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Comments on the Aquatic Ecosystem components of the Integrated Water Use Licence Application for the proposed Mokolo Crocodile Water Augmentation Project Phase 2 (MCWAP-2)

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1 Introduction

The report was compiled in response to a request for a review of the WULA submitted by TCTA for the MCWAP2 (Mokolo Crocodile Water Augmentation Project Phase 2).

The review has looked specifically at potential impacts on aquatic ecosystems. The aquatic biodiversity and biomonitoring aspects were therefore considered although the wetland

This report is based on a review of the following reports:

- Trans-Caledon Tunnel Authority (TCTA) 2022. Consulting Services for the Mokolo Crocodile Water Augmentation Project Phase 2 (MCWAP-2) Contract № TCTA 20-041 Integrated Water Use License Application
- Trans-Caledon Tunnel Authority (TCTA) 2022. Consulting Services for the Mokolo Crocodile Water Augmentation Project Phase 2 (MCWAP-2) Contract № TCTA 20-041 Amended Construction Environmental Management Programme
- Galago 2021. High Flow Aquatic Baseline Study for the MCWAP-2A: Water Transfer Infrastructure & Borrow Pits, Limpopo.
- ENVASS 2021: Mokolo Crocodile Water Augmentation Project Phase 2 (MCWAP-2) Environmental Baseline Surface Water Quality - Annual Monitoring Report.
- EnviRoss 2021: Mokolo Crocodile Water Augmentation Project Phase 2 (MCWAP-2) Environmental Baseline Studies - Fishway Assessment.
- Scientific Aquatic Services (SAS) 2021. Freshwater Ecosystem Assessment as part of the Environmental Assessment and Authorisation and Water Use License Application Processes for the Proposed Borrow Pits for the Mokolo and Crocodile River (West) Water Augmentation Project (Phase 2a) (MCWAP-2a) between Thabazimbi and Lephalale, Limpopo Province.
- Index 2018. Specialist Study: Wetland Impact Assessment for the Proposed Mokolo and Crocodile River (West) Water Augmentation Project (Phase 2a) (MCWAP-2A)
- Department of Water and Sanitation (DWS) 2019. Determination of Water Resource Classes and Resource Quality Objectives for Mokolo, Matlabas, Crocodile (West) and Marico Catchments. Government Gazette No. 42775, 18 October 2019.

2 Background Information

The MCWAP-2 will deliver 75 million m3/a from the Vlieëpoort Abstraction Works in the Crocodile (West) River at the Vlieëpoort Weir, 8 km south-west of Thabazimbi to the town of Lephalale, where the water will be used for industry, mining and coal-fired power stations.

The following infrastructure is required:

- Abstraction weir (Vlieëpoort Weir),
    - River abstraction pumping station,
    - Desilting works,
    - Sediment return pipeline (into Crocodile River),
- Pipeline:

    - Pipeline of varying diameters
    - Alternatives to the central pipeline,
- Gauging Weirs located at the:
    - Bierspruit,
    - Sandspruit,
    - New Paul Hugo Weir,
- Borrow pits for the sourcing of additional materials.

The proposed development will impact on various watercourses, most notably the Crocodile (West) and Matlabas Rivers and, indirectly, the Mokolo. The map given in the Aquatic Biomonitoring Report (Galago 2021) is shown in Figure 1.

