Mersey-Forth Water Management Review

TECHNICAL AND SOCIAL STUDY 2013

Acid Drainage Investigation Downstream of Wilmot Dam and in the Cethana Power Station

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Executive Summary

Hydro Tasmania is conducting a water management review in the Mersey-Forth River catchments which includes identifying and investigating knowledge gaps relating to the environmental issues associated with Hydro Tasmania's operations in the catchments.

One issue which has been identified through the catchment review process is the presence of small volumes of acid drainage in the seepage from the Wilmot Dam and within the Cethana Power Station. This report summarises a desk top review and short field investigation which was completed related to this issue.

Lake Gairdner was created through damming of the Wilmot River by the Wilmot Dam. The dam is a concrete faced, rock fill dam and spillway which was constructed during the late 1960s using local material sourced from the local Moina Sandstone. Units within the Moina sandstone contain acid forming sulphide minerals, and it is theorised that this is the source of the acid drainage. This is consistent with there being no evidence of acidification within Lake Gairdner, and acidic water being more commonly detected at the toe of the dam when water levels in the lake are low. During periods of low water level oxygen can enter the dam wall, leading to the oxidation of the sulphide minerals. Acidic drainage is less common under typical lake level conditions because the dam wall is saturated which prevents oxidation of the material.

The presence of the acid drainage at the toe of the dam is not considered to pose a significant environmental threat as the volumes are low and rapidly diluted in the Wilmot River. It is also likely that as water levels in the lake increase, which could increase the flushing of acid drainage from the dam wall, catchment inflows will also increase, resulting in the rapid dilution of the acid drainage downstream. The acid drainage is considered a low risk for migratory fish which may enter the pool at the toe of the dam following 'spills' from the lake. Under these conditions acid drainage would be at a minimum due to high lake levels, and it is likely that low dissolved oxygen levels rather than acidic water would pose the largest risk to trapped fish.

Acidic seeps were identified within the tunnels of the Cethana Power Station. The volumes were very low, and although the water may pose management challenges with respect to corrosion of materials in contact with the water, the seeps are due to the movement of natural groundwater through mineral rich bedrock and are not considered to pose an environmental risk to surface waters in the catchment.

Document Information

DOCUMENT TYPE:	Report	
TITLE:	Acid drainage investigation downstream of Wilmot Dam and in the Cethana Power Station	
SUGGESTED REPORT CITATION	Koehnken, L., 2013, Acid drainage investigation downstream of Wilmot Dam and in the Cethana Power Station, memo to Hydro Tasmania.	
VERSION:	V1.0	
CLIENT:	Hydro Tasmania	
PREPARED BY:	L Koehnken, Technical Advice on Water	Date: 14 February 2013
DISTRIBUTED TO:	Alison Howman – Hydro Tasmania Carolyn Maxwell – Hydro Tasmania	Date: 14 February 2013 Electronic Copies: MS Word

Cover photograph: Monitoring of water quality in the Wilmot River immediately downstream of Wilmot Dam.

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1. Introduction

Hydro Tasmania is conducting a water management review in the Mersey-Forth catchments (Hydro Tasmania, 2011). As part of this process, issues and knowledge gaps are identified and addressed, with the aim of understanding the relationship between Hydro Tasmania's operations and existing, or potential, environmental issues in the catchment (Hydro Tasmania, 2012). One issue which has been identified through the catchment review process is the potential presence of acid drainage downstream of the Wilmot Dam and within the Cethana Power Station.

The concern is based on the following information:

- The area has been identified as a potential acid drainage producing region based on the presence of potentially acid forming rocks, and low pH high sulphate and metal bearing surface waters during a State-wide desktop assessment of acid drainage potential (Gurung, 2001);
- The visual presence of iron-staining within the Cethana Power Station and Wilmot River downstream of the Wilmot Dam;
- The intermittent presence of 'blue' water downstream of the Wilmot Dam which is characteristic of elevated metal concentrations; and
- Elevated metal levels in a subset of water quality samples collected from the toe of the Wilmot dam wall.

This report summarises the findings of the investigation into identifying the source of the acid drainage, and evaluating the impact of Hydro Tasmania's operations on the production and potential impact of the acid drainage on the environment.

