ASHTON COAL
SUBSIDENCE MANAGEMENT PLAN
LONGWALL/MINIWALLS 5 TO 9

AQUATIC ECOLOGY ASPECTS

REPORT PREPARED FOR
ASHTON COAL OPERATIONS PTY LTD

MARINE POLLUTION RESEARCH PTY LTD
AUGUST 2008

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APPENDIX A

1 INTRODUCTION

Ashton Coal Operations Pty Ltd (ACOL) currently operates a combined open cut and underground (longwall) mine in the middle reaches of the Hunter River valley at Camberwell, some 14 km north of Singleton. The open cut mine is located on the north eastern side of the New England Highway and the underground mine is located south west of the highway. The underground mine is bounded by Glennies Creek to the east, the New England Highway to the north and Ravensworth open cut mine to the west (see Figure 1 below). Details of the approved mine project plans are contained in the development consent (DA No 309-11-2001-i) dated 11 October 2002 (DoP 2002).

The underground operation comprises nine panels orientated north-south (Fig 1). Approval for the second workings within the Pikes Gully Seam for longwalls 1 to 4 (LW1 to LW4) was granted by the Department of Primary Industries (DPI) in February 2007, extraction commenced in March 2007, with extraction of LW3 currently underway.

ACOL have undertaken or commissioned a number of studies of Bowmans Creek and its immediate surrounds in order to prepare a proposed mine plan for longwalls/ miniwalls 5 to 9 (LW/MW 5–9) which are partially located under Bowmans Creek (see literature review in Section 3.1 below). These studies have assisted in defining key design parameters for coal extraction methods in the vicinity of Bowmans Creek to achieve minimal environmental impact. The resultant mine plan adopts the use of miniwall extraction beneath Bowmans Creek and the saturated alluvium, with panel extraction widths dependant on depth of cover, and with due consideration to the extent and quality of the saturated alluvium (see Fig 1 below). ACOL are now preparing a Subsidence Management Plan (SMP) for this adopted mine plan to gain approval for mining. Miniwalls 5 to 9 are designed to limit hydraulic connection between the mine and Bowmans Creek and its associated alluvium. The panels are narrowed directly under the creek and alluvium but are mined full width elsewhere. The width of Longwall 9 is limited by proximity to the lease boundary.

Marine Pollution Research Pty Ltd (MPR) has been commissioned to provide an aquatic ecology assessment report to be submitted as part of the SMP. The main objectives of this report are to:

(i) Assess what possible impacts the predicted subsidence may have on aquatic ecology within Bowmans Creek,
(ii) Provide mitigation measures where appropriate.
(iii) Provide details of an aquatic ecology monitoring program to assess possible subsidence impacts.

