ATTACHMENT BB
Fluvial Geomorphological Assessment for Stratford Extension Project EIS
[Fluvial Systems Pty Ltd, 2012]

Fluvial geomorphological assessment for Stratford Extension Project EIS

Dr Christopher J Gippel

For

Stratford Coal Pty Ltd

May 2012

FLUVIAL SYSTEMS

GEOMORPHOLOGY • CATCHMENT HYDROLOGY
RIVER REHABILITATION • ENVIRONMENTAL FLOWS

Fluvial geomorphological assessment for Stratford Extension Project EIS

by Dr Christopher J Gippel

Fluvial Systems Pty Ltd

Please cite as follows:

Gippel, C.J. 2012. Fluvial geomorphological assessment for Stratford Extension Project EIS. Fluvial Systems Pty Ltd, Stockton. Stratford Coal Pty Ltd, May.

Document history and status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
A	18/03/2012	Tony Dwyer	C. Gippel	18/03/2011	Draft
B	19/04/2012	Tony Dwyer	C. Gippel	19/04/2012	Draft
C	17/05/2012	Tony Dwyer	C. Gippel	17/05/2012	Final

Distribution of copies

Revision	Copy no	Quantity	Issued to
A	1	1	Tony Dwyer
B	1	1	Tony Dwyer
C	1	1	Tony Dwyer

Printed:	Not printed
Last saved:	17/05/2012
File location:	C:\...\12003_Stratford Coal EIS\Reports\Stratford Extension EIS_Fluvial Geomorphology_Final_17 May 2012.docx
Author:	Dr Christopher J Gippel
Project manager:	Tony Dwyer
Name of organisation:	Stratford Coal Pty Ltd
Name of project:	Stratford Extension Project
Name of document:	Fluvial geomorphology assessment report
Document version:	Final

Fluvial Systems Pty Ltd
PO Box 49
Stockton NSW 2295
fluvialsystems@fastmail.net
Ph/Fax: 02 49284128; Mobile: 0404 472 114

Disclaimer

Fluvial Systems Pty Ltd prepared this report for the use of Stratford Coal Pty Ltd, and any other parties that may rely on the report, in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal.

Fluvial Systems Pty Ltd does not warrant this document is definitive nor free from error and does not accept liability for any loss caused, or arising from, reliance upon the information provided herein.

The methodology adopted and sources of information used by Fluvial Systems Pty Ltd are provided in this report. Fluvial Systems Pty Ltd has made no independent verification of this information beyond the agreed scope of works and Fluvial Systems Pty Ltd assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to Fluvial Systems Pty Ltd was false.

This report is based on the conditions encountered and information reviewed at the time of collection of data and report preparation. Fluvial Systems Pty Ltd disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Copyright

Table of Contents

List of Tables

List of Figures

1 Introduction

1.1 Background

Stratford Coal Pty Ltd (SCPL), a wholly owned subsidiary of Gloucester Coal Limited, is seeking consent for the continuation and extension of open cut coal mining and processing activities at the Stratford Coal Mine and Bowens Road North Open Cut (BRNOC), collectively known as the Stratford Mining Complex, herein referred to as the Stratford Extension Project (the Project).

An Environmental Impact Statement (EIS) for the Project is being prepared by Resource Strategies Pty Ltd. Gilbert & Associates is primarily responsible for the Surface Water Assessment (SWA) component of the EIS for the Project. Fluvial Systems Pty Ltd was engaged by SCPL to contribute the fluvial geomorphology component of the SWA.

1.2 Director-General's Requirements

The Director-General's Requirements (DGRs) under Section 78A of the *Environmental Planning and Assessment Act 1979* include a number of requirements that relate to the fluvial geomorphology of the Project area. These include:

- "*a description of the existing environment, using sufficient baseline data;*
- *an assessment of the potential impacts of the project, including any potential cumulative impacts, taking into consideration any relevant guidelines, policies, plans and statutes; and*
- *a description of the measures that would be implemented to avoid, minimise, and if necessary, offset the potential impacts of the project, including detailed contingency plans for adaptive management and/or contingency plans to manage any significant risks to the environment…*"

The Key Issues of the DGRs with relevance to the fluvial geomorphology of the Project area are "Biodiversity" and "Water Resources". Fluvial geomorphology is relevant to biodiversity in the sense that aquatic ecological communities and ecosystems rely on aquatic habitats, and the geomorphic characteristics, together with the hydraulic and hydrologic characteristics of water courses, determine the physical nature of aquatic habitats. While this report characterises the fluvial geomorphology of the Project area, it makes no inferences about habitat availability or quality. However, the information provided here is sufficient that a suitably qualified person can assess the geomorphic characteristics of the Project area from the perspective of the availability and quality of aquatic habitat for particular species or communities of interest.

The key water resources issue of the DGRs relevant to fluvial geomorphology is:

- "*a detailed assessment of potential impacts on the quality and quantity of existing surface and ground water resources, including:..*
  - o *Impacts on riparian, ecological, geo-morphological and hydrological values of watercourse, including environmental flows;…*"

This report addresses the fluvial geomorphological component of this requirement.

1.3 Brief history of the mine and brief description of the Project

Construction at the Stratford Mining Complex commenced in 1995 and the Stratford Main Pit was mined for eight years. The BRNOC has been in operation since 2003. The SMC currently extracts coal from the Roseville West Pit, which commenced in 2007 and from the BRNOC.

The Project would include the following activities:

- run-of-mine (ROM) coal production up to 2.6 million tonnes per annum (Mtpa) for an additional 11 years (commencing approximately 1 July 2013 or upon the grant of all required approvals), including mining operations associated with:
  - completion of the BRNOC;
  - extension of the existing Roseville West Pit; and
  - development of the new Avon North and Stratford East Open Cuts;
- exploration activities;
- progressive backfilling of mine voids with waste rock behind the advancing open cut mining operations;
- continued and expanded placement of waste rock in the Stratford Waste Emplacement and Northern Waste Emplacement;
- progressive development of new haul roads and internal roads;
- coal processing at the existing coal handling and preparation plant (CHPP) including Project ROM coal, sized ROM coal received and unloaded from the Duralie Coal Mine and material recovered periodically from the western co disposal area;
- stockpiling and loading of product coal to trains for transport on the North Coast Railway to Newcastle;
- disposal of CHPP rejects via pipeline to the existing co-disposal area in the Stratford Main Pit and, later in the Project life, the Avon North Open Cut void;
- realignments of Wheatleys Lane, Bowens Road, and Wenham Cox/Bowens Road;
- realignment of a 132 kilovolt (kV) power line for the Stratford East Open Cut;
- continued use of existing contained water storages/dams and progressive development of additional sediment dams, pumps, pipelines, irrigation infrastructure and other water management equipment and structures;
- development of soil stockpiles, laydown areas and gravel/borrow areas, including modifications and alterations to existing infrastructure as required;
- monitoring and rehabilitation;
- all activities approved under DA 23-98/99 and DA 39-02-01; and
- other associated minor infrastructure, plant, equipment and activities, including minor modifications and alterations to existing infrastructure as required.

1.4 Hydrological changes associated with the Project that are relevant to fluvial geomorphology

The potential for impacts on fluvial geomorphology of the Project area are linked to alteration of stream hydrology. The Stratford Mining Complex contains surface water runoff controls that are aimed at preventing up-catchment runoff water from entering open cut mining operational areas.

Under pre-mining conditions, the water from the eastern hills flowed west to Avondale Creek via a number of small drainages (Figure 1). Two eastern diversion drains/bunds have been constructed upslope of the Stratford East Dam and the Eastern Emplacement Area, diverting upslope runoff (from the foothills east of the Stratford Mining Complex) to the north and south respectively (Figure 2). The existing diversion had the effect of redirecting runoff from a 1.28 square kilometers (km^2) area of the hills northwards to the headwaters of a small unnamed tributary of Avondale Creek that runs between the Stratford Main Pit and the BRNOC (Figure 2). This increased the catchment area of the creek at the diversion outfall from 0.40 km^2 to 1.69 km^2, which represents an increase of 318 percent (%) on the pre-mine catchment area (Figure 2). This existing diversion would be retained for the Project, and progressively augmented in advance of the Stratford East Open Cut mining operation (Figure 3). The effect of this would be to progressively further increase the catchment area that drains to the small unnamed tributary of Avondale Creek. Ultimately the area at the diversion outfall would increase by 1.41 km^2 to 3.10 km^2, which would represent an increase of 84% on the existing area (Figure 3). At a distance 425 metres (m) further downstream, just downstream of the junction of the northern arm of the creek, the additional catchment area represents an increase of 67% percent on the existing area (Figure 3).

A new eastern diversion would be constructed for the Avon North Open Cut to divert up-catchment runoff to the south (Figure 3). This south-flowing runoff would be diverted to the headwaters of the same small unnamed tributary of Avondale Creek that currently receives diverted water. Under existing conditions, the runoff from this area naturally flows to the unnamed tributary of Avondale Creek (Figure 2), so the diversion would cause little difference in overall flow to the creek. There could be an increase in peak flow rates from the tributary due to the reduction of the total length of its flow path. The impact of the diversion would be to deliver the flow to the creek at a point about 620 m upstream of where it currently enters (Figure 3).

As the Stratford East Open Cut mining area progresses further south, an additional eastern diversion would be constructed to divert up-catchment runoff (from the foothills to the east) to the south, and then to the headwaters of Avondale Creek (Figure 3). Under existing conditions, the runoff from this area naturally flows to the Avondale Creek (Figure 2), so the diversion would cause little difference in overall flow to the creek. Also, this south flowing diversion would involve such a small catchment area (0.10 km^2) (Figure 3) that it would have an insignificant impact on the fluvial geomorphology of Avondale Creek, so it is not considered further in this report.

A replacement western diversion would be developed in advance of the Roseville West Pit Extension to divert upslope runoff to the north towards Avondale Creek (Figure 3). This diversion would involve a slight redirection of runoff from what is currently a relatively small and low relief catchment that naturally drains northwards to the same point on Avondale Creek. Thus, this diversion would have an insignificant impact on the fluvial geomorphology Avondale Creek, so it is not considered further in this report.

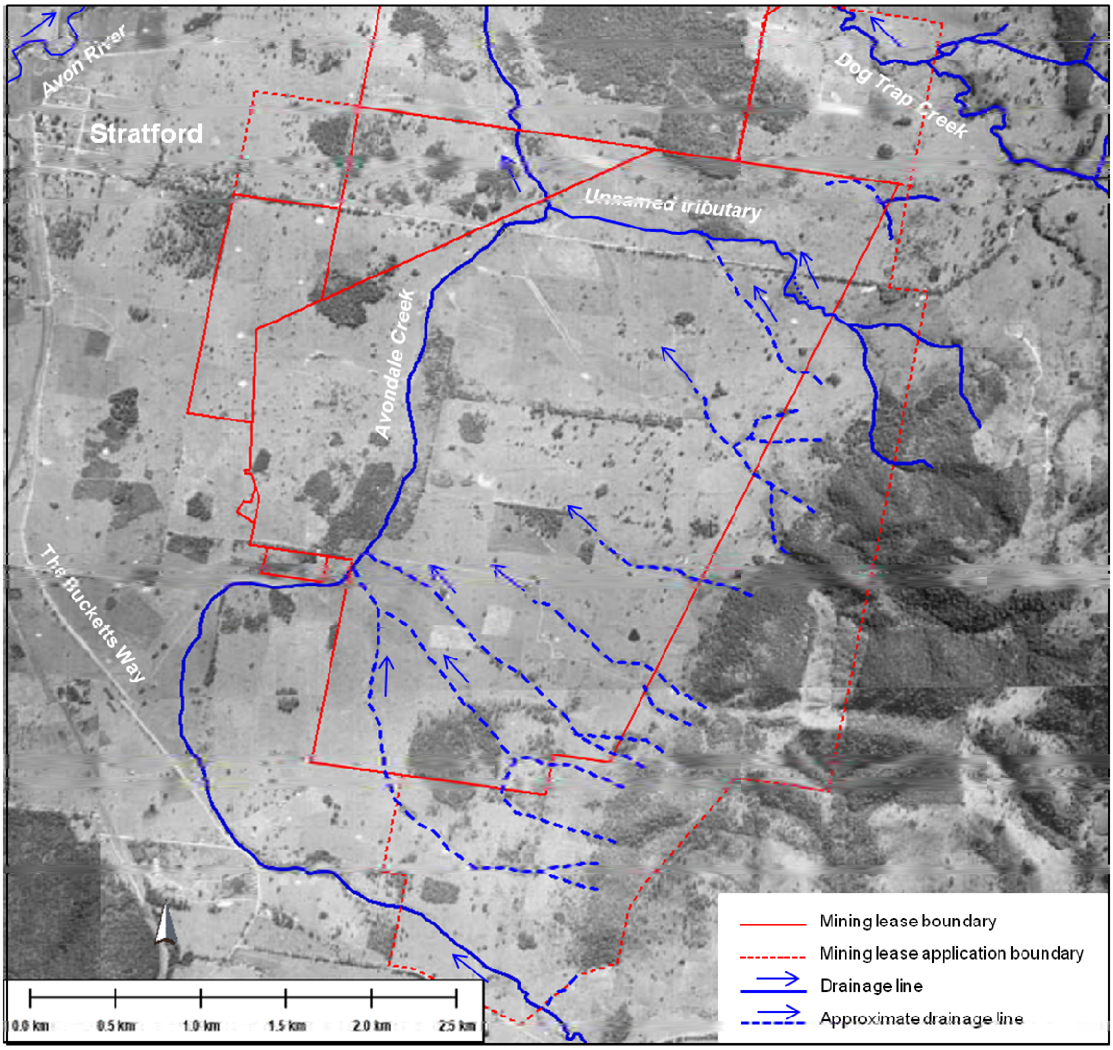


Figure 1. Pre-mine (pre-1995) drainage pattern of the Project area interpreted from rectified 1964 aerial photograph. The western flowing tributaries are indistinct on the historical aerial photographs.

