NSW Department of Industry

Derelict Mines - Macleay Catchment

Arsenic and Antimony Assessment Stages 2 and 2a

October 2016

Executive summary

Background

The Macleay River Catchment hosts many areas that contain relatively elevated concentrations of certain metals and metalloids, including gold, arsenic and antimony. The presence of these mineralised areas within the Macleay Catchment has led to a mining history of over 140 years. Historically, mineralised mining waste, including tailings and waste rock, were consciously disposed of in-stream, and / or poorly stored on many mine sites, as was the practice of the day. Subsequent erosion has seen mineralised waste deposited into tributaries within the Macleay Catchment. This, in turn, has resulted in elevated concentrations of arsenic and antimony in stream sediments for in excess of 300 kilometres within the Macleay Catchment.

A study was commissioned to address Strategy 30.1 of the *Macleay River Estuary: Coastal Zone Management Plan*; an initiative borne to improve water quality in the Macleay River by Kempsey Shire Council with financial assistance from the NSW Government's Estuary Program as administered by the NSW Office of Environment and Heritage (OEH). Specifically, Strategy 30.1 aims to identify and manage existing sources of contamination from mines in the upper Macleay catchment, thereby seeking to prevent further contamination of waterways by addressing those upstream contaminant sources.

Stage 1 of the study involved a desktop review of existing information, which was reported by GHD to the NSW Derelict Mines Program in 2015. Stage 1 used existing sediment and water quality data to identify the top five sub-catchments within the Macleay that contributed the largest arsenic and antimony flux. These were Bakers Creek, Chandler, Commissioners Waters, Hickeys and Mungay Creeks, and Apsley sub-catchments. Stages 2 and 2a of the study included undertaking additional mineral waste, sediment and surface water sampling and analysis within those nominated five sub-catchments to attempt to identify key point or diffuse sources of arsenic and antimony for priority remedial action.

This document reports on Stages 2 and 2a of the study that included an assessment of key arsenic and antimony sources from derelict mine sites within the Macleay Catchment, such that priority rehabilitation works may be implemented. Based on the data assessed during Stage 1, the key contributor of antimony to the Macleay Catchment was found to be the Bakers Creek sub-catchment (around 77 percent of total antimony flux). This, presumably, was mostly sourced from historic mine workings and in stream sediment within the Hillgrove Mineral Field. Ashley and Graham (2001) reported that Bakers Creek and some of its tributaries had been historic repositories for up to seven million tonnes of mineralised waste rock and tailings. Ashley and Graham (2001) subsequently concluded that the in-stream mineral waste was likely to be the major source of arsenic and antinomy contamination in Bakers Creek; the remediation of which it is unlikely to be cost-effective based on current technology.

The second largest antimony contributor by flux was the Chandler sub-catchment (around 4.5 percent), which hosts the Halls Peak and Rockvale derelict mines, amongst others, followed by the Hickey and Mungay Creek sub-catchment that contributes some 3.2 percent of the antimony flux—the latter possibly sourced from the Mungay Creek Antimony Mine. Then came Commissioners Waters (around 1 percent) and Apsley (0 4 percent). It was considered that Apsley may have been identified based on the method used, being a function of catchment size. i.e. a potentially small point source contribution and relatively large catchment area; thereby yielding a relatively significant antimony flux. The balance was comprised largely of naturally mineralised though unmined catchments (around 8 percent), the transitional Trunk Macleay (around 4 percent) and the depositional Macleay Floodplain (around 1 percent).

The top five arsenic contributors were found to be the Chandler sub-catchment with around 35 percent, Bakers Creek with around 25 percent, Commissioners Waters (7.2 percent), Apsley (2.6 percent) and Hickey and Mungay Creek sub-catchment with 1.2 percent. The balance was comprised largely of naturally mineralised though unmined catchments (around 10.6 percent), the transitional Trunk Macleay (around 10 percent) and the depositional Macleay Floodplain (around 3 percent).

It is important to recognise that an estimated 13 percent of the antimony flux and around 30 percent of the arsenic flux appears to be sourced from non-mining catchments that are naturally elevated in antimony and arsenic, the Trunk Macleay and the Macleay Floodplains themselves.

To further investigate which individual sites within the top five antimony and arsenic generating sub-catchment listed above were contributing the most contamination, GHD collected the following samples during Stages 2 and 2a:

- 27 mineral waste samples from 10 individual mine sites / mining areas in 5 sub-catchments
- 74 sediment samples from 15 sites in 6 sub catchments (Warbro Brook was the addition)
- 52 surface water samples from 14 sites in 6 sub catchments (Khans Creek being the exception; Warbro Brook being the addition).

Results

Overall, the data collected in Stages 2 and 2a were remarkably consistent with the historic data set and published literature used in Stage 1. This in itself provides a level of confidence in the data and suggests that reasonably consistent arsenic and antimony concentrations are being reported by site for mineral waste, sediment and surface water over time. This in turn would indicate that the key contaminant sources remain relatively consistent over time, thereby allowing for their identification and ranking for priority remedial action.

The results indicated that sediment and surface water at concentrations above nominated environmental screening criteria were leaving site at the following locations:

- The Hillgrove Mineral Field
- Phoenix Gold, Ruby Silver and Rockvale Arsenic in the Upper Chandler
- Khans Creek, Gibsons, Faints and Firefly in the Lower Chandler
- Kapunda and Mary Anderson in the Commissioners Waters sub-catchment
- Mungay Creek in the Hickeys and Mungay Creek sub-catchment.

Further, the results of antimony and arsenic flux calculations based on Macleay Catchment rainfall, catchment size, surface water arsenic and antimony data and discharge modelling indicate that the Bakers Creek sub-catchment contributes around 72 tonnes per year of antimony under normal flow conditions into the Macleay Catchment—not all of which would find its way to the Macleay Floodplains due to in-catchment geochemical processes. The Bakers Creek sub-catchment also contributed an estimated 4 tonnes of arsenic per year under normal flow conditions. To reduce arsenic and antimony loads entering the system into the future, the data supports a strategy whereby the resources available are best utilised by targeting the historic mining legacy within the Hillgrove Mineral Field.

The data indicates that the mineralised waste rock resident within the Bakers Creek sub-catchment contains elevated concentrations of arsenic and particularly, antimony. The mechanism for contaminant transport into Bakers Creek and ultimately, the Macleay River, appears to be weathering and erosion of the waste rock into drainage lines whereby it becomes contaminated sediment. Clean water then comes into contact with the contaminated waste rock and sediment and becomes contaminated itself through mineral dissolution processes. Downstream transport of the antimony and arsenic while adsorbed to suspended solids or bedload sediment would appear to become the transport mechanism. This mechanism would be influenced by natural conditions within the Macleay catchment including pH and redox, amongst others.

The sediment and surface water data suggests that the bulk of the arsenic and antimony contamination in the Bakers Creek sub-catchment is being generated from historic mine workings reporting to Bakers Creek along a reach of the Creek of around 4.6 kms in length, that receives contaminated sediment and surface water from:

- the historic Black Lode, Syndicate and Sunlight mines
- Golden Gate Gully
- the historic mine processing area
- the historic Eleanora mine
- the historic Bakers Creek Proprietary Mine waste rock dump
- the historic Brackins Spur mine
- the historic Freehold / Smiths mine.

In terms of prioritising the site works within the Bakers Creek sub-catchment, the data indicated that the majority (estimated at approximately 40 tonnes per annum of the total Bakers Creek antimony flux appears to be reporting from the historic Freeholds / Smiths mine workings under normal flow conditions, noting that this flux calculation is based on one surface water sample collected during the Stage 2a fieldwork. Given that there are 200 individual mineral occurrences in the Hillgrove Mineral Field (NSW Department of Mineral Resources 1992), and over 500 known individual mine features (EA Systems 2003) from historic operations at Hillgrove, it is not possible to categorically apportion contamination by point source in this reach of Bakers Creek without additional work. Rather, the surface water and sediment data should be used to prioritise high priority areas for future work upon which a remedial strategy should be based.

Table ES1 and ES2 provides summaries of the Stage 2 and 2a environmental risk by site.

Table ES1: Summary of Stage 2 and 2a environmental risk by site

Sample	AMD risk	Saline drainage risk	Metalliferous drainage risk	Off-site migration?
Chandler - Upper				
Phoenix Gold	Low - Med	Med	**High** (As and Sb)	**Yes. Sediment and surface water**
Rockvale	Low - Med	Med-**High**	**High** (As and Sb)	**Yes. Sediment and surface water**
Ruby Silver	Low	Med-**High**	**High** (As and Sb)	**Yes. Sediment and surface water**
Tulloch	Med - **High**	Low-Med	**High** (Sb)	**No.**
Chandler - Lower				
Khans Creek	**High**	Low-**High**	**High** (other metals)	**Yes. (Sediment)**
Mickey Mouse	Med	Med	**High** (Sb)	**No**
Commissioners Waters				
Kapunda	Low	Low	**High** (As and Sb)	**Yes. Sediment and surface water**
Mary Anderson	Low	Low	**High** (As and Sb)	**Yes. Sediment and surface water**
Apsley				
Europambela	Med-**High**	Low-Med	**High** (other metals)	**No.**
Hickeys / Mungay Creeks				
Mungay Ck	Low-Med	Low	High (Sb)	**Yes. Sediment and surface water**
Bakers Creek				
Bakers Ck 1 – Brackins Spur Mine Waste	Low	Low	**High** (As)	**Yes. Sediment and surface water**
Bakers Ck 2 – Smiths Mine Waste	Low	Low	**High** (As and Sb)	**Yes. Sediment and surface water**
Bakers Ck 3 – Bakers Ck Mine Waste	Low	Low	**High** (As and Sb)	**Yes. Sediment and surface water**
Bakers Ck 4 – Black Lode Mine Waste	Low	Low	**High** (As and Sb)	**Yes. Sediment and surface water**
Bakers Ck 5 – Cosmopolitan Mine Waste	Low	**High**	**High** (As and Sb)	**Yes. Sediment and surface water**
Bakers Ck 6 – Lady Hopetoun Mine Waste	Low	Low	**High** (As and Sb)	**Yes. Sediment and surface water**

Table ES2: Summary of mineral waste, sediment and surface water results by site

Sample	Mineral waste	Sediment	Surface water	Off-site migration (contaminant)?	Comment
Chandler - Upper					
Phoenix Gold	**X**	**X**	**X**	**Yes (As)**	Acid rock drainage present
Ruby Silver	**X**	**X**	**X**	**Yes (As)**	-
Tulloch	**X**	**X**	**X**	No	Potentially Acid Forming (PAF) waste rock on site
Rockvale	**X**	**X**	**X**	**Yes (As)**	Acid rock drainage present
Chandler - Lower					
Chandler (Rathbones Point East and Stuart Reef)	NS	√	√	No	-
Khans Creek	**X**	**X**	NS	**Yes (Sb, As)**	Contaminated sediment down-catchment. PAF waste rock on site. No water sample.
Keys Prospect	NS	√	√	No	-
Mickey Mouse	NS	√	√	No	-
Sunnyside	NS	√	√	No	-
Commissioners Waters					
Kapunda	**X**	**X**	**X**	**Yes (As)**	Up-catchment contaminant sources likely
Mary Anderson	**X**	**X**	**X**	**Yes (Sb)**[1]	Neutral mine drainage present
Apsley					
Europambela	**X**	√	√	No	PAF waste rock on site
Hickeys / Mungay Creeks					

Sample	Mineral waste	Sediment	Surface water	Off-site migration (contaminant)?	Comment
Mungay Ck	**X**	**X**	**X**	**Yes (As, Sb)**[1]	-
Toorumbee Creek and Warbro Brook					
Warbro Brook	NS	**X**	**X**	NA	Naturally elevated background from known mineral prospects
Bakers Creek					
Bakers Ck 1 – Brackins Spur Mine Waste	**X**	**X**	**X**	**Yes (As)**	-
Bakers Ck 2 – Smiths Mine Waste	**X**	**X**	**X**	**Yes (As and Sb)**	-
Bakers Ck 3 – Bakers Ck Mine Waste	**X**	**X**	**X**	**Yes (As)**	-
Bakers Ck 4 – Black Lode Mine Waste	**X**	**X**	**X**	**Yes (As and Sb)**	-
Bakers Ck 5 – Cosmopolitan Mine Waste	**X**	**X**	**X**	**Yes (As and Sb)**	-
Bakers Ck 6 – Lady Hopetoun Mine Waste	**X**	**X**	**X**	**Yes (As)**	-

X contaminated; √ not contaminated; NS that media not sampled; NA not applicable – no ‘site’ *per se*. 1: This depends on where the ‘site’ boundary is located.

Remedial strategy

Considering the data, it becomes apparent that if the antimony and arsenic-rich waste rock in the Bakers Creek sub-catchment were remediated, significant contaminant point sources would be removed, thereby reducing the likelihood of future generation and transport of contaminated sediment and water.

The remedial strategy acknowledges the historic slug of contaminated sediment currently resident as bedload within Bakers Creek, which will naturally attenuate over geological time. The strategy focuses on reducing additional contaminated sediment finding its way into Bakers Creek by proactively managing mineral waste elevated in arsenic and antimony. Limitations to this strategy include the physical terrain, safety considerations, tenure and the risk / reward both socially and environmentally of committing to remediating individual point sources within the Bakers Creek sub-catchment.

It is also important to recognise that the Bakers Creek sub-catchment is naturally mineralised, and rainwater in the form of runoff flowing over exposed stibnite veins will generate a natural antimony flux through mineral dissolution. This is a natural phenomenon that will elevate antimony concentrations in certain sub-catchments within Bakers Creek above non-mineralised sub-catchments. Therefore, the strategy focuses on proactive, remedial solutions for those areas of exposed waste rock whose remediation can positively impact water quality within the Bakers Creek sub-catchment. (Note that this study assumed current operations at the Hillgrove Mine, on care and maintenance at the time of writing, maintained compliance with all environmental approval conditions).

Recommendations

Bakers Creek sub-catchment

It is deemed premature to recommend individual remedial actions within the Bakers Creek sub-catchment based on the data available to date. That is, that the data set collected during Stage 2a is useful as a first pass, indicative indictor of priority remedial areas. Follow up monitoring should be completed to increase confidence and confirm the priority remedial areas. This should incorporate surface water sampling and flow rate monitoring such that contaminant flux can be estimated and ranked to confirm areas for priority remedial works. The data should build upon that reported herein.

It is therefore recommended that the Bakers Creek sub-catchment issues be incorporated into the existing Macleay River Working Group for priority action. The Group should include the current mine operator—Bracken Resources, the NSW Department of Planning, the NSW EPA, The NSW Department of Industry (Resources and Energy), the NSW Office of Environment and Heritage, University of New England environmental geochemistry specialists, representatives from Armidale Regional Council, Kempsey Council and the Derelict Mines Program.

The aim being to reduce the antimony and arsenic contamination being generated from historic mine workings within the Bakers Creek sub-catchment. (i.e. it is assumed that the current operations at Hillgrove maintain environmental compliance with their approval and mining lease conditions, and EPL). To achieve this aim, there will be a requirement to demarcate rehabilitation responsibility under mining title, and then address current approval conditions with respect to waste rock storage and management within the Mining Leases issued to Bracken Resources. The working philosophy should be reducing the volumes of arsenic and antimony contaminated waste rock on the surface.

Other sub-catchments

Recommendations made in this report have considered both the terms of reference for this study, and also the derelict mine site governance and priority funding arrangements as they relate to private and public lands, and off-site contamination migrating. This acknowledges that contaminants leaving some sites include species beyond arsenic and antimony. In that regard, for the remainder of the sites not located within the Bakers Creek sub-catchment, priority actions have been recommended based on an objective ranking method, in addition to a more subjective ranking based on an informed, though perceived hierarchy of relative contaminant contribution, and therefore, site significance. Their absolute remedial priority, however, should be assessed within the state-wide context of priority sites requiring remediation, such that the most appropriate investment decisions for public funds are realised.

Of the remaining sites not located within the Bakers Creek sub-catchment, the following works should be considered, noting that the data indicates that their relative contribution to antimony and arsenic loads within the Macleay River Catchment are relatively insignificant from a whole of catchment perspective:

1. Complete detailed investigations in the Commissioners Waters sub-catchment (up-catchment of Kapunda Arsenic) and at Mungay Creek to determine:
   - What contamination is present up-catchment from Kapunda that is contributing to the arsenic load in the Commissioners Waters sub-catchment. There remain up to 20 small metallic mineral prospects within the Commissioners Waters sub-catchment that may be contributing loads in excess of Kapunda itself.
   - The full extent of the antimony contamination at Mungay Creek, including accessing all sites on which the historic mine was located.
2. Update the remediation strategy at Gibson's Open Cut to consider the mineral waste geochemistry in addition to the physical works, noting that this is a very physically challenging site to remediate. Implement the remedial works at Gibson's Open Cut should funding become available.
3. Complete the recommended remedial works at Rockvale Arsenic which should see Rockvale fully rehabilitated.
4. Complete remedial works at the Khans Creek, Faints and Firefly sites, noting that these would be physically challenging sites to remediate.
5. Mary Anderson and Ruby Silver are lower priority and can be completed over time; although securing the open shaft at Ruby Silver should be completed as a priority to reduce human safety risk.
6. Monitor the remediation actions at Phoenix Gold and re-assess the site and any remedial requirements upon its conclusion.

A general note

As a general note, much of the historic remediation completed to date, such as at Rockvale Arsenic and Tulloch Silver mines for example, appear to focus purely on physical works. While the physical remediation of sites is important, it should not come at the expense of geochemical stabilisation of potentially acid-forming materials. This requires a specialised site assessment and a bespoke rehabilitation plan that integrates with the site physical works. That is, a holistic site wide remediation strategy and plan should be developed for each site considered.

With respect to this study, this observation is applicable to sites in the upper and lower Chandler sub-catchment that show varyingly levels of acid potential based on the oxidation of polymetallic sulfide mineral waste on these sites. Those sites are specifically Phoenix Gold, Rockvale Arsenic, Ruby Silver, Khans Creek, Faints, Firefly and Gibsons. This working ethos, however, should extend beyond the Macleay Catchment when planning site remediation to effect long term success, and therefore, maximise the environmental and safety return on investment of public funds.

Table of contents

Table index

Figure index

Appendices

Cover photo: The Chandler River below Gibsons Open Cut, Halls Peak Mineral Field.

1. Introduction

1.1 Project Overview

The Macleay River Catchment hosts many areas that contain relatively elevated concentrations of certain metals and metalloids, including gold, arsenic and antimony. The presence of these mineralised areas within the Macleay Catchment has led to a mining history of over 140 years. Historically, mineralised mining waste, including tailings and waste rock, were consciously disposed of in-stream, and / or poorly stored on many mine sites, as was the practice of the day. Subsequent erosion has seen mineralised waste deposited into tributaries within the Macleay Catchment (Ashley and Graham 2001). This, in turn, has resulted in elevated concentrations of arsenic and antimony in stream sediments for in excess of 300 kilometres within the Macleay Catchment (Ashley and Graham 2001). The ultimate fate of this arsenic and antimony-rich sediment is the Macleay River floodplain and estuary at the river's Pacific Ocean terminus at Kempsey (Ashley 2001, Tighe 2005). The location of the Macleay Catchment, including its sub-catchments, is shown on Figure 1.

Over the past decade, the NSW Government has introduced reforms to ensure the long-term health of State waterways, including the Macleay Catchment, by improving water quality and establishing river flow objectives. Within this State policy framework, the *Macleay River Estuary: Coastal Zone Management Plan* (Geolink 2012) was commissioned by Kempsey Shire Council with financial assistance from the States' Estuary Program as administered by the NSW Office of Environment and Heritage (OEH).

Strategy 30.1 of the *Macleay River Estuary: Coastal Zone Management Plan* (Geolink 2012) contains actions relating to the identification and management of existing sources of contamination from mines in the upper Macleay catchment, seeking to prevent further contamination of waterways, by addressing those upstream contaminant sources. Specifically, the tasks were to undertake measures to (Geolink 2012):

- Address existing sources of contamination from mines in the upper catchment, seeking to prevent further contamination of waterways
- Address upstream sources of antimony and arsenic (e.g. map location, extent, volume, concentration, degree of hazard, remediation options, and implementation practicality).

OEH requested assistance with executing Strategy 30.1 from the (then) NSW Department of Trade and Investment, Regional Infrastructure and Services (Trade and Investment – now simply the Department of Industry, or DoI); from which this project was instigated. Within DoI resides the Division of Resources and Energy, Derelict Mines Program (DMP).

The DMP subsequently commissioned GHD Pty Ltd (GHD) to assist with delivery of DoI's tasks under Strategy 30.1; specifically, as it related to derelict mines within the Macleay Catchment.

The overall project has been completed in stages; being:

- Stage 1: an initial desktop assessment to identify potential point sources of arsenic and antimony from historical mining operations in the Macleay Catchment to prioritise each site for further investigation. Stage 1 was reported to the (then) NSW Department of Trade and Investment in 2015 (GHD 2015).
- Stage 2: site investigations for those sites that required additional data as identified during Stage 1. The purpose of Stage 2 was to characterise the extent of arsenic and antimony contamination from selected sites, identify whether any off-site impacts were occurring, assess environmental risk, and propose remediation options

Paper Size A3

0 3.75 7.5 15 22.5 30

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Major Towns
- Subcatchment Boundaries
- Major Watercourse
- Minor Watercourse 1
- Minor Watercourse 2
- Major Roads

NSW Department of Trade and Investment
Macleay Catchment Arsenic and Antimony Investigation

Job Number	21-23815
Revision	A
Date	18 May 2016

Macleay Catchment with Sub-Catchments - Regional Context

Figure 1

\\ghdnet\ghd\AU\Sydney\Projects\21\23815\GIS\Maps\Deliverables\STAGE 2\2123815_F1_Z020_MACLEAY_MacleayLocality.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI Created by:mweber

- Stage 2a. As per Stage 2 although specifically for the Bakers Creek sub-catchment—previously intentionally omitted from Stage 2 due to the operational mine in the sub-catchment. Stage 2a also included additional sampling from the Mungay Creek Mine which was under-sampled in Stage 2 due to restricted site access.

This document reports on Stages 2 and 2a, and follows on from the Stage 1 report (GHD 2015).

1.2 Project aim and objectives

1.2.1 Aim

The overall aim of this project was to undertake an assessment of key arsenic and antimony sources from derelict mine sites in the Macleay Catchment to inform priority rehabilitation works.

1.2.2 Objectives

Project objectives were to:

- Identify potential sources of arsenic and antimony from historical mining in the Macleay Catchment
- Quantify the extent, volume and concentration of arsenic and antimony contamination at the sites on a priority basis
- Assess the potential risk to the environment, particularly surface waters
- Outline remediation options and costs for sites that were investigated where remediation is deemed feasible.

1.3 Scope of work

The scope of work for Stages 2 and 2a of the project was developed to remain consistent with that originally outlined in the DoI's tender number DM14/116, which was originally tendered with the Stage 1 works, then deferred pending the completion of Stage 1. Rationale for this deferral was to better scope the requirements of Stages 2 and 2a such that the overall aims and objectives of the project could be met.

The scope of works for Stages 2 and 2a of the Project were:

- Development of Occupational Health, Safety, and Environment (OHSE) Plans, including managing site access arrangements with land owners, for Stages 2 and 2a.
- Mineral waste sampling at the nominated derelict mine sites.
- Sediment sampling upstream on the tributary or drainage line entering the derelict mine site, and downstream on the tributary or drainage line exiting the mine site, as was reasonably practicable.
- Surface water sampling on the tributary or drainage line entering the derelict mine site, and downstream on the tributary or drainage line exiting the mine site, as was reasonably practicable.
- Recording site observations as they would inform future site rehabilitation including ease of access, vegetation cover, site features such as shafts, waste rock dumps, water storages etc.
- Reporting on Stages 2 and 2a (this report).

1.4 Report structure

This report addresses the scope of works as follows:

- Section 1 – Introduction
- Section 2 – Summary of Stage 1 (GHD 2015)
- Section 3 – Method
- Section 4 – Environmental guidance
- Section 5 – Summary results
- Section 6 – Summary results – Bakers Creek
- Section 7 – Site Ranking
- Section 8 – Summary, conclusions and recommendations.

1.5 Limitations and assumptions

This report has been prepared by GHD for the NSW Department of Industry and may only be used and relied on by NSW Department of Industry for the purpose agreed between GHD and NSW Department of Industry as set out in Section 1 of this report.

GHD otherwise disclaims responsibility to any person other than the NSW Department of Industry arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by the NSW Department of Industry and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report that were caused by errors or omissions in that information.

Note that this study assumed that current operations at the Hillgrove Mine operated by Bracken Resources (on care and maintenance at the time of writing), maintained compliance with all environmental approval conditions.

2. Summary of Stage 1

2.1 Method

Stage 1 was a desktop review of information that aimed to screen out insignificant sites with respect to their relative arsenic and antimony contribution to the Macleay catchment. Stage 1 also identified gaps in the data that required closing in order to meet the overall project aim and objectives as defined in Section 1.2.

To achieve the aim of Stage 1 of the project, the Macleay Catchment was divided into 22 sub-catchments that were used as screening surrogates for contaminant contributions for mine sites. The 22 sub-catchments were used as a first-pass, high level screening tool to rank the sub-catchments in terms of arsenic and antimony contaminant flux. Logically, sub-catchments with higher contaminant fluxes are more likely to host historic mine sites yielding arsenic and antimony contamination into the Macleay Catchment—prospective unmined mineral deposits and / or anthropogenic contaminant sources being two possible exceptions to this logic.

The available background data was collated to develop a consolidated database of surface water and sediment analytical data for the Macleay Catchment. Visual output in the form of arsenic and antimony contaminant maps were generated for surface water and sediment across the Macleay Catchment. Contaminant flux modelling using local rainfall and stream flow data was then completed on a sub-catchment basis.

The contaminant flux results for the sub-catchments known to host historic mine workings were then compared to background (or baseline) arsenic and antimony values in non-mining sub-catchments, with all 22 sub-catchments ranked using arsenic and antimony contaminant flux.

Using the sub-catchment ranking method described above, the top five arsenic and antimony-producing sub-catchments were identified. Based on the available information and data, the top five sub-catchments were interrogated to identify which specific mines, and potentially, mine domains, were potentially contributing arsenic and antimony contamination into the Macleay Catchment. These mines or mine domains formed the basis of the Stage 2 site investigations.

2.2 Results

The summary results from GHD (2015) showing the relative percent arsenic and antimony flux from the top five of 22 Macleay River sub-catchments hosting historic mines are provided below (Table 1).

Based on the data assessed during Stage 1, the key contributor of antimony to the Macleay Catchment was the Bakers Creek sub-catchment (around 77 percent of total antimony flux). This, presumably, is mostly sourced from historic mine workings and in stream sediment within the Hillgrove Mineral Field. Ashley and Graham (2001) reported that Bakers Creek and some of its tributaries had been historic repositories for up to seven million tonnes of mineralised waste rock and tailings. Ashley and Graham (2001) subsequently concluded that the in-stream mineral waste was likely to be the major source of arsenic and antinomy contamination in Bakers Creek; the remediation of which it is unlikely to be cost-effective based on current technology.

Hillgrove Mine is located within the Bakers Creek sub-catchment over some 21 Mining Leases, held by Bracken Resources. At the time of writing, the mine was on care and maintenance as it transitioned from being an antimony to a gold-focused mine. GHD does not imply that Bracken Resources is directly responsible for the historic antimony or arsenic contamination within the Bakers Creek sub-catchment.

Table 1: Summary table of Macleay River sub-catchment arsenic and antimony surface water and sediment quality

Sub-catchment	Mines present	Water Chemistry Exceedances (mg/L) – 80th percentiles							Sediment Exceedances (mg/kg) – 80th percentiles						Relative flux contribution (%)	
		As SSTV 0.003	As ADWG 0.010	As III ANZECC 0.013	As V ANZECC 0.024	Sb SSTV 0.0025	Sb ADWG 0.003	Sb ANZECC 0.009	As SSTV 12.48	As ISQC (low) 20.0	As ISQC (high) 70.0	Sb SSTV 1.20	Sb ISQC (low) 2.0	As ISQC (high) 25.0	As	Sb
Chandler	mines	Y	Y	Y		Y	Y		Y	Y		Y	Y		34.9	4.5
Bakers Creek	mines	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	25.1	77.4
Trunk Macleay	no mines	Y				Y	Y		Y			Y	Y			
Commissioners Waters	mines	Y				Y	Y		Y			Y	Y		7.2	1.0
Gara River	no mines	Y										Y				
Salisbury Waters	no mines															
Toorumbee Creek and Warbro Brook	no mines	Y				Y	Y		Y	Y		Y				
Macleay floodplain & Estuary	no mines					Y			Y			Y	Y			
Apsley	mines														2.6	0.4
Nulla Nulla Creek	no mines	Y				Y	Y	Y				Y	Y			
Hickeys and Mungay Creeks	mines	Y				Y	Y	Y				Y	Y	Y	1.2	3.2
Blue Mountain Creek	mines											Y				
Yarrowitch River and Green Gully	mines															
Kunderang Brook	no mines											Y				
Tia River	no mines															
Boringalla Creek and Mount Yarrahapinni Creek	no mines	Y				Y			Y	Y						
Styx Rivers	no mines															
Five Day Creek	no mines											Y	Y			
Dungay Creek	no mines											Y				

Sub-catchment	Mines present	Water Chemistry Exceedances (mg/L) – 80th percentiles							Sediment Exceedances (mg/kg) – 80th percentiles						Relative flux contribution (%)	
		As SSTV 0.003	As ADWG 0.010	As III ANZECC 0.013	As V ANZECC 0.024	Sb SSTV 0.0025	Sb ADWG 0.003	Sb ANZECC 0.009	As SSTV 12.48	As ISQC (low) 20.0	As ISQC (high) 70.0	Sb SSTV 1.20	Sb ISQC (low) 2.0	As ISQC (high) 25.0	As	Sb
Georges and Dykes Rivers	no mines															
Stockyard Creek	no mines															
Christmas & Collombatti Cks	no mines															

The second largest antimony contributor by flux was the Chandler sub-catchment (around 4.5 percent), which hosts the Halls Peak and Rockvale derelict mines, amongst others, followed by the Hickey and Mungay Creek sub-catchment that contributes some 3.2 percent of the antimony flux—the latter possibly sourced from the Mungay Creek Antimony Mine. Then came Commissioners Waters (around 1 percent) and Apsley (0.4 percent). It was considered that Apsley may have been identified based on the method used, being a function of catchment size. i.e. a potentially small point source contribution and relatively large catchment area; thereby yielding a relatively significant antimony flux.

The top five arsenic contributors were found to be the Chandler sub-catchment with around 35 percent, Bakers Creek with around 25 percent, Commissioners Waters (7.2 percent), Apsley (2.6 percent) and Hickey and Mungay Creek sub-catchment with 1.2 percent.

The Stage 1 findings supported previous studies undertaken through the University of New England (UNE) that reported the Bakers Creek sub-catchment as the main contributor of arsenic and antimony contamination within the Macleay Catchment (e.g. Ashley and Graham 2001, Ashley *et al*. 2006).

2.3 Stage 1 recommendations

Due to limitations within the surface water dataset used in Stage 1 of the project, largely due to spatial considerations and a subsequent lack of stream flow data, it was not possible to calculate specific contaminant flux from individual mine sites nor flux from individual mine domains within the five priority sub-catchments identified above. Therefore, additional targeted surface water and sediment sampling was recommended for the Chandler, Bakers Creek, Hickey and Mungay Creek, Commissioners Waters and Apsley sub-catchments to be undertaken during Stages 2 and 2a (refer to Table 2). The new data generated would be used to help identify key point sources of arsenic and antimony within each of the five priority sub-catchments listed above.

GHD also recommended that the following be completed whilst on site during Stages 2 and 2a:

- Document site condition and surrounds during the site walkover
- Quantitatively delineate the spatial area and volume of any obvious mineralised mine waste resident on site (i.e. point and/or diffuse contaminant sources)
- Characterise the aquatic chemistry of the sites though sediment and surface water sampling
- Assess whether the site posed an unacceptable risk to human health and the environment from arsenic and/or antimony contaminated mineral waste, sediment and / or surface water leaving site
- Assess the effectiveness of any historical remediation or safety works on site, and identify potential opportunities for targeted remediation works, including a consideration of site access and any practical limitations that may preclude future works being successfully undertaken.

Given that the aims and objectives for the project relate specifically to identifying the major contributors of arsenic and antimony flux from derelict mines within the Macleay Catchment for the purpose of allocating priority remediation works, no further action was recommended in regard to sub-catchments with no known mine workings, though with water and / or sediment qualities exceeding adopted guideline values. These sub-catchments included:

- Nulla Nulla Creek (possibly a statistically unrepresentative dataset used in Stage 1 and/or locally mineralised geology containing naturally elevated arsenic and antimony concentrations, likely present in as yet unmined prospects)

- Boringalla and Mt Yarrahapinni Creeks (very minor historic mining on Mt Yarrahapinni and / or crop reside in soils)
- Toorumbee and Warbro Brooks (which host the Willi Willi prospect – i.e. mineralised geology containing naturally elevated concentrations of arsenic and antimony, as yet unmined).

GHD (2015) also recommended that it would be prudent to assess how readily arsenic and antimony were liberated from waste rock and sediment by undertaking leach testing using the Australian Standard Leaching Procedure (ASLP). This would assist with framing environmental risk.

Table 2: Stage 2 site sampling recommended from Stage 1 (GHD 2015)

Sub Catchment	Mines	Comment
Bakers Creek (No 1 Sb flux No 2 As flux)	Hillgrove Mineral Field	Stage 2a
Chandler (No 2 Sb flux No 1 As flux)	Tulloch Silver	Rathbones Point East and Stuart Reef assessed during Stage 2 using Macleay River sediment and surface water samples due to access and safety limitations
	Rockvale Arsenic	
	Phoenix Gold	
	Ruby Silver	
	Stuart Reef	
	Rathbones Point East	
	Keys Prospect – Halls Peak	
	Firefly – Halls Peak	Site has been assessed E.A. Systems and CivilTech (2003), therefore, no additional investigation required. Gibsons inspected during Stage 2 but no sampling undertaken
	Faints - Halls Peak	
	Gibsons Open Cut - Halls Peak	
	Unnamed	Further investigation required. Refer to Section 3.1.1 of this report for Stage 2 variance from Stage 1 recommended sites
	Mickey Mouse Prospect – Halls Peak	
	Khans Creek Prospect - Halls Peak	
Hickeys/Mungay Creek (No 3 Sb flux No 5 As flux)	Mungay Creek Antimony	
Commissioner Waters (No 4 Sb flux No 3 As flux)	Kookabookra Reef	
	Kapunda Arsenic Deposit	
	Bow Gully	
Apsley (No 5 Sb flux No 4 As flux)	Europambela	
	TM Smith	

3. Method

3.1 Sites visited

GHD visited and sampled the sites shown in Table 3 during Stages 2 and 2a.

Table 3: Site visited and sampled during Stages 2 and 2a

Sub catchment	Site	Mineral Waste sampled	Sediment sampled	Surface water sampled
Bakers Creek	Hillgrove Mineral Field	Y	Y	Y
Chandler – Upper	Phoenix Gold	Y	Y	Y
	Rockvale Arsenic	Y	Y	Y
	Ruby Silver	Y	Y	Y
	Tulloch Silver	Y	Y	Y
Chandler - Lower	Mickey Mouse Adit	Y	Y	Y
	Stuart Reef	Mines were not sampled as agreed prior to site works with DoI – however samples were collected downgradient of mine in the Chandler River – refer to Section 3.1.1		
	Rathbones Point East			
	Keys Prospect	Mine site could not be accessed due to difficult terrain. Water and sediment samples were collected downgradient and in the Chandler River – refer to Section 3.1.1		
	Khans Creek	Y	Y	N
	Sunnyside	Mine site could not be accessed due to difficult terrain. Water and sediment samples were collected downgradient and in the Chandler River – refer to Section 3.1.1		
	Unnamed	No sampling completed as site did not appear mined – refer to Section 3.1.1		
	Firefly	Sites were not visited as previous assessment was completed by others which is used in the prioritisation of rehabilitation herein (EA Systems and CivilTech 2003)		
	Faints			
	Gibsons Open Cut			
Commissioners Waters	Kapunda Arsenic Deposit	Y	Y	Y
	Kookabookra Reef	Mine was deemed to be outside the Macleay Catchment. Nearest mine was Mary Anderson which was sampled instead – refer to Section 3.1.1.		
	Mary Anderson	Y	Y	Y
	Bow Gully	Removed from list due to the mineral deposit being alluvial in agreement with DoI – refer to Section 3.1.1		
Apsley	Europambela	Y	Y	Y
	TM Smith	Removed from the list due to unknown location with minimal disturbance and no metallurgy nearby in agreement with DoI – refer to Section 3.1.1		
Hickeys / Mungay Creek	Mungay Creek	Y	Y	Y
Toorumbee Creek / Warbro Brook	Warbro Brook	N	Y	Y

3.1.1 Variance from Stage 1 recommendations

Any variance in the sites sampled during Stages 2 and 2a as shown in Table 3 relative to those recommended for sampling in Stage 1 as shown in Table 2 is explained below.

Pre site works

During preparation for the Stage 2 and 2a site works, a desktop review of the proposed mines to sample as recommended in Stage 1 was undertaken, with the following sites being excluded in agreement with DoI:

- Stuart Reef (access issues - lower Chandler sub-catchment)
- Rathbones Point East (access issues - lower Chandler sub-catchment)
- Bow Gully (depleted alluvial mine - Commissioners Waters sub-catchment)
- TM Smith (Minimal or no evidence of mining impact - Apsley sub-catchment).

Stuart Reef and Rathbones Point East were located in difficult to access terrain. Furthermore, from available imagery the areas surrounding the location of these sites showed no loss of vegetation from contamination or vegetation clearing for mine access requirements. Based on discussions with the DoI, the decision was made to not visit Stuart Reef and Rathbones Point East. Rather, two surface water samples (C_SW01 and 02) and two sediment samples (C_SD01 and 02) were collected from the Chandler River immediately downstream of these two sites. The samples were collected on the Chandler River immediately up-catchment from the confluence of the Styx River to remove any influence from the Styx River sub-catchment.

Bow Gully was identified as an historic and depleted alluvial mine and therefore not investigated further due to the perceived lack of residual contamination—as agreed with DoI.

The TM Smith Mine was located in an area that did not hosted any mapped metallurgy (NSW Department of Mineral Resources 1992), nor showed evidence of any disturbance on aerial photography. It was therefore agreed with DoI that no further investigation was warranted.

In addition to the four sites listed above, the DoI decided to include the Tulloch Silver mine in the Stage 2 investigations despite previous data existing (Coffey Environments 2008). This decision was made as rehabilitation had previously been undertaken on site and DoI wanted to assess the success of the remedial work in reducing the off cite migration of arsenic and antimony.

In field

In addition to the four sites noted above that were excluded prior to the Stage 2 and 2a fieldwork being undertaken, GHD was unable to physically locate two sites once in the field. These were Kookabookra Reef in the Commissioners Waters sub-catchment and the Unnamed mine in the Halls Peak Mineral Field of the Lower Chandler sub-catchment.

Kookabookra Reef was deemed to be located outside of the Macleay Catchment. GPS coordinates sourced from the Minview[1] database shows the closest historical mine to Kookabookra Reef being the Mary Anderson Mine within the Commissioners Waters sub-catchment. Therefore, the Mary Anderson Mine was investigated based on its proximity to the DoI grid reference for Kookabookra Reef.

The Unnamed mine, located within the Halls Peak Mineral Field of the Lower Chandler sub-catchment, was found to be overgrown with no evidence of any past mining activity. An area encompassing approximately a 50 metre radius around the GPS coordinate for the Unnamed Mine was searched, until the search was ultimately abandoned.

GHD were unable to access the Keys Prospect site in the Halls Peak Mineral Field of the Lower Chandler sub-catchment due to difficult terrain, and therefore, safety considerations. Subsequently, surface water and sediment samples (KP_SW01 and KP_SD01 respectively) for this site were collected from the unnamed watercourse that drains the mine area, in addition to

[1] DoI database http://minview.minerals.nsw.gov.au/mv2web/mv2?cmd=MainMap&topic=min

sample being collected upstream (KP_SW03 and KP_SD03 respectively) and downstream (KP_SW02 and KP_SD02 respectively) of the confluence of the unnamed mine creek and the Chandler River. Information sourced from Minview indicated that the site appears to have been prospected historically, however, no evidence of mining was physically apparent—thus the name Keys Prospect.

GHD was also unable to access the Sunnyside site due to safety considerations. One sediment (SS_SD01) and one surface water sample (SS_SW01) were therefore collected from the Chandler River approximately 800 metres downgradient from the mine to assess environmental risk. Note that GHD (2015) did not recommend Sunnyside for additional sampling, so any additional data generated was in addition to that scoped. As GHD were in the location of Sunnyside during Stage 2, it was decided that samples should be collected if possible. (Flexibility in the Stage 2 and 2a sampling program allowed for situations such as Sunnyside whereby any additional opportunistic sampling that would value-add to the data set for decision-making purposes could be used as long as it aligned with the project's aims and objectives).

Similarly, one surface water sample (WB_SW01) and one sediment sample (WB_SD01) were collected from Warbro Brook immediately above its confluence with the Macleay River. The Warbro Brook sub-catchment is known to contain an unmined Sn-Cu-Ag resource being the Willi Willi Prospect (Ashley and Graham 2001). As the deposit remains unmined, the Warbro Brook samples were collected to compare against the Macleay Catchment natural background arsenic and antimony concentrations as a sensitivity analysis regarding arsenic and antimony concentrations emanating from known areas of natural mineralisation—often a neglected and unconsidered contaminant source in the Macleay Catchment.

3.2 Sampling rationale

To realise the project's aims and objectives within the project constraints, a strategic sampling plan was required to best capture geochemical data for decision making purposes. To that end, and in agreement with the DoI as documented in the sampling, analysis and quality plans developed for the Stages 2 and 2a fieldwork, the approach described below was undertaken.

Where possible, surface water and sediment sampling undertaken during Stages 2 and 2a within the nominated five sub-catchments (plus a background catchment; Warbro Brook as explained above in Section 3.1.1), consisted largely of coincident up and downstream surface water and sediment sampling of individual mines (and mine domains if possible on any larger sites). This was completed to assist with quantifying contaminated surface water and sediment migrating from each site or domain relative to the potentially uncontaminated samples collected from higher up the catchment. This assumed minimal up-catchment contamination in the form of arsenic and antimony; which the Stage 2 and 2a results proved was not always so (e.g. Kapunda Arsenic Mine).

Due to the weather conditions prior to, and during the Stage 2 and 2a fieldwork (Stage 2 in September 2015 and Stage 2a in February 2016), adherence to the proposed sampling methodology was not always possible due to the ephemeral nature of many watercourses. For sites where field conditions were dry with no surface flow, the surface water samples were collected up and downstream from the junction of the 'mine creek' draining the site and the higher order watercourse down-catchment. This was to quantify any contaminant contribution that the mine's drainage line may be making to the larger catchment.

Targeted mineral waste sampling was also completed on most sites. Logically, contaminated surface water results from clean water flowing over contaminated sediment and / or waste rock, through the elemental contributions of mineral dissolution processes. Therefore, data generated through mineral waste sampling and analysis were used as indicative of point or diffuse contaminant sources on site. All sample locations were recorded using geo-referenced photography to accurately locate contaminant point sources for priority rehabilitation purposes.

As requested by DoI, sampling within the Bakers Creek sub-catchment attempted to remain broadly consistent with the 11 historic mine domains documented by E.A. Systems and CivilTech (2003); as best as was reasonably practical. Sediment and surface water sampling included the main Bakers Creek channel so that an attempt could be made to estimate the contribution of each historic mine domain to the total contaminant load within the Bakers Creek sub-catchment.

3.3 Sample locations

Figure 2 shows the individual sites sampled on a Macleay Catchment-wide level. Georeferenced photographs for each site sampled that provide context to the sample locations, are provided in the GIS-based ArcViewer that accompanies this report. A selective amount of site photographs are also presented herein.

3.4 Analytical suite

Analyte sample numbers completed during Stage 2 and Stage 2a are summarised in Table 4 (for mineral waste and sediment) and Table 5 (for surface water). Samples were analysed by NATA accredited ALS in Brisbane.

Table 4: Stage 2 and 2a sample numbers and analytical suite – mineral waste and sediment

Analyte	Sample number - sediment	Sample number - mineral waste	Method
Moisture Content	74 (incl 7 dup)	27	Gravimetric (NEPM 2013)
pH (1:5)	74 (incl 7 dup)	27	Soil / Water 1:5 (APHA 21st ed. 4500H+)
Net acid production potential (NAPP)	54 (4 dup)	27	By calculation
EC	74 (incl 7 dup)	27	APHA 2150 Soil/Water 1:5
Net acid generation (NAG)	54 (4 dup)	21	Miller (1998)
pH saturated paste	54 (4 dup)	27	USEPA 600/2-78-054 / Modified Sobek
Acid neutralising capacity (ANC)	54 (4 dup)	27	USEPA 600/2-78-054 / Miller (2000)
Alkalinity in soil	74 (incl 7 dup)	27	APHA 2320B 1:5 soil/water leach
Acidity in Soil	74 (incl 7 dup)	27	APHA 21st Edition 2310B
Major Anions - soluble	74 (incl 7 dup)	27	1:5 Soil / Water extract
Total sulfur as S	74 (incl 7 dup)	27	LECO at 1350 deg C.
Major Cations - soluble	74 (incl 7 dup)	27	APHA 3120; USEPA SW846-6010
Total Metals (8)	74 (incl 7 dup)	27	APHA 3120, USEPA SW846-6010 acid digestion in soils

Analyte	Sample number - sediment	Sample number - mineral waste	Method
Total Mercury	74 (incl 7 dup)	27	AS 3550, APHA 3112 Hg-B
ASLP – metals leachable	33	20	APHA 3120, USEPA SW846-6010; AS 4439.3, ALS QWI-EN/EG020
ASLP – mercury leachable	33	20	AS 3550, APHA 3112 Hg-B with a bromate/bromide reagent to oxidise in solution

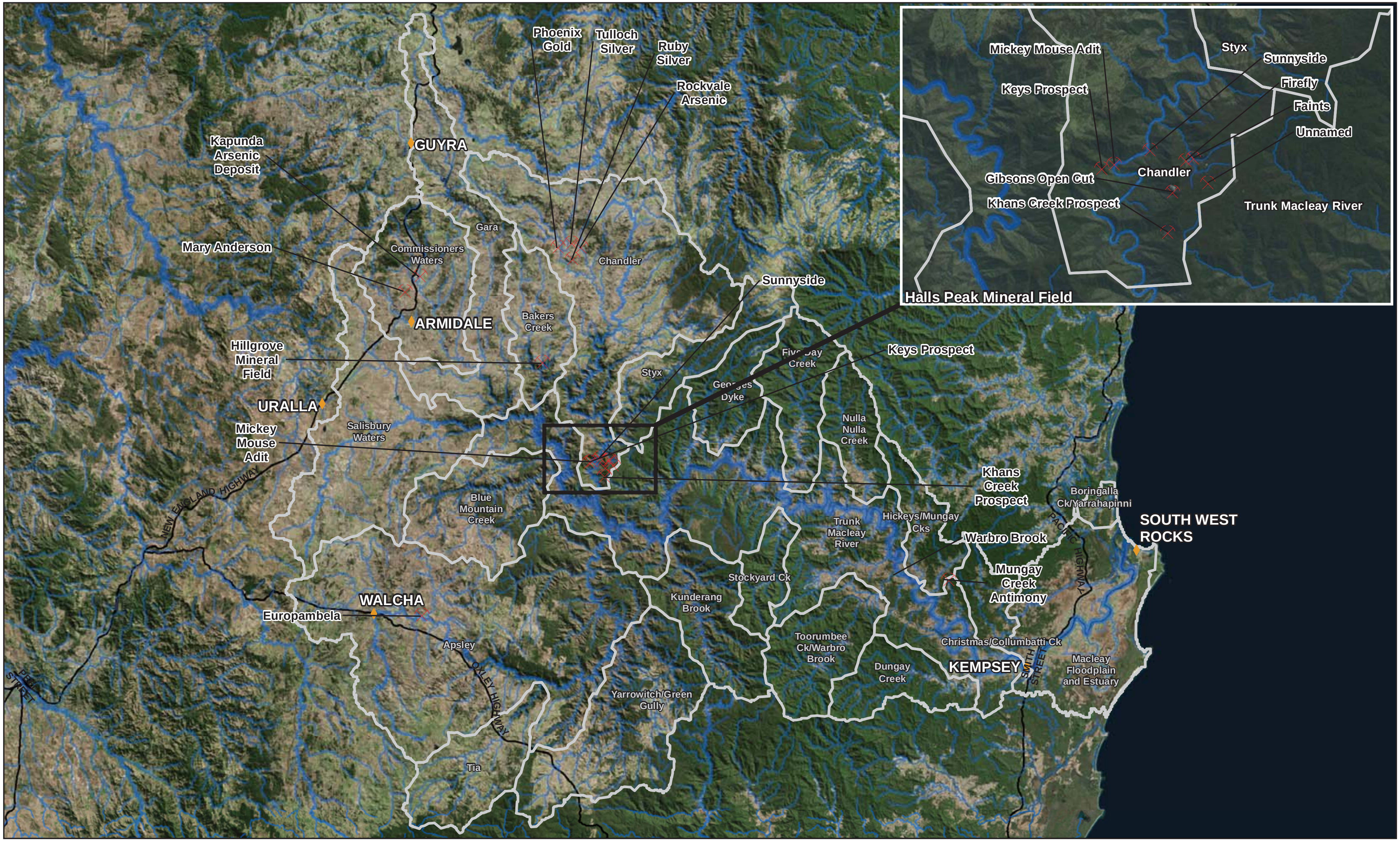
Table 5: Stage 2 and 2a sample numbers and analytical suite – surface water

Analyte	Sample number – surface water	Method
pH	51 (incl 5 dup)	APHA 21st ed. 4500H+
EC	51 (incl 5 dup)	APHA 2510 B
TDS	51 (incl 5 dup)	APHA 2540C gravimetric
Alkalinity	51 (incl 5 dup)	APHA 2320 B titration
Acidity as CaCO3	51 (incl 5 dup)	APHA 2310 B
Sulfate (turbidimetric) as SO_4^{2-}	51 (incl 5 dup)	APHA 4500-SO4
Chloride	51 (incl 5 dup)	Chloride discrete analyser APHA 4500 Cl-G
Major Cations – dissolved	51 (incl 5 dup)	APHA 3120 and 3125; USEPA SW846-6010 and 6020
Dissolved metals (ICP-MS)	52 (incl 5 dup)	APHA 3125; USEPA SW846-6020, ALS QWI-EN/EG020
Total Metals (ICP-MS)	52 (incl 5 dup)	APHA 3125; USEPA SW846-6020, ALS QWI-EN/EG020
Dissolved Mercury	52 (incl 5 dup)	AS 3550, APHA 3112 Hg –B with a bromate/bromide reagent to oxidise in solution
Total Mercury	52 (incl 5 dup)	AS 3550, APHA 3112 Hg –B with a bromate/bromide reagent to oxidise in solution
TOC	52 (incl 5 dup)	APHA 5310B

3.5 Quality Assurance and Quality Control

GHD applied a data quality objectives (DQO) process to the investigation to ensure that data and the data collection and analytical process were appropriate to achieve the project objectives. The process for establishing data quality objectives appropriate to the study was adopted from the *National Environment Protection (Assessment of Site Contamination) Measure* (NEPM) (2013).

The data quality objectives, along with the data quality assurance and controls are reported in Appendix C.



Paper Size A3

0 3.75 7.5 15 22.5 30

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Major Towns
- Mines
- Subcatchment Boundaries
- Major Watercourse
- Minor Watercourse 1
- Minor Watercourse 2

GHD

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	24 May 2016

Sampled Sites

Figure 2

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

\\ghdnet\ghd\AU\Sydney\Projects\21\23815\GIS\Maps\Deliverables\STAGE 2\2123815_F2_Z021_MACLEAY_SubcatchmentsMinerals.mxd

Data source: Imagery - ESRI Created by:mweber

3.6 Flux calculations

Section 2.2 provided a summary of the Stage 1 (GHD 2015) findings across the 22 Macleay sub-catchments determined using historic data.

3.6.1 Stage 1 antimony and arsenic loads

Stage 1 showed the following top five contributors to Macleay antimony loads from mined catchments, and excluding the trunk Macleay that contains contaminated sediment from historic mining operations (Ashley and Graham 2001):

- Bakers Creek - around 77 percent of the total antimony flux within the Macleay Catchment of an estimated 205 kilograms per day (based on historic data; or 75 tonnes per year) under suitable flow conditions. (It has been estimated that the flux of antimony into the Pacific Ocean at South West Rocks approximates 8 tonnes per annum, with the majority being in particulate form Ashley *et al*. 2006. The variance may be due to changing geoenvironmental conditions along the Macleay Catchment altering the availability and therefore transport mechanisms of the metalloids, along with uptake by various aquatic and riparian species acting as sinks).
- Chandler - around 4.5 percent
- Hickeys and Mungay Creek - 3.2 percent
- Commissioners Waters - 1 percent
- Apsley - 0.4 percent.

The top five arsenic contributors were found to be:

- Chandler - around 35 percent of the total arsenic flux within the Macleay Catchment of an estimated 50 kilograms per day (or some 19 tonnes per year) under suitable flow conditions.
- Bakers Creek - 25 percent
- Commissioners Waters - 7.2 percent
- Apsley - 2.6 percent
- Hickeys and Mungay Creek - 1.2 percent.

3.6.2 Stage 2 and 2a method

Contaminant fluxes for the Chandler, Hickeys and Mungay Creek, Commissioners Waters and Apsley sub-catchments were calculated on a site by site basis using data generated through Stages 2 and 2a of this study. This was completed by using the 80th percentile of arsenic and antimony concentrations for the down-catchment surface water sample at each site (i.e.) the water quality sample draining mine workings.

Those sites where the down-catchment surface water sample indicated that no arsenic or antimony was present in surface water (defined as reported results of <LOR) were not considered further given the purpose of this study. Further, whilst there is likely to be some flux coming from naturally mineralised catchments as shown by the Warbro Brook sample (0.004 mg/L arsenic; slightly above the non-mineralised catchment background concentration of 0.003 mg/L—for an annual arsenic flux estimated to be at around 0.16 tonnes), these are deemed inconsequential for the stated purposes of this study which is to identify the major arsenic and antimony contributing derelict mines in the Macleay Catchment for priority remedial action.

Sub-catchment areas were calculated for the eight surface water sample locations collected within the Bakers Creek sub-catchment not within Bakers Creek itself, being samples SW01, SW08, SW09, SW10, SW15, SW19, SW27, and SW33. Arsenic and antimony fluxes were then calculated for those eight sub-catchments to further demarcate contaminant sources within the Bakers Creek sub-catchment, as sub-sets of the overall Bakers Creek sub-catchment contaminant flux. As noted above, this was a somewhat spatially limited exercise given the dry conditions at the time of sampling.

The concept of a contaminant flux calculation using rainfall records at Bellbrook to rank relative site contamination contribution to the overall Macleay Catchment contaminant loads should be considered indicative at best. Whilst based on actual data in the field, the data set does have some statistical outliers, despite the consistency between historic sampling and GHD's sampling reported herein. There is a range of spatial and temporal reasons that this may be so, including for example the sample location, the climate, and flow conditions at the time.

For that reason, GHD undertook sensitivity analysis on the data as follows:

- Determining the relative percent flux by utilising only those surface water samples from locations draining derelict mine sites whilst removing all <LOR results within that data set.
- Determining the relative percent flux by utilising only those surface water samples from locations draining derelict mine sites whilst including all <LOR results within that data set.
- Determining the relative percent flux by utilising all surface water samples from locations within the immediate catchment draining the derelict mine site whilst removing all <LOR results within that data set.
- Determining the relative percent flux by utilising all surface water samples from locations within the immediate catchment draining the derelict mine site whilst including all <LOR results within that data set.
- Determining the relative percent flux by utilising all historic surface water samples from locations within the Bakers Creek sub-catchment.

There was less than a 1 % variance in results when all sensitivity analysis scenarios were run. This indicated relatively good confidence in the results, notwithstanding the limitations of the method.

Further quality assurance was conducted to provide context to the flux calculations, and confidence in the numbers. This was undertaken by assessing where on the flow event probability curve the field sampling was completed. Conceptually it is expected that under lower flow conditions concentrations in surface water would be higher as they would be less diluted by increased surface run-off. This may over estimate flux. Similarly, under high flow conditions, contaminant concentrations would be diluted, potentially leading to an underestimated of flux.

Therefore, a cumulative frequency plot of daily flows recorded in the Macleay River at Georges Junction between 1969 and the current day was established (Figure 3). The flow monitoring site, which remains consistent with the Stage 1 report (GHD 2015) is approximately 100 km downstream of the entry point for the Bakers Creek sub-catchment. While it is expected that the flows at Bakers Creek would be much lower because it is further up the Macleay catchment, Figure 3 provides a realistic representation of the likely flow conditions at Bakers Creek on any given day relative to the overall flow conditions expected to occur.

As indicated in Figure 3, this has allowed identification of the specific flow at the time of surface water sampling within the overall spectrum of flow conditions reported at Georges Junction (and hence an assumed proportional flow condition at Bakers Creek).

The surface water sampling events represented in Figure 3 are as follows:

- BC1 – which included 7 samples collected from surface water at various locations in Bakers Creek on 9 February 2016
- BC2 – which included 3 samples collected from surface water at various locations in Bakers Creek on 10 February 2016
- BC3 – which included 4 samples collected from surface water at various locations in Bakers Creek on 11 February 2016
- BC4 – which included 1 sample collected from surface water in Bakers Creek on 4 May 1999
- BC5 – which included 2 samples collected from surface water at two locations in Bakers Creek on 21 September 1999
- BC6 – which included 1 sample collected from surface water in Bakers Creek on 15 August 1999
- BC7 – which included 1 sample collected from surface water in Bakers Creek on 11 September 1999
- BC8 – which included 1 sample collected from surface water in Bakers Creek on 30 September 1999

Figure 3: Stream flow cumulative frequency

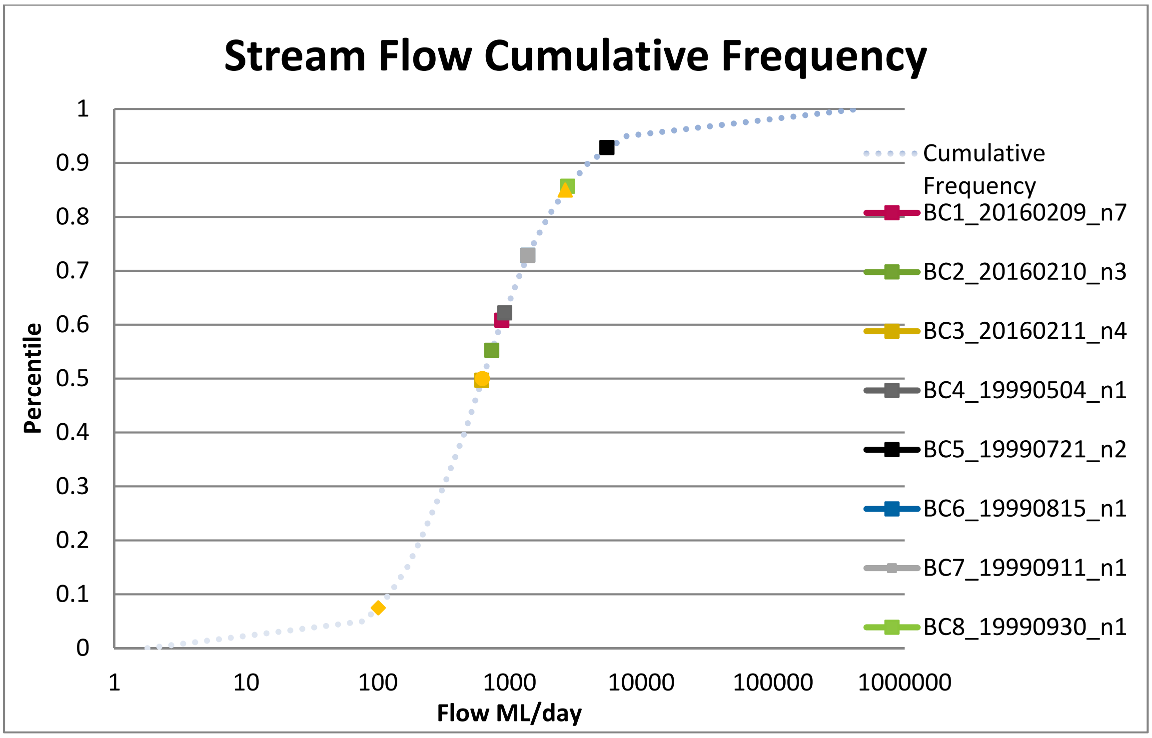


Figure 3 shows that the distribution of the sampling dates has generally ranged between the 50th and 93rd percentile flow conditions.

When the flows occurring at the time of sampling as shown in Figure 3 are compared against the average flow conditions (i.e. the 85th percentile flow), it can be concluded that sampling evens have generally been conducted at times when lower than average flows have been occurring. The most recent sampling undertaken during February 2016 by GHD, however, generally occurred during the 50th and 60th percentile flows. Based on this assessment, it can be expected that the current flux estimates are slightly conservative, or represent a small over prediction of flux. The results should therefore be used as indicative and comparative for a relative assessment of priority rehabilitation targets.

When the flux is used, along with the absolute sub-catchment contaminant levels shown in 7.2.1 and 7.2.2, and the site data results reported in Sections 5 and 6, a sound feel for the key contaminating sites can be developed, and priority actions defined accordingly.

4. Environmental guidance

4.1 Introduction

For consistency and comparability reasons, Stages 2 and 2a remained consistent with, and built on, the environmental guidance used in Stage 1 (GHD 2015).

More generally, the methods and guidance was consistent with methodology outlined in the following documents:

- (AMIRA 2002). *Project P387A Prediction & Kinetic Control of Acid Mine Drainage - ARD Test Handbook.* AMIRA International Limited, Melbourne.
- ANZECC & ARMCANZ (2000). *National Water Quality Management Strategy, Australian and New Zealand Guidelines for Fresh and Marine Water Quality.*
- NEPC (2013). *National Environment Protection (Assessment of Site Contamination) Measure* (herein referred to as the "NEPM"), National Environment Protection Council (NEPC).
- NHRMC and NRMMC (2011). *Australian Drinking Water Guidelines* Paper 6 National Water Quality Management Strategy (herein referred to as "ADWG").
- Department of Industry Tourism and Resources (DITR) (2007). *Managing Acid and Metalliferous Drainage*. Manual in the Leading Practice Sustainable Development Program for the Mining Industry series. Commonwealth of Australia.
- INAP (2009). *Global Acid Rock Drainage Guide* (GARD Guide) http://www.inap.com.au/GARDGuide.htm The International Network for Acid Prevention.

4.2 Mineral waste investigation levels

4.2.1 Overview

The overarching reference used for mineral waste was the *National Environment Protection (Assessment of Site Contamination) Measure 2013,* herein referred to as the NEPM (NEPC 2013). The NEPM contains investigation and screening levels suitable for the assessment of potential contaminants in soil (used as a surrogate for mineral waste).

The project uses results from the mineral waste geochemistry as an initial indicator of the potential for arsenic and antimony contamination from the investigated sites. It is not intended to be prescriptive, rather, informs the risk of a point source generating contaminated sediment and surface water for subsequent transport.

Importantly, Section 1.5 of Schedule B1 of the NEPM recognises that some geological provinces may contain naturally elevated concentrations of metals and metalloids; over and above crustal averages (NEPC 2013). This is logical in a catchment such as the Macleay that hosts a large number of historic mines and mine workings. To screen for this phenomenon, relative concentrations of arsenic, antimony and other metals in mineral waste and sediment samples were assessed using the geochemical abundance index (GAI) method (refer to Section 4.2.2).

4.2.2 Relative indicators of elevated metal concentrations

A comparison between the metal and metalloid concentrations as reported by ALS and their median crustal abundance can be undertaken using the Geochemical Abundance Index (GAI). GAI is a preliminary method of assessment, which does not consider the solubility and / or mobility of the metals and metalloids, nor their relative toxicity to the receiving environment.

Rather, it highlights those metals and metalloids present in concentrations exceeding median crustal abundance as documented in industry-accepted references (e.g. Bowen 1979). GAI is therefore useful as a first pass screening tool. Accordingly, all waste rock and sediment samples were assessed using the GAI method.

A GAI of 0 indicates that the concentration of an element in a sample relative to crustal abundance is less than, or similar to, the crustal abundance. A GAI of 3 corresponds to a 12-fold enrichment above the crustal-abundance; and so forth, up to a GAI of 6 which corresponds to a 96-fold, or greater, enrichment above crustal abundances. A GAI of 3 or greater is considered significantly elevated and is used as a flag for further investigation (DITR 2007). The relative GAI scales are provided in Table 6.

Table 6: Geochemical abundance exceedances and GAI number

Sample exceeds crustal abundance by	GAI
1.5 < sample < 3	0
3 ≤ sample < 6	1
6 ≤ sample < 12	2
12 ≤ sample < 24	3
24 ≤ sample < 48	4
48 ≤ sample < 96	5
96 ≤ sample < 192	6

The GAI for an element is calculated by:

$$GAI = \log_2 [C / (1.5 * S)]$$

(Where C is the elemental concentration in a sample; and S is the median concentration of that element in the reference material (generally a similar rock type reported in the literature).

4.2.3 Metal screening criteria

Arsenic and antimony screening was completed using a preliminary environmental risk assessment approach. To achieve this, appropriate Ecological Investigation Levels (EILs) from NEPM (2013) were selected as an indicator of risk.

Sites visited and sampled during Stages 2 and 2a were a mixture of private lands, national parks and State forest. To achieve the project's aims and objectives, the following two screening criteria were adopted:

- areas of ecological significance; and
- urban residential and public open space.

The use of screening criteria in this study is not prescriptive, rather, provides an indication of those sites that may require priority rehabilitation, if any.

The 2013 NEPM does not, however, present any appropriate investigation levels for antimony in mineral waste. In lieu of this fact, Regional Screening Levels (RSLs) for residential and industrial soil were used as an indicative guide (USEPA 2014).

The investigation levels for arsenic and antimony in mineral waste are provided in Table 7.

Table 7: Mineral waste arsenic and antimony screening criteria

Analyte	Units	EIL[1]	EIL[2]	USEPA[3]	USEPA[4]
		Aged			
Antimony	mg/kg	-	-	31	470
Arsenic		40	100	-	-

1: Ecological investigation level – area of ecological significance (Schedule B5a NEPM 2013). 'Aged' represents material that has been exposed and weathering for over two years'. The 'fresh' value is 20 mg/kg.

2: Ecological investigation level – urban residential / public open space (Schedule B5a NEPM 2013). The 'fresh' value is 50 mg/kg.

3: Regional Screening Level (RSL) for residential soil (US EPA 2014)

4: RSL for industrial soil (US EPA 2014).

4.2.4 Mineral Waste Leaching

To determine the risk posed from elevated arsenic and antimony concentrations in mineral waste, the mobility of the metalloids must be established. To achieve this, accelerated weathering tests were undertaken using the Australian Standards Leaching procedure (ASLP) using a deionised water solution. ASLP, rather than the toxicity characteristics leaching procedure (TCLP) test, was undertaken to better represent regional drainage pH values within the Macleay Catchment, which are known to be circumneutral (around pH 7.0) or slightly alkaline—with isolated exceptions largely in the Chandler sub-catchment (Ashley and Graham 2001).

ASLP leaching tests completed during Stages 2 and 2a were intended to be indicative only for the purposes of identifying the risk of arsenic and/or antimony leaching from mineral waste and sediment, and therefore, potentially causing an environmental risk. The leaching test results therefore, cannot be directly extrapolated to predict leachate quality in the field. Rather, the results remain useful as being indicative of potentially leachable elements from mineral waste and sediments across the Macleay Catchment.

ASLP results were, however, compared against the 95 % freshwater aquatic ecosystem survival guideline trigger values (ANZECC & ARMCANZ 2000) (refer Table 9) for indicative purposes. The comparison does not consider natural processes such as dilution and/or adsorption that may occur; therefore, the comparison was intended for indicative risk screening only.

4.3 Sediment

Arsenic and antimony concentrations in sediment were compared against the *Interim Sediment Quality Guidelines* (ISQG) (ANZECC & ARMCANZ 2000), which define ISQG-high and ISQG-low values. These values represent the lower 10th percentile and the 50th percentile respectively, of chemical concentrations associated with adverse biological effects.

Having derived the baseline sediment arsenic and antimony values from the data set for non-mining catchments in Stage 1, the 80th percentile values were also used as site-specific screening criteria for the Macleay Catchment (refer to Table 8).

Table 8: Arsenic and antimony sediment screening criteria

	Units	Arsenic	Antimony
Baseline derived 80th percentile; or site specific screening criteria[1]	mg/kg	12.5	1.2
ISQG (low)		20.0	2.0
ISQG (high)		70.0	25.0

1: Based on the 80th percentile values for sediment data collected in the 12 non-mining sub-catchments (refer to GHD 2015)

ISQG – Interim sediment guidelines.

Note that the arsenic value for the Ecological Investigation Level (area of ecological significance) for mineral waste shown in Table 7 (being 40 mg/kg) is approximately half way between the low and high ISQG values provided for arsenic in sediment in Table 8, demonstrating relative consistency in selected screening criteria. In contrast, the USEPA (2014) guideline value for residential soil antimony of 31 mg/kg slightly exceeds the ISQC (high) value for sediment antimony of 25 mg/kg; however, remains consistent at order of magnitude level for the stated purposes of screening undertaken in this project.

As a point of comparison, Ashley *et al* (2007) using data originally documented in Ashley and Graham (2001) reported stream sediment background concentrations of arsenic at 7.9 mg/kg and antimony at 1.1 mg/kg.

4.4 Surface Water

Site-specific background or baseline surface water values were derived for arsenic and antimony using the historic surface water data reported in GHD (2015); a method consistent with that outlined in ANZECC & ARMCANZ (2000).

The method adopted was percentile based—it used data within one standard deviation from the mean to determine 'average' or 'typical' water chemistry values. Specifically, the 80th percentile established for non-mining sub-catchments was used to determine the baseline or background concentration value (refer to Table 9). This was deemed appropriate as those sub-catchments with no mining history, though with known prospects, could be compared against the baseline surface water values established for arsenic and antimony in non-mining sub catchments to quantify any variance accounted for by naturally occurring arsenic and antimony flux.

Under the ANZECC & ARMCANZ (2000) guidelines, the Macleay River may be considered a 'slightly modified freshwater system'. Therefore, values for the 95 % species protection level were used as a screening tool for arsenic and antimony concentration in surface water—noting that ANZECC & ARMCANZ (2000) provide only a 'low reliability' value for antimony.

Given the land use in the lower Macleay Catchment, surface water arsenic and antimony concentrations were also compared against stock watering and short and long-term irrigation screening criteria (ANZECC & ARMCANZ 2000).

Surface water arsenic and antimony results were also compared against the Australian Drinking Water Guidelines (ADWG) (NHRMC and NRMMC 2011) values for arsenic and antimony.

All surface water screening criteria used herein to assess arsenic and antimony concentrations are provided in Table 9.

As a point of comparison, Ashley *et al.* (2007), using data originally documented in Ashley and Graham (2001), reported surface water background concentrations of arsenic at 0.004 mg/L and antimony at 0.003 mg/L. Ashley *et al.* (2007) also reported that background pH values in the Macleay were slightly alkaline at 7.7, while background electrical conductivity (EC) values were reported at 200 µS/cm.

Table 9: Surface water chemistry arsenic and antimony criteria

Guideline value	Units	Arsenic	Antimony
Baseline derived 80th percentile; or site-specific screening value[4]	mg/L	0.003	0.0025
Australian Drinking Water Guidelines (2011)		0.010	0.003
ANZECC & ARMCANZ (2000) 95% species protection limit		0.013[1] 0.024[2]	0.009[3]
ANZECC & ARMCANZ (2000) irrigation (long term)		0.1	-
ANZECC & ARMCANZ (2000) stock watering		0.5	-
ANZECC & ARMCANZ (2000) irrigation (short term)		2.0	-

1: As V. 2: As III. 3: Low reliability value. 4: Based on the 80th percentile values for surface water data collected in the 12 non-mining catchments (GHD 2015).

5. Results

5.1 Introduction

Summary analytical results for the mineral waste, sediment and surface water are presented in this chapter, with summary results of the mineral waste, sediment and surface water results for the Bakers Creek sub-catchment presented in Chapter 6.

Consistent with the NEPM (2013) methodology for a preliminary ecological risk assessment, and the contaminant source and pathway logic previously described in Section 3.2, the results are presented as follows:

- Mineral waste geochemistry – identifies if any elevated arsenic and antimony is present in waste rock on site that may act as a point or diffuse contaminant source. Also determines the risk of acid, saline and / or metalliferous drainage from mineral waste.
- Sediment geochemistry – identifies any variance between arsenic and antimony concentrations in sediment down-catchment relative to up-catchment of any mineral waste point or diffuse source. Also determines the risk of acid, saline and / or metalliferous drainage from sediment. The data were used to assess if arsenic and / or antimony contaminated sediment is migrating from site.
- Surface water - identifies any variance between arsenic and antimony concentrations in surface water down-catchment relative to up-catchment of any mineral waste point or diffuse source. The data were used to assess if any contaminated runoff is leaving site.

By assessing the arsenic and antimony results for the mineral waste, sediment and surface water, a snapshot of the overall contamination risk posed on, and from, each site can be made to inform priority remedial action as required.

Detailed results are provided in Appendix A, summary tables showing analytical results for mineral waste, sediment and surface water provided in Appendix D, with geochemical abundance index calculations being provided in Appendix E.

5.2 Site location and condition

To help provide context to any arsenic and antimony risk by site as assessed from mineral waste, sediment and surface water results, a summary table of site features is provided in Appendix B. Information such as location, land use and accessibility to site for example, are important inputs when ranking sites for priority remedial action.

Information for each site visited, as provided in Appendix B, includes:

- The site name
- Any other names the site has or does is known by
- The site location (latitude and longitude)
- Macleay sub-catchment in which the site is located and the size of that sub-catchment
- Distance to the nearest town
- Commodity explored or mined
- Dates mined if applicable
- Date inspected
- General site data and features

- Heritage
- Rehabilitation status
- Surface materials and their stability
- Landforms
- Distance to the nearest watercourse
- Site vegetation cover
- Hazards
- Distance key mine features are from site perimeter
- Safety risk rating
- Environmental risk rating.

5.3 Mineral Waste

Detailed mineral waste geochemical results are located in Appendix A. Table 10 shows a summary of the risk of acid, saline and / or metalliferous drainage from the 10 sites from which mineral waste was sampled and analysed.

Table 10: Summary of mineral waste acid, saline and metalliferous drainage risk by site

Sample	AMD risk	Saline drainage risk	Metalliferous drainage risk
Chandler - Upper			
Phoenix Gold	Low - Med	Med	**High** (As and Sb)
Rockvale	Low - Med	Med-**High**	**High** (As and Sb)
Ruby Silver	Low	Med-**High**	**High** (As and Sb)
Tulloch	Med - **High**	Low-Med	**High** (Sb)
Chandler - Lower			
Khans Creek	**High**	Low-**High**	**High** (other metals)
Mickey Mouse	Med	Med	**High** (Sb)
Commissioners Waters			
Kapunda	Low	Low	**High** (As and Sb)
Mary Anderson	Low	Low	**High** (As and Sb)
Apsley			
Europambela	Med-**High**	Low-Med	**High** (other metals)
Hickeys / Mungay Creeks			
Mungay Ck	Low-Med	Low	**High** (Sb)

The summary provided in Table 10 broadly support existing descriptions of the environmental geochemistry of the Macleay Catchment in the published literature. That is, that orogenic gold-arsenic-antimony mesothermal vein type deposits give rise to extensive, as well as localised, naturally-occurring stream sediment and water geochemical anomalies due to the dissolution of oxidised stibnite (Sb_2S_3), arsenopyrite (FeAsS) and pyrite (FeS_2). The anomalies also occur as a result of mineral waste oxidation and dissolution (e.g. NSW Department of Mineral Resources 1992, Ashley *et al.* 2007, Ashley and Graham 2001, Ashley and Wolfenden 2005).

Considering the regional geology of the various sub-catchments, this generally leads to a (relatively) low overall risk of acid and saline drainage, albeit slightly higher in the Halls Peak Mineral Field in the Lower Chandler, the Rockvale area in the Upper Chandler, and on the Europambela site in the Apsley sub-catchment. There does however, remain a high risk of metalliferous drainage from all 10 sites sampled.

5.4 Sediment

Detailed sediment geochemical results are located in Appendix A. Table 11 provides a summary of the risk of acid, saline and / or metalliferous drainage from sediment for each of the 13 sites from which sediment was sampled.

Table 11: Summary of sediment acid, saline and metalliferous drainage risk by site

Sample	AMD risk	Saline drainage risk	Metalliferous drainage risk
Chandler - Upper			
Phoenix Gold	Low-Med	Low	**High (As, Sb)**
Rockvale	Low	Low	**High (As, Sb)**
Ruby Silver	Low	Low	Low - Med
Tulloch	Low-Med	Low	**High (As, Sb)**
Chandler - Lower			
Chandler	Low	Low	Low
Khans Creek	Low	Low	**High (Sb, As)**
Mickey Mouse	Low	Low	Med (other metals)
Sunnyside	Low	Low	Med (other metals)
Commissioners Waters			
Kapunda	Low	Low	Med-**High (As)**
Mary Anderson	Low	Low	Med-**High (As, Sb)**
Apsley			
Europambela	Low	Low	Med (other metals)
Hickeys / Mungay Creeks			
Mungay Ck	Low	Low	**High (As, Sb)**
Toorumbee Creek and Warbro Brook			
Warbro Brook	Low	Low	Med (As)

Table 11 shows that the sediment geochemical results are broadly consistent with the mineral waste geochemical summary in Table 10—particularly as it pertains to the risk of metalliferous drainage. This suggests that sediment is generally sourced from arsenic and antimony-contaminated mineral waste. The variance in acid drainage risk between sediment and mineral waste is likely due to the sediment being largely oxidised as it interfaces with aqueous and atmospheric oxygen in drainage lines.

An overview of the sediment results presented in detail in Appendix A is provided below for each site by sub-catchment.

5.4.1 Chandler – Upper

Phoenix Gold

One down-catchment sediment sample at Phoenix Gold returned an acidic pH value and had limited self-buffering potential. Two down-catchment samples also returned GAI values with relatively elevated arsenic and one with relatively elevated antimony. Two samples contained antimony concentrations above ISQG high trigger values, with one arsenic value exceeding the ISQG low trigger value. One sample leached antimony above ANZECC / ARMCANZ (2000) guidelines. By and large, the down-catchment sediment values are consistent with the mineral waste, suggesting that the weathering waste rock may be migrating downslope and offsite as sediment.

Ruby Silver

Both sediment samples at Ruby Silver did not have adequate self-buffering capacity. The down-catchment sediment sample had arsenic concentrations above background concentrations and leached arsenic above ANZECC (2000) guidelines. The results are broadly consistent with the mineral waste results suggesting that weathered material from the waste rock dump may be migrating downslope and offsite as sediment.

Tulloch

The sediment sample collected immediately below the site workings (TS_SD02) did not have adequate self-buffering capacity and returned a NAPP value of 8.9 kg H_2SO_4/tonne. This is consistent with the mineral waste samples collected on site, one of which was potentially acid forming (PAF). Samples had both relatively elevated arsenic and antimony as measured using the GAI, with both metalloids leaching above ANZECC (2000) guidelines. Down-catchment samples in Boundary Creek returned results reasonably consistent with background metals concentrations indicating that the contaminated sediment may not be reporting off site.

Rockvale

The sediment sample collected immediately below the site workings (RA_SD03) did not have adequate self-buffering capacity. All three samples, including the up-catchment sample (RA_SD01) returned elevated arsenic values as measured using the GAI, suggesting a regional arsenic anomaly. Sample RA_SD03 below the mine workings also returned an elevated antimony concentration as measured using the GAI, which was also over the ISQG low trigger. It also leached both arsenic and antimony above ANZECC (2000) guidelines. The down-catchment sample in Lambs Creek (RA_SD02) returned an antimony concentration that was in excess of the ISQG high trigger value. The results are consistent with the mineral waste geochemical results and suggest that weathered waste rock may be reporting offsite to Lambs Valley Creek as sediment.

5.4.2 Chandler – Lower

Chandler

The Chandler samples collected to account for Stuarts Reef and Rathbones Point East contained no anomalous results, indicating that these two sites may not be an issue with respect to the aim of this study.

Khans Creek

The Khans Creek down-catchment sediment sample (KC_SD01) had elevated arsenic relative to the GAI; and had arsenic and antimony concentrations in excess of the ISQG low trigger values. The results are consistent with the mineral waste metals results and suggest that weathered waste rock in the form of sediment may be reporting offsite.

Keys Prospect

One anomalous result was reported from the Keys Prospect being the upriver sample (KP_SD03). This returned arsenic concentrations slightly in excess of background concentrations, indicating that the Keys Prospect is not contributing to off-site contamination and that there remain anomalous sediment metals concentrations in the Chandler River itself in the area containing the Halls Peak Mineral Field—noting that the result did not exceed ISQG low trigger values.

Mickey Mouse

The two Mickey Mouse samples collected contained no anomalous results, indicating that this site may not be an issue with respect to the aim of this study. Note that the leached sample (MM_SD01) did contain elevated cadmium and zinc as measured using GAI and leached aluminium, cadmium, chromium, copper, lead and zinc at concentrations above ANZECC (2000) guidelines.

Sunnyside

The one Sunnyside sample collected contained no anomalous results, indicating that this site may not be an issue with respect to the aim of this study. Note that the leached sample (SS_SD01) did leach aluminium, chromium, copper, lead and zinc at concentrations above ANZECC (2000) guidelines.

5.4.3 Commissioners Waters

Kapunda

Both Kapunda sediment samples contained relatively elevated arsenic concentrations using the GAI, with both the up and down-catchment samples exceeding ISQG low trigger values. The leached sample (KA_SD02) leached arsenic (as well as aluminium, chromium, copper and zinc). The results are consistent with the single waste rock sample indicting that arsenic rich sediment may be migrating off site into Tilbuster Ponds.

Mary Anderson

The down-catchment sample (MA_SD01) contained relatively elevated arsenic concentrations using the GAI, with arsenic concentrations marginally exceeding background, though not the ISQG low trigger value. The up-catchment sample (MA_SD02) collected from a water dam leached various metals though not arsenic or antimony, exceeded the ISQG low trigger value for arsenic and the high trigger value for antimony—consistent with mineral waste metals results. As there were mine workings and scalds over this site, the results may indicate that the water dams on site are doing a reasonable job at containing contaminated sediment, with down-catchment metals concentrations approaching background. There may be antimony-contaminated sediment migrating off site, depending on where the 'site boundary' is demarcated.

5.4.4 Apsley

Europambela

The three samples collected at Europambela are all relatively benign, although the downstream sample (E_SD02) did leach various metals, although not arsenic or antimony. As the mineral waste on site was PAF and contained elevated arsenic concentrations, these results would suggest that little to no contaminated sediment is moving off site into the Apsley River.

5.4.5 Hickeys / Mungay Creeks

Mungay Creek

All three sediment samples at Mungay Creek were elevated in arsenic using GAI, and two were elevated in antimony. Both samples collected on site (MC_SD01 and 02) leached antimony at concentrations above ANZECC (2000) and had antimony concentrations that exceeded the ISQG high trigger value. One sample (MC_SD02) exceeded the ISQG high trigger value for arsenic. Mineral waste samples showed significantly elevated antimony (up to 0.4%). However, the sample collected from well down-catchment (MC_SD03) was approaching background concentrations, indicating that contaminated sediment may be migrating off site, depending on where the 'site boundary' is demarcated.

5.4.6 Toorumbee Creek and Warbro Brook

Warbro Brook

The single Warbro Brook sample contained relatively elevated arsenic using the GAI method, with arsenic concentrations being above the ISQG low trigger value. This suggests that the sub-catchment is naturally elevated in arsenic from known mineral prospects (Willi Willi), as it has not been mined. This result suggests that sub-catchments naturally elevated in arsenic and/or antimony are likely contributing to the overall load of contaminated sediment in the Macleay River itself.

5.4.7 Sediment summary

In summary, the following sites may have contaminated sediment migrating off site:

- Upper Chandler sub-catchment: Phoenix Gold, Ruby Silver, Rockvale Arsenic
- Lower Chandler sub-catchment: Khans Creek
- Commissioners Waters sub-catchment: Kapunda Arsenic, Mary Anderson
- Hickeys / Mungay Creek sub-catchment: Mungay Creek.

As the geochemistry of the contaminated sediment is relatively consistent with that of the mineral waste on the same site, it is likely that the sediment is being generated from weathering mineral waste on each respective site. This information is useful to help inform an overall rehabilitation strategy for those sites showing evidence of off-site migration of arsenic and antimony contamination.

5.5 Surface Water

This section summarises the arsenic and antimony surface water results as compared to the environment screening criteria shown in Section 4.4. Detailed surface water results are shown in Table G, Appendix D. Figures for each site showing surface water sample locations are provided in Appendix F.

The results below are limited to those that exceeded the most conservative screening criteria, being the background arsenic (0.003 mg/L) and antimony (0.0025 mg/L) values. Sites that did not exceed these nominated minimal criteria, and are therefore not discussed further in this section, are:

- Chandler – Lower: Stuart Reef and Rathbone Point East (Chandler samples), Keys Prospect, Sunnyside, and Mickey Mouse
- Aspley – Europambela.

Note also that no surface water sample could be collected at Khans Creek in the Lower Chandler as there was no surface water evident anywhere on or proximal to site.

5.5.1 Chandler – Upper

Phoenix Gold

Arsenic and antimony contaminated acid (pH value ~ 3) water with elevated EC values (~1,500 µS/cm) was sampled on site emanating from an historic mine shaft and reporting to an on-site water dam. As a result, there were arsenic concentrations in the down-catchment sample suggesting off site migration of arsenic in surface water. This is consistent with the sediment and mineral waste results for site.

Ruby Silver

The up-catchment surface water sample had elevated arsenic as did the down-catchment sample. Antimony does not appear to be an issue. These results are consistent with the sediment and mineral waste results that suggest that arsenic contaminated sediment and surface water may be migrating off site.

Tulloch

An up-catchment surface water sample suggests natural mineralisation above the current workings as it contained above background concentrations of arsenic and antimony. Arsenic and antimony contaminated drainage persists downslope of the mine workings, although reduce to below background concentrations once the mine creek meets Boundary Creek. The surface water results mirror the sediment results indicating that the contaminated sediment may not be reporting off site.

Rockvale

The up-catchment sample showed elevated arsenic, as did the acidic (pH ~ 4.3; EC ~ 1,000 µS/cm) drainage line leaving the mine workings. The down-catchment sample on Lambs Valley Creek also exceeded ANZECC 95 % criteria. These results are consistent with the sediment and mineral waste results that suggest that arsenic contaminated sediment and surface water may be migrating off site.

5.5.2 Chandler – Lower

Chandler

Consistent with the sediment results, the Chandler samples collected to account for Stuarts Reef and Rathbones Point East contained no anomalous results, indicating that these two sites may not be an issue with respect to the aim of this study.

Khans Creek

No surface water sample could be collected. However, the Khans Creek down-catchment sediment sample (KC_SD01) had elevated arsenic relative to the GAI; and had arsenic and antimony concentrations in excess of the ISQG low trigger values. The results are consistent with the mineral waste metals results and suggest that weathered waste rock may be reporting offsite in the form of contaminated sediment.

Keys Prospect

None of the three surface water samples exceeded background arsenic or antimony concentrations. The only anomalous result at Keys Prospect was the upriver sample (KP_SD03) that returned arsenic concentrations slightly in excess of background concentrations. This indicates that the Keys Prospect is not contributing to off-site contamination and that there remain anomalous sediment metals concentrations in the Chandler River itself in the area containing the Halls Peak Mineral Field—noting that the result did not exceed ISQG low trigger values.

Mickey Mouse

Neither of the two surface water (or sediment) samples exceeded background arsenic or antimony concentrations.

Sunnyside

The one Sunnyside surface water (and sediment) sample collected did not exceed background arsenic or antimony concentrations.

5.5.3 Commissioners Waters

Kapunda

The up-catchment surface water sample on Tilbuster Ponds returned slightly elevated arsenic concentrations, as did the down-catchment sample. These data are consistent with sediment data collected at the same locations. Antimony appears not to be an issue. Whilst the waste rock on site was also elevated in arsenic, the upstream data suggests there may be other influences impacting drainage quality in this sub-catchment beyond this site.

Mary Anderson

Surface water samples collected from site indicate elevated arsenic concentrations, with down-catchment samples returning arsenic slightly exceeding background concentrations, and antimony above ADWG (2011) levels, circumneutral pH values, elevated sulfate (~ 300 mg/L) and elevated EC (~ 1,000 μS/cm). The data are reasonably consistent with mineral waste and sediment data and indicate that a small amount of contaminated sediment and water may be leaving site, depending on where the site boundary is demarcated.