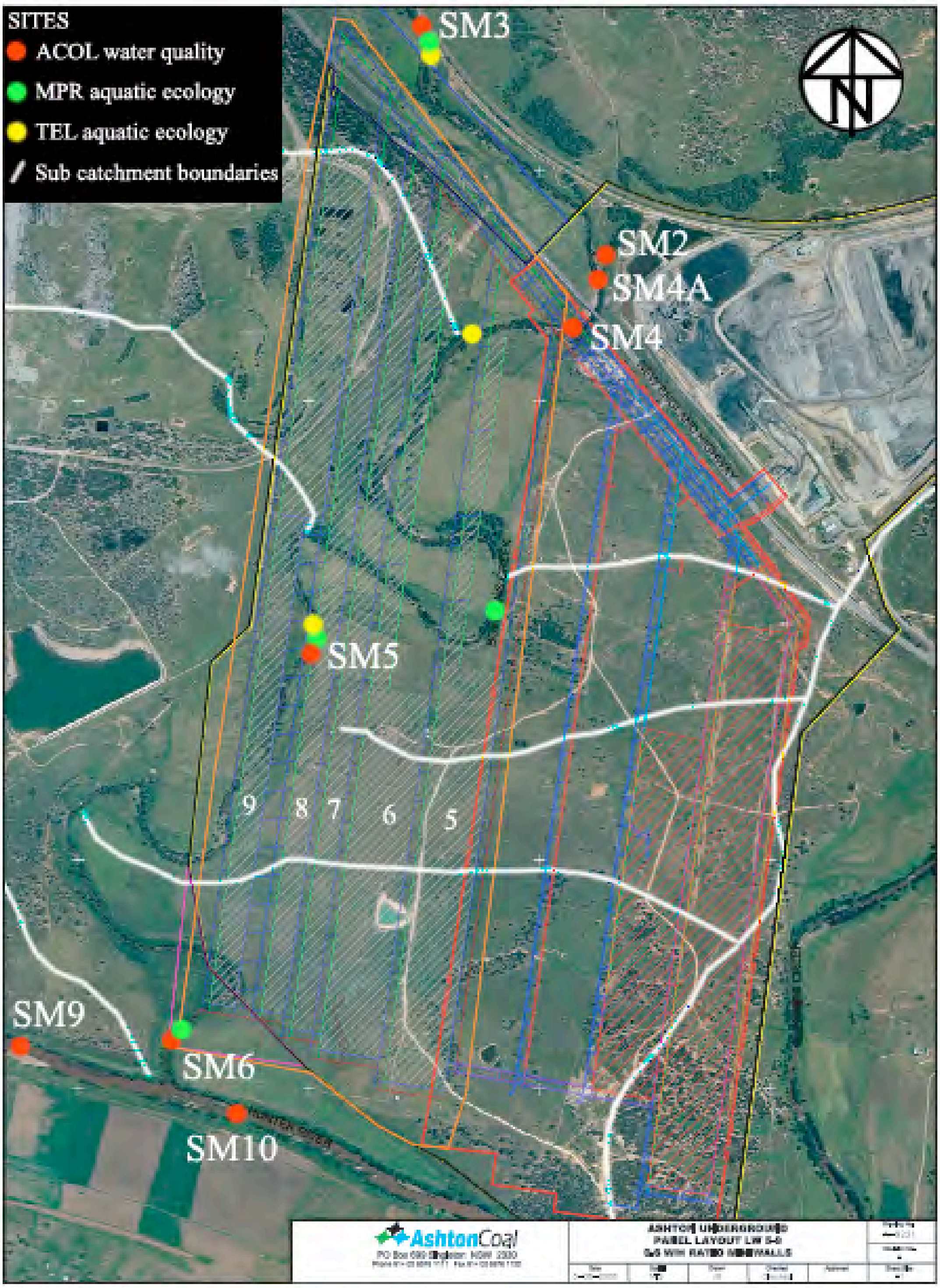

Fig 1 Site layout showing proposed longwall panels and existing aquatic and water quality monitoring sites on Bowmans and Bettys Creeks.

(Note that the mine plan depicted in Fig1 has been modified since production of Fig 1 by the shortening of MW8 and 9 at their southern ends to remain within the original approved mine footprint- see SMP Ashton Mineplan Longwalls and Miniwalls 5-9 Drawing A-0000, Rev A dated 7-10-08).

1.1 Bowmans Creek Site Attributes

Bowmans Creek is about 35 kilometres (km) long and the headwaters are located in the Little Brothers Range, at an elevation of about 650m Australian Height Datum (AHD). It has a catchment area of approximately 265 km^2. The lower section of Bowmans Creek between the New England Highway and the Hunter River confluence is 6 km long and approximately 4.5km of this section is located within the ACOL Mining Lease overlying LW/MW 5-9. Patterson Britton & Partners (PBP 2001) concluded that Bowmans Creek experiences variable flow and that it is generally perennial, although flow reportedly ceases during severe droughts.

2 STUDY METHODS

In order to assess the possible impact on aquatic ecology of the predicted subsidence, the following tasks were undertaken:

- A review of literature regarding the potential for long-wall related mining impacts on Bowmans Creek structure and function.
- A review of all aquatic ecology monitoring conducted in Bowmans Creek to date to summarise creek aquatic ecology attributes.
- A field walkover inspection of Bowmans Creek and tributaries within the mine lease area, to ascertain aquatic habitat conditions and fish passage attributes post 2006 floods.
- An update literature review of regional aquatic ecology information to assess the potential for threatened and protected species to utilise Bowmans Creek.

The field investigations were undertaken by MPR staff over two days (1 to 2 July 2008) during a period of high base flow (around 37 ML/day). The study area extended the full length of Bowmans Creek between the New England Highway to the downstream limit of the lease area (400m above the Hunter River confluence). Channel morphology maps (ERM 2006a) and subsidence prediction maps (SCT 2008) were used as aids for determining the areas of potential concern for aquatic ecosystems. Miniwall and longwall footprints were overlaid onto the ERM maps so as to locate areas of potential concern.