The blue lines marked on 1:25,000 topographic sheets Gloucester (92331N, 1974) and Craven (92331S, 1981) were digitised and the contour lines used to determine the pre-mine catchment areas of Avondale Creek and the unnamed tributary of Avondale Creek (Figure 4). The catchments and drainage lines were also delineated for current (2012) and for the proposed project (Figure 4, Table 1), using available digital elevation models and details of the existing and proposed mine structures and layout. The sequence of the changes in drainage clearly show that the catchment area of the unnamed tributary of Avondale Creek increased substantially post-mine, and would increase even further under the proposed Project (Figure 4, Table 1). The hydrological impact of the increases in area upstream of the inlet of the diversion are not significantly offset by the decreases in catchment area downstream of the inlet because the upstream area is the main runoff producing zone of the catchment.

The above review of the proposed surface water runoff control system suggests that the focus of this investigation should be on the unnamed tributary of Avondale Creek that currently receives water from a diversion, the catchment area of which will progressively increase during the life of the Project (Figure 3). Also, an approximately 600 m long section of the unnamed tributary of Avondale Creek will require realignment in order to avoid the Avon North Open Cut (Figure 3).

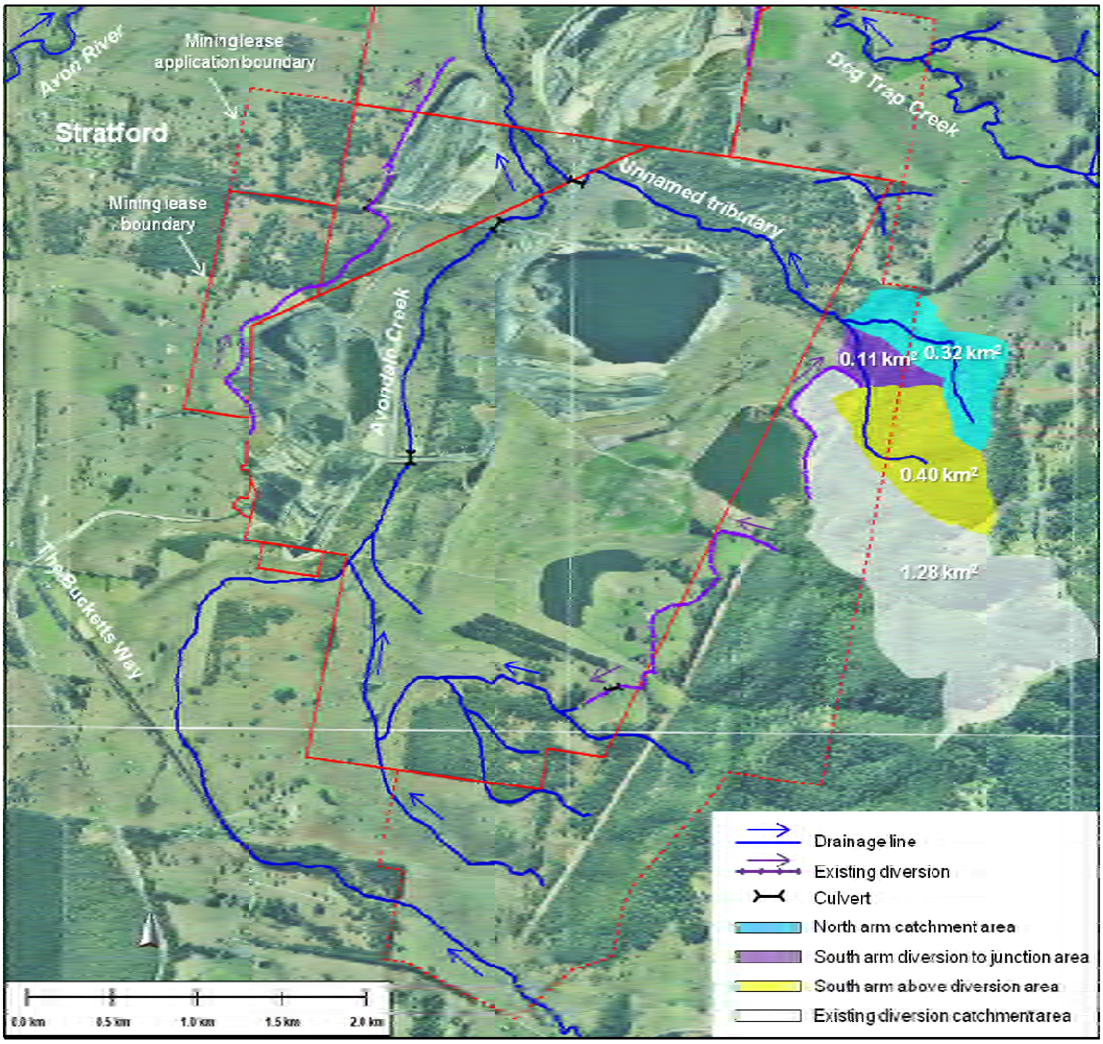


Figure 2. Existing drainage pattern of the Stratford mine area overlaid on 2011 aerial photograph. Catchment areas associated with the headwaters of the unnamed tributary of Avondale Creek are shown. The existing course of the unnamed tributary of Avondale Creek was ground-truthed in the field using hand-held GPS.

Table 1.
Summary of catchment areas of Avondale Creek and Unnamed tributary.

Catchment	Catchment area (km^2)		
	Pre-mine	Existing 2012	Proposed Project
Total catchment area of Avondale Ck (including the unnamed tributary of Avondale Ck)	18.479	17.092	17.005
Total catchment area of the unnamed tributary of Avondale Ck	3.038	3.639	4.964
Total catchment area upstream of the post-mine diversion to the unnamed tributary of Avondale Ck	0.403	1.685	3.098
Percentage increase in area from previous area	-	*318%*	*84%*

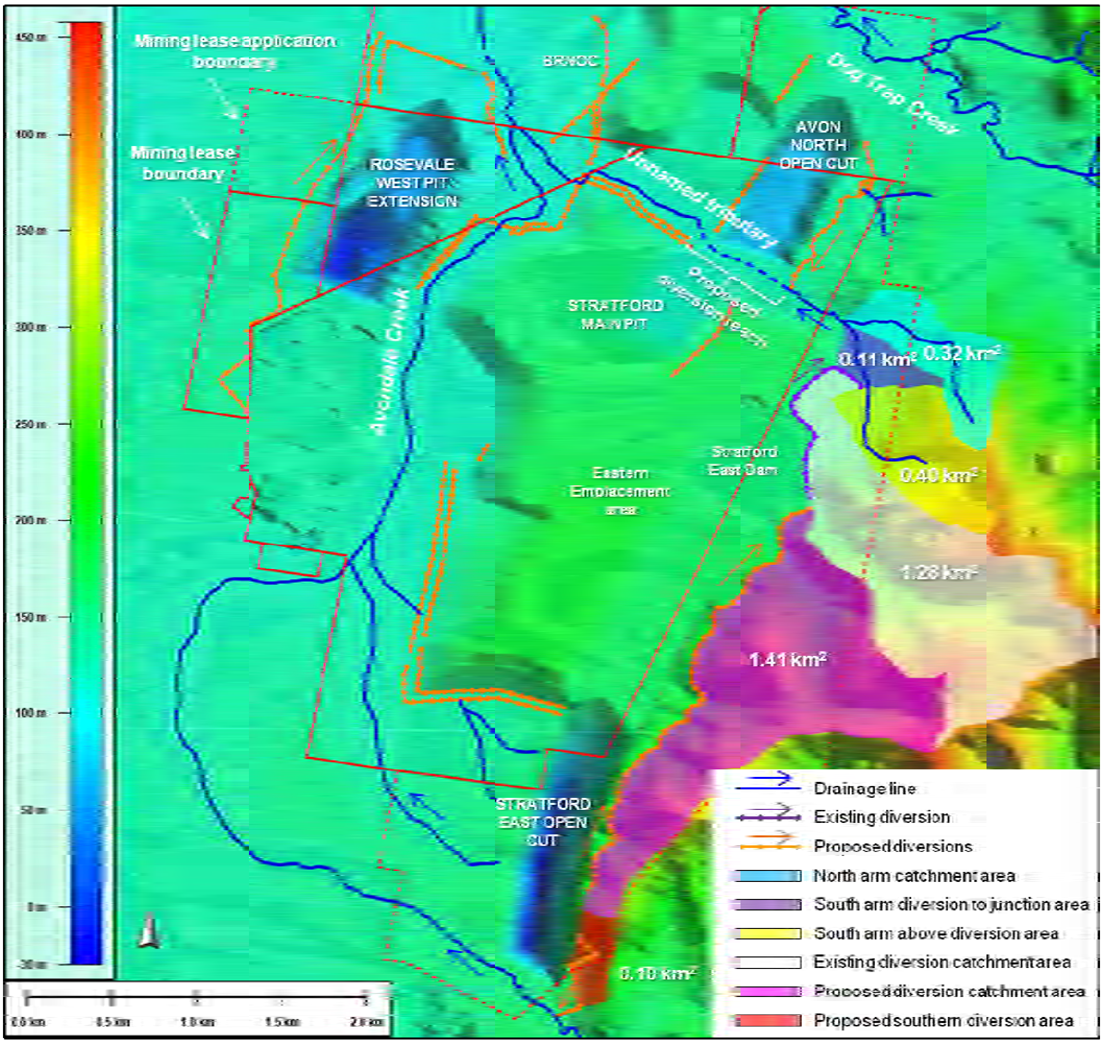


Figure 3. Proposed drainage pattern of the Project area overlaid on digital elevation model (which includes fully developed mine plan), and semi-transparent 2011 aerial photograph. Catchment areas associated with the headwaters of the unnamed tributary of Avondale Creek are shown. A section of the unnamed tributary of Avondale Creek will require diversion (dashed blue line) in order to avoid the Avon North Open Cut.

1.5 Scope of this report

The key tasks of this report are to:

- Utilising a previous fluvial geomorphological survey of the area (Gilbert and Sutherland, 1997), historical aerial photographs, and field inspection, describe the existing geomorphological character of the unnamed tributary of Avondale Creek that runs between the Stratford Main Pit and the BRNOC.
- Assess potential impacts of the proposed Project on the unnamed tributary of Avondale Creek.
- Recommend, if necessary, actions designed to mitigate fluvial geomorphological-related risks to the unnamed creek that are associated with the proposed Project.