The investigation has included the following elements:

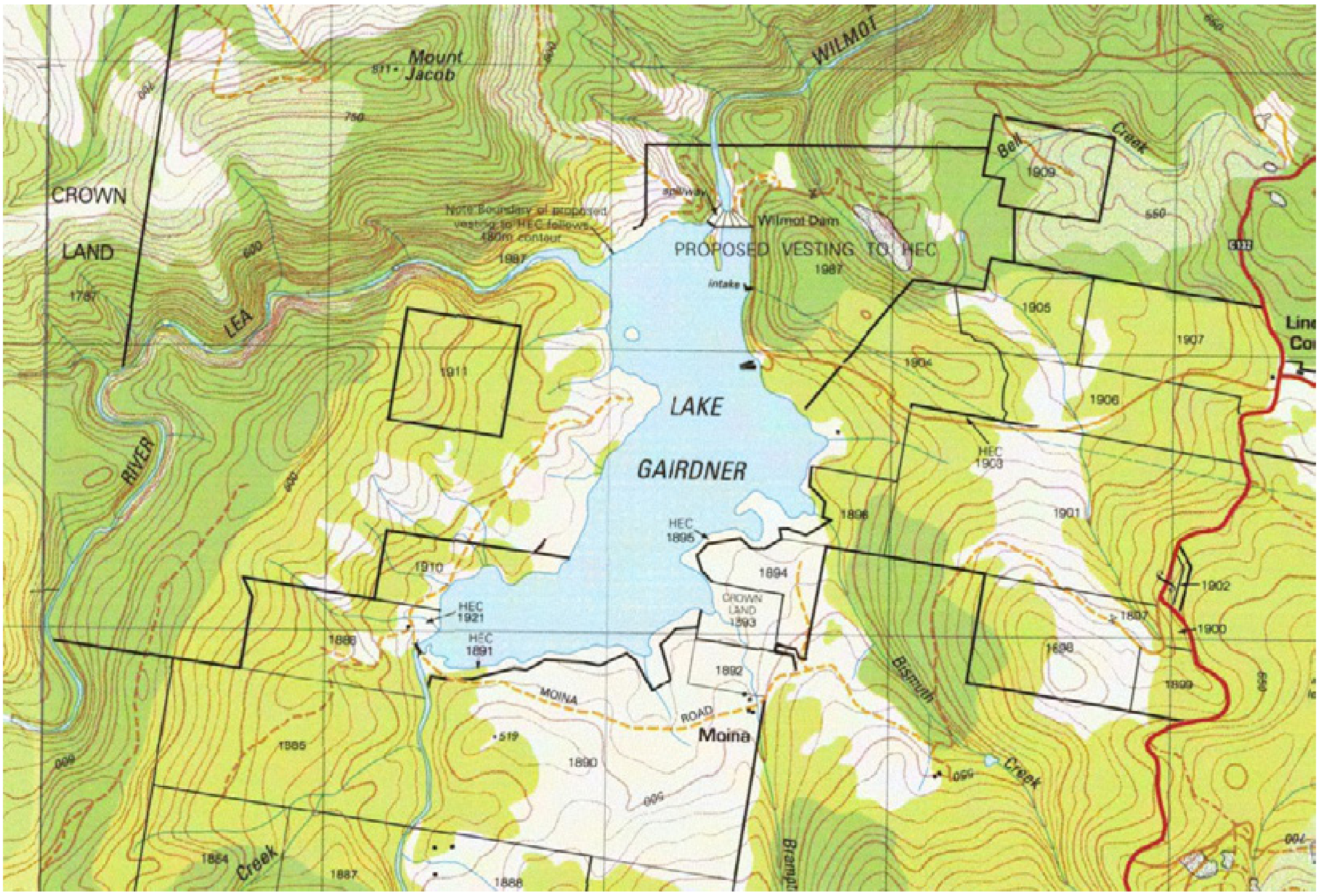
- Review of three sets of water quality results for samples collected downstream of the Wilmot Dam;
- An analysis of lake levels in Lake Gairdner between 1970 and 2012;
- A field visit on 12 November 2012 to Cethana Power Station, Wilmot Dam and Lake Gairdner which included Hydro Tasmania personnel familiar with the operation of the Mersey Forth power scheme and environmental issues in the catchment; and
- Field measurement of pH, EC and dissolved oxygen at numerous sites in the Wilmot River from the toe of the dam to approximately 500 m downstream.

