Dewatering Discharge in the Goldfields: Ecology, Monitoring, Management and Mitigation

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Abstract

Ephemeral waterbodies and in particular salt lakes are a dominant feature of the Goldfields region, which supports substantial exploration and mining for minerals such as gold, nickel, potash and uranium. Mines that intercept the groundwater table require dewatering, with nearby salt lakes often providing a cost effective disposal option.

MWH Australia Pty Ltd (MWH) (previously Outback Ecology) have studied more than 20 waterbodies throughout the Goldfields, to determine ecological impacts related to mine dewatering discharge. The documented impacts vary and include an increased hydroperiod, salt crust formation, elevated salts, metals and nutrients, reduced biological activity, erosion of the playa and foreshore, and degradation of riparian vegetation. The severity of impacts is dependent on the characteristics of the discharge water and the receiving environment.

MWH has numerous case studies that highlight the importance of collecting baseline data prior to dewatering and monitoring during and after cessation of dewatering. This allows impacts to be effectively assessed, and management strategies to be implemented as required, to maintain ecological integrity. Assessment should focus on biological indicator organisms that are representative of the broader environment and monitoring should be tailored to suit each individual ecosystem.

The results of salt lake monitoring by MWH over the last 15 years suggests that larger playas may recover naturally over time, following major flood events that can dilute and disperse contaminants. However, while dewatering discharge mainly occurs to salt lakes, creeklines, wetlands and claypans are also potential receiving environments and pose unique considerations for proponents. Proponents can minimise impacts through the implementation of a range of engineering options for the treatment of discharge water, the design of the discharge outfall and by appropriately managing the discharge regime, in combination with a suitable ecological monitoring program.

Introduction

Ephemeral waterbodies and in particular salt lakes, are a dominant feature of the Goldfields region, which supports substantial exploration and mining for minerals such as gold, nickel, potash and uranium. Many of these operations are located on or adjacent to salt lakes, claypans and creeklines, which may be considered a relatively simple and cost-effective solution for the disposal of excess mine water. MWH Australia Pty Ltd (MWH) (previously Outback Ecology) specialises in assessing the effects of mine dewatering discharge on aquatic ecosystems, with over 15 years of experience in the field of salt lake ecology.

While typically dry, waterbodies in the Goldfields region experience major flood events on average, approximately once every 10 years. This is usually associated with tropical lows or ex-cyclonic activity originating in north Western Australia during the summer months. In contrast, minor flooding occurs more regularly, usually every two to three years after intense rainfall events. During flooding, the ephemeral waterbodies of the Goldfields can become highly productive ecosystems, and while once thought to be barren environments, are now known to support diverse biological assemblages (Williams 1998).

Waterbodies in the Goldfields exhibit a range of characteristics, although the majority are shallow (<1 m) and internally draining. They range from freshwater (<3,000 mg/L) to hypersaline (>50,000 mg/L), with the salinity of many salt lakes approaching saturation point (approximately 300,000 mg/L) towards the end of their hydroperiod (McComb and Lake 1990). Surface water pH varies, although is typically circumneutral to alkaline during flooding (Gregory 2007). The aquatic organisms inhabiting Goldfields waterbodies also show substantial variation dependent on water quality, although most salt lake biota have broad salinity tolerance limits (Williams 1998).

A range of potential dewatering discharge impacts on the ecology of salt lakes have been documented in Western Australia (Gregory 2007), although there is a paucity of information on dewatering to freshwater or low salinity creeklines and claypans. The nature and extent of influence is dependent not only on water quality but also on the quantity of the discharge water (Outback Ecology 2009), which varies according to the scale of mining operations. However, in most cases the disturbance created by dewatering is considered temporary and is usually localised to within the vicinity of the discharge outfall (**Plate 1**).

This paper provides a synthesis of information associated with dewatering discharge to waterbodies in the Goldfields. It includes an outline of potential ecological impacts and amplifying factors as well as providing a broad overview of monitoring, management and mitigation measures and strategies, supported by numerous case studies. This paper was also recently presented in shortened form to the Department of Environment and Regulation (DER) in Kalgoorlie.