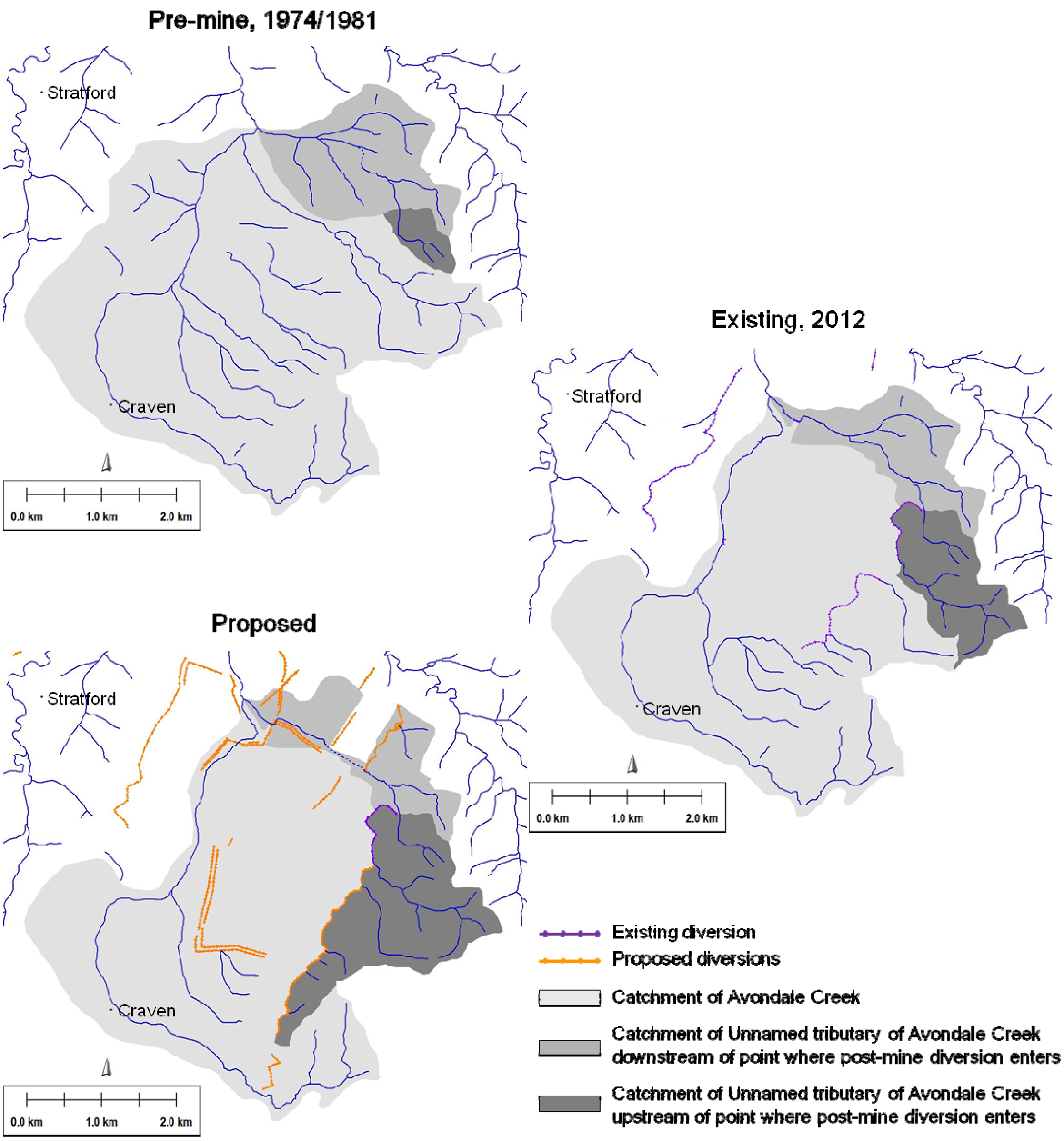


Figure 4. Catchment of Avondale Creek to the point where it is joined by the unnamed tributary of Avondale Creek, and catchment of the unnamed tributary of Avondale Creek upstream and downstream of the point where the post-mine diversion enters. The sequence of maps illustrates the change in catchment area over time. The internal (enclosed) catchment areas of pits that are internal to the catchment of Avondale Creek are not shown.

2 Methodology

Characterisation of the fluvial geomorphology of the unnamed tributary of Avondale Creek was approached using three methods:

1. Comparison of historical aerial photographs to determine the extent of channel change over time, especially in relation to the increased catchment area since 1995.
2. Review of a previous investigation of the fluvial geomorphology of the stream by Gilbert and Sutherland (1997).

3. Field inspection, conducted on 9th February 2012, which consisted of walking the entire length of the creek and noting and photographing any relevant observations.

3 Results

3.1 Comparison of historical aerial photographs

3.1.1 Available images

Five historical aerial photographs of the Project area were available, dated 1964, 1971, 1989, 1996 and 2011. In general, the photographs were of low resolution and not georeferenced. However, the 2011 photograph was not distorted, and it was easily rectified to the available GIS layers using common cultural features. In contrast, the other images had varying degrees of distortion that could only be partially corrected through rectification. The 1964 image contained an east-west oriented mosaic discontinuity about two-thirds of the way down the image that could not be corrected (Figure 1).

3.1.2 Channel change

Within the limitations of the aerial images, the unnamed tributary of Avondale Creek did not appear to substantially change its course between 1964 and 1989 (Figure 5). Sometime after 1989 and before 1997 there was short section in the mid-reaches that took a new dominant course (Figure 5). The 1:25,000 Gloucester topographic sheet, dated 1974, marks that section of the creek in the same position that was interpreted from 1964, 1971 and 1989 aerial photographs (Figure 5), and the uncertain course is not indicated on that sheet. When Gilbert and Sutherland (1997) surveyed the creek in 1997, they plotted the course of that section of the creek close to its current position. There is no evidence to link this course change to the onset of mining activity. Some changes occurred after mining began; by 2011 the lower section of the tributary creek had been diverted to avoid a dam, and to pass under a haul road. In the mid-reaches, the course appeared to straighten slightly sometime between 1997 and 2011. It is however noted that here the creek is laterally unconfined, running across a relatively broad valley fill, so it would be naturally prone to course changes.

After 1989, the coverage of forest/woodland noticeably increased in the middle section of the creek corridor. Thus, the section where the course change occurred between 1989 and 1997 flowed mostly through pasture at least until 1989, but by 2011 it flowed mostly through forest/woodland.

3.2 Review of Gilbert and Sutherland (1997)

Gilbert and Sutherland (1997) surveyed the unnamed tributary of Avondale Creek over three days in mid-August 1997. Their objective was to characterise the stability of the creek, with stability judged visually using a 5-point descriptive scale. This survey pre-dated construction of the diversion channel that increased the catchment area of the southern arm of the headwaters of the creek by 318% (Figure 2).

The map of the creek alignment drawn by Gilbert and Sutherland (1997, Fig 2) was rectified and overlaid on the creek alignment mapped for this report in February 2012 (Figure 6).

The 2012 creek alignment was mapped using a hand-held GPS and is accurate to a few metres. The method of mapping the position of the 1997 creek alignment was not detailed by Gilbert and Sutherland (1997). Given the possibility of inaccuracies in the 1997 mapping, plus error in the rectification procedure, some apparent differences in creek alignment between the 1997 and 2012 surveys (Figure 6) might not be real.

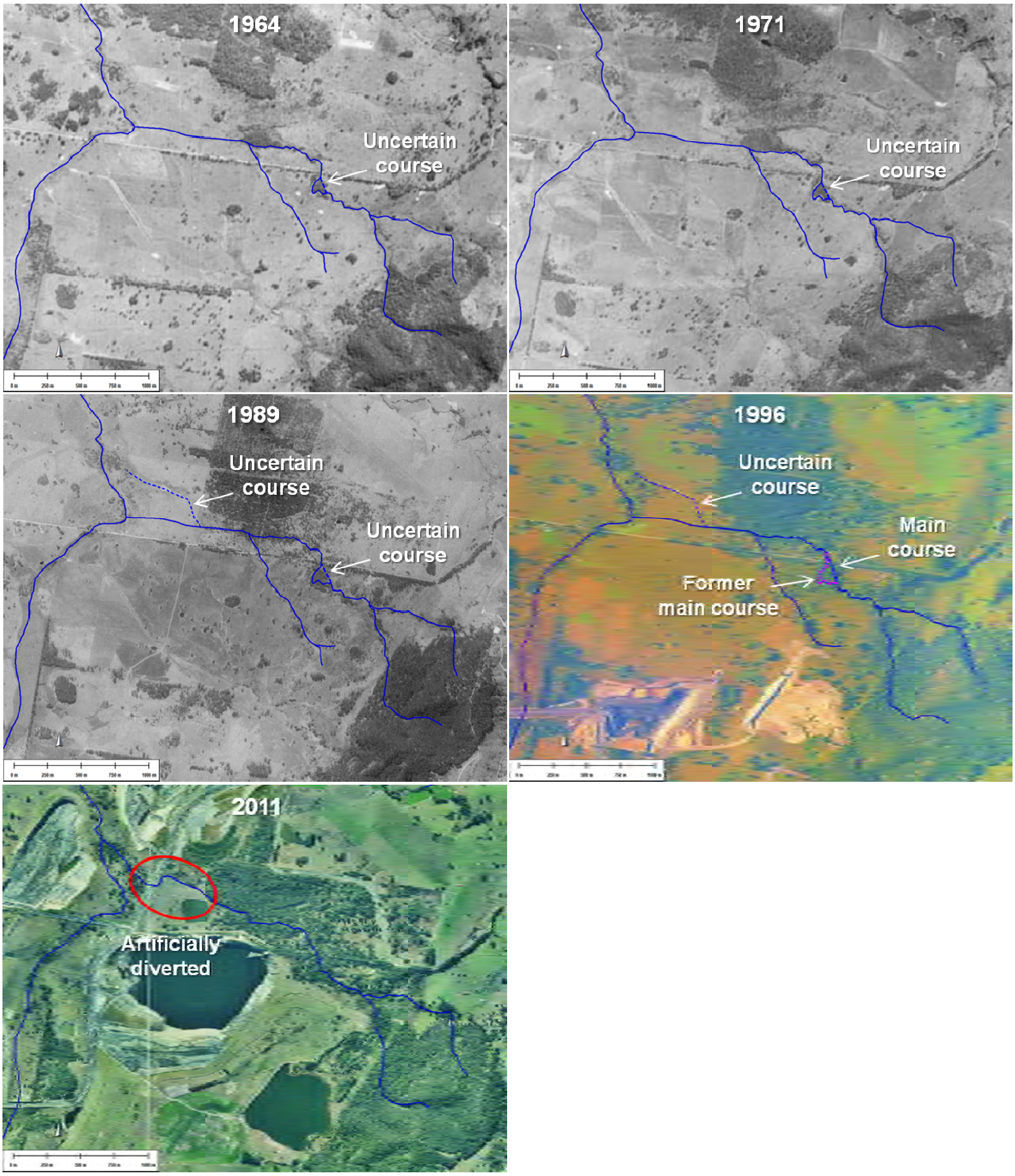


Figure 5. Alignment of unnamed tributary of Avondale Creek from 1964 to 2011.

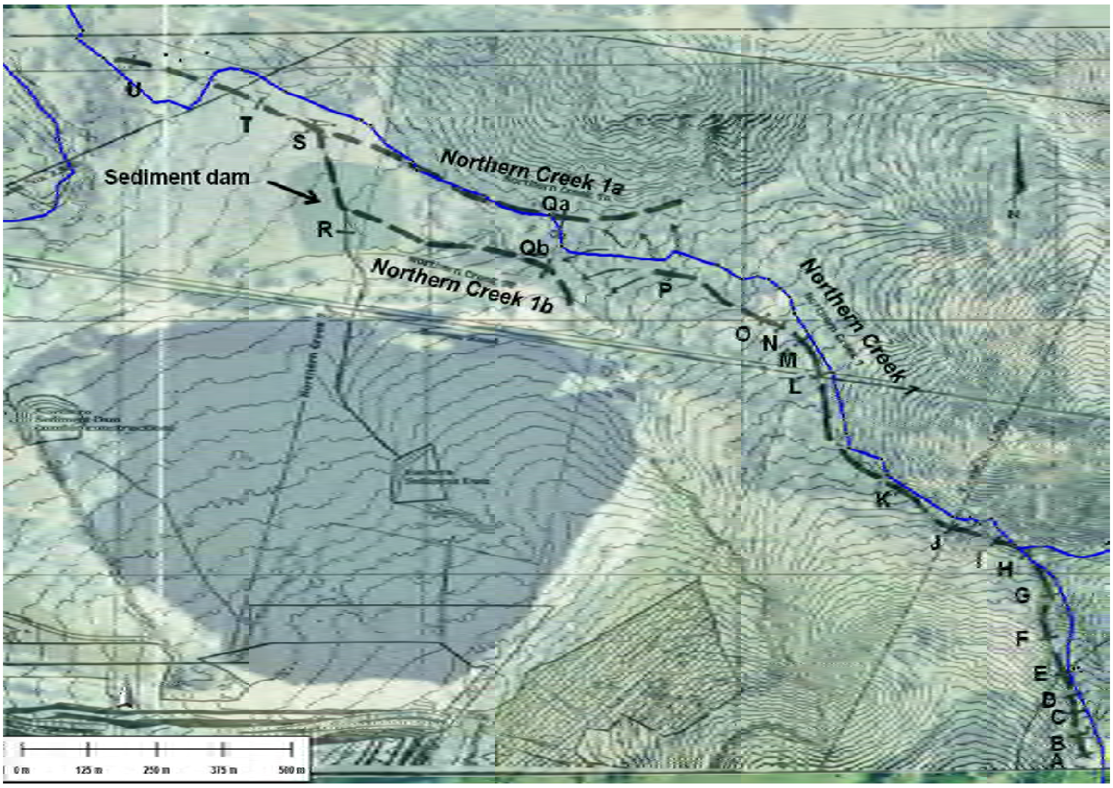


Figure 6. Creek alignment surveyed by Gilbert and Sutherland (1997) overlaid on alignment surveyed for this report in February 2012. Figure 2 from Gilbert and Sutherland (1997) was rectified, made semi-transparent, and overlaid on the 2011 aerial photograph. The blue line marks the path walked along the creek in February 2012.

