Appendix F

Surface Water Flow and Geomorphology Assessment

HUME COAL

Surface Water Flow and Geomorphology Assessment

HUME COAL PROJECT

16 January 2017

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Surface Water Flow and Geomorphology Assessment

Hume Coal

Project no: 2200540A-SFW-REP-001 RevI.docx
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REV	DATE	DETAILS
A	02/02/2016	In progress draft report
B	12/08/2016	Draft report
C	14/09/2016	Second draft report addressing comments from HEC and EMM
D	17/09/2016	Updated draft following HEC review
E	30/09/2016	Updated draft following HEC review
F	17/10/2016	Final draft for HEC, EMM and Hume Coal review
G	25/11/2016	Final draft for submission
H	19/12/2016	Final report
I	16/01/2017	Updated final report to address flow impact value error

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GLOSSARY

Catchment	Land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Digital terrain model (DTM)	Digital representation of ground surface topography or terrain. It is also widely known as a digital elevation model (DEM).
Discharge	Rate of flow of water measured in terms of volume per unit time — for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving — for example, metres per second (m/s).
Erosion	The action of surface processes such as water flow that remove soil, rock, or dissolved material from one location on the Earth's crust, then transport it away to another location.
Flow	Water moving steadily and continuously in a current or stream.
Geomorphology	The scientific study of the origin and evolution of topographic and bathymetric features created by physical, chemical or biological processes operating at or near the Earth's surface.
Light detection and ranging (LiDAR)	Optical remote-sensing technology that can measure the distance to, or other properties of, a target by illuminating the target with light (often pulses from a laser).
Model	Mathematical representation of the physical processes involved in runoff generation and streamflow. Models are often run on computers, due to the complexity of the mathematical relationships between runoff, streamflow and the distribution of flows across the floodplain.
Overland flow	The movement of water over the land, downslope toward a surface water body.
Runoff	Amount of rainfall that actually ends up as streamflow; also known as rainfall excess.
Scour	The removal of sediment such as sand or silt from around objects which disturb the flow, causing local high velocities which can remove the sediment particles and leave a local depression.
Yield	The total outflow from a drainage basin through surface channels within a given period of time.

ABBREVIATIONS

AWBM	Australian Water Balance Model
BOM	Bureau of Meteorology
CPP	Coal preparation plant
DP&E	NSW Department of Planning and Environment
DPI	NSW Department of Primary Industries
DSITIA	Queensland Department of Science, Information Technology, Innovation and the Arts
DTM	Digital terrain model
EIS	Environmental impact statement
EPA	NSW Environment Protection Authority
EV	Environmental value
ha	Hectares
HRC	Healthy Rivers Commission
km	Kilometres
LiDAR	Light detection and ranging
LGA	Local government area
LPI	NSW Land and Property Information
MHRDC	Maximum harvestable right dam capacity
ML	Megalitres
mm/day	Millimetres per day
Mtpa	Million tonnes per annum
NSW	New South Wales
PWD	Primary water dam
ROM	Run of mine
SCA	Sydney Catchment Authority
SEARs	Secretary’s environmental assessment requirements
WAL	Water access licence
WTP	Water treatment plant
WM Act	NSW Water Management Act 2000
WSC	Wingecarribee Shire Council

EXECUTIVE SUMMARY

A surface water flow and geomorphology impact assessment was undertaken for the Hume Coal Project (or 'the project'), a proposed underground coal mine in the Southern Coalfield, New South Wales.

The Hume Coal Project has been designed to avoid or minimise potential impacts on flow and bed and bank stability in local streams. Key aspects of the design that achieve these outcomes are as follows:

- the project does not involve the take of water directly from streams
- the project does not involve any stream diversions
- the project will use low impact underground mining methods, which have negligible subsidence impacts
- only minor instream works across Medway Rivulet are proposed for the project
- the water management system for the project will involve maximising the reuse of water on-site to minimise off-site discharge of water to local streams.

Aspects of the project which have the potential to impact on flow and bed and bank stability in local streams include:

- loss of catchment area due to the capture of runoff by the water management system;
- releases from selected stormwater basins following containment of the first flush within the water management system; and
- reduction in stream baseflow due to aquifer depressurisation associated with underground coal mining.

These impacts were assessed for the Medway Rivulet catchment (including the Oldbury Creek catchment) where the project is located, as well as for the Lower Wingecarribee River, Lower Wollondilly River and Bundanoon Creek management zones where impacts to stream baseflow may occur.

Flow impacts were assessed as follows:

- Existing flow conditions were established using the Australian Water Balance Model (AWBM) rainfall-runoff model.
- The reduction in catchment area associated with project storages was calculated and the resulting changes in flow to Medway Rivulet and Oldbury Creek were assessed using the AWBM.
- The releases from SB03 and SB04 to Oldbury Creek were estimated for dry and wet climate sequences using the GoldSim water balance model and the resulting changes in flow were applied to the flow duration curve for Oldbury Creek.
- The interception of natural baseflow to streams associated with depressurisation of groundwater systems during underground mining was estimated using the numerical groundwater flow model for the project and the resulting changes in flow were applied to the flow duration curves for streams.

The results show that the flow regimes in Medway Rivulet and Oldbury Creek during operation of the project will be similar to pre-mining conditions, assuming continuance of the constant low flow discharges from the Moss Vale and Berrima sewage treatment plants (STPs). When the low flow discharge from the Moss Vale STP is excluded from the analysis, changes in the low flow regime in Medway Rivulet below approximately 5 ML/day would occur, with the number of no flow days increasing by up to 30%. However, this is unlikely to occur given that the STP is likely to continue to operate throughout the period of mining.

The potential impacts to instream ecosystems associated with these predicted changes are discussed in the *Hume Coal Project Biodiversity Assessment Report* (EMM 2016b). Impacts to the flow regimes in Medway

Rivulet and Oldbury Creek during construction and rehabilitation of the project will be less than impacts during operation.

Local impacts on yield in the Oldbury Creek catchment will be up to 4.2%; however impacts will be less than 1.4% for the Medway Rivulet management zone overall (which includes the Oldbury Creek catchment).

Under wet conditions, the project will result in up to a 0.5% reduction in yield for the Medway Dam catchment, and under dry conditions the project will result in up to a 0.9% reduction in yield. This is an approximation for the reduction in yield to Medway Dam.

Under wet conditions, the project will result in a 0.1% reduction in yield for the Lower Wingecarribee River management zone, and under dry conditions the project will result in a 0.2% reduction in yield. Less than 0.001% reduction in yield is predicted for other catchments affected by groundwater depressurisation under wet and dry conditions.

The potential for stream bank erosion associated with the project is low considering the minimal change in flow regime and the confined valley setting of Medway Rivulet and Oldbury Creek adjacent to and downstream of the surface infrastructure area. Scour protection will be provided around the conveyor crossing pilings in Medway Rivulet and at the inlets and outlets of the culverts to prevent impacts to bed and bank stability. During construction, operation and rehabilitation, erosion and sedimentation control plans will be prepared to ensure the erosion and sedimentation induced by the project will not adversely affect the surrounding environment.

Proposed discharge of water to Oldbury Creek from SB03 and SB04 will be undertaken via pipe outlets incorporating rock protection to minimise the potential for erosion of downstream creek beds and banks. The discharge to Oldbury Creek will be upstream or into the existing instream storage on the creek, and therefore an assessment of the increased overtopping risk of the storage during times of discharge will need to be made during the detailed design phase to determine whether any reinforcement of the existing spillways may be necessary.

Cumulative impacts on flow and bed and bank stability associated with the Hume Coal Project and Berrima Rail Project will be negligible because the Berrima Rail Project will not involve take of water from streams or discharge to streams. The rail infrastructure will not reduce the volume flow as culvert structures will be constructed where the rail crosses waterways and mitigation measures will be implemented upstream and downstream of culvert structures to prevent erosion and scour impacts.

1 INTRODUCTION

Parsons Brinckerhoff was engaged by Hume Coal Pty Limited (Hume Coal) to undertake a surface water flow and geomorphology impact assessment for the Hume Coal Project (or 'the project'), a proposed underground coal mine in the Southern Coalfield, New South Wales (NSW).

This report provides an assessment of the impacts of the project on streamflow and bed and bank stability in local catchments and mitigation measures required to minimise potential impacts.

1.1 Project location

The project area is approximately 100 km south-west of Sydney and 4.5 km west of Moss Vale town centre in the Wingecarribee LGA (refer to Figure 1.1 and Figure 1.2). The nearest area of surface disturbance will be associated with the surface infrastructure area, which will be 7.2 km north-west of Moss Vale town centre. It is in the Southern Highlands region of NSW and the Sydney Basin Biogeographic Region.

The project area is in a semi-rural setting, with the wider region characterised by grazing properties, small-scale farm businesses, natural areas, forestry, scattered rural residences, villages and towns, industrial activities such as the Berrima Cement work and Berrima Feed Mill, and some extractive industry and major transport infrastructure such as the Hume Highway.

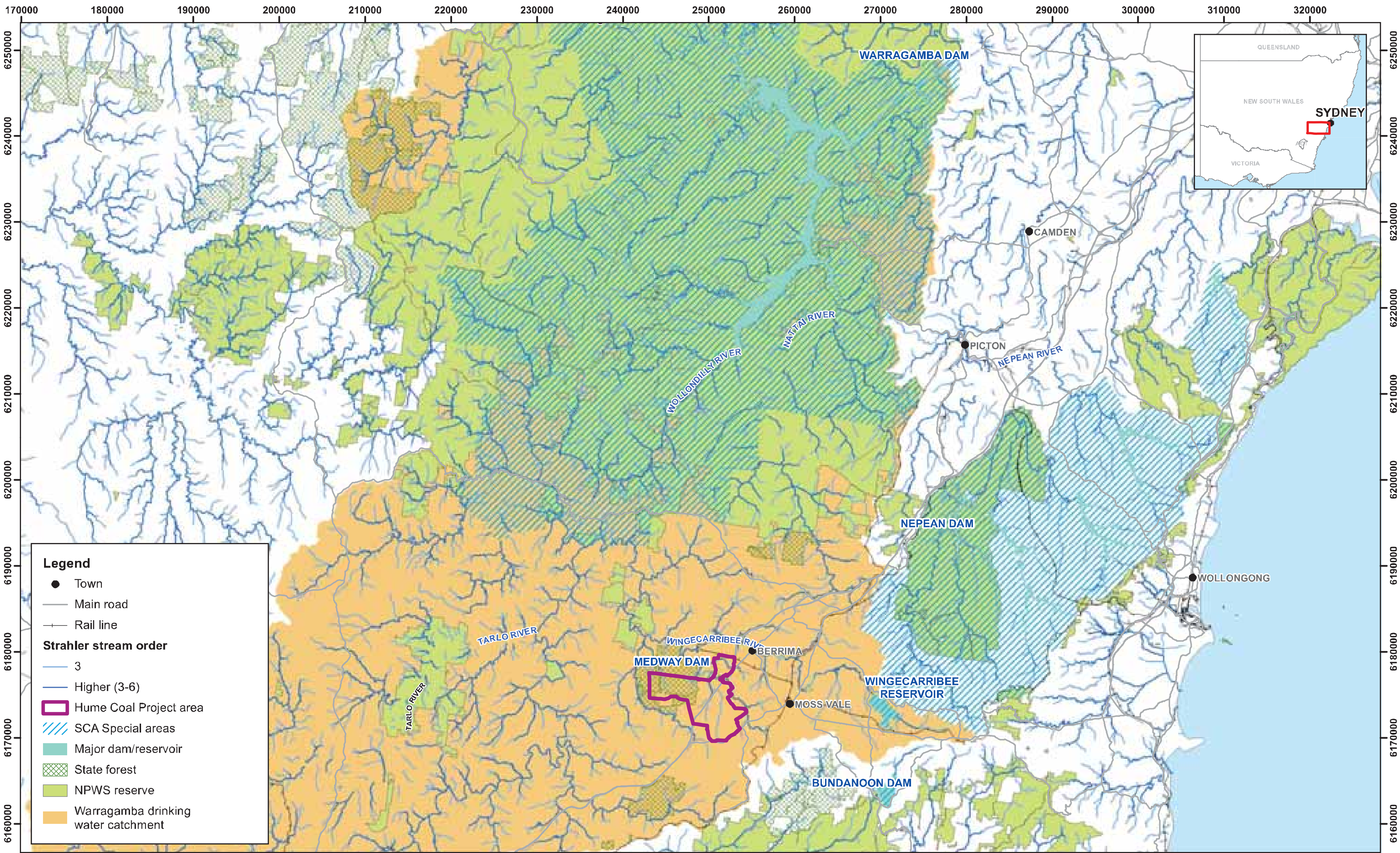
Surface infrastructure is proposed to be developed on predominately cleared land owned by Hume Coal or affiliated entities, or for which there are appropriate access agreements in place with the landowner. Over half of the remainder of the project area (principally land above the underground mining area) comprises cleared land that is, and will continue to be, used for livestock grazing and small-scale farm businesses. Belanglo State Forest covers the north-western portion of the project area and contains introduced pine forest plantations, areas of native vegetation and several creeks that flow through deep sandstone gorges. Native vegetation within the project area is largely restricted to parts of Belanglo State Forest and riparian corridors along some watercourses.

The project area is traversed by several drainage lines including Oldbury Creek, Medway Rivulet, Wells Creek, Wells Creek Tributary, Belanglo Creek and Longacre Creek, all of which ultimately discharge to the Wingecarribee River, at least 5 km downstream of the project area (Figure 1.2). The Wingecarribee River's catchment forms part of the broader Warragamba Dam and Hawkesbury-Nepean catchments. Medway Dam is also adjacent to the northern portion of the project area (Figure 1.2).

Most of the central and eastern parts of the project area have very low rolling hills with occasional elevated ridge lines. However, there are steeper slopes and deep gorges in the west in Belanglo State Forest.

Existing built features across the project area include scattered rural residences and farm improvements such as outbuildings, dams, access tracks, fences, yards and gardens, as well as infrastructure and utilities including roads, electricity lines, communications cables and water and gas pipelines. Key roads that traverse the project area are the Hume Highway and Golden Vale Road. The Illawarra Highway borders the south-east section of the project area.

Industrial and manufacturing facilities adjacent to the project area include the Berrima Cement Works and Berrima Feed Mill on the fringe of New Berrima. Berrima Colliery's mining lease (CCL 748) also adjoins the project area's northern boundary. Berrima colliery is currently not operating with production having ceased in 2013 after almost 100 years of operation. The mine is currently undergoing closure.



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Hume Coal Project
Surface Water Flow and Geomorphology Assessment
Figure 1.1
Project location

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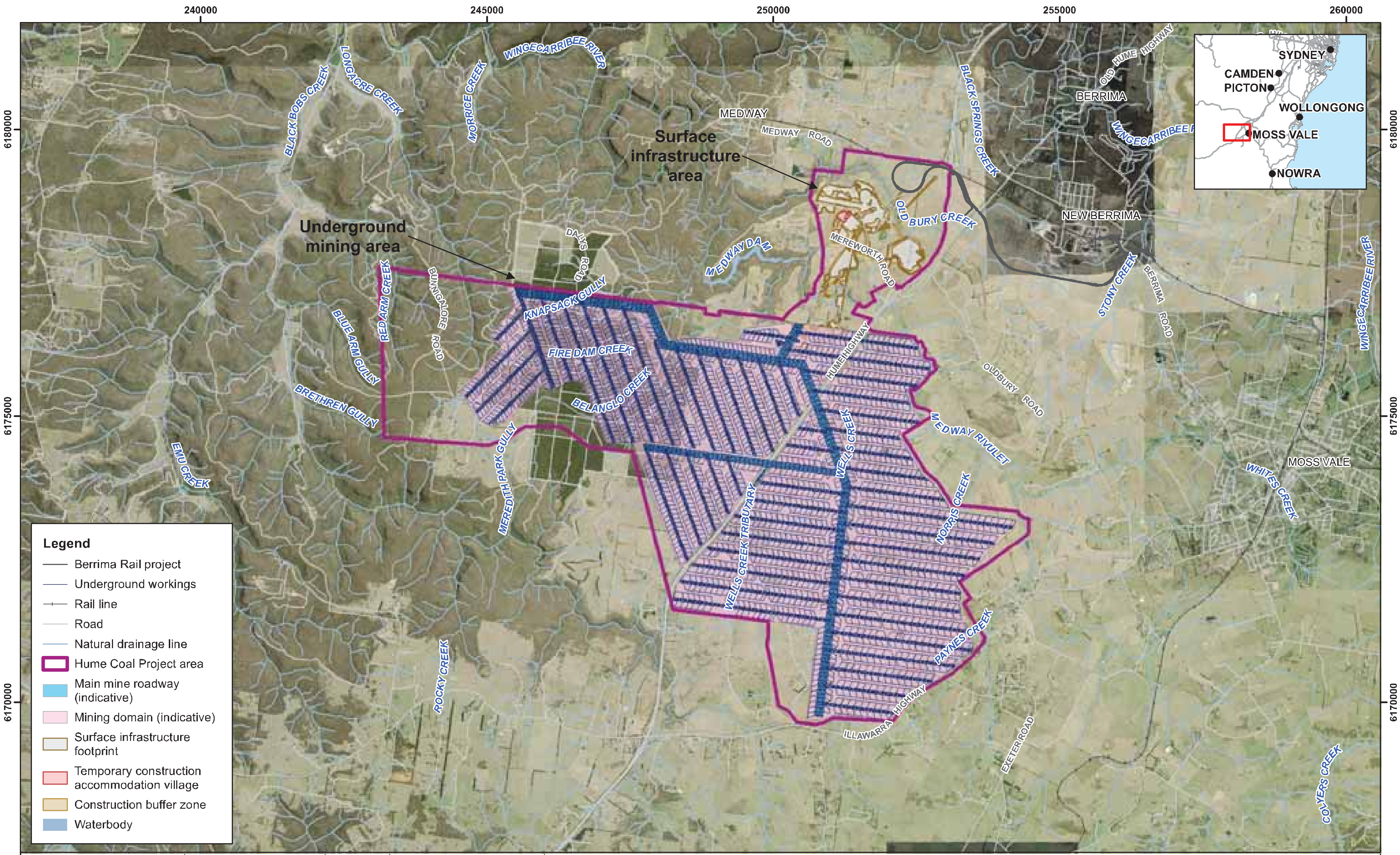

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Hume Coal Project

Surface Water Flow and Geomorphology Assessment

Figure 1.2

Project area

1.2 Project description

The project involves developing and operating an underground coal mine and associated infrastructure over a total estimated project life of 23 years. Indicative mine and surface infrastructure plans are provided in Figure 1.2 and Figure 1.3. A full description of the project, as assessed in this report, is provided in Chapter 2 of the main EIS (EMM 2016a).

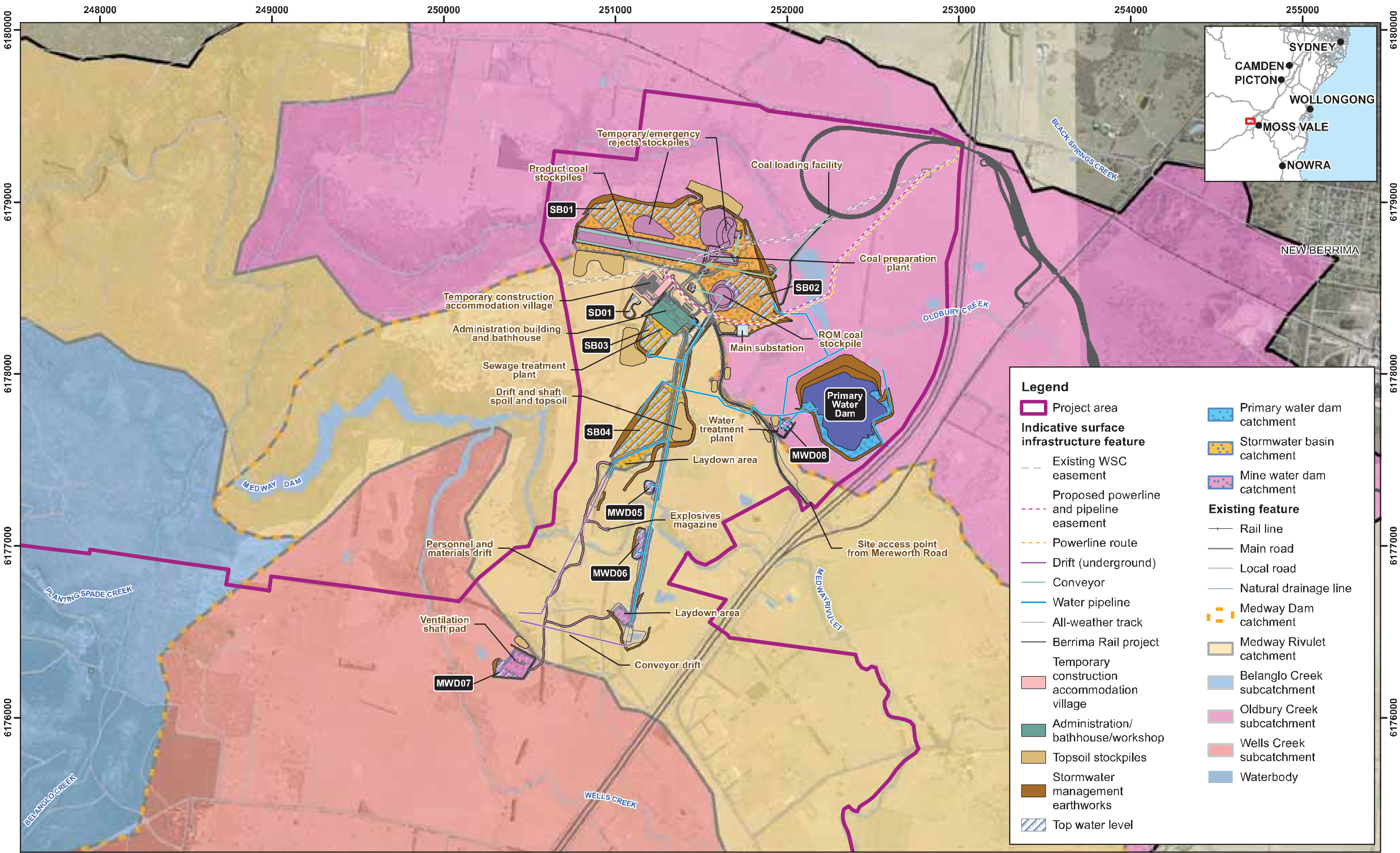
In summary it involves:

- Ongoing resource definition activities, along with geotechnical and engineering testing, and other low impact fieldwork to facilitate detailed design.
- Establishment of a temporary construction accommodation village.
- Development and operation of an underground coal mine, comprising of approximately two years of construction and 19 years of mining, followed by a closure and rehabilitation phase of up to two years, leading to a total project life of 23 years. Some coal extraction will commence during the second year of construction during installation of the drifts, and hence there will be some overlap between the construction and operational phases.
- Extraction of approximately 50 million tonnes (Mt) of run-of-mine (ROM) coal from the Wongawilli Seam, at a rate of up to 3.5 million tonnes per annum (Mtpa). Low impact mining methods will be used, which will have negligible subsidence impacts.
- Following processing of ROM coal in the coal preparation plant (CPP), production of up to 3 Mtpa of metallurgical and thermal coal for sale to international and domestic markets.
- Construction and operation of associated mine infrastructure, mostly on cleared land, including:
  - one personnel and materials drift access and one conveyor drift access from the surface to the coal seam;
  - ventilation shafts, comprising one upcast ventilation shaft and fans, and up to two downcast shafts installed over the life of the mine, depending on ventilation requirements as the mine progresses;
  - a surface infrastructure area, including administration, bathhouse, washdown and workshop facilities, fuel and lubrication storage, warehouses, laydown areas, and other facilities. The surface infrastructure area will also comprise the CPP and ROM coal, product coal and emergency reject stockpiles;
  - surface and groundwater management and treatment facilities, including storages, pipelines, pumps and associated infrastructure;
  - overland conveyors;
  - rail load-out facilities;
  - explosives magazine;
  - ancillary facilities, including fences, access roads, car parking areas, helipad and communications infrastructure; and
  - environmental management and monitoring equipment.
- Establishment of site access from Mereworth Road, and minor internal road modifications and relocation of some existing utilities.
- Coal reject emplacement underground, in the mined-out voids.
- Peak workforces of approximately 414 full-time equivalent employees during construction and approximately 300 full-time equivalent employees during operations.
- Decommissioning of mine infrastructure and rehabilitating the area once mining is complete, so that it can support land uses similar to current land uses.

The project area, shown in Figure 1.2, is approximately 5,051 hectares (ha). Surface disturbance will mainly be restricted to the surface infrastructure areas shown indicatively on Figure 1.3, though will include some other areas above the underground mine, such as drill pads and access tracks. The project area generally comprises direct surface disturbance areas of up to approximately 117 ha, and an underground mining area of approximately 3,472 ha, where negligible subsidence impacts are anticipated.

A construction buffer zone will be provided around the direct disturbance areas. The buffer zone will provide an area for construction vehicle and equipment movements, minor stockpiling and equipment laydown, as well as allowing for minor realignments of surface infrastructure. Ground disturbance will generally be minor and associated with temporary vehicle tracks and sediment controls as well as minor works such as backfilled trenches associated with realignment of existing services. Notwithstanding, environmental features identified in the relevant technical assessments will be marked as avoidance zones so that activities in this area do not have an environmental impact.

Product coal will be transported by rail, primarily to Port Kembla terminal for the international market, and possibly to the domestic market depending on market demand. Rail works and use are the subject of a separate EIS and State significant development application for the Berrima Rail Project.



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Hume Coal Project
Surface Water Flow and Geomorphology Assessment
Figure 1.3
Surface infrastructure layout

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1.3 Study area

The study area for the flow and geomorphology impact assessment comprises the streams with potential to be impacted by the project. The project has the potential to impact on the flow regime and geomorphology of local streams through:

- loss of catchment area due to the capture of runoff by the water management system, resulting in a reduction in runoff and streamflow;
- releases from selected stormwater basins following containment of the first flush within the water management system; and
- reduction in stream baseflow due to aquifer depressurisation associated with underground coal mining.

The potential impacts on streamflow and geomorphology that have been considered in this assessment include:

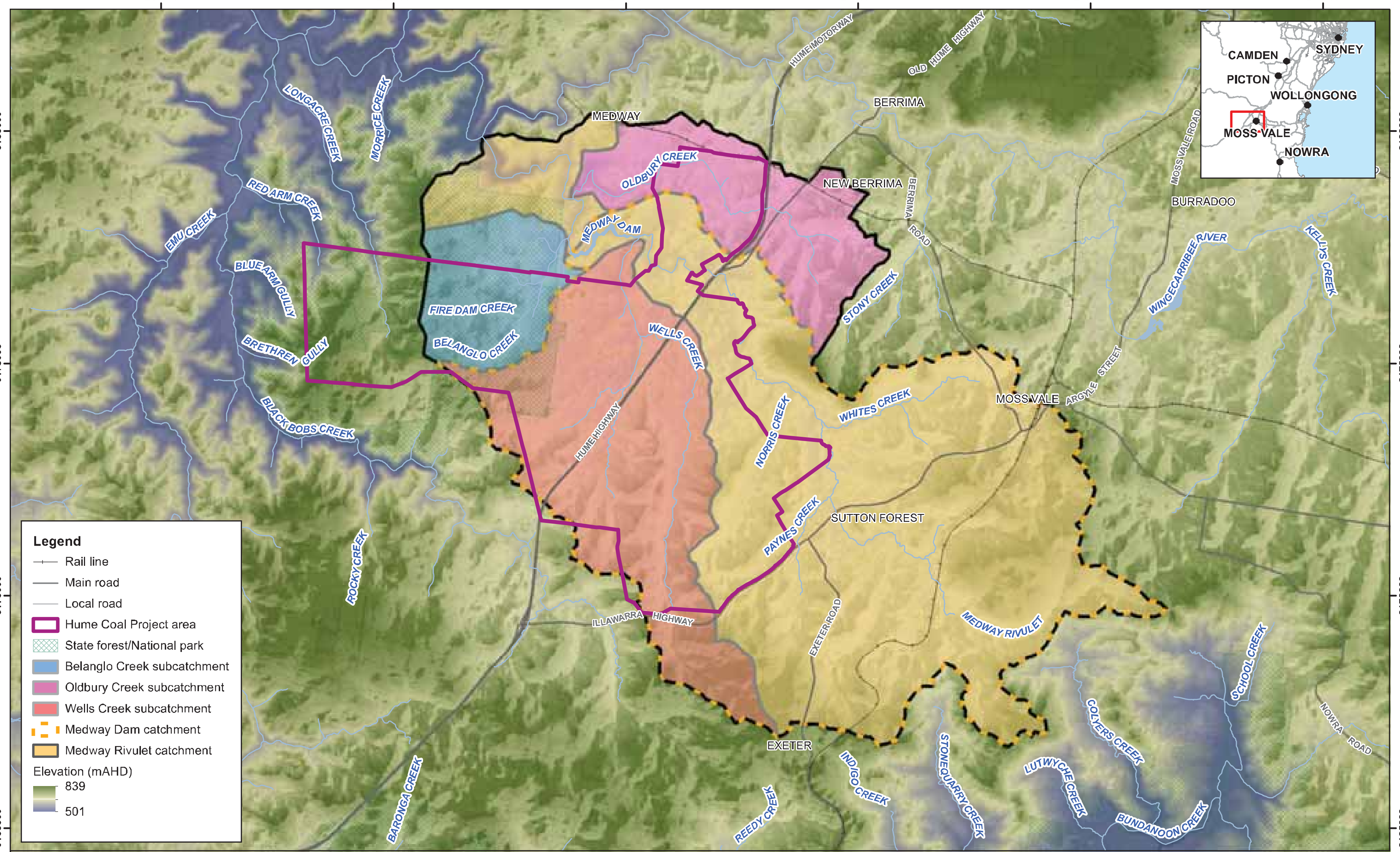
- bed scour and bank instability associated with change in streamflow and local flooding due to mining operations;
- reduced access for downstream water users; and
- reduced availability of water for instream and riparian ecosystems associated with a reduction in streamflow.

Surface water taken directly from streams will not be used as a water supply for the project; therefore impacts associated with take directly from streams do not need to be addressed.

The underground mine workings will result in negligible impacts on flow and geomorphology in overlying catchments. Worst case estimates of subsidence associated with the proposed first workings mining system predict 'imperceptible' surface disturbance due to mining (Mine Advice 2016). Such disturbances are sufficiently low in magnitude as to not impact on streamflow regimes or geomorphology.

The study area therefore comprises:

- streams adjacent to and downstream of the surface infrastructure areas within the Medway Rivulet and Oldbury Creek catchments; and
- streams affected by loss of baseflow due to aquifer depressurisation.



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Hume Coal Project
Surface Water Flow and Geomorphology Assessment
Figure 1.4
Study area

1.4 Environmental assessment requirements

This assessment has been prepared in accordance with the relevant governmental assessment requirements, guidelines and policies, and in consultation with the relevant government agencies. Guidelines and policies considered are as follows:

- *Greater Metropolitan Region Unregulated Water Sources Water Sharing Plan 2011*
- *NSW State Rivers and Estuary Policy 1993*
- *NSW Government Water Quality and River Flow Objectives 2006*
- *WaterNSW Principles for Managing Mining and Coal Seam Gas Impacts in Declared Catchment Areas 2014.*

Further details of these guidelines and policies, and how they apply to this assessment, are provided in Section 2 of this report.

The Secretary's Environmental Assessment Requirements (SEARs) related to flow and geomorphology, and the section of this report where the requirement is addressed, are provided in Table 1.1.

Table 1.1 Flow and geomorphology related SEARs

REQUIREMENT	SECTION ADDRESSED
An assessment of the likely impacts of the development on the quantity of the region's surface water resources, having regard to the EPA's, DPI's and WaterNSW's requirements and recommendations (see Attachment 2)	Section 5.4
An assessment of the likely impacts of the development on watercourses, water-related infrastructure and other water users	Section 5.4

To inform preparation of the SEARs, the NSW Department of Planning and Environment (DP&E) invited other government agencies to recommend matters for address in the Environmental Impact Statement (EIS). These matters were then taken into account by the Secretary for DP&E when preparing the SEARs. Copies of the government agencies' advice to DP&E was attached to the SEARs.

Two agencies, the NSW Department of Primary Industries (DPI), WaterNSW and the NSW Office of Environment and Heritage (OEH), raised matters relevant to the flow and geomorphology assessment. These were mainly their standard requirements for projects of this nature, though included some project-specific requirements. These matters are listed in Table 1.2 and have been taken into account in preparing this report, as indicated.

Table 1.2 Agency requirements

REQUIREMENT	SECTION ADDRESSED
DPI, FISHERIES NSW	
Impacts on flow from subsidence and groundwater interactions resulting from surface and underground construction and ongoing operation of the coal mine.	Section 1.3 (subsidence) Section 5.4 (groundwater interactions)
Analysis of impacts of subsidence on water flow within and downstream of all waterways within the proposal area	Section 1.3
Analysis of impacts of groundwater interference and drawdown on water flow within and downstream of all waterways within the proposal area	Section 5.4

REQUIREMENT	SECTION ADDRESSED
Safeguards to mitigate any impacts upon water flow within and downstream of all waterways within the proposal area during construction and ongoing operation of the proposed coal mine. In particular provide details on proposals for erosion and sediment control (to be incorporated into a Construction Environmental Management Plan – CEMP) and proposed stormwater and ongoing drainage management measures.	Section 6.1
Details of ongoing monitoring programs to assess any impacts upon water flow within and downstream of all waterways within the proposal area.	Section 6.2
DPI WATER	
Assessment of impacts on surface water sources (including quantity), related infrastructure, adjacent licensed water users, basic landholder rights and watercourses, and measures proposed to reduce and mitigate these impacts	Section 5 (impacts) Section 6 (mitigation measures)
Full technical details and data of all surface water modelling	Section 5.3 (technical details) Section 3 (data)
Proposed surface water monitoring activities and methodologies	Section 6.2
Assessment of any potential cumulative impacts on water resources, and any proposed options to manage the cumulative impacts	Section 5.4.3
Consideration of relevant policies and guidelines	Section 2
Identification of all surface water features including watercourses, wetlands and floodplains transected by or adjacent to the proposed project.	Section 3.1
Identification of all surface water sources as described by the relevant water sharing plan.	Section 2.1
Detailed description of dependent ecosystems and existing surface water users within the area, including basic landholder rights to water and adjacent/downstream licensed water users	Section 4.2
Assessment of predicted impacts on the flow of surface water, sediment movement, channel stability and hydraulic regime	Section 5.4.1 (flow impacts) Section 5.2.1 (channel stability)
Assessment of predicted impacts on existing surface water users	Section 5.4.2
It is recommended the EIS provides details on all watercourses potentially affected by the proposal, including scaled plans showing the location of wetlands/swamps and watercourses, the site boundary and the footprint of the proposal in relation to the watercourses.	There are no wetlands/swamps in the project area Figure 1,4 (watercourse and project footprint)
Photographs of the watercourses/wetlands and a map showing the point from which the photos were taken.	Section 3.4
A detailed description of all potential impacts on the watercourses/riparian land.	Section 5.4.1
A detailed description of all potential impacts on the wetlands, including potential impacts to the wetlands hydrologic regime.	There are no wetlands in the project area (other than natural drainage lines)
A description of the design features and measures to be incorporated to mitigate potential impacts.	Section 6
Geomorphic and hydrological assessment of watercourses including details of stream order (Strahler System), river style and energy regimes both in channel and on adjacent floodplains	Section 3.1.2 (Strahler stream order) Section 3.4 (river style and energy regimes)

REQUIREMENT	SECTION ADDRESSED
OFFICE OF ENVIRONMENT AND HERITAGE	
The EIS must map rivers, streams, wetlands, estuaries	There are no wetlands or estuaries in the project area Figure 1,4 (rivers and streams)
The EIS must describe background conditions for any water resource likely to be affected by the development, including hydrology.	Section 3.3
The EIS must assess the impact of the development on hydrology, including:	
→ Effects to downstream rivers, wetlands, estuaries, marine waters and floodplain areas	Section 5.4.1
→ Changes to environmental water availability, both regulated/licensed and unregulated/rules based sources of such water	Section 5.4.2
→ Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options	Section 6.1
→ Identification of proposed monitoring of hydrological attributes.	Section 6.2

The Hume Coal Project was declared as a controlled action on 1 December 2015 by the then Commonwealth Department of the Environment (now Department of Environment and Energy). The project will be assessed under the Bilateral Agreement between the NSW Government and the Commonwealth Government. Accordingly, the Commonwealth Department of the Environment and Energy has issued supplementary SEARs to address matters of national environmental significance relevant to the project. These matters are provided in Table 1.3, and have been taken into account in preparing this report, as indicated in the table.