Field notes and observations were made throughout the study area, with particular attention paid to the aforementioned possible impact zones. Creek and channel riparian areas were inspected for attributes such as bank stability, bank undercutting, closeness of riparian trees to water, recently fallen trees, instream logs, pool retention devices, locations of shallow and deeper pool areas, and fish passage potential.

All tributaries entering the creek within the study area were inspected from their confluences with Bowmans to the upper limits of creek structure, as indicated by channel incision, water availability or vegetation. Photographic records were made along the study area creek-line and tributaries, to support field notes and observations

3 RESULTS

3.1 Literature Review

The literature review has been split into two sections. Section 3.1.1 documents the studies undertaken on behalf of Ashton Coal to assess and predict likely impacts on Bowmans Creek structure and function arising from the proposed underground mining, and Section 3.1.2 documents the aquatic ecology and water quality studies that have been undertaken in Bowmans Creek.

3.1.1 Bowmans Creek Underground Mining Impact Studies

The Ashton Coal Project Environmental Impact Statement (EIS) prepared by HLA-Envirosciences Pty Ltd (HLA 2001) included a proposal to divert Bowmans Creek from immediately below the New England Highway, around proposed underground mining operations. As part of that proposal, a geomorphology and hydraulic assessment of Bowmans Creek was prepared by Patterson Britton and Partners Pty Ltd (PBP 2001) as a basis for the proposed creek rehabilitation works. This report provided a detailed description of creek structure and function and summarised the relationship between surface water attributes and local alluvial and Permian groundwater resources. A summary of the main finding of the PBP (2001) report was included in ERM (2006a) as discussed below.

Following DPI approval of the final modified mining plan (which no longer included Bowmans Creek diversion), conditional approval for the mining under Bowmans Creek was granted. Conditions of consent included additional subsidence and groundwater monitoring studies, to be used to develop a mine plan which would meet minimum subsidence and groundwater connectivity requirements (to be determined in consultation with relevant government departments). To that end there have been a number of studies commissioned by ACOL to address these questions and to develop the SMP:

- Environmental Resources Management Australia Pty Ltd (ERM) provided a detailed geomorphology report for Bowmans Creek (ERM 2006a) based on survey and field work undertaken in the first half of 2006. The report was commissioned to address relevant consent conditions, namely to establish a geomorphology baseline for ongoing monitoring during and after the potential mining beneath Bowmans Creek. This report provides a baseline of creek geomorphology against which the impacts of the 2007 floods can be assessed and is currently being reviewed and updated to identify any major morphology changes following flooding in June 2007.
- ERM (2006b) prepared a baseline flora and fauna report for Bowmans Creek which provides a pre-mining assessment of the riparian and aquatic habitat along Bowmans Creek, prepared in accordance with the Ashton Coal Flora and Fauna Management Plan (Part 2 prepared in August, 2005). It provides the results of riparian flora and fauna habitat studies undertaken in Autumn 2005 and 2006 and the results of aquatic ecology surveys undertaken in December 2005 and May/June 2006 (see Section 3.1.2 below for more details of the aquatic ecology surveys). As for the geomorphology study, the riparian flora study provides a baseline against which the impacts of the 2007 floods can be assessed.
- SCT Operations Pty Ltd (SCT) modelled and prepared initial subsidence estimates for the adopted mine plan for LW/MW 5-9 using (*inter alia*) the results of subsidence monitoring for LW1 and LW2 (see Table 1 below). Overburden depth ranges from 85 to 190 m within the SMP area with 100 to 190 m over the longwall panels. The seam thickness ranges from 2.2 to 3.2 m but is generally 2.4 m thick. The maximum mining height adopted for the proposed mine plan is 2.5 m.
- SCT (2008) concluded that the proposed miniwall design would reduce subsidence to sufficiently low levels (less than 350mm; generally less than 200mm of vertical subsidence under Bowmans Creek - see Table 1), and that a substantially intact barrier of sound rock would remain between the base of the alluvium and underground goaf so as to prevent significant loss of water from the creek and saturated alluvium.
- At the southern ends of Longwalls 5 and 6 where 215m wide panels are proposed, the maximum subsidence is expected to be less than 1600mm and most likely in the range 1.2-1.3m. At the northern end of Longwall 9 the maximum subsidence is expected to be less than 1200mm and most likely in the range 0.5-1.0m. Mining subsidence is expected to cause cracking in the ground surface above Longwalls 5 and 6, and there may be localised ponding areas following rain in flatter areas over Longwalls 5 and 6.
- Aquaterra (2008) provided the results of groundwater modelling and monitoring studies undertaken for the Ashton underground mine. The report summarises data