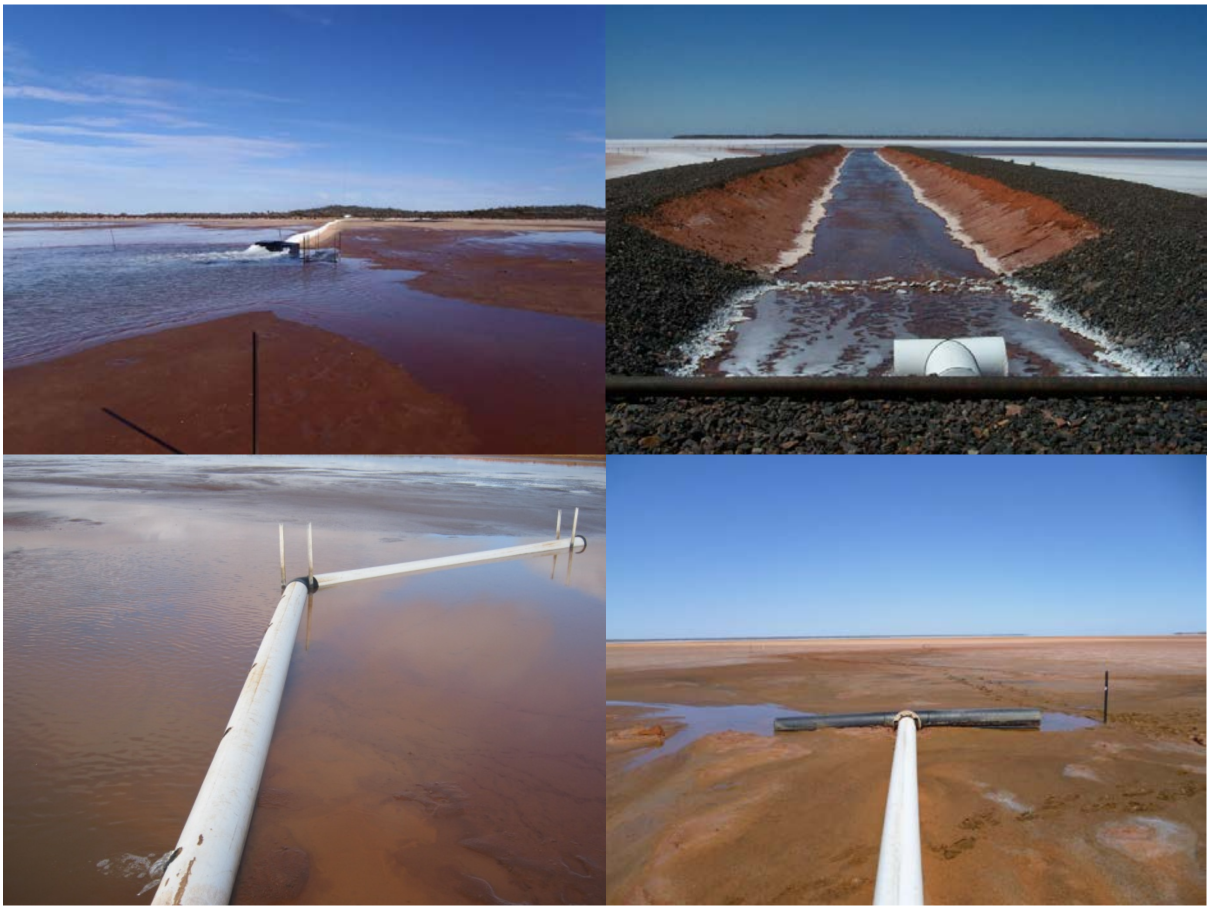

Plate 1: Localised influence of dewatering discharge on salt lakes in the Goldfields.

Results and Discussion

Dewatering Discharge to Waterbodies in the Goldfields

MWH have completed studies on more than 20 waterbodies throughout the Goldfields, to aid in determining potential ecological impacts related to mine dewatering discharge. While the majority of these have been on salt lakes, which are often located within highly mineralised environments, studies have also been undertaken on freshwater or low salinity creeklines, wetlands and claypans.

As an overview, work by MWH and Gregory (2007) indicates that approximately 10 salt lakes in the Goldfields region actively receive dewatering discharge, with a further 10 having formerly been subject to discharge. There are also numerous smaller claypans, wetlands and creeklines that actively receive or have received discharge. As these waterbodies are often located in the lowest point within the landscape, they act as sinks for salts, metals and nutrients contained in the discharge water, which are a reflection of the local hydrogeological environment.

Ecological Impacts

The documented impacts on aquatic ecology from dewatering discharge vary greatly, although an increase in the hydroperiod is consistent for all waterbodies. In the Goldfields, groundwater is typically saline and therefore the formation of a halite crust, as a result dewatering, is often observed (**Plate 2**). In some cases, such as at Lake Lefroy and Lake Cowan, the salt crust can be several centimetres thick, due to the accumulation of salts over time. Elevated metal concentrations, high nutrients and suspended solids may also be associated with discharge waters, characteristics also reflected in the sediments. Adverse conditions such as high salinity, suspended solids and elevated metals generally prove inhospitable for aquatic biota, with pooled discharge waters usually devoid of organisms. The presence of a thick salt crust may also be prohibitive to the germination or hatching of biological propagules present in the sediments.

