



**Land and Water**

# **Independent Peer Review of the Public Environmental Review (PER) for the former Cresco Fertiliser Site, Bayswater**

**Report to CSBP Ltd**

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*Independent Peer Review*

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## **Independent Peer Review of the Public Environmental Review (PER) for the former Cresco Fertiliser Site, Bayswater**

*Prepared by CSIRO Land and Water*

### **Scope**

CSIRO was requested to carry out an Independent Peer Review of the draft Public Environmental Review (PER) prepared for the former Cresco Fertiliser Site located at Bayswater – focussed on the soil and groundwater risk assessment. CSIRO was asked to form a view as to the adequacy of the risk assessment and the recommended remedial strategies.

Initially, to carry out the review CSIRO was provided with Chapters 4, 5 and 6 of the PER entitled the “Rationale for Site Remediation”, “Assessment of Remediation Options” and “Remediation Approach” respectively. An initial draft review was prepared in September 2004. Further data were provided to address comments raised in the draft review. This document constitutes the final review document.

### **General comments**

The draft Public Environmental Review (PER) document constitutes a comprehensive investigation of the nature of the contamination present at the Bayswater site in both on site soils and groundwater on site and off site – although the PER summarises the main trends in data rather than providing detail. In general, the main chemicals of concern identified were aluminium, copper, zinc, fluoride and low pH water.

The rationale for site assessment and setting of remediation goals is based on the national site contamination assessment approach as outlined in the *National Environmental Protection (Assessment of Site Contamination) Measure 1999 (NEPM)*. This risk assessment protocol appears appropriate for the assessment of contamination at the Bayswater site and the concomitant remediation strategy, but should also be seen in the light of the Western Australian Department of Environment’s adoption of the NEPM for Western Australian conditions.

In addition, there is an assessment of “off the shelf” and potential remediation options to deal with contaminated soils and groundwater.

Below are comments by CSIRO on the PER document which highlight a number of issues.

#### **(i) Contaminant pathways**

For potential contaminant pathways, the PER concludes that:

1. The Bayswater Main Drain (BMD) largely captures groundwater contaminants emanating from the site.
2. Due to the extended travel distance (1300 m) contaminated groundwater is unlikely to discharge directly to the Swan River, unless preferential flows are occurring.

3. Due to the urbanisation and commercialisation of the area immediately down gradient of the site, and the local presence of naturally-occurring acid sulphate soils, that groundwater would not be used as a potable water supply.

Irrigation could usefully be included here as a pathway. Irrigation is certainly considered later in the PER as a pathway and the risks are discussed (see Section 4.5.3.2).

Items 1. and 2. relate to technical matters, whereas Item 3. relates to regulation of the superficial aquifer by the Western Australian Department of Environment and the Western Australian Department of Health, as pointed out in the PER.

The distribution of contaminated groundwater in the subsurface appears to have been explored extensively. While there is substantial evidence that the BMD captures most if not all of the contaminated groundwater – it is difficult to conclude the extent of this from the data presented. Further discussion in the PER indicates that the BMD seasonally oscillates between being a receiving drain (i.e., groundwater discharges to the drain in summer) and a discharging drain (i.e., water discharges from the drain to groundwater in peak flow periods in winter). In addition, sections of the drain may be impervious to groundwater flow or in some sections is piped flow, raising the possibility of groundwater flow bypassing these regions. Supplemental data provided to CSIRO indicates seasonal pH reductions to 3-5 in the BMD water, indicating that acidic groundwater capture is occurring. . However, at present it remains difficult to assess accurately the actual percentage of groundwater captured by the BMD that emanates from beneath the Cresco site and flows further down gradient. Modelling may help with such an assessment.

