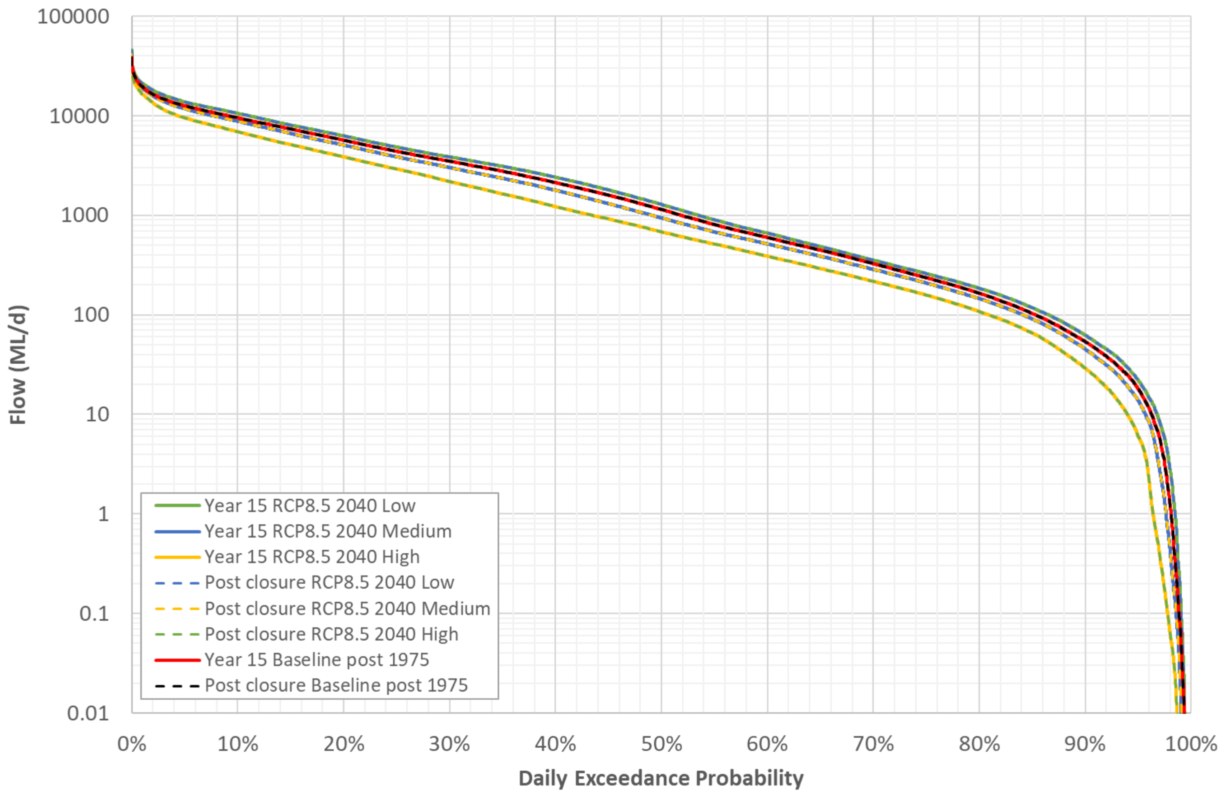

Figure 22 Glenaladale Flow Duration Curve – Base Case and RCP 8.5 2040 Climate Change Scenarios (with mine water extractions)

Table 9 Glenaladale 1,400 ML/day Exceedance Threshold Data – Base Case and 2040 Climate Change Scenarios (with mine water extractions)

Scenario	Pre-mining	Y5	Y8	Y15	Post-closure
Baseline post 1975	47.03%	47.01%	47.01%	47.02%	47.03%
Step change post 1997	43.16%	43.15%	43.14%	43.15%	43.16%
RCP4.5 2040 Low	-	-	-	49.38%	49.38%
RCP4.5 2040 Medium	-	-	-	44.79%	44.79%
RCP4.5 2040 High	-	-	-	35.88%	35.90%
RCP8.5 2040 Low	-	-	-	48.77%	48.78%
RCP8.5 2040 Medium	-	-	-	43.95%	43.95%
RCP8.5 2040 High	-	-	-	37.81%	37.81%
RCP4.5 2065 Low	-	-	-	-	48.60%
RCP4.5 2065 Medium	-	-	-	-	42.59%
RCP4.5 2065 High	-	-	-	-	32.93%
RCP8.5 2065 Low	-	-	-	-	46.50%
RCP8.5 2065 Medium	-	-	-	-	40.72%
RCP8.5 2065 High	-	-	-	-	27.70%

