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# TECHNICAL MEMORANDUM

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| **DATE** | 20 December 2022 | **REF** | NSWDPE239607 |
| **TO** | Ms Rose-Anne Hawkeswood – NSW Department of Planning and Environment | **REV** | Rev1: Final |
| **FROM** | Sophie Pape, Earth Systems<br>Jeff Taylor, Earth Systems | **PROJECT** | Bowdens Silver Mine |

## UPDATE ON INDEPENDENT REVIEW – WATER BALANCE MODELLING AND SURFACE WATER MANAGEMENT

## INTRODUCTION

The New South Wales Department of Planning and Environment (NSWDPE) has requested an independent review and advice in relation to acid and metalliferous drainage (AMD), water balance modelling and surface water management aspects of the proposed Bowden Silver Mine. Earth Systems were contributing authors to the Federal Government's Leading Practice handbook on "*Water Management*" (2008).

A Memorandum was prepared on 8 June 2022, summarising the key findings of Earth Systems' independent high-level review with a focus on water balance modelling and surface water management aspects of the proposed mine development. The Memorandum is included as Attachment A.

A response to Earth Systems' Memorandum dated 8 June 2022, was subsequently received in October 2022 (Corkery, 2022a).

Taking this into consideration, NSWDPE has requested an update of Earth Systems advice relating to water balance modelling and surface water management for the proposed Bowdens Silver Mine, as outlined below.

# UPDATED REVIEW COMMENTS

Some updates to the water balance model have been conducted and errors corrected in response to Earth Systems' Memorandum dated 8 June 2022 Key outstanding concerns and potential conditions of approval are summarised in Table 1.

**Table 1. Summary of findings and recommendations from Earth Systems' Memorandum dated 8 June 2022, additional relevant information, and potential conditions for NSWDPE approval. Refer to Attachment A for further context and more detailed recommendations to support the potential conditions outlined here.**

| Earth Systems Recommendation - 8 June 2022 | Additional Information | Potential Conditions for NSWDPE Approval |
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| *Site Water Balance* | | |
| 1. Seek clarification of the implications of under-estimating climate variance for the risk of uncontrolled discharge.<br>Seek clarification of the implications of over-estimating site rainfall for project water supply reliability. | Regarding the first recommendation, clarification provided by Corkery (2022a; Table A1) indicates that long-term variance (3-5+ days) would be well replicated by SILO, while short-term variance (<3 days) would not present any risk of uncontrolled discharge due to the design capacities of the water management system.<br>Regarding the second recommendation, this has been misunderstood in the response, as Figure 3.3 implied that site rainfall is 7% less (not more) than long-term SILO rainfall. However, an updated figure provided by Corkery (2022; Figure 3) suggests the discrepancy is 4-5% which is less of a concern. | Not applicable based on the response provided. |
| 2. An independent check on modelled runoff coefficients / parameters should be conducted based on available measured site rainfall and flow data for Hawkins Creek. | The response by Corkery (2022a; Table A1) notes that "*the derived runoff coefficients were much lower than would be expected with WRM suspecting this partly due to upstream water extraction /dams*" and also that "*it is possible that it's because the site rainfall is not representative*". This is considered acceptable in the absence of reliable site rainfall and runoff data. | Not applicable based on the response provided. |
| 3. Water balance model results should be provided for all site water volumes, on a daily basis, throughout the mine life.<br>A site water quality model is required to assess whether site water is fit for purpose, | Regarding the first recommendation, the response by Corkery (2022a; Table A1) clarifies that "*Some dams were modelled as lumped storages. These can be remodelled separately but, as the dams have been sized to contain the design rainfall (i.e. fixed ratio to catchment area), the outcomes would be the same.*" | Prior to mining, develop a site water quality model to fully assess potential impacts on receiving waters (eg. from TSF seepage), determine treatment requirements or other site water |

| Earth Systems Recommendation - 8 June 2022 | Additional Information | Potential Conditions for NSWDPE Approval |
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| to fully assess potential impacts on receiving waters (eg. from TSF seepage) and/or to develop treatment or other site water management strategies. | Regarding the second recommendation, it appears that no further work has been conducted to address this concern. Previous solute transport modelling did not consider the AMD risk from the tailings and was therefore not conservative, yet still indicated a significant risk to downstream water quality. | management strategies beyond those already documented. |
| 4. Seek further clarification of the water balance modelling method and the sensitivity of model outputs to uncertainties in runoff characteristics of different land use types. | Clarification has been provided by Corkery (2022a; Table A1) on WRM's water balance modelling method relating to:<br>► Representation of land use types.<br>► TSF seepage pump-back.<br>► Waste rock dump seepage pump-back.<br>► TSF seepage losses to groundwater.<br>While not quantified, it is inferred from the response that volumes of TSF seepage pump-back <u>as well as</u> TSF losses to groundwater are minor in comparison with other site water balance flows.<br>It is understood that TSF pond surface areas were modelled, therefore it may be inferred that evaporation rates were based on pond areas, although not specifically stated in the response. | Not applicable based on the response provided. |
| 5. Seek further clarification of the water balance modelling method and the sensitivity of model outputs to uncertainties in runoff characteristics of different land use types. | Clarification has been provided by Corkery (2022a; Table A1) on WRM's water balance modelling method relating to lined surfaces, natural/disturbed areas and rehabilitated areas. | Not applicable based on the response provided. |
| 6. Seek further clarification of the water balance modelling method and any implications for model outputs. | Note that this recommendation relates to a statement that groundwater and surface water collected in the main open cut pit were used as the first preference for meeting site water demands (WRM, 2020 and 2022), which appears to be inconsistent with current plans to prioritise other water sources (eg. leachate dam, TSF decant pond).<br>The response provided by Corkery (2022a; Table A1) states:<br>"*Noted and acknowledged for checking. This statement considered to refer to any shortfalls in nett requirements after supply from the TSF decant pond.*" | *Pending results of checking as indicated.* |

| Earth Systems Recommendation - 8 June 2022 | Additional Information | Potential Conditions for NSWDPE Approval |
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| 7. Impacts on mean annual streamflow in downstream waters need to be predicted for the proposed amendment.<br>Implications for WAL requirements may need to be reviewed. | The response provided by Corkery (2022a; Table A1) states:<br>*"The 550 ha is made up of the TSF, Pit and Processing Plant catchments and the "NAF materials" catchments shown on Figure 8.2 of WRM (2022).*<br>*Apart from clean water harvest sub-catchments in Blackmans Gully, runoff from the undisturbed catchment upstream of the Southern Barrier will not be contained on site. Rather it will be allowed to pass through the Southern Barrier via drainage pipes.*<br>*Clean water harvesting is excluded from the catchment loss analysis as it is a basic landholder right under Section 53 of the Water Management Act 2000 with water able to be taken irrespective of Project approval."*<br>Drainage/seepage water quality from "NAF" waste rock in the Southern Barrier may be found to be unsuitable for off site release, and it appears possible that some of this drainage/seepage could report directly to Blackmans Gully. If Blackmans Gully was affected by this seepage it would need to be contained on site, with potential implications for WAL requirements.<br>It is understood that clean water harvesting is a basic landholder right, nevertheless it is relevant to understanding the cumulative impact of the project on downstream water flows and should not be excluded from the impact assessment. | Prior to construction:<br>▸ Review Southern Barrier design to ensure that it includes provision for containment of <u>all</u> drainage (runoff or seepage) from the barrier and/or develop a water quality contingency plan for Blackmans Gully.<br>▸ Re-assess impacts on mean annual streamflow in downstream waters for the proposed amendment, with consideration of clean water harvesting as well as the provision to contain <u>all</u> drainage/seepage from the Southern Barrier. Also see Item 8. |
| 8. Seek clarification of "rainfall and runoff" terminology in water balance outputs (which appears to be inaccurate) or update impact predictions if predicted "rainfall and runoff" is actually as high as 806 ML/year (or 856 ML/year).<br>For further context (Earth Systems, 2022):<br>▸ The water balance outputs indicate "rainfall and runoff" as the primary inflow to the site, averaging 806 ML/year between Year 1 and Year 14 of mining operations (WRM, 2020). This | The response provided by Corkery (2022a; Table A1) states:<br>*" The key reason for the difference between the 177ML/year and 856ML/year rainfall and runoff component of the water balance is that runoff rates are much higher within the disturbed Mine Site catchments (e.g. TSF and open cut pit) when compared to the existing undisturbed catchments.*<br>*The increase from 806ML/y to 856ML/y is attributed to the TSF liner and addition of clean water harvesting."*<br>On this basis, it is a concern that impacts on surface water / baseflow / groundwater could be much higher than presented in the EIS, which indicates a loss of 177 ML/y based on surface water runoff losses only. | Prior to construction:<br>▸ Re-assess impacts on local surface water, baseflow and groundwater, noting the removal of 856 ML/year from the project area catchments, rather than 177 ML/y based on surface water runoff losses only. |

