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## **REFERENCE: BIODIVERSITY INDICATORS – PEER REVIEW**

### **INTRODUCTION**

Worsley Alumina (Worsley) currently has a proposal (the Proposal) under assessment by the EPA for a mining expansion within the Boddington Region. The Proposal's Environmental Review Document (South32, 2022) was released for public comment in July 2022 with final submissions received on the 18 October 2022. A significant component of these responses were from the Department of Water and Environmental Regulation (DWER). Within these responses was a requirement for Worsley to develop Biodiversity Indicators to demonstrate that its operations were not having a significant impact on the health of the Northern Jarrah Forest. As part of that, it was required that the proposed Indicators be peer reviewed.

The scope of work is to undertake a peer review of the Biodiversity Indicators developed by Worsley (**Appendix 1**). The following scope items were required to be addressed in the report of the Peer Review:

- detail of the suitability of each the proposed Biodiversity Indicators separated into the relevant factors;
- details of any recommended amendments to the Biodiversity Indicators including justification for amendment;
- detail of relevant references used to undertake the review; and
- declaration of the suitability of personnel providing the advice to undertake the peer review.

### **SUMMARY OF THE PROPOSAL**

Worsley's operation currently includes bauxite mining, ore conveyor and alumina refinery. The BBM is located 130 km southeast of Perth, and the Refinery is located 20 km northwest of Collie. Alumina produced at the refinery is then transported by train to Bunbury and shipped to smelters. Worsley is currently authorized to produce up to 4.7 Mtpa of alumina. The Proposal currently under consideration by the EPA includes the continued operations and expansion of the existing mining area and the development of a bauxite transport corridor at the Boddington Bauxite Mine (BBM), as well as contingency mining and maintenance activities at the Refinery. There will be no increase in bauxite mining rate or processing rate. The Proposal primarily focuses on expansion activities in three different development envelopes, namely the:

- Worsley Mine Development Envelope (WMDE)
- Bauxite transport corridor (BTC)
- Contingency Bauxite Mining Envelope (CBME) (includes the Bauxite Residue Disposal Area (BRDA))

The three development envelopes are collectively referred to as the Primary Assessment Area (PAA). The existing mining operations are situated in a landscape that is highly modified by agricultural, tree farming plantations and mining activities, including the Newmont Boddington Gold Mine. The Proposal would result in clearing an additional 4,399 ha of native vegetation to expand the mining envelope, transport the bauxite via conveyor and truck (largely on haul roads) and expand the refinery area footprint. There would also be a 400 ML/a increase in water requirements due to mining (from 500 ML/a to 900 ML/a). The area of disturbance that is the subject of the Proposal is proposed to be progressively cleared during mining operations, with the majority of the area progressively rehabilitated under existing operational procedures. As part of the Proposal, Worsley has committed to reducing the proportion of unrehabilitated land (the rehabilitation deficit) from approximately 45% currently, to less than 35% over the next 10 years.

In terms of cumulative impact, the Worsley Proposal reflects increased mining and an extension of the existing development envelope (i.e. the primary bauxite area) by approximately 33% (9,545 ha) to a PAA of 29,357 ha. Currently approved native vegetation clearing accounts for up to 5,263 ha within the existing PAA, and an additional 8,400 ha within the Extended Mining Areas (subject to conditions of MS 719). The proposed additional native vegetation clearing (4,399 ha) required as a result of the Proposal, brings the total clearing of remnant native vegetation within the PAA to 9,662 ha, although the Extended Mining Areas (8,400 ha) are not within the PAA boundary. Up to a total of 23,479 ha of native vegetation will be collectively cleared by Worsley and Newmont Boddington. This equates to approximately 0.6% of the Northern Jarrah Forest, although the additional impact of the fragmentary effect of clearing for bauxite mining also needs to be considered. Progressive rehabilitation will result in 70-80% of the proposed clearing for bauxite mining to be rehabilitated within 10 years of clearing, and the whole area will be rehabilitated at closure.

## CONTEXT FOR BIODIVERSITY INDICATORS

The EP Act (1986), administered by the DWER, is the primary piece of State legislative regulating the "...protection of the environment in Western Australia." The EP Act also allows for the EPA to "...prevent, control and abate pollution and environmental harm, for the conservation, preservation, protection, enhancement and management of the environment and for matters incidental to or connected with the foregoing." Clearing of native vegetation is also regulated by the DWER under the EP Act. The Statement of Environmental Principles, Factors and Objectives (EPA, 2021) identifies 14 environmental factors across five themes: Sea, Land, Water, Air and People.

The draft Forest Management Plan 2024-2033 (FMP) (Conservation and Parks Commission, 2022a) is the key guidance document for protecting the biodiversity and ecological integrity of the jarrah forest in the area of Worsley's operations. The strategic goals of the draft FMP align with legislation, government policy, ecological sustainable forest management practices, and the Montreal Process Criteria (Montreal Process Working Group, 2015). The Montreal Process adopts seven criteria (with 54 indicators) for sustainable forest management: conservation of biological diversity; maintenance of productive capacity of forest ecosystems; maintenance of ecosystem health and vitality; conservation and maintenance of soil and water resources; maintenance of forest contribution to global carbon cycles; maintenance and enhancement of long-term socio-economic benefits to meet the needs of societies; and legal, institutional and economic frameworks for forest conservation and sustainable management. Australia is one of 12 member countries that have adopted this set of criteria and indicators to assess and monitor national forest trends and success in sustainable management (Montreal Process Implementation Group for Australia and National Forest Inventory Steering Committee, 2018). In addition to the FMP, another recent Australian example that incorporates biodiversity indicators has been developed by the state of NSW and CSIRO (OEH & CSIRO, 2019).