5.5.4 Apsley

Europambela

Neither of the three surface water (or two sediment) samples exceeded background arsenic or antimony concentrations. As the mineral waste on site was potentially acid forming and contained elevated arsenic concentrations, these results would suggest that little to no contaminated sediment is moving off site into the Apsley River.

5.5.5 Hickeys / Mungay Creeks

Mungay Creek

Consistent with the sediment samples, on site surface water samples indicate elevated arsenic and antimony below the mine workings. These concentrations have returned to below background levels by around 1.7 km downstream. All three sediment samples at Mungay Creek were elevated in arsenic using the geochemical abundance index, and two were elevated in antimony. Both samples collected on site (MC_SD01 and 02) leached antimony at concentrations above ANZECC (2000) and had antimony concentrations that exceeded the ISQG high trigger value. One sample (MC_SD02) exceeded the ISQG high trigger value for arsenic. Mineral waste samples showed significantly elevated antimony (up to 0.4%). However, the sediment sample collected from well down-catchment (MC_SD03) was approaching background concentrations. These results indicate that contaminated sediment and surface water may be migrating off site, depending on where the site boundary is demarcated.

5.5.6 Toorumbee Creek and Warbro Brook:

Warbro Brook

The single surface water sample returned arsenic concentrations above background. Antimony was below background. This is consistent with the sediment sample and suggests that the sub-catchment is naturally elevated in arsenic from known, unmined mineral resource prospects (Willi Willi).

5.5.7 Surface water summary

In summary, the following sites may have contaminated sediment migrating off site:

- Upper Chandler sub-catchment: Phoenix Gold, Ruby Silver, Rockvale Arsenic
- Commissioners Waters sub-catchment: Kapunda Arsenic, Mary Anderson
- Hickeys / Mungay Creek sub-catchment: Mungay Creek.

The sites are consistent with those showing evidence of contaminated waste rock and sediment, indicating that clean water is becoming contaminated on those sites with contaminated waste rock and tailings. This information is useful to help inform an overall rehabilitation strategy for those sites showing evidence of off-site migration of arsenic and antimony contamination

5.6 Summary

Table 12 provides a high-level summary of the mineral waste, sediment, and surface water results for each site as they relate to their respective assessment criteria provided in Section 4. Those sites where the data indicate likely off site migration of contaminants are noted and have been bolded. Relative contributions of each site to the overall Macleay Catchment contamination are provided in Section 7, following presentation of the Bakers Creek sub-catchment data in Section 6.

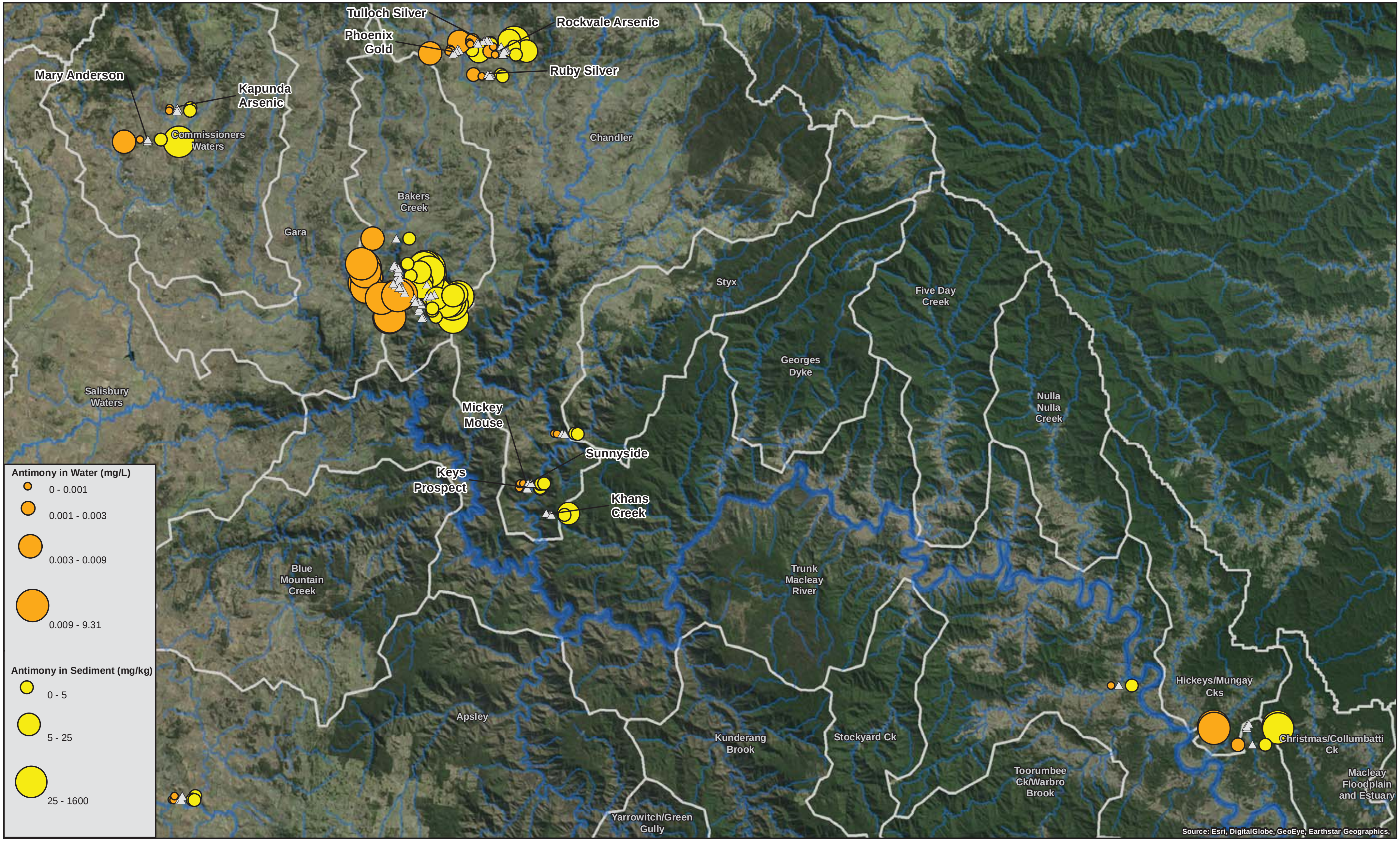
Figure 4 shows a catchment-wide snapshot of antimony results in sediment and surface water, while Figure 5 presents a catchment-wide snapshot of arsenic results in sediment and surface water. Sub-catchment specific figures showing arsenic and antimony are provided in Appendix F.

Table 12: Summary of mineral waste, sediment and surface water results by site

Sample	Mineral waste	Sediment	Surface water	Off-site migration (contaminant)?	Comment
Chandler - Upper					
Phoenix Gold	**X**	**X**	**X**	**Yes (As)**	Acid rock drainage present
Ruby Silver	**X**	**X**	**X**	**Yes (As)**	-
Tulloch	**X**	**X**	**X**	No	PAF waste rock on site
Rockvale	**X**	**X**	**X**	**Yes (As)**	Acid rock drainage present
Chandler - Lower					
Chandler (Rathbones Point East and Stuart Reef)	NS	√	√	No	-
Khans Creek	**X**	**X**	NS	**Yes (Sb, As)**	Contaminated sediment down-catchment. PAF waste rock on site. No water sample.
Keys Prospect	NS	√	√	No	-
Mickey Mouse	NS	√	√	No	-
Sunnyside	NS	√	√	No	-
Commissioners Waters					
Kapunda	**X**	**X**	**X**	**Yes (As)**	Up-catchment contaminant sources likely
Mary Anderson	**X**	**X**	**X**	**Yes (Sb)**[1]	Neutral mine drainage present
Apsley					
Europambela	**X**	√	√	No	PAF waste rock on site
Hickeys / Mungay Creeks					

Sample	Mineral waste	Sediment	Surface water	Off-site migration (contaminant)?	Comment
Mungay Ck	**X**	**X**	**X**	**Yes (As, Sb)**[1]	-
Toorumbee Creek and Warbro Brook					
Warbro Brook	NS	**X**	**X**	NA	Naturally elevated background from known mineral prospects

X contaminated; √ not contaminated; NS that media not sampled; NA not applicable – no 'site' *per se*. 1: This depends on where the 'site' boundary is located.



Note: Where duplicate samples were collected, the highest of the two readings was used
Sample results have been offset to the left/right of the sample locations

Paper Size A3

0 2,250 4,500 9,000 13,500

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND
Subcatchment Boundaries
Sample Locations
Watercourses

NSW Department of Trade and Investment
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	24 May 2016

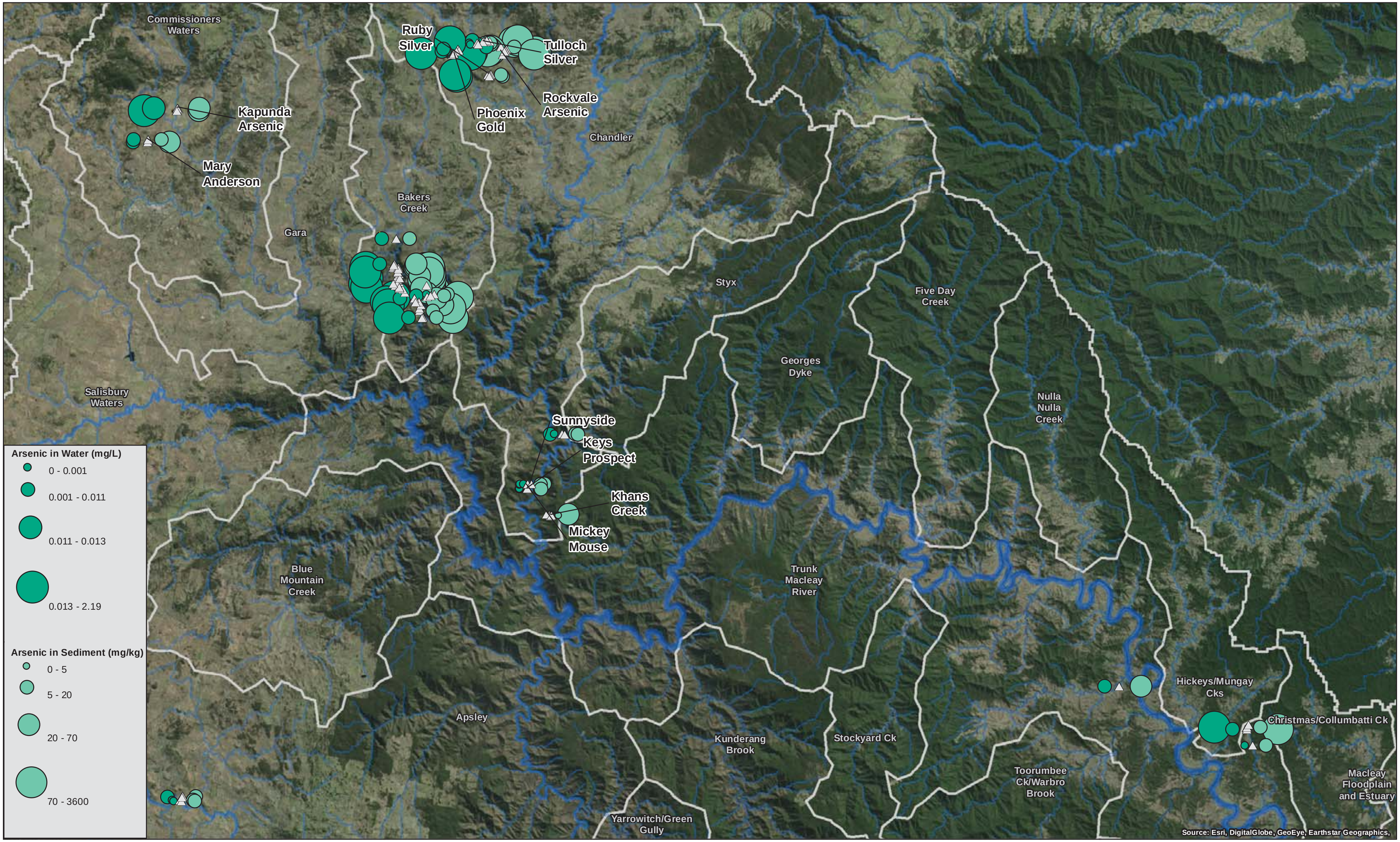
Macleay Catchment
Antimony in Sediment and Water

Figure 4

\\ghdnet\ghd\AU\Sydney\Projects\21\23815\GIS\Maps\Deliverables\STAGE 2\2123815_Z017_MINEVISITS_OverviewAntimonyArsenic.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:mweber



Note: Where duplicate samples were collected, the highest of the two readings was used
Sample results have been offset to the left/right of the sample locations

Paper Size A3

0 2,250 4,500 9,000 13,500

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND
Subcatchment Boundaries
Sample Locations
Watercourses

NSW Department of Trade and Investment
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	19 May 2016

Macleay Catchment
Arsenic in Sediment and Water

Figure 5

\\ghdnet\ghd\AU\Sydney\Projects\21\23815\GIS\Maps\Deliverables\STAGE 2\2123815_Z017_MINEVISITS_OverviewAntimonyArsenic.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:mweber

6. Results - Bakers Creek

6.1 Introduction

The environmental geochemistry of the Hillgrove Mineral Field within the Bakers Creek sub-catchment was completed during Stage 2a of the project. The Hillgrove mineral field is the major mineralised region in the Macleay Catchment, dominated by the orogenic antimony – arsenic – gold vein associations (Ashley *et al*. 2007). Ashley *et al.* (2003) noted that there were:

> "no acid drainage issues in the Hillgrove mineral field due to the presence of hydrothermal carbonate in the ore and host rock that buffers acid production from the oxidative breakdown of sulfides."

Notwithstanding the above, the presence of over 200 individual mineral occurrences in the Hillgrove Mineral Field (NSW Department of Mineral Resources 1992), and over 500 known individual mine features (EA Systems 2003) from historic operations at Hillgrove has left a complex mining legacy to manage. This is further complicated by:

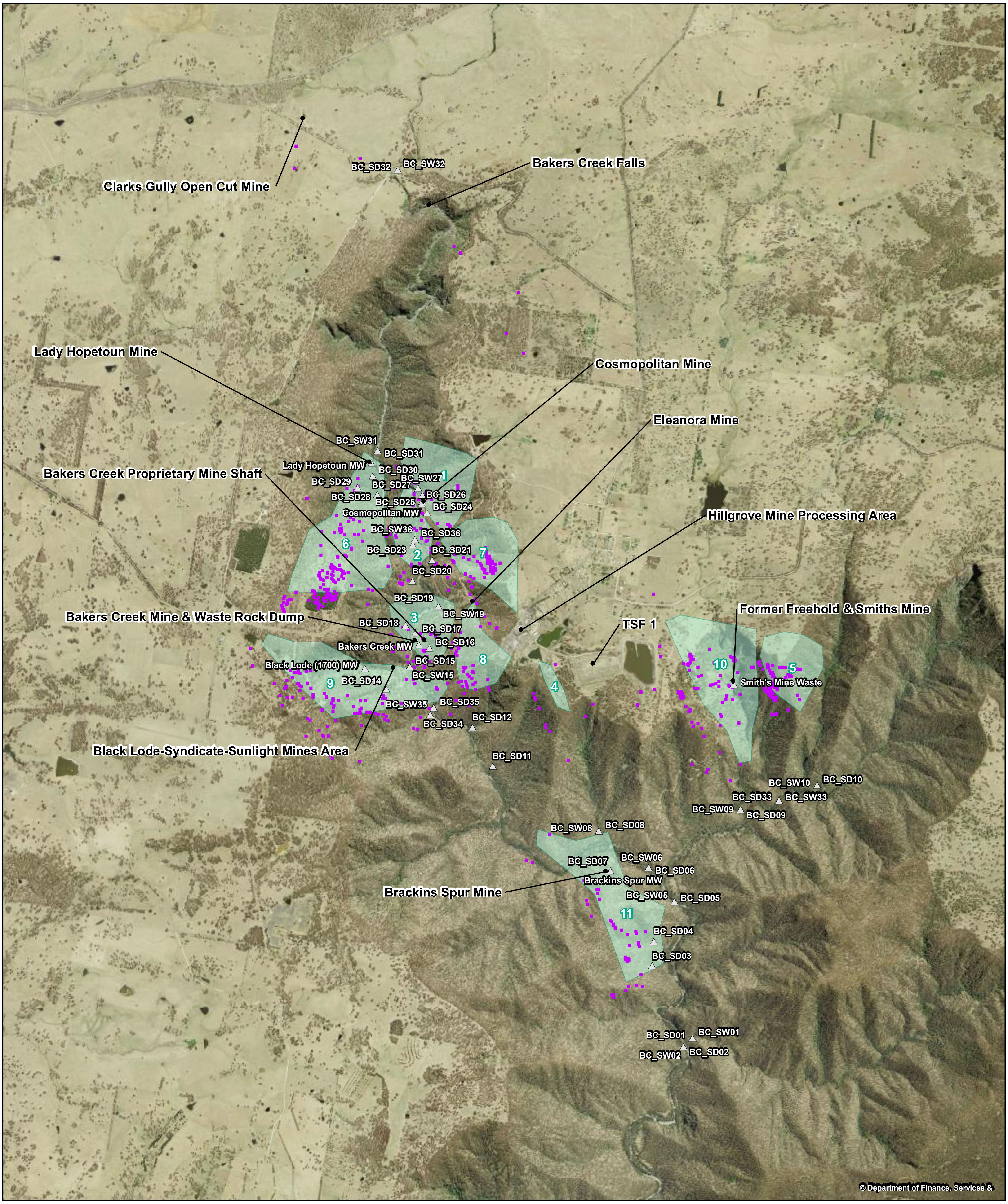
- attempting to demarcate contaminant loads by mine feature
- ongoing work on determining the responsible party for rehabilitating each of the 500 plus individual mining features
- historic mining practices where ore and waste were deposited in creek lines have led to an environmental geochemical legacy which may have no practical and cost-effective ameliorative solution using today's technology other than time.

The following section presents a summary of the geochemical results from the samples collected in the Hillgrove Mineral Field during Stage 2a of the project. Mineral waste is presented first, then sediment geochemistry followed by metals results for sediment and surface water.

The ultimate approach to assessing the key contaminant point sources through a series of strategically located sample locations within Bakers Creek, and selected sample locations at key suspected contaminant input points was deemed appropriate for the Bakers Creek sub-catchment.

The assessment method as agreed with the Derelict Mines Program of remaining consistent with the EA Systems (2003) domains of mine workings had limited practical application when attempting to demarcate key contaminant inputs down the Bakers Creek system. This was due to the EA Systems (2003) mine working domains not being aligned with natural catchment boundaries. This may be due to the EA Systems (2003) report being an inventory of disturbed mining areas rather than a higher-level assessment of key contributing sub-catchments, with a view to identifying those key features within each sub-catchment that may be contributing to the contaminant load. Furthermore, there remain a large number of mining surface features identified, though not accounted for in EA Systems (2003) mine domains. This approach was deemed necessary for this study given the scope; i.e. it was not feasible to assess the individual contaminant contributions of over 500 mine workings in this study.

GHD's Bakers Creek sub-catchment sample locations for Stages 2 and 2a are presented along with the 11 main mine domains from EA Systems (2003) report on Figure 6.



MW = Mineral Waste

LEGEND

- Mine Domains
- Watercourses
- Minor Watercourses
- Mine Workings
- Sample Point Locations

Paper Size A3

0 140 280 560 840 1,120

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	08 May 2018

Baker's Creek Sampling Locations

Figure 6

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_F6_Z018_BAKERSCREEK_SampleLocations.mxd Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: Imagery - ©Land and Property Information (Extracted: 08/05/18); Streets, Waterways - NSW LPI 2012 DTDB. Created by:jrbacani

6.2 Mineral Waste

Detailed mineral waste geochemical results are located in Appendix A. Table 13 shows a summary of the risk of acid, saline and / or metalliferous drainage from the 16 sites within the Bakers Creek sub-catchment from which mineral waste was sampled and analysed.

Table 13: Summary of mineral waste acid, saline and metalliferous drainage risk by site

Sample	AMD risk	Saline drainage risk	Metalliferous drainage risk
Bakers Creek			
Bakers Ck 1 – Brackins Spur Mine Waste	Low	Low	**High** (As)
Bakers Ck 2 – Smiths Mine Waste	Low	Low	**High** (As and Sb)
Bakers Ck 3 – Bakers Ck Mine Waste	Low	Low	**High** (As and Sb)
Bakers Ck 4 – Black Lode Mine Waste	Low	Low	**High** (As and Sb)
Bakers Ck 5 – Cosmopolitan Mine Waste	Low	**High**	**High** (As and Sb)
Bakers Ck 6 – Lady Hopetoun Mine Waste	Low	Low	**High** (As and Sb)

The summary provided in Table 13 broadly support existing descriptions of the environmental geochemistry of the Hillgrove Mineral Field in the published literature (Ashley and Graham 2001). That is, a low risk of acid drainage, though a high metalliferous drainage risk. Note also that the mineral waste sample analysed from the Cosmopolitan Mine Waste had a high saline drainage risk (1,610 µS/cm).

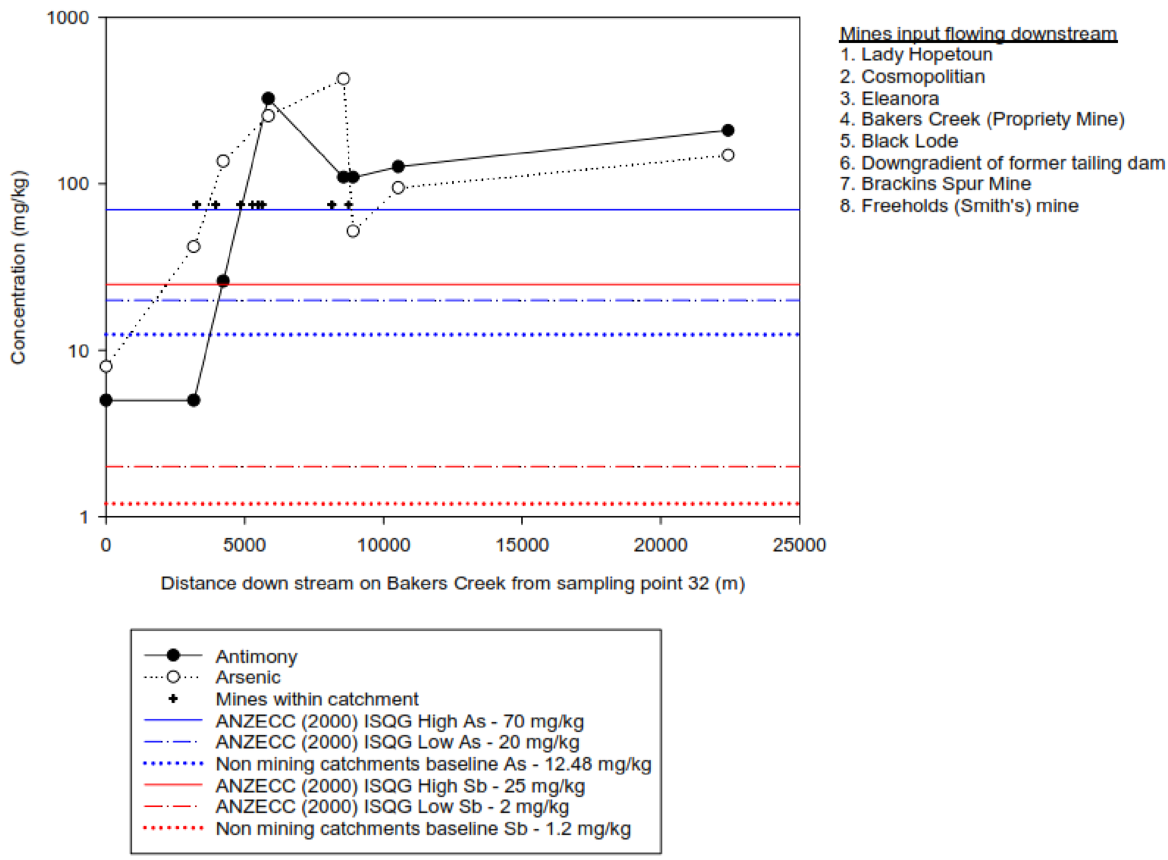
6.3 Sediment

Sediment data for all 36 samples collected within the Bakers Creek sub-catchment are presented in Appendix A. In summary:

- pH values were generally neutral to alkaline indicating a low risk of acid drainage
- electrical conductivity values were generally very low, indicating a low risk of saline drainage
- values for net acid production potential and net acid generation were generally low further indicating a low risk of acid drainage
- most samples were elevated in arsenic and / or antimony, and of those elevated in arsenic and antimony, most leached both arsenic and / or antimony indicating a high risk of metalliferous drainage.

As a visual indicator, Figure 7 shows a long section of the level of arsenic and antimony contamination in sediment along Bakers Creek downstream from the up-catchment sample point 32 (on the 'y axis' on Figure 7). The Black crosses from left to right are shown as inputs from various historic workings in the Bakers Creek sub-catchment to the right of the graph. The arsenic and antimony point at approximately 22 kilometres down Bakers Creek is taken from Ashley and Graham (2001), and shows remarkable temporal consistency with the GHD data.

Figure 7: Bakers Creek sediment contamination long section



6.4 Surface Water

Surface water data for all 15 samples collected within the Bakers Creek sub-catchment are presented in Appendix A. Note that as many of the sample locations were positioned in ephemeral streamlines, there are less surface water samples (n= 15) in the Bakers Creek sub-catchment than sediment samples (n = 36). This is not deemed problematic as Ashley and Graham (2001) noted that the clean water travelling over contaminated sediment was the main mode of water contamination in the Macleay Catchment. Therefore, identifying the key contributors of contaminated sediment remains paramount in managing water quality.

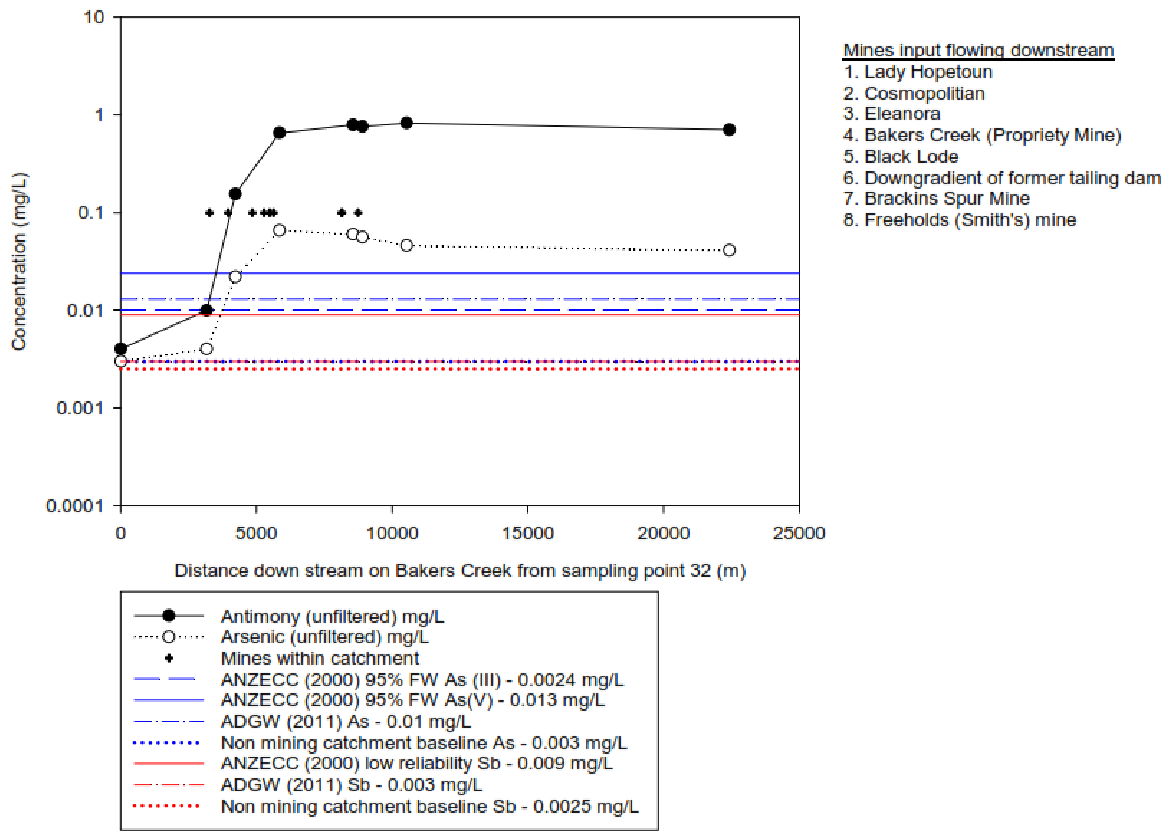
In summary:

- Antimony contamination appears to be higher than arsenic contamination in surface water in the Bakers Creek sub-catchment
- The maximum surface water value for antimony was 9.31 mg/L in Swamp Creek which drain the Smiths mineral waste
- The maximum surface water value for arsenic was 0.245 mg/L in the main gully draining the Black Lode-Syndicate-Sunlight mines.

As a visual indicator, Figure 8 shows a long section of the level of arsenic and antimony contamination in unfiltered surface water along Bakers Creek downstream from the up-catchment sample point 32 (on the ‘y axis’ on Figure 8). The Black crosses from left to right are shown as inputs from various historic workings in the Bakers Creek sub-catchment to the right of the graph. The arsenic and antimony point at approximately 22 kms down Bakers Creek is taken from Ashley and Graham (2001), and again shows remarkable temporal consistency with the GHD data, as did the sediment data.

Note that as the results show that some 15 % of antimony and close to 0 % of arsenic appear to be transported in Bakers Creek in the dissolved form. This is as there was little or no difference between the filtered and unfiltered surface water data. This indicates that adsorption of antimony and arsenic to suspended solids appears to be a key contaminant transport mechanism.

Figure 8: Bakers Creek (unfiltered) surface water contamination long section



6.5 Summary

The implication from GHD's and prior sampling is that there is a large 'slug' of strongly contaminated stream sediment in Bakers Creek for a distance exceeding 15 km. Ashley *et al*. (2007) estimate this to contain around 1,500 tonnes of antimony and 1,000 tonnes of arsenic

The contaminated sediment contains arsenic and antimony concentrations that exceed catchment background concentrations by one to more than two orders of magnitude, and which exceed the ISQG high guidelines by up to 12 times for antimony and 6 times for arsenic. Due to this contaminated sediment, stream water equilibrating with it under ambient conditions (i.e. pH values of 7 to 8 and variable redox) maintain high values of antimony (typically up to 300 times ADWG 2011) and arsenic (typically up to 6 times ADWG 2011) from Hillgrove mine to the Macleay junction.

It would appear that the bulk of the arsenic and antimony contamination in the Bakers Creek sub-catchment is being generated from workings reporting to Bakers Creek between 4.3 kms and 8.9 km downstream from the background sample collected on the plateau (refer to Figure 9 and Figure 10). This stretch of Bakers Creek is around 4.6 km in length receives contaminated sediment and surface water from:

- the historic Black Lode, Syndicate and Sunlight mines
- Golden Gate Gully

- the mine processing area
- the historic Eleanora mine
- the historic Bakers Creek Proprietary Mine waste rock dump
- the historic Brackins Spur mine
- the historic Freehold and Smiths mines.

Refer to Figure 6 for the locations of the six main mineral waste dumps within the Bakers Creek sub-catchment.

This in no way implies that the current operation at the Hillgrove Mine contributes to contamination in the Bakers Creek sub-catchment.

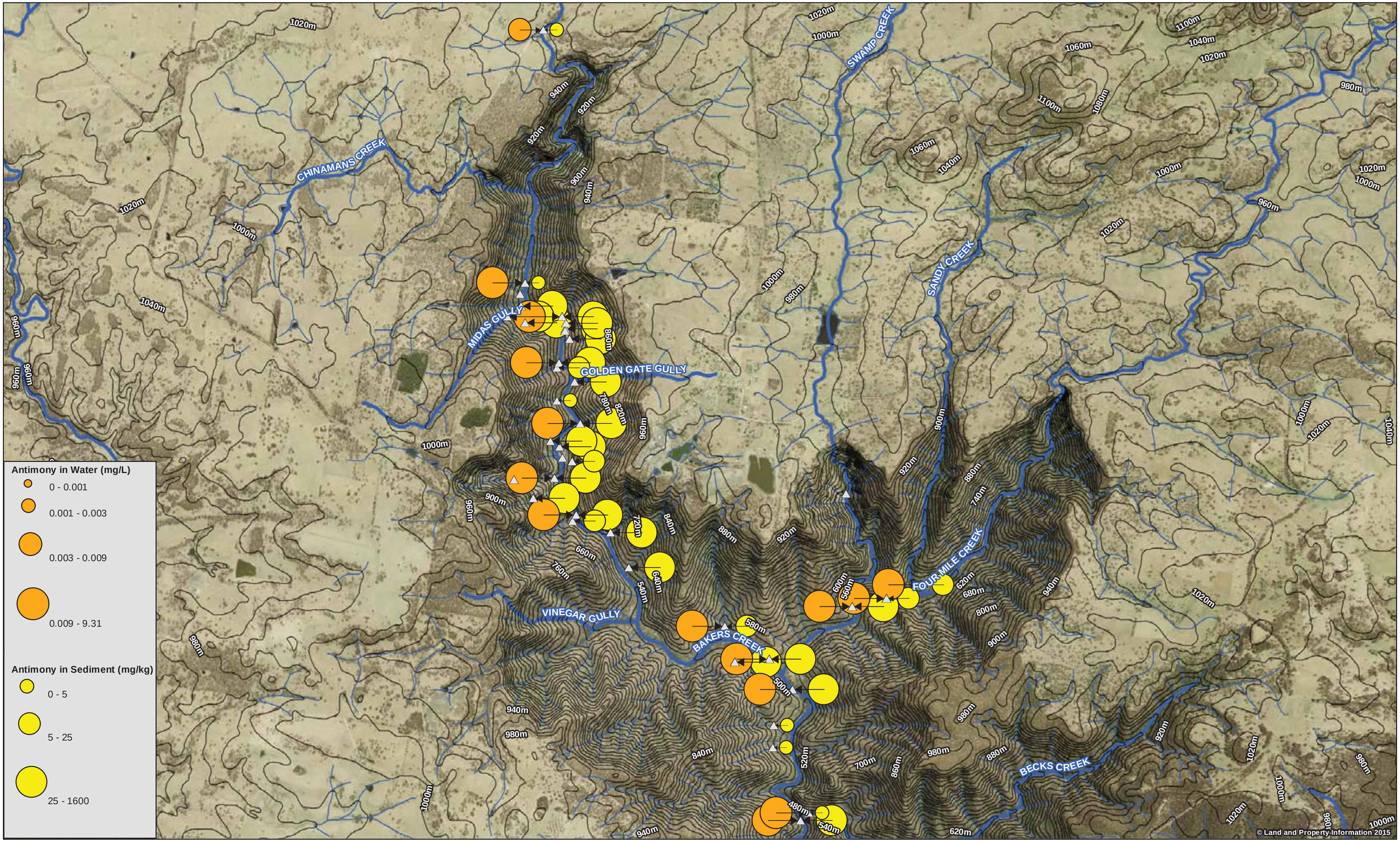
Table 14 is a summary of the mineral waste, sediment and surface water data for the Bakers Creek sub-catchment.

Figure 9 shows spatially the sediment and surface water antimony concentrations in the Bakers Creek sub-catchment, while Figure 10 shows spatially the sediment and surface water arsenic concentrations in the Bakers Creek sub-catchment.

Table 14: Summary of mineral waste, sediment and surface water results by Bakers Creek mine waste

Sample	Mineral waste	Sediment	Surface water	Key contaminant
Bakers Creek				
Bakers Ck 1 – Brackins Spur Mine Waste	**X**	**X**	**X**	**As**
Bakers Ck 2 – Smiths Mine Waste	**X**	**X**	**X**	**As and Sb**
Bakers Ck 3 – Bakers Ck Mine Waste	**X**	**X**	**X**	**As**
Bakers Ck 4 – Black Lode Mine Waste	**X**	**X**	**X**	**As and Sb**
Bakers Ck 5 – Cosmopolitan Mine Waste	**X**	**X**	**X**	**As and Sb**
Bakers Ck 6 – Lady Hopetoun Mine Waste	**X**	**X**	**X**	**As**

X contaminated; √ not contaminated



Note: Where duplicate samples were collected, the highest of the two readings was used

Paper Size A3

0 170 340 680 1,020 1,360

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Sample Locations
- Flow Direction
- Contour (mADH)
- Watercourses
- Drainage

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	19 May 2016

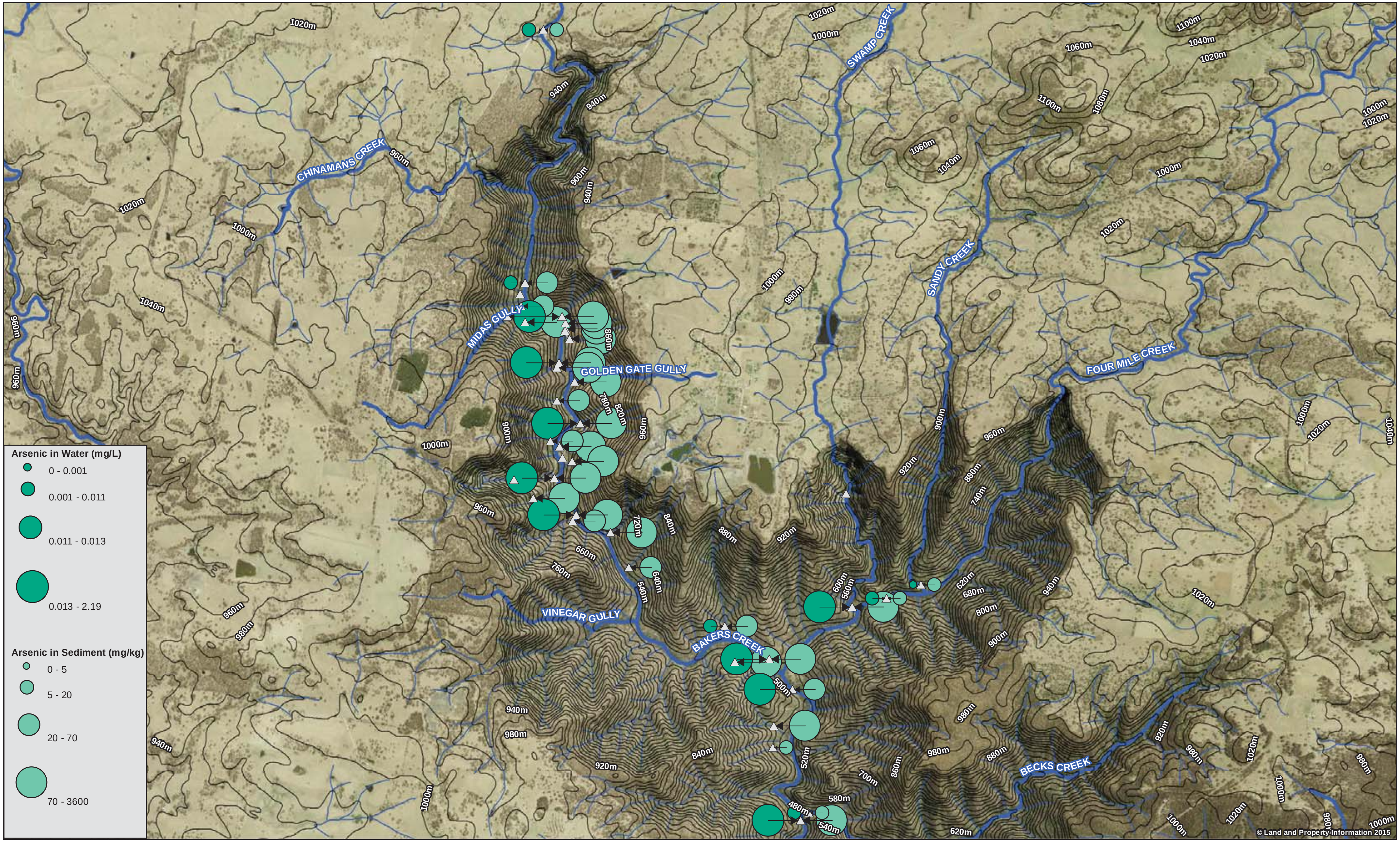
Bakers Creek
Antimony in Sediment and Water

Figure 9

\\ghdnet\ghd\AU\Sydney\Projects\21\23815\GIS\Maps\Deliverables\STAGE 2\2123815_Z015_MINEVISITS_DDP_Antimony.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery, Waterways, Contours - Land and Property Information. Created by:mweber



Note: Where duplicate samples were collected, the highest of the two readings was used

Paper Size A3

0 170 340 680 1,020 1,360

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Sample Locations
- Flow Direction
- Contour (mADH)
- Watercourses
- Drainage

GHD

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	19 May 2016

Bakers Creek
Arsenic in Sediment and Water

Figure 10

\\ghdnet\ghd\AU\Sydney\Projects\21\23815\GIS\Maps\Deliverables\STAGE 2\2123815_2016_MINEVISITS_DDP_Arsenic.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery, Waterways, Contours - Land and Property Information. Created by:mweber

7. Site Ranking

7.1 Introduction

Two screening tools were used to rank the sites for priority remedial action. These remain consistent with GHD (2015) and were:

- An absolute measure of arsenic and antimony in sediment and surface water against the relevant assessment criteria as detailed in Section 4.2. This uses the 80th percentile of all sediment and surface water data collected within each sub-catchment.
- A relative contaminant contribution from each sub-catchment within the Macleay River catchment for antimony and arsenic. The method for this was detailed in GHD (2015) and involves determining the overall arsenic and antimony flux by sub-catchment and / or specific site based on:
  - historic rainfall data referenced to a catchment point (Bellbrook)
  - the size of the catchment area
  - the surface water arsenic and antimony concentrations as measured from the catchment outlet sample location (or the down-catchment sample location within that sub-catchment.

This further interrogates the absolute measure by taking things to a site level. Each is presented in further detail below.

7.2 Absolute contaminant levels

The Stage 2 and 2a data were incorporated into the historic data set used in Stage 1 (GHD 2015) to update the 80^{th} percentile value for arsenic and antimony assess the arsenic and antimony contamination by sub-catchment for both sediment and surface water. These data are used as a high-level quality assurance check to show which sub-catchments are an issue by comparing the 80^{th} percentiles against relevant assessment criteria.

7.2.1 Sediment

Figure 11 shows the 80^{th} percentiles for sediment antimony concentrations in the six sub-catchments visited, while Figure 12 shows the 80^{th} percentiles for sediment arsenic concentrations. As for the surface water, GHD's data set that was added to the historic data to generate Figure 11 and Figure 12 were remarkably consistent with the historic data set, indicating consistent concentrations of sediment arsenic and antimony in the six sub-catchments over time.

Of note for the antimony results are:

- Bakers Creek, Mungay Creek, Chandler, Commissioners Waters and Warbro Brook have 80th percentiles above the non-mining background concentration of 1.2 mg/kg.
- Bakers Creek, Mungay Creek, Chandler, Commissioners Waters and Warbro Brook have 80th percentiles above the ANZECC (2000) ISQG (low) antimony trigger value of 2.0 mg/kg.
- Bakers Creek and Mungay Creek have 80th percentiles above the ANZECC (2000) ISQG (high) antimony trigger value of 25.0 mg/kg.

Interestingly, Warbro Brook is a non-mining catchment that contains the Willi Will Prospect.

This demonstrates that natural mineralisation in the Macleay Catchment can elevate sediment antimony concentrations above background, and also above ANZECC (2000) ISQG (low) guideline values.

Figure 11: Sediment antimony

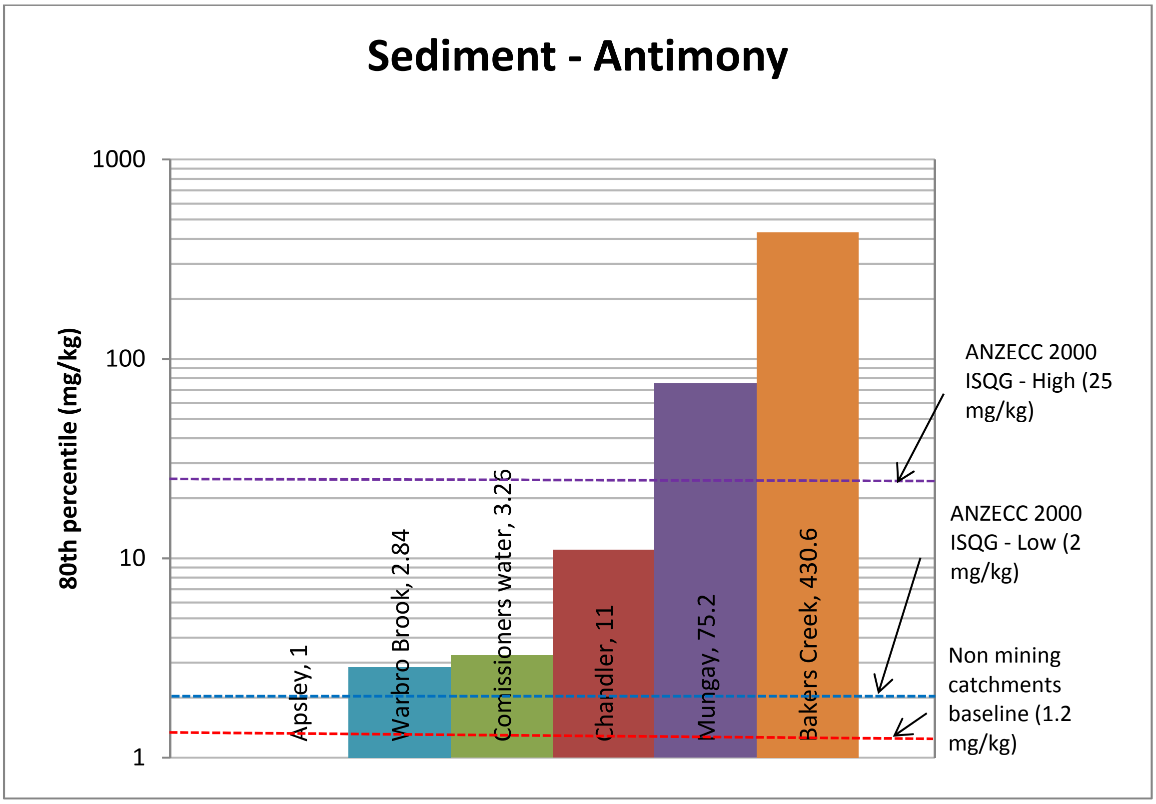
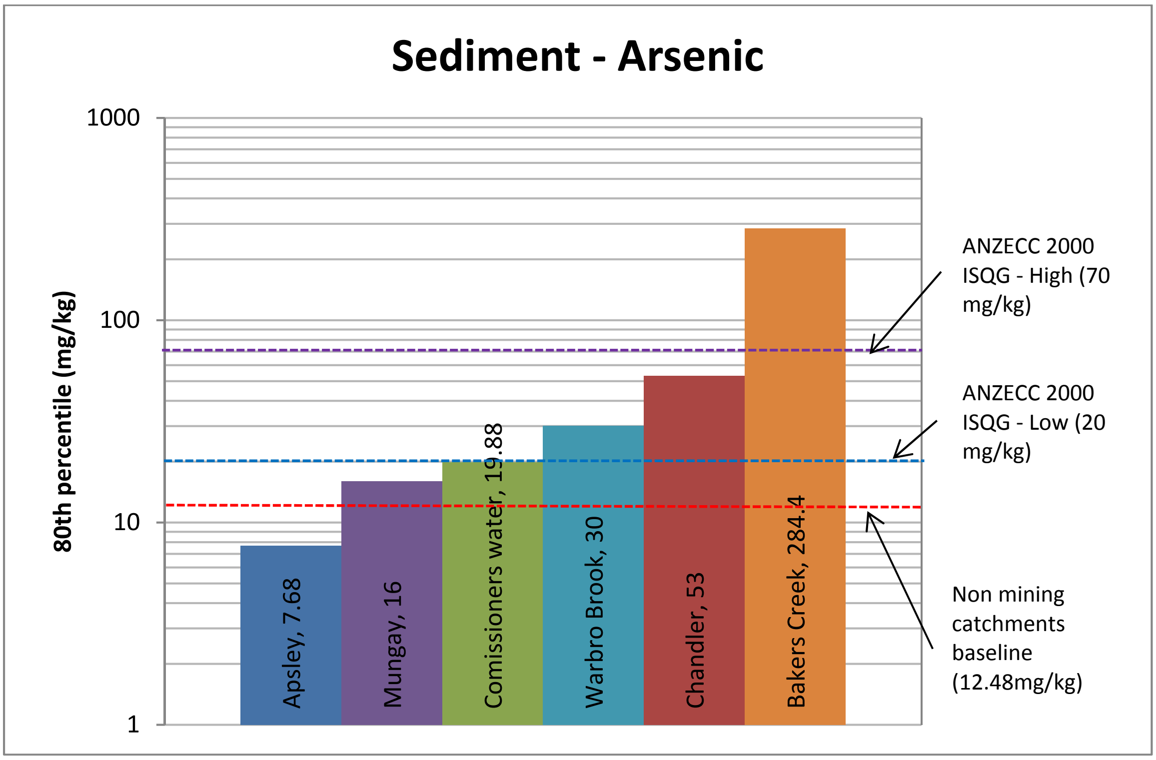


Figure 12: Sediment arsenic



Of note for the arsenic results are:

- Bakers Creek, Chandler, Warbro Brook, Commissioners Waters and Mungay Creek have 80th percentiles above the non-mining background concentration of 12.48 mg/kg.
- Bakers Creek, Chandler and Warbro Brook have 80th percentiles above the ANZECC (2000) ISQG (low) arsenic trigger value of 20.0 mg/kg.
- Bakers Creek has an 80th percentile above the ANZECC (2000) ISQG (high) arsenic trigger value of 70.0 mg/kg.

As for sediment antimony, Warbro Brook, a non-mining catchment that contains the Willi Will Prospect, returned elevated sediment arsenic concentrations above background, and indeed, above ANZECC (2000) ISQG (low) guideline values.

7.2.2 Surface water

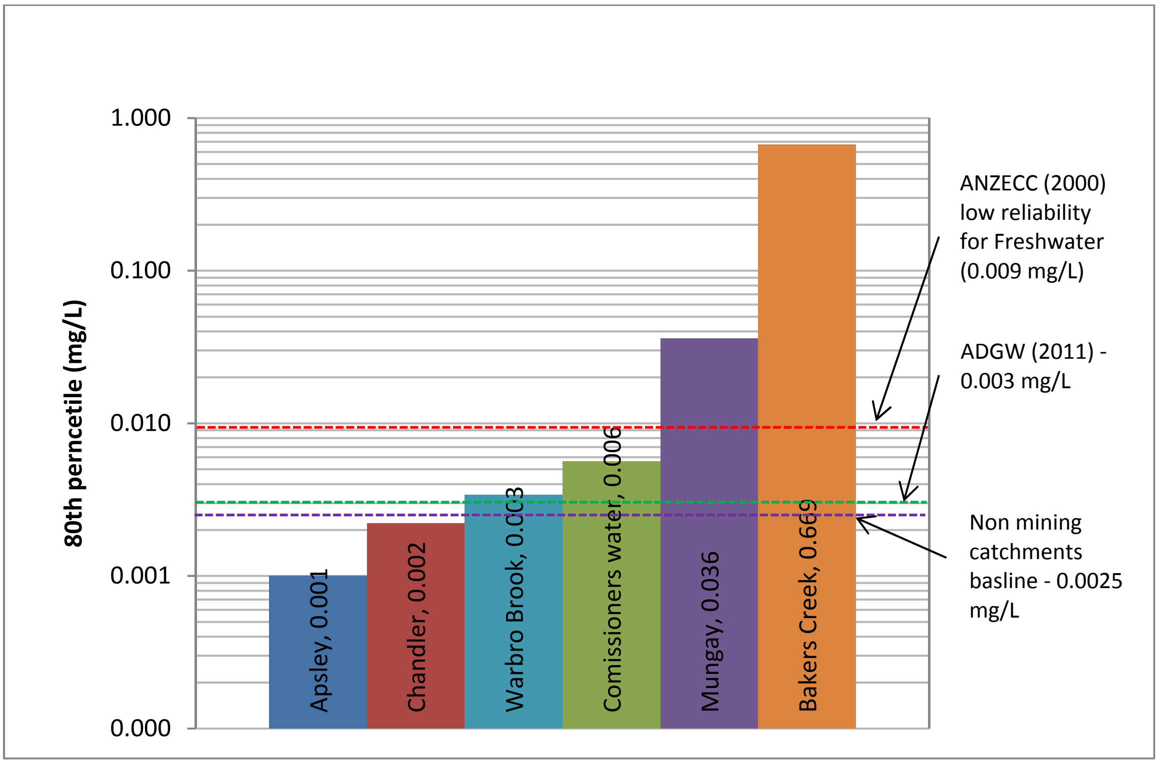
Figure 13 shows the 80th percentiles for total antimony concentrations in the six sub-catchments visited, while Figure 14 shows the 80th percentiles for total arsenic concentrations. GHD's data set that was added to the historic data to generate Figure 13 and Figure 14 were remarkably consistent with the historic data set, indicating consistent concentrations of arsenic and antimony in the six sub-catchments over time.

Of note for the antimony results are:

- Bakers Creek, Mungay Creek, Commissioners Waters and Warbro Brook have 80th percentiles above the non-mining background concentration of 0.0025 mg/L.
- Bakers Creek, Mungay Creek, Commissioners Waters and Warbro Brook have 80th percentiles above the ADWG (2011) antimony trigger value of 0.003 mg/L.
- Bakers Creek and Mungay Creek have 80th percentiles above the ANZECC (2000) 95% freshwater trigger value of 0.009 mg/L.

As for the sediment data, the Warbro Brook result showed that non-mining catchments can contain antimony concentrations above background, and indeed, above drinking water guidelines.

Figure 13: Surface water total antimony

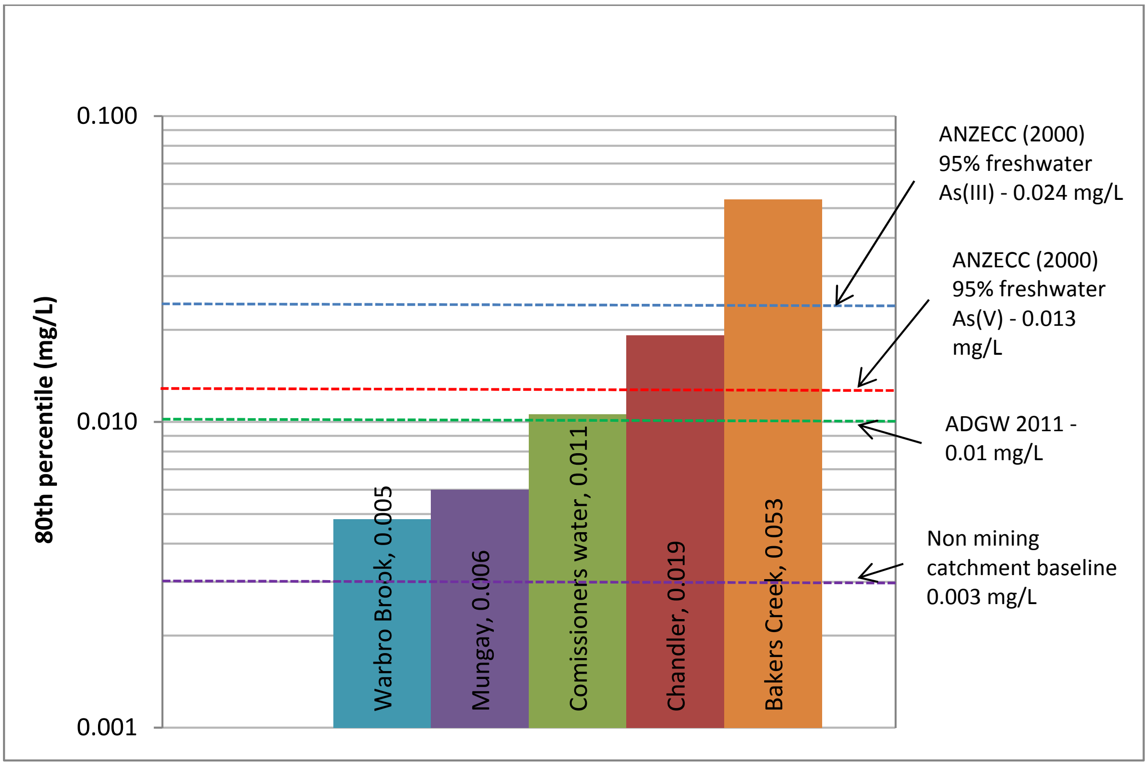


Of note for the arsenic results are:

- Bakers Creek, Chandler, Commissioners Waters, Mungay Creek and Warbro Brook have 80th percentiles above the non-mining background concentration of 0.003 mg/L.
- Bakers Creek, Chandler and Commissioners Waters have 80th percentiles above the ADWG (2011) arsenic trigger value of 0.01 mg/L.
- Bakers Creek and Chandler have 80th percentiles above the ANZECC (2000) 95% freshwater trigger value for arsenic (V) of 0.013 mg/L. It is likely that the majority of arsenic in surface waters is as arsenic V given redox conditions.
- Bakers Creek has 80th percentiles above the ANZECC (2000) 95% freshwater trigger value for arsenic (III) of 0.024 mg/L.

Note that the non-mined Warbro Brook sub-catchment 80th percentile is above the background concentration for arsenic of 0.003 mg/L; consistent with the sample result reported by GHD in this study of 0.004 mg/L.

Figure 14: Surface water total arsenic



The surface water data are remarkably consistent with the sediment data presented above, with only minor variance. Essentially, those sites that returned sediment arsenic and antimony 80th percentiles above the ANZECC (2000) ISQG (low) trigger values also had surface water total antimony and arsenic concentrations above the ADWG (2011). The exceptions being Chandler for antimony and Warbro Brook for arsenic.

Further, those sub-catchments that had sediment arsenic and antimony 80th percentiles above the ANZECC (2000) ISQG (high) trigger values also had surface water total antimony and arsenic concentrations above their respective ANZECC (2000) 95% ecological trigger values.

The data indicates that clean water coming into contact with arsenic and antimony contaminated sediment is itself, becoming contaminated with arsenic and antimony. This is consistent with the mineral waste and sediment leachability data that was reported earlier in this report showing how readily leachable the arsenic and antimony (and other metals) are in those solid media. This is further evidence that minimising the opportunity for contaminants to migrate off site at the source is a sound management strategy.

7.3 Arsenic and antimony flux

Results for antimony flux are presented in Table 15, with arsenic flux shown in Table 16.

The concept of a contaminant flux calculation using rainfall records at Bellbrook to rank relative site contamination contribution to the overall Macleay Catchment contaminant loads should be considered indicative at best. Whilst based on actual data in the field, the data set does have some statistical outliers, despite the consistency between historic sampling and GHD's sampling reported herein. There is a range of spatial and temporal reasons that this may be so, including for example the sample location, the climate, and flow conditions at the time.

When the flux is used, along with the absolute sub-catchment contaminant levels and the site data results reported herein, a sound feel for the key contaminating sites can be developed, and priority actions defined accordingly.

The data below excludes Mickey Mouse, Sunnyside, Warbro Brook and Europambela as these sites showed little or no contamination and were therefore not considered further. The flux calculations also exclude those non-mining sub-catchments that were eliminated from consideration in Stage 1 (GHD 2015). It is acknowledged that there will likely be some metalloid flux coming from those sub-catchments, along with flux from other historic mining areas potentially excluded from the derelict mine database used to inform this study.

Based on the discussion above, it remains important to remember that the percent flux contribution shown below is therefore not for the entirety of the Macleay Catchment, rather, it is for the entirety of those catchments and sites considered within Stage 2 of the project—the rest having been screened out.

This is consistent with the project aim and objectives which were to identify those priority remediation targets as represented by the identifying the highest absolute (against adopted trigger values) and relative (using flux calculations) contaminant sources within the Macleay Catchment.

Note also that the contaminant sources are limited to derelict mines listed on the Derelict Mines Program database, in addition to the Bakers Creek sub-catchment hosting the Hillgrove Mineral Field.

Table 15: Antimony flux by sub-catchment and site

Sub-catchment	Site	Unit	Value	Catchment Area km²	Flows M³/sec	Flux kg/day	Rank
Bakers Creek (total)	BC_SW02 - Most down gradient point on Bakers Creek – approximately 10.53 km down gradient from bakers Creek 32 point	mg/L	0.822	236.01	2.78	197	1
Bakers Creek (sub-set)	BC_SW09: Swamp Creek, 67 m up gradient of Four Mile Creek drains Smiths (Freeholds)	mg/L	9.31	11.59	0.136	109.6724	1a
Bakers Creek (sub-set)	BC_SW15: Gully draining into Bakers Creek, approximately 40 m west of Bakers Creek – drains Black Lode, Sunlight and Syndicate mines)	mg/L	5.98	0.94	0.011	5.7134	1b
Bakers Creek (sub-set)	BC_SW19: Gully draining into Bakers Creek, approximately 34 m east of Bakers Creek – drains Eleanora mine and the haul road	mg/L	5.19	0.29	0.003	1.5227	1c
Bakers Creek (sub-set)	BC_SW33: Four Mile Creek, between Swamp Creek and Sandy Creek – non mining area	mg/L	0.018	46.38	0.546	0.8485	1d
Bakers Creek (sub-set)	BC_SW27: Gully draining into Bakers Creek, approximately 50 m east of Bakers Creek – Hillgrove Weir and former small mine workings	mg/L	0.29	1.22	0.014	0.3559	1e
Bakers Creek (sub-set)	BC_SW01: Becks Creek, approximately 90 m west of Bakers Creek – minimal mine workings	mg/L	0.045	7.42	0.087	0.3394	1f
Bakers Creek (sub-set)	BC_SW10: Sandy Creek, 85 m up gradient of Four Mile Creek – former small mine workings	mg/L	0.042	4.73	0.056	0.2019	1g
Bakers Creek (sub-set)	BC_SW08: Gully draining into Bakers Creek, approximately 125 m north of Bakers Creek – drains TSF1 and current Hillgrove TSF	mg/L	0.045	1.02	0.012	0.0467	1h
Chandler – Upper	Phoenix Gold	mg/L	0.0005	4.42	0.05	0.002	7
	Ruby Silver	mg/L	0.001	0.74	0.01	0.001	8
	Rockvale Arsenic	mg/L	0.001	23.31	0.27	0.024	3
Chandler – Lower	Khans Creek[1]	mg/L	No sample	NA	NA	NA	NA
	Gibsons[2]	mg/L	0.0005	1.70	0.02	0.001	9
	Faints and Firefly[2]	mg/L	0.002	5.77	0.07	0.012	=5
Commissioners Waters	Kapunda Arsenic	mg/L	0.005	76.79	0.90	0.039	2

Sub-catchment	Site	Unit	Value	Catchment Area km^2	Flows M^3/sec	Flux kg/day	Rank
	Mary Anderson	mg/L	0.008	1.36	0.02	0.011	=5
Hickeys Mungay Creeks/	Mungay Creek	mg/L	0.086	0.26	0.00	0.023	4

1: A water quality sample has been estimated based on relationships between Chandler sediment and water quality samples collected as part for this study – refer to Table 18. 2: Data from EA Systems (2003).

Table 16: Arsenic flux by sub-catchment and site

Sub-catchment	Site	Unit	Value	Catchment Area km²	Flows M³/sec	Flux kg/day	Rank
Bakers Creek (total)	BC_SW02 - Most down gradient point on Bakers Creek – approximately 10.53 km down gradient from bakers Creek 32 point	mg/L	0.046	236.013	2.78	11.035	1
Bakers Creek (sub-set)	BC_SW09: Swamp Creek, 67 m up gradient of Four Mile Creek drains Smiths (Freeholds)	mg/L	0.200	11.59	0.14	2.3560	1a
Bakers Creek (sub-set)	BC_SW15: Gully draining into Bakers Creek, approximately 40 m west of Bakers Creek – drains Black Lode, Sunlight and Syndicate mines)	mg/L	0.245	0.94	0.01	0.2341	1b
Bakers Creek (sub-set)	BC_SW19: Gully draining into Bakers Creek, approximately 34 m east of Bakers Creek – drains Eleanora mine and the haul road	mg/L	0.249	0.29	0.00	0.0733	1d
Bakers Creek (sub-set)	BC_SW33: Four Mile Creek, between Swamp Creek and Sandy Creek – non mining area	mg/L	0.002	46.38	0.55	0.0943	1c
Bakers Creek (sub-set)	BC_SW27: Gully draining into Bakers Creek, approximately 50 m east of Bakers Creek – Hillgrove Weir and former small mine workings	mg/L	0.030	1.22	0.01	0.0372	1e
Bakers Creek (sub-set)	BC_SW01: Becks Creek, approximately 90 m west of Bakers Creek – minimal mine workings	mg/L	0.002	7.42	0.09	0.0151	1f
Bakers Creek (sub-set)	BC_SW10: Sandy Creek, 85 m up gradient of Four Mile Creek – former small mine workings	mg/L	0.0005	4.73	0.06	0.0024	1h
Bakers Creek (sub-set)	BC_SW08: Gully draining into Bakers Creek, approximately 125 m north of Bakers Creek – drains TSF1 and current Hillgrove TSF	mg/L	0.008	1.02	0.01	0.0083	1g
Chandler – Upper	Phoenix Gold	mg/L	0.010	4.42	0.05	0.045	4
	Ruby Silver	mg/L	0.024	0.74	0.01	0.018	5
	Rockvale Arsenic	mg/L	0.029	23.31	0.27	0.687	3
Chandler – Lower	Khans Creek[1]	mg/L	No sample	NA	NA	NA	NA
	Gibsons[2]	mg/L	0.005	1.70	0.020	0.0009	9
	Faints and Firefly[2]	mg/L	0.005	5.77	0.068	0.0029	8
Commissioners Waters	Kapunda Arsenic	mg/L	0.014	76.79	0.90	1.093	2

Sub-catchment	Site	Unit	Value	Catchment Area **km²**	Flows **M³/sec**	Flux **kg/day**	Rank
	Mary Anderson	mg/L	0.009	1.36	0.02	0.012	6
Hickeys Mungay Creeks/	Mungay Creek	mg/L	0.031	0.26	0.00	0.008	7

1: A water quality sample has been estimated based on relationships between Chandler sediment and water quality samples collected as part for this study – refer to Table 18. 2: Data from EA Systems (2003).

The data in Table 15 and Table 16 is summarised in Table 17. As noted above, the following were excluded from the calculations:

- non-mining but naturally mineralised catchments (e.g. Warbro Brook and those other sub-catchments excluded in Stage 1 as insignificant for the stated purpose of the study)
- mined catchments with no arsenic and antimony surface water concentrations above LOR (e.g. Europambela in the Apsley sub-catchment)
- the Trunk Macleay and Macleay floodplain which contain contaminated sediment and would therefore yield a surface water metalloid flux; however, are not relevant as considered within the stated purpose of this study.

Table 17: Consolidated arsenic and antimony rankings

Sub-catchment	Site	Sb flux (kg/day)	Rank	As flux (kg/day)	Rank
Bakers Creek	Various	197	1	11.035	1
Chandler	Phoenix Gold	0.002	7	0.045	4
	Ruby Silver	0.001	8	0.018	5
	Rockvale Arsenic	0.024	3	0.687	3
	Khans Creek[1]	NA	NA	NA	NA
	Gibsons[2]	0.001	9	0.0009	9
	Faints and Firefly[2]	0.012	=5	0.0029	8
Commissioners Waters	Kapunda Arsenic	0.039	2	1.093	2
	Mary Anderson	0.011	=5	0.012	6
Hickeys/Mungay Creek	Mungay Creek	0.023	4	0.008	7
Total		**197.11**	**-**	**12.90**	**-**

1: A water quality sample has been estimated based on relationships between Chandler sediment and water quality samples collected as part for this study – refer to Table 18. 2: Data from EA Systems (2003).

Note also in Table 15 and Table 16 that the Bakers Creek sub-catchments sampled for surface water account for some 60 % of the estimated Bakers Creek antimony flux, though only around 25% of the arsenic flux. This suggests that the remaining 40 and 75 % of antimony and arsenic contamination is either:

- Being contributed from sub-catchments draining to Bakers Creek that did not have water samples available for collection due to the dry conditions. Certainly the sediment data reported herein suggests this may be the case; and / or
- Reporting from the historic contaminated sediment slug resident in the Bakers Creek main channel, and is therefore not being contributed from Bakers Creek sub-catchments, rather, the channel itself.

In fact, based on the mineral waste, sediment and surface water data within the Bakers Creek sub-catchment, it is likely that both explanations are valid.

7.4 Rehabilitation priorities

7.4.1 Introduction and risk assessment categories

The site rankings for estimated antimony and arsenic flux shown above in Table 17 are only one input into the overall priority rehabilitation site ranking, which is developed using a broader range of considerations than simply the contaminant flux. In addition to variables that can be interpreted and managed to make priority site remediation decisions, there remain a number of ambiguities and/or historic issues that may preclude any immediate remedial actions being undertaken. An example may be a lack of suitable cost-effective engineering solutions at this point in time given the geographic location and topography of some sites.

To inform the priority remedial action list, Table 18 consolidates a range of inputs that must inform prioritising any remedial spend. Each table column heading is explained below. To determine priority remediation targets relatively objectively, key inputs were assigned weightings against entries as they would inform the decision making process, as explained below.

Sub-catchment: The discrete sub-catchment within the overall Macleay River Catchment in which the mine is located. For the Bakers Creek sub-catchment, assessment was completed to sub-catchment level within the Bakers Creek sub-catchment itself where data would permit.

No weighting was assigned to the sub-catchment for decision-making purposes.

Site: The individual derelict mine site within their respective sub-catchment. For Bakers Creek, this was not possible and each of the nine contaminant flux results would therefore include a number of historic workings. EA Systems (2003) identified over 500 individual workings over their 11 mine domain areas that could not be correlated against individual Bakers Creek sub-catchments given their spatial locations relative to discrete sub-catchment drainage areas.

No weighting was assigned to the site for decision-making purposes. However, based on the data reported herein, the arsenic and antimony rich mineral waste stored in various locations within the Bakers Creek sub-catchment is clearly the number one remedial priority. The priority rehabilitation ranking proceeded assuming as much, and was therefore developed primarily to assist with a relatively objective method to prioritise the remaining sites outside the Bakers Creek sub-catchment.

Estimated antimony load per annum (tonnes): The annual estimated tonnes of antimony leaving site based on the calculated flux, itself generated using calibrated rainfall and discharge data (refer GHD 2015), catchment size and an 80th percentile of the down-catchment water quality sample at each site. Sensitivity testing was undertaken to ensure data consistency over time, and therefore, that the data were broadly representative of estimated contaminant loads. For Bakers Creek, there will likely be a number of historic mine features contributing to the antimony load at each point. The known limitations of the method used to calculate contaminant flux, both spatial and temporal were discussed in GHD (2015).

Reverse weightings were allocated for antimony rankings based on the flux estimated in Table 18, whereby Bakers Creek was allocated 10 points and Ruby Silver and Gibsons two points each.

Estimated arsenic load per annum (tonnes): The annual estimated tonnes of arsenic leaving site based on the calculated flux, itself generated using calibrated rainfall and discharge data (refer GHD 2015), catchment size and the down-catchment water quality sample at each site. Sensitivity testing was undertaken to ensure data consistency over time, and therefore, that the data were broadly representative of estimated contaminant loads. For Bakers Creek, there will likely be a number of historic mine features contributing to the arsenic load at each point. The known limitations of the method used to calculate contaminant flux, both spatial and temporal were discussed in GHD (2015).

Reverse weightings were allocated for antimony rankings based on the flux estimated in Table 18, whereby Bakers Creek was allocated 10 points and Mungay Creek one point.

Environmental risk: Is the risk that the site contamination is contributing to off-site environmental receptors; both aquatic and terrestrial. Includes consideration of soil contamination, surface and groundwater contamination, erosion and sedimentation, site stability and subsidence, and containment structure failure. The method remains entirely consistent with the *NSW Derelict Mines Program: General Site Information and Preliminary Risk Assessment* field sheet.

It is important to recognise that significant work has been undertaken in the Macleay Catchment on arsenic and antimony environmental fate, with some 16 peer reviewed published papers available in the public domain from current and former UNE staff. This includes several reports that show antimony, and to a lesser extent, arsenic, are taken up in algae, macroinvertebrates, fish, and plants which remained inconclusive on ecotoxicological impacts (e.g. Tighe *et al.* 2005, Ashley *et al*. 2006, Ashley *et al*. 2007, Telford *et al*. 2009).

Weightings were allocated according to the *Derelict Mines Program: General Site Information and Preliminary Risk Assessment,* whereby an extreme environmental risk was allocated a score of 5 and a negligible risk a score of 1, with other categories including minor (2), moderate (3) and high (4).

(Human) safety risk: Is the risk associated with human health and safety. The method remains entirely consistent with the *NSW Derelict Mines Program: General Site Information and Preliminary Risk Assessment* field sheet. It includes a traditional likelihood and consequence matrix that considers; locations, land use, accessibility, visitation, barriers to entry (likelihood) and consequences ranging from no medical treatment to multiple fatalities.

Weightings were allocated according to the *Derelict Mines Program: General Site Information and Preliminary Risk Assessment,* whereby an extreme safety risk was allocated a score of 4 and a low risk a score of 1, with other categories including medium (2) and high (3).

Work description: A description of the works required is a very high level summary only. More detail is provided below Table 18 for context by site. It considers those site domains most impacted whereby value for money would be best realised by targeting those key contributing contaminant sources on site.

Feasibility of works: Relates to the practicality and constructability of remedial works on site. This includes consideration of site location and accessibility, previously covered under the likelihood weightings in (human) safety risk; however, site physical factors including slope and rockiness for example are also considered. This relates specifically to the ease that plant and equipment could safely and practically access and negotiate site.

Sites where remedial works were deemed feasible were weighted 2 with unfeasible sites being weighted 1.

Estimated cost: A high level costing that would include the physical works noted under 'description of works' above, including an estimate of civil plant and equipment, safety improvements, the costs of any remedial media required (e.g. limestone, topsoil etc), estimated consulting fees, and an estimate of the cost of any approval documentation required. It is order of magnitude only and likely to represent a +/- 30% estimate. Note that it in no way equates to a fee proposal, and remains indicative at best.

Priority: Based on the headings from Table 18 as also listed above, an objective score to priority rank the sites are given for remedial works. This is discussed further below Table 18, with site commentary provided, and recommendations made accordingly.

Table 18: Site rehabilitation objective priority ranking matrix

Sub-catchment	Site	Estimated antimony flux per annum (tonnes)	Sb rank	Estimated arsenic flux per annum (tonnes)	As rank	Environmental risk	Safety risk	Work description[3]	Feasibility of works	Estimated cost ($AUD – GST inclusive estimate)	Priority based on objective ranking
Bakers Creek	Various	71.9	1	4.03	1	High	Various (Low to extreme depending on mine feature)	Various	Various	Indeterminable. More input information required.	1
Chandler – Upper	Phoenix Gold	0.00082	7	0.347	4	High	Low	Rehabilitation works on hold at behest of landholder. No action	Feasible with landholder limitations	0	7
	Ruby Silver	0.00027	=9	0.0066	6	High	Low	Waste rock burial, cover, seed, make shaft(s) safe	Feasible – good access	40,000	10
	Rockvale Arsenic	0.00865	4	0.2508	3	High	Low	Liming, add growing media, seeding	Feasible – good access	90,000	4
Chandler – Lower	Khans Creek[1]	0.00036	8	0.0041	8	High	Medium	Access track re-establishment, liming, soil amendment, revegetation	Very difficult, steep and remote terrain up to 40 degree slopes	85,000	8
	Gibsons[2]	0.00032	=9	0.0032	9	Extreme	High	Security, liming, soil amendment, revegetation	Difficult and remote access	1,000,000	9
	Faints / Firefly[2]	0.00442	5	0.110	5	High	High	Run-on diversion, revegetation	Difficult and remote access	365,000	3
Commissioners Waters	Kapunda Arsenic	0.01424	3	0.3988	2	High	Medium	Additional study needed	Feasible – good access	55,000	2
	Mary Anderson	0.00404	6	0.0045	7	High	Medium	Waste rock burial, cover, seed	Feasible – good access	60,000	5
Hickeys Mungay Creeks	Mungay Creek	0.11203	2	0.0030	10	High	Medium	Additional study needed	Feasible – access would require some clearing / intrusive site investigation to characterise and delineate contamination	90,000	6

1: Khans Creek could not be sampled for water; however, an estimate of arsenic in water was made using the sediment/surface water data correlation for the data collected in the Chandler. The r^2 for arsenic was sound at 0.80 (high confidence); however, for antimony it is low confidence at r^2 = 0.10. Estimates based on sediment concentrations were: surface water arsenic at KC_SD01

0.0114 mg/L and surface water antimony at the same location 0.001 mg/L. Note that arsenic (and other heavy metals) is the issue in the Chandler, not antimony. Therefore, the arsenic and antimony rankings will be slightly different to those shown in Table 15, Table 16 and Table 17. 2: Data from EA Systems (2003). 3: Additional detail on works required below the table.

7.4.2 Suggested remedial works by site

Bakers Creek – Ranked 1

Introduction

At the time of writing, Hillgrove Mine operated by Bracken Resources held Environment Protection Licence 921 applicable to Mining Leases (MLs) 1440,1442, 749, 205, 219, 231, 391, 392, 592, 600, 849, 655, 714, 772, 810, 961, 972, 1020, 1026, 1100, 1101, 1332, 1441, 5643, 6282, and 945 (refer to Figure 15). An additional five Mining Purpose Leases (MPLs), six Private Land Leases (PLLs) and three Gold Leases (GLs) were also under EPL921.

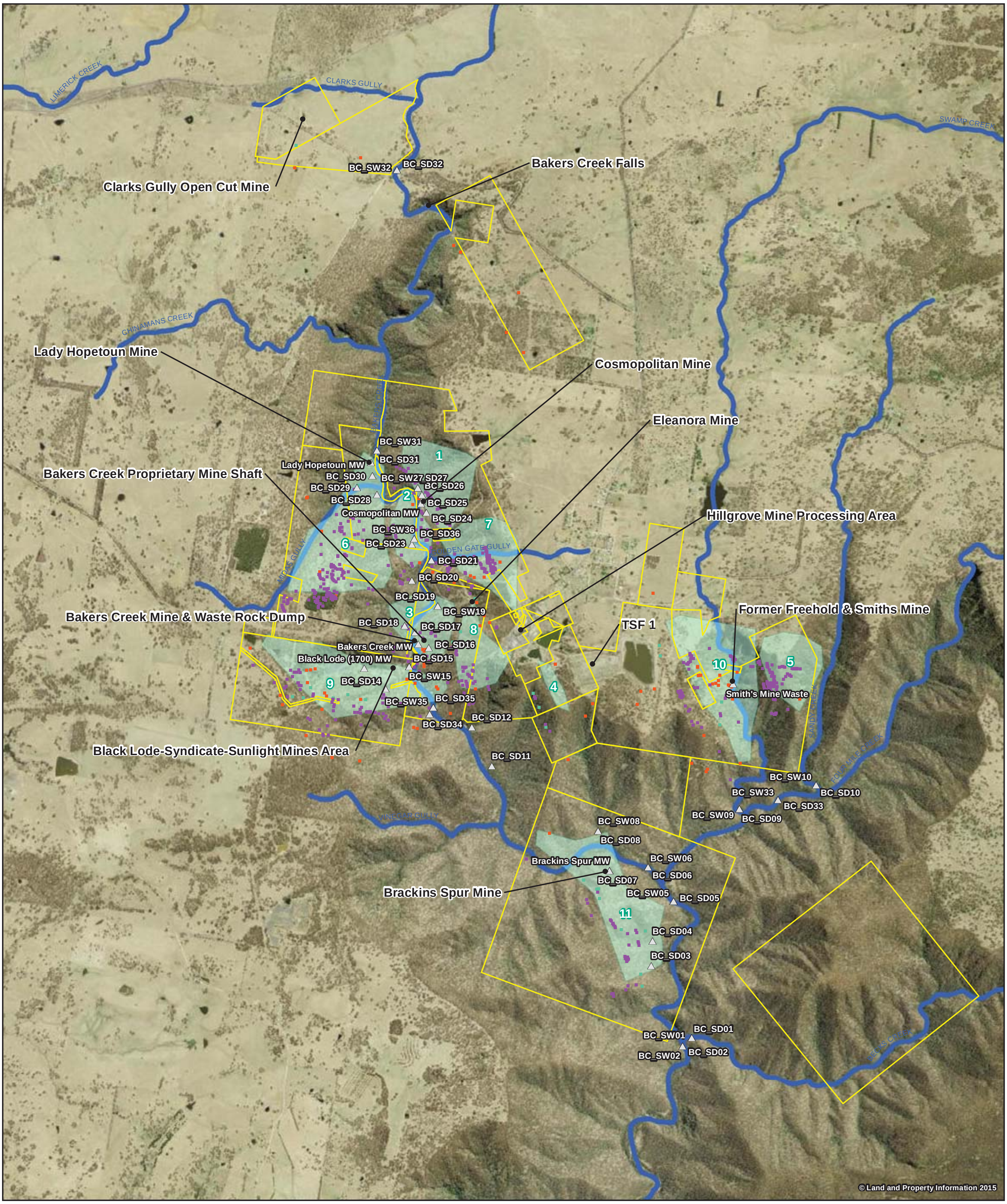
Complicating the demarcation of contaminant sources within the Bakers Creek sub-catchment is that Hillgrove Mines are licenced to discharge a finite volume of water from:

- Hopetoun Level 5 adit
- Cosmopolitan Level 6 adit
- Eleanora Level 9 adit
- Golden Gate Mine level 6 adit
- Lower Cooney Tunnel adit
- Sunlight Level 5 adit
- Black Lode Level 5, 6 and 7 adits
- Freehold Level 10 adit
- Smith's Mine Level 4 adit.

Additionally, Hillgrove pump water from Eleanora Mine workings Sunlight Level 5 adit into the recycled water system on site.

The implications of the current operations on site with regard to apportioning responsibility for remediation across the Bakers Creek sub-catchment become immediately apparent. There are several considerations that complicate interpretation. This includes for example, historic mine workings and mineral waste within the Bakers Creek sub-catchment and Bakers Creek itself, respectively. GHD is unaware of any arrangement between Bracken Resources and the NSW Department of Resources and Energy whereby historic workings within the 26 MLs detailed above are excised from those MLs with respect to rehabilitation responsibility; with one exception. The exception is the waste rock dump located adjacent to Bakers Creek in the vicinity of the old Bakers Creek mine (from where Bakers Creek mineral waste sample 3 was collected). GHD understand that this waste rock dump is on the Derelict Mine Program's register. The old Bakers Creek waste rock dump was intersected by the current mine haul road at the time of sampling.

Further, EA Systems (2003) allocated rehabilitation responsibility to over 500 individual mine features in 11 domains across the Bakers Creek sub-catchment. This demarcation was limited to whether or not the mine operator at the time (New England Antimony Mines) were known to have worked those features; otherwise they were allocated to the NSW Department of Mineral Resources, now the Division of Resources and Energy within the Department of Industry. Many of the sites responsibility remained unknown in the EA Systems (2003) report. There are several legal considerations pertaining to continuity of title, and other agreements between the current operator and the Department of Industry under the 26 MLs as to who actually has legal rehabilitation responsibility for the mine features.



MW = Mineral Waste

LEGEND

- Mineral Titles
- Mine Domains
- Watercourses
- Minor Watercourses
- Mine Workings Responsibility - DMP
- Mine Workings Responsibility - Miner
- Mine Workings Responsibility - ND
- Sample Point Locations

Paper Size A3

0 140 280 560 840 1,120

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	19 May 2016

Bakers Creek Mineral Titles

Figure 15

\\ghdnet\ghd\AU\Sydney\Projects\21\23815\GIS\Maps\Deliverables\STAGE 2\2123815_F6_Z018_BAKERSCREEK_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: Imagery - ©Land and Property Information (Extracted: 19/05/16); Streets, Waterways - NSW LPI 2012 DTDB. Created by:mweber

There is little that can be done cost-effectively with current technology to remediate the historic slug of contaminated sediment in Bakers Creek itself.

It will, in geological time, work its way through the system, and be deposited into the ocean and/or onto the Macleay River floodplains, where it will ultimately be buried by other sediment. This changes the geochemical state of the arsenic and antimony such that it will likely become environmentally unavailable.

What can be done, however, is to prevent additional contaminated sediment finding its way into Bakers Creek from point sources stored around the sub-catchment by ensuring appropriate rehabilitation. The six samples of mineral waste collected around the Brackins Spur, Smiths, Bakers Creek, Black Lode, Cosmopolitan and Lady Hopetoun Mine openings returned whole rock arsenic concentrations of up to 2,700 mg/kg and up to 3,480 mg/kg antimony. The sediment data show that this mineral waste material is finding its way into drainage lines as contaminated sediment, whereby clean rainfall and throughflow is becoming contaminated with arsenic and antimony, creating a large annual contaminant flux from the catchment. Refer to Table A48 in Appendix A for arsenic and metals values for mineral waste sampled within the Bakers Creek sub-catchment.

A final consideration when demarcating responsibility for remedial priority are the Derelict Mines Funding Priority Guidelines, under which, the Derelict Mines Program can only fund derelict mines. This is as against mine features on current mining leases that may be, in fact, part of tenure continuity to past operations whereby the current operator would assume rehabilitation liability. This is a matter beyond the scope of this report, which simply highlights the type and level of contamination within the Bakers Creek sub-catchment.

It remains important to note that various authors (e.g. Ashley *et al*. 2006 and Wilson *et al*. 2010) have published on the environmental geochemistry and behaviour of antimony and arsenic in the Macleay Catchment. In summary, as the environmental conditions change down-catchment from reducing to aerobic commensurate with dissolved oxygen loads, vegetation conditions, oxidation-reduction potential, pH and electrical conductivity, the valence of the arsenic and antimony also changes, making it either bioavailable or otherwise.

For example, based on rainfall and catchment size and therefore, estimated discharge at sample location BC_SW02, GHD used the 80^{th} percentile to estimate the dissolved contaminant flux of approximately 72 tonnes of antimony per annum at BC_SW02. Ashley *et al*. (2006) reported that the antinomy flux in water in the Macleay River itself was generally consistent at around 10 mg/L, which is approximately 0.32 tonnes per annum. Ashley *et al*. (2006) also noted that antimony fluxes in Bakers Creek downstream of Hillgrove Mine decrease rapidly due to antimony adsorption onto amorphous iron oxyhydroxides. This phenomenon may help explain, in part, the variance on antimony loads within Bakers Creek relative to the trunk Macleay—i.e. changing environmental geochemical conditions affecting dissolved antimony loads. Other antimony uptake mechanisms include aquatic algae, riparian plants which have antimony concentrations between 3 and 100 times background concentrations of the same species for up to 50 kilometres down-catchment of Hillgrove Mine - up to 100 mg/kg (Ashley *et al*. 2006), and the Macleay floodplain and its pastures (Tighe *et al*. 2005).

Priority sites

In terms of prioritising the site works within the Bakers Creek sub-catchment, the data collected shows that the majority (around 110 kg/day) of the antimony contamination appears to be reporting from the creek line that drains the historic Freeholds / Smiths mine workings. This is based on one surface water sample and a contaminant flux calculated by catchment area estimates. Additional data should be generated to confirm this observation. Large colluvial fans with unvegetated scree slopes dominate (refer to Plate 1 and Plate 2), with mineral waste arsenic concentrations of 2,560 mg/kg and 2,150 mg/kg antimony. Note that the contaminant flux calculations used to rank this site are based on the down-catchment water quality sample (BC_SW09), which returned a statistical outlier in terms of its total antimony concentration (9.31 mg/L). It is recommended that additional water quality sampling be undertaken to verify this result.

Plate 1: Smiths Mine waste rock dumps 1

Plate 2: Smiths Mine waste rock dumps 2

In diminishing priority based on the calculated contaminant flux, the priority sites within the Bakers Creek sub-catchments, based on calculated antimony (the priority metalloid in this sub-catchment) flux, itself, based on surface water sampling are:

- Waste rock at the Black Lode, Sunlight and Syndicate mine area
- Waste rock at the Eleanora mine

- Four Mile Creek – a non-mined area so likely elevated background antimony levels with a large catchment area meaning a large flux
- Small mine workings around the Hillgrove Weir
- A series of small mine workings in the BC_SW01 sub-catchment
- A series of small mine workings in the BC_SW10 sub-catchment
- The TSF1 and current Hillgrove mine area catchment.

From a priority perspective, it is important to note that all 8 calculated antimony fluxes from those Bakers Creek sub-catchments where water samples were collected and therefore flux was able to be determined ('lowest' calculated antimony flux being 0.17 tonnes per year), exceeded the highest annual antimony flux from the most antimony contaminated non-Bakers Creek site, being Kapunda Arsenic (0.014 tonnes per year). For arsenic, the most contaminating non-Bakers Creek site is Kapunda Arsenic (0.399 tonnes per year) which would rank second within the Bakers Creek sub-catchment behind the Smiths Mine drainage (0.859 tonnes per year)—noting that arsenic is not the key Bakers Creek contaminant.