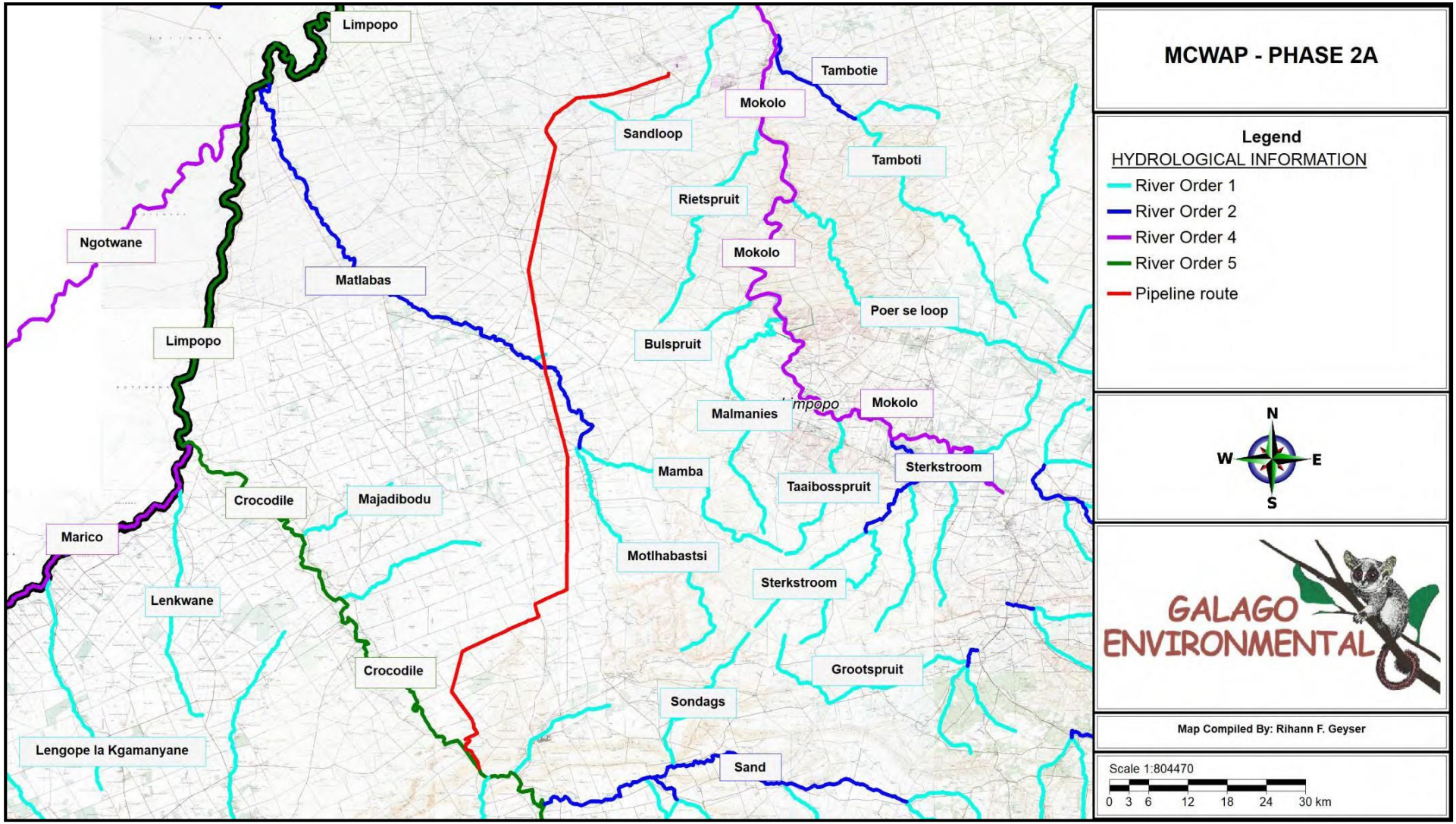

Figure 1. Map of the study area showing rivers (Source: Galago 2021)

3 Consideration of the Ecological Reserve

The RQO and Ecological Water Requirements (EWR) of the Crocodile (West)/Marico River, or how the Reserve will be met have not been considered as part of this application. It is understood that 75 m3/a increasing to 125 m3/a will be abstracted from this river. This will affect the flow, habitat and water quality in the receiving Crocodile River downstream of the weir, which may have implications for downstream users.

Abstraction from the weir may cause hydrological changes such as longer low flow periods or reduced high flows. This may, in turn affect aquatic habitats and biota. The main impacts are briefly described below:

- There may be a decline in abundance of species requiring high flows for migration or spawning
- Water quality will decline and become more saline and eutrophic (through reduced dilution). This in turn may cause a proliferation in algae accompanied by highly variable oxygen concentrations. Proliferation of blue-green algae may become problematic.
- Pools will become shallower and warmer, creating unfavourable conditions with low oxygen concentrations during drier and/or warmer months. This may negatively affect certain sensitive fish species but favour more tolerant species.
- Hardy, exotic species such as Mosquito fish may be favoured by these conditions. Mosquito fish, which are already present within the Crocodile (West) River, are very tolerant to harsh conditions and are notoriously invasive. They also outcompete indigenous species, which are often more sensitive to environmental change. The Global Invasive Species Database (2022) classifies mosquitofish as among the world's worst invasive species. Invasive exotic species displace native species through resource competition.
- Marginal habitats become less suitable and available as water levels drop.
- Riparian and floodplain habitats may become more restricted due to reduced lateral connectivity and a diminished channel.

These potential impacts to aquatic biota due to flow changes have not been considered in the Aquatic Biodiversity Report (Galago 2021). This represents a significant gap in knowledge. It is uncertain whether the Ecological Reserve will be met once abstraction commences during the operational phase of MCWAP 2.

The RQO for the Crocodile River downstream of the proposed Vlieëpoort Weir is given in Appendix 1. The Recommended Ecological Category is specified as Present Ecological State (PES) C (Moderately Modified) to D (Largely Modified). According to the Aquatic Biomonitoring Report (Galago 2021), the PES is already considered Category D for fish and aquatic macroinvertebrates. The report lists 22 species of fish which are expected to occur within the study area under natural (undisturbed) conditions. Of these, only 3-5 species were recorded during the field survey. This suggests seriously compromised ecological integrity and emphasises the need for a comprehensive assessment of impacts due to flow changes during the operational phase.

Table 1 shows how the RQO are already not being met in terms of fish and aquatic macroinvertebrates. Any further deterioration may result in irreversible losses with an

accompanying loss of resilience (i.e. an inability to recover after disturbance). It is essential that the impacts due to abstraction from the Vlieëpoort Weir are adequately assessed.

The objective of the NWA is to ensure that development takes place in a sustainable manner, as quoted below:

- "Recognising that the ultimate aim of water resource management is to achieve the sustainable use of water for the benefit of all users;
- "Recognising that the protection of the quality of water resources is necessary to ensure sustainability of the nation's water resources in the interests of all water users"

The purpose of a Water Use Licence is to ensure that activities are sustainable and that the needs of all downstream users are met. This includes, not only farmers requiring water for irrigation of crops and communities using water for domestic activities - but also the health and integrity of aquatic ecosystems. To demonstrate that these needs are being met, an assessment of impacts to water quality, flow and habitats is required in the Crocodile (West) River downstream of the Vlieëpoort abstraction point.

Table 1. Comparison between the results given in the Aquatic Biomonitoring Report (Galago 2021) and the RQO given in DWS 2019. Exceedances are highlighted orange. Red font represent gaps in knowledge.