We understand that the Biodiversity Indicators developed by Worsley that are the subject of this review have been developed to align with the Montreal Process and the FMP, specifically Foundation 2 – Biodiversity Conservation and Foundation 3: Forest health and climate resilience. Our review of the proposed Biological Indicators was in the context of the comments from DWER on the Worsley Proposal (**Appendix 2**) relating to the need for biodiversity indicators to be adequate, scientifically robust and appropriate to assess and monitor the status and trends in the key biodiversity indicators to ensure:

- Potential impacts are managed;
- Environmental outcomes for the whole of mine life (including post-closure);
- Whether the EPA's objectives for all applicable key environmental can be met; and
- Whether the proposal is likely to be consistent with the ongoing ecological integrity of the Northern Jarrah Forest.

The EPA objectives (**Appendix 3**) define ongoing ecological integrity as "*the composition, structure, function and processes of ecosystems, and the natural range of variation of these elements*" (EPA, 2016).

## REVIEW OF PROPOSED BIODIVERSITY INDICATORS

The structure of the draft Biodiversity Indicators framework reviewed by Stantec aligns largely with four of the EPA's Key Environmental Factors likely to be affected by the proposal. Specifically, the draft framework provides biodiversity indicators and associated programs/monitoring and measures/outcomes, for the Key Environmental Factors of Flora and Vegetation, Terrestrial Fauna, Terrestrial Environmental Quality, and Inland Waters. All these factors are directly related to the EPA's Key Environmental Factors. A fifth factor in the draft framework is Climate Change, which does not directly relate to the EPA Greenhouse Gas Emissions factor.

### Flora and Vegetation

The EPA's stated objective for the environmental factor Flora and Vegetation is "To protect flora and vegetation so that biological diversity and ecological integrity are maintained" (EPA 2016). The EPA defines flora as native vascular plants and vegetation as the groupings of different flora patterns across the landscape that occur in response to environmental conditions. Therefore, vegetation is considered a surrogate for ecological processes and interactions.

Bauxite mining results in the direct loss of native vegetation through clearing. The current proposed expansion has been noted to include loss of some locally significant vegetation communities, riparian vegetation and Priority flora taxa (South32 2022). Potential indirect impacts on vegetation include further fragmentation of local vegetation communities, the introduction or spread of invasive species, including weeds and pathogens, dust generation, increased water use for mining operations, alteration of surface water drainage patterns and flows, groundwater level changes (drawdown or rise) and cumulative vegetation loss or landscape alteration.

Worsley Alumina maintains a progressive rehabilitation program for disturbed areas once mining has ceased. It has been stated that 70-80% of the proposed vegetation clearing is anticipated to be rehabilitated within 10 years of clearing (South32 2022; p226). The area of forest that has been cleared but remains unrehabilitated is referred to as the rehabilitation deficit (expressed as a percentage of total disturbance) and a commitment to reduce the rehabilitation deficit from approximately 45% to less than 35% over a ten year period to 2033 has also been expressed (South32, 2022).

In the context of the direct and potential indirect impacts outlined in the Proposal, Worsley has identified 12 biodiversity indicators related to Flora and Vegetation (**Table 1**). These indicators are broadly relevant and relate to areas of forest not impacted directly by mining activities, including Protected Areas, rehabilitation post-mining, or both. Comments relating to these Indicators are listed in **Table 1**. More detailed comments regarding the structure and detail of the associated *Program/Monitoring* and *Measure/Outcomes* are also included later in this section.

**Table 1: Specific comments on biodiversity indicators for Flora and Vegetation**

<b>Biodiversity Indicator</b>	<b>Stantec comment</b>
Species composition of the forest and regional changes within the area of operations	Species composition is a key indicator, however technically does not include relative abundance of species and therefore overall vegetation structure. Recommend that 'diversity' is also referred to specifically and that measures of diversity encompass both richness (i.e. number of species) and evenness (i.e. relative abundance of species).
Health of PEC/TEC systems	These could be joined into presence of threatened and priority flora species and overall health of PEC/TEC systems. However, if combined then the reporting approach for each element would need to clearly defined.
Presence of threatened flora species	
Presence and health of indicator species	Clarification recommended on whether this applies to both unmined forest (but not PEC/TEC systems) and rehabilitation.
Declared weeds	Declared weeds (as well as Weeds of National Significance) are important to prioritise for control, however this could be broadened to include other environmental weeds, given the nature of the disturbance provides opportunity for a range of weeds to establish in rehabilitation areas and potentially spread.
Dieback spread/movement	These are recommended to be joined and broadened into plant pathogen presence and spread. The ERD also identified <i>Armillaria luteobubalina</i> (Australian honey fungus) causing Armillaria Root Disease (ARD) as known in the area.
Marri Canker	
Use of ecological linkages by fauna species	Assessment of direct fauna use is recommended to be moved to the Terrestrial Fauna section. This section could focus on the provision of suitable fauna habitat values in linkages.
Decrease in fragmentation	This appears to overlap with the indicator "Landscape vegetation connectivity (Habitat Fragmentation)", recommend combining into one indicator
Protected remnant vegetation	A definition of 'protected remnant vegetation' would be helpful and whether these areas are encompassed by the PEC/TEC systems. Specify whether the indicator is referring to extent, health or both. Where this is relevant to PEC/TEC systems, then indicators that relate to extent/area and health (as above) could be joined
Resilience of vegetation to fire	Specify whether this indicator is intended to be specific to rehabilitation systems. Assuming it is, based on text provided in the Measure/Outcome column, consideration should be given to a broader indicator of forest fire resilience (rehabilitation and forest controls) and appropriate fire regimes in the context of climate change (i.e. drying, warming climate).
Landscape vegetation connectivity (Habitat Fragmentation)	See comments above for 'Decrease in fragmentation'

There are a number of monitoring programs, some of which appear to overlap and only some refer to relevant timeframes. The following eight programs are referred to in the framework (below list identifies where no timeframe provided):

- Rehabilitation monitoring (annual) including forest control plots (3-5 yearly)
- Review of holistic rehabilitation success (at minimum every 5 years)
- Targeted monitoring of PEC / TEC / Protected Areas for priority / threatened species and areas (timing?)
- Vegetation mapping (annual)
- Forest disease mapping (timing?)
- Fauna monitoring undertaken in linkages (timing?)