As noted earlier, attempting to demarcate the EA Systems (2003) mine working inventory split into 11 domains using the sub-catchment approach undertaken herein is not feasible as:

- Several mine workings identified by EA Systems (2003) do not sit in any mine domain
- The 11 domains span several sub-catchments that drain beyond discrete GHD sample points
- Not all sub-catchments could be sampled given the dry conditions at the time of fieldwork, and the ephemeral nature of many of the drainage lines within the Bakers Creek sub-catchment.

Therefore, it is clear that the waste rock resident within the Bakers Creek sub-catchment contains elevated concentrations of arsenic and particularly, antimony. The mechanism for contaminant transport into Bakers Creek and the Macleay River is weathering and erosion of the contaminated waste rock into drainage lines where it becomes contaminated sediment. Clean water comes into contact with the contaminated waste rock and sediment and becomes contaminated through mineral dissolution processes.

Ashley *et al*. (2006) note that of the approximately 8 tonnes per annum of antimony that makes its way to the mouth of the Macleay River per annum, only around 20 % is in the dissolved form. Therefore, it becomes apparent that if the contaminated waste rock was rehabilitated, significant surface contaminant point sources would be removed from the Bakers Creek sub-catchment, thereby reducing the future generation and transport of contaminated sediment and water. Selected photos of areas of waste rock are shown below in Plate 3, Plate 4 and Plate 5.

The remedial strategy takes into consideration the historic slug of contaminated sediment currently resident as bedload within Bakers Creek, which will naturally abate over geological time. The strategy focuses on reducing additional contaminated sediment finding its way into Bakers Creek by proactively managing mineral waste elevated in arsenic and antimony. It is also important to recognise that the area is naturally mineralised, and rainwater in the form of runoff flowing over exposed stibnite veins will generate a small antimony flux through mineral dissolution. This is a natural phenomenon that will elevate antimony concentrations in certain sub-catchments within Bakers Creek above non-mineralised sub-catchments. Therefore, the strategy focuses on proactive, remedial solutions for those areas of exposed waste rock whose remediation can positively impact water quality within the Bakers Creek sub-catchment.

Potential constraints to the implementation of this strategy may include current Hillgrove Mine approval conditions, issued pursuant to both the *Mining Act* 1992 and the *Environmental Planning and Assessment Act* 1979, the approved Mining Operations Plan (MOP), and potentially, certain conditions within EPL912—particularly how they relate to managing mineral waste on site.

Plate 3: Black Lode mine waste

Plate 4: Bakers Creek Mine (Proprietary Mine) waste rock dump – (foreground) and the Eleanora mine (background)

Plate 5: Brackins Spur mine waste – partially rehabilitated

It is recommended that discussions are held between the mine operator, the NSW Department of Planning, the NSW EPA, The NSW Department of Industry (Resources and Energy), the NSW Office of Environment and Heritage, University of New England environmental geochemistry specialists, representatives from Armidale Regional Council, Kempsey Council and the Derelict Mines Program to demarcate rehabilitation responsibility under mining title, and then, address current approval conditions with respect to waste rock storage and management within the MLs issued to Bracken Resources. Once the question of rehabilitation responsibility has been addressed, there may be opportunities to pursue third party funding to finance priority remedial works on a project by project basis.

It is anticipated that group of stakeholders outlined above would sit within existing governance frameworks for environmental management within the Macleay Catchment, being the Macleay River Working Group, with subject matter experts seconded into the Group as required to assist with technical matters.

It is therefore deemed premature to discuss specific remedial actions and costs within the Bakers Creek sub-catchment until the above stakeholders discuss an overall strategy and develop an action plan.

Recommendations:

It is deemed premature to recommend individual remedial actions within the Bakers Creek sub-catchment based on the data available to date. That is, that the data set collected during Stage 2a is useful as a first pass, indicative indictor of priority remedial areas. Follow up monitoring should be completed to increase confidence and confirm the priority remedial areas. This should incorporate surface water sampling and flow rate monitoring such that contaminant flux can be estimated and ranked to confirm areas for priority remedial works. The data should build upon that reported herein.

In terms of prioritising the site works within the Bakers Creek sub-catchment, the data indicated that the majority (estimated at approximately 40 tonnes per annum of the total Bakers Creek antimony flux appears to be reporting from the historic Freeholds / Smiths mine workings under normal flow conditions, noting that this flux calculation is based on one surface water sample collected during the Stage 2a fieldwork. Given that there are 200 individual mineral occurrences in the Hillgrove Mineral Field (NSW Department of Mineral Resources 1992), and over 500 known individual mine features (EA Systems 2003) from historic operations at Hillgrove, it is not possible to categorically apportion contamination by point source in this reach of Bakers Creek without additional work. Rather, the surface water and sediment data should be used to prioritise high priority areas for future work upon which a remedial strategy should be based.

It is therefore recommended that the Bakers Creek sub-catchment issues be incorporated into the existing Macleay River Working Group for priority action. The Group should include the current mine operator—Bracken Resources, the NSW Department of Planning, the NSW EPA, The NSW Department of Industry (Resources and Energy), the NSW Office of Environment and Heritage, University of New England environmental geochemistry specialists, representatives from Armidale Regional Council, Kempsey Council and the Derelict Mines Program. The aim being to reduce the antimony and arsenic contamination being generated from historic mine workings within the Bakers Creek sub-catchment. (i.e. it is assumed that the current operations at Hillgrove maintain environmental compliance with their approval and mining lease conditions, and EPL). To achieve this aim, there will be a requirement to demarcate rehabilitation responsibility under mining title, and then address current approval conditions with respect to waste rock storage and management within the MLs issued to Bracken Resources. The working philosophy should be reducing the volumes of arsenic and antimony contaminated waste rock on the surface.

Kapunda Arsenic – Ranked 2

Kapunda Arsenic mine is largely ranked two due to the downstream sediment and surface water quality at location KA_SD02 and KA_SW02 respectively. The site is well vegetated though did return a non-acid forming waste rock sample on site that contained elevated arsenic concentrations (1,640 mg/kg). Plate 6 shows the small area of waste rock; approximately 10m^3 in size, representing a grassy knoll on site, with potential heritage structures, pending an investigation by a heritage professional.

Plate 6: Kapunda Arsenic site with Tilbuster ponds in the background

Complicating factors with recommending any follow up remedial work on this site is that the upstream sediment and water samples (KA_SD01 and KA_SW01) collected on Tilbuster Ponds returned concentrations consistent with the downstream samples, both being above the ISQG high for sediment, and above or on the ANZECC 95% trigger for surface water. This strongly implies that while there is a small point source of contamination resident on site, there may well be background concentrations of arsenic coming from up-catchment. This was noted by Ashley and Graham in 2001, who suggested bedrock sources may be responsible. Ashley and Graham (2001) identified some 20 small metallic mineral prospects in the Commissioners Waters sub-catchment. There are several historic mines on record topographically above Kapunda Arsenic that may warrant further identification and characterisation to better quantify actual arsenic contaminant loads coming from Kapunda.

As the arsenic flux (almost 400 kg/year) reported for Kapunda were calculated from the arsenic contaminated Tilbuster Ponds, we cannot recommend any additional remedial actions on site until the remainder of the catchment (upstream) is investigated, with any contaminated sediment and surface water quantified through sampling and analysis to better define the Kapunda site's contribution to the overall arsenic contamination in the Commissioners Waters sub-catchment.

Recommendation:

Undertake an up-catchment investigation to better determine the likely source of arsenic contamination within the Commissioners Waters sub-catchment.

It is estimated that a nominal fee of $55,000 (GST inclusive) would suffice for labour and disbursements to complete the study.

Faints / Firefly – Ranked 3

GHD did not visit the Faints and Firefly sites due to safety and timing issues. This information is therefore drawn from a report completed by E.A. Systems and Civiltech (2003).

A large challenge for environmental management in the Halls Peak region is the nature of the terrain at most of the contaminated sites. Except for the small dumps of sulfide ore material, which are located on gently sloping areas on the margins of the plateau east of the Chandler River gorge, the other sites (Gibsons, Khans Creek, Faints, Firefly, Sunnyside, Mickey Mouse and Keys) are all located in steep terrain in the Chandler River gorge and its tributaries. Typically, natural slopes in these regions are 20 to 40 degrees, meaning that mineral waste from waste rock dumps originally placed on such slopes have migrated downslope under gravity and variably filled natural gullies, with transport of fine through to coarse (boulder) fractions down local streams into the Chandler River. This is particularly the case for:

- Asens Creek draining the Faints and Firefly area
- Barkers Creek draining Gibson's Open Cut
- Khans Creek draining the Khans Creek site.

The Firefly site, located some 2 km north of the Gibsons site, drains to Asens Creek then into the Chandler River. There remain three open adits and between 10,000 m^3 of mineralised waste rock (galena, pyrrhotite and sphalerite) on site (EA Systems and CivilTech 2003) and 200,000 m^3 (Lottermoser *et al.* 1997). Access is poor, and slopes are steep at up to 40 degrees, making rehabilitation a challenge.

The Faints site is some 300 m east of Firefly adjoining Camp Gully Creek, a tributary of Asens Creek. There is a single adit on site, with poor site access. An undisclosed amount of mineralised waste rock remains in and around Camp Gully Creek.

By GHD's estimates in this report, a combined 4 kg per year of antimony and around 110 kg per year of arsenic are leaving the two sites combined; however, the data suggests that there is relatively little negative influence realised in the Chandler River, and therefore, in the Macleay itself (e.g. Lottermoser *et al*. 1997; Ashley and Graham 2001; Wolfenden 2002). Lottermoser *et al*. (1997) suggest that heavy metal bearing minerals such as jarosite and anglesite reach the stream bed immediately downstream of the Halls Peak deposits by physical erosion, rather than through precipitation from solution in the water column. Further downstream, increasing pH values through catchment dilution subsequently sees co-precipitation of heavy metals with iron and manganese oxyhydroxides.

To access these sites, roads would need to be re-established using what are essentially derelict fire trails. An alternative would be to helicopter smaller plant and equipment in and out; clearly an expensive exercise.

The following work was recommended by EA Systems (2003).

<u>Firefly:</u> Catchment minimisation civil works, re-vegetation, and a creek diversion. EA Systems (2003) estimated these works would cost around $175,000 in 2003. Using a 3 % cumulative multiplier value to account for inflation, the estimated cost of these works today would be around $280,000 (GST inclusive).

<u>Faints:</u> Selective waste rock placement and run-on diversions, barricade the adit. EA Systems (2003) estimated these works would cost around $32,000 in 2003. Using a 3 % cumulative multiplier to account for inflation, the estimated cost of these works today would be around $55,000 (GST inclusive).

Further, the Review of Environmental Factors (REF) document for remediation approval under Part 5 of the *NSW Environmental Planning and Assessment Act* 1979 would require updating. This would be estimated to cost up to $30,000 (GST inclusive) as a site inspection would be required.

GHD understand that the E.A. Systems (2003) historically recommended remedial works have not yet been implemented at Faints and Firefly.

Recommendation: Faints and Firefly are very remote with safety issues. It is argued that based on scale, Gibsons should be a priority over these two sites despite the results of the objective rankings herein. The rankings documented herein pertain to arsenic and antimony contamination; however, the ore in this area is elevated in antimony, arsenic, cadmium, copper, lead, mercury and zinc, and leached aluminium, cadmium, chromium, copper, nickel and zinc at concentrations exceeding the ANZECC (2000) 95 % trigger value. Therefore, based on a purely volume based discussion, Gibsons, with an order of magnitude more waste rock on site, should take priority.

If rehabilitation of Faints and Firefly are to be considered, it is recommended that appropriately qualified and experienced geoenvironmental practitioners re-inspect the site and update the rehabilitation options and costs prior to any works being implemented; including consideration of the environmental geochemistry with respect to acid potential, not simply focusing on physical rehabilitation.

Rockvale Arsenic – Ranked 4

The Rockvale Arsenic site contains mineralised waste rock with up to 0.7 % arsenic content. GHD's sediment and surface water sampling indicates that arsenic contaminated sediment and surface water are reporting off site into Lambs Valley Creek, a tributary of the Chandler River. However, whilst there may be off site migration, data suggests that there is very little influence of the upper Chandler geochemistry on the Macleay River itself, despite an arsenic anomaly in stream sediment persisting downstream of Rockvale, sediment and surface water return to near background levels below the Chandler (Wollomombi) Falls (Ashley and Graham 2001).

There are three bare areas remaining on site, likely old waste rock storage areas and / or filled shafts (Plate 7). Contaminated sediment and surface water are migrating down the drainage line (Plate 8) and into Lambs Valley Creek.

Plate 7: Bare areas at Rockvale Arsenic

GHD has reviewed a memorandum from the Derelict Mines Unit dated 6 February 2009 offering a tranche of remedial works on site to the landholder. The works included:

- Back filling 4 shafts
- Fencing another shaft
- Reusing the 'mullock dump' on site to infill shafts and rehabilitate other site areas
- Capping and rehabilitating 3 tailings dams on site
- Drainage works
- General site clean-up
- Weed and feral animal management
- Soil amendment and revegetation.

While no formal letter of completion has been sited, the GHD site inspection would indicate that the proposed works above have been completed. However, it appears that the material used to backfill the shafts is now leaching arsenic. Further, the material contains levels of metals such that natural revegetation is not occurring, leading to an erosion hazard. The estimated area of the three scalds combined is around 1,500 m^2.

Plate 8: Drainage line on site below surface scald at Rockvale

Recommendations: Source a growing media to place over the three scalds to a depth of around 300 mm and revegetate. The estimated volume required is around 450m^3. Alternate growing media may be used such as a base soil mix bulked out with appropriately graded biosolids and crushed / powdered limestone or other alkaline amendment. GHD determined that the mineralised waste on site was potentially acid forming (low capacity). Therefore, crushed or powdered limestone should be added on top of the scalds prior to adding the growing media at a rate approximating 10 kg/m^2 to account for the future acid potential of the remaining mineral waste (i.e. around 15 tonnes of powdered limestone).

The estimated cost for these works including preparing a brief remedial action plan (RAP), approval documents (REF), site works including contractors and managing consultant, soil and limestone sourcing, delivery and spreading, and seeding is approximately $90,000 (GST inclusive). Implementing these works should see Rockvale Arsenic mine fully rehabilitated.

Mary Anderson – Ranked 5

The Mary Anderson site contains three small waste rock dumps; two of which are residual surface scalds from previous mineralised material stored on the location. Plate 9 shows the small waste rock dump from where the Mary Anderson mineral waste sample 2 was collected. The waste rock samples returned relatively elevated arsenic (up to 674 mg/kg) and antimony (190 mg/kg), with sediment arsenic up to 41 mg/kg and antimony at up to 27 mg/kg. Surface water showed elevated antimony moving down-catchment at concentrations exceeding the ADWG (2011).

Plate 9: Waste rock dump on site at Mary Anderson

The estimated total volume of waste rock in the three dumps is around 60m^3. The waste rock material was classified as non-acid forming in this report. It was estimated herein that around 4 kg of arsenic and the same flux of antimony may be moving off site per annum.

Note that this site is deemed relatively insignificant in the context of Macleay Catchment-wide contamination.

Recommendations: If remediation is to proceed on site, it is recommended that the three mineral waste stockpiles are buried, covered with around 300 mm of appropriate growing media, and revegetated. This will reduce exposure of the mineralised waste to the elements, and also allow revegetation to occur, further reducing the risk of erosion and transport of arsenic and antimony contaminated sediment.

The estimated volume of topsoil required to cover the buried material is around 20 m^3. Soil testing of the material on site proposed for use as a waste rock cover and growing media should be undertaken to ensure it has metals concentrations suitable for plant growth. It is not anticipated that liming is required.

The estimated cost for these works including preparing a brief remedial action plan (RAP), approval documents (REF), site works including contractors and managing consultant, and seeding is approximately $60,000 (GST inclusive). Implementing these works should see Mary Anderson fully rehabilitated.

Mungay Creek – Ranked 6

The Mungay Creek site generally is somewhat overgrown with natural rehabilitation occurring across various mine features including an old ore stockpile and waste rock dump. Waste rock samples on site returned elevated antimony concentrations of up to 4,080 mg/kg and arsenic of up to 90 mg/kg. Sediment exceeded the ISQG high guidelines for both arsenic (72 mg/kg) and antimony (307 mg/kg), with surface water showing arsenic (0.031 mg/L) and antimony (0.086 mg/L) above the ANZECC 95% trigger value adopted herein.

Plate 10 shows what may be a naturally rehabilitated tailings storage facility on site, while Plate 11 shows the historic ore stockpile. Given the scope of work for this study, GHD were not able to penetrate the possible tailings storage facility to a depth commensurate with positive identification of the structure.

Plate 10: Possible naturally rehabilitated tailings storage facility at Mungay Creek

Plate 11: Ore stockpile at Mungay Creek

The ore stockpile is estimated to be around 50 m^3 in size, the waste rock dump on site around the same size, with one cleared area on site of around 250 m^2 being a possible tailings storage facility. There are also some old mine building features on site which may warrant a heritage study should any remedial works be undertaken. It is likely that an adjacent property that could not be accessed also contains mine features.

As contaminated sediment and surface water appears to be migrating off site and into State Forest, the following works are recommended. GHD estimates that some 112 kg of antimony and around 3 kg of arsenic may be migrating off site in surface water each year. However, the data suggests that very little, if any, is finding its way into the Macleay River given the downstream results at MC_SW03.

Recommendation: The scope of work at Mungay Creek Antimony Mine for this study was such that clear recommendations on remedial actions cannot be categorically stated beyond rehabilitation of the ore stockpile and waste rock dump. This site would benefit from additional works being undertaken to adequately assess the extent of site contamination.

As such, it is recommended that an intrusive environmental site investigation be undertaken at Mungay Creek including mineral waste, sediment and surface water sampling. The site boundaries should be clearly demarcated, with all stakeholders involved to develop target remedial criteria.

Given the location of the site, and the level of overgrown vegetation on site, GHD estimates that a budget of around $90,000 (GST inclusive) should be sufficient for this purpose, inclusive of contractors and laboratory analytical costs.

Phoenix Gold – Ranked 7

The Phoenix Gold site is located on private property and was undergoing rehabilitation at the time of writing (refer to Plate 12 and Plate 13).

The site needed rehabilitation as GHD's geochemical data reported herein indicated that the mineral waste samples contained elevated arsenic (up to 308 mg/kg), and that arsenic contaminated sediment and surface water may be reporting off site.

Recommendation: No further action is recommended at this stage pending the outcome of the current site rehabilitation.

Plate 12: Unrehabilitated area on site at Phoenix Gold

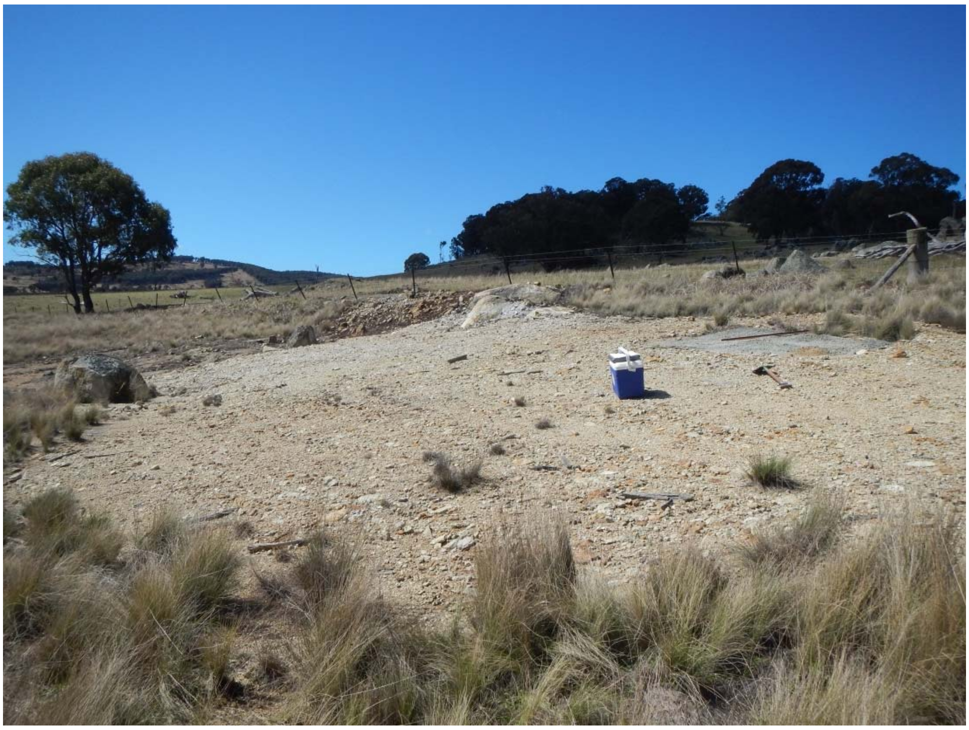


Plate 13: Area being rehabilitated at Phoenix Gold

Khans Creek – Ranked 8

The Khans Creek site is part of the Halls Peak Mineral Field, which has regionally elevated metals including cadmium, copper, lead, mercury, zinc and to a lesser extent, arsenic and antimony (GHD this report; Lottermoser *et al*. 1997). From a rehabilitation perspective, the site is reasonably remote; being some two hours from Armidale by road, and access is via fire trails of varying quality. Two to three remnant adits remain on site (Plate 14), across three reasonably steep, fashioned platforms or benches (refer to Plate 15). Site rehabilitation would prove difficult due to access and the skeletal nature of soil on site.

The geochemical data for the site indicates that this site has mineral waste classified as potentially acid-forming (high capacity); leading to acid and metalliferous drainage from site. The downstream sediment sample contained arsenic at 24 mg/kg. While no water sample was able to be collected, an estimated flux leaving site is around 4 kg/year arsenic and 0.4 kg/year antimony. It is likely that lead and zinc far exceed the arsenic and antimony flux leaving site (the down-catchment sediment sample contained 4,460 mg/kg zinc, 643 mg/kg lead and 292 mg/kg copper).

Recommendation: Works should include placing grates over the adits for safety, liming exposed mineralised rock, and attempting to revegetate the three platforms on site using a growing media and native seed mix. Run-on diversion should be undertaken if possible given the site topography. Additional waste rock samples should be collected to determine liming rates. Based on the three samples analysed, an estimated liming rate would be approximately 20 to 30 kilograms per square metre. Given the condition of site access roads and the location of site, relatively small plant would be required. Each platform is estimated at around 200 to 300 m^2, meaning that some 25 tonnes of powdered lime would be required prior to the addition of a growing media and revegetating the site.

Khans Creek is a low priority remediation site given its location and relatively small arsenic and antimony flux. An estimated rehabilitation costs including approvals, contractors, limestone and soil supply, and supervision would be around $85,000 (GST inclusive).

Plate 14: Remnant adit at Khans Creek

Plate 15: One of three platforms or benches at Khans Creek

Gibsons – Ranked 9

Gibson's open cut is located in topographically challenging terrain, with slopes of up to 40 degrees reported (EA Systems and CivilTech 2003), which introduces significant safety risks when considering site rehabilitation (Plate 16). The NSW Department of Lands (2008) stated that the site was 'very unstable and unsafe, with a high potential for rock slides', and subsequently recommended that the access gate be permanently locked to prevent unauthorised access. GHD could access site with no apparent security restraints, so security upgrade to site is required.

Sampling at Gibsons was not in the Stage 2 or 2a scope; however, GHD did visit the site to undertake a visual inspection. EA Systems and CivilTech (2003) completed a remediation action plan and review of environmental factors from which rehabilitation objectives have been drawn, with costs updated to 2016 estimates.

Plate 16: View from the top of Gibsons open cut

Lottermoser *et al*. (1997) and EA Systems and CivilTech (2003) estimated that some 100,000 m^3 of mineralised waste rock still reside on site, with an estimated disturbance footprint of approximately 5 hectares. Localised acid and metalliferous drainage has been reported from site (Ashley and Graham 2001).

Earlier sections provided an overview of the rehabilitation works undertaken under EA Systems and CivilTech's (2003) remediation action plan, including the installation of sediment dams on site (Plate 17). The remedial works undertaken in 2004 focused on drainage improvements to reduce run on and runoff, and capture eroded material to retain it on site. Minor lime amendment was undertaken in 2008.

There remain large exposed rock and mineral waste surfaces on site that will continue to erode without revegetation. The EA Systems (2004) remediation completion report noted that:

'as identified in the RAP, erosion control and sediment loss will require vegetation establishment. Soil treatment, such as amending the soil with lime, organic matter and fertiliser and the incorporation of topsoil, to adjust key soil properties would also be required to provide a suitable growing environment for plants.'

EA Systems and Civiltech (2003) provided detail on soil media and revegetation species. This work, being Stage 4 in EA Systems and CivilTech's (2003) remediation action plan, remains to be completed.

The data reported to date suggests that while contaminated sediment and surface water may be migrating off site at Gibsons, the actual influence on the Chandler River, and then the Macleay itself, is relatively trivial in the Macleay Catchment-wide discussion (e.g. Ashley and Graham 2001, Wolfenden 2002).

Note that remediation of Gibsons would be a significant engineering undertaking and serious consideration should be given to balancing the safety risks and the financial commitment against any realised environmental benefits.

Plate 17: Sediment dam at Gibsons Open Cut

Recommendation: Implement EA Systems and CivilTech's (2003) Stage 4 works, or a more informed variation thereof, estimated to cost $566,000 in 2003. Using a 3 % cumulative multiplier value to account for inflation, the estimated cost of these works today would be around $830,000 plus GST; being around. $915,000. Costs would also be borne for updating the review of environmental factors document, and *ad hoc* consulting fees and safety works. It is therefore estimated that approximately $1,000,000 (GST inclusive) would be required to complete site rehabilitation at Gibsons.

It is critical that a full geochemical understanding of the waste rock mineralogy is undertaken prior to re-designing remedial works such that an adequate volume of alkaline ameliorant can be determined. The remedial works must address both the chemical and physical. Previous work has largely focused on the physical only.

Ruby Silver – Ranked 10

Ruby Silver had mineral waste on site in the form of two small waste rock dumps of around 25 m^3 each in size, containing arsenic at concentrations up to 8,420 mg/kg (Plate 18). The mineral waste had acid drainage characteristics though was classified as uncertain with respect to its acid potential. There is also an open shaft on site (Plate 19), and minor slumping around a few previously filled shafts. The up-catchment unfiltered surface water sample (RS_SW01) exceeded the baseline concentration, the ADWG (2011) and the ANZECC 95% guidelines for arsenic. The down-catchment unfiltered sample (RS_SW02) also exceeded both the ADWG (2011) and the ANZECC 95% guidelines.

The results suggest that there may be locally elevated background arsenic concentrations. The results at RS_SW02 suggest that arsenic contaminated surface water may be migrating offsite, although it remains inconclusive given the results for RS_SW01. Note that this site is deemed relatively insignificant in the context of Macleay Catchment-wide contamination.

Notwithstanding the above, the site would benefit from minor rehabilitation works including:

- On site encapsulation of the mineralised waste rock in two small waste rock dumps (potentially used to backfill the open shaft following a bat survey). It is not anticipated that the site requires liming
- Fencing off, or placing a grate over the open shaft if a bat survey finds that bats are present
- Repairing minor slumping around historically filled shafts
- Revegetating surface scalds post encapsulation and / or backfilling. It may be required to import approximately 15m3 of topsoil to assist revegetation.

Recommendation: Whilst a low priority, the remedial works above should be completed if funding becomes available. The estimated cost for the undertaking the minor rehabilitation works at Ruby Silver, including approvals, is $40,000 (GST inclusive).

Plate 18: Two small waste rock dumps at Ruby Silver

Plate 19: Open shaft at Ruby Silver

8. Summary, conclusions and recommendations

8.1 Summary

8.1.1 Introduction

The Macleay Catchment contains many areas that contain elevated concentrations of naturally occurring metals and metalloids, including gold, arsenic and antimony. The presence of mineralised areas within the Macleay Catchment has led to a long mining history stemming some 140 years. Historically, mineralised mining waste, including tailings and waste rock, were consciously disposed of in-stream, and / or poorly stored on many mine sites, as was the practice of the day. Subsequent erosion has seen mineralised waste deposited into tributaries within the Macleay Catchment (Ashley and Graham 2001). This, in turn, has resulted in elevated concentrations of arsenic and antimony in stream sediments for in excess of 300 kilometres within the Macleay Catchment (Ashley and Graham 2001).

Over the past decade, the NSW Government has introduced reforms to ensure the long-term health of State waterways, including the Macleay Catchment, by improving water quality and establishing river flow objectives. Within this State policy framework, the Macleay River Estuary: Coastal Zone Management Plan (Geolink 2012) was commissioned by Kempsey Shire Council with Macleay River with financial assistance from the NSW Government's Estuary Program as administered by the NSW Office of Environment and Heritage (OEH).

Strategy 30.1 of the Macleay River Estuary: Coastal Zone Management Plan (Geolink 2012) contains actions relating to the identification and management of existing sources of contamination from mines in the upper Macleay catchment, seeking to prevent further contamination of waterways, by addressing those upstream contaminant sources. Specifically, the tasks were to undertake measures to (Geolink 2012):

- Address existing sources of contamination from mines in the upper catchment, seeking to prevent further contamination of waterways
- Address upstream sources of antimony and arsenic (e.g. map location, extent, volume, concentration, degree of hazard, remediation options, and implementation practicality.

OEH requested assistance with executing Strategy 30.1 from the (then) NSW Department of Trade and Investment, Regional Infrastructure and Services (Trade and Investment – now simply the Department of Industry, or DoI); from which this Project was instigated. Within DoI resides the Division of Resources and Energy, Derelict Mines Program.

DoI's Derelict Mines Program subsequently commissioned GHD Pty Ltd (GHD) to assist with delivery of DoI's tasks under Strategy 30.1; specifically, as it related to derelict mines within the Macleay Catchment. This document reports on Stages 2 and 2a of the project, and follows on from the Stage 1 report (GHD 2015).

The overall aim of this project was to undertake an assessment of key arsenic and antimony sources from derelict mine sites in the Macleay Catchment, such that priority rehabilitation works can be implemented.

Project objectives were to:

- Identify potential sources of arsenic and antimony from historical mining in the Macleay Catchment

- Quantify the extent, volume and concentration of arsenic and antimony contamination at the sites on a priority basis
- Assess the potential risk to the environment, particularly surface waters
- Outline remediation options and costs for sites that are investigated and where remediation is feasible.

8.1.2 Stage 1 study

To achieve those project objectives, GHD undertook a Stage 1 desktop study (GHD 2015) using historical data that found that:

- The key contributor of antimony to the Macleay Catchment was found to be the Bakers Creek sub-catchment (around 77 percent of total antimony flux). This, presumably, is mostly sourced from historic mine workings within the Hillgrove Mineral Field.
- The second largest antimony contributor by flux was the Chandler sub-catchment (around 4.5 percent), which hosts the Halls Peak and Rockvale derelict mines, amongst others, followed by the Hickey and Mungay Creek sub-catchment that contributes some 3.2 percent of the antimony flux. This is likely stemming from the Mungay Creek Antimony Mine. Then comes Commissioners Waters (around 1 percent) and Apsley (0.4 percent); the latter possibly a relative contributor based on small point source contribution and large catchment area, thereby yielding a relatively significant flux.
- Key arsenic contributors include the Chandler sub-catchment with around 35 percent, Bakers Creek with around 25 percent, Commissioners Waters (7.2 percent), Apsley (2.6 percent) and Hickey and Mungay Creek sub-catchment with 1.2 percent.

The Stage 1 findings supported previous studies undertaken through the University of New England (UNE) that reported the Bakers Creek sub-catchment as the main contributor of arsenic and antimony contamination within the Macleay Catchment (e.g. Ashley and Graham 2001, Ashley *et al*. 2006).

GHD (2015) stated that due to inherent limitations within the surface water dataset used in Stage 1 of the Project, largely due to spatial considerations and the lack of stream flow data, it was not possible to calculate specific contaminant flux from individual mine sites nor flux from individual mine domains within the priority sub-catchments. GHD (2015) therefore recommended additional targeted mineral waste, sediment and water and sampling in the Chandler, Bakers Creek, Hickey and Mungay Creek, Commissioners Waters and Apsley sub-catchments.

8.1.3 Stages 2 and 2a

The data were used to identify key point sources of arsenic and antimony within each of the five priority sub-catchments in this Stage 2 and 2a report. To that end, during Stage 2a GHD collected:

- 27 mineral waste samples from 10 individual mine sites / areas in 5 sub catchments
- 74 sediment samples from 15 sites in 6 sub catchments
- 52 surface water samples from 14 sites in 6 sub catchments (Khans Creek being the exception).

A summary of the mineral waste, sediment and surface water results as they relate to the various screening criteria used to assess if each site was ‘contaminated’ is provided in Table 19.

Overall, the data collected in Stages 2 and 2a were remarkably consistent with an historic data set and published literature used in Stage 1. This provides a level of confidence in the data and suggests that reasonably consistent arsenic and antimony concentrations are being reported by site for mineral waste, sediment and surface water over time. This in turn would indicate that the key contaminant sources remain relatively consistent over time, thereby allowing for their identification and ranking for priority remedial action.

Table 19: Summary of mineral waste, sediment and surface water results by site

Sample	Mineral waste	Sediment	Surface water	Off-site migration (contaminant)?	Comment
Bakers Creek					
Hillgrove Mineral Field	X	X	X	**Yes (As, Sb)**	Numerous individual sites rolled up in this table to inform the summary
Chandler - Upper					
Phoenix Gold	X	X	X	**Yes (As)**	Acid rock drainage present
Ruby Silver	X	X	X	**Yes (As)**	-
Tulloch	X	X	X	No	PAF waste rock on site
Rockvale	X	X	X	**Yes (As)**	Acid rock drainage present
Chandler - Lower					
Chandler (Rathbones Point East and Stuart Reef)	NS	√	√	No	-
Khans Creek	X	X	NS	**Yes (Sb, As)**	Contaminated sediment down-catchment. PAF waste rock on site. No water sample.
Keys Prospect	NS	√	√	No	-
Mickey Mouse	NS	√	√	No	-
Sunnyside	NS	√	√	No	-
Commissioners Waters					
Kapunda	X	X	X	**Yes (As)**	Up-catchment contaminant sources likely
Mary Anderson	X	X	X	**Yes (Sb)**[1]	Neutral mine drainage present
Apsley					
Europambela	X	√	√	No	PAF waste rock on site
Hickeys / Mungay Creeks					
Mungay Ck	X	X	X	**Yes (As, Sb)**[1]	-
Toorumbee Creek and Warbro Brook					
Warbro Brook	NS	X	X	NA	Naturally elevated background from known mineral prospects

X contaminated; √ not contaminated; NS that media not sampled; NA not applicable – no 'site' *per se*. 1: Dependant on where the 'site boundary' is located.

8.1.4 Bakers Creek

The sediment and surface water data suggests that the bulk of the arsenic and antimony contamination in the Bakers Creek sub-catchment is being generated from workings reporting to Bakers Creek between GHD sample locations 36 (around 4.3 km downstream from the up-catchment sample at sample location 32) and sample location 5 (around 8.9 kms downstream from the up-catchment sample at sample location 32). This stretch of Bakers Creek being some 4.6 km in length receives contaminated sediment and surface water from:

- the historic Black Lode, Syndicate and Sunlight mines
- Golden Gate Gully
- the mine processing area
- the historic Eleanora mine
- the historic Bakers Creek Proprietary Mine waste rock dump
- the historic Brackins Spur mine
- the historic Freehold / Smiths mine.

This in no way implies that the current operation at the Hillgrove Mine is contributing to contamination in the Bakers Creek sub-catchment.

Swamp Creek provides the major input of antimony into Four Mile Creek, and therefore, into Bakers Creek. Mine waste material at Smiths mine (GHD mine waste sample 2) contains 2,150 mg/kg antimony and 2,560 mg/kg arsenic. At sample location 9 in Swamp Creek, sediment antimony and arsenic are strongly elevated (381 mg/kg and 177 mg/kg respectively), and surface water antimony is significantly elevated, being 9.31 mg/L, along with an arsenic value of 0.2 mg/L. No sediment or surface water samples were collected in Four Mile Creek prior to its confluence with Bakers Creek, although earlier data from Ashley and Graham (2001) showed sediment antimony at 636 mg/kg and arsenic at 159 mg/kg.

Although no sampling was undertaken in Bakers Creek by GHD below sample location 2 as part of this study, it is pertinent to note that antimony and arsenic sediment and surface water concentrations are retained to the Macleay River junction, a further 10 km downstream—some 15 km downstream from the major antimony and arsenic influxes of the Hillgrove Mineral Field. Data from Bakers Creek at the Macleay junction (from Ashley and Graham 2001, and Ashley *et al*. 2007) show that sediments contain 197 mg/kg antimony and 103 mg/kg arsenic (which is an average of three analyses), with surface water containing 0.642 mg/L antimony and 0.043 mg/L arsenic (an average of two analyses).

Further demarcating major contaminating areas or point sources with the current data set within the Bakers Creek sub catchment is complicated by the historic slug of contaminated sediment that has been shown to exist down-catchment to the Macleay River junction (Ashley and Graham 2001). The implication from both GHD's, and published and non-published historic sampling, is that the large 'slug' of strongly contaminated sediment in Bakers Creek is present for a distance exceeding 15 km (i.e. exceeding GHD's spatial sampling area). Ashley *et al*. (2007) estimate this to contain around 1,500 tonnes of antimony and 1,000 tonnes of arsenic. The contaminated sediment contains arsenic and antimony concentrations that exceed catchment background concentrations by one to more than two orders of magnitude, and which exceed the ISQG high guidelines by up to 12 times for antimony and 6 times for arsenic. Due to this contaminated sediment, stream water equilibrating with it under ambient conditions (i.e. pH values of 7 to 8 and variable redox) maintain high values of antimony (typically up to 300 times ADWG 2011) and arsenic (typically up to 6 times ADWG 2011) from Hillgrove mine to the Macleay junction.

8.1.5 Other sub-catchments

Of the other sub-catchments in which GHD sampled, the data suggested that contaminated sediment and surface water may be leaving site at:

- Chandler Upper: Phoenix Gold, Ruby Silver, Rockvale Arsenic
- Chandler Lower: Khans Creek
- Commissioners Waters: Kapunda, Mary Anderson
- Hickeys / Mungay Creek: Mungay Creek.

Of note, the single sediment and surface water sample collected in Warbro Brook returned arsenic concentrations above applicable screening criteria, implying that naturally mineralised sub-catchments in the Macleay River Catchment can generate metalloid fluxes that may contribute to the overall contaminant loads.

On a macro scale, by and large, the surface water data are remarkably consistent with the sediment data, with only minor exceptions. Essentially, those sites that returned sediment arsenic and antimony 80th percentiles above the ANZECC (2000) ISQG (low) trigger values also had surface water total antimony and arsenic concentrations above the ADWG (2011). The exceptions being the Chandler sub-catchment for antimony and Warbro Brook for arsenic.

Further, those sub-catchments that showed sediment arsenic and antimony 80th percentiles above the ANZECC (2000) ISQG (high) trigger values also had surface water total antimony and arsenic concentrations above their respective ANZECC (2000) 95% ecological trigger values.

These observations suggest that clean water coming into contact with arsenic and antimony contaminated sediment is itself, becoming contaminated with arsenic and antimony; likely through dissolution. This is broadly consistent with the mineral waste and sediment leachability data that was reported earlier in this report, suggesting how readily soluble the arsenic and antimony (and other metals) are in the solid media leached.

8.1.6 Antimony and arsenic flux

Flux calculations based on rainfall, catchment size and surface water data indicated that:

- Approximately 197 kg per day of antimony is being generated in the Bakers Creek sub-catchment.
- Around 11 kg per day of arsenic is being generated in the Bakers Creek sub-catchment.
- Within the Bakers Creek sub-catchment, and based on the surface water data collected in Stage 2a, it is estimated that around 50 % of the total Bakers Creek antimony flux, and some 80 % of the total arsenic flux may be attributed to Swamp Creek, which drains the Freehold / Smiths mine area. Interestingly, mineral waste from this area did show a slightly different geochemical signature to other areas within Bakers Creek.
- The remaining antimony and arsenic contamination within the Bakers Creek sub-catchment is:
- Being contributed from sub-catchments draining to Bakers Creek where water samples were not collected due to the dry conditions. The sediment data reported herein suggests this may be the case; and
- Reporting from historic contaminated sediment within Bakers Creek.

Based on the mineral waste, sediment and surface water data generated from within the Bakers Creek sub-catchment, it is likely that both contamination sources described above are valid.

Of the other sites, Kapunda arsenic accounted for around 1 kg per day of arsenic flux, with Rockvale contributing an around 0.7 kg per day of arsenic.

The total estimated flux of antimony and arsenic are shown in Table 20. Note the total estimated Bakers Creek flux of 197 kilograms per day (or 72 tonnes per year) and 11 kilograms per day (or 4 tonnes per year) of arsenic. It has been estimated that the flux of antimony into the Pacific Ocean at South West Rocks approximates 8 tonnes per annum, with around 80 % being in particulate form (Ashley *et al*. 2006). The variance between GHD's Bakers Creek numbers and that of Ashley *et al*. (2006) may be due to changing geoenvironmental conditions along the Macleay River, thereby altering the geoenvironmental availability of the metalloids, and therefore, their environmental fate through various transport and uptake mechanisms (e.g. Tighe et al. 2005a; Ashley *et al*. 2007; Wilson *et al*. 2010). Tighe *et al*. (2005b) estimated that around 600 and 500 tonnes of arsenic and antimony respectively are deposited on the Kempsey floodplains, with some evidence of pasture uptake of the two metalloids.

The concept of a contaminant flux calculation using rainfall records at Bellbrook to rank relative site contamination contribution to the overall Macleay Catchment contaminant loads should be used as indicative at best. Whilst based on actual data in the field, the data set does have some statistical outliers, despite the consistency between historic sampling and GHD's sampling reported herein. There are a range of spatial and temporal reasons that this may be so, including for example the sample location, the climate, and flow conditions at the time.

Table 20: Consolidated arsenic and antimony rankings

Sub-catchment	Site	Sb flux (kg/day)	Rank	As flux (kg/day)	Rank
Bakers Creek	Various	197	1	11.035	1
Chandler	Phoenix Gold	0.002	7	0.045	4
	Ruby Silver	0.001	8	0.018	5
	Rockvale Arsenic	0.024	3	0.687	3
	Khans Creek[1]	NA	NA	NA	NA
	Gibsons[2]	0.001	9	0.0009	9
	Faints and Firefly[2]	0.012	=5	0.0029	8
Commissioners Waters	Kapunda Arsenic	0.039	2	1.093	2
	Mary Anderson	0.011	=5	0.012	6
Hickeys/Mungay Creek	Mungay Creek	0.023	4	0.008	7
Total		**197.11**	**-**	**12.90**	**-**

1: A water quality sample has been estimated based on relationships between Chandler sediment and water quality samples collected as part for this study – refer to Table 18. 2: Data from EA Systems (2003).

8.1.7 Rehabilitation priority rankings

Objective rehabilitation priority rankings were calculated using, amongst other inputs, the estimated contaminant flux reported above. The rankings included Gibsons, Faints and Firefly in the Halls Peak Mineral Field of the lower Chandler River sub-catchment; all of which were not in GHD's scope to sample. Therefore, data from EA Systems and CivilTech (2003) were used to calculate contaminant flux.

Based on the data reported herein, the arsenic and antimony rich mineral waste stored in various locations within the Bakers Creek sub-catchment is clearly the number one remedial priority. The priority rehabilitation ranking proceeded assuming as much, and was therefore developed primarily to assist with a relatively objective method to prioritise the remaining sites outside the Bakers Creek sub-catchment for rehabilitation.

Table 21 provides the results of the objective rehabilitation priority rankings.

Table 21: Site rehabilitation objective priority ranking matrix

Sub-catchment	Site	Estimated antimony flux per annum (tonnes)	Sb rank	Estimated arsenic flux per annum (tonnes)	As rank	Environmental risk	Safety risk	Work description[3]	Feasibility of works	Estimated cost ($AUD – GST inclusive estimate)	Priority based on objective ranking
Bakers Creek	Various	71.9	1	4.03	1	High	Various (Low to extreme depending on mine feature)	Various	Various	Indeterminable. More input information required.	1
Chandler – Upper	Phoenix Gold	0.00082	7	0.347	4	High	Low	Rehabilitation works on hold at behest of landholder. No action	Feasible with landholder limitations	0	7
	Ruby Silver	0.00027	=9	0.0066	6	High	Low	Waste rock burial, cover, seed, make shaft(s) safe	Feasible – good access	40,000	10
	Rockvale Arsenic	0.00865	4	0.2508	3	High	Low	Liming, add growing media, seeding	Feasible – good access	90,000	4
Chandler – Lower	Khans Creek[1]	0.00036	8	0.0041	8	High	Medium	Access track re-establishment, liming, soil amendment, revegetation	Very difficult, steep and remote terrain up to 40 degree slopes	85,000	8
	Gibsons[2]	0.00032	=9	0.0032	9	Extreme	High	Security, liming, soil amendment, revegetation	Difficult and remote access	1,000,000	9
	Faints / Firefly[2]	0.00442	5	0.110	5	High	High	Run-on diversion, revegetation	Difficult and remote access	365,000	3
Commissioners Waters	Kapunda Arsenic	0.01424	3	0.3988	2	High	Medium	Additional study needed	Feasible – good access	55,000	2
	Mary Anderson	0.00404	6	0.0045	7	High	Medium	Waste rock burial, cover, seed	Feasible – good access	60,000	5
Hickeys Mungay Creeks	Mungay Creek	0.11203	2	0.0030	10	High	Medium	Additional study needed	Feasible – access would require some clearing / intrusive site investigation to characterise and delineate contamination	90,000	6

1: Khans Creek could not be sampled for water; however, an estimate of arsenic in water was made using the sediment/surface water data correlation for the data collected in the Chandler. The r^2 for arsenic was sound at 0.80 (high confidence); however, for antimony it is low confidence at r^2 = 0.10. Estimates based on sediment concentrations were: surface water arsenic at KC_SD01 0.0114 mg/L and surface water antimony at the same location 0.001 mg/L. Note that arsenic (and other heavy metals) is the issue in the Chandler, not antimony. 2: Data from EA Systems (2003). 3: Additional detail on works required below the table.

8.2 Conclusions and recommendations

8.2.1 Contaminant source and transport

It remains important to note that various authors (e.g. Ashley *et al*. 2006 and Wilson *et al*. 2010) have published on the environmental geochemistry and behaviour of antimony and arsenic in the Macleay Catchment. In summary, as the environmental conditions change down-catchment from reducing to aerobic commensurate with dissolved oxygen loads, vegetation conditions, oxidation-reduction potential, pH and electrical conductivity, the valence of the arsenic and antimony also changes, making it either bioavailable or otherwise.

For example, based on rainfall and catchment size and therefore, estimated discharge at sample location BC_SW02, GHD used the 80th percentile to estimate the dissolved contaminant flux of approximately 72 tonnes of antimony per annum. Ashley *et al*. (2006) reported that the antinomy flux in water in the Macleay River itself was generally consistent at around 10 mg/L, which is approximately 0.32 tonnes per annum. Ashley *et al*. (2006) and Tighe *et al.* (2015b) also noted that antimony fluxes in Bakers Creek downstream of Hillgrove Mine and on the Macleay floodplain decrease rapidly due to antimony adsorption onto amorphous iron oxyhydroxides. This phenomenon may help explain, in part, the variance on antimony loads within Bakers Creek relative to the trunk Macleay—i.e. changing environmental geochemical conditions affecting dissolved antimony loads. Other antimony uptake mechanisms include aquatic algae, riparian plants which have antimony concentrations between 3 and 100 times background concentrations of the same species for up to 50 kilometres down-catchment of Hillgrove Mine - up to 100 mg/kg (Ashley *et al*. 2006), and the Macleay floodplain and its pastures (Tighe *et al*. 2005).

Further, GHD's data from the Bakers Creek sub-catchment showed that only around 15 % of antimony and almost none of the arsenic is transported in the dissolved form. That is that there were very little or no difference between the filtered and unfiltered surface water data. This suggests that adsorption of antimony and arsenic to suspended solids and sediment is a key transport mechanism. This, when added to past observations that very little of the overall Macleay Catchment load of antimony or arsenic is directly attributable to point sources of contaminated water from historic mining adits (e.g. Ashley and Graham 2001), an overall rehabilitation strategy becomes apparent.

8.2.2 Rehabilitation responsibility

The implications of the current operations in the Bakers Creek sub-catchment with regard to apportioning responsibility for remediation become immediately apparent. There are several considerations that introduce ambiguity. This includes for example, historic mine workings and mineral waste within the Bakers Creek sub-catchment and Bakers Creek itself, respectively.

GHD is unaware of any arrangement between Bracken Resources and the NSW Department of Resources and Energy whereby historic workings within the 26 mining leases are excised from those leases with respect to rehabilitation responsibility; with one exception. The exception is the waste rock dump located adjacent to Bakers Creek in the vicinity of the old Bakers Creek mine (from where Bakers Creek mineral waste sample 3 was collected). GHD understand that this waste rock dump is on the Derelict Mine Program's register. The old Bakers Creek waste rock dump was intersected by the current mine haul road at the time of sampling.

Further, EA Systems (2003) allocated rehabilitation responsibility to over 500 individual mine features in 11 domains across the Bakers Creek sub-catchment. This demarcation was limited to whether or not the mine operator at the time (New England Antimony Mines) were known to have worked those features; otherwise they were allocated to the NSW Department of Mineral Resources, now the Division of Resources and Energy within the Department of Industry. Many of the sites responsibility remained unknown in the EA Systems (2003) report. There are several legal considerations pertaining to continuity of title, and other agreements between the current operator and the Department of Industry under the 26 mining leases as to who actually has legal rehabilitation responsibility for the mine features.

EA Systems (2003) identified over 500 potentially contaminating mine features in mine 11 domains in the Bakers Creek sub-catchment. There are undoubtedly many more. It is not possible, nor may it be safe or practical given current technologies, to attempt to quantify point source contamination emanating from over 500 individual mine features. It is instead, beneficial to identify those highest relative contributors to overall contaminant loads, and selectively remediate those, if safe and possible to do so.

In addition, there appears little that can be done cost-effectively with current technology to remediate the historic slug of contaminated sediment in Bakers Creek itself. It will, in geological time, work its way through the system, and be deposited into the ocean and / or onto the Macleay River floodplains, where it will ultimately be buried by other sediment. This changes the geochemical state of the arsenic and antimony such that it will likely become environmentally unavailable.

A final consideration when demarcating responsibility for remedial priority are the Derelict Mines Funding Priority Guidelines, under which, the Derelict Mines Program can only fund derelict mines. This is as against mine features on current mining leases that may be, in fact, part of tenure continuity to past operations whereby the current operator would assume rehabilitation liability. This is a matter beyond the scope of this report, which simply highlights the type and level of contamination within the Bakers Creek sub-catchment.

The discussion above in Section 8.2.2 should not be a reason to delay remediation activities in the Bakers Creek sub-catchment; however, remain a key priority issue that requires resolution to ensure that a remedial strategy is implemented in the Bakers Creek sub-catchment.

8.2.3 A proposed way forward

General observations and suggested strategy

The data in this and historic reports continue to find that the vast majority of antimony and arsenic contamination in the Macleay River Catchment is being generated from historic mine workings and contaminated sediment in the Bakers Creek sub-catchment. This in no way negates the importance of discrete contributions from other historic workings in the Macleay Catchment, or contributions from naturally mineralised sub-catchments.

It is clear that the waste rock resident within the Bakers Creek sub-catchment contains elevated concentrations of arsenic and particularly, antimony. The mechanism for contaminant transport into Bakers Creek and the Macleay River is weathering and erosion of the waste rock into drainage lines where it becomes contaminated sediment. Clean water comes into contact with the contaminated waste rock and sediment and becomes contaminated through mineral dissolution processes. Downstream transport of the antimony and arsenic while adsorbed to suspended solids or bedload sediment become the transport mechanisms.

Therefore, it becomes apparent that if the contaminated waste rock in the Bakers Creek sub-catchment was rehabilitated, significant contaminant point sources would be removed, thereby reducing the future generation and transport of contaminated sediment and water.

The remedial strategy takes into consideration the historic slug of contaminated sediment currently resident as bedload within Bakers Creek, which will naturally attenuate over geological time. The strategy focuses on reducing additional contaminated sediment finding its way into Bakers Creek by proactively managing mineral waste elevated in arsenic and antimony. It is also important to recognise that the area is naturally mineralised, and rainwater in the form of runoff flowing over exposed stibnite veins will generate a small antimony flux through mineral dissolution. This is a natural phenomenon that will elevate antimony concentrations in certain sub-catchments within Bakers Creek above non-mineralised sub-catchments. Therefore, the strategy focuses on proactive, remedial solutions for those areas of exposed waste rock whose remediation can positively impact water quality within the Bakers Creek sub-catchment.

Those contaminant point sources identified in other sub-catchments can also be prioritised and managed as funding becomes available.

Opportunities and constraints

Considering the Pareto Principal, it is recommended that the strategy to reduce future point source (diffuse source refers to historic contaminated sediment in drainage lines that is likely not cost-effective or possible to remediate) arsenic and antimony contamination from derelict mines in the Macleay Catchment becomes a dual responsibility.

It is recommended that discussions are held between the mine operator, the NSW Department of Planning, the NSW EPA, The NSW Department of Industry (Resources and Energy), the NSW Office of Environment and Heritage, University of New England environmental geochemistry specialists, representatives from Armidale Regional Council, Kempsey Council and the Derelict Mines Program to demarcate rehabilitation responsibility under mining title, and then, address current approval conditions with respect to waste rock storage and management within the MLs issued to Bracken Resources. Once the question of rehabilitation responsibility has been addressed, there may be opportunities to pursue third party funding to finance priority remedial works on a project by project basis.

It is anticipated that group of stakeholders outlined above would sit within existing governance frameworks for environmental management within the Macleay Catchment, being the Macleay River Working Group, with subject matter experts seconded into the Group as required to assist with technical matters.

Potential constraints to the implementation of this strategy may include current Hillgrove Mine approval conditions, issued pursuant to both the *Mining Act* 1992 and the *Environmental Planning and Assessment Act* 1979, the approved Mining Operations Plan (MOP), and potentially, certain conditions within EPL912—particularly how they relate to managing mineral waste on site.

The derelict mine sites located in sub-catchments other than Bakers Creek would remain the management responsibility of the Derelict Mines Program, for action on a priority basis as funding would permit. This of course must consider their priority ranking with other legacy sites beyond the Macleay Catchment.

8.2.4 Objective priority rehabilitation recommendations

Bakers Creek – ranked 1

Recommendations

It is deemed premature to recommend individual remedial actions within the Bakers Creek sub-catchment based on the data available to date. That is, that the data set collected during Stage 2a is useful as a first pass, indicative indictor of priority remedial areas. Follow up monitoring should be completed to increase confidence and confirm the priority remedial areas. This should incorporate surface water sampling and flow rate monitoring such that contaminant flux can be estimated and ranked to confirm areas for priority remedial works. The data should build upon that reported herein.

In terms of prioritising the site works within the Bakers Creek sub-catchment, the data indicated that the majority (estimated at approximately 40 tonnes per annum of the total Bakers Creek antimony flux appears to be reporting from the historic Freeholds / Smiths mine workings under normal flow conditions, noting that this flux calculation is based on one surface water sample collected during the Stage 2a fieldwork. Given that there are 200 individual mineral occurrences in the Hillgrove Mineral Field (NSW Department of Mineral Resources 1992), and over 500 known individual mine features (EA Systems 2003) from historic operations at Hillgrove, it is not possible to categorically apportion contamination by point source in this reach of Bakers Creek without additional work. Rather, the surface water and sediment data should be used to prioritise high priority areas for future work upon which a remedial strategy should be based.

It is therefore recommended that the Bakers Creek sub-catchment issues be incorporated into the existing Macleay River Working Group for priority action. The Group should include the current mine operator—Bracken Resources, the NSW Department of Planning, the NSW EPA, The NSW Department of Industry (Resources and Energy), the NSW Office of Environment and Heritage, University of New England environmental geochemistry specialists, representatives from Armidale Regional Council, Kempsey Council and the Derelict Mines Program. The aim being to reduce the antimony and arsenic contamination being generated from historic mine workings within the Bakers Creek sub-catchment. (i.e. it is assumed that the current operations at Hillgrove maintain environmental compliance with their approval and mining lease conditions, and EPL). To achieve this aim, there will be a requirement to demarcate rehabilitation responsibility under mining title, and then address current approval conditions with respect to waste rock storage and management within the MLs issued to Bracken Resources. The working philosophy should be reducing the volumes of arsenic and antimony contaminated waste rock on the surface.

Kapunda Arsenic – ranked 2

GHD cannot recommend any additional remedial actions on site until the remainder of the catchment (upstream) is investigated, with any contaminated sediment and surface water quantified through sampling and analysis to better define the Kapunda site's contribution to the overall arsenic contamination in the Commissioners Waters sub-catchment.

Recommendations

- Undertake an up-catchment investigation to better determine the likely source of arsenic contamination within the Commissioners Waters sub-catchment. It is estimated that a nominal fee of $55,000 (GST inclusive) would suffice for labour and disbursements to complete the study

Faints / Firefly – ranked 3

Faints and Firefly are very remote with safety issues. Considering order of magnitude contamination of other metals beyond simply arsenic and antimony, Gibsons should arguably be a priority over these two sites, despite the rankings herein. The ranks herein pertain to arsenic and antimony contamination; however, the mineral waste in the Halls Peak Mineral Field is elevated (using the geochemical abundance index method) in antimony, arsenic, cadmium, copper, lead, mercury and zinc. It also leached aluminium, cadmium, chromium, copper, nickel and zinc at concentrations exceeding the ANZECC (2000) 95 % trigger value. Therefore, based on a purely volume based discussion, Gibsons, with an order of magnitude more waste rock on site, should take priority.

Recommendations

- If rehabilitation of Faints and Firefly are to be considered, it is recommended that appropriately qualified and experienced geoenvironmental practitioners re-inspect the site and update the rehabilitation options and costs prior to any works being implemented; including consideration of the environmental geochemistry with respect to acid potential, not simply focusing on physical rehabilitation.

- Faints and Firefly are very remote with safety issues. It is argued that based on scale, Gibsons should be a priority over these two sites despite the results of the objective rankings herein. The rankings documented herein pertain to arsenic and antimony contamination; however, the ore and waste in this area is elevated in antimony, arsenic, cadmium, copper, lead, mercury and zinc, and leached aluminium, cadmium, chromium, copper, nickel and zinc at concentrations exceeding the ANZECC (2000) 95 % trigger value.

Rockvale Arsenic – ranked 4

Recommendations

- Source a growing media to place over the three scalds to a depth of around 300 mm and revegetate. The estimated volume required is around 450m3. Alternate growing media may be used such as a base soil mix bulked out with appropriately graded biosolids and crushed / powdered limestone or other alkaline amendment. GHD determined that the mineralised waste on site was potentially acid forming (low capacity). Therefore, crushed or powdered limestone should be added on top of the scalds prior to adding the growing media at a rate approximating 10 kilograms per square metre to account for the future acid potential of the remaining mineral waste (i.e. around 15 tonnes of powdered limestone).
- The estimated cost for these works including preparing a brief remedial action plan (RAP), approval documents (REF), site works including contractors and managing consultant, soil and limestone sourcing, delivery and spreading, and seeding is approximately $90,000 (GST inclusive). Implementing these works should see Rockvale Arsenic mine fully rehabilitated.

Mary Anderson – ranked 5

Recommendations

- If remediation is to proceed on site, it is recommended that the three mineral waste stockpiles are buried, covered with around 300 mm of appropriate growing media, and revegetated. This will reduce exposure of the mineralised waste to the elements, and also allow revegetation to occur, further reducing the risk of erosion and transport of arsenic and antimony contaminated sediment.
- The estimated volume of topsoil required to cover the buried material is around 20 m3. Soil testing of the material on site proposed for use as a waste rock cover and growing media should be undertaken to ensure it has metals concentrations suitable for plant growth. It is not anticipated that liming is required.
- The estimated cost for these works including preparing a brief remedial action plan (RAP), approval documents (REF), site works including contractors and managing consultant, and seeding is approximately $60,000 (GST inclusive). Implementing these works should see Mary Anderson fully rehabilitated.

Mungay Creek – ranked 7

The scope of work at Mungay Creek Antimony Mine for this study was such that clear recommendations on remedial actions cannot be categorically stated beyond rehabilitation of the ore stockpile and waste rock dump. This site would benefit from additional works being undertaken to adequately assess the extent of site contamination, noting that while the data shows that contamination may be migrating off site, very little if any would be finding its way into the Macleay River itself.

Recommendations

- It is recommended that an intrusive environmental site investigation be undertaken at Mungay Creek including mineral waste, sediment and surface water sampling. The site boundaries should be clearly demarcated, with all stakeholders involved to develop target remedial criteria.
- Given the location of the site, and the level of overgrown vegetation on site, GHD estimates that a budget of around $90,000 (GST inclusive) should be sufficient for this purpose, inclusive of contractors and laboratory analytical costs.

Phoenix Gold ranked 8

Recommendations

No further action is recommended at this stage pending the outcome of the current rehabilitation.

Khans Creek – ranked 9

Recommendation

- Works should include placing grates over the adits for safety, liming exposed mineralised rock, and attempting to revegetate the three platforms on site using a growing media and native seed mix. Run-on diversion should be undertaken if possible given the site topography. Additional waste rock samples should be collected to determine liming rates. Based on the three samples analysed, an estimated liming rate would be approximately 20 to 30 kilograms per square metre. Given the condition of site access roads and the location of site, relatively small plant would be required. Each platform is estimated at around 200 to 300 m2, meaning that some 25 tonnes of powdered lime would be required prior to the addition of a growing media and revegetating the site.
- Khans Creek is a low priority remediation site given its location and relatively small arsenic and antimony flux. An estimated rehabilitation costs including approvals, contractors, limestone and soil supply, and supervision would be around $85,000 (GST inclusive).

Gibsons – ranked 9

Recommendations

- Implement EA Systems and CivilTech's (2003) Stage 4 works, or a more informed variation thereof, estimated to cost $566,000 in 2003. Using a 3 % cumulative multiplier value to account for inflation, the estimated cost of these works today would be around $830,000 plus GST; being around. $915,000. Costs would also be borne for updating the review of environmental factors document, and ad hoc consulting fees and safety works. It is therefore estimated that approximately $1,000,000 (GST inclusive) would be required to complete site rehabilitation at Gibsons.
- It is critical that a full geochemical understanding of the waste rock mineralogy is undertaken prior to re-designing remedial works such that an adequate volume of alkaline ameliorant can be determined. The remedial works must address both the chemical and physical. Previous work has largely focused on the physical only.
- Note also the comments above under Faints and Firefly regarding priority remediation of this site.
- Note that remediation of Gibsons would be a significant engineering undertaking and serious consideration should be given to balancing the safety risks and the financial commitment against any realised environmental benefits.

Ruby Silver – ranked 10

Recommendations

- Whilst a low priority, the remedial works should be completed if funding becomes available; particularly making the open shaft secure. The estimated cost for the undertaking the minor rehabilitation works at Ruby Silver, including approvals, is $40,000 (GST inclusive).

8.2.5 Subjective priority rehabilitation recommendations

The primary recommendation is to build on the historic data and the data provided herein to prioritise a more detailed understanding of the key Bakers Creek sub-catchment point sources of contamination for priority remedial action. It is recommended that this progress as a multi-stakeholder, inter-Governmental working group as outlined above with clear terms of reference and a mandate to reduce antimony and arsenic loads being generated from the Bakers Creek sub-catchment.

With regard to the overall purpose and aims of this study, the data reported herein are broadly in agreement with historic data that suggest that the remaining sites listed below are relatively insignificant in their contribution to the overall Macleay Catchment arsenic and antimony loads. However, given that the Derelict Mines Program commissioned this study and report; a selection of these sites may be deemed appropriate for remedial action commensurate with the Derelict Mines Funding Priority Guidelines and the governance decisions made thereunder. This acknowledges that contaminants leaving some sites include species beyond arsenic and antimony. Their absolute remedial priority, however, should be assessed within the state-wide context of priority sites requiring remediation, such that the most appropriate investment decisions for public funds are realised.

Of the remaining sites not located within the Bakers Creek sub-catchment, the following works should be considered, noting that the data indicates that their relative contribution to antimony and arsenic loads within the Macleay River Catchment are relatively insignificant from a whole of catchment perspective:

1. Complete detailed investigations in the Commissioners Waters sub-catchment (up-catchment of Kapunda Arsenic) and at Mungay Creek to determine:
   - What contamination is present up-catchment from Kapunda that is contributing to the arsenic load in the Commissioners Waters sub-catchment. There remain up to 20 small metallic mineral prospects within the Commissioners Waters sub-catchment that may be contributing loads in excess of Kapunda itself.
   - The full extent of the antimony contamination at Mungay Creek, including accessing all sites on which the historic mine was located.
2. Update the remediation strategy at Gibson's Open Cut to consider the mineral waste geochemistry in addition to the physical works, noting that this is a very physically challenging site to remediate. Implement the remedial works at Gibson's Open Cut should funding become available.
3. Complete the recommended remedial works at Rockvale Arsenic which should see Rockvale fully rehabilitated.
4. Complete remedial works at the Khans Creek, Faints and Firefly sites, noting that these would be physically challenging sites to remediate.

5. Mary Anderson and Ruby Silver are lower priority and can be completed over time; although securing the open shaft at Ruby Silver should be completed as a priority to reduce human safety risk.
6. Monitor the remediation actions at Phoenix Gold and re-assess the site and any remedial requirements upon its conclusion.

As a general note, much of the historic remediation completed to date, such as at Rockvale Arsenic and Tulloch Silver for example, appear to focus purely on physical works. While the physical remediation of sites is important, it should not come at the expense of geochemical stabilisation of potentially acid forming materials. This requires a specialised site assessment and a bespoke rehabilitation plan that integrates with the site physical works. That is, a holistic site wide remediation strategy and plan should be developed for each site considered.

With respect to this study, this observation is applicable to sites in the upper and lower Chandler sub-catchment that show varyingly levels of acid potential based on the oxidation of polymetallic sulfide mineral waste on these sites. Those sites are specifically Phoenix Gold, Rockvale Arsenic, Ruby Silver, Khans Creek, Faints, Firefly and Gibsons. This working ethos, however, should extend beyond the Macleay Catchment when planning site remediation to effect long term success, and therefore, maximise the environmental and safety return on investment of public funds.

9. References

AMIRA (2002). *Project P387A Prediction & Kinetic Control of Acid Mine Drainage - ARD Test Handbook.* AMIRA International Limited, Melbourne

Ashley, P. A. and Graham B. (2001). Heavy Metal Loadings of streams in the Macleay River Catchment. *Geological Survey of New South Wales Open File Report GS2001/303*, 129

Ashley, P.M. and Wolfenden, B.J., 2005: Halls Peak massive sulfide deposits, New England Orogen, NSW. In: C.R.M. Butt, M. Cornelius, K.M. Scott and I.D.M. Robertson (eds). *Regolith Expression of Australian Ore Systems, Cooperative Research Centre for Landscape Environments and Mineral Exploration*, Perth. Pp: 163-164.

Ashley P.M., Craw D., Tighe M.K., Wilson N.J. (2006). Magnitudes, spatial scales and processes of environmental antimony mobility from orogenic gold-antimony mineral deposits, Australasia. *Environmental Geology*. Vol 51, pp 499-507.

Ashley, P.M., Graham, B.P., Tighe, M.K. and Wolfenden, B.J. (2007). Antimony and arsenic dispersion in the Macleay River catchment, New South Wales, Australia: a study of the environmental geochemical consequences. *Australian Journal of Earth Sciences*. Vol 54, pp: 83-103.

ANZECC & ARMCANZ (2000). *National Water Quality Management Strategy, Australian and New Zealand Guidelines for Fresh and Marine Water Quality.*

Bowen H. J. M. (1979). *Environmental Chemistry of the Elements*. Academic Press, New York.

Cooper, V. (2013). *Rockvale arsenic mine, NSW: an investigation of acid mine drainage and the potential contamination by heavy metals and metalloids of the surrounding environment.* Third Year Project report, Earth Sciences, University of New England, Armidale (unpublished).

Coffey Environments Pty Ltd. (2008). *Silver Valley Minerals Tulloch Mine – rehabilitation action plan and review of environmental factors* (DM0708E-1). Report ENVILCOV00421-RO2 to NSW Department of Primary Industries.

Coffey Geotechnics (2008). *Analysis of Halls Peak Soil Samples Report for Metals*. Letter report providing analysis of metals in soil collected by Tim Elder of Soil Conservation Service, Department of Lands.

Department of Industry Tourism and Resources (DITR) (2007). *Managing Acid and Metalliferous Drainage*. Manual in the Leading Practice Sustainable Development Program for the Mining Industry series. Commonwealth of Australia.

Queensland Department of Mines and Energy (1995). *Assessment and Management of Acid Drainage*. Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland. 12pp.

Doherty, A. (1999). *An environmental impact study of the Comet gold mine and the Tulloch silver mine, Rockvale, northern NSW, on the surrounding environment*. GEOL308 project report, University of New England, Armidale.

E.A. Systems Pty Ltd and Civiltech Pty Ltd. (2003). *Review of environmental factors and remediation action plan, Halls Peak derelict mines*. Report to NSW Department of Mineral Resources, May, 2003 (unpublished).

E.A. Systems Pty Ltd. (2004). *Completion Report. Remediation of Gibson's open cut mine, Halls Peak*. Report # 20533.3353 to NSW Department of Primary Industries, Mineral Resources (unpublished).

Geolink. (2012). *Macleay River Estuary, Coastal Zone Management Plan*.

GHD (2015). *Derelict Mines – Macleay Catchment Arsenica and Antimony Assessment*. Unpublished report prepared for the Derelict Mines Unit.

Hanly, B. (2012). *Tulloch derelict mine. Mine Inspection Report*. NSW Department of Primary Industries Soil Conservation Service.

INAP (2009). *Global Acid Rock Drainage Guide* (GARD Guide) http://www.inap.com.au/GARDGuide.htm The International Network for Acid Prevention.

Kent A.J.R. (1989). *Geology of the Rockvale area, Northeastern New South Wales*. BSc Honours thesis, University of New England, Armidale (unpublished).

Lottermoser, B.G., Ashley, P.M., Muller, M. and Whistler, B.D. (1997): Metal contamination due to mining activities at the Halls Peak massive sulfide deposits, New South Wales. *Geological Society of Australia Special Publication* 19, pp: 290-299.

Miller, S.D. (1996). Advances in acid mine drainage prediction and implications for risk management. *In: Proceedings of the 3rd International and the 21st Annual Minerals Council of Australia, Environmental Workshop.* Vol 1, 14-18 October, Newcastle Australia. Minerals Council of Australia, Canberra, 149-57.

NEPC (2013). *National Environment Protection (Assessment of Site Contamination) Measure* - as amended in 2013 (herein referred to as the "NEPM"), National Environment Protection Council (NEPC).

NHRMC and NRMMC (2011). *Australian Drinking Water Guidelines* Paper 6 National Water Quality Management Strategy (herein referred to as "ADWG").

NSW Department of Lands (2008). *Job Closure Report – Halls Peak Mine Maintenance*. Soil Conservation Division.

NSW Department of Mineral Resources (1992). Dorrigo-Coffs Harbour 1:250,000 Metallogenic Map; Explanatory Notes. SH/56-10, SH/56-11.

McClatchie, L. and Sylvester, G.C. (1970). *The Tulloch silver mine, Rockvale, northern New South Wales.* NSW Geological Survey Records 12 (1), 5-28.

McClatchie L (2004). Exploration Licence 5926 annual report for Mount Conqueror Minerals NL and Central West Gold NL.

Peel Mining (2016). http://www.peelmining.com.au/projects/ruby/. Accessed 25 February 2016.

Precious Metal Resources (2014). *Quarterly operations report*. Period ending 30 October 2014.

Telford, K., Maher, W., Krikowa, F., Foster S., Ellwood, M.J., Ashley, P.M., Lockwood, P.V. and Wilson, S.C. (2009): Bioaccumulation, biotransference and biogeochemical cycling of antimony with comparisons to arsenic. *Environmental Chemistry* 6, pp:133-143.

Tighe M., Lockwood P. and Wilson S. (2005a). Adsorption of antimony (V) by floodplain soils, amorphous iron (III) hydroxide and humic acid. *Journal of Environmental Monitoring*. Vol 7; pp 1177-1185.

Tighe M., Ashley P., Lockwood P. and Wilson S. (2005b). Soil, water and pasture enrichment of antimony and arsenic within a coastal floodplain system. *Sci. Total Env*. Vol 347: pp 175-186.

US EPA (2015). *Regional Screening Levels – Generic Tables*, November 2015. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-november-2015

Wolfenden, B.J. (2002). *Geochemical behaviour of metalliferous contaminants in the upper Macleay gorges, northern NSW*. BSc Honours thesis, University of New England, Armidale (unpublished).

Appendices

Appendix A – Detailed results

Mineral waste geochemistry

Slurry pH and EC

Slurry pH and electrical conductivity (EC) parameters provide a relatively cheap and rapid indication of the acidity and salinity of a sample at the time of testing. The degree of weathering the material has undergone, in addition to the availability of readily soluble salts may be inferred from these parameters.

Two methods were used herein being the 1:5 solid to water ratio (for pH and EC), and a saturated paste pH.

An acidic slurry paste pH value of less than approximately 4.5 may indicate the presence of stored acidity, or stored sulfide oxidation products within a sample, and subsequent potential for acid generating conditions. Conversely, alkaline slurry pH values may indicate the presence of reactive neutralising minerals in a sample.

Slurry EC may provide an indication of soluble salt loads associated with the sample. If the sample originates from a naturally saline environment, elevated slurry EC values may indicate salinity. Where natural salinity is low, elevated slurry EC values would likely indicate the presence of salt from sulfide mineral oxidation.

Acidic slurry pH values, and / or elevated slurry EC values may be indicative of the potential of a sample to negatively impact the quality of drainage water emanating from waste stockpiles following dissolution of minerals following rainfall.

Noting that ANZECC & ARMCANZ (2000) does not provide pH and EC target values for mineral waste being a solid rather than water, sample classification for pH and EC values against alternate indicative classification guidelines (DME 1995) are presented below in Table A1. Results are shown in Table A2 for all mineral waste samples excluding Bakers Creek, with pH (1:5) values below 4.5 and EC values above 1,000 µS/cm bolded. Generally, a pH (1:5) value of less than 4.5 indicates stored acidity—generally a sign of historic sulfide oxidation as noted above, while EC values over 1,000 µS/cm are indicative of saline drainage (INAP 2009).

Table A1: Slurry pH and EC classification

Test	Unit	Very low	Low	Med.	High	Very high
pH (1:5)	pH unit	<4.5	4.5 – 5.5	5.5 – 7.0	7.0 – 9.0	>9.0
EC (1:5)	µS/cm	150	150 - 450	450 - 900	900 – 2,000	>2,000

Table A2: Slurry pH and EC results

Sample	pH (1:5)	pH (sat paste)	Classification[1]	EC (1:5) µS/cm	Classification[1]	Sample location
Chandler - Upper						
Phoenix Gold 1	**3.5**	4.3	Very low	234	Low	Bare surface scald – minor waste rock
Phoenix Gold 2	**3.4**	4.0	Very low	741	Medium	Bare surface scald – minor waste rock
Rockvale 1	**3.5**	4.4	Very low	192	Low	Bare surface scald[2]
Rockvale 2	**3.4**	4.3	Very low	270	Low	Bare surface scald
Rockvale 3	**2.8**	3.7	Very low	**1,240**	High	Bare surface scald
Ruby Silver 1	**3.9**	5.2	Very low	**1,010**	High	Waste rock dump
Ruby Silver 2	**4.1**	4.8	Very low	119	Very low	Waste rock dump
Tulloch 1	4.8	5.0	Low	220	Low	Former mill area – minor waste rock
Tulloch 2	**4.5**	5.0	Low	213	Low	Bare surface scald – minor waste rock
Chandler – Lower						
Khans Creek 1	**3.7**	4.9	Very low	291	Low	Scattered waste rock lower platform
Khans Creek 2	**3.0**	3.9	Very low	**1,780**	High	Scattered waste rock middle platform
Khans Creek 3	5.6	6.0	Medium	53	Very low	Scattered waste rock higher platform
Mickey Mouse 1	6.7	6.8	Medium	522	Medium	Scattered waste rock
Commissioners Waters						
Kapunda 1	7.0	7.2	High	104	Very low	Bare surface scald
Mary Anderson 1	6.1	6.7	Medium	90	Very low	Waste rock dump
Mary Anderson 2	5.6	6	Medium	80	Very low	Waste rock dump
Mary Anderson 3	5.7	5.8	Medium	200	Low	Waste rock dump
Apsley						
Europambela 1	**3.9**	5.6	Very low	263	Low	Bare surface scald
Europambela 2	**3.9**	4.4	Very low	138	Very low	Bare surface scald
Hickeys / Mungay Creek						
Mungay Ck 1	6.1	6.7	Medium	22	Very low	Waste rock dump
Mungay Ck 2	4.6	4.9	Low	56	Very low	Ore Stockpile

1: Based on DME (1995). pH classified using pH (1:5) results.

2: Three composite mine waste samples were collected (Rockvale 1, 2 and 3)—being a sample from each of the former (now backfilled) shafts that were backfilled using mineralised waste rock from site, thereby leaving surface scalds. This material constituted rock fragments and finer sandy to clayey material, commonly showing conspicuous yellow to orange pigmentation by supergene iron oxides and locally by pale green scorodite (hydrated iron arsenic oxide).

Of the pH and EC data presented in Table A2, mineral waste samples collected from Phoenix Gold, Rockvale, Ruby Silver, Tulloch, Khans Creek and Europambela showed potential for acidic and/or saline drainage.

The presence of pH values below around 4.5 to 5 when combined with EC values approaching or greater than around 1,000 mg/L generally indicate the presence of acid-forming sulfide minerals such as pyrite and / or arsenopyrite. Such values were identified at the following sub-catchments and sites:

- Chandler – Upper: Phoenix Gold (medium EC values), Rockvale and Ruby Silver
- Chandler – lower: Khans Creek

Tulloch Silver in the Upper Chandler sub-catchment returned acidic pH values though low EC values. Slurry pH and EC values in the Commissioners Waters sub-catchment were circumneutral to slightly acidic, while Europambela in the Apsley sub-catchment was acidic though had low to very low EC. Mungay Creek returned slightly acidic pH values with very low EC.

Acid base accounting

Acid base accounting is a term that incorporates a range of static geochemical tests to determine the theoretical maximum potential acidity (MPA) of a sample through the oxidation of sulfide minerals, the theoretical maximum acid neutralising capacity (ANC) of a sample through the dissolution of alkaline carbonates, the displacement of exchangeable bases, and the weathering of silicates, and therefore, the net acid producing potential (NAPP) of a sample (AMIRA 2002). The static geochemical techniques are defined by AMIRA (2002) as initial screening tools. The results are the used to classify the samples and identify any uncertain samples whereby additional, more detailed testing may be required.

In order to determine the MPA of a sample, the total sulfur percent must first be determined. Calculating the MPA of a sample using total sulfur assumes that all sulfur is ‘pyritic’ or reactive (likely in the form of arsenopyrite in the Macleay Catchment), and available to form acid when oxidised; an assumption that is not always correct, depending on the oxidation state of a sample or the type of sulfide present. The procedure may therefore overestimate the acid potential of a sample, and is therefore deemed to be a somewhat conservative approach. In this regard, sulfate sulfur was also analysed and subtracted from the total sulfur to yield a more accurate MPA value. This net sulfur value is often known as ‘reactive’ or ‘pyritic’ sulfur.

The above methodology may also overestimate the ANC of a sample due to assumptions related to the type of carbonate present; i.e. that it is all present as neutralising calcite. Kinetic testing is often undertaken to determine a more accurate AMD risk to compliment the static testing, however was beyond the scope of this study. The net acid production potential (NAPP) is then determined by subtracting the ANC from the MPA as calculated using the pyritic sulfur value. If a sample returns a negative NAPP value, it is unlikely to generate acidity upon oxidation and / or may actually consume acid, while if it returns a positive value, it is likely to generate acid upon oxidation.

Similarly, the net potential ratio (NPR) of a sample, determined by the ANC:MPA ratio, indicates its inherent buffering capacity. AMIRA (2002) report that a NPR in excess of 2 suggests that the sample likely has inherent buffering capacity. A NPR below 2 suggests that the sample is likely to generate acid upon oxidation.

The entire ABA data set is provided in Table A (Appendix D), with a summary provided below in Table A3 for all sub-catchments except for Bakers Creek. Samples that returned NAPP values of potentially acid forming (high capacity) (PAF-HC); being greater than 10 kgH_2SO_4/tonne, and/or have limited self-buffering capacity as determined by a NPR of less than two are bolded.

Table A3: Mineral waste NAPP and NPR results

Sample	NAPP[1] kgH_2SO_4/tonne	NPR	Sample location
Chandler - Upper			
Phoenix Gold 1	3.18	**0.0**	Bare surface scald – minor waste rock
Phoenix Gold 2	5.36	**0.0**	Bare surface scald – minor waste rock
Rockvale 1	7.53	**0.0**	Bare surface scald
Rockvale 2	8.14	**0.0**	Bare surface scald
Rockvale 3	0.86	**0.0**	Bare surface scald
Ruby Silver 1	3.06	**0.0**	Waste rock dump
Ruby Silver 2	2.33	**0.0**	Waste rock dump
Tulloch 1	**16.16**	**0.0**	Former mill area – minor waste rock
Tulloch 2	0.00	NA	Bare surface scald – minor waste rock
Chandler – Lower			
Khans Creek 1	6.82	**0.1**	Scattered waste rock lower platform
Khans Creek 2	**73.65**	**0.0**	Scattered waste rock middle platform
Khans Creek 3	**17.35**	**0.3**	Scattered waste rock higher platform
Mickey Mouse 1	4.90	**0.7**	Scattered waste rock
Commissioners Waters			
Kapunda 1	-12.05	4.8	Bare surface scald
Mary Anderson 1	-1.64	2.4	Waste rock dump
Mary Anderson 2	-0.81	**1.4**	Waste rock dump
Mary Anderson 3	0.79	**0.6**	Waste rock dump
Apsley			
Europambela 1	**12.50**	**0.0**	Bare surface scald
Europambela 2	**14.38**	**0.0**	Bare surface scald
Hickeys / Mungay Creeks			
Mungay Ck 1	3.58	**0.0**	Waste rock dump
Mungay Ck 2	5.4	0.0	Ore Stockpile

1: NAPP calculated from adjusted of pyritic sulfur values being total S – SO_4-S.

The data shown above in Table A3 indicate that by and large, the mineral waste analysed across the 10 derelict mines has the potential to generate some acid upon oxidation, the exceptions being Kapunda and Mary Anderson in the Commissioners Waters sub-catchment, which both showed acid neutralising properties. These two sites were also the only two that returned low-risk NPR values of greater than two, indicating a self-buffering capacity that minimises the potential for acid drainage. This is consistent with the low risk shown from their slurry pH and EC values above.

Khans Creek in the lower Chandler sub-catchment returned the highest NAPP value of around 74 kgH_2SO_4/tonne, with Europambela in the Apsley sub-catchment and Tulloch in the upper Chandler sub-catchment also containing potentially acid generating mineral waste. Two samples from Rockvale in the upper Chandler sub-catchment were also approaching values that would see them classified as potentially acid generating mineral waste.

Mineral waste net acid generation (NAG) testing

The single addition NAG test is a laboratory procedure that allows both the acid forming and acid neutralising reactions to occur to completion. The assumption is that all acid generating and neutralising reactions continue to completion through the use of an aggressive oxidant, being hydrogen peroxide. The NAG test therefore provides additional clarity on the net acid generating potential of a sample. Individually, the NAPP and NAG tests have limitations, but in combination, the reliability of predicting the potential for acid generation is greatly enhanced.

NAG testing provides an indication of the net behaviour of rock when fully oxidised (AMIRA 2002). As noted above, it is performed by rapidly oxidising the pulped rock sample with a hydrogen peroxide solution. It is a relatively aggressive reaction as this method is required to fully oxidise the sulfides and carbonates in the sample in a short period of time. From the resulting aliquot, the pH value is measured and reported, and the aliquot is then titrated to measure the acidity. The titration is to endpoints of pH 4.5, which is indicative of typical pyrite oxidation acidity, and pH 7.0 to assess remaining acidity from other oxidised minerals in addition to metals hydrolysis reactions.

Following the NAG tests, the samples may be classified using both the NAG and NAPP results. Samples may be classified as potentially acid forming – high capacity (PAF-HC), potentially acid forming – low capacity (PAF-LC), uncertain (UC), non-acid forming (NAF) or acid consuming (AC)—refer to Table A4.

Table A4: Sample classification

Primary Geochemical Material Type	NAPP[1] (kgH_2SO_4/tonne)	NAG pH[1] (pH units)
Potentially Acid Forming – High Capacity (PAF-HC)	> 10	<4.5
Potentially Acid Forming – Low Capacity (PAF–LC)	0 – 10[2]	<4.5
Non-Acid Forming (NAF)	Negative	≥4.5
Acid Consuming (AC)	< -50	≥4.5
Uncertain[3]	Positive	≥4.5
	Negative	<4.5

1: From Miller (1996), AMIRA (2002), and INAP (2009). 2: Site-specific but typically in the range of 5 to 20 kgH_2SO_4/tonne. 3: Further testing required to confirm material classification.

Results of the single addition NAG tests and NAG_{pH} values are provided in Table A5, with NAG values returning PAF-HC values bolded, being only Khans Creek 2. Also bolded are samples with NAG_{pH} values below 4.5—generally an accepted threshold for acid generation risk.

Table A5: Mineral waste NAG_{pH} and NAG results

Sample	NAG pH	NAG (pH. 4.5) (kgH_2SO_4/tonne)	NAG (pH 7.0) (kgH_2SO_4/tonne)	Sample location
Chandler - Upper				
Phoenix Gold 1	**3.8**	0.8	2.8	Bare surface scald – minor waste rock
Phoenix Gold 2	**4.1**	0.4	1.5	Bare surface scald – minor waste rock
Rockvale 1	**4.2**	0.3	1.5	Bare surface scald
Rockvale 2	**4.0**	0.6	2.3	Bare surface scald
Rockvale 3	**3.6**	1.3	3.0	Bare surface scald
Ruby Silver 1	4.6	<0.1	1.1	Waste rock dump
Ruby Silver 2	**4.5**	<0.1	1.9	Waste rock dump
Tulloch 1	**3.3**	2.6	2.8	Former mill area – minor waste rock
Tulloch 2	5.9	<0.1	0.5	Bare surface scald – minor waste rock
Chandler - Lower				
Khans Creek 1	5.2	<0.1	0.7	Scattered waste rock lower platform
Khans Creek 2	**2.7**	9.8	**22.9**	Scattered waste rock middle platform
Khans Creek 3	6.3	<0.1	1.3	Scattered waste rock higher platform
Mickey Mouse 1	**3.0**	6	8.8	Scattered waste rock
Commissioners Waters				
Kapunda 1	7.6	<0.1	<0.1	Bare surface scald
Mary Anderson 1	6.3	<0.1	0.5	Waste rock dump
Mary Anderson 2	6.7	<0.1	0.4	Waste rock dump
Mary Anderson 3	7.0	<0.1	<0.1	Waste rock dump
Apsley				
Europambela 1	5.0	<0.1	0.9	Bare surface scald
Europambela 2	**4.0**	0.4	2.2	Bare surface scald
Hickeys / Mungay Creeks				
Mungay Ck 1	**4.0**	0.8	2.8	Waste rock dump
Mungay Ck 2	3.7	1.2	2.8	Ore Stockpile

These results indicate that samples from Europambela, Khans Creek, Mickey Mouse, Phoenix Gold, Rockvale, Ruby Silver, Tulloch and Mungay Creek all generate reaction pH values that are acidic; although only Khans Creek and Mickey Mouse, both in the lower Chandler sub-catchment, returned any NAG values approaching a risk. Khans Creek in the lower Chandler generated the most acid upon oxidation being 22.9 kgH_2SO_4/tonne; consistent with its high NAPP value shown in Table A3.

The NAG_{pH} results in Table A5 were plotted along with the (pyritic) NAPP values to further classify the mineral waste samples according to Table A4 above. The plot is shown as Figure A1 below, with the sample classifications provided in Table A6 below.