RQO (DWS 2019)				Galago (2021)
Instream	Habitat diversity should be improved from D ecological category to C/D ecological category. Maintain good low flows to sustain habitat for substrate and habitat sensitive species and taxa.	Index of Habitat Integrity, Rapid Habitat Assessment Method and Model (RHAMM)	Instream Habitat Integrity EC = C/D ≥ 58%	Not Assessed
Riparian habitat	Indigenous vegetation must be protected (unique *Acacia galpinii* (Monkey thorn). Riparian vegetation should be improved from D ecological category to C/D ecological category.	Index of Habitat Integrity, Vegetation Response Assessment Index	VEGRAI EC = C/D ≥ 58%	Not Assessed
Fish	Fish community should be maintained within a D ecological category. Flow velocity/depth must be maintained for *CPAR, MACU* and *LMOL*, and habitat sensitive species – *MMAC, BANN.*	Fish Response Assessment Index (FRAI)	Fish ecology category = D FRAI ≥ 42% Sample 6+ species per sample effort	FRAI <38% at all sites PES D/E 3-5 species per sampling effort
Semi- aquatic biota	The suitability of this stretch of river to serve as a habitat for aquatic bird and mammal populations must be maintained through proper habitat management. Maintain good riparian cover for otters.	Aquatic birds/Indicator mammal species	A baseline assessment should be conducted to determine the aquatic bird community and representative mammal species along the river reach. There is a need to set a numerical RQO for density of animals/birds based on the available/collected data.	Not Assessed
Aquatic invertebrat es	Macroinvertebrate assemblage must be maintained within a C/D ecological category or improved upon.	Macroinvertebrate Response Assessment Index, and the South African Scoring System Version 5 (SASS5)	MIRAI EC = C/D ≥ 58% SASS ≥ 120 ASPT ≥ 5.0	MIRAI for Crocodile River not assessed per SQ reach (instead combined with Bierspruit) SASS<100 (65-74) ASPT <4.1

RQO (DWS 2019)				Galago (2021)
Diatoms	Diatom assemblage must be maintained within a largely modified condition or improved upon.	Specific Pollution Index (SPI)	Diatom EC ≥ 42%	SPI < 7

4 Gaps in Knowledge

A review of both the Aquatics and Wetland Delineation reports revealed an absence of key information that will need to be considered for an informed decision to be taken. The Aquatic Biodiversity Assessment (Galago 2021) is a high-level biomonitoring report based on a single survey. The level of detail provided is considered inadequate to accurately describe the aquatic ecosystem integrity and the impacts to these aquatic ecosystems from a large-scale in-stream activity such as a water transfer scheme.

The following information is not available:

- The PES of riparian zones has not been assessed along the Crocodile River. Riparian areas should be delineated and assessment using VEGRAI (Vegetation Response Assessment Index). The RQO requirements for the lower Crocodile River (Appendix A) include: “Indigenous vegetation must be protected (unique *Acacia galpinii* (Monkey thorn). Riparian vegetation should be improved from D ecological category to C/D.” The continuity of riparian corridors for animal movement have also not been considered.
- The Index of Habitat Integrity (IHI) was not applied to assess instream or riparian habitat integrity along the Crocodile, Bierspruit, Sandspruit or the Matlabas Rivers. The IHI is required to monitor compliance with the RQO (Appendix A). The RQO requirements for the lower Crocodile River (RU 13.3) includes: “Habitat diversity should be improved from D ecological category to C/D ecological category. Maintain good low flows to sustain habitat for substrate and habitat sensitive species and taxa.” While Galago (2021) used IHAS (Integrated Habitat Assessment Index) to assess habitats, this is a site-specific descriptive index and not an ecostatus index for determining the PES of a river reach.
- MIRAI (Macroinvertebrate Response Assessment Index) has not been applied to the Crocodile River downstream of the proposed weir. Instead, the results have been combined with the Bierspruit, resulting in a higher PES category. This high-level assessment, based on a single survey, is misleading and does not accurately reflect the ecological integrity of the Crocodile River downstream of the weir. The Bierspruit has a different flow regime to the Crocodile River, and it is inappropriate for the results to be lumped together.
- No sampling took place upstream of the proposed Vlieëpoort Weir so the habitats and biota that will be impacted by inundation is not known.
- The RQO requirements for the lower Crocodile River (RU 13.3) include that “The suitability of this stretch of river to serve as a habitat for aquatic bird and mammal populations must be maintained through proper habitat management. Maintain good riparian cover for otters. A baseline assessment should be conducted to determine the aquatic bird community and representative mammal species along the river reach. There is a need to set a numerical RQO for density of animals/birds based on the available/collected data.” This has not been conducted as part of the WULA.

- Pans have not been assessed for pan-adapted biota (such as phyllopod crustaceans). The presence of African Bullfrog and pan-adapted bird species have also not been confirmed.
- There are discrepancies between the list of expected species given in the Fishway Assessment (EnviRoss 2021) and the Aquatic Biomonitoring (Galago 2021) reports. EnviRoss (2021) states that the Crocodile River "supports a large diversity of fish species, which includes an eel species, namely *Anguilla mossambica* (African longfin eel). This species has been observed during previous monitoring at the site (pers. obs.) as well as being listed as a reference species for the river reach by DWS in a relatively high abundance (DWS Fish FROC reference data, 2009)". Eels are not mentioned in the Galago (2021) report. It is clear that a more comprehensive aquatic assessment is required.
- Borrow pit BB-SS1 "is situated on the banks of the Crocodile (West) River within the Zone of Regulation and will trigger Sections 21c and i water uses". It is understood that water will be diverted around the borrow pit in a diversion. However, the impact of this diversion has also not been assessed in Galago (2021) and no management recommendations have been given for either. The diversion will have significant impacts to sensitive aquatic biota during the construction phase and it will be essential to manage these impacts. This information is required to approve the water uses related to BB S1.
- The impact assessment does not provide sufficient detail to describe impacts of specific activities to the biota, nor are the management measures detailed enough to assess their effectiveness. This is discussed further in Section 6 of the report.

In addition to the above, there is also a lack of detail provided on groundwater abstraction volumes and potential effects on the water table within the vicinity of the Crocodile (West) River. Water will be needed for construction, but no abstraction volumes are available. This activity would need a 21 (a) WUL. A lowering of the water table beneath the river due to groundwater abstraction will intensify low flow conditions which may affect the survival of certain fish species.