- Percentage of remnant vegetation contained within protected areas inside of the PAA (timing?)
- Remote review and assessment against a fragmentation index for the Development Envelope and 5 km outside of the Development Envelope (3 yearly)
- Fire control management in rehabilitated areas (timing?)

For clarity within the framework, it is recommended that the above programs be:

- assessed for overlap and whether a separate program is required in each case;
- a broad indication of timing of implementation for all; and
- a link to further documentation (e.g. procedure/manual) on the monitoring approach where the program is already in existence, and thereby also indicate which programs require development of the monitoring procedure.

In addition, the Program referred to as “Understanding spread, resistance and research into disease management” is unclear as to timing, whether this is an internal Worsley initiative or whether this links to external research funding, and how this outcome is assessed and how information is fed back into management practices. To partly address this, an additional “Measure/Outcome” could be to audit and review topsoil management and other procedures implemented to minimize the spread of plant pathogens.

Broadly, the proposed *Measure/Outcomes* encompass specific, relevant, quantitative and measurable outcomes for many of the biodiversity indicators. The most detailed outcomes relate to rehabilitation vegetation targets. However, there are also flora and vegetation biodiversity indicators that appear to lack an associated specific “measure / outcome” including:

- Species composition of the forest and regional changes within the area of operations – all outcomes listed relate to rehabilitation success. There is no outcome that relates to any broader changes in plant diversity and composition within the unmined forest (e.g. the forest control plots used in the rehabilitation monitoring would be one source of data) which may result from indirect impacts of mining, other regional disturbances (e.g. wildfires) and the influence/pressure of ongoing climate change;
- Health of PEC/TEC system, presence of threatened flora species, presence and health of indicator species – no intended outcome specified;
- Landscape vegetation connectivity/habitat fragmentation – in addition to the identified measures and outcomes this could be linked to the reduced rehabilitation deficit target;
- Resilience of vegetation to fire – the current outcome relates to rehabilitation areas meeting criteria (tree bark thickness and litter densities) for integration of rehabilitated areas into the forest prescribed burning program. These criteria are important to fire resiliency but may not encompass all the factors important to fire resiliency such as the development of height separation between overstorey and understorey strata, and the proportions of seeder versus re-sprouter plant species (Grant et al. 2007). The current outcome also does not address actual measured resilience to fire which could be addressed in a specific monitoring or research program.

Ideally, the measures or outcomes that relate specifically to rehabilitation success should align with the vegetation-relevant completion criteria specified in the mine closure plan, and revised in accordance with updates to the mine closure plan. While some of the outcomes specially relate rehabilitation metrics to forest control data (e.g. species diversity of post-1993 rehabilitation at 70% of the control forest by 20 years) others represent fixed targets with no information on the derivation of the target (e.g. greater than 35 species per 80m<sup>2</sup> at >12 years rehabilitation). Ideally fixed targets would be linked to a reference or report that explains how this target was derived. This review has not included an assessment of the appropriateness of all such detailed quantitative rehabilitation targets, nor whether early-stage rehabilitation targets are compatible with achievement of late-stage rehabilitation targets, or alignment with the current completion criteria.

A final point of note is that the tree density target of “>200 trees/ha at 20 years”, while specific, does not directly relate to the biodiversity indicators and typically tree density targets require a minimum and a maximum density that should not be exceeded (and act as a trigger for the management action of silvicultural thinning) as it is known that high overstorey density can restrict lower-storey diversity (e.g. Daws et al. 2023).

## **Terrestrial Fauna**

The EPA’s objective for the factor Terrestrial Fauna is ‘to protect terrestrial fauna so that biological diversity and ecological integrity are maintained’ (EPA 2021). In relation to this factor, the EPA defines terrestrial fauna as animals living on land or using land (including aquatic systems) for all or part of their lives (EPA 2016a). Terrestrial fauna includes vertebrate and invertebrate groups. Fauna habitat is defined as the natural environment of an animal or assemblage of animals, including biotic and abiotic elements, that provides a suitable place for them to live (e.g. breed, forage, roost or seek refuge). The scale at which fauna habitat is defined will depend on the ecological requirements of the species considered. The EPA

recognises that there are inherent links between the factor Terrestrial Fauna and other environmental factors, and that individual factors should not be considered in isolation. For example, impacts or changes to the factors Flora and Vegetation, Landforms and Inland Waters, can impact terrestrial fauna.

Worsley's bauxite mining process has potential to affect terrestrial fauna, both directly through loss of habitat due to vegetation clearing, and indirectly via habitat fragmentation, injury, mortality, displacement of fauna, vehicle strikes, impacts from dust, noise and vibration, increased competition or predation by feral species, and cumulative impacts in relation to the direct loss and fragmentation of habitat for fauna. In the context of these potential impacts, Worsley has identified the following indicators:

- Species composition of the forest and regional changes within the area of operations.
- Presence / density of MNES and state conservation species
- Presence of feral animals
- Black cockatoo breeding information
- Presence / density of MNES utilising ecologically restored land
- Habitat structures

These indicators are broadly appropriate and relevant to protecting terrestrial fauna. However, a key requirement for developing indicators for biodiversity is inclusive of all levels of biological organisation: diversity within and between species and diversity of ecosystems (within the meaning of the Biodiversity Conservation Act 2016). Evaluation of threats and extinction risk should be extended beyond those species and ecological communities currently listed as threatened or conservation significant. Specific comments relating to this are listed below (**Table 2**). In addition two additional indicators are listed and recommended for consideration.