It is agreed that discharge of unmodified, low pH metal-rich groundwater to the Swan River is unlikely. However, the subsurface is quite variable with increasing clay content with depth and inter-fingered sands and clays. Presentation in the PER of averaged or typical soil and groundwater contour data for some of the key chemicals of concern may assist in visualising the pathways and risks posed by the site. While the accurate assessment of the spatial distribution of impact is difficult, some summary or depth-averaged distribution within and surrounding the former Cresco fertiliser site and across to the BMD would be useful to present (as per Figure 5.1). This would serve as an aid to the visualization and interpretation of individual contaminant distribution. As presented, it is difficult to understand the extent and inter-relationship, if any between the contaminants. Further monitoring and modelling of the contaminant distributions may aid this understanding, and also assist in deciphering geochemical relationships.

## **(ii) Natural attenuation of groundwater acidity**

Given the often high concentrations of dissolved contaminants within the most acidic portions of the groundwater plume and correspondingly low contaminant concentrations and circum-neutral pH within the Bayswater Main Drain (BMD), it is apparent that a significant degree of natural attenuation is occurring in the interceding aquifer – and/or mixing in the BMD with up gradient drainage water. Although this process is undoubtedly operative, it would be useful to include some discussion of this process and its implications for the remediation of the Bayswater site, particularly in the context of neutralization of residual acidity not addressed in the groundwater remediation works currently proposed and being undertaken. In addition, given the likely progress of acidic groundwater towards the BMD as part of the regional groundwater gradient, it would be useful to estimate possible travel times to interception by the BMD. It is recognised that some of this acidity will be removed during remediation works. Furthermore, it would be instructive to have data on contaminant concentrations both in the solid aquifer material and in

groundwater between the former Cresco site and the BMD to assess the actual extent of natural attenuation.

Natural attenuation arising from an increase in pH may substantially reduce the concentration of a range of metals and metalloids, primarily by adsorption/co-precipitation to Fe-oxyhydroxide phases. Uncontaminated Bayswater soils (Bassendean Sands) have little or no capacity to neutralize the acidity present within the groundwater plume, although the underlying clays and sandy clays may have an increased capacity to neutralise the pH. Quantification of these processes and mechanisms are likely to be important to have greater confidence that natural attenuation will cope with residual levels of acid generation and labile metals and metalloids. It is understood that such an investigation is currently underway.

### **(iii) Historical records of site use**

The absence of detailed historical records presents an additional challenge in the management and remediation of the Bayswater site. It is acknowledged that the legacy of considerably less stringent environmental and occupational health and safety practices in the early to mid 20<sup>th</sup> century may provide gaps in the records. The summary compilation of the manufacturing and associated activities undertaken onsite and included in the PER is a useful introduction to the issues at the site.

### **(iv) Sampling and interpretation of Bayswater Main Drain water chemistry**

Much of the discussion of the water chemistry of the Bayswater Main Drain (BMD) is based on one sample taken on 26 November 2003 - this sample had an average pH of *ca.* 7. It is well known that the chemistry of receiving drains and surface water bodies can change seasonally and even within storm or flushing events. Information on longer-term or transient pH (and other chemistry) fluctuations within the BMD could be usefully included, and perhaps also drain height/flow data. The potential variability of the pH and other chemistry is particularly relevant when considering metal toxicity, not only Al which as noted has a highly variable toxicity (and mobility) with pH, but also metals and metalloids that may be associated with Fe-oxyhydroxides.

The low concentration of many of the potential contaminants found in the BMD is not surprising given the pH of the reported sample. It is not clear if this is typical and representative of the BMD discharges. End of summer and peak winter period sampling may provide a better measure of the extremes of pH and chemistry changes (this may also depend on up gradient discharges to the drain over these periods). Longer term monitoring over the period of the remediation activities could ensure that the pH within the BMD remains circum-neutral to minimize the potential for toxicity to aquatic biota. This has been recognised as an element in the on-going monitoring plan for the site (see Section 6.2). It is recommended that a specific monitoring plan be developed for the BMD, to determine success of the remediation strategy and act as a sentinel for any potential aquatic impacts.

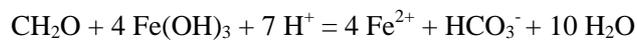
Further data provided to CSIRO on water quality in the BMD and other drains nearby, indicated that the outfall of the BMD had a pH of 6-7 over a year of sampling. Hence the drain water quality data chosen for comparison in the PER appears typical of what might be expected within the BMD.