The creek was described by Gilbert and Sutherland (1997, pp. 5-6) as follows:

> "*The upper reaches of the channel (from Point A down to Point O) are relatively steep and exhibit well defined flow paths, with a few flatter areas where low to medium flows tend to spread. Active erosional features occur along the majority of the reach, with channel cross-sections exhibiting vertical sides and undercutting. Eroded sections of the channel increase in frequency and extent moving downstream from initially intermittent eroded sections of approximately 300 mm depth in Segment C to D, to a maximum gully depth of approximately 1.5 to 2.0 metres at Segment I to J.*"

> "*Between Point O and Point P the creek line undergoes a transition from a single line of flow into an area which appears to exhibit sheet flow across a wide area. No single defined channel is evident. At Point P the drainage line followed to this point basically ends, with the flow of water slowing, dividing and spreading out to enter two other drainage lines, one to the north (Creek 1a) and one to the south (Creek 1b) of the original. Between Point P and Segment R to S, the topography of the area is more "low lying" with flow paths not well defined and evidence of the flow splitting into two main directions. The area within this section of creek line consists of generally flat to slightly undulating terrain, with swampy depressions and slightly raised drier areas. Creeks 1a and 1b, into which flow from the upstream creek splits, exist along each edge of the central low-lying area.*"

"*Downstream of Point R, the drainage path is again very flat, however a single significant drainage gully has formed (possibly originally man-made for the purpose of paddock drainage) along the drainage line and all flow from the two drainage lines entering this creek concentrates within this gully. The gully extends from Point R to Point T, with Point R representing the main confluence point between Creek 1a and the eroded gully, and Point S the main confluence between Creek 1b and eroded gully. During periods of higher flow, it is likely that flow within Creeks 1a and 1b would exceed the capacity of the two low flow channels and combine within the low lying area between the creeks. Under these conditions, flow would occur as overland flow into the section of Creek 2 between Points R and S. Below Point T gullying due to erosion becomes more sporadic with sections of deep cutting interspersed with areas of no gullying, until the flow path meets Avondale Creek in a wide, low-lying and swampy area downstream of Point U.*"

Gilbert and Sutherland (1997) rated the creek stability as moderate to poor. It was implied that poor vegetative cover was at least partly responsible for the instability of the creek. Given that the intended flow diversion to the headwaters of the creek was predicted to increase peak flow rates in the creek by around 25%, Gilbert and Sutherland (1997, p. 14) suggested a suite of works to assist with stabilisation of the creek. The recommended approach was to:

- construct a detention basin at the outlet of the diversion drain;
- fencing and planting the riparian zone;
- construction of a bund to prevent natural creek runoff entering the sediment dam; and
- construction of a channel with pool-riffle sequences in the north-western reach where the creek flows north of the sediment dam (Figure 6).

Of the construction works recommended by Gilbert and Sutherland (1997), field observations in February 2012 suggest that only the bund was built. However, it appears that stock has been excluded from the creek area, and the tree cover has markedly increased since 1997 (Figure 5).

3.3 February 2012 field inspection

One of the main purposes of the February 2012 field inspection was to compare the condition of the creek with that observed in August 1997 by Gilbert and Sutherland (1997). Northern Creek 1b is now isolated by a bund, and section R to S is within a sediment dam, so these sections are no longer active. Otherwise, much of the description provided by Gilbert and Sutherland (1997) could equally apply to the creek as it was observed in 2012.

Although Gilbert and Sutherland (1997) did not provide the exact locations of their photographs, photographs taken in 2012 in the same vicinities suggest that the creek had the same general character as it did in 1997 (Figure 7, Figure 8 and Figure 9). The only point where there was an apparent difference was Point Qa, where Gilbert and Sutherland (1997) observed erosion, and in 2012 this section was not eroded (Figure 8).

Figure 7. Comparison of photographs (Plates 1 to 3) from Gilbert and Sutherland (1997) and those taken in 2012 from similar locations. Descriptions on 1997 photographs are from Gilbert and Sutherland (1997).

The 2012 inspection began just downstream of the diversion outlet (Point E on Figure 6). At the time, the flow was relatively high (recession of a storm flow event). The upper part of the creek, down to Point O on Figure 6, had the form of a series of discontinuous knickpoints. These knickpoints appeared to be actively cutting headwards. In the absence of any other information, this would not be surprising, considering the large percentage increase in catchment area due to the diversion. However, this channel form was also observed by Gilbert and Sutherland (1997) in this section of the creek prior to the diversion being active. Further downstream, the morphology of the lower-gradient reaches with poorly defined channels appear to be little changed since 1997.

The section of creek between Points Qa and S on Figure 6 runs along the northern side of a bund, constructed after 1997. The drainage runs along vehicle wheel tracks, which in places are rutted (Figure 10).

Figure 8. Comparison of photographs (Plates 4, 5 and 8) from Gilbert and Sutherland (1997) and those taken in 2012 from similar locations. Descriptions on 1997 photographs are from Gilbert and Sutherland (1997).

Just downstream of the sediment dam outlet, the bund has eroded (Figure 11) allowing the creek to flow south of the bund, although this appears to be inconsequential in terms of channel stability.

The section of creek from the culvert under the haul road to the junction of Avondale Creek is a very low gradient wetland area, with multiple shallow flow paths and pools present. The creek here is very well vegetated and stable (Figure 12).

Figure 9. Point O on the map of Gilbert and Sutherland (1997), photographed in February 2012. In August 1997 this point was described as "*…an area which appears to exhibit sheet flow across a wide area. No single defined channel is evident.*".

Figure 10. Midway between Points Qa and S on the map of Gilbert and Sutherland (1997), photographed in February 2012. Creek flows in wheel ruts that are not healing.

Figure 11. Just upstream of Point S on the map of Gilbert and Sutherland (1997), near the outlet of the sediment dam, photographed in February 2012. The bund has eroded, allowing the creek to flow south of the bund.

Figure 12. The unnamed tributary of Avondale Creek, 100 m upstream of its confluence with Avondale Creek, photographed in February 2012.

3.4 Stream type, condition and fragility

The upper reach of the unnamed tributary of Avondale Creek, down to Point O on the map of Gilbert and Sutherland (1997) (Figure 6), is Confined Valley Setting, Headwater, (here, termed Headwater, Discontinuous Incision). The creek flows through a narrow and shallow ribbon of alluvium (bedrock outcrops are not a feature of the creek). Downstream of Point O, to the junction of the creek with Avondale Creek is Confined Valley Setting, Valley Fill, Fine-Grained (here, termed Swampy Meadow, Discontinuous Channel). The creek flows through a narrow to broad expanse of alluvium. The extent of the alluvium was not mapped here, but in the broad areas it is several hundred metres wide.

Outhet and Cook (2004) (see Cook and Schneider, 2006) defined "geomorphic condition" in terms of three categories (Table 2). By this definition, the Headwater, Discontinuous Incision stream type is in overall Moderate condition (due to incision). The Swampy Meadow, Discontinuous Channel is also in overall Moderate condition (due to presence of vehicle tracks in one area, and areas of poor tree and shrub cover).

Table 2.
Categories of stream geomorphic condition defined by Outhet and Cook (2004).

Geomorphic condition	Description (simplified from the original)
Good condition	Natural and intact; self-adjusting and fast recovery from natural disturbance; intact vegetation
Moderate condition	Localised degradation; geomorphic units modified, such as unexpected grainsize; patchy vegetation cover
Poor condition	Accelerated rates of erosion; high volumes of sediment with low diversity of form; vegetation absent

Brierley et al. (2011) used the term "fragility", defined as the ease of adjustment of bed material, channel geometry, and channel planform when subjected to degradation or certain threatening activities (Cook and Schneider, 2006). Fragility also includes the concept of resilience. In a fragile stream with low resilience, a significant adjustment may result in a change to a different type of river, if a certain threshold (level of disturbance) is exceeded (Brierley et al., 2011). Categories of fragility were defined by Cook and Schneider (2006) (Table 3). By this definition, the Headwater, Discontinuous Incision stream type has overall Medium fragility (incision is present, but a degree of resilience has been demonstrated since the diversion became active). The Swampy Meadow, Discontinuous Channel is Medium fragility in the higher elevation (higher gradient) areas, and Low fragility in the lowland section close to Avondale Creek (due to the very low gradient, and depositional environment).

Table 3.
Categories of stream geomorphic fragility defined by Cook and Schneider (2006).

Fragility	Description
Low fragility:	Resilient ('unbreakable'). Minimal or no adjustment potential. Only minor changes occur such as bedform alteration and the likelihood of river change is minimal, regardless of the level of damaging impact.
Medium fragility:	Local adjustment potential. The reach may adjust over short sections within the vicinity of the threatening process. Major changes to river character can occur, but only when a high threshold of damaging impact is exceeded. For example, a catastrophic flood, sediment slug or clearing of all vegetation from bed, banks and floodplain may be required to induce change.
High fragility:	Significant adjustment potential and sensitive to change. The reach may be dramatically altered or degraded over long sections. Major character changes can occur when a low threshold of damaging impact is exceeded (e.g. clearing of bank toe vegetation alone).

3.5 Alluvium in the Project area

The extent of alluvium was not mapped as part of the fluvial geomorphology survey. However, definition of the extent of alluvium is of interest from the perspective of groundwater, and the following general comments are intended to help clarify the situation.

The Quaternary alluvium extent indicated by the Dungog New South Wales, 1:100,000 Geological Sheet 9233 (Roberts et al., 1991) is inaccurate at the local scale, as evidenced by the boundary occasionally running over hilltops and dissecting alluvial streams.

The Soil map produced for the Project on the basis of 68 test pits is reasonable, but in places the boundaries could be improved by taking account of geomorphological indicators of alluvium (valley bottoms with low lateral gradients, alluvial stream corridors).

The Soil Landscapes map produced for the Project indicates two variants of Alluvial Plain (a and b). Variant a corresponds reasonably well with the alluvial valley fill of the unnamed tributary of Avondale Creek, and Variant b corresponds with the deeper and lower gradient alluvium associated with the larger Avondale Creek.

A transient electromagnetic (TEM) survey conducted by Groundwater Imaging Pty Ltd in March 2011 of some parts of the Project area identified corridors of alluvium associated with the main drainage lines (Avondale Creek and Dog Trap Creek). These boundaries correspond with a geomorphologically-defined alluvium boundary (a high degree of valley bottom flatness).

4 Potential Impacts of the Proposed Project

It was deduced that the potential for impact of the Project on the geomorphological character of the streams in the area was mainly isolated to the unnamed northern tributary of Avondale Creek. A diversion associated with the existing Stratford Mining Complex has enlarged the catchment area of the creek by 318% (where the diversion meets the creek). Although this diversion has been in place for over 10 years, the creek has retained its basic character, as evidenced by comparison of geomorphological inspections done in 1997 and 2012. Over that time, the knickpoints have probably migrated further upstream, and some might have deepened, but there are no indications of major change in channel form. This apparent resilience might be explained by the dense vegetation cover re-established in the headwater reaches (due to the exclusion of live stock), high channel roughness, and the relatively low absolute catchment area (even though it has been enlarged by the diversion).

The lower Swampy Meadow areas have remained stable, despite the increased catchment area. This is probably explained by the intact groundcover, relatively low gradients, and wide extent of the valley bottom, which allows storm flow to spread out at shallow depths, rather than concentrate within a central channel.

The Project will further increase the catchment area of the unnamed tributary Avondale Creek by 84% where the diversion meets the tributary creek. This is a significant increase, which would normally result in a measureable geomorphological response (such as widening or deepening of the channel). How the channel form might change, and to what extent, is highly uncertain, for three main reasons:

1. Any change would first require exceedance of the creek's inherent hydraulic threshold of resistance to erosion, and this threshold naturally varies over time and space with the state of the vegetative cover.
2. Initiation of erosion, if it occurred, would not necessarily mean ongoing erosion, as this would depend on the resilience of the stream to geomorphic change.
3. Streams have multiple modes of adjustment to changed flows (width, depth, slope, roughness and sinuosity) and the adjustment process is largely indeterminate (Richards 1982, p. 25).