Figure A1: NAG_{pH} and NAPP geochemical plot – mineral waste samples

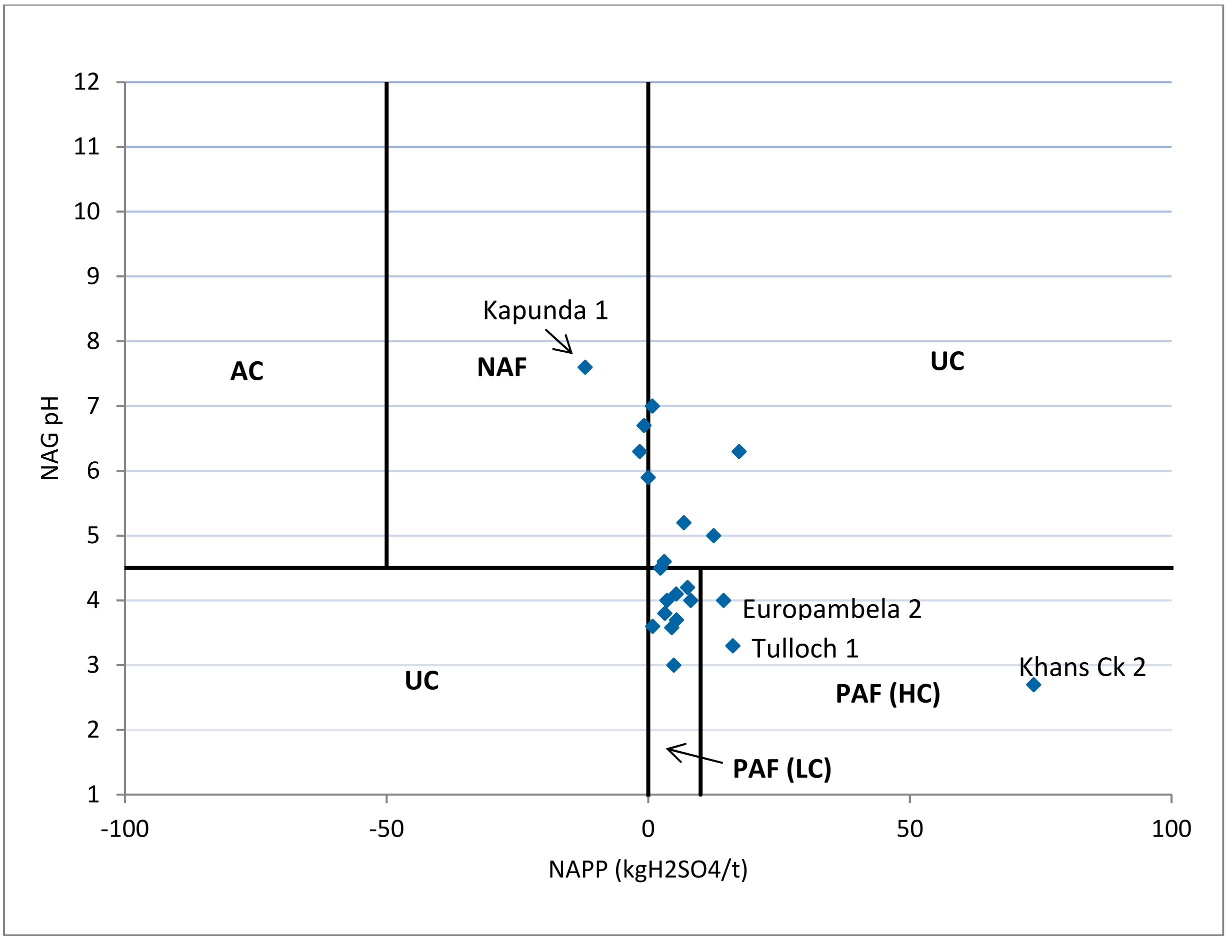


Figure A1 above shows that Kapunda 1 plots as non-acid forming (NAF), Khans Creek 2, Eurpoambela 2 and Tulloch 1 plot as PAF-HC, while all other samples plot as NAF, potentially acid forming – low capacity (PAF-LC) or uncertain (UC). Those samples plotting in the north-eastern quadrant (UC) are likely to include samples that have a non-pyritic sulfur content. This is usually sulfate sulfur and / or less reactive sulfides than pyrite such as galena (lead sulfide) for example. This is so due to the fact that static test-based sulfide is accounted for, however oxidation-neutralisation reactions completed using the NAG test do not result in pH values declining to 4.5. If sulfur speciation were to occur, it is probable that several samples plotting in the upper right UC quadrant may shift left to the NAF quadrant.

Table A6 below shows the NAPP and NAG_{pH} values, and classifies the samples according to Table A4. Samples classified as PAF-HC have been bolded; being Europambela 2, Khans Creek 2 and Tulloch1.

Table A6: NAPP and NAG pH values, and classification

Sample	NAG pH	NAPP ($kgH_2SO_4/tonne$)	Classification	Sample location
Chandler - Upper				
Phoenix Gold 1	3.8	3.18	PAF-LC	Bare surface scald – minor waste rock
Phoenix Gold 2	4.1	5.36	PAF-LC	Bare surface scald – minor waste rock
Rockvale 1	4.2	7.53	PAF-LC	Bare surface scald
Rockvale 2	4.0	8.14	PAF-LC	Bare surface scald
Rockvale 3	3.6	0.86	PAF-LC	Bare surface scald
Ruby Silver 1	4.6	3.06	UC	Waste rock dump
Ruby Silver 2	4.5	2.33	UC	Waste rock dump
Tulloch 1	3.3	16.16	**PAF-HC**	Former mill area – minor waste rock
Tulloch 2	5.9	0.00	NAF	Bare surface scald – minor waste rock
Chandler - Lower				
Khans Creek 1	5.2	6.82	UC	Scattered waste rock lower platform
Khans Creek 2	2.7	73.65	**PAF-HC**	Scattered waste rock middle platform
Khans Creek 3	6.3	17.35	UC	Scattered waste rock higher platform
Mickey Mouse 1	3.0	4.90	PAF-LC	Scattered waste rock
Commissioners Waters				
Kapunda 1	7.6	-12.05	NAF	Bare surface scald
Mary Anderson 1	6.3	-1.64	NAF	Waste rock dump
Mary Anderson 2	6.7	-0.81	NAF	Waste rock dump
Mary Anderson 3	7.0	0.79	UC	Waste rock dump
Apsley				
Europambela 1	5.0	12.50	UC	Bare surface scald
Europambela 2	4.0	14.38	**PAF-HC**	Bare surface scald
Hickeys / Mungay Creeks				
Mungay Ck 1	4.0	3.58	PAF-LC	Waste rock dump
Mungay Ck 2	3.7	5.4	PAF-LC	Ore Stockpile

1: NAPP calculated from adjusted of pyritic sulfur values being total S – SO_4-S.

Geochemical abundance index

A comparison between the metal concentrations reported by the laboratory and the median crustal abundance can be assessed using the Geochemical Abundance Index (GAI). This is a simple, preliminary method of assessment, as it does not take in to account the solubility and / or mobility of the metals, nor their relative toxicity to the receiving environment.

A result with a GAI value of 3 or greater indicates relative enrichment of that particular metal. Results of metals with a GAI of 3 or higher are shown in Table A7, with arsenic and antimony bolded as they appear. It is noted that this report is specific to arsenic and antimony contamination in the Macleay Catchment, however, as other metals were analysed for; those metals with GAI values above 3 are also reported in A7. The complete GAI assessment is provided as Appendix E.

Table A7: Mineral waste GAI exceedances

Sample	Metals with GAI > 3	Sample location
Chandler - Upper		
Phoenix Gold 1	**Sb**, **As**	Bare surface scald – minor waste rock
Phoenix Gold 2	**Sb**, **As**	Bare surface scald – minor waste rock
Rockvale 1	**Sb**, **As**, Pb	Bare surface scald
Rockvale 2	**Sb**, **As**, Pb, Hg	Bare surface scald
Rockvale 3	**Sb**, **As**, Cu, Pb, Hg	Bare surface scald
Ruby Silver 1	**Sb**, **As**, Pb, Hg	Waste rock dump
Ruby Silver 2	**Sb**, **As**	Waste rock dump
Tulloch 1	**Sb**, **As**, Pb, Hg	Former mill area – minor waste rock
Tulloch 2	**Sb**, **As**	Bare surface scald – minor waste rock
Chandler - Lower		
Khans Creek 1	**Sb**, **As**, Cd, Cu, Pb, Hg, Zn	Scattered waste rock lower platform
Khans Creek 2	**Sb**, **As**, Cd, Cu, Pb, Hg, Zn	Scattered waste rock middle platform
Khans Creek 3	**Sb**, **As**, Cd, Cu, Pb, Hg, Zn	Scattered waste rock higher platform
Mickey Mouse 1	**Sb**	Scattered waste rock
Kapunda 1	**Sb**, **As**, Pb, Hg	Bare surface scald
Mary Anderson 1	**Sb**, **As**	Waste rock dump
Mary Anderson 2	**Sb**, **As**, Hg	Waste rock dump
Mary Anderson 3	**Sb**, **As**	Waste rock dump
Apsley		
Europambela 1	**As**, Cu, Hg	Bare surface scald
Europambela 2	**As**, Cu, Hg	Bare surface scald
Hickeys / Mungay Creek		
Mungay Ck 1	**Sb**, **As**, Hg	Waste rock dump
Mungay Ck 2	**Sb**, **As,** Hg	Ore Stockpile

The results in Table A7 show that all 10 sites had arsenic and antimony elevated relative to median crustal abundance, with the exception of Europambela (arsenic only) and Mickey Mouse (antimony only).

The presence of lead and zinc at the polymetallic Khans Creek deposit may go some way to explaining the UC classification reported above in Table A6, being the likely presence of non-pyritic galena and sphalerite respectively. These two sulfides may be accounted for in the NAPP classification, however, depending on the environmental geochemistry, may generate relatively limited acidity upon oxidation as compared to pyrite, thereby maintaining pH values above around 4.5. This may also be the case at Ruby Silver.

Metals screening

Arsenic and antimony results were compared to the nominated metals screening criteria shown in Section 4 of the main report. Results are presented in Table A8, with full details provided in Table B, Appendix D.

Table A8: Mineral waste metals screening

Sample	As (mg/kg)	Sb (mg/kg)	Sample location
Ecological investigation level – area of ecological significance (Schedule B5a NEPM 2013).	**40**	-	-
Ecological investigation level – urban residential / public open space (Schedule B5a NEPM 2013).	**100**	-	-
Regional Screening Level (RSL) for residential soil (US EPA 2014)	-	**31**	-
RSL for industrial soil (US EPA 2014).	-	**470**	-
Chandler - Upper			
Phoenix Gold 1	**230**	18	Bare surface scald – minor waste rock
Phoenix Gold 2	**308**	**108**	Bare surface scald – minor waste rock
Rockvale 1	**40,400**	**48**	Bare surface scald
Rockvale 2	**36,500**	**69**	Bare surface scald
Rockvale 3	**74,300**	**286**	Bare surface scald
Ruby Silver 1	**8,420**	**210**	Waste rock dump
Ruby Silver 2	**1,190**	29	Waste rock dump
Tulloch 1	**904**	**2,220**	Former mill area – minor waste rock
Tulloch 2	**69**	7	Bare surface scald – minor waste rock
Chandler - Lower			
Khans Creek 1	**194**	24	Scattered waste rock lower platform
Khans Creek 2	**334**	**74**	Scattered waste rock middle platform
Khans Creek 3	**674**	**165**	Scattered waste rock higher platform
Mickey Mouse 1	15	**190**	Scattered waste rock
Commissioners Waters			
Kapunda 1	**1,640**	**422**	Bare surface scald
Mary Anderson 1	**244**	**619**	Waste rock dump

Sample	As (mg/kg)	Sb (mg/kg)	Sample location
Mary Anderson 2	**394**	**656**	Waste rock dump
Mary Anderson 3	**1,170**	**7,890**	Waste rock dump
Apsley			
Europambela 1	**71**	<5	Bare surface scald
Europambela 2	32	<5	Bare surface scald
Hickeys / Mungay Creek			
Mungay Ck 1	24	**4,080**	Waste rock dump
Mungay Ck 2	**90**	**2,430**	Ore Stockpile

The results in Table A8 indicate that all sites with the exception of Mickey Mouse had mineral waste with arsenic concentrations that exceeded the NEPM (2013) ecological investigation value for areas of ecological significance. All sites except Mickey Mouse, Europambela and Mungay Creek had mineral waste with arsenic concentrations that exceeded the NEPM (2013) ecological investigation value for public open space.

The results in Table A8 indicate that all sites with the exception of Europambela had mineral waste with antimony concentrations that exceeded the US EPA (2014) regional screening level for residential soil. In addition, antimony concentrations were elevated enough at Tulloch, Mary Anderson and Mungay Creek sites to exceed the US EPA (2014) regional screening level for industrial soil.

While not prescriptive for the purposes of this study, the comparison above does provide a relative indicator of arsenic and antimony concentrations against widely used screening criteria.

Leach testing

The 20 leach tests were completed using Australian Standard Leaching Procedure (ASLP) with a deionised water solution, which is intended to provide data that is indicative of *in situ* rainwater leaching. It is designed to provide longer term accelerated weathering data than the $pH_{1:5}$ and $EC_{1:5}$ tests reported earlier, which are intended to provide indicative, 'contact' results between rain water and mineral waste on site.

Table A9 shows those metals that leached values greater than the 95% ANZECC/ARMCANZ (2000) freshwater aquatic ecosystem guideline value.

As noted earlier, the leach tests are intended to be indicative only to identify potentially leachable elements for ecological risk assessment purposes. The leachate results cannot therefore, be directly extrapolated to predict leachate quality in the field due to dilution effects in natural catchments; however, remain useful as being an indicator of potentially leachable elements within the mineral waste samples.

Given the arsenic and antimony focus of this study, both metalloids have been bolded in Table A9 below where they were present in whole rock assay and leached above the 95% ANZECC/ARMCANZ (2000) freshwater aquatic ecosystem guideline value. It is noted that this report is specific to arsenic and antimony contamination in the Macleay Catchment, however, as the data were generated; other analysed metals with GAI values above 3 are also reported in Table A9. Full results are provided in Table C, Appendix D.

Table A9: Mineral waste GAI and leachate exceedances

Sample	Metals with GAI > 3	Leachable elements > 95% ANZECC (2000)	Sample location
Chandler - Upper			
Phoenix Gold 1	**Sb**, **As**	Not leached	Bare surface scald – minor waste rock
Phoenix Gold 2	**Sb**, **As**	Al, **Sb, As** Cd, Cu, Zn	Bare surface scald – minor waste rock
Rockvale 1	**Sb**, **As**, Pb	**Sb, As** Cd, Cu, Zn	Bare surface scald
Rockvale 2	**Sb**, **As**, Pb, Hg	Al, **As**, Cd, Cu, Zn	Bare surface scald
Rockvale 3	**Sb**, **As**, Cu, Pb, Hg	Al, **Sb, As** Cd, Cr, Cu, Zn	Bare surface scald
Ruby Silver 1	**Sb**, **As**, Pb, Hg	Al, **Sb, As** Cd, Cu, Ni, Zn	Waste rock dump
Ruby Silver 2	**Sb**, **As**	Not leached	Waste rock dump
Tulloch 1	**Sb**, **As**, Pb, Hg	**Sb**, Cu, Pb, Zn	Former mill area – minor waste rock
Tulloch 2	**Sb**, **As**	Not leached	Bare surface scald – minor waste rock
Chandler - Lower			
Khans Creek 1	**Sb**, **As**, Cd, Cu, Pb, Hg, Zn	Not leached	Scattered waste rock lower platform
Khans Creek 2	**Sb**, **As**, Cd, Cu, Pb, Hg, Zn	Al, Cd, Cr, Cu, Pb, Ni, Zn	Scattered waste rock middle platform
Khans Creek 3	**Sb**, **As**, Cd, Cu, Pb, Hg, Zn	Cd, Cu, Pb, Zn	Scattered waste rock higher platform
Mickey Mouse 1	**Sb**	**Sb**, Cu, Zn	Scattered waste rock
Commissioners Waters			
Kapunda 1	**Sb**, **As**, Pb, Hg	Al, **Sb, As** Cr, Cu, Pb, Ni, Zn	Bare surface scald
Mary Anderson 1	**Sb**, **As**	Not leached	Waste rock dump
Mary Anderson 2	**Sb**, **As**, Hg	Not leached	Waste rock dump
Mary Anderson 3	**Sb**, **As**	Al, **Sb, As** Cu, Pb, Ni, Zn	Waste rock dump

Apsley			
Europambela 1	**As**, Cu, Hg	Al, Cu, Zn	Bare surface scald
Europambela 2	**As**, Cu, Hg	Not leached	Bare surface scald
Hickeys / Mungay Creek			
Mungay Ck 1	**Sb**, **As**, Hg	Al, **Sb**, Cu, Zn	Waste rock dump
Mungay Ck 2	**Sb**, **As,** Hg	**Al,** As, Cd, Cr, Cu, Pb, Zn	Ore Stockpile

The results in Table A9 indicate that antimony is likely to leach at concentrations greater than the 95% species protection levels (ANZECC/ARMCANZ 2000) at Mickey Mouse, Phoenix Gold, Rockvale, Ruby Silver, Tulloch, Kapunda, Mary Anderson and Mungay Creek. Arsenic is likely to leach at concentrations greater than the 95% species protection levels (ANZECC/ARMCANZ 2000) at Bakers Creek, Phoenix Gold, Rockvale, Ruby Silver, Kapunda and Mary Anderson.

Leachable aluminium is detected, however may not be a significant issue *in situ* given the circumneutral solution pH levels—meaning that aluminium is relatively insoluble, and therefore would be present as a store of latent acidity in site drainage. It is also of note that the relatively elevated mercury concentrations in the whole rock assay did not leach at concentrations to present an environmental risk. Interestingly, zinc leached from all 20 mineral waste samples that underwent leach testing at concentrations above the 95% species protection level—consistent with the sediment leaching results.

Summary of mineral waste geochemistry

A summary of the results of the mineral waste geochemical characterisation from ten sites within five sub-catchments is presented in Table A10. The items bolded or underlined show elevated results relative to nominated screening criteria provided in Section 4 of the main report. Essentially, the greater the number of bolded results, the higher the geochemical risk.

Table A10: Mineral waste geochemistry summary table

Sample	pH (1:5) < 4.5	EC (1:5) > 1,000 µS/cm	NAPP > 10 kgH_2SO_4/t	NPR < 2	NAGpH < 4.5	NAG (4.5) > 10 kgH_2SO_4/t	NAG (7.0) > 10 kgH_2SO_4/t	Classification	GAI > 3	Metals leaching above ANZECC (2000) 95%	Metals screening (mg/kg)[1]		Sample location
											As	Sb	
Chandler - Upper													
Phoenix Gold 1	**3.5**	234	3.18	**0.0**	**3.8**	0.8	2.8	PAF-LC	**Sb**, **As**	Not leached	**230**	18	Bare surface scald – minor waste rock
Phoenix Gold 2	**3.4**	741	5.36	**0.0**	**4.1**	0.4	1.5	PAF-LC	**Sb**, **As**	Al, **Sb, As** Cd, Cu, Zn	**308**	**108**	Bare surface scald – minor waste rock
Rockvale 1	**3.5**	192	7.53	**0.0**	**4.2**	0.3	1.5	PAF-LC	**Sb**, **As**, Pb	**Sb, As** Cd, Cu, Zn	**40,400**	**48**	Bare surface scald
Rockvale 2	**3.4**	270	8.14	**0.0**	**4.0**	0.6	2.3	PAF-LC	**Sb**, **As**, Pb, Hg	Al, **As**, Cd, Cu, Zn	**36,500**	**69**	Bare surface scald
Rockvale 3	**2.8**	**1,240**	0.86	**0.0**	**3.6**	1.3	3.0	PAF-LC	**Sb**, **As**, Cu, Pb, Hg	Al, **Sb, As** Cd, Cr, Cu, Zn	**74,300**	**286**	Bare surface scald
Ruby Silver 1	**3.9**	**1,010**	3.06	**0.0**	4.6	<0.1	1.1	UC	**Sb**, **As**, Pb, Hg	Al, **Sb, As** Cd, Cu, Ni, Zn	**8,420**	**210**	Waste rock dump
Ruby Silver 2	**4.1**	119	2.33	**0.0**	**4.5**	<0.1	1.9	UC	**Sb**, **As**	Not leached	**1,190**	29	Waste rock dump
Tulloch 1	4.8	220	**16.16**	**0.0**	**3.3**	2.6	2.8	**PAF-HC**	**Sb**, **As**, Pb, Hg	**Sb**, Cu, Pb, Zn	**904**	**2,220**	Former mill area – minor waste rock
Tulloch 2	**4.5**	213	0.00	NA	5.9	<0.1	0.5	NAF	**Sb**, **As**	Not leached	**69**	7	Bare surface scald – minor waste rock
Chandler - Lower													
Khans Creek 1	**3.7**	291	6.82	**0.1**	5.2	<0.1	0.7	UC	**Sb**, **As**, Cd, Cu, Pb, Hg, Zn	Not leached	**194**	24	Scattered waste rock lower platform

Sample	pH (1:5) < 4.5	EC (1:5) > 1,000 µS/cm	NAPP > 10 kgH_2SO_4/t	NPR < 2	NAGpH < 4.5	NAG (4.5) > 10 kgH_2SO_4/t	NAG (7.0) > 10 kgH_2SO_4/t	Classification	GAI > 3	Metals leaching above ANZECC (2000) 95%	Metals screening (mg/kg)[1]		Sample location
											As	Sb	
Khans Creek 2	**3.0**	**1,780**	**73.65**	**0.0**	**2.7**	9.8	**22.9**	**PAF-HC**	**Sb**, **As**, Cd, Cu, Pb, Hg, Zn	Al, Cd, Cr, Cu, Pb, Ni, Zn	**334**	**74**	Scattered waste rock middle platform
Khans Creek 3	5.6	53	**17.35**	**0.3**	6.3	<0.1	1.3	UC	**Sb**, **As**, Cd, Cu, Pb, Hg, Zn	Cd, Cu, Pb, Zn	**674**	**165**	Scattered waste rock higher platform
Mickey Mouse 1	6.7	522	4.90	**0.7**	**3.0**	6	8.8	PAF-LC	**Sb**	**Sb**, Cu, Zn	15	**190**	Scattered waste rock
Commissioners Waters													
Kapunda 1	7.0	104	-12.05	4.8	7.6	<0.1	<0.1	NAF	**Sb**, **As**, Pb, Hg	Al, **Sb**, **As** Cr, Cu, Pb, Ni, Zn	**194**	24	Bare surface scald
Mary Anderson 1	6.1	90	-1.64	2.4	6.3	<0.1	0.5	NAF	**Sb**, **As**	Not leached	**334**	**74**	Waste rock dump
Mary Anderson 2	5.6	80	-0.81	**1.4**	6.7	<0.1	0.4	NAF	**Sb**, **As**, Hg	Not leached	**674**	**165**	Waste rock dump
Mary Anderson 3	5.7	200	0.79	**0.6**	7.0	<0.1	<0.1	UC	**Sb**, **As**	Al, **Sb**, **As** Cu, Pb, Ni, Zn	15	**190**	Waste rock dump
Apsley													
Europambela 1	**3.9**	263	**12.50**	**0.0**	5.0	<0.1	0.9	UC	**As**, Cu, Hg	Al, Cu, Zn	**71**	<5	Bare surface scald
Europambela 2	**3.9**	138	**14.38**	**0.0**	**4.0**	0.4	2.2	**PAF-HC**	**As**, Cu, Hg	Not leached	32	<5	Bare surface scald
Hickeys / Mungay Creeks													
Mungay Ck 1	6.1	22	3.58	**0.0**	**4.0**	0.8	2.8	PAF-LC	**Sb**, **As**, Hg	Al, **Sb**, Cu, Zn	24	**4,080**	Waste rock dump
Mungay Ck 2	4.6	56	5.4	0.0	3.7	1.2	2.8	PAF-LC	**Sb**, **As**, Hg	**Al**, As, Cd, Cr, Cu, Pb, Zn	**90**	**2,430**	Ore Stockpile

1: Refer to Table A8 for trigger values

The geochemical summary data in Table A10 suggests the following with regard to the environmental risk of the residual mineral waste on site.

Chandler – Upper

Phoenix Gold: The data suggest that upon oxidation, mineral waste at Phoenix Gold has the capacity to generate low levels of acidity, and has limited self-buffering capacity. It has a medium capacity to generate saline drainage. The mineral waste has relatively elevated concentrations of both arsenic and antimony, which both leach at concentrations that may pose an environmental risk.

Rockvale: The Rockvale data is similar to that of Phoenix Gold, which is consistent with their geological proximity. i.e. that the mineral waste can become quite acidic upon oxidation and has limited self-buffering capacity. However, the Rockvale mineral waste samples returned arsenic concentrations at between 3.5 and 7.5 %. Both arsenic and antimony were shown to leach at concentrations that may pose an environmental risk. The mineral waste samples had a medium to high capacity to generate saline drainage.

Ruby Silver: Consistent with its proximity and similar geology, the mineral waste at Ruby Silver behaves geochemically similar to that at Phoenix Gold and Rockvale. i.e. that the mineral waste can become quite acidic upon oxidation and has limited self-buffering capacity. The mineral waste samples had a medium to high capacity to generate saline drainage. Arsenic and antimony were relatively elevated in whole rock concentrations and both leached at concentrations that may pose an environmental risk.

Tulloch: The mineral waste at Tulloch demonstrated a higher capacity to generate acidity upon oxidation as measured using static geochemical testing than the other three sites located in the Upper Chandler sub-catchment. It has limited capacity to self-neutralise though did not generate significant acidity upon oxidation using the NAG test. It showed a low to moderate risk of generating saline drainage, though had leachable antimony (but not arsenic) at concentrations that may pose an environmental risk.

Chandler – Lower

Khans Creek: The mineral waste at Khans Creek generated significant acidity upon oxidation and had limited self-neutralising capacity. It also showed a range of saline drainage potential, with the higher potential correlating to relatively elevated concentrations of arsenic, antimony and several other metals that would be present in metal sulfide minerals (i.e. elevated EC is due to sulfate from oxidising sulfides). Interestingly, while other base metals leached at concentrations that may pose an environmental risk, arsenic and antimony did not. This is reasonably consistent with the Gibsons, Faints and Firefly geochemistry (EA Systems and CivilTech 2003), and suggest regional similarity between Halls Peak Mineral Field deposits.

Mickey Mouse: The mineral waste at the Mickey Mouse deposit generated some acidity upon oxidation and had limited self-buffering capacity. It had a medium risk of saline drainage. Antimony though not arsenic was relatively elevated in whole rock concentrations with antimony also leaching at concentrations that may pose an environmental risk.

Commissioners Waters

Kapunda: The Kapunda mineral waste was acid consuming and had ample self-buffering capacity. It had a low risk of saline drainage. It did, however, contain relatively elevated concentrations of arsenic and antimony which both leached at concentrations that may pose an environmental risk.

Mary Anderson: Mary Anderson is not dissimilar to Kapunda in that it is relatively inert mineral waste from an acid and saline drainage perspective. It does however; contain relatively elevated concentrations of arsenic and antimony which both leached at concentrations that may pose an environmental risk.

Apsley

Europambela: The mineral waste at Europambela generated medium to high risk levels of acidity upon oxidation, and had very limited self-neutralising capacity. It had a relatively low to medium risk of saline drainage. It did contain relatively elevated arsenic concentrations that did not leach at concentrations that may pose an environmental risk, along with concentrations of whole rock antimony below the laboratory detection limit which did not leach.

Hickeys / Mungay Creeks

Mungay Creek: The mineral waste at Mungay Creek generated low to medium risk levels of acidity upon oxidation, and had very limited self-neutralising capacity. It had a relatively low risk of saline drainage. It returned relatively high whole rock concentrations of antimony (up to 0.4%) and elevated arsenic—although only the antimony leached at concentrations that may pose an environmental risk.

Table A11 provides a high level summary table for the risk of acid, saline and metalliferous drainage from mineral waste by site.

Table A11: Summary of mineral waste acid, saline and metalliferous drainage risk by site

Sample	AMD risk	Saline drainage risk	Metalliferous drainage risk
Chandler - Upper			
Phoenix Gold	Low - Med	Med	**High** (As and Sb)
Rockvale	Low - Med	Med-**High**	**High** (As and Sb)
Ruby Silver	Low	Med-**High**	**High** (As and Sb)
Tulloch	Med - **High**	Low-Med	**High** (Sb)
Chandler - Lower			
Khans Creek	**High**	Low-**High**	**High** (other metals)
Mickey Mouse	Med	Med	**High** (Sb)
Commissioners Waters			
Kapunda	Low	Low	**High** (As and Sb)
Mary Anderson	Low	Low	**High** (As and Sb)
Apsley			
Europambela	Med-**High**	Low-Med	**High** (other metals)
Hickeys / Mungay Creeks			
Mungay Ck	Low-Med	Low	**High** (Sb)

By and large, the results discussed above support existing descriptions of the environmental geochemistry of the Macleay Catchment in the published literature. That is, that orogenic gold-arsenic-antimony mesothermal vein type deposits give rise to extensive, as well as localised, stream sediment and water geochemical anomalies due to dissolution of oxidised stibnite

(Sb_2S_3), arsenopyrite (FeAsS) and pyrite (FeS_2) (e.g. NSW Department of Mineral Resources 1992, Ashley *et al* 2007, Ashley and Graham 2001, Ashley and Wolfenden 2005). Considering the regional geology of the various sub-catchment, this generally leads to a (relatively) low overall risk of acid and saline drainage, albeit slightly higher in the Halls Peak Mineral Field in the Lower Chandler, however a high risk of metalliferous drainage.

Sediment

Slurry pH and EC

Slurry pH and EC results are shown in Table A12, with classification against the screening values provided in Section 4 of the main report. As indicative only, pH (1:5) values below 4.5 and EC values above 1,000 µS/cm have been bolded. Generally, a pH (1:5) value of less than 4.5 indicates stored acidity—generally a sign of historic sulfide oxidation as noted above, while EC values over 1,000 µS/cm are indicative of saline drainage (INAP 2009). Full results are provided in Table D, Appendix D.

Table A12: Sediment slurry pH and EC results

Sample	pH (1:5)	pH (sat paste)	pH Classification[1]	EC (1:5) µS/cm	EC Classification[1]	Sample location
Chandler - Upper						
Phoenix Gold 1	6.8	6.2	Medium	47	Very low	Up-catchment on unnamed drainage line located perpendicular to the mine
Phoenix Gold 2	7.1	6.5	High	113	Very low	Approximately 400 m Down-catchment on same unnamed drainage line.
Phoenix Gold 3	**4.4**	4.0	Very low	186	Low	Drainage line from the former mine to the unnamed water course. Approximately 50 m from the last mine feature
Ruby Silver 1	6.0	5.2	Medium	41	Very low	Up-catchment northern end of a water dam. The drainage line is located perpendicular to the mine
Ruby Silver 2	5.7	4.7	Medium	10	Very low	Down-catchment of mine features on the same drainage line.
Tulloch 1	6.6	5.4	Medium	24	Very low	Up-catchment from former mine on a unnamed drainage line
Tulloch 2	5.9	4.7	Medium	154	Low	Down-catchment of the remaining mine features on the same unnamed drainage line.
Tulloch 3	6.4	6	Medium	21	Very low	Up-catchment on Boundary Creek – located perpendicular to former mine area
Tulloch 4	6.7	6.3	Medium	21	Very low	Approximately 155 m Down-catchment on Boundary Creek from mine area.

Sample	pH (1:5)	pH (sat paste)	pH Classification[1]	EC (1:5) µS/cm	EC Classification[1]	Sample location
Rockvale 1	6.1	5.8	Medium	55	Very low	Up-catchment on Lambs Valley Creek located perpendicular to the former mine
Rockvale 2	6.3	5.5	Medium	33	Very low	Approximately 860 m Down-catchment on Lambs Valley Creek
Rockvale 3	5.6	4.9	Medium	87	Very low	Drainage line from the former waste rock dumps. Approximately 135 m from the last scald area
Chandler - Lower						
Chandler 1	7.7	6.8	High	16	Very low	Chandler River approx. 2 km from Stuart Reef and Rathbones Point East mines. Approx. 900 m above the confluence of the Chandler and Styx Rivers
Chandler 2	7.3	7.2	High	10	Very low	Approximately 300 m down stream of Chandler 1 on the Chandler River
Khans Creek 1	7.2	6.8	High	26	Very low	Approximately 330 m down gradient from mine on same drainage line
Khans Creek 2	7.4	7.4	High	161	Low	Up-catchment of former mine site in drainage line running adjacent to site
Keys Prospect 1	7.6	7.5	High	20	Very low	Keys Creek approx. 630 m east of mine
Keys Prospect 2	6.5	5.5	Medium	19	Very low	Down-catchment of the confluence of Keys Creek and the Chandler River
Keys Prospect 3	6.3	5.2	Medium	24	Very low	Up-catchment of the confluence of Keys Creek and the Chandler River
Mickey Mouse 1	6.4	6.6	Medium	110	Very low	Up-catchment of the mine adit on the Chandler River
Mickey Mouse 2	6.6	6.5	Medium	28	Very low	Approximately 65 m Down-catchment of the Mickey Mouse 1 sample on the Chandler River
Sunnyside 1	6.6	6.4	Medium	51	Very low	Chandler River approx. 1.45 km downstream of the former mine
Commissioners Waters						
Kapunda 1	7.1	7.1	High	70	Very low	Up-catchment on Tilbuster Ponds that

Sample	pH (1:5)	pH (sat paste)	pH Classification[1]	EC (1:5) µS/cm	EC Classification[1]	Sample location
						flow perpendicular to the former mine
Kapunda 2	6.7	6.3	Medium	37	Very low	Approximately 260 m Down-catchment of Kapunda 1 sample
Mary Anderson 1	6.6	5.9	Medium	94	Very low	Down-catchment from northern edge of water dam on unnamed drainage line
Mary Anderson 2	6.8	6.3	Medium	34	Very low	Up-catchment from northern edge of water dam on unnamed drainage line
Apsley						
Europambela 1	6.4	6.3	Medium	68	Very low	Up-catchment on the Apsley River that flows perpendicular to the former mine
Europambela 2	6.6	6.0	Medium	61	Very low	Approximately 150 m Down-catchment of Europambela 1 on the Apsley River
Europambela Dam Sediment	7.0	7.3	Medium	71	Very low	Collected from the sediment stockpile that had been recently dredged from the dam located immediately Down-catchment of the site
Hickeys / Mungay Creek						
Mungay Ck 1	5.6	4.7	Medium	50	Very low	Down-catchment of mine site, below water dam, near former adit on Deep Creek which runs through site
Mungay Ck 2	6.3	6.3	Medium	22	Very low	Approximately 330 m Down-catchment of Mungay Ck 1 on Deep Creek
Mungay Ck 3	7.1	7.6	High	21	Very low	Approximately 1.67 km Down-catchment of Mungay Ck 2 on Deep Creek
Toorumbee Creek and Warbro Brook						
Warbro Brook 1	5.2	4.4	Low	142	Very low	Collected on Warbro Brook approximately 2.37 km from Macleay confluence

1: Based on DME (1995). pH classified using pH (1:5) results

The data in Table A12 shows one sediment pH (1:5) result below 4.5 being from Phoenix Gold. The sample was collected from an unnamed stream approximately 50 metres below the mine workings. The pH result is broadly consistent with the mineral waste samples collected at Phoenix Gold, indicating that the sediment sample likely originated from the mineral waste on site.

The data in Table A12 also shows that all sediment EC values are low to very low.

Acid base accounting

In order to determine the MPA of a sample, the total sulfur percent must first be determined. A total of 51 geochemical samples from 15 sites underwent total sulfur analysis. The entire sediment ABA data set is provided in Table D (Appendix D), with a summary provided below in Table A13. Samples that returned NAPP values of potentially acid forming (high capacity) (PAF-HC); being greater than 10 kgH_2SO_4/tonne and/or have limited self-buffering capacity as determined by a NPR of less than two are bolded.

Table A13: Sediment NAPP and NPR results

Sample	NAPP[1] kgH_2SO_4/tonne	NPR	Sample location
Chandler - Upper			
Phoenix Gold 1	-7.1	5.0	Up-catchment on unnamed drainage line located perpendicular to the mine
Phoenix Gold 2	-4.2	4.0	Approximately 400 m Down-catchment on same unnamed drainage line.
Phoenix Gold 3	3.0	**0.1**	Drainage line from the former mine to the unnamed water course. Approximately 50 m from the last mine feature
Ruby Silver 1	-0.6	**1.4**	Up-catchment northern end of a water dam. The drainage line is located perpendicular to the mine
Ruby Silver 2	0.4	**0.7**	Down-catchment of mine features on the same drainage line.
Tulloch 1	-2.8	4.2	Up-catchment from former mine on a unnamed drainage line
Tulloch 2	8.9	**0.3**	Down-catchment of the remaining mine features on the same unnamed drainage line.
Tulloch 3	-4.4	8.4	Up-catchment on Boundary Creek – located perpendicular to former mine area
Tulloch 4	-3.9	7.5	Approximately 155 m Down-catchment on Boundary Creek from mine area.
Rockvale 1	-2.9	5.9	Up-catchment on Lambs Valley Creek located perpendicular to the former mine
Rockvale 2	-2.8	3.4	Approximately 860 m Down-catchment on Lambs Valley Creek
Rockvale 3	0.6	**0.3**	Drainage line from the former waste rock dumps. Approximately 135 m from the last scald area
Chandler - Lower			
Chandler 1	-10.1	17.9	Chandler River approx. 2 km from Stuart Reef and Rathbones Point East mines. Approx. 900 m above the confluence of the Chandler and Styx Rivers
Chandler 2	-20.5	35.4	Approximately 300 m down stream of Chandler 1 on the Chandler River
Khans Creek 1	-4.7	6.2	Approximately 330 m down gradient from mine on same drainage line
Khans Creek 2	-10.7	6.1	Up-catchment of former mine site in drainage line running adjacent to site
Keys Prospect 1	-4.0	7.7	Keys Creek approx. 630 m east of mine
Keys Prospect 2	-7.1	9.0	Down-catchment of the confluence of Keys Creek and the Chandler River
Keys Prospect 3	-2.3	3.9	Up-catchment of the confluence of Keys Creek and the Chandler River
Mickey Mouse 1	-8.4	8.0	Up-catchment of the mine adit on the Chandler River

Sample	NAPP[1] $kgH_2SO_4/tonne$	NPR	Sample location
Mickey Mouse 2	-9.0	16.1	Approximately 65 m Down-catchment of the Mickey Mouse 1 sample on the Chandler River
Sunnyside 1	-10.0	12.1	Chandler River approx. 1.45 km downstream of the former mine
Commissioners Waters			
Kapunda 1	-5.7	10.6	Up-catchment on Tilbuster Ponds that flow perpendicular to the former mine
Kapunda 2	-3.1	6.2	Approximately 260 m Down-catchment of Kapunda 1 sample
Mary Anderson 1	-2.2	2.5	Down-catchment from northern edge of water dam on unnamed drainage line
Mary Anderson 2	-8.0	14.4	Up-catchment from northern edge of water dam on unnamed drainage line
Apsley			
Europambela 1	-5.5	7.1	Up-catchment on the Apsley River that flows perpendicular to the former mine
Europambela 2	-4.1	7.9	Approximately 150 m Down-catchment of Europambela 1 on the Apsley River
Europambela Dam Sediment	-13.4	37.6	Collected from the sediment stockpile that had been recently dredged from the dam located immediately Down-catchment of the site
Hickeys / Mungay Creek			
Mungay Ck 1	-12.2	18.3	Down-catchment of mine site, below water dam, near former adit on Deep Creek which runs through site
Mungay Ck 2	-0.7	2.0	Approximately 330 m Down-catchment of Mungay Ck 1 on Deep Creek
Mungay Ck 3	-5.6	93.1	Approximately 1.67 km Down-catchment of Mungay Ck 2 on Deep Creek
Toorumbee Creek and Warbro Brook			
Warbro Brook 1	-1.1	2.5	Collected on Warbro Brook approximately 2.37 km from Macleay confluence

1: NAPP calculated from adjusted of pyritic sulfur values being total S – SO_4-S.

The data in Table A13 shows that no sediment sample is classified as potentially acid forming-high capacity (PAF-HC), with most samples returning negative NAPP values. Only the Tulloch 2 sample, collected from immediately downgradient of the old mine workings, approached PAF-HC classification with a value of 8.9 kgH_2SO_4/tonne, indicating that it likely originated from sulfidic mineral waste.

Consistent with the mineral waste geochemistry, all four Upper Chandler sites returned at least one positive NAPP value and one NPR below 2.0, indicating the likely presence of sulfidic mineral waste derived sediment in drainage lines on these sites.

Net acid generation (NAG) testing

Results of the single addition NAG tests and NAG_{pH} values are provided in Table A14, with NAG_{pH} values below 4.5, and NAG results over 10 kgH_2SO_4/tonne bolded. The sediment samples have also been classified using their NAPP and NAG_{pH} results, as per the classification shown in Table A14.

Table A14: Sediment NAG_{pH}, NAG and AMD classification

Sample	NAG pH	NAG (pH. 4.5) (kgH_2SO_4/tonne)	NAG (pH 7.0) (kgH_2SO_4/tonne)	AMD class'n	Sample location
Chandler - Upper					
Phoenix 1	7.3	<0.1	<0.1	NAF	Up-catchment on unnamed drainage line located perpendicular to the mine
Phoenix 2	7.4	<0.1	<0.1	NAF	Approximately 400 m Down-catchment on same unnamed drainage line.
Phoenix 3	6.9	<0.1	0.3	UC	Drainage line from the former mine to the unnamed water course. Approximately 50 m from the last mine feature
Ruby Silver 1	6.4	<0.1	0.8	NAF	Up-catchment northern end of a water dam. The drainage line is located perpendicular to the mine
Ruby Silver 2	6.8	<0.1	0.3	UC	Down-catchment of mine features on the same drainage line.
Tulloch 1	6.8	<0.1	0.6	NAF	Up-catchment from former mine on a unnamed drainage line
Tulloch 2	6.2	<0.1	2.6	UC	Down-catchment of the remaining mine features on the same unnamed drainage line.
Tulloch 3	7.2	<0.1	<0.1	NAF	Up-catchment on Boundary Creek – located perpendicular to former mine area
Tulloch 4	7.0	<0.1	<0.1	NAF	Approximately 155 m Down-catchment on Boundary Creek from mine area.
Rockvale 1	7.0	<0.1	<0.1	NAF	Up-catchment on Lambs Valley Creek located perpendicular to the former mine
Rockvale 2	7.1	<0.1	<0.1	NAF	Approximately 860 m Down-catchment on Lambs Valley Creek
Rockvale 3	6.4	<0.1	0.4	UC	Drainage line from the former waste rock dumps. Approximately 135 m from the last scald area
Chandler - Lower					
Chandler 1	7.4	<0.1	<0.1	NAF	Chandler River approx. 2 km from Stuart Reef and Rathbones Point East mines. Approx. 900 m above the confluence of the Chandler and Styx Rivers

Sample	NAG pH	NAG (pH. 4.5) (kgH_2SO_4/tonne)	NAG (pH 7.0) (kgH_2SO_4/tonne)	AMD class'n	Sample location
Chandler 2	7.8	<0.1	<0.1	NAF	Approximately 300 m down stream of Chandler 1 on the Chandler River
Khans Creek 1	7.0	<0.1	<0.1	NAF	Approximately 330 m down gradient from mine on same drainage line
Khans Creek 2	6.3	<0.1	0.5	NAF	Up-catchment of former mine site in drainage line running adjacent to site
Keys Prospect 1	7.3	<0.1	<0.1	NAF	Keys Creek approx. 630 m east of mine
Keys Prospect 2	7.6	<0.1	<0.1	NAF	Down-catchment of the confluence of Keys Creek and the Chandler River
Keys Prospect 3	6.9	<0.1	0.4	NAF	Up-catchment of the confluence of Keys Creek and the Chandler River
Mickey Mouse 1	7.2	<0.1	<0.1	NAF	Up-catchment of the mine adit on the Chandler River
Mickey Mouse 2	7.3	<0.1	<0.1	NAF	Approximately 65 m Down-catchment of the Mickey Mouse 1 sample on the Chandler River
Sunnyside 1	7.6	<0.1	<0.1	NAF	Chandler River approx. 1.45 km downstream of the former mine
Commissioners Waters					
Kapunda 1	7.1	<0.1	<0.1	NAF	Up-catchment on Tilbuster Ponds that flow perpendicular to the former mine
Kapunda 2	6.8	<0.1	0.2	NAF	Approximately 260 m Down-catchment of Kapunda 1 sample
Mary Anderson 1	6.8	<0.1	0.2	NAF	Down-catchment from northern edge of water dam on unnamed drainage line
Mary Anderson 2	6.7	<0.1	0.4	NAF	Up-catchment from northern edge of water dam on unnamed drainage line
Apsley					
Europambela 1	7.1	<0.1	<0.1	NAF	Up-catchment on the Apsley River that flows perpendicular to the former mine
Europambela 2	6.8	<0.1	0.2	NAF	Approximately 150 m Down-catchment of Europambela 1 on the Apsley River
Europambela Dam Sediment	8.4	<0.1	<0.1	NAF	Collected from the sediment stockpile that had been recently dredged from the dam located immediately

Sample	NAG pH	NAG (pH. 4.5) (kgH_2SO_4/tonne)	NAG (pH 7.0) (kgH_2SO_4/tonne)	AMD class'n	Sample location
					Down-catchment of the site
Hickeys / Mungay Creek					
Mungay Ck 1	7.3	<0.1	<0.1	NAF	Down-catchment of mine site, below water dam, near former adit on Deep Creek which runs through site
Mungay Ck 2	7.0	<0.1	<0.1	NAF	Approximately 330 m Down-catchment of Mungay Ck 1 on Deep Creek
Mungay Ck 3	7.9	<0.1	<0.1	NAF	Approximately 1.67 km Down-catchment of Mungay Ck 2 on Deep Creek
Toorumbee Creek and Warbro Brook					
Warbro Brook 1	7.4	<0.1	<0.1	NAF	Collected on Warbro Brook approximately 2.37 km from Macleay confluence

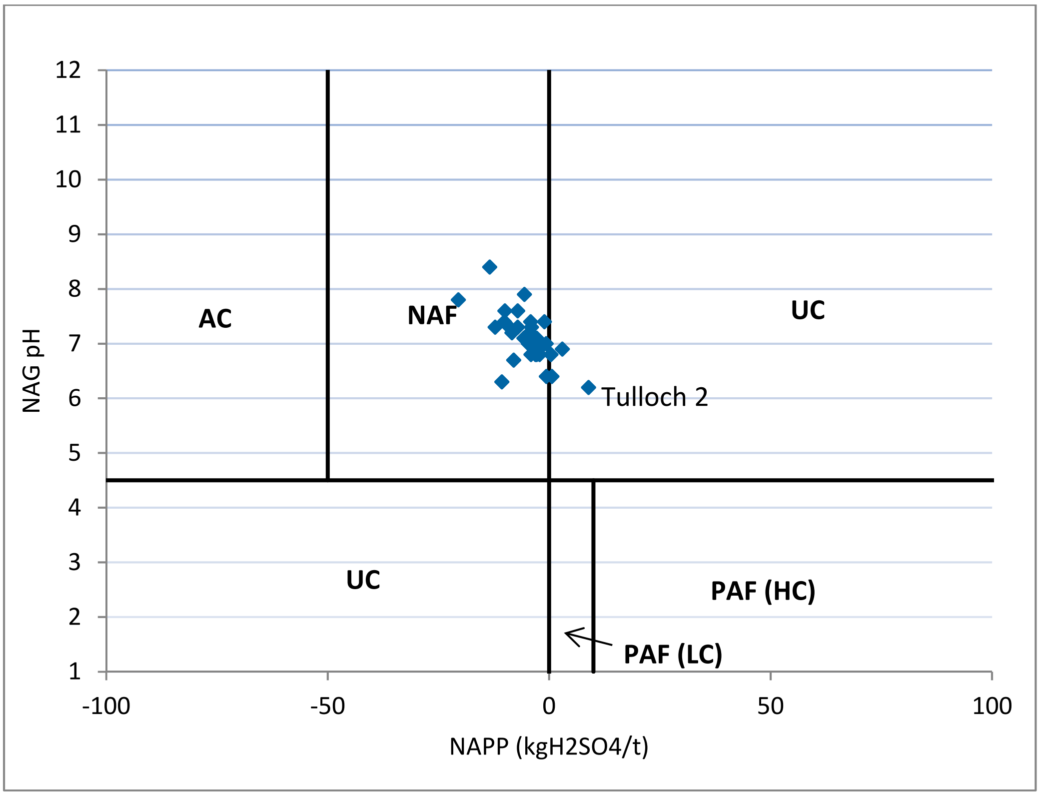
The data in Table A14 shows that all sediment returned circumneutral NAG_{pH} values, indicating that the sediment is relatively benign from an acid generation perspective. This is slightly at odds with the slurry (1:5) pH results for the Upper Chandler sites shown in Table A12.

No sediment sample generated acid at the NAG (pH 4.5) value, indicating minimal residual pyrite in the samples; while the highest NAG pH (7.0) value was 2.6 kgH_2SO_4/tonne for the Tulloch 2 sample. This is consistent with the NAPP and NPR data in Table A13. All four Upper Chandler sites generated some minor acidity at NAG $pH_{7.0}$, as did Khans Creek and Keys Prospect in the Lower Chandler, Kapunda and Mary Anderson in Commissioners Waters, and Europambela in Apsley.

Overall, however, the sediment samples appear to pose little risk of generating acid drainage through oxidising sulfides. All samples were classified as not acid forming (NAF) with the exception of Rockvale 3, Phoenix Gold 3, Ruby Silver 2, and Tulloch 2 which were uncertain due to slightly positive NAPP values. This does not negate the risk of metalliferous drainage from metals adsorbed to sediment, or from release of metals within the sediment through weathering and mineral dissolution. This is assessed further using the GAI and metals leaching data below.

The NAG pH results in Table A14 were graphed along with the (pyritic) NAPP values to further classify the mineral waste samples according to Table A4 (refer to Figure A2). Sample classifications were provided in Table A14, above.

Figure A2: NAG_{pH} and NAPP geochemical plot – sediment samples



The plotted NAPP/NAG_{pH} data on Figure A2 shows that all samples may be classified as non-acid forming (NAF), with four Upper Chandler samples plotting as uncertain as noted above, being Tulloch 2, Rockvale 3, Phoenix Gold 3 and Ruby Silver 2—all having slightly positive NAPP values though NAG_{pH} values above 4.5. This is likely due to non-pyritic sulfur artificially elevating the MPA under the static geochemical tests used herein. Overall, the sediment samples are generally low risk of generating acid drainage from oxidising sulfides; however, remain a risk of generating metalliferous drainage through metal leaching and potentially, subsequent acidity through metals hydrolysis reactions. This is assessed and reported on below.

Geochemical abundance index

The GAI concept was explained earlier—any result with a value of 3 or greater indicates relative enrichment of that particular metal. It is noted that median data for crustal abundance was used for this indicative comparison (Bowen 1979). Results of metals with a GAI of three or higher are shown in Table A15, with arsenic and antimony bolded as they appear. A summary of those metals that exceeded the adopted sediment guidelines in this study is also provided in Table A15. The entire sediment GAI assessment is provided as Table B in Appendix E.

Note that the laboratory level of reporting (LOR) for antimony in sediment (5 mg/kg) exceeded the low ISQG trigger value (2 mg/kg); therefore, when a <LOR value was reported, a value of 50% of the LOR (2.5 mg/kg) was adopted for the purposes of this study, approximately equal to the low ISQG sediment value.

Table A15: Sediment GAI and ISQG exceedances

Sample	Metals with GAI > 3	Exceed low ISQG	Exceed high ISQG	Sample location
Chandler - Upper				
Phoenix Gold 1	-	-	-	Up-catchment on unnamed drainage line located perpendicular to the mine
Phoenix Gold 2	**As**	**As**, Cu, Hg, Ni	**As**	Approximately 400 m Down-catchment on same unnamed drainage line.
Phoenix Gold 3	**As**, **Sb**	**Sb, As**, Cu	**As**	Drainage line from the former mine to the unnamed water course. Approximately 50 m from the last mine feature
Ruby Silver 1	-	-	-	Up-catchment northern end of a water dam. The drainage line is located perpendicular to the mine
Ruby Silver 2	-	-	-	Down-catchment of mine features on the same drainage line.
Tulloch 1	**As**	**Sb, As**	**As**	Up-catchment from former mine on a unnamed drainage line
Tulloch 2	**Sb**, **As**	**Sb, As**, Cd, Cu, Pb	**Sb, As**	Down-catchment of the remaining mine features on the same unnamed drainage line.
Tulloch 3	-	-	-	Up-catchment on Boundary Creek – located perpendicular to former mine area
Tulloch 4	**As**	Ni	-	Approximately 155 m Down-catchment on Boundary Creek from mine area.
Rockvale 1	**As**	-	-	Up-catchment on Lambs Valley Creek located perpendicular to the former mine
Rockvale 2	**As**	**As**	**As**	Approximately 860 m Down-catchment on Lambs Valley Creek
Rockvale 3	**Sb**, **As**	**Sb, As**, Cd, Cu, Pb	**As**, Cu	Drainage line from the former waste rock dumps. Approximately 135 m from the last scald area
Chandler - Lower				
Chandler 1	-			Chandler River approx. 2 km from Stuart Reef and Rathbones Point East mines. Approx. 900 m above the confluence of the Chandler and Styx Rivers
Chandler 2	-			Approximately 300 m down stream of Chandler 1 on the Chandler River
Khans Creek 1	**As**, Cd, Pb, Zn	**Sb, As**, Cd, Cu, Pb, Hg, Zn	Cu, Pb, Zn	Approximately 330 m down gradient from mine on same drainage line
Khans Creek 2	-	Pb, Hg	-	Up-catchment of former mine site in drainage line running adjacent to site
Keys Prospect 1	-	Pb, Hg, Zn	-	Keys Creek approx. 630 m east of mine

Sample	Metals with GAI > 3	Exceed low ISQG	Exceed high ISQG	Sample location
Keys Prospect 2	-	-	-	Down-catchment of the confluence of Keys Creek and the Chandler River
Keys Prospect 3	-	Ni	-	Up-catchment of the confluence of Keys Creek and the Chandler River
Mickey Mouse 1	Cd, Zn	Cd, Hg, Zn	Zn	Up-catchment of the mine adit on the Chandler River
Mickey Mouse 2	-	-	-	Approximately 65 m Down-catchment of the Mickey Mouse 1 sample on the Chandler River
Sunnyside 1	-	-	-	Chandler River approx. 1.45 km downstream of the former mine
Commissioners Waters				
Kapunda 1	**As**	**As**	-	Up-catchment on Tilbuster Ponds that flow perpendicular to the former mine
Kapunda 2	**As**	**As**	-	Approximately 260 m Down-catchment of Kapunda 1 sample
Mary Anderson 1	**Sb**, **As**	**Sb, As**, Cr, Ni	**Sb**	Down-catchment from northern edge of water dam on unnamed drainage line
Mary Anderson 2	-	Cr, Ni	Ni	Up-catchment from northern edge of water dam on unnamed drainage line
Apsley				
Europambela 1	-	Ni	-	Up-catchment on the Apsley River that flows perpendicular to the former mine
Europambela 2	-	-	-	Approximately 150 m Down-catchment of Europambela 1 on the Apsley River
Europambela Dam Sediment	-	Cu, Ni	Cu	Collected from the sediment stockpile that had been recently dredged from the dam located immediately Down-catchment of the site
Hickeys / Mungay Creek				
Mungay Ck 1	**Sb**, **As**	**Sb,** Hg	**Sb**	Down-catchment of mine site, below water dam, near former adit on Deep Creek which runs through site
Mungay Ck 2	**Sb, As**	**Sb, As,** Hg	**Sb, As**	Approximately 330 m Down-catchment of Mungay Ck 1 on Deep Creek
Mungay Ck 3	**As**	**-**	**-**	Approximately 1.67 km Down-catchment of Mungay Ck 2 on Deep Creek
Toorumbee Creek and Warbro Brook				
Warbro Brook 1	**As**	**As,** Hg	**As**	Collected on Warbro Brook approximately 2.37 km from Macleay confluence

The GAI data shown in Table A15 indicates that arsenic is present at relatively elevated concentrations in the sediment at Rockvale, Phoenix Gold and Tulloch (Upper Chandler), Khans Creek (Lower Chandler), Kapunda and Mary Anderson (Commissioners Water), Mungay Creek and Warbro Brook—all of which exceeded the low ISQG. Rockvale, Tulloch, Phoenix Gold, Mungay Creek and Warbro Brook also exceeded the high ISQG for arsenic. This is interesting as Warbro Brook was essentially a background sample from a non-mining catchment; albeit one with the Willi Willi prospect located in the sub-catchment.

The sediment data also shows that antimony is present at relatively elevated concentrations in the sediment at Rockvale, Phoenix Gold, Tulloch, Mary Anderson and Mungay Creek. Sediment at Rockvale, Khans Creek, Phoenix Gold, Tulloch, Mary Anderson and Mungay Creek exceeded the low ISQG for antimony, while Tulloch, Mary Anderson and Mungay Creek also exceeded the high ISQG for antimony.

Metals screening

Arsenic and antimony results were compared to the nominated metals screening criteria for sediment shown in Section 4 of the main report. Rather than discuss all sites, this section is limited to those sites that exceeded the most conservative screening criteria, which were the calculated background values of 1.2 mg/kg for antimony and 12.5 mg/kg for arsenic.

As noted above, the laboratory LOR for antimony in sediment (5 mg/kg) exceeded the background concentration of 1.2 mg/kg. For the indicative purposes of this study, results reporting a <LOR value for antimony was deemed to not be present. This study is, after all, focused on identifying the largest contributors of arsenic and antimony to the Macleay Catchment, so this method is deemed appropriate for the stated use of the data.

Results in the metals screening tables below are underlined and/or bolded relative to an exceedance of the metals screening criteria. The results have also been arranged vertically in the tables from up-catchment to down-catchment, i.e. the direction of water flow.

Sites that will not be discussed further in this section due to no sediment arsenic or antimony exceedances of the nominated screening criteria are:

- Aspley sub-catchment: Europambela
- Lower Chandler: Stuart Reef, Rathbone Point East (Chandler samples), Sunnyside and Mickey Mouse.

Results for those excluded sites listed above may be found in Table E, Appendix D.

Chandler – Upper

Phoenix Gold

The Phoenix Gold Mine was undergoing rehabilitation works during the site visit. The landholder had, however, ceased all rehabilitation works as allegedly contaminated mulch was being imported to site. The rehabilitation works included:

- backfilling five mine shafts
- demolishing redundant buildings
- partial site revegetation.

Table A16 shows the results of the sediment metals screening. Please refer to Figure A, Appendix F for the site aerial photograph showing sample locations.

Table A16: Phoenix Gold sediment metals screening results

Sample ID	Location	Antimony (mg/kg)	Arsenic (mg/kg)
Baseline concentration Stage 1 (GHD 2015)		1.2	12.5
ANZECC ISQG low trigger values		**2**	**20**
ANZECC ISQG high trigger values		**25**	**70**
PG_SD01	Up-catchment on unnamed drainage line located perpendicular to the mine	<5	5
PG_SD03	Drainage line from the former mine to the unnamed water course. Approximately 50 m from the last mine feature	***13***	***106***
PG_SD02	Approximately 190 m Down-catchment on same unnamed drainage line.	<5	***119***

Sample PG_SD02, being the furthest down-gradient sample collected approximately 400 metres down-catchment from the mine area, exceeded the ISQG high trigger value for arsenic, with a result of 119 mg/kg. The results in Table A16 indicate that arsenic contaminated sediment is leaving site. Antimony concentrations are above ISQG high trigger values on site, though return to levels consistent with background concentrations at the down-catchment sample location (PG_SD02).

Rockvale Arsenic

The Rockvale deposit was discovered in 1923 and operated between around 1923 and 1928 to produce arsenic oxide. It produced around 3,000 tonnes of ore for 600 tonnes of white arsenic (Peel Mining 2016). Exploration for silver and base metals occurred in the late 1960s and again in around 2011, with soil geochemistry, drilling and geophysical surveys undertaken (NSW Department of Mineral Resources 1992; Ashley *pers. comm.* 2016).

The orebody occurred as irregular steeply dipping shoots in altered aplite hosted in a northeast-trending structure within the Rockvale Monzogranite. The ore comprised mainly arsenopyrite and pyrite, however, galena, sphalerite, chalcopyrite, tetrahedrite, silver and lead sulfosalts such as those found at Tulloch and Ruby Silver mines were also reported (NSW Department of Mineral Resources 1992; McClatchie 2004).

Geological mapping demonstrated that the mineralised structure and associated alteration persists over a strike length of at least 1,120 metres. Outcropping lode material comprises gossanous, ferruginous and locally scorodite-rich, sericitised quartzo-feldspathic rock (Peel Mining 2016).

Although the site is partly rehabilitated, mineralised waste rock remains in three main locations where it was used to backfill shafts—with sulfide-bearing and oxidised altered granitic rock being prevalent. Scalds are also apparent on site (refer to Plate A1).

Plate A1 Rockvale Arsenic site photos

Legacy waste rock dump scald	Gully erosion on site.
	

A geochemical survey of the Rockvale Arsenic Mine by Cooper (2013) showed that the arsenic contamination (and to a smaller extent, heavy metals including copper, lead and zinc) was largely restricted to limited downslope dispersion in soil, and to a small volume of sediment and water in gullies draining from the mine area. Cooper (2013) reported that the waste rock on site contained up to 11 percent arsenic, 1,088 mg/kg copper, 1,144 mg/kg lead, 440 mg/kg antimony and 84 mg/kg silver. The mineral waste was also found to be acid producing (paste test pH 4.4, oxidation test pH 1.6).

Cooper (2013) reported that soils immediately downslope of the mine dumps and outcropping gossan contained arsenic values of up to 1,279 mg/kg (local background 46 mg/kg), copper at 202 mg/kg (background 22 mg/kg), lead at 429 mg/kg (background 86 mg/kg), zinc at 342 mg/kg (background 71 mg/kg) and antimony at 44 mg/kg (background 18 mg/kg). Cooper (2013) noted that the gully draining the immediate mine site (Plate 1) has strong contamination of stream sediments, but with values decreasing downstream to the confluence with Lambs Valley Creek, e.g. arsenic decreases from 63,800 mg/kg to 4,600 mg/kg percent, copper from 720 mg/kg to 386 mg/kg, lead from 367 mg/kg to 271 mg/kg and antimony from 252 mg/kg to 33 mg/kg. Seepage water immediately downstream of the mine had a pH of 4.23 with arsenic concentrations of 0.3 mg/L.

In Lambs Valley Creek upstream of any influence from the Rockvale arsenic mine, Cooper (2013) found an arsenic concentration of 28 mg/kg in stream sediment. This result is moderately consistent with a nearby result from Ashley and Graham (2001) of 41 mg/kg. Immediately downstream of the confluence of the contaminated stream draining the Rockvale arsenic mine, sediment from Lambs Valley Creek had strongly anomalous arsenic of 158 mg/kg (Cooper, 2013) and 181 mg/kg (Ashley and Graham, 2001). At the same sample locations, values of copper and lead were elevated to approximately twice the Macleay catchment background of Ashley and Graham (2001) being 18 and 13 mg/kg respectively. Approximately 5 km downstream, sediment arsenic concentrations in Lambs Valley Creek had returned to around background levels (27 mg/kg), with copper and lead values also having decreased to around regional background values (Ashley and Graham, 2001).

It is noted that in the late 2000s, the original waste dumps at the main mine area (being three dumps totalling a few thousand cubic metres of sulfide-bearing arsenic-rich rock) were bulldozed, with some of the material used to backfill open shafts. Residual material was largely flattened into low profile masses and a fence erected around the site in order to exclude stock. Since that time, there has been minor subsidence of infill material at shaft sites. No rehabilitation, except for fencing off, was performed at small mine shafts that represent the south-westerly extension along strike of the Rockvale arsenic mine vein system on the western side of Lambs Valley Creek, and there was no attempt to remediate scalded areas and gully erosion.

As noted above, the main mine area is characterised by historic waste rock used to infill three shafts, with localised subsidence over one of those filled shaft. The waste dumps remain as scalded areas on the landscape; with areas from a few hundred up to around 1,000 m^2 in size—generally with no vegetation cover, or only minor peripheral colonisation by pioneer species (refer to Plate 1).

Downslope of the scalded areas, there remain smaller areas of scalding and a paucity of vegetation, with the gully leading away from the main workings a site of significant erosion. The gully has permanent seepage with a typical pH value of around 4, and elevated EC values of around 670 µS/cm—likely derived from former underground workings (Ashley *pers comm* 2016). Under normal 'dry' conditions, this seepage extends some 50 to 100 metres downgradient before infiltrating so does not directly enter Lambs Valley Creek.

Table A17 shows the results of the sediment metals screening for Rockvale. Please refer to Figure B, Appendix F for the site aerial photograph showing sample locations.

Table A17: Rockvale Arsenic sediment metals screening results

Sample ID	Location	Antimony (mg/kg)	Arsenic (mg/kg)
Baseline concentration Stage 1 (GHD 2015)		1.2	12.5
ANZECC ISQG low trigger values		***2***	***20***
ANZECC ISQG high trigger values		***25***	***70***
RA_SD01	Up-catchment on Lambs Valley Creek located perpendicular to the former mine	<5	17
RA_SD03	Drainage line from the former waste rock dumps. Approximately 135 m from the last scald area	***14***	***3,600***
RA_SD02	Approximately 860 m Down-catchment on Lambs Valley Creek	<5	***87***

Stream sediment sample RA_SD1 upstream of the mine has near-background values of heavy metals and arsenic and are below ANZECC ISQG guideline values. Sample RA_SD2 downstream of the mine influence contains an elevated arsenic value (87 mg/kg, being approximately seven times the catchment background). Sample RA_SD3 from the gully immediately below the mine contains very high arsenic and strongly anomalous concentrations of antimony (and cadmium, copper and lead) in comparison to GAI values, reflecting a strong input of contaminated material from the mine.

Table A18 presents a comparison of historic data to that of GHD (2016), with the table sample numbers being ordered by Up-catchment at the top (RA_SD01) to Down-catchment at the bottom (MYSS236).

Table A18: Comparative Rockvale sediment metals results

Data source	location	Sample ID	Sb	As	Cd	Cu	Pb	Zn
			(mg/kg)					
Baseline concentration Stage 1 (GHD 2015)			1.2	12.5				
ANZECC ISQG low trigger values			**2**	**20**				
ANZECC ISQG high trigger values			**25**	**70**				
GHD	LVC up	RASD01	<5	17	<1	6	10	26
Cooper	LVC up	RASS04	**23**	**28**		20	25	81
AG	LVC up	MYSS234	**2.1**	**40.8**	0.2	18	15	41
GHD	RAMC	RASD03	**14**	**3,600**	6	396	205	130
Cooper	RAMC	RASS06	**252**	**63,826**		720	367	53
GHD	LVC nr jcn	RASD02	<5	**87**	<1	6	19	38
Cooper	LVC nr jcn	RASS01	**26**	**158**	-	37	41	94
AG	LVC nr jcn	MYSS235	**4.1**	**181**	0.4	29	42	67
AG	LVC down	MYSS236	**6.2**	15.5	0.1	13	16	42

Data sources: Cooper (2013); GHD, September 2015; Ashley & Graham (2001). Locations: LVC up = Lambs Valley Creek upstream of gully draining Rockvale arsenic mine, LVC nr jcn = Lambs Valley Creek just downstream (50-150 m) of junction with gully draining Rockvale arsenic mine. RAMC = gully draining Rockvale arsenic mine ~100 m downstream of mine. LVC down = Lambs Valley Creek ~ 5 km downstream of mine area.

Geochemical results from the Rockvale arsenic mine area, shown in Table A17 and Table A18 show reasonable consistency despite the sampling taking place over 14 years and utilising differing analytical methods. It is clear that the unnamed creek draining the mine area carries an arsenic load, and to a lesser extent, heavy metals and antimony in the form of stream sediments, but the actual volumes being transported and subsequently entering the local catchment of Lambs Valley Creek appear to be relatively minor.

Stream sediment samples collected between 50 and 150 metres downstream of where the unnamed creek joins Lambs Valley Creek show a significant increase in arsenic in stream sediment. However, approximately five kilometres downstream of the mine area, arsenic in stream sediments has decreased by approximately an order of magnitude to approximate the Macleay catchment background.

The data indicate that the three main mine waste dump scalds are point sources of contamination into local soils and stream sediments; albeit that relative amounts of arsenic being exported off-site within the context of the overall Macleay Catchment are likely to be small.

Ruby Silver

Two sediment samples were collected at this site. As the surface water and sediment samples were paired, sediment sample (RS_SD01) was collected from the corner of a dam as there was no flowing water in the tributary up-catchment of the mine site (refer Plate 2). The down-gradient sediment sample (RS_SD02) was also collected from within a small pool of water as shown in Plate A2.

Plate A2: Ruby silver site photos

RS_SD01 sample location	RS_SD02 sample location
	

Table A19 shows the results of the sediment metals screening. Please refer to Figure C, Appendix F for the site aerial photograph showing sample locations.

Table A19 Ruby Silver sediment metals screening results

Sample ID	Location	Antimony (mg/kg)	Arsenic (mg/kg)
Baseline concentration Stage 1 (GHD 2015)		1.2	12.5
ANZECC ISQG low trigger values		***2***	***20***
ANZECC ISQG high trigger values		***25***	***70***
RS_SD01	Up-catchment northern end of a water dam. The drainage line is located perpendicular to the mine	<5	9
RS_SD02	Down-catchment of mine features on the same drainage line.	<5	13

The results in Table A19 show that arsenic marginally exceeded the baseline concentration in the down-catchment sediment sample (RS_SD02); however, all results were below ISQG trigger values.

Tulloch Silver

Tulloch Silver was mined from a complex, polymetallic, vein-hosted mineral deposit, with processing of ore material on-site. This would have generated both waste rock and tailings as potential arsenic and antimony contamination sources. Site photos are provided in Plate A3.

There are several similar mineral deposits in the New England region of northern NSW and adjacent southern Queensland and all have produced significant environmental problems due to high concentrations of metalloids (arsenic and antimony) and heavy metals (including copper, lead, zinc, silver and cadmium) as well as being sources of acid and metalliferous drainage.

The Tulloch mineralised vein system was discovered in 1913 and worked underground intermittently until 1932. Following more exploration, it was worked again in the early 1970s. Ore material from other mine sites (e.g. Comet gold mine) was treated at Tulloch in the early 1980s adding to the waste rock and tailings repository (Gilligan *et al*., 1992; Doherty, 1999).

Due to the legacy problem of environmental contamination, the Tulloch site was recommended for rehabilitation, with a remediation action plan and review of environmental factors report being prepared by Coffey (2008). Subsequent rehabilitation works and follow-up maintenance were performed by the NSW Soil Conservation Service (SCS) in 2009 and 2012, respectively.

Plate A3: Tulloch Silver site photos

Seepage from the former tailings dams	Sample location TS_SD02
	

Geological data on Tulloch from McClatchie and Sylvester (1970), Kent (1989) and NSW Department of Mineral Resources (1992) shows that the mineralised vein system at Tulloch strikes approximately north-south, and also northeast, and is steeply dipping, evidently controlled by zones of shearing. It occurs adjacent to the contact between the Carboniferous age metasedimentary rocks of the Girrakool Beds and the early Permian-late Carboniferous Rockvale Monzogranite. Mineralisation is hosted in strongly hydrothermally altered rocks and is expressed in a complex sulfide mineral assemblage with arsenopyrite, galena, sphalerite, chalcopyrite, pyrite, tetrahedrite and silver sulfosalts. The vein system and host rocks have little carbonate present and hence limited buffering potential on oxidation and production of acidity; with subsequent potential for transport of dissolved metals.

Following the cessation of mining and ore treatment at Tulloch in the 1980s, the site was abandoned. Most building infrastructure was removed, but there was no environmental rehabilitation performed and the site lay derelict for over 20 years. During this period, the site contained a major waste rock dump of mineralised rock material near the abandoned shafts, and three tailings repositories (dams) located in an adjacent stream valley immediately north of the mine, amongst other smaller surface disturbances. Immediately down-valley from the tailings dams were two catch dams constructed to intercept and hold contaminated water egress from the mine, processing site and tailings dams. The valley north of Tulloch drains approximately westwards for approximately 700 metres to join Boundary Creek, a largely permanent tributary of the Wollomombi River, in turn a tributary of the Chandler and thence the Macleay River.

A limited environmental geochemical survey of the Tulloch site and downstream was performed as part of a student project at the University of New England in 1999 (Doherty, 1999), prior to any rehabilitation work having been undertaken. In this study, samples were taken of waste rock dumps, tailings dam material, soil, and sediment from settling ponds and downstream, including from Boundary Creek. Concurrent with Doherty's (1999) study, additional stream sediment and water samples were collected, including in Boundary Creek and the downstream Wollomombi River (Ashley and Graham, 2001).

Waste rock dumps at Tulloch were found to have strongly elevated values of copper (mean 311 mg/kg), lead (1,089 mg/kg), zinc (656 mg/kg), arsenic (1,649 mg/kg) and antimony (3,880 mg/kg). Tailings dam contents contained elevated arsenic (308 mg/kg), antimony (355 mg/kg), but not significantly anomalous amounts of copper, lead or zinc (Doherty, 1999). Water in the tailings and catch dams was acidic with pH values of between 3 and 4, with elevated amounts of copper, lead, zinc and sulfate. Downstream, the creek sediments contain strongly anomalous arsenic and moderately anomalous copper and antimony, but on joining Boundary Creek, stream sediment values diminish such that only arsenic and antimony were slightly above regional background values of Ashley and Graham (2001).

In 2007, limited sampling was performed at Tulloch by Sally Franco of the (then) NSW Department of Primary Industries (DPI). This work involved collection of three 'soil' (probably tailings dam material) and four water samples from the tailings dams, catch dams and downstream. The 'soil' samples contained anomalous values of arsenic (mean 539 mg/kg) and lead (221 mg/kg), but concentrations of copper and zinc were not significantly anomalous—antimony was not analysed for.

In 2008, Coffey Environments (Coffey) were contracted by the NSW Department of Primary Industries to develop a remediation action plan and a review of environmental factors report on the Tulloch mine area in order to provide recommendations for, and approval of, site rehabilitation. Coffey (2008) undertook somewhat more comprehensive, though similar, environmental geochemical sampling to what had been done previously by Doherty (1999) and Franco (2007).

Sample media included waste rock, tailings dam material, soil and surface water. Results for waste rock and tailings were similar to previously reported data by Doherty (1999) and Franco (2007), with generally elevated (compared to crustal abundances), though strongly variable amounts of arsenic, antimony, copper, lead and zinc. The tailings were shown to be strongly acid-producing (pH values of 2 to 5).

Soil samples collected and analysed from on and around the mine site by Coffey (2008) included those with near-background values of heavy metals and metalloids. One sample returned strongly anomalous arsenic (482 mg/kg) and antimony (4,130 mg/kg), and anomalous copper (172 mg/kg) and lead (137 mg/kg).

Stream sediment samples were taken in similar position to those of Doherty (1999) from the creek draining west from Tulloch and in Boundary Creek. The sediment samples show initially strongly anomalous values of arsenic, antimony and lead close to the catch dams, but diminishing substantially downstream, with values in Boundary Creek close to the regional background values of Ashley and Graham (2001).

Following the Coffey (2008) investigations and recommendations, and as noted above, major rehabilitation works were performed at Tulloch by the NSW Soil Conservation Service (SCS) in 2009 (Hanly 2012). The SCS works included:

- Fencing the main shaft and the filling of three other shafts
- Removal of the 'mullock heap' (waste rock)
- Capping the surface, and stabilising the walls of the three tailings dams
- Improving the condition of the two water retention ponds
- Improving the surface water management on and around the tailings dams
- Controlling noxious weeds and animals on site
- Removing rubbish from site
- Revegetating all disturbed areas.

Mullock heap material (waste rock) was placed on to one of the tailings dams and subsequently covered with soil obtained from a soil borrow dam south of the mine site, prior to being revegetated. In 2012, further maintenance was performed by SCS that included further filling of shafts and re-engineering of the soil borrow dam (Hanly, 2012).

At the time of the GHD sampling in September 2015, it was evident that the rehabilitation process described above had led to considerable pasture regrowth at the mine site, including on former waste rock dumps, and on the capped tailings dams. However, on the steeper slopes adjacent to the tailings dams (sites of the former mill) and on the margin of one dam, there was exposed mineralised rock and tailings that had evidently not been adequately covered and has been subject to further physical erosion. As no ameliorating agent (e.g. limestone) had been placed at the toe of the lowest tailings dam, acidic, metal-bearing-bearing leachate continues to be emitted into the catch dams.

The locations of the GHD samples are similar to (surface water and) stream sediment samples collected by Coffey (2008) and by Doherty (1999) as part of the Ashley and Graham (2001) study, thereby allowing for comparisons to be made over time to determine the effectiveness of the remedial works.

Table A20 shows the results of the sediment metals screening. Please refer to Figure D, Appendix F for the site aerial photograph showing sample locations.

Table A20: Tulloch Silver sediment metals screening results

Sample ID	Location	Antimony (mg/kg)	Arsenic (mg/kg)
Baseline concentration Stage 1 (GHD 2015)		1.2	12.5
ANZECC ISQG low trigger values		***2***	***20***
ANZECC ISQG high trigger values		***25***	***70***
TS_SD03	Up-catchment on Boundary Creek – located perpendicular to former mine area	<5	15
TS_SD01	Up-catchment from former mine on a unnamed drainage line	***8***	***143***
TS_SD02	Down-catchment of the remaining mine features on the same unnamed drainage line.	***106***	***691***
TS_SD04	Approximately 155 m Down-catchment on Boundary Creek from mine area.	<5	16

The drainage channel sample (TS_SD02) collected from below the tailings dam is elevated in antimony and arsenic, with both exceeding the ISQG high trigger values. However, the down-gradient sample collected on Boundary Creek (TS_SS04) is below all sediment screening criteria for antimony, with arsenic almost back to baseline concentrations.

The up-gradient sample (TS_SD03) and the down-gradient (TS_SD04) sample collected on Boundary Creek are similar in concentrations for arsenic and antimony. This would indicate that the contamination from the mine site is not contributing contaminated sediment to Boundary Creek in any measurable quantity.

Table A21 presents a comparison of historic data to that of GHD (2016), with the table sample numbers being ordered by up-catchment at the top (RA_SD01) to down-catchment at the bottom (BCD).

Table A21: Comparative Tulloch Silver sediment metals results

Data source	location	Sample ID	Sb	As	Cd	Cu	Pb	Zn
			(mg/kg)					
Baseline concentration Stage 1 (GHD 2015)			1.2	12.5				
ANZECC ISQG low trigger values			***2***	***20***				
ANZECC ISQG high trigger values			***25***	***70***				
GHD	T Ck up	SD01	8	143	<1	9	20	25
Coffey	T Ck up	DLU	<5	**45**	<1	14	16	41
AG	T Ck up	MYSS27	**29**	**91**	<0.1	25	21	73
AG	CD	MYSS28	**21**	**162**	<0.1	112	23	109
GHD	Below CD	SD02	**106**	**691**	2	116	90	193
Coffey	Below CD	FO	**6**	**133**	<1	50	18	94
AG	T Ck down	MYSS29	**17**	**107**	<0.1	50	25	71
Coffey	T Ck down	DLD	**17**	**332**	<1	45	136	98
GHD	B Ck up	SD03	<5	15	<1	8	10	47
AG	B Ck up	MYSS30	**6**	13	<0.1	17	14	68
Coffey	B Ck up	BCU	<5	11	<1	7	7	37
Coffey	B Ck jcn	BCM	<5	13	<1	8	8	40
GHD	B Ck down	SD04	<5	16	<1	8	8	43
AG	B Ck down	MYSS31	**12**	**22**	<0.1	12	16	68
Coffey	B Ck down	BCD	<5	16	<1	6	9	48

Data sources: Coffey (2008); GHD, September 2015; Ashley & Graham (2001). Locations: T Ck up = small creek upstream of Tulloch, CD = catch dam, below CD = immediately below catch dam, T Ck down = 400 m below catch dam, BCU = Boundary Creek upstream of Tulloch creek, BCM = Boundary Creek at junction of Tulloch creek, BCD = Boundary Creek downstream of Tulloch creek.

Data in Table A21 are grouped by sample locations that are approximately equivalent, albeit there could be spatial differences between samples in a group of up to around 100 metres and this variation might explain some of the geochemical scatter seen between samples collected at different times—along with the relatively small size of the sample group.

The geochemical data for stream sediment over time are broadly comparable for the sample grouping. For example, stream sediment samples collected from the small creek north of the Tulloch mine and immediately upstream of the remediated tailings dams show anomalous values approximating seven times the arsenic and 20 times the antimony background values of 12.5 and 1.2 mg/kg respectively for these elements (GHD 2015). This is interpreted to reflect an influence from the Tulloch mineralisation upstream of the mine workings pointing to a natural extension of the mineralisation to the east.

There is an insignificant difference between sediment samples from Boundary Creek upstream and downstream of the junction with the unnamed creek draining the Tulloch mine over time. Sediment geochemical values approach background concentrations down-catchment.

In summary, the GHD (2016) and previous data shown in Table A21 show little measurable influence from the Tulloch mine in Boundary Creek as determined by sediment concentrations over time. This position appears to have been maintained prior to, and subsequent to, rehabilitation of the site.

Chandler – Lower

A visual snapshot of sediment and surface water antimony and arsenic concentrations across the Stage 2 and 2a sample locations for the Lower Chandler is provided as Figures R and S respectively, in Appendix F.

Introduction and previous work

GHD did not visit some historic mine areas in the Halls Peak Mineral Field of the Lower Chandler sub-catchment, including Faints and Firefly. This is as they have been previously assessed by others including EA Systems and CivilTech (2003). GHD did, however, visit the Gibsons Open Cut (no sampling completed as it was not in scope), Keys Prospect and Khans Creek mine in the Halls Peak Mineral Field; the results from which are discussed below. GHD also visited Sunnyside and Mickey Mouse, and collected down-catchment samples intended to be representative of Stuarts Reef and Rathbones Point East (the two Chandler samples); the results of which are provided in Appendices D and E as they were below trigger values, and are therefore not of consequence in this study.

The following introduction is provided to provide context to the GHD (2016) results provided herein and also to introduce historic data for those Halls Peak Mineral Field sites not visited by GHD.

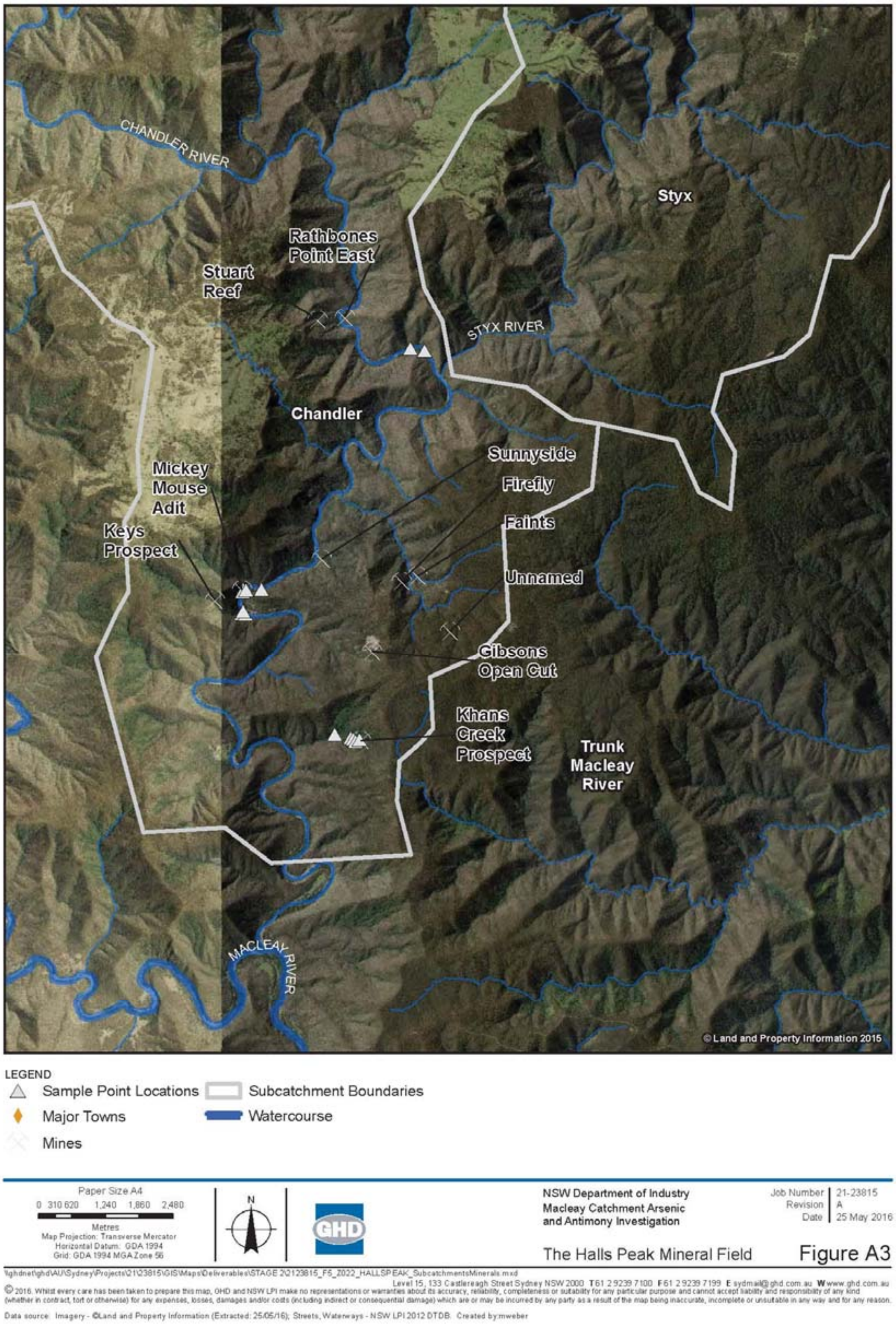
It is important to note that what is often referred to as 'The Halls Peak Mineral Field' is larger than simply one mine. The main mines and prospects are shown in Figure A3. Ashley and Graham (2001) noted that the area hosts eight mines and prospects and recorded historic production is stated at about 16,000 tonnes of high grade (30-50 %) zinc and lead ore, with minor copper and silver.

Mining of several deposits within the Halls Peak Mineral Field took place intermittently in the 1890s to 1920s, and again in the 1960s to 1970s. In addition, there has been a number of exploration programs performed in the area since the 1950s (NSW Department of Mineral Resources. 1992; Precious Metal Resources 2014).

The Halls Peak Mineral Field contains several discrete abandoned mine sites and smaller contamination point sources as unconstrained sulfide ore dumps. Rehabilitation works have historically been performed at Gibson's Open Cut and a few of the smaller scattered sulphide ore dump sites. Many of the other sites have not been rehabilitated, and they, as well as the Gibson's location, continue to contribute significant concentrations of base metals, metalloids and minor acidity into the Chandler River. As a result, minor impacts remain detectable in Macleay River sediments for up to 120 kilometres downstream of Halls Peak (Ashley *pers comm* 2016).

The mineral deposits in the Halls Peak area are of the volcanic-associated massive sulfide type and are characterised by high concentrations of zinc and lead, and locally copper, as well as having substantial (ore grade) silver and strongly anomalous values of gold, cadmium, arsenic and antimony (NSW Department of Mineral Resources, 1992; Lottermoser *et al*., 1997; Precious Metal Resources, 2014). Average values of sulfide ore material from Gibson's Open Cut were 19.5 % zinc, 10.2 % lead, 4.5 % copper, 319 mg/kg silver, 0.52 mg/kg gold, 531 mg/kg cadmium, 973 mg/kg arsenic, and 297 mg/kg antimony (Lottermoser *et al*., 1997). Similar concentrations were found in intercepts obtained in recent exploration (Precious Metal Resources, 2014).

Figure A3: The Halls Peak Mineral Field



Natural outcrops of the deposits historically formed gossans and mineralised alteration zones with high base metal and metalloid values. Waste rock dumps developed during historic mining also have strongly anomalous values of elements including all of the above (e.g. zinc 0.17 %, lead 4.24 %, copper 2.09 %, silver 284 mg/kg, gold 0.22 mg/kg, cadmium 5 mg/kg, arsenic 708 mg/kg, antimony 54 mg/kg) (Lottermoser *et al*., 1997; Ashley and Wolfenden, 2005). A legacy of the prior mining of several deposits (Gibson's open cut, Khans Creek, Faints and Firefly) has included formation of several unstable sulfidic waste rock dumps, bare eroded areas, leading to dispersion of heavy metals and metalloids by physical (erosion and sedimentation) and chemical transport (acid and metalliferous drainage) (Lottermoser *et al*., 1997; Ashley and Graham, 2001; Wolfenden, 2002; E.A. Systems and CivilTech, 2003).

Due to the legacy problem of environmental contamination within the Chandler River sub-catchment, Gibson's Open Cut and a few of its associated sulfidic waste rock and ore stockpiles (termed Base Camp and Silver Gully) were historically recommended for rehabilitation, with a review of environmental factors and remediation action plan having prepared by E.A. Systems and Civiltech (2003). Subsequent remedial actions were described by E.A. Systems (2004); however, it is noted that no remediation was completed at the Khans Creek, Faints and / or Firefly locations.

As mentioned above, significant historic mining has occurred at several locations within the Halls Peak area, with mined material ranging from approximately 1,000 to 100,000 tonnes depending on location. Gibson's open cut has produced the greatest volume of ore and waste rock material, with smaller volumes coming from Khans Creek, Faints and Firefly. Other locations, including Sunnyside, Mickey Mouse, Gossan Tunnel and Keys, were essentially prospecting sites with no or insignificant production.