collected for the original EIS, monitoring data collected for LW1 and LW2 and additional Bowmans Creek alluvium data collected in 2007. The main aquifers in the Mining Lease are the coal seams (with permeability developed in cleat fractures), and unconsolidated aquifers within the alluvium associated with the Hunter River and Bowmans Creek. Glennies Creek and its alluvial floodplain are located to the east of the underground mine, and do not overlap the mining area. Groundwater studies undertaken for the project show that creek flow is governed by upstream rainfall with minimal contribution from surrounding saline alluvium.

- The Bowmans Creek alluvium merges with colluvium along the flanks of its floodplain, and has an abrupt boundary with Hunter River alluvium at the southern end of the valley. The bed of Bowmans Creek is incised directly into bedrock (Permian coal measures) in a small number of locations, and is overlain by at least 4 metres of saturated alluvium in other places.
- There are three outcrops of Permian coal measures in the creek-bed of Bowmans Creek. Two of these (the upper and lower rock bars) are located outside the area of longwall mining and the middle rock bar section is located under the eastern edge of miniwall 9 (coinciding with the weir pool for the DWE stream gauging station). The upper outcrop is associated with elevated saline groundwater seepage sustained by seepage from the Permian rock outcropping beside and/or beneath the pool (see also Section 3.3.1 below).

Table 1
Predicted Subsidence Impacts

Longwall	Panel Width (m)	Overburden Depth (m)	Maximum Subsidence (mm)
LW5	216	110-155	1600
MW5	60	100-125	200
LW6	216	130-160	1600
MW6	70	115-150	350
MW7	81	130-170	350
MW8	87	140-175	350
MW9	93	160-190	200
LW9	141	140-180	1200

Data from STC (2008)

3.1.2 Bowmans Creek Aquatic Ecology and Water Quality Studies

With respect to aquatic ecological assessments within the Bowmans Creek study area and locality, a number of studies have been conducted to date. These studies are summarised below and the results of the studies in terms of summarising the aquatic ecology of the study area are provided where appropriate in the remaining sub-sections of Section 3:

- In 2001 Marine Pollution Research Pty Ltd (MPR) undertook a qualitative assessment of aquatic ecology (fish habitat) aspects for the Ashton Coal Project EIS (HLA 2001). The study incorporated a review of existing literature and field studies of fish passage potential in Bowmans and Glennies Creeks.
- ACOL has been undertaking monthly 'whole of mine' water quality monitoring of sites in Bowmans Creek, Bettys Creek, Glennies Creek and the Hunter River since September 2004. Water quality parameters include pH, electrical conductivity (EC), alkalinity (total hardness as mg/L CaCO3), total dissolved solids (TDS), total suspended solids (TSS) and oil & grease.
- ERM (2006b) summarised initial aquatic ecology monitoring results for Ashton Mine for the spring 2005 to autumn 2006 period. The monitoring was undertaken by The Ecology Lab (TEL) and the full monitoring reports are contained as appendices to the ERM (2006) report (TEL 2006a, 2006b). Monitoring included macroinvertebrate, fish (using electro-fishing) and water quality sampling. The TEL reports also provided an updated literature review for aquatic ecosystems in Bowmans Creek and confirmed that Bowmans Creek supported native fish populations (see Section 3.4.2 below).
- MPR undertook aquatic ecology monitoring as part of the EMP for Liddell Open Cut mine over the same survey period as the TEL studies (MPR 2005, 2007). Monitoring studies included macroinvertebrate, fish and water quality sampling from three sites located upstream of the Ashton lease area on Bowmans Creek. This study confirmed both the intermittent nature of surface flow and the persistence of shallow sub-surface seepage flow in Bowmans Creek.
- MPR have been undertaking bi-annual aquatic ecology monitoring studies within Bowmans Creek on behalf of ACOL, from 2007 onwards. To date there have been three ‘during mining’ aquatic ecology monitoring surveys conducted; in autumn and spring 2007 and autumn 2008 (MPR 2007, 2008a, 2008b).
- Walkover surveys of Bowmans Creek and tributaries within the study area were undertaken in July 2008 for the present study. For the July 2008 field inspections surface flow was present throughout the whole creek length within the study area (stream flow 37ML/day).