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| was updated to 856 ML/year in WRM (2022).<br>▸ This key model output is confusing to the reader as it suggests 806 ML/year (or 856 ML/year) of surface runoff would be removed from the Lawsons Creek catchment, well in excess of losses presented elsewhere in the EIS (177 ML/year). If this is correct, surface water impacts will be much higher than presented in the EIS. The reason for the increase from 806 to 856 ML/year is also unclear. | | |
| 9. Larger sediment dam sizes are supported from both a water quality perspective (lower risk of uncontrolled discharge) and a project water supply reliability perspective. Until a sediment dam sizing is confirmed, water balance modelling should be conducted for both potential scenarios (small versus large sediment dam capacities).<br>A water management strategy is required in the event that Blackmans Gully water is contaminated by acidic runoff or NMD from the southern barrier. Implications for the site water balance, downstream creek flow impacts and WAL requirements and may also need to be considered. | The first recommendation was accepted in the response by Corkery (2022a; Table A1).<br>Regarding the second recommendation, the response by Corkery (2022a; Table A1) infers that only clean water from undisturbed catchments will will enter Blackmans Gully. However, it appears possible that some of the Southern Barrier drainage/seepage could report directly to Blackmans Gully. | As per Item 7. |
| 10. A site water quality model is required to assess whether site water is fit for purpose | The response by Corkery (2022a; Table A1) states that:<br>*"Where required, water recovered from water management infrastructure will be treated for use in the processing plant.* | As per Item 3. |

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| and/or to develop treatment or other site water quality management strategies.<br>For further context (Earth Systems, 2022):<br>▸ In the SEARs, the EPA requires "a water balance including water requirements (quantity, quality and source(s)) and proposed storm and wastewater disposal, including type, volumes, proposed treatment and management methods and re-use options".<br>▸ Water quality has not been included in the site water balance model by WRM.<br>▸ Proposed treatment methods have not been documented. | *Should discharge be proposed during operations, it would only occur from the ESC zone where water quality parameters meet those described in the Project's Environmental Protection Licence."*<br>A site water quality model has not been developed, therefore it has not been possible to provide any detail on water treatment requirements. | |
| 11. Seek further clarification and/or request supporting data to justify this conclusion. | The response by Corkery (2022a; Table A1) clarifies that:<br>*"Some dams were modelled as lumped storages. However, they would still not discharge if separately modelled separately as the volume to catchment ratio would be unchanged".* | Not applicable based on the response provided. |
| 12. Seek further clarification of these water balance model outputs. | The response by Corkery (2022a; Table A1) clarifies that:<br>*"The TSF liner arrangement and tailings solids content has been amended since WRM (2020). Therefore, modelling of the full liner and filling rates/TSF surfaces and shape have changed.*<br>*The Turkeys Nest Dam is operated full, with an operating level chosen to allow freeboard for the maximum direct rainfall on the surface so that it never overflows. The dam would be designed with an operating level set to achieve this."*<br>It remains unclear why the maximum modelled TSF pond volume (3,340ML) in Table 5.6 differs from that in Table 5.7 (3,517ML), and any implications for site water impact assessment or management. | *Pending clarification of modelled TSF pond volume discrepancy and site water impact assessment or management implications.* |
| 13. Seek clarification of the sensitivity of the model to other key input variables, and implications for the risk of uncontrolled discharge or project water supply reliability. | The response by Corkery (2022a; Table A1) states that:<br>*"Errors reported in these tables are acknowledged and will be identified and clarified.*<br>*However, the similar runoff parameters for the "waste rock emplacement", "rehabilitation" and "lined" in the low runoff and* | *Pending clarification of model sensitivity to other variables, and cumulative sensitivity (multiple parameters), and implications for the risk of uncontrolled discharge or project water supply reliability.* |

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| For further context (Earth Systems, 2022):<br>▸ The sensitivity analysis for the water balance model considered 2 sets of AWBM parameters to reflect "low runoff" and "high runoff", as shown in Table 5.8 and 5.9 of WRM (2020 and 2022).<br>▸ A further sensitivity analysis was conducted in which groundwater inflows were assumed to be half the predicted values. | *base case scenarios parameters are considered justifiable as the different runoff coefficients were very low to start with.*<br>*Refer Item 1 for response on site vs SILO rainfall data.*<br>*High and low rainfall scenarios have been modelled via the wet and dry periods included in the 130-year SILO dataset year)."*<br>It is inferred that the "errors" referred to above have been addressed in Table 1 and 2 in Corkery (2022a).<br>It appears that sensitivity analysis has not been conducted on:<br>▸ Evaporation rates.<br>▸ Dust suppression water volumes.<br>▸ Other key model input variables.<br>▸ Cumulative sensitivity associated with multiple parameters (not just sensitivity analysis of one parameter at a time). | |
| 14. Seek further clarification of what the "stored volume" actually refers to and how this excess water would be managed. | The response by Corkery (2022a; Table A1) clarifies that:<br>"*Annual increase in "stored volume" is the volume in all storages at the end of the simulation period minus the sum of the volume at its commencement (zero in this case).*<br>*The water balance predicts a small average annual excess of inflow over outflow. Therefore, on average the water balance predicts a small volume of water remaining in storage at the end of the simulation. To expedite equilibrium final void pit lake water levels and allow TSF decommissioning/rehabilitation, the water balance model transfers excess water from the TSF decant pond to the open cut pit at the cessation of operations.*" | Not applicable based on the response provided. |
| 15. Seek clarification of the implications of under-estimating water requirements for dust suppression for project water supply reliability.<br>For further context (Earth Systems, 2022):<br>▸ In the updated water balance model (WRM, 2022) water requirements for haul road dust suppression have been significantly lowered (from 204 ML/year | The response by Corkery (2022a; Table A1) states that:<br>*"The reduction has been derived from recent usage metering at a nearby upper Hunter Coal mines before and after utilisation of a proprietary dust suppressant."*<br>Supporting data were not provided, nor were uncertainties in dust suppression requirements considered in the sensitivity analysis of the water balance model. | *Pending clarification of model sensitivity to uncertainty in water requirements for dust suppression, details on the proposed chemical composition, application rates and toxicity, and implications for the impact assessment.* |

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| to 131 ML/year on average) "based on experience at nearby operations".<br>▸ No supporting data were provided.<br>▸ No information on the proposed chemical composition has been provided, nor application rates or toxicity. | Even if a dust suppressant is proprietary, information on the indicative chemical composition, application rates and toxicity should be available from the supplier. | |
| 16. Seek clarification of the project viability and the sensitivity of water supply reliability estimates to uncertainties that have not yet been modelled. | The response by Corkery (2022a; Table A1) states that:<br>"*Bowdens has weighed up the magnitude and duration of the loss of production in deciding what is commercially sustainable for the project.*" | Not applicable based on the response provided. |
| *Final Pit Void Water Balance* | | |
| 17. Seek clarification of the final pit void catchment area and whether this includes waste rock dump runoff. | The response by Corkery (2022a; Table A1) clarifies that the waste rock dump would <u>not</u> drain to the final void. | Not applicable based on the response provided. |
| 18. Seek clarification of the sensitivity of modelled water levels in the final pit void to pit wall evaporation rates. | The response by Corkery (2022a; Table A1) states that this recommendation is "noted" but it has not yet been addressed. | *Pending clarification of the sensitivity of modelled water levels in the final pit void to pit wall evaporation rate.* |
| 19. Seek clarification of the sensitivity of modelled water levels in the final pit void to groundwater inflow rates.<br>For further context (Earth Systems, 2022):<br>▸ Sensitivity analysis was conducted including:<br>• Reducing the evaporation factor to 0.7 (WRM, 2020) or 0.8 (WRM, 2022) at the top of void.<br>• Modifying AWBM parameters to increase runoff to the void.<br>• Increasing groundwater inflows by a factor of 1.5 or 2.0.<br>▸ It is unclear why the "increased" groundwater inflow rates (49.7 ML/year | The response by Corkery (2022a; Table A1) states that the storage evaporation factors were derived from the results of monitoring of evaporation from coal mine voids at various locations in NSW and Queensland and provides a weblink reference to support this.<br>The response by Corkery (2022a; Table A1) also notes that:<br>"*Groundwater inflow rates are reduced by pit lake water level rises*".<br>This does not specifically address the query raised, which relates to discrepancies in equilibrium groundwater inflow rates in Table 7.3 (WRM, 2020 and 2022).<br>Notwithstanding this, it appears that the final pit void water balance reported by WRM (2020 and 2022) is now superseded by Corkery (2022b). | Not applicable assuming that the final pit void water balance reported by WRM (2020 and 2022) is now superseded by Corkery (2022b). |