2. Downstream Wilmot Dam

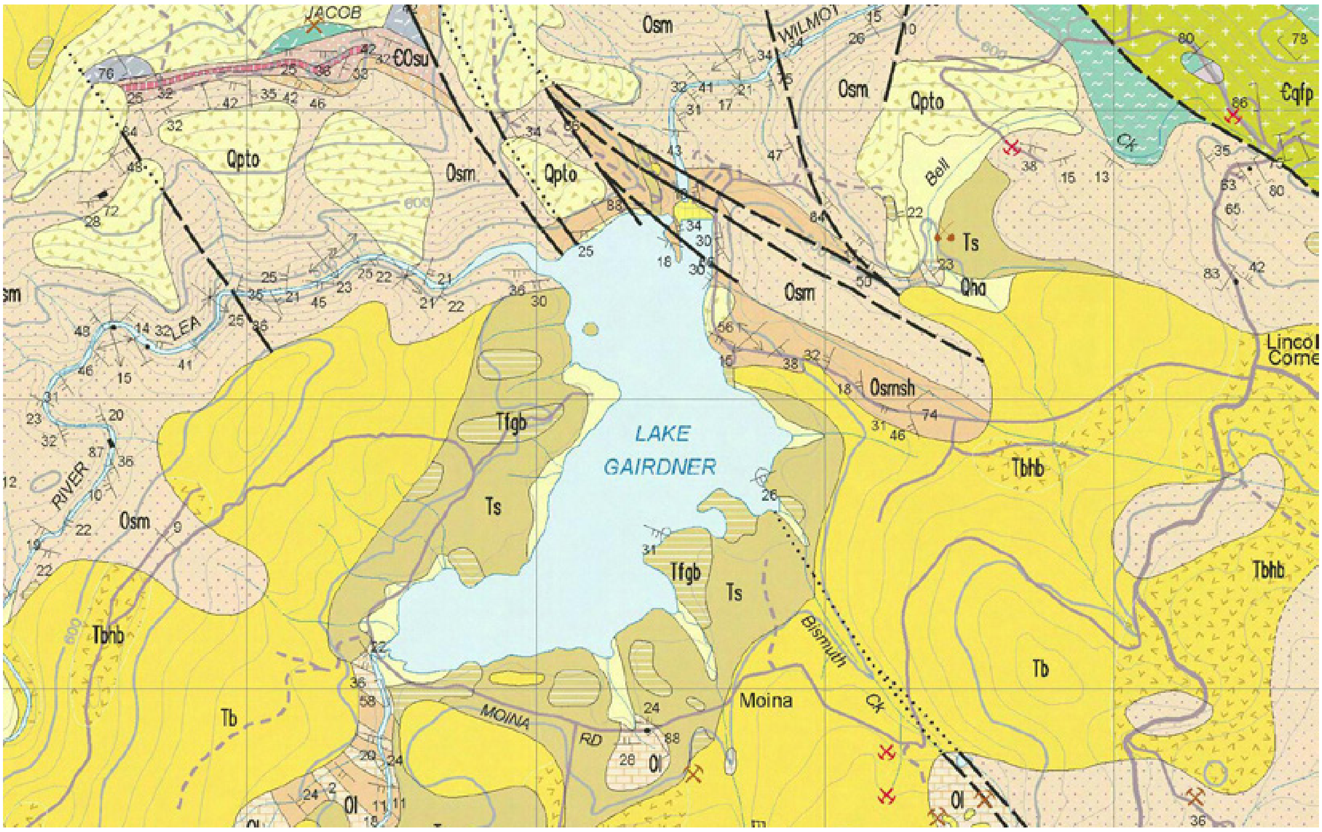
2.1 Characteristics of Wilmot Dam

Lake Gairdner was created through damming of the Wilmot River by the Wilmot Dam (Photograph 2.1). The dam is located at the northern end of the impoundment and is a concrete faced, rock fill dam and spillway which was constructed during the late 1960s and commissioned in 1971. The fill material for the dam was locally sourced Moina Sandstone, the excavation of which resulted in the creation of a borrow pit shown in Map 2.1 and in Map 2.2 where the location is superimposed on a geologic map of the region.