5 Recommended Mitigations and Monitoring

5.1 Mitigations

The suggestion by Gilbert and Sutherland (1997) to construct a storm water detention basin at the outlet of the diversion remains relevant. This would lower the risk of substantial geomorphic change by lowering the peak shear stress of storm events. This strategy will increase the duration of storm event flow, but this is probably of lower consequence than high peak shear stress. Periodic emptying of existing dam that forms part of the clean water diversion, would also lower such risk.

The Swampy Meadow sections of the unnamed tributary of Avondale Creek should be retained as such, rather than converted to a pool and riffle type. If good vegetation cover can be maintained at all times, the Swampy Meadow form appears to be stable in this setting.

A 600 m long section of Swampy Meadow creek type (with discontinuous channel) on the unnamed tributary of Avondale Creek would need to be diverted south by up to about 150 m (laterally) to avoid the Avon North Open Cut. The narrower valley bottom, squeezed between the new Avon North Open Cut and the Stratford Main Pit (Figure 3), would concentrate the flow under high flow conditions, and potentially cause scour of the valley fill. This would represent an undesirable geomorphic change. Prior to diversion of this 600 m section of the unnamed tributary of Avondale Creek to avoid the Avon North Open Cut, an investigation should be undertaken to determine the overall performance of the unnamed tributary of Avondale Creek along its entire length (via survey) to inform the final design. A separate investigation including modelling of peak flows should also be undertaken to support the final design of this 600 m section of the unnamed tributary of Avondale Creek.

5.2 Monitoring

Monitoring of channel form is a vital component of the future management of the unnamed tributary of Avondale Creek. Prior to commencement of the additional eastern diversion, the long profile of the tributary creek should be surveyed from the diversion outlet to the junction of Avondale Creek, to define the location and size of all knickpoints. This survey should also include cross-section surveys at approximately 50 m spaced monumented points. The survey should be repeated every 2 years for the life of the Project.

The survey data should be interpreted by a qualified, independent, fluvial geomorphologist with experience in river management. An adaptive management approach should be undertaken whereby the geomorphologist should determine whether the measured change is within the normal range of variability, or whether a program of works is required to stabilise the creek.

6 References

Brierley, G.J. and Fryirs, K.A., Cook, N., Outhet, D., Raine, A., Parsons, L. and Healey, M. 2011. Geomorphology in action: Linking policy with on-the-ground actions through applications of the River Styles framework. *Applied Geography* **31**: 1132-1143.

Cook, N. and Schneider, G. 2006. River Styles® in the Hunter catchment. NSW Government, Department of Natural Resources.

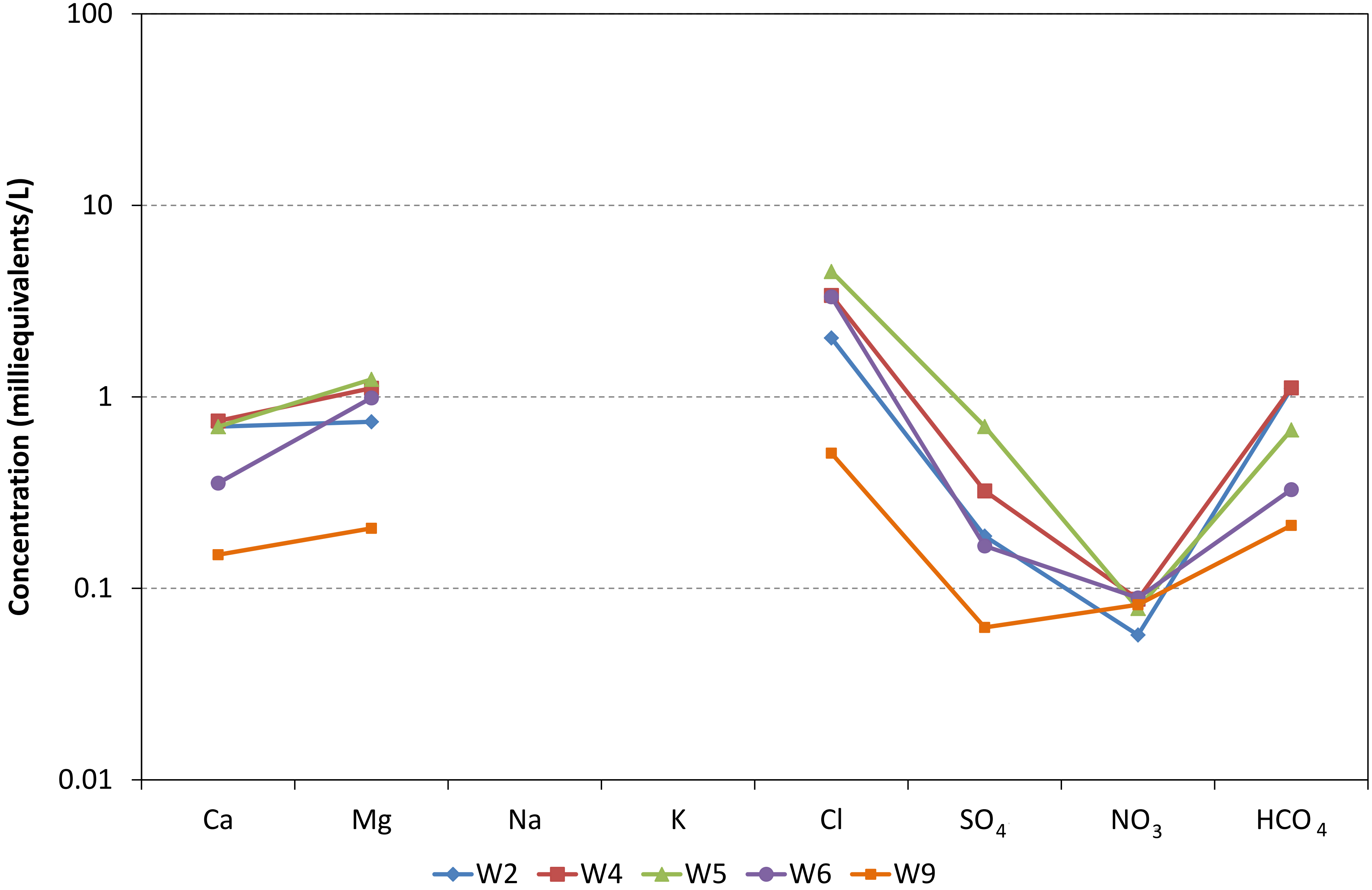
Gilbert and Sutherland 1997. Stability of tributary drainages affected by clean water diversions. Stratford Coal Project. Stratford Coal, Stratford, December.

Outhet, D. and Cook, N. 2004. Definitions of geomorphic condition categories for streams. Unpublished internal draft paper for use throughout NSW by the Department of Infrastructure, Planning and Natural Resources.

Richards, K. 1982. Rivers, Form and Process in Alluvial Channels. Methuen & Co. London.

Roberts, J., Engel, B., Lennox, M. and Chapman, J. 1991. Dungog, New South Wales 1:100 000 Geological Sheet 9233, Geological Survey of New South Wales. 1:100,000 geological sheet series, 1v, Map.

ATTACHMENT BC
Schoeller Plots



100
10
1
0.1
0.01
Concentration (milliequivalents/L)
Ca
Mg
Na
K
Cl
SO4
NO3
HCO 4
W2
W4
W5
W6
W9

ATTACHMENT BD
Stratford Extension Project Geotechnical Characterisation of CHPP Rejects [Allan Watson Associates, 2012]

GLOUCESTER BASIN/GLOUCESTER COAL

STRATFORD EXTENSION PROJECT
GEOTECHNICAL CHARACTERISATION OF CHPP REJECTS

Client:
Resource Strategies Pty Ltd

Project:
Stratford Extension Project

Date:
March 2012

AWA Project No:
111386-02 (R01/r001-b)

ALLAN WATSON ASSOCIATES
Waste and Water Management Consultants

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

SECTION 1.0 - INTRODUCTION

1.1 BACKGROUND

In support of an Environmental Impact Statement for the proposed Stratford Extension Project, Resource Strategies Pty Ltd, on behalf of Gloucester Basin, has commissioned Allan Watson Associates (a division of ATC Williams Pty Ltd) to undertake geotechnical characterisation of rejects derived from the Stratford coal handling and preparation plant (CHPP). The purpose of this study is to substantiate a range of deposited reject dry densities achievable under operating conditions, which is relevant to water balance modelling for the rejects disposal system.

Background to this rejects characterisation assessment, relevant to the Stratford Extension Project, is summarised as follows:

- Both coarse and fine rejects streams will be produced though washing of sized coal (maximum 50mm), with the cut-off between these streams being 1.4mm particle size. The following reject sizing results:
  - Coarse Reject 1.4 to 50mm
  - Fine Reject <1.4mm
- Coarse and fine (slimes) rejects are combined as a single low solids concentration stream, for co-disposal within a storage or impoundment.
- It is understood that rejects are placed subaerially (i.e. above water), with supernatant liberated from the deposited reject material accumulating within a pond formed at the toe of the beach. Supernatant is recovered to control the water level within the pond, with recovered water used as process make up. It is understood that the level of the supernatant pond is varied as required to maintain inundation of potentially acid forming (PAF) reject that is placed within the impoundment.
- Under current operating conditions at Stratford, mining from three deposits is occurring, viz
  - Bowen Road North (BRN) deposit
  - Roseville West deposit
  - Duralie deposit

  Rejects samples from processing of ROM coal from each of these deposits has been made available for the purpose of this assessment.
- The typical (average) ratio between coarse and fine rejects quantities is 2.1 (coarse) : 1 (fine)
- The combined reject stream is pumped to the impoundment typically at a solids concentration of 28.5% (solids concentration [wt/wt]).

1.2 REPORT CONTEXT AND STRUCTURE

The purpose of this report is to present a geotechnical characterisation of CHPP rejects, including coarse, fine (slimes) and combined rejects streams for the Stratford Extension Project.

The basis of this characterisation is as follows:

- Review of available data related to the existing Stratford operation;
- Review of available literature related to co-disposed coal rejects for operations principally within southern Queensland and NSW; and
- Geotechnical testwork carried out on coarse and fine (slimes) reject samples derived from the BRN, Roseville West and Duralie deposits.

From these characteristics, geotechnical analysis derives key geotechnical properties for the combined rejects stream, on which benchmark in-storage rejects dry densities can be assessed.

The structure of this report to achieve the scope as outlined in **Section 1.1** is as follows:

Section 2.0 - Presents the scope and results of geotechnical testing and associated analyses on rejects samples provided.

Section 3.0 - Summarises the outcome of data reviews completed to assess geotechnical characteristics of coal rejects materials.

Section 4.0 - Presents an interpretation of geotechnical characteristics for co- disposed coal reject

SECTION 2.0 - GEOTECHNICAL TESTING ON REJECTS SAMPLES

2.1 SCOPE

Samples of reject produced from the existing Stratford operation were supplied by Gloucester Basin to Gilbert and Associates Pty Ltd, who are undertaking water balance modelling for the Stratford Expansion Project. Samples comprised the following:

- BRN Deposit — Coarse Reject
  Fine Reject
- Roseville West Deposit — Coarse Reject
  Fine Reject
- Duralie Deposit — Coarse Reject
  Fine Reject

All samples were ex-plant, and delivered in slurry form to Trilab Pty Ltd in Brisbane for geotechnical testing purposes.

Gilbert and Associates initiated the Trilab testwork program, with soil particle density testing carried out on all samples. Certificates for this testing are provided in **Appendix A**. In support of this current study, AWA arranged for the following testwork:

- Particle Size Distribution coarse (AS 12893.6.1) — BRN, Roseville West and Duralie reject samples
- Particle Size Distribution with fine Hydromatic Analysis (AS 12893.6.3,3.5.1) — BRN, Roseville West and Duralie reject samples
- Moisture Content (AS 12892.1.1) — All samples[1]

Testwork certificates for this testwork are reproduced as **Appendix B**.