These significant gaps in knowledge mean that an informed decision regarding impacts to aquatic ecosystems cannot be made with a reliable level of confidence.

5 Matlabas River

The Matlabas River has a high ecological integrity (PES B) and good water quality (low salinity and nutrient concentrations (Galago 2021). This system is considered to "be ecologically important at the affected site and the biodiversity of these systems may be sensitive to flow and habitat modifications" (Index 2018).

This essentially means that the aquatic ecosystem is more vulnerable (sensitive) to disturbance. Impacts to the integrity of the river are likely to have a higher magnitude and a higher likelihood. The impact ratings provided by Galago (2021) do not take this into account and the impacts are not described in their report, making it difficult to understand what exactly these impacts will be.

For example, the salinity of the Crocodile River water is likely to be much higher than the water in the Matlabas River. Spills and leaks are likely to be accompanied by a decline in water

quality in the Matlabas River. Other contaminants are also likely to be present (such as nutrients and metals) which are likely to have significant impacts on water quality. This, in turn, will affect algal production and oxygen concentrations in the Matlabas River, with negative consequences for aquatic biota. The presence of harmful algal blooms and cyanotoxins cannot be ruled out. These have been recorded from the Crocodile (West) and Limpopo Rivers but not from the Matlabas River.

Mitigation measures are also not described in sufficient detail and exclude certain important measures, such as:

- Measures should be put in place to prevent contamination from evaporation ponds during scouring and a maintenance plan should be compiled for the pipeline.
- It is essential that an emergency preparedness plan be compiled to address pipeline leaks or spills during scouring.

Mitigation measures should be included for the operational phase (only the construction phase EMPR was available for review).

6 Impact Assessment and Management Recommendations

6.1 Impact Assessment - Aquatic Ecosystems

Impacts on aquatic ecosystems (Galago 2021) have been generically assessed at a high level. The impact assessment is contained within a single table for the entire project and not per individual activity or ecosystem.

Impacts have not been considered individually for:

- each activity (e.g. weirs, abstraction, sediment management, pipeline scouring, borrow pits, road crossings), nor for
- each water use, nor for
- each phase of the development (construction and operational).

As such, it is difficult to understand what the impacts will be on aquatic ecosystems for each activity as they are not described. This represents a significant gap in knowledge in terms of facilitating informed decision-making. The ratings given in the impact assessment tables are considered of low confidence, being based on insufficient detail, and are not considered reliable.

In addition, only impacts associated with the construction phase are considered. Operational phase impacts due to abstraction and pumping of water from the Vlieëpoort Weir to Lephalale have been excluded, as have management recommendations associated with these operational phase activities.

Operational phase impacts due to abstraction have been excluded from both the Aquatic Biomonitoring Report and the WULA Technical Report. This information is required for an activity 21 (a) application (“taking water from a water resource”). The report refers to flow velocity but not to flow volumes, nor to changes to the hydrological regime (duration of low flow periods or frequency of flood events, for example).

In addition to managing flows at the weir, the following impacts and management recommendations have been excluded:

- Maintenance measures required to comply with dam safety requirements at the Vlieepoort Weir.
- Maintenance and emergency preparedness plan for the pipeline at the Matlabas River crossing.
- Impacts to water quality (and therefore aquatic biota) due to sewage effluent during the construction and operational phases.
- Impacts to water quality (and aquatic biota) in the Matlabas River due to spills, leaks and scouring during the operational phase.
- Impacts due to flushing of boulder/gravel traps.

6.2 Operational Phase Mitigation and Management

An Environmental Management Plan has been compiled (TCTA 2022) for the construction phase. While various 21(c) and 21(i) activities are listed for the construction phase, operational phase activities are excluded, particularly those relating to:

- 21 (a) taking water from a water resource (abstraction from the Crocodile (West) River during the operational phase).
- 21 (f) discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit (This applies to sediment management during the operational phase as well as release of potential release of water into the Matlabas River during scouring).
- 21 (g) disposing of waste in a manner which may impact on water resources (e.g. domestic effluent, including sewage effluent, will need to be managed during the operational phase. Water treatment may also be necessary).

A comprehensive WULA for MCWAP2 would need to consider these uses.

7 Climate Change

Climate change projections for the region indicate hotter conditions with longer and more frequent drought periods, which will reduce water availability. Higher temperatures will, in turn, cause an increase in evaporation losses from dams and rivers. These conditions will lead to decreased surface water and an increase demand for groundwater and abstraction, particularly for agricultural irrigation. Water required for irrigation along the Crocodile (West) River will increase, as may groundwater requirements in the Lephalale area. Mbokodo *et al.* (2020) state:

- “Simulations indicated that the 30-year period average maximum temperatures may rise by up to 6 degrees C across much of the interior of South Africa by 2070–2099”.
- “Heat wave occurrences will last longer and become more intense”.
- “Increases in heat wave frequency and duration across South Africa may have significant impacts on human health, economic activities, and livelihoods in vulnerable communities.”

Udall (2018) states: “The strong preponderance of scientific evidence from all recent and relevant scientific studies indicates that flows in the Mokolo and Crocodile (West) rivers will likely decline as the 21st century warms. Even if some increases in precipitation were to occur, flows will still decline due to higher evaporation and evapotranspiration..... Thus, it seems

very likely that Mokolo and Crocodile (West) River flows will decline as the 21st century unfolds, with the decline proportional to the temperature increase. This finding is considered very likely.... What precipitation does occur will come on fewer days, with more intensity."

Udall adds that the problem is exacerbated by increased emission of greenhouse gas emissions associated with coal-fired power stations, which merely exacerbate the rise in temperature and associated evaporative losses.