**Table 2: Specific comments on biodiversity indicators for Terrestrial Fauna**

Biodiversity Indicator	Stantec comment
Species composition of the forest and regional changes within the area of operations.	Broaden this indicator to capture faunal diversity beyond conservation significant species
Presence / density of MNES utilising ecologically restored land	This indicator could be expanded to capture significant species beyond MNES, including short range endemics (SREs). The MNES recorded from the area are not colonizing species and typically require established forests, so in themselves would not be suitable indicator species to evaluate the success of rehabilitation/restoration
<b>Suggested additional Indicators</b>	
Fauna interactions and encounters during clearing and operations	Direct mortality of fauna during clearing is arguably a notable threat and could be mitigated via multi-stage trapping and translocation programs combined with fauna spotting/ removing during clearing. The potential for collision between vehicles and fauna during construction and operational stages could be minimized via traffic, driver and road controls. Procedures for reporting vehicle/fauna interactions could be implemented to monitor progress.
Ecological Linkages	<p>The presence of ecological linkages between forested areas and remnant vegetation in the southwest of WA is an essential component for facilitating the movement of fauna between habitats (DSEWPac, 2012). Up to 10% of the area mapped as Ecological Linkages (962 ha) will be cleared during implementation of the Proposal, therefore Ecological Linkages could be a meaningful indicator to include.</p> <p>An aspect that could be included is the partially-disturbed and fragmented riparian vegetation within the PAA, which provides important habitat for semi-aquatic species, such as the Rakali (<i>Hydromys chrysogaster</i>), and numerous wetland bird and frog species, and also provide movement corridors for MNES such as Common Brushtail Possum (<i>Trichosurus vulpecula</i>), Chuditch (<i>Dasyurus geoffroi</i>) and Quenda (<i>Isodon fusciventer</i>).</p>

For some, but not all of the Terrestrial Fauna indicators, a relevant monitoring or management plan is identified as part of *Program/Monitoring* or *Measure/Outcomes*. It is recommended that the relevant documents are identified for all of the indicators to facilitate better appreciation of each. Examples of specific queries that could be answered might include: details on regional reference sites; which feral species are targeted out of the eight species of feral mammals known from the PAA; monitoring locations and intensity for feral animals, and specifics of control programs used or planned.

### Terrestrial Environmental Quality

Terrestrial Environmental Quality is identified as a key factor by the EPA, with the following objective: 'To maintain the quality of land and soils so that environmental values are protected' (EPA 2021). In relation to this factor, the EPA defines terrestrial environmental quality as the chemical, physical, biological and aesthetic characteristics of soils (EPA 2016b).

Worsley's bauxite mining process has potential to affect the environmental values of land and soils, through topsoil stripping, removal of the bauxite ore, and subsequent reconstruction of a soil profile for revegetation and an appropriate drainage system. In addition, infrastructure associated with the mining operation, such as haul roads and ore conveyors, require road cuttings and river crossings. In the context of these potential impacts, Worsley has identified the following indicators:

- Dryland salinity risk assessed
- Groundwater table rise / decline and evidence of mounding
- Acid sulphate impacts to surface water or soils
- Landform stability
- No inappropriate access/dumping

The first four of these indicators are appropriate and relevant to protecting terrestrial environmental quality. The related *Program/Monitoring* and *Measure/Outcomes* also seem appropriate.

The final indicator 'No inappropriate access/dumping' is relevant, but focuses principally on preventing external access. This indicator could be broadened to consider potential contamination, that may occur during mining, for example from spills. This would be consistent with the ERD (Table ES3), in which 'Contamination of land and soils from fuel and chemical storage leaks, waste products being released into the receiving environment', is already identified as a direct potential impact, with associated mitigation measures also identified.

**Table 3: Specific comments on biodiversity indicators for Terrestrial Environmental Quality**

Biodiversity Indicator	Stantec comment
No inappropriate access/dumping	As it stands this does not read as an indicator, more a policy. As a minimum, suggest re-wording by taking out 'No'. Broaden this indicator to consider potential contamination that may occur during mining, for example from spills and leaks.

### Inland Waters

According to EPA, the environmental objective of the factor Inland Waters is 'To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected' (EPA 2021). In relation to this factor, the EPA defines inland waters as the occurrence, distribution, connectivity, movement, and quantity (hydrological regimes) of inland water, including its chemical, physical, biological and aesthetic characteristics (quality).

Worsley's bauxite mining process has potential to affect the environmental values of inland waters, through riverbank erosion, sedimentation, scouring of streams, decline in aquatic fauna due to changes in flow regime and water quality, the increases water use (including from groundwater sources) for mining activities, and contamination of ground and/or surface water and a deterioration in the water quality, which may subsequently impact on ground and/or surface water values. In the context of these potential impacts, Worsley has identified the following indicators:

- Changes in salinity of the rivers in the operating area
- Changes in groundwater table level and quality
- Maintenance of water quality in downstream water reservoirs
- Groundwater recharge and stream flow comparable to long term averages, as adjusted for regional fluctuations over time.

The first three of these indicators are appropriate and relevant to protecting the quality of inland waters. As detailed in **Table 4**, the fourth and second indicators could be combined, given their overall similarities. The related *Program/Monitoring* and *Measure/Outcomes* seem appropriate, although the direct relationship with the relevant indicator could be made clearer (see General Recommendations below). In addition, the impact of the discharge of waste, or use of water, appears to not be sufficiently addressed in relation to the EPA objective for Inland Waters (**Table 4**).

Contamination of surface water and/or groundwater from spills, chemicals or stormwater run-off is arguably a factor related to indicators 2 and 3 above. The relevant monitoring programs should be linked to Spill Management Standard Work Instruction (SWI) (referred to in South32, 2021), especially for construction of river crossings and mining activities.