2.2 SUMMARY TESTWORK RESULTS

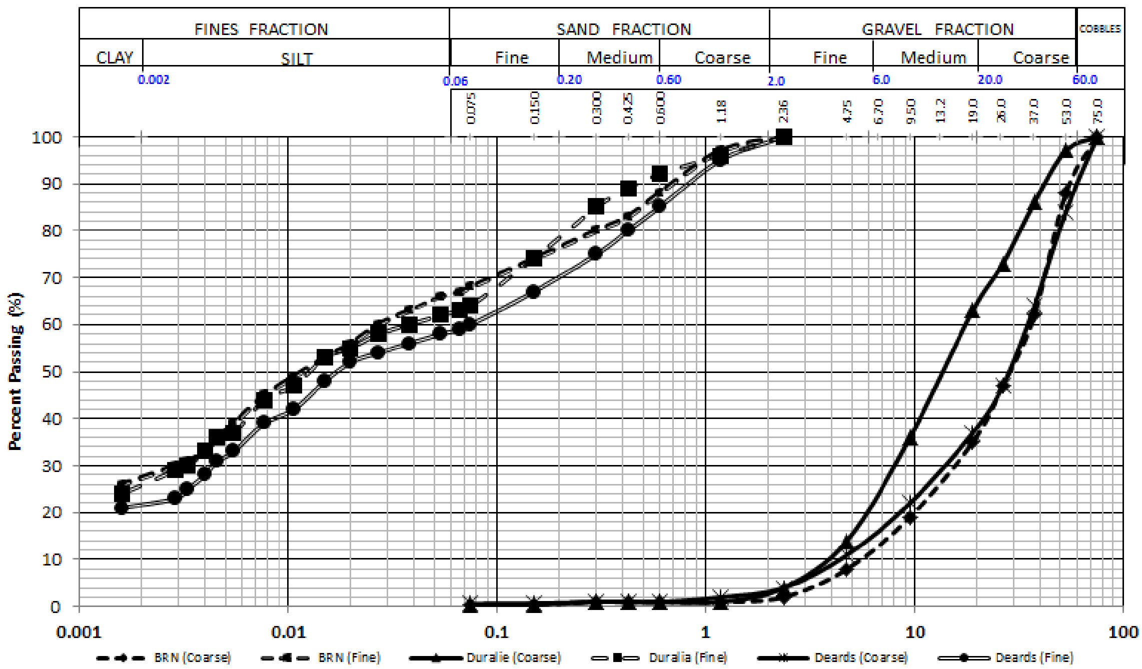
A summary of geotechnical testing carried out on rejects samples is provided in **Table 1**, with particle size distribution analysis plotted in **Plate 1**.

[1] Moisture content carried out on decanted reject samples

Table 1 – Summary of Geotechnical Testwork Results

Sample	Moisture Content (%)	Soil Particle Density (t/m^3)	Particle Size Distribution Passing Particle Size (%)				
			75mm	19mm	0.6mm	0.075mm	0.001mm
BRN Coarse	11.7	2.30	100	35	1	0.3	0
BRW Fine	139.2	2.10	100	100	88	68	26
Roseville West Coarse	17.6	2.17	100	37	1	0.6	0
Roseville West Fine	86.5	2.10	100	100	85	60	21
Duralie Coarse	7.3	2.30	100	63	1	0.4	0
Duralie Fine	106.9	1.89	100	100	92	4	24

Plate 1 – Particle Size Distribution Plates



The geotechnical classification of each rejects sample based on particle size distribution results, are as follows:

- BRN — Coarse Reject — Fine to medium grained GRAVEL
  - Fine Reject — CLAYEY SILT
- Roseville West — Coarse Reject — Fine to medium grained GRAVEL
  - Fine Reject — CLAYEY SILT
- Duralie — Coarse Reject — Fine to medium grained GRAVEL
  - Fine Reject — CLAYEY SILT

The soil particle densities are similar for all samples being in the range of 2.10 to 2.30 t/m^3, with the exception being Duralie Fines possessing a particle size density of 1.89t/m^3. This difference is likely due to ash/carbon content.

Low moisture contents for all coarse reject samples (in the range of 7 to 17%) indicate the higher permeabilities (and greater drainage potential) of these materials, while the high fine rejects moistures (up to 170%) indicate high rates of moisture retention and low permeability. The high moisture contents for fine reject also indicate solids concentration of between 40 and 50%, which represents a pseudo-settlement condition.

2.3 GEOTECHNICAL ANALYSIS AND INTERPRETATION

The principle geotechnical analysis was to generate particle size distributions for combined reject streams as follows:

(i) BRN Coarse and Fine

(ii) Roseville West Coarse and Fine

(iii) Duralie Coarse and Fine

From **Section 1.1**, the ratio (by weight) for combining rejects was 2.1 (coarse) : 1 (fine). The results of this analysis are plotted in **Plate 2**.

Plate 2 – Generated Particle Size Distribution for Combined Reject Samples

(a) BRN Deposit

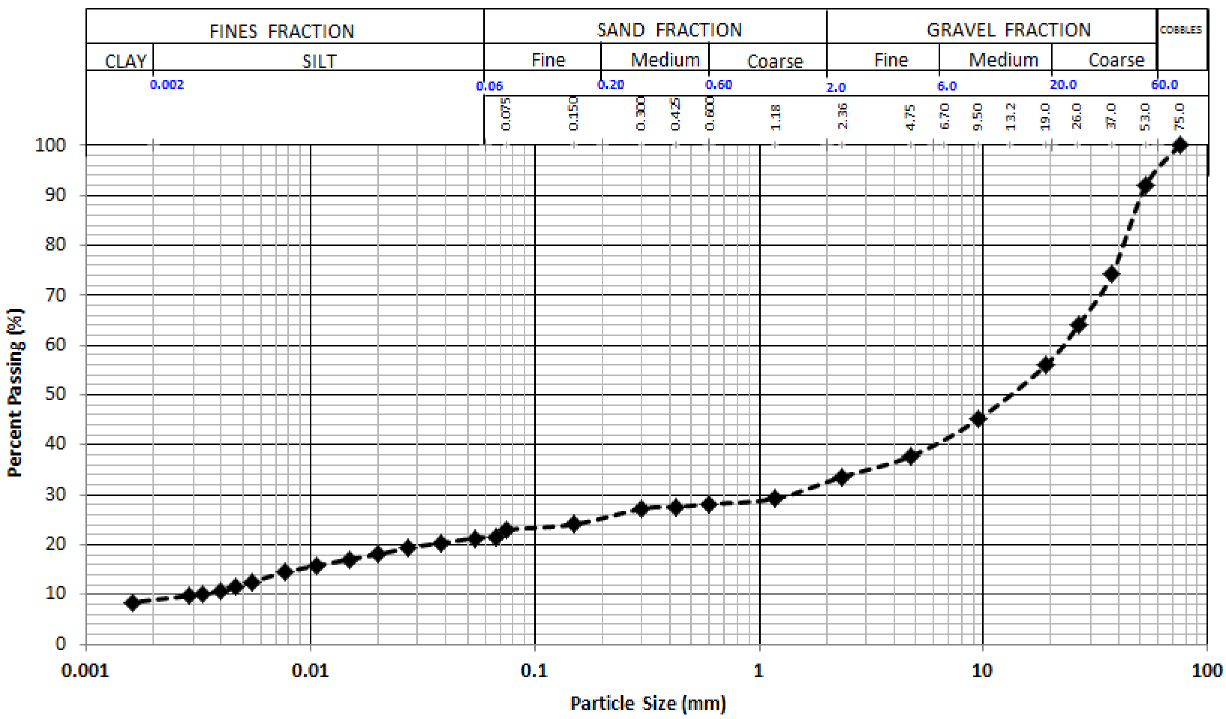
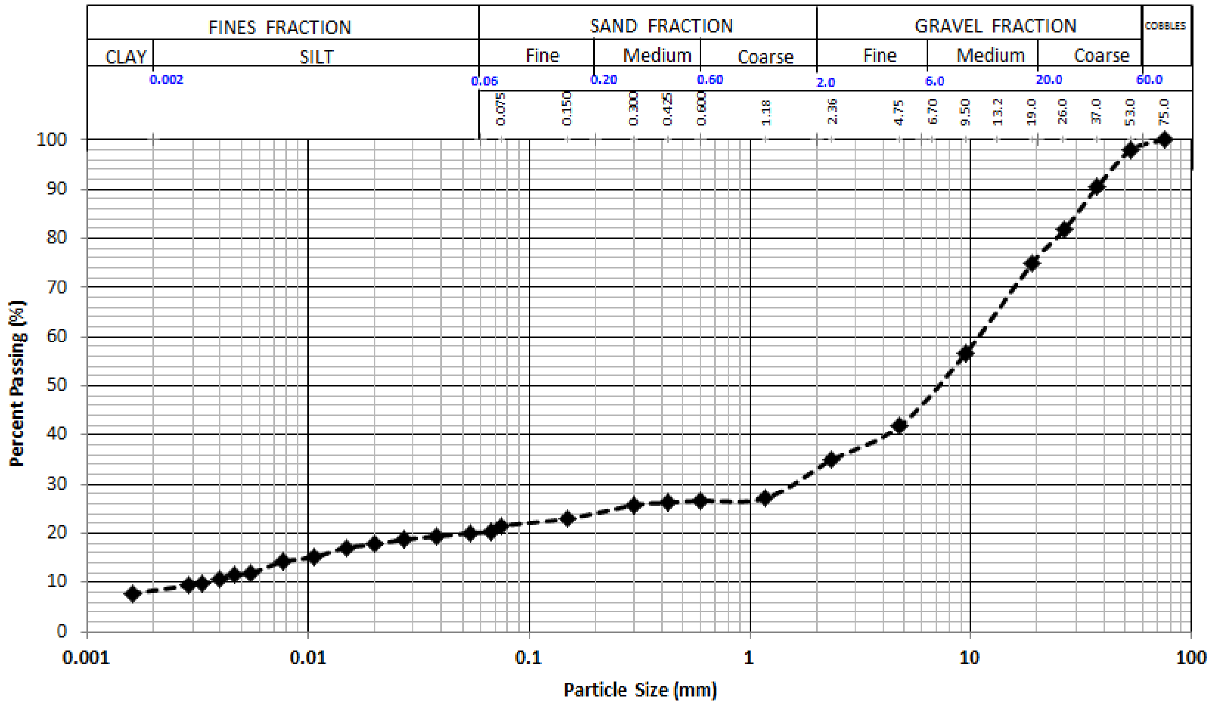
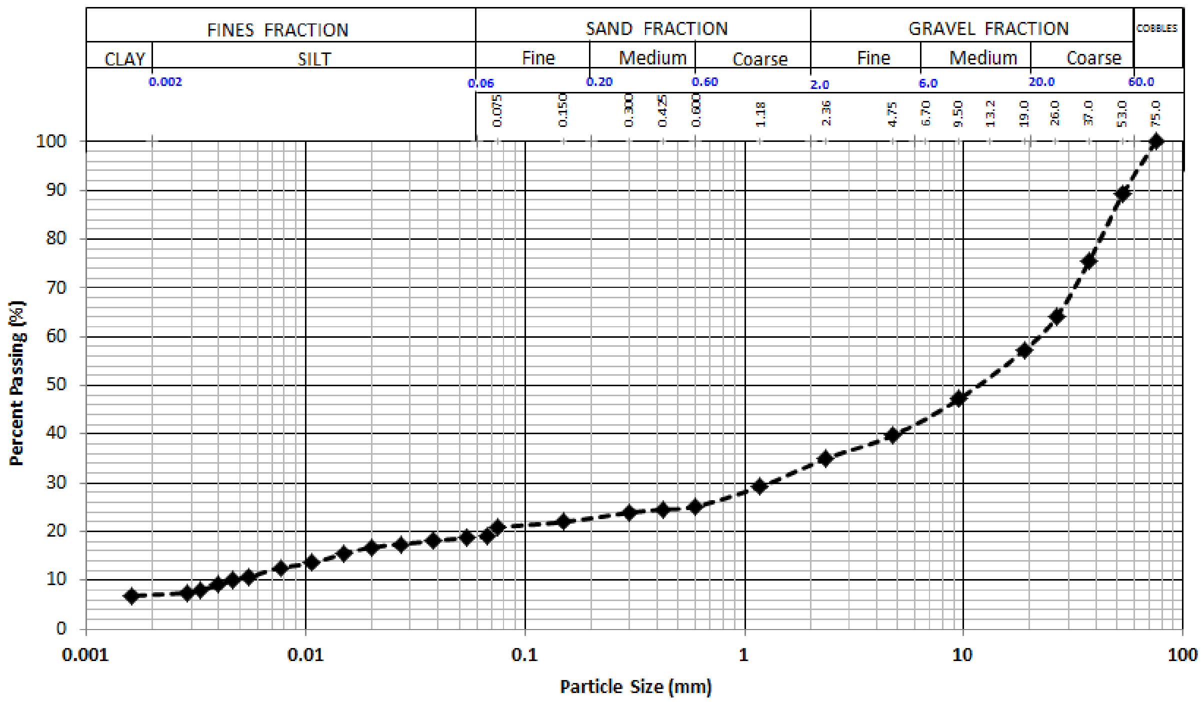