A further consideration is that future water shortages during more frequent and longer dry periods may result in water restrictions or increased recycling of water being implemented in Gauteng. This will reduce the amount of water reaching the Vlieepoort Weir thus exacerbating existing impacts to flows downstream of the weir.

How this will impact on aquatic biota is well summarised in the Fishway Report (EnviRoss 2021). During low flow periods in the dry season, isolated pools remain within the channel. These act as refugia for many fish species. Here they can survive until flows are restored with the summer rains.

- "Artificially inhibiting longitudinal habitat connectivity would ultimately affect the survivability of fish communities as a whole, especially as the cumulative impact due to historical instream infrastructure developments is high and the system is subject to a relatively high abstraction rate to support agriculture and industry".
- "The locality of the proposed Vlieepoort abstraction weir falls within a very active agricultural region and therefore water abstraction directly from the river as well as groundwater abstraction through numerous boreholes, is high. This lowering of the water volume within the watercourse tends to exacerbate the impacts of the small-scale migratory barriers."

In other words, as abstraction rates increase (from both the MCWAP scheme and increased abstraction by farmers under climate change conditions), these isolated pockets of habitat during the dry season will become shallower, more isolated and warmer. This will affect survival rates of sensitive species and ultimately species diversity. Exotic, predatory species such as Mosquito Fish which are tolerant and hardy, will increase in abundance, while. indigenous species, which may be more sensitive, will decline in abundance.

Climate change will undeniably affect the availability of water resources in the Crocodile (West) and Limpopo Rivers. These effects will be exacerbated by further abstraction for MCWAP2. This may affect the effectiveness of the RMS and its capability to meet the Reserve for these rivers. Future water-use scenarios within the context of climate change and decreased flows must be factored into the RMS and considered as part of the WULA.

Without this information, decision-makers do not have sufficient information for an informed decision to be taken. An informed decision needs to consider how the Reserve of the Crocodile (West) and Limpopo Rivers will be met in the long term, including future climate change scenarios.

8 Cumulative and Indirect Impacts

There are likely to be cumulative impacts associated with groundwater contamination in the Mokolo Catchment once mining developments begin to expand into new areas around Lephalale. This is likely to be associated with seepage from waste rock dumps, tailings

disposal facilities and ash dams associated with the power stations. These activities usually result in increased salinity, acidity and metals, which can be toxic to aquatic biota. Ammonia, for instance, is often associated with nitrates from blasting or sewage treatment facilities. Ammonia is highly toxic to aquatic biota.

It is likely therefore that the surface and ground water quality will decline in the Mokolo, Lephalale and Limpopo Rivers, either directly through runoff or (more likely) indirectly through groundwater contamination associated with mining.

As discussed above, there are also likely to be cumulative impacts to flow conditions due to abstraction within the Crocodile River (West) and Limpopo Rivers. This abstraction will exacerbate existing and growing impacts due to irrigation along the Crocodile (West) River and will intensify as temperatures continue to rise with climate change.

Cumulative and indirect impacts were not considered in the Aquatic Biomonitoring Report (Galago 2021), nor the Technical Report (TCTA 2022).

The impact of reduced flows and a decrease in flows and water quality (through reduced dilution and increased groundwater contamination) in the Limpopo River are not clear. The Limpopo River is an international river which forms the border between Botswana, Zimbabwe and South Africa. It also flows along the norther border of the Kruger National Park. It is assumed that flows and water quality in this river will be considered in the “River Management System” but, again, no information is provided.

9 International Rivers

The Limpopo River forms the border between Botswana, Zimbabwe and South Africa. It also flows along the norther border of the Kruger National Park. It is presumed that this is considered in the “River Management System” but, again, no information is provided. While flows in the Crocodile River may be regulated by the RMS, runoff from mining expansions in the Lephalale area will have additional cumulative impacts to surface water and groundwater which may result in the reserve not being met in the receiving Limpopo River.

The SADC Water Protocol requires all signatory Parties to ensure that their water use in a shared river basin does not cause appreciable harm to a neighbouring country.

10 Wetland delineation and Assessment Report (Index 2018)

The following omissions apply to the wetland delineation report:

- Riparian areas and riparian integrity have not been delineated or assessed. This is required to establish whether RQO can be met.
- Pans have not been assessed for pan-adapted fauna. These may contain endemic or rare species.
- Operational phase impacts have not been assessed.

The wetland specialist report identified floodplain areas (including oxbow lakes) upstream of the weir. The report states that the area of inundation will not extend into these riparian and floodplain areas. Instead, it states, “Abstracting water at the Vlieëpoort Weir will likely cause fluctuating river levels upstream. Flow level variation is a natural process at present. While the

effect may be exaggerated when pumping commences, the impact is unlikely to be significant. The riparian zone may increase in size because of the raised water level."

These floodplain wetlands play an important role in biodiversity support (including providing habitat for threatened species) although no details are provided. The impact of inundation and associated fluctuations in water levels on biodiversity is therefore unclear. It seems likely that fluctuating water levels will impact on riparian zones and floodplains, at least at certain times of the year.

There is also no discussion on the effect of reduced flows downstream of the weir on adjacent riparian and floodplain areas.

Several pans were identified along the pipeline routes. No detailed information has been provided on the wetland vegetation or fauna found within these pans. The Terrestrial Fauna and Flora Specialist Report (Nemai 2018) mentions that habitat for threatened species exists within certain pans. It is likely that specialised pan-adapted phyllopod crustaceans are present in certain pans, providing food for waterbirds.

11 Conclusion

Considering the significant gaps in knowledge discussed above, it is my opinion that decision-makers do not have access to sufficient information to make an informed decision with confidence.