Photograph 2.1: Wilmot Dam viewed from downstream in Wilmot River



Map 2.1: 1:25,000 topographic map of Lake Gairdner showing the Wilmot Dam, Wilmot River downstream of the dam, and the borrow pit from which material was extracted for construction of the dam and spillway



Map 2.2: Geologic map of Wilmot Dam area. Osm and Osmsh indicate the Ordovician Moina sandstone units. Red circle shows general area of borrow pit. Geologic map from www.thelist.tas.gov.au

The Moina sandstone is an Ordovician unit comprised of sandstones and siltstones. The intrusion of granite into the unit during the Devonian resulted in the formation of base metal rich deposits in the region (Map 2.3). Known metal deposits include copper, arsenic, silver, gold, tin and zinc. The mineralisation is characterised by sulfide minerals, with pyrite commonly occurring within the mineralised zones.

2.2 Water quality downstream of Wilmot Dam

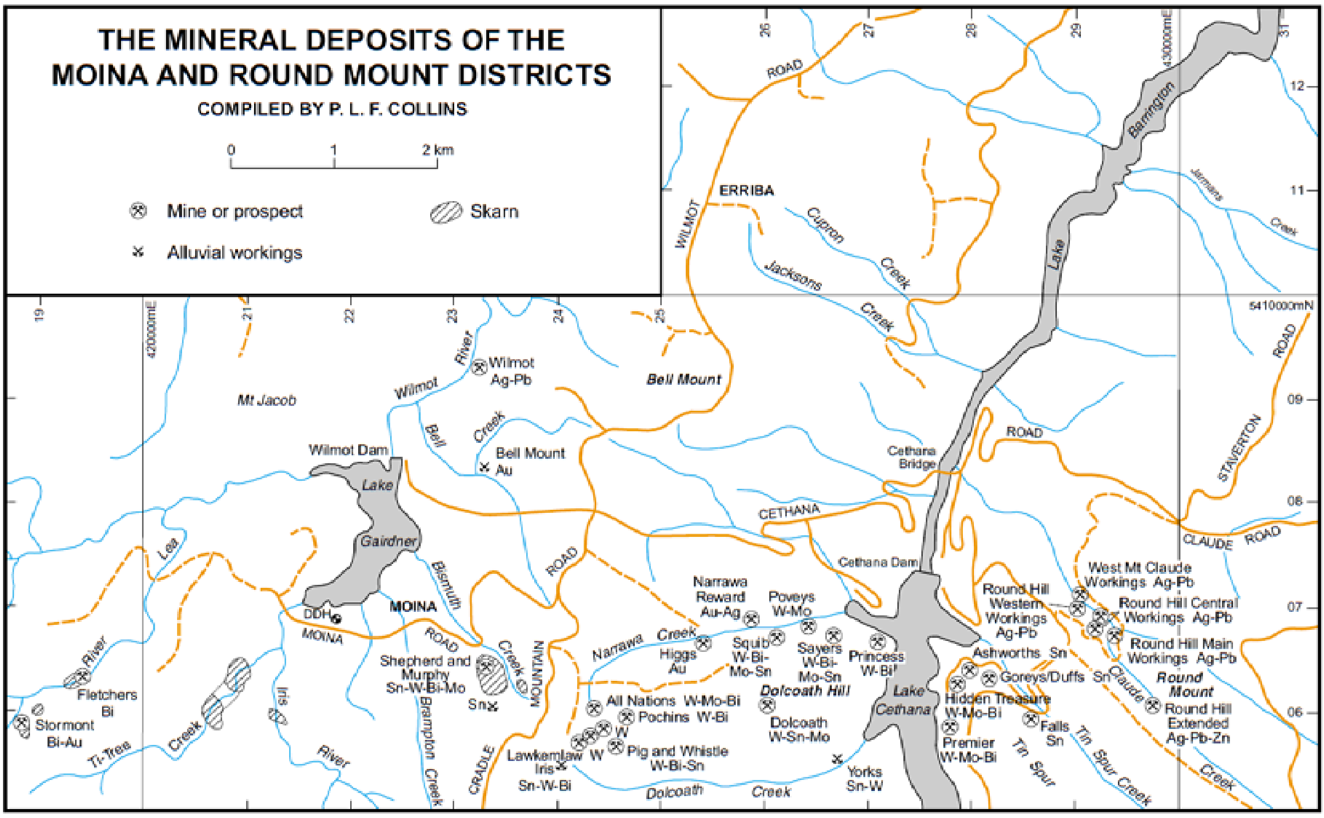
The limited water quality results available for the Wilmot River downstream of Wilmot Dam are summarised in Table 2.1. Also available are photos of the pool at the toe of the dam taken in October 1999 (Photograph 2.2), and presented in an internal Hydro Tasmania memo prepared by Mick Howland, and similar photos obtained in November 2012 (Photograph 2.3).