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| and 52.2 ML/year) are much lower than the reported groundwater inflow rate of 76 ML/year WRM (2020; Table 7.3). In the 2022 update, the "increased" groundwater inflow rates were much higher (87 ML/year and 95 ML/year) and yet comparable to the "average" of 92 ML/year (WRM, 2022; Table 7.3). | | |
| 20. Conduct detailed review of the water balance data to better understand these issues.<br>For further context (Earth Systems, 2022):<br>▸ The modelled outputs for the "existing" climate scenario changed significantly from WRM (2020) to WRM (2022) despite the same rainfall and evaporation input data. | The response by Corkery (2022a; Table A1) clarifies that:<br>*"WRM inadvertently enabled unscheduled timesteps in the final void model water balance model which introduced surprisingly high errors in the incorporated AWBM runoff model (which is strictly a daily timestep model).*<br>*Figure 7.4 of WRM (2022) identifies decreasing groundwater inflows with increasing pit lake elevation that reduces to 0 at approximately 590mAHD. The increased groundwater inflows at equilibrium of WRM (2022) reflect lower final void pit lake water level at equilibrium."* | Not applicable based on the response provided. |
| 21. Conduct a quantitative assessment of the potential impacts of pit lake water migration through groundwater on receiving surface waters.<br>For further context (Earth Systems, 2022):<br>▸ There is also a possibility of seepage towards Hawkins Creek post-mining and potential implications for receiving water quality. The sensitivity analysis in WRM (2022) indicates pit lake water levels up to 583.7 m AHD, well in excess of the elevation at which the pit lake would transition from a "sink" to throughflow conditions, which is ~579 m AHD (Jacobs, 2022). Indeed, the Response to Submissions (Corkery, 2021) refers to post mining water table contours (Jacobs, 2021) which indicate a gradient from the pit lake towards | The response by Corkery (2022a; Table A1) states that [the possibility of seepage towards Hawkins Creek] has not been ignored and is the subject of the groundwater assessment.<br>A *Final Void Uncertainty Analysis Report* was provided in October 2022 (Corkery, 2022b). Key findings include:<br>▸ The updated modelling indicates a "greater than 50% probability of final void lake water levels exceeding 579 m AHD", the level at which throughflow conditions are expected to occur.<br>▸ "In the event that the final void is considered likely to develop to a throughflow system, following equilibrium, travel time to Hawkins Creek would be in the order of 100 to 200 years." This is broadly consistent with the groundwater travel time reported by Jacobs (2021). | Conduct pit water quality modelling (taking into account acid, metals, salinity and any other contaminants) and solute transport modelling to assess potential water quality impacts in Hawkins Creek associated with throughflow from the final pit void, with and without implementation of mitigation measures. |

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| Hawkins Creek, with a potential groundwater travel time in excess of 100 years. | | |
| *Water Management* | | |
| *22. Refer to recommendations in Earth Systems (2022b).* | *Refer to Earth Systems (2022b).* | *Refer to Earth Systems (2022b).* |
| 23. A water quality monitoring program and response management plan is required. | A water quality monitoring program and response management plan has not been developed. | Prior to construction, develop a water quality monitoring program and response management plan. |
| 24. An assessment of potential water quality impacts associated with process chemicals is required, with management measures developed accordingly. | An assessment of potential water quality impacts associated with process chemicals has not been conducted, therefore it has not been possible to develop management measures. Impacts of TSF seepage on receiving surface water or groundwater remains a key concern. | Prior to construction, conduct an assessment of potential water quality impacts associated with process chemicals (including impacts associated with TSF seepage) and develop management measures accordingly. |
| 25. A strategy for TSF and waste rock dump seepage flow / water quality management post-closure is required. | The response by Corkery (2022a; Table A1) states that:<br>"*ATC Williams prepared preliminary TSF design based on significant consequence category dam due to presence of PAF tailings. Therefore, engineered design accounts for impacted water quality within TSF. Additional TSF design elements proposed in Submissions Report to reduce seepage. Reactive transport modelling report prepared.*<br><br>*The closure capping design includes measures to prevent ingress of meteoric water entering stored PAF materials. Water quality and flow into leachate management dam is therefore expected to reduce over time. The WRE would be a HDPE lined facility with seepage not anticipated.*"<br>It appears that no additional work has been conducted to address the concerns raised. Cover systems and HDPE liners have a limited design life and therefore seepage to surface and/or groundwater will be inevitable in the long term. Furthermore, even if seepage | Prior to construction, develop a strategy for TSF and waste rock dump seepage flow / water quality management post-closure. |

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| | volumes are low, contaminant loads and downstream impacts can be significant. | |
| 26. A comprehensive pit lake water quality assessment and management strategy is required.<br>A comprehensive TSF seepage quality management strategy is required. | Regarding the first recommendation, Corkery (2022a; Table A1) states that *"modelling identifies the final void pit lake will remain a groundwater sink with water levels well below the pit rim".*<br>This response does not consider the potential for seepage from the pit lake towards Hawkins Creek. Refer to Item 21.<br>Regarding the second recommendation, Corkery (2022a; Table A1) refers to Item 25. As noted above, no additional work appears to have been conducted to address the concerns raised in Item 25. | Prior to construction, develop:<br>► A comprehensive pit lake water quality assessment and management strategy.<br>► A comprehensive TSF seepage quality management strategy.<br>When pit lakes are to be used as groundwater sinks, consideration needs to be given to the behaviour of hypersaline pit water having an impact on the groundwater system as its high density (salinity) overcomes "pit sink" migration controls. |
| 27. A management strategy for cyanide is required. | The response by Corkery (2022a; Table A1) states that:<br>*"The use of sodium cyanide is regulated in NSW through the Protection of Environment Operations Act 1997 that is administered by the NSW Environment Protection Authority. Cyanide concentrations in tailings discharge is regulated at many NSW mine sites via Environmental Protection Licences issued by the Environment Protection Authority. Section 5.9.3 of the Submissions Report identifies a Cyanide Management Plan would be prepared for the Project post-approval. This plan would describe the measures to maintain cyanide levels in accordance with any Environmental Protection Licence issued for the Project."* | Not applicable based on the response provided. |
| 28. This information needs to be provided in advance of any off site discharge from sediment basins. | The response by Corkery (2022a; Table A1) accepts this recommendation. | Not applicable based on the response provided. |
| 29. Seek a detailed independent review of baseline surface and groundwater quality data to ensure that appropriate discharge limits or trigger values are established. | The response by Corkery (2022a; Table A1) clarifies that:<br>"*ANZG aquatic ecosystem trigger values (95% species protection for slightly to moderately disturbed ecosystems) would be adopted for comparison of ambient surface water quality monitoring data."* | Prior to construction, develop a water quality monitoring program and response management plan (as per Item 23), including management responses that would be implemented if ANZG aquatic ecosystem trigger values (95% species |

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| | It is inferred that these trigger values would also be used for identification of potential impacts on receiving groundwater quality as well as surface water quality.<br>If reliable and independently reviewed baseline surface and groundwater quality data are not available, the use of ANZG aquatic ecosystem trigger values (95% species protection for slightly to moderately disturbed ecosystems) is supported. | protection for slightly to moderately disturbed ecosystems) are exceeded in receiving surface water or groundwater. |
| 30. A clear strategy is needed for management of "NAF" waste rock stockpile runoff, as well as sulfidic ore stockpile runoff, and the site water management system updated to reflect this. | The response by Corkery (2022a; Table A1) states that:<br>*"Section 4.6 of WRM (2022) describes the Mine Site water management strategy with NAF and oxide ore stockpiles situated within the ESC zone. The containment zone would also include some NAF that would be used as construction materials. Whilst release of water from the ESC zone has been considered and described in reporting, all site water management infrastructure has been sized to provide containment should quality of stored water be impaired. Table 5.6 of WRM (2022) presents maximum modelled storage volumes that identifies no discharge from site."*<br>This does not address the possibility of some drainage/seepage from the Southern Barrier (which is a "NAF" waste rock stockpile) entering receiving waters beyond the "containment zone" or "ESC zone".<br>The response does not consider sulfidic ore stockpile runoff. | Prior to construction, update the site water management strategy to include drainage/seepage from all "NAF" waste rock stockpile runoff (including the Southern Barrier) as well as sulfidic ore stockpile runoff. |
| 31. A clear strategy is needed for management of sediment dam water.<br>Use of contaminated water for dust suppression should be avoided. | The response by Corkery (2022a; Table A1) clarifies that:<br>*"Water for dust suppression would only be sourced from clean water or advanced dewatering (production) bores."* | Not applicable based on the response provided. |
| 32. Clarification is required on the source/s of dust suppression water.<br>Use of contaminated water for dust suppression should be avoided. | See Item 31. | Not applicable based on the response provided. |
| 33. Flood protection for permanent landforms should be based on a PMP design event. | The response by Corkery (2022a; Table A1) clarifies that: | Not applicable based on the response provided. |