In particular, the following critical information would be required.

- A detailed description of the impacts to flow, water quality, habitats and biota in the receiving Crocodile (West) River during the operational phase, and how the Reserve will be met in the long term (including climate change scenarios).

- The high-level impact assessment given in the Aquatic Biomonitoring Report (Galago 2021) does not provide sufficient detail to understand the impacts of each activity to aquatic ecosystems with a reliable level of confidence. The ratings given are therefore of low confidence. These ratings have been incorporated into the WUL Technical Report.

- Impacts to water quality in the Matlabas River and the direct and indirect consequences for aquatic biota and algal proliferation (including blue-green algae).

- Management of operational phase activities (abstraction rates, flow regulation and pipeline operation and maintenance) are excluded.

- The impacts associated with the implementation of the River Management System and associated “Operational Rules” should be assessed and integrated into the WUL authorisation process. Phase 2A should not be authorised based on the assumption that the RMS will be effectively administered and that the Reserve will be met – i.e. the effectiveness of the RMS to achieve the EWR and RQO in the Crocodile (West) and Limpopo systems needs to be demonstrated first, particularly in light of the fact that certain RQO are already not being met. In addition, future climate change predictions are for hotter, drier conditions. The associated increase in water requirements due to climate change must therefore be factored into the allocation of water resources to the Reserve.

- Cumulative impacts to the Crocodile and Limpopo Rivers due to a progressive decline in groundwater quality which is likely to follow large-scale mining and industrial developments in the Lephalale area, also need to be considered in terms of the Reserve and meeting the needs of all water users in the vicinity as well as downstream in the Mokolo and Limpopo Rivers (most notably aquatic ecosystems and the irrigation needs of farmers).

- Consideration of international agreements, the Limpopo River being an international River.

Appendix A RQO for the Crocodile (West) River

Table 15: Resource Quality Objectives for RIVERS AND DAMS in priority Resource Units in the Integrated Unit of Analysis 13: LOWER CROCODILE (From Government Gazette 18: 192 (No. 42775))

IUA	Class	River	Resource Unit	Ecological Category	Component	Sub-component	Narrative RQO	Indicator	Numerical Limit RQO		
13: LOWER CROCODILE	III	Crocodile outflow Roodekopjes Dam to Sand river confluence, Sleepfontein-spruit, Klipspruit tributaries (A21L, A24A, A24B, A24C)	13_1	C/D	Quantity	Low flows	EWR maintenance low and drought flows: Crocodile River at CROC_EWR7 in A24C NMAR = 463.4x10^{6}m^3 REC=D category The maintenance low flows and drought flows must be attained to support the aquatic ecosystem and the downstream users.	Base Flows Maintenance flows and drought flows. Monitoring of Crocodile River at A2H132		Maintenance Low flows (m^3/s)	Drought flows (m^3/s)
									Oct	1.134	1.134
									Nov	1.362	1.362
									Dec	1.481	1.481
									Jan	1.938	1.938
									Feb	2.638	2.488
									Mar	2.481	2.481
									Apr	2.118	2.118
									May	1.745	1.745
									Jun	1.574	1.574
									Jul	1.389	1.389
									Aug	1.262	1.262
									Sep	1.172	1.172
						High flows	EWR high flows: Crocodile River at CROC_EWR7 in A24C NMAR = 463.4x10^{6}m^3 REC=D category High flows must be attained as specified to support aquatic ecostem requirements.	Floods High flow also specified as individual flood requirements in terms of size and duration (See Appendix A) Monitoring of Crocodile River at A2H132		High flows (m^3/s)	
									Oct	0	
									Nov	0.790	
									Dec	1.529	
									Jan	0	
									Feb	1.270	
									Mar	0	
									Apr	0.790	
									May	0	
									Jun	0	
									Jul	0	
									Aug	0	
									Sep	0	

IUA	Class	River	Resource Unit	Ecological Category	Component	Sub-component	Narrative RQO	Indicator	Numerical Limit RQO
					Quality	Nutrients	Instream concentration of nutrients must be improved to sustain aquatic ecosystem health and ensure the prescribed ecological category is met. Concentrations should not be allowed to deteriorate.	) as Phosphorus	≤ 0.060 milligrams/litre (mg/l) (50th percentile)
								Nitrate (NO_3^-) & Nitrite (NO_2^-) as Nitrogen	≤ 1.0 milligrams/litre (50th percentile)
						Salts	Instream salinity must be maintained at the levels specified to support a healthy aquatic ecosystem and the water quality requirements of water users. Concentrations should not be allowed to deteriorate.	Electrical conductivity (EC)	≤ 85 milliSiemens/metre (mS/m) (95thpercentile)
								Sulphate (SO_4)	≤ 100 milligrams/litre (95th percentile)
								Sodium (Na)	≤ 80 milligrams/litre (95th percentile)
								Chloride (Cl)	≤ 80 milligrams/litre (95th percentile)
						Pathogens	The presence of pathogens should pose no risk to human health.	*Escherichia coli* (*E.coli*)	130 counts/100 millilitres (ml) (95th percentile)
						System Variables	pH range must be maintained within limits specified to support the aquatic ecosystem and water user requirements.	pH range	6.5 (5th percentile) and 8.5 (95th percentile)
							A baseline assessment to determine the present state instream turbidity is required.	Turbidity	A 10% variation from background concentration is allowed.
							Dissolved oxygen levels must be attained to support the aquatic ecosystem.	Dissolved oxygen	≥ 6 milligrams/litre (mg/l)
						Toxics	The concentrations of toxicants must pose no risk to aquatic	Atrazine	≤0.078 milligrams/litre (mg/l)