Field observations in November 2012 found seepage entering the pool from the toe of the dam and from the nearby diversion tunnel. These waters had a low to moderate pH, and there was extensive iron staining in the channel. The water upstream of the V-notch, indicative of dam seepage, also had low oxygen levels (~50% saturation).

Iron staining was also present in the Wilmot River downstream of the dam, associated with natural seeps entering the river. The seepage from the dam is undoubtedly related to the fill material in the dam, but the seepage from the diversion tunnel and in the natural seeps is indicative of naturally iron-rich ground water in the region. Iron rich ground water is not necessarily indicative of acid drainage, as typically, oxygen levels in ground water are low and iron remains in solution. When the water flows from a spring or a seep, the iron oxidises and precipitates. This reaction results in the deposition of iron-floc in the stream, and can also decrease the pH of the water if iron oxidation occurs. These reactions are independent of the presence of sulfide minerals and are not considered acid-drainage.

The water quality results (Table 2.1) show that metal concentrations associated with the samples collected in 2010 and 2011 are low, but elevated in the sample collected in October 2012, especially in the V-notch weir at the base of the dam. Given the blue coloration of the water in the photos in 1999, along with the white and red precipitation in the pool, it is probable that water quality during this period was also characterised by elevated metal concentrations. These results suggest that metal concentrations are intermittently elevated downstream of the dam.

The water level in Lake Gairdner is also shown in the Table, with the water quality samples corresponding to water levels ranging between 464.7 mASL (metres above sea level) and 471.5 mASL. The variability of the water quality results is likely linked to fluctuations in lake level, as discussed in the following section.



Map 2.3: Map of the Lake Gairdner and Lake Cethana area showing mining activity

Table 2.1: Water quality results from the Wilmot River downstream of Wilmot Dam. The results from October 2010, March 2011 and November 2011 were obtained approximately 500 m downstream of the Wilmot Dam. The results from August 2012 were obtained in the V-notch weir pond at the base of the dam reflecting seepage from the dam wall

Date	Lake Level (m)	pH	EC (μS/cm)	DO (mg/L)	TN (mg/L)	TP (mg/L)	Al (total, mg/L)	Cu (total, mg/L)	Fe (dissolved, mg/L)	Fe (total, mg/L)	Mn (total, mg/L)	Z (total, mg/L)
Wilmot R 500 m d/s dam												
26/10/10	469.0	5.7	46	11.2	0.24	0.005	0.31	0.001		0.329	0.031	0.039
11/03/11	471.5	6.3	73		0.22	0.010	0.25	0.001		0.368	0.053	0.062
16/8/12	464.7						0.04	0.001	<0.02	0.980	0.308	0.079
12/11/12	469.3	5.4	88									
V-notch at dam toe												
16/8/12	464.7						29.1	0.090	0.248		2.70	1.90
12/11/12	469.3	3.5	134	5.0								

Photograph 2.2: Photos obtained of 'blue pool' at toe of Wilmot dam (top), iron floc deposition (middle), and white floc deposition (bottom)

Photograph 2.3: Photos taken on 12 Nov 2012 downstream of Wilmot Dam. V-notch at toe of dam (top), pool downstream of V-notch showing seepage from diversion tunnel entering downstream end of pool (middle), and Wilmot River downstream of dam (bottom)

2.3 Lake Gairdner water level

Water level is managed by Hydro Tasmania to maximise the amount of water captured in the impoundment. This generally results in the lake being drawn down in late summer and early autumn to provide storage capacity for the winter rainfall. Lake level has fluctuated between ~461 mASL and 473 mASL since 1970 (Figure 2.1). Lake levels recorded around the time of the October 1999 site visit, and more recent water quality sampling periods are shown in Figure 2.2 and Figure 2.3, respectively, and indicate that the October 1999 and August 2012 results were obtained during periods of relatively low lake level. The results obtained in 2010 and 2011 corresponded to high lake levels, and the most recent site visit, in November 2012, coincided with a period of rapidly rising lake levels following a low period.