Plate 2 – Generated Particle Size Distribution for Combined Reject Samples (Cont'd)

(b) Roseville West Deposit

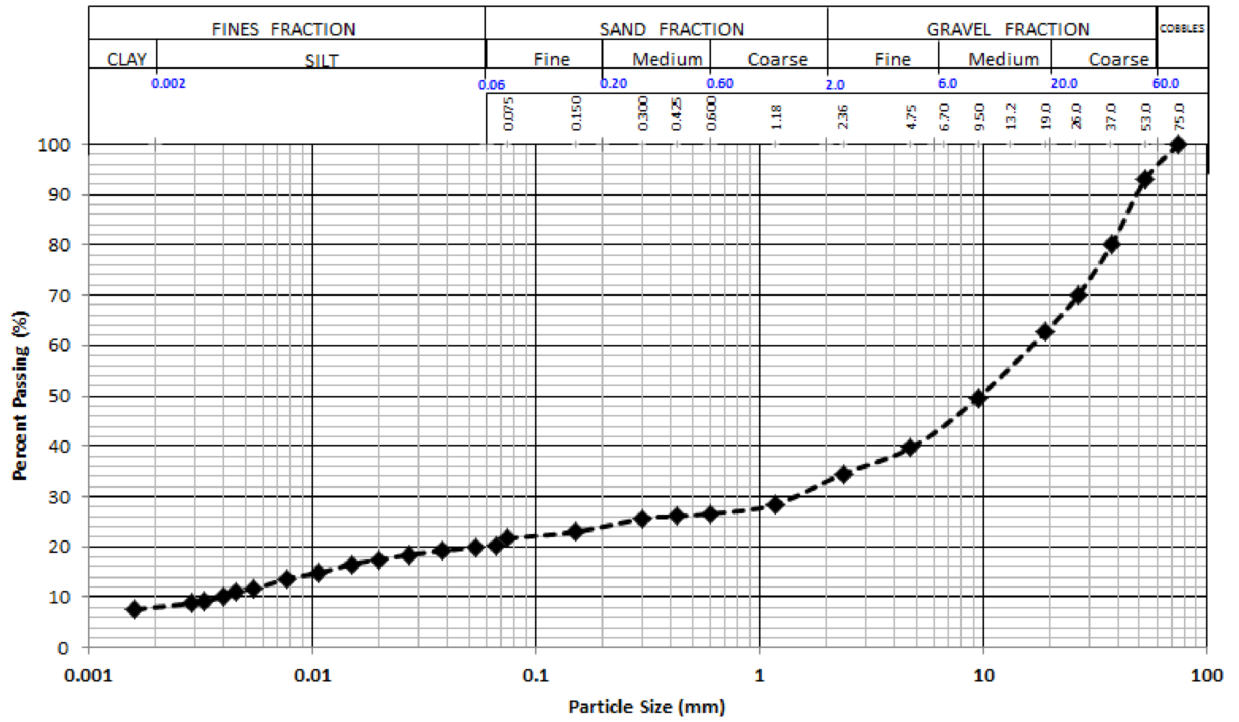


(c) Duralie Deposit



Further analysis was carried out for a total combined reject sample, assuming equal properties of BRN, Roseville West and Duralie combined rejects. The generated particle size distribution for this stream is provided in **Plate 3**.

Plate 3 – Generated Particle Size Distribution for Total Combined Reject Samples



A summary of characteristics for these combined rejects samples is provided in **Table 2**.

Table 2 – Summary of Combined Rejects Characterisation

Sample	Weighted Soil Particle Density	Particle Size/Percent Passing		
		D_{85}	D_{50}	D_{15}
BRN Combined	2.24	49	15	0.009
Roseville West Combined	2.15	32	7	0.01
Duralie Combined	2.17	49	13	0.014
Total Combined	2.19	41	9.4	0.0108

SECTION 3.0 - LITERATURE DATA REVIEW

3.1 LITERATURE SUMMARY

The literature contained several technical references related to co-disposal of coarse and fine coal CHPP rejects, centered around full-scale prototype operations in southern Queensland, and trials in the Bowen Basin and Hunter Valley regions. The bulk of this work was carried out between 1994 and 1997, culminating in an ACARP (Australian Coal Association Research Program) report titled *Elimination of Wet Tailings Deposits – Co-Disposal of Washery Waste* (1997). A list of associated references is presented in **Section 5.0**.

The focus of the previous research has been on co-disposal delta development, related to delta morphology/beaching slope configuration and particle sorting. The relevant aspect of this work to the current study is that particle segregation of the combined reject stream will occur on deposition, creating a steeper upper delta and flatter lower delta. It is reported that the segregation is attributed to the gap grading of the combined stream, the result being the partial separation of fines which are deposited at the base of the beach (possibly into a decant pond). A contrast therefore exists in deposited rejects dry density along the length of the beach for the upper delta (which is typically accessible by foot and 4WD vehicle immediately following deposition) to the lower delta (formed as a slimes deposit) and typically inaccessible. The general inference from the literature is that the mass of reject deposited across the lower delta is 25 to 30% of the total reject mass. This proportion has been adopted as a “rule of thumb”.

3.2 REPORTED GEOTECHNICAL CHARACTERISTICS

Correlation between geotechnical characteristics of Stratford Project rejects and the available data indicates the following geotechnical and deposited properties.

TAILINGS (FINE REJECT – GEOTECHNICAL) PROPERTIES

- Atterberg Limit — Liquid Limit 30 to 50%
  Plasticity Index 15 to 25%
- Soil Classification — CLAYEY SILT (CL/MC)

COMBINED (CO-DISPOSED) REJECT – DEPOSITIONAL CHARACTERISTICS

Stream	Bulk Density	Moisture Content	Depositional Dry Density
Tailings	1.0 to 1.2 t/m^3	70 to 120%	0.5 to 0.75t/m^3
Loose Coarse Reject	1.3 to 1.4 t/m^3	10 to 15%	1.1 to 1.25t/m^3
Co-Disposal Reject* Best Case	1.7 to 1.9 t/m^3	15 to 20%	1.4 to 1.65/m^3
Co-Disposal Reject* Worse Case	1.5 to 1.8 t/m^3	20 to 30%	1.3 to 1.45t/m^3

* Average across the deposited delta

SECTION 4.0 - GEOTECHNICAL INTERPRETATION

The overview of potential geotechnical and depositional characteristics for combined reject streams as presented in **Section 3.3**, provides a benchmark in terms of achievable deposited conditions. Under a full-scale operating scenario at Stratford (and proposed under the Stratford Expansion Project), a number of variables exist that may influence these conditions, such as:

- Solids concentration (currently adopted as 45% wt/wt)
- Impoundment water management practices, with decant pond/tail water conditions impacting a final beach configuration (impacted by particle sorting/segregation and reject stream rheology).
- Configuration of rejects impoundment, related to 3-dimensional beaching profile.

With consideration of the possible variability in relation to these factors, as indicated in the Rejects Disposal Plan for the current Operation (Stratford Coal, 2009), the following depositional characteristics can be inferred:

COARSE REJECT

The coarse reject generated from all deposits (BRN, Roseville West and Duralie), deposited as a single stream, would settle and consolidate rapidly based on grading, inferred permeability and particle density. Deposited characteristics (considered typical for all deposits) would be as follows:

Placement Condition	Bulk Density	Moisture Content	Deposited Dry Density
Loose Placed (Mechanical placement/End Dumping)	1.2 to 1.4t/m^3	10 to 15%	1.0 to 1.4t/m^3
Compacted (Hydraulically placed)	1.3 to 1.6 t/m^3	10 to 15%	1.1 to 1.6t/m^3

FINE REJECT

The typical behaviour for fine reject derived at Stratford, deposited as a single stream, would be for solids settlement to occur over a 24 to 48 hour period. The deposited condition likely to be achieved following this settlement phase would be as follows:

Placement Condition	Bulk Density	Moisture Content	Deposited Dry Density
Settlement (24 to 48 hours)	1.75 to 1.45t/m^3	70 to 90%*	0.65 to 0.85t/m^3

* Equivalent solids concentration of 50 to 60% solids (wt/wt)

CO-DISPOSED STREAM

The inferred depositional characteristics for the range of co-disposed reject streams at Stratford (i.e. BRN, Roseville West, Duralie and total samples), correlated against conditions described for individual coarse and fine rejects streams, are as summarised below. These characteristics are based on hydraulic placement of the combined rejects:

Placement Condition	Bulk Density	Moisture Content	Deposited Dry Density
Average across Delta	1.55 to 1.80 t/m^3	15 to 25%	1.35 to 1.60t/m^3
Upper Delta (Average)	1.8 to 1.90 t/m^3	10 to 15%	1.60 to 1.75t/m^3
Lower Delta (Average)	1.3 to 1.90 t/m	30 to 60%	0.95 to 1.30 t/m^3

Based on the conditions as tabled above, and assuming an initial solids concentration of 45% (wt/wt), the average quantity of water to be liberated would be 1.0 to 1.2 tonnes per tonne of reject solids.

Associated geotechnical parameters for combined reject placement conditions are as follows:

Placement Condition	Voids Ratio	Porosity	Saturated Permeability
Average across Delta	0.65 to 0.85	0.25 to 0.45	10^{-6} to 10^{-7} m/s
Upper Delta (Average)	0.55 to 0.70	0.35 to 0.40	
Lower Delta (Average)	0.70 to 1.0	0.40 to 0.50	

SECTION 5.0 - REFERENCES

1. ACARP (1997), *Eliniation of Wet Tailings Deposits Co-Disposal of Washery Waste*, February 1997

2. Balkema, A.A., Rotterdam, Brookfield*, Tailings & Mine Waste '94*

3. Gilbert and Associates (2009), *Stratford Coal Mine – Life of Mine – Reject Disposal Plan*, December 2009

4. Minesite Water Management Handbook, 2007

5. Morris, P.H., Williams, D.J., *Co-disposal of Washery Wastes at Jeebropilly Colliery, Queensland, Australia*

6. Morris, P.H., Williams, D.J., *Results of Field Trials of Co-Disposal of Coarse and Fine Coal Wastes*

7. Stratford Extension Project – Environmental Impact Statement

APPENDICES

APPENDIX A

LABORATORY TESTWORK CERTIFICATES
(SOIL PARTICLE DENSITY)

Trilab
www.trilab.com.au

Brisbane
10/104 Newmarket Rd, Windsor
QLD 4030
Ph: +61 7 3357 5535

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

SOIL PARTICLE DENSITY TEST REPORT

Test Method: AS 1289 3.5.1

Client	Gilbert & Associates Pty Ltd	**Report No.**	11040158-SG
Project	SCM	**Test Date**	07/04/2011
		Report Date	18/04/2011

Sample No.	11040158	11040159	11040160	11040161	11040162	11040163	-
Client ID	BRN Coarse	Duralie Coarse	Duralie Fines	BRN Fines	Fines Deards	Coarse Deards	-
Depth (m)	-	-	-	-	-	-	-
Soil Particle Density (t/m³)	2.30	2.30	1.89	2.10	2.10	2.17	-

Sample No.	-	-	-	-	-	-	-
Client ID	-	-	-	-	-	-	-
Depth (m)	-	-	-	-	-	-	-
Soil Particle Density (t/m³)	-	-	-	-	-	-	-

Sample No.	-	-	-	-	-	-	-
Client ID	-	-	-	-	-	-	-
Depth (m)	-	-	-	-	-	-	-
Soil Particle Density (t/m³)	-	-	-	-	-	-	-

NOTES/REMARKS:

Sample/s supplied by the client

Authorised Signatory

J. Russell

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

APPENDIX B

LABORATORY TESTWORK CERTIFICATES
(PARTICLE SIZE DISTRIBUTION AND MOISTURE CONTENTS)