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| Consideration should be given to the potential implications for both flood water quality and stability of the waste rock dump. | "*Final WRE landform would remain beyond the extent of PMF envelope*". | |
| 34. Clarification is required on the long term flood protection strategy for the waste rock dump. | See Item 33. | Not applicable based on the response provided. |

# KEY CONCLUSIONS AND RECOMMENDATIONS

Updated conclusions and recommendations relating to water balance modelling and surface water management for the proposed Bowdens Silver mine are outlined below, and should be read in conjunction with the review of acid and metalliferous drainage (AMD) / geochemical aspects (Earth Systems, 2022b):

- TSF seepage modelling indicates potential surface water quality impacts (eg. copper, zinc, cyanide and phosphorus) in Lawsons Creek, as well as groundwater quality impacts. Such impacts could be further exacerbated by AMD generation from PAF tailings, addition of other contaminants from the mine site / process plant water, or concentration of contaminants due to water re-circulation, none of which were considered in seepage modelling. A comprehensive TSF seepage quality management strategy is required.
- The site water balance model does not incorporate a water quality component. This is required to fully assess potential impacts on receiving waters (eg. from TSF seepage) and to develop treatment or other management strategies.
- Potential water quality impacts associated with process chemicals need to be quantitatively assessed and management measures developed accordingly, taking into account their toxicity / ecotoxicity and chemical behaviour, such as adsorption and decomposition rates.
- It has been confirmed that 856 ML/year of surface runoff would be removed from the Lawsons Creek catchment. This is well in excess of losses presented elsewhere in the EIS (177 ML/year; which relates to surface water runoff losses only). A review of impacts on downstream surface water, baseflow and groundwater is therefore warranted.
- It is understood that Blackmans Gully would flow beneath the Southern Barrier (a "NAF" waste rock dump) and discharge off site, but there appears to remain a risk of drainage/seepage from the barrier entering Blackmans Gully. The Southern Barrier design should include provision for containment of <u>all</u> drainage (runoff or seepage) from the barrier and/or a contingency plan should be developed for Blackmans Gully.
- Noting a greater than 50% risk of pit lake water throughflow in groundwater towards Hawkins Creek, and the potential for acid, metals and high salinity in pit water, impacts on receiving water quality need to be assessed, with and without mitigation measures. This also needs to consider potential contaminants in pit water from other sources (eg. leachate dam, TSF, process water). A comprehensive pit lake water quality assessment is required to support solute transport modelling and impact assessment.
- Where water management strategies are provided, they are generally focussed on managing water flows, but not water quality. Treatment of contaminated water is occasionally mentioned in passing, but no details are provided. Clear and comprehensive management strategies are required for surface water (and groundwater) to avoid over-reliance on modelling, monitoring and reactive management.
- For the proposed amendment, sensitivity analysis indicates that only 86% (average) or 65% (worst case) of the processing plant water requirement may be met. Furthermore, the sensitivity analysis did not include evaporation rates, dust suppressant effectiveness, other key input variables (aside from AWBM parameters and groundwater flows) or cumulative sensitivity for multiple parameters. Bowdens Silver nevertheless considers this risk acceptable in terms of the financial viability of the project.

Refer to Attachment A for further context and more detailed findings and comments to support the above recommendations.

# REFERENCES

Advisian (2020a). *Preliminary Design of PAF Waste Rock Emplacement, Oxide Ore Stockpile and the Southern Barrier. Bowdens Silver Project.* Consultants report prepared by Advisian for Bowdens Silver Pty Ltd. 7 May 2020. 201010-00790—REP-002.

Advisian (2020b). *TSF and WRE Closure Cover Design. Bowdens Silver Project.* Consultants report prepared by Advisian for Bowdens Silver Pty Ltd. 7 May 2020. 201012-00683-SS-REP-0001.

Corkery (2022a). *Response to Earth Systems Review – Water Balance Modelling and Surface Water Management*. Consultants report prepared by R. W. Corkery & Co. Pty Ltd. October 2022.

Corkery (2022b). *Final Void Uncertainty Analysis Report*. Consultants report prepared by R. W. Corkery & Co. Pty Ltd. October 2022.

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GCA (2020). Materials Characterisation Assessment. *Bowdens Silver Project.* Consultants report prepared by Graeme Campbell & Associates Pty Ltd for Bowdens Silver Pty Ltd. May 2020.

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Jacobs (2022). *Updated Groundwater Assessment*. Consultants report prepared by Jacobs Group (Australia) Pty Ltd for Bowdens Silver Pty Ltd. February 2022.

WRM (2020). *Surface Water Assessment*. Consultants report prepared by WRM Water and Environment Pty Ltd for Bowdens Silver Pty Ltd . May 2020.

WRM (2022). *Updated Surface Water Assessment*. Consultants report prepared by WRM Water and Environment Pty Ltd for Bowdens Silver Pty Ltd. February 2022.

# Attachment A

# Independent Review – Water Balance Modelling and Surface Water Management

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Environment · Water · Sustainability

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# TECHNICAL MEMORANDUM

| | | | |
|---|---|---|---|
| **DATE** | 8 June 2022 | **REF** | NSWDPE239604 |
| **TO** | Ms Rose-Anne Hawkeswood – NSW Department of Planning and Environment | **REV** | 1 |
| **FROM** | Sophie Pape, Earth Systems<br>Jeff Taylor, Earth Systems | **PROJECT** | Bowdens Silver Mine |

## INDEPENDENT REVIEW – WATER BALANCE MODELLING AND SURFACE WATER MANAGEMENT

## INTRODUCTION

The New South Wales Department of Planning and Environment (NSWDPE) has requested an independent review and advice in relation to acid and metalliferous drainage (AMD), water balance modelling and surface water management aspects of the proposed Bowden Silver Mine.

Earth Systems were contributing authors to the Federal Government's Leading Practice handbook on "*Water Management*" (2008).

This Memorandum provides a summary of the documents available for review and the key findings of Earth Systems' independent high level review with a focus on water balance modelling and surface water management aspects of the proposed mine development. AMD / geochemical characterisation, impact assessment and related management aspects have been reviewed in a separate memorandum.

## SCOPE OF REVIEW

Sections of the following reports relevant to water balance modelling and surface water management were reviewed:

***"EIS" documents:***

- EIS Bowdens Silver Project – 2020. 764 pages.
- Vol 1_Part 3_Materials Charact - May 2020. 562 pages.
- Vol 5_Part 16A_TSF Design Report - May 2020 (TSF Preliminary Design). 91 pages.

- Vol 5_Part 16B_Prelim Design - WRE, Oxide Ore (Preliminary Design of PAF Waste Rock Emplacement, Oxide Ore Stockpile and the Southern Barrier). 44 pages.
- Vol 5_Part 16C_Closure Cover Design – May (TSF and WRE Closure Cover Design). 44 pages.
- Vol 2_Part 6_SWater Assessment - May 2020 (Surface water assessment). 134 pages.
- Vol 2_Part 6_SWater Assessment_Annexures – May (Annexures to Surface water assessment):
  - Annexure A Watercourse Assessment (120 pages).
  - Annexure B Flood Impact Assessment (206 pages).
  - Annexure C Peer Review (6 pages).
- Vol 2_Part 5_Gwater - May 2020 (Groundwater assessment). 320 pages.

***Submission and Response documents:***

- Submissions:
  - Dr Haydn Washington, environmental scientist, former Experimental Scientist in CSIRO working on heavy metal pollution from mine sites, 16/7/20. 7 pages.
  - Dr Haydn Washington, environmental scientist, former Experimental Scientist in CSIRO working on heavy metal pollution from mine sites, 12/8/21. 10 pages.
  - 4.12. WRE and Leachate Dam. 3 pages.
  - 4.11. TSF leakage risk. 4 pages.
- Submissions Report - Response to Submissions on EIS - June 2021. 514 pages.