Plate 2: Salt crust attributed to dewatering discharge on salt lakes in the Goldfields.

Physical effects such as the erosion of sediments may result from high volumes of water being discharged, or high water flow from a poorly designed discharge outfall. In addition, indirect impacts have been observed on the riparian vegetation of larger waterbodies such as Lake Carey, where dewatering of mine voids has led to groundwater drawdown on parts of the playa. This in turn can reduce the moisture content of sediments, causing mobilisation and resulting in a shift in the zonation of riparian vegetation.

Amplifying Factors

There are a range of environmental and anthropogenic factors that can potentially amplify the adverse effects of dewatering discharge. Waterbodies situated within highly mineralised zones of the Goldfields typically support groundwaters naturally elevated in metals such as copper, lead, nickel and zinc (Gregory 2007). The discharge of highly mineralised and saline water to smaller, closed basins may be more detrimental than discharge to larger waterbodies, as smaller systems have less buffering capacity and natural mitigation potential. Examples of smaller salt lakes in the Goldfields subject to active or historic dewatering discharge include White Flag Lake, Lake Fore and Lake Tee. Smaller, closed basins or the embayments of larger waterbodies may also accumulate contaminants more readily than larger salt lakes. Riparian vegetation is also more likely to be inundated by discharge waters or influenced by windblown salts in smaller waterbodies (Foster 2004; Outback Ecology 2009).

Man-made structures such as causeways (found at Lake Lefroy and Lake Carey) partition waterbodies and restrict surface water flow, leading to the accumulation of contaminants within a localised area. While permeable sediments may allow for the movement of salts and metals into sub-surface layers or into underlying aquifers, impermeable sediments may prevent vertical movement of contaminants and promote accumulation (Outback Ecology 2009).

The Goldfields experiences a semi-arid climate and natural mitigation in the form of dispersal and dilution of contaminants during large rainfall events is irregular and unpredictable. In addition, strong prevailing winds can disperse highly saline discharge water and salts into other parts of the lake. Cumulative impacts should also be a consideration, with the potential for interactive effects to occur from several discharges on a single waterbody (Outback Ecology 2009).

Monitoring, Management and Mitigation

Minimising Impacts

While there are potentially adverse ecological impacts associated with dewatering discharge, the effects can be minimised by proponents taking into consideration the following:

- Location of the discharge outfall:
    - preferably away from embayments or creek openings and pre-existing or historic discharge outfalls;
    - preferably within deeper parts of the basin;
    - in areas subject to flushing during flooding; and
    - away from riparian vegetation.
- Design of the discharge outfall/s:
    - secure the pipeline to prevent movement during large flood events; and
    - installation of energy diffusing devices to minimise scouring and erosion.
- Discharge characteristics and the potential for pre-treatment options to reduce suspended solids, salts, metals or nutrients, if these parameters are likely to be an issue.
- Duration of the discharge and alternative discharge options:
    - multi-spigotted outfall or potential for several discharge outfalls located in different areas, alternating over time
    - discharging to a disused mine void or pit to reduce discharge volume to a waterbody
    - cessation of discharge during major floods, allowing aquatic biota to complete lifecycles, without the potentially harmful influence of contaminants

Baseline Studies and Ongoing Ecological Monitoring

The importance of collecting baseline data prior to discharging to waterbodies should not be underestimated and should be followed by the implementation of an ongoing monitoring program during active dewatering (to assess potential impacts) and monitoring post discharge or mine closure, if necessary (to determine recovery). This will allow dewatering impacts to be more accurately assessed and inform the development of management strategies as required, to maintain ecological integrity.

Prior to discharge, the holding capacity of the waterbody should be investigated and water balance modelling completed under dry and flooded scenarios. This is particularly important for smaller, closed basins or for creeklines and their associated terminus point (often a claypan or salt lake). Hydrological modelling should also consider the additional input of salts to a system if discharge waters are highly saline, in comparison to natural salt loads present within the catchment.