The lake level information, combined with the composition of the Moina Sandstone present in the dam wall can account for the water quality results as follows:

- During periods of elevated lake level, the dam wall remains saturated, and water quality in the dam seepage is 'good', although likely to be iron-rich and low in oxygen (Oct 10, Mar 11);
- When the water level in Lake Gairdner is low, saturation of the dam wall is reduced, with allows the oxidation of any pyrite, chalcopyrite, galena or other sulfide minerals present in the Moina Sandstone. This leads to low pH, metal rich seepage draining from the toe of the dam (Oct 99, Aug 12); and
- As water level increases in the lake, oxidation products (sulphate, metals) will continue to be flushed from the dam wall, but metal concentrations are likely to be diluted by 'clean' seepage (Nov 12).

Because the volume of material in the dam wall is finite, over time the production of acid drainage is likely to decrease. The rate of decrease will depend on the duration of exposure to oxygen.

The concentrations of metals present at the V-notch weir in August 2012 are very high compared to the concentrations recorded downstream. Several processes are likely contributing to the decrease. As the acid water mixes with less acidic water, the pH will increase, and metals such as iron and aluminium will precipitate at pH levels between 3.5 (iron) and 5.0 (aluminium). The presence of the iron-staining in the channel and white floc in the photos obtained in 1999 are consistent with these precipitation processes. The concentrations of metals which are not precipitated at the pH range in the Wilmot (e.g. zinc and manganese) will be reduced through dilution. Based on the water quality results, there was a 10 to 20-fold dilution of metal concentrations within the first 500 m downstream of the dam.

A water level duration curve for Lake Gairdner is shown in Figure 2.4 based on daily lake level results between 1970 and 2012. If it is assumed that poor water quality is associated with lake levels of less than 466 m, then these conditions can be expected approximately 25% of the time. The actual duration of acid drainage generation is probably lower, as the interior of the dam wall will remain saturation for a period following the decrease in lake level.

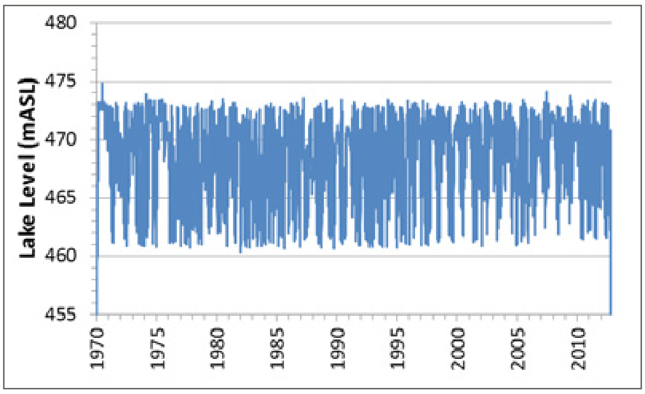


Figure 2.1: Lake level in Lake Gairdner between 1970 and 2012

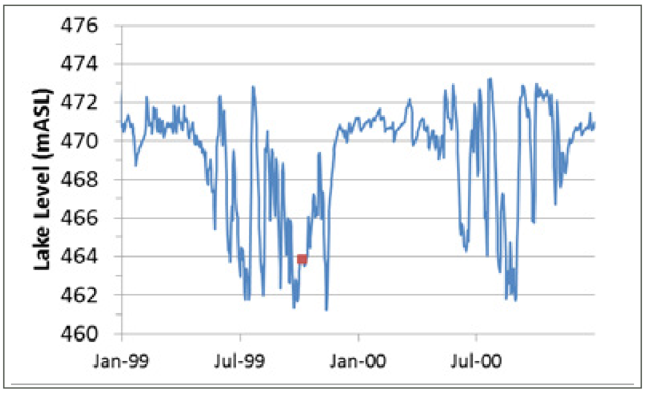


Figure 2.2: Lake Gairdner lake level between January 1999 and January 2001. Red dot shows date of 'blue pool' photos