3.2 Aquatic Habitat Assessment

STC (2008) describe Bowmans Creek within the study area as follows: "The stream channel comprises a series of pools retained behind gravel bars. There are conglomerate rock exposures in the banks at several locations, typically near sharp changes in direction, but along most of its length, the channel is cut into the alluvium and the banks comprise sand, silt, and clay material. There are two ponded sections of a previous stream channel that have become disconnected from the main channel and several tributaries draining off the surrounding countryside".

3.2.1 Bowmans Creek Geomorphology

The elevation of the Bowmans Creek channel bed at the upper limit of the lease boundary is about 62m and the elevation at the confluence with the Hunter River is about 49m. PBP (2001) noted that downstream bed-load transport of gravels and cobbles occurs upstream of the New England Highway bridge and that for 5 of the 6 km between the bridge and the confluence with the Hunter River, the creek expands into a much wider valley formed by Pleistocene alluvial terraces and coarse gravel/cobble riffles. Contemporary gravels thin out and become sandier towards the downstream limit of present day progradation of gravels, occurring near a bedrock control point about 1 km upstream of the confluence. Beyond this point a steep scour ramp has been created within the southern-most 300 to 400 metres, in response to the much lower bed level of the Hunter River relative to Bowmans Creek.

Overall, with downstream progression, the channel bed grades from cobble lining with a gravely silty substrate, to a silty sand substrate. Bed slope varies between 0.01% to 0.8% with a mean slope of 0.23% and the Bowmans Creek floodplain width varies from 700 to 1300 metres (ERM 2006a).

Within the study area, the channel of Bowmans Creek is generally incised up to eight metres below the surrounding alluvial flats and up to twelve metres below the bank of the Hunter River (ERM 2006a). The channel banks are alternately steep, gently sloping and terraced, with no clear pattern to channel form evident within the study area.

Whilst the three small billabong formations some 1 to 1.5 km downstream of the Highway are indicative of channel migration in the past, ERM (2006a) concluded that there had been very little channel migration since 1983 based on a review of historical aerial photography. The 2006 geomorphology study indicated that there may have been some recent lateral migration in some reaches although most reach profiles appeared to be constrained on one bank and therefore only exhibited terracing on the opposite bank.

3.2.2 Bowmans Creek Riparian Corridor

The riparian vegetation corridor is characterised by *Casuarina* woodland with small sections of River Red Gum (*Eucalyptus camaldulensis*) open forest (ERM 2006b). The River Red Gum population in the Hunter Catchment is listed as an endangered population under the *Threatened Species Conservation Act 1995* (TSC Act), and is confined to the riparian corridor outside of the mining lease area approximately 1km upstream from the Hunter River confluence.

The area adjoining the riparian vegetation is characterised by continually grazed pasture and relatively isolated patches of open woodland. Surrounding land uses consist of agriculture with mining activities occurring immediately to the north of the New England Highway and to the west of Bowmans Creek.

All studies, including the July 2008 walkover, noted that cattle have access to the creek along most of the study area creek banks, and riparian cattle tracks (parallel to the creek-line) were present along many sections, contributing to minor terracing on steep riparian slopes and facilitating active erosion of the banks.

Some steep sided banks were noted to be unstable, as they are typically in areas with limited riparian vegetation with coverage often consisting of grasses, weeds, or well spaced riparian trees. Whilst active bank erosion was visible in some areas, annual erosion rates appear to be relatively low to moderate (Amanda Kerr *pers com*, September 2008). Submerged bank undercutting at the base of steep sided banks was common along most of the study area creek length.

Riparian trees, where present, generally comprised a single line running parallel to the creek within 5m of the water edge. The most common riparian trees were River She-Oak (*Casuarina cunninghamia*) and the introduced Willow (*Salix babylonica*).