Table 1.3 Supplementary SEARs

REQUIREMENT	SECTION ADDRESSED
An assessment of the relevant impacts of the action on water resources, including:	
→ A description and detailed assessment of the nature and extent of the likely direct, indirect and consequential impacts, including short terms and long-term relevant impacts	Section 5.4
→ A statement whether any relevant impacts are likely to be known, unpredictable or irreversible, and analysis of the significance of the impacts	Section 5.4
→ Any technical data and other information used or needed to make a detailed assessment of the impacts.	Sections 3 and 4
Information on proposed avoidance and mitigation measures to manage the relevant impacts of the action including:	
→ A description of the proposed avoidance and mitigation measures to address the impacts of the action	Section 6.1
→ Assessment of the expected or predicted effectiveness of the mitigation measures	Section 6.1
→ The cost of the mitigation measures	Refer to the EIS Economic Report
→ A description of the outcomes that the avoidance and mitigation measures will achieve.	Section 6.1
The assessment of impacts should include information on any substantial and measurable changes to the hydrological regime of the water resources, for example a substantial change to the volume, timing, duration or frequency of surface water flows.	Section 5.4

REQUIREMENT	SECTION ADDRESSED
The assessment of impacts should include information on substantial and measurable change in the quantity of the water resource.	Section 5.4

2 REGULATORY FRAMEWORK

2.1 NSW Water Management Act 2000

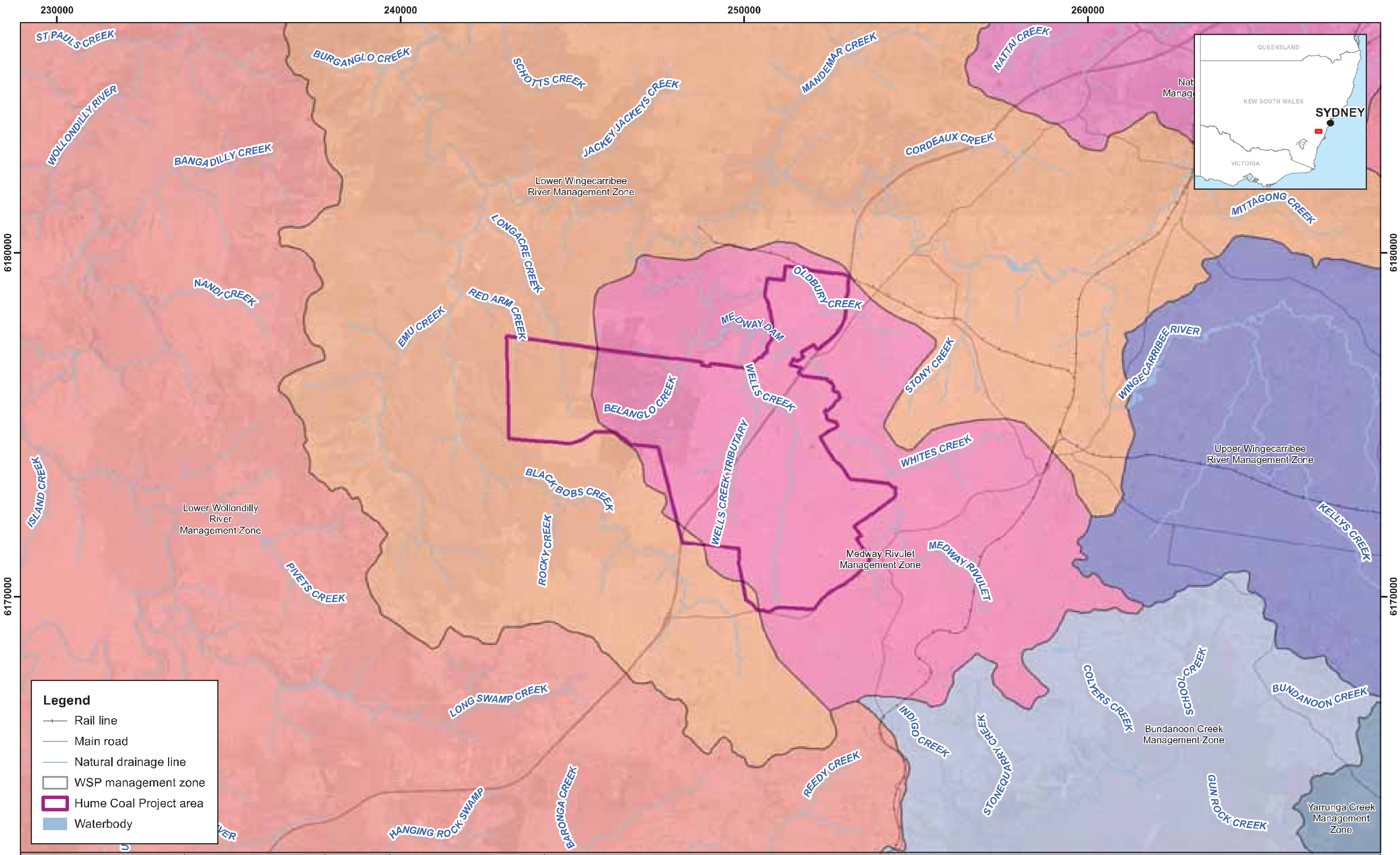
The *NSW Water Management Act 2000* (WM Act) recognises the need to allocate and provide water for the environmental health of our rivers and groundwater systems, while also providing licence holders with access to water. The main tool the WM Act provides for managing the state's water resources are water sharing plans. These are used to set out the rules for the sharing of water in a particular water source between water users and the environment and rules for the trading of water in a particular water source.

Surface water in the project area is managed under the *Greater Metropolitan Region Unregulated Water Sources Water Sharing Plan 2011*. The project area is located largely within the Upper Nepean and Upstream Warragamba Water Source, mostly within the Medway Rivulet management zone with small sections located in the Lower Wingecarribee River management zone (Figure 2.1).

Surface water users (other than stock or domestic) must hold a water access licence (WAL) to take water from streams in the project area. The WAL specifies the annual volume that may be taken and the conditions under which water may be taken. In the Medway Rivulet management zone, WALs have an Environmental Flow Protection Rule that prevents pumping when there is no visible flow at the pump site. In the Lower Wingecarribee River management zone, WALs are divided into classes (A, B and C) and have flow conditions that indicate when pumping may commence and/or must cease. A class WAL holders are subject to daily flow sharing within a total daily extraction limit to protect instream values from risks associated with over extraction.

Water trading is not permitted between management zones. Water trading within the management zones is allowed subject to assessment.

Water may be taken for stock or domestic purposes without a licence under basic water rights. Landholders can take water from streams, or collect a proportion of the rainfall runoff on their property and store it in one or more dams, up to a certain size. The total dam capacity allowed on a property under a harvestable right is determined by calculating the maximum harvestable right dam capacity (MHRDC) for a particular property.



Map: 2200540A_GIS_055_A2	Author: RP
Date: 19/10/2016	Approved by: LR

Data source: NSW Property and Information 2015, Hume Coal, Google Earth

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

Hume Coal Project

Surface Water Flow and Geomorphology Assessment

Figure 2.1

Surface water management zones

2.2 NSW State Rivers and Estuary Policy 1993

The *NSW State Rivers and Estuary Policy 1993* aims to encourage the sustainable management of the State's rivers, estuaries, wetlands and adjacent riverine plains. The overall objectives are to manage NSW rivers and estuaries in ways which:

- slow, halt or reverse the overall rate of degradation in their systems;
- ensure the long-term sustainability of their essential biophysical function; and
- maintain the beneficial use of these resources.

A set of component policies has been developed, identifying management needs and opportunities and providing clear management principles and guidelines.

In applying the *NSW State Rivers and Estuary Policy 1993*, the Hume Coal Project must prevent damage to river banks and channels and maintain the beneficial use of surface water resources, including for the environment.

2.3 NSW Water Quality and River Flow Objectives 2006

The NSW Water Quality and River Flow Objectives (OEH 2006) are the agreed high-level goals for surface water quality and flow management for catchments throughout the state. The river flow objectives identify the key elements of the flow regime that protect river health and water quality for ecosystems and human uses.

River flow objectives are not available for the Hawkesbury-Nepean Basin. At the time the water quality and river flow objectives were approved by the NSW government (September 1999) the Healthy Rivers Commission (HRC) had completed public inquiries for the Hawkesbury-Nepean river catchment. The HRC recommended water quality objectives in its final report for the catchment, however river flow objectives were not provided.

2.4 WaterNSW Principles for Managing Mining and Coal Seam Gas Impacts in Declared Catchment Areas 2014

WaterNSW has an obligation to protect water quality, quantity and its infrastructure within its land and Sydney drinking water catchments. WaterNSW has established a comprehensive governance framework to protect water supply infrastructure and access conditions for mining activities via development of the report *WaterNSW Principles for Managing Mining and Coal Seam Gas Impacts in Declared Catchment Areas* (ie the WaterNSW Principles) (WaterNSW 2014).

Underground longwall mining occurs under much of the Metropolitan Special Area. WaterNSW is particularly focused on the potential for impacts on ground and surface water quality and quantity. During 2007–08 the Southern Coalfields Independent Inquiry sought submissions from stakeholders. Focus areas included the medium and long-term impacts of mining related subsidence on water resources and ecosystems, risks to groundwater and aquifers from subsidence, and the possible remediation of the impacts of mining.

New research and scientific understanding of mining impacts has enabled greater cooperation and coordination of actions between WaterNSW, other government departments and companies involved in mining operations.

In applying the WaterNSW Principles, the Hume Coal Project must provide for the protection of water quantity. In Declared Catchment Areas, mining companies must demonstrate a very low risk of water loss from catchment streams or storages and that appropriate safeguards are in place to prevent or minimise any loss. Predicted impacts to surface water quantity are presented in Section 5 of this report and safeguards to prevent or minimise loss are discussed in Section 6.

3 EXISTING ENVIRONMENT

3.1 Catchment overview

Medway Rivulet and its tributary Oldbury Creek are the primary waterways that flow through the project area. The combined catchment area of both creek systems (including the Wells Creek and Belanglo Creek tributaries) is 12,264 ha to the confluence with Wingecarrribee River (refer to Table 3.2). The major tributaries of Medway Rivulet are Wells Creek, Whites Creek, Paynes Creek, Oldbury Creek and Belanglo Creek (refer to Figure 1.4).

Medway Rivulet has its headwaters near Moss Vale, NSW and flows in predominantly west to north-west direction towards the Wingecarribee River. Land use in the upper reaches of the catchment is highly disturbed and cleared for agriculture. River behaviour east of the Hume Highway is characterised by several instream storages that impede the natural flow within the upper catchment and ponded water connected by run/riffle sequences. Medway Rivulet and its major tributaries receive runoff from adjacent farm land. Whites Creek receives urban stormwater and treated sewage effluent from the suburb of Moss Vale.

West of the Hume Highway, Medway Rivulet is confined by steep gullies formed by Hawkesbury Sandstone. Downstream of the project area, Medway Rivulet has been dammed to create a 1,350 ML reservoir. The reservoir is commonly referred to as ‘Medway Dam’ and is ordinarily part of Wingecarribee Shire Council’s (WSC’s) water supply system (although Medway Water Treatment Plant, which treats water from the reservoir, is not currently operational – refer Section 4.2.1.1). Approximately 5.5 km downstream from the reservoir, Medway Rivulet joins the Wingecarribee River.

Oldbury Creek joins Medway Rivulet approximately 1.5 km downstream from the reservoir. The upper reaches of Oldbury Creek commence near New Berrima, NSW. East of the Old Hume Highway, in the upper reaches, the creek is characterised by disconnected instream storages used for agricultural water supply. A large instream farm dam is located adjacent to the proposed CPP precinct. To the north of the proposed CPP the creek becomes confined in gullies formed by the Hawkesbury Sandstone. From the proposed CPP downstream, the creek is characterised by pools connected with run and riffle sequences.

Belanglo Creek joins the Medway Rivulet approximately 300 m downstream of Medway Dam and receives runoff from the Belanglo State Forest (refer to Figure 1.4). The upper reaches of Belanglo Creek are predominately ephemeral with isolated disconnected pools during low flow conditions.

3.1.1 Stream network

The stream network was identified as those streams marked with a blue line on the regional topographic data provided by Land and Property Information (2014). The streams in the project area generally drain in a north-west direction and flow into the Wingecarribee River. The Wingecarribee River joins the Wollondilly River downstream of the project area.

3.1.2 Stream order

The Strahler stream classification system is a method of classifying waterways according to the number of tributaries associated with each waterway (Strahler 1957). Small tributaries at the top of the catchment are assigned as first order streams. Where two first order streams join, the waterway downstream of the junction is referred to as a second order stream and so on. Higher order streams are found in the lower parts of the catchment.

The Strahler stream classification was applied to the stream network (LPI 2014) within the study area and considered when identifying river styles for the geomorphology assessment (refer Section 3.4). The Strahler classification within the study area is presented in Figure 3.1.

3.1.3 Catchment delineation

Areas for the management zones in Figure 2.1 are provided in Table 3.1. The management zones are the catchments in the *Greater Metropolitan Region Unregulated Water Sources Water Sharing Plan 2011*.

Table 3.1 Management zone areas

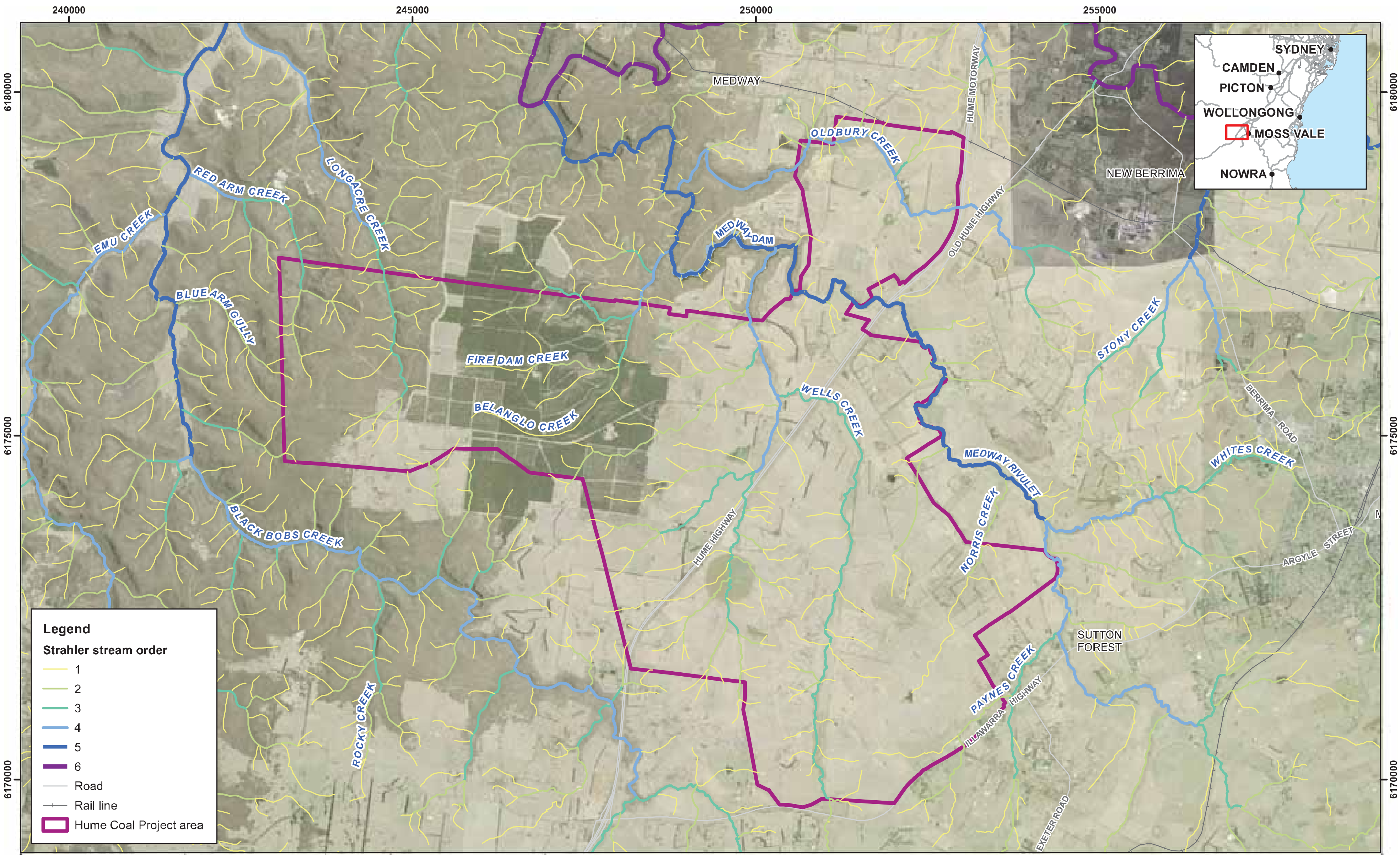
MANAGEMENT ZONE	AREA (HA)
Medway Rivulet	12,347
Lower Wingecarribee	50,546
Lower Wollondilly	265,763
Bundanoon Creek	31,947

A more detailed catchment delineation of the Medway Rivulet catchment, where the project is to be located, has been undertaken to provide for more detailed analysis of potential impacts. Light detection and ranging (LiDAR) data obtained from aerial laser survey of the project area on 25 October 2013 (Hume Coal 2013) and publically available topographic contour data has been used to delineate the Medway Rivulet catchment and its sub-catchments. The Medway Rivulet catchment and its sub-catchments are shown on Figure 1.4 and catchment areas are provided in Table 3.2.

Table 3.2 Medway Rivulet sub-catchment areas

SUB-CATCHMENT	AREA (HA)
Medway Rivulet upstream of Medway Dam	6,529
Medway Rivulet downstream of Medway Dam	626
Oldbury Creek (to the confluence with Medway Rivulet)	1,355
Wells Creek, including Wells Creek Tributary (to the confluence with Medway Rivulet)	2,869
Belanglo Creek	885
TOTAL	**12,264**

The LiDAR and contour data was used together with aerial photography to estimate surface parameters in the hydrological models developed for the project (Parsons Brinckerhoff 2016a and 2016c).



Map: 2200540A_GIS_056_A3	Author: RP
Date: 19/10/2016	Approved by: LR

Data source: © Land and Property Information 2015, Hume Coal, ESRI DigitalGlobe

0 1,000 2,000 m

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

Hume Coal Project
Surface Water Flow and Geomorphology Assessment
Figure 3.1
Strahler network

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3.2 Climate records

The flow impact assessment used outputs from the modelling undertaken for the water balance assessment (Parsons Brinckerhoff 2016c) to assess the potential impacts of the project on streamflow. The climate data used for the water balance assessment was based on historical daily data sourced from the Data Drill database (DSITIA 2015).

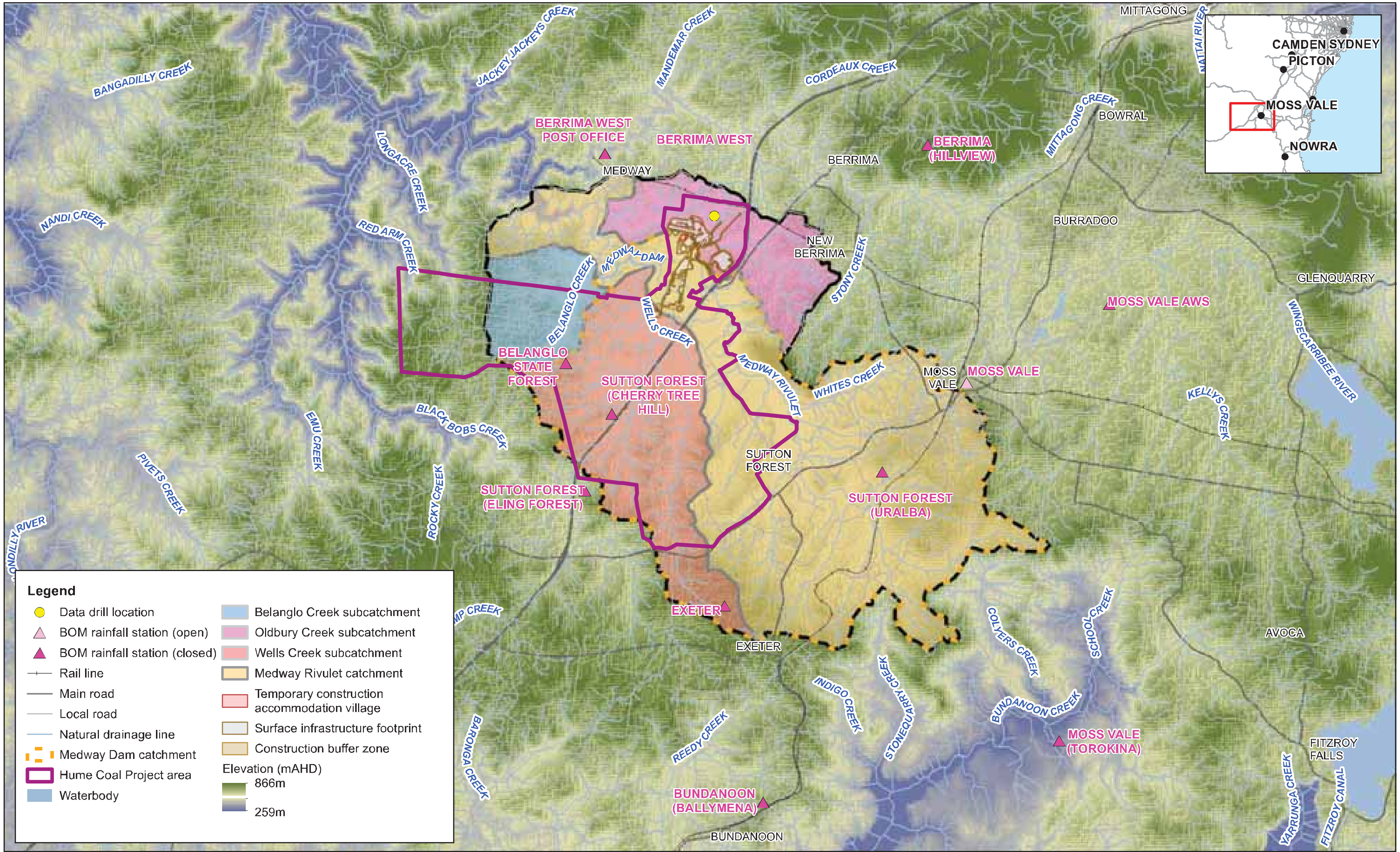
Data Drill is a daily time series of data at a point location consisting entirely of interpolated estimates. The data are taken from the gridded datasets and are available at any grid point over the land area of Australia. Data Drill is considered superior to individual Bureau of Meteorology (BOM) station records and site observations for water balance modelling purposes because it draws on a greater dataset, both spatially and in time, and does not contain gaps.

The Data Drill for the water balance assessment was obtained for latitude -34.50 and longitude 150.30 (in decimal degrees), which is 0.5 km north of SB01 and SB02. Figure 3.2 shows the Data Drill location and BOM rain gauges located around the Medway Rivulet and Oldbury Creek catchments. The available data for the Data Drill location is for a 127 year period from 1889 to 2015.

A plot of the Data Drill annual rainfall is provided in Figure 3.3. This plot also contains a 10-year moving average time series, which identifies the period from 1949 to1969 as the wettest period. Similarly the period from 1999 to 2015 appears to be one of the sustained dry periods.

A plot of monthly distribution of average daily evaporation from the Data Drill for the site is provided in Figure 3.4. Lake evaporation data was used in the water balance assessment to estimate evaporation from storages and evapotranspiration data was used for other areas. In the project area, lake evaporation and evapotranspiration is lowest in winter months and highest in summer months.

Summary statistics for rainfall and evaporation are provided in Table 3.3. Further details of the climate data used for the water balance assessment are provided in the water balance assessment report (Parsons Brinckerhoff 2016c).



Map: 2200540A_GIS_050_A5	Author: RP		1:100,000
Date: 14/11/2016	Approved by: LR		Coordinate system: GDA 1994 MGA Zone 56
Data source: , Hume Coal, Google Earth			Scale ratio correct when printed at A3

Hume Coal Project
Surface Water Flow and Geomorphology Assessment
Figure 3.2
Climate data

Hume Coal
www.wsp-pb.com

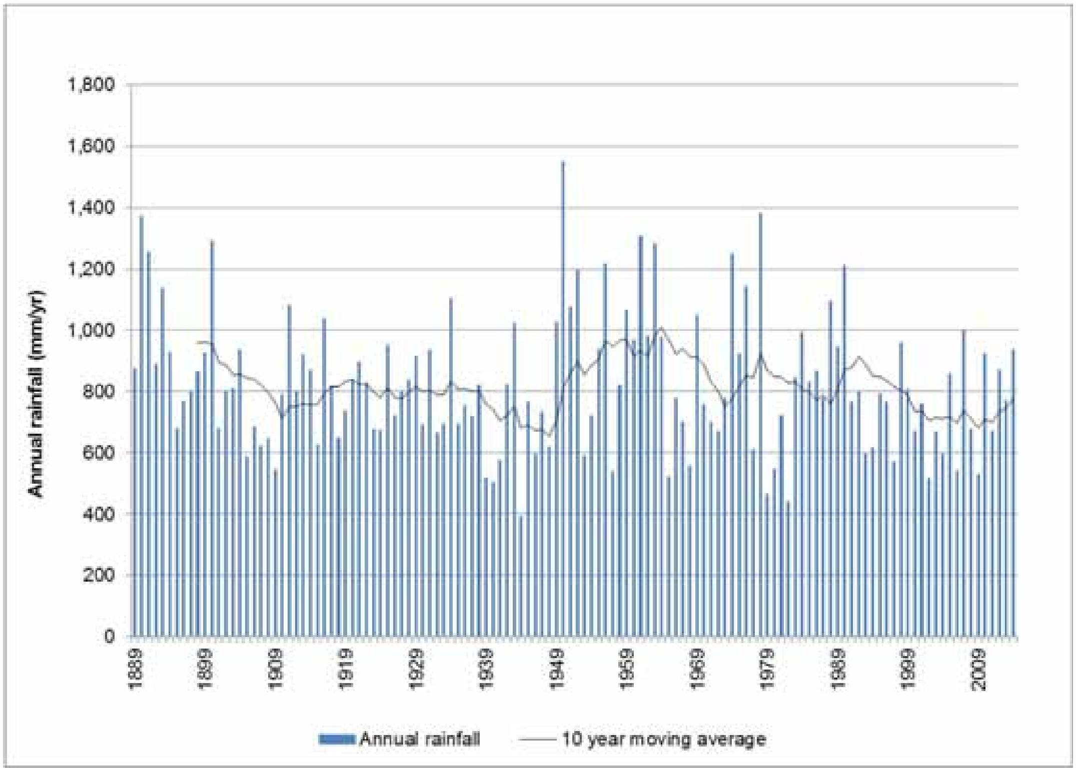


Figure 3.3 Annual rainfall for Hume Coal Project site — Data Drill (1889 to 2015)

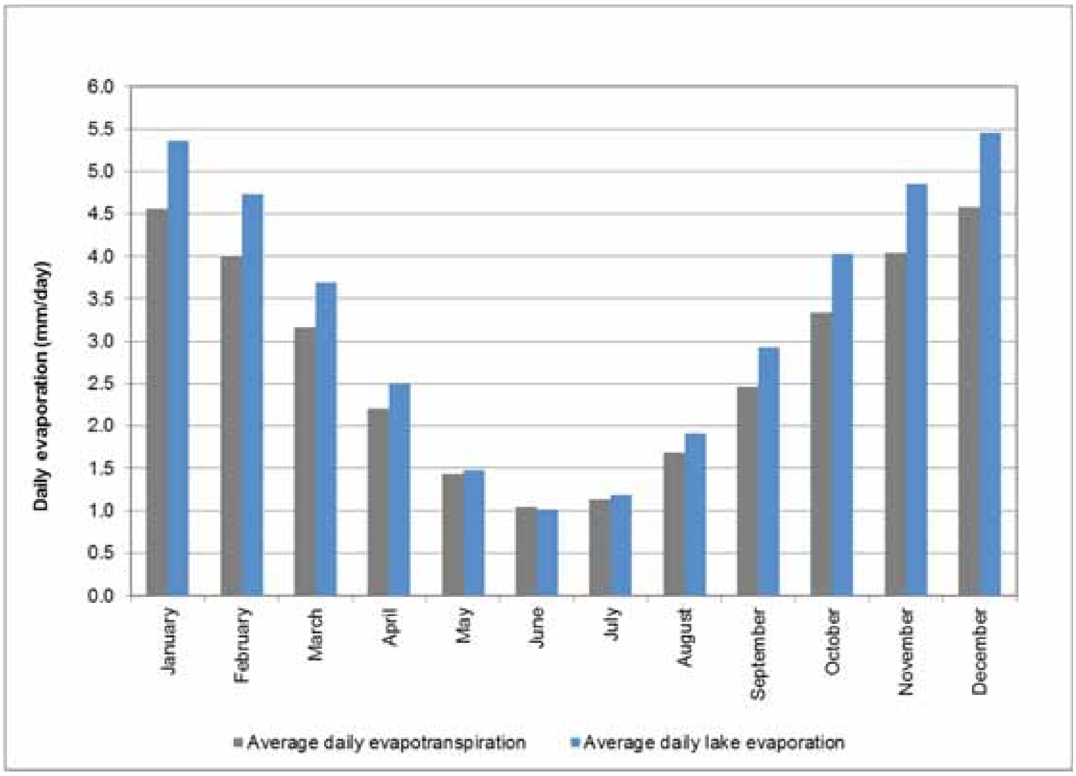


Figure 3.4 Average daily evaporation for Hume Coal Project site — Data Drill (1889 to 2015)

Table 3.3 Summary climate statistics for Hume Coal Project site — Data Drill (1889 to 2015)

STATISTIC	ANNUAL RAINFALL (MM)	ANNUAL POTENTIAL EVAPOTRANSPIRATION[1] (MM)	ANNUAL LAKE EVAPORATION[2] (MM)
Minimum	393	878	1,034
5th percentile (dry)	525	930	1,095
10th percentile	564	946	1,114
50th percentile (median)	800	1,016	1,190
90th percentile	1,120	1,109	1,264
95th percentile (wet)	1,256	1,122	1,275
Maximum	1,550	1,180	1,306
Average	824	1,021	1,187
Standard deviation	220	60	57

(1) Potential evapotranspiration calculated using the Penman-Monteith formula (Food and Agriculture Organization of the United Nations, 1998)

(2) Lake evaporation calculated using the Morton formula for shallow lakes (Morton, 1983)

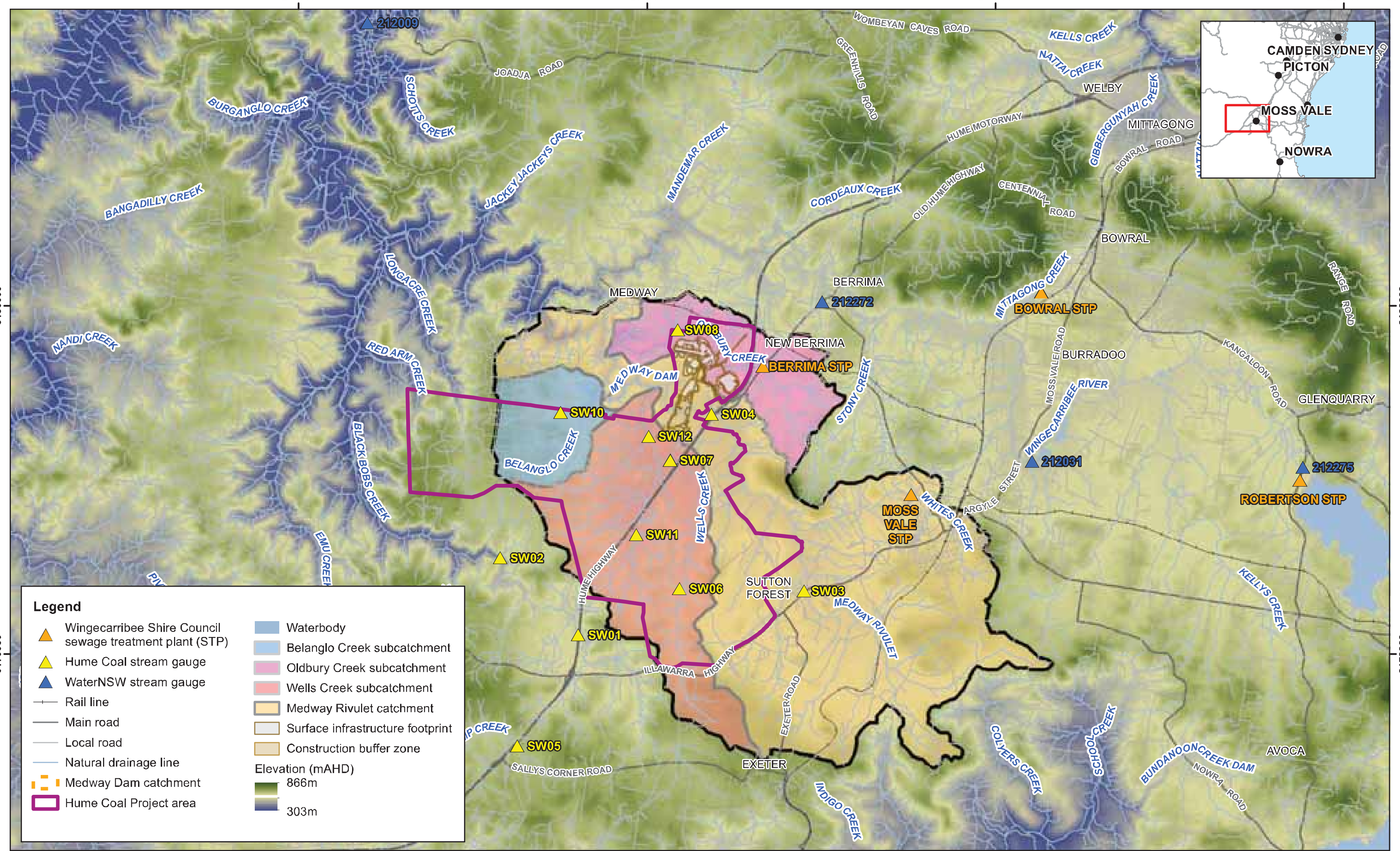
3.3 Stream gauge records

Stream gauging stations in the vicinity of the project area are operated by WaterNSW and Hume Coal. The locations of the stream gauges are shown on Figure 3.5 and available stream gauging data is summarised in Table 3.4.