***"Amendment" documents:***

- Water Pipeline Amendment - Amendment Report (2nd Amendment). 132 pages.
- Water Pipeline Amendment - Appendix 1 - Updated Project Description. 96 pages.
- Water Pipeline Amendment - Appendix 2 - Updated Summary of Environmental Management and Monitoring Measures. 16 pages.
- Water Pipeline Amendment - Appendix 4 - Groundwater Assessment. 446 pages.
- Water Pipeline Amendment - Appendix 3 - Surface Water Assessment. 506 pages.

# REVIEW FINDINGS

| Review Finding | Earth Systems Comment | Recommendation to NSWDPE |
|---|---|---|
| *Site Water Balance* | | |
| The long term daily rainfall dataset (January 1889 to December 2018) is all synthetic data from the Queensland government SILO database, as there are no original meteorological station data available (WRM, 2020). | This approach is generally considered reasonable given the lack of sufficient site data, with the following caveats:<br>► A key limitation of the SILO data (as noted by WRM) is that it may result in some reduction in the variance of the climate record compared to the observed data. As a result, peak rainfall and drought conditions may therefore not be adequately modelled on a daily basis, and therefore the risk of uncontrolled discharge or a shortfall in water supply for the project could be under-estimated. This type of uncertainty was not addressed through sensitivity analysis.<br>► A comparison of the SILO data with (limited) available site rainfall data indicates that monthly rainfall in the project area is on average 7% lower than the SILO rainfall data based on the regression equation presented in Figure 3.3 of WRM (2020). This does not seem to have been considered in the assessment or sensitivity analysis. | Seek clarification of the implications of under-estimating climate variance for the risk of uncontrolled discharge.<br>Seek clarification of the implications of over-estimating site rainfall for project water supply reliability. |
| WRM (2020 and 2022; Section 3.5.3) states that there are no rainfall stations located within Hawkins Creek catchment upstream of the mine site, and the available flow record is of relatively short duration.<br>In the absence of site-specific long-term data to characterise streamflow in Hawkins Creek and Lawsons Creek, the Australian Water Balance Model (AWBM) was used to represent runoff characteristics of local catchments. | The initial statement appears to be somewhat misleading as it appears that a rainfall gauging station does exist near Hawkins Creek as mapped in Figure 3.5 (WRM, 2020 and 2022).<br>An assessment of site runoff coefficients based on the available (albeit limited) data for the site would have been helpful as an independent check on the theoretical estimates obtained via the AWBM method. | An independent check on modelled runoff coefficients / parameters should be conducted based on available measured site rainfall and flow data for Hawkins Creek. |
| A Goldsim model was developed to simulate the operation of the water management system and "keep complete account of all site water volumes and representative water quality on a daily time step". | Water balance model results for all site water volumes were not presented. | Water balance model results should be provided for all site water volumes, on a daily basis, throughout the mine life. |

| Review Finding | Earth Systems Comment | Recommendation to NSWDPE |
|---|---|---|
| | It is unclear whether each site water storage facility was modelled individually, or whether some water storages were combined for simplicity (which could potentially affect uncontrolled discharge).<br>A water quality model was not presented for the water management system. Therefore, it has not been possible to assess whether site water is fit for purpose, to fully assess potential impacts on receiving waters (eg. from TSF seepage), or to develop treatment or other site water management strategies.<br>The water balance model outputs presented were averages over the mine life. Daily model outputs were generally not presented.<br>This prevents a detailed independent assessment of the data and lowers confidence in conclusions relating to the risk of uncontrolled discharge and water supply reliability. | A site water quality model is required to assess whether site water is fit for purpose, to fully assess potential impacts on receiving waters (eg. from TSF seepage) and/or to develop treatment or other site water management strategies. |
| To model catchment yield in the site water balance model, a total of 8 land use types were identified:<br>▶ Lined (eg. HDPE liner or equivalent).<br>▶ Natural/undisturbed, representing areas in their current state.<br>▶ Pit and hardstand (combined) which include:<br>• Walls and floor of the open cut pit.<br>• Pads, processing plant areas and roads.<br>▶ Rock and capped combined, which include:<br>• Placed NAF/PAF waste rock.<br>• Soil capping layer installed over PAF waste rock placed in the WRE.<br>▶ Rehab, representing fully rehabilitated/revegetated areas.<br>▶ Tailings, representing tailings beach in the TSF. | The reliability of model outputs will be affected by how accurately each of these land use types are represented.<br>Examples of land use types with different runoff characteristics include:<br>▶ Different types of natural/undisturbed land, such as forested, agricultural or grazing land.<br>▶ Pit walls versus pit floor rock.<br>▶ Waste rock dumps before versus after capping.<br>It is also unclear whether / how open water bodies have been modelled (eg. TSF pond area and its effect on evaporation rates).<br>It is unclear whether the model includes TSF seepage pump-back (for the previous and updated TSF liner designs), waste rock dump seepage (leachate dam) pump-back, or TSF seepage losses to groundwater (for the previous and updated TSF liner designs).<br>Confidence in the model outputs is therefore limited. | Seek further clarification of the water balance modelling method and the sensitivity of model outputs to uncertainties in runoff characteristics of different land use types. |
| In the absence of site-specific data, AWBM parameters for disturbed areas were adopted based on "experience with catchment modelling at upper Hunter Valley mine sites". | Notwithstanding the concerns noted above, the AWBM parameters result in runoff coefficients that do not always appear to reflect the corresponding land cover type. Some examples include:<br>▶ Lined surfaces, where the modelled runoff coefficient was only 44.6% (unclear why this is so low for HDPE lined areas). | Seek further clarification of the water balance modelling method and the sensitivity of model outputs to uncertainties in runoff characteristics of different land use types. |

| Review Finding | Earth Systems Comment | Recommendation to NSWDPE |
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| The appropriateness of AWBM parameter values was raised as an issue during the peer review by HEC in February 2020. | ► Natural/undisturbed areas, where the modelled runoff coefficient was 4.6% despite an earlier estimate of 4.9% (Table 3.1) for the Lawsons / Hawkins Creek catchments.<br>► Rehabilitated areas, where the modelled runoff coefficient was the same as that for place waste rock (2.7%) and notably lower than that assigned to "natural/undisturbed" areas. | |
| Groundwater and surface water collected in the main open cut pit were used as the first preference for meeting site water demands (WRM, 2020 and 2022). | This appears to be inconsistent with current plans to prioritise other water sources (eg. leachate dam, TSF decant pond) over pit water.<br>Implications for water balance model outputs are unknown. | Seek further clarification of the water balance modelling method and any implications for model outputs. |
| The catchment area of the "Containment" system is expected to peak at 550 ha, including 300 ha in the TSF catchment and 250 ha in the remainder of the water management system (WRM, 2020). This results in an estimated surface water runoff loss of 177 ML/year. | It is unclear whether all catchment areas containing NAF waste rock, dumps are included in this estimate. If they are not included, then surface water runoff losses could be higher than 177 ML/year.<br>For example, the data in Table 4.4 (WRM, 2020) indicates a possible total catchment area of up to around 670 ha if the southern barrier and lower haul road (comprising NAF waste rock) are included.<br>Furthermore, the proposed addition of clean water harvesting (WRM, 2022) results in surface water losses from an additional 144.5 ha of catchment area.<br>This suggest that the impacted catchment area could peak at around 815 ha in total, rather than 550 ha as indicated, representing around 3.0% of the Lawsons Creek catchment area (272 $km^2$).<br>Despite the proposed amendment, there were no changes in the summary of predicted impact on mean annual streamflow in downstream waters (WRM, 2020 and 2022; Table 8.1).<br>Implications for Lawsons Creek flow rates and Water Access Licence (WAL) requirements may need to be reviewed. | Impacts on mean annual streamflow in downstream waters need to be predicted for the proposed amendment.<br>Implications for WAL requirements may need to be reviewed. |
| The water balance outputs indicate "rainfall and runoff" as the primary inflow to the site, averaging 806 ML/year between Year 1 and Year 14 of mining operations (WRM, 2020). This was updated to 856 ML/year in WRM (2022). | This key model output is confusing to the reader as it suggests 806 ML/year (or 856 ML/year) of surface runoff would be removed from the Lawsons Creek catchment, well in excess of losses presented elsewhere in the EIS (177 ML/year). If this is correct, surface water impacts will be much higher than presented in the EIS. The reason for the increase from 806 to 856 ML/year is also unclear.<br>Although not stated, this estimate may include process water from the TSF decant pond, in addition to "rainfall and runoff". | Seek clarification of "rainfall and runoff" terminology in water balance outputs (which appears to be inaccurate) or update impact predictions if predicted "rainfall and runoff" is actually as high as 806 ML/year (or 856 ML/year). |