**Table 4: Specific comments on biodiversity indicators for Inland Waters**

<b>Biodiversity Indicator</b>	<b>Stantec comment</b>
Changes in groundwater table level and quality	Consider combining these two Indicators.
Groundwater recharge and stream flow comparable to long term averages, as adjusted for regional fluctuations over time	The impact of the discharge of waste, or use of water, is not sufficiently addressed in relation to the EPA objective for Inland Waters of maintaining water quality, local hydrological regime, and the environmental values that inland waters support. The relevant monitoring program for groundwater level and quality should be linked to the Spill Management Standard Work Instruction (SWI) (referred to in South32, 2021), especially for construction of river crossings and mining activities
Maintenance of water quality in downstream water reservoirs	The relevant monitoring program for this Indicator should be linked to the Spill Management Standard Work Instruction (SWI) (referred to in South32, 2021), especially for construction of river crossings and mining activities
<b>Suggested additional Indicators</b>	
<b>Diversity of abundance of aquatic fauna.</b>	The Hotham River will be directly impacted by the construction of river crossings and Augustus River is likely to have alterations. Aquatic fauna could be impacted from changes in flow regime and water quality, including potentially leading to impediment of upstream pre-spawning migrations of freshwater fishes. Continuation of existing monitoring programs, with alterations as required need to be considered to determine and identify any impacts to aquatic fauna.
<b>Groundwater-dependent ecosystems (GDEs)</b>	Alteration of the hydrological regimes could have significant impacts on GDEs and their environmental values. Monitoring of and development of trigger levels for the protection of GDEs, especially, vegetation health assessments, is best discussed under Inland Waters
<b>Habitat connectivity of the riparian zone</b>	See comments for Ecological Linkages in <b>Table 2</b> (Terrestrial Fauna)

## Climate Change

Climate change is expected to be a persistent, escalating stressor on all ecosystems in the Northern Jarrah Forest with the main anticipated or predicted changes over the coming decades expected to be drier and warmer conditions (Conservation and Parks Commission, 2022b). These drier and warmer conditions are expected to interact with other pressures affecting southwest forests, such as fire, disease, weeds and pest animals. The outcomes of these interactions are difficult to predict but are anticipated to include changes to hydrology, vegetation structure, critical fauna habitat, carbon carrying capacity and forest productivity (Conservation and Parks Commission 2022a). Furthermore, extreme climate-related events (heatwaves, higher bushfire intensities, storms), may amplify the impact of other pressures at the species and ecosystem level. In the development of biodiversity indicators for southwest forests, it is therefore important to identify indicators that can assess the capacity of these forests to adapt or recover from changes or disturbances that may be associated with climate change, and still retain biological diversity (OEH & CSIRO, 2019). However, the EPA has not identified Climate Change as a key environmental factor. Although, under the theme of Air, Greenhouse Gas (GHG) Emissions are listed as a key environmental factor.

The EPA's objective related to GHG Emissions is "To reduce net greenhouse gas emissions in order to minimise the risk of environmental harm associated with climate change". Worsley acknowledges that GHG emissions from the Proposal will contribute to cumulative global emissions (South32, 2022) and has included three biodiversity indicators related to measuring the impact of climate change in the PAA under a Climate Change factor. These include;

- Increase in Marri Canker disease
- Increase of Leaf Miner on jarrah
- Water stress on plants

We suggest that climate change could be considered as a pressure/stressor that threatens the biodiversity and ecological integrity of the Northern Jarrah Forest by acting on key factors, rather than as a key environmental factor in itself. As such,

consideration could be given to integrating the existing biodiversity indicators and associated programs/monitoring tasks and measures/outcomes under Climate Change, into Flora and Vegetation (**Table 5**). Indicators considered under these factors could also be modified to include assessment of resilience to pressures of climate change, or measures of attributes that may be most likely to be affected. Some specific comments related to the *Program/Monitoring* and *Measure/Outcomes* are detailed below and summarised in **Table 5**.

**Table 5: Specific comments on biodiversity indicators for Climate Change**

<b>Biodiversity Indicator</b>	<b>Stantec comment</b>
Increase in marri canker disease	Suggest integrating these Indicators, and associated <i>Program/Monitoring</i> tasks and <i>Measure/Outcomes</i> , into Flora and Vegetation
Increase of Leaf Miner on jarrah	
Water stress on plants	The specific indicator of <i>'increasing the proportion of wandoo in the seed mix'</i> used in rehabilitation could be broadened to <i>'increasing the proportion of key species from drier forest regions in the seed mix'</i>
Bioaccumulation of carbon in forest plots vs rehabilitation.	These indicators are each relevant to defining Worsley's carbon footprint, but are not useful indicators of biodiversity or ecological integrity for the region. The performance of rehabilitation in terms of productivity and biodiversity is already being assessed under other indicators, and defining the amount of carbon sequestered is not considered to be critical in that context. It is recommended that assessments relating to carbon sequestration are not included here, but incorporated into other reporting frameworks relating to the EPA's objective for GHG Emissions.
Role of restoration as sequestration	

## GENERAL RECOMMENDATIONS

### Structure of the Biodiversity Indicator Framework table

In the provided framework of proposed Biodiversity Indicators (Appendix 1), multiple *Measure/Outcomes* are often grouped against multiple *Programs/Monitoring*, for a single Indicator. This lack of structure hampers understanding of the overall framework. It is recommended the framework is presented in a more-detailed structure, clearly indicating the relationship of each *Measure/Outcomes* to a specific *Program/Monitoring* for each Indicator.

### Identifying relevant Plans or Procedures

As detailed previously, for some but not all of the indicators, a relevant monitoring or management plan or procedure is identified as part of *Program/Monitoring* or *Measure/Outcomes*. It is recommended that the appropriate documents are consistently identified, with specific and consistent terminology, for all of the indicators to facilitate better understanding. These documents should also provide detail on how the monitoring outcomes are integrated into existing internal, regional, state and national biodiversity reporting frameworks to detect changes to biodiversity and ecological integrity. As identified in the FMP, this is an important component of an adaptive management framework, allowing management to be adjusted if it is not successfully meeting its objectives (Conservation and Parks Commission 2022a).

### Assessment of cumulative impacts

Adopting consistent indicators for assessment of changes in biodiversity and ecological integrity of the NJF would create data that would be comparable across operations allowing for a greater integration into policy-setting, and would be valuable in the development of predictive models for biodiversity and ecological integrity. The ERD highlights the establishment of the Southwest Biodiversity Partnership (ERD, p238) as a collaborative arrangement to facilitate sharing of information and collaboration to improve biodiversity outcomes in the region by leveraging access to resources and funding to achieve objectives. In order to assess and mitigate cumulative impacts, the objectives of this partnership could be aligned with the resulting and agreed upon biodiversity indicators. This would require collaboration with regional operators around the development of indicators, assessment and monitoring, and related biodiversity research programs.