It is noted that background drain water quality is an important issues, and it is given prominence in the PER. Data from a number of drains and sampling events are provided to assess typical background drainage water quality. This is a useful approach to regional drain quality issues.

#### **(v) Modelling of contaminant mobility in residual soil**

It is not clear if ferrollysis was considered as a possible mechanism for mobilization/precipitation of contaminants - possibly on a seasonal basis. Ferrollysis is likely to be important given the high Fe content of attenuation soils. A short summary is given below.

In the absence of oxygen (*e.g.* in water-saturated soils with reducing organic matter), ferric oxides and hydroxides are reduced to Fe<sup>2+</sup>-compounds which go into solution:



During this '*reduction phase*', H<sup>+</sup>-ions are consumed and the soil-pH rises. Fe<sup>2+</sup>-ions replace adsorbed basic cations and aluminium; the replaced ions are partly leached out (together with some of the Fe<sup>2+</sup>). Once the soil-pH has risen to about pH 5 to 5.5, Al<sup>3+</sup>-ions and OH<sup>-</sup>-ions may polymerize to hydroxy-Al-polymers. It is surmised that part of the polynuclear Al-polymers are 'trapped' in the interlayer spaces of lattice clays thereby changing the properties of the clay (lower CEC, water content, swell-shrink properties). Remaining polymers are leached out of the soil.

When air re-enters the soil in a subsequent dry period, an '*oxidation phase*' sets in; exchangeable Fe<sup>2+</sup> is oxidized again to insoluble Fe<sup>3+</sup>-hydroxide. This produces two H<sup>+</sup>-ions for each Fe<sup>2+</sup>-ion oxidized:



The clay may become partially protonated, which converts to aluminium-magnesium clay as adsorbed hydrogen ions are replaced by aluminium and basic cations dissolved from the clay structure. Silica is dissolved from the clay lattices at the same time; it may partly be removed and partly re-precipitate in an amorphous form when the horizon dries out. During the next wet season, a new cycle would commence with another '*reduction phase*'.

Ferrollysis may not constitute the only natural attenuation pathway at the Bayswater site. Drillhole X-ray diffraction (XRD) data supplied by Parsons Brinckerhoff to CSIRO suggests that isolated occurrences of up to 25% calcite and minor dolomite may be present. Both minerals are able to neutralize acidity. Substantial gypsum (CaSO<sub>4</sub> - up to 55%) also present in some drillholes may signify the end product of the neutralization of groundwater acidity. Otherwise, XRD data indicate the presence of jarosite (K,Na-Fe<sub>3</sub>(SO<sub>4</sub>)<sub>2</sub>(OH)<sub>6</sub>) in some drillholes which is compatible with PHREEQC modelling results for CSBP and regional groundwater of circum-neutral pH.

A second modelling aspect involves the modelling of the geochemistry and reactivity of residual soils (post-remediation) using PHREEQC. The PER reports some of the outcomes of the modelling, but suggests that the modelling may be unreliable. This type of modelling can be complex, but very useful – and further efforts to model the effects of the chemistry changes during and after remediation would be beneficial. In particular, the modelling should be undertaken over a range of Eh-pH conditions encompassing seasonal variations in aquifer

geochemistry and regional/longitudinal gradients between the former Cresco site and the BMD in both contaminated and uncontaminated sites.

**(vii) Groundwater chemistry and dilution factors**

As with the assessment of the water quality of the BMD, the groundwater quality discussion is based on a single groundwater chemistry result from borehole H10 taken on 26 November 2003, although Table 6.3 also displays groundwater analysis from 10 December 2003. The groundwater sample from the 10 December had slightly higher concentrations for most analytes compared to the groundwater sample from the 10 November 2003, apart from the Fe concentration, which was a factor of 20 lower. It is not clear why the different groundwater data are shown. Inclusion in the PER of groundwater quality time trends, averages, ranges of concentrations and standard deviation measures for quality parameters – would provide greater confidence in the assessment presented. This would become available as further monitoring is undertaken.