IUA	Class	River	Resource Unit	Ecological Category	Component	Sub-component	Narrative RQO	Indicator	Numerical Limit RQO
							organisms and to human health.	Metolachlor	≤0.30 milligrams/litre (mg/l)
								Aluminium (Al)	≤ 0.1 milligrams/litre (mg/l) (95th percentile)
								Manganese (Mn)	≤ 0.15 milligrams/litre (mg/l) (95th percentile)
								Iron (Fe)	≤ 0.3 milligrams/litre (mg/l) (95th percentile)
								Lead (Pb) hard	≤ 0.0095 milligrams/litre (mg/l) (95th percentile)
								Copper (Cu) hard	≤ 0.0073 milligrams/litre (mg/l) (95th percentile)
								Nickel (Ni)	≤ 0.07 milligrams/litre (mg/l) (95th percentile)
								Cobalt (Co)	≤ 0.05 milligrams/litre (mg/l) (95th percentile)
								Zinc (Zn)	≤ 0.002 milligrams/litre (mg/l) (95th percentile)
								Aluminium (Al)	≤ 0.1 milligrams/litre (mg/l) (95th percentile)
					Habitat	Instream	Habitat diversity should be maintained within a D ecological category or better condition. Maintain good low flows to sustain habitat for substrate and habitat sensitive species and taxa.	Index of Habitat Integrity, Rapid Habitat Assessment Method and Model (RHAMM)	Instream Habitat Integrity EC = D ≥ 42%
						Riparian habitat	Rehabilitation/remediation required. Indigenous vegetation must be protected (unique *Acacia galpinii* (Monkey thorn). Riparian vegetation should be maintained within a D ecological category or better condition. Maintain riparian zone in cultivated areas. Control development.	Vegetation Response Assessment Index	VEGRAI EC = D ≥ 42%

IUA	Class	River	Resource Unit	Ecological Category	Component	Sub-component	Narrative RQO	Indicator	Numerical Limit RQO		
					Biota	Fish	Fish community should be maintained within a D ecological category or better condition. Flow velocity/depth must be adequate for flow sensitive species *CPRE* and *LMOL* and habitat sensitive species – *AJOH.*	Fish Response Assessment Index (FRAI)	Fish ecology category = D FRAI ≥ 42% Sample 6+ species per sample effort Indicator species *Sensitive fish species. Course substrate, CPRE, LMOL*		
						Aquatic macroinvertebrates	Macroinvertebrate assemblage must be maintained within a D ecological category or improved upon.	Macroinvertebrate Response Assessment Index, and the South African Scoring System Version 5 (SASS5)	MIRAI EC = D ≥ 42% SASS ≥ 60 ASPT ≥ 4.5 (Site A2CROC-KOEDO)		
		Sand River to confluence with Crocodile River (A24G, A24H)	13_2		Quantity	Lows flows	EWR maintenance low and drought flows: Sand River upstream of Sondags River confluence at S24.6289, E27.6223 in A24H NMAR = 26.56x10^{6}m^3 REC=B category The maintenance low flows and drought flows must be attained to support the aquatic ecosystem and the downstream users.	Base flows Maintenance flows and drought flows. Monitoring of discharge of the Sand River during biological surveys		Maintenance Low flows (m^3/s)	Drought flows (m^3/s)
									Oct	0.085	0.042
									Nov	0.104	0.024
									Dec	0.120	0.021
									Jan	0.196	0.063
									Feb	0.263	0.105
									Mar	0.199	0.055
									Apr	0.158	0.071
									May	0.127	0.059
									Jun	0.119	0.056
									Jul	0.108	0.051
									Aug	0.098	0.047
									Sep	0.089	0.044
						High flows	EWR high flows: Sand River Monitoring of discharge of the Sand River during biological surveys at S24.6289, E27.6223 in A24H NMAR = 26.56x10^{6}m^3 REC=B category High flows must be attained to ensure freshets for fish communities.	Freshets for fish High flow also specified as individual flood requirements in terms of size and duration (see Appendix A)		High flows (m^3/s)	
									Oct	0.009	
									Nov	0.056	
									Dec	0.090	
									Jan	0.181	
									Feb	0.500	
									Mar	0.181	
									Apr	0.093	
									May	0	
									Jun	0	
									Jul	0	
									Aug	0	
									Sep	0	

IUA	Class	River	Resource Unit	Ecological Category	Component	Sub-component	Narrative RQO	Indicator	Numerical Limit RQO
					Quality	Nutrients Salts	Instream concentration of nutrients as specified must be attained to sustain aquatic ecosystem health and ensure the prescribed ecological category is met. Instream salinity levels as specified must be attained to sustain aquatic ecosystem health and ensure the prescribed ecological category is met.	Orthophosphate (PO_4^-) as Phosphorus	≤ 0.020 milligrams/litre (mg/l) (50th percentile)
								Nitrate (NO_3^-) & Nitrite (NO_2^-) as Nitrogen	≤ 0.5 milligrams/litre (50th percentile)
								Electrical Conductivity	≤ 30 milliSiemens/metre (mS/m) (95th percentile)
								Sulphate	≤ 20 milligrams/litre (95th percentile)
								Chloride	≤ 20 milligrams/litre (95th percentile)
					Habitat	Instream	Habitat diversity should be maintained within a B ecological category.	Index of Habitat Integrity, Rapid Habitat Assessment Method and Model (RHAMM)	Instream Habitat Integrity EC = B ≥ 82%
						Riparian habitat	Riparian vegetation should be maintained within a B ecological category or better condition.	Vegetation Response Assessment Index	VEGRAI EC = B ≥ 82%
					Biota	Fish	The fish community must be maintained in a B ecological category. An assessment of the fish community should be conducted annually to monitor against the prescribed ecological category.Habitat and flow must be adequate for *seasonal f*low dependent species, *CPAR.*	Fish Response Assessment Index (FRAI)	Fish ecology category = B FRAI ≥ 82%
						Aquatic macroinvertebrates	Macroinvertebrate assemblage must be maintained within a C ecological category or improved upon.	Macroinvertebrate Response Assessment Index, and the South African Scoring System Version 5 (SASS5)	MIRAI EC = C ≥ 62% SASS ≥ 100 ASPT ≥ 5.5 (Site A2SUND-WATER)