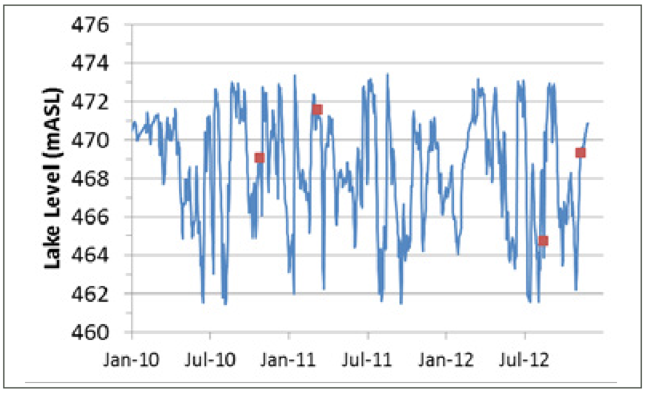


Figure 2.3: Lake Gairdner lake level between January 2010 and December 2012. Red dots show dates of water quality sampling

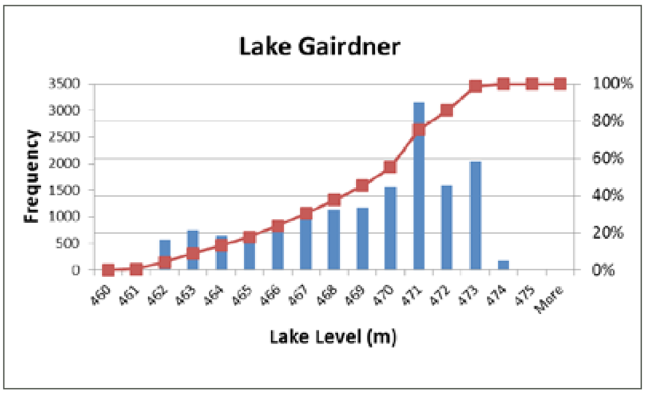


Figure 2.4: Histogram and cumulative percentage of Lake Gairdner lake levels between 1970 and 2012

2.4 Impact of acid drainage on Wilmot River

The environmental impact of acid drainage produced by oxidation of the Moina Sandstone in the Wilmot dam is likely to be low for the following reasons:

- The volume of seepage is low compared to the natural pickup of the catchment. In August and November 2012 there were indications of acid drainage in the V-notch (low pH, elevated metals), however metal concentrations decreased and the pH increased substantially within a few hundred metres downstream of the dam wall; and
- Lake levels tend to be low in late summer and early autumn. Lake levels will increase as rainfall increases, so acid drainage will be 'flushed' from the dam during periods of high catchment inflows, which are likely to reduce the impact of acid drainage on the downstream environment.

The generation of acid drainage is likely to reduce over time, as the sulfide minerals in the Moina sandstone are oxidised. In the shorter term, acid drainage production is likely to increase if lake levels are reduced to lower levels than have occurred historically, or if lake levels are maintained at low levels for longer periods.

M Howland (1999) noted that the presence of the acidic pool at the base of the dam could impact on migratory fish species if they arrived at the spillway during a spill and were then stranded in dry weather. Should this occur, other issues, such as low dissolved oxygen would be more likely to impact the fish than the slow accumulation of acidic water in the pool, especially following a 'spill' when the contribution of acid drainage from the dam wall would be at a minimum due to the high water levels in the lake.

2.5 Cethana Power Station

In the tunnels within the Cethana Power Station, there is acidic seepage, and the walls and floors of the tunnels show extensive iron-staining. Observations are difficult due to the lack of light, but water pathways appear to be associated with typical ground water pathways such as rock bolts and shear zones (Photograph 2.4). Where there was sufficient flow to be sampled, the pH was low (as low as 2.8).

Although no water quality results are available, the Cethana Power Station is situated in a mineralised area, and it is possible that the seepage has an acid drainage component as well as an iron-rich ground water component. The volumes of flow were very low, and are unlikely to have any environmental impact on the downstream environment. The acidic water may create management issues within the power station with respect to corrosion of materials which come into contact with the acidic flows.

The seepage at the toe of the Cethana Dam (Photograph 2.5) was similar in colour to that at Wilmot Dam, and consistent with iron-rich water oxidising on contact with air.