| Review Finding | Earth Systems Comment | Recommendation to NSWDPE |
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| | Clarification of terminology / impacts is required. | |
| The key sediment dams within the mine site and their associated capacities were presented in Section 4.6 of WRM (2020 and 2022). | Two alternative capacities are provided for each sediment dam.  It is assumed that the smaller capacities would apply if water quality was acceptable for discharge, and the larger capacities if water needed to be retained on site, however water balance modelling appears to have been conducted only for the latter scenario.  The alternative scenario (smaller sediment dams) was not modelled, but would lower water supply reliability for the project.<br>It appears that the sediment dams for the southern barrier have not been designed to contain flows from Blackmans Gully, which lies beneath this barrier and presumably is allowed to discharge off site without treatment, despite the potential for "impoundment" of Blackmans Gully water behind the "NAF" waste rock in the southern barrier (Advisian, 2020), and despite the potential for drainage/seepage from the southern barrier into Blackmans Gully.<br>There does not appear to be any contingency water management strategy in the event that Blackmans Gully water is contaminated by acidic runoff or NMD from the southern barrier, nor does this appear to have been considered in the water balance or assessment of downstream creek flow impacts.<br>Finally, if Blackmans Gully water needs to be retained on site due to contamination from the southern barrier material, a WAL would be required (WAL exemptions do not apply to 3rd order streams). | Larger sediment dam sizes are supported from both a water quality perspective (lower risk of uncontrolled discharge) and a project water supply reliability perspective.<br>Until a sediment dam sizing is confirmed, water balance modelling should be conducted for both potential scenarios (small versus large sediment dam capacities).<br>A water management strategy is required in the event that Blackmans Gully water is contaminated by acidic runoff or NMD from the southern barrier.  Implications for the site water balance, downstream creek flow impacts and WAL requirements and may also need to be considered. |
| In the SEARs, the EPA requires "a water balance including water requirements (quantity, quality and source(s)) and proposed storm and wastewater disposal, including type, volumes, proposed treatment and management methods and re-use options". | Water quality has not been included in the site water balance model by WRM (2020 and 2022).<br>Proposed treatment methods have not been documented. | A site water quality model is required to assess whether site water is fit for purpose and/or to develop treatment or other site water quality management strategies. |
| A key conclusion of water balance modelling is "dam overflows" which are predicted to average 0 ML/year (WRM, 2020 and 2022).<br>From the maximum modelled volumes in Table 5.6, it appears that "processing plant dams" have been modelled collectively, as have "other combined sediment dams (modelled as containment structures)". | It is unclear whether zero discharge would still be predicted if:<br>▸ Site water storage dams were modelled individually; and<br>▸ The results were presented for each individual dam on a daily basis, rather than averaged over 14 years.<br>It appears that sediment dams are included in this estimate of "dam overflows" and that their larger storage capacities were assumed. | Seek further clarification and/or request supporting data to justify this conclusion. |

| Review Finding | Earth Systems Comment | Recommendation to NSWDPE |
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| The maximum modelled stored water volumes were presented in Section 5.5 of WRM (2020) and updated in WRM (2022). | The estimated TSF decant pond volumes have approximately doubled between the WRM (2020) and WRM (2022) reports. The reason for this significant change is unclear.<br>It is also unclear why modelled evaporation rates are so similar – 440 ML/year (WRM, 2020) versus 448 ML/year (WRM, 2022) despite the significant increase in TSF decant pond size.<br>It is also unclear why the maximum modelled TSF pond volume (3340 ML) in Table 5.6 differs from that in Table 5.7 (3517 ML).<br>It is unclear why maximum modelled water volumes are not presented for the Turkeys Nest (130 ML capacity) in Table 5.6. | Seek further clarification of these water balance model outputs. |
| The sensitivity analysis for the water balance model considered 2 sets of AWBM parameters to reflect "low runoff" and "high runoff", as shown in Table 5.8 and 5.9 of WRM (2020 and 2022).<br>A further sensitivity analysis was conducted in which groundwater inflows were assumed to be half the predicted values. | Notwithstanding previous concerns relating to modelled runoff coefficient values, for the "low runoff" scenario modelled average runoff coefficients were higher for "waste rock emplacement", "rehabilitation" and "lined" land use categories, in comparison with values used for the original model. This seems to be at odds with a "low runoff" scenario and could result in over-estimation of water availability for the project.<br>Furthermore, the sensitivity analysis conducted to date is limited, with no consideration of:<br>► Low or high rainfall scenarios.<br>► Under-estimation of variance in the SILO data.<br>► Lower rainfall measured at site relative to corresponding SILO data (eg. on average 7% lower rainfall as noted above).<br>► Evaporation.<br>► Other key model input variables.<br>► Cumulative sensitivity associated with multiple parameters (not just sensitivity analysis of one parameter at a time). | Seek clarification of the sensitivity of the model to other key input variables, and implications for the risk of uncontrolled discharge or project water supply reliability. |
| A key output of water balance modelling is "annual increase in stored volume" which are predicted to average 41 ML/year (WRM, 2020). This was updated to 31 ML/year (WRM, 2022). | The average value reported is equivalent to 574 ML (2020 estimate) or 434 ML (2022 estimate) of water accumulating in site water storages over 14 years.<br>It is unclear what the "stored volume" actually refers to and how this excess water would be managed. | Seek further clarification of what the "stored volume" actually refers to and how this excess water would be managed. |
| In the updated water balance model (WRM, 2022) water requirements for haul road dust suppression | No supporting data were provided. | Seek clarification of the implications of under-estimating water |

| Review Finding | Earth Systems Comment | Recommendation to NSWDPE |
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| have been significantly lowered (from 204 ML/year to 131 ML/year on average) "based on experience at nearby operations". | No information on the proposed chemical composition has been provided, nor application rates or toxicity. | requirements for dust suppression for project water supply reliability. |
| For the proposed amendment, water supply reliability was estimated at (WRM, 2022):<br>▸ Processing plant (average 99.4%; low 94.5%).<br>• For a "low runoff" scenario this decreased to 98.4% (average) and 90.0% (low).<br>• For a low groundwater inflow scenario this decreased to 86% (average) and 65% (low).<br>▸ Dust suppression (average 99.8%; low 99.5%). | Despite only 86% reliability on average under a low groundwater inflow scenario (and 65% in the worst case scenario modelled), the implications for mine operations were discussed only briefly (Corkery, 2022) and it was noted that "Bowdens Silver does not consider this a risk to the financial viability of the Project".<br>Sensitivity analysis was not conducted for dust suppression water supply reliability, which could also be affected by uncertainty in runoff coefficients and groundwater availability.<br>Water supply reliability could be over-estimated (see comments above relating to analysis for the water balance model). | Seek clarification of the project viability and the sensitivity of water supply reliability estimates to uncertainties that have not yet been modelled. |
| *Final Pit Void Water Balance* | | |
| The main open cut pit would be left as a void covering ~53 ha and allowed to progressively fill largely with groundwater as surface water would be diverted around the void (EIS Section 2.13.3).<br>WRM (2020) states that "following completion of the final raise, when the cell reaches its maximum height, the top section of the cell would be reshaped, capped and covered to drain back towards the main open cut pit". The same report later states that "all upslope catchments will be diverted around the final void". | It is unclear whether waste rock dump drainage will be directed to the main pit.<br>This could significantly affect the final pit void water balance model outputs. | Seek clarification of the final pit void catchment area and whether this includes waste rock dump runoff. |
| Groundwater inflow was predicted to peak in Year 4 (1066 ML/year), with a daily peak of ~3.5 ML/day and average of 2.4 ML/day (although only ~1.75 ML/day would reach the pit sump due to evaporation losses from the pit walls (EIS Section 4.6.5.3). | This indicates an evaporation loss of 27% from the pit walls. Elsewhere reference is made to an evaporation loss of 20% from the pit walls (WRM, 2020 and 2022; Section 4.3). The reliability of pit wall evaporation losses is unclear, but model outputs could be highly sensitive to this. | Seek clarification of the sensitivity of modelled water levels in the final pit void to pit wall evaporation rates. |
| The storage evaporation factors for pit lake water used as model inputs ranged from 0.5 (bottom of void) to | No justification was provided for the original storage evaporation factors (WRM, 2020) or the changed "top of void" factor (WRM, 2022). This is despite the significant difference in pit evaporation | Seek clarification of the sensitivity of modelled water levels in the final pit void to groundwater inflow rates. |