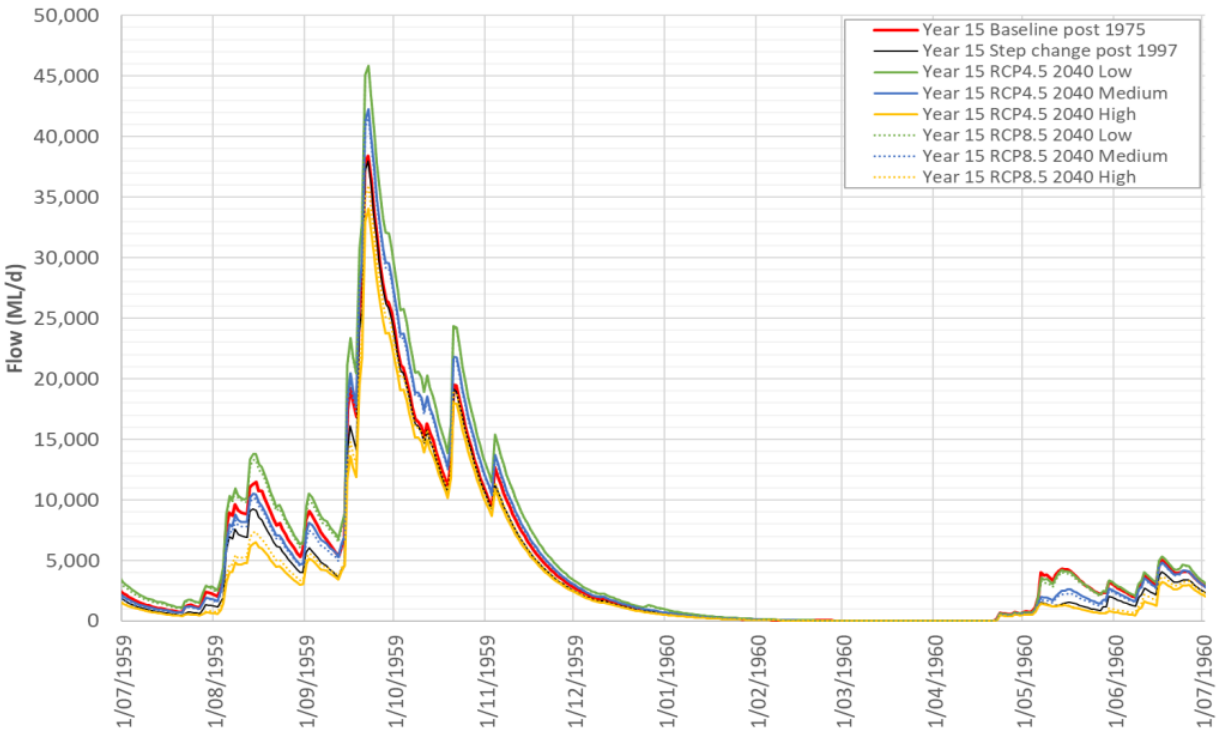

Figure 23 Year 15 mining daily flow comparison at Glenaladale, July 1959 to July 1960 (normal y axis)

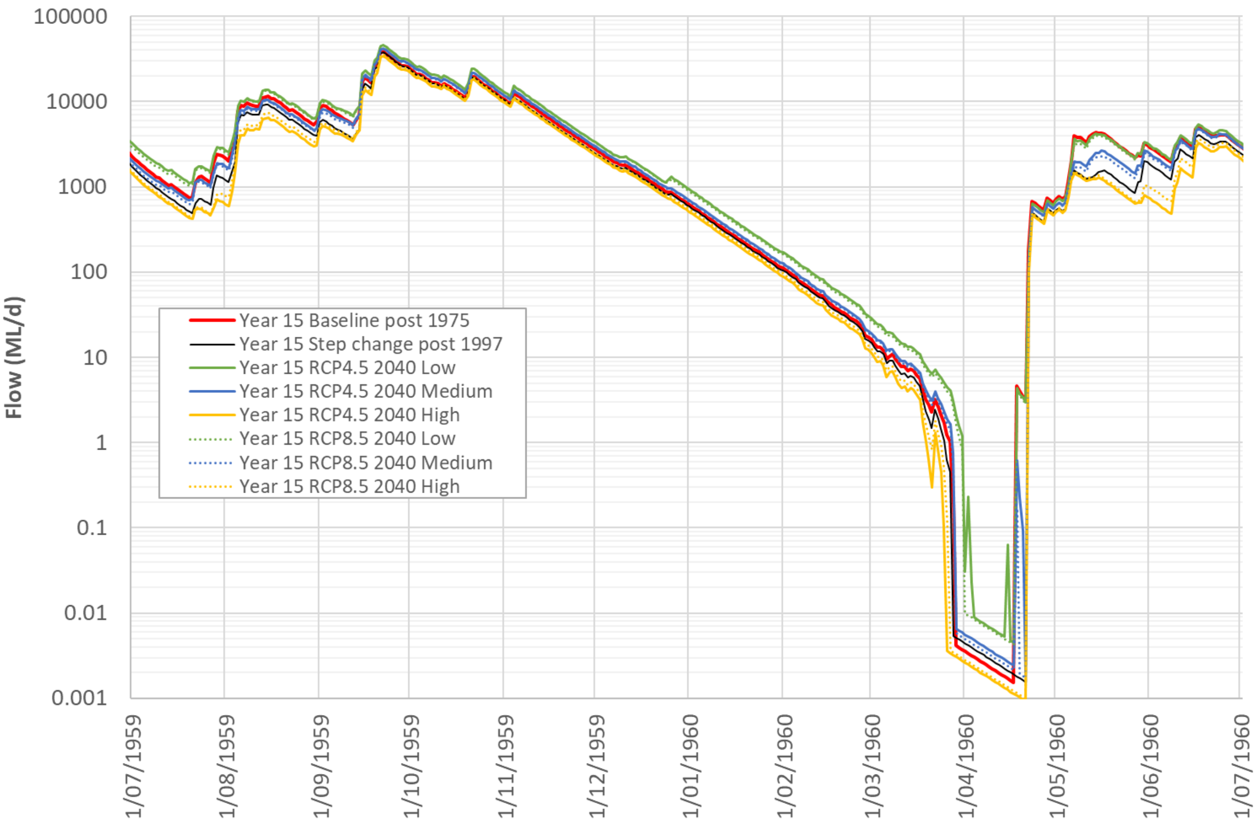

Figure 24 Year 15 mining daily flow comparison at Glenaladale, July 1959 to July 1960 (log y axis)

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