During baseline studies, a whole of ecosystem approach should be undertaken, with sampling completed during flooded and dry conditions (**Plate 3**) to establish natural variability. Ecological components assessed at the baseline stage may include algae, macrophytes, aquatic invertebrates, aquatic vertebrates, waterbirds and riparian vegetation, as well as the analysis of water and sediments. During active dewatering, an ongoing ecological monitoring program should comprise sampling at discharge and control sites, to allow spatial and temporal trends to be determined, in relation to discharge or other influential factors.

During active dewatering, monitoring should occur at regular intervals and is typically conducted on an annual or biannual basis. As conditions will mostly be dry, ecological assessment should include appropriate abiotic and biotic parameters. In addition to water and sediment analysis, algae (specifically diatoms) and resting stages (dormant propagules of algae, macrophytes and aquatic invertebrates) should be sampled. Both diatoms and resting stages will persist in the moist sediments of waterbodies and provide an indicator of potential productivity during flooding. If discharge waters are proximal to riparian vegetation, this should also be included in monitoring. In flooded conditions, waterbodies in the Goldfields are at their most productive and the assessment of primary producers such as algae and macrophytes, as well as higher order consumers including aquatic invertebrates, fish and waterbirds should be undertaken where possible.

Appropriate monitoring and management strategies should be implemented by proponents to address regulator concerns and promote environmental stewardship. In some cases, this may require more comprehensive action such as monitoring against key performance indicators or trigger values during active dewatering and potentially following cessation, to determine recovery. In addition, where there are multiple discharges to a single waterbody (and potential cumulative effects), catchment-level management strategies should be considered (such as the formation of a catchment group). This will allow for the coordination of environmental management, information sharing to improve the knowledge base and a reduction in the cost associated with monitoring studies.

When designing an ecological monitoring program for waterbodies in the Goldfields it is also pertinent to consider potential historic anthropogenic impacts (e.g. mining or pastoral activities), as well as the current ecological values of the waterbody; often the two are closely linked. Monitoring programs should also be tailored to suit the unique characteristics of each individual ecosystem and the properties of the discharge water.

Plate 3: Aquatic biota found in dry (top) and flooded conditions (middle and bottom).

Natural Mitigation and Recovery

Studies to date of waterbodies such as Lake Miranda and Kurrawang White Lake, historically influenced by dewatering, suggest impacts may be temporary, with several consistent trends observed as time from cessation of discharge increases. These include a decrease in salts and metals in the sediments over time and gradual dissipation of the salt crust on the lake bed (Finucane *et al.* 2003; Outback Ecology 2009). Large rainfall events appear to aid natural recovery, via dilution and dispersal mechanisms during major flooding, with historically impacted dewatering discharge sites becoming biologically productive (e.g. Lake Carey).

Studies have also shown that there are no cumulative trends (such as at Lake Carey) in relation to potential contaminants and their bioavailability. This may be related to the presence of fine clay sediments and ions, which readily adsorb to metals, substantially decreasing bioavailability and toxicity to aquatic biota. Often the most prominent and visible impact on Goldfields waterbodies is the presence of a salt crust, with mechanisms for natural mitigation including dilution, dispersal and vertical movement into underlying aquifers (although the latter is not well understood). Any physical intervention involving the removal of salt crusts should be carefully considered, due to the risk of disturbing lake sediments that contain the bulk of biological propagules and are the key to continued ecosystem productivity. Any disturbance to sediments may therefore compromise the ability of an aquatic a waterbody to recover during flooding.

The most effective way for proponents to manage dewatering discharge, in order to minimise ecological impacts are to ensure that suitable baseline studies are completed on the receiving environment. This will ensure that proponents and regulators can more confidently understand and maintain the ecological integrity of the ecosystem. In addition, where contaminants are identified, pre-treatment options should be implemented to prevent long-term or residual impacts to waterbodies, where possible.

Summary

Ephemeral waterbodies in the Goldfields provide an important refuge for aquatic biota and can support a diverse range of organisms during flooding. Dewatering discharge that is high in salts and metals may adversely effect ecosystems, albeit in most cases, temporarily. Effective monitoring and management strategies can reduce the severity of impacts and often recovery will occur naturally, dependent on nature of the discharge and the characteristics of the waterbody. The results of studies by MWH over the last 15 years suggest that salt lakes recover naturally over time, aided by major flooding that dilutes and disperses contaminants. However, while dewatering discharge in the region mainly occurs is mainly to salt lakes, freshwater and low salinity creeklines, wetlands and claypans are also potential receiving environments that pose unique considerations for proponents. Ecological impacts can be minimised through the implementation of a range of engineering options for the pre-treatment of discharge water, the design of the discharge outfall and by appropriately managing the dewatering regime, combined with suitable monitoring program.

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