3.2.3 June 2007 Flood Impacts

With regard to impacts on creek geomorphology arising from the June 2007 flood, recent bank erosion was evident at all four survey sites following the June 2007 floods (photos 1, 2 & 3).

During the autumn 2007 sampling survey (two weeks after the flood), MPR noted peak flood levels (by observations of debris deposition in trees) to be approximately 5m above dry weather creek levels at upstream sites and 10-15m higher at downstream sites near the Hunter

River confluence. At all sampling sites, riparian environments had been subjected to deposition by sediment and areas of minor bank collapse were common along most creek sections inspected. Groundcover had been severely scoured at the downstream sites (see photo 1). Fallen riparian trees were present all along the study area bank and at locations where they had fallen in, there was obvious bank collapse (photo 2). Instream logs from fallen riparian trees were present throughout the whole creek length, though not overly abundant.

Photo 1: Riparian and instream scouring at the downstream aquatic ecology monitoring site on Bowmans Creek.

Photo 2: Flood impacts at a mid-stream aquatic ecology monitoring site, autumn 2007

3.2.4 Bowmans Creek Aquatic Habitats

The number of pools in the Bowmans Creek study area varies with flow conditions. In the 2006 geomorphology study, undertaken during low flow conditions, there were 44 separate pools identified (ERM 2006a). For the June 2008 walkover inspection there was moderate surface flow and there were around 24 pools within the study area, ranging in length from 10m to 500m. Most pools are wide (10m) and shallow (to 1m deep) with some deeper pools (to 2.5m deep). Several pools (the top pool and the weir pool) are located within exposed basement rock, although neither are rock-bar constrained. Most of the pools are connected by cobble riffle zones and the remaining pools are structured as "chain-of-ponds" type (see Rutherford et al 2000), with more or less permanent pools (dependent on depth) separated by bars of sediment stabilised with vegetation. Many riffle or narrow pool sections are bordered by exposed cobble beds on one side with steep sided banks on the other. Pools at the lower end of the study area are steep sided on both sides as the creek erodes down to the level of the Hunter River.

MPR (2001) concluded that ‘no major barriers to fish migration were found within the Bowmans Creek study area'. The small DLWC gauging weir (located approximately 2.6km downstream from the New England Highway) was deemed to potentially inhibit fish passage during drought conditions, and there were some minor impoundments noted upstream of New England Highway behind road crossings, however all structures were considered suitable for fish passage during most flow conditions. Subsequent surveys confirm that this still remains the case (see for example MPR 2008a.b).

Observations of water availability during 2006 drought periods noted minimal or zero surface water available in the upper reaches of the study area (i.e., for about 2.5km of creek immediately downstream of the New England Highway). From this point (at around Pool 21 in ERM 2006a), the surface water flow then resumed downstream to the Hunter River.

The combined TEL and MPR 2005 to 2008 monitoring studies indicate that during dry times when pool water levels are low, the Bowmans Creek exposed channel is colonised by terrestrial species, such as spike rushes (*Juncus sp*), and Casuarinas. Grasses and weeds rapidly colonise previously wet bank areas or newly settled sediment deposits. The newly established in-stream vegetated areas have the potential to form islands or extended terrestrial banks, if flow conditions remain low for sufficient time for trees to develop to a mature enough stage, and can influence the localised formations of flow channels during and following subsequent high flow periods.

For the July 2008 walkover inspection and for most of the earlier monitoring studies, Cumbungi (*Typha sp*) stands were the most commonly encountered emergent macrophytes, with Curly Pondweed (*Potamogeton crispus*) and Watermilfoil (*Myriophyllum sp*) the most common submerged macrophytes. An additional six submerged and emergent macrophyte species have been recorded over all Bowmans Creek surveys, they are; Clasped Pondweed (*Potamogeton perfoliatus*), Sago Pondweed (*Stuckenia pectinata*), Slender Knotweed (*Persicaria decipens*), Maundia (*Maundia triglochinoides*), Common Reed (*Phragmites australis*) and the introduced Watercress (*Nasturtium officinale*).