The PER uses fluoride (F) as a conservative compound and bases dilution factors on the dilution of F between its groundwater concentration at bore H10 on 26 November 2003, and its concentration in surface water at the BMD outfall on the same date. The justification for using F, although stated, is not clear. It would be good to see the same calculations carried through for other analytes such as zinc, copper etc – where dilution seems to have been less extensive. This would give a range of dilution factors as in Table 6.1, which are 37-533, and then give a broader range of predicted BMD outfall values. In essence, this would not change the assessment greatly (apart from including zinc as exceeding Marine Trigger values based on prediction) – but again inclusion of the broader range of dilution factors would give greater confidence in the predicted estimates.

An additional uncertainty in the use of F as a tracer arises due to possible precipitation as fluorite. In Section 6.1.3 it is stated that fluorite may potentially be formed with its effect on metal concentrations being modelled using PHREEQC. Thus, depending on the major ion chemistry of the groundwater, and in particular Ca and F concentrations, F may be a less reliable tracer, particularly when pH approaches circum-neutral values. In particular, modelling groundwater quality using PHREEQC for a number of boreholes within or near the Cresco site suggests that a number of groundwater samples may be oversaturated with respect to fluorite (CaF<sub>2</sub>). Interestingly, one borehole sediment sample does contain fluorite which is consistent with the PHREEQC modelling prediction. The presence of actual fluorite and the modelling output has major implications for the interpretation of the dispersion of the contaminant plume based on groundwater F concentrations, which were assumed to be conservative. Thus, the absence or reduced concentrations of F in groundwater may in some cases not reflect the true extent of dispersion of the contaminant plume at the Cresco site.

**(viii) Use of representative data sets**

As indicated above, the use of single values of groundwater and BMD surface water chemistry does not necessarily span the range of concentrations apparent at the site. The use of averages, ranges and/or standard deviation measures would provide a better assessment of variability. In particular, CSIRO suggest that the distribution of actual contaminant plumes should be depicted in the PER, rather than just the HILF representations alone. The HILF criteria and resultant representations tend to obscure the primary geochemical data and devolve the interpretation to an

abstract representation, albeit one that serves to display the most contaminated area(s) at the Bayswater site.

### **(ix) Remediation options**

The discussion of soil remediation options seems sound, although no independent assessment of soil volumes that may require excavation and remediation, or that may be left as residual materials at the site has been carried out by CSIRO. Correctly, the PER points out that the main concern for remediation of the soils on site is the acid forming potential of the residual iron oxide cinders and their resulting potential impact on groundwater. This should be taken into account when developing the monitoring plan for the site.

Initially, the groundwater remediation option recommended is pump and containment, to retard any further migration of impacted groundwater off site. This groundwater is to be placed back on site in trenches. It was planned to implement treatment of pumped groundwater in late 2004. It is not clear how the 4-5 year timeframe for pump and treat cleanup was estimated, although reference is given to some modelling carried out for the site. No data is given on the volume of impacted groundwater that may need to be captured and treated. The volume requiring treatment would be a combination of the impacted groundwater resident in the subsurface, the additional annual recharge and leachate from the residual soil materials, and re-mobilised metals that redissolve in groundwater due to remediation actions or changed groundwater chemistry. The 4-5 year timeframe may be optimistic based on overseas experience with pump and treat systems, although there is less documented experience with pump and treat systems applied to low pH and metal-impacted groundwater. The ongoing monitoring of groundwater quality both in ground and as pumped groundwater during treatment will provide greater guidance on timeframes, especially if linked to a model of the site groundwater dynamics during pumping. Longer timeframes of pumping and treatment lead to greater maintenance and treatment costs, which may make it less cost-effective compared to other remedial options (especially when pumping low-pH groundwater). This could be considered further by additional modelling and site monitoring and characterisation, which would reduce data and prediction uncertainties.