Table 3.4 Stream gauging data in vicinity of Hume Coal Project site

STATION ID	OPERATOR	LOCATION	APPROX. CATCHMENT AREA (km^2)	PERIOD OF RECORD
212009	WaterNSW	Wingecarribee River at Greenstead	587	26/10/1989 to 3/12/2015
212272	WaterNSW	Wingecarribee River at Berrima	201	22/08/1975 to 1/01/2016
212031	WaterNSW	Wingecarribee River at Bong Bong (downstream of Bong Boing Reservoir)	134	07/06/1989 to 1/01/2016
SW01	Hume Coal	Black Bobs Creek near Hume Hwy	21	21/1/2012 to 8/10/2015
SW02	Hume Coal	Black Bobs Creek near Belanglo Forest	12	06/09/2012 to 3/07/2015
SW03	Hume Coal	Medway Rivulet near Illawarra Hwy	0.02	22/01/2012 to 8/10/2015
SW04	Hume Coal	Medway Rivulet near Hume Hwy	37	21/1/2012 to 8/10/2015
SW05	Hume Coal	Long Swamp Creek near Hume Hwy	3	22/06/2015 to 8/10/2015
SW08	Hume Coal	Oldbury Creek adjacent to proposed mine surface infrastructure area	10.52	14/05/2015 to 8/10/2015

Stream gauge records were obtained from WaterNSW for the Wingecarribee River at Bong Bong (No. 212031), Berrima (No. 212272) and Greenstead (No. 212009) gauging stations. Stream gauge water level data was obtained from Hume Coal for SW04 and SW08. Water level data was converted to flow data using rating curves developed for each site using the respective hydraulic models (refer to the Flooding Assessment Report (Parsons Brinckerhoff 2016a) for further details). The streamflow data were analysed using flow duration curves and volumetric runoff coefficients.



Map: 2200540A_GIS_051_A6 | Author: RP
Date: 14/11/2016 | Approved by: LR
Data source: , Hume Coal, Google Earth

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Coordinate system: GDA 1994 MGA Zone 56
Scale ratio correct when printed at A3

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Surface Water Flow and Geomorphology Assessment
Figure 3.5
Hume Coal stream gauges and catchments

Daily flow duration curves for the gauging stations in the Wingecarribee River for the data period from 1989 to 2015 are provided in Figure 3.6. Flows are represented as runoff depths (volume per unit area) to allow comparison between the three gauging stations. Only 1% of the daily runoff depths are greater than 7 mm/day at all gauging sites. For 99% of the data points the Bong Bong (No. 212031) and Berrima (No. 212272) gauging sites were greater than the Greenstead (No. 212009) gauging site, the former being the greatest. This is potentially due to the relative proportion of instream weir volume capacity per unit catchment area and illustrates the effects of river streamflow regulation by weir structures.

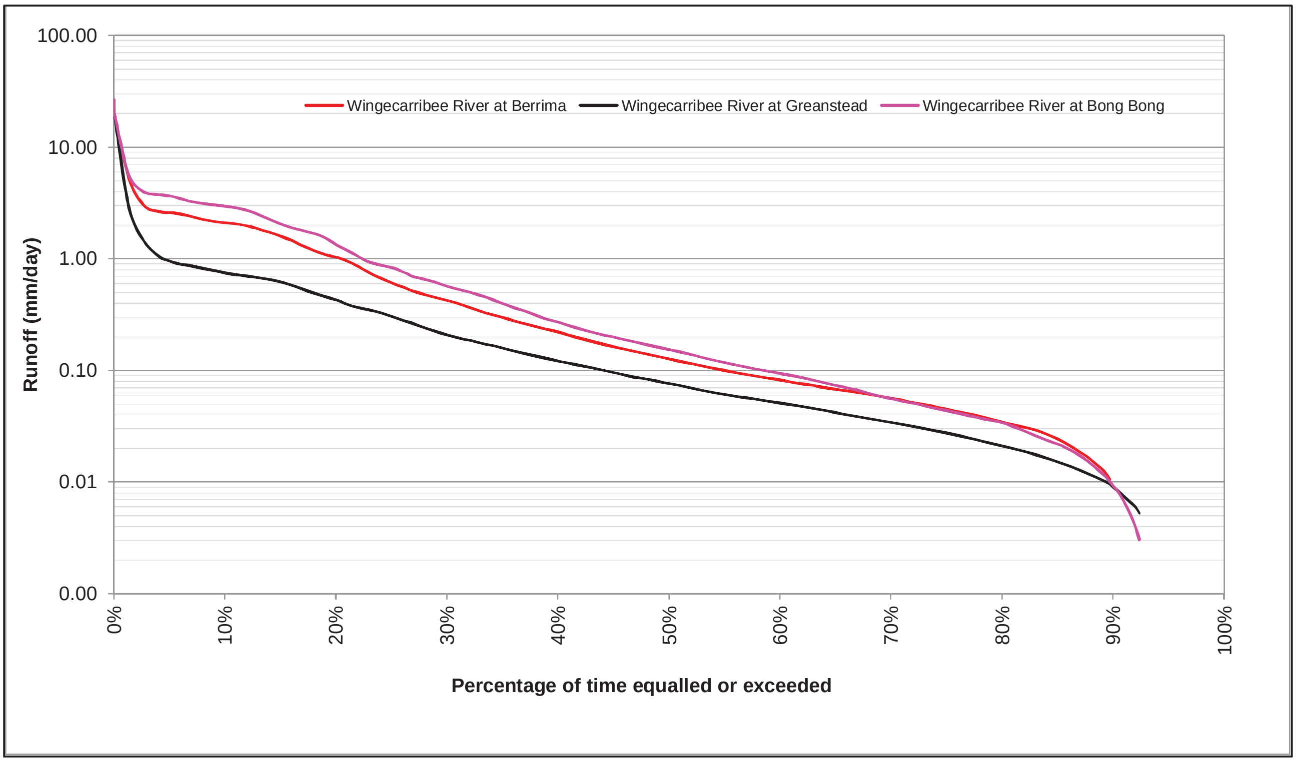


Figure 3.6 Flow duration curves for WaterNSW gauging stations on the Wingecarribee River (1989 to 2015)

3.4 Geomorphology assessment

The objective of the field geomorphological survey was to verify desktop assessments, which used aerial imagery and topographic data, and obtain sufficient information to enable identification of river styles and geomorphic features within the study area. The geomorphology assessment was completed using principles and terminology of the River Styles® Framework (Brierly and Fryirs 2005). Field assessments of watercourses at several locations were completed between May 2012 and October 2015. The timing of field assessments was based on land access approvals and development and refinement of the mine layout plan. The geomorphological survey provides a snapshot of the current geomorphic conditions and identifies the various river styles within the study area.

3.4.1 Approach

The River Styles® framework was designed to cover all Australian stream types, and can be applied at a large scale, where a range of different styles would be expected. The River Styles® classification is based on valley setting, level of floodplain development, bed materials and geomorphic units.

Characterisation of the fluvial geomorphology of the study area was approached at two measurement scales:

- Catchment scale – predominately a desktop assessment of the study area and downstream to the confluence between Black Bobs Creek and the Wingecarribee River (100s to 1,000s of metres).
- Reach scale – field verification and assessment at geomorphology survey locations (10s to 100s of metres).

Procedures to identify river styles were broadly based on the following parameters:

- Degree of valley confinement;
- Presence and continuity of a channel;
- Channel planform (number of channels, sinuosity); and
- Geomorphic units and features.

3.4.2 Site selection

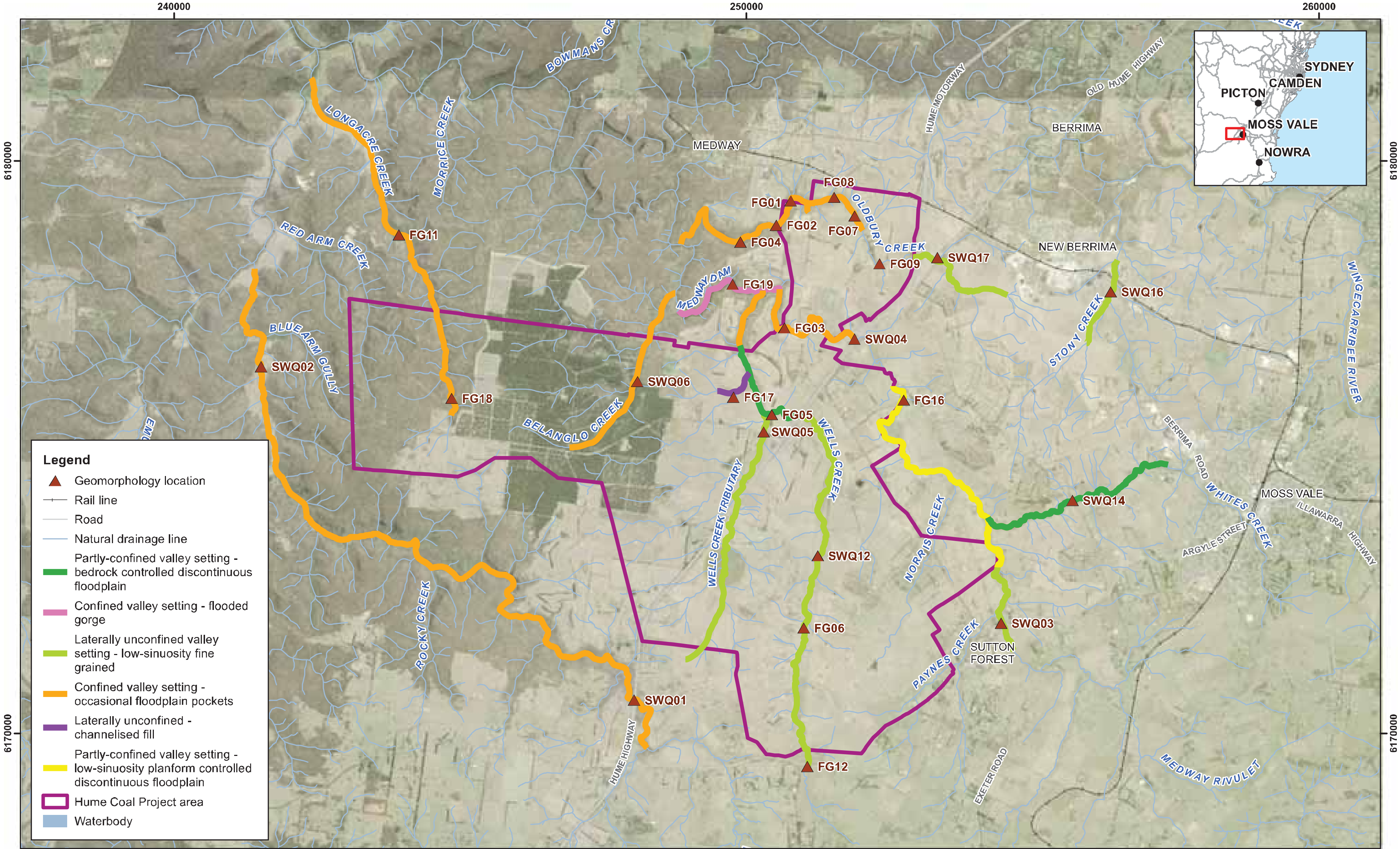
The geomorphology assessment focussed on the project area, including surface infrastructure areas and streams above the proposed underground mining area. In addition, streams surrounding the project area and downstream of surface infrastructure were included in the assessment.

The approach to the assessment was to select representative reaches or reaches with noteworthy geomorphic features based on the desktop selection criteria. Site selection for geomorphic field assessment was based on the following criteria:

- Headwaters originating within the project area;
- Underlying geology;
- Representative reach based on desktop assessment;
- Underlying groundwater levels based on preliminary groundwater modelling;
- Spatial land use characteristics;
- Stream order; and/or
- Unique areas of interest identified in aerial photography.

Geomorphological assessments were also completed at existing surface water quality monitoring sites (Parsons Brinckerhoff 2016d).

The geomorphology site assessment locations are shown in Figure 3.7.



Map: 2200540A_GIS_007_A3	Author: RP		0 1,000 2,000 m 1:60,000 Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A3
Date: 20/10/2016	Approved by: LR		

Data source: © Land and Property Information 2015, Hume Coal, Google Earth

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Hume Coal Project
Surface Water Flow and Geomorphology Assessment
Figure 3.7
Geomorphology assessment locations

3.4.3 Field survey results

The results of the field geomorphic surveys are summarised in Table 3.5. Photographs of the sites visited are provided in Photos 3.1 to 3.49 and include photographs taken facing upstream (US), downstream (DS) and across stream (AS). Detailed field survey results are provided in Appendix A.

Table 3.5 Field geomorphic survey results

SITE ID	STREAM	VALLEY SETTING	RIVER STYLE	SINUOSITY	GEOMORPHIC UNITS	BED AND BANK COMPOSITION	CHANNEL GEOMETRY	RIVER BEHAVIOUR			CONTROLS
								LOW	BANK FULL	OVERBANK	
FG01	Oldbury Creek	Confined valley setting	Occasional floodplain pockets	Low	Flood runners, bank scour, bench onto floodplain, riffle	Bedrock, sands, boulders, cobbles	Irregular	Supply, maintenance, sediment transport	Mobilise sand, minimal rework, bank erosion	Active channel, deposit on benches, flood chutes activated, erosion in channel	Valley, vegetated sandy bank, flood runners
FG02	Oldbury Creek	Confined valley setting	Occasional floodplain pockets	None	Bedrock outcrop, attached sandy bank/bar, channel scour	Sands	Symmetrical	Scarcely perceptible flow, pooled water	Active channel	Reworking, erosion/deposition on banks	Riparian vegetation, bedrock margins
FG03	Medway Rivulet	Confined valley setting	Occasional floodplain pockets	Low	Bedrock outcrop, bench up to floodplain, flood runners	Bedrock, silty sand, sand	Asymmetrical	Pooled water	Active channel	Flood runners activate, erosion/deposition	Bedrock, instream trees, upstream weir/causeway
FG04	Oldbury Creek	Confined valley setting	Occasional floodplain pockets	Low	Bedrock outcrop	Bedrock, clay, sand	Symmetrical	Scarcely perceptible flow, pooled water	Active channel	Reworking, erosion/deposition on banks	Riparian vegetation, bedrock margins, submerged log
FG05	Wells Creek	Partly-confined valley setting	Bedrock-controlled discontinuous floodplain	Low	Bedrock outcrop, riffle, pools, chute channels, benches, undercutting	Bedrock, clay, sand	Asymmetrical	Scarcely perceptible flow, pooled water	Active channel	Erosion of banks, deposition on floodplain	Riparian vegetation (grass), bedrock margins, instream reeds, submerge block
FG06	Wells Creek	Laterally unconfined valley setting	Low-sinuosity fine grained	Low	Pools, man-made rock weirs, island, bank attached bars, nick points, disconnected pool, abandoned channel	Clay	Symmetrical	Scarcely perceptible flow, pooled water	Active channel, bank erosion	Erosion of banks, deposition on floodplains	Rock weirs (man-made), riparian vegetation (grass)
FG07	Oldbury Creek	Confined valley setting	Occasional floodplain pockets	Low	Bedrock outcrop, pools. benches, instream trees, chute channels, undercutting	Silt clay, sand	Asymmetrical	Scarcely perceptible flow, pooled water	Active channel	Deposition on floodplain	Upstream farm dam (instream storage), bedrock margins, instream trees, riparian vegetation
FG08	Oldbury Creek	Confined valley setting	Occasional floodplain pockets	Low	Sandy bar, bedrock outcrop, run, benches, dense riparian vegetation	Bedrock, overlying sand	Asymmetrical	Standing water	Maintenance, transport	Minimal rework, some erosion/deposition	Bedrock margins, riparian vegetation
FG09	Oldbury Creek	Partly-confined valley setting	Low-sinuosity planform-controlled discontinuous floodplain	Low	High flow chute, dense instream reeds	Sand, silt, clay	Incised symmetrical	Standing water	Mobilised sediment	Overbank floodplain deposition, channel erosion	Planform controlled, dense instream reeds, riparian vegetation
FG11	Longacre Creek	Confined valley setting	Occasional floodplain pockets	None	Riffle, runs, chutes, pooled water, dense instream vegetation	Sand, silt, clay bedrock visible	Undefined channel	Standing water	Active channel	Slight reworking	Dense instream vegetation, fire trail crossing stream
FG12	Wells Creek	Confined valley setting	Occasional floodplain pockets	None	Riffle, bank scour, dense instream vegetation, benches	Sand	Symmetrical	Standing water	Active channel, bank erosion	Deposition	Dense instream reeds, instream trees, riparian vegetation (grass/trees), fence across stream

SITE ID	STREAM	VALLEY SETTING	RIVER STYLE	SINUOSITY	GEOMORPHIC UNITS	BED AND BANK COMPOSITION	CHANNEL GEOMETRY	RIVER BEHAVIOUR			CONTROL
								LOW	BANK FULL	OVERBANK	
FG16	Medway Rivulet	Laterally unconfined valley setting	Low-sinuosity fine grained	Low	Pooled water, riffle downstream of causeway, riparian predominantly grass, some trees	Sandy clay/silt	Symmetrical	Maintenance, pooled water, settling	Supply, entrainment of sediment	Erosion, deposition on floodplain	Causeway, instream trees, fence, riparian vegetation
FG17	Small tributary of Wells Creek	Laterally unconfined valley setting	Channelised fill	Low	Pooled water, bank scour	Sand, silt, clay	Symmetrical/ undefined channel	Standing water	Active channel, reworking	Channel erosion / floodplain deposition	Riparian vegetation (grass), instream vegetation (grass). Pipe culvert and crossing
FG18	Longacre Creek	Confined valley setting	Occasional floodplain pockets	None	Bedrock outcrop, pooled water, dense instream vegetation	Bedrock, sand, silt, clay	Asymmetrical/ undefined channel	Standing water	Slight reworking	Floodplain deposition, flood runners activate	Bedrock outcrop, fire trail and pipe culvert, dense vegetation
FG19	Medway Dam	Confined valley setting	Flooded gorge	Low	Flooded gorge, bedrock outcrop, benches	Bedrock, silt, clay, sand	Asymmetrical	Standing water (reservoir)	Bank erosion, reworking	Floodplain pocket deposition	Bedrock margins, riparian vegetation (trees), Medway Dam downstream
SWQ01	Black Bobs Creek	Confined valley setting	Occasional floodplain pockets	Low	Bedrock outcrop, pools, riffles, benches, gravel bars, steep banks	Bedrock with silt/sand infill in pools	Symmetrical	Scarcely perceptible flow, pooled water	Transport	Deposition on benches	Bedrock margins, riparian vegetation, bridge abutments
SWQ02	Black Bobs Creek	Confined valley setting	Occasional floodplain pockets	Intermediate	Benches, riffles, chutes, spillway, fallen tree	Bedrock with gravel/sand infill in pools	Asymmetrical	Supply, riffles, chutes, high sediment load and iron staining suggests local erosion and potentially groundwater baseflow to the stream	Flood runners engaged	Bed erosion, floodplain deposition	Vegetation on benches (mosses/sedges/grass), riparian vegetation (trees/grass), some bedrock, fallen tree log and spillway
SWQ03	Medway Rivulet	Laterally unconfined valley setting	Low-sinuosity fine grained	Low	Pools and riffles, bank scour, benches	Gravel, sand, silt/clay	Symmetrical/ irregular	Dry, boggy	Bank erosion	Erosion, floodplain deposition	Instream vegetation (reeds/woody debris), riparian vegetation (grass/trees), riffles and pipe culvert, bridge abutments
SWQ04	Medway Rivulet	Confined valley setting	Occasional floodplain pockets	None	Bedrock outcrop, pools, runs, benches	Sand, silt/clay, exposed boulders and bedrock	Irregular	Supply, maintenance, sediment transport	Mobilise sand, minimal rework, bank erosion, active channel	Bench deposition, activated flood chutes, erosion in channels	Boulders, bedrock outcrop, instream vegetation (grass/reeds), bridge abutment and piers
SWQ05	Wells Creek tributary	Laterally unconfined valley setting	Low-sinuosity fine grained	None	Pools, bank scour, riffles	Gravel, clay/silt	Symmetrical/ irregular	Scarcely perceptible flow	Active channel, bank erosion	Erosion, deposition on banks, flood runners activate	Instream vegetation (reeds), riparian vegetation (grass), riffles, forest track and pipe culverts
SWQ06	Belanglo Creek	Confined valley setting	Occasional floodplain pockets	Low	Pools, bedrock outcrop, gravel bars, fallen tree log	Bedrock, sand, clay/silt	Irregular	Pooled water	Active channel	Erosion, deposition on floodplain pockets	Bedrock margins, instream and riparian vegetation (grasses, shrubs, trees), fallen tree log and crossing and pipe culvert
SWQ12	Wells Creek	Laterally unconfined valley setting	Low-sinuosity fine grained	None	Bank scour, pools, gravel bars, nick points	Clay, sand	Asymmetrical	Standing pooled water	Bank erosion, sediment transport	Erosion, deposition on floodplain	Man-made rock weirs, riparian vegetation (grass)

SITE ID	STREAM	VALLEY SETTING	RIVER STYLE	SINUOSITY	GEOMORPHIC UNITS	BED AND BANK COMPOSITION	CHANNEL GEOMETRY	RIVER BEHAVIOUR			CONTROL
								LOW	LOW	LOW	
SWQ14	Whites Creek	Partly-confined valley setting	Low-sinuosity planform-controlled discontinuous floodplain	Low	Pools, sand bars	Silt/clay	Symmetrical/ irregular	Pooled water	Active channel	Erosion, deposition on floodplain pockets	Causeway, man-made rock weirs, instream and riparian trees and reeds, bridge abutment
SWQ16	Stony Creek	Laterally unconfined valley setting	Low-sinuosity fine grained	None	Pools, bank scour	Sands and silts	Symmetrical	Standing water	Mobilise sediment, bank erosion	Floodplain deposition, bank erosion	Instream and riparian vegetation (grass/reeds), rail crossing, crossway and culverts
SWQ17	Oldbury Creek	Laterally unconfined valley setting	Low-sinuosity fine grained	None	Pools	Fine sands, silts, clay	Symmetrical	Maintenance, pooled, settling	Supply, entrainment of sediment	Erosion of banks, deposition on floodplains	Instream and riparian vegetation (grass/reeds), bridge abutments

Photo 3.1 Oldbury Creek FG01 (DS)

Photo 3.2 Oldbury Creek FG01 (DS)

Photo 3.3 Oldbury Creek FG02 (DS)

Photo 3.4 Oldbury Creek FG02 (US)

Photo 3.5 Medway Rivulet FG03 (US)

Photo 3.6 Medway Rivulet FG03 (DS)

Photo 3.7 Oldbury Creek FG04 (US)

Photo 3.8 Oldbury Creek FG04 (AS)

Photo 3.9 Wells Creek FG05 (DS)

Photo 3.10 Wells Creek FG05 (DS)

Photo 3.11 Wells Creek FG06 (DS)

Photo 3.12 Wells Creek FG06 (DS)

Photo 3.13 Oldbury Creek FG07 (US)

Photo 3.14 Oldbury Creek FG07 (DS)

Photo 3.15 Oldbury Creek FG07 (DS)

Photo 3.16 Oldbury Creek FG08 (DS)

Photo 3.17 Oldbury Creek FG08 (US)

Photo 3.18 Oldbury Creek FG09 (US)

Photo 3.19 Longacre Creek FG11 (AS)

Photo 3.20 Longacre Creek FG11 (US)

Photo 3.21 Wells Creek FG12 (DS)

Photo 3.22 Wells Creek FG12 (US)

Photo 3.23 Medway Rivulet FG16 (DS)

Photo 3.24 Medway Rivulet FG16 (US)

Photo 3.25 Small tributary of Wells Creek FG17 (DS)

Photo 3.26 Small tributary of Wells Creek FG17 (US)

Photo 3.27 Longacre Creek FG18 (DS)

Photo 3.28 Longacre Creek FG18 (DS)

Photo 3.29 Black Bobs Creek SWQ01

Photo 3.30 Black Bobs Creek SWQ02 (US)

Photo 3.31 Black Bobs Creek SWQ02 (US)

Photo 3.32 Medway Rivulet SWQ03 (US)

Photo 3.33 Medway Rivulet SWQ03 (US)

Photo 3.34 Medway Rivulet SWQ04 (DS)

Photo 3.35 Medway Rivulet SWQ04 (US)

Photo 3.36 Wells Creek Tributary SWQ05 (DS)

Photo 3.37 Wells Creek Tributary SWQ05 (US)

Photo 3.38 Wells Creek Tributary SWQ05 (DS)

Photo 3.39 Belanglo Creek SWQ06 (DS)

Photo 3.40 Belanglo Creek SWQ06 (US)

Photo 3.41 Wells Creek SWQ12 (DS)

Photo 3.42 Wells Creek SWQ12 (DS)

Photo 3.43 Whites Creek SWQ14 (DS)

Photo 3.44 Stony Creek SWQ16 (US)

Photo 3.45 Stony Creek SWQ16 (DS)

Photo 3.46 Oldbury Creek SWQ17 (DS)

Photo 3.47 Oldbury Creek SWQ17 (US)

Photo 3.48 Inline storage on Oldbury Creek (AS)

Photo 3.49 Inline storage on Oldbury Creek (DS)

3.4.4 Geomorphic characterisation

Watercourses and other waterbodies were classified into groups of similar geomorphic characters using the River Styles® framework (Brierley & Fryirs 2005). River Style® classifications found within the study area are presented in Table 3.5.

Table 3.6 River Styles® classifications found within the study area

VALLEY SETTING	RIVER STYLE	LOCATIONS WITHIN THE PROJECT AREA
Laterally Unconfined Valley Setting	Low-sinuosity fine grained	FG06, SWQ03, SWQ05, SWQ12, SWQ16 and SWQ17
	Channelised fill	FG17
Confined Valley Setting	Occasional floodplain pockets	FG01, FG02, FG03, FG04, FG07, FG11, FG12, FG18, SWQ01, SWQ02, SWQ04 and SWQ06
	Gorge (flooded by Medway Dam)	FG19 (Medway Rivulet immediately upstream of Medway Dam)
Partly-confined valley setting	Bedrock-controlled discontinuous floodplain	FG05
	Low-sinuosity planform-controlled discontinuous floodplain	FG08, FG09, FG16 and SWQ14

In the east of the project area, the valley setting is predominately an alluvial valley setting, characterised by low stream power and fine grained materials. River morphology is largely controlled by the low gradient and low stream power.

As the streams flow to the north, river styles transition to confined valley settings. Before transitioning to a confined valley, the streams move through a section with partly-confined valley setting. Both planform controlled and bedrock controlled river styles were observed, although bedrock control is the predominant river style. Wells Creek and Wells Creek Tributary go through a gradual transition zone whereas Oldbury Creek has a more abrupt transition zone.

3.4.5 River behaviour

The groundwater level in the project area is typically higher than the beds of streams, hence the streams in the area are classified as streams that receive baseflow from groundwater (Coffey 2016). In much of the project area the streams are also considered ephemeral. Ephemeral streams are defined as those streams that do not flow continuously year round, and mainly flow following precipitation events. This is confirmed by analysis of the stream gauge data (refer to Parsons Brinckerhoff 2016d) which indicates significant periods of no flow. During periods of no or low rainfall, the groundwater contribution to the streams is therefore likely to manifest as persistent connected or unconnected pools rather than continuous streamflow.

River behaviour varies markedly at differing flow stages, and low flow, bank full and overbank stages are used to define the behavioural regime (Fryirs and Brierley 2013). The variety of valley settings encountered in the project area will result in changes to river behaviour. River behaviour is governed by bed and bank composition and vegetation characteristics.

The upper reaches of the watercourses have low gradients resulting in low flow energy. The capacity for change in the channel geometry and erosional forces are limited as the channel does not generate sufficient energy to cause bank erosion or major changes to instream geomorphic features. As the river transitions to partly-confined valley settings, geometry change is localised and erosion is restricted to reaches where flow energy increases. Channels with non-cohesive bed and bank materials are particularly prone to adjustment. River behaviour for the sites visited for the geomorphic survey are shown on Figure 3.7. River behaviour for the valley settings within the study area, as described in Fryirs and Brierley (2013), is presented in Table 3.6.

Table 3.7 River behaviour for river styles within the study area

VALLEY SETTING	LOW FLOW	BANK FULL	OVERBANK
Laterally unconfined valley setting	Typically disconnected pools, sometimes dry and boggy with no apparent flow between pools. Cohesive sediments comprised of fine grained material generally restrict lateral channel movement. Instream geomorphic features generally include vegetation, woody debris, tree stumps and roots and man-made structures such as dams and weirs. Pools with standing water will accumulate sediments and may partially infill behind geomorphic features.	Channel activates and the system is predominately a suspended-load system supplying fine grained materials downstream. Channels do not generate enough energy to cause substantial erosion due to the low gradients. Cohesive fine grained sediments such as fine sand, silt and clay further limit erosion. There is lack of geomorphic features given the lack of material (such as cobbles and boulders) capable to form such features. During waning stages following a flood event, fine grained materials may accumulate on channel bars and floodplains.	Vertical accretion of fine grained material on floodplains will occur during the waning stages of a flood event. Low levees and back swamps may form. There is little capacity for the channel to migrate in shallower channels.
Partly confined valley setting	Low flow stages are confined to run-riffle and pool sequences caused by geomorphic units within the channel. Fine grained materials (such as silts and clays) accumulate in low energy environments such as pools and standing water. Channel adjustment will depend on the cohesiveness of sediments in planform controlled rivers. Fine grained silts and clays within the study area are more cohesive than sand dominated rivers.	Channel activates mobilising fine grained materials. Erosion and channel adjustment is restricted to local reaches adjacent to floodplain pockets. Instream geomorphic features (such as benches and ledges) can be created and reworked at bank full stages. Pools can be scoured of accumulated material.	Instream and floodplain features are formed and reworked during overbank flows. Flood channels may be scoured or infilled. Floodplain pockets may be stripped in high magnitude events, however, vertical accretion occurs during the waning stages of a flood event as flow magnitude decreases and fine grained sediment settles.
Confined valley setting	Flow paths are restricted by instream geomorphic units and bedrock. Reworking of finer grained sediment by erosional and depositional processes is generally negligible, and localised. Flow is constrained by the confined nature of the river.	Rivers in confined valley settings do not have readily definable channel banks and floodplains, bank full and overbank includes flows that span the valley. Bed materials may be locally redistributed with coarse cobbles or boulders the only materials retained for any length of time. Fine-grained materials that locally accumulate behind instream geomorphic features are flushed by higher magnitude flow events. Channel size and shape is imposed by bedrock and bank erosion is negligible.	See bank full river behaviour.

Source: Adopted from Fryirs and Brierley (2013)

4 WATER RELATED VALUES AND ASSETS

4.1 Environmental values

Environmental values (EVs) are values that the community considers important for water use (HRC 1998). EVs for the Hawkesbury River Catchment are set out in the *Healthy Rivers Commission Inquiry into the Hawkesbury-Nepean River System* (HRC 1998).

Regional EVs are assigned based on land use regions within the Hawkesbury-Nepean catchment. The land use regions within the study area and applicable EVs are provided in Table 4.1.

Table 4.1 Environmental values for surface water in the study area

LAND USE REGIONS	REGIONAL ENVIRONMENTAL VALUES
Predominately forested	Aquatic ecosystems Primary contact recreation Secondary contact recreation Visual amenity Homestead water supply Livestock water supply
Mixed-use Rural and Drinking Water with Clarification and Disinfection	Aquatic ecosystems Primary contact recreation Secondary contact recreation Visual amenity Drinking water – clarification and disinfection Irrigation water supply Homestead water supply Aquatic foods (cooked)

Source: Healthy Rivers Commission Inquiry into the Hawkesbury-Nepean River System (HRC 1998)

Downstream of the confluence of the Wollondilly and Wingecarribee Rivers, the land use region is predominantly drinking water catchment where EVs include; aquatic ecosystems, visual amenity, drinking water – disinfection only, and drinking water - groundwater.

4.2 Surface water assets

The surface water-related assets with potential to be impacted by the project are located in the Medway Rivulet, Lower Wingecarribee River, Lower Wollondilly River and Bundanoon Creek management zones and include:

- Storages used for town water supply, including Medway Reservoir (Medway Dam), Lake Burragorang (Warragamba Dam) and Bundanoon Creek Reservoir;
- Diversion works (pumps) and instream storages used by local water users to extract surface water for water supply;
- Landholders with basic water rights; and
- Ecosystems reliant on streamflow, including:

- Instream ecosystems dependent on streamflow; and
- Riparian ecosystems dependent on overbank flows and flooding.

Further details of surface water-related assets in the study area are provided in Sections 4.2.1, 4.2.2 and 4.2.3. Potential risks to surface water-related assets associated with the project are discussed in Section 5.

4.2.1 Storages used for town water supply

4.2.1.1 MEDWAY RESERVOIR (MEDWAY DAM)

Medway Dam is located on Medway Rivulet and has a storage capacity of 1,350 ML. The dam was constructed in 1964 and is operated by WSC. Water from the reservoir is ordinarily treated at Medway Water Treatment Plant which has a capacity of 8 ML/day, and supplies the village of Berrima and western parts of Bowral and Mittagong.

WSC hold a 900 ML WAL to take water for town water supply from Medway Dam. Available information from WSC indicates that in the year 2012-2013, Medway Water Treatment Plant (WTP) treated 414 ML of water from the dam; however the plant was shut down in June 2013. The shutdown, which lasted nearly two years, was used to change the filter media and install a temporary Poly Aluminium Chloride plant to help reduce taste and odour effects from released algal toxins (Beca 2010). Medway Dam is prone to algal blooms in summer due to catchment runoff and nutrient loading, including from Moss Vale Sewage Treatment Plant (STP) upstream. Toxic cyanobacteria (blue-green algae) species have been demonstrated to be present and have been prevalent in historic blooms, resulting in the Medway WTP having to be shut down for prolonged periods (Beca 2010). It is understood that WSC has plans to upgrade the plant over the next 3 years.

Medway Dam is located downstream of the administration and workshop area precinct and receives runoff from pasture lands in the upper and lower reaches of the Medway Rivulet catchment, as well as from the Moss Vale urban area via the Whites Creek tributary.

The location of Medway Dam is shown on Figure 4.1.

4.2.1.2 LAKE BURRAGORANG (WARRAGAMBA DAM)

Lake Burragorang is located on the Wollondilly River downstream of the project. The lake is WaterNSW’s largest reservoir with a total capacity of more than two million megalitres (SCA 2013). It sits behind Warragamba Dam and has a catchment area of 9,051 km^2.

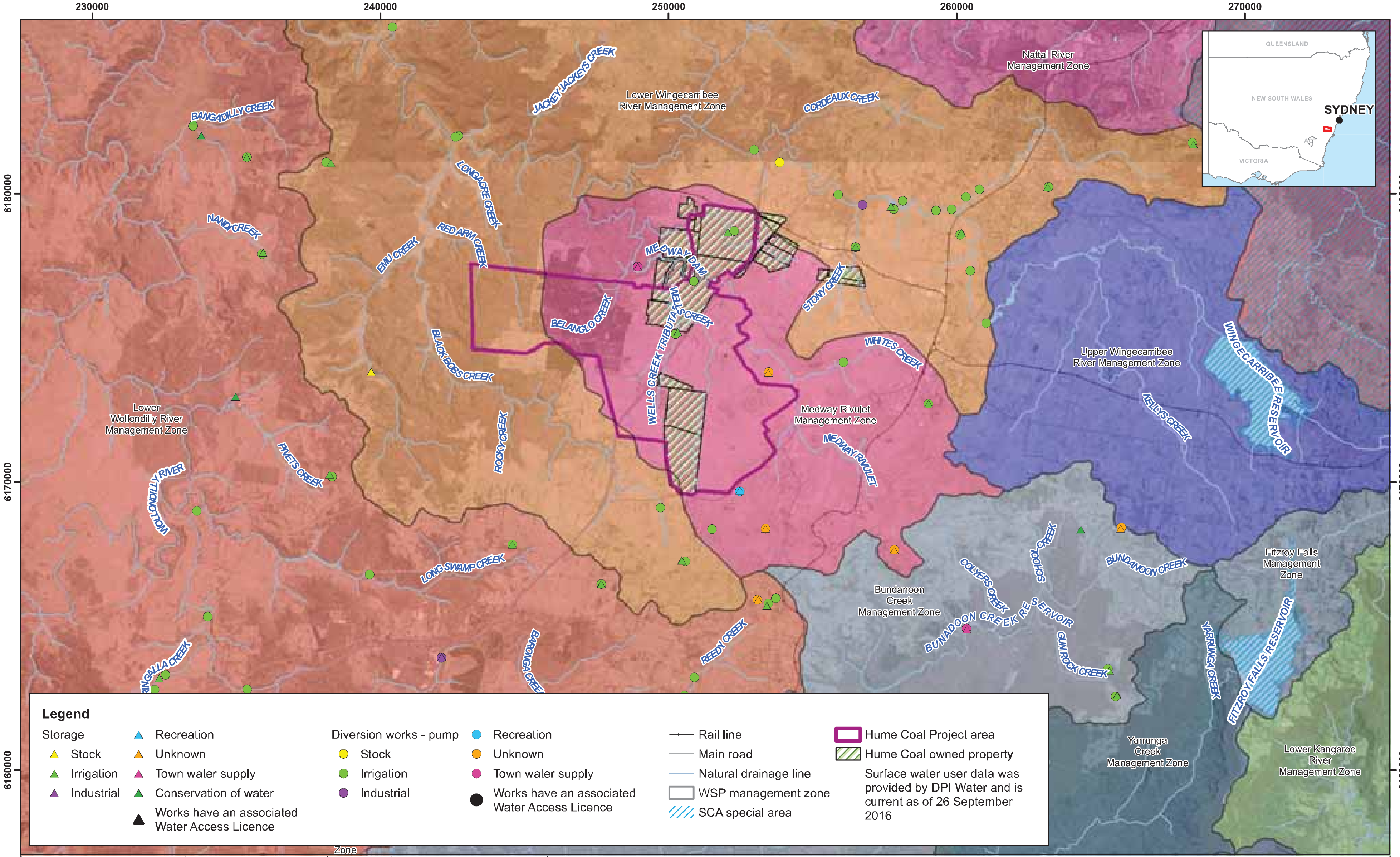
Lake Burragorang has the capacity to supply up to 80% of Sydney’s water. One quarter of the catchment is a declared Special Area, where public access is restricted to protect water quality.