At Gibson's Open Cut, there are a number of exposures of massive sulphides and metal-rich gossans in mine walls and in outcrops. However, volumetrically, these are small, and are insignificant in comparison to the large amount of mineralised waste rock material that has cascaded down steep slopes for between approximately 100 and 200 metres altitude below the main mine workings. Estimates of around 100,000 tonnes of waste rock, averaging some 3.2 % combined copper, lead and zinc, and also containing anomalous amounts of silver, cadmium, arsenic and antimony have previously been reported (Lottermoser *et al*., 1997).

Waters seeping from below the sulfide mineral-bearing waste rock mass, and from the open cut, have typical pH values of 3.3 and contain high (to extreme) concentrations of zinc, lead, copper, iron, manganese, cadmium, arsenic and sulfate (Ashley *pers comm* 2016). Stream sediments have similar types and magnitudes of anomalism in Barkers Creek, below Gibson's (Lottermoser *et al*., 1997). These impacts extend with diminishing magnitude for up to 120 kilometres down the Chandler and Macleay Rivers (Ashley and Graham, 2001). The Khans Creek, Faints and Firefly occurrences, although much smaller than Gibson's, have caused moderate to extreme contamination of stream sediments by zinc, lead, copper, arsenic and antimony in Khans and Asens Creeks, extending downstream into the Chandler River (Wolfenden, 2002).

The scattered sulfide ore dumps in the Halls Peak Mineral Field have undergone partial oxidation, with local liberations of acidic drainage and heavy metals, leading to localised soil contamination, a subsequent lack of vegetation, and erosion issues. These sites are generally less than one hectare in size. Environmental impacts from Sunnyside, Mickey Mouse and Keys prospects are generally very minor, with only small amounts of mineralised waste rock present, and in the case of Keys and Mickey Mouse, minor downstream anomalism of zinc, lead and copper in stream sediments (Ashley *pers comm* 2016).

The massive sulfide mineral deposits in the Halls Peak area are hosted in early Permian age sedimentary and felsic volcanic rocks (e.g. shale, siltstone, volcanic sandstone, tuff, and rhyolite). The mineral deposits contain abundant sphalerite and galena, with less common amounts of chalcopyrite and pyrite. Notably, neither the mineral deposits, nor the host rock, contain any significant carbonate, so there is essentially no buffering agent for acid production when the sulfide minerals undergo oxidation.

It is important to recognise that because of the presence of the mineral deposits and their associated natural heavy element dispersion haloes (hydrothermal alteration zones), there are natural geochemical anomalies (of zinc, lead, copper, arsenic and antimony) that are considerably spatially larger than the deposits themselves. These anomalous concentrations of elements add to the natural loadings in soils and stream sediments.

Studies at the University of New England (UNE) provided the first environmental geochemical data for the Halls Peak mining area. The initial work was summarised in Lottermoser *et al*. (1997), which focussed on the environmental 'footprint' of Gibson's Open Cut. Effects on the Chandler River and downstream into the Macleay River were further assessed by Ashley and Graham (2001) and more detailed follow-up studies were performed by Wolfenden (2002).

Results of the studies summarised by Lottermoser *et al*. (1997) included the geochemical characterisation of the large waste rock masses, stream sediments and waters. As noted above, the waste rock contained heavy metals, while stream sediment samples from the most contaminated sites were found to contain zinc concentrations of up to 0.73 %, lead of up to 1.9 % and copper up to 0.43 %. Values gradually decreased downstream in Barkers Creek to its confluence with the Chandler River.

Upstream, Chandler River sediments and waters were found to have near background values of zinc, lead and copper, similar to those determined for the Macleay catchment as a whole by Ashley and Graham (2001), being 51 mg/kg zinc, 13 mg/kg lead, and 18 mg/kg copper for sediments, and 0.04 mg/L Zn, 0.003 mg/L lead and 0.005 mg/L copper for surface water.

Although acidic water draining from Gibson's area contains extreme values of dissolved zinc, lead, copper, cadmium, iron and manganese, as well as anomalous arsenic (Lottermoser *et al*., 1997), it is evident that most elements precipitate into stream sediments as neutralisation of water proceeds. Further dilution occurs on entry to the Chandler River, such that near the confluence with the Macleay River, only zinc and cadmium values in stream water are modestly above the catchment background values (Ashley and Graham, 2001).

The investigation by Wolfenden (2002) in the Halls Peak region involved sampling of stream sediment, water, riparian vegetation and aquatic algae from background sites upstream of Halls Peak in the Chandler and Styx Rivers, the same media in the Chandler and Macleay Rivers adjacent to their confluence, and sediment, vegetation and aquatic algae at sites in Khans, Barkers and Asens Creeks downstream of mine workings. In the latter three streams, stream sediments were found to be highly contaminated (zinc up to 2,179 mg/kg, lead up to 5,943 mg/kg, copper up to 922 mg/kg, arsenic up to 142 mg/kg, and antimony up to 76 mg/kg). These anomalies were mimicked in aquatic algae and riparian vegetation species, with bracken fern locally containing extreme heavy metal values (e.g. 1.38 % zinc, 0.24 % lead and 522 mg/kg copper, dry weight).

In the Chandler, Styx and Macleay Rivers upstream of any Halls Peak influence, stream sediment and surface water values of zinc, lead and copper are close to the catchment background values determined by Ashley and Graham (2001). Riparian vegetation concentrations of zinc, lead, copper, arsenic and antimony are typically a fraction (<10%-50%) of the background values in stream sediments. Downstream of the inputs from Halls Peak, sediments in the Chandler and Macleay Rivers showed significant increases in zinc and lead contents, and a modest increase in copper, when compared to upstream, with this being slightly mimicked in riparian vegetation and aquatic algae.

E.A. Systems and CivilTech (2003) developed a remediation action plan and completed a review of environmental factors for the Halls Peak area, focussing on Gibson's open cut, but also covering the Faints and Firefly locations and sulphide ore dumps at Base Camp and Silver Gully. At each location, waste rock dumps were sampled (including the landslide area at Gibson's) and these were found to have high concentrations of zinc (628 mg/kg to 4.23 %), lead (1,610 mg/kg to 4.41 %), copper (469 mg/kg to 1.36 %), cadmium (up to 36 mg/kg), arsenic (20 to 466 mg/kg), antimony (2.5 to 482 mg/kg) and sulfur (0.01 to 6.7%)—and were acid producing. Results overall are similar to those reported by Lottermoser *et al*. (1997).

Waste rock material from the much smaller dumps at Faints and Firefly were found to have similar compositions to that at Gibson's, although material from Faints had notably higher concentrations of zinc (up to 35.27 %) and lead (24 %), as well as cadmium, arsenic and antimony, probably because some of the samples were of massive sulfides. Apart from taking selective soil and sulfide ore dump samples, and one water sample, E.A. Systems and CivilTech (2003) utilised prior stream sediment, water and vegetation geochemical results from the UNE investigations (e.g. Lottermoser *et al*., 1997; Ashley and Graham, 2001; Wolfenden, 2002).

Stream sediment and water data were further assessed along Asens and Barkers Creeks and in the Chandler River as it passed the contaminated inputs. Both creeks showed strongly contaminated values of zinc, lead, copper, cadmium, arsenic and antimony in sediment and water, decreasing downstream. The Chandler River has spike values of these elements adjacent to the contaminated stream inputs. Concentrations in stream waters largely diminish to near-background values in the Chandler River at the Macleay River confluence. Soil samples taken at the sulfide ore stockpile sites contained high heavy metal contents, especially lead, with results similar to those reported by Lottermoser *et al*. (1997).

To better characterise acid and metalliferous drainage potential, E.A. Systems and CivilTech (2003) undertook static geochemical tests to determine acid neutralisation capacity (ANC) in addition to net acid generating (NAG) tests on waste rock material from the Gibson's, Faints and Firefly sites. Although most samples tested gave net acid production potential results that were in the 'uncertain' category (i.e. may or may not produce acid in the long term), some samples from Gibson's and the Silver Gully dump were acid producing. This is consistent with GHD's data for Khans Creek reported herein. The E.A. Systems and Civiltech (2003) results appear to be consistent with measurements obtained from UNE testing of effluent waters in the Gibson's area over many years, which have consistently shown that waters in the catch dams below the open cut and at the toe of the landslide area have pH values in the 3.3 to 3.6 range, with high zinc, copper and sulfate concentrations, indicating that the waste rock is acid-producing.

The E.A. Systems and CivilTech (2003) report proposed a detailed rehabilitation plan and costing for the Gibson's open cut site, Faints and Firefly, as well as for the sulfide ore dumps at Base Camp and Silver Gully. The following actions were recommended:

- Re-location of sulfide ore and contaminated soil at the Base Camp and Silver Gully stockpile sites to an old mine shaft and small open cut at Gibson's, i.e. potentially returning the material from where it was derived
- Minimise stormwater runoff over disturbed land (i.e. re-routing drainage lines), with local re-vegetation and water treatment. This was to require some earthworks by reconstruction of existing benches and tracks (e.g. with banding, embankments)
- Development of a three-compartment sedimentation catch dam at the base of the main landslide zone of waste rock that would intersect the majority of re-directed runoff. The catch dam would be built to proper engineering standards in order to prevent future failure

- Soil treatment and revegetation proposed for the Gibson's site included targeted application of neutralising agent (lime) and organic matter, laying of polymer erosion matting on batter slopes, as well as topsoil, fertiliser and seeding
- Safety issues to be addressed including the filling of a dangerous mine shaft and erection of fencing, gates and warning signage
- The small Faints and Firefly sites are in very difficult terrain and were considered to be of lower priority than Gibson's, but rehabilitation measures proposed included creek diversions at both sites. In addition, at Firefly, catchment minimisation was recommended by re-directing runoff flows, followed by re-vegetation after placement of erosion control matting. Safety issues including adit filling and erection of mesh barriers and a locked gate were also recommended.

The actual work performed for rehabilitation is explained in detail in a report by E.A. Systems (2004). Significant earthworks were performed by NSW Department of Lands, Soil Services Division, as managed by E.A. Systems, largely in accordance with the rehabilitation action plan of E.A. Systems and CivilTech (2003). The earthworks were undertaken during 2004 and broadly covered the above points, except that there was no work carried out at the Faints and Firefly. One of the access tracks approaching Firefly was partly cleared and bunded for some distance, and a former adit (Gossan tunnel) was buried. Most work focussed on the Gibson's site, with minor works at the Base Camp and Silver Gully sulfide ore stockpile sites. The earthworks performed are summarised as follows:

- Improvement of access roads into, and in the vicinity of, Gibson's mine. This included clearing and grading prior access tracks and adding berms along some tracks to increase safety.
- Removal and disposal of sulfide ore material and contaminated soil from the Base Camp and Silver Gully sites, with placement of uncontaminated topsoil at the former and attempts at erosion control at the latter (e.g. placement of logs across previously scalded, sloping areas. Sulfide ore material and contaminated soil was in part placed into a former mine shaft adjacent to Gibson's open cut, but when that was filled, it was placed into a constructed containment cell at the northern part of the Gibson's mine area. This cell was underlain and capped by clay and was in an area where any runoff would be captured by sediment basins (catch dams) further down the mountainside at the base of the landslide below Gibson's.
- Re-grading of benches / berms (and some old haul roads) to define lines of surface water flow capture and redirection. This involved considerable earthworks along existing (generally highly degraded) tracks, in order to control runoff from the overall site and redirect it (at much lower gradients) to the base of the landslide area and into a three-celled sediment basin (catch dam system). A small sediment catch dam was also constructed on the bench immediately north of Gibson's open cut.
- Construction, adjacent to the base of the landslide below Gibson's, of a three-celled sedimentation basin (catch dams). It had been stated in the earlier E.A. Systems and Civiltech (2003) investigation that the landslide mass was relatively stable, and hence was not expected to move significantly and overwhelm the catch dams. The three-celled system was constructed such it would intercept most of the anticipated contaminated sediment.

No treatment of the waste rock constituting the landslide area and adjacent bare regions of loose waste rock or rock outcrops was performed at Gibson's, e.g. application of neutralising agents, organic material, matting, fertiliser or reseeding. Following completion of the works, E.A. Systems (2004) made recommendations for future management of the site. These included:

- inspection of the site in 6 to 12 months in order to monitor performance
- cleaning (meaning excavation) of contaminated sediment from the sediment basins every two years or when deemed appropriate, and placement of the material ‘in a secure area outside the cells’
- construction of a bund or fence across the track that leads to the general site of the filled mine shaft in order to restrict access
- suggest that Cell 3 of the sediment basin be enlarged
- acquisition of more geotechnical data on the landslide if more works were to be required in that area.

There appears to have been little change at the Gibson’s open cut site since the 2004 remediation. The NSW Soil Conservation Service completed some minor reparative civil works with some liming undertaken on site in 2008 (NSW Department of Lands), with Coffey Geotechnics (2008) completing minor soil / rock testing as part of those works. Coffey Geotechnics (2008) reported elevated arsenic, copper, lead and zinc (with leachable lead) based on NSW EPA contaminant guidelines for solid waste.

The Silver Gully sulfide stockpile site shows some success in lessening of erosion effects, and there has been some re-colonisation of formerly scalded ground by local native species. Similarly, the Base Camp stockpile site also shows minor revegetation. At Gibson’s, the general concept of re-direction of runoff appears to have performed satisfactorily and there is little evidence to indicate any further downslope movement of the waste rock landslide (Ashley *pers. comm.* 2016).

However, since 2004, there has been a series of below-average rainfall years in the region and thus judgement of longer-term stability cannot be made. The catch dam immediately below the open cut and the three-celled catch dam adjacent to the toe of the landslide continue to capture small volumes of contaminated sediment, and they mostly also contain small volumes of acid mine drainage water (pH values typically range between 3.3 and 3.6 with high copper and zinc values) (Ashley *pers. comm.* 2016).

In 2014, site maintenance via contaminated sediment removal from the catch dam adjacent to the landslide toe was undertaken and placed nearby; clearly an unsustainable solution. There has been minor subsidence of the waste rock filling of the old mine shaft immediately east of the open cut. Over the past 11 to 12 years since the physical rehabilitation, there has been little change in the native vegetation cover of the site and this reflects the lack of any topsoil and continued occurrence of acid-forming and heavy metal-liberating reactions in waste rock.

As there was no rehabilitation performed at the Khans Creek, Faints and Firefly locations, there has been little change at these sites over the intervening years. Each has:

- sulfide-bearing waste rock dumps (at least one to two orders of magnitude less than at Gibson’s in size)
- downstream dispersion of mineralised rock material (in Khans Creek and Asens Creek respectively)
- local areas of little or no vegetation (due to removal of soil and local acid production / heavy metal liberation)

In addition, Khans Creek shows localised collapse of underground workings. Each of these sites is in remote, difficult terrain and likely to be little-known to the general public.

Khans Creek

GHD collected two sediment samples at Khans Creek (refer to Table A22). Please refer to Figure E, Appendix F for the site aerial photograph showing sample locations. Note that no water samples were collected at Khans Creek as there was no visible surface water at the time of GHD's site visit.

Table A22: Khans Creek sediment metals screening results

Sample ID	Location	Antimony (mg/kg)	Arsenic (mg/kg)
Baseline concentration Stage 1 (GHD 2015)		1.2	12.5
ANZECC ISQG low trigger values		***2***	***20***
ANZECC ISQG high trigger values		***25***	***70***
KC_SD02	Up-catchment of former mine site in drainage line running adjacent to site	<5	<5
KC_SD01	Approximately 330 m down gradient from mine on same drainage line	***8***	***24***

Stream sediment sample KC_SD02, collected up-catchment of the mine contained concentrations of arsenic and antimony consistent with background levels. Sample KC_SD01 collected approximately 330 metres downstream of the mine contained arsenic and antimony concentrations that exceeded the ISQG high trigger values.

In addition, sample KC_SD01 also contained strongly anomalous zinc (0.45 %) as well as relatively elevated values of lead, copper, arsenic, antimony, cadmium and mercury (consistent with results presented earlier). In contrast, KC_SD02, collected approximately 100 metres upstream of the mine area, contained near-background values of elements as noted above, except for lead (which is around five times background concentrations and may reflect a mineralised halo effect—*cf*. Ashley and Graham, 2001).

Keys Prospect

Keys Prospect could not be samples due to inaccessible terrain and associated safety issues, however one stream sediment sample (KP_SD01) was collected approximately 500 metres downstream of the assumed prospect site in 'Keys Creek'. Sediment samples KP_SD03 and KP_SD02 were collected from the Chandler River within 100 metres up and downstream of where 'Keys Creek' joins the Chandler respectively. The sediment sample results are presented in Table A23. Please refer to Figure F, Appendix F for the site aerial photograph showing sample locations.

Table A23: Keys Prospect sediment metals screening results

Sample ID	Location	Antimony (mg/kg)	Arsenic (mg/kg)
Baseline concentration Stage 1 (GHD 2015)		1.2	12.5
ANZECC ISQG low trigger values		***2***	***20***
ANZECC ISQG high trigger values		***25***	***70***
KP_SD01	Keys Creek approx. 630 m east of mine	<5	9
KP_SD03	Up-catchment of the confluence of Keys Creek and the Chandler River	<5	*15*
KP_SD02	Down-catchment of the confluence of Keys Creek and the Chandler River	<5	6

The key result for Keys Prospect is KP_SD01, as this sample was collected from the near the outlet of 'Keys Creek' before it flows into the Chandler River. Both the arsenic and antimony results for KP_SD01 were below background concentrations, as they were for the downstream sediment sample on the Macleay (KP_SD02). The upstream sample on the Macleay (KP_SD03) had arsenic concentrations slightly above background values, though below the ISQG low trigger value. The results suggest a negligible contribution from Keys Prospect into the Chandler via Keys Creek.

Interpretation

Despite the rehabilitation actions implemented in Gibson's Open Cut area and at the Silver Gully and Base Camp sulfide dump in 2004, observations between 2005 and 2015 (Ashley *pers. comm*. 2016) indicate there remains continuing transport of contaminated waste rock and stream sediment from the Gibson's site via Barkers Creek into the Chandler River. However, it is important to note that there has been some stabilisation at the Gibson's site following remediation, with reduced loss of fine-grained sediment in those areas where the catch-dams are installed and effective. It is noted that there remain areas on site where free draining mineral waste reports to the drainage lines, and ultimately, the Chandler River.

Little or no revegetation has occurred and any onset of above-average rainfall and sustained heavy rainfall events may lead to further significant erosion and destabilisation of mineral waste stockpiles.

Since no remediation was performed at Khans Creek, Faints and Firefly, mineral waste and contaminated stream sediment continue to be channelled down Khans and Asens Creeks into the Chandler River, although volumes are likely to be relatively insignificant (at least from Faints and Firefly). This was evidenced by near-background stream sediment and surface water results from the Chandler River downstream of the Asens Creek confluence (e.g. in the Sunnyside-Mickey Mouse-'Keys Creek' areas. Sunnyside and Mickey Mouse data are presented in Tables D and E, Appendix D).

The data suggests that the influences of Sunnyside, Mickey Mouse and Keys Prospects on the Chandler River are either trivial (undetectable) or very localised and restricted to sediment.

Commissioners Waters

A visual snapshot of sediment and surface water antimony and arsenic concentrations across the Stage 2 and 2a sample locations for the Commissioners Waters sub-catchment is provided as Figures T and U respectively, in Appendix F.

Kapunda Arsenic

The Kapunda Arsenic site had no surface drainage present at the time of visiting, with the nearest creek being approximately 100 meters to the east of site. Therefore, sample (KA_SD01) was collected up-catchment with the paired surface water sample on the Tilbuster Ponds drainage line, with KA_SD02 and its paired water sample collected approximately 260 m down-catchment of site, also on the Tilbuster Ponds drainage line. The sediment sample results are presented in Table A24. Please refer to Figure G, Appendix F for the site aerial photograph showing sample locations.

Table A24: Kapunda Arsenic sediment metals screening results

Sample ID	Location	Antimony (mg/kg)	Arsenic (mg/kg)
Baseline concentration Stage 1 (GHD 2015)		1.2	12.5
ANZECC ISQG low trigger values		***2***	***20***
ANZECC ISQG high trigger values		***25***	***70***
KA_SD01	Up-catchment on Tilbuster Ponds that flow perpendicular to the former mine	<5	***36***
KA_SD02	Approximately 260 m down-catchment of Kapunda 1 sample	<5	***41***

The results in Table A24 show that both the up and down-catchment samples exceed the ISQG low trigger value for arsenic, with the down-catchment sample being slightly higher than the up-catchment sample. Antimony results for both samples were at background concentrations. The elevated Up-catchment sample result suggests that there may be a contaminant source up-catchment on the Tilbuster Ponds.

Mary Anderson

The Mary Anderson site contained numerous former mine features. The small waste rock dumps were located proximal to surface drainage. Both sediment samples were collected from small water dams on site (refer to Plate A4). Table A25 presents the results of the two sediment samples. Please refer to Figure H, Appendix F for the site aerial photograph showing sample locations.

Plate A4: Mary Anderson site photos

Sample location MA_SD01	Sample location MA_SD02
	

Table A25: Mary Anderson sediment metals screening results

Sample ID	Location	Antimony (mg/kg)	Arsenic (mg/kg)
Baseline concentration Stage 1 (GHD 2015)		1.2	12.5
ANZECC ISQG low trigger values		***2***	***20***
ANZECC ISQG high trigger values		***25***	***70***
MA_SD02	Up-catchment from northern edge of water dam on unnamed drainage line	***27***	***21***
MA_SD01	Down-catchment from northern edge of water dam on unnamed drainage line	<5	14

The results show that the up-catchment sample (MA_SD02) exceeds the ISQG high trigger value for antimony and the ISQG low trigger value for arsenic. This may be due to the fact that the sample was collected from a stock watering dam where contaminated sediment can collect. The dam does span an area where contaminated sediment could collect from up gradient mine features.

The down gradient sample (MA_SD01) was collected from below another stock watering dam, and only marginally exceeded the baseline concentration for arsenic. This may show that the stock watering dams are collecting contaminated sediment, such that minimal contaminated sediment is leaving site.

Hickeys / Mungay Creeks Sub-catchment

A visual snapshot of sediment and surface water antimony and arsenic concentrations across the Stage 2 and 2a sample locations for the Hickeys / Mungay Creek sub-catchment is provided as Figures V and W respectively, in Appendix F.

Mungay Creek

The Mungay Creek Antimony Mine is located on Deep Creek, which was a chain of ponds rather than running water at the time of sampling. All samples were located downstream from the Mungay Creek mine ore dump, which was accessed and sampled; however, no apparent creek lines were located topographically above it for sampling as it was close to the catchment interfluve. One small dam was identified on an adjacent property for which GHD did not have permission to access. Plate A5 shows site photographs from Mungay Creek.

Plate A5 Mungay Creek site photos

Sample location MC_SD01	Sample location MC_SD02
	
Sample location MC_SD03	
	

Table A26 presents the results of the three sediment samples for Mungay Creek. Please refer to Figure I, Appendix F for the site aerial photograph showing sample locations.

Table A26: Mungay Creek Antimony metals screening results

Sample ID	Location	Antimony (mg/kg)	Arsenic (mg/kg)
Baseline concentration Stage 1 (GHD 2015)		1.2	12.5
ANZECC ISQG low trigger values		***2***	***20***
ANZECC ISQG high trigger values		***25***	***70***
MC_SD01	Down-catchment of mine site, below water dam, near former adit on Deep Creek which runs through site	***307***	16
MC_SD02	Approximately 330 m down-catchment of Mungay Ck 1 on Deep Creek	***83***	***72***
MC_SD03	Approximately 1.67 km down-catchment of Mungay Ck 2 on Deep Creek	<5	16

The results in Table A26 indicate that antimony concentrations exceed the ISQG high trigger value at locations MC_SD01 and 02, decreasing downstream to approximate background concentrations. Arsenic concentrations for sample MC_SD02 exceed the ISQG high trigger value, with the up and down stream samples slightly exceeding background concentrations. Depending on where the site 'boundary' is located, it is likely that contaminated sediment is migrating off site at Mungay Creek.

Toorumbee Creek and Warbro Brook

Warbro Brook

One sediment sample was collected up-catchment of the Warbro Brook / Macleay River confluence. This sub-catchment has had no historical or current mines, although is known to contain a significant metalliferous anomaly in the form of the Willi Willi Prospect. Table A27 presents the results of the one sediment sample for Warbro Brook. Please refer to Figure J, Appendix F for the site aerial photograph showing sample location.

Table A27: Warbro Brook sediment metals screening results

Sample ID	Location	Sediment Results **Antimony**	Sediment Results **Arsenic**
Baseline concentration Stage 1 (GHD 2015)		1.2	12.5
ANZECC ISQG low trigger values		***2***	***20***
ANZECC ISQG high trigger values		***25***	***70***
WB_SD01	Collected on Warbro Brook approximately 2.37 km from Macleay confluence	<5	**30**

The results show that Warbro Brook appears to be naturally elevated in arsenic, given the arsenic result for sample WB_SD01 exceeded the ISQG low trigger value for arsenic. This suggests that unmined sub-catchments with natural mineralisation can impact stream sediment metalloid concentrations. Antimony was at background concentrations.

Leach testing

As noted above, the GAI does not consider the solubility of the relatively elevated metalloids, nor does comparison against threshold concentrations. Therefore, in order to assess the mobility of any elevated metals and metalloids, there was a need to complete leach testing. To that end, 15 sediment samples (excluding Bakers Creek) were analysed for 10 leachable metals.

Table A28 expands on the sediment GAI and metals results reported above, and presents those metals that leached at values greater than the 95% ANZECC/ARMCANZ (2000) freshwater aquatic ecosystem guideline trigger values. All leachate data is presented in Table F, Appendix D.

It is important to remember that leach tests are intended to be indicative only to identify potentially leachable elements for environmental management and decision making purposes. The leachate results cannot therefore, be directly extrapolated to predict leachate quality in the field due to dilution effects in natural catchments; however, remain useful as being an indicator of potentially leachable elements from the sediment samples. It therefore represents a 'worst case' position. Given the arsenic and antimony focus of this study, both metalloids have been bolded in Table A28 below where they were present in sediment assay, when they exceeded the low and high ISQG values, and when they leached above the 95% ANZECC/ARMCANZ (2000) freshwater aquatic ecosystem guideline trigger values.

Table A28: Sediment GAI and leachate exceedances

Sample	Metals with GAI > 3	Exceed low ISQG	Exceed high ISQG	Leachable elements > 95% ANZECC (2000)	Sample location
Chandler – Upper					
Phoenix Gold 1	-	-	-	Not leached	Up-catchment on unnamed drainage line located perpendicular to the mine
Phoenix Gold 2	**As**	**As**, Cu, Hg, Ni	**As**	Not leached	Approximately 400 m Down-catchment on same unnamed drainage line.
Phoenix Gold 3	**As**, **Sb**	**Sb, As**, Cu	**As**	Al, **Sb**, Cd, Cu, Pb, Zn	Drainage line from the former mine to the unnamed water course. Approximately 50 m from the last mine feature
Ruby Silver 1	-	-	-	Not leached	Up-catchment northern end of a water dam. The drainage line is located perpendicular to the mine
Ruby Silver 2	-	-	-	Al, **As**, Cr, Cu, Pb, Zn	Down-catchment of mine features on the same drainage line.
Tulloch 1	**As**	**Sb, As**	**As**	Not leached	Up-catchment from former mine on a unnamed drainage line
Tulloch 2	**Sb**, **As**	**Sb**, **As**, Cd, Cu, Pb	**Sb, As**	Al, **Sb**, **As**, Cd, Cr, Cu, Pb, Zn	Down-catchment of the remaining mine features on the same unnamed drainage line.
Tulloch 3	-	-	-	Not leached	Up-catchment on Boundary Creek – located perpendicular to former mine area
Tulloch 4	**As**	Ni	-	Not leached	Approximately 155 m down-catchment on Boundary Creek from mine area.
Rockvale 1	**As**	-	-	Not leached	Up-catchment on Lambs Valley Creek located perpendicular to the former mine
Rockvale 2	**As**	**As**	**As**	Not leached	Approximately 860 m Down-catchment on Lambs Valley Creek
Rockvale 3	**Sb**, **As**	**Sb**, **As**, Cd, Cu, Pb	**As**, Cu	Al, **Sb**, **As**, Cd, Cr, Cu, Pb, Zn	Drainage line from the former waste rock dumps. Approximately 135 m from the last scald area
Chandler - Lower					
Chandler 1	-	-	-	Al, Cr, Cu, Zn	Chandler River approx. 2 km from Stuart Reef and Rathbones Point East mines. Approx. 900 m above the confluence of the Chandler and Styx Rivers
Chandler 2	-			Not leached	Approximately 300 m down stream of Chandler 1 on the Chandler River
Khans Creek 1	**As**, Cd, Pb, Zn	**Sb, As**, Cd, Cu, Pb, Hg, Zn	Cu, Pb, Zn	Al, Cd, Cr, Cu, Pb, Zn	Approximately 330 m down gradient from mine on same drainage line
Khans Creek 2	-	Pb, Hg	-	Not leached	Up-catchment of former mine site in drainage line running adjacent to site
Keys Prospect 1	-	Pb, Hg, Zn	-	Al, Cr, Cu, Pb, Zn	Keys Creek approx. 630 m east of mine

Sample	Metals with GAI > 3	Exceed low ISQG	Exceed high ISQG	Leachable elements > 95% ANZECC (2000)	Sample location
Keys Prospect 2	-	-	-	Not leached	Down-catchment of the confluence of Keys Creek and the Chandler River
Keys Prospect 3	-	Ni	-	Not leached	Up-catchment of the confluence of Keys Creek and the Chandler River
Mickey Mouse 1	Cd, Zn	Cd, Hg, Zn	Zn	Al, Cd, Cr, Cu, Pb, Zn	Up-catchment of the mine adit on the Chandler River
Mickey Mouse 2	-	-	-	Not leached	Approximately 65 m down-catchment of the Mickey Mouse 1 sample on the Chandler River
Sunnyside 1	-	-	-	Al, Cr, Cu, Pb, Zn	Chandler River approx. 1.45 km downstream of the former mine
Commissioners Waters					
Kapunda 1	**As**	**As**	-	Not leached	Up-catchment on Tilbuster Ponds that flow perpendicular to the former mine
Kapunda 2	**As**	**As**	-	Al, **As**, Cr, Cu, Zn	Approximately 260 m Down-catchment of Kapunda 1 sample
Mary Anderson 1	**Sb**, **As**	**Sb, As**, Cr, Ni	**Sb**	Not leached	Down-catchment from northern edge of water dam on unnamed drainage line
Mary Anderson 2	-	Cr, Ni	Ni	Al, Cr, Cu, Pb, Ni, Zn	Up-catchment from northern edge of water dam on unnamed drainage line
Apsley					
Europambela 1	-	Ni	-	Not leached	Up-catchment on the Apsley River that flows perpendicular to the former mine
Europambela 2	-	-	-	Al, Cr, Cu, Pb, Ni, Zn	Approximately 150 m down-catchment of Europambela 1 on the Apsley River
Europambela Dam Sediment	-	Cu, Ni	Cu	Not leached	Collected from the sediment stockpile that had been recently dredged from the dam located immediately Down-catchment of the site
Hickeys / Mungay Creeks					
Mungay Ck 1	**Sb**, **As**	**Sb,** Hg	**Sb**	Al, **Sb**, Cr, Cu, Pb, Zn	Down-catchment of mine site, below water dam, near former adit on Deep Creek which runs through site
Mungay Ck 2	**Sb**, **As**	**Sb, As,** Hg	**Sb, As**	Al, **Sb**, Cr, Zn	Approximately 330 m down-catchment of Mungay Ck 1 on Deep Creek
Mungay Ck 3	**As**	**-**	**-**	Al, Cr, Zn	Approximately 1.67 km down-catchment of Mungay Ck 2 on Deep Creek
Toorumbee Creek and Warbro Brook					
Warbro Brook 1	**As**	**As,** Hg	**As**	Not leached	Collected on Warbro Brook approximately 2.37 km from Macleay confluence

The results in Table A28 indicate that antimony is likely to leach from sediment at concentrations greater than the 95 % species protection levels (ANZECC/ARMCANZ 2000) at Rockvale, Phoenix Gold, Tulloch, and Mungay Creek. Arsenic is likely to leach at concentrations greater than the 95 % species protection levels (ANZECC/ARMCANZ 2000) at Rockvale, Ruby Silver, Tulloch, and Kapunda.

Leachable aluminium was detected above ANZECC 95 % species protection levels in all samples. Several other metals species were also found above ANZECC 95 % species protection levels including cadmium, chromium, copper, lead and nickel. Zinc, chromium and aluminium leached from every sediment sample at concentrations above the 95 % species protection level.

Summary of sediment geochemistry

A summary of the results of the sediment geochemical characterisation is presented in Table A29. The items bolded or underlined show elevated results relative to nominated screening criteria provided in Section 4 of the main report. Essentially, the greater the number of bolded results, the higher the geochemical risk.

Table A29: Sediment geochemistry summary table

Sample	pH (1:5) < 4.5	EC (1:5) > 1,000 µS/cm	NAPP > 10 kgH_2SO_4/t	NPR < 2	NAGpH < 4.5	NAG (4.5) > 10 kgH_2SO_4/t	NAG (7.0) > 10 kgH_2SO_4/t	Classification	GAI > 3	Metals leaching above ANZECC (2000) 95%	Metals screening – ISQG (mg/kg)[1]		Sample location
											As	Sb	
Chandler - Upper													
Phoenix Gold 1	6.8	47	-7.1	5.0	7.3	<0.1	<0.1	NAF	-	Not leached	5	<5	Up-catchment
Phoenix Gold 2	7.1	113	-4.2	4.0	7.4	<0.1	<0.1	NAF	**As**	Not leached	***119***	<5	Down-catchment
Phoenix Gold 3	**4.4**	186	3.0	**0.1**	6.9	<0.1	0.3	UC	**As**, **Sb**	Al, **Sb**, Cd, Cu, Pb, Zn	***106***	***13***	Down-catchment
Ruby Silver 1	6.0	41	-0.6	**1.4**	6.4	<0.1	0.8	NAF	-	Not leached	9	<5	Up-catchment
Ruby Silver 2	5.7	10	0.4	**0.7**	6.8	<0.1	0.3	UC	-	Al, **As**, Cr, Cu, Pb, Zn	13	<5	Down-catchment.
Tulloch 1	6.6	24	-2.8	4.2	6.8	<0.1	0.6	NAF	**As**	Not leached	***143***	***8***	Up-catchment
Tulloch 2	5.9	154	8.9	**0.3**	6.2	<0.1	2.6	UC	**Sb**, **As**	Al, **Sb**, **As**, Cd, Cr, Cu, Pb, Zn	***691***	***106***	Down-catchment.
Tulloch 3	6.4	21	-4.4	8.4	7.2	<0.1	<0.1	NAF	-	Not leached	15	<5	Up-catchment
Tulloch 4	6.7	21	-3.9	7.5	7.0	<0.1	<0.1	NAF	**As**	Not leached	16	<5	Down-catchment
Rockvale 1	6.1	55	-2.9	5.9	7.0	<0.1	<0.1	NAF	**As**	Not leached	17	<5	Up-catchment
Rockvale 2	6.3	33	-2.8	3.4	7.1	<0.1	<0.1	NAF	**As**	Not leached	***87***	<5	Down-catchment
Rockvale 3	5.6	87	0.6	**0.3**	6.4	<0.1	0.4	UC	**Sb**, **As**	Al, **Sb**, **As**, Cd, Cr, Cu, Pb, Zn	***3,600***	***14***	Down-catchment
Chandler - Lower													
Chandler 1	7.7	16	-10.1	17.9	7.4	<0.1	<0.1	NAF	-	Al, Cr, Cu, Zn	7	<5	Up river

Sample	pH (1:5) < 4.5	EC (1:5) > 1,000 µS/cm	NAPP > 10 kgH_2SO_4/t	NPR < 2	NAGpH < 4.5	NAG (4.5) > 10 kgH_2SO_4/t	NAG (7.0) > 10 kgH_2SO_4/t	Classification	GAI > 3	Metals leaching above ANZECC (2000) 95%	Metals screening – ISQG (mg/kg)[1]		Sample location
											As	Sb	
Chandler 2	7.3	10	-20.5	35.4	7.8	<0.1	<0.1	NAF	-	Not leached	7	<5	Down river
Khans Creek 1	7.2	26	-4.7	6.2	7.0	<0.1	<0.1	NAF	**As**, Cd, Pb, Zn	Al, Cd, Cr, Cu, Pb, Zn	***24***	***8***	Down-catchment
Khans Creek 2	7.4	161	-10.7	6.1	6.3	<0.1	0.5	NAF	-	Not leached	<5	<5	Up-catchment
Keys Prospect 1	7.6	20	-4.0	7.7	7.3	<0.1	<0.1	NAF	-	Al, Cr, Cu, Pb, Zn	9	<5	Down-catchment
Keys Prospect 2	6.5	19	-7.1	9.0	7.6	<0.1	<0.1	NAF	-	Not leached	6	<5	Down river
Keys Prospect 3	6.3	24	-2.3	3.9	6.9	<0.1	0.4	NAF	-	Not leached	15	<5	Up river
Mickey Mouse 1	6.4	110	-8.4	8.0	7.2	<0.1	<0.1	NAF	Cd, Zn	Al, Cd, Cr, Cu, Pb, Zn	7	<5	Up river
Mickey Mouse 2	6.6	28	-9.0	16.1	7.3	<0.1	<0.1	NAF	-	Not leached	8	<5	Down river
Sunnyside 1	6.6	51	-10.0	12.1	7.6	<0.1	<0.1	NAF	-	Al, Cr, Cu, Pb, Zn	8	<5	Down river
Commissioners Waters													
Kapunda 1	7.1	70	-5.7	10.6	7.1	<0.1	<0.1	NAF	**As**	Not leached	***36***	<5	Up-catchment
Kapunda 2	6.7	37	-3.1	6.2	6.8	<0.1	0.2	NAF	**As**	Al, **As**, Cr, Cu, Zn	***41***	<5	Down-catchment
Mary Anderson 1	6.6	94	-2.2	2.5	6.8	<0.1	0.2	NAF	**Sb**, **As**	Not leached	14	<5	Down-catchment
Mary Anderson 2	6.8	34	-8.0	14.4	6.7	<0.1	0.4	NAF	-	Al, Cr, Cu, Pb, Ni, Zn	***21***	***27***	Up-catchment

Sample	pH (1:5) < 4.5	EC (1:5) > 1,000 µS/cm	NAPP > 10 kgH_2SO_4/t	NPR < 2	NAGpH < 4.5	NAG (4.5) > 10 kgH_2SO_4/t	NAG (7.0) > 10 kgH_2SO_4/t	Classification	GAI > 3	Metals leaching above ANZECC (2000) 95%	Metals screening – ISQG (mg/kg)[1] As	Sb	Sample location
Apsley													
Europambela 1	6.4	68	-5.5	7.1	7.1	<0.1	<0.1	NAF	-	Not leached	8	<5	Up river
Europambela 2	6.6	61	-4.1	7.9	6.8	<0.1	0.2	NAF	-	Al, Cr, Cu, Pb, Ni, Zn	6	<5	Down river
Europambela Dam Sediment	7.0	71	-13.4	37.6	8.4	<0.1	<0.1	NAF	-	Not leached	9	<5	Dam sediment
Hickeys / Mungay Creeks													
Mungay Ck 1	5.6	50	-12.2	18.3	7.3	<0.1	<0.1	NAF	**Sb, As**	Al, **Sb**, Cr, Cu, Pb, Zn	16	***307***	Down-catchment
Mungay Ck 2	6.3	22	-0.7	2.0	7.0	<0.1	<0.1	NAF	**Sb, As**	Al, **Sb**, Cr, Zn	***72***	***83***	Down-catchment
Mungay Ck 3	7.1	21	-5.6	93.1	7.9	<0.1	<0.1	NAF	**As**	Al, Cr, Zn	16	<5	Down-catchment
Toorumbee Creek and Warbro Brook													
Warbro Brook 1	5.2	142	-1.1	2.5	7.4	<0.1	<0.1	NAF	**As**	Not leached	<5	***30***	Background sample

1: Refer to Section 4 of the main report for trigger values

The geochemical summary data in Table A29 suggests the following with regard to the environmental risk from sediment at the sites sampled.

Chandler – Upper

Phoenix Gold: One down-catchment sediment sample at Phoenix Gold returned an acidic pH value and had limited self-buffering potential. Two down-catchment samples also returned GAI values with relatively elevated arsenic and one with relatively elevated antimony. Two samples contained antimony concentrations above ISQG high trigger values, with one arsenic value exceeding the ISQG lower trigger value. One sample leached antimony above ANZECC / ARMCANZ (2000) guidelines. By and large, the down-catchment sediment values are consistent with the mineral waste, suggesting that the weathering waste rock may be migrating downslope and offsite.

Ruby Silver: Both sediment samples at Ruby Silver did not have adequate self-buffering capacity. The down-catchment sediment sample had arsenic concentrations above background concentrations and leached arsenic above ANZECC (2000) guidelines. The results are broadly consistent with the mineral waste results suggesting that weathered material from the waste rock dump may be migrating downslope and offsite.

Tulloch: The sediment sample collected immediately below the site workings (TS_SD02) did not have adequate self-buffering capacity and returned a NAPP value of 8.9 kg H_2SO_4/tonne. This is consistent with the mineral waste samples collected on suite, one of which was PAF. Samples had both relatively elevated arsenic and antimony as measured using the GAI, with both metalloids leaching above ANZECC (2000) guidelines. Down-catchment samples in Boundary Creek returned results reasonably consistent with background metals concentrations indicating that the contaminated sediment may not be reporting off site.

Rockvale: The sediment sample collected immediately below the site workings (RA_SD03) did not have adequate self-buffering capacity. All three samples, including the up-catchment sample (RA_SD01) returned elevated arsenic values as measured using the GAI, indicating a regional arsenic anomaly. Sample RA_SD03 below the mine workings also returned an elevated antimony concentration as measured using the GAI, which was also over the ISQG low trigger. It also leached both arsenic and antimony above ANZECC (2000) guidelines. The down-catchment sample in Lambs Creek (RA_SD02) returned an antimony concentration that was in excess of the ISQG high trigger value. The results are consistent with the mineral waste geochemical results and suggest that weathered waste rock may be reporting offsite to Lambs Valley Creek.

Chandler – Lower

Chandler: The Chandler samples collected to account for Stuarts Reef and Rathbones Point East contained no anomalous results, indicating that these two sites may not be an issue with respect to the aim of this study.

Khans Creek: The Khans Creek down-catchment sediment sample (KC_SD01) had elevated arsenic relative to the GAI; and had arsenic and antimony concentrations in excess of the ISQG low trigger values. The results are consistent with the mineral waste metals results and suggest that weathered waste rock in the form of sediment may be reporting offsite.

Keys Prospect: The only anomalous result at Keys Prospect was the upriver sample (KP_SD03) that returned arsenic concentrations slightly in excess of background concentrations. This indicates that the Keys Prospect is not contributing to off-site contamination and that there remain anomalous sediment metals concentrations in the Chandler River itself in the area containing the Halls Peak Mineral Field—noting that the result did not exceed ISQG low trigger values.

Mickey Mouse: The two Mickey Mouse samples collected contained no anomalous results, indicating that this site may not be an issue with respect to the aim of this study. Note that the leached sample (MM_SD01) did contain elevated cadmium and zinc as measured using GAI and leached aluminium, cadmium, chromium, copper, lead and zinc at concentrations above ANZECC (2000) guidelines.

Sunnyside: The one Sunnyside sample collected contained no anomalous results, indicating that this site may not be an issue with respect to the aim of this study. Note that the leached sample (SS_SD01) did leach aluminium, chromium, copper, lead and zinc at concentrations above ANZECC (2000) guidelines.

Commissioners Waters

Kapunda: Both Kapunda sediment samples contained relatively elevated arsenic concentrations using the GAI, with both the up and down-catchment samples exceeding ISQG low trigger values. The leached sample (KA_SD02) leached arsenic (as well as aluminium, chromium, copper and zinc). The results are consistent with the single waste rock sample indicting that arsenic rich sediment may be migrating off site into Tilbuster Ponds.

Mary Anderson: The down-catchment sample (MA_SD01) contained relatively elevated arsenic concentrations using the GAI, with arsenic concentrations marginally exceeding background, though not the ISQG low trigger value. The up-catchment sample (MA_SD02) collected from a water dam leached various metals though not arsenic or antimony, exceeded the ISQG low trigger value for arsenic and the high trigger value for antimony—consistent with mineral waste metals results. As there were mine workings and scalds over this site, the results may indicate that the water dams on site are doing a reasonable job at containing contaminated sediment, with Down-catchment metals concentrations approaching background. There may be antimony contaminated sediment migrating off site, depending on where the site boundary is demarcated.

Apsley

Europambela: The three samples collected at Europambela are all relatively benign, although the downstream sample (E_SD02) did leach various metals, although not arsenic or antimony. As the mineral waste on site was PAF and contained elevated arsenic concentrations, these results would suggest that little to no contaminated sediment is moving off site into the Apsley River.

Hickeys / Mungay Creeks

Mungay Creek: All three sediment samples at Mungay Creek were elevated in arsenic using GAI, and two were elevated in antimony. Both samples collected on site (MC_SD01 and 02) leached antimony at concentrations above ANZECC (2000) and had antimony concentrations that exceeded the ISQG high trigger value. One sample (MC_SD02) exceeded the ISQG high trigger value for arsenic. Mineral waste samples showed significantly elevated antimony (up to 0.4%). However, the sample collected from well down-catchment (MC_SD03) was approaching background concentrations, indicating that contaminated sediment may be migrating off site, depending on where the 'site boundary' is located.

Toorumbee Creek and Warbro Brook

Warbro Brook: The single Warbro Brook sample contained relatively elevated arsenic using the GAI method, with arsenic concentrations being above the ISQG low trigger value. This suggests that the sub-catchment is naturally elevated in arsenic from known mineral prospects (Willi Willi), as it has not been mined.

Table A30 provides a high-level risk summary table for sediment acid, saline and metalliferous drainage risk by site.

Table A30: Summary of sediment acid, saline and metalliferous drainage risk by site

Sample	AMD risk	Saline drainage risk	Metalliferous drainage risk
Chandler - Upper			
Phoenix Gold	Low-Med	Low	**High (As, Sb)**
Rockvale	Low	Low	**High (As, Sb)**
Ruby Silver	Low	Low	Low - Med
Tulloch	Low-Med	Low	**High (As, Sb)**
Chandler - Lower			
Chandler	Low	Low	Low
Khans Creek	Low	Low	**High (Sb, As)**
Mickey Mouse	Low	Low	Med (other metals)
Sunnyside	Low	Low	Med (other metals)
Commissioners Waters			
Kapunda	Low	Low	Med-**High (As)**
Mary Anderson	Low	Low	Med-**High (As, Sb)**
Apsley			
Europambela	Low	Low	Med (other metals)
Hickeys / Mungay Creeks			
Mungay Ck	Low	Low	**High (As, Sb)**
Toorumbee Creek and Warbro Brook			
Warbro Brook	Low	Low	Med (As)

The sediment results discussed above are broadly consistent with the mineral waste results and risks shown in Table A29 and A30. This suggests that the sediment on certain sites is derived from arsenic and antimony contaminated mineral waste, and may be impacting beyond the immediacy of that particular site.

Based on the sediment results, the following sites may have contaminated sediment sourced from weathering waste rock on site migrating off site:

- Chandler – Upper: Phoenix Gold, Ruby Silver, Rockvale Arsenic
- Chandler – Lower: Khans Creek
- Commissioners Waters: Kapunda Arsenic, Mary Anderson
- Hickeys / Mungay Creek – Mungay Creek.

Surface Water

Introduction

This section discusses arsenic and antimony surface water results as compared against environment screening criteria shown in Section 4 of the main report

The results below are limited to those that exceeded the most conservative screening criteria, being the background arsenic (0.003 mg/L) and antimony (0.0025 mg/L) values. Sites that did not exceed these nominated minimal criteria, and are therefore not discussed further in this section, are:

- Chandler – Lower: Stuart Reef and Rathbone Point East (Chandler samples), Keys Prospect, Sunnyside, and Mickey Mouse
- Aspley – Europambela.

Note also that no surface water sample could be collected at Khans Creek in the Lower Chandler as there was no surface water evident anywhere on or proximal to site.

All surface water results are shown in Table F, Appendix D. Figures for each site showing surface water sample locations are provided in Appendix F.

Sample locations in each of the following tables have been arranged largely to represent up-catchment samples first, through the mine site, with down-catchment samples at the bottom of the table; i.e. the surface water flow direction.

Chandler - Upper

Phoenix Gold

Table A31 presents the surface water results from the four samples collected on site. Plate A6 shows site photographs.

Table A31: Phoenix Gold surface water results

Sample ID	Location	Surface Water Results Antimony (mg/L)		Surface Water Results Arsenic (mg/L)	
		Unfiltered	Filtered	Unfiltered	Filtered
Baseline concentration (GHD 2015)		0.0025		0.003	
ADWG (2011)		***0.003***		***0.01***	
ANZECC 95% (2000)		***0.009***[1]		***0.013***	
ANZECC & ARMCANZ (2000) irrigation trigger value (long term)		-		0.1	
ANZECC & ARMCANZ (2000) stock watering trigger value		-		**0.5**	
ANZECC & ARMCANZ (2000) irrigation trigger value (short term)		-		**2.0**	
PG_SW01	Up-catchment on unnamed drainage line located perpendicular to the mine	<0.001	<0.001	0.005	0.004
PG_SW03	Drainage line from the former mine to the unnamed water course. Approximately 50 m from the last mine feature	<0.001	<0.001	0.007	0.004
PG_SW04	Mine shaft/bore	***0.006***	***0.004***	**2.19**	**1.57**
PG_SW02	Approximately 400 m down-catchment on same unnamed drainage line.	<0.001	<0.001	**0.01**	0.002

1. Low reliability guidelines

The up-gradient sample (PG_SW01) was collected from a drainage line that does not flow through the mine, however a drainage channel from the mine site flows into the tributary further down gradient, therefore, potentially mine impacted water was not sampled in the up-gradient sample making it fit for purpose. The results of the up-gradient sample show that arsenic is above the baseline concentration of 0.003 mg/L, while antimony is not recorded above the LOR.

Sample PG_SW03, collected immediately downstream of the mine workings returned arsenic concentrations above baseline though below ADWG (2011).

Sample location PG_SW04 was a point source of contaminated water emanating from a flowing well head (refer to Plate 6). The water flowing from the well drains into a dam with a second dam located immediately down-gradient to capture any overflow (refer to Plate 6). Iron staining due to the presence of iron oxyhydroxides was apparent, indicating the oxidation of ferrous to ferric iron; an acidity generating reaction as confirmed by drainage pH values of 3.09 and an acidity value of 411 mg/L (as $CaCO_3$) at PG_SW04. Sulfate was also elevated at 716 mg/L indicating typical characteristics of acid and metalliferous drainage.

Results from PG_SW04 exceed:

- the drinking water guidelines for antimony for both total and dissolved samples
- the freshwater 95% (ANZECC 2000), the long (0.1 mg/L) and short term irrigation (2 mg/L), and the stock watering (0.5 mg/L) for arsenic for both total and dissolved samples.

Plate A6: Phoenix Gold Photos

Location PG_SW04	Dam capturing water from PG_SW04
	

Sample PG_SW02, being the furthest down-gradient sample collected approximately 400 metres from the mine area exceeded the baseline criteria for arsenic of 0.003 mg/L, and the ADWG (2011) although not the ANZECC (2000) 95%. It returned a neutral pH value of 7.86, acidity of 6 mg/L (as $CaCO_3$) and sulfate of 96 mg/L. These data are consistent with the sediment results and suggest that the contaminated drainage reported at sampling location PG_SW04 may be reporting off site, given the arsenic contaminated results at point PG_SW02.

Ruby Silver

Two surface water samples were collected at this site on a tributary that runs adjacent to the mine and would receive runoff from the mine. The up-catchment sample (RS_SW01) was collected from a water dam while the down-catchment sample was also collected from a small pool of water as there was no flowing water at the time of sampling. Table A32 presents the surface water results.

Table A32: Ruby Silver surface water results

Sample ID	Location	Surface Water Results **Antimony (mg/L)**		Surface Water Results **Arsenic (mg/L)**	
		Unfiltered	Filtered	Unfiltered	Filtered
Baseline concentration (GHD 2015)		0.0025		0.003	
ADWG (2011)		***0.003***		***0.01***	
ANZECC 95% (2000)		***0.009***[1]		***0.013***	
ANZECC & ARMCANZ (2000) irrigation trigger value (long term)		-		0.1	
ANZECC & ARMCANZ (2000) stock watering trigger value		-		**0.5**	
ANZECC & ARMCANZ (2000) irrigation trigger value (short term)		-		**2.0**	
RS_SW01	Up-catchment northern end of a water dam. The drainage line is located perpendicular to the mine	0.002	<0.001	***0.018***	0.001
RS_SW02	Down-catchment of mine features on the same drainage line.	0.001	<0.001	***0.024***	0.004

1. Low reliability guidelines

The results in Table A32 show that antimony results are below the background concentration for both samples. The up-catchment unfiltered sample (RS_SW01) exceeded the baseline concentration for arsenic, while the filtered sample did not. The up-catchment unfiltered sample also exceeded the ADWG (2011) and the ANZECC 95% guidelines. The down-catchment unfiltered sample (RS_SW02) also exceeded both the ADWG (2011) and the ANZECC 95% guidelines.

These results suggest that there may be locally elevated background arsenic concentrations, and that the arsenic may be adsorbing to suspended sediment in the surface water. The results at RS_SW02 suggest that arsenic contaminated surface water may be migrating offsite; consistent with the sediment results at the same site.

Tulloch Silver

Table A33 shows the results of the four surface water samples collected from site.

Table A33: Tulloch Silver surface water results

Sample ID	Location	Surface Water Results **Antimony (mg/L)**		Surface Water Results **Arsenic (mg/L)**	
		Unfiltered	Filtered	Unfiltered	Filtered
Baseline concentration (GHD 2015)		0.0025		0.003	
ADWG (2011)		***0.003***		***0.01***	
ANZECC 95% (2000)		***0.009*** [1]		***0.013***	
ANZECC & ARMCANZ (2000) irrigation trigger value (long term)		-		0.1	
ANZECC & ARMCANZ (2000) stock watering trigger value		-		**0.5**	
ANZECC & ARMCANZ (2000) irrigation trigger value (short term)		-		**2.0**	
TS_SW03	Up-catchment on Boundary Creek – located perpendicular to former mine area	<0.001	<0.001	<0.001	0.001
TS_SW01	Up-catchment from former mine on a unnamed drainage line	0.003	0.002	0.006	0.001
TS_SW02	Down-catchment of the remaining mine features on the same unnamed drainage line.	***0.009***	***0.008***	***0.026***	0.006
TS_SW04	Approximately 155 m Down-catchment on Boundary Creek from mine area.	<0.001	<0.001	<0.001	0.002

1. Low reliability guidelines

Samples TS_SW01 and 02 were collected from a chain of ponds due to the lack of flowing water at the time of sampling. The results in Table A32 show that the unfiltered arsenic result for TS_SW01 topographically above the former mine is above baseline concentration for arsenic and on the baseline concentration for antimony. However, the up-catchment sample collected from Boundary Creek (TS_SW03—from a large continuous water source) was below the baseline concentrations. This is interpreted to reflect an influence from the Tulloch mineralisation upstream of the mine workings pointing to a natural extension of the mineralisation to the east.

The sample collected in the drainage line draining the mine workings (TS_SW02) returned unfiltered antimony and arsenic concentrations over the ANZECC 95% threshold. However, the down-catchment sample on Boundary Creek (TS_SW04) shows arsenic and antimony below background concentrations.

The GHD data is compared to historic data from previous studies on site in Table A34, with Up-catchment samples at the top of the table and down-catchment (Boundary Creek) at the bottom of the table.

Table A34: Comparative Tulloch surface water results

Data source	location	Sample ID	pH	EC	Sb	As	Cd	Cu	Pb	Zn
Baseline concentration (GHD 2015)					0.0025	0.003				
ADWG (2011)					***0.003***	***0.01***				
ANZECC 95% (2000)					***0.009[1]***	***0.013***				
ANZECC & ARMCANZ (2000) irrigation trigger value (long term)					-	0.1				
ANZECC & ARMCANZ (2000) stock watering trigger value					-	**0.5**				
ANZECC & ARMCANZ (2000) irrigation trigger value (short term)					-	**2.0**				
GHD	T Ck up	SW01	7.31	89	0.003	0.006	<0.0001	0.006	0.002	0.01
Coffey	CD	SP1	6.77	2113	0.025	0.215	0.0017	0.034	0.009	0.220
GHD	Below CD	SW02	6.77	550	***0.009***	***0.026***	0.0002	0.007	0.001	0.068
Coffey	T Ck down	DLD	-	-	0.001	***0.011***	<0.0001	0.002	<0.0034	0.014
GHD	B Ck up	SW03	7.92	216	<0.001	<0.001	<0.0001	0.002	<0.001	<0.005
AG	B Ck up	MYW7	8.67	160	<0.001	<0.001	<0.005	0.004	<0.001	0.036
Coffey	B Ck up	BCU	8.39	327	<0.005	0.002	0.0002	0.002	<0.0034	<0.008
Coffey	B Ck jcn	BCM	7.37	1697	<0.005	0.002	0.0001	0.002	<0.0034	<0.008
Coffey	B Ck down	BCD	8.11	340	<0.005	0.002	0.0001	<0.0014	<0.0034	<0.008
GHD	B Ck down	SW04	7.99	218	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.005

Data sources: Coffey (2008); GHD, September 2015; Ashley & Graham (2001). EC values in microS, element values in mg/L Locations: T Ck up = small creek upstream of Tulloch, CD = catch dam, below CD = immediately below catch dam, T Ck down = 400 m below catch dam, BCU = Boundary Creek upstream of Tulloch creek, BCM = Boundary Creek at junction of Tulloch creek, BCD = Boundary Creek downstream of Tulloch creek.

In summary, there appears to be little measurable influence from the Tulloch mine in Boundary Creek as determined by surface water (and sediment) concentrations over time. This position appears to have been maintained prior to, and subsequent to, site rehabilitation.

Rockvale Arsenic

Table A35 presents the results of the three surface water samples collected on site.

Table A35: Rockvale Arsenic surface water results

Sample ID	Location	Surface Water Results **Antimony (mg/L)**		Surface Water Results **Arsenic (mg/L)**	
		Unfiltered	Filtered	Unfiltered	Filtered
Baseline concentration (GHD 2015)		0.0025		0.003	
ADWG (2011)		***0.003***		***0.01***	
ANZECC 95% (2000)		***0.009[1]***		***0.013***	
ANZECC & ARMCANZ (2000) irrigation trigger value (long term)		-		0.1	
ANZECC & ARMCANZ (2000) stock watering trigger value		-		**0.5**	
ANZECC & ARMCANZ (2000) irrigation trigger value (short term)		-		**2.0**	
RA_SW01	Up-catchment on Lambs Valley Creek located perpendicular to the former mine	<0.001	<0.001	0.008	0.003

Sample ID	Location	Surface Water Results **Antimony (mg/L)**		Surface Water Results **Arsenic (mg/L)**	
		Unfiltered	Filtered	Unfiltered	Filtered
RA_SW03	Drainage line from the former waste rock dumps. Approximately 135 m from the last scald area	0.002	0.002	***0.073***	***0.064***
RA_SW02	Approximately 860 m Down-catchment on Lambs Valley Creek	0.001	<0.001	***0.029***	***0.019***

1. Low reliability guidelines

The surface water results in Table A35 show that the unfiltered up-catchment sample (RA_SW01) was above the background concentration for arsenic. Both the filtered and unfiltered sample draining the mine workings (RA_SW03) exceeded the ANZECC 95% criteria, as did the down-catchment sample in Lambs Valley Creek (RA_SW02). These are slightly lower than results of seepage water collected immediately downstream of the mine by Cooper (2013) which had arsenic concentrations of 0.3 mg/L. In contrast to Ruby Silver, there is little difference in arsenic concentrations between the filtered and unfiltered, indicating that most arsenic at this site appears to be in the dissolved form.

No sample returned antimony concentrations above background levels.

Table A36 compares previous data for Rockvale with the GHD data.

Table A36: Comparative Rockvale surface water results

Data source	location	Sample ID	pH	EC	Sb	As	Cu	Pb	Zn	SO_4
Baseline concentration (GHD 2015)					0.0025	0.003				
ADWG (2011)					***0.003***	***0.01***				
ANZECC 95% (2000)					***0.009*** [1]	***0.013***				
ANZECC & ARMCANZ (2000) irrigation trigger value (long term)					-	0.1				
ANZECC & ARMCANZ (2000) stock watering trigger value					-	**0.5**				
ANZECC & ARMCANZ (2000) irrigation trigger value (short term)					-	**2.0**				
GHD	LVC up	RASW01	6.43	124	<0.001	0.008	<0.001	<1	<5	-
Cooper	LVC up	RAW03	7.75	130	-	0.005	-	-	-	-
AG	LVC up				-	-	-	-	-	-
GHD	RAMC	RASW03	4.56	631	0.002	***0.073***	2.52	0.002	301.0	-
Cooper	RAMC	RAW04	4.23	670	-	**0.300**	-	-	-	-
AG	RAMC	MYW40	6.45	410	0.002	**1.34**	0.018	0.003	0.103	0.066
GHD	LVC nr jcn	RASW02	6.78	183	0.001	***0.029***	0.001	<0.001	<0.005	-
Cooper	LVC nr jcn	RAW01	7.7	200	-	0.005	-	-	-	-
AG	LVC nr jcn	MYW41	7.32	70	***0.035***	***0.018***	0.004	0.003	0.079	<0.001

Data sources: Cooper (2013); GHD, September 2015; Ashley & Graham (2001). EC values in microS, analyte values in mg/L. Locations: LVC up = Lambs Valley Creek upstream of gully draining Rockvale arsenic mine, LVC nr jcn = Lambs Valley Creek just downstream (50-150 m) of junction with gully draining Rockvale arsenic mine. RAMC = gully draining Rockvale arsenic mine ~100 m downstream of mine.

The data in Table A35 and A36 show that the unnamed creek draining the mine area carries an arsenic load, and to a lesser extent, heavy metals including some antimony in the surface water, but the actual volumes being transported and subsequently entering the local catchment of

Lambs Valley Creek appear to be relatively minor within the context of the broader Macleay contamination.

The data suggest that the three main scaled areas are contaminant point sources. Seepage from underground mine workings along with surface water runoff appears to be entering the drainage gully immediately southwest of the mine area. The actual amount of arsenic being exported off-site is likely to be relatively small, given that areas of soil and gully erosion are relatively small (i.e. from bare, scalded ground), and the volume of contaminated water seeping from site is generally minor (it was less than and up to around one litre per second at the time of GHD's visit in September 2015)—with most water re-infiltrating prior to reaching Lambs Valley Creek.

That said, the paired sediment sample to RA_SW02 being RA_SD02 also returned elevated concentrations of arsenic, so it is apparent that there is arsenic leaving site in both surface water and sediment.

Chandler - Lower

Halls Peak Mineral Field

Surface water results for Stuarts Reef and Rathbones Point East (Chandler samples), Keys Prospect, Mickey Mouse and Sunnyside were all below selected screening criteria for arsenic and antimony and are therefore not discussed further here (Refer to Table G, Appendix D).

Note also that no surface water sample could be collected at Khans Creek in the Lower Chandler as there was no surface water evident anywhere on or proximal to site. This was unfortunate as the mineral waste and sediment results at Khans Creek returned elevated concentrations of arsenic and antimony, in addition to showing that the arsenic and antimony contaminated sediment appeared to be migrating off site.

No rehabilitation work was completed at Khans Creek, Faints and / or Firefly. Despite the rehabilitation works at Gibsons Open Cut, there remains a large amount of mineralised waste rock material that has cascaded down steep slopes for between approximately 100 and 200 m altitude below the main mine workings. Waters emanating below this sulfide mineral-bearing waste rock mass, and from the open cut, have a typical pH of 3.3 and contain high (to extreme) concentrations of heavy metals (Lottermoser *et al*., 1997). These impacts extend with diminishing magnitude for up to 120 kilometres down the Chandler and Macleay Rivers (Ashley and Graham, 2001). The Khans Creek, Faints and Firefly occurrences, although much smaller than Gibson's, have caused moderate to extreme heavy metal contamination of stream sediments in Khans and Asens Creeks, extending downstream into the Chandler River (Wolfenden, 2002).

The steep slopes in the area result in mineral waste migrating downslope under gravity to variably fill natural gullies, with transport of fine through to coarse (boulder) fractions down local streams into the Chandler River. This is particularly the case for:

- Asens Creek draining the Faints and Firefly area
- Barkers Creek draining Gibson's Open Cut
- Khans Creek draining the Khans Creek mine.

Effects on the Chandler River and downstream into the Macleay River were further assessed by Ashley and Graham (2001) and more detailed follow-up studies were performed by Wolfenden (2002).

Although acidic water draining from Gibson's area contains extreme values of dissolved heavy metals and metalloids (Lottermoser *et al*., 1997), it is evident that most elements precipitate into stream sediments as neutralisation of water proceeds. Further dilution occurs on entry into the Chandler River, such that near the confluence with the Macleay River, only zinc and cadmium values in stream water are modestly above the catchment background values (Ashley and Graham, 2001). EA Systems and CivilTech (2003), using historic data, showed that there were contamination spikes in both Asens and Barkers Creeks, as well as in the Chandler River as it passed the contaminated inputs. Concentrations in stream waters largely diminish to near-background values in the Chandler River at the Macleay River confluence.

Despite the rehabilitation actions implemented in Gibson's Open Cut area and at the Silver Gully and Base Camp sulfide dump in 2004, observations between 2005 and 2015 (Ashley *pers. comm*. 2016) indicate there remains continued transport of contaminated waste rock and stream sediment from the Gibson's site via Barkers Creek into the Chandler River. However, it is important to note that there has been some stabilisation at the Gibson's site following remediation, with reduced loss of fine-grained sediment from site in those areas where the catch-dams are installed and effective. It is noted that there remain areas on site where free draining mineral waste reports to the drainage lines, and ultimately, the Chandler River.

Since no remediation was performed at Khans Creek, Faints and Firefly, mineral waste and contaminated stream sediment continue to be channelled down Khans and Asens Creeks into the Chandler River, although volumes are likely to be relatively insignificant within the Macleay context (at least from Faints and Firefly). This was evidenced by near-background stream sediment and surface water results from the Chandler River downstream of the Asens Creek confluence (e.g. in the Sunnyside-Mickey Mouse-'Keys Creek' areas) during GHD's 2015 / 16 sampling program.

Commissioners Waters

Kapunda Arsenic

Table A37 presents the results of the two surface water samples at Kapunda.

Table A37: Kapunda Arsenic surface wter results

Sample ID	Location	Surface Water Results **Antimony (mg/L)**		Surface Water Results **Arsenic (mg/L)**	
		Unfiltered	Filtered	Unfiltered	Filtered
Baseline concentration (GHD 2015)		0.0025		0.003	
ADWG (2011)		***0.003***		***0.01***	
ANZECC 95% (2000)		***0.009[1]***		***0.013***	
ANZECC & ARMCANZ (2000) irrigation trigger value (long term)		-		0.1	
ANZECC & ARMCANZ (2000) stock watering trigger value		-		**0.5**	
ANZECC & ARMCANZ (2000) irrigation trigger value (short term)		-		**2.0**	
KA_SW01	Up-catchment on Tilbuster Ponds that flow perpendicular to the former mine	<0.001	<0.001	***0.013***	0.009
KA_SW02	Approximately 260 m Down-catchment of Kapunda 1 sample	<0.001	<0.001	***0.014***	0.009

1. Low reliability guidelines

The results show that water quality at sample locations up and down gradient of the site are fairly consistent in concentrations for antimony and arsenic. Filtered arsenic concentrations exceeded baseline concentrations while the unfiltered concentrations from up-catchment exceeded the ADWG (2001) trigger value. The down-catchment sample (KA_SW02) also exceeded the ANZECC 95% (2000) trigger value. Antimony was not detected either up or down-catchment in the surface water.

The surface water results are consistent with mineral waste and sediment samples which returned elevated concentrations of arsenic on site (mineral waste), and up and down-catchment (sediment). The results may indicate that contaminated mineral waste and sediment continues to impact surface water off site, although the presence of arsenic contaminated sediment and surface water Up-catchment suggests a broader issue within the Commissioners Waters sub-catchment; possibly from other historic mines in the sub-catchment.

Mary Anderson

Table A38 presents the results of the two surface water samples collected on site.

Table A38: Mary Anderson surface water results

Sample ID	Location	Surface Water Results **Antimony (mg/L)**		Surface Water Results **Arsenic (mg/L)**	
		Unfiltered	Filtered	Unfiltered	Filtered
Baseline concentration (GHD 2015)		0.0025		0.003	
ADWG (2011)		***0.003***		***0.01***	
ANZECC 95% (2000)		***0.009***[1]		***0.013***	
ANZECC & ARMCANZ (2000) irrigation trigger value (long term)		-		0.1	
ANZECC & ARMCANZ (2000) stock watering trigger value		-		**0.5**	
ANZECC & ARMCANZ (2000) irrigation trigger value (short term)		-		**2.0**	
MA_SW02	Up-catchment from northern edge of water dam on unnamed drainage line	0.001	<0.001	***0.006***	0.001
MA_SW01	Down-catchment from northern edge of water dam on unnamed drainage line	***0.008***	***0.005***	0.009	0.004

1. Low reliability guidelines

The results in Table A38 show that the up-gradient unfiltered surface water sample (MA_SW02) exceeds the ADWG (2011) for arsenic, while the filtered samples are below background concentrations. The up-gradient sample is below background concentrations for antimony, both filtered and unfiltered. Both the filtered and unfiltered down gradient samples (MA_SW01) exceed the background concentration for arsenic and exceed the ADWG (2011) for antimony.

The results are consistent with the sediment results and imply that there may be contaminated surface water leaving site under certain flow conditions; depending on where the site boundary is defined.

Hickeys / Mungay Creeks

Mungay Creek Antimony Mine

Table A39 presents the results of the three surface water samples collected on site.

Table A39: Mungay Creek Antimony surface water results

Sample ID	Location	Surface Water Results **Antimony (mg/L)**		Surface Water Results **Arsenic (mg/L)**	
		Unfiltered	Filtered	Unfiltered	Filtered
Baseline concentration (GHD 2015)		0.0025		0.003	
ADWG (2011)		***0.003***		***0.01***	
ANZECC 95% (2000)		***0.009***[1]		***0.013***	

Sample ID	Location	Surface Water Results **Antimony (mg/L)**		Surface Water Results **Arsenic (mg/L)**	
		Unfiltered	Filtered	Unfiltered	Filtered
ANZECC & ARMCANZ (2000) irrigation trigger value (long term)		-		0.1	
ANZECC & ARMCANZ (2000) stock watering trigger value		-		**0.5**	
ANZECC & ARMCANZ (2000) irrigation trigger value (short term)		-		**2.0**	
MC_SW01	Down-catchment of mine site, below water dam, near former adit on Deep Creek which runs through site	***0.086***	***0.028***	***0.031***	**0.01**
MC_SW02	Approximately 330 m down-catchment of Mungay Ck 1 on Deep Creek	***0.015***	***0.007***	0.006	0.002
MC_SW03	Approximately 1.67 km down-catchment of Mungay Ck 2 on Deep Creek	0.002	0.001	<0.001	<0.001

1. Low reliability guidelines

The results in Table A39 show arsenic and antimony contaminated surface water is present at diminishing concentrations below the mine workings at MC_SW01 and 02, with antimony persisting at higher concentrations than arsenic. All surface water results at the down gradient sample (MC_SW03) were below the nominated screening criteria.

The data are consistent with the sediment results and suggest that contaminated sediment and surface water may be migrating off site; depending on where the site boundary is defined.

Toorumbee Creek and Warbro Brook

Warbro Brook

Table A40 presents the results of the single surface water sample collected.

Table A40: Warbro Brook surface water results

Sample ID	Location	Surface Water Results **Antimony (mg/L)**		Surface Water Results **Arsenic (mg/L)**	
		Unfiltered	Filtered	Unfiltered	Filtered
Baseline concentration (GHD 2015)		0.0025		0.003	
ADWG (2011)		***0.003***		***0.01***	
ANZECC 95% (2000)		***0.009***[1]		***0.013***	
ANZECC & ARMCANZ (2000) irrigation trigger value (long term)		-		0.1	
ANZECC & ARMCANZ (2000) stock watering trigger value		-		**0.5**	
ANZECC & ARMCANZ (2000) irrigation trigger value (short term)		-		**2.0**	
WB_SW01	Collected on Warbro Brook approximately 2.37 km from Macleay confluence	<0.001	<0.001	0.004	0.003

1. Low reliability guidelines

The data in Table A40 indicates that arsenic concentrations in Warbro Brook slightly exceed background arsenic concentrations. This is consistent with the sediment result and shows that the presence of known mineralisation in the sub-catchment (the Willi Willi prospect) can result in relatively elevated sediment and surface water arsenic concentrations.

Overview of surface water results

Chandler – Upper

Phoenix Gold: Arsenic and antimony contaminated acid (pH value ~ 3) water with elevated EC values (~1,500 µS/cm) was sampled on site emanating from an historic mine shaft and reporting to an on-site water dam. As a result, there were arsenic concentrations in the down-catchment sample suggesting off site migration of arsenic in surface water. This is consistent with the sediment and mineral waste results for site.

Ruby Silver: The Up-catchment surface water sample had elevated arsenic as did the down-catchment sample. Antimony does not appear to be an issue. These results are consistent with the sediment and mineral waste results that suggest that arsenic contaminated sediment and surface water may be migrating off site.

Tulloch: An u-catchment surface water sample suggests natural mineralisation above the current workings as it contained above background concentrations of arsenic and antimony. Arsenic and antimony contaminated drainage persists downslope of the mine workings, although dissipate to below background concentrations once the mine creek meets Boundary Creek. The surface water results mirror the sediment results indicating that the contaminated sediment may not be reporting off site.

Rockvale: The up-catchment sample showed elevated arsenic, as did the acidic (pH ~ 4.3; EC ~ 1,000 µS/cm) drainage line leaving the mine workings. The down-catchment sample on Lambs Valley Creek also exceeded ANZECC 95% criteria. These results are consistent with the sediment and mineral waste results that suggest that arsenic contaminated sediment and surface water may be migrating off site.

Chandler – Lower

Chandler: Consistent with the sediment results, the Chandler samples collected to account for Stuarts Reef and Rathbones Point East contained no anomalous results, indicating that these two sites may not be an issue with respect to the aim of this study.

Khans Creek: No surface water sample could be collected. However, the Khans Creek down-catchment sediment sample (KC_SD01) had elevated arsenic relative to the GAI; and had arsenic and antimony concentrations in excess of the ISQG low trigger values. The results are consistent with the mineral waste metals results and suggest that weathered waste rock may be reporting offsite.

Keys Prospect: None of the three surface water samples exceeded background arsenic or antimony concentrations. The only anomalous result at Keys Prospect was the upriver sample (KP_SD03) that returned arsenic concentrations slightly in excess of background concentrations. This indicates that the Keys Prospect is not contributing to off-site contamination and that there remain anomalous sediment metals concentrations in the Chandler River itself in the area containing the Halls Peak Mineral Field—noting that the result did not exceed ISQG low trigger values.

Mickey Mouse: Neither of the two surface water (or sediment) samples exceeded background arsenic or antimony concentrations.

Sunnyside: The one Sunnyside surface water (and sediment) sample collected did not exceed background arsenic or antimony concentrations.

Commissioners Waters

Kapunda: The up-catchment surface water sample on Tilbuster Ponds returned slightly elevated arsenic concentrations, as did the down-catchment sample. These data are consistent with sediment data collected at the same locations. Antimony appears not to be an issue. Whilst the waste rock on site was also elevated in arsenic, the upstream data suggests there may be other influences impacting drainage quality in this sub-catchment beyond this site.

Mary Anderson: Surface water samples collected from site indicate elevated arsenic concentrations, with Down-catchment samples returning arsenic slightly exceeding background concentrations, and antimony above ADWG (2011) levels, circumneutral pH values, elevated sulfate (~ 300 mg/L) and elevated EC (~ 1,000 µS/cm). The data are reasonably consistent with mineral waste and sediment data and indicate that a small amount of contaminated sediment and water may be leaving site, depending on where the site boundary is demarcated.

Apsley

Europambela: Neither of the three surface water (or two sediment) samples exceeded background arsenic or antimony concentrations. As the mineral waste on site was PAF and contained elevated arsenic concentrations, these results would suggest that little to no contaminated sediment is moving off site into the Apsley River.

Hickeys / Mungay Creeks

Mungay Creek: On site surface water samples indicate elevated arsenic and antimony below the mine workings. These concentrations have returned to below background levels by around 1.7 km downstream. All three sediment samples at Mungay Creek were elevated in arsenic using GAI, and two were elevated in antimony. Both samples collected on site (MC_SD01 and 02) leached antimony at concentrations above ANZECC (2000) and had antimony concentrations that exceeded the ISQG high trigger value. One sample (MC_SD02) exceeded the ISQG high trigger value for arsenic. Mineral waste samples showed significantly elevated antimony (up to 0.4%). However, the sediment sample collected from well down-catchment (MC_SD03) was approaching background concentrations, indicating that contaminated sediment may be migrating off site, depending on where the site boundary is demarcated.

Toorumbee Creek and Warbro Brook:

Warbro Brook: The single surface water sample returned arsenic concentrations above background. Antimony was below background. This is consistent with the sediment sample and suggests that the sub-catchment is naturally elevated in arsenic from known mineral prospects (Willi Willi), as it has not been mined.

Table A41 provides a high level summary of the mineral waste, sediment, and surface water results for each site as they related to their respective assessment criteria. Those sites where the data indicate likely off site migration of contaminants are noted and have been bolded. Relative contributions of each site to the overall Macleay Catchment contamination are provided in Section 7 of the main report, following presentation of the Bakers Creek sub-catchment data in Section 6 of the main report.

Table A41: Summary of mineral waste, sediment and surface water results by site

Sample	Mineral waste	Sediment	Surface water	Off-site migration (contaminant)?	Comment
Chandler - Upper					
Phoenix Gold	X	X	X	**Yes (As)**	Acid rock drainage present
Ruby Silver	X	X	X	**Yes (As)**	-
Tulloch	X	X	X	No	PAF waste rock on site
Rockvale	X	X	X	**Yes (As)**	Acid rock drainage present
Chandler - Lower					
Chandler (Rathbones Point East and Stuart Reef)	NS	√	√	No	-
Khans Creek	X	X	NS	**Yes (Sb, As)**	Contaminated sediment down-catchment. PAF waste rock on site. No water sample.
Keys Prospect	NS	√	√	No	-
Mickey Mouse	NS	√	√	No	-
Sunnyside	NS	√	√	No	-
Commissioners Waters					
Kapunda	X	X	X	**Yes (As)**	Up-catchment contaminant sources likely
Mary Anderson	X	X	X	**Yes (Sb)**[1]	Neutral mine drainage present
Apsley					
Europambela	X	√	√	No	PAF waste rock on site
Hickeys / Mungay Creeks					

Sample	Mineral waste	Sediment	Surface water	Off-site migration (contaminant)?	Comment
Mungay Ck	**X**	**X**	**X**	**Yes (As, Sb)**[1]	-
Toorumbee Creek and Warbro Brook					
Warbro Brook	NS	**X**	**X**	NA	Naturally elevated background from known mineral prospects

X contaminated; √ not contaminated; NS that media not sampled; NA not applicable – no ‘site’ *per se*. 1: This depends on where the ‘site’ boundary is located.

Bakers Creek Mineral waste

Slurry pH and EC

Sample classification for pH and EC values against indicative classification values (DME 1995) are presented below in Table A43. DME (1995) classification guidelines are reproduced in Table A42 for ease of reference. Sample pH (1:5) values below 4.5 and EC values above 1,000 µS/cm have been bolded. Generally, a pH (1:5) value of less than 4.5 indicates stored acidity—generally a sign of historic sulfide oxidation as noted above, while EC values over 1,000 µS/cm are indicative of saline drainage (INAP 2009); noting that there would be dilution effects *in situ*—therefore, the comparison is for order of magnitude risk flagging only.

Table A42: Slurry pH and EC classification

Test	Unit	Very low	Low	Med.	High	Very high
pH (1:5)	pH unit	<4.5	4.5 – 5.5	5.5 – 7.0	7.0 – 9.0	>9.0
EC (1:5)	µS/cm	150	150 - 450	450 - 900	900 – 2,000	>2,000

Table A43: Slurry pH and EC results

Sample	pH (1:5)	pH (sat paste)	Classification[1]	EC (1:5) µS/cm	Classification[1]	Sample location
Bakers Ck 1 – Brackins Spur Mine Waste	9.1	8.3	Very high	70	Very low	Bund wall adjacent to mine entrance
Bakers Ck 2 – Smiths Mine Waste	8.1	7.8	High	150	Low	Mine entrance
Bakers Ck 3 – Bakers Ck Mine Waste	8.8	8.2	High	66	Very low	Bund wall adjacent to haul road
Bakers Ck 4 – Black Lode Mine Waste	9.1	8.6	Very high	110	Very low	Mine entrance
Bakers Ck 5 – Cosmopolitan Mine Waste	6.7	7.4	Medium	**1,610**	High	Beneath former cart line
Bakers Ck 6 – Lady Hopetoun Mine Waste	8.5	8.4	High	216	Low	Mine entrance

1: Based on DME (1995). pH classified using pH (1:5) results

The pH and EC data presented above in Table A43 shows alkaline drainage at all six sample locations. Saline drainage risk is deemed low with the exception of the Cosmopolitan mine waste sample which returned an EC of 1,610 µS/cm.

Acid base accounting

A total of six geochemical samples from six sites underwent total sulfur analysis, with the entire ABA data set provided in Table H (Appendix D), with a sub-set provide below in Table A44. Samples that returned potentially acid forming (high capacity) (PAF-HC) NAPP values—being greater than 10 kgH_2SO_4/tonne, and/or have limited self-buffering capacity as determined by a NPR of less than two are bolded.

Table A44: Mineral waste NAPP and NPR results

Sample	NAPP[1] $kgH_2SO_4/tonne$	NPR	Sample location
Bakers Ck 1 – Brackins Spur Mine Waste	-70.87	9.9	Bund wall adjacent to mine entrance
Bakers Ck 2 – Smiths Mine Waste	-4.32	**1.4**	Mine entrance
Bakers Ck 3 – Bakers Ck Mine Waste	-26.67	2.8	Bund wall adjacent to haul road
Bakers Ck 4 – Black Lode Mine Waste	-8.31	4.1	Mine entrance
Bakers Ck 5 – Cosmopolitan Mine Waste	-18.90	NA	Beneath former cart line
Bakers Ck 6 – Lady Hopetoun Mine Waste	-43.54	4.3	Mine entrance

1: NAPP calculated from adjusted of pyritic sulfur values being total S – SO_4-S.

The data shown above in Table A44 indicates that by and large, the mineral waste analysed at all six Bakers Creek sites returned acid consuming NAPP results, and largely contained sufficient self-buffering capacity to mitigate acid risk—Smiths being the exception.

Mineral waste net acid generation (NAG) testing

Results of the single addition NAG tests and NAG pH values are provided in Table A45.

Table A45: Mineral waste NAG_{pH} and NAG results

Sample	NAG pH	NAG (pH. 4.5) ($kgH_2SO_4/tonne$)	NAG (pH 7.0) ($kgH_2SO_4/tonne$)	Sample location
Bakers Ck 1 – Brackins Spur Mine Waste	10.4	<0.1	<0.1	Bund wall adjacent to mine entrance
Bakers Ck 2 – Smiths Mine Waste	6.3	<0.1	0.3	Mine entrance
Bakers Ck 3 – Bakers Ck Mine Waste	9.0	<0.1	<0.1	Bund wall adjacent to haul road
Bakers Ck 4 – Black Lode Mine Waste	7.9	<0.1	<0.1	Mine entrance
Bakers Ck 5 – Cosmopolitan Mine Waste	8.0	<0.1	<0.1	Beneath former cart line
Bakers Ck 6 – Lady Hopetoun Mine Waste	10.6	<0.1	<0.1	Mine entrance

The results in Table A45 indicate that all Bakers Creek samples were non-acid generating with mostly alkaline oxidation pH values—Smiths being the exception with minimal acid generating capacity.

The NAG_{pH} results in A45 were plotted along with the (pyritic) NAPP values to further classify the mineral waste samples. The plot is shown as Figure A4 below, with the sample classifications provided in Table A46 below.

Figure A4: NAG_{pH} and NAPP geochemical plot – mineral waste samples

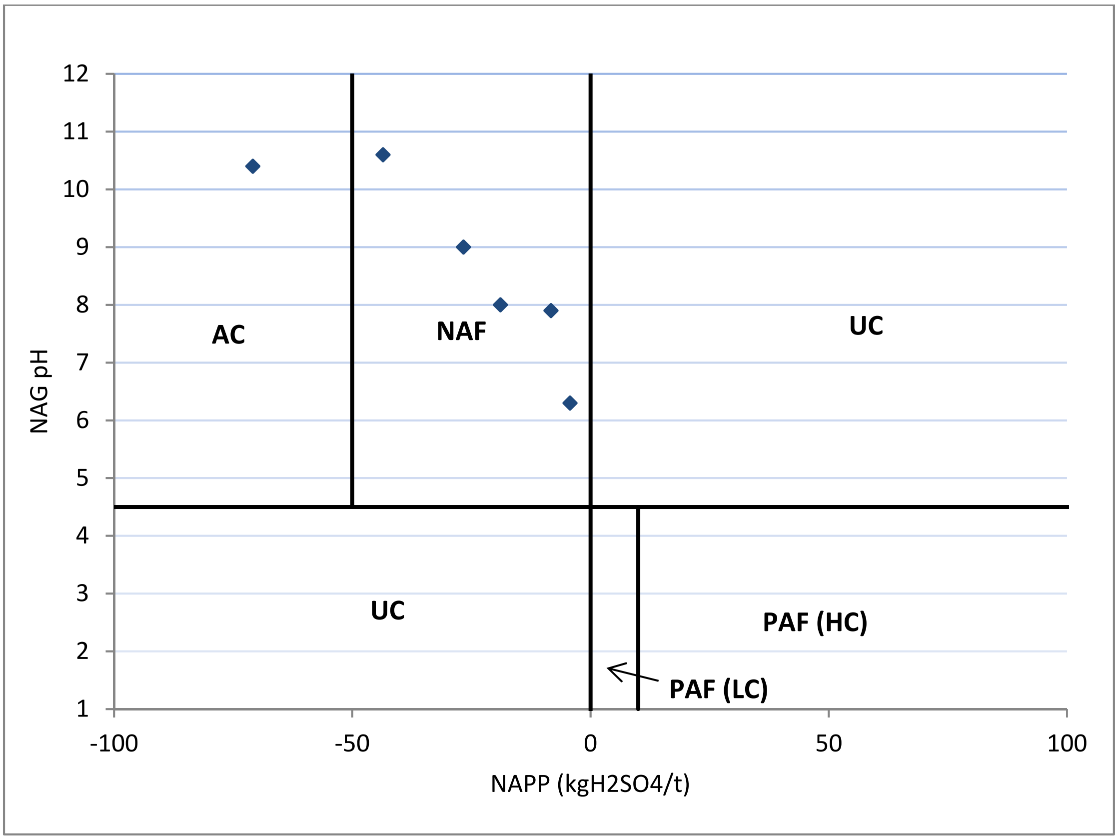


Figure A4 above shows that five of the six samples are non-acid forming with the Brackens Spur sample being classified as acid consuming. Table A46 confirms these classifications.

Table A46: NAPP and NAG pH values, and classification

Sample	NAG pH	NAPP (kgH_2SO_4/tonne)	Classification	Sample location
Bakers Ck 1 – Brackins Spur Mine Waste	10.4	-70.87	AC	Bund wall adjacent to mine entrance
Bakers Ck 2 – Smiths Mine Waste	6.3	-4.32	NAF	Mine entrance
Bakers Ck 3 – Bakers Ck Mine Waste	9.0	-26.67	NAF	Bund wall adjacent to haul road
Bakers Ck 4 – Black Lode Mine Waste	7.9	-8.31	NAF	Mine entrance
Bakers Ck 5 – Cosmopolitan Mine Waste	8.0	-18.90	NAF	Beneath former cart line
Bakers Ck 6 – Lady Hopetoun Mine Waste	10.6	-43.54	NAF	Mine entrance

1: NAPP calculated from adjusted of pyritic sulfur values being total S – SO_4-S.

Geochemical abundance index

Table A47 shows the Bakers Creek mineral waste samples that returned a GAI of three or over, indicating relative enrichment of that particular metal or metalloid. Arsenic and antimony have been bolded. The complete GAI assessment is provided as Table C Appendix E.