| Review Finding | Earth Systems Comment | Recommendation to NSWDPE |
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| 0.8 (top of void) as outlined in Section 7.7 of WRM (2020).<br>The "top of void" factor was subsequently updated to 0.95 (WRM, 2022).<br>Sensitivity analysis was conducted including:<br>▸ Reducing the evaporation factor to 0.7 (WRM, 2020) or 0.8 (WRM, 2022) at the top of void.<br>▸ Modifying AWBM parameters to increase runoff to the void).<br>▸ Increasing groundwater inflows by a factor of 1.5 or 2.0. | losses predicted for the "existing" climate scenario (295 ML/year predicted in 2020 versus 325 ML/year predicted in 2022).<br>The sensitivity analysis demonstrates significant uncertainty in the final pit lake water level, which would peak at 587.3 m AHD (WRM, 2020) or 583.7 m AHD (WRM, 2022) under the worst-case scenario modelled.<br>It is unclear why the "increased" groundwater inflow rates (49.7 ML/year and 52.2 ML/year) are much lower than the reported groundwater inflow rate of 76 ML/year WRM (2020; Table 7.3). In the 2022 update, the "increased" groundwater inflow rates were much higher (87 ML/year and 95 ML/year) and yet comparable to the "average" of 92 ML/year (WRM, 2022; Table 7.3). | |
| The modelled outputs for the "existing" climate scenario changed significantly from WRM (2020) to WRM (2022) despite the same rainfall and evaporation input data. | It is understood that an error in the 2020 model was identified and rectified for the 2022 model, however no explanation of this change was provided in the 2022 report.<br>The reason for different groundwater inflow rates for the "existing" climate scenario (76 ML/year predicted in 2020 versus 92 ML/year predicted in 2022) is unclear.<br>A detailed review of the water balance data would be required to better understand these issues. | Conduct detailed review of the water balance data to better understand these issues. |
| On the basis of the final void water balance model, the pit lake would not overflow to the surface and remain a groundwater sink post-mining (WRM, 2020 and 2022). | This statement ignores the possibility of seepage towards Hawkins Creek post-mining and potential implications for receiving water quality. The sensitivity analysis in WRM (2022) indicates pit lake water levels up to 583.7 m AHD, well in excess of the elevation at which the pit lake would transition from a "sink" to throughflow conditions, which is ~579 m AHD (Jacobs, 2022). Indeed, the Response to Submissions (Corkery, 2021) refers to post mining water table contours (Jacobs, 2021) which indicate a gradient from the pit lake towards Hawkins Creek, with a potential groundwater travel time in excess of 100 years. | Conduct a quantitative assessment of the potential impacts of pit lake water migration through groundwater on receiving surface waters. |
| *Water Management* | | |
| Water quality issues and management implications relating to sulfidic mine materials and the potential for acid and metalliferous drainage (AMD) or neutral | *Refer to comments in Earth Systems (2022).* | *Refer to recommendations in Earth Systems (2022).* |

| Review Finding | Earth Systems Comment | Recommendation to NSWDPE |
|---|---|---|
| metalliferous drainage (NMD) were reviewed in Earth Systems (2022). | | |
| In the SEARs, the EPA requires a water quality monitoring program and response management plan. | This has not yet been provided in the EIS or more recent documentation. | A water quality monitoring program and response management plan is required. |
| Table 2.4 of the EIS identifies processing plant reagents including hydrated lime / soda ash, copper sulfate, MIBC, sodium cyanide, flocculant, lead collector, zinc collector, caustic soda and antiscalant. The fate of these is generally assumed to be tailings, if not concentrate, with some decomposition of chemicals such as MIBC and NaCN.<br>In contradiction to this, the EIS also states that the bulk of the chemical reagents would report to the produced silver/lead and zinc concentrates. | This discrepancy is also acknowledged In the Response to Submissions (Corkery, 2021) but dismissed as an issue on the basis of the small tonnages of chemicals relative to tonnages of tailings.<br>The fate of process chemicals remains uncertain. Furthermore, Corkery (2021) incorrectly states that zinc and copper are non-toxic.<br>No assessment of potential water quality impacts, or management implications, associated with process chemicals was conducted.<br>The toxicity and ecotoxicity of process chemicals, and implications for OHS and the receiving environment have not been considered.<br>The chemical behaviour, such as adsorption and decomposition rates, have not been considered in any detail. | An assessment of potential water quality impacts associated with process chemicals is required, with management measures developed accordingly. |
| Allowance has been made for 4 years for TSF rehabilitation works and 3 years for maintenance, but it is also acknowledged that relinquishment would only occur "once revegetation satisfies the requirements of the Resources Regulator and leachate generation from the WRE ceases" (EIS Section 2.13.3).<br>It is later stated that "no time limit would be placed on post-mining rehabilitation monitoring and maintenance". | The status of TSF seepage at the time of relinquishment is not mentioned, but indications are that this could occur over 200 years (EIS Section 4.6.5.3). There is no strategy for TSF seepage flow / water quality management during this time.<br>The potential for long term ongoing seepage from the waste rock dump has not been considered or assessed.<br>The proposed rehabilitation monitoring and maintenance program (EIS Section 2.16.7) refers to ongoing monitoring for "evidence of any acidic runoff" but doesn't consider the possibility of acidic seepage (nor other potential long term water quality issues). | A strategy for TSF and waste rock dump seepage flow / water quality management post-closure is required. |

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<tr><th>Review Finding</th><th>Earth Systems Comment</th><th>Recommendation to NSWDPE</th></tr>
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<tr><td>Potential impacts on groundwater quality associated with the open cut pit lake and tailings were dismissed in the EIS (Section 4.6.7.4) as follows:<ul><li>Pit lake impacts were dismissed on the basis of the lake acting as a groundwater sink, preventing discharge of saline water to the regional groundwater system.</li><li>Tailings impacts were dismissed on the basis of assumed tailings pore water salinity / pH / metal concentrations and the assumption that any impacts would be localised to areas of groundwater mounding and not extend beyond 40 metres from the mine site boundary.</li></ul>It is stated that pit water quality “would generally reflect the quality of the combined natural groundwater and surface water inflows to the pits” (EIS Section 4.7.4.4) and that salinity would increase over time only due to evaporative concentration (EIS Section 4.7.5.6).</td><td>The risk of pit lake water throughflow towards Hawkins Creek (see above), and the potential for AMD in pit water (Earth Systems, 2022), needs to be considered and impacts on receiving water quality assessed. This also needs to consider potential contaminants in pit water from other sources (eg. leachate dam, TSF, process water).<br><br>As a result, no pit lake water quality management strategy has been developed.<br><br>Predicted tailings pore water quality is based on leachate test work conducted by GCA (2020) and does not consider the risk of AMD generation from PAF tailings (Earth Systems, 2022), nor does it consider the addition of other contaminants from the mine site / process plant water, or the potential for concentration of contaminants due to water re-circulation (see earlier comments regarding site water quality modelling).<br><br>The prediction of no groundwater quality impacts beyond 40 metres of the mine site boundary was not justified. Solute transport modelling was subsequently conducted for the TSF (Corkery, 2021) and indicates that:<ul><li>The modelled solute concentrations at Lawsons Creek exceed water quality guidelines for some parameters (eg. copper, zinc, cyanide and phosphorus) even under the currently proposed TSF Design Option 1 which will substantially lower seepage concentrations relative to the previous design presented in the EIS.</li><li>Modelled solute concentrations in groundwater (BGW16 and BGW17) were also elevated relative to background concentrations and guideline values for copper, cyanide and phosphorus, presented in Table 3.1 of Corkery (2021).</li><li>Even poorer water quality could be expected in the modelling allowed for the potential impacts of AMD from PAF tailings (Earth Systems, 2022).</li></ul>Despite the clear risk to receiving water quality in Lawsons Creek, no clear management strategy was presented to address this.<br><br>A commitment was only made to conduct “reactive transport modelling to further quantify the geochemical processes and</td><td>A comprehensive pit lake water quality assessment and management strategy is required.<br><br>A comprehensive TSF seepage quality management strategy is required.</td></tr>
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| | natural attenuation of potential seepage from the TSF to inform detailed design". Reliance on optimistic outcomes of future modelling is not sufficient given the risks already identified. | |
| It is stated that "for cyanide, it is proposed that the WAD cyanide concentration in the tailings pumped to the TSF would be approximately 7 mg/L", with 10 mg/L nominated as a safe level for fauna. | No management strategy for cyanide has been presented, in the event that WAD cyanide concentrations exceed this "safe level". | A management strategy for cyanide is required. |
| The EPA requires that "where the management of sediment basins requires the use of flocculants, the EIS should include information about the type, toxicity and management of flocculants proposed to treat captured water before discharge". | This information has not been provided. | This information needs to be provided in advance of any off site discharge from sediment basins. |
| In the Response to Submissions (Corkery, 2021; Section 5.11.19) it is noted that the methodology used to assess groundwater quality statistics has been reviewed and updated statistics are provided in Jacobs (2021). | This raises the question of whether surface water quality statistics also needed to be updated, and whether this has any implications for the impact assessment results and management requirements.<br>Any changes to baseline data statistics could also affect future site discharge limits or trigger values for monitoring data. | Seek a detailed independent review of baseline surface and groundwater quality data to ensure that appropriate discharge limits or trigger values are established. |
| The surface water management strategy comprises 3 main zones, according to expected water types and management requirements:<br>► Clean water zone.<br>► Erosion and sediment control (ESC) zone.<br>► Containment zone. | Surface water management strategy is unclear as the ESC and Containment zones both appear to include "NAF" waste rock stockpile runoff.<br>The fate of sediment dam water appears to depend on whether it is suitable quality for off site discharge and is therefore uncertain (EIS Section 2.10.1, Section 4.7.4).<br>It is assumed that the sulfidic ore stockpile drainage (a potential source of AMD) forms part of the Containment zone but this is unclear. | A clear strategy is needed for management of "NAF" waste rock stockpile runoff, as well as sulfidic ore stockpile runoff, and the site water management system updated to reflect this. |
| The executive summary of WRM (2020) states that if water quality is found to be unsuitable for release during operations, sediment dams would be dewatered and the water used for dust suppression.<br>The same report (Section 4.5) later states that this water would actually either be treated prior to release, or recycled in mine site applications. | These statements appear to contradict each other and need to be clarified.<br>Use of contaminated water for dust suppression should be avoided. | A clear strategy is needed for management of sediment dam water.<br>Use of contaminated water for dust suppression should be avoided. |