Since the 1970s, during times of drought, water from the Shoalhaven catchment to the south has been pumped to Wingecarribee Reservoir and the Wingecarribee River channel has been used to transport bulk water to Warragamba Dam.

4.2.1.3 BUNDANOON CREEK RESERVOIR (BUNDANOON CREEK DAM)

Bundanoon Creek Dam is located on Bundanoon Creek and has a storage capacity of approximately 2,000 ML. The dam was constructed in the mid 1960s and is operated by WSC. Water from the reservoir is treated at Bundanoon Creek Water Treatment Plant which has a capacity of 10 ML/day, and provides supply to Bundanoon, Moss Vale, Bowral and Mittagong.

WSC hold a 1,000 ML WAL to take water for town water supply from Bundanoon Creek Reservoir. The location of Bundanoon Creek Reservoir is shown on Figure 4.1.



Map: 2200540A_GIS_054_A4	Author: RP
Date: 18/11/2016	Approved by: LR

Data source: © Land and Property Information 2015, Hume Coal, NSW Office of Water

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

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Hume Coal Project
Surface Water Flow and Geomorphology Assessment
Figure 4.1
Surface water users

4.2.2 Local water users

Surface water users in the study area were identified using data obtained directly from the Land and Property Information WAL Register and are current as of 26 September 2016.

4.2.2.1 DIVERSION WORKS AND STORAGES

Figure 4.1 shows the location of surface water diversion works (pumps) and storages (dams) in the Medway Rivulet, Lower Wingecarribee River, Lower Wollondilly River and Bundanoon Creek management zones current as at 26 September 2016. The number of surface water diversion works (pumps) and storages dams in each management zone is summarised in Table 4.2.

There are 6 dams and 11 pumps in the Medway Rivulet management zone. Of these, only Medway Dam and its associated pumps are located downstream of the project area. An additional dam and 2 pumps are located on properties owned by Hume Coal or subsidiaries of Hume Coal.

Figure 4.2 shows the number of pumps and dams in the Medway Rivulet, Lower Wingecarribee River, Lower Wollondilly and Bundanoon Creek management zones by purpose. Most pumps and dams in the study area are used for irrigation purposes or a combination of irrigation, stock and domestic purposes.

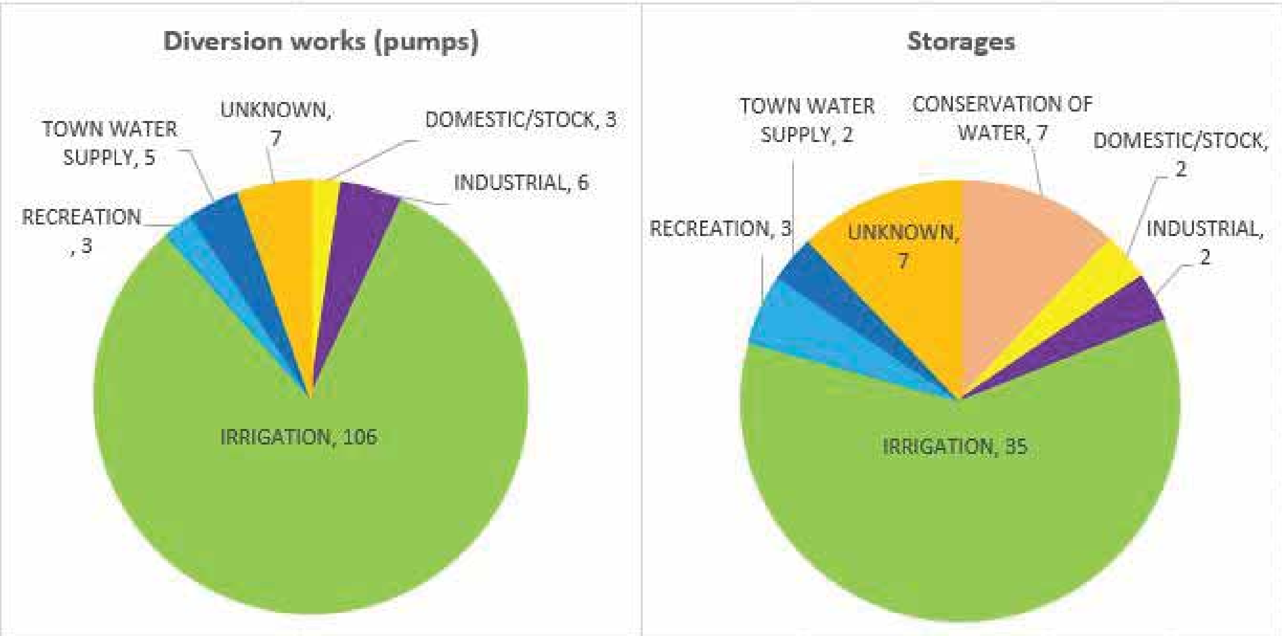


Figure 4.2 Number of surface water diversion works and storages by purpose (LPI 2016)

4.2.2.2 WATER ACCESS LICENCES

Figure 4.1 shows the location of pumps and dams with associated WALs in the Medway Rivulet, Lower Wingecarribee River, Lower Wollondilly River and Bundanoon Creek management zones. A breakdown of the WAL volumes by water source and management zone is presented in Table 4.2.

Table 4.2 Water management zones

WATER SOURCE AND MANAGEMENT ZONE	NUMBER OF DIVERSION WORKS (PUMPS)	NO OF STORAGES	TOTAL VOLUME ML/A
UPPER NEPEAN AND WARRAGAMBA WATER SOURCE			
Medway Rivulet management zone	13	7	1,027
Lower Wingecarribee River management zone	29	12	1,072
Lower Wollondilly River management zone	86	32	4,138
SHOALHAVEN WATER SOURCE			
Bundanoon Creek management zone	5	4	1,007

4.2.2.3 BASIC WATER RIGHTS

Basic water rights for landholders in the study area include:

- Domestic and stock rights – Owners or occupiers of land which has stream frontage can take water without a licence. Water taken under a domestic and stock right may be used for normal household purposes and garden and/or for drinking water for stock.
- Harvestable rights – Landholders are allowed to build dams on minor streams that capture 10% of the average regional rainfall-runoff on their property without a licence to take water.

Figure 4.1 shows properties owned by Hume Coal or subsidiaries of Hume Coal. There are a number of properties downstream of the project area on Medway Rivulet and Oldbury Creek that may be taking water under basic water rights. There are no native title rights with respect to water in the study area.

The *Greater Metropolitan Region Unregulated Water Sources Water Sharing Plan 2011*, estimates the water requirements of persons entitled to domestic and stock rights to be:

- 13.6 ML/day in the Shoalhaven River Water Source; and
- 21 ML/day in the Upper Nepean and Warragamba Water Source.

4.2.3 Ecosystems reliant on streamflow

Ecosystems reliant on streamflow in the project area include:

- Instream ecosystems dependent on streamflow; and
- Riparian ecosystems dependent on overbank flows and flooding.

Details of these ecosystems are provided in the *Hume Coal Project Biodiversity Assessment Report* (EMM 2016b).

5 IMPACT ASSESSMENT

5.1 Project activities with potential to impact on flow

The natural flow regimes of Medway Rivulet, Oldbury Creek and their tributaries are highly disturbed as the catchments have been extensively cleared for agriculture and multiple instream storages, which impede the natural flow, have been constructed along the length of the streams. The Hume Coal Project has the potential to further impact on the flow regime of local streams due to:

- Reduction in catchment area and runoff associated with the water management system for the project;
- Releases from selected stormwater basins following containment of the first flush within the water management system; and
- Interception of natural baseflow to streams associated with depressurisation of groundwater systems during underground mining.

Details of these project activities and how they may impact on the flow regime of local streams are provided below.

5.1.1 Water management system

The surface infrastructure for the Hume Coal Project is shown on Figure 1.3. The infrastructure located in the Medway Rivulet catchment includes:

- administration and workshop area;
- overland conveyor and conveyor portal;
- man and materials portal;
- ventilation shaft; and
- construction camp.

The infrastructure located in the Oldbury Creek catchment includes:

- product stockpiles;
- CPP;
- ROM stockpile;
- site WTP;
- pipeline for discharge of surplus water; and
- train load out.

Runoff from operational areas of the site within the Medway Rivulet catchment will be captured in five project storages; SB03, SB04, MWD05, MWD06 and MWD07 (refer to Figure 3.5). Runoff from operational areas of the site within the Oldbury Creek catchment will be captured in two project storages; SB01 and SB02.

MWD08 is a provisional storage dam associated with the site WTP that would be used to store excess water prior to treatment. It does not receive direct runoff from operational areas. As discussed in detail in the water balance assessment (Parsons Brinckerhoff 2016c), the project includes the site WTP as a provision to treat surplus water from the Primary Water Dam (PWD) before release to local creeks; however, the water balance modelling demonstrates that this facility is unlikely to be needed and it has therefore not been assessed in this report.

The PWD is located in the Oldbury Creek catchment and will store runoff from the local catchment, water pumped from the SBs and MWDs and underground mine sump dewatering.

The water management system for the project is detailed in the Water Balance Assessment Report (Parsons Brinckerhoff 2016c). The water management philosophy adopted for the project can be summarised as follows:

- Runoff from undisturbed catchments will be diverted around the mine infrastructure areas and into natural watercourses via diversion drains as much as practical.
- Runoff from operational areas of the site will be directed to the project storages:
  - Runoff from high risk coal contact areas will be transferred to the PWD for storage and reuse.
  - Runoff from other operational areas, including low risk coal contact areas, may be discharged to local creeks if rainfall exceeds the adopted first flush criteria – this applies to SB03 and SB04.

The first flush criteria adopted for the Hume Coal Project are based on the NSW Environmental Protection Authority (EPA) guidance provided at http://www.epa.nsw.gov.au/mao/stormwater.htm:

- The first flush is assumed to have occurred once the daily rainfall exceeds 20 mm in one day. The first flush volume from SB03 and SB04 is pumped to the PWD for reuse. Runoff after this rainfall is exceeded is allowed to be released from SB03 and SB04 to Oldbury Creek.
- From the day of occurrence of the first flush, any subsequent rainfall amount less than 20 mm/day for the next four days is assumed to produce clean runoff and is allowed to be released to Oldbury Creek.
- If the daily rainfall depth remains less than 10 mm/day after the fifth day, no runoff is released to Oldbury Creek until the next first flush event.

5.1.2 Reduction in catchment area

Containment and reuse of water from operational areas of the site will result in a reduction in catchment area and runoff to local streams. A reduction in runoff has the potential to alter the flow regime of the stream.

The catchment areas associated with the project storages are provided in Table 5.1. The reduction in catchment area for Medway Rivulet is estimated to be 26.6 ha, which represents 0.2% of the catchment area to its confluence with Wingecarribee River. A reduction in catchment area for Oldbury Creek is estimated to be 67.6 ha, which is 5.0% of the total catchment area. The Medway Rivulet and Oldbury Creek catchments are shown on Figure 1.4.

Table 5.1 Reduction in catchment area associated with project storage dams

DAM	DESCRIPTION	STORAGE CATCHMENT AREA (HA)	DRAINS TO	TOTAL CATCHMENT AREA (HA)	% REDUCTION IN CATCHMENT AREA
SB03	Proposed SB capturing runoff from administration and workshop area	5.91	Medway Rivulet (including Wells Creek and Belanglo Creek sub-catchments)	10,909	0.2%
SB04	Proposed SB capturing runoff from mine road and conveyor embankment	14.73			
MWD05	Proposed MWD capturing runoff from north of Medway Rivulet - overland conveyor no. 1	0.64			
MWD06	Proposed MWD capturing runoff from south of Medway Rivulet - conveyor portal	2.69			
MWD07	Proposed MWD capturing runoff from ventilation shaft pad dam	2.60			
SB01	Proposed SB capturing runoff from product stockpile area	26.36	Oldbury Creek	1,355	5.0%
SB02	Proposed SB capturing runoff from CPP and ROM areas	22.64			
MWD08	Stores water before treatment and release to Oldbury Creek	0.27			
PWD	Dam storing water pumped from SBs and MWDs and underground mine sump dewatering	18.28			
Total Medway Rivulet and Oldbury Creek		94.12	Medway Rivulet and Oldbury Creek	12,264	0.8%

5.1.3 Releases from stormwater basins to Oldbury Creek

A water balance model was developed for the Hume Coal Project water management system using GoldSim software (Parsons Brinckerhoff 2016c). The GoldSim model was used to calculate the volume of water in storages at the end of each day by taking into account daily rainfall-runoff inflow, groundwater inflow, reinjection to the mine void, evaporation from the storage, water usage, pumping between storages and storage overflow. A key output of the model was an estimation of water surpluses and deficits for the mining duration.

In undertaking the water balance for the project, it has been assumed that water from SB03 and SB04 can be released to Oldbury Creek, once the first flush criteria have been met (refer Section 5.1.1). Details of the releases from SB03 and SB04 are presented in the Water Balance Assessment Report (Parsons Brinckerhoff 2016c). Wet year annual releases are expected to be in the ranges from 29 ML to 31 ML from SB03 and 38 ML to 41 ML from SB04. Dry year releases are expected to be less than 1 ML per year.

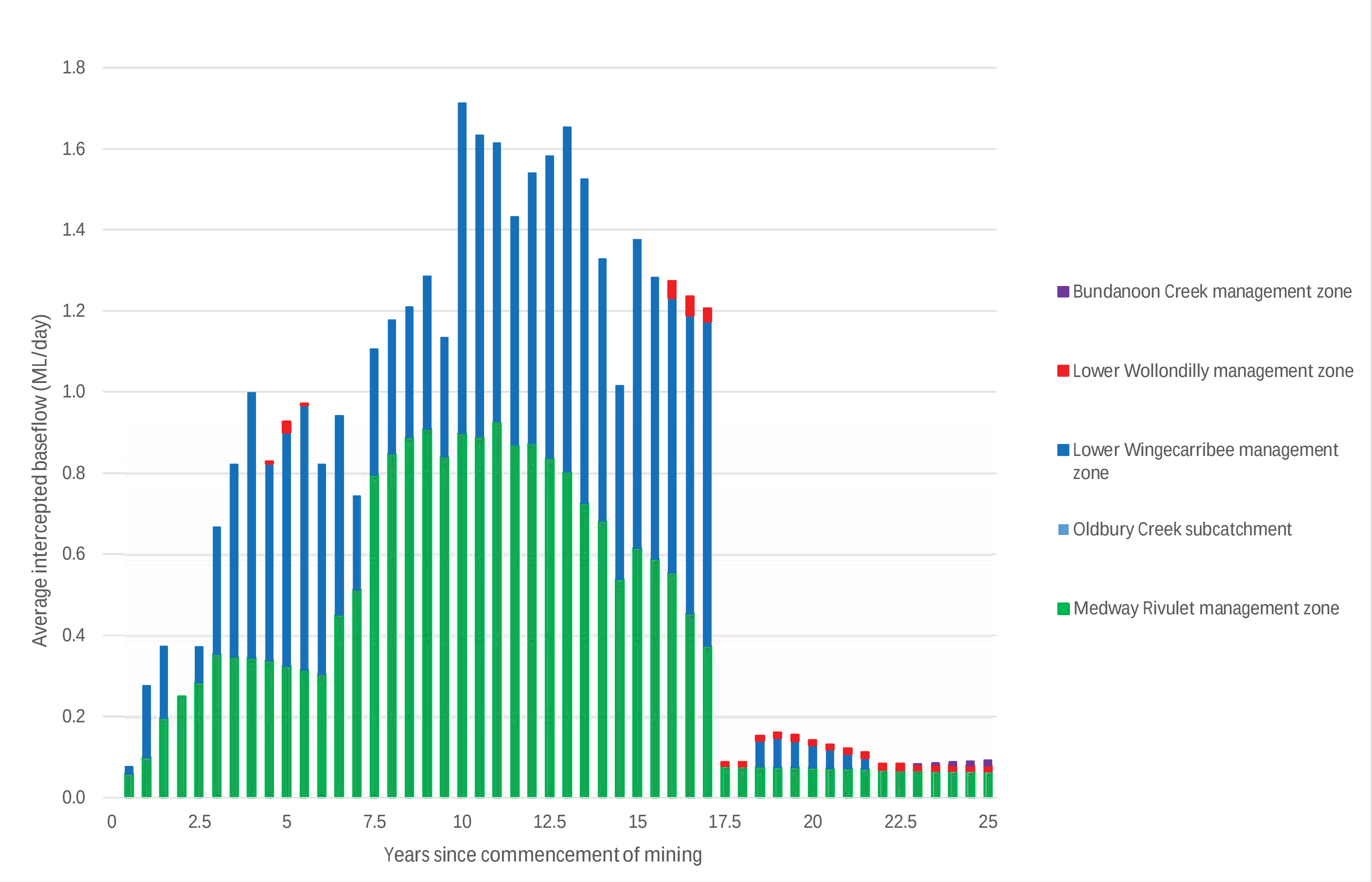
5.1.4 Depressurisation of groundwater systems for underground mining

The groundwater level in the project area is typically higher than the beds of streams, hence the streams in the area are classified as streams that receive baseflow from groundwater (Coffey 2016), which will manifest as persistent unconnected or connected pools in dry conditions.

Depressurisation of groundwater systems will occur during underground mining. Dewatering of an unconfined or semi confined groundwater system will result in water level drawdown of the water table (ie lowering of piezometric pressures). In areas where there are overlying streams that receive baseflow from groundwater, this will mean some level of interception of natural baseflow resulting in reduced streamflow, particularly during low flows.

The interception of natural baseflow due to underground mining has been calculated for stream reaches in the project area (Figure 1.4) using the numerical groundwater flow model for the project (Coffey 2016). The interception of natural baseflow was provided for 6 monthly intervals for 50 years from the commencement of mining. Figure 5.1 presents intercepted baseflow for the period of mining and 5 years after mining. A sharp decline in intercepted baseflow occurs after 17 years of mining when dewatering ceases and groundwater levels recover in mine voids (Coffey 2016).

Figure 5.1 Intercepted baseflow



5.2 Potential impacts associated with changes in flow regime

Potential impacts associated with changes in flow regime that have been assessed include:

- Erosion of stream banks associated with an increase in stream energy and bank full flow events (due to water releases from SB03 and SB04);
- Reduced access for water users associated with a reduction in streamflow (due to reduced catchment area and intercepted baseflow); and
- Reduced availability of water for instream and riparian ecosystems associated with a reduction in streamflow (due to reduced catchment area and intercepted baseflow).

5.2.1 Stream bank erosion

All watercourses in the study area identified as prone to erosion are located upstream of the surface infrastructure area for the project (refer to Figure 5.2). Adjacent to and downstream of the surface infrastructure area, Medway Rivulet and Oldbury Creek are in confined valley settings and the channels are bedrock controlled.

5.2.1.1 OPERATION

The discharges to Oldbury Creek would occur in a reach classified as Confined Valley Setting – Occasional Floodplain Pockets (refer to Figure 3.7). The discharge would be in the form of piped outflows from SB03 and SB04 (combined) into or just upstream of the existing instream storage. Scour protection will be required at the outlet and an assessment of the increased overtopping risk of the storage during times of discharge will need to be made to determine whether any reinforcement of the existing spillways from the storage may be necessary. The channel of Oldbury Creek downstream of the discharge point is bedrock controlled and the risk of stream bank erosion due to this discharge is considered to be negligible.

5.2.1.2 CONSTRUCTION AND REHABILITATION

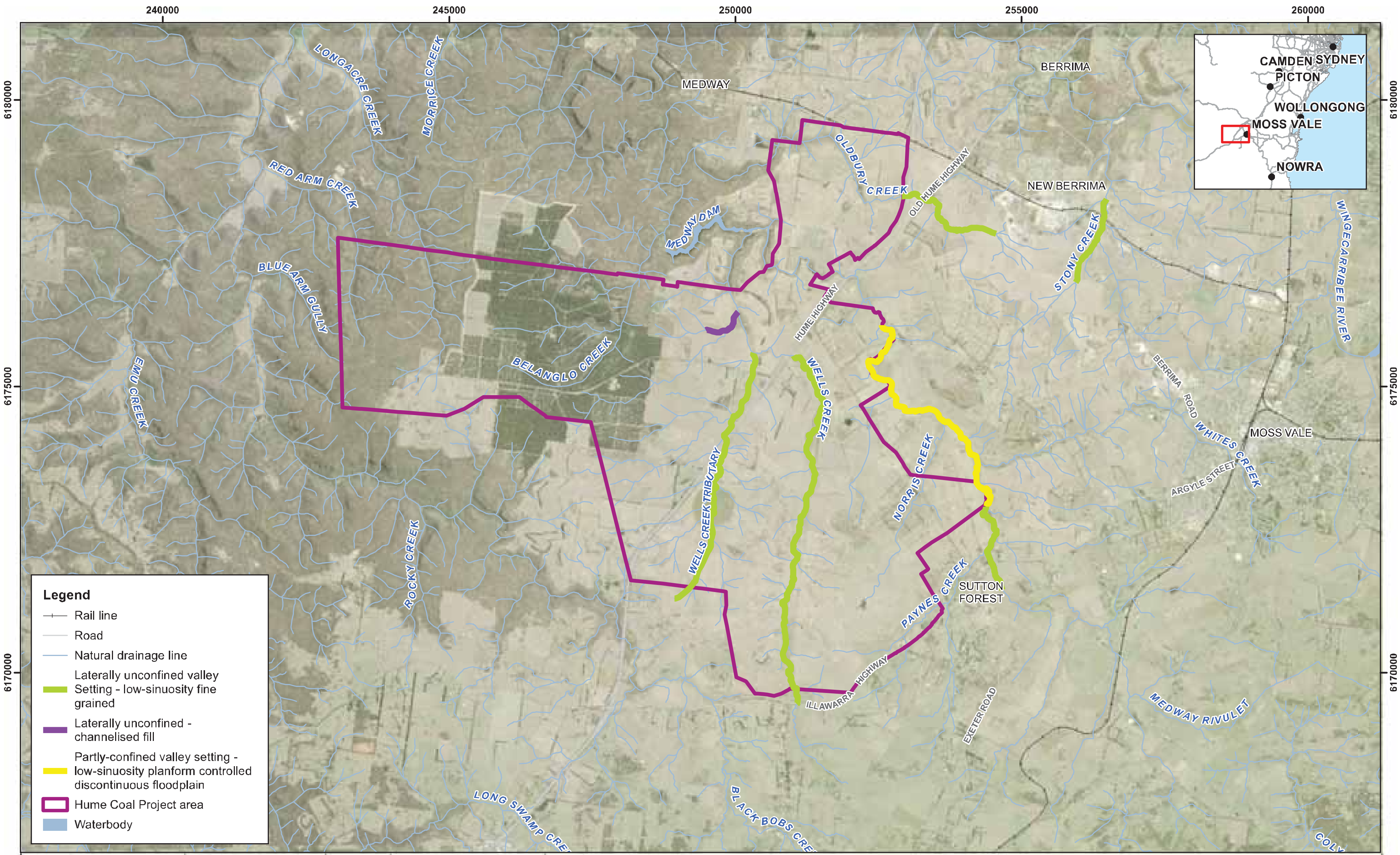
An erosion and sedimentation control plan, developed in accordance with Landcom (2004) and DECC (2008) guidelines, will be prepared to ensure the erosion and sedimentation induced by the project will not adversely affect the surrounding environment. With the implementation of this plan, erosion and sedimentation impacts during the construction and rehabilitation phases are expected to be minimal.

Temporary erosion and sedimentation controls applicable to the construction and rehabilitation phases include sediment basins, sediment fences, diversions banks (for on and off-site water), check dams, batter chutes, temporary culverts and scour protection. Depending on the construction staging and the extent of disturbance at each stage, the temporary works may involve local controls, such as sediment fences and diversion berms that are expected to be utilised by the civil works contractor in day to day management, or more extensive measures such as temporary sediment basins.

The intent of the erosion and sediment control practices used on site will be to:

- Minimise the extent of disturbance, by clearing only as required, by clearing and grubbing to leave the surface rough and by minimising the time in which watercourses are disturbed.
- Control stormwater flows onto, through and from the site by separating runoff from disturbed and undisturbed areas, by constructing drainage structures early including sediment basins, cut-off drains and drainage culverts and by minimising runoff down batters by using batter drains.
- Minimise scour in waterways by using linings as appropriate.
- Have surfaces revegetated as soon as possible to minimise the duration of disturbance.

- Have the civil works contractor utilise local controls such as diversion banks and sediment fences to minimise erosion and sediment transport and have them progressively update these measures as required during construction.
- Have the civil works contractor maintain and inspect the erosion and sediment control measures to ensure their effectiveness remains intact.



Map: 2200540A_GIS_057_A2 | Author: RP
Date: 20/10/2016 | Approved by: LR

Data source: © Land and Property Information 2015, Hume Coal, Google Earth

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

Hume Coal Project

Surface Water Flow and Geomorphology Assessment

Figure 5.2

Stream reaches at risk of erosion due to changes in flow regime

5.2.2 Reduced access for water users

Reduction in streamflow associated with project storage catchments and interception of baseflow due to underground mining has the potential to reduce access to surface water for downstream water users.

As described in Section 4.2.1.1, Medway Dam is located downstream of the project area and was operated prior to 2013 by WSC for town water supply. The associated water treatment plant is currently not operational but may be upgraded by WSC in the future.

There are no other licensed surface water users in the Medway Rivulet catchment that are located downstream of the project (Figure 4.1). Landholders with basic water rights are located downstream of the project and there is potential for these landholders to be impacted by a reduction in streamflow in Oldbury Creek and Medway Rivulet – this is addressed in Section 5.4.1.

5.2.3 Ecological impacts

Reduction in streamflow associated with project storage catchments and interception of baseflow due to underground mining has the potential to reduce streamflows available to instream ecosystems and overbank flows and flooding available to riparian ecosystems. Potential ecological impacts associated with the predicted changes in flow regime and sedimentation processes have been assessed in the *Hume Coal Project Biodiversity Assessment Report* (EMM 2016b).

5.3 Flow impact assessment methodology

Flow impacts have been assessed for:

- The Medway Rivulet and Oldbury Creek catchments where the surface and underground infrastructure for the mine is located; and
- The Lower Wingecarribee River, Lower Wollondilly River and Bundanoon Creek management zones (Figure 5.1). These catchments are located outside the project area, however interception of natural baseflow to surface water systems in these catchments is predicted to occur as a result of depressurisation associated with underground mining for the project.

5.3.1 Medway Rivulet and Oldbury Creek catchments

Existing flow conditions for Medway Rivulet and Oldbury Creek were established using the AWBM rainfall-runoff model as outlined in the Water Balance Assessment Report (Parsons Brinckerhoff 2016c). The flow conditions during operation of the mine were assessed and the resulting changes in flow were analysed by comparing flow duration curves for existing conditions and operational mining conditions. A flow duration curve represents how often any given flow discharge is likely to be equalled or exceeded. The x axis corresponds to probabilities of exceedance, while the y axis corresponds to streamflow discharges.

Changes in flow were assessed due to the following operational impacts:

- The reduction in catchment area associated with project storages.
- The discharge of water from SB03 and SB04 to Oldbury Creek was estimated for dry and wet years using the GoldSim water balance model developed for the Water Balance Assessment (Parsons Brinckerhoff 2016c).
- The interception of natural baseflow to streams associated with depressurisation of groundwater systems during underground mining was estimated using the numerical groundwater flow model for the project.

5.3.2 Other catchments

Existing case (pre-mining) flows for the Lower Wingecarribee River, Lower Wollondilly River and Bundanoon Creek management zones were approximated using the AWBM runoff for the Medway Rivulet management zone scaled to the subject catchment area. This was considered a reasonable approach given that the AWBM model was calibrated to observed flows at gauge 212009 on the Wingecarribee River, which receives runoff from a total catchment area of 58,700 ha and is therefore representative of regional scale flows (refer to the Water Balance Assessment Report (Parsons Brinckerhoff 2016c) for details). These pre-mining flows were then compared against the intercepted baseflow volumes estimated by the groundwater model (see Section 5.1.5) to assess the potential change in yield for these catchments.

5.4 Impact assessment results

Impact assessment results are presented for two climate sequences:

- Climate sequence 58 (1946 to 1964), which is the climate sequence with the maximum volume of water discharged to Oldbury Creek form SB03 and SB04 of the 107 realisations simulated in GoldSim.
- Climate sequence 103 (1991 to 2009), which is the climate sequence with the lowest simulated rainfall-runoff volume of the 107 realisations simulated in GoldSim.

5.4.1 Flow impacts

5.4.1.1 MEDWAY RIVULET CATCHMENT

The Medway Rivulet catchment extends to the confluence with Wingecarribee River and includes the Wells Creek, Belanglo Creek and Oldbury Creek sub-catchments (Figure 1.4).

Flow duration curves for the wet and dry climate scenarios in the Medway Rivulet catchment (excluding the Oldbury Creek catchment) are presented in Figures 5.3 and 5.4. The flow duration curves for the operation case include the impacts of a reduction in catchment area associated with project storages and the interception of natural baseflow to Medway Rivulet and its tributaries associated with depressurisation of groundwater systems during underground mining. The flow duration curves in Figure 5.4 include low flow discharges from the Moss Vale sewage treatment plant (STP) located on Whites Creek for both the existing and operation cases, which are approximated at 2.3 ML/day based on effluent data provided by WSC.

The results show that with constant low flow discharges from the Moss Vale STP, the flow regimes in Medway Rivulet for the existing and operation cases are similar. If the constant discharges from the Moss Vale STP are excluded, changes in the low flow regime below approximately 5 ML/day may occur and the number of no flow days may increase by approximately 20% under the wet climatic scenario and by approximately 30% under the dry climatic scenario. Yield impacts for Medway Rivulet are discussed in Section 5.4.2.1.

The potential impacts to the low flow regime are mainly attributable to the interception of baseflow associated with depressurisation of groundwater systems for underground mining. The interception of baseflow in the Medway Rivulet catchment will decrease to less than 0.1 ML/day 17 years after the commencement of mining (Figure 5.2) and will decrease to 0 ML/day 38 years after the commencement of mining as groundwater levels recover (Coffey 2016).

The reduction in low flows in the Medway Rivulet catchment if discharges from the Moss Vale STP do not occur has the potential to reduce the connectivity of pools and increase the potential for pools to dry out. This has the potential to impact on access for landholders with basic water rights. However, the Moss Vale STP discharges are likely to continue throughout the mining operational period and therefore impacts on access for landholders with basic water rights are unlikely. The potential impacts to instream ecosystems associated with these predicted changes are discussed in the *Hume Coal Project Biodiversity Assessment Report* (EMM 2016b).

The reduction in low flows in the Medway Rivulet catchment excluding the discharges from the Moss Vale STP also has the potential to increase sedimentation and infilling of pools. As the discharges are likely to continue through the mining period and the high flow regime will remain unaltered and high flow events will flush these sediments through the system, the impacts of sedimentation on the flow regime are considered low. Potential impacts to instream ecosystems associated with an increase in siltation under low flow conditions are discussed in the *Hume Coal Project Biodiversity Assessment Report* (EMM 2016b).