Table A47: Mineral waste GAI exceedances

Sample	Metals with GAI > 3	Sample location
Bakers Ck 1 – Brackins Spur Mine Waste	**Sb, As,** Hg	Bund wall adjacent to mine entrance
Bakers Ck 2 – Smiths Mine Waste	**Sb, As,** Hg	Mine entrance
Bakers Ck 3 – Bakers Ck Mine Waste	**Sb, As**	Bund wall adjacent to haul road
Bakers Ck 4 – Black Lode Mine Waste	**Sb, As**	Mine entrance
Bakers Ck 5 – Cosmopolitan Mine Waste	**Sb, As**	Beneath former cart line
Bakers Ck 6 – Lady Hopetoun Mine Waste	**Sb, As,** Hg	Mine entrance

The results in Table A47 show that all six samples had arsenic and antimony elevated relative to median crustal abundance. Mercury was also elevated at three of the six locations.

Metals screening

Arsenic and antimony results were compared to the nominated metals screening criteria shown in Section 4 of the main report. Results are presented in Table A48. Complete results are shown in Table I, Appendix D.

Table A48: Mineral waste metals screening

Sample	As (mg/kg)	Sb (mg/kg)	Sample location
Ecological investigation level – area of ecological significance (Schedule B5a NEPM 2013).	**40**	-	-
Ecological investigation level – urban residential / public open space (Schedule B5a NEPM 2013).	**<u>100</u>**	-	-
Regional Screening Level (RSL) for residential soil (US EPA 2014)	-	**31**	-
RSL for industrial soil (US EPA 2014).	-	**<u>470</u>**	-
Bakers Ck 1 – Brackins Spur Mine Waste	**<u>1,090</u>**	20	Bund wall adjacent to mine entrance
Bakers Ck 2 – Smiths Mine Waste	**<u>2,560</u>**	**<u>2,150</u>**	Mine entrance
Bakers Ck 3 – Bakers Ck Mine Waste	**<u>2,700</u>**	**313**	Bund wall adjacent to haul road
Bakers Ck 4 – Black Lode Mine Waste	**<u>510</u>**	**<u>887</u>**	Mine entrance
Bakers Ck 5 – Cosmopolitan Mine Waste	**<u>1,570</u>**	**<u>3,480</u>**	Beneath former cart line
Bakers Ck 6 – Lady Hopetoun Mine Waste	**<u>930</u>**	**113**	Mine entrance

The results in Table A48 indicate that all six sites had mineral waste with arsenic concentrations that exceeded the NEPM (2013) ecological investigation value for areas of ecological significance. All sites also had arsenic concentrations that exceeded the NEPM (2013) ecological investigation value for public open space.

The results in Table A48 also indicate that for antimony, all sites with the exception of Brackins Spur had mineral waste with antimony concentrations that exceeded the US EPA (2014) regional screening level for residential soil. In addition, antimony concentrations were high enough at Smiths, Black Lode and Cosmopolitan to exceed the US EPA (2014) regional screening level for industrial soil.

While not prescriptive for the purposes of this study, the comparison above does provide a relative indicator of arsenic and antimony concentrations against relevant threshold concentrations.

Leach testing

As noted above, the GAI and metals screenings do not consider the solubility of the relatively elevated metals—thus the requirement to undertake leach testing. To that end, all six samples were analysed for 10 leachable metals. Table A49 expands on the GAI results above, and presents those metals that leached values greater than the 95% ANZECC/ARMCANZ (2000) freshwater aquatic ecosystem guideline trigger values. All results are shown in Table J, Appendix D.

Table A49: Mineral waste GAI and leachate exceedances

Sample	Metals with GAI > 3	Leachable elements > 95% ANZECC (2000)	Sample location
Bakers Ck 1 – Brackins Spur Mine Waste	**Sb, As,** Hg	Al**, Sb**, **As**, Cr, Zn	Bund wall adjacent to mine entrance
Bakers Ck 2 – Smiths Mine Waste	**Sb, As,** Hg	Al**, Sb**, **As**, Cr, Cu, Pb, Zn	Mine entrance
Bakers Ck 3 – Bakers Ck Mine Waste	**Sb, As**	Al**, Sb**, **As**, Cr, Cu, Pb, Zn	Bund wall adjacent to haul road
Bakers Ck 4 – Black Lode Mine Waste	**Sb, As**	Al**, Sb**, **As**, Cr, Zn	Mine entrance
Bakers Ck 5 – Cosmopolitan Mine Waste	**Sb, As**	**As, Sb**, Zn	Beneath former cart line
Bakers Ck 6 – Lady Hopetoun Mine Waste	**Sb, As,** Hg	Al**, Sb**, **As**, Cd, Cr, Cu, Pb, Zn	Mine entrance

The results in Table A49 indicate that both arsenic and antimony leached at concentrations greater than the 95% species protection levels (ANZECC/ARMCANZ 2000) at all six sample locations. Several other metals also leached at concentrations including aluminium, cadmium, chromium, copper, lead, and zinc. The comparison is relative only and is to flag leachable metals and metalloids that may cause an environmental nuisance.

Summary of Bakers Creek mineral waste geochemistry

A summary of the results of the mineral waste geochemical characterisation of the six Bakers Creek samples is presented in Table A50. The items bolded or underlined show elevated results relative to nominated threshold concentrations. Essentially, the greater the number of bolded results, the higher the geochemical risk.

Table A50: Summary of Bakers Creek Mineral Waste Geochemistry

Sample	pH (1:5) < 4.5	EC (1:5) > 1,000 µS/cm	NAPP > 10 kgH_2SO_4/t	NPR < 2	NAGpH < 4.5	NAG (4.5) > 10 kgH_2SO_4/t	NAG (7.0) > 10 kgH_2SO_4/t	Class'n	GAI > 3	Metals leaching above ANZECC (2000) 95%	Metals screening (mg/kg)		Sample location
											As	Sb	
Bakers Ck 1 – Brackins Spur Mine Waste	9.1	70	-70.87	9.9	10.4	<0.1	<0.1	AC	**Sb, As,** Hg	Al, **Sb**, **As**, Cr, Zn	**1,090**	20	Bund wall adjacent to mine entrance
Bakers Ck 2 – Smiths Mine Waste	8.1	150	-4.32	**1.4**	6.3	<0.1	0.3	NAF	**Sb, As,** Hg	Al, **Sb**, **As**, Cr, Cu, Pb, Zn	**2,560**	**2,150**	Mine entrance
Bakers Ck 3 – Bakers Ck Mine Waste	8.8	66	-26.67	2.8	9.0	<0.1	<0.1	NAF	**Sb, As**	Al, **Sb**, **As**, Cr, Cu, Pb, Zn	**2,700**	**313**	Bund wall adjacent to haul road
Bakers Ck 4 – Black Lode Mine Waste	9.1	110	-8.31	4.1	7.9	<0.1	<0.1	NAF	**Sb, As**	Al, **Sb**, **As**, Cr, Zn	**510**	**887**	Mine entrance
Bakers Ck 5 – Cosmopolitan Mine Waste	6.7	**1,610**	-18.90	NA	8.0	<0.1	<0.1	NAF	**Sb, As**	**As, Sb,** Zn	**1,570**	**3,480**	Beneath former cart line
Bakers Ck 6 – Lady Hopetoun Mine Waste	8.5	216	-43.54	4.3	10.6	<0.1	<0.1	NAF	**Sb, As,** Hg	Al, **Sb**, **As**, Cd, Cr, Cu, Pb, Zn	**930**	**113**	Mine entrance

The summary geochemical results provided above in Table A50 indicate the following risks:

Acid drainage: Very low. All samples returned negative NAPP values and alkaline NAG_{pH} values with the exception of Smiths.

Saline drainage: Very low (with the exception of Cosmopolitan Mine which is high based on one result)

Metalliferous drainage: High. All six samples returned relatively elevated concentrations of arsenic and antimony, and all six samples leached both and antimony (and other metals) at concentrations that may pose an environmental risk.

Bakers Creek Sediment and surface water

Sediment slurry pH and EC

Sample classification for pH and EC values against indicative classification values (DME 1995) are presented below in Table A52. DME (1995) classification guidelines are reproduced in Table A51 for ease of reference. Sample pH (1:5) values below 4.5 and EC values above 1,000 µS/cm have been bolded. Generally, a pH (1:5) value of less than 4.5 indicates stored acidity—generally a sign of historic sulfide oxidation as noted above, while EC values over 1,000 µS/cm are indicative of saline drainage (INAP 2009); noting that there would be dilution effects *in situ*—therefore, the comparison is for order of magnitude risk flagging only.

Table A51: Slurry pH and EC classification

Test	Unit	Very low	Low	Med.	High	Very high
pH (1:5)	pH unit	<4.5	4.5 – 5.5	5.5 – 7.0	7.0 – 9.0	>9.0
EC (1:5)	µS/cm	150	150 - 450	450 - 900	900 – 2,000	>2,000

Table A52: Sediment slurry pH and EC results – Bakers Creek

Sample	pH (1:5)	pH (sat paste)	Classification[1]	EC (1:5) µS/cm	Classification[1]	Sample location
Bakers Creek 1	8.4	7.7	High	46	Very low	Becks Creek, approximately 90 m west of Bakers Creek
Bakers Creek 2	6.9	6.2	Medium	53	Very low	Most down gradient point on Bakers Creek – approximately 10.53 km down gradient from bakers Creek 32 point
Bakers Creek 3	7.2	NA	High	28	Very low	Gully draining into Bakers Creek, approximately 165 m west of Bakers Creek
Bakers Creek 4	7.0	NA	High	10	Very low	Gully draining into Bakers Creek, approximately 165 m west of Bakers Creek
Bakers Creek 5	7.2	7.2	High	19	Very low	Bakers Creek – approximately 8.91 km down gradient from Bakers Creek sample location 32
Bakers Creek 6	7.2	7.8	High	22	Very low	Bakers Creek – approximately 8.55 km down gradient from Bakers Creek sample location 32

Sample	pH (1:5)	pH (sat paste)	Classification[1]	EC (1:5) µS/cm	Classification[1]	Sample location
Bakers Creek 7	7.4	NA	High	28	Very low	Gully draining into Bakers Creek, approximately 180 m south of Bakers Creek
Bakers Creek 8	7.5	7.4	High	504	Medium	Gully draining into Bakers Creek, approximately 125 m north of Bakers Creek
Bakers Creek 9	7.5	8.0	High	106	Very low	Swamp Creek, 67 m up gradient of Four Mile Creek
Bakers Creek 10	7.1	NA	High	34	Very low	Sandy Creek, 85 m up gradient of Four Mile Creek
Bakers Creek 11	6.8	NA	Medium	20	Very low	Gully draining into Bakers Creek, approximately 80 m east of Bakers Creek
Bakers Creek 12	6.4	NA	Medium	41	Very low	Gully draining into Bakers Creek, approximately 38 m east of Bakers Creek
Bakers Creek 14	6.8	6.2	Medium	27	Very low	Gully draining into Bakers Creek, approximately 225 m west of Bakers Creek
Bakers Creek 15	8.1	7.4	High	107	Very low	Gully draining into Bakers Creek, approximately 40 m west of Bakers Creek
Bakers Creek 16	6.8	NA	Medium	8	Very low	Gully draining into Bakers Creek, approximately 120 m east of Bakers Creek
Bakers Creek 17	6.9	6.6	Medium	32	Very low	Gully draining into Bakers Creek, approximately 62 m east of Bakers Creek
Bakers Creek 18	7.2	-	High	65	Very low	Gully draining into Bakers Creek, approximately 50 m west of Bakers Creek
Bakers Creek 19	7.8	7.4	High	182	Low	Gully draining into Bakers Creek, approximately 34 m east of Bakers Creek
Bakers Creek 20	7.7	-	High	15	Very low	Gully draining into Bakers Creek, approximately 36 m west of Bakers Creek
Bakers Creek 21	8.7	7.6	High	40	Very low	Golden Gate Gully draining into Bakers Creek, approximately 57 m east of Bakers Creek
Bakers Creek 23	7.2	-	High	16	Very low	Gully draining into Bakers Creek, approximately 32 m west of Bakers Creek
Bakers Creek 24	7.2	-	High	54	Very low	Gully draining into Bakers Creek, approximately 80 m east of Bakers Creek
Bakers Creek 25	7.5	7.3	High	42	Very low	Gully draining into Bakers Creek, approximately 26 m east of Bakers Creek
Bakers Creek 26	7.3	-	High	33	Very low	Gully draining into Bakers Creek, approximately 35 m east of Bakers Creek
Bakers Creek 27	7.6	7.4	High	113	Very low	Gully draining into Bakers Creek, approximately 50 m east of Bakers Creek
Bakers Creek 28	6.8	-	Medium	49	Very low	Gully draining into Bakers Creek, approximately 45 m west of Bakers Creek
Bakers Creek 29	7.4	7.5	High	10	Very low	Midas Gully draining into Bakers Creek,

Sample	pH (1:5)	pH (sat paste)	Classification[1]	EC (1:5) µS/cm	Classification[1]	Sample location
						approximately 215 m west of Bakers Creek
Bakers Creek 30	7.7	-	High	61	Very low	Gully draining into Bakers Creek, approximately 50 m west of Bakers Creek
Bakers Creek 31	7.4	7.8	High	29	Very low	Bakers Creek – approximately 3.17 km down gradient from Bakers Creek sample location 32
Bakers Creek 32	7.2	7.2	High	12	Very low	Bakers Creek – north side of Old Hillgrove Road
Bakers Creek 33	7.1	-	High	54	Very low	Four Mile Creek, between Swamp Creek and Sandy Creek
Bakers Creek 34	8.2	-	High	95	Very low	Gully draining into Bakers Creek, approximately 30 m west of Bakers Creek
Bakers Creek 35	7.9	7.5	High	22	Very low	Bakers Creek – approximately 5.85 km down gradient from Bakers Creek sample location 32
Bakers Creek 36	7.2	7.6	High	12	Very low	Bakers Creek – approximately 4.22 km down gradient from Bakers Creek sample location 32

1: Based on DME (1995). pH classified using pH (1:5) results. Note: There are no samples Bakers Creek 13 or 22. NA: Not analysed.

The data in Table A52 shows that the pH data for the 34 Bakers Creek sediment samples indicates generally circumneutral to alkaline pH values, generally classified as medium or high (non-acidic) pH values. Sediment EC values were broadly very low, and as for sediment samples from other sub-catchments, would suggest that the EC levels pose little evidence that saline drainage is being generated from sediment samples.

Sediment acid base accounting

Eighteen samples underwent total sulfur analysis, with the entire ABA data set provided in Table K (Appendix D), with a sub-set provide below in Table A53. Samples that returned potentially acid forming (high capacity) (PAF-HC) NAPP values—being greater than 10 kgH_2SO_4/tonne, and/or have limited self-buffering capacity as determined by a NPR of less than two are bolded.

The NAPP and NPR results for Bakers Creek sub-catchment for those samples that underwent geochemical assay are shown in Table A53.

Table A53: Sediment NAPP and NPR results – Bakers Creek

Sample	NAPP[1] kgH_2SO_4/tonne	NPR	Sample location
Bakers Creek 1	-0.5	2.1	Becks Creek, approximately 90 m west of Bakers Creek
Bakers Creek 2	-0.2	**1.5**	Most down gradient point on Bakers Creek – approximately 10.53 km down gradient from bakers Creek 32 point
Bakers Creek 5	-0.5	**1.8**	Bakers Creek – approximately 8.91 km down gradient from Bakers Creek sample location 32
Bakers Creek 6	-0.3	**1.5**	Bakers Creek – approximately 8.55 km down gradient from Bakers Creek sample location 32
Bakers Creek 8	-1.0	NA	Gully draining into Bakers Creek, approximately 125 m north of Bakers Creek
Bakers Creek 9	-0.4	2.6	Swamp Creek, 67 m up gradient of Four Mile Creek
Bakers Creek 14	1.4	**0.2**	Gully draining into Bakers Creek, approximately 225 m west of Bakers Creek
Bakers Creek 15	1.2	**0.5**	Gully draining into Bakers Creek, approximately 40 m west of Bakers Creek
Bakers Creek 17	1.1	**0.5**	Gully draining into Bakers Creek, approximately 62 m east of Bakers Creek
Bakers Creek 19	-0.6	2.4	Gully draining into Bakers Creek, approximately 34 m east of Bakers Creek
Bakers Creek 21	0.1	**0.9**	Golden Gate Gully draining into Bakers Creek, approximately 57 m east of Bakers Creek
Bakers Creek 25	1.0	**0.6**	Gully draining into Bakers Creek, approximately 26 m east of Bakers Creek
Bakers Creek 27	0.1	**0.9**	Gully draining into Bakers Creek, approximately 50 m east of Bakers Creek
Bakers Creek 29	0.2	**0.7**	Midas Gully draining into Bakers Creek, approximately 215 m west of Bakers Creek
Bakers Creek 31	-0.1	**1.1**	Bakers Creek – approximately 3.17 km down gradient from Bakers Creek sample location 32
Bakers Creek 32	0.3	**0.5**	Bakers Creek – north side of Old Hillgrove Road
Bakers Creek 35	-0.2	**1.2**	Bakers Creek – approximately 5.85 km down gradient from Bakers Creek sample location 32
Bakers Creek 36	0.9	**0.6**	Bakers Creek – approximately 4.22 km down gradient from Bakers Creek sample location 32

1: NAPP calculated from adjusted of pyritic sulfur values being total S – SO_4-S.

The data in Table A53 indicates that whilst most samples do not have inherent buffering capacity to self-neutralise as shown by NPR values generally below 2, there are no samples with a NAPP value above 1.4 kgH_2SO_4/tonne meaning that there is very low risk of the sediment samples generating acidic drainage. These results are consistent with the circum-neutral and alkaline pH results shown above in Table A52, and the literature on the Bakers Creek mineral deposit (e.g. Ashley and Graham 2001, Ashley *et al*. 2006).

Sediment net acid generation (NAG) testing

Results of the single addition NAG tests and NAG pH values are provided in Table A55. Following the NAG tests, the samples may be classified using both the NAG and NAPP results. Samples may be classified as potentially acid forming – high capacity (PAF-HC), potentially acid forming – low capacity (PAF-LC), uncertain (UC), non-acid forming (NAF) or acid consuming (AC)—refer to Table A54.

Table A54: Sample classification

Primary Geochemical Material Type	NAPP[1] (kgH_2SO_4/tonne)	NAG pH[1] (pH units)
Potentially Acid Forming – High Capacity (PAF-HC)	> 10	<4.5
Potentially Acid Forming – Low Capacity (PAF–LC)	0 – 10[2]	<4.5
Non-Acid Forming (NAF)	Negative	≥4.5
Acid Consuming (AC)	< -50	≥4.5
Uncertain[3]	Positive	≥4.5
	Negative	<4.5

1: From Miller (1996), AMIRA (2002), ACARP (2008) and INAP (2009).
2: Site-specific but typically in the range of 5 to 20 kgH_2SO_4/tonne.
3: Further testing required to confirm material classification.

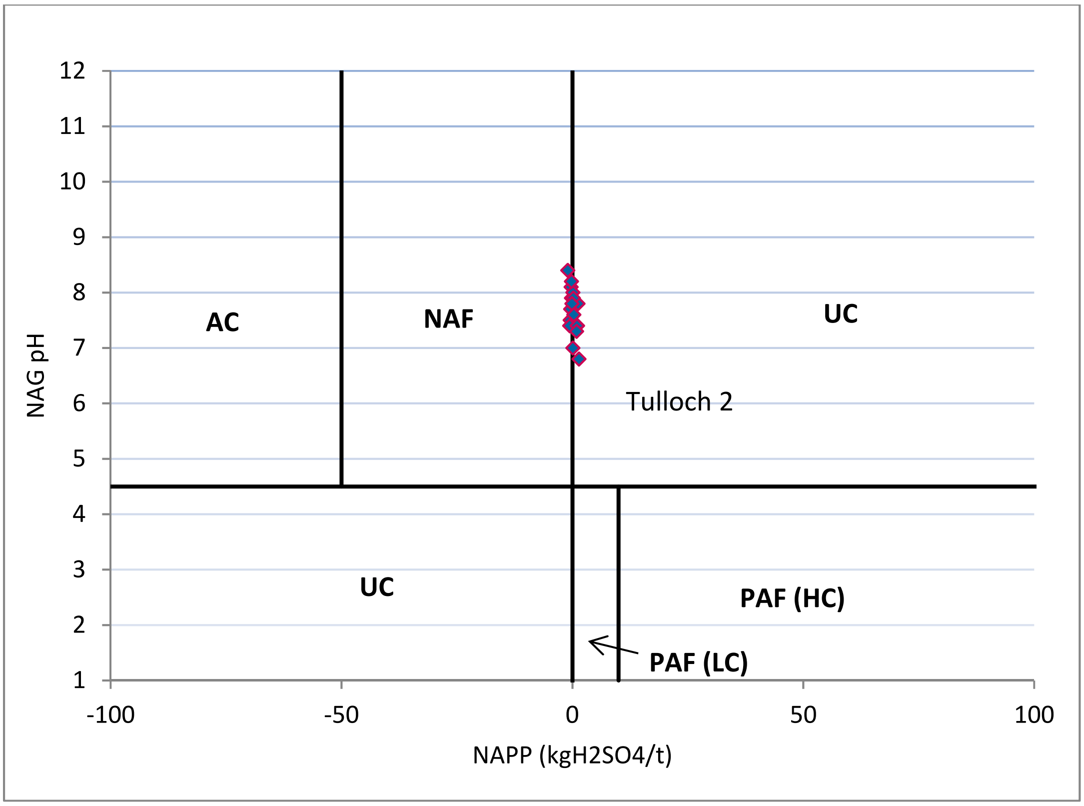
Table A55: Bakers Creek sediment NAG_{pH}, NAG and AMD classification

Sample	NAG pH	NAG (pH. 4.5) (kgH_2SO_4/tonne)	NAG (pH 7.0) (kgH_2SO_4/tonne)	AMD class'n	Sample location
Bakers Creek 1	7.5	<0.1	<0.1	NAF	Becks Creek, approximately 90 m west of Bakers Creek
Bakers Creek 2	7.9	<0.1	<0.1	NAF	Most down gradient point on Bakers Creek – approximately 10.53 km down gradient from bakers Creek 32 point
Bakers Creek 5	7.4	<0.1	<0.1	NAF	Bakers Creek – approximately 8.91 km down gradient from Bakers Creek sample location 32
Bakers Creek 6	8.1	<0.1	<0.1	NAF	Bakers Creek – approximately 8.55 km down gradient from Bakers Creek sample location 32
Bakers Creek 8	8.4	<0.1	<0.1	NAF	Gully draining into Bakers Creek, approximately 125 m north of Bakers Creek
Bakers Creek 9	7.7	<0.1	<0.1	NAF	Swamp Creek, 67 m up gradient of Four Mile Creek
Bakers Creek 14	6.8	<0.1	<0.1	UC	Gully draining into Bakers Creek, approximately 225 m west of Bakers Creek
Bakers Creek 15	7.8	<0.1	<0.1	UC	Gully draining into Bakers Creek, approximately 40 m west of Bakers Creek
Bakers Creek 17	7.4	<0.1	<0.1	UC	Gully draining into Bakers Creek, approximately 62 m east of Bakers Creek
Bakers Creek 19	7.4	<0.1	<0.1	NAF	Gully draining into Bakers Creek, approximately 34 m east of Bakers Creek
Bakers Creek 21	8.0	<0.1	<0.1	UC	Golden Gate Gully draining into Bakers Creek, approximately 57 m east of Bakers Creek
Bakers Creek 25	7.4	<0.1	<0.1	UC	Gully draining into Bakers Creek, approximately 26 m east of Bakers Creek
Bakers Creek 27	7.0	<0.1	<0.1	UC	Gully draining into Bakers Creek, approximately 50 m east of Bakers Creek
Bakers Creek 29	7.9	<0.1	<0.1	UC	Midas Gully draining into Bakers Creek, approximately 215 m west of Bakers Creek
Bakers Creek 31	7.8	<0.1	<0.1	NAF	Bakers Creek – approximately 3.17 km down gradient from Bakers Creek sample location 32
Bakers Creek 32	7.6	<0.1	<0.1	UC	Bakers Creek – north side of Old Hillgrove Road
Bakers Creek 35	8.2	<0.1	<0.1	NAF	Bakers Creek – approximately 5.85 km down gradient from Bakers Creek sample location 32
Bakers Creek 36	7.3	<0.1	<0.1	UC	Bakers Creek – approximately 4.22 km down gradient from Bakers Creek sample location 32

The data in Table A55 indicates that all sediment oxidation pH values were slightly alkaline or circumneutral, with no acid being generated at oxidation pH values of 4.5 or 7.0. Half of the 18 samples were classified as NAF with the other half being classified as uncertain due to slightly positive NAPP values though NAG_{pH} values over 4.5. The slightly positive NAPP values are likely due to non-pyritic sulfide species being accounted for in the sulfide sulfur, artificially inflating the risk of AMD. In reality, the Bakers Creek drainage pH values are circumneutral to alkaline, indicating little risk of acidic drainage from direct pyrite oxidation due to the presence of abundant carbonate in the groundmass.

The NAG pH results in Table A55 were graphed along with the (pyritic) NAPP values from Table A53 to further classify the mineral waste samples according to Table A54 above. The graph is shown as Figure A5 below. Figure A5 shows the data set straddling the NAF / UC boundary, with circumneutral to alkaline oxidation pH values. It is likely that additional sulfur speciation testing would demonstrate the presence of non-acid forming sulfur species, thereby shifting the dataset further left into the NAF classification zone.

Figure A5: NAG_{pH} and NAPP geochemical plot – Bakers Creek sediment samples



Sediment geochemical abundance index, ISQG triggers and leach testing

Table A56 shows the Bakers Creek mineral waste samples that returned a GAI of three or over, indicating relative enrichment of that particular metal or metalloid. Arsenic and antimony have been bolded. The complete GAI assessment is provided as Table D, Appendix E, while Bakers Creek sediment leaching results are provided in Table M, Appendix D.

Additionally, metals that exceeded the ANZECC/ARMCANZ (2000) low and high sediment trigger values (interim sediment quality guideline, or ISQG) are also shown. Note that the laboratory LOR for antimony (5 mg/kg) exceeded the low trigger value (2 mg/kg); therefore, when a <LOR was reported, a value of 50 % of the LOR (2.5 mg/kg) was adopted and for the purposes of this study.

Table A56 expands on the elevated whole rock metals results above, and presents those metals that leached values greater than the 95% ANZECC/ARMCANZ (2000) freshwater aquatic ecosystem guideline trigger values as an indicative risk guide.

Table A56: Sediment GAI, ISQG and leaching exceedances – Bakers Creek

Sample	Metals with GAI > 3	Exceed low ISQG	Exceed high ISQG	Leachable elements > 95% ANZECC (2000)	Sample location
Bakers Creek 1	-	Ni	-	Al, Cr, Cu, Zn	Becks Creek, approximately 90 m west of Bakers Creek
Bakers Creek 2	**Sb, As**	**Sb, As**	**Sb, As**	Al, **Sb, As**, Cr, Cu, Zn	Most down gradient point on Bakers Creek – approximately 10.53 km down gradient from bakers Creek 32 point
Bakers Creek 3	**As**	-	-	Not leached	Gully draining into Bakers Creek, approximately 165 m west of Bakers Creek
Bakers Creek 4	**As**	**As**, Cr, Ni	**As**	Not leached	Gully draining into Bakers Creek, approximately 165 m west of Bakers Creek
Bakers Creek 5	**Sb, As**	**Sb**	**Sb**	Al, **Sb, As**, Cr, Cu, Zn	Bakers Creek – approximately 8.91 km down gradient from Bakers Creek sample location 32
Bakers Creek 6	**Sb, As**	**Sb, As**	**Sb, As**	Al, **Sb, As**, Cr, Cu, Zn	Bakers Creek – approximately 8.55 km down gradient from Bakers Creek sample location 32
Bakers Creek 7	**Sb, As**	**Sb, As**, Cr, Ni	**Sb, As**	Not leached	Gully draining into Bakers Creek, approximately 180 m south of Bakers Creek
Bakers Creek 8	**As**	**Sb**	-	Al, **Sb, As**, Cr, Zn	Gully draining into Bakers Creek, approximately 125 m north of Bakers Creek
Bakers Creek 9	**Sb, As**	**Sb, As**, Ni	**Sb, As**	Al, **Sb, As**, Cr, Cu, Zn	Swamp Creek, 67 m up gradient of Four Mile Creek
Bakers Creek 10	**Sb**	**Sb**	-	Not leached	Sandy Creek, 85 m up gradient of Four Mile Creek
Bakers Creek 11	**Sb**	**Sb**	**Sb**	Not leached	Gully draining into Bakers Creek, approximately 80 m east of Bakers Creek
Bakers Creek 12	**Sb**, Hg, **As**	**Sb, As**, Hg, Ni	**Sb, As**	Not leached	Gully draining into Bakers Creek, approximately 38 m east of Bakers Creek
Bakers Creek 14	**Sb, As**	**Sb, As**, Hg	**Sb, As**	Al, **Sb, As**, Cr, Cu, Zn	Gully draining into Bakers Creek, approximately 225 m west of Bakers Creek
Bakers Creek 15	**Sb, As**	**Sb, As**, Ni	**Sb, As**	Al, **Sb, As**, Cr, Cu, Zn	Gully draining into Bakers Creek, approximately 40 m west of Bakers Creek
Bakers Creek 16	**Sb, As**	**Sb, As**, Hg	As	Not leached	Gully draining into Bakers Creek, approximately 120 m east of Bakers Creek
Bakers Creek 17	**Sb, As**	Sb, As, Hg, Ni	**Sb, As**	Al, **Sb, As**, Cr, Cu, Zn	Gully draining into Bakers Creek, approximately 62 m east of Bakers Creek
Bakers Creek 18	**Sb, As**	**Sb**	**Sb**	Not leached	Gully draining into Bakers Creek, approximately 50 m west of Bakers Creek

Sample	Metals with GAI > 3	Exceed low ISQG	Exceed high ISQG	Leachable elements > 95% ANZECC (2000)	Sample location
Bakers Creek 19	**Sb, As**	**Sb, As,** Ni	**Sb, As**	Al, **Sb, As**, Cr, Cu, Pb, Zn	Gully draining into Bakers Creek, approximately 34 m east of Bakers Creek
Bakers Creek 20	**As**	**Sb, As**	-	Not leached	Gully draining into Bakers Creek, approximately 36 m west of Bakers Creek
Bakers Creek 21	**Sb, As**	**Sb, As**, Ni	**Sb, As**	Al, **Sb, As**, Cr, Cu, Pb, Zn	Golden Gate Gully draining into Bakers Creek, approximately 57 m east of Bakers Creek
Bakers Creek 23	**As**	**Sb, As**	**As**	Not leached	Gully draining into Bakers Creek, approximately 32 m west of Bakers Creek
Bakers Creek 24	**Sb, As**	**Sb, As**, Hg, Ni	**Sb, As**	Not leached	Gully draining into Bakers Creek, approximately 80 m east of Bakers Creek
Bakers Creek 25	**Sb, As**	S**b, As,** Cu, Hg, Ni	**Sb, As**	Al, **Sb, As**, Cr, Cu, Pb, Zn	Gully draining into Bakers Creek, approximately 26 m east of Bakers Creek
Bakers Creek 26	**Sb, As**	**Sb, As**	**Sb, As**	Not leached	Gully draining into Bakers Creek, approximately 35 m east of Bakers Creek
Bakers Creek 27	**Sb**, Hg, **As**	**Sb, As**, Hg	**Sb, As**	Al, **Sb, As**, Cr, Cu, Zn	Gully draining into Bakers Creek, approximately 50 m east of Bakers Creek
Bakers Creek 28	**Sb, As**	**Sb, As**	**Sb, As**	Not leached	Gully draining into Bakers Creek, approximately 45 m west of Bakers Creek
Bakers Creek 29	**Sb, As**	**Sb**	**Sb**	Al, **Sb, As**, Cr, Zn	Midas Gully draining into Bakers Creek, approximately 215 m west of Bakers Creek
Bakers Creek 30	**Sb, As**	**Sb**	**Sb**	Not leached	Gully draining into Bakers Creek, approximately 50 m west of Bakers Creek
Bakers Creek 31	**As**	-	-	Al, **As**, Cr, Zn	Bakers Creek – approximately 3.17 km down gradient from Bakers Creek sample location 32
Bakers Creek 32	-	-	-	Al, Cr, Zn	Bakers Creek – north side of Old Hillgrove Road
Bakers Creek 33	-	-	-	Not leached	Four Mile Creek, between Swamp Creek and Sandy Creek
Bakers Creek 34	**Sb, As**	**Sb**, Ni	-	Not leached	Gully draining into Bakers Creek, approximately 30 m west of Bakers Creek
Bakers Creek 35	**Sb, As**	**Sb, As**, Hg, Ni	**Sb, As**	Al, **Sb, As**, Cr, Cu, Zn	Bakers Creek – approximately 5.85 km down gradient from Bakers Creek sample location 32
Bakers Creek 36	**Sb, As**	**Sb, As**	**Sb, As**	Al, **Sb, As**, Cr, Cu, Zn	Bakers Creek – approximately 4.22 km down gradient from Bakers Creek sample location 32

The data in Table A56 above indicate that more than half of the Bakers Creek samples returned relatively elevated arsenic and antimony concentrations using the GAI, that also exceeded both the low and the high ANZECC (2000) sediment quality guidelines, and leached metals including antimony and arsenic at concentrations above the ANZECC (2000) 95% trigger values.

Note that sample Bakers Creek 32 was the up-catchment sample that returned no exceedances, although did leach aluminium, chromium and zinc, while sample Bakers Creek 1 was collected in a non-mining catchment and did not return elevated arsenic or antimony results, although did leach aluminium, chromium, copper and zinc.

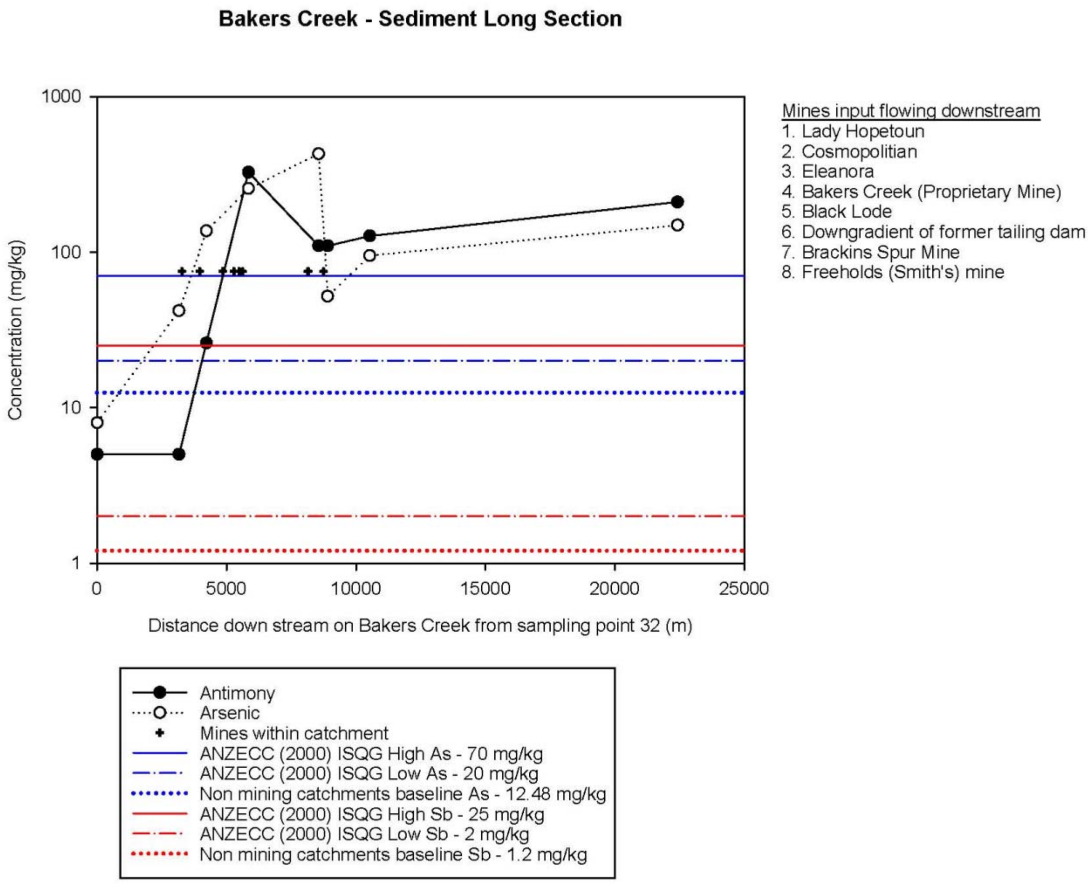
Metals screening – sediment and surface water

Sediment

Arsenic and antimony results for sediment were compared to the nominated metals screening criteria shown in Section 4 of the main report. Results are presented in the tables below. Bakers Creek sediment metals results are presented as Table L, Appendix D.

As a visual indicator, Figure A6 shows a long section of the level of arsenic and antimony contamination in sediment along Bakers Creek downstream from the up-catchment sample point 32 (on the 'y axis' on Figure A6). The Black crosses from left to right are shown as inputs from various historic workings in the Bakers Creek sub-catchment to the right of the graph. The arsenic and antimony point at approximately 22 kms down Bakers Creek is taken from Ashley and Graham (2001), and shows remarkable temporal consistency with the GHD data.

Figure A6: Bakers Creek sediment contamination long section



The data used to compile Figure A6 is presented below in Table A57.

Table A57: Bakers Creek in stream sediment metals results

Sample ID	Location	Sediment Results Antimony (mg/kg)	Sediment Results Arsenic (mg/kg)
Baseline concentration Stage 1 (GHD 2015)		1.2	12.5
ANZECC ISQG low trigger values		**2**	**20**
ANZECC ISQG high trigger values		**25**	**70**
BC_SD32	Bakers Creek – north side of Old Hillgrove Road	<5	8
BC_SD31	Bakers Creek – approximately 3.17 km down gradient from Bakers Creek sample location 32	<5	**42**
BC_SD36	Bakers Creek – approximately 4.22 km down gradient from Bakers Creek sample location 32	**26**	**137**
BC_SD35	Bakers Creek – approximately 5.85 km down gradient from Bakers Creek sample location 32	**326**	**256**
BC_SD06	Bakers Creek – approximately 8.55 km down gradient from Bakers Creek sample location 32	**110**	**429**
BC_SD05	Bakers Creek – approximately 8.91 km down gradient from Bakers Creek sample location 32	**110**	**52**
BC_SD02	Most down gradient point on Bakers Creek – approximately 10.53 km down gradient from bakers Creek 32 point	**127**	**95**

The remaining sediment results collected within the Bakers Creek sub-catchment are presented in Table A58. A discussion of both the sediment and surface water metals results follows.

Table A58: Remaining Bakers Creek in stream sediment metals results

Sample ID	Location	Sediment Results Antimony (mg/kg)	Sediment Results Arsenic (mg/kg)
Baseline concentration Stage 1 (GHD 2015)		1.2	12.5
ANZECC ISQG low trigger values		**2**	**20**
ANZECC ISQG high trigger values		**25**	**70**
BC_SW01	Becks Creek, approximately 90 m west of Bakers Creek	<5	11
BC_SD03	Gully draining into Bakers Creek, approximately 165 m west of Bakers Creek	<5	17
BC_SD04	Gully draining into Bakers Creek, approximately 165 m west of Bakers Creek	<5	**77**
BC_SD07	Gully draining into Bakers Creek, approximately 180 m south of Bakers Creek	**71**	**212**
BC_SD08	Gully draining into Bakers Creek, approximately 125 m north of Bakers Creek	**11**	**38**
BC_SW09	Swamp Creek, 67 m up gradient of Four Mile Creek	**381**	**177**
BC_SD10	Sandy Creek, 85 m up gradient of Four Mile Creek	**17**	10
BC_SD11	Gully draining into Bakers Creek, approximately 80 m east of Bakers Creek	**49**	**62**
BC_SD12	Gully draining into Bakers Creek, approximately 38 m east of Bakers Creek	**952**	**330**

BC_SD14	Gully draining into Bakers Creek, approximately 225 m west of Bakers Creek	**183**	**1,990**
BC_SD15	Gully draining into Bakers Creek, approximately 40 m west of Bakers Creek	**263**	**204**
BC_SD16	Gully draining into Bakers Creek, approximately 120 m east of Bakers Creek	**21**	**209**
BC_SD17	Gully draining into Bakers Creek, approximately 62 m east of Bakers Creek	**1,600**	**499**
BC_SD18	Gully draining into Bakers Creek, approximately 50 m west of Bakers Creek	**28**	**45**
BC_SD19	Gully draining into Bakers Creek, approximately 34 m east of Bakers Creek	**252**	**180**
BC_SD20	Gully draining into Bakers Creek, approximately 36 m west of Bakers Creek	<5	**42**
BC_SD21	Golden Gate Gully draining into Bakers Creek, approximately 57 m east of Bakers Creek	**243**	**173**
BC_SD23	Gully draining into Bakers Creek, approximately 32 m west of Bakers Creek	**9**	**85**
BC_SD24	Gully draining into Bakers Creek, approximately 80 m east of Bakers Creek	**700**	**336**
BC_SD25	Gully draining into Bakers Creek, approximately 26 m east of Bakers Creek	**629**	**216**
BC_SD26	Gully draining into Bakers Creek, approximately 35 m east of Bakers Creek	**54**	**138**
BC_SD27	Gully draining into Bakers Creek, approximately 50 m east of Bakers Creek	**265**	**123**
BC_SD28	Gully draining into Bakers Creek, approximately 45 m west of Bakers Creek	**78**	**193**
BC_SD29	Midas Gully draining into Bakers Creek, approximately 215 m west of Bakers Creek	**26**	**70**
BC_SD30	Gully draining into Bakers Creek, approximately 50 m west of Bakers Creek	**29**	**47**
BC_SD33	Four Mile Creek, between Swamp Creek and Sandy Creek	**9**	8
BC_SD34	Gully draining into Bakers Creek, approximately 30 m west of Bakers Creek	**20**	**34**

Surface Water

Arsenic and antimony results for unfiltered surface water were compared to the nominated metals screening criteria shown in Section 4 of the main report. Results are presented in the tables below. All data are provided in Table N, Appendix D.

As a visual indicator, Figure A7 shows a long section of the level of arsenic and antimony contamination in unfiltered surface water along Bakers Creek downstream from the up-catchment sample point 32 (on the 'y axis' on Figure A7). The Black crosses from left to right are shown as inputs from various historic workings in the Bakers Creek sub-catchment to the right of the graph. The arsenic and antimony point at approximately 22 kms down Bakers Creek is taken from Ashley and Graham (2001), and again shows remarkable temporal consistency with the GHD data, as did the sediment data.

The data used to compile Figure A7 are presented below in Table A59. Note that as the results show that some 15 % of antimony and close to 0 % of arsenic appear to be transported in Bakers Creek in the dissolved form. This is as there was little or no difference between the filtered and unfiltered surface water data. This indicates that adsorption of antimony and arsenic to suspended solids appears to be a key contaminant transport mechanism.

In that regard, only the unfiltered data are presented here, with all data provided in Table N, Appendix D.

Figure A7: Bakers Creek (unfiltered) surface water contamination long section

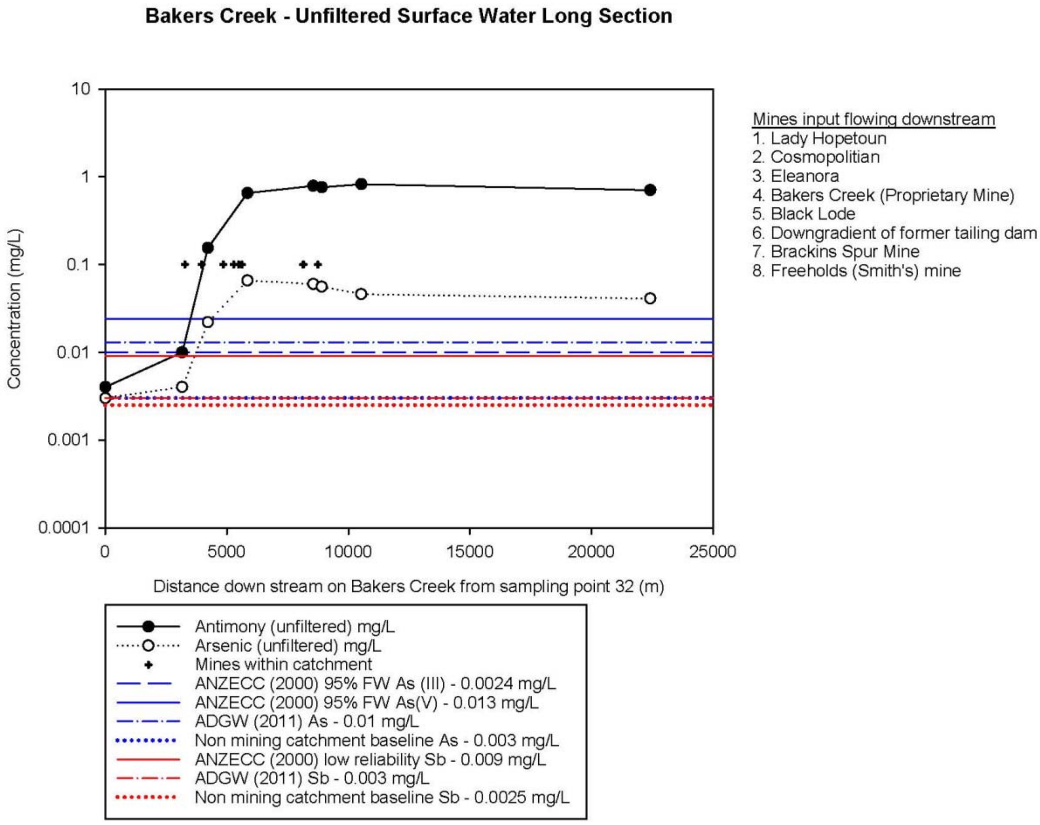


Table A59: Bakers Creek in stream unfiltered surface water metals results

Sample ID	Location	Surface water Results Antimony (mg/L)	Surface water Results Arsenic (mg/L)
Baseline concentration (GHD 2015)		0.0025	0.003
ADWG (2011)		**0.003**	**0.01**
ANZECC 95% (2000)		**0.009[1]**	**0.013**
ANZECC & ARMCANZ (2000) irrigation trigger value (long term)		-	0.1
ANZECC & ARMCANZ (2000) stock watering trigger value		-	**0.5**
ANZECC & ARMCANZ (2000) irrigation trigger value (short term)		-	**2.0**
BC_SW32	Bakers Creek – north side of Old Hillgrove Road	**0.004**	0.002
BC_SW31	Bakers Creek – approximately 3.17 km down gradient from Bakers Creek sample location 32	**0.01**	0.004

BC_SW36	Bakers Creek – approximately 4.22 km down gradient from Bakers Creek sample location 32	**0.155**	**0.022**
BC_SW35	Bakers Creek – approximately 5.85 km down gradient from Bakers Creek sample location 32	**0.654**	**0.066**
BC_SW06	Bakers Creek – approximately 8.55 km down gradient from Bakers Creek sample location 32	**0.789**	**0.060**
BC_SW05	Bakers Creek – approximately 8.91 km down gradient from Bakers Creek sample location 32	**0.762**	**0.056**
BC_SW02	Most down gradient point on Bakers Creek – approximately 10.53 km down gradient from bakers Creek 32 point	**0.822**	**0.046**

The remaining surface water results collected within the Bakers Creek sub-catchment are presented in Table A60. A discussion of both the sediment and surface water metals results follows.

Note that as many of the sample locations were positioned in ephemeral streamlines, there are less surface water samples in the Bakers Creek sub-catchment than sediment samples. This is not deemed problematic as Ashley and Graham (2001) noted that the clean water travelling over contaminated sediment was the main mode of water contamination in the Macleay Catchment. Therefore, identifying the key contributors of contaminated sediment remains paramount in managing water quality.

Table A60: Remaining Bakers Creek in stream unfiltered surface water metals results

Sample ID	Location	Surface water Results Antimony (mg/L)	Surface water Results Arsenic (mg/L)
Baseline concentration (GHD 2015)		0.0025	0.003
ADWG (2011)		**0.003**	**0.01**
ANZECC 95% (2000)		**0.009[1]**	**0.013**
ANZECC & ARMCANZ (2000) irrigation trigger value (long term)		-	0.1
ANZECC & ARMCANZ (2000) stock watering trigger value		-	**0.5**
ANZECC & ARMCANZ (2000) irrigation trigger value (short term)		-	**2.0**
BC_SW01	Becks Creek, approximately 90 m west of Bakers Creek	**0.045**	0.002
BC_SW8	Gully draining into Bakers Creek, approximately 125 m north of Bakers Creek	**0.045**	0.008
BC_SW09	Swamp Creek, 67 m up gradient of Four Mile Creek	**9.31**	0.2
BC_SW10	Sandy Creek, 85 m up gradient of Four Mile Creek	**0.042**	<0.001
BC_SW15	Gully draining into Bakers Creek, approximately 40 m west of Bakers Creek	**5.98**	0.245
BC_SW19	Gully draining into Bakers Creek, approximately 34 m east of Bakers Creek	**5.19**	0.244
BC_SW27	Gully draining into Bakers Creek, approximately 50 m east of Bakers Creek	**0.290**	**0.030**
BC_SW33	Four Mile Creek, between Swamp Creek and Sandy Creek	**0.018**	0.002

Sediment and water discussion

In total, stream sediment samples were collected from 34 sites along Bakers Creek and its tributaries (being locations 1 to 36, except for locations 13 and 22, which were not sampled). Surface water samples were obtained from 15 sites, with other sites unable to be sampled due to the absence of water.

From upstream (location 32) to downstream (location 2), the total distance along Bakers Creek is approximately 10.6 km from north to south. Location 32 is above Bakers Creek Falls and upstream of almost all known mine workings, although Clarks Gully (draining the Clarks Gully open cut mine site) is further upstream.

Location 2 is immediately downstream of the confluence with Becks Creek, and downstream of all significant mine workings in the Hillgrove area. Sites at which paired stream sediment and water samples were collected along Bakers Creek, from upstream (north) to downstream (south) are in order as follows: 32, 31, 36, 35, 6, 5 and 2. All other locations sampled (for stream sediments and some waters) were from tributary streams and smaller gullies that drain into Bakers Creek, some of which encompassed sub-catchments containing significant modern and / or historic mine workings, including waste dump material.

Location 32, upstream of Bakers Creek Falls and the gorge displays near-background values of antimony and arsenic in stream sediment and water. The values are <5 mg/kg antimony and 8 mg/kg arsenic (sediment), and 0.004 mg/L antimony and 0.002 mg/L arsenic (surface water), respectively. Such results are comparable to those obtained by Ashley and Graham (2001) and Ashley *et al*. 2007. The results are also comparable to the Macleay Catchment background values for stream sediments (1.1 mg/kg antimony and 7.9 mg/kg arsenic) and surface water (0.003 mg/L antimony and 0.004 mg/L arsenic) reported by Ashley and Graham (2001) and Ashley *et al.* (2007). It is notable that location 32 is downstream of the Clarks Gully open cut mine site, yet there is little influence from the prior workings, from exposed mineralisation, or from mineral exploration activities that have been performed intermittently at the site between 2005 and 2016.

The first sampling location downstream of location 32 was at location 31, some 3.1 km downstream in the gorge, immediately upstream of the Lady Hopetoun mine site. Between the Bakers Creek Falls and location 31, there are only a few small historic mine sites (mainly east of Bakers Creek). These sites and potentially outcropping mineralisation have probably led to the anomalism of arsenic in stream sediments (<5 mg/kg antimony; 42 mg/kg arsenic) and slight increase in surface water concentrations (0.01 mg/L antimony; 0.004 mg/L arsenic). The catchment reporting to sample location 31 does not contain any EA Systems (2003) mine domains.

In the reach of Bakers Creek between location 31 and location 36 (some 4.3 km downstream of location 32), there is the first major influx of contaminated material into Bakers Creek. On the western (Metz) side of Bakers Creek, there are inputs from the Lady Hopetoun mine (unstable mine waste dump with metalloid concentrations in the mineral waste sample (sample Bakers Creek 6) of 113 mg/kg antimony and 930 mg/kg arsenic, as well as a small water seepage), and from gullies at:

- location 30 (sediment antimony 29 mg/kg; arsenic 47 mg/kg)
- location 29 (sediment antimony 26 mg/kg; arsenic 70 mg/kg)
- location 28 (sediment antimony 78 mg/kg; arsenic 193 mg/kg).

On the eastern (Hillgrove) side, there are inputs from gullies in the vicinity of, and to the north of, the Cosmopolitan mine, and from a small repository of mine waste at this mine (mineral waste sample Bakers Creek 5) with 3,480 mg/kg antimony and 1,570 mg/kg arsenic). The gullies in this area have strongly elevated values of antimony and arsenic; e.g. from:

- location 27 (sediment antimony 265 mg/kg and 123 mg/kg arsenic; surface water 0.290 mg/L antimony and 0.03 mg/L arsenic)
- location 26 (sediment antimony 54 mg/kg; arsenic 138 mg/kg)
- location 25 draining the Cosmopolitan site (sediment antimony 629 mg/kg; arsenic 216 mg/kg) location 24 (sediment antimony 700 mg/kg; arsenic 336 mg/kg).

These influxes, from historic mine sites (Lady Hopetoun, Cosmopolitan, and dozens of small sites) have led to relatively modest increases of antimony and arsenic values in Bakers Creek at location 36 (*viz*: sediment antimony 26 mg/kg and arsenic 137 mg/kg; surface water antimony 0.155 mg/L and arsenic 0.022 mg/L). When compared to downstream data, the sediment and surface water increases in arsenic and antimony at location 36 are indicative of the limited amount of contamination inputs between locations 31 and 36.

GHD sample location 36 receives drainage from EA Systems (2003) mine domains 1, 2 and 3 (in part). There are point sources in EA Systems (2003) mine domains 2 and 3 that would report down-catchment of GHD's sample location 36.

In the reach of Bakers Creek between location 36 and location 35 (around 6.1 km downstream of location 32) there are major influxes of antimony and arsenic from some of the largest historic, as well as modern, mine and processing sites in the Hillgrove region. This input is reflected in the sediment and water values for arsenic and antimony at location 35.

On the western side of Bakers Creek, north of the major gully that drains from the Black Lode-Syndicate-Sunlight mines area (refer to location 15 below), smaller gullies draining into Bakers Creek have modest values in stream sediments. For example:

- location 23 (antimony 9 mg/kg; arsenic 85 mg/kg)
- location 20 (antimony <5 mg/kg; arsenic 42 mg/kg)
- location 18 (antimony 28 mg/kg; arsenic 45 mg/kg).

However, the main gully draining the Black Lode-Syndicate-Sunlight mines (sample location 15) adds significant antimony and arsenic (sediment antimony 269 mg/kg, arsenic 204 mg/kg; surface water antimony 5.98 mg/L, As 0.245 mg/L) as does the next gully to the south that drains from old workings adjacent to the Sunlight mine area (sample location 14 - sediment antimony 183 ppm, arsenic 1,990 ppm; no surface water sample). This is consistent with the source material with waste rock from the Black Lode mine (sample 4) containing 887 mg/kg antimony and 510 mg/kg arsenic.

On the Hillgrove side of Bakers Creek gorge, there are significant antimony and arsenic influxes from:

- Golden Gate gully (sample location 21 - sediment antimony 243 mg/kg and arsenic 173 mg/kg)
- the large gully draining from the Eleanora mine area (sample location 19 - sediment antimony 252 mg/kg and arsenic 180 mg/kg; surface water antimony 5.19 mg/L and arsenic 0.244 mg/L)
- the waste rock dump adjacent to the former Bakers Creek Proprietary Mine and its associated large waste rock dump (mineral waste antimony 313 mg/L and arsenic 2,700 mg/kg)
- sample location 17 (sediment antimony 1600 mg/kg and arsenic 499 mg/kg).

A gully adjacent to the Bakers Creek Proprietary mine shaft (sample location 16) has relatively low sediment antimony (21 mg/kg), though high arsenic concentrations (209 mg/kg). Cumulatively, the influxes into Bakers Creek from these strongly mineralised areas have added significant antimony and arsenic to the system as demonstrated at sample location 35 (sediment antimony 326 mg/kg and arsenic 256 mg/kg; surface water antimony 654 mg/L and arsenic 66 mg/L). This represents at least a three-fold increase in contaminants as compared to sample location 36. Although there are extreme values of antimony in surface water entering Bakers Creek at sample locations 15 and 19, the actual volume of water flowing at the time of sampling were small ~ up to approximately one litre per second.

GHD sample location 35 receives drainage from EA Systems (2003) mine domains 4, 5, 6 and 7 (in part). There are point sources in EA Systems (2003) mine domain 6 that would report down-catchment of GHD's sample location 35.

The reach of Bakers Creek between location 35, downstream to location 6 (the latter being some 8.5 km downstream of location 32) receives influxes of antimony and arsenic initially from the processing and tailings dam sites on the plateau at Hillgrove (via gullies at locations 12, 11 and 8, and from the Brackins Spur mine site (sample location 7). These inputs, along with historic material already present as bedload in Bakers Creek, maintain strongly elevated antimony and arsenic values in both sediment and surface water. A gully at sample location 34, draining the Metz (western) side of Bakers Creek immediately downstream of sample location 35, displays only subdued values of antimony (20 mg/kg) and arsenic (34 mg/kg) in sediment, despite several small historic workings in the sub-catchment.

Sample location 12—a gully draining the processing plant area and water storage dams at Hillgrove—contains strongly elevated antimony (952 mg/kg) and arsenic (330 mg/kg). These data may reflect the long history of ore processing and resultant antimony and arsenic dispersion in this area, rather than current contributions. Another gully at sample location 11 contains more subdued values of sediment antimony (49 mg/kg) and arsenic (62 mg/kg), despite draining a region adjacent to the Hillgrove processing plant, and containing several old workings within the sub-catchment.

Another gully at sample location 8 drains from the area on the plateau hosting Hillgrove mine tailings storage facility TSF1. Perhaps surprisingly, values of antimony and arsenic at this location are relatively low (sediment antimony 11 mg/kg and arsenic 38 mg/kg; surface water antimony 0.045 mg/L and arsenic 0.008 mg/L). It may be that the small catch dams located immediately below TSF1 are successfully intercepting most particulate and dissolved antimony and arsenic. Towards sample location 6 on Bakers Creek, there is an influx of contaminated material from a gully adjacent to the Brackins Spur mine (sample location 7), with sediment antimony 71 mg/kg and arsenic 212 mg/kg, and from the Brackins Spur mine waste dump (mine waste sample 1 - antimony 20 mg/kg, arsenic 1,090 mg/kg). At sample location 6 itself, Bakers Creek sediment contains 110 mg/kg antimony and 429 mg/kg arsenic, with surface water containing 0.789 mg/L antimony and 0.060 mg/L arsenic. When compared to upstream sample location 35, it is apparent that the antimony sediment concentration has decreased by around three times, though arsenic has increased about once and a half times, with both antimony and arsenic concentrations in surface water being maintained at concentrations relatively consistent with sample location 35.

GHD sample location 6 receives drainage from EA Systems (2003) mine domains 6, 7, 8 and 11 (in part). There are point sources in EA Systems (2003) mine domain 11 that would report down-catchment of GHD's sample location 6, with some of mine domain 6 reporting to GHD's sample location 35.

Between sample locations 6 and 5 (located further downstream in Bakers Creek and some 8.9 km from location 32), there is the confluence of Bakers Creek and a major tributary being Four Mile Creek. The latter has a significant tributary (Swamp Creek) joining about 700 m upstream of the Four Mile Creek / Bakers Creek confluence. Swamp Creek drains a strongly mineralised region encompassing the former Freehold / Smiths Mine and their associated waste rock dumps. Upstream of the Swamp Creek confluence, Four Mile Creek and its tributary Sandy Creek display only weakly anomalous values of antimony and background arsenic. For example, at sample location 10, Sandy Creek has sediment antimony of 17 mg/kg and arsenic at 10 mg/kg, and surface water antimony concentrations of 0.042 mg/L and arsenic at <0.001 mg/L. Similarly, at sample location 33 in Four Mile Creek, values are also low with sediment antimony at 9 mg/kg and arsenic at 8 mg/kg, and surface water concentrations being antimony 0.018 mg/L and arsenic 0.002 mg/L.

Swamp Creek provides the major input of antimony into Four Mile Creek, and therefore, into Bakers Creek. Mine waste material at Smiths mine (mine waste sample 2) contains 2,150 mg/kg antimony and 2,560 mg/kg arsenic. At sample location 9 in Swamp Creek, sediment antimony and arsenic are strongly elevated (381 mg/kg and 177 mg/kg respectively), and surface water antimony is significantly elevated, being 9.31 mg/L, along with an arsenic value of 0.2 mg/L. No sediment or surface water samples were collected in Four Mile Creek prior to its confluence with Bakers Creek, although earlier data from Ashley and Graham (2001) showed sediment antimony at 636 mg/kg and arsenic at 159 mg/kg.

Due to the antimony and arsenic input from Four Mile Creek, and the contaminated bedload material within Bakers Creek itself, antimony concentrations are largely maintained at sample location 5 within Bakers Creek (as compared to location 6), with sediment antimony at 110 mg/kg and surface water antimony at 0.762 mg/L. However, while the surface water arsenic concentration is maintained at 0.056 mg/L, sediment arsenic concentrations have decreased by approximately eight times to 52 mg/kg. These data are moderately comparable with results from Telford *et al*. (2009) from the same site, being sediment antimony 777 mg/kg and arsenic 60 mg/kg, and surface water antimony at 0.381 mg/L and arsenic at 0.046 mg/L.

GHD sample location 5 receives drainage from EA Systems (2003) mine domains 9, 10 and 11 (in part). There are point sources in EA Systems (2003) mine domain 11 that would report down-catchment of GHD’s sample location 5 to sample location 2.

Downstream from sample location 5 in Bakers Creek, there are potentially limited influxes of antimony and arsenic from gullies draining the western areas of Bakers Creek from potential extensions of the Brackins Spur mineralised zone. These may also impact the stream located beyond the southern extent of GHD’s sample traverse that terminated at sample location 2, approximately 10.5 km downstream of location 32. The gullies draining the Brackins Spur extension area show modest antimony in sediment (e.g. sample location 4 which had <5 mg/kg antimony and 77 mg/kg arsenic, and sample location 3 with <5 mg/kg antimony and 17 mg/kg arsenic.

Near the end of the sample traverse at sample location 2, results from the Bakers Creek tributary Becks Creek (sample location 1) showed only small inputs of antimony and arsenic, with sediment antimony <5 mg/kg and arsenic at 11 mg/kg, and surface water antimony at 0.045 mg/L and arsenic at 0.002 mg/L. Despite the limited inputs of antimony and arsenic downstream of sample location 5, values are maintained at sample location 2, with sediment antimony at 127 mg/kg and arsenic at 95 mg/kg, and surface water antimony at 0.822 mg/L and arsenic at 0.046 mg/L. The sediment data from location 2 are largely consistent with earlier data from an immediately nearby site from Ashley and Graham (2001), which returned 189 mg/kg antimony and 89 mg/kg arsenic.

Although no sampling was undertaken in Bakers Creek by GHD below sample location 2 as part of this study, it is pertinent to note that antimony and arsenic sediment and surface water concentrations are retained to the Macleay River junction, a further 10 km downstream—some 15 km downstream from the major antimony and arsenic influxes of the Hillgrove Mineral Field. Data from Bakers Creek at the Macleay junction (from Ashley and Graham 2001, and Ashley *et al*. 2007) show that sediments contain 197 mg/kg antimony and 103 mg/kg arsenic (which is an average of three analyses), with surface water containing 0.642 mg/L antimony and 0.043 mg/L arsenic (an average of two analyses).

The implication from GHD's and prior sampling is that there is a large 'slug' of strongly contaminated stream sediment in Bakers Creek for a distance exceeding 15 km. Ashley *et al*. (2007) estimate this to contain around 1,500 tonnes of antimony and 1,000 tonnes of arsenic. The contaminated sediment contains arsenic and antimony concentrations that exceed catchment background concentrations by one to more than two orders of magnitude, and which exceed the ISQG high guidelines by up to 12 times for antimony and 6 times for arsenic. Due to this contaminated sediment, stream water equilibrating with it under ambient conditions (i.e. pH values of 7 to 8 and variable redox) maintain high values of antimony (typically up to 300 times ADWG 2011) and arsenic (typically up to 6 times ADWG 2011) from Hillgrove mine to the Macleay junction.

Therefore, based on the GHD sampling data, it would appear that the bulk of the arsenic and antimony contamination in the Bakers Creek sub-catchment is being generated from workings reporting to Bakers Creek between sample locations 36 (around 4.3 kms downstream from the up-catchment sample at sample location 32) and sample location 5 (around 8.9 km downstream from the up-catchment sample at sample location 32). This stretch of Bakers Creek being some 4.6 km in length receives contaminated sediment and surface water from:

- the historic Black Lode, Syndicate and Sunlight mines
- Golden Gate Gully
- the mine processing area
- the historic Eleanora mine
- the historic Bakers Creek Proprietary Mine waste rock dump
- the historic Brackins Spur mine
- the historic Freehold and Smiths mines.

This in no way implies that the current operation at the Hillgrove Mine contributes to contamination in the Bakers Creek sub-catchment.

Further defining major contaminating areas within the Bakers Creek sub catchment is complicated by the historic slug of contaminated sediment that has been shown to exist down-catchment to the Macleay River junction (Ashley and Graham 2001). EA Systems (2003) have identified over 500 potentially contaminating mine features in 11 domains in the Bakers Creek sub-catchment. There are undoubtedly many more. It is not possible, nor is it safe or practical given current technologies, to attempt to quantify point source contamination emanating from over 500 individual mine features. It is instead, beneficial to identify those highest relative contributors to overall contaminant loads, and selectively remediate those, if safe and possible to do so.

GHD attempted to identify areas within the Bakers Creek sub catchment that contribute contaminant loads disproportionally large relative to their contributing sub-catchment spatial area, and therefore, discharge. This process was hindered somewhat by:

- it being relatively dry during GHD's field sampling, therefore, only 15 surface water samples were able to be collected
- the lack of provision of surface water monitoring data by Hillgrove Mines
- the lack of stream gauging data in the Bakers Creek sib-catchment that would allow for quantified historic flow data to be utilised in calculating contaminant fluxes from certain sub-catchments within the Bakers Creek sub-catchment

- the steep nature of the terrain and therefore safety considerations
- the budget for the project, and therefore the time available to traverse the Bakers Creek sub-catchment (i.e. three full days).

Nonetheless, Section 7 of this report provides GHD’s attempt to locate some of the largest contaminant contributors within the Bakers Creek sub-catchment.

Appendix B – Summary table of sites visited

Mine	Europambela	Mickey Mouse Adit	Rockvale Arsenic	Tulloch Silver	Ruby Silver	Mary Anderson	Khans Creek	Keys Prospect
Sub-Catchment	Aspley	Chandler	Chandler	Chandler	Chandler	Commissioners Waters	Chandler	Chandler
Size of sub catchment (km2)	1781.21	1186.08	1186.08	1186.08	1186.08	476.67	1186.08	1186.08
Mine	Europambela	Mickey Mouse Adit	Rockvale Arsenic	Tulloch Silver	Ruby Silver	Mary Anderson	Khans Creek Prospect	Keys Prospect
Other Site Names	Little Wonder Copper Mine	-	-	-	-	-	Khans Creek	-
Distance to nearest town	Walcha 11 Km	Armidale 90.4 km	Armidale 44 km	Armidale 41 km	Armidale 45 km	Armidale 8 km	Armidale 88 km	Armidale 91 km
Approximate Date of Mine abandonment	1884	1910	Early 20th century	1980s	1902	1930	Unknown	Unknown
Commodities	Gold, Copper and Silver	No production, however lead, copper and silver were the commodities sought	Arsenic	Gold, lead and Silver	Arsenic, Copper, lead, Silver zinc	Gold possible arsenic and antimony	Copper, Gold, lead and zinc	Copper, Lead, zinc
Date of Inspection	11/09/2015	13/09/2015	9/09/2015	10/09/2015	10/09/2015	11/09/2015	12/09/2015	13/9/15 Could not access
GPS coordinates (zone GDA94 - MGA 56)	E 374397.796	405232	403349	401472	401977	371393	407256	404706.082
	N 6571018.829	6598892	6637738	6638384	6635469	6629571	6596113	6598689.833
General Site Data	Former Shaft - Filled in with general rubbish from the farm. One waste dump and a dam is immediately down gradient of the waste dump and former shaft. Site is generally tidy	Adit and open cut Site is generally tidy	Shafts (one across Lambs Valley Creek), four waste dumps, possible onsite processing. Site is generally tidy. Some recent exploration boreholes have occurred	Shafts - fenced off, foundations of mill and other structures. There was onsite processing and known to have process Phoenix gold ore. The site was generally tidy. Of note there were several dead sheep within the fenced perimeter of the mine site	Waste Dumps and shafts. Uncertain if any onsite processing occurred (unlikely). The site was generally tidy	Waste dumps, filled in shafts and adits. No mine structures or onsite processing. The site was generally tidy	Waste dumps, shafts and adits and small underground workings. No remaining mine structures. There was onsite mine processing and scrap metals was scattered across the site.	Unknown
Heritage Items	None	None	none	Foundations of former the mill processing area and fenced off shafts	Open Shaft	None	Shafts, miners camp near sediment sample #2. Some piping and other infrastructure	Unknown
Rehabilitation	Undertaken by farmer to fill in the shaft	None	Waste dump area has been fenced off. Original waste dumps have been flattened and shafts infilled.	Previous rehabilitation as described in the main report.	Farmer - bulldozed some of the shafts	Bulldozed mine shafts	None	Unknown
Surface materials	Mostly benign. Some acid and sulphide bearing around the waste dump	Benign	Heavy metals and sulphide bearing soils on and around the waste dumps areas	Benign, some sulphide bearing zones but mostly covered.	Mostly benign with some limited sulphide bearing	Benign and uncertain	acid and sulphide bearing especially at the 2nd highest waste dump level	Unknown
Stability of Surface materials	Slight erosion and slumping	Stable	Gully erosion, leaching and seepage with some subsidence especially around the southern waste dump	Scalding around the former mill and tailings dam, leeching round the dams, and slight erosion	Slight erosion, undercutting and slumping along the shaft line with possible collapse. Some scalding on surface	Slight erosion	erosion and slumping. Adit between the 2nd and third level has collapsed	Unknown
Landform	Gentle slope to Aspley River.	Hillslope (near bank of river)	Sloped down to lambs valley creek	Sloped down to Boundary creek	Gently sloped	Gently sloped	Steep hillside	Unknown

Mine	Europambela	Mickey Mouse Adit	Rockvale Arsenic	Tulloch Silver	Ruby Silver	Mary Anderson	Khans Creek	Keys Prospect
Distance to nearest water course	413 m	5 m	306 m	There is a drainage line running adjacent to the mine, some areas had ponded water. Nearest flowing water course is Boundary creek 590 m west	200 m of unnamed water course	<5 m unnamed water course	A small drainage channel runs adjacent to the mine, with the Chandler river 1.15 km east of the mine	
Site Cover	80- 100 % grasses and indicative of the surrounding farmland. No coverage over former waste dump	Grasses and weeds, consistent with surrounding area. Rock outcrops	Grasses around 60 - 80 % coverage and consistent with the area except on and around the waste dumps.	Grasses 80-100 % and is consistent with the surrounding area. Some evidence of toxic soils	80-100 % grasses and consistent with surrounding area. scalding in places around shafts and waste dumps	80-100 % of shrubs and grasses and consistent with the surrounding area. Small amounts of scalding near waste dumps	0-20 % no cover with some regrowth around the site. Evidence of precipitate - zinc sulphide at waste dump #2	Unknown
Hazards	Area around former shaft has some subsidence but stable	Adit is open	Subsidence at southern waste dump and seepage water in drainage channel from southern waste dump	One of the shafts that has been fenced off has subsided and is undermined the fencing.	Shafts and subsidence	Pockmarked landscape - no real hazard	Steep terrain and tricky access	Unknown
Access	Easy	Hard	Easy	Easy	Easy	Easy	Hard	Impossible
Distance from site perimeter	55 m from Moona Plains Road	No perimeter, however across the River from a camp site	< 5 m from perimeter fence then Tulloch Road	2.7 km to Lyndhurst Road entry	2.7 km from Chandler Road	340 m from Cluny Road	1km from unlocked gate (no fence)	Unknown
Safety Rating	Low Risk Rating	Low Risk Ranking	Low Risk Ranking	Medium Risk ranking (due to subsidence at the shaft)	Low risk ranking	Medium risk ranking	Medium risk ranking	Unknown
Environment Risk Rating	Moderate	Negligible	High	Moderate	High	High	High	Negligible
Recommendations	Refer main report	Refer main report	Refer main report	Refer main report	Refer main report	Refer main report	Refer main report	Refer main report

Mine	Mungay Creek Antimony	Kapunda Arsenic	Phoenix Gold
Sub-Catchment	Hickeys and Mungay Creek	Commissioners waters	Chandler
Size of sub catchment (km2)	186.46	476.67	1186.08
Mine	Mungay Creek Antimony	Kapunda Arsenic	Phoenix Gold
Other Site Names	Munga Creek	-	Comet
Distance to nearest town	Willawarrin 8.5 km	Armidale 10 Km	Armidale 34 km
Approximate Date of Mine abandonment	1974	1928	1992
Commodities	Antimony	Arsenic	Gold
Date of Inspection	15/09/2015 - Could not fully access due to unsure of land ownership. Revisited on 12/2/16 - only accessed Peter Thorpe's property	11/09/2015	9/09/2015
GPS coordinates (zone GDA94 - MGA 56)	469523	374058	398599
	6577378	6632395	6637343
General Site Data	One waste dump was found near lower adit. On site processing did occur at the mine site. There were several adits, shafts and tailings dams during mine operation but could not be located during the site inspection. Domestic rubbish and scrap metal	Shafts, pits and waste dump. Foundations of possible winder/crusher. Uncertain of onsite processing. Rubble remaining on ground with landfill in the open pits	Shafts and areas of former waste dumps
Heritage Items	Foundations of former amenities and other infrastructure	Concrete foundations of possible former mill.	none
Rehabilitation	No obvious remediation. However; the former mine features including the tailings dam were unable to be located.	Farmer- bulldozed general farm rubbish in open hole	The area was in the process of being remediated by WSP on behalf Hillgrove Resources. Wayne however has thrown them offsite due to imported mulch that contains a high amount of general landfill plastic rubbish. All shafts have been fenced off and covered with concrete, dams have been lined and the remaining small amount of exposed waste ore is located above the dams.
Surface materials	Evidence of orange staining in the creek line only	Benign	Exposed waste dump is acid producing but limited area
Stability of Surface materials	Stable surfaces	Slumping and possible collapse	Gully and sheet erosion with leaching and seepage
Landform	slight slope	slight slope	Gentle slop

Mine	Mungay Creek Antimony	Kapunda Arsenic	Phoenix Gold
Distance to nearest water course	adjacent to Deep Creek	150 m west to Tilbuster ponds	350 m to tributary of Boundary creek
Site Cover	80-100% coverage with weeds and shrubs	80-100% grass coverage and consistent with the surrounding area	Shrubs, grasses and weeds cover 60-80% of the mine
Hazards	None	possible slumping	none
Access	Moderate	Easy	Easy
Distance from site perimeter	405 m from fenced perimeter of mines road	100 m to paddock fence gate	370 m from access road gate
Safety Rating	Medium risk ranking	Medium risk ranking	Low risk ranking
Environment Risk Rating	High	High	High
Recommendations	Refer main report	Refer main report	Refer main report

Appendix C – Data Quality Objectives and QA/QC assessment

Data Quality Objectives and QA/QC Assessment

Data quality objectives

Overview

The Data Quality Objective (DQO) process was applied to the investigation, as described below, to ensure that data collection method and analyses were appropriate to achieve the project objectives.

A process for establishing data quality objectives for site investigations has been defined by the National Environment Protection (Assessment of Site Contamination) Measure (1999 amended 2013). The DQO process involved seven steps as defined below.

Step 1: State the problem

Macleay Catchment: Previous investigations have identified contamination sources associated with historical mines located in the Macleay Catchment. The problem is that there remains limited information to identify the main contamination sources within chosen sub-catchments (based on the Stage 1 assessment).

Bakers Creek Sub-Catchment: The 'problem' is that the Bakers Creek sub-catchment has over 500 historical mine features that have been demarcated to be the responsibility of DoI, Bracken or whose responsibility remains unknown (EA Systems 2003). Limited geochemical characterisation for the purposes of application to this Project has been undertaken in the Bakers Creek sub-catchment and more information is required to identify derelict mine features that are contributing relatively significant arsenic and / or antimony contaminant loads, and subsequently, prioritise them for remediation.

Step 2: Identify the decisions

Key decisions to be made based on the results of the investigation are summarised as follows:

- Identify point sources that are contributing relatively significant arsenic and / or antimony contaminant loads.
- Quantify the extent, volume and concentration of arsenic and antimony contamination at the identified point sources and/or sites on a priority basis.
- For the Bakers Creek sub-catchment, compare the relative arsenic and antimony contribution from each sub-catchment with sediment loads already entrained within Bakers Creek to attempt to demarcate contributing sub-catchments.

Step 3: Identify inputs to the decision

Data to be input to the decision making process includes:

- Information from previous reports.
- Field observations.
- Quantitative arsenic and antimony analytical data obtained during the mineral waste, sediment and surface water sampling. Additional surface water, sediment and mineral waste data was collected using the methodology outlined in Section 3 of the main report.

Step 4: Define the study boundaries

The boundaries of the study are stated in the objectives of the study (Section 1.2), the scope of works (Section 1.3), the site assessment criteria (Section 4) and the sampling methodology (Section 3).

With respect to physical boundaries, the lateral boundaries of the investigation area are defined on Figure 1.

The temporal boundaries of the investigation are 9 to 15 September 2015 and 9 to 12 February 2016. Where previous data is used, it is assumed to be unchanged from the time of sampling and analysis.

Step 5: Develop a decision rule

In order to decide whether the data obtained is precise, accurate, reliable and reproducible at the time of the assessment, field and laboratory quality control and quality assurance (QA/QC) procedures were utilised throughout the sampling programs. Further, all sampling work was carried out in accordance with GHD’s Standard Field Operating Procedures, which are based on standard industry practice.

It is noted that the laboratory’s limit detection for antimony in sediments of 5 mg/kg is higher than the nominated screening criteria. Whilst imperfect, it does not affect the overall assessment, as the objectives for the study are to use the data as a screening tool only to calculate the areas that are the highest contributors of antimony and arsenic into the catchment.

QA/QC results were compared to nominal acceptance limits. On the basis of this comparison, a decision was made as to whether the data was appropriate for the purpose of the investigation.

Step 6: Specify limits on decision errors

Two primary decision error-types may occur due to uncertainties or limitations in the project data set:

- A sample/area may be deemed to pass the nominated criteria, when in fact it does not. This may occur if contamination is ‘missed’ due to limitations in the sampling plan, or if the project analytical data set is unreliable.
- A sample/area may be deemed to fail the nominated criteria, when in fact it does not. This may occur if the project analytical data set is unreliable, due to inappropriate sampling, sample handling, or analytical procedures.

An assessment will be made as to the likelihood of a decision error being made based on the results of a QA/QC assessment and the closeness of the data to the assessment criteria. The QA/QC assessment will include reference these data quality indicators.

It remains important to remember that this study was commissioned to determine the highest arsenic and antimony point sources contributing to the Macleay contaminant loads, rather than as a traditional contaminated sites investigation.

Step 7: Optimise the design for obtaining data

This was achieved through the preparation of a sampling, analysis and quality plan, which was reviewed and refined as necessary during the Stage 2 and 2a assessment evaluating field observations and analytical results.

Quality Assurance (QA) procedures were used and Quality Control (QC) samples collected to allow evaluation of data quality indicators (DQIs). Details of quality control procedures that were followed during the course of sampling are provided below.

Data quality indicators

DQIs have been established for representativeness, completeness, comparability, precision and accuracy.

The DQIs for sampling techniques and laboratory analysis of collected samples identify the acceptable level of error for this investigation. The DQI were assessed by reference to the following data quality indicators.

Data Representativeness - expresses the degree which sample data accurately and precisely represents a characteristic of a population or an environmental condition. Representativeness is achieved by collecting samples in an appropriate pattern across the site, and by using an adequate number of sample locations to characterise the site. Consistent and repeatable sampling techniques and methods are utilised throughout the sampling.

Completeness - defined as the percentage of measurements made which are judged to be valid measurements. The completeness goal is set at there being sufficient valid data generated during the study. If there is insufficient valid data, then additional data are required to be collected.

Comparability - is a qualitative parameter expressing the confidence with which one data set can be compared with the other. This is achieved through maintaining a level of consistency in techniques used to collect samples and ensuring analysing laboratories use consistent analysis techniques and reporting methods.

Precision - measures the reproducibility of measurements under a given set of conditions. The precision of the data is assessed by calculating the Relative Percent Difference (RPD) between duplicate sample pairs.

$$RPD(\%) = \frac{|C_o - C_d|}{C_o + C_d} \times 200$$

Where C_o = Analyte concentration of the original sample

C_d = Analyte concentration of the duplicate sample

GHD adopts a nominal acceptance criterion of 30% RPD for field duplicates and splits for inorganics and a nominal acceptance criterion of 50% RPD for field duplicates and splits for organics. However, it is noted that this will not always be achieved, particularly in heterogeneous soil or fill materials, or at low analyte concentrations.

Accuracy - measures the bias in a measurement system. Accuracy can be undermined by such factors as field contamination of samples, poor preservation of samples, poor sample preparation techniques and poor selection of analytical techniques by the analysing laboratory. Accuracy is assessed by reference to the analytical results of laboratory control samples, laboratory spikes, laboratory blanks and analyses against reference standards.

Quality assurance (QA) and quality control (QC)

Field programme

All fieldwork was conducted in general accordance with GHD's Standard Field Operating Procedures, which are aimed at ensuring that all environmental samples are collected using a set of uniform and systematic methods, as required by GHD's Quality Assurance system. Key requirements of these procedures are as follows:

- Sample identification procedures – once collected, samples are immediately transferred to sample containers of appropriate composition and preservation for the required laboratory analysis for surface water. Mineral waste and sediment were in appropriate containers for their analytical requirements. All sample containers are clearly labelled with a sample number, sample location, sample date and sampler's initials. The sample containers are then to be transferred to a chilled ice box for sample preservation prior to and during shipment to the testing laboratory.
- Sample QA/AC – one field duplicate sample will be collected per 10 samples for sediment and surface water.
- Chain of custody information requirements - chain-of-custody forms are completed and forwarded to the testing laboratory.

Laboratory programme

The project laboratory (ALS Group) adopted their internal procedures and NATA accredited methods in accordance with their quality assurance systems. The Practical Quantitation Limit (PQL) for all analytes was suitable to allow comparison with applicable site criteria, wherever made possible by currently available commercial analytical laboratory techniques.

Laboratory quality control

A summary of laboratory QA/QC procedures implemented during the project is provided in Table C1.

Table C1 Laboratory QA/QC programme

Procedure	Description	Acceptance Limits
Laboratory Duplicate Sample	The analytical laboratory collects duplicate sub samples from one sample submitted for analytical testing at a rate equivalent to one in twenty samples per analytical batch, or one sample per batch if less than twenty samples are analysed in a batch. A laboratory duplicate provides data on the analytical precision and reproducibility of the test result.	If contaminant concentration is less than 10 times the (PQL): no RPD limit. If concentration 10 to 20 times the PQL: 0% to 50% RPD. If greater than 20 times the PQL: 0% to 20% RPD
Spiked Sample	An authentic field sample is 'spiked' by adding an aliquot of known concentration of the target analyte(s) prior to sample extraction and analysis. A spike documents the effect of the sample matrix on the extraction and analytical techniques. Spiked samples will be analysed for each batch where samples are analysed for organic chemicals of concern.	70-130% recovery for metals / inorganics and 60-140% for organics
Surrogate Standard / Spike	These are organic compounds which are similar to the analyte of interest in terms of chemical composition, extractability, and chromatographic conditions (retention time), but which are not normally found in environmental samples. These surrogate compounds are 'spiked' into blanks, standards and samples submitted for organic analyses by gas-chromatographic techniques prior to sample extraction. Surrogate Standard/Spikes provide a means of checking that no gross errors have occurred	60% - 140% recovery (organics only)

Procedure	Description	Acceptance Limits
	during any stage of the test method leading to significant analyte loss.	
Method Blank	Usually an organic or aqueous solution that is as free as possible of analytes of interest to which is added all the reagents, in the same volume, as used in the preparation and subsequent analysis of the samples. The reagent blank is carried through the complete sample preparation procedure and contains the same reagent concentrations in the final solution as in the sample solution used for analysis. The reagent blank is used to correct for possible contamination resulting from the preparation or processing of the sample.	<PQL

The laboratory is required to provide this information to GHD. Although, the individual testing laboratories conduct an assessment of the laboratory QC programme, the results are also independently reviewed and assessed by GHD.

Laboratory duplicate samples should return RPDs within the NEPM acceptance criteria of ±30%. The percentage recovery is used to assess spiked samples and surrogate standards. The percentage recovery, although dependent on the type of analyte tested, the concentrations of analytes, and the sample matrix; should normally range from about 70 to 130%. Method (laboratory) blanks should return analyte concentrations as ‘below the PQL’.

QA/QC

Field program sediment

Sediment duplicate samples were collected and analysed for the contaminants of potential concern at a rate of 10%. Duplicates were as follows:

- QA01 / BC_SD19
- QA02 / BC_SD25
- QA03 / BC_SD32
- QA04 / MC_SD02
- QC02 10/9/15 / RS_SD02
- QC04 13/9/15 / MM_SD02
- QC05 15/9/15 / WB_SD01

Table C2 provides a summary of the RPD exceedances.

Table C2 Sediment duplicate – RPD % exceedances

Field ID	Analyte	RPD %	Comment
QC02 10/9/15 / RS_SD02	Net acid production potential	57	Results are less than 10 times the EQL and therefore the RPD is not meaningful.
	Aluminium	48	Marginally over heterogeneous nature of the material.
	Bicarbonate (& Alkalinity)	64	Marginally over and heterogeneous nature of the material.
QC04 13/9/15 / MM_SD02	Lead	52	Results are less than 10 times the EQL and therefore the RPD is not meaningful.
	Bicarbonate (& Alkalinity)	88	Marginally over heterogeneous nature of the material.

Field ID	Analyte	RPD %	Comment
QC05 15/9/15 / WB_SD01	Electrical Conductivity	57	Marginal exceedance and a field parameter.
	Calcium	133	Results are less than 10 times the EQL and therefore the RPD is not meaningful.
	Magnesium	100	
	Sodium	52	Marginal exceedance and heterogeneous nature of the material.
	Sulphate	72	Heterogeneous nature of the material.
QA01 / BC_SD19	moisture	76	Marginal exceedance and heterogeneous nature of the material.
	calcium	55	Results are less than 10 times the EQL and therefore the RPD is not meaningful.
	magnesium	67	
QA02 / BC_SD25	Sulphur as S (%)	67	Heterogeneous nature of the material.
	electrical Conductivity	54	
	moisture	104	
	Silica	98	
	Sulphur as S	120	
	Silicon	97	
	Calcium	67	Results are less than 10 times the EQL and therefore the RPD is not meaningful.
	Magnesium	67	
	Sodium	143	
	Sulphate	106	Heterogeneous nature of the material.
QA03 / BC_SD32	electrical Conductivity	70	Heterogeneous nature of the material
	Silica	152	
	Silicon	152	
	Sodium	150	
	Sulphate	67	
QA04 / MC_SD02	Arsenic	94	Results are less than 10 times the EQL and therefore the RPD is not meaningful.
	Nickel	40	
	Silicon	47	Heterogeneous nature of the material
	Zinc	33	Results are less than 10 times the EQL and therefore the RPD is not meaningful.
	Magnesium	86	
	Potassium	70	Heterogeneous nature of the material

Overall the vast majority of the QA/QC from the field programme met the required RPD limits, and it is considered that the above exceedances do not affect the integrity of the overall dataset. Most exceedances are likely to be due to the inherent heterogeneity of the sediment.

Importantly, only 1 RPD exceeding 50% was returned for arsenic; one of the two key analytes under the terms of reference.

In summary, the sediment sampling programme and analytical data was considered to meet the appropriate QA/QC standards.

Field program surface water

Surface water duplicate samples were collected and analysed for the contaminants of potential concern at a rate of 10 %. Duplicates were as follows:

- QA01 / BC_SW19
- QA03 / BC_SW32
- QC01 / TS_SW04
- QC03 / KP_SW03
- QC06 / WB_SW01

Table C3 provides a summary of the RPD exceedances.

Table C3 Surface water duplicates – RPD % exceedances

Field ID	Analyte	RPD %	Comment
QC01 / TS_SW04	Arsenic	67	Results are less than 10 times the EQL and therefore the RPD is not meaningful.
	Nickel	67	
QC03 / KP_SW03	Copper	67	Results are less than 10 times the EQL and therefore the RPD is not meaningful.
	Zinc	67	
	acidity	67	
	potassium	67	
QC04 / BC_SW19	TOC	67	Results are less than 10 times the EQL and therefore the RPD is not meaningful.
	Copper (filtered)	67	
	Nickel	67	
QA03 / BC_SW32	Arsenic	40	Results are less than 10 times the EQL and therefore the RPD is not meaningful.
	Copper	120	
	Nickel (filtered)	67	

Overall the majority of the QA/QC from the surface water field programme met the required criteria, and it is considered that the above exceedances did not affect the integrity of the overall dataset.