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

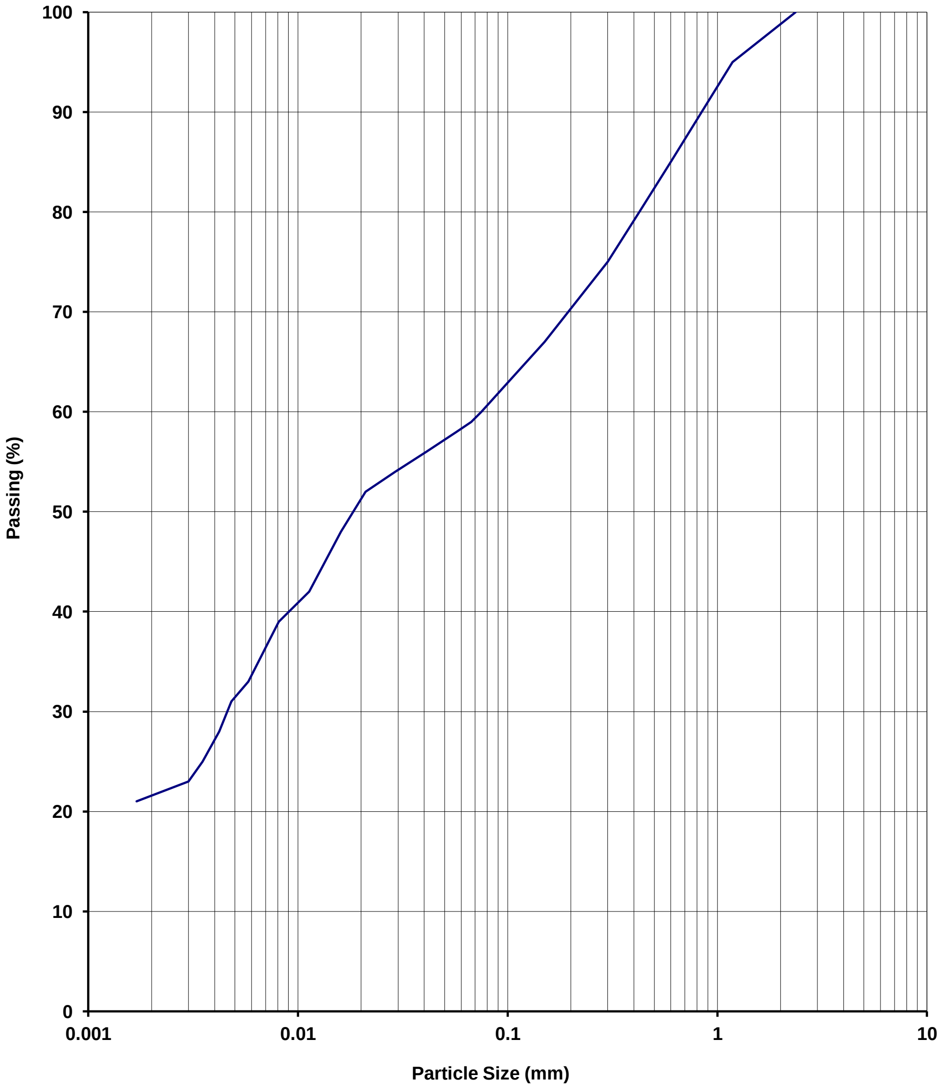
Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client	Allan Watson Associates Pty Ltd	**Report No.**	12020129-G
Project	Material Analysis	**Test Date**	02-07/02/2012
		Report Date	8/2/2012
Client ID	Fines Deards	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
53.0	
37.5	
26.5	
19.0	
9.5	
4.75	
2.36	100
1.18	95
0.600	85
0.425	80
0.300	75
0.150	67
0.075	60
0.067	59
0.057	58
0.041	56
0.029	54
0.021	52
0.016	48
0.0113	42
0.0081	39
0.0058	33
0.0048	31
0.0042	28
0.0035	25
0.003	23
0.0017	21



NOTES/REMARKS: -

Moisture Content 86.5% -2.36mm Soil Particle Density(t/m^3) 2.09

Sample/s supplied by the client

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IES 17025. The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Authorised Signatory

J. Russell

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

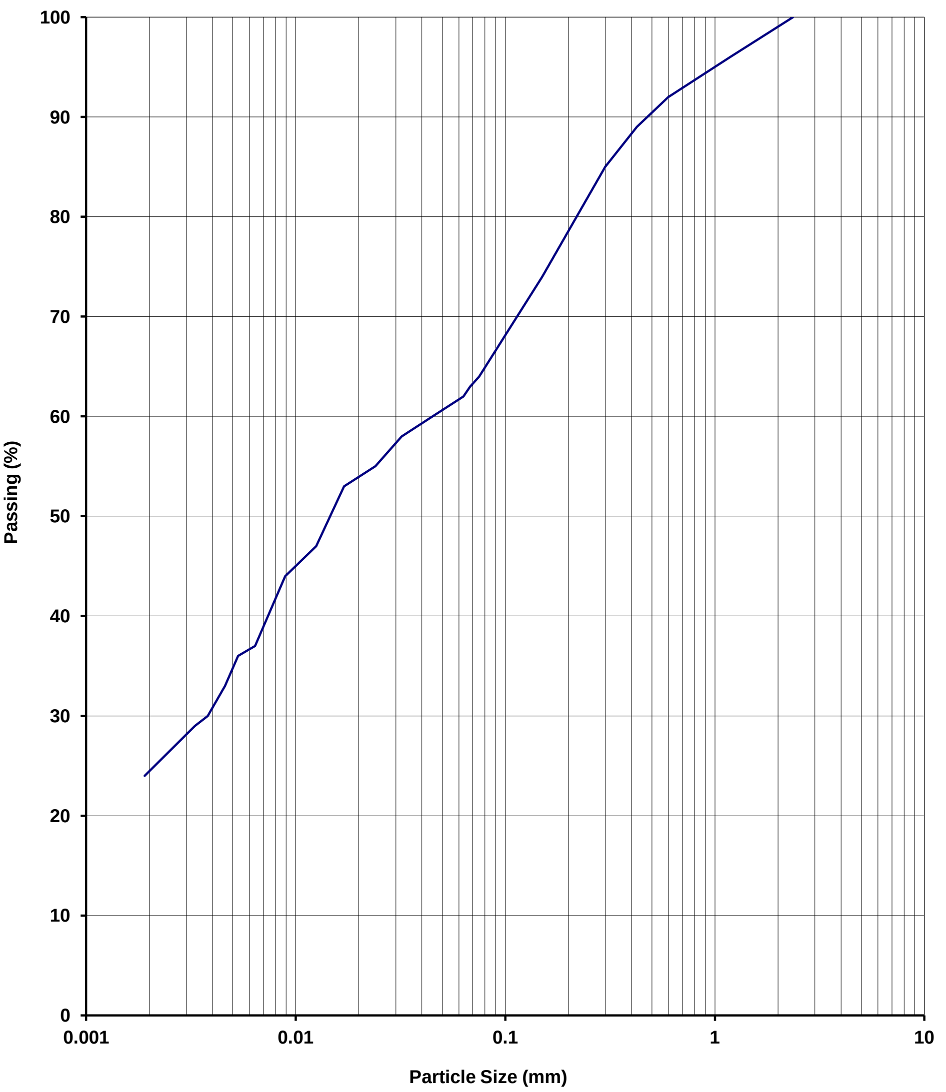
Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client	Allan Watson Associates Pty Ltd	**Report No.**	12020128-G
Project	Material Analysis	**Test Date**	02-07/02/2012
		Report Date	8/2/2012
Client ID	Duralie Fines	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
53.0	
37.5	
26.5	
19.0	
9.5	
4.75	
2.36	100
1.18	96
0.600	92
0.425	89
0.300	85
0.150	74
0.075	64
0.068	63
0.063	62
0.045	60
0.032	58
0.024	55
0.017	53
0.0125	47
0.0089	44
0.0064	37
0.0053	36
0.0046	33
0.0038	30
0.0033	29
0.0019	24



NOTES/REMARKS: -

Moisture Content 106.9% -2.36mm Soil Particle Density(t/m^3) 1.90

Sample/s supplied by the client

Authorised Signatory

J. Russell

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

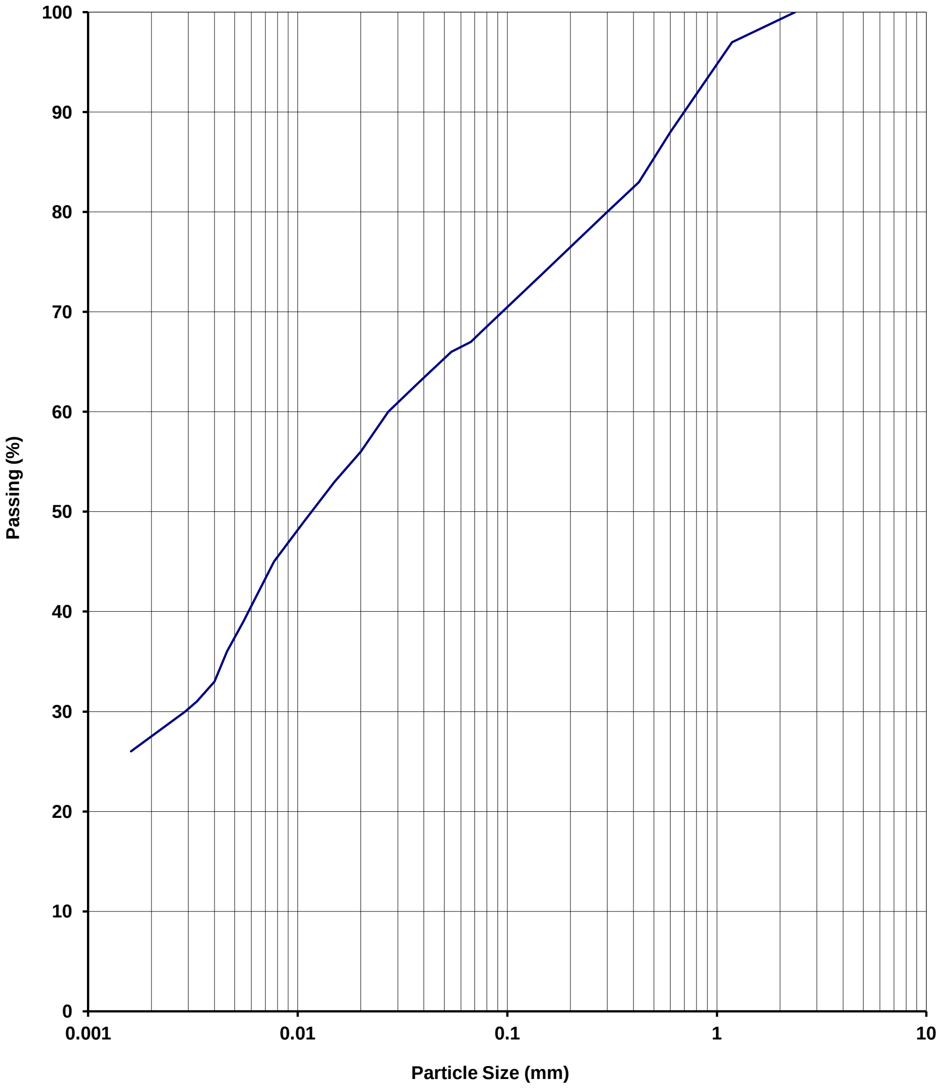
Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client	Allan Watson Associates Pty Ltd	**Report No.**	12020127-G
Project	Material Analysis	**Test Date**	02-07/02/2012
		Report Date	8/2/2012
Client ID	BRN Fines	**Depth (m)**	Not Supplied

Sieve Size (mm)	Passing %
150.0	
75.0	
53.0	
37.5	
26.5	
19.0	
9.5	
4.75	
2.36	100
1.18	97
0.600	88
0.425	83
0.300	80
0.150	74
0.075	68
0.067	67
0.054	66
0.038	63
0.027	60
0.02	56
0.015	53
0.0107	49
0.0077	45
0.0055	39
0.0046	36
0.004	33
0.0033	31
0.0029	30
0.0016	26



NOTES/REMARKS: -

Moisture Content 139.2% -2.36mm Soil Particle Density(t/m^3) 2.18

Sample/s supplied by the client

Authorised Signatory

J. Russell

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client Allan Watson Associates Pty Ltd

Project Material Analysis

Report No. 12020124-G

Test Date 08/02/2012

Report Date 20/02/2012

Sample No.	12020124	12020125	12020126	-	-	-	-
Client ID	BRN Coarse	Duralie Coarse	Coarse Deards	-	-	-	-
Depth (m)	Not Supplied	Not Supplied	Not Supplied	-	-	-	-
Moisture (%)	11.7	7.3	17.6	-	-	-	-
AS SIEVE SIZE (mm)	**PERCENT PASSING**						
150				-	-	-	-
75	100	100	100	-	-	-	-
53	88	97	84	-	-	-	-
37.5	62	86	64	-	-	-	-
26.5	47	73	47	-	-	-	-
19	35	63	37	-	-	-	-
9.5	19	36	22	-	-	-	-
4.75	8	14	11	-	-	-	-
2.36	2	4	4	-	-	-	-
1.18	1	1	2	-	-	-	-
0.600	1	1	1	-	-	-	-
0.425	1	1	1	-	-	-	-
0.300	1	1	1	-	-	-	-
0.150	0.4	0.5	0.7	-	-	-	-
0.075	0.3	0.4	0.6	-	-	-	-

NOTES/REMARKS: -

Sample/s supplied by the client