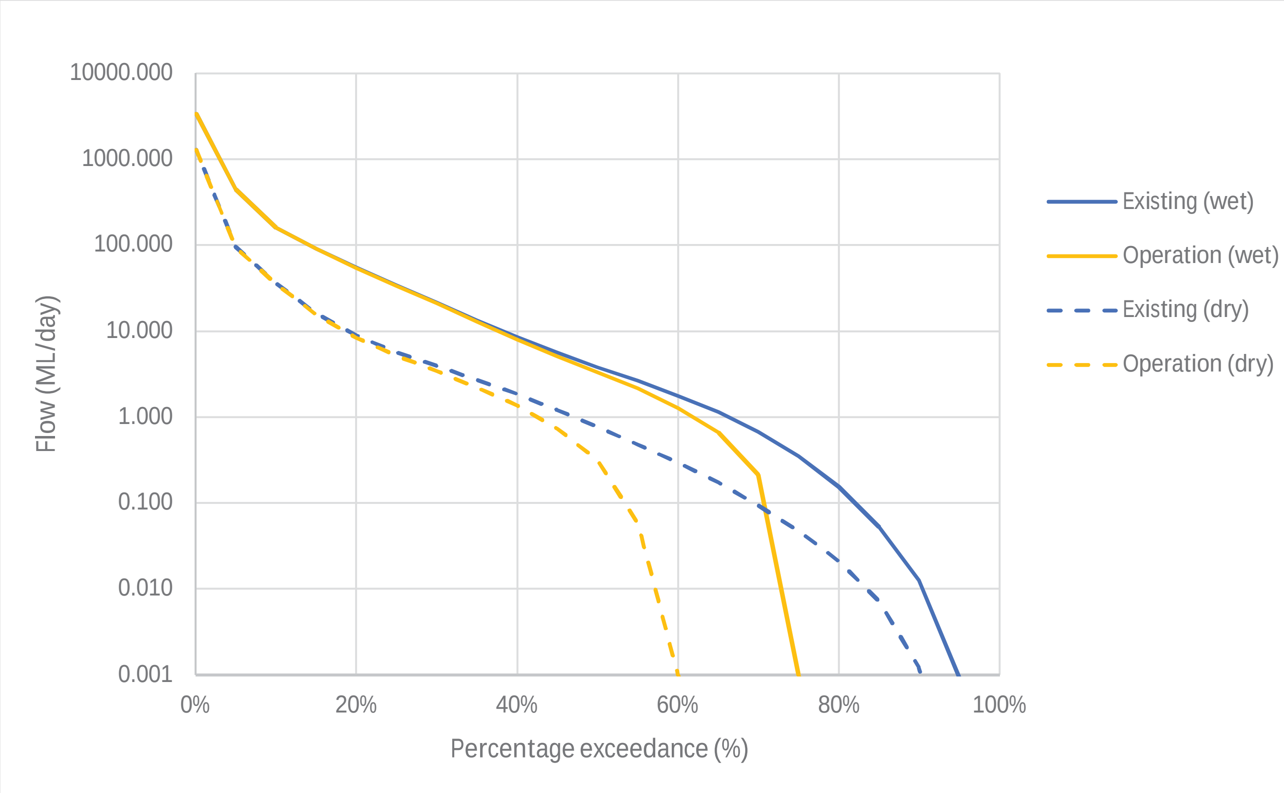

Figure 5.3 Flow duration curves for Medway Rivulet excluding Moss Vale STP discharges (wet and dry climate sequences)

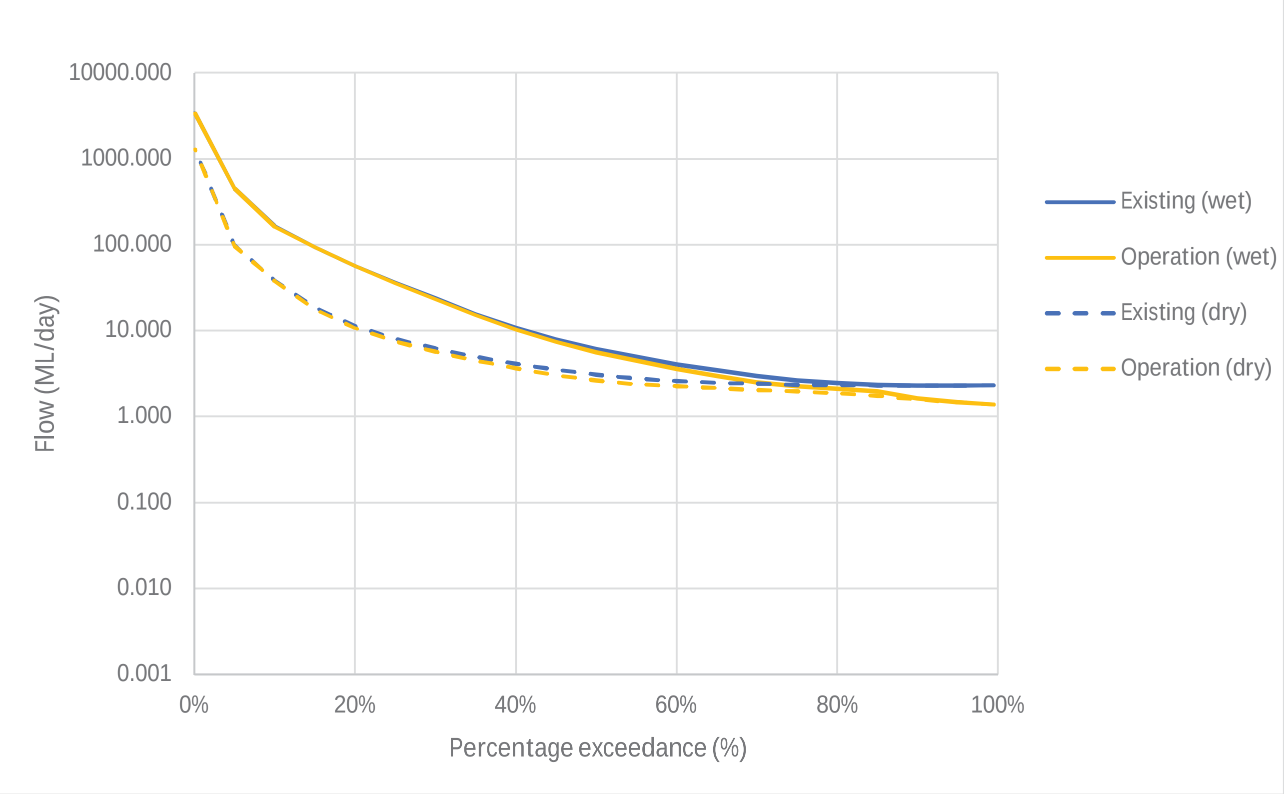

Figure 5.4 Flow duration curves for Medway Rivulet including Moss Vale STP discharges (wet and dry climate sequences)

5.4.1.2 OLDBURY CREEK

Flow duration curves for the wet and dry climate scenarios in Oldbury Creek are presented in Figure 5.4. The flow duration curves for the operation case include the impacts of a reduction in catchment area associated with project storages, discharge of water from SB03 and SB04 after the first flush and the interception of natural baseflow to Oldbury Creek associated with depressurisation of groundwater systems during underground mining. The flow duration curves for Oldbury Creek with and without constant low flow discharges from the Berrima STP are approximately the same. This is because discharges from the Berrima STP to Oldbury Creek are low, at approximately 0.2 ML/day.

The results show that alteration of the flow regime in Oldbury Creek during operation of the mine will be minor compared to pre-mining conditions, with discharges from SB03 and SB04 to some extent offsetting impacts to flow associated with a reduction in catchment for project storages and interception of baseflow associated with depressurisation of groundwater systems. Yield impacts for Oldbury Creek are discussed in Section 5.4.2.2.

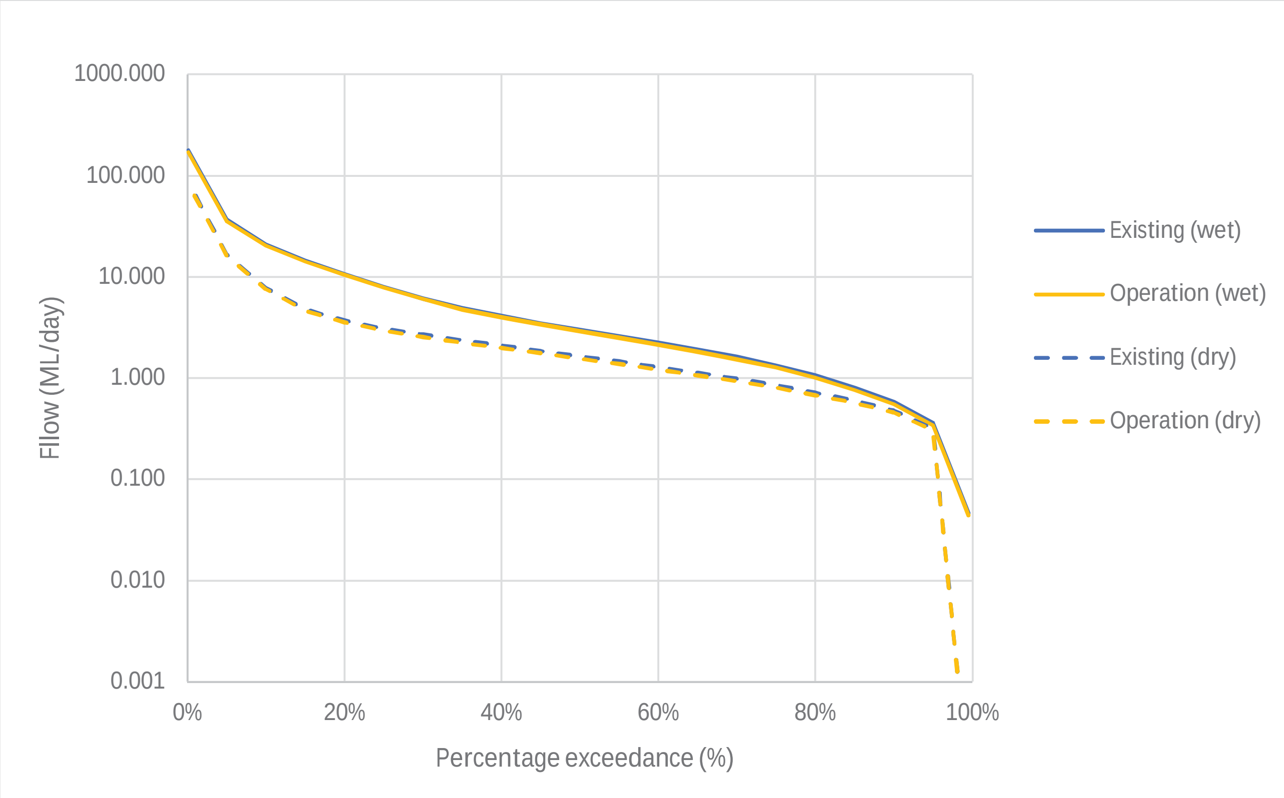

Figure 5.5 Flow duration curves for Oldbury Creek (wet and dry climatic sequence)

5.4.2 Yield impacts

5.4.2.1 MEDWAY RIVULET MANAGEMENT ZONE AND MEDWAY DAM

The change in streamflow due to the project with and without STP discharges has been estimated for wet and dry climate sequences to assess the change in surface water yield for:

- the Medway Dam catchment
- the Medway Rivulet catchment, excluding the Oldbury Creek sub-catchment
- the Oldbury Creek sub-catchment
- the Medway Rivulet management zone.

The catchments are shown on Figure 1.4 and the results are presented in Table 5.2. The results indicate that under wet conditions, the project will result in a 0.8% reduction in yield for the Medway Rivulet management zone, and under dry conditions the project will result in a 1.4% reduction in yield. Locally impacts to yield will be greater in the Oldbury Creek sub-catchment, with up to a 4.1% reduction in yield under wet conditions and up to a 4.2% reduction in yield under dry conditions.

Under wet conditions, the project will result in up to a 0.5% reduction in surface water yield in the Medway Dam catchment, and under dry conditions the project will result in up to a 0.9% reduction in yield. These values represent the approximate reduction in yield to Medway Dam.

The *Hume Coal Project Groundwater Assessment Volume 2: Numerical Modelling and Impact Assessment* (Coffey 2016) indicates that under existing (pre-mining) conditions, Medway Dam loses approximately 0.5 ML/day to underlying aquifers. The numerical groundwater flow model for the project predicts that during operation of the mine, losses from Medway Dam to underlying aquifers will increase to 0.6 ML/day. These additional losses from Medway Dam over the life of the project are approximated at 37 ML/year.

Evaporative losses from Medway Dam are approximately 100 ML/year. This is a conservatively low estimate of the losses based on the lake evaporation data used in the assessment and the water surface area of the Medway Dam waterbody from the DPI Water dataset, with a reduction factor applied to the dam water surface area based on monthly variation in the lake evaporation data.

The additional losses from Medway Dam therefore constitute approximately 37% of the yearly evaporative loss from the dam.

Table 5.2 Yield impacts for Medway Rivulet

CATCHMENT	INCLUDED SUB-CATCHMENTS	IMPACT DUE TO	YIELD IMPACT	
			WET CLIMATE SEQUENCE	DRY CLIMATE SEQUENCE
Medway Dam	→ Medway Rivulet → Wells Creek	→ Reduction in catchment area due to project storages (SB03, SB04, MWD05, MWD06 and MWD07) → Intercepted baseflow for Medway Rivulet (scaled to catchment area) and Wells Creek	0.5%	0.9%
Medway Rivulet at the confluence with Wingecarribee River (excluding Oldbury Creek)	→ Medway Rivulet → Wells Creek → Belanglo Creek	→ Reduction in catchment area due to project storages (SB03, SB04, MWD05, MWD06 and MWD07) → Intercepted baseflow for Medway Rivulet, Wells Creek and Belanglo Creek	0.6%	1.1%
Oldbury Creek	→ Oldbury Creek	→ Reduction in catchment area due to project storages (SB01, SB02, MWD08 and PWD) → Releases from SB03 and SB04 after a first flush → Intercepted baseflow for Oldbury Creek	4.1%	4.2%
Medway Rivulet management zone		→ Reduction in catchment area due to project storages (SB01, SB02, SB03, SB04, MWD05, MWD06, MWD07, MWD08 and PWD) → Releases from SB03 and SB04 to Oldbury Creek after a first flush → Intercepted baseflow for Medway Rivulet, Wells Creek, Belanglo Creek and Oldbury Creek	0.8%	1.4%

5.4.2.2 LOWER WINGECARRIBEE RIVER MANAGEMENT ZONE AND WARRAGAMBA DAM

Existing case (pre-mining) flows in the Lower Wingecarribee River management zone were approximated using the AWBM runoff for the Medway Rivulet management zone scaled to the Lower Wingecarribee River management zone area (50,546 ha) (refer to Section 5.3.2).

The interception of natural baseflow associated with depressurisation of groundwater systems during underground mining was estimated using the numerical groundwater flow model for the project (Coffey 2016). The resulting changes in flow were applied to the existing case flow duration curve for the Lower Wingecarribee River to assess the percentage change in surface water yield for the catchment.

The results indicate that under wet conditions, the loss of baseflow will result in a 0.1% reduction in yield for the Lower Wingecarribee River catchment, and under dry conditions the loss of baseflow will result in a 0.-2% reduction in yield.

The Medway Rivulet management zone is upstream of the Lower Wingecarribee River management zone. Under wet conditions the project will result in a 0.8% reduction in yield for the Medway Rivulet management zone, and under dry conditions the project will result in a 1.4% reduction in yield. These changes in the Medway Rivulet management zone would produce negligible impacts downstream in the substantially larger Lower Wingecarribee management zone.

5.4.2.3 LOWER WOLLONDILLY AND BUNDANOON CREEK MANAGEMENT ZONES

Existing case (pre-mining) flows in the Lower Wollondilly River and Bundanoon Creek management zones were approximated using the AWBM runoff for the Medway Rivulet catchment scaled to the area of each catchment (refer to Section 5.3.2).

The interception of natural baseflow associated with depressurisation of groundwater systems during underground mining was estimated for each water management zone using the numerical groundwater flow model for the project (Coffey 2016). The resulting changes in flow were applied to the existing case flow duration curves to assess the percentage change in surface water yield for the catchments. The results are presented in Table 5.3 below.

The results indicate that under wet and dry conditions, the project would result in up to a 0.0004% reduction in yield for the Lower Wollondilly River management zone and no reduction in yield in the Bundanoon Creek management zone.

Table 5.3 Reduction in yield due to intercepted baseflow

WATER MANAGEMENT ZONE	CATCHMENT AREA (HA)	REDUCTION IN YIELD (WET CONDITIONS)	REDUCTION IN YIELD (DRY CONDITIONS)
Lower Wollondilly River	265,763	0.0001%	0.0004%
Bundanoon Creek	31,947	None	None

5.4.3 Cumulative impacts

The proposed Berrima Rail Project is located upstream of the Hume Coal Project in the Oldbury Creek catchment (Figure 1.2). Surface water flows will not be impacted by construction, operation or rehabilitation of the Berrima Rail Project. The Berrima Rail Project will not involve take of water from streams, water discharge to streams or groundwater impacts that would reduce baseflow to streams. In addition, the rail infrastructure for the Berrima Rail Project will not reduce the volume of flow as culvert structures will be constructed where the rail crosses waterways. Cumulative impacts to flow and bed and bank stability associated with the Hume Coal and Berrima Rail projects is predicted to be negligible – refer to the Berrima Rail Project EIS (EMM 2016c).

6 MITIGATION MEASURES AND MONITORING

6.1 Mitigation measures

The Hume Coal Project has been designed to avoid or minimise potential impacts to flow and associated erosion and scour impacts in local streams hence mitigation measures are minimal. Key aspects of the design that avoid or minimise impacts are as follows:

- The project does not involve the take of water directly from streams as a water supply for the project.
- The project does not involve any stream diversions.
- The project involves the use of low impact underground mining methods, which will have negligible subsidence impacts.
  - Worst case estimates of surface subsidence associated with the proposed first workings mining system predict ‘imperceptible’ surface disturbance due to mining (Mine Advice 2016). Such disturbances are sufficiently low in magnitude as to not impact on streamflow regimes or geomorphology.
  - The proposed first workings mining system will minimise overburden fracturing and potential impacts to groundwater resources, thereby limiting the interception of baseflow to streams.
- The project infrastructure is located outside floodplains with the exception of an existing embankment crossing Oldbury Creek and proposed minor instream works across Medway Rivulet: a conveyor crossing and a road crossing. Pilings will be used for the conveyor crossing and culvert structures will be constructed where the road crosses the stream so that the downstream flow volume will not be reduced.
- The water management system for the project will involve:
  - diverting water from undisturbed areas around mine infrastructure areas and into local streams via diversion drains to minimise flow impacts associated with loss of catchment area; and
  - maximising the reuse of water on-site to minimise off-site discharge of water to local streams, which could alter the natural flow regime.

The impact assessment has shown that impacts to flow and geomorphology in Medway Rivulet, Oldbury Creek and surrounding catchments will be limited. The following mitigation measures will be implemented to further reduce the potential for impacts in these catchments:

- Scour protection will be provided around conveyor crossing pilings in Medway Rivulet.
- Scour protection will be provided at the upstream and downstream end of the culverts under the road across Medway Rivulet so that localised increases in outlet velocity do not cause erosion of the channel lining downstream of the culvert.
- The discharge point for water from SB03 and SB04 to Oldbury Creek will be designed with appropriate rock protection at outlet pipes and channels to prevent scour due to high outlet velocities.

6.2 Monitoring

A surface water flow and quality monitoring program will be implemented in local catchments during construction, operation and rehabilitation of the Hume Coal Project.

The flow monitoring program will involve:

- monitoring of stream gauges in Medway Rivulet and Oldbury Creek upstream and downstream of surface infrastructure areas
- monitoring of the volume of water discharged from SB03 and SB04 to Oldbury Creek.

Results of the flow monitoring will be compared to the pre-mining baseline flow statistics. The objective of the program will be to confirm that flow impacts during mining operation are negligible.

The surface water quality monitoring program will involve surface water quality monitoring in Medway Rivulet and Oldbury Creek upstream and downstream of surface infrastructure areas. The objective of the program will be to confirm the effectiveness of the mitigation measures implemented to minimise erosion and scour in local streams. Details of the program are provided in the *Hume Coal Project Surface Water Quality Impact Assessment* (Parsons Brinckerhoff 2016b).

7 CONCLUSIONS

The flow regimes in Medway Rivulet and Oldbury Creek during operation of the project will be similar to pre-mining conditions, assuming constant low flow discharges from the Moss Vale and Berrima STPs. Without constant discharges from the Moss Vale STP, changes in the low flow regime in Medway Rivulet below approximately 5 ML/day are predicted with the number of no flow days increasing by up to 30%, however, this is unlikely to occur given that the STP is likely to continue to operate throughout the mining period. The potential impacts to instream ecosystems associated with these predicted changes are discussed in the *Hume Coal Project Biodiversity Assessment Report* (EMM 2016b).

Impacts to the flow regimes in Medway Rivulet and Oldbury Creek during construction and rehabilitation of the project will be less than impacts during operation. No take from streams or discharge to streams is proposed during construction and rehabilitation.

Local impacts on yield in the Oldbury Creek sub-catchment will be up to 4.2%; however impacts will be less than 1.4% for the Medway Rivulet management zone overall (which includes the Oldbury Creek catchment).

Under wet conditions, the project will result in up to a 0.5% reduction in yield for the Medway Dam catchment, and under dry conditions the project will result in up to a 0.9% reduction in yield. These values represent the approximate reduction in yield to Medway Dam.

Under wet conditions, the project will result in a 0.1% reduction in yield for the Lower Wingecarribee River management zone, and under dry conditions the project will result in a 0.2% reduction in yield. Less than 0.001% reduction in yield is predicted for other catchments under wet and dry conditions.

The potential for stream bank erosion associated with the project is low considering the minimal change in flow regime and the confined valley setting of Medway Rivulet and Oldbury Creek adjacent to and downstream of the surface infrastructure area. Scour protection will be provided around the conveyor crossing pilings in Medway Rivulet and at the upstream and downstream end of the culverts under the road across Medway Rivulet to prevent impacts to bed and bank stability. During construction, operation and rehabilitation, erosion and sedimentation control plans will be prepared to ensure the erosion and sedimentation induced by construction activities will not adversely affect the surrounding environment. With the implementation of this plan, erosion and sedimentation impacts during the construction, operation and rehabilitation phases are expected to be minimal.

Discharge of water to Oldbury Creek will occur via channel/pipe outlets and spillways with rock protection measures to prevent scouring at the discharge point. The discharge will be upstream or into the existing instream storage on the creek, and therefore an assessment of the increased overtopping risk of the storage during times of discharge will need to be made during the detailed design phase to determine whether any reinforcement of the existing spillways may be necessary.

Impacts on flow and bed and bank stability associated with the Berrima Rail Project will be negligible hence cumulative impacts will be limited to those identified for the Hume Coal Project.

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Appendix A

GEOMORPHOLOGY ASSESSMENT FIELD SHEETS

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	Hume				Date	~~06/09/2012~~
Surveyor	CR	Reach code: CG01 FG01 Oldbury Creek			Time	~~12:30~~ 9:00
Drainage channel ☐	Creek ☑	River ☐	Estuary ☐	Pond ☐	Wetland ☐	Lake ☐
Weather conditions	Overcast, drizzle		U-S Grid ref		D-S grid ref 54H 56H	0250770 6179304
Upstream elevation (m)	636		Downstream elevation (m)	634		Slope

Watercourse attributes

Dimensions	Width (m)	4m	Max. depth (m)		Velocity (ms^{-1})	N/A
Shape description			Roughness Height (m)	Logs / Twigs to water level	Bank erosion	
Instream vegetation (% cover (emergent, floating, submerged, algae, moss))	0%	Bank vegetation (% cover)	Grasses 100% Shrubs 20%	Bench vegetation (% cover)		Organic matter: Logs ☑ Twigs / Leaves ☑ Detritus ☐

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	☑ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	Low ~~Low Intermed.~~	*Form*	Single ☑	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops ☐		Riparian strip ☑	Floodplain connectivity	
Floodplain land use	Forest Grazing				Bank structure (concave, convex, straight, undercut) height & angle	

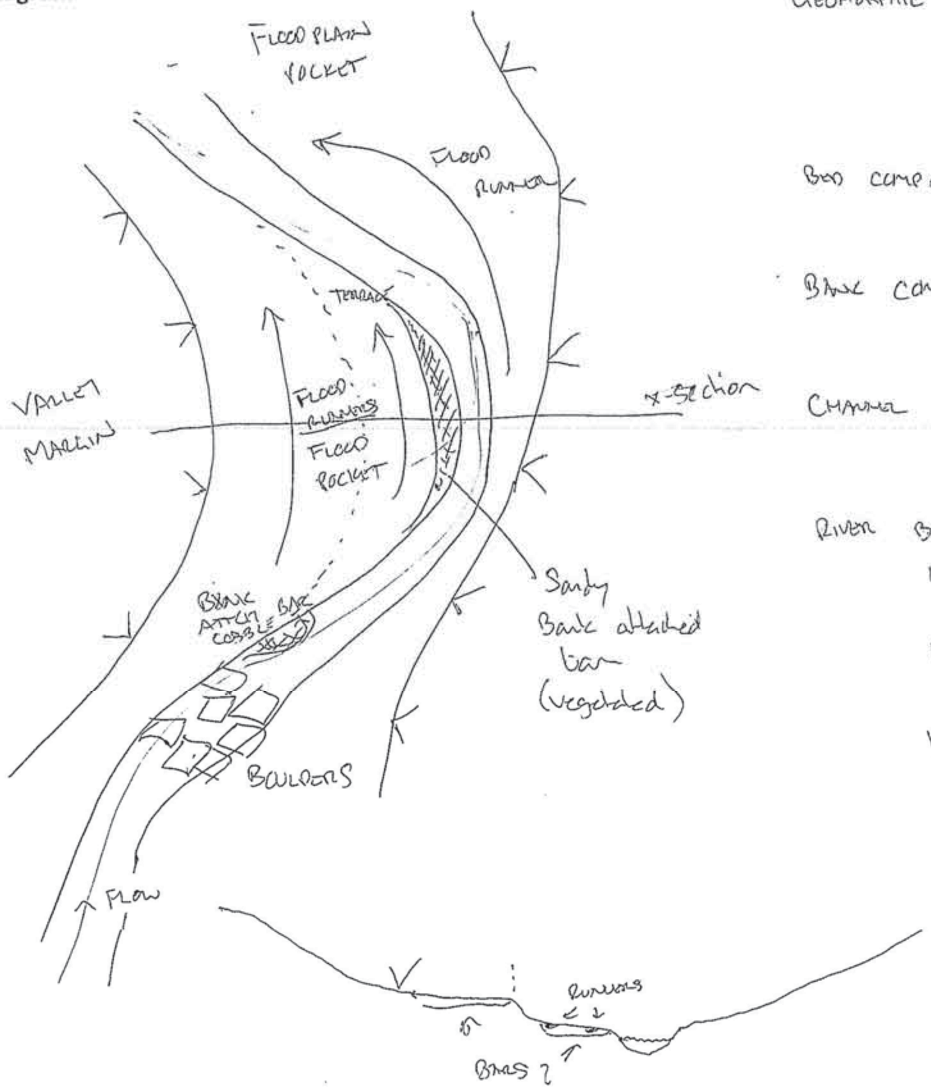
Bed character

% composition	Boulder U-S	Boulder D-S	Cobble U-S	Cobble D-S	Gravel U-S	Gravel D-S	Sand U-S	Sand D-S	Fine sand U-S	Fine sand D-S	Silt / clay U-S	Silt / clay D-S
	40	0	10				~~30~~ 80	80	~~20~~ 20	20		

		Supply	Deposition	Erosion	Conveying
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Low compaction	☐	☐	☑	☑

Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

Site setting diagram



GEOMORPHIC UNITS:

FLOOD RUNNERS
BANK SCOUR
BENCH ONTO FLOODPLAIN
RIPPLE
~~SEE~~ U/S BEDROCK
COBBLE BAR (BANK ATT'D)
ROUGHNESS ON RIPARIAN
BEDLOAD DOMINATES

BED COMPOSITION:

SANDY, BOULDERS, COBBLES

BANK COMPOSITION:

SANDY, FINE SAND

CHANNEL GEOMETRY:

IRREGULAR

RIVER BEHAVIOUR

LOW: Supply, ~~[illegible]~~ Maintenance, Sediment transport

MED: MOBILISE SAND, ~~[illegible]~~ MINIMAL REWORK BANK EROSION

BB: ACTIVE CHANNEL DEPOSITION ON BENCHES FLOOD CHUTES ACTIVATED EROSION IN CHANNEL.

VALLEY CONTROL

Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	HUME				Date	~~06/09/2012~~
Surveyor	Reach code: GEO2 FG02 Oldbury Creek				Time	~~12:30~~ 10:15
Drainage channel ☐	Creek ☑	River ☐	Estuary ☐	Pond ☐	Wetland ☐	Lake ☐
Weather conditions	O'CAST DRIZZLE		U-S Grid ref 56H ±6	0250517 6178880	~~D-S grid ref~~	
Upstream elevation (m)			Downstream elevation (m)		Slope	

Watercourse attributes					
Dimensions Width (m)	2-3 m	Max. depth (m)	<1m (Deep near bedrock)	Velocity (ms^{-1})	0
Shape description	RECTANGULAR	Roughness Height (m)		Bank erosion	
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	0%	Bank vegetation (% cover)	100% Grasses / Shrubs	Bench vegetation (% cover)	Organic matter: Logs ☑ Twigs / Leaves ☐ Detritus ☐

Flow type								
Smooth surface flow ☐ [H1]	Broken standing waves ☐ [H2]	Unbroken standing waves ☐ [H3]	Chute ☐ [H4]	Rippled ☐ [H5]	Scarcely perceptible flow ☑ [H6]	Upwelling ☐ [H7]	Free fall ☐ [H8]	Standing water ☐ [H9]

Channel Planform						
Sinuosity (straight, low, intermediate, high)	Low	*Form*	Single ☑	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops ☐		Riparian strip ☑	Floodplain connectivity	None
Floodplain land use	~~Forest~~ Riparian / Scrub				Bank structure (concave, convex, straight, undercut) height & angle	

Bed character						
% composition	Boulder U-S D-S	Cobble U-S D-S	Gravel U-S D-S	Sand U-S D-S	Fine sand U-S D-S	Silt / clay U-S D-S
	DIDN'T INSPECT / MOSTLY SAND FROM OBSERVATIONS					
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)			Supply ☑	Deposition ☑	Erosion ☑	Conveying ☐

Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

GEOMORPH:

ATTACHED SANDY BANK/BAR
SCOUR CHANNEL
NO INSTREAM GEOMORPH

BED/BANK: SANDY

NO SINUOSITY:

SHAPE: SYMMETRICAL

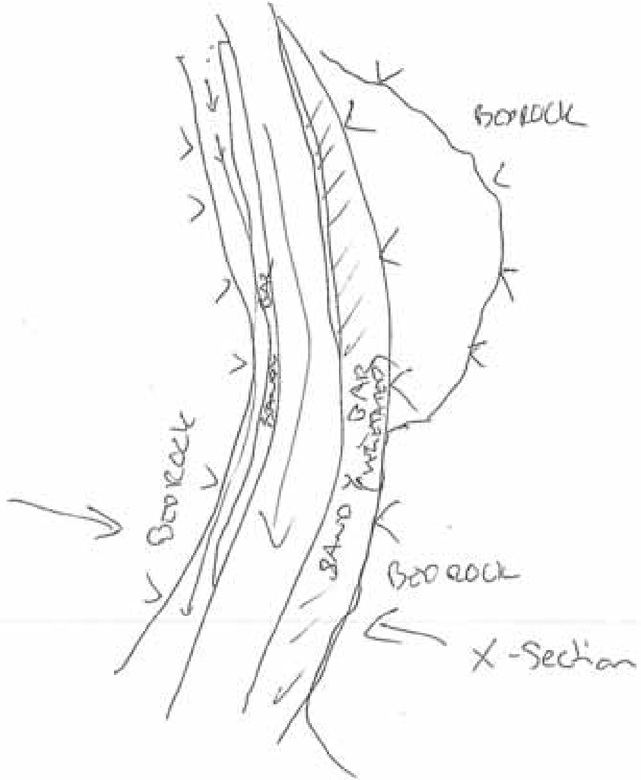
BEHAVIOUR: LOW: SCARCELY PERCEPTIBLE FLOW
POOLED WATER

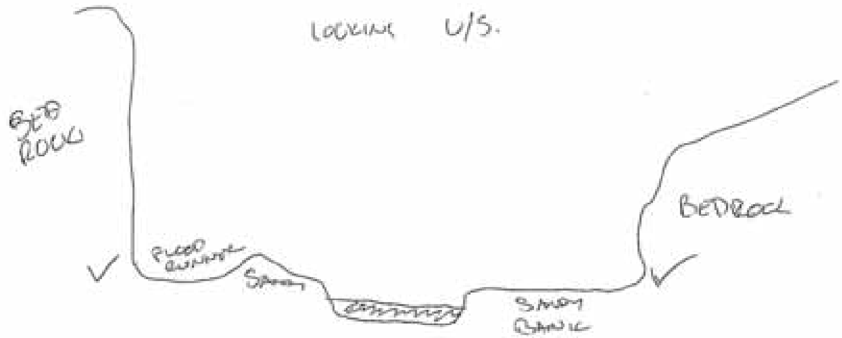
MED: CHANNEL ACTIVATES

OB: REWORKING - EROSION/DEPOSITION ON BANKS

CONTROLS: RIPARIAN VEG
BEDROCK MARGINS

BEDROCK CONTROLLED





Created 04/08/2011 Dan Evans (after Thompson et al, 2011, Aq Conserve, 11, 373 – 389)

Site setting diagram

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project						**Date**	06/09/2012
Surveyor		**Reach code:** GE03 FG03 Medway Rivulet				**Time**	12:30
Drainage channel ☐	**Creek** ☑	**River** ☐	**Estuary** ☐	**Pond** ☐		**Wetland** ☐	**Lake** ☐
Weather conditions	O'CAST			**U-S Grid ref**	0250801 6177004	**D-S grid ref** 56M ± 7m	0250662 6177084
Upstream elevation (m)	638			**Downstream elevation (m)**	636		**Slope**

Watercourse attributes

Dimensions Width (m)	≈10m	Max. depth (m)		Velocity (ms^{-1})	
Shape description	A. SYMMETRICAL	Roughness Height (m)	NO INSTREAM VEG	Bank erosion	
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	EMERGENT REEDS ALGAE	Bank vegetation (% cover)	GRASSES 100%	Bench vegetation (% cover)	
Organic matter	Logs ☐ Twigs / Leaves ☑ Detritus ☑				

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	☑ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

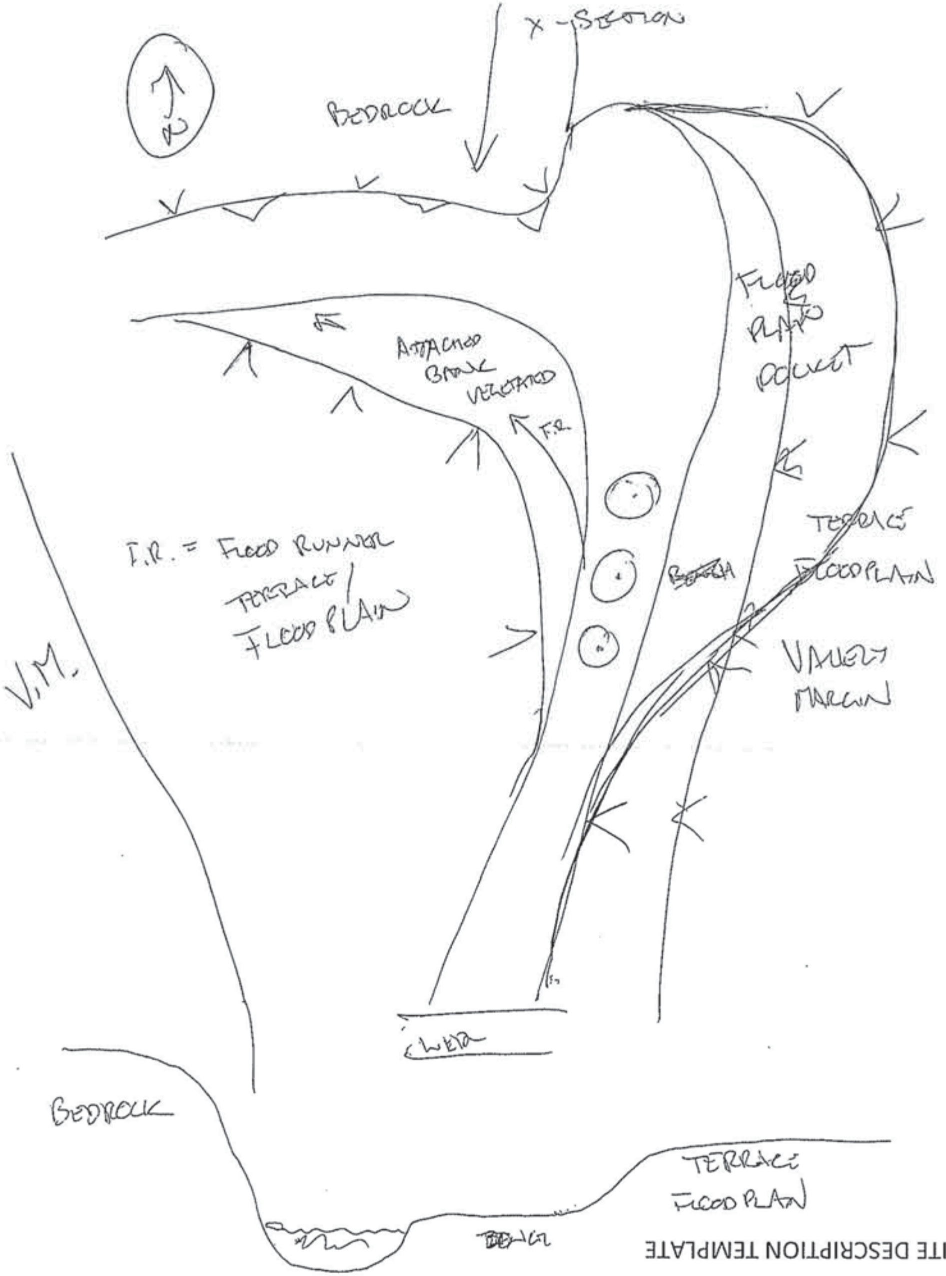
Sinuosity (straight, low, intermediate, high)	Low	*Form*	Single ☑	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops ☐	Riparian strip ☑	Floodplain connectivity		
Floodplain land use	~~Forest~~ Grazing			Bank structure (concave, convex, straight, undercut) height & angle		

Bed character

% composition	Boulder U-S D-S	Cobble U-S D-S	Gravel U-S D-S	Sand U-S D-S	Fine sand U-S D-S	Silt / clay U-S D-S
	BEDROCK					
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)			Supply ☑	Deposition ☐	Erosion ☐	Conveying ☐

Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

Site setting diagram



GEOMORPH UNITS:
BEDROCK CONTROL
BENCH UP TO FLOODPLAIN
FLOOD RUNNERS

BED COMP: BEDROCK
SILTY SAND

BANK: SANDY

SHAPE: ASSYMETRICAL

BEHAVIOUR: LOW: POOLED
MED: ACTIVE CHANNEL
FLOOD: FLOOD RUNNERS ACTIVATE
EROSION | DEPOSITION

CONTROLS: BEDROCK
INSTREAM TREES
UPSTREAM WEIR | CAUSEWAY

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ HUME COAL				Date		22/01/2013
Surveyor	DE	Reach code: ~~R651~~ FG04 - OLDBURY CREEK			Time		~~10:30~~ 16:30
Drainage channel ☐	Creek X	River ☐	Estuary ☐	Pond ☐	Wetland ☐		Lake ☐
Weather conditions	Bright sunshine ~~No rain (6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~			~~U-S~~ Grid ref Central	0249893 6175584	D-S grid ref	
Upstream elevation (m)				Downstream elevation (m)			Slope

Watercourse attributes							
Dimensions	Width (m)	5.4	Max. depth (m)		Velocity (ms^{-1})	0.1	
Shape description		U-shaped	Roughness Height (m)	N/A	Bank erosion	10%	
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	N/A	Bank vegetation (% cover)	90%	Bench vegetation (% cover)	100%	Organic matter Logs ☑ Twigs / Leaves ☑ Detritus ☑	

Flow type								
Smooth surface flow ☐ [H1]	Broken standing waves ☐ [H2]	Unbroken standing waves ☐ [H3]	Chute ☐ [H4]	Rippled ☐ [H5]	Scarcely perceptible flow ☐ [H6]	Upwelling ☐ [H7]	Free fall ☐ [H8]	Standing water ☐ [H9]

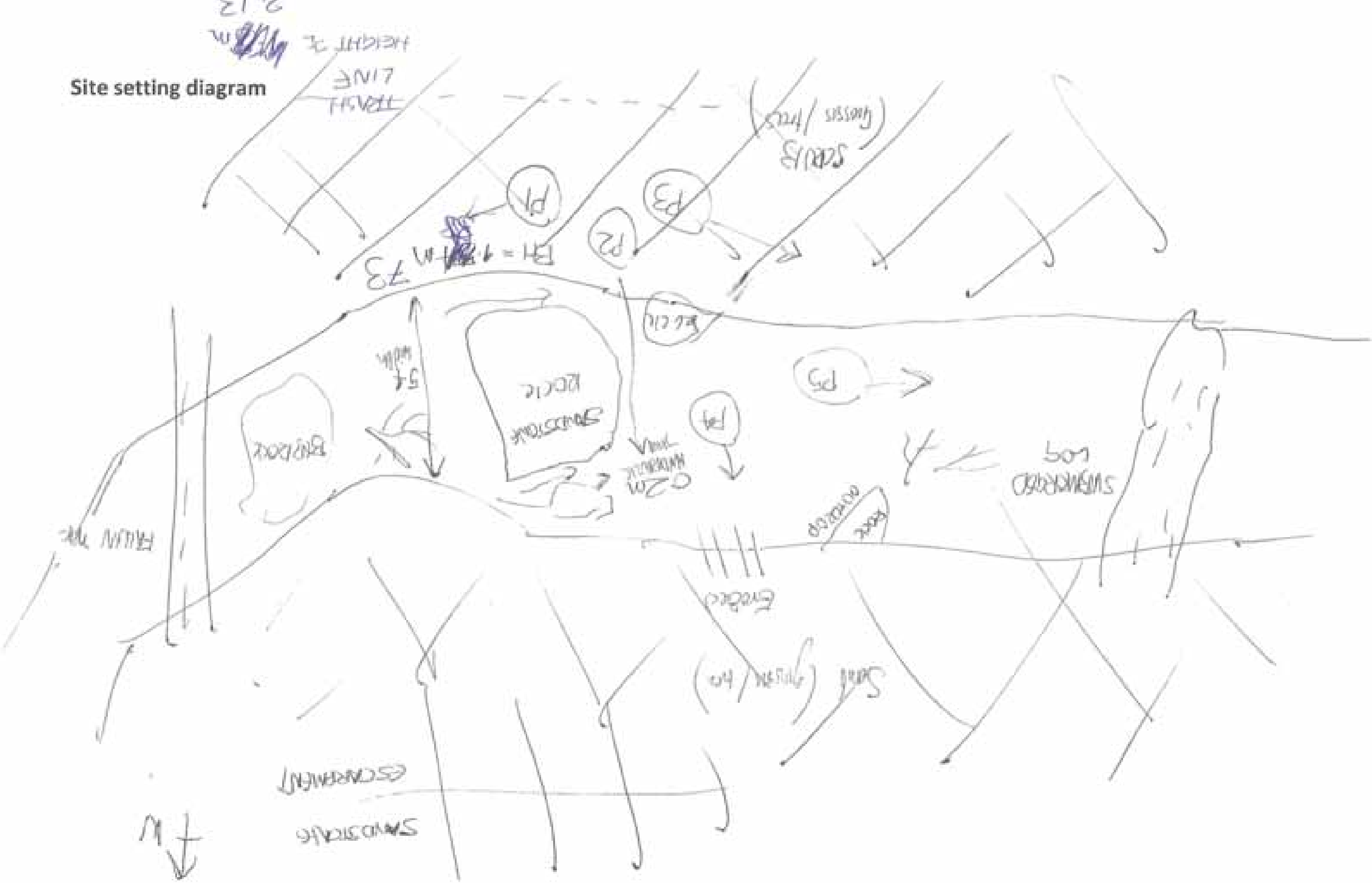
Channel Planform						
Sinuosity (straight, low, intermediate, high)	LOW	*Form*	Single X	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops X	Riparian strip ☐	Floodplain connectivity	LOW CONFINED DEEP CHANNEL	
Floodplain land use				Bank structure (concave, convex, straight, undercut) & slope	CONVEX 70°	

Bed character							
% composition	Boulder U-S ☐ D-S ☐	Cobble U-S ☐ D-S ☐	Gravel U-S ☐ D-S ☐	Sand U-S ☐ D-S 10	Fine sand U-S ☐ D-S 20		Silt / clay U-S ☐ D-S 70
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	LOW COMPACTION		Supply ☐	Deposition ☑ NO	Erosion ☑		Conveying ☑

Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ HUME COAL			Date	~~22/01/2013~~ 08/04/15
Surveyor	DE	Reach code: ~~RGS1~~ F405	WELLS CREEK INLET	Time	~~10:30~~ 11:10

Drainage channel	Creek	River	Estuary	Pond	Wetland	Lake
☐	X	☐	☐	☐	☐	☐

Weather conditions	Bright sunshine ~~No rain (6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~	U-S Grid ref	0250441 6175569	D-S grid ref	0250319 6175576
Upstream elevation (m)		Downstream elevation (m)		Slope	

Watercourse attributes

Dimensions Width (m)	4 - 22	Max. depth (m)	UNKNOWN	Velocity (ms^{-1})	0
Shape description	TRAPEZOIDAL	Roughness Height (m)	N/A	Bank erosion	LIMITED SOUTH BANK
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	\	Bank vegetation (% cover)	SEDGE & WEEDS THICK GRASS 40%	Bench vegetation (% cover)	GRASS
Organic matter	Logs ☐ Twigs / Leaves ☐ Detritus ☐				

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	X [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	LOW	*Form*	Single X	Forked X	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops X	Riparian strip ☐	Floodplain connectivity	SOUTH SIDE OPEN CONFINED NORTH	
Floodplain land use				Bank structure (concave, convex, straight, undercut) & slope	STRAIGHT NORTH 90°	

Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
U-S	0	0	10	30	20	40
D-S	0	0	10	20	20	40

Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Supply	Deposition	Erosion	Conveying
LOOSE GRAVEL OVERLYING PACKED CLAY/SAND LOAM	X	X	☐	X

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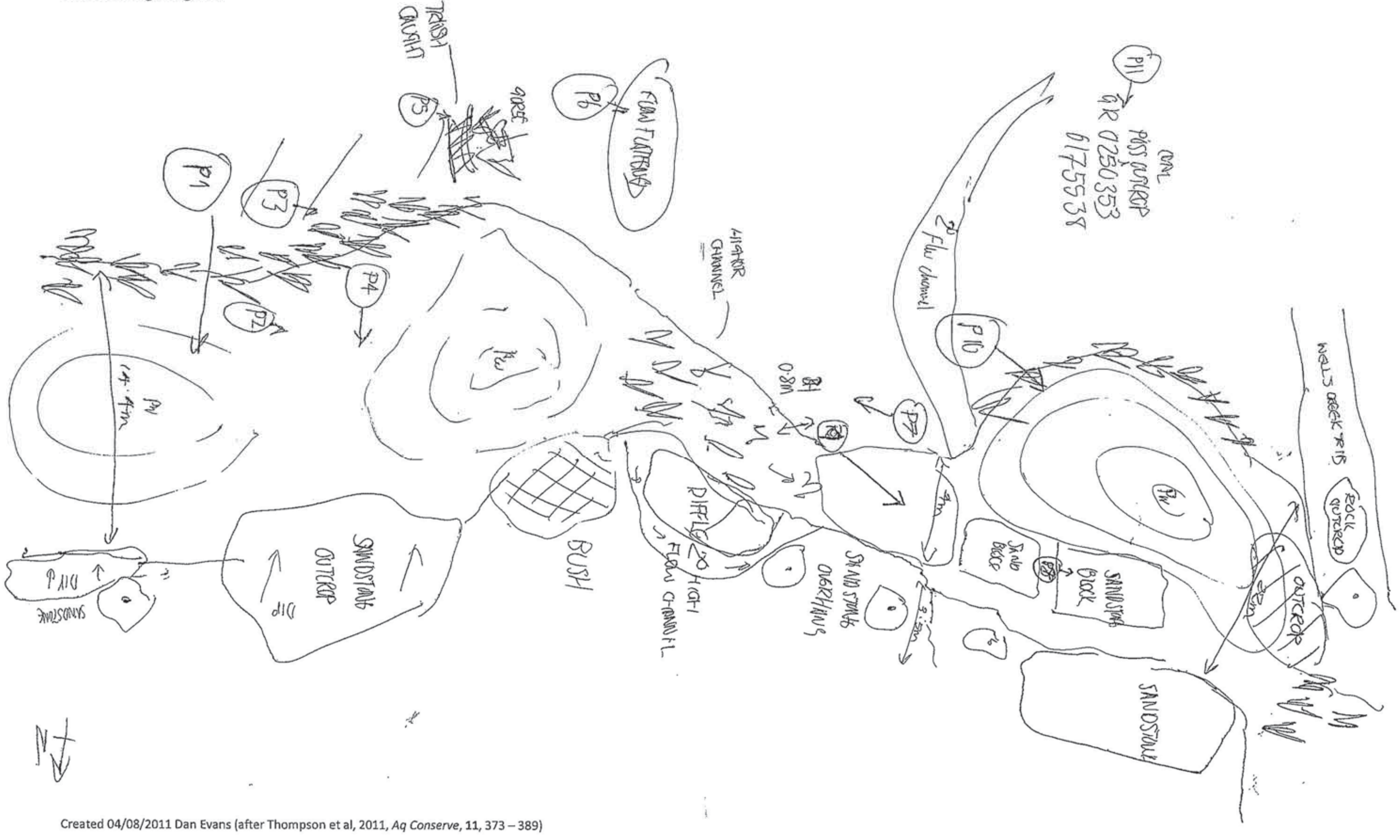
FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, 11, 373 – 389)

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ HUME COAL - WELLS CREEK					Date	~~R~~ 3/3/14 ~~22/01/2013~~
Surveyor	DE	Reach code: ~~R651~~ FC06				Time	1400 ~~10:30~~
Drainage channel ☐	Creek X	River ☐	Estuary ☐	Pond ☐		Wetland ☐	Lake ☐
Weather conditions	~~Bright sunshine~~ ~~No rain (6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~			U-S Grid ref	0250999 617845	D-S grid ref	0251007 617907
Upstream elevation (m)				Downstream elevation (m)		Slope	

Watercourse attributes

Dimensions	Width (m)	US 3.8m DS 3.8	Max. depth (m)	1.0m	Velocity (ms^{-1})	SCARCELY PERCEPTIBLE
Shape description		RECTANGULAR	Roughness Height (m)	GRASS 10cm BOULDER 0.5m	Bank erosion	70%
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	10% Submerged grass	Bank vegetation (% cover)	30% GRASS	Bench vegetation (% cover)	90% GRASS 10% GRASS	Organic matter: Logs ☒ Twigs / Leaves ☐ Detritus ☐

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled IN CONC AREA	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☑ [H5]	☑ [H6]	☐ [H7]	☐ [H8]	☑ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	Low / STRAIGHT	*Form*	Single ☑	Forked ☐	ABANDONED CHANNEL ✓	Braided ☐	Open ☐
Sand bars ☑	Gravel bars ☐	Rock outcrops ☐	Riparian strip ☐	Floodplain connectivity	HIGHLY CONNECTED	
Floodplain land use	GRAZING			Bank structure (concave, convex, straight, undercut) & slope	STRAIGHT	

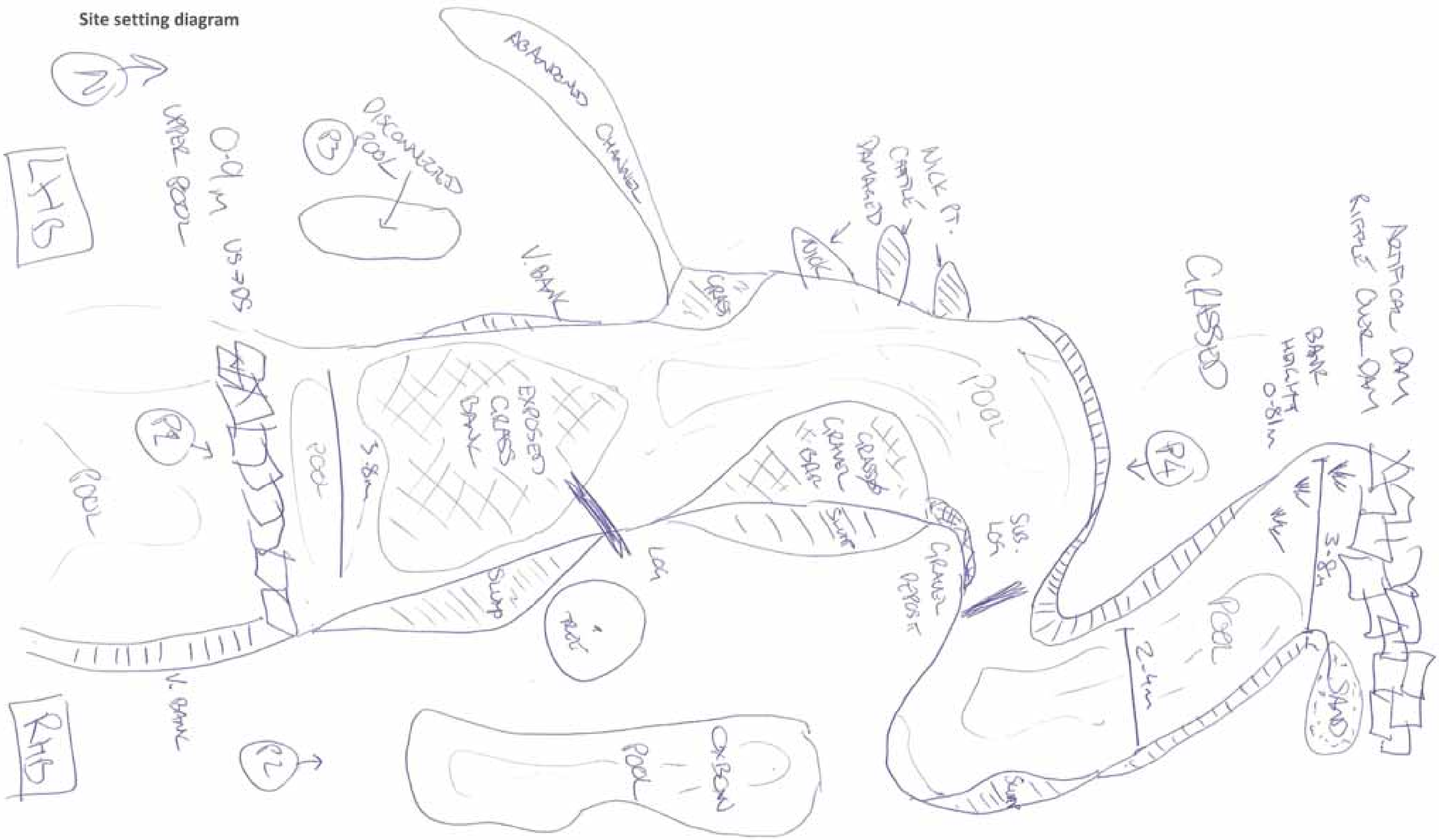
Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S 5 D-S ☐	U-S 15 D-S 10	U-S ☐ D-S 10	U-S 80 D-S 80
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	NO ARMOUR, MODERATE COMPACTION		Supply ☒	Deposition ☒	Erosion ☒	Conveying ☒

Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	HUME	Date	~~06/09/2012~~
Surveyor	CR	Reach code: GE05 FG07 Oldbury Creek	Time	~~12:30~~ 12:10

Drainage channel	Creek	River	Estuary	Pond	Wetland	Lake
☐	☑	☐	☐	☐	☐	☐

Weather conditions	O'CAST	U-S Grid ref 58H ±6m	0251990 6178826	D-S grid ref ±10m 58H	0251888 6179642
Upstream elevation (m)	653	Downstream elevation (m)	649	Slope	

Watercourse attributes

Dimensions Width (m)	US ≤ 0.5m	Max. depth (m)		Velocity (ms^{-1})	0
Shape description		Roughness Height (m)	300mm	Bank erosion	
Instream vegetation (% cover (emergent, floating, submerged, algae, moss))		Bank vegetation (% cover)		Bench vegetation (% cover)	Organic matter: Logs ☐ Twigs / Leaves ☐ Detritus ☐

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	☑ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	Low	*Form*	Single ☑	Forked ☐	Braided ☐	Open ☐

Sand bars	Gravel bars	Rock outcrops	Riparian strip	Floodplain connectivity	
☐	☐	☐	☐		NONE

Floodplain land use	~~Forest~~	Bank structure (concave, convex, straight, undercut) height & angle	

Bed character

% composition	Boulder (U-S / D-S)	Cobble (U-S / D-S)	Gravel (U-S / D-S)	Sand (U-S / D-S)	Fine sand (U-S / D-S)	Silt / clay (U-S / D-S)
				10	20	70

		Supply	Deposition	Erosion	Conveying
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)		☐	☐	☐	☐

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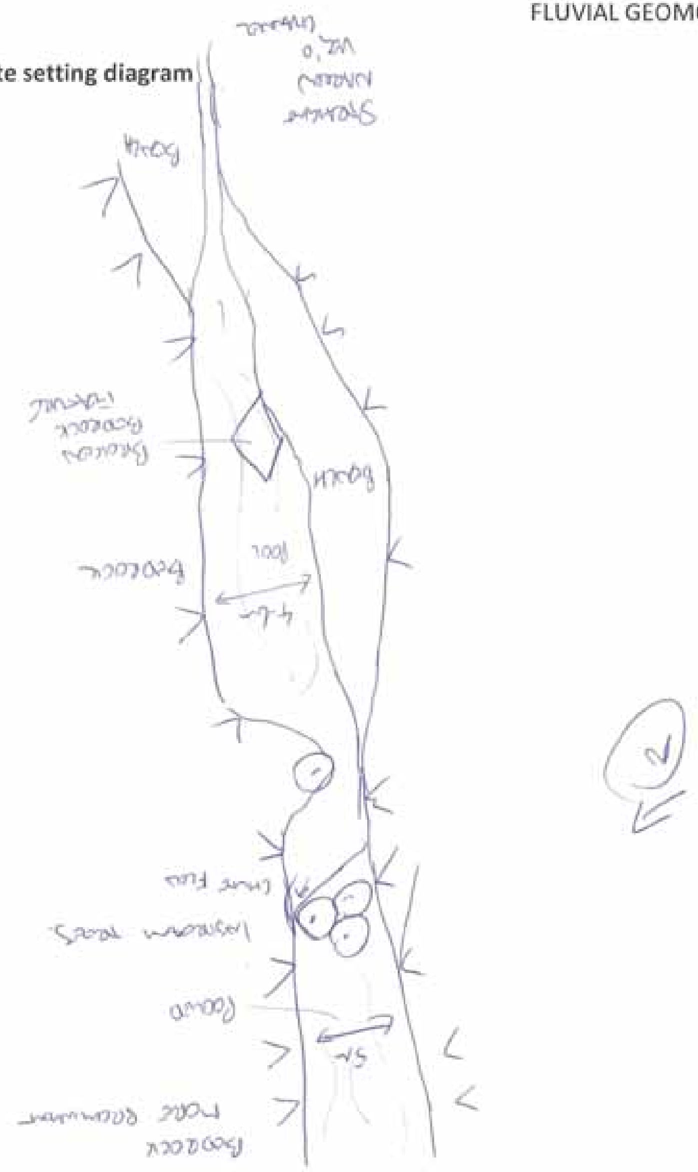
FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

Ponded: ~~[illegible]~~ 0251955
~~[illegible]~~ 6178925

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	Hume					Date	06/09/2012
Surveyor	CK	Reach code: CE04 FG08 Oldbury Creek				Time	12:30
Drainage channel ☐	Creek ☑	River ☐	Estuary ☐	Pond ☐		Wetland ☐	Lake ☐
Weather conditions	O'CAST			U-S Grid ref	0251529 6179365	D-S grid ref 56H ±15m	0251485 6179326
Upstream elevation (m)				Downstream elevation (m)	646		Slope

Watercourse attributes

Dimensions Width (m)	1-2m	Max. depth (m)	N/A	Velocity (ms^{-1}) 0	0
Shape description	ASYMETRICAL	Roughness Height (m)	N/A	Bank erosion	N/A
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	N/A	Bank vegetation (% cover)		Bench vegetation (% cover)	GRASS, SHRUBS, WEEDS 100%
Organic matter	Logs ☐ Twigs / Leaves ☐ Detritus ☐				

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	☑ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

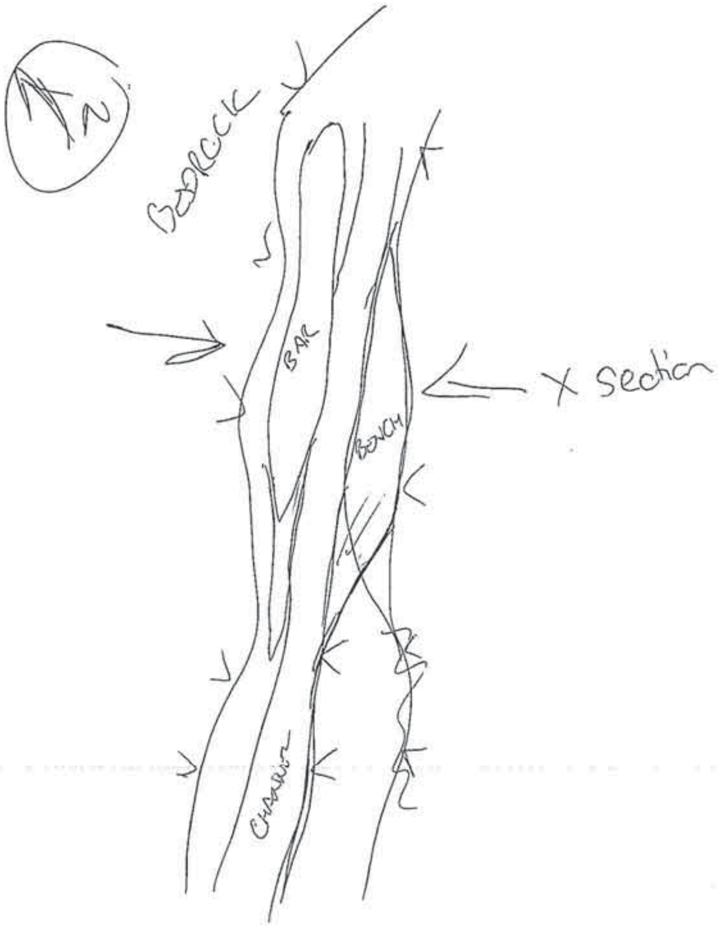
Channel Planform

Sinuosity (straight, low, intermediate, high)	Low	*Form*	Single ☑	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops ☐	Riparian strip ☐	Floodplain connectivity		
Floodplain land use	Forest			Bank structure (concave, convex, straight, undercut) height & angle		

Bed character

% composition	Boulder U-S D-S	Cobble U-S D-S	Gravel U-S D-S	Sand U-S D-S	Fine sand U-S D-S	Silt / clay U-S D-S
N/A COULDN'T ACCESS 100% BEDROCK CONTROL						
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)			Supply ☐	Deposition ☐	Erosion ☐	Conveying ☐

Created 04/08/2011 Dan Evans (after Thompson et al, 2011, Aq Conserve, 11, 373 – 389)

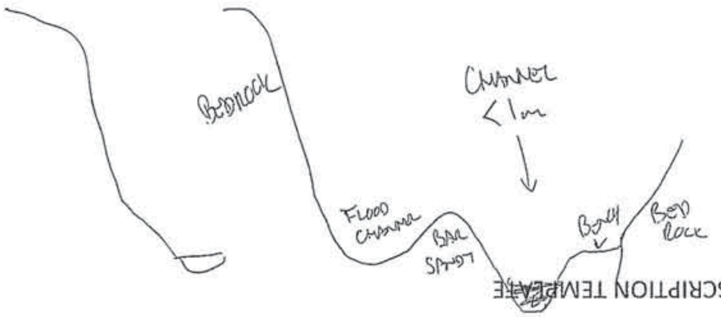


GEOMORPHIC UNITS: BAR, BEDROCK FORMED
(U/S BRIDGE)
RUN
~~RE~~ RIPARIAN DENSE, SHRUBS, TREES

BED/BANK: BEDROCK
SAND DEPOSITS / OVERLYING

GEOM: ~~?~~ ASYMMETRICAL

~~GEOM~~ BEHAVIOUR: LOW: STANDING /
MOD: MAINTENANCE, TRANSPORT
HIGH: MINIMAL REWORK
SOME EROSION / DEPOSITION



Site setting diagram

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	HUME					Date	06/09/2012
Surveyor	CR	Reach code: GE06 FG09 Oldbury Creek				Time	12:30
Drainage channel ☐	Creek ☑	River ☐	Estuary ☐	Pond ☐		Wetland ☐	Lake ☐
Weather conditions	O'CAST DRIZZLE			U-S Grid ref		D-S grid ref	0252322 617820
Upstream elevation (m)				Downstream elevation (m)	657		Slope

Watercourse attributes						
Dimensions	Width (m)	2-10m	Max. depth (m)		Velocity (ms^{-1})	
Shape description			Roughness Height (m)	1m	Bank erosion	
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	Emergent reeds 100%	Bank vegetation (% cover)		Bench vegetation (% cover)	100% Grass / Pasture	Organic matter: Logs ☐ Twigs / Leaves ☐ Detritus ☑

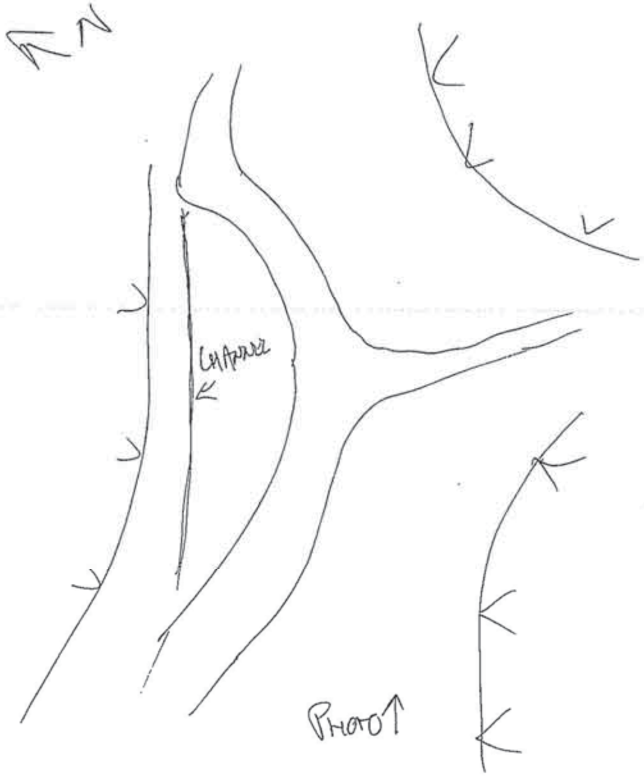
Flow type								
Smooth surface flow ☐ [H1]	Broken standing waves ☐ [H2]	Unbroken standing waves ☐ [H3]	Chute ☐ [H4]	Rippled ☐ [H5]	Scarcely perceptible flow ☐ [H6]	Upwelling ☐ [H7]	Free fall ☐ [H8]	Standing water ☑ [H9]

Channel Planform						
Sinuosity (straight, low, intermediate, high)	Low	*Form*	Single ☑	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops ☐		Riparian strip ☐	Floodplain connectivity	
Floodplain land use	Forest Grazing				Bank structure (concave, convex, straight, undercut) height & angle	

Bed character						
% composition	Boulder U-S D-S	Cobble U-S D-S	Gravel U-S D-S	Sand U-S D-S	Fine sand U-S D-S: 20	Silt / clay U-S D-S: 80
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	No armour No packing		Supply ☑	Deposition ☐	Erosion ☑	Conveying ☐

Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

Site setting diagram



UNITS: ~~[illegible]~~ HIGH FLOW CHUTE

BED | BANK: SANDY SILT & CLAY

SHAPE: INCISED SYMMETRICAL
LOW SINUOSITY
PLANFORM CONTROL

BEHAVIOUR: LOW: STANDING WATER
MED: MOBILISED SEDIMENT
HIGH: OB FLOODPLAIN DEPOS'N
CHANNEL EROSION

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ HUME COAL		Date	~~22/01/2013~~ 04/04/14
Surveyor	DE	Reach code: ~~RS01~~ FG 11 LONGACRE CREEK	Time	~~10:30~~ 09 10

Drainage channel	Creek	River	Estuary	Pond	Wetland	Lake
☐	X	☐	☐	☐	☐	☐

Weather conditions	~~Bright sunshine~~ Drizzle, Cool ~~No rain (6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~	~~U-S~~ Grid ref	0243326 6178713	~~D-S grid ref~~	
Upstream elevation (m)		Downstream elevation (m)		Slope	

Watercourse attributes

Dimensions	~~Width (m)~~ (Valley floor) 500m	Max. depth (m)	n/a	Velocity (ms^{-1})	n/a
Shape description	Broad U-shape valley	Roughness Height (m)	n/a	Bank erosion	n/a
Instream vegetation (% cover (emergent, floating, submerged, algae, moss))	n/a	Bank vegetation (% cover)	n/a	Bench vegetation (% cover)	100% Natural bush Gum trees + ferns
Organic matter	n/a	Logs ☐ Twigs / Leaves ☐ Detritus ☐			

Flow type [H10] No defined channel ; dry valley

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	☐ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	Straight	Form	Single ☐	Forked ☐	Braided ☐	Open X
Sand bars ☐	Gravel bars ☐	Rock outcrops ☐	Riparian strip ☐	Floodplain connectivity	High	
Floodplain land use	Natural bush			Bank structure (concave, convex, straight, undercut) & slope	n/a	

Bed character

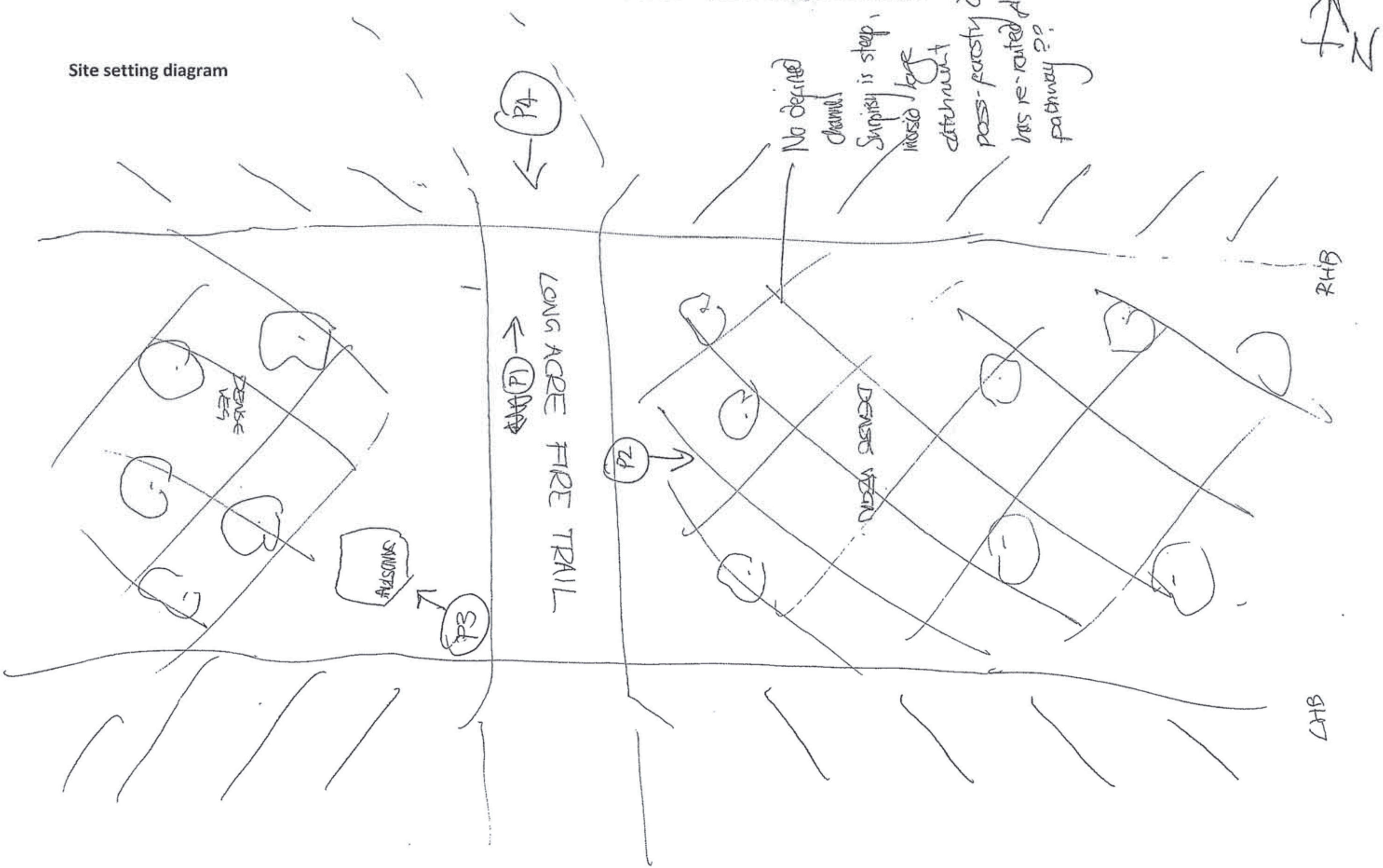
% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
n/a	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S 80 D-S ☐	U-S 20 D-S ☐	U-S ☐ D-S ☐

Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	n/a	Supply ☐	Deposition ☐	Erosion ☐	Conveying ☐

Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ HUME COAL		Date	3/3/17	~~22/01/2013~~
Surveyor	DE	Reach code: ~~R651~~ FCR WELLS CREEK	Time	1430	~~10:30~~

Drainage channel	Creek	River	Estuary	Pond	Wetland	Lake
☐	X	☐	☐	☐	☐	☐

Weather conditions	~~Bright sunshine~~ ~~No rain (6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~	U-S Grid ref	@ Fence 0251060 6169429	D-S grid ref	0251077 6169454
Upstream elevation (m)		Downstream elevation (m)		Slope	

Watercourse attributes

Dimensions Width (m)	3.1 @ Fence line	Max. depth (m)		Velocity (ms^{-1})	
Shape description	U-Shaped	Roughness Height (m)	2m	Bank erosion	80% US / 0% DS

Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	Bank vegetation (% cover)	Bench vegetation (% cover)	Organic matter
U/S Grass D/S Reeds			Logs ☐ Twigs / Leaves ☐ Detritus ☐

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☑ [H5]	☑ [H6]	☐ [H7]	☐ [H8]	☑ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	Straight	*Form*	Single ☑	Forked ☐	Braided ☐	Open ☐

Sand bars	Gravel bars	Rock outcrops	Riparian strip	Floodplain connectivity
☐	☐	☐	☑	N/A

Floodplain land use	Grazing	Bank structure (concave, convex, straight, undercut) & slope	Straight 45%

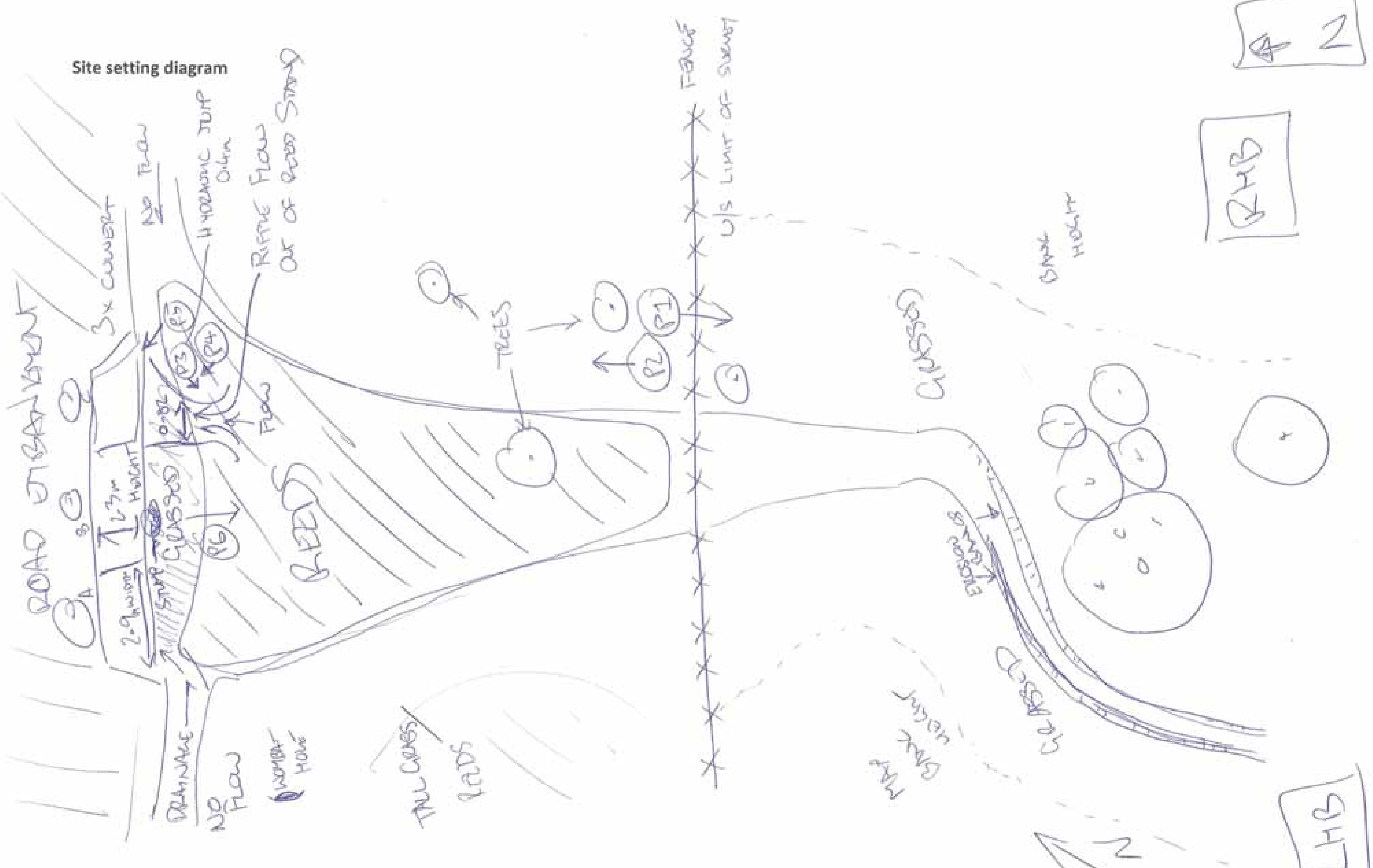
Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S 100 D-S ☐	U-S ☐ D-S ☐

Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Supply	Deposition	Erosion	Conveying
NO ARMOUR MOD. COMPACTION	☒	☒	☒	☐

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	HUME					Date	06/09/2012
Surveyor	CR	Reach code: ~~C~~ ~~C006~~ C007 FG16 Medway Rivulet				Time	12:30
Drainage channel ☐	Creek ☑	River ☐	Estuary ☐	Pond ☐		Wetland ☐	Lake ☐
Weather conditions	O'cast			U-S Grid ref		D-S grid ref	
Upstream elevation (m)				Downstream elevation (m)			Slope

Watercourse attributes

Dimensions Width (m)	~ 10m	Max. depth (m)		Velocity (ms⁻¹)	
Shape description		Roughness Height (m)	~ 1m	Bank erosion	

Instream vegetation (% cover (emergent, floating, submerged, algae, moss))	Emergent reeds algae	Bank vegetation (% cover)	Minimal riparian. Sparse	Bench vegetation (% cover)	Pasture / grass Some trees	Organic matter Logs ☑ Twigs / Leaves ☑ Detritus ☐

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	☑ [H6]	☐ [H7]	☐ [H8]	☑ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	Low	*Form*	Single ☑	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops ☐	Riparian strip ☐	Floodplain connectivity		
Floodplain land use	Forest			Bank structure (concave, convex, straight, undercut) height & angle		

Bed character

% composition	Boulder U-S D-S	Cobble U-S D-S	Gravel U-S D-S	Sand U-S D-S	Fine sand U-S D-S	Silt / clay U-S D-S
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)		Supply ☑	Deposition ☑	Erosion ☑	Conveying ☐	

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GEOMORPHIC UNITS:

POOLED WATER

D/S CAUSEWAY IS A RIFFLE

RIPARIAN PREDOMINATELY GRASS, SOME TREES

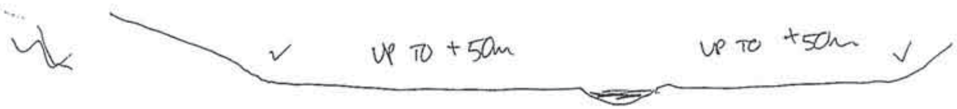
BED | BANK: SANDY CLAY | SILT

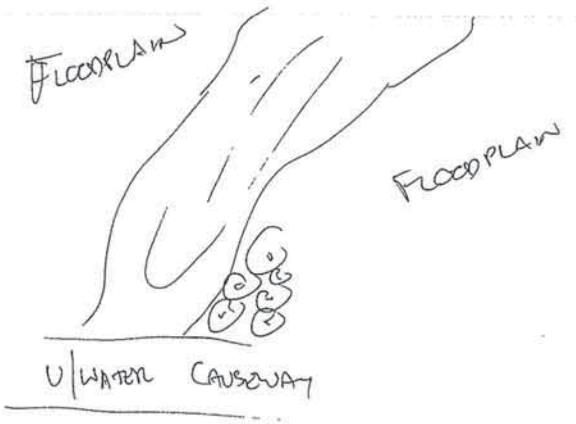
GEOMETRY: SYMMETRICAL

BEHAVIOUR: LOW: MAINTENANCE, POOLED, SETTLING

MED: SUPPLY, ENTRAINMENT OF SEDIMENTS

BB: EROSION, DEPOSIT'N OF FLOODPLAIN





Site setting diagram

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ Hume Coal Small tributary of Wells Creek				Date	~~22/01/2013~~ 08/04/14
Surveyor	DE	Reach code: ~~RUS1~~ FG17			Time	~~10:30~~ 09:45
Drainage channel ☐	Creek X	River ☐	Estuary ☐	Pond ☐	Wetland ☐	Lake ☐
Weather conditions	Bright sunshine ~~No rain (6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~		U-S Grid ref 56H	0249772 6175576	D-S grid ref	0249840 6175969
Upstream elevation (m)			Downstream elevation (m)			Slope

Watercourse attributes

Dimensions Width (m)	U-S N/A	Max. depth (m)	U-S N/A	Velocity (ms^{-1})	N/A DRY
Shape description	U-S b-shp open	Roughness Height (m)	~~10~~ 3cm	Bank erosion	U-S N/A
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	GRASS/SEDGE 80%	Bank vegetation (% cover)	N/A	Bench vegetation (% cover) 100% GRASS	Organic matter U-S NONE; Logs ☐ Twigs / Leaves ☐ Detritus ☐

Flow type H10 DRY

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	☐ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	LOW	*Form*	Single X	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐		Rock outcrops ☐	Riparian strip ☐	Floodplain connectivity	U-S OPEN CHANNEL
Floodplain land use	CATTLE GRAZING				Bank structure (concave, convex, straight, undercut) & slope	U-S N/A D-S straight

Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S 40	U-S ☐ D-S 20	U-S ☐ D-S 30	U-S 100 D-S 10
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Packed not armoured		Supply ☐	Deposition ☐	Erosion ☐	Conveying X

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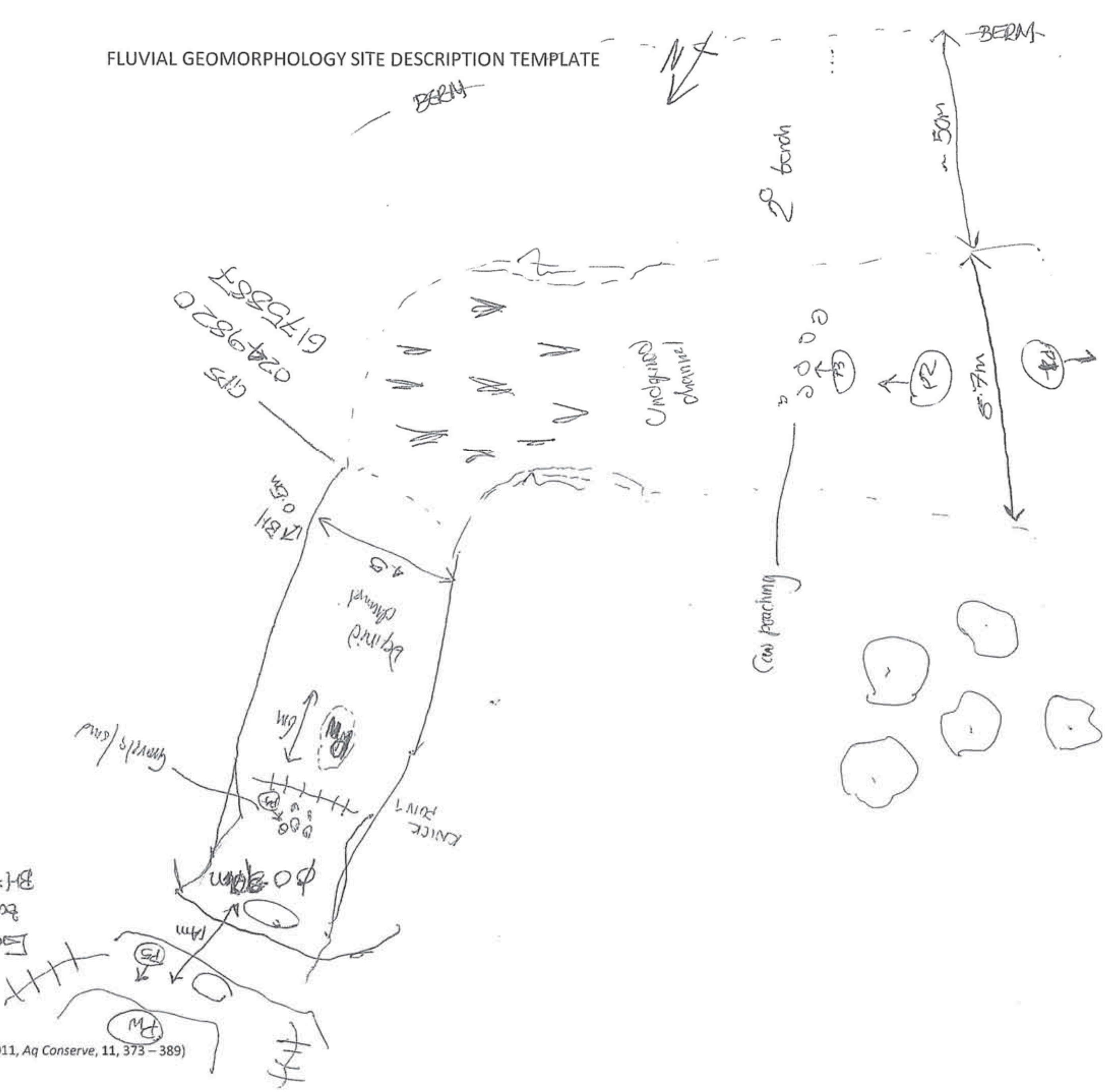
Site setting diagram



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FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ HUME COAL					Date	22/01/2013
Surveyor	DE	Reach code: ~~RGS1~~ FG18		LONGACRE CREEK		Time	10:30
Drainage channel ☐	Creek ☒	River ☐	Estuary ☐	Pond ☐	Wetland ☐	Lake ☐	Valley ☒
Weather conditions	~~Bright sunshine~~ Drizzle, cool No rain ~~(6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~			~~U-S~~ Grid ref Central	0244853 6175855	D-S grid ref	
Upstream elevation (m)				Downstream elevation (m)		Slope	

Watercourse attributes

Dimensions	Width (m)	n/a	Max. depth (m)		Velocity (ms^{-1})	
Shape description			Roughness Height (m)		Bank erosion	
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])		Bank vegetation (% cover)		Bench vegetation (% cover)	100% natural forest (non bark + eucalypt)	Organic matter: Logs ☐ Twigs / Leaves ☐ Detritus ☐

Flow type [All] Dry channel; valley flat

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	☐ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

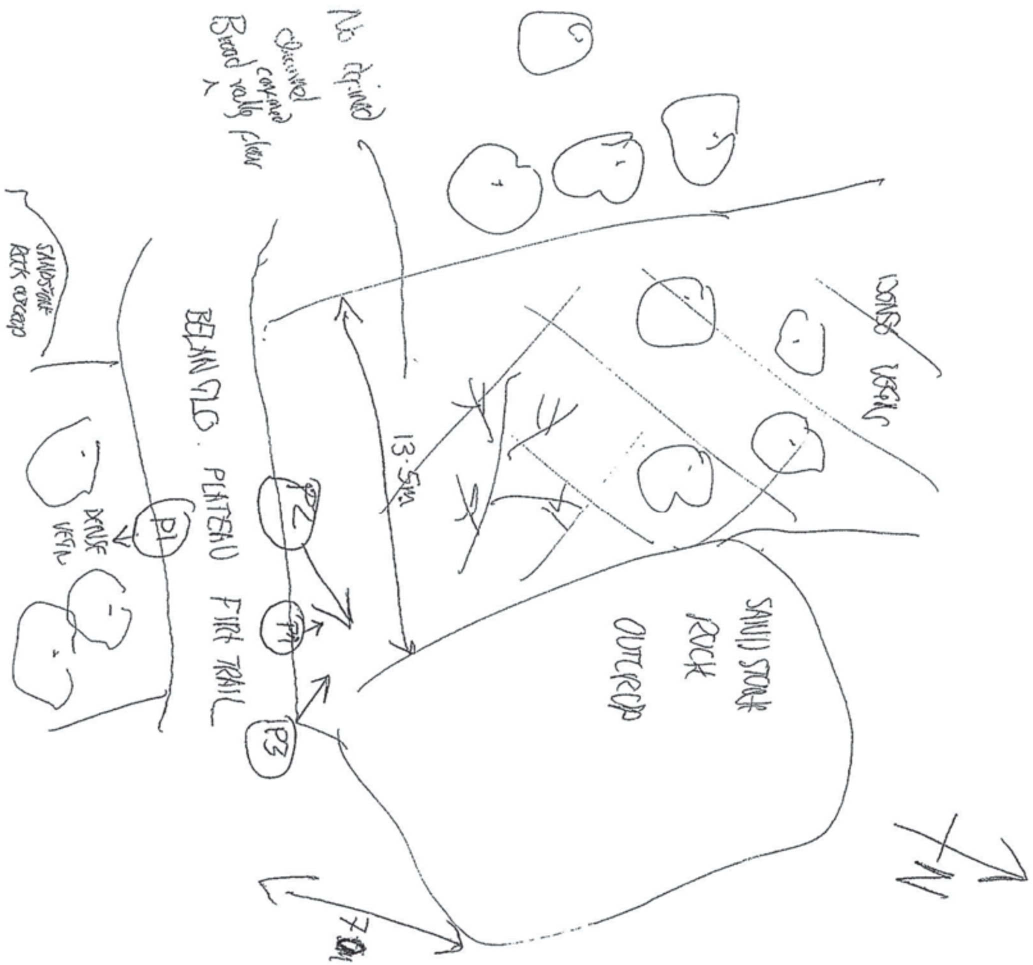
Sinuosity (straight, low, intermediate, high)	Straight	*Form*	Single ☒	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops ☒	Riparian strip ☐	Floodplain connectivity	Open	
Floodplain land use	Natural forest			Bank structure (concave, convex, straight, undercut) & slope		

Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
N/A	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S 80 D-S ☐	U-S 20 D-S ☐	U-S ☐ D-S ☐

Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)		Supply	Deposition	Erosion	Conveying
	N/A	☐	☐	☐	☐

Site setting diagram



FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	HUME COAL				**Date**	19/12/2013
Surveyor	DE	**Reach code:** SWO1			**Time**	11:50
Drainage channel ☐	**Creek** ☒	**River** ☐	**Estuary** ☐	**Pond** ☐	**Wetland** ☐	**Lake** ☐
Weather conditions	BRIGHT SUNSHINE (8.2mm rain previous 7 days) Moss Vale @ Hoskins St BOM		**U-S Grid ref**	-34.575512 150.253613	**D-S grid ref**	-34.575377; 150.252768
Upstream elevation (m)	—		**Downstream elevation (m)**	—	**Slope**	

Watercourse attributes

Dimensions	**Width (m)** 5.6 (U-S) & 1.8 (D-S)	**Max. depth (m)**	1.25	**Velocity (ms^{-1})**	≈0 - 0.2
Shape description	U-shape	**Roughness Height (m)**	0.3	**Bank erosion**	None
Instream vegetation (% cover [emergent, floating, submerged, algae, moss]) 5% SEDGES/EMERGENTS 10% BENTHIC ALGAE ON ROCKS	**Bank vegetation** (% cover) 50% SEDGES 50% GRASS	10% SEDGES/EMERGENTS 40% GRASSES 30% GORSE 20% BEDROCK	**Bench vegetation** (% cover)		**Organic matter** Logs ☒ Twigs / Leaves ☒ Detritus ☒

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☒ [H3]	☒ [H4]	☒ [H5]	☒ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	LOW	***Form***	**Single** ☒	**Forked** ☐	**Braided** ☐ / **Open** ☐
Sand bars ☐	**Gravel bars** ☒	**Rock outcrops** ☒	**Riparian strip** ☒	**Floodplain connectivity**	ENTRENCHED CHANNEL U-S SEMI-OPEN D-S
Floodplain land use	Grazing D-S HUME HIGHWAY NATURAL BUSHLAND			**Bank structure** (concave, convex, straight, undercut) **height & angle**	STRAIGHT 60° 0.85m (D-S) CONCAVE 50° 1.3m (U-S)

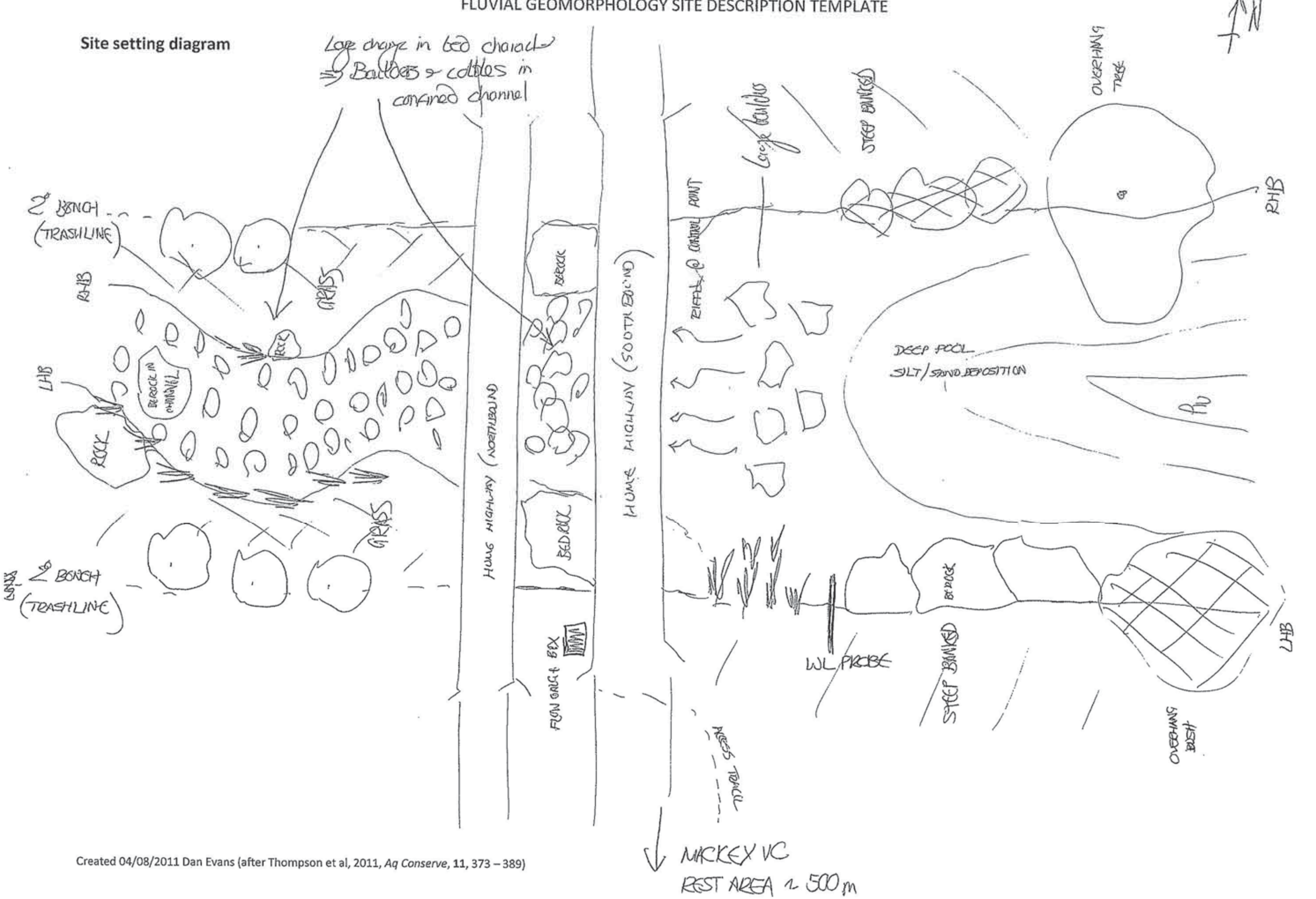
Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
U-S	20	10	10	30	10	20
D-S	20	40	20	10	10	0

Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing) PACKED & ARMOURED D-S PACKED NOT ARMOURED U-S	**Supply** ☐	**Deposition** ☒	**Erosion** ☐	**Conveying** ☒

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



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FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	HUNG COAL				Date	22/05/2012
Surveyor	DE	Reach code: SWQ02			Time	12:45
Drainage channel ☐	Creek ☒	River ☐	Estuary ☐	Pond ☐	Wetland ☐	Lake ☐
Weather conditions	SUNNY, COOL (0.2mm RAIN IN PREVIOUS 7 DAYS; BoM MOSS VALE @ HOSKINS ST GAUGE)		U-S Grid ref	-34.521948;	D-S grid ref	-34.521554; 150.184119
Upstream elevation (m)			Downstream elevation (m)	150.18405		Slope

Watercourse attributes

Dimensions Width (m)	3.2 (D-S) & 1.9 (D-S)	Max. depth (m)	0.24	Velocity (ms^{-1})	0.1 – 0.3
Shape description	TRAPAZOID	Roughness Height (m)	0.25	Bank erosion	5% AT CATTLE ACCESS POINT D-S
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	50% BENTHIC (INC IRON REDUCING BACTERIA · REDSTAIN ON CHANNEL BED)	Bank vegetation (% cover)	95% MOSS, GRASS & SEDGE	Bench vegetation (% cover): 100% BRAMBLE, TREES & GRASS	Organic matter: Logs ☐ Twigs / Leaves ☐ Detritus ☒

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☒ [H1]	☐ [H2]	☐ [H3]	☒ [H4]	☒ [H5]	☐ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	~~LOW~~ INTERMEDIATE	*Form*	Single ☒	Forked ☐	Braided ☐ / Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops ☐	Riparian strip ☐	Floodplain connectivity	OPEN (ESP. EAST BANK)
Floodplain land use	Grazing Natural Forest ~ 100 m from floodplain.			Bank structure (concave, convex, straight, undercut) height & angle	CONVEX 30° 0.1M D-S CONVEX 45° 0.2M D-S

Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
U-S	0	0	20	40	20	20
D-S	0	0	30	40	20	10

Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	PACKED NOT ARMOURED D-S MOD COMPACTION U-S	Supply ☐	Deposition ☒	Erosion ☐	Conveying ☒

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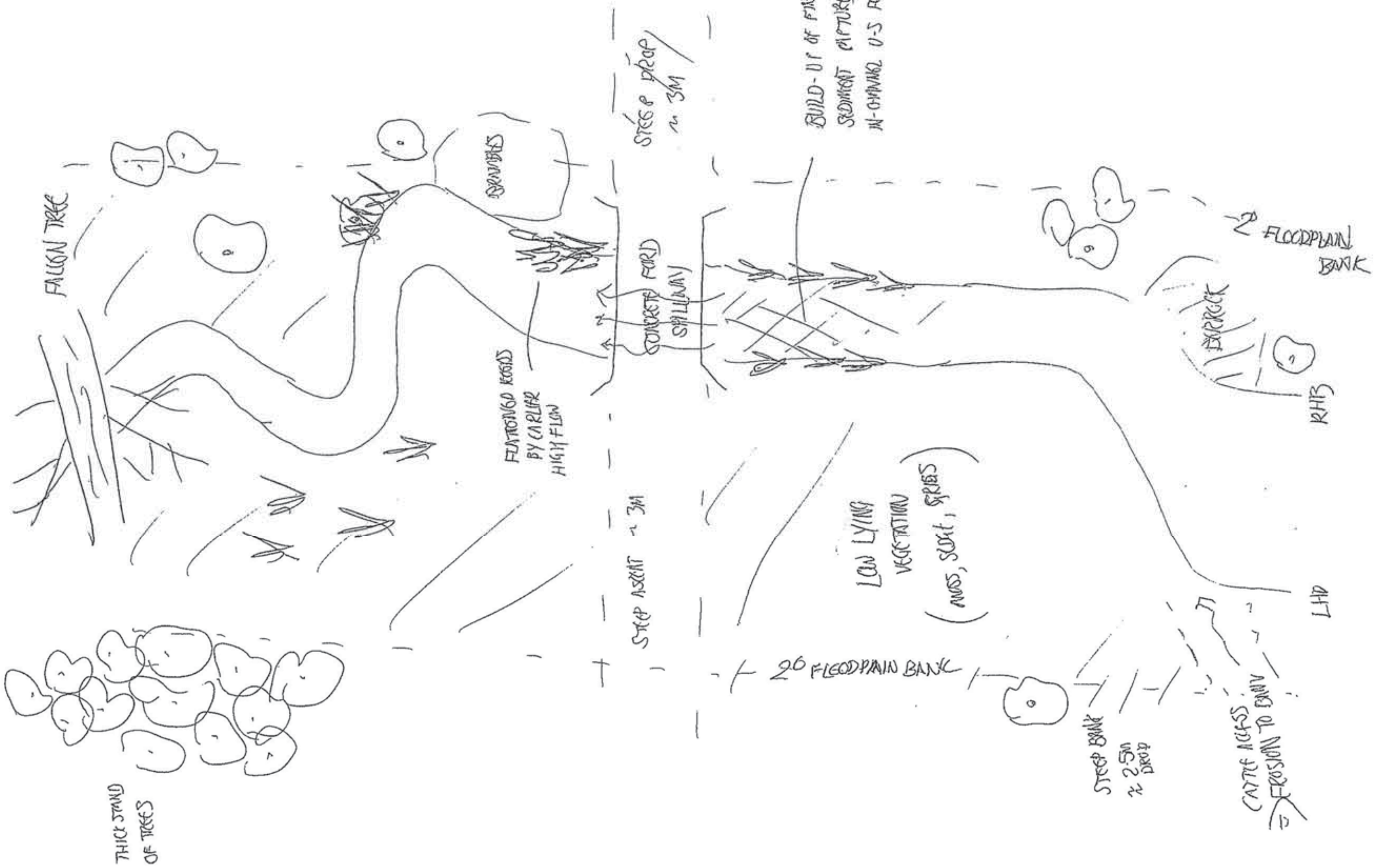
FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ HUME COAL				Date	22/01/2013
Surveyor	DE	Reach code: ~~R051~~ SWQ03 - MEDWAY RIVULET			Time	10:30
Drainage channel ☐	Creek X	River ☐	Estuary ☐	Pond ☐	Wetland ☐	Lake ☐
Weather conditions	~~Bright sunshine~~ ~~No rain (6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~		U-S Grid ref		D-S grid ref	0254444 6171928
Upstream elevation (m)			Downstream elevation (m)		Slope	

Watercourse attributes

Dimensions Width (m)	9.5m US 9.2m DS	Max. depth (m)		Velocity (ms^{-1})	0
Shape description		Roughness Height (m)	2m	Bank erosion	20% Vegetated D/S & U/S
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	40% Emergent Reeds	Bank vegetation (% cover) 80% Grassed / Sedge	Bench vegetation (% cover) 100% Grass, Shrubs, Trees		Organic matter: Logs ☐ Twigs / Leaves ☑ Detritus ☑

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	CONC. AREA ☑ [H5]	☑ [H6]	☐ [H7]	☐ [H8]	☑ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)		*Form*	Single ☑	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops ☐	Riparian strip ☐	Floodplain connectivity	HIGH D/S	
Floodplain land use	Residential / Domestic (DS) GRAZING (US)			Bank structure (concave, convex, straight, undercut) & slope	Convex.	

Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
	U-S ☐ D-S ☐	U-S 10 D-S ☐	U-S 30 D-S ☐	U-S 40 D-S ☐	U-S ☐ D-S ☐	U-S 20 D-S ☐
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	SOME ARMOUR MOD. COMPACTION (NOT TESTED)		Supply ☐	Deposition ☒	Erosion ☒	Conveying ☒

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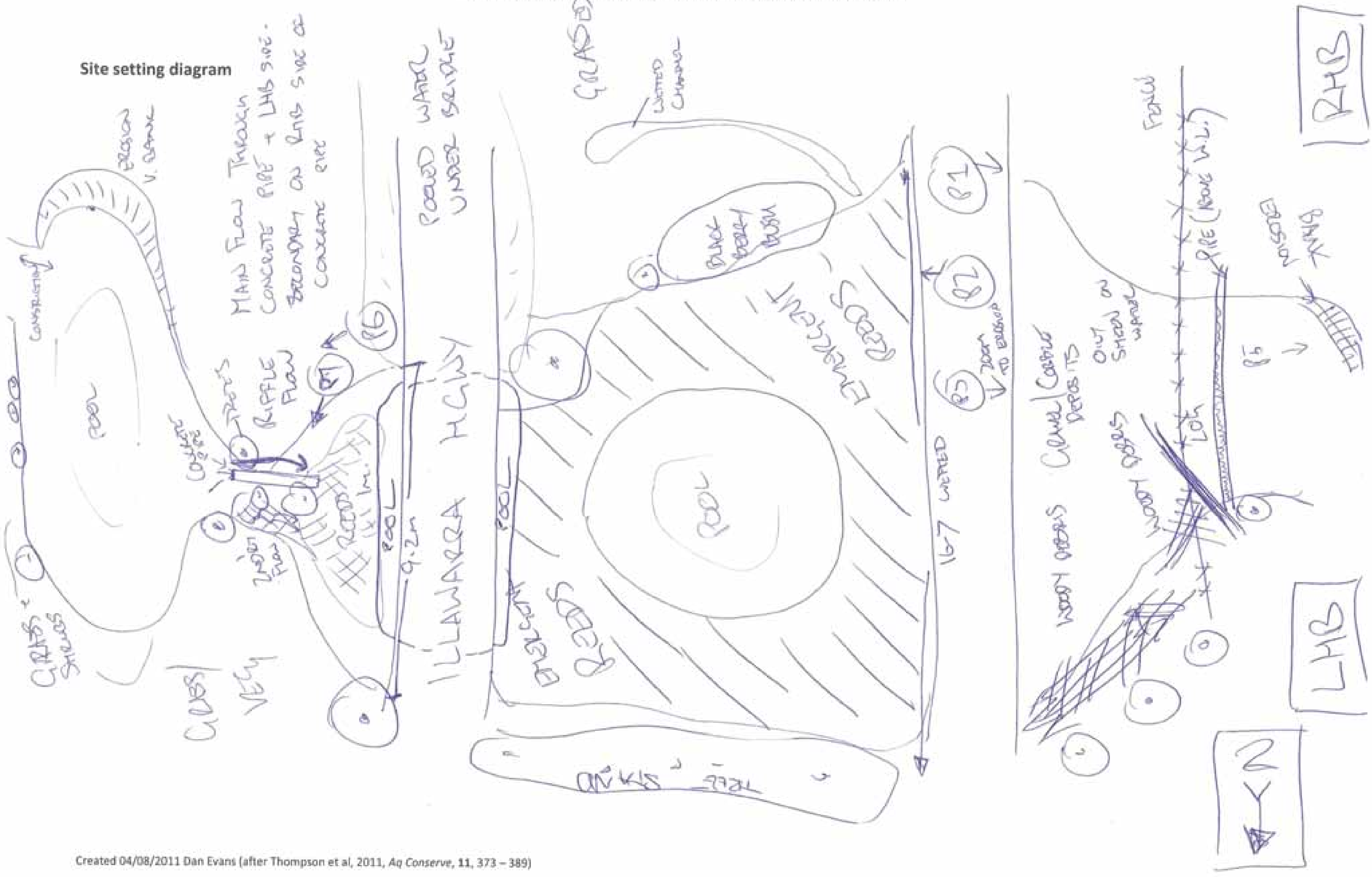
FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ HUME COAL	Date	~~22/01/2013~~ 09/04/14
Surveyor	DE — Reach code: ~~RGS1~~ SW04 MEDWAY RIVULET	Time	~~10:30~~ 12:13

Drainage channel	Creek	River	Estuary	Pond	Wetland	Lake
☐	X	☐	☐	☐	☐	☐

Weather conditions	~~Bright sunshine~~ CLOUDY ~~No rain (6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~	U-S Grid ref	0251886 6176893	D-S grid ref	0251863 6176914
Upstream elevation (m)		Downstream elevation (m)		Slope	

Watercourse attributes

Dimensions Width (m)	1.8 – 5m U-S D-S	Max. depth (m)	1.1m	Velocity (ms^{-1})	0 – 0.5
Shape description	U-shaped	Roughness Height (m)	0.4	Bank erosion	None
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])		Bank vegetation (% cover)	80% grass 20% bedrock	Bench vegetation (% cover)	100% grass
Organic matter	Logs ☒ Twigs / Leaves ☒ Detritus ☐				

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☒ [H1]	☐ [H2]	☐ [H3]	☒ [H4]	☒ [H5]	☒ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	STRAIGHT	*Form*	Single X	Forked ☐	Braided ☐	Open ☐	
Sand bars ☐	Gravel bars ☐	Rock outcrops ☒	Riparian strip ☐	Floodplain connectivity	LOW, ENTRENCHED CHANNEL		
Floodplain land use	Road Pasture			Bank structure (concave, convex, straight, undercut) & slope	CONCAVE 50°		

Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S 50 D-S ☐	U-S 10 D-S ☐	U-S 40 D-S ☐

Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Supply	Deposition	Erosion	Conveying
Some armouring Bed moderately packed structure	☐	☐	☐	☒

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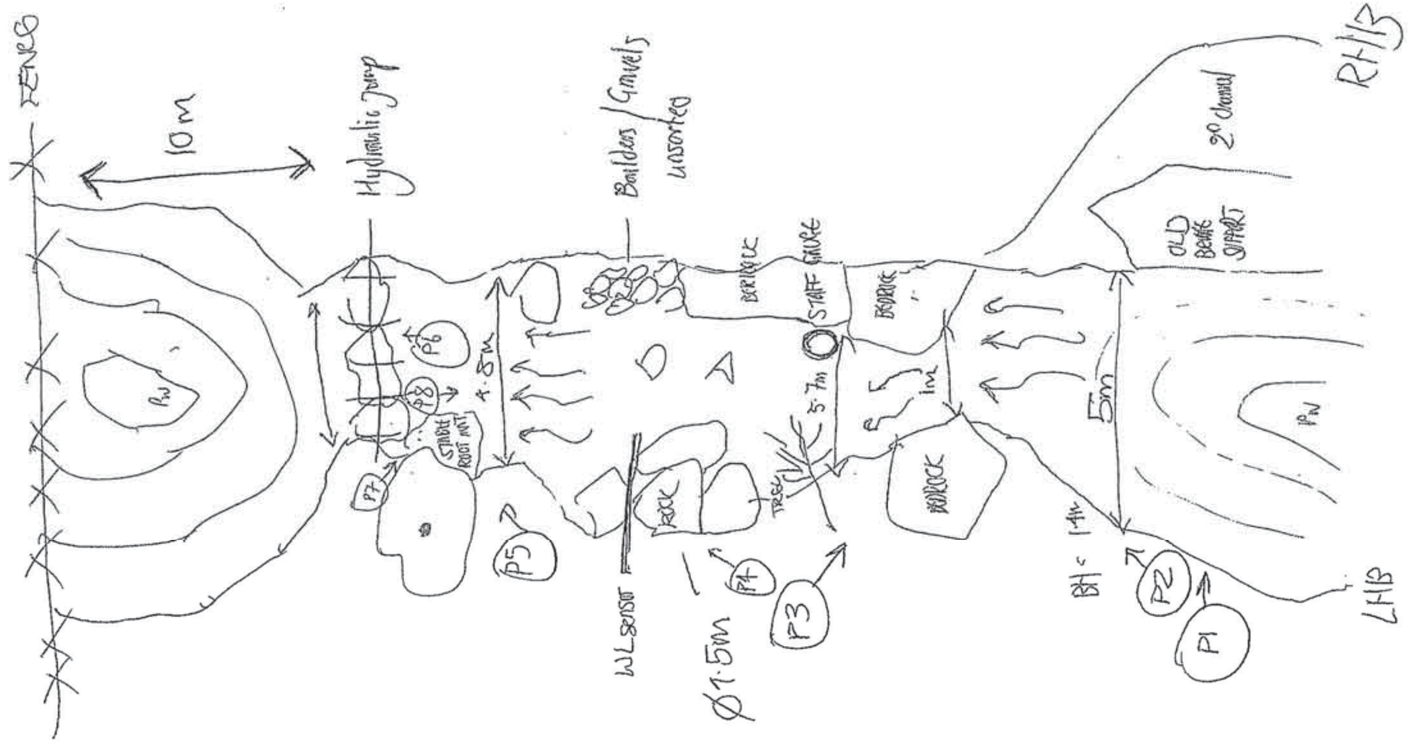
FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ HUME COAL	Date	~~23/02/2013~~ 08/04/15
Surveyor	DE — Reach code: ~~RDS3~~ ~~SW05~~ SWQ07 WELLS CREEK TRIBUTARY	Time	10:30

Drainage channel	Creek	River	Estuary	Pond	Wetland	Lake
☐	X	☐	☐	☐	☐	☐

Weather conditions	Bright sunshine ~~No rain (6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~	U-S Grid ref	0250298 6175272	D-S grid ref	0250332 6175382
Upstream elevation (m)		Downstream elevation (m)		Slope	

Watercourse attributes

Dimensions Width (m)	2.0 – 6.5	Max. depth (m)	0.2	Velocity (ms^{-1})	0.3
Shape description		Roughness Height (m)		Bank erosion	
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	\	Bank vegetation (% cover)	SEDGE / GRASS 70%	Bench vegetation (% cover)	GRASS / SEDGE 100%

Organic matter: Logs ☐ Twigs / Leaves ☐ Detritus ☐

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☒ [H5]	☐ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)		*Form*	Single ☐	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☒	Rock outcrops ☐	Riparian strip 30m ☒	Floodplain connectivity	OPEN	
Floodplain land use	Livestock			Bank structure (concave, convex, straight, undercut) & slope	Convex 50	

Bed character

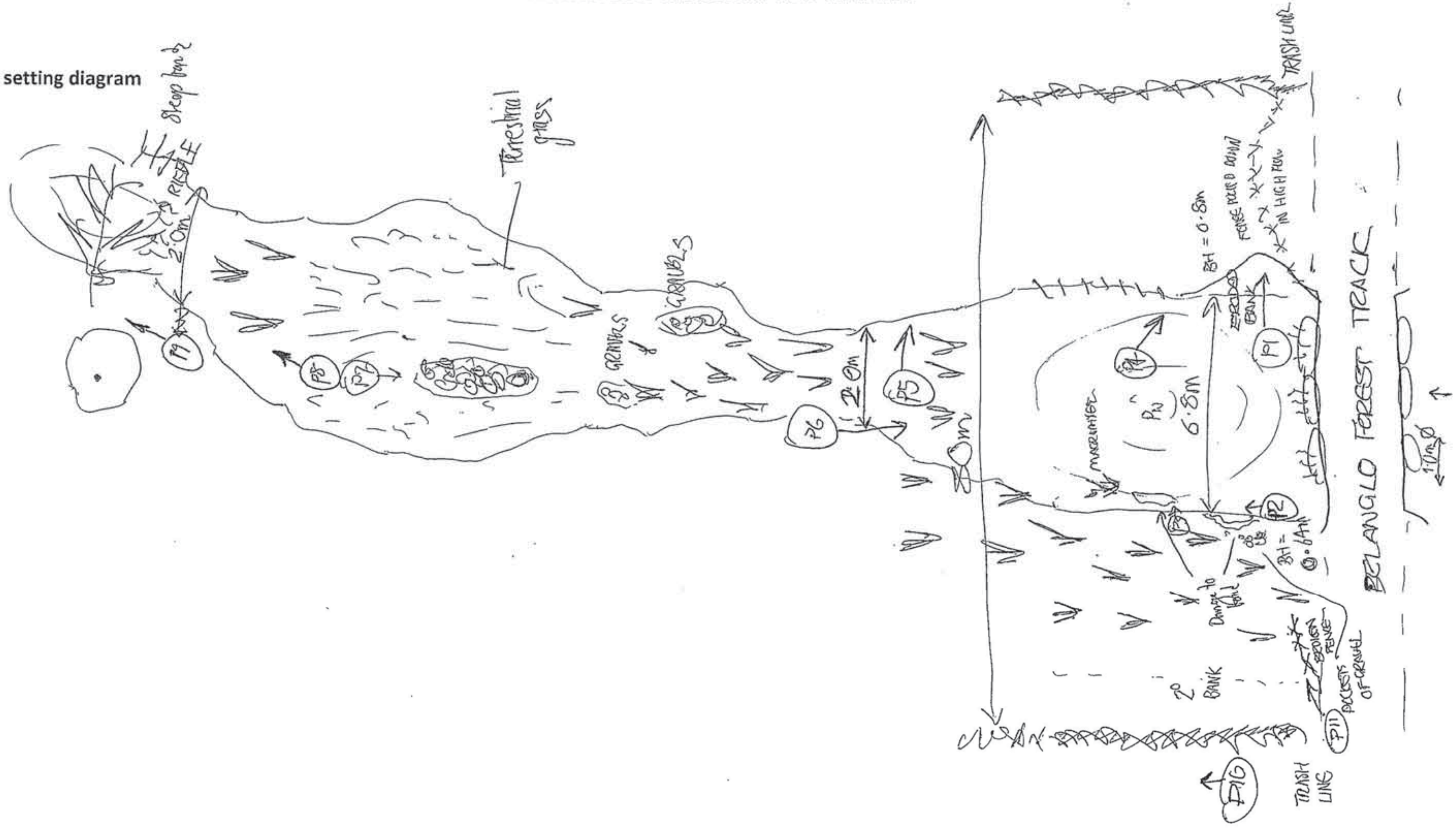
% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐

Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Supply	Deposition	Erosion	Conveying
Packed not armoured	☒	☒	☒	☒

Created 04/08/2011 Dan Evans (after Thompson et al, 2011, *Aq Conserve*, **11**, 373 – 389)

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



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FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ HUME COAL				Date	~~22/01/2013~~ 09/04/14
Surveyor	DE	Reach code: ~~RGS1~~ SWQ06 BELANGLO CREEK			Time	~~10:30~~ 10:15
Drainage channel ☐	Creek X	River ☐	Estuary ☐	Pond ☐	Wetland ☐	Lake ☐
Weather conditions	~~Bright sunshine~~ Drizzle / Cold ~~No rain (6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~		U-S Grid ref	02480942 6176152	D-S grid ref	0248107 6176201
Upstream elevation (m)			Downstream elevation (m)		Slope	

Watercourse attributes

Dimensions Width (m)	0.8m	Max. depth (m)	n/a	Velocity (ms^{-1})	n/a
Shape description		Roughness Height (m)	0.6m	Bank erosion	None
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	50% bread leaf	Bank vegetation (% cover)	50% broad leaf	Bench vegetation (% cover)	Pine trees Box Alder
Organic matter	Logs ☐ Twigs / Leaves ☐ Detritus ☐				

Flow type [H10] Dry

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	☐ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	Low	*Form*	Single X	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops ☐	Riparian strip ☐	Floodplain connectivity	Open	
Floodplain land use	Pine forest (state-owned)			Bank structure (concave, convex, straight, undercut) & slope	Straight 30°	

Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
U-S	☐	☐	☐	20	40	40
D-S	☐	☐	☐	☐	40	60

Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Packed not armoured	Supply ☐	Deposition ☐	Erosion ☐	Conveying X

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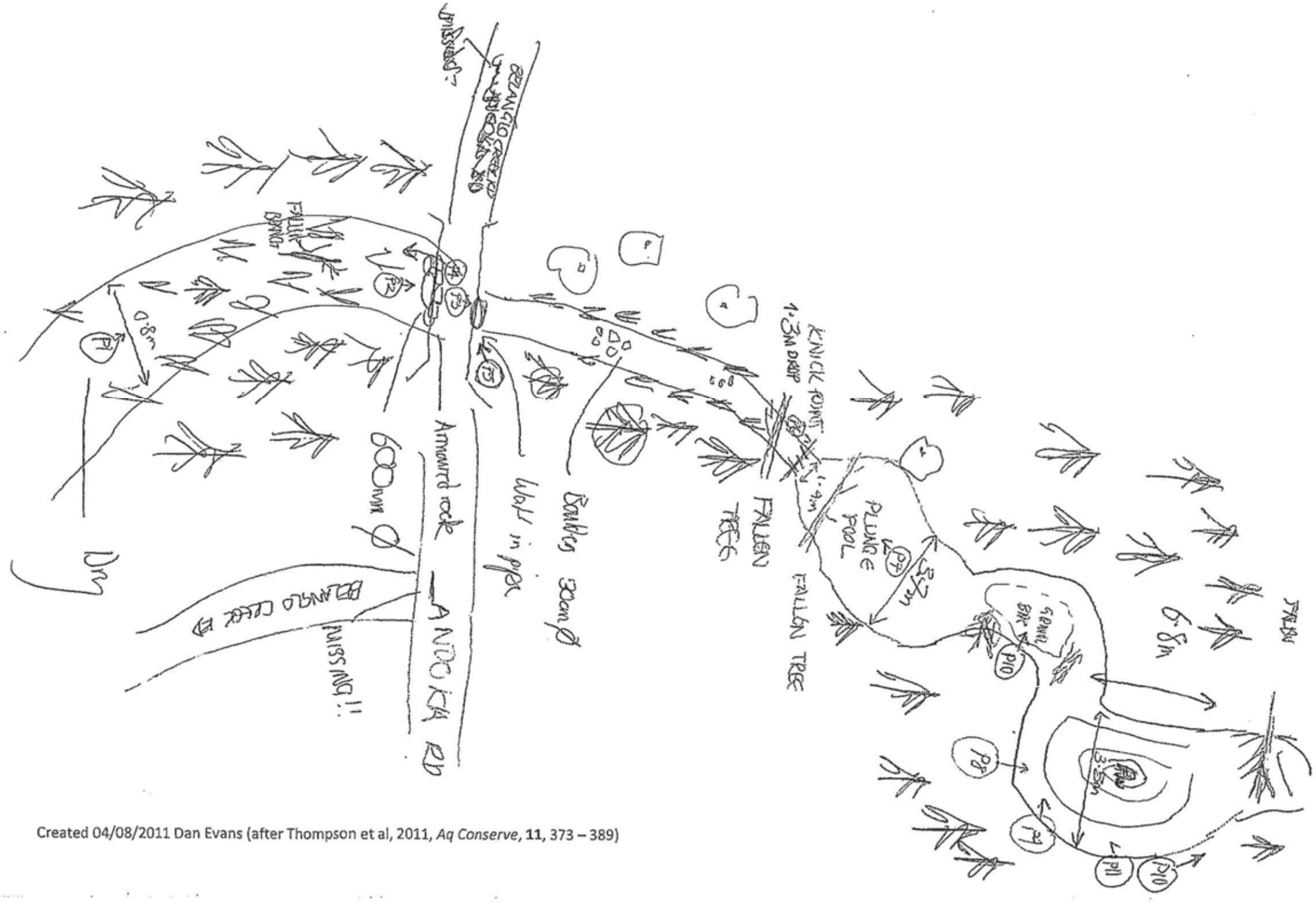
Site setting diagram



FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ HOME COAL	Date	3/3/14	~~22/01/2013~~
Surveyor	DE — Reach code: ~~RG5T~~ SLQ17 WELLS CREEK	Time	1315	~~10:30~~

Drainage channel	Creek	River	Estuary	Pond	Wetland	Lake
☐	X	☐	☐	☐	☐	☐

Weather conditions	~~Bright sunshine No rain (6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~	U-S Grid ref		D-S grid ref	0251245 6173105
Upstream elevation (m)		Downstream elevation (m)			Slope

Watercourse attributes

Dimensions — Width (m)	U/S 5.3	Max. depth (m)	1m	Velocity (ms^{-1})	0
Shape description	RECTANGULAR	Roughness Height (m)	20cm	Bank erosion	90%
Instream vegetation (% cover (emergent, floating, submerged, algae, moss))	10% 50/50 EMERGENT SUBMERGED	Bank vegetation (% cover)	10% GRASS	Bench vegetation (% cover) 100% GRASS LEFT BANK SHRUBS RIGHT BANK	Organic matter NIL — Logs ☐ Twigs / Leaves ☐ Detritus ☐

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	☒ [H6]	☐ [H7]	☐ [H8]	☒ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	STRAIGHT	*Form*	Single ☒	Forked ☐	Braided ☐	Open ☐

Sand bars	Gravel bars	Rock outcrops	Riparian strip	Floodplain connectivity	
☐	☒	☐	☒		HIGHLY CONNECTED

Floodplain land use	GRAZING / STOCK	Bank structure (concave, convex, straight, undercut) & slope	STRAIGHT 90%

Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S 10 D-S 20	U-S 10 D-S 20	U-S [illegible] D-S ☐	U-S 80 D-S 60

		Supply	Deposition	Erosion	Conveying
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	NO ARMOUR MODERATE COMPACTION	☒	☒	☒	☒

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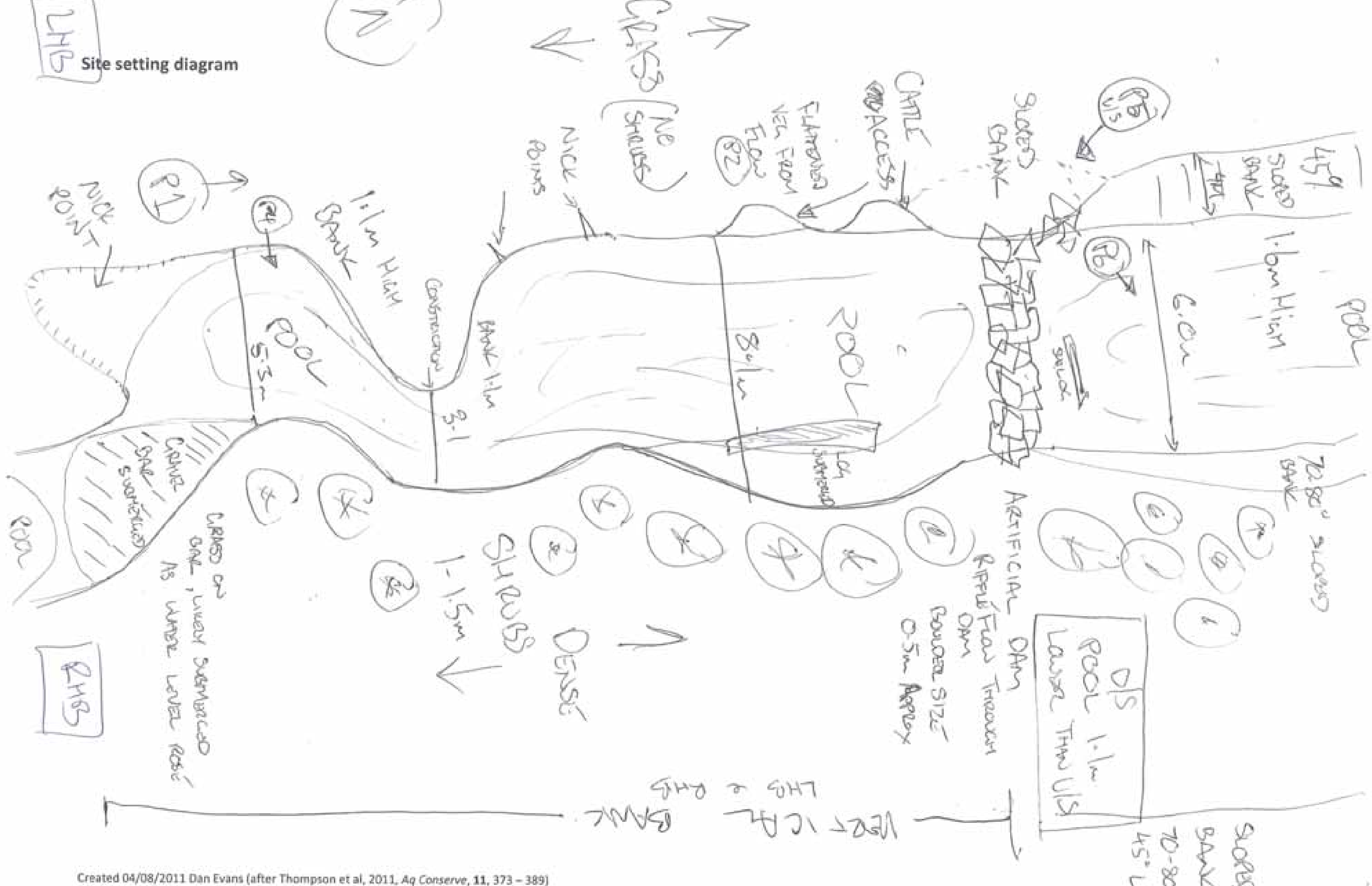
FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



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FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ HUME COAL WHITES CREEK					Date	~~22/01/2013~~ 03/04/2012
Surveyor	DE	Reach code: ~~RGS1~~ SWQ14 – MEDWAY RIVULET TRIBUTARY				Time	~~1030~~ 18:05
Drainage channel ☐	Creek X	River ☐	Estuary ☐	Pond ☐	Wetland ☐	Lake ☐	
Weather conditions	Bright ~~sunshine~~ Cloudy ~~No rain (6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~			U-S Grid ref	0255688 6174073	D-S grid ref (Control)	0255679 6174067
Upstream elevation (m)				Downstream elevation (m)		Slope	

Watercourse attributes

Dimensions Width (m)	4.9 - 6.7	Max. depth (m)	0.8m	Velocity (ms[-1])	0 - 0.4
Shape description	Rectangle	Roughness Height (m)	0.7m	Bank erosion	20% RHB
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	—	Bank vegetation (% cover)	20% grass	Bench vegetation (% cover)	100% trees
Organic matter	Logs ☒ Twigs / Leaves ☒ Detritus ☒				

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☒ [H4]	☒ [H5]	☒ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

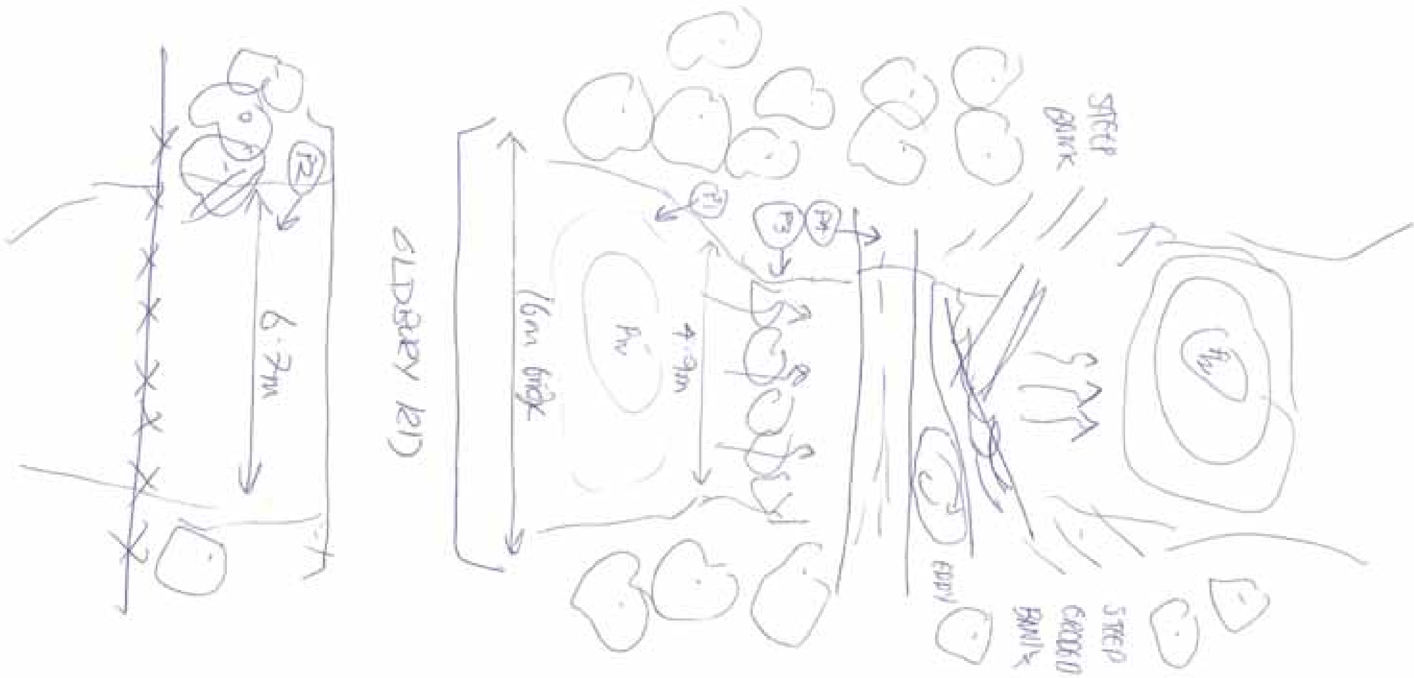
Sinuosity (straight, low, intermediate, high)	LOW	*Form*	Single ☒	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops ☐	Riparian strip ☐	Floodplain connectivity	OPEN U-S LOW D-S	
Floodplain land use	LIVESTOCK + VINYARD U-S LIVESTOCK D-S			Bank structure (concave, convex, straight, undercut) & slope	CONCAVE 10°	

Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S 100 D-S 100
Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	~~NB~~ LOW COMPACTION	Supply ☐	Deposition ☐	Erosion ☐	Conveying ☒	

FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ HUME COAL					Date	~~22/01/2013~~ 03/04/18
Surveyor	DE	Reach code: ~~RGS1~~ SWR16		STONY CREEK		Time	~~10:30~~ 17:30
Drainage channel ☐	Creek X	River ☐	Estuary ☐	Pond ☐		Wetland ☐	Lake ☐
Weather conditions	~~Bright sunshine~~ Cloudy ~~No rain (6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~			~~U-S~~ Grid ref Central	0256362 6177716	D-S grid ref	
Upstream elevation (m)				Downstream elevation (m)		Slope	

Watercourse attributes

Dimensions	Width (m) 5 8m	Max. depth (m)	0.2m	Velocity (ms^{-1})	Ø
Shape description		Roughness Height (m)		Bank erosion	
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])		Bank vegetation (% cover) 80% grass		Bench vegetation (% cover) 100% grass	Organic matter: Logs ☐ Twigs / Leaves ☐ Detritus ☐

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	X [H6]	☐ [H7]	☐ [H8]	X [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	STRAIGHT	*Form*	Single X	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops ☐		Riparian strip ☐	Floodplain connectivity	HIGH
Floodplain land use	LIVESTOCK GRAZING U-S				Bank structure (concave, convex, straight, undercut) & slope	

Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S 30 D-S 5	U-S 70 D-S 95

Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)	Supply	Deposition	Erosion	Conveying
PACKED NOT ARMOURED	☐	☐	X	X

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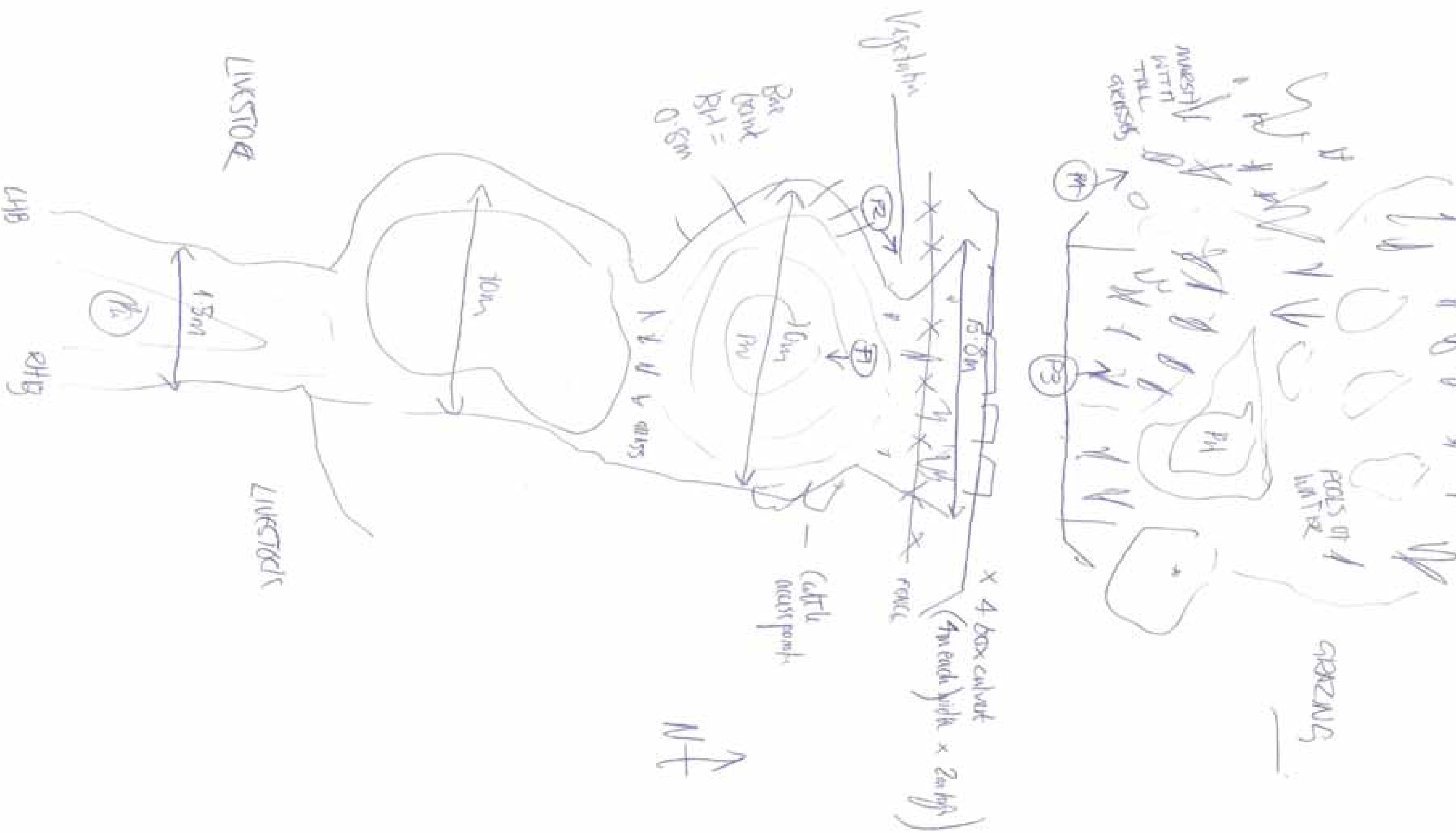
FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Project	~~STRANGERS CREEK REHABILITATION~~ HUME COAL				Date	~~22/01/2013~~ 03/04/2014
Surveyor	DE	Reach code: ~~RGS1~~ SWQ17 – OLDBURY CREEK			Time	~~10:30~~ 17:10
Drainage channel ☐	Creek X	River ☐	Estuary ☐	Pond ☐	Wetland ☐	Lake ☐
Weather conditions	Bright sunshine ~~No rain (6.4mm in previous 48 hours at BoM Castle Hill #67100 site)~~		~~U-S~~ Grid ref Central	0253272 6178269	D-S grid ref	
Upstream elevation (m)			Downstream elevation (m)		Slope	

Watercourse attributes

Dimensions Width (m)	5.6	Max. depth (m)	??	Velocity (ms^{-1})	0
Shape description		Roughness Height (m)	0.5	Bank erosion	
Instream vegetation (% cover [emergent, floating, submerged, algae, moss])	Reeds 40%	Bank vegetation (% cover)	100% grass	Bench vegetation (% cover)	100% GRASS

Organic matter: Logs ☐ Twigs / Leaves ☒ Detritus ☐

Flow type

Smooth surface flow	Broken standing waves	Unbroken standing waves	Chute	Rippled	Scarcely perceptible flow	Upwelling	Free fall	Standing water
☐ [H1]	☐ [H2]	☐ [H3]	☐ [H4]	☐ [H5]	☒ [H6]	☐ [H7]	☐ [H8]	☐ [H9]

Channel Planform

Sinuosity (straight, low, intermediate, high)	STRAIGHT	*Form*	Single ☒	Forked ☐	Braided ☐	Open ☐
Sand bars ☐	Gravel bars ☐	Rock outcrops ☐	Riparian strip ☐	Floodplain connectivity	MEDIUM	
Floodplain land use	ROADS BRIDGE RIPARIAN ~ 30m LIVESTOCK			Bank structure (concave, convex, straight, undercut) & slope	STRAIGHT 80°	

Bed character

% composition	Boulder	Cobble	Gravel	Sand	Fine sand	Silt / clay
UNKNOWN	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐	U-S ☐ D-S ☐

Bed stability (packed & armoured, packed not armoured, mod compaction, low compaction, no packing)		Supply	Deposition	Erosion	Conveying
	??	☐	☐	☐	☒

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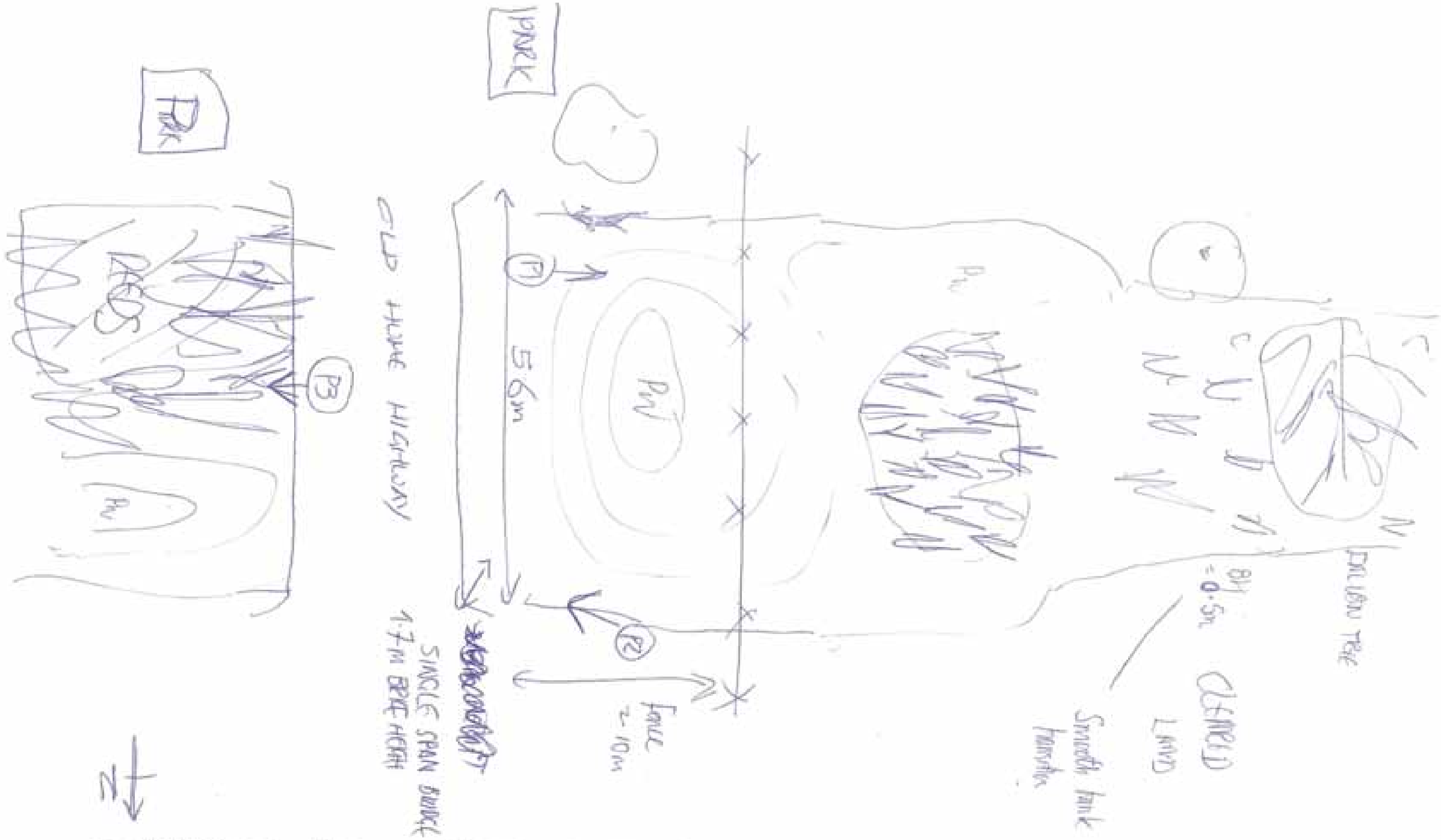
FLUVIAL GEOMORPHOLOGY SITE DESCRIPTION TEMPLATE

Site setting diagram



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