Importantly, only 2 RPDs exceeding 50% were returned for arsenic; one of the two key analytes under the terms of reference.

Laboratory programme

The NATA certified laboratory utilised for this assessment (ALS) completed their own quality assurance and quality control procedures for sample analysis. GHD has reviewed the internal laboratory control data provided within the laboratory reports, which are available as a separate file.

Laboratory reports associated with this assessment were:

- ES1530957
- ES1531313
- EB1532334
- ES1603307
- ES1606081

Method Blanks

Method blanks were analysed for each laboratory report. There were no detectable concentrations of any analytes reported in the method blanks for any of the reports.

Laboratory Control Samples (LCS)

Analysis of a LCS was analysed for each laboratory report. In all instances the recoveries were within the laboratories internal QA/QC requirements (70%-130% for inorganics/metals (applicable), 60%-140% for organics (N/A) and 10%-140% for SVOC and speciated phenols (both N/A) - with the exception of laboratory report ES1603307 which had acidity recovery less than lower control limit.

Matrix Spikes

Analysis of matrix spikes was undertaken for each laboratory report and all were within the acceptable range except for the following in Table C4 below.

Table C4 Matrix spike outliers

Sample ID	Analyte	Results / Comment
Laboratory report ES1531313		
Phoenix Comet Gold Mine Waste #2	Arsenic	Not determined / MS Recovery not determined, background level greater than or equal to 4x spike level
Phoenix Comet Gold Mine Waste #2	Copper	142% / Recovery greater than upper data quality objective
Laboratory report ES1603307		
Bakers Creek Mine Waste	Arsenic	Not determined / MS recovery not determined, background level greater than or equal to 4x spike level

Holding Times

In most instances soil, surface water and sediment samples were analysed within the holding times as recommended by testing laboratories, based on holding times set out in the NEPM (2013). Exceedances of holding times are discussed below:

- Laboratory report ES1531313: All mineral waste samples (21) were outside the holding times for pH and EC. 5 mine waste samples were outside the holding times for moisture content. 19 water samples were outside the holding times for pH
- Laboratory report ES1530957: All water samples (13) were outside the holding times for pH.
- Laboratory report ES1603307: 18 water samples were outside the holding times for pH and one sample was outside the holding time for TDS.
- Laboratory report ES1606081: 7 mineral waste samples were outside the holding times for total sulfur by LECO.

None of the holding time exceedances are considered material due to most of the exceedances being for pH and has a holding time of 24 hours. pH was collected in the field to confirm laboratory results. Mineral waste was collected from exposure rock surfaces and therefore holding times are not applicable.

Laboratory Duplicates

ALS's quality control acceptance criteria for duplicates are that for less than ten times the PQL, any relative percent difference (RPD) any RPD is acceptable, and for any sample greater 10 and 20 x PQL 0-50% is acceptable and results greater than 20 x PQL than 0-20% is acceptable. Table C5 shows the exceedances for the laboratory duplicate.

Table C5 Laboratory duplicate outliers

Sample ID	Analyte	Comment
Laboratory report: ES1531313		
Mungay Creek Mine Waste #1	Aluminium	RPD exceeds LOR based limits
Mungay Creek Mine Waste #1	Antimony	RPD exceeds LOR based limits
Mary Anderson Mine Waste Dump #2	Arsenic	RPD exceeds LOR based limits
Phoenix Comet Gold Mine Waste #1	Copper	RPD exceeds LOR based limits
KC_SD01	Lead	RPD exceeds LOR based limits
Laboratory report: ES1530957		
RS_SD01	Alkalinity	RPD exceeds LOR based limits
Laboratory report ES1603307		
BC_SD02	Silica	RPD exceeds LOR based limits
Anonymous	Aluminium	RPD exceeds LOR based limits

In summary, all of the RPD exceedances were reported for mineral waste and sediment which are expected to show higher variation, compared to homogeneous water samples.

Summary of QA/QC results

Overall the QA/QC data for this project are considered to meet the adopted standards and therefore the data were considered to be of sufficient quality to for the purposes of this assessment.

Appendix D – Results summary tables

Appendix D
Table A
Mineral Waste Geochemistry

				NAG				ABA								pH (Saturated Paste)	Inorganics		Alkalinity				Major Ions			
				pHOX	NAG (pH 4.5)	NAG (pH 7.0)	Fizz Rating	Total Sulphur (LECO)	Sulphate	Sulfide S (calc)	Maximum potential acidity	ANC as H2SO4	NAPP	NAPP (using Sulfide S)	NPR	pH (Saturated Paste)	Electrical conductivity (lab)	pH (Lab)	Alkalinity (Carbonate as CaCO3)	Alkalinity (total as CaCO3)	Bicarbonate Alkalinity as CaCO3	Acidity	Calcium	Magnesium	Potassium	Sodium
				pH Units	kg H2SO4/t	kg H2SO4/t	Fizz Unit	mg/kg	mg/kg	mg/kg	kg H2SO4/t	kg H2SO4/t	kg H2SO4/t	kg H2SO4/t	Ratio	pH Unit	µS/cm	pH Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL				0.1	0.1	0.1	0	100	10	10	-	0.5	0.5	0.5	0.1	0.1	1	0.1	1	1	1	1	10	10	10	10
NEPM 2013 Table 1A(1) HILs Res A Soil																										
NEPM 2013 Table 1A(1) HILs Rec C Soil																										
Monitoring_Zone	**Field_ID**	**Location_Code**	**Sampled_Date**																							
Aspley	EUROPAMBELA MINE WASTE DUMP #1 - 11/9/15	E MINE WASTE #1	11-Sep-15	5.0	<0.1	0.9	0	4600	480	4120	12.61	0.11	13	12.50	0.0	5.6	263	3.9	<5	<5	<5	1040	100	30	60	<10
Aspley	EUROPAMBELA MINE WASTE DUMP #2 - 11/9/15	E MINE WASTE #2	11-Sep-15	4.0	0.4	2.2	0	4900	200	4700	14.38	<0.05	15	14.38	0.0	4.4	138	3.9	<5	<5	<5	926	20	20	30	<10
Chandler	KHANS CREEK WASTE DUMP #1 - 12/9/15	KC WASTE DUMP #1	12-Sep-15	5.2	<0.1	0.7	0	3200	580	2620	8.02	1.2	8.6	6.82	0.1	4.9	291	3.7	<5	<5	<5	860	60	40	10	<10
Chandler	KHANS CREEK WASTE DUMP #2 - 12/9/15	KC WASTE DUMP #2	12-Sep-15	2.7	9.8	22.9	0	29,800	5730	24070	73.65	<0.05	91.2	73.65	0.0	3.9	1780	3	<5	<5	<5	5010	60	320	<10	<10
Chandler	KHANS CREEK WASTE DUMP #3 - 12/9/15	KC WASTE DUMP #3	12-Sep-15	6.3	<0.1	1.3	1	8700	90	8610	26.35	9	17.6	17.35	0.3	6	53	5.6	<5	56	56	209	10	10	20	<10
Chandler	MICKEY MOUSE MINE WASTE #1 - 13/9/15	MM MINE WASTE #1	13-Sep-15	3.0	6	8.8	1	7100	990	6110	18.70	13.8	7.9	4.90	0.7	6.8	522	6.7	<5	50	50	14	130	210	30	80
Chandler	PHOENIX COMET GOLD MINE WATSE #1 - 9/9/15	PC MINE WASTE #1	09-Sep-15	3.8	0.8	2.8	0	1300	260	1040	3.18	<0.05	4	3.18	0.0	4.3	234	3.5	<5	<5	<5	679	20	10	20	<10
Chandler	PHOENIX COMET GOLD MINE WATSE #2 - 9/9/15	PC MINE WASTE #2	09-Sep-15	4.1	0.4	1.5	0	3500	1750	1750	5.36	<0.05	10.7	5.36	0.0	4	741	3.4	<5	<5	<5	1620	390	60	10	<10
Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #1 - 9/9/15	RA MINE WASTE #1	09-Sep-15	4.2	0.3	1.5	0	2700	240	2460	7.53	<0.05	8.3	7.53	0.0	4.4	192	3.5	<5	<5	<5	826	20	<10	20	10
Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #2 - 9/9/15	RA MINE WASTE #2	09-Sep-15	4.0	0.6	2.3	0	3000	340	2660	8.14	<0.05	9.2	8.14	0.0	4.3	270	3.4	<5	<5	<5	940	10	20	20	<10
Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #3 - 9/9/15	RA MINE WASTE #3	09-Sep-15	3.6	1.3	3	0	3800	3520	280	0.86	<0.05	11.6	0.86	0.0	3.7	1240	2.8	<5	<5	<5	3700	30	60	<10	<10
Chandler	RUBY SILVER WASTE DUMP #1 - 10/9/15	RS WASTE DUMP #1	10-Sep-15	4.6	<0.1	1.1	0	3700	2700	1000	3.06	<0.05	11.3	3.06	0.0	5.2	1010	3.9	<5	<5	<5	1240	1070	30	50	10
Chandler	RUBY SILVER WASTE DUMP #2 - 10/9/15	RS WASTE DUMP #2	10-Sep-15	4.5	<0.1	1.9	0	900	140	760	2.33	<0.05	2.8	2.33	0.0	4.8	119	4.1	<5	<5	<5	1040	10	20	30	30
Chandler	TULLOCH MILL WASTE #1 - 10/9/15	T MILL WASTE #1	10-Sep-15	3.3	2.6	2.8	0	5800	520	5280	16.16	<0.05	17.7	16.16	0.0	5	220	4.8	<5	6	6	323	160	10	40	<10
Chandler	TULLOCH MILL WASTE #2 - 10/9/15	T MILL WASTE #2	10-Sep-15	5.9	<0.1	0.5	0	300	380	0	0.00	<0.05	0.9	0.00	NA	5	213	4.5	<5	<5	<5	636	60	40	40	40
Commissioners Waters	KAPUNDA ARSENIC MINE WASTE DUMP #1 - 11/9/15	KA MINE WASTE #1	11-Sep-15	7.6	<0.1	<0.1	1	1100	70	1030	3.15	15.2	-11.8	-12.05	4.8	7.2	104	7	<5	168	168	133	60	10	50	<10
Commissioners Waters	MARY ANDERSEN MINE WASTE DUMP #1 - 11/9/15	MA MINE WASTE #1	11-Sep-15	6.3	<0.1	0.5	0	400	20	380	1.16	2.8	-1.6	-1.64	2.4	6.7	90	6.1	<5	87	87	233	40	20	50	<10
Commissioners Waters	MARY ANDERSEN MINE WASTE DUMP #2 - 11/9/15	MA MINE WASTE #2	11-Sep-15	6.7	<0.1	0.4	0	700	50	650	1.99	2.8	-0.6	-0.81	1.4	6	80	5.6	<5	56	56	309	30	20	50	<10
Commissioners Waters	MARY ANDERSEN MINE WASTE DUMP #3 - 11/9/15	MA MINE WASTE #3	11-Sep-15	7.0	<0.1	<0.1	0	900	250	650	1.99	1.2	1.6	0.79	0.6	5.8	200	5.7	<5	62	62	432	70	40	110	<10
Hickeys and Mungay Creeks	MUNGAY CREEK MINE WASTE #1 - 15/9/15	MC MINE WASTE #1	15-Sep-15	4.0	0.8	2.8	0	1200	30	1170	3.58	<0.05	3.7	3.58	0.0	6.7	22	6.1	<5	19	19	14	<10	<10	10	<10
Hickeys and Mungay Creeks	Mungay Ck Ore Dump	Mungay Ck ore dump	12-Feb-16	3.7	1.2	2.8	0	1,800	40	1760	5.39	<0.05	5.4	5.39	0.0	4.9	56	4.6	<5	192	192	1880	<10	<10	20	40

Appendix D
Table B
Mineral Waste Metal Results

					Metals									
					Aluminium	Antimony	Arsenic	Cadmium	Chromium (III+VI)	Copper	Lead	Mercury	Nickel	Zinc
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					50	5	5	1	2	5	5	0.1	2	5
NEPM 2013 EIL-Areas of Ecological Significance							40			20	470		5	15
NEPM 2013 EIL-Urban Residential- Public Open Space							100			60	1100		30	70
US EPA (2015) Residential Soil Screening Level - Residential Soil						31								
US EPA (2015) Residential Soil Screening Level - Industrial Soil						470								
Site_ID	**Monitoring_Zone**	**Field_ID**	**Location_Code**	**Sampled_Date**										
Macleay River Catchment	Aspley	EUROPAMBELA MINE WASTE DUMP #1 - 11/9/15	E MINE WASTE #1	11-Sep-15	7380	<5	71	<1	19	985	87	2.1	6	73
Macleay River Catchment	Aspley	EUROPAMBELA MINE WASTE DUMP #1 - 11/9/15	E MINE WASTE #1	11-Sep-15	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Aspley	EUROPAMBELA MINE WASTE DUMP #2 - 11/9/15	E MINE WASTE #2	11-Sep-15	17,400	<5	32	<1	33	745	43	1.1	10	68
Macleay River Catchment	Bakers Creek	BAKERS CREEK MINE WASTE	Bakers Creek MW	10-Feb-16	6880	313	2700	<1	11	60	23	1	24	83
Macleay River Catchment	Bakers Creek	BAKERS CREEK MINE WASTE-10/2/16	Bakers Creek MW	10-Feb-16	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Bakers Creek	BLACK LODE (1700) MINE WASTE	Black Lode (1700) MW	10-Feb-16	9170	887	510	<1	12	33	15	0.2	16	89
Macleay River Catchment	Bakers Creek	BLACK LODE (1700) MINE WASTE-10/2/16	Black Lode (1700) MW	10-Feb-16	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Bakers Creek	BRACKINS SPUR MINE WASTE #1	Brackins Spur MW	09-Feb-16	13,800	20	1090	<1	83	7	21	0.1	22	47
Macleay River Catchment	Bakers Creek	BRACKINS SPUR MINE WASTE #1-9/2/16	Brackins Spur MW	09-Feb-16	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Bakers Creek	COSMOPOLITAN MINE WASTE	Cosmopolitan MW	11-Feb-16	11,200	3480	1570	<1	18	33	19	0.5	11	71
Macleay River Catchment	Bakers Creek	COSMOPOLITAN MINE WASTE-11/2/16	Cosmopolitan MW	11-Feb-16	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Bakers Creek	LADY HOPETOUN MINE WASTE	Lady Hopetoun MW	11-Feb-16	4690	113	930	<1	11	16	49	0.7	12	79
Macleay River Catchment	Bakers Creek	LADY HOPETOUN MINE WASTE-11/2/16	Lady Hopetoun MW	11-Feb-16	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Bakers Creek	SMITH'S MINE WASTE	Smith's Mine Waste	09-Feb-16	8900	2150	2560	<1	9	22	20	0.3	9	111
Macleay River Catchment	Bakers Creek	SMITH'S MINE WASTE-9/2/16	Smith's Mine Waste	09-Feb-16	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Chandler	KHANS CREEK WASTE DUMP #1 - 12/9/15	KC WASTE DUMP #1	12-Sep-15	18,500	24	194	7	22	1040	6400	6.7	13	4880
Macleay River Catchment	Chandler	KHANS CREEK WASTE DUMP #2 - 12/9/15	KC WASTE DUMP #2	12-Sep-15	24,300	74	334	16	34	5620	39,200	57.9	9	12,400
Macleay River Catchment	Chandler	KHANS CREEK WASTE DUMP #2 - 12/9/15	KC WASTE DUMP #2	12-Sep-15	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Chandler	KHANS CREEK WASTE DUMP #3 - 12/9/15	KC WASTE DUMP #3	12-Sep-15	30,800	165	674	5	39	6220	41,800	49.5	18	7520
Macleay River Catchment	Chandler	KHANS CREEK WASTE DUMP #3 - 12/9/15	KC WASTE DUMP #3	12-Sep-15	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Chandler	MICKEY MOUSE MINE WASTE #1 - 13/9/15	MM MINE WASTE #1	13-Sep-15	14,100	190	15	<1	14	303	66	<0.1	15	404
Macleay River Catchment	Chandler	MICKEY MOUSE MINE WASTE #1 - 13/9/15	MM MINE WASTE #1	13-Sep-15	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Chandler	PHOENIX COMET GOLD MINE WATSE #1 - 9/9/15	PC MINE WASTE #1	09-Sep-15	6400	18	230	<1	12	489	37	<0.1	5	12
Macleay River Catchment	Chandler	PHOENIX COMET GOLD MINE WATSE #2 - 9/9/15	PC MINE WASTE #1	09-Sep-15	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Chandler	PHOENIX COMET GOLD MINE WATSE #2 - 9/9/15	PC MINE WASTE #2	09-Sep-15	3590	108	308	<1	5	80	91	0.1	4	13
Macleay River Catchment	Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #1 - 9/9/15	RA MINE WASTE #1	09-Sep-15	9070	48	40,400	2	10	342	371	0.2	4	121
Macleay River Catchment	Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #1 - 9/9/15	RA MINE WASTE #1	09-Sep-15	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #2 - 9/9/15	RA MINE WASTE #2	09-Sep-15	9010	68	36,500	3	13	488	617	0.6	4	178
Macleay River Catchment	Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #2 - 9/9/15	RA MINE WASTE #2	09-Sep-15	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #3 - 9/9/15	RA MINE WASTE #3	09-Sep-15	4250	286	74,300	2	6	1080	535	0.7	<2	36
Macleay River Catchment	Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #3 - 9/9/15	RA MINE WASTE #3	09-Sep-15	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Chandler	RUBY SILVER WASTE DUMP #1 - 10/9/15	RS WASTE DUMP #1	10-Sep-15	4220	210	8420	<1	4	37	515	2.1	4	58
Macleay River Catchment	Chandler	RUBY SILVER WASTE DUMP #1 - 10/9/15	RS WASTE DUMP #1	10-Sep-15	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Chandler	RUBY SILVER WASTE DUMP #2 - 10/9/15	RS WASTE DUMP #2	10-Sep-15	7080	29	1190	<1	7	11	18	0.2	3	16
Macleay River Catchment	Chandler	TULLOCH MILL WASTE #1 - 10/9/15	T MILL WASTE #1	10-Sep-15	3660	2220	904	<1	29	326	245	0.9	18	177
Macleay River Catchment	Chandler	TULLOCH MILL WASTE #1 - 10/9/15	T MILL WASTE #1	10-Sep-15	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Chandler	TULLOCH MILL WASTE #2 - 10/9/15	T MILL WASTE #2	10-Sep-15	11,300	7	69	<1	9	8	16	<0.1	3	23
Macleay River Catchment	Commissioners Waters	KAPUNDA ARSENIC MINE WASTE DUMP #1 - 11/9/15	KA MINE WASTE #1	11-Sep-15	9300	422	1640	<1	34	47	136	0.7	32	188
Macleay River Catchment	Commissioners Waters	KAPUNDA ARSENIC MINE WASTE DUMP #1 - 11/9/15	KA MINE WASTE #1	11-Sep-15	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Commissioners Waters	MARY ANDERSEN MINE WASTE DUMP #1 - 11/9/15	MA MINE WASTE #1	11-Sep-15	9320	619	244	<1	10	32	25	0.2	19	87
Macleay River Catchment	Commissioners Waters	MARY ANDERSEN MINE WASTE DUMP #2 - 11/9/15	MA MINE WASTE #2	11-Sep-15	15,900	656	394	<1	14	30	30	0.7	11	63
Macleay River Catchment	Commissioners Waters	MARY ANDERSEN MINE WASTE DUMP #3 - 11/9/15	MA MINE WASTE #3	11-Sep-15	4460	7890	1170	<1	4	35	56	0.4	17	96
Macleay River Catchment	Commissioners Waters	MARY ANDERSEN MINE WASTE DUMP #3 - 11/9/15	MA MINE WASTE #3	11-Sep-15	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Hickeys and Mungay Creeks	MUNGAY CREEK MINE WASTE #1 - 15/9/15	MC MINE WASTE #1	15-Sep-15	1550	4080	24	<1	4	16	21	4.5	<2	16
Macleay River Catchment	Hickeys and Mungay Creeks	MUNGAY CREEK MINE WASTE #1 - 15/9/15	MC MINE WASTE #1	15-Sep-15	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Hickeys and Mungay Creeks	MUNGAY CREEK ORE DUMP	Mungay Ore Dump	12-Feb-16	5020	2430	90	<1	5	15	18	0.9	2	15
Macleay River Catchment	Hickeys and Mungay Creeks	MUNGAY CREEK ORE DUMP 12/2/16	Mungay Ore Dump	12-Feb-16	-	-	-	-	-	-	-	-	-	-

Appendix D
Table C
Mineral Waste Leaching Results

						Metals									
						Aluminium	Antimony	Arsenic	Cadmium	Chromium (III+VI)	Copper	Lead	Mercury	Nickel	Zinc
						mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL						0.01	0.001	0.001	0.0001	0.001	0.001	0.001	0.0001	0.001	0.005
ANZECC 95%						0.055	0.009	0.024	0.0002	0.001	0.0014	0.0034	0.0006	0.011	0.008
							(low reliabilty)								
Monitoring_Zone	**Field_ID**	**Location_Code**	**Sampled_Date**	**Matrix_Type**	**Matrix**										
Aspley	EUROPAMBELA MINE WASTE DUMP #1 - 11/9/15	E MINE WASTE #1	11-Sep-15	SOIL	leachate	**0.01**	0.002	<0.001	0.0002	<0.001	**0.072**	<0.001	<0.0001	0.01	**0.802**
Chandler	KHANS CREEK WASTE DUMP #2 - 12/9/15	KC WASTE DUMP #2	12-Sep-15	SOIL	leachate	**6.26**	0.002	0.002	**0.209**	**0.003**	**4.6**	**4.17**	0.0002	**0.012**	**123**
Chandler	KHANS CREEK WASTE DUMP #3 - 12/9/15	KC WASTE DUMP #3	12-Sep-15	SOIL	leachate	0.02	<0.001	<0.001	**0.0124**	<0.001	**0.01**	**0.006**	<0.0001	0.002	**1.64**
Chandler	MICKEY MOUSE MINE WASTE #1 - 13/9/15	MM MINE WASTE #1	13-Sep-15	SOIL	leachate	0.02	**0.02**	<0.001	<0.0001	<0.001	**0.002**	0.003	<0.0001	<0.001	**0.024**
Chandler	PHOENIX COMET GOLD MINE WATSE #2 - 9/9/15	PC MINE WASTE #1	09-Sep-15	Soil	leachate	**2.28**	**0.027**	**0.034**	**0.0004**	<0.001	**0.604**	0.001	<0.0001	0.009	**1.42**
Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #1 - 9/9/15	RA MINE WASTE #1	09-Sep-15	SOIL	leachate	0.28	**0.01**	**0.322**	**0.0023**	<0.001	**0.134**	<0.001	<0.0001	0.001	**0.683**
Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #2 - 9/9/15	RA MINE WASTE #2	09-Sep-15	SOIL	leachate	**1.06**	0.007	**0.171**	**0.0102**	0.001	**0.572**	<0.001	<0.0001	0.005	**0.759**
Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #3 - 9/9/15	RA MINE WASTE #3	09-Sep-15	SOIL	leachate	**12.4**	**0.013**	**0.106**	**0.0161**	**0.004**	**5.92**	<0.001	<0.0001	0.005	**0.378**
Chandler	RUBY SILVER WASTE DUMP #1 - 10/9/15	RS WASTE DUMP #1	10-Sep-15	SOIL	leachate	**0.08**	**0.095**	**0.78**	**0.0006**	<0.001	**0.011**	<0.001	<0.0001	**0.016**	**1.19**
Chandler	TULLOCH MILL WASTE #1 - 10/9/15	T MILL WASTE #1	10-Sep-15	SOIL	leachate	0.11	**0.153**	0.017	<0.0001	<0.001	**0.01**	**0.006**	<0.0001	0.006	**0.084**
Commissioners Waters	KAPUNDA ARSENIC MINE WASTE DUMP #1 - 11/9/15	KA MINE WASTE #1	11-Sep-15	SOIL	leachate	**2.49**	**0.314**	**0.528**	<0.0001	**0.006**	**0.019**	**0.04**	0.0002	**0.012**	**0.455**
Commissioners Waters	MARY ANDERSEN MINE WASTE DUMP #3 - 11/9/15	MA MINE WASTE #3	11-Sep-15	SOIL	leachate	**1.3**	**2.35**	**0.209**	<0.0001	<0.001	**0.014**	**0.043**	0.0001	**0.012**	**0.633**
Hickeys and Mungay Creeks	MUNGAY CREEK MINE WASTE #1 - 15/9/15	MC MINE WASTE #1	15-Sep-15	SOIL	leachate	**0.56**	**3.2**	0.003	<0.0001	<0.001	**0.002**	0.002	0.0004	<0.001	**0.068**

Appendix D
Table D
Sediment Geochemistry

				NAG				ABA								pH (Saturated Paste)	Inorganics		Alkalinity				Major Ions			
				pHOX	NAG (pH 4.5)	NAG (pH 7.0)	Fizz Rating	Total Sulphur (LECO)	Sulphate	Sulfide S (calc)	Maximum potential acidity	ANC as H2SO4	NAPP	NAPP (using Sulfide S)	NPR	pH (Saturated Paste)	Electrical conductivity (lab)	pH (Lab)	Alkalinity (Carbonate as CaCO3)	Alkalinity (total as CaCO3)	Bicarbonate Alkalinity as CaCO3	Acidity	Calcium	Magnesium	Potassium	Sodium
				pH Units	kg H2SO4/t	kg H2SO4/t	Fizz Unit	mg/kg	mg/kg	mg/kg	kg H2SO4/t	kg H2SO4/t	kg H2SO4/t	kg H2SO4/t	Ratio	pH Unit	µS/cm	pH Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL				0.1	0.1	0.1	0	100	10	10	-	0.5	0.5	0.5	0.1	0.1	1	0.1	1	1	1	1	10	10	10	10
NEPM 2013 Table 1A(1) HILs Res A Soil																										
NEPM 2013 Table 1A(1) HILs Rec C Soil																										
Monitoring_Zone	**Field_ID**	**Location_Code**	**Sampled_Date**																							
Aspley	E_SD01 11/9/15	E_SD01	11-Sep-15	7.1	<0.1	<0.1	0	300	<10	295	0.90	6.4	-5.5	-5.5	7.1	6.3	68	6.4	<5	486	486	180	10	<10	20	<10
Aspley	E_SD02 11/9/15	E_SD02	11-Sep-15	6.8	<0.1	0.2	0	200	<10	195	0.60	4.7	-4.1	-4.1	7.9	6	61	6.6	<5	268	268	209	10	<10	20	20
Aspley	EUROPAMBELA MINE DAM SEDIMENT - 11/9/15	E MINE DAM SEDIMENT	11-Sep-15	8.4	<0.1	<0.1	1	200	80	120	0.37	13.8	-13.2	-13.4	37.6	7.3	71	7	<5	237	237	223	20	10	<10	30
Chandler	AR_SD01 9/9/15	RA_SD01	09-Sep-15	7	<0.1	<0.1	0	200	<10	195	0.60	3.5	-2.9	-2.9	5.9	5.8	55	6.1	<5	64	64	148	10	<10	20	10
Chandler	AR_SD02 9/9/15	RA_SD02	09-Sep-15	7.1	<0.1	<0.1	0	400	10	390	1.19	4	-2.8	-2.8	3.4	5.5	33	6.3	<5	18	18	53	<10	<10	10	20
Chandler	AR_SD03 9/9/15	RA_SD03	09-Sep-15	6.4	<0.1	0.4	0	400	120	280	0.86	<0.5	1.2	0.6	0.3	4.9	87	5.6	<5	19	19	220	20	10	20	<10
Chandler	C_SD01 14/9/15	C_SD01	14-Sep-15	7.4	<0.1	<0.1	1	200	<10	195	0.60	10.7	-10.1	-10.1	17.9	6.8	16	7.7	<5	44	44	17	<10	<10	<10	<10
Chandler	C_SD02 14/9/15	C_SD02	14-Sep-15	7.8	<0.1	<0.1	1	200	<10	195	0.60	21.1	-20.5	-20.5	35.4	7.2	10	7.3	<5	62	62	21	<10	<10	<10	<10
Chandler	KC_SD01 12/9/15	KC_SD01	12-Sep-15	7	<0.1	<0.1	0	300	<10	295	0.90	5.6	-4.7	-4.7	6.2	6.8	26	7.2	<5	399	399	24	<10	<10	10	<10
Chandler	KC_SD02 12/9/15	KC_SD02	12-Sep-15	6.3	<0.1	0.5	1	700	10	690	2.11	12.8	-10.6	-10.7	6.1	7.4	161	7.4	<5	3170	3170	218	60	10	100	<10
Chandler	KP_SD01 13/9/15	KP_SD01	13-Sep-15	7.3	<0.1	<0.1	0	200	<10	195	0.60	4.6	-4	-4.0	7.7	7.5	20	7.6	<5	218	218	24	<10	<10	<10	<10
Chandler	KP_SD02 13/9/15	KP_SD02	13-Sep-15	7.6	<0.1	<0.1	1	300	10	290	0.89	8	-7.1	-7.1	9.0	5.5	19	6.5	<5	187	187	152	<10	<10	<10	10
Chandler	KP_SD03 13/9/15	KP_SD03	13-Sep-15	6.9	<0.1	0.4	0	300	40	260	0.80	3.1	-2.2	-2.3	3.9	5.2	24	6.3	<5	368	368	864	10	<10	<10	40
Chandler	MM_SD01 13/9/15	MM_SD01	13-Sep-15	7.2	<0.1	<0.1	1	600	210	390	1.19	9.6	-7.8	-8.4	8.0	6.6	110	6.4	<5	711	711	332	20	60	10	50
Chandler	MM_SD02 13/9/15	MM_SD02	13-Sep-15	7.3	<0.1	<0.1	1	200	<10	195	0.60	9.6	-9	-9.0	16.1	6.5	28	6.6	<5	75	75	38	<10	<10	<10	<10
Chandler	PG_SD01 9/9/15	PG_SD01	09-Sep-15	7.3	<0.1	<0.1	0	600	20	580	1.77	8.9	-7.1	-7.1	5.0	6.2	47	6.8	<5	68	68	89	10	<10	20	30
Chandler	PG_SD02 9/9/15	PG_SD02	09-Sep-15	7.4	<0.1	<0.1	0	500	40	460	1.41	5.6	-4.1	-4.2	4.0	6.5	113	7.1	<5	154	154	243	60	30	30	40
Chandler	PG_SD03 9/9/15	PG_SD03	09-Sep-15	6.9	<0.1	0.3	0	1500	450	1050	3.21	<0.5	4.6	3.0	0.1	4	186	4.4	<5	11	11	1410	80	40	20	30
Chandler	RS_SD01 10/9/15	RS_SD01	10-Sep-15	6.4	<0.1	0.8	0	500	20	480	1.47	2.1	-0.6	-0.6	1.4	5.2	41	6	<5	75	75	295	20	10	60	20
Chandler	RS_SD02 10/9/15	RS_SD02	10-Sep-15	6.8	<0.1	0.3	0	400	<10	395	1.21	0.8	<0.5	0.4	0.7	4.7	10	5.7	<5	15	15	499	<10	<10	<10	<10
Chandler	SS_SD01 13/9/15	SS_SD01	13-Sep-15	7.6	<0.1	<0.1	1	300	<10	295	0.90	10.9	-10	-10.0	12.1	6.4	51	6.6	<5	437	437	171	<10	<10	<10	30
Chandler	TS_SD01 10/9/15	TS_SD01	10-Sep-15	6.8	<0.1	0.6	0	300	10	290	0.89	3.7	-2.8	-2.8	4.2	5.4	24	6.6	<5	67	67	410	20	40	60	20
Chandler	TS_SD02 10/9/15	TS_SD02	10-Sep-15	6.2	<0.1	2.6	0	5100	760	4340	13.28	4.4	11.2	8.9	0.3	4.7	154	5.9	<5	71	71	623	150	50	10	100
Chandler	TS_SD03 10/9/15	TS_SD03	10-Sep-15	7.2	<0.1	<0.1	0	200	<10	195	0.60	5	-4.4	-4.4	8.4	6	21	6.4	<5	37	37	65	<10	<10	<10	10
Chandler	TS_SD04 10/9/15	TS_SD04	10-Sep-15	7	<0.1	<0.1	0	200	<10	195	0.60	4.5	-3.9	-3.9	7.5	6.3	21	6.7	<5	46	46	48	<10	<10	<10	<10
Commissioners Waters	KA_SD01 11/9/15	KA_SD01	11-Sep-15	7.1	<0.1	<0.1	0	200	<10	195	0.60	6.3	-5.7	-5.7	10.6	7.1	70	7.1	<5	998	998	119	20	30	20	20
Commissioners Waters	KA_SD02 11/9/15	KA_SD02	11-Sep-15	6.8	<0.1	0.2	0	200	<10	195	0.60	3.7	-3.1	-3.1	6.2	6.3	37	6.7	<5	193	193	109	<10	<10	<10	10
Commissioners Waters	MA_SD01 11/9/15	MA_SD01	11-Sep-15	6.8	<0.1	0.2	0	600	130	470	1.44	3.6	-1.8	-2.2	2.5	5.9	94	6.6	<5	474	474	280	50	100	40	100
Commissioners Waters	MA_SD02 11/9/15	MA_SD02	11-Sep-15	6.7	<0.1	0.4	1	200	<10	195	0.60	8.6	-8	-8.0	14.4	6.3	34	6.8	<5	330	330	209	30	50	30	20
Hickeys and Mungay Creeks	MG_SD01 15/9/15	MG_SD01	15-Sep-15	7.3	<0.1	<0.1	1	300	70	230	0.70	12.9	-12	-12.2	18.3	4.7	50	5.6	<5	137	137	437	<10	<10	10	20
Hickeys and Mungay Creeks	MC_SD02	MC_SD02	12-Feb-16	7	<0.1	<0.1	0	300	50	250	0.77	1.5	-0.6	-0.7	2.0	6.3	22	6.3	<5	146	146	580	40	150	270	140
Hickeys and Mungay Creeks	MC_SD03	MC_SD03	12-Feb-16	7.9	<0.1	<0.1	0	50	30	20	0.06	5.7	-5.7	-5.6	93.1	7.6	21	7.1	<5	417	417	95	<10	<10	20	60
Toorumbee Creek and Warbro Creek	WB_SD01 15/9/15	WB_SD01	15-Sep-15	7.4	<0.1	<0.1	0	400	160	240	0.73	1.8	-0.6	-1.1	2.5	4.4	142	5.2	<5	100	100	1010	10	<10	<10	170

Appendix D
Table E
Sediment Metal Results

Monitoring_Zone	SampleCode	Field_ID	Location_Code	Sampled_Date	Aluminium	Antimony	Arsenic	Cadmium	Chromium (III+VI)	Copper	Lead	Mercury	Nickel	Silicon	Zinc
					Metals										
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					50	5	5	1	2	5	5	0.1	2	1	5
Baseline GHD Stage 1 2015						1.2	12.48								
ANZECC 2000 ISQG -Low						2	20	1.5	80	65	50	0.15	21		200
ANZECC 2000 ISQG -High						25	70	10	370	270	220	1	52		410
Aspley	ES1531313045	EUROPAMBELA MINE DAM SEDIMENT - 11/9/15	E MINE DAM SEDIMENT	11-Sep-15	30,200	<5	9	<1	76	286	12	<0.1	33	-	38
Aspley	ES1531313001	E_SD01 11/9/15	E_SD01	11-Sep-15	5340	<5	8	<1	61	12	<5	<0.1	23	-	22
Aspley	ES1531313002	E_SD02 11/9/15	E_SD02	11-Sep-15	7960	<5	6	<1	28	12	5	<0.1	19	-	21
Chandler	ES1531313016	C_SD01 14/9/15	C_SD01	14-Sep-15	8780	<5	7	<1	12	5	<5	<0.1	8	-	36
Chandler	ES1531313017	C_SD02 14/9/15	C_SD02	14-Sep-15	8910	<5	7	<1	13	6	5	<0.1	9	-	37
Chandler	ES1531313007	KC_SD01 12/9/15	KC_SD01	12-Sep-15	12,900	8	24	9	21	292	643	0.6	21	-	4460
Chandler	ES1531313008	KC_SD02 12/9/15	KC_SD02	12-Sep-15	9570	<5	<5	<1	10	19	65	0.2	8	-	69
Chandler	ES1531313009	KP_SD01 13/9/15	KP_SD01	13-Sep-15	8940	<5	9	<1	8	26	82	0.2	12	-	330
Chandler	ES1531313010	KP_SD02 13/9/15	KP_SD02	13-Sep-15	13,200	<5	6	<1	15	15	35	0.1	11	-	123
Chandler	ES1531313011	KP_SD03 13/9/15	KP_SD03	13-Sep-15	21,300	<5	15	<1	29	27	23	0.1	22	-	72
Chandler	ES1531313012	MM_SD01 13/9/15	MM_SD01	13-Sep-15	20,400	<5	7	5	24	57	31	0.2	19	-	1870
Chandler	ES1531313013	MM_SD02 13/9/15	MM_SD02	13-Sep-15	11,400	<5	8	<1	14	8	17	0.1	10	-	67
Chandler	ES1531313014	QC04 13/9/15	MM_SD02	13-Sep-15	9730	<5	6	<1	12	7	10	<0.1	9	-	50
Chandler	ES1530957015	PG_SD01 9/9/15	PG_SD01	09-Sep-15	3360	<5	5	<1	18	22	5	<0.1	7	-	16
Chandler	ES1530957016	PG_SD02 9/9/15	PG_SD02	09-Sep-15	11,300	<5	119	<1	25	138	29	0.4	41	-	195
Chandler	ES1530957017	PG_SD03 9/9/15	PG_SD03	09-Sep-15	8210	13	106	<1	14	194	17	<0.1	8	-	24
Chandler	ES1530957018	AR_SD01 9/9/15	RA_SD01	09-Sep-15	5210	<5	17	<1	8	6	10	<0.1	4	-	26
Chandler	ES1530957019	AR_SD02 9/9/15	RA_SD02	09-Sep-15	3260	<5	87	<1	7	6	19	<0.1	3	-	38
Chandler	ES1530957020	AR_SD03 9/9/15	RA_SD03	09-Sep-15	4860	14	3600	6	10	396	205	<0.1	2	-	130
Chandler	ES1530957025	RS_SD01 10/9/15	RS_SD01	10-Sep-15	17,900	<5	9	<1	37	25	14	<0.1	20	-	65
Chandler	ES1530957026	RS_SD02 10/9/15	RS_SD02	10-Sep-15	6080	<5	13	<1	11	7	6	<0.1	5	-	23
Chandler	ES1530957027	QC02 10/9/15	RS_SD02	10-Sep-15	3730	<5	14	<1	12	8	6	<0.1	6	-	26
Chandler	ES1531313015	SS_SD01 13/9/15	SS_SD01	13-Sep-15	13,500	<5	8	<1	16	12	18	<0.1	12	-	81
Chandler	ES1530957021	TS_SD01 10/9/15	TS_SD01	10-Sep-15	14,000	8	143	<1	17	9	20	<0.1	6	-	25
Chandler	ES1530957022	TS_SD02 10/9/15	TS_SD02	10-Sep-15	11,600	106	691	2	10	116	90	0.1	9	-	193
Chandler	ES1530957023	TS_SD03 10/9/15	TS_SD03	10-Sep-15	7960	<5	15	<1	37	8	10	<0.1	20	-	47
Chandler	ES1530957024	TS_SD04 10/9/15	TS_SD04	10-Sep-15	7230	<5	16	<1	34	8	8	<0.1	25	-	43
Commissioners Waters	ES1531313003	KA_SD01 11/9/15	KA_SD01	11-Sep-15	14,400	<5	36	<1	42	15	8	<0.1	20	-	28
Commissioners Waters	ES1531313004	KA_SD02 11/9/15	KA_SD02	11-Sep-15	6280	<5	41	<1	17	6	<5	<0.1	14	-	18
Commissioners Waters	ES1531313005	MA_SD01 11/9/15	MA_SD01	11-Sep-15	18,400	27	21	<1	131	20	12	0.1	43	-	30
Commissioners Waters	ES1531313006	MA_SD02 11/9/15	MA_SD02	11-Sep-15	22,700	<5	14	<1	138	29	13	<0.1	74	-	32
Hickeys and Mungay Creeks	ES1603307057	MC_SD02	MC_SD02	12-Feb-16	8760	83	72	<1	11	12	17	0.2	8	2820	35
Hickeys and Mungay Creeks	ES1603307059	QA04	MC_SD02	12-Feb-16	9280	70	26	<1	9	13	13	0.2	12	1740	49
Hickeys and Mungay Creeks	ES1603307058	MC_SD03	MC_SD03	12-Feb-16	8040	<5	16	<1	10	10	13	<0.1	8	176	40
Hickeys and Mungay Creeks	ES1531313018	MG_SD01 15/9/15	MG_SD01	15-Sep-15	9610	307	16	<1	12	21	15	0.4	10	-	60
Toorumbee Creek and Warbro Creek	ES1531313019	WB_SD01 15/9/15	WB_SD01	15-Sep-15	11,700	<5	30	<1	12	11	12	0.2	10	-	43
Toorumbee Creek and Warbro Creek	ES1531313020	QC05 15/9/15	WB_SD01	15-Sep-15	13,100	<5	30	<1	12	13	14	0.2	11	-	45

Appendix D
Table F
Sediment Leaching Results

Monitoring_Zone	Field_ID	Location_Code	Sampled_Date	Matrix_Description	Metals: Aluminium	Metals: Antimony	Metals: Arsenic	Metals: Cadmium	Metals: Chromium (III+VI)	Metals: Copper	Metals: Lead	Metals: Mercury	Metals: Nickel	Metals: Zinc
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL					0.01	0.001	0.001	0.0001	0.001	0.001	0.001	0.0001	0.001	0.005
ANZECC (2000) Freshwater 95%					**0.055**	**0.009** (low reliabilty)	**0.024**	**0.0002**	**0.001**	**0.0014**	**0.0034**	**0.0006**	**0.011**	**0.008**
Aspley	E_SD02 11/9/15	E_SD02	11-Sep-15	Leachate	**7.58**	<0.001	0.005	<0.0001	**0.029**	**0.008**	**0.004**	<0.0001	**0.017**	**0.164**
Chandler	AR_SD03 9/9/15	RA_SD03	09-Sep-15	Leachate	**3.7**	**0.464**	**1.45**	**0.003**	**0.004**	**0.166**	**0.172**	<0.0001	0.002	**0.153**
Chandler	C_SD01 14/9/15	C_SD01	14-Sep-15	Leachate	**2.14**	<0.001	0.003	<0.0001	**0.002**	**0.003**	0.002	<0.0001	<0.001	**0.089**
Chandler	KC_SD01 12/9/15	KC_SD01	12-Sep-15	Leachate	**3.55**	0.002	0.012	**0.0026**	**0.007**	**0.049**	**0.108**	0.0003	0.005	**1.25**
Chandler	KP_SD01 13/9/15	KP_SD01	13-Sep-15	Leachate	**3.45**	<0.001	0.007	0.0001	**0.003**	**0.008**	**0.024**	0.0001	0.002	**0.21**
Chandler	MM_SD01 13/9/15	MM_SD01	13-Sep-15	Leachate	**13.4**	<0.001	0.004	**0.0008**	**0.014**	**0.015**	**0.01**	<0.0001	0.008	**0.709**
Chandler	PG_SD03 9/9/15	PG_SD03	09-Sep-15	Leachate	**1.19**	**0.028**	0.006	**0.0004**	<0.001	**0.032**	**0.005**	<0.0001	0.01	**0.099**
Chandler	RS_SD02 10/9/15	RS_SD02	10-Sep-15	Leachate	**4.29**	0.001	**0.034**	<0.0001	**0.005**	**0.004**	**0.004**	<0.0001	0.003	**0.211**
Chandler	SS_SD01 13/9/15	SS_SD01	13-Sep-15	Leachate	**1.89**	<0.001	0.004	<0.0001	**0.002**	**0.003**	**0.004**	<0.0001	0.001	**0.12**
Chandler	TS_SD02 10/9/15	TS_SD02	10-Sep-15	Leachate	**1.02**	**0.026**	**0.639**	**0.0003**	**0.001**	**0.023**	**0.014**	<0.0001	0.002	**0.185**
Commissioners Waters	KA_SD02 11/9/15	KA_SD02	11-Sep-15	Leachate	**3.19**	0.002	**0.038**	<0.0001	**0.01**	**0.003**	0.003	<0.0001	0.006	**0.088**
Commissioners Waters	MA_SD02 11/9/15	MA_SD02	11-Sep-15	Leachate	**116**	<0.001	0.014	<0.0001	**0.296**	**0.09**	**0.02**	<0.0001	**0.23**	**0.6**
Hickeys and Mungay Creeks	MG_SD01 15/9/15	MG_SD01	15-Sep-15	Leachate	**9.89**	**0.684**	0.01	<0.0001	**0.012**	**0.014**	**0.012**	0.0002	0.006	**0.307**
Hickeys and Mungay Creeks	MC_SD02	MC_SD02	12-Feb-16	Leachate	**1.2**	**0.135**	0.002	<0.0001	0.001	0.001	<0.001	<0.0001	<0.001	0.04
Hickeys and Mungay Creeks	MC_SD03	MC_SD03	12-Feb-16	Leachate	**1.41**	0.003	0.001	<0.0001	0.002	<0.001	<0.001	<0.0001	<0.001	0.044

Appendix D
Table G
Surface Water Results

Monitoring_Zone	SampleCode	Field_ID	Location_Code	Sampled_Date	Inorganics						Metals																		Acidity	Alkalinity			
					Electrical conductivity (lab)	pH (Lab)	Total Dissolved Solids	Total Organic Carbon	Bicarbonate	Carbonate	Antimony	Antimony (Filtered)	Arsenic	Arsenic (Filtered)	Cadmium	Cadmium (Filtered)	Chromium (III+VI)	Chromium (III+VI) (Filtered)	Copper	Copper (Filtered)	Lead	Lead (Filtered)	Mercury	Mercury (Filtered)	Nickel	Nickel (Filtered)	Zinc	Zinc (Filtered)	Acidity (as CaCO3)	Alkalinity (Hydroxide as CaCO3)	Alkalinity (total as CaCO3)	Calcium (Filtered)	Chloride
					µS/cm	pH Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL					1	0.01	10	1	1	1	0.001	0.001	0.001	0.001	0.0001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001	0.0001	0.001	0.001	0.005	0.005	1	1	1	1	1
ADWG 2011 Aesthetic						6.5-8.5	600												1	1							3	3					250
ADWG 2011 Health											0.003	0.003	0.01	0.01	0.002	0.002			2	2	0.01	0.01	0.001	0.001	0.02	0.02							
ANZECC 2000 FW 95%													0.013[#1]	0.013[#1]	0.0002	0.0002	0.001[#2]	0.001[#2]	0.0014	0.0014	0.0034	0.0034	0.0006	0.0006	0.011	0.011	0.008	0.008					
ANZECC 2000 FW Med-Low Reliability											0.009	0.009	0.013[#1]	0.013[#1]	0.0002	0.0002			0.0014	0.0014	0.0034	0.0034			0.011	0.011	0.008	0.008					
Baseline GHD Stage 1 2015											**0.0025**	**0.0025**	**0.003**	**0.003**																			
ANZECC 2000 Irrigation - Short-term Trigger Values													2	2	0.05	0.05	1	1	5	5	10	10	0.002	0.002	2	2	5	5					
ANZECC 2000 Irrigation - Long-term Trigger Values													0.1	0.1	0.01	0.01	0.1	0.1	0.2	0.2	0.2	0.2	0.002	0.002	0.2	0.2	2	2					
ANZECC 2000 Stock Watering							4000[#3]						0.5	0.5	0.01	0.01	1	1	0.5[#4]	0.5[#4]	0.1	0.1	0.002	0.002	1	1	20	20				1000	
Monitoring_Zone	**SampleCode**	**Field_ID**	**Location_Code**	**Sampled_Date**																													
Aspley	ES1531313057	E_SW03	E_SW03	15-Sep-15	951	7.91	694	34	174	<1	<0.001	<0.001	0.002	0.001	<0.0001	<0.0001	0.007	<0.001	0.04	0.002	0.002	<0.001	<0.0001	<0.0001	0.011	0.005	0.011	<0.005	8	<1	174	54	151
Aspley	ES1531313058	E_SW01	E_SW01	11-Sep-15	220	7.77	120	13	80	<1	<0.001	<0.001	0.001	0.001	<0.0001	<0.0001	<0.001	<0.001	0.002	0.002	<0.001	<0.001	<0.0001	<0.0001	0.001	0.001	<0.005	<0.005	2	<1	80	14	17
Aspley	ES1531313059	E_SW02	E_SW02	11-Sep-15	220	7.68	130	13	80	<1	<0.001	<0.001	0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	0.002	0.001	<0.001	<0.001	<0.0001	<0.0001	0.002	<0.001	<0.005	<0.005	2	<1	80	13	17
Chandler	ES1530957001	PG_SW01	PG_SW01	09-Sep-15	266	7.92	138	18	87	<1	<0.001	<0.001	**0.005**	**0.004**	<0.0001	<0.0001	0.001	<0.001	0.005	0.004	<0.001	<0.001	<0.0001	<0.0001	0.002	0.002	0.006	<0.005	6	<1	87	13	22
Chandler	ES1530957002	PG_SW02	PG_SW02	09-Sep-15	416	7.86	220	12	66	<1	<0.001	<0.001	**0.01**	0.002	0.0001	<0.0001	<0.001	<0.001	0.021	0.013	<0.001	<0.001	<0.0001	<0.0001	0.012	0.008	0.042	0.02	6	<1	66	26	23
Chandler	ES1530957003	PG_SW03	PG_SW03	09-Sep-15	857	3.49	552	5	<1	<1	<0.001	<0.001	**0.007**	**0.004**	0.0045	0.0044	<0.001	<0.001	0.426	0.418	0.003	0.003	<0.0001	<0.0001	0.113	0.112	0.668	0.718	92	<1	<1	56	16
Chandler	ES1530957004	PG_SW04	PG_SW04	09-Sep-15	1580	3.09	852	3	<1	<1	**0.006**	**0.004**	**2.19**	**1.57**	0.0001	0.0001	<0.001	<0.001	0.006	0.001	<0.001	<0.001	<0.0001	<0.0001	0.144	0.118	0.584	0.542	411	<1	<1	84	24
Chandler	ES1530957005	AR_SW01	RA_SW01	09-Sep-15	143	7.12	98	6	25	<1	<0.001	<0.001	**0.008**	0.003	<0.0001	<0.0001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	<0.005	6	<1	25	6	17
Chandler	ES1530957006	AR_SW02	RA_SW02	09-Sep-15	219	7.55	156	6	42	<1	0.001	<0.001	**0.029**	**0.019**	<0.0001	<0.0001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	0.006	5	<1	42	12	28
Chandler	ES1530957007	AR_SW03	RA_SW03	09-Sep-15	930	4.36	430	3	<1	<1	0.002	0.002	**0.073**	**0.064**	0.0528	0.0498	<0.001	<0.001	2.52	2.42	0.002	0.002	<0.0001	<0.0001	0.035	0.031	3.01	2.98	34	<1	<1	72	28
Chandler	ES1530957008	RS_SW01	RS_SW01	10-Sep-15	135	7.13	250	19	33	<1	0.002	<0.001	**0.018**	0.001	0.0004	<0.0001	0.009	0.001	0.009	0.002	0.004	0.001	<0.0001	<0.0001	0.007	0.003	0.03	0.022	6	<1	33	7	15
Chandler	ES1530957009	RS_SW02	RS_SW02	10-Sep-15	125	7.48	132	22	42	<1	0.001	<0.001	**0.024**	**0.004**	0.0001	<0.0001	0.005	<0.001	0.007	0.003	0.004	<0.001	<0.0001	<0.0001	0.004	0.002	0.024	<0.005	5	<1	42	9	9
Chandler	ES1530957010	TS_SW01	TS_SW01	10-Sep-15	89	7.31	116	22	25	<1	**0.003**	0.002	**0.006**	0.001	<0.0001	<0.0001	0.003	<0.001	0.006	0.004	0.002	<0.001	<0.0001	<0.0001	0.004	0.002	0.01	<0.005	10	<1	25	3	9
Chandler	ES1530957011	TS_SW02	TS_SW02	10-Sep-15	550	6.77	234	6	6	<1	**0.009**	**0.008**	**0.026**	**0.006**	0.0002	0.0001	<0.001	<0.001	0.007	0.002	0.001	<0.001	<0.0001	<0.0001	0.002	0.002	0.068	0.062	13	<1	6	47	14
Chandler	ES1530957012	TS_SW03	TS_SW03	10-Sep-15	216	7.92	94	8	85	<1	<0.001	<0.001	<0.001	0.001	<0.0001	<0.0001	<0.001	<0.001	0.002	0.001	<0.001	<0.001	<0.0001	<0.0001	0.002	0.001	<0.005	<0.005	3	<1	85	13	11
Chandler	ES1530957013	TS_SW04	TS_SW04	10-Sep-15	218	7.99	94	8	83	<1	<0.001	<0.001	<0.001	0.002	<0.0001	<0.0001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.0001	<0.0001	0.002	0.002	<0.005	<0.005	2	<1	83	14	11
Chandler	ES1530957014	QC01	TS_SW04	10-Sep-15	218	8	97	8	83	<1	<0.001	<0.001	<0.001	0.001	<0.0001	<0.0001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.0001	<0.0001	0.001	0.002	<0.005	<0.005	2	<1	83	14	11
Chandler	ES1531313051	SS_SW01	SS_SW01	13-Sep-15	119	7.19	74	4	39	<1	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	0.007	<0.005	2	<1	39	8	8
Chandler	ES1531313052	C_SW01	C_SW01	14-Sep-15	186	7.48	94	4	62	<1	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	<0.005	2	<1	62	12	12
Chandler	ES1531313053	C_SW02	C_SW02	14-Sep-15	189	7.53	106	5	63	<1	<0.001	<0.001	0.002	<0.001	<0.0001	<0.0001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	<0.005	2	<1	63	13	12
Chandler	ES1531313064	KP_SW01	KP_SW01	13-Sep-15	516	7.24	265	2	68	<1	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	0.002	0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	0.04	0.037	6	<1	68	32	20
Chandler	ES1531313065	KP_SW02	KP_SW02	13-Sep-15	120	7.25	52	3	46	<1	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	0.006	2	<1	46	8	8
Chandler	ES1531313066	KP_SW03	KP_SW03	13-Sep-15	118	7.13	65	3	38	<1	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	0.01	<0.005	1	<1	38	7	8
Chandler	ES1531313067	NM_SW01	MM_SW01	13-Sep-15	120	7.12	48	3	39	<1	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	<0.005	2	<1	39	8	8
Chandler	ES1531313068	NM_SW02	MM_SW02	13-Sep-15	120	7.17	44	3	40	<1	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	<0.005	<1	<1	40	8	8
Chandler	ES1531313069	QC03	KP_SW03	13-Sep-15	117	6.78	52	3	36	<1	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	<0.005	2	<1	36	8	8
Commissioners Waters	ES1531313060	KA_SW01	KA_SW01	11-Sep-15	272	7.51	128	7	100	<1	<0.001	<0.001	**0.013**	**0.009**	<0.0001	<0.0001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	0.001	0.001	<0.005	<0.005	2	<1	100	16	16
Commissioners Waters	ES1531313061	KA_SW02	KA_SW02	11-Sep-15	278	7.92	144	7	105	<1	<0.001	<0.001	**0.014**	**0.009**	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	0.002	<0.005	<0.005	2	<1	105	16	17
Commissioners Waters	ES1531313062	MA_SW01	MA_SW01	11-Sep-15	1040	7.84	550	31	176	<1	**0.008**	**0.005**	**0.009**	**0.004**	<0.0001	<0.0001	0.001	<0.001	0.006	0.002	<0.001	<0.001	<0.0001	<0.0001	0.012	0.01	0.014	<0.005	10	<1	176	51	23
Commissioners Waters	ES1531313063	MA_SW02	MA_SW02	11-Sep-15	117	7.12	206	10	34	<1	0.001	<0.001	**0.006**	0.001	<0.0001	<0.0001	0.014	<0.001	0.009	0.002	0.002	<0.001	<0.0001	<0.0001	0.018	0.007	0.013	<0.005	6	<1	34	6	14
Hickeys and Mungay Creeks	ES1531313054	MC_SW01	MC_SW01	15-Sep-15	291	6.72	177	9	35	<1	**0.086**	**0.028**	**0.031**	**0.01**	<0.0001	<0.0001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	0.012	0.008	0.018	0.009	19	<1	35	14	34
Hickeys and Mungay Creeks	ES1603307018	MC_SW02	MC_SW02	11-Feb-16	186	6.76	157	10	55	<1	**0.015**	**0.007**	**0.006**	0.002	<0.0001	<0.0001	<0.001	<0.001	0.025	<0.001	0.002	<0.001	<0.0001	<0.0001	0.005	0.003	0.031	<0.005	8	<1	55	8	22
Hickeys and Mungay Creeks	ES1603307019	MC_SW03	MC_SW03	11-Feb-16	231	7.05	142	5	43	<1	0.002	0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	<0.005	4	<1	43	9	36
Toorumbee Creek and Warbro Creek	ES1531313055	WB_SW01	WB_SW01	15-Sep-15	426	7.97	223	1	147	<1	<0.001	<0.001	**0.004**	0.003	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	<0.005	5	<1	147	49	32
Toorumbee Creek and Warbro Creek	ES1531313056	QC06	WB_SW01	15-Sep-15	421	8.13	207	1	149	<1	<0.001	<0.001	**0.004**	0.003	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	<0.005	4	<1	149	49	32

Env Stds Description
ADWG 2011 Aesthetic:Version 3.1 Updated March 2015
ADWG 2011 Health:Version 3.1 Updated March 2015

Env Stds Comments
#1:As (V) used as conservative value
#2:Cr(VI) guideline has been adopted
#3:Cattles including dairy cattle
#4:Guideline value for sheep

Appendix D
Table G
Surface Water Results

Monitoring_Zone	SampleCode	Field_ID	Location_Code	Sampled_Date	Major Ions						
					Magnesium (Filtered)	Anions Total	Potassium (Filtered)	Sodium (Filtered)	Cations Total	Sulphate (Filtered)	Ionic Balance
					mg/L	meq/L	mg/L	mg/L	meq/L	mg/L	%
EQL					1	0.01	1	1	0.01	1	0.01
ADWG 2011 Aesthetic								*180*		*250*	
ADWG 2011 Health										*500*	
ANZECC 2000 FW 95%											
ANZECC 2000 FW Med-Low Reliability											
Baseline GHD Stage 1 2015											
ANZECC 2000 Irrigation - Short-term Trigger Values											
ANZECC 2000 Irrigation - Long-term Trigger Values											
ANZECC 2000 Stock Watering										1000	
Aspley	ES1531313057	E_SW03	E_SW03	15-Sep-15	44	9.32	8	54	8.87	76	2.46
Aspley	ES1531313058	E_SW01	E_SW01	11-Sep-15	9	2.16	5	13	2.13	4	-
Aspley	ES1531313059	E_SW02	E_SW02	11-Sep-15	9	2.16	4	13	2.06	4	-
Chandler	ES1530957001	PG_SW01	PG_SW01	09-Sep-15	11	2.59	3	25	2.72	11	-
Chandler	ES1530957002	PG_SW02	PG_SW02	09-Sep-15	17	3.97	4	30	4.1	96	1.7
Chandler	ES1530957003	PG_SW03	PG_SW03	09-Sep-15	30	7.28	4	25	7.54	*328*	1.75
Chandler	ES1530957004	PG_SW04	PG_SW04	09-Sep-15	35	15.6	5	24	17	*716*	4.28
Chandler	ES1530957005	AR_SW01	RA_SW01	09-Sep-15	4	1.31	2	13	1.24	16	-
Chandler	ES1530957006	AR_SW02	RA_SW02	09-Sep-15	8	2.02	2	19	2.13	19	-
Chandler	ES1530957007	AR_SW03	RA_SW03	09-Sep-15	50	-	5	26	-	*361*	-
Chandler	ES1530957008	RS_SW01	RS_SW01	10-Sep-15	4	1.14	9	8	1.26	3	-
Chandler	ES1530957009	RS_SW02	RS_SW02	10-Sep-15	5	1.09	4	10	1.4	<10	-
Chandler	ES1530957010	TS_SW01	TS_SW01	10-Sep-15	3	0.75	1	10	0.86	<10	-
Chandler	ES1530957011	TS_SW02	TS_SW02	10-Sep-15	21	5.16	1	23	5.1	223	0.55
Chandler	ES1530957012	TS_SW03	TS_SW03	10-Sep-15	12	2.18	2	11	2.16	8	-
Chandler	ES1530957013	TS_SW04	TS_SW04	10-Sep-15	12	2.2	2	11	2.22	11	-
Chandler	ES1530957014	QC01	TS_SW04	10-Sep-15	12	2.2	2	11	2.22	11	-
Chandler	ES1531313051	SS_SW01	SS_SW01	13-Sep-15	4	1.15	2	8	1.13	7	-
Chandler	ES1531313052	C_SW01	C_SW01	14-Sep-15	7	1.83	2	12	1.75	12	-
Chandler	ES1531313053	C_SW02	C_SW02	14-Sep-15	7	1.85	2	12	1.8	12	-
Chandler	ES1531313064	KP_SW01	KP_SW01	13-Sep-15	27	4.8	2	26	5	138	2.09
Chandler	ES1531313065	KP_SW02	KP_SW02	13-Sep-15	5	1.29	2	8	1.21	7	-
Chandler	ES1531313066	KP_SW03	KP_SW03	13-Sep-15	4	1.13	2	8	1.08	7	-
Chandler	ES1531313067	NM_SW01	MM_SW01	13-Sep-15	4	1.15	2	8	1.13	7	-
Chandler	ES1531313068	NM_SW02	MM_SW02	13-Sep-15	4	1.17	1	8	1.1	7	-
Chandler	ES1531313069	QC03	KP_SW03	13-Sep-15	4	1.09	1	8	1.1	7	-
Commissioners Waters	ES1531313060	KA_SW01	KA_SW01	11-Sep-15	14	2.72	2	17	2.74	13	-
Commissioners Waters	ES1531313061	KA_SW02	KA_SW02	11-Sep-15	15	2.85	2	18	2.87	13	-
Commissioners Waters	ES1531313062	MA_SW01	MA_SW01	11-Sep-15	48	10.6	2	121	11.8	*310*	5.28
Commissioners Waters	ES1531313063	MA_SW02	MA_SW02	11-Sep-15	5	1.12	4	12	1.34	2	-
Hickeys and Mungay Creeks	ES1531313054	MC_SW01	MC_SW01	15-Sep-15	11	2.64	1	19	2.46	47	-
Hickeys and Mungay Creeks	ES1603307018	MC_SW02	MC_SW02	11-Feb-16	7	-	<1	16	-	2	-
Hickeys and Mungay Creeks	ES1603307019	MC_SW03	MC_SW03	11-Feb-16	7	-	2	22	-	10	-
Toorumbee Creek and Warbro Creek	ES1531313055	WB_SW01	WB_SW01	15-Sep-15	10	4.28	2	20	4.19	21	1.02
Toorumbee Creek and Warbro Creek	ES1531313056	QC06	WB_SW01	15-Sep-15	10	4.3	2	20	4.19	20	1.24

Env Stds Description
ADWG 2011 Aesthetic:Version 3.1 Updated March 2015
ADWG 2011 Health:Version 3.1 Updated March 2015

Env Stds Comments
#1:As (V) used as conservative value
#2:Cr(VI) guideline has been adopted
#3:Cattles including dairy cattle
#4:Guideline value for sheep

Appendix D
Table H
Bakers Creek Geochemistry

				NAG				ABA							
				pHOX	NAG (pH 4.5)	NAG (pH 7.0)	Fizz Rating	Total Sulphur (LECO)	Sulphate	Sulfide S (calc)	Maximum potential acidity	ANC as H2SO4	NAPP	NAPP (using Sulfide S)	NPR
				pH Units	kg H2SO4/t	kg H2SO4/t	Fizz Unit	mg/kg	mg/kg	mg/kg	kg H2SO4/t	kg H2SO4/t	kg H2SO4/t	kg H2SO4/t	Ratio
EQL				0.1	0.1	0.1	0	100	10	10	-	0.5	0.5	0.5	0.1
NEPM 2013 Table 1A(1) HILs Res A Soil															
NEPM 2013 Table 1A(1) HILs Rec C Soil															
Monitoring_Zone	**Field_ID**	**Location_Code**	**Sampled_Date**												
Bakers Creek	Brackins Spur Mine Waste	Bakers Ck	09-Feb-16	10.4	<0.1	<0.1	2	2600	10	2590	7.93	78.8	-70.8	-70.87	9.9
Bakers Creek	Smiths Mine Waste	Bakers Ck	09-Feb-16	6.3	<0.1	0.3	1	3500	140	3360	10.28	14.6	-3.9	-4.32	1.4
Bakers Creek	Bakers Creek Mine Waste	Bakers Ck	10-Feb-16	9.0	<0.1	<0.1	2	4900	20	4880	14.93	41.6	-26.6	-26.67	2.8
Bakers Creek	Black Lode Mine Waste	Bakers Ck	10-Feb-16	7.9	<0.1	<0.1	1	1000	120	880	2.69	11	-7.9	-8.31	4.1
Bakers Creek	Cosmopolitan Mine Waste	Bakers Ck	11-Feb-16	8.0	<0.1	<0.1	1	3300	4520	0	0.00	18.9	-8.8	-18.90	NA
Bakers Creek	Lady Hopetoun Mine Waste	Bakers Ck	11-Feb-16	10.6	<0.1	<0.1	2	4400	100	4300	13.16	56.7	-43.2	-43.54	4.3

				pH (Saturated Paste)	Inorganics		Alkalinity				Major Ions			
				pH (Saturated Paste)	Electrical conductivity (lab)	pH (Lab)	Alkalinity (Carbonate as CaCO3)	Alkalinity (total as CaCO3)	Bicarbonate Alkalinity as CaCO3	Acidity	Calcium	Magnesium	Potassium	Sodium
				pH Unit	µS/cm	pH Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL				0.1	1	0.1	1	1	1	1	10	10	10	10
NEPM 2013 Table 1A(1) HILs Res A Soil														
NEPM 2013 Table 1A(1) HILs Rec C Soil														
Monitoring_Zone	**Field_ID**	**Location_Code**	**Sampled_Date**											
Bakers Creek	Brackins Spur Mine Waste	Bakers Ck	09-Feb-16	8.3	70	9.1	<5	3120	3120	<5	30	10	<10	<10
Bakers Creek	Smiths Mine Waste	Bakers Ck	09-Feb-16	7.8	150	8.1	<5	1230	1230	24	50	20	20	10
Bakers Creek	Bakers Creek Mine Waste	Bakers Ck	10-Feb-16	8.2	66	8.8	<5	560	560	<5	30	10	<10	10
Bakers Creek	Black Lode Mine Waste	Bakers Ck	10-Feb-16	8.6	110	9.1	35	1610	1580	<5	60	<10	<10	<10
Bakers Creek	Cosmopolitan Mine Waste	Bakers Ck	11-Feb-16	7.4	1610	6.7	<5	4020	4020	147	1430	300	50	140
Bakers Creek	Lady Hopetoun Mine Waste	Bakers Ck	11-Feb-16	8.4	216	8.5	35	1920	1890	<5	70	40	30	80

Appendix D
Table I
Bakers Creek Mineral Waste Metals Results

					Metals									
					Aluminium	Antimony	Arsenic	Cadmium	Chromium (III+VI)	Copper	Lead	Mercury	Nickel	Zinc
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					50	5	5	1	2	5	5	0.1	2	5
NEPM 2013 EIL-Areas of Ecological Significance							*40*			*20*	*470*		*5*	*15*
NEPM 2013 EIL-Urban Residential- Public Open Space							**100**			**60**	**1100**		**30**	**70**
US EPA (2015) Residential Soil Screening Level - Residential Soil						31								
US EPA (2015) Residential Soil Screening Level - Industrial Soil						470								
Site_ID	**Monitoring_Zone**	**Field_ID**	**Location_Code**	**Sampled_Date**										
Macleay River Catchment	Bakers Creek	BAKERS CREEK MINE WASTE	Bakers Creek MW	10-Feb-16	6880	313	***2700***	<1	11	*60*	23	1	*24*	***83***
Macleay River Catchment	Bakers Creek	BAKERS CREEK MINE WASTE-10/2/16	Bakers Creek MW	10-Feb-16	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Bakers Creek	BLACK LODE (1700) MINE WASTE	Black Lode (1700) MW	10-Feb-16	9170	887	***510***	<1	12	*33*	15	0.2	*16*	***89***
Macleay River Catchment	Bakers Creek	BLACK LODE (1700) MINE WASTE-10/2/16	Black Lode (1700) MW	10-Feb-16	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Bakers Creek	BRACKINS SPUR MINE WASTE #1	Brackins Spur MW	09-Feb-16	13,800	20	***1090***	<1	83	7	21	0.1	*22*	*47*
Macleay River Catchment	Bakers Creek	BRACKINS SPUR MINE WASTE #1-9/2/16	Brackins Spur MW	09-Feb-16	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Bakers Creek	COSMOPOLITAN MINE WASTE	Cosmopolitan MW	11-Feb-16	11,200	3480	***1570***	<1	18	*33*	19	0.5	*11*	***71***
Macleay River Catchment	Bakers Creek	COSMOPOLITAN MINE WASTE-11/2/16	Cosmopolitan MW	11-Feb-16	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Bakers Creek	LADY HOPETOUN MINE WASTE	Lady Hopetoun MW	11-Feb-16	4690	113	***930***	<1	11	16	49	0.7	*12*	***79***
Macleay River Catchment	Bakers Creek	LADY HOPETOUN MINE WASTE-11/2/16	Lady Hopetoun MW	11-Feb-16	-	-	-	-	-	-	-	-	-	-
Macleay River Catchment	Bakers Creek	SMITH'S MINE WASTE	Smith's Mine Waste	09-Feb-16	8900	2150	***2560***	<1	9	*22*	20	0.3	*9*	***111***
Macleay River Catchment	Bakers Creek	SMITH'S MINE WASTE-9/2/16	Smith's Mine Waste	09-Feb-16	-	-	-	-	-	-	-	-	-	-

Appendix D
Table J
Bakers Creek Mineral Waste Leaching Results

Monitoring_Zone	Field_ID	Location_Code	Sampled_Date	Sample_Type	Metals									
					Aluminium	Antimony	Arsenic	Cadmium	Chromium (III+VI)	Copper	Lead	Mercury	Nickel	Zinc
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL					0.01	0.001	0.001	0.0001	0.001	0.001	0.001	0.0001	0.001	0.005
ANZECC 2000 FW 95%					*0.055*	*0.009*	*0.013*	*0.0002*	*0.001*	*0.001*	*0.003*	*0.0006*	*0.011*	*0.008*
ADWG 2011 Health						**0.003**	**0.010**	**0.002**		**2**	**0.010**	**0.001**	**0.020**	
Bakers Creek	BAKERS CREEK MINE WASTE-10/2/16	Bakers Creek MW	10-Feb-16	Leached	*1.92*	***0.724***	***1.16***	<0.0001	*0.002*	*0.008*	*0.006*	0.0004	0.003	*0.144*
Bakers Creek	BLACK LODE (1700) MINE WASTE-10/2/16	Black Lode (1700) MW	10-Feb-16	Leached	*1.43*	***4.4***	***0.258***	<0.0001	*0.001*	<0.001	0.003	<0.0001	0.002	*0.147*
Bakers Creek	BRACKINS SPUR MINE WASTE #1-9/2/16	Brackins Spur MW	09-Feb-16	Leached	*0.86*	***0.051***	***0.518***	<0.0001	*0.004*	<0.001	<0.001	<0.0001	<0.001	*0.058*
Bakers Creek	COSMOPOLITAN MINE WASTE-11/2/16	Cosmopolitan MW	11-Feb-16	Leached	0.04	***3.03***	***0.26***	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	*0.03*
Bakers Creek	LADY HOPETOUN MINE WASTE-11/2/16	Lady Hopetoun MW	11-Feb-16	Leached	*1.93*	***0.215***	***0.248***	*0.001*	*0.004*	*0.005*	***0.021***	0.0003	0.003	*0.755*
Bakers Creek	SMITH'S MINE WASTE-9/2/16	Smith's Mine Waste	09-Feb-16	Leached	*1.54*	***3.51***	***2.17***	<0.0001	*0.001*	*0.003*	*0.006*	0.0001	0.001	*0.116*

Appendix D
Table K
Bakers Creek Sediment Geochemistry

					NAG												pH (Saturated Paste)	Inorganics		Alkalinity			Major Ions			
					pHOX	NAG (pH 4.5)	NAG (pH 7.0)	Fizz Rating	Total Sulphur (LECO)	Sulphate S	Sulfide S (calc)	Maximum potential acidity	ANC as H2SO4	NAPP	NAPP (using sulfide S)	NPR	pH (Saturated Paste)	Electrical conductivity (lab)	pH (Lab)	Alkalinity (Carbonate as CaCO3)	Alkalinity (total as CaCO3)	Bicarbonate Alkalinity as CaCO3	Calcium	Magnesium	Potassium	Sodium
					pH Units	kg H2SO4/t	kg H2SO4/t	Fizz Unit	mg/kg	mg/kg	mg/kg	kg H2SO4/t	kg H2SO4/t	kg H2SO4/t	kg H2SO4/t		pH Unit	µS/cm	pH Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					0.1	0.1	0.1	0	100	10	10	-	0.5	0.5	0.5		0.1	1	0.1	1	1	1	10	10	10	10
Baseline GHD Stage 1 2015																										
ANZECC 2000 ISQG -Low																										
ANZECC 2000 ISQG -High																										
Monitoring_Zone	**SampleCode**	**Field_ID**	**Location_Code**	**Sampled_Date**																						
Bakers Creek	ES1603307020	BC_SD01	BC_SD01	09-Feb-16	7.5	<0.1	<0.1	1	200	30	170	0.5	1.07	10.1	-0.5	2.1	7.7	46	8.4	<5	208	208	10	<10	<10	60
Bakers Creek	ES1603307021	BC_SD02	BC_SD02	09-Feb-16	7.9	<0.1	<0.1	1	200	50	150	0.5	0.7	6.4	-0.2	1.5	6.2	53	6.9	<5	458	458	<10	<10	<10	40
Bakers Creek	ES1603307022	BC_SD03	BC_SD03	09-Feb-16	-	-	-	-	200	5	195	0.6	-	-	-	-	-	28	7.2	<5	333	333	<10	<10	<10	20
Bakers Creek	ES1603307023	BC_SD04	BC_SD04	09-Feb-16	-	-	-	-	50	5	45	0.1	-	-	-	-	-	10	7	<5	229	229	<10	<10	<10	<10
Bakers Creek	ES1603307024	BC_SD05	BC_SD05	09-Feb-16	7.4	<0.1	<0.1	1	200	5	195	0.6	1.09	10.3	-0.5	1.8	7.2	19	7.2	<5	125	125	<10	<10	<10	<10
Bakers Creek	ES1603307025	BC_SD06	BC_SD06	09-Feb-16	8.1	<0.1	<0.1	1	200	5	195	0.6	0.87	8.1	-0.3	1.5	7.8	22	7.2	<5	229	229	<10	<10	<10	<10
Bakers Creek	ES1603307026	BC_SD07	BC_SD07	09-Feb-16	-	-	-	-	200	30	170	0.5	-	-	-	-	-	28	7.4	<5	562	562	30	20	<10	50
Bakers Creek	ES1603307027	BC_SD08	BC_SD08	09-Feb-16	8.4	<0.1	<0.1	1	800	1260	0	0.0	1	7.6	-1.0	NA	7.4	504	7.5	<5	1190	1190	240	110	20	220
Bakers Creek	ES1603307068	BC_SD09	BC_SD09	09-Feb-16	7.7	<0.1	<0.1	1	200	120	80	0.2	0.63	5.7	-0.4	2.6	8	106	7.5	<5	595	595	40	20	<10	40
Bakers Creek	ES1603307028	BC_SD10	BC_SD10	09-Feb-16	-	-	-	-	200	10	190	0.6	-	-	-	-	-	34	7.1	<5	271	271	<10	<10	<10	20
Bakers Creek	ES1603307030	BC_SD11	BC_SD11	09-Feb-16	-	-	-	-	200	5	195	0.6	-	-	-	-	-	20	6.8	<5	229	229	<10	<10	<10	<10
Bakers Creek	ES1603307031	BC_SD12	BC_SD12	10-Feb-16	-	-	-	-	400	10	390	1.2	-	-	-	-	-	41	6.4	<5	604	604	20	<10	<10	<10
Bakers Creek	ES1603307037	BC_SD14	BC_SD14	10-Feb-16	6.8	<0.1	0.4	0	600	5	595	1.8	0.38	2	1.4	0.2	6.2	27	6.8	<5	438	438	<10	<10	20	<10
Bakers Creek	ES1603307036	BC_SD15	BC_SD15	10-Feb-16	7.8	<0.1	<0.1	1	1000	160	840	2.6	1.38	10.7	1.2	0.5	7.4	107	8.1	<5	771	771	50	20	<10	10
Bakers Creek	ES1603307034	BC_SD16	BC_SD16	10-Feb-16	-	-	-	-	200	5	195	0.6	-	-	-	-	-	8	6.8	<5	167	167	<10	<10	<10	<10
Bakers Creek	ES1603307035	BC_SD17	BC_SD17	10-Feb-16	7.4	<0.1	<0.1	1	800	30	770	2.4	1.24	10	1.1	0.5	6.6	32	6.9	<5	333	333	20	<10	<10	<10
Bakers Creek	ES1603307038	BC_SD18	BC_SD18	10-Feb-16	-	-	-	-	200	40	160	0.5	-	-	-	-	-	65	7.2	<5	896	896	40	10	20	80
Bakers Creek	ES1603307039	BC-SD19	BC_SD19	10-Feb-16	7.4	<0.1	<0.1	1	500	350	150	0.5	1.1	9.5	-0.6	2.4	7.4	182	7.8	<5	229	229	70	40	<10	50
Bakers Creek	ES1603307040	BC_SD20	BC_SD20	10-Feb-16	-	-	-	-	50	5	45	0.1	-	-	-	-	-	15	7.7	<5	333	333	<10	<10	<10	<10
Bakers Creek	ES1603307041	BC_SD21	BC_SD21	10-Feb-16	8	<0.1	<0.1	1	400	20	380	1.2	1.05	9.3	0.1	0.9	7.6	40	8.7	<5	250	250	10	<10	<10	10
Bakers Creek	ES1603307043	BC_SD23	BC_SD23	11-Feb-16	-	-	-	-	50	5	45	0.1	-	-	-	-	-	16	7.2	<5	188	188	<10	<10	<10	<10
Bakers Creek	ES1603307044	BC_SD24	BC_SD24	11-Feb-16	-	-	-	-	600	60	540	1.7	-	-	-	-	-	54	7.2	<5	146	146	20	<10	<10	<10
Bakers Creek	ES1603307045	BC-SD25	BC_SD25	11-Feb-16	7.4	<0.1	<0.1	1	800	40	760	2.3	1.29	10.4	1.0	0.6	7.3	42	7.5	<5	146	146	20	<10	<10	<10
Bakers Creek	ES1603307046	BC_SD26	BC_SD26	11-Feb-16	-	-	-	-	200	40	160	0.5	-	-	-	-	-	33	7.3	<5	500	500	10	<10	<10	70
Bakers Creek	ES1603307047	BC_SD27	BC_SD27	11-Feb-16	7	<0.1	<0.1	1	400	30	370	1.1	0.99	8.7	0.1	0.9	7.4	113	7.6	<5	1380	1380	40	20	20	40
Bakers Creek	ES1603307048	BC_SD28	BC_SD28	11-Feb-16	-	-	-	-	200	20	180	0.6	-	-	-	-	-	49	6.8	<5	958	958	20	<10	10	40
Bakers Creek	ES1603307050	BC_SD29	BC_SD29	11-Feb-16	7.9	<0.1	<0.1	0	200	5	195	0.6	0.44	3.8	0.2	0.7	7.5	10	7.4	<5	167	167	<10	<10	<10	<10
Bakers Creek	ES1603307051	BC_SD30	BC_SD30	11-Feb-16	-	-	-	-	200	5	195	0.6	-	-	-	-	-	61	7.7	<5	167	167	20	<10	40	<10
Bakers Creek	ES1603307052	BC_SD31	BC_SD31	11-Feb-16	7.8	<0.1	<0.1	0	200	5	195	0.6	0.68	6.2	-0.1	1.1	7.8	29	7.4	<5	250	250	<10	<10	<10	<10
Bakers Creek	ES1603307053	BC_SD32	BC_SD32	11-Feb-16	7.6	<0.1	<0.1	0	200	20	180	0.6	0.28	2.2	0.3	0.5	7.2	12	7.2	<5	208	208	<10	<10	<10	10
Bakers Creek	ES1603307029	BC_SD33	BC_SD33	09-Feb-16	-	-	-	-	400	5	395	1.2	-	-	-	-	-	54	7.1	<5	875	875	10	<10	20	20
Bakers Creek	ES1603307032	BC_SD34	BC_SD34	10-Feb-16	-	-	-	-	300	20	280	0.9	-	-	-	-	-	95	8.2	<5	1540	1540	50	20	<10	20
Bakers Creek	ES1603307033	BC_SD35	BC_SD35	10-Feb-16	8.2	<0.1	<0.1	1	300	5	295	0.9	1.06	9.7	-0.2	1.2	7.5	22	7.9	<5	229	229	<10	<10	<10	<10
Bakers Creek	ES1603307054	BC_SD36	BC_SD36	11-Feb-16	7.3	<0.1	<0.1	1	700	20	680	2.1	1.22	10	0.9	0.6	7.6	12	7.2	35	2280	2240	<10	<10	<10	30

Appendix D
Table L
Bakers Creek Sediment Metals Results

Monitoring_Zone	SampleCode	Field_ID	Location_Code	Sampled_Date	Metals: Aluminium	Antimony	Arsenic	Cadmium	Chromium (III+VI)	Copper	Lead	Mercury	Nickel	Silicon	Zinc
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					50	5	5	1	2	5	5	0.1	2	1	5
Baseline GHD Stage 1 2015						**1.2**	**12.48**								
ANZECC 2000 ISQG -Low						*2*	*20*	*1.5*	*80*	*65*	*50*	*0.15*	*21*		*200*
ANZECC 2000 ISQG -High						25	70	10	370	270	220	1	52		410
Bakers Creek	ES1603307020	BC_SD01	BC_SD01	09-Feb-16	12,000	<5	11	<1	26	19	7	0.1	*36*	31	51
Bakers Creek	ES1603307021	BC_SD02	BC_SD02	09-Feb-16	10,400	***127***	***95***	<1	22	15	8	<0.1	14	43	38
Bakers Creek	ES1603307022	BC_SD03	BC_SD03	09-Feb-16	7830	<5	**17**	<1	12	14	16	<0.1	10	51	53
Bakers Creek	ES1603307023	BC_SD04	BC_SD04	09-Feb-16	20,200	<5	***77***	<1	*103*	13	<5	<0.1	*27*	146	26
Bakers Creek	ES1603307024	BC_SD05	BC_SD05	09-Feb-16	6270	***110***	***52***	<1	10	11	<5	<0.1	10	21	26
Bakers Creek	ES1603307025	BC_SD06	BC_SD06	09-Feb-16	5800	***110***	***429***	<1	12	10	<5	0.1	7	33	26
Bakers Creek	ES1603307026	BC_SD07	BC_SD07	09-Feb-16	23,900	***71***	***212***	<1	*115*	23	<5	<0.1	*28*	544	32
Bakers Creek	ES1603307027	BC_SD08	BC_SD08	09-Feb-16	9360	***11***	***38***	<1	32	7	<5	<0.1	9	13	31
Bakers Creek	ES1603307068	BC_SD09	BC_SD09	09-Feb-16	14,900	***381***	***177***	<1	32	46	16	0.1	*28*	22	70
Bakers Creek	ES1603307028	BC_SD10	BC_SD10	09-Feb-16	8120	***17***	10	<1	11	16	5	<0.1	7	22	29
Bakers Creek	ES1603307030	BC_SD11	BC_SD11	09-Feb-16	13,200	***49***	***62***	<1	22	16	13	<0.1	17	25	167
Bakers Creek	ES1603307031	BC_SD12	BC_SD12	10-Feb-16	15,000	***952***	***330***	<1	17	45	32	*0.6*	*34*	31	198
Bakers Creek	ES1603307037	BC_SD14	BC_SD14	10-Feb-16	14,800	***183***	***1990***	<1	13	26	23	*0.4*	16	71	83
Bakers Creek	ES1603307036	BC_SD15	BC_SD15	10-Feb-16	10,200	***269***	***204***	<1	31	41	7	0.1	*31*	18	42
Bakers Creek	ES1603307034	BC_SD16	BC_SD16	10-Feb-16	13,400	***21***	***209***	<1	16	56	17	*0.2*	20	26	84
Bakers Creek	ES1603307035	BC_SD17	BC_SD17	10-Feb-16	11,500	***1600***	***499***	<1	38	56	15	*0.3*	*40*	66	59
Bakers Creek	ES1603307038	BC_SD18	BC_SD18	10-Feb-16	14,100	***28***	***45***	<1	20	8	8	<0.1	8	56	51
Bakers Creek	ES1603307039	BC-SD19	BC_SD19	10-Feb-16	12,900	***252***	***180***	<1	38	58	13	<0.1	*37*	12	53
Bakers Creek	ES1603307042	QA01	BC_SD19	10-Feb-16	11,300	***230***	***141***	<1	36	53	10	0.1	*34*	13	47
Bakers Creek	ES1603307040	BC_SD20	BC_SD20	10-Feb-16	17,700	<5	***42***	<1	36	41	10	<0.1	16	53	79
Bakers Creek	ES1603307041	BC_SD21	BC_SD21	10-Feb-16	10,900	***243***	***173***	<1	38	44	14	0.1	*38*	28	40
Bakers Creek	ES1603307043	BC_SD23	BC_SD23	11-Feb-16	13,500	***9***	***85***	<1	26	18	9	<0.1	11	23	63
Bakers Creek	ES1603307044	BC_SD24	BC_SD24	11-Feb-16	11,500	***700***	***336***	<1	38	41	11	*0.2*	*33*	14	48
Bakers Creek	ES1603307045	BC-SD25	BC_SD25	11-Feb-16	13,900	***629***	***216***	<1	56	*66*	10	*0.2*	*49*	25	46
Bakers Creek	ES1603307055	QA02	BC_SD25	11-Feb-16	11,700	***808***	***273***	<1	48	50	9	*0.2*	*42*	72	42
Bakers Creek	ES1603307046	BC_SD26	BC_SD26	11-Feb-16	10,000	***54***	***138***	<1	16	13	12	0.1	10	97	46
Bakers Creek	ES1603307047	BC_SD27	BC_SD27	11-Feb-16	10,200	***265***	***123***	<1	14	14	13	*0.5*	9	27	67
Bakers Creek	ES1603307048	BC_SD28	BC_SD28	11-Feb-16	10,400	***78***	***193***	<1	16	16	10	0.1	8	43	49
Bakers Creek	ES1603307050	BC_SD29	BC_SD29	11-Feb-16	7610	***26***	***70***	<1	15	10	9	<0.1	6	17	38
Bakers Creek	ES1603307051	BC_SD30	BC_SD30	11-Feb-16	6520	***29***	***47***	<1	10	9	6	<0.1	5	34	37
Bakers Creek	ES1603307052	BC_SD31	BC_SD31	11-Feb-16	9010	<5	***42***	<1	15	8	6	<0.1	8	53	36
Bakers Creek	ES1603307053	BC_SD32	BC_SD32	11-Feb-16	5360	<5	8	<1	7	<5	<5	<0.1	5	37	12
Bakers Creek	ES1603307056	QA03	BC_SD32	11-Feb-16	5210	<5	6	<1	7	<5	<5	<0.1	4	271	11
Bakers Creek	ES1603307029	BC_SD33	BC_SD33	09-Feb-16	10,300	***9***	8	<1	17	8	6	<0.1	8	65	29
Bakers Creek	ES1603307032	BC_SD34	BC_SD34	10-Feb-16	13,800	***20***	***34***	<1	57	15	8	0.1	*26*	86	44
Bakers Creek	ES1603307033	BC_SD35	BC_SD35	10-Feb-16	11,400	***326***	***256***	<1	39	45	11	*0.2*	*35*	31	48
Bakers Creek	ES1603307054	BC_SD36	BC_SD36	11-Feb-16	5130	***26***	***137***	<1	7	6	5	0.1	5	26	21