### Noongar knowledge and cultural values

Noongar knowledge of plants, animals, ecosystems and seasons is noted in the FMP as contributing to biodiversity conservation, just as the protection of biodiversity helps conserve and protect Noongar cultural values (Conservation and Parks Commission 2022a). Consideration could be given to strengthening the link of the proposed indicators with Noongar knowledge and values.



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**PERSONNEL CONTRIBUTING TO THE REVIEW**

The following personnel contributed to this review: Dr David Jasper, Dr Natasha Banning, Dr Briony Lalor, Dr Ru Somaweera and Peter Tapsell. The team members have appropriate experience in natural and mining-affected environments, in the relevant areas of soils and landforms, flora and vegetation, fauna, aquatic systems and climate change, and the WA environmental assessment process.

**Appendix 1: Draft Biodiversity Indicators (from Scope of Works,  
14 Feb, 2023)**

Key Environmental Factor	Biodiversity Indicator	Program / Monitoring	Measure / Outcome
<b>Flora and Vegetation</b>	<ul style="list-style-type: none"> <li>Species composition of the forest and regional changes within the area of operations.</li> <li>Health of PEC/TEC systems</li> <li>Presence of threatened flora species</li> <li>Presence and health of indicator species</li> </ul>	<ul style="list-style-type: none"> <li>Rehabilitation monitoring (annual) and forest control plot monitoring (3-5 yearly) and review of holistic rehabilitation success at minimum every 5 years.</li> <li>Targeted monitoring of PEC / TEC / Protected Areas for priority / threatened species and areas.</li> <li>3-5 yearly monitoring of forest control plots and annual monitoring of selected rehabilitation sites of various ages / types. Eg jarrah dominant or wandoo dominant.</li> </ul>	<ul style="list-style-type: none"> <li>Species diversity of post 1993 rehabilitation at 70% of the control forest blocks by 20 years.</li> <li>Greater than 35 species per 80m<sup>2</sup> at &gt;12 years rehabilitation.</li> <li>Demonstrated increase in recalcitrant species numbers in rehabilitation over time.</li> <li>75% of recalcitrant species identified within rehabilitation.</li> <li>Mean 3 native plants/m<sup>2</sup> in rehabilitation (excluding tree species) at 15 months age of rehabilitation.</li> <li>&gt;35% foliar cover in rehabilitation after 10 years</li> <li>Jarrah/Marri/Wandoo density &gt;200 trees/ha at 20 years rehabilitation.</li> <li>Litter density at 50% of reference plot after 20 years. (dependent on fire)</li> </ul>
	<ul style="list-style-type: none"> <li>Declared weeds</li> </ul>	<ul style="list-style-type: none"> <li>Annual vegetation mapping</li> </ul>	<ul style="list-style-type: none"> <li>No declared weeds present in remnant vegetation or rehabilitation/restoration within the PAA</li> </ul>
	<ul style="list-style-type: none"> <li>Dieback spread/movement</li> <li>Marri Canker</li> </ul>	<ul style="list-style-type: none"> <li>Forest disease mapping,</li> <li>Understanding spread, resistance and research into disease management.</li> </ul>	<ul style="list-style-type: none"> <li>Percentage of remnant vegetation area impacted by disease within PAA is equivalent to or less than percentage of land impacted by disease in Northern Jarrah Forest. (&lt;= 15% as stated in Draft FMP (DBCA 2022))</li> </ul>
	<ul style="list-style-type: none"> <li>Use of ecological linkages by fauna species</li> <li>Decrease in fragmentation</li> </ul>	<ul style="list-style-type: none"> <li>Implementation of ecological linkages as described in the ERD.</li> <li>Protected Area Plan updated to provide protection for linkages and reduced fragmentation.</li> <li>Fauna monitoring undertaken in linkages to determine use.</li> <li>Rehabilitation priority given to connecting remnant vegetation.</li> </ul>	<ul style="list-style-type: none"> <li>Linkages identified and established in conjunction with EMLG annually</li> <li>10 Year Mine Plan updated annually to include priority rehabilitation areas to establish linkages.</li> <li>Observed use of key fauna indicator species of linkages for movement between remnant vegetation</li> </ul>
	<ul style="list-style-type: none"> <li>Protected Remnant Vegetation</li> </ul>	<ul style="list-style-type: none"> <li>Percentage of remnant vegetation contained within protected areas inside of the PAA</li> </ul>	<ul style="list-style-type: none"> <li>More than 30% of remnant vegetation within PAA maintained based on 1980 footprint,</li> <li>No decline in area of TEC/PEC areas protected within the PAA.</li> </ul>
	<ul style="list-style-type: none"> <li>Resilience of vegetation to fire</li> </ul>	<ul style="list-style-type: none"> <li>Fire control management undertaken in Rehabilitated and restored areas</li> </ul>	<ul style="list-style-type: none"> <li>Rehabilitated areas made available to be integrated into prescribed burning program for the purpose of fire management when the following criteria are met: <ul style="list-style-type: none"> <li>Tree bark thickness (TBD)</li> <li>Litter Densities (TBD).</li> </ul> </li> </ul>
	<ul style="list-style-type: none"> <li>Landscape vegetation connectivity (Habitat Fragmentation)</li> </ul>	<ul style="list-style-type: none"> <li>Three yearly remote review (eg use of aerial photos) and assessment against a fragmentation index (to be agreed) – for the Development Envelope and 5km’s outside of the Development Envelope</li> </ul>	<ul style="list-style-type: none"> <li>Retaining or establishment of ecological linkages within the development envelope (to promote dispersal from within and across and promote re-establishment of populations following rehabilitation)</li> <li>Improvements in habitat connectivity from a 2020 baseline on 10 yearly intervals</li> </ul>
	<b>Terrestrial Fauna</b>	<ul style="list-style-type: none"> <li>Species composition of the forest and regional changes within the area of operations.</li> <li>Presence / density of MNES and state conservation species</li> </ul>	<ul style="list-style-type: none"> <li>Fauna monitoring in rehabilitation and forest control plots (three yearly rotation)</li> </ul>