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| It has been stated that water for haul road dust suppression was to be drawn from:<br>▸ The Oxide Ore Dam as a first priority and then from the processing plant dams or Turkeys Nest Dam, if required (WRM, 2020).<br>▸ Clean water dams or advanced dewatering bores (WRM, 2022)<br>▸ Sediment dams (WRM, 2020 and 2022). | These statements appear to contradict each other and need to be clarified.<br>Use of contaminated water for dust suppression should be avoided. | Clarification is required on the source/s of dust suppression water.<br>Use of contaminated water for dust suppression should be avoided. |
| Post-closure flood modelling was conducted to assess peak velocities along Price Creek adjacent to the waste rock dump.<br>The surface water assessment (WRM, 2020) indicates that the embankment crests of the waste rock dump and leachate management dam are above the water level of the PMP design event.<br>The waste rock dump design report (Advisian, 2020) indicates that flood protection bund design for the waste rock dump is based on events up to a 1:100 AEP flood. | These statements appear to contradict each other and need to be clarified.<br>A PMP design event rather than 1:100 AEP design event is considered more appropriate for permanent landforms such as the waste rock dump, given the potential physical stability / water quality implications.<br>Flood modelling results are presented in WRM (2020) for a 1% AEP, with some additional discussion of events up to a 0.2% AEP.<br>It is conceivable that floodwaters could come into contact with PAF material in the base of the waste rock dump. The potential for erosion of the waste rock dump was considered, but implications for flood water quality were not specifically discussed. | Flood protection for permanent landforms should be based on a PMP design event.<br>Consideration should be given to the potential implications for both flood water quality and stability of the waste rock dump. |
| The waste rock dump design report (Advisian, 2020) indicates that flood protection for the waste rock dump would be removed during rehabilitation and closure.<br>The surface water assessment (WRM, 2020; Section 6.2.2) indicates that rock protection installed along the toe of the haul road embankment would be retained. | These statements appear to contradict each other and need to be clarified. | Clarification is required on the long term flood protection strategy for the waste rock dump. |

# KEY CONCLUSIONS AND RECOMMENDATIONS

Key conclusions and recommendations relating to water balance modelling and surface water management for the proposed Bowdens Silver mine are outlined below, and should be read in conjunction with the review of acid and metalliferous drainage (AMD) / geochemical aspects (Earth Systems, 2022):

- The site water balance model results are considered preliminary only due to a lack of long term site rainfall and flow data, simplification of land use types, and uncertain runoff characteristics. Furthermore, the modelling method presented is lacking in some key details, and clear justification for model assumptions is not always provided. The sensitivity analysis is also very limited. Clarification of the method, more detailed review (QA/QC) and further sensitivity analysis would improve understanding of water supply reliability and the risk of uncontrolled discharge.
- The site water balance model does not incorporate a water quality component. This is required to assess whether site water is fit for purpose, to fully assess potential impacts on receiving waters (eg. from TSF seepage) and to develop treatment or other management strategies.
- Outputs of the site water balance model are generally only presented as a single average value over a 14 year mine life. This level of detail is insufficient to independently assess water volumes and flows for individual water storage facilities, and how these will vary over time throughout the mine life. Furthermore, confidence in the model outputs is limited by the unclear terminology / definitions for some model "inflows" and "outflows" and a lack of clear explanation of some significant changes in the model outputs from 2020 to 2022. More detailed presentation of model outputs and/or clarification of recent changes is warranted.
- The water balance modelling results for the proposed amendment (WRM, 2022) indicate an increased risk of a water supply shortfall for the project, relative to the original project design in the EIS. For the proposed amendment, sensitivity analysis indicates that only 86% (average) or 65% (worst case) of the processing plant water requirement may be met. This risk was considered acceptable to Bowdens Silver in terms of the financial viability of the project. A review of this conclusion may be warranted in light of the model limitations outlined herein.
- For the final pit void water balance model, there appear to be significant uncertainties in some key model input parameters such as pit catchment area, pit wall evaporation rates and pit lake evaporation rates. Confidence in the final pit void model outputs is limited by the lack of a clear explanation of some significant changes in the model outputs from 2020 to 2022. More detailed presentation of model outputs and/or clarification of recent changes is warranted.
- The risk of pit lake water throughflow in groundwater towards Hawkins Creek, and the potential for AMD in pit water, needs to be considered and impacts on receiving water quality assessed. This also needs to consider potential contaminants in pit water from other sources (eg. leachate dam, TSF, process water). A comprehensive pit lake water quality assessment and management strategy is required.
- TSF seepage modelling indicates potential surface water quality impacts (eg. copper, zinc, cyanide and phosphorus) in Lawsons Creek, as well as groundwater quality impacts. Such impacts could be further exacerbated by AMD generation from PAF tailings, addition of other contaminants from the mine site / process plant water, or concentration of contaminants due to water re-circulation. A comprehensive TSF seepage quality management strategy is required.
- It appears that Blackmans Gully would flow beneath the southern barrier and discharge off site, despite the potential for "impoundment" of water behind the barrier, and despite the potential for acidic runoff or neutral metalliferous drainage (NMD) from the barrier into Blackmans Gully. A contingency water management strategy is required in the event that Blackmans Gully water is

contaminated by acidic runoff or NMD from the southern barrier. Implications for the site water balance, downstream creek flow impacts and Water Access Licence (WAL) requirements, may also need to be considered.

- Potential water quality impacts associated with process chemicals need to be quantitatively assessed and management measures developed accordingly, taking into account their toxicity / ecotoxicity and chemical behaviour, such as adsorption and decomposition rates.
- Water management strategies for various other aspects of the project are either absent, unconfirmed or unclear / inconsistent through the documentation reviewed (eg. sediment dams, ore stockpiles, dust suppression, flood protection for the waste rock dump). Where water management strategies are provided, they are generally focussed on managing water flows, but not water quality. Treatment of contaminated water is occasionally mentioned in passing, but no details are provided. Clear and comprehensive management strategies are required for surface water (and groundwater) to avoid over-reliance on modelling, monitoring and reactive management.
- An independent review of baseline surface water and groundwater quality data is warranted to ensure that appropriate discharge limits or trigger values are established.

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