IUA	Class	River	Resource Unit	Ecological Category	Component	Sub-component	Narrative RQO	Indicator	Numerical Limit RQO		
							EWR maintenance low and drought			Maintenance	Drought
		Lower Crocodile from Bierspruit to border (Limpopo River) (A24J)	13_3		Quantity	Low flows	flows: Crocodile River at A2H128 in A24J NMAR = 565.16x10^{6}m^3 REC=C/D category The maintenance low flows and drought flows must be attained to support the aquatic ecosystem and the downstream users.	Base Flows Maintenance flows and drought flows. Monitoring of Crocodile River at A2H128		Low flows (m^3/s)	flows (m^3/s)
									Oct	1.246	1.057
									Nov	1.454	1.228
									Dec	1.536	1.294
									Jan	1.932	1.616
									Feb	2.488	2.074
									Mar	2.128	1.776
									Apr	1.791	1.503
									May	1.548	1.303
									Jun	1.524	1.285
									Jul	1.425	1.203
									Aug	1.345	1.138
									Sep	1.287	1.091
						High flows	EWR high flows: Crocodile River at A2H128 in A24J NMAR = 565.16x10^{6}m^3 REC=C/D category High flows must be attained to ensure flood requirements for fish communities.	Floods High flow also specified as individual flood requirements in terms of size and duration (see Appendix A). Monitoring of Crocodile River at A2H128		High flows (m^3/s)	
									Oct	0	
									Nov	0.395	
									Dec	2.829	
									Jan	0	
									Feb	0.423	
									Mar	0	
									Apr	0	
									May	0	
									Jun	0	
									Jul	0	
									Aug	0	
									Sep	0	
					Quality	Nutrients	Instream concentration of nutrients must be improved to sustain aquatic ecosystem health and ensure the prescribed ecological category is met. Concentrations should not be allowed to deteriorate.	Orthophosphate (PO_4^-) as Phosphorus	≤ 0.06 milligrams/litre (mg/l) (50th percentile)		
								Nitrate (NO_3^-) & Nitrite (NO_2^-) as Nitrogen	≤ 1.0 milligrams/litre (50th		
						Salts	Instream salinity must be maintained at the levels specified to support a healthy aquatic ecosystem and the water quality requirements of water users. Concentrations should not be	Electrical conductivity (EC)	≤ 85 milliSiemens/metre (mS/m) (95thpercentile)		
								Sulphate (SO_4)	≤ 100 milligrams/litre (95th		
								Sodium (Na)	≤ 80 milligrams/litre (95th percentile)		

							allowed to deteriorate.	Chloride (Cl)	≤ 100 milligrams/litre (95th percentile)
						Pathogens	The presence of pathogens should pose no risk to human health.	*Escherichia coli* (*E.coli*)	130 counts/100 millilitres (ml) (95th percentile)
						System Variables	pH range must be maintained within limits specified to support the aquatic ecosystem and water user requirements.	pH range	6.5 (5th percentile) and 8.5 (95th percentile)
							A baseline assessment to determine the present state instream turbidity is required.	Turbidity	A 10% variation from background concentration is allowed.
							Dissolved oxygen levels must be attained to support the aquatic ecosystem.	Dissolved oxygen	≥ 6 milligrams/litre (mg/l)
						Toxics	The concentrations of toxicants must pose no risk to aquatic organisms and to human health	Atrazine	≤0.078 milligrams/litre (mg/l)
								Mancozeb	0.009 milligrams/litre (mg/l)
					Habitat	Instream	Habitat diversity should be improved from D ecological category to C/D ecological category. Maintain good low flows to sustain habitat for substrate and habitat sensitive species and taxa.	Index of Habitat Integrity, Rapid Habitat Assessment Method and Model (RHAMM)	Instream Habitat Integrity EC = C/D ≥ 58%
						Riparian habitat	Indigenous vegetation must be protected (unique *Acacia galpinii* (Monkey thorn). Riparian vegetation should be improved from D ecological category to C/D ecological category.	Index of Habitat Integrity, Vegetation Response Assessment Index	VEGRAI EC = C/D ≥ 58%
						Fish	Fish community should be maintained within a D ecological category. Flow velocity/depth must be maintained for *CPAR, MACU* and *LMOL*, and habitat sensitive species – *MMAC, BANN.*	Fish Response Assessment Index (FRAI)	Fish ecology category = D FRAI ≥ 42% Sample 6+ species per sample effort

					Biota	Semi-aquatic biota	The suitability of this stretch of river to serve as a habitat for aquatic bird and mammal populations must be maintained through proper habitat management. Maintain good riparian cover for otters.	Aquatic birds/Indicator mammal species	A baseline assessment should be conducted to determine the aquatic bird community and representative mammal species along the river reach. There is a need to set a numerical RQO for density of animals/birds based on the available/collected data.
						Aquatic invertebrates	Macroinvertebrate assemblage must be maintained within a C/D ecological category or improved upon.	Macroinvertebrate Response Assessment Index, and the South African Scoring System Version 5 (SASS5)	MIRAI EC = C/D ≥ 58% SASS ≥ 120 ASPT ≥ 5.0
						Diatoms	Diatom assemblage must be maintained within a largely modified condition or improved upon.	Specific Pollution Index	Diatom EC ≥ 42%

Appendix B: References

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