Key Environmental Factor	Biodiversity Indicator	Program / Monitoring	Measure / Outcome
	<ul style="list-style-type: none"> <li>Presence of feral animals</li> </ul>	<ul style="list-style-type: none"> <li>Feral animal control/monitoring</li> <li>Continued/increased participation in Western Shield</li> <li>Implementation of alternative control measures e.g., trapping, felixer etc.</li> </ul>	<ul style="list-style-type: none"> <li>Support understanding of feral animal densities within mining operational areas and adjacent state forest               <ul style="list-style-type: none"> <li>Feral animal densities (per/ha) comparable or less than equivalent state forest.</li> </ul> </li> <li>Minimum 8,000 ha of Worsley controlled land baited for feral animals 6 times annually.</li> </ul>
	<ul style="list-style-type: none"> <li>Black cockatoo breeding information</li> </ul>	<ul style="list-style-type: none"> <li>Pre clearance surveys for potential and confirmed hollow use.</li> <li>Survey of remnant vegetation for use of suitable breeding trees</li> <li>Avoidance of confirmed / very high potential breeding trees during clearing of mine area</li> <li>Annual monitoring of Confirmed Black Cockatoo hollows and artificial hollows for utilisation and breeding success.</li> </ul>	<ul style="list-style-type: none"> <li>Evidence of continued use of remnant vegetation for roosting and breeding</li> <li>Evidence of use of rehabilitation/restoration areas for foraging (recorded observations)</li> <li>Evidence of use of breeding trees protected in accordance with the Protected Areas Plan</li> </ul>
	<ul style="list-style-type: none"> <li>Presence / density of MNES utilising ecologically restored land</li> </ul>	<ul style="list-style-type: none"> <li>Offset monitoring, including research in habitat creation / restoration</li> </ul>	<ul style="list-style-type: none"> <li>Observations/densities of key fauna species compared to adjacent remnant vegetation.</li> </ul>
	<ul style="list-style-type: none"> <li>Habitat structures</li> </ul>	<ul style="list-style-type: none"> <li>Artificial habitat creation</li> <li>Support research in determining alternative hollows/designs for habitat</li> <li>Enhance coarse woody debris incorporated into rehabilitation/ecological restoration to enhance termite activity.</li> </ul>	<ul style="list-style-type: none"> <li>Artificial habitat consisting of logs, stumps rock and soil placed at a minimum of 4 habitats per hectare in rehabilitation and restoration areas.</li> <li>Installation of artificial breeding hollows as per the Offset Implementation Plan, Offset 4 - Black Cockatoo Artificial Hollows Installation</li> <li>Research programme developed.</li> <li>Termite structures identified in 20 year age rehabilitation.</li> </ul>
<b>Terrestrial Environmental Quality</b>	<ul style="list-style-type: none"> <li>Dryland salinity risk assessed</li> <li>Groundwater table rise / decline and evidence of mounding</li> </ul>	<ul style="list-style-type: none"> <li>Salinity - Flux density analysis is assessed, and risk monitored through groundwater monitoring program</li> <li>GDE monitoring</li> </ul>	<ul style="list-style-type: none"> <li>Changes in salinity in low-lying soils across PAA comparable or less than reference sites</li> <li>Groundwater levels of post mining catchments demonstrate recovery to equivalent unmined catchment levels within 10 years following rehabilitation as corrected for regional fluctuations over time</li> <li>Groundwater levels maintained adjacent to GDE's comparable to reference sites and corrected for regional fluctuations over time</li> </ul>
	<ul style="list-style-type: none"> <li>Acid sulphate impacts to surface water or soils</li> </ul>	<ul style="list-style-type: none"> <li>Acid Sulphate / Potentially Acid Sulphate soil monitoring in areas identified as likely PASS</li> </ul>	<ul style="list-style-type: none"> <li>No acid drainage or contamination of soils or water within the PAA as a result of Worsley activities (eg exposure).</li> </ul>
	<ul style="list-style-type: none"> <li>Landform stability</li> </ul>	<ul style="list-style-type: none"> <li>Monitoring of erosion in disturbed areas</li> <li>Monitoring of downstream environment for sedimentation/turbidity as part of water monitoring programme</li> </ul>	<ul style="list-style-type: none"> <li>No cuttings or drains narrower than 3m</li> <li>Rehabilitation faces returned to 1V:3H or less unless steeper prior to disturbance.</li> <li>Downstream water quality (turbidity) comparable to reference upstream sites.</li> </ul>
	<ul style="list-style-type: none"> <li>No inappropriate access/dumping</li> </ul>	<ul style="list-style-type: none"> <li>Unauthorised entry/activities (FMP 5.5.10)</li> </ul>	<ul style="list-style-type: none"> <li>No unauthorised dumping of waste on Worsley controlled Land</li> <li>Waste removed to appropriate landfill</li> <li>Inappropriate access points blocked and/or maintained.</li> </ul>
<b>Inland Waters</b>	<ul style="list-style-type: none"> <li>Changes in salinity of the rivers in the operating area</li> </ul>	<ul style="list-style-type: none"> <li>Surface Water monitoring program – as outlined in the Water Management Plan</li> </ul>	<ul style="list-style-type: none"> <li>No direct negative impact downstream of operations measured in comparison to upstream locations.</li> </ul>