An extensive assessment of each of the possible remediation technologies has not been undertaken here. There are several other possible options for *in situ* and ex-situ groundwater remediation – including carbon and chemical amendments strategies (e.g., delivery of molasses, ethanol, vegetable oils). Each of the carbon amendment strategies seeks to buffer the pH and precipitate metal sulphides.

### **(x) Criteria for remediation success**

The stated criteria for success is (see Section 6.2.4.3 and 6.2.4.5) “When the median onsite groundwater quality (measured at bore location H10) remains within a 20% standard deviation of the background water analyte concentration (the defined remediation endpoint), then the risk of potential ecosystem impacts are considered to be mitigated to background levels and the remediation activities are successful.” This criteria is reasonable, but is reliant on water quality from a single borehole, and the adequate definition of background groundwater quality. Bore location H10 appears to be a reasonably appropriate location and bore – but it may be that groundwater near this area is cleaned preferentially due to the close proximity of remedial pumping wells to capture impacted groundwater. Other parts of the site (to the north) may not be as well represented by the groundwater quality at H10. Whilst considerable effort and discussion

in the PER is devoted to defining the background water quality of the surface drains, there is much less discussion of background groundwater quality issues. The definition of 'background groundwater quality' for the site is not clear from the PER. It is likely that groundwater moving on-site would have a range of chemical signatures from the adjoining urban and industrial areas, including chemicals of concern for the site. This issue may require further attention.

The intensive monitoring program suggested in Section 6.2.4.3 is commended, although the key may be defining which boreholes (on and perhaps offsite) to monitor at what frequency, and what overall monitoring of the site is planned. It is recommended that a monitoring plan for the site be developed incorporating monitoring of groundwater bore locations across the site, the BMD and other drains where appropriate, and the effluent waters from groundwater treatment. The program should have as its aim, the monitoring of key site parameters that would indicate success or otherwise of the remediation strategy, and where uncertainties exist. It should be reviewed periodically, based on monitoring (and also perhaps geochemical modelling) outcomes.

**Other minor comments:**

1. It is not clear why a seven fold increase in concentration relative to 'trigger values' was chosen to indicate a 'high' risk in Section 4.5.4.2.
2. Should Aluminium be included as an element in Table 4.2?
3. In Section 4.4.1 the cumulative or synergistic effects of metal accumulation may be worth discussing.
4. The last paragraph in Section 4.5.2 says that the soils are moderate risk so only on-going monitoring would occur (in accord with the second last dot point in Section 4.5.1), and it implies that remediation may not occur. It is clear later that remediation of the soil is intended. Perhaps the intent here is to say that the residual material left after excavation/remediation would pose a moderate risk. Some rephrasing of this Section may be useful.
5. In Section 4.6.2.1, because of the changed groundwater conditions due to remediation, re-release of some precipitated or sorbed metals from the sediments may occur, although moderated pH values should minimise this effect.
6. In Section 5.3.2.3 no mention is made of the final pH of the treated water using lime. Only a small degree of overdosing will result in waters with a high pH (*ca.* 11) with the immediate (into the wastewater) or longer term (*e.g.* in landfill) potential for the release of oxyanions (*e.g.* As and Se) from the neutralized material.
7. The last column of Table 6.5 appears to have 'Yes' in the incorrect rows and should be in the Cu and Zn rows. The row alignment for other columns (such as the Marine Trigger values) may also be askew. This should be checked and corrected.
8. Section 6.2.2 – It is stated that Al toxicity is reduced by complexation with humic substances and/or F. This seems reasonable for humic substances, particularly in the absence of very low or very high pH, however, advice from CSIRO ecotoxicologists and information contained in a recent manuscript forwarded to PB and CSBP during

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discussions suggest that Al-F complexes can remain toxic to a range of biota under a wide range of conditions.

9. Reactive transport modelling and coupling to potential attenuation observed via PHREEQC and groundwater flow would be useful to consider as part of future activities to provide a more holistic understanding of contaminant fate, especially post remediation.

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