Appendix D
Table M
Bakers Creek Sediment Leaching Results

Monitoring_Zone	SampleCode	Field_ID	Location_Code	Sampled_Date	Matrix_Type	Metals									
						Aluminium	Antimony	Arsenic	Cadmium	Chromium (III+VI)	Copper	Lead	Mercury	Nickel	Zinc
						mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL						0.01	0.001	0.001	0.0001	0.001	0.001	0.001	0.0001	0.001	0.005
ANZECC 2000 FW 95%						0.055	0.009	0.013	0.0002	0.001	0.0014	0.0034	0.0006	0.011	0.008
ADWG 2011 Health							0.003	0.010	0.002		2	0.01	0.001	0.020	
Bakers Creek	ES1603307020	BC_SD01	BC_SD01	09-Feb-16	Sediment leached	1.73	0.009	0.005	<0.0001	0.003	0.002	<0.001	<0.0001	0.004	0.032
Bakers Creek	ES1603307021	BC_SD02	BC_SD02	09-Feb-16	Sediment leached	1.26	0.149	0.041	<0.0001	0.003	0.002	0.001	<0.0001	0.002	0.053
Bakers Creek	ES1603307024	BC_SD05	BC_SD05	09-Feb-16	Sediment leached	1.47	0.224	0.055	<0.0001	0.003	0.002	0.002	<0.0001	0.002	0.023
Bakers Creek	ES1603307025	BC_SD06	BC_SD06	09-Feb-16	Sediment leached	2.78	0.215	0.085	<0.0001	0.005	0.004	0.003	<0.0001	0.004	0.033
Bakers Creek	ES1603307027	BC_SD08	BC_SD08	09-Feb-16	Sediment leached	1.03	0.074	0.012	<0.0001	0.003	0.001	<0.001	<0.0001	<0.001	0.015
Bakers Creek	ES1603307033	BC_SD35	BC_SD35	10-Feb-16	Sediment leached	1.06	0.483	0.137	<0.0001	0.002	0.002	0.002	<0.0001	0.002	0.029
Bakers Creek	ES1603307035	BC_SD17	BC_SD17	10-Feb-16	Sediment leached	1.21	6.56	0.275	<0.0001	0.004	0.005	0.002	<0.0001	0.003	0.038
Bakers Creek	ES1603307036	BC_SD15	BC_SD15	10-Feb-16	Sediment leached	1.7	1.84	0.162	<0.0001	0.004	0.004	0.002	<0.0001	0.003	0.02
Bakers Creek	ES1603307037	BC_SD14	BC_SD14	10-Feb-16	Sediment leached	1.75	0.134	0.679	<0.0001	0.001	0.002	0.002	<0.0001	0.002	0.038
Bakers Creek	ES1603307039	BC-SD19	BC_SD19	10-Feb-16	Sediment leached	1.83	2	0.08	<0.0001	0.008	0.008	0.004	<0.0001	0.005	0.022
Bakers Creek	ES1603307041	BC_SD21	BC_SD21	10-Feb-16	Sediment leached	1.53	2.74	0.135	<0.0001	0.007	0.006	0.007	<0.0001	0.006	0.019
Bakers Creek	ES1603307045	BC-SD25	BC_SD25	11-Feb-16	Sediment leached	1.75	4.47	0.098	<0.0001	0.008	0.008	0.004	<0.0001	0.007	0.019
Bakers Creek	ES1603307047	BC_SD27	BC_SD27	11-Feb-16	Sediment leached	1.69	0.153	0.075	<0.0001	0.002	0.002	0.002	<0.0001	0.001	0.035
Bakers Creek	ES1603307050	BC_SD29	BC_SD29	11-Feb-16	Sediment leached	1.48	0.058	0.047	<0.0001	0.002	0.001	0.002	<0.0001	<0.001	0.026
Bakers Creek	ES1603307052	BC_SD31	BC_SD31	11-Feb-16	Sediment leached	1.6	0.006	0.019	<0.0001	0.004	0.001	0.001	<0.0001	0.002	0.036
Bakers Creek	ES1603307053	BC_SD32	BC_SD32	11-Feb-16	Sediment leached	1.55	0.006	0.003	<0.0001	0.002	<0.001	0.001	<0.0001	0.002	0.043
Bakers Creek	ES1603307054	BC_SD36	BC_SD36	11-Feb-16	Sediment leached	1.61	0.067	0.059	<0.0001	0.004	0.002	0.002	<0.0001	0.002	0.024
Bakers Creek	ES1603307068	BC_SD09	BC_SD09	09-Feb-16	Sediment leached	1.48	2.64	0.068	<0.0001	0.002	0.006	0.002	<0.0001	0.002	0.017

Appendix D
Table N
Bakers Creek Surface Water Results

					Inorganics						Metals							
					Electrical conductivity (lab)	pH (Lab)	Total Dissolved Solids	Total Organic Carbon	Bicarbonate	Carbonate	Antimony	Antimony (Filtered)	Arsenic	Arsenic (Filtered)	Cadmium	Cadmium (Filtered)	Chromium (III+VI)	Chromium (III+VI) (Filtered)
					µS/cm	pH Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL					1	0.01	10	1	1	1	0.001	0.001	0.001	0.001	0.0001	0.0001	0.001	0.001
ADWG 2011 Aesthetic						*6.5-8.5*	*600*											
ADWG 2011 Health											*0.003*	*0.003*	*0.01*	*0.01*	*0.002*	*0.002*		
ANZECC 2000 FW 95%													0.013[#1]	0.013[#1]	0.0002	0.0002	0.001[#2]	0.001[#2]
ANZECC 2000 FW Med-Low Reliability											0.009	0.009	0.013[#1]	0.013[#1]	0.0002	0.0002		
Baseline GHD Stage 1 2015											**0.0025**	**0.0025**	**0.003**	**0.003**				
ANZECC 2000 Irrigation - Short-term Trigger Values													2	2	0.05	0.05	1	1
ANZECC 2000 Irrigation - Long-term Trigger Values													0.1	0.1	0.01	0.01	0.1	0.1
ANZECC 2000 Stock Watering							4000[#3]						0.5	0.5	0.01	0.01	1	1
Monitoring_Zone	**SampleCode**	**Field_ID**	**Location_Code**	**Sampled_Date**														
Bakers Creek	ES1603307001	BC_SW01	BC_SW01	09-Feb-16	588	7.72	362	4	211	<1	**0.045**	**0.035**	0.002	0.002	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307002	BC_SW02	BC_SW02	09-Feb-16	396	7.96	271	2	96	<1	**0.822**	**0.689**	**0.046**	**0.05**	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307003	BC_SW05	BC_SW05	09-Feb-16	376	7.78	256	3	93	<1	**0.762**	**0.639**	**0.056**	**0.058**	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307004	BC_SW06	BC_SW06	09-Feb-16	394	7.9	252	2	98	<1	**0.789**	**0.653**	**0.06**	**0.064**	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307005	BC_SW08	BC_SW08	09-Feb-16	4960	7.71	*4750*	4	211	<1	**0.045**	**0.037**	**0.008**	**0.007**	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307006	BC_SW10	BC_SW10	09-Feb-16	234	7.06	147	2	76	<1	**0.042**	**0.035**	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307007	BC_SW09	BC_SW09	09-Feb-16	820	7.9	575	2	140	<1	**9.31**	**7.57**	**0.2**	**0.21**	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307008	BC_SW33	BC_SW33	09-Feb-16	210	7.75	138	4	66	<1	**0.018**	**0.017**	0.002	0.002	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307009	BC_SW35	BC_SW35	10-Feb-16	368	7.9	240	3	93	<1	**0.654**	**0.531**	**0.066**	**0.072**	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307010	BC_SW15	BC_SW15	10-Feb-16	1850	7.9	*1690*	2	62	<1	**5.98**	**5.47**	**0.245**	**0.249**	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307011	BC_SW19	BC_SW19	10-Feb-16	2620	*8.53*	*2340*	<1	119	26	**5.19**	**4.36**	**0.244**	**0.26**	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307012	QA01	BC_SW19	10-Feb-16	2640	*8.54*	*2420*	2	120	28	**5.07**	**4.44**	**0.25**	**0.265**	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307013	BC_SW27	BC_SW27	11-Feb-16	-	-	-	9	-	-	**0.287**	**0.232**	**0.03**	**0.029**	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307014	BC_SW31	BC_SW31	11-Feb-16	266	7.84	167	5	82	<1	**0.01**	**0.006**	**0.004**	**0.004**	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307015	BC_SW36	BC_SW36	11-Feb-16	273	8.02	166	4	84	<1	**0.155**	**0.125**	**0.022**	**0.023**	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307016	BC_SW32	BC_SW32	11-Feb-16	247	8.32	156	10	77	<1	**0.004**	0.001	0.002	0.002	<0.0001	<0.0001	<0.001	<0.001
Bakers Creek	ES1603307017	QA03	BC_SW32	11-Feb-16	248	8.27	158	10	78	<1	**0.003**	0.001	0.003	0.002	<0.0001	<0.0001	<0.001	<0.001

	Metals										Acidity	Alkalinity		Major Ions					
	Copper	Copper (Filtered)	Lead	Lead (Filtered)	Mercury	Mercury (Filtered)	Nickel	Nickel (Filtered)	Zinc	Zinc (Filtered)	Acidity (as CaCO3)	Alkalinity (Hydroxide as CaCO3)	Alkalinity (total as CaCO3)	Calcium (Filtered)	Chloride	Magnesium (Filtered)	Potassium (Filtered)	Sodium (Filtered)	Sulphate (Filtered)
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL	0.001	0.001	0.001	0.001	0.0001	0.0001	0.001	0.001	0.005	0.005	1	1	1	1	1	1	1	1	1
ADWG 2011 Aesthetic	*1*	*1*							*3*	*3*					*250*			*180*	*250*
ADWG 2011 Health	*2*	*2*	*0.01*	*0.01*	*0.001*	*0.001*	*0.02*	*0.02*											*500*
ANZECC 2000 FW 95%	0.0014	0.0014	0.0034	0.0034	0.0006	0.0006	0.011	0.011	0.008	0.008									
ANZECC 2000 FW Med-Low Reliability	0.0014	0.0014	0.0034	0.0034			0.011	0.011	0.008	0.008									
Baseline GHD Stage 1 2015																			
ANZECC 2000 Irrigation - Short-term Trigger Values	5	5	10	10	0.002	0.002	2	2	5	5									
ANZECC 2000 Irrigation - Long-term Trigger Values	0.2	0.2	0.2	0.2	0.002	0.002	0.2	0.2	2	2									
ANZECC 2000 Stock Watering	0.5[#4]	0.5[#4]	0.1	0.1	0.002	0.002	1	1	20	20				1000					1000
SampleCode																			
ES1603307001	0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	<0.005	5	<1	211	45	49	27	2	33	23
ES1603307002	0.001	0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	0.002	<0.005	<0.005	2	<1	96	26	30	16	3	27	61
ES1603307003	0.001	0.002	<0.001	<0.001	<0.0001	<0.0001	<0.001	0.001	<0.005	<0.005	2	<1	93	24	29	14	3	26	50
ES1603307004	0.002	0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	<0.005	2	<1	98	25	30	16	3	27	58
ES1603307005	0.002	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	0.002	<0.005	<0.005	13	<1	211	521	73	272	12	*452*	*3380*
ES1603307006	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	<0.005	4	<1	76	14	18	8	3	19	16
ES1603307007	0.002	0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	0.001	<0.005	<0.005	3	<1	140	72	34	36	4	48	*252*
ES1603307008	0.002	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	0.001	<0.005	<0.005	2	<1	66	10	21	7	3	19	4
ES1603307009	0.003	0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	0.001	<0.005	<0.005	2	<1	93	24	25	14	3	25	57
ES1603307010	0.002	<0.001	<0.001	<0.001	<0.0001	<0.0001	0.001	0.002	<0.005	<0.005	3	<1	62	253	4	104	6	35	*1030*
ES1603307011	0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	0.002	0.002	<0.005	<0.005	<1	<1	145	275	42	183	6	137	*1640*
ES1603307012	0.001	0.002	<0.001	<0.001	<0.0001	<0.0001	0.001	0.002	<0.005	<0.005	<1	<1	148	278	43	185	6	137	*1660*
ES1603307013	0.002	0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	0.002	0.006	<0.005	-	-	-	-	-	-	-	-	-
ES1603307014	0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.005	<0.005	<1	<1	82	16	20	10	3	22	22
ES1603307015	0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	0.001	<0.005	<0.005	<1	<1	84	15	22	10	3	24	22
ES1603307016	0.004	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	0.001	<0.005	<0.005	<1	<1	78	15	19	9	2	21	19
ES1603307017	0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	0.002	<0.005	<0.005	<1	<1	78	14	20	9	2	21	19

Env Stds Description
ADWG 2011 Aesthetic:Version 3.1 Updated March 2015
ADWG 2011 Health:Version 3.1 Updated March 2015

Env Stds Comments
#1:As (V) used as conservative value
#2:Cr(VI) guideline has been adopted
#3:Cattles including dairy cattle
#4:Guideline value for sheep

Appendix E – Geochemical abundance index

Appendix F
Table A
Mineral Waste Geochemical Abundance Index

				Metals																			
				Aluminium	Al GAI	Antimony	Sb GAI	Arsenic	As GAI	Cadmium	Cd GAI	Chromium (III+VI)	Cr GAI	Copper	Cu GAI	Lead	Pb GAI	Mercury	Hg GAI	Nickel	Ni GAI	Zinc	Zn GAI
				mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg	
EQL				50		5		5		1		2		5		5		0.1		2		5	
GAI				82,300		1.5		1.8		0.3		102		60		14		0.085		84		70	
Monitoring_Zone	Field_ID	Location_Code	Sampled_Date																				
Aspley	EUROPAMBELA MINE WASTE DUMP #1 - 11/9/15	E MINE WASTE #1	11-Sep-15	7,380	-4	2.5	0	71	5	0.5	0	19	-3	985	3	87	2	2.1	5	6	-4	73	-1
Aspley	EUROPAMBELA MINE WASTE DUMP #2 - 11/9/15	E MINE WASTE #2	11-Sep-15	17,400	-3	2.5	0	32	4	0.5	0	33	-2	745	3	43	1	1.1	4	10	-4	68	-1
Bakers Creek	BAKERS CREEK MINE WASTE-10/2/16	Bakers Creek MW	10-Feb-16	13,800	-3	20	3	1090	9	0.5	0	83	-1	7	-4	21	0	0.1	0	22	-3	47	-1
Bakers Creek	BLACK LODE (1700) MINE WASTE-10/2/16	Black Lode (1700) MW	10-Feb-16	8,900	-4	2150	10	2560	10	0.5	0	9	-4	22	-2	20	0	0.3	2	9	-4	111	0
Bakers Creek	BRACKINS SPUR MINE WASTE #1-9/2/16	Brackins Spur MW	09-Feb-16	6,880	-4	313	7	2700	10	0.5	0	11	-4	60	-1	23	0	1	4	24	-2	83	0
Bakers Creek	COSMOPOLITAN MINE WASTE-11/2/16	Cosmopolitan MW	11-Feb-16	9,170	-4	887	9	510	8	0.5	0	12	-4	33	-1	15	0	0.2	1	16	-3	89	0
Bakers Creek	LADY HOPETOUN MINE WASTE-11/2/16	Lady Hopetoun MW	11-Feb-16	11,200	-3	3480	11	1570	9	0.5	0	18	-3	33	-1	19	0	0.5	3	11	-4	71	-1
Bakers Creek	SMITH'S MINE WASTE-9/2/16	Smith's Mine Waste	09-Feb-16	4,690	-5	113	6	930	8	0.5	0	11	-4	16	-2	49	1	0.7	3	12	-3	79	0
Chandler	KHANS CREEK WASTE DUMP #1 - 12/9/15	KC WASTE DUMP #1	12-Sep-15	18,500	-3	24	3	194	6	7	4	22	-3	1040	4	6,400	8	6.7	6	13	-3	4880	6
Chandler	KHANS CREEK WASTE DUMP #2 - 12/9/15	KC WASTE DUMP #2	12-Sep-15	24,300	-2	74	5	334	7	16	5	34	-2	5620	6	39,200	11	57.9	10	9	-4	12,400	7
Chandler	KHANS CREEK WASTE DUMP #3 - 12/9/15	KC WASTE DUMP #3	12-Sep-15	30,800	-2	165	6	674	8	5	3	39	-2	6220	6	41,800	11	49.5	9	18	-3	7520	6
Chandler	MICKEY MOUSE MINE WASTE #1 - 13/9/15	MM MINE WASTE #1	13-Sep-15	14,100	-3	190	6	15	2	0.5	0	14	-3	303	2	66	2	0.05	-1	15	-3	404	2
Chandler	PHOENIX COMET GOLD MINE WATSE #1 - 9/9/15	PC MINE WASTE #1	09-Sep-15	6400	-4	18	3	230	6	0.5	0	12	-4	489	2	37	1	0.05	-1	5	-5	12	-3
Chandler	PHOENIX COMET GOLD MINE WATSE #2 - 9/9/15	PC MINE WASTE #2	09-Sep-15	3590	-5	108	6	308	7	0.5	0	5	-5	80	0	91	2	0.1	0	4	-5	13	-3
Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #1 - 9/9/15	RA MINE WASTE #1	09-Sep-15	9070	-4	48	4	40,400	14	2	2	10	-4	342	2	371	4	0.2	1	4	-5	121	0
Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #2 - 9/9/15	RA MINE WASTE #2	09-Sep-15	9010	-4	68	5	36,500	14	3	3	13	-4	488	2	617	5	0.6	3	4	-5	178	1
Chandler	ROCKVALE ARSENIC MINE WASTE DUMP #3 - 9/9/15	RA MINE WASTE #3	09-Sep-15	4250	-5	286	7	74,300	15	2	2	6	-5	1080	4	535	5	0.7	3	1	-7	36	-2
Chandler	RUBY SILVER WASTE DUMP #1 - 10/9/15	RS WASTE DUMP #1	10-Sep-15	4220	-5	210	7	8420	12	0.5	0	4	-5	37	-1	515	5	2.1	5	4	-5	58	-1
Chandler	RUBY SILVER WASTE DUMP #2 - 10/9/15	RS WASTE DUMP #2	10-Sep-15	7080	-4	29	4	1190	9	0.5	0	7	-4	11	-3	18	0	0.2	1	3	-5	16	-3
Chandler	TULLOCH MILL WASTE #1 - 10/9/15	T MILL WASTE #1	10-Sep-15	3660	-5	2220	10	904	8	0.5	0	29	-2	326	2	245	4	0.9	4	18	-3	177	1
Chandler	TULLOCH MILL WASTE #2 - 10/9/15	T MILL WASTE #2	10-Sep-15	11,300	-3	7	2	69	5	0.5	0	9	-4	8	-3	16	0	0.05	-1	3	-5	23	-2
Commissioners Waters	KAPUNDA ARSENIC MINE WASTE DUMP #1 - 11/9/15	KA MINE WASTE #1	11-Sep-15	9300	-4	422	8	1640	9	0.5	0	34	-2	47	-1	136	3	0.7	3	32	-2	188	1
Commissioners Waters	MARY ANDERSEN MINE WASTE DUMP #1 - 11/9/15	MA MINE WASTE #1	11-Sep-15	9320	-4	619	8	244	6	0.5	0	10	-4	32	-1	25	0	0.2	1	19	-3	87	0
Commissioners Waters	MARY ANDERSEN MINE WASTE DUMP #2 - 11/9/15	MA MINE WASTE #2	11-Sep-15	15,900	-3	656	8	394	7	0.5	0	14	-3	30	-2	30	1	0.7	3	11	-4	63	-1
Commissioners Waters	MARY ANDERSEN MINE WASTE DUMP #3 - 11/9/15	MA MINE WASTE #3	11-Sep-15	4460	-5	7890	12	1170	9	0.5	0	4	-5	35	-1	56	1	0.4	2	17	-3	96	0
Hickeys and Mungay Creeks	MUNGAY CREEK MINE WASTE #1 - 15/9/15	MC MINE WASTE #1	15-Sep-15	1550	-6	4080	11	24	3	0.5	0	4	-5	16	-2	21	0	4.5	6	1	-7	16	-3

Appendix F
Table B
Sediment Geochemical Abundance Index

				Metals																			
				Aluminium	Al GAI	Antimony	Sb GAI	Arsenic	As GAI	Cadmium	Cd GAI	Chromium (III+VI)	Cr GAI	Copper	Cu GAI	Lead	Pb GAI	Mercury	Hg GAI	Nickel	Ni GAI	Zinc	Zn GAI
				mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg	
EQL				50		5		5		1		2		5		5		0.1		2		5	
GAI				82,300		1.5		1.8		0.3		102		60		14		0.085		84		70	
Monitoring_Zone	**Field_ID**	**Location_Code**	**Sampled_Date**																				
Aspley	E_SD01 11/9/15	E_SD01	11-Sep-15	5340	-5	2.5	0	8	2	0.5	0	61	-1	12	-3	2.5	-3	0.05	-1	23	-2	22	-2
Aspley	E_SD02 11/9/15	E_SD02	11-Sep-15	7960	-4	2.5	0	6	1	0.5	0	28	-2	12	-3	5	-2	0.05	-1	19	-3	21	-2
Aspley	EUROPAMBELA MINE DAM SEDIMENT - 11/9/15	E MINE DAM SEDIMENT	11-Sep-15	30,200	-2	2.5	0	9	2	0.5	0	76	-1	286	2	12	-1	0.05	-1	33	-2	38	-1
Chandler	AR_SD01 9/9/15	RA_SD01	09-Sep-15	5210	-5	3	0	17	**3**	0.5	0	8	-4	6	-4	10	-1	0	-1	4	-5	26	-2
Chandler	AR_SD02 9/9/15	RA_SD02	09-Sep-15	3260	-5	2.5	0	87	**5**	0.5	0	7	-4	6	-4	19	0	0.05	-1	3	-5	38	-1
Chandler	AR_SD03 9/9/15	RA_SD03	09-Sep-15	4860	-5	14	**3**	3600	**10**	6	**4**	10	-4	396	2	205	**3**	0.05	-1	2	-6	130	0
Chandler	C_SD01 14/9/15	C_SD01	14-Sep-15	8780	-4	2.5	0	7	1	0.5	0	12	-4	5	-4	2.5	-3	0.05	-1	8	-4	36	-2
Chandler	C_SD02 14/9/15	C_SD02	14-Sep-15	8910	-4	2.5	0	7	1	0.5	0	13	-4	6	-4	5	-2	0.05	-1	9	-4	37	-2
Chandler	KC_SD01 12/9/15	KC_SD01	12-Sep-15	12,900	-3	8	2	24	**3**	9	**4**	21	-3	292	2	643	**5**	0.6	3	21	-3	4460	**5**
Chandler	KC_SD02 12/9/15	KC_SD02	12-Sep-15	9570	-4	2.5	0	2.5	0	0.5	0	10	-4	19	-2	65	2	0.2	1	8	-4	69	-1
Chandler	KP_SD01 13/9/15	KP_SD01	13-Sep-15	8940	-4	2.5	0	9	2	0.5	0	8	-4	26	-2	82	2	0.2	1	12	-3	330	2
Chandler	KP_SD02 13/9/15	KP_SD02	13-Sep-15	13,200	-3	2.5	0	6	1	0.5	0	15	-3	15	-3	35	1	0.1	0	11	-4	123	0
Chandler	KP_SD03 13/9/15	KP_SD03	13-Sep-15	21,300	-3	2.5	0	15	2	0.5	0	29	-2	27	-2	23	0	0.1	0	22	-3	72	-1
Chandler	MM_SD01 13/9/15	MM_SD01	13-Sep-15	20,400	-3	2.5	0	7	1	5	**3**	24	-3	57	-1	31	1	0.2	1	19	-3	1870	**4**
Chandler	MM_SD02 13/9/15	MM_SD02	13-Sep-15	11,400	-3	2.5	0	8	2	0.5	0	14	-3	8	-3	17	0	0.1	0	10	-4	67	-1
Chandler	PG_SD01 9/9/15	PG_SD01	09-Sep-15	3360	-5	2.5	0	5	1	0.5	0	18	-3	22	-2	5	-2	0.05	-1	7	-4	16	-3
Chandler	PG_SD02 9/9/15	PG_SD02	09-Sep-15	11,300	-3	2.5	0	119	**5**	0.5	0	25	-3	138	1	29	0	0.4	2	41	-2	195	1
Chandler	PG_SD03 9/9/15	PG_SD03	09-Sep-15	8210	-4	13	**3**	106	**5**	0.5	0	14	-3	194	1	17	0	0.05	-1	8	-4	24	-2
Chandler	RS_SD01 10/9/15	RS_SD01	10-Sep-15	17,900	-3	2.5	0	9	2	0.5	0	37	-2	25	-2	14	-1	0.05	-1	20	-3	65	-1
Chandler	RS_SD02 10/9/15	RS_SD02	10-Sep-15	6080	-4	2.5	0	13	2	0.5	0	11	-4	7	-4	6	-2	0.05	-1	5	-5	23	-2
Chandler	SS_SD01 13/9/15	SS_SD01	13-Sep-15	13,500	-3	2.5	0	8	2	0.5	0	16	-3	12	-3	18	0	0.05	-1	12	-3	81	0
Chandler	TS_SD01 10/9/15	TS_SD01	10-Sep-15	14,000	-3	8	2	143	**6**	0.5	0	17	-3	9	-3	20	0	0.05	-1	6	-4	25	-2
Chandler	TS_SD02 10/9/15	TS_SD02	10-Sep-15	11,600	-3	106	**6**	691	**8**	2	2	10	-4	116	0	90	2	0.1	0	9	-4	193	1
Chandler	TS_SD03 10/9/15	TS_SD03	10-Sep-15	7960	-4	2.5	0	15	2	0.5	0	37	-2	8	-3	10	-1	0.05	-1	20	-3	47	-1
Chandler	TS_SD04 10/9/15	TS_SD04	10-Sep-15	7230	-4	2.5	0	16	**3**	0.5	0	34	-2	8	-3	8	-1	0.05	-1	25	-2	43	-1
Commissioners Waters	KA_SD01 11/9/15	KA_SD01	11-Sep-15	14,400	-3	2.5	0	36	**4**	0.5	0	42	-2	15	-3	8	-1	0.05	-1	20	-3	28	-2
Commissioners Waters	KA_SD02 11/9/15	KA_SD02	11-Sep-15	6280	-4	2.5	0	41	**4**	0.5	0	17	-3	6	-4	2.5	-3	0.05	-1	14	-3	18	-3
Commissioners Waters	MA_SD01 11/9/15	MA_SD01	11-Sep-15	18,400	-3	27	**4**	21	**3**	0.5	0	131	0	20	-2	12	-1	0.1	0	43	-2	30	-2
Commissioners Waters	MA_SD02 11/9/15	MA_SD02	11-Sep-15	22,700	-2	2.5	0	14	2	0.5	0	138	0	29	-2	13	-1	0.05	-1	74	-1	32	-2
Hickeys and Mungay Creeks	MG_SD01 15/9/15	MG_SD01	15-Sep-15	9610	-4	307	**7**	16	**3**	0.5	0	12	-4	21	-2	15	0	0.4	2	10	-4	60	-1
Hickeys and Mungay Creeks	MC_SD02	MC_SD02	12-Feb-16	8760	-4	83	**5**	72	**5**	0.5	0	11	-4	12	-3	17	0	0.2	1	8	-4	35	-2
Hickeys and Mungay Creeks	MC_SD03	MC_SD03	12-Feb-16	8040	-4	2.5	**0**	16	**3**	0.5	0	10	-4	10	-3	13	-1	0.05	-1	8	-4	40	-1
Toorumbee Creek and Warbro C	WB_SD01 15/9/15	WB_SD01	15-Sep-15	11,700	-3	2.5	0	30	**3**	0.5	0	12	-4	11	-3	12	-1	0.2	1	10	-4	43	-1

Appendix F
Table C
Bakers Creek Mineral Waste Geochemical Abundance Index

				Metals																			
				Aluminium	**Al GAI**	**Antimony**	**Sb GAI**	**Arsenic**	**As GAI**	**Cadmium**	**Cd GAI**	**Chromium (III+VI)**	**Cr GAI**	**Copper**	**Cu GAI**	**Lead**	**Pb GAI**	**Mercury**	**Hg GAI**	**Nickel**	**Ni GAI**	**Zinc**	**Zn GAI**
				mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg	
EQL				50		5		5		1		2		5		5		0.1		2		5	
GAI				82,300		1.5		1.8		0.3		102		60		14		0.085		84		70	
Monitoring_Zone	**Field_ID**	**Location_Code**	**Sampled_Date**																				
Bakers Creek	BAKERS CREEK MINE WASTE-10/2/16	Bakers Creek MW	10-Feb-16	13800	-3	20	**3**	1090	**9**	0.5	0	83	-1	7	-4	21	0	0.1	0	22	-3	47	-1
Bakers Creek	BLACK LODE (1700) MINE WASTE-10/2/16	Black Lode (1700) MW	10-Feb-16	8900	-4	2150	**10**	2560	**10**	0.5	0	9	-4	22	-2	20	0	0.3	2	9	-4	111	0
Bakers Creek	BRACKINS SPUR MINE WASTE #1-9/2/16	Brackins Spur MW	09-Feb-16	6880	-4	313	**7**	2700	**10**	0.5	0	11	-4	60	-1	23	0	1	**4**	24	-2	83	0
Bakers Creek	COSMOPOLITAN MINE WASTE-11/2/16	Cosmopolitan MW	11-Feb-16	9170	-4	887	**9**	510	**8**	0.5	0	12	-4	33	-1	15	0	0.2	1	16	-3	89	0
Bakers Creek	LADY HOPETOUN MINE WASTE-11/2/16	Lady Hopetoun MW	11-Feb-16	11200	-3	3480	**11**	1570	**9**	0.5	0	18	-3	33	-1	19	0	0.5	**3**	11	-4	71	-1
Bakers Creek	SMITH'S MINE WASTE-9/2/16	Smith's Mine Waste	09-Feb-16	4690	-5	113	**6**	930	**8**	0.5	0	11	-4	16	-2	49	1	0.7	**3**	12	-3	79	0

Appendix F
Table D
Bakers Creek Sediment Geochemical Abundance Index

				Metals																			
				Aluminium	Al GAI	Antimony	Sb GAI	Arsenic	As GAI	Cadmium	Cd GAI	Chromium (III+VI)	Cr GAI	Copper	Cu GAI	Lead	Pb GAI	Mercury	Hg GAI	Nickel	Ni GAI	Zinc	Zn GAI
				mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg	
EQL				50		5		5		1		2		5		5		0.1		2		5	
GAI				82,300		1.5		1.8		0.3		102		60		14		0.085		84		70	
Monitoring_Zone	**Field_ID**	**Location_Code**	**Sampled_Date**																				
Bakers Creek	ES1603307020	BC_SD01	09-Feb-16	12,000	-3	3	0	11	2	0.5	0	26	-3	19	-2	7	-2	0.1	0	36	-2	51	-1
Bakers Creek	ES1603307021	BC_SD02	09-Feb-16	10,400	-4	127	**6**	95	**5**	0.5	0	22	-3	15	-3	8	-1	0	-1	14	-3	38	-1
Bakers Creek	ES1603307022	BC_SD03	09-Feb-16	7830	-4	3	0	17	**3**	0.5	0	12	-4	14	-3	16	0	0	-1	10	-4	53	-1
Bakers Creek	ES1603307023	BC_SD04	09-Feb-16	20,200	-3	3	0	77	**5**	0.5	0	103	-1	13	-3	3	-3	0	-1	27	-2	26	-2
Bakers Creek	ES1603307024	BC_SD05	09-Feb-16	6270	-4	110	**6**	52	**4**	0.5	0	10	-4	11	-3	3	-3	0	-1	10	-4	26	-2
Bakers Creek	ES1603307025	BC_SD06	09-Feb-16	5800	-4	110	**6**	429	**7**	0.5	0	12	-4	10	-3	3	-3	0.1	0	7	-4	26	-2
Bakers Creek	ES1603307026	BC_SD07	09-Feb-16	23,900	-2	71	**5**	212	**6**	0.5	0	115	0	23	-2	3	-3	0	-1	28	-2	32	-2
Bakers Creek	ES1603307027	BC_SD08	09-Feb-16	9360	-4	11	2	38	**4**	0.5	0	32	-2	7	-4	3	-3	0	-1	9	-4	31	-2
Bakers Creek	ES1603307068	BC_SD09	09-Feb-16	14,900	-3	381	**7**	177	**6**	0.5	0	32	-2	46	-1	16	0	0.1	0	28	-2	70	-1
Bakers Creek	ES1603307028	BC_SD10	09-Feb-16	8120	-4	17	**3**	10	2	0.5	0	11	-4	16	-2	5	-2	0	-1	7	-4	29	-2
Bakers Creek	ES1603307030	BC_SD11	09-Feb-16	13,200	-3	49	**4**	62	**5**	0.5	0	22	-3	16	-2	13	-1	0	-1	17	-3	167	1
Bakers Creek	ES1603307031	BC_SD12	10-Feb-16	15,000	-3	952	**9**	330	**7**	0.5	0	17	-3	45	-1	32	1	0.6	**3**	34	-2	198	1
Bakers Creek	ES1603307037	BC_SD14	10-Feb-16	14,800	-3	183	**6**	1990	**10**	0.5	0	13	-4	26	-2	23	0	0.4	2	16	-3	83	0
Bakers Creek	ES1603307036	BC_SD15	10-Feb-16	10,200	-4	269	**7**	204	**6**	0.5	0	31	-2	41	-1	7	-2	0.1	0	31	-2	42	-1
Bakers Creek	ES1603307034	BC_SD16	10-Feb-16	13,400	-3	21	**3**	209	**6**	0.5	0	16	-3	56	-1	17	0	0.2	1	20	-3	84	0
Bakers Creek	ES1603307035	BC_SD17	10-Feb-16	11,500	-3	1600	**9**	499	**8**	0.5	0	38	-2	56	-1	15	0	0.3	2	40	-2	59	-1
Bakers Creek	ES1603307038	BC_SD18	10-Feb-16	14,100	-3	28	**4**	45	**4**	0.5	0	20	-3	8	-3	8	-1	0	-1	8	-4	51	-1
Bakers Creek	ES1603307039	BC-SD19	10-Feb-16	12,900	-3	252	**7**	180	**6**	0.5	0	38	-2	58	-1	13	-1	0	-1	37	-2	53	-1
Bakers Creek	ES1603307040	BC_SD20	10-Feb-16	17,700	-3	3	0	42	**4**	0.5	0	36	-2	41	-1	10	-1	0	-1	16	-3	79	0
Bakers Creek	ES1603307041	BC_SD21	10-Feb-16	10,900	-4	243	**7**	173	**6**	0.5	0	38	-2	44	-1	14	-1	0.1	0	38	-2	40	-1
Bakers Creek	ES1603307043	BC_SD23	11-Feb-16	13,500	-3	9	2	85	**5**	0.5	0	26	-3	18	-2	9	-1	0	-1	11	-4	63	-1
Bakers Creek	ES1603307044	BC_SD24	11-Feb-16	11,500	-3	700	**8**	336	**7**	0.5	0	38	-2	41	-1	11	-1	0.2	1	33	-2	48	-1
Bakers Creek	ES1603307045	BC-SD25	11-Feb-16	13,900	-3	629	**8**	216	**6**	0.5	0	56	-1	66	0	10	-1	0.2	1	49	-1	46	-1
Bakers Creek	ES1603307046	BC_SD26	11-Feb-16	10,000	-4	54	**5**	138	**6**	0.5	0	16	-3	13	-3	12	-1	0.1	0	10	-4	46	-1
Bakers Creek	ES1603307047	BC_SD27	11-Feb-16	10,200	-4	265	**7**	123	**6**	0.5	0	14	-3	14	-3	13	-1	0.5	**3**	9	-4	67	-1
Bakers Creek	ES1603307048	BC_SD28	11-Feb-16	10,400	-4	78	**5**	193	**6**	0.5	0	16	-3	16	-2	10	-1	0.1	0	8	-4	49	-1
Bakers Creek	ES1603307050	BC_SD29	11-Feb-16	7610	-4	26	**4**	70	**5**	0.5	0	15	-3	10	-3	9	-1	0	-1	6	-4	38	-1
Bakers Creek	ES1603307051	BC_SD30	11-Feb-16	6520	-4	29	**4**	47	**4**	0.5	0	10	-4	9	-3	6	-2	0	-1	5	-5	37	-2
Bakers Creek	ES1603307052	BC_SD31	11-Feb-16	9010	-4	3	0	42	**4**	0.5	0	15	-3	8	-3	6	-2	0	-1	8	-4	36	-2
Bakers Creek	ES1603307053	BC_SD32	11-Feb-16	5360	-5	3	0	8	2	0.5	0	7	-4	2	-5	3	-3	0	-1	5	-5	12	-3
Bakers Creek	ES1603307029	BC_SD33	09-Feb-16	10,300	-4	9	2	8	2	0.5	0	17	-3	8	-3	6	-2	0	-1	8	-4	29	-2
Bakers Creek	ES1603307032	BC_SD34	10-Feb-16	13,800	-3	20	**3**	34	**4**	0.5	0	57	-1	15	-3	8	-1	0.1	0	26	-2	44	-1
Bakers Creek	ES1603307033	BC_SD35	10-Feb-16	11,400	-3	326	**7**	256	**7**	0.5	0	39	-2	45	-1	11	-1	0.2	1	35	-2	48	-1
Bakers Creek	ES1603307054	BC_SD36	11-Feb-16	5130	-5	26	**4**	137	**6**	0.5	0	7	-4	6	-4	5	-2	0.1	0	5	-5	21	-2

Where a result returned a non-detect; a value of 50% of the lab EQL was used to calculate GAIs.

Appendix F – Figures

Paper Size A3

0 30 60 120 180

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

△ Sample Point Locations

✕ Mine Site

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Upper Chandler - Phoenix Gold
Sample Point Locations

Job Number	21-23815
Revision	A
Date	08 May 2018

Figure A

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani

Paper Size A3

0 30 60 120 180

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

△ Sample Point Locations

Mine Site

GHD

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Upper Chandler - Rockvale Arsenic
Sample Point Locations

Job Number	21-23815
Revision	A
Date	08 May 2018

Figure B

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani

Paper Size A3

0 15 30 60 90

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Sample Point Locations
- Mine Site

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Upper Chandler - Ruby Silver
Sample Point Locations

Job Number	21-23815
Revision	A
Date	08 May 2018

Figure C

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani

Paper Size A3

0 25 50 100 150

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Sample Point Locations

Mine Site

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Upper Chandler - Tulloch Silver
Sample Point Locations

Job Number 21-23815
Revision A
Date 08 May 2018

Figure D

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani

Paper Size A3

0 40 80 160 240

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND
- Sample Point Locations
- Mine Site

GHD

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number 21-23815
Revision A
Date 08 May 2018

Lower Chandler - Khans Creek
Sample Point Locations

Figure E

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani

Paper Size A3

0 20 40 80 120

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Sample Point Locations

Mine Site

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Lower Chandler - Keys Prospect
Sample Point Locations

Job Number	21-23815
Revision	A
Date	08 May 2018

Figure F

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani

Paper Size A3

0 15 30 60 90

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Sample Point Locations
- Mine Site

GHD

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number 21-23815
Revision A
Date 08 May 2018

Commissioners Waters - Kapunda Arsenic
Sample Point Locations

Figure G

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani

Paper Size A3

0 25 50 100 150

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

△ Sample Point Locations

Mine Site

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Commissioners Waters - Mary Anderson
Mary Anderson Sample Point Locations

Job Number	21-23815
Revision	A
Date	08 May 2018

Figure H

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani

Paper Size A3

0 65 130 260 390

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Sample Point Locations
- Mine Site

GHD

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number 21-23815
Revision A
Date 08 May 2018

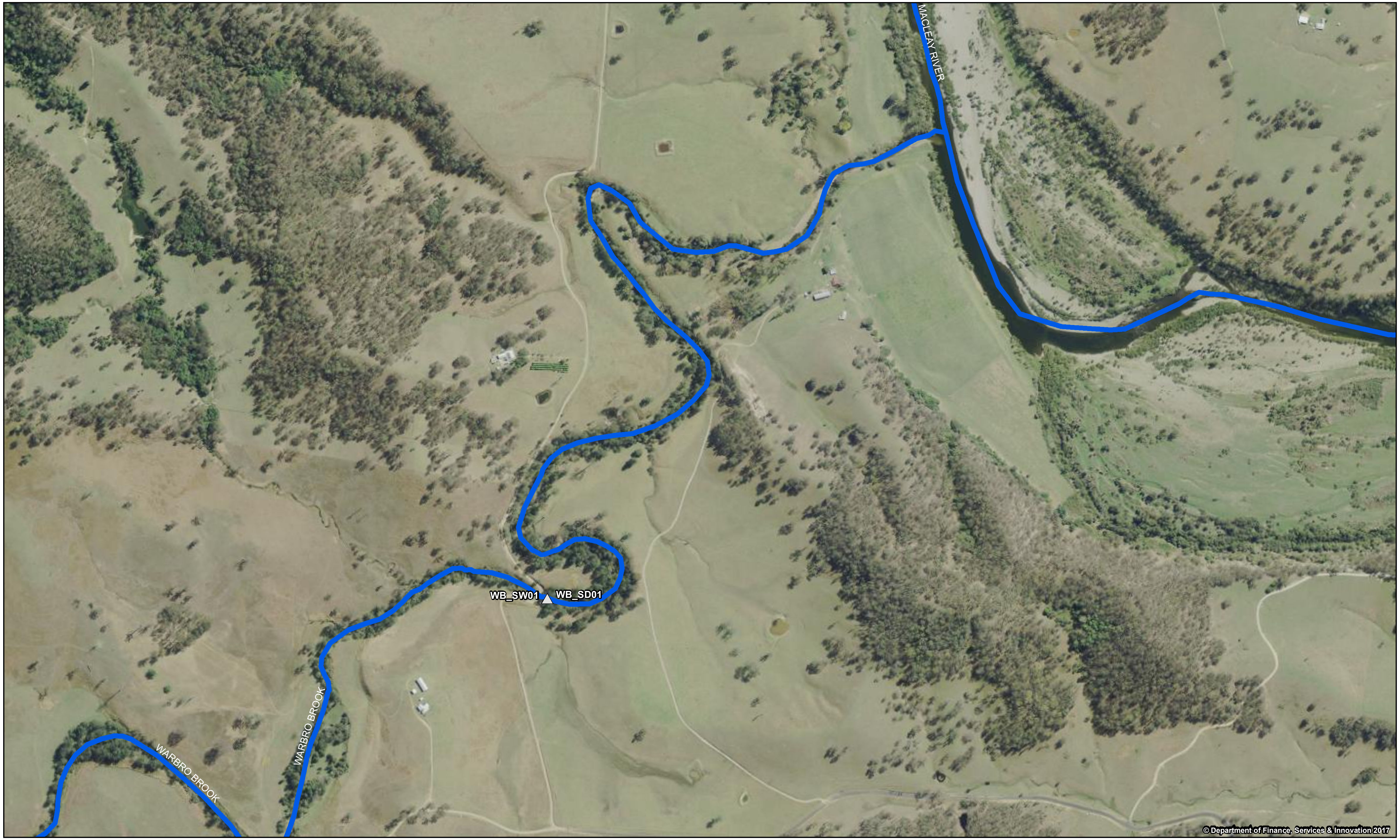
Macleay Catchment - Mungay Creek Sample Point Locations

Figure I

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani



Paper Size A3

0 50 100 200 300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Sample Point Locations
- Mine Site

GHD

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	08 May 2018

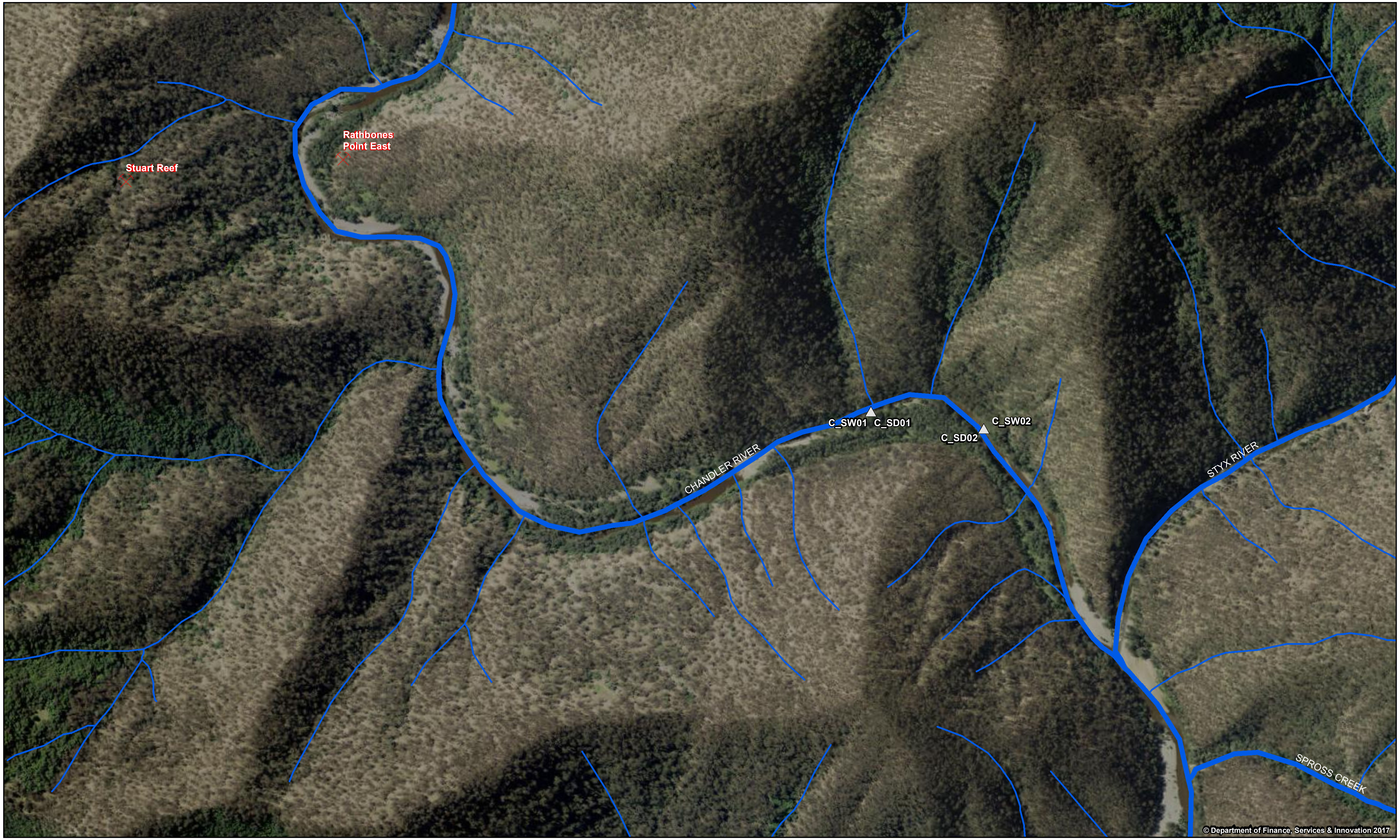
Toorumbee Creek and Warbro Brook - Warbro Brook Sample Point Locations

Figure J

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani



Paper Size A3

0 60 120 240 360

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Sample Point Locations
- Mine Site

NSW Department of Industry
Macleay Catchment Arsenic and Antimony Investigation

Job Number 21-23815
Revision A
Date 08 May 2018

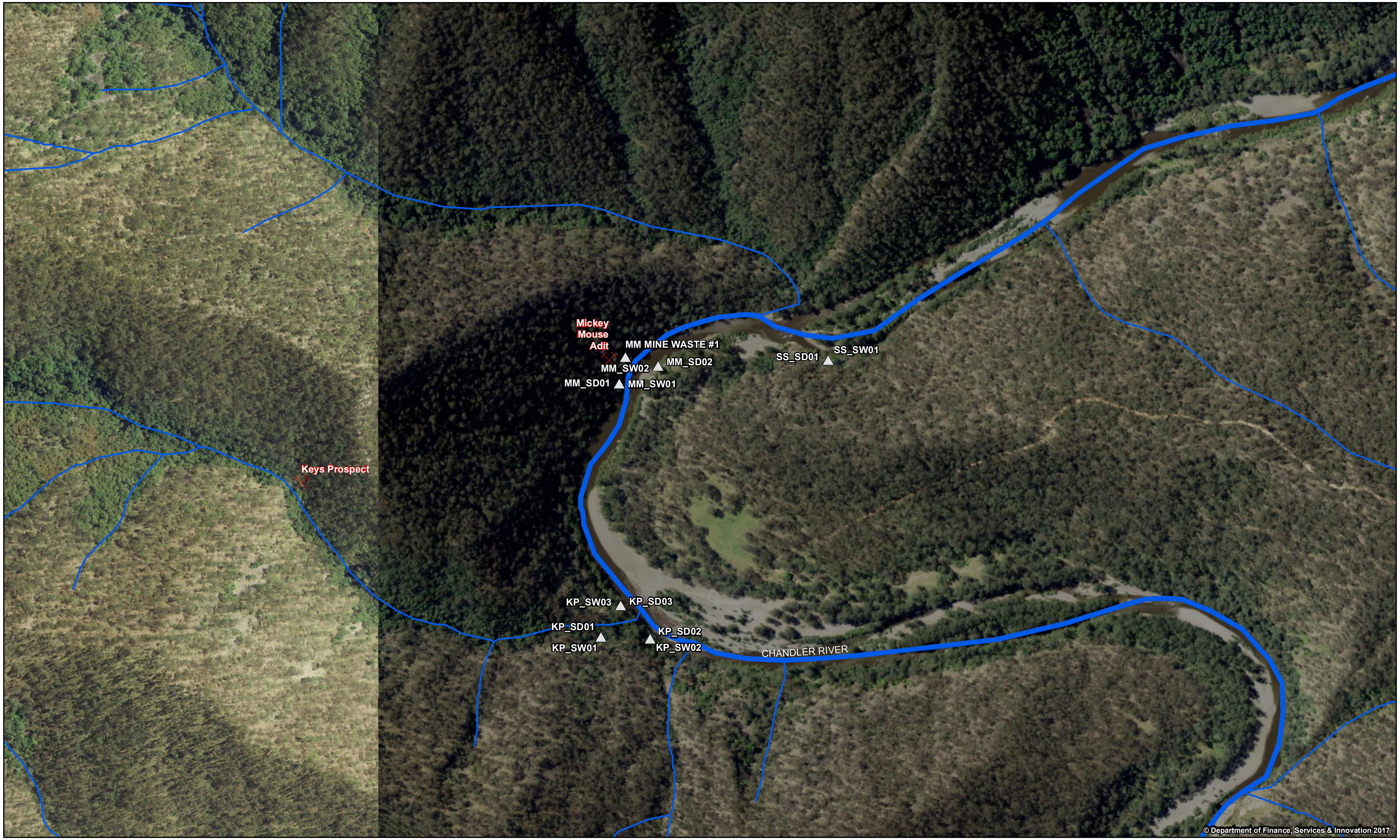
Lower Chandler - Chandler Confluence
Stuart Reef and Rathbones Point East Sample Point Locations

Figure K

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani



Paper Size A3

0 40 80 160 240

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Sample Point Locations
- Mine Site

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Lower Chandler - Mickey Mouse Sample Point Locations

Job Number	21-23815
Revision	A
Date	08 May 2018

Figure L

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani

Paper Size A3

0 25 50 100 150

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Sample Point Locations

Mine Site

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Lower Chandler - Sunnyside
Sample Point Locations

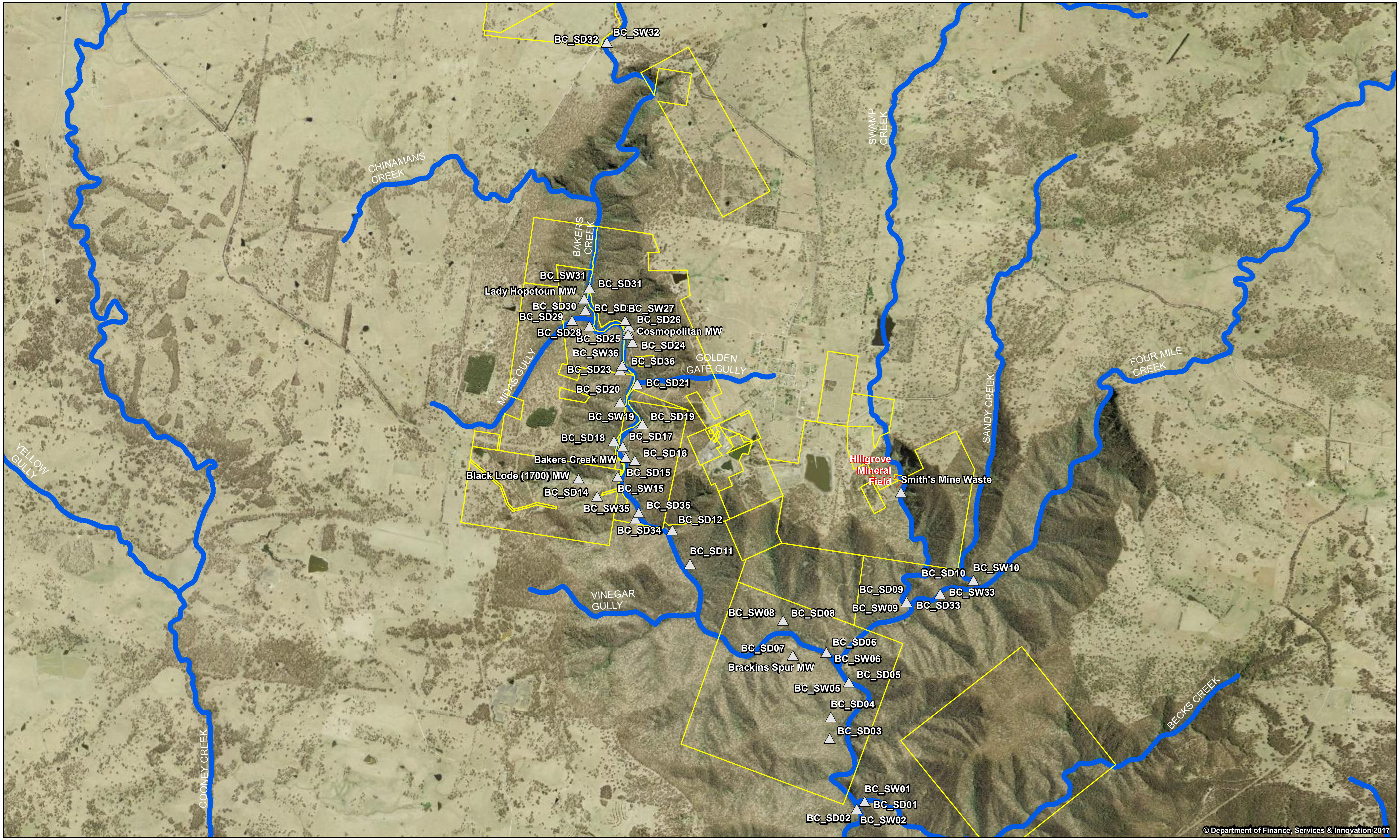
Job Number	21-23815
Revision	A
Date	08 May 2018

Figure M

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani



Paper Size A3

0 235 470 940 1,410

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Sample Point Locations
- Mine Site
- Mineral Titles

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

GHD

Bakers Creek - Bakers Creek
Sample Point Locations

Job Number	21-23815
Revision	A
Date	08 May 2018

Figure N

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Paper Size A3

0 25 50 100 150

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Sample Point Locations
- Mine Site

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Aspley - Europambela Sample Point Locations

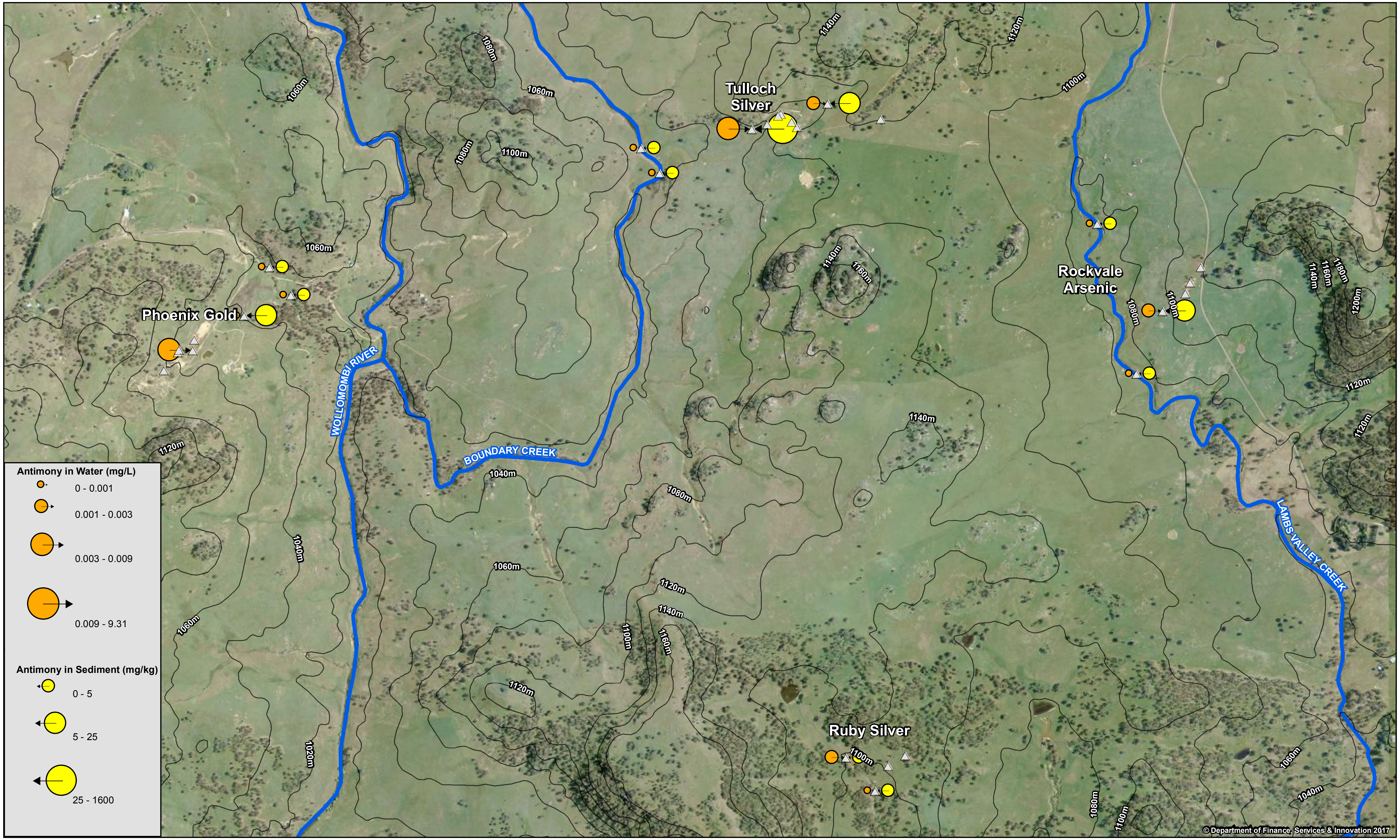
Job Number	21-23815
Revision	A
Date	08 May 2018

Figure O

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z019_MINEVISITS_SampleLocations.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery - ESRI; Waterways, Subcatchments - NSW LPI. Created by:jrbacani



Note: Where duplicate samples were collected, the highest of the two readings was used

Paper Size A3

0 90 180 360 540 720

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Sample Locations
- Flow Direction
- Contour (mADH)
- Watercourses
- Drainage

GHD

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	08 May 2018

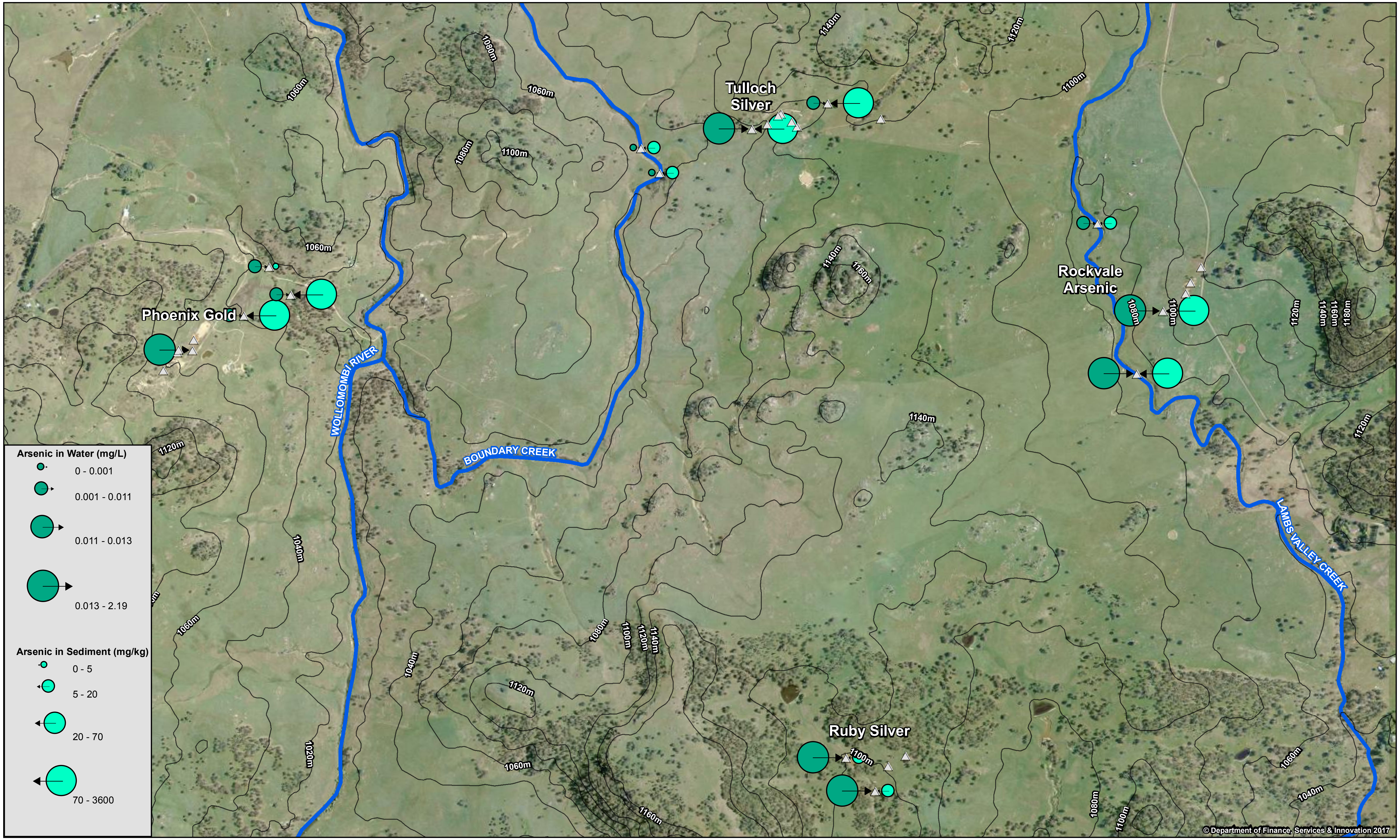
Upper Chandler
Antimony in Sediment and Water

Figure P

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z015_MINEVISITS_DDP_Antimony.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com

Data source: Imagery, Waterways, Contours - Land and Property Information. Created by:jrbacani



Note: Where duplicate samples were collected, the highest of the two readings was used

Paper Size A3

0 90 180 360 540 720

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

LEGEND

- Sample Locations
- Flow Direction
- Contour (mADH)
- Watercourses
- Drainage

NSW Department of Industry
Macleay Catchment Arsenic and Antimony Investigation

Job Number	21-23815
Revision	A
Date	08 May 2018

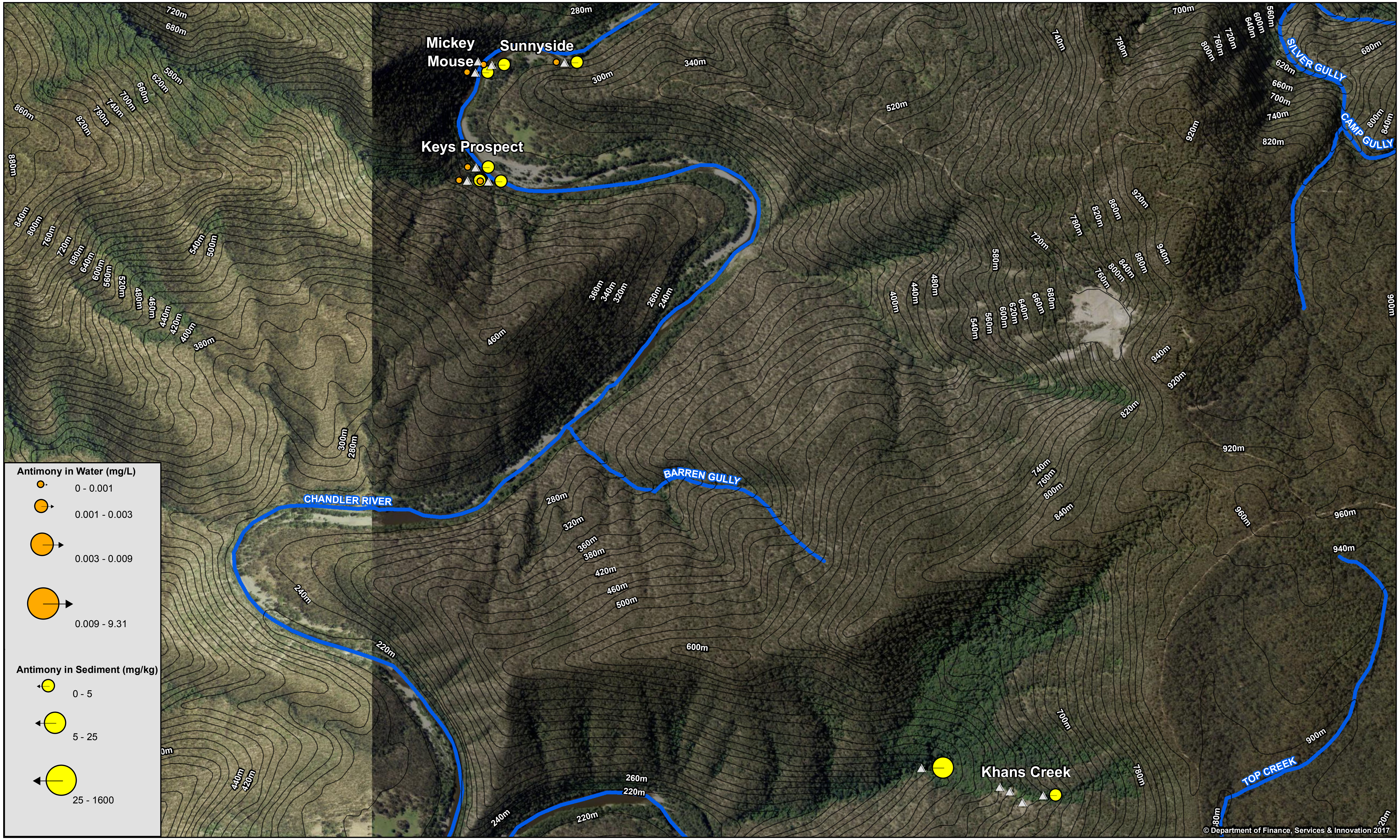
Upper Chandler
Arsenic in Sediment and Water

Figure Q

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z016_MINEVISITS_DDP_Arsenic.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery, Waterways, Contours - Land and Property Information. Created by:jrbacani



Note: Where duplicate samples were collected, the highest of the two readings was used

Paper Size A3

0 70 140 280 420 560

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Sample Locations
- Flow Direction
- Contour (mADH)
- Watercourses
- Drainage

GHD

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	08 May 2018

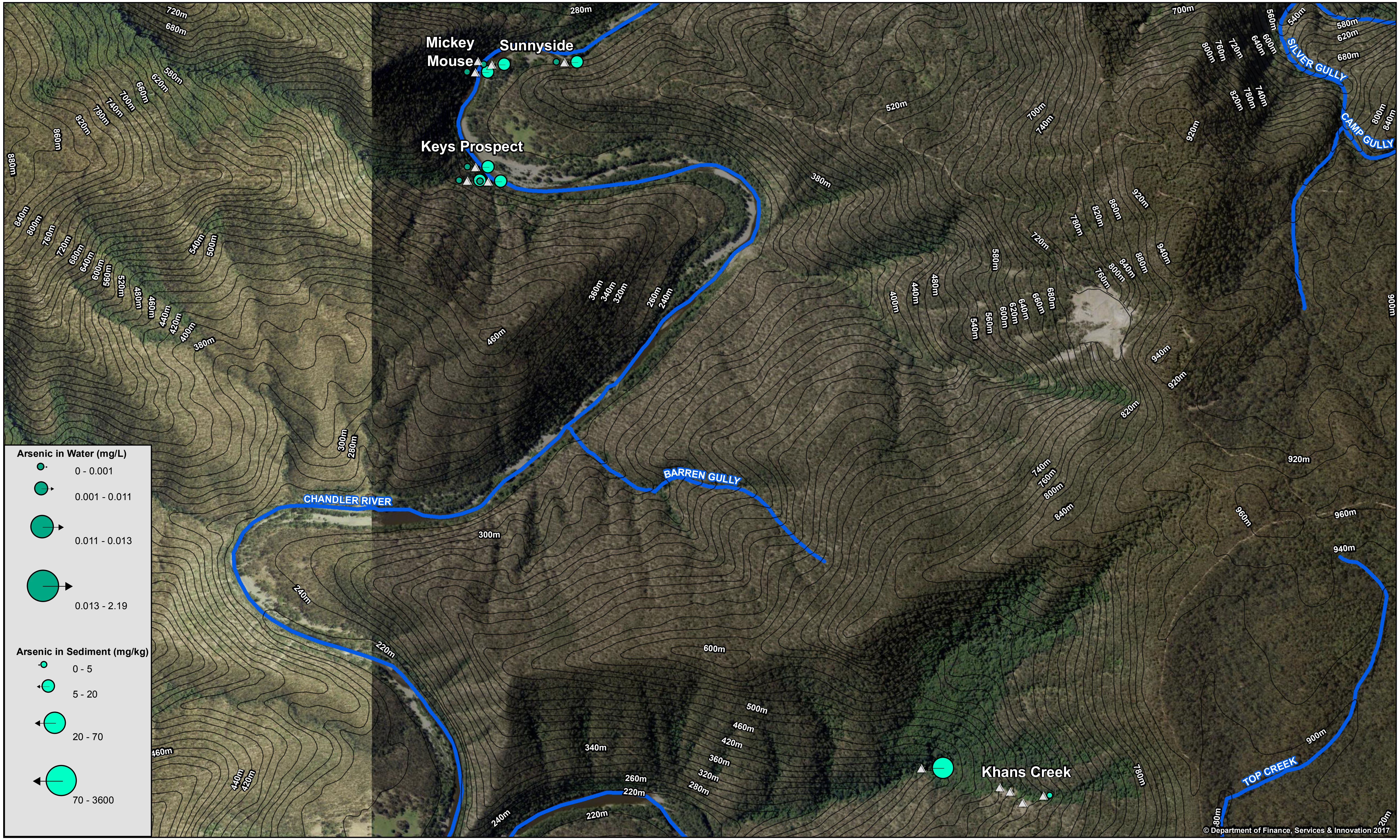
Lower Chandler
Antimony in Sediment and Water

Figure R

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z015_MINEVISITS_DDP_Antimony.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery, Waterways, Contours - Land and Property Information. Created by:jrbacani



Note: Where duplicate samples were collected, the highest of the two readings was used

Paper Size A3

0 70 140 280 420 560

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Sample Locations
- Flow Direction
- Contour (mADH)
- Watercourses
- Drainage

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	08 May 2018

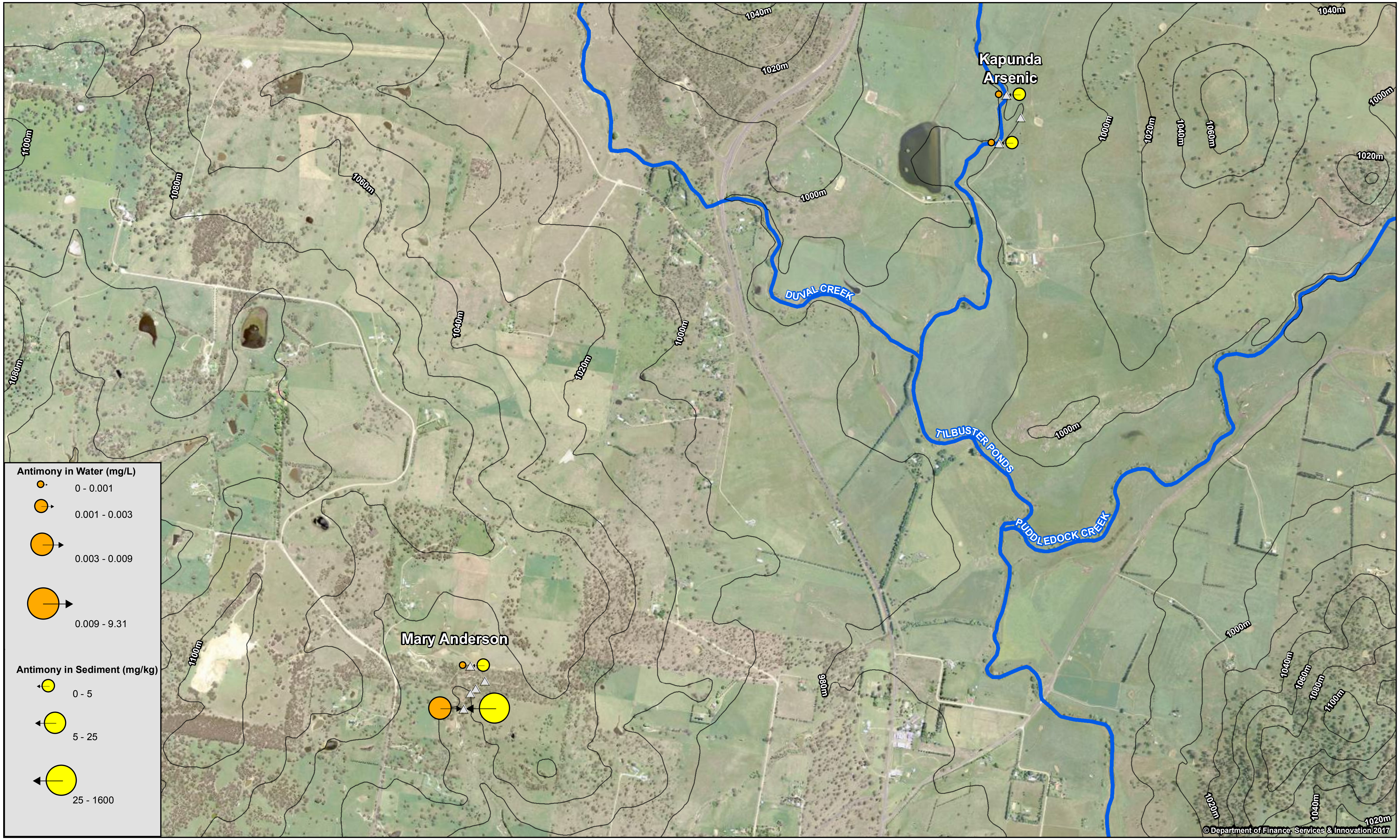
Lower Chandler
Arsenic in Sediment and Water

Figure S

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z016_MINEVISITS_DDP_Arsenic.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery, Waterways, Contours - Land and Property Information. Created by:jrbacani



Note: Where duplicate samples were collected, the highest of the two readings was used

Paper Size A3

0 95 190 380 570 760

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND
- Sample Locations
- Flow Direction
- Contour (mADH)
- Watercourses
- Drainage

GHD

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	08 May 2018

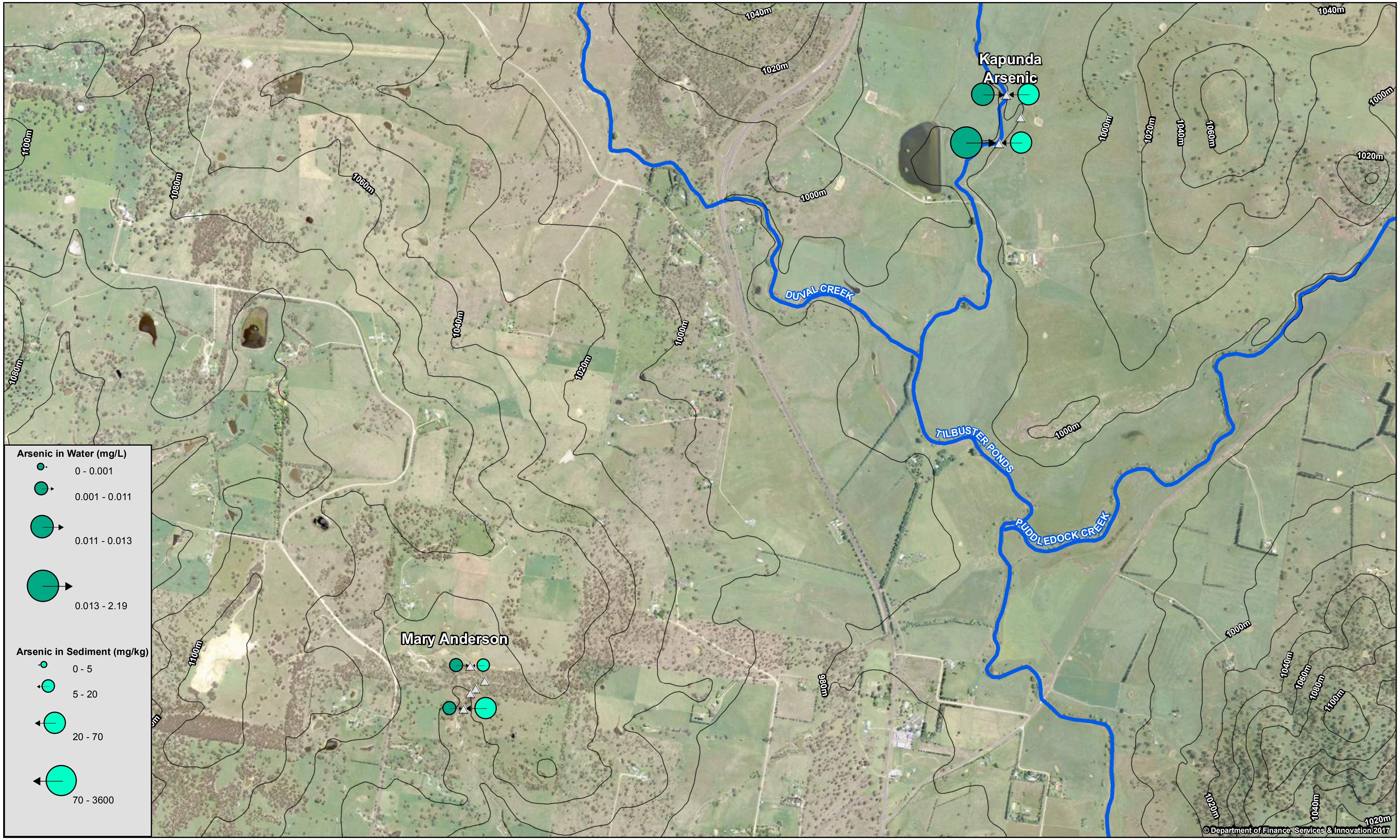
Commissioners Waters
Antimony in Sediment and Water

Figure T

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z015_MINEVISITS_DDP_Antimony.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery, Waterways, Contours - Land and Property Information. Created by:jrbacani



Note: Where duplicate samples were collected, the highest of the two readings was used

Paper Size A3

0 95 190 380 570 760

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Sample Locations
Flow Direction
Contour (mADH)
Watercourses
Drainage

GHD

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	08 May 2018

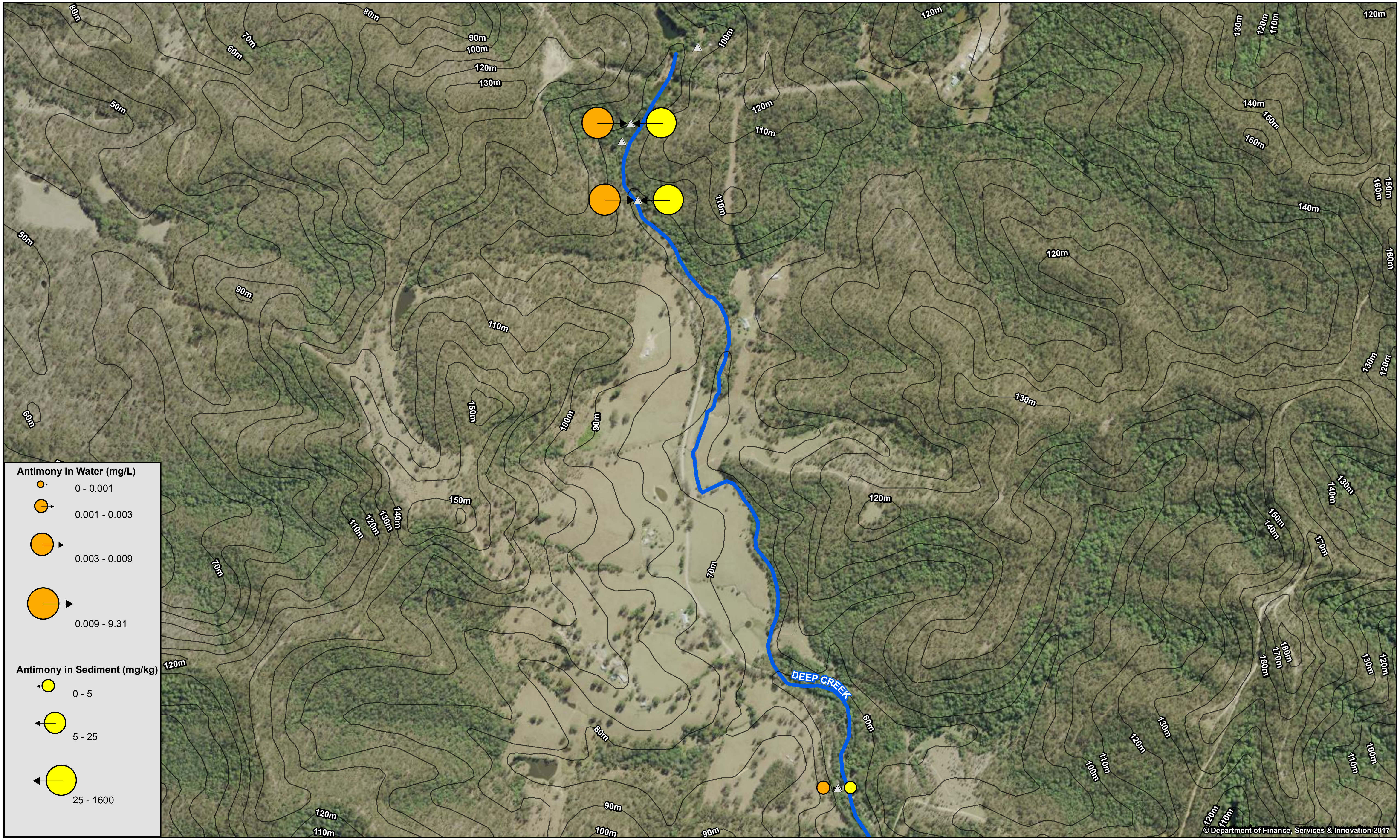
Commissioners Waters
Arsenic in Sediment and Water

Figure U

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z016_MINEVISITS_DDP_Arsenic.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery, Waterways, Contours - Land and Property Information. Created by:jrbacani



Note: Where duplicate samples were collected, the highest of the two readings was used

Paper Size A3

0 45 90 180 270 360

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Sample Locations | Flow Direction

Contour (mADH)

Watercourses

Drainage

GHD

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	08 May 2018

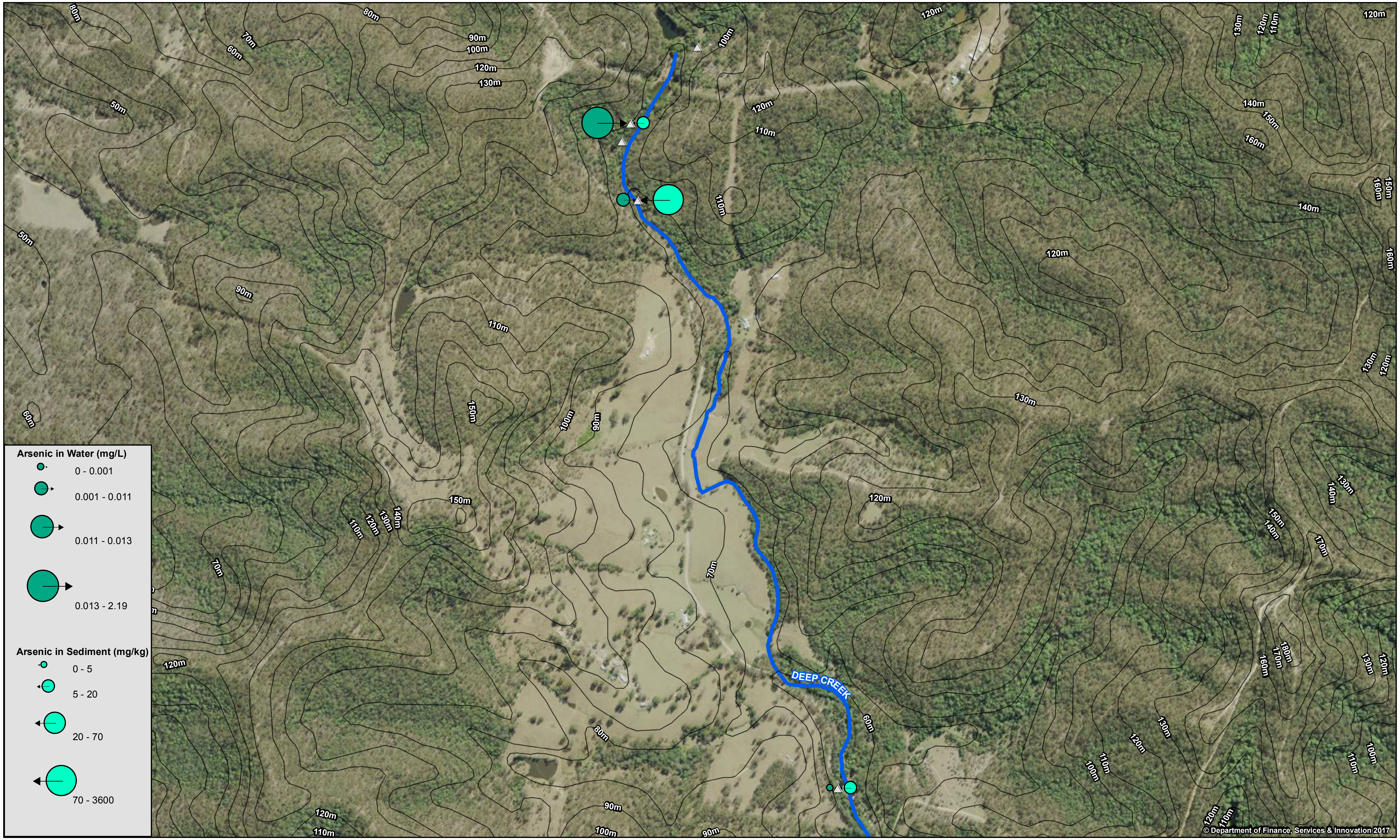
Hickeys and Mungay Creeks
Antimony in Sediment and Water

Figure V

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z015_MINEVISITS_DDP_Antimony.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery, Waterways, Contours - Land and Property Information. Created by:jrbacani



Note: Where duplicate samples were collected, the highest of the two readings was used

Paper Size A3

0 45 90 180 270 360

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Sample Locations
- Flow Direction
- Contour (mADH)
- Watercourses
- Drainage

NSW Department of Industry
Macleay Catchment Arsenic
and Antimony Investigation

Job Number	21-23815
Revision	A
Date	08 May 2018

Hickeys and Mungay Creeks
Arsenic in Sediment and Water

Figure W

G:\21\0101203\2018 proposals (temp)\26 Macleay variation for Legacy Mines Program\GIS\Maps\Deliverables\May 2018\2123815_Z016_MINEVISITS_DDP_Arsenic.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Data source: Imagery, Waterways, Contours - Land and Property Information. Created by:jrbacani

GHD

133 Castlereagh St Sydney NSW 2000
-
T: +61 2 9239 7100   F: +61 2 9239 7199   E: sydmail@ghd.com.au

n:\au\sydney\projects\21\23815\WP\211564.docx

Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	Nicole Rosen Assoc Prof. Paul Ashley Dr Stuart Winchester	Rob Virtue Assoc Prof. Paul Ashley Dr Stuart Winchester	On file	Dr Stuart Winchester	On file	30/05/2016
B	Nicole Rosen Assoc Prof. Paul Ashley Dr Stuart Winchester	Rob Virtue Assoc Prof. Paul Ashley Dr Stuart Winchester	On file	Dr Stuart Winchester	On file	17/07/2016
C	Nicole Rosen Assoc Prof. Paul Ashley Dr Stuart Winchester	Rob Virtue Assoc Prof. Paul Ashley Dr Stuart Winchester	On file	Dr Stuart Winchester	On file	28/07/2016
0	Nicole Rosen Assoc Prof. Paul Ashley Dr Stuart Winchester	Rob Virtue Assoc Prof. Paul Ashley Dr Stuart Winchester	On file	Dr Stuart Winchester		13/10/2016

www.ghd.com