Key Environmental Factor	Biodiversity Indicator	Program / Monitoring	Measure / Outcome
	<ul style="list-style-type: none"> <li>Changes in groundwater table level and quality</li> </ul>	<ul style="list-style-type: none"> <li>Groundwater monitoring program – as outlined in the Water Management Plan</li> <li>Triennial aquifer review</li> </ul>	<ul style="list-style-type: none"> <li>Groundwater levels and quality equivalent to regional fluctuations (measured at control locations)</li> <li>Groundwater levels of post mining catchments demonstrate recovery to equivalent unmined catchment levels within 10 years following rehabilitation as corrected for regional fluctuations over time</li> </ul>
	<ul style="list-style-type: none"> <li>Maintenance of water quality in downstream water reservoirs</li> </ul>	<ul style="list-style-type: none"> <li>Operations in Public drinking water source areas managed in accordance with agreed working arrangements</li> <li>Monitoring of downstream (from operations) for water quality as per the Water Resource Management Plan.</li> </ul>	<ul style="list-style-type: none"> <li>Water quality entering streams is comparable than background stream water quality.</li> <li>Working arrangements reporting program, includes reporting in the Annual Environmental Report</li> <li>Implement remedial controls if required</li> </ul>
	<ul style="list-style-type: none"> <li>Groundwater recharge and stream flow comparable to long term averages, as adjusted for regional fluctuations over time.</li> </ul>	<ul style="list-style-type: none"> <li>Forest/rehabilitation thinning within the parameters of plant density objectives to promote groundwater recharge</li> </ul>	<ul style="list-style-type: none"> <li>Demonstrated groundwater flow equivalent to reference catchment as specified in the Water Management Plan</li> </ul>
<b>Climate Change</b>	<ul style="list-style-type: none"> <li>Increase in marri canker disease</li> <li>Increase of Leaf Miner on jarrah</li> <li>Water stress on plants</li> </ul>	<ul style="list-style-type: none"> <li>Monitoring remnant vegetation within PAA for disease</li> <li>Building resilience by increasing the wandoo in the seed mix.</li> <li>Monitor vegetation for signs of water stress</li> <li>Bioaccumulation of carbon in forest plots vs rehabilitation.</li> <li>Role of restoration as sequestration</li> </ul>	<ul style="list-style-type: none"> <li>Support research to reduce impact caused by disease (Marri Canker and Leaf Minor).</li> <li>Extend provenance area for seed collection to source seed from drier region for key species used in rehabilitation (FMP states sourcing seed from dryer areas as preparation for the drying climate (Page 82 Draft FMP 2022)</li> <li>Quantify carbon storage in selected revegetation areas.</li> <li>Evidence of water stress on rehabilitation tree canopy equal to or less than surrounding forest.</li> </ul>

**Appendix 2: DWER response to South32 Environmental Review Document (ERD)**

**STATEMENT #13*****Biodiversity and ecological impacts – cumulative and holistic assessment***

*While information is provided on revegetation outcomes, there is insufficient information provided to understand how forest ecosystem function and forest biodiversity will be protected and restored at a holistic level. The following work is considered to be required to provide a holistic understanding of cumulative impacts to forest ecology and to demonstrate that there are no significant impacts to biodiversity in the Northern Jarrah Forest region.*

*Identify the key biodiversity indicators (relevant to all applicable key factors, i.e., not just flora and vegetation) which are adequate, scientifically robust and appropriate to assess impacts of, and likely environmental outcomes resulting from, the proposal on the ongoing ecological integrity of the Northern Jarrah Forest. Key biodiversity indicators must take account of the impacts of the proposal, cumulative impacts from past, current and reasonably foreseeable future activities, and ongoing pressures such as fire, water resource availability and climate change.*

*Provide a detailed framework which describes how Worsley will assess, and monitor, across the whole of mine life (including post-closure), the status and trends in the key biodiversity indicators used to assess whether the potential impacts are managed, and that environmental outcomes of the proposal are likely to be consistent with the ongoing ecological integrity of the Northern Jarrah Forest.*

*Provide a comparison of the key biodiversity indicators and ecological values between:*

- *undisturbed vegetation areas within the proposal area;*
- *protected areas; and*
- *revegetated areas of previously disturbed mining areas.*

*Taking into account the key biodiversity indicators, describe how the proposed revegetation can successfully restore a reasonable degree of ongoing ecological function post-disturbance, at a large scale, taking into account the key biodiversity indicators. Provide information the expected changes between current ecological functioning and post disturbance ecological functioning.*

*Commission and include an independent peer review of the key biodiversity indicators and detailed framework, to ensure it is adequate, scientifically robust and appropriate, to assess and monitor:*

- *environmental outcomes for the whole of mine life (including post- closure)*
- *whether the EPA's objectives for all applicable key environmental factors can be met, and*
- *whether the proposal is likely to be consistent with the ongoing ecological integrity of the Northern Jarrah Forest.*

### Appendix 3: The EPA's key environmental principles, factors and objectives identified by South32 as relevant to the Revised Proposal (EPA, 2021)

Theme	Factor	Objective	Relevance to the proposed Biodiversity Indicators
<b>Sea</b>	Benthic Communities and Habitats	To protect benthic communities and habitats so that biological diversity and ecological integrity are maintained.	Not applicable#
	Coastal Processes	To maintain the geophysical processes that shape coastal morphology so that the environmental values of the coast are protected.	Not applicable#
	Marine Environmental Quality	To maintain the quality of water, sediment and biota so that environmental values are protected.	Not applicable#
	Marine Fauna	To protect marine fauna so that biological diversity and ecological integrity are maintained.	Not applicable#
<b>Land</b>	Flora and Vegetation	To protect flora and vegetation so that biological diversity and ecological integrity are maintained.	
	Landforms	To maintain the variety and integrity of distinctive physical landforms so that environmental values are protected.	
	Subterranean Fauna	To protect subterranean fauna so that biological diversity and ecological integrity are maintained.	
	Terrestrial Environmental Quality	To maintain the quality of land and soils so that environmental values are protected.	
	Terrestrial Fauna	To protect terrestrial fauna so that biological diversity and ecological integrity are maintained.	
<b>Water</b>	Inland Waters	To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.	
<b>Air</b>	Air Quality	To maintain air quality and minimise emissions so that environmental values are protected.	
	Greenhouse Gas Emissions	To reduce net greenhouse gas emissions in order to minimise the risk of environmental harm associated with climate change.	
<b>People</b>	Social Surroundings	To protect social surroundings from significant harm.	Not applicable#
	Human Health	To protect human health from significant harm.	Not applicable#