Photograph 2.4: Iron staining and acidic water in the Cethana Power Station

Photograph 2.5: Seepage at the base of Cethana Dam showing iron coloration

3. Interaction of Hydro Tasmania Operations with Acid Drainage

Hydro Tasmania's operations in the Mersey-Forth include the management of lake volumes and power stations for the generation of hydroelectric power. The production of acid drainage is the result of interactions between sulfide minerals, oxygen and water; therefore, any management action by Hydro Tasmania which results in the contact of these three components has the potential to increase acid drainage production. Actions which might promote acid drainage creation include:

- Alteration of lake and river levels such that sulfide minerals are exposed more than occur under 'natural' conditions; and
- Excavations which increase the exposure of acid producing material to the atmosphere.

Both of these circumstances occur at the Wilmot Dam, where excavation and construction of the dam has resulted in the exposure of sulfide minerals present in the Moina sandstone, and lake level management controls the exposure of this material to oxygen. Other areas where acid drainage may be exacerbated by hydropower activities includes the remnant borrow pits from which material was extracted for dam construction, and road cuts or power station tunnels which expose sulfidic rocks.

Give the small scale of these disturbances compared to the size of the catchment, and the very large volumes of water which flow through the waterways, there is a low risk of large scale environmental impact. Because of the possible impacts on migratory fish identified by M Howland (1999) at the base of Wilmot Dam, Hydro Tasmania should be aware that lake level management can have a (limited) impact on the downstream environment, and minimise the duration of low lake levels in Lake Gairdner where practicable.

Hydro Tasmania should also be aware that the potential for acid drainage production occurs within the region, and factor it into risk analyses associated with environmental or engineering activities or investigations (e.g. determination of environmental flows, placement of fish ladders, future excavations, etc.).

4. Elevated Aluminium Concentrations

The national guidelines for water quality (ANZECC and ARMCANZ, 2000) prescribe a trigger value of 0.055 mg/L for aluminium in freshwaters with pH > 6.5. The guidelines do not prescribe a trigger value for aluminium in freshwater with pH < 6.5 due to insufficient data. Data collected by Hydro Tasmania as part of this project and during routine monitoring (Hydro Tasmania, 2011) show that aluminium concentrations are sometimes in excess of the trigger values prescribed by the national guidelines (ANZECC and ARMCANZ, 2000)[1].

Some of the aluminium concentrations determined in surface waters of the Mersey - Forth catchment are elevated compared to the ANZECC and ARMCANZ (2000) water quality guidelines for the protection of aquatic ecosystems. This is a common occurrence in western Tasmania, where surface waters are naturally dilute and contain moderate to high concentrations of dissolved organic acids. These organic compounds have the capability to complex iron, aluminium and other metals within their structure, such that the metals remain 'dissolved', although the biological availability of the metal is low. It has been estimated that 1 mg/L of dissolved organic carbon (DOC) can complex 25 µg/L of aluminium, with the ability to complex aluminium increasing as pH increases (CCME, 2003). The Canadian interim water quality guideline for aluminium reflects this process (Table 4.1) with guideline values in waters with elevated DOC being two to three times greater as compared to low DOC water.

Table 4.1: The Canadian interim water quality guidelines for total aluminium (µg/L) for the protection of freshwater life. Total Al in µg/L. A safety factor is not applied to these values (CCME, 2003)

	DOC (mg/L)				
pH	0.5	2.5	5	7.5	10
5.2	84	87	120	154	201
5.6	98	116	149	193	252
6.0	92	108	137	178	232
6.4	74	82	97	121	156
>6.4	74	82	97	121	156

Although the aluminium concentrations in the surface waters exceed the ANZECC and ARMCANZ (2000) criteria, it is unlikely that this presents an environmental risk if (a) the waters are DOC rich and (b) there is no other indication of water quality impacts, e.g. high EC, elevated sulfate, elevated levels of other metals.

Therefore, although the aluminium concentrations in the surface waters exceed the national guidelines (ANZECC and ARMCANZ, 2000), it is unlikely that this presents an environmental risk when the waters are rich in dissolved organic acids and there are no other indications of water quality impacts, for example, high electrical conductivity, elevated sulphate, elevated concentrations of other metals (Koehnken, 2013).

[1] *This paragraph is explanatory text added by Hydro Tasmania.*

5. For More Information

The fact sheet for this study is available at **www.hydro.com.au/MFWMR-studies**.

To see all the Mersey-Forth Water Management Review technical and social studies go to **www.hydro.com.au/MFWMR-studies**.

Find out more about the Mersey-Forth Water Management Review at **www.hydro.com.au/MFWMR**.

6. References

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