Sections of Bowmans Creek that will be potentially impacted by mining-induced subsidence have been divided into four zones or groupings of continuous creek sections overlying miniwalls. Note however that Zone 2 comprises a split zone of two areas overlying MW5:

Zone 1

One of the two zones where up to 350 mm of maximum vertical subsidence is predicted. Zone 1 is located from around 600m to 1.1km downstream of the New England Highway. This section overlies MW6 and 7 at a bend in the creek before the ox-bow. The area consists of a series of broad, flat bottomed pools connected by constricted flow channels. Pool lengths range between 100m and 300m, and are generally straight with few backwaters or zones that would provide refuge in high flows. At least two retaining fences exist along sections of the western bank, in some parts actively stabilising the bank edge. Bank gradients are generally shallow with few steep areas along pool edges. Pool depths at the time of field inspection averaged 1m, with 1.5m maximum depths. Riffle section water depths averaged 0.3m depth. There were two small pools located within this zone during the ponding survey conducted by Pegasus Technical Pty Ltd (ERM 2006a) in March 2006 (ponds 8 and 9).

Zone 2

Zone 2 is located on the north (upstream) and south (downstream) bends of the ox-bow where MW5 intersects Bowmans Creek, over a section of approximately 50m in length on each bend. The upstream section is a meandering creek channel consisting of a series of short narrow pools 10 to 20m in length, separated by shallow constricted riffle sections. ERM (2006a) recorded two isolated pools overlapping into the area during March 2006 (ponds 11 and 12). Riparian banks are less than 1m high with a series of three man-made dams bordering the creekline to the north within a former creek bed. During the walkover survey (1 July 2008) seepage was noted along the bank edges adjacent to the dams).

Photo 3: Looking down from top of eastern bank at eroded bank section (July 2008).

The downstream creek section overlying MW5 is located on the southern bend of the ox-bow, also a section of approximately 50m in length. The eastern (outside) bank is very steep and approximately 5m high, eroded and with undercut banks (see photo 3 above).

The inside bank is more depositional with lower gradient, and consists of a grassed cobble bed. A continuous pool existed throughout the southern bend of Zone 2 overlying MW5 in July 2008 and during the survey in March 2006 (pond 16).

Zone 3

Zone 3 is the second of the two zones where up to 350 mm of maximum subsidence is predicted. This zone extends across MW6-9 in the straight creek section downstream of the southern ox-bow bend, then around the bend where the DLWC weir is located, before heading due south toward the Hunter River. At the upstream limits overlying MW6, the creek is narrow with short pool sections (to 1.5m deep) all connected by shallow, constricted cobble-riffle zones that alternate flow routes within the channel between consecutive pool sequences. In March 2006 there was one small pool (pond 20), and the start of a long pool (pond 21) over MW6. The banks bordering the channel on the western bank are steep with riparian trees abutting the bank edge, some of which are in the process of falling into the stream.

In July 2008 a single narrow, straight pool extended for a distance of approximately 500m from the upstream limits overlying MW7 to the bend just upstream from the DWE stream gauge and weir (overlying MW9). Banks on both sides of the creek are relatively similar and vary between 2 and 3m height, with sections of bank showing signs of recent slumping. Average pool depth along the pool section is around 1m, with maximum depths to 1.5-2m. In March 2006 ERM (2006a) also recorded a single pool for the entire length overlying MW7 and MW8 (pond 21).

There is a short cobble riffle section on the bend of the creek bordered by large concrete blocks and a retaining fence on the western bank. The riffle coincides with the start of the creek section overlying MW9, which turns due south and extends into a 1m deep pool (pond 22 in ERM 2006a) which terminates at the weir. There are a number of bedrock outcrops through this creek section that could act as fish passage barriers during periods of low flows. The creek channel immediately below the weir contains a number of boulders, with bedrock present in-stream and on the western bank. The pool extends for around 150m, near the downstream limit overlying MW9 and has a depth of 1.5 to 2m (pond 24 in ERM 2006a).

The next section of creek is situated over the proposed chain pillars between miniwalls 8 and 9, for a distance of around 500m. The creek channel through this section is narrow (to 5m width) and relatively deep (to 2m), with very steep banks, mostly along the eastern edges. The western edge of MW8 borders the eastern bank of MPR aquatic ecology monitoring site BCLW7 (see Figure 1). Four ponds (ponds 24 to 27) were noted in March 2006 in the creek sections overlying the chain pillars between MW8 and 9 (ERM 2006a).

MW9 underlies the next downstream section of creek for approximately 180m. The creek channel through this section is similar to that encountered immediately upstream (BLCW7) and consists of a narrow channel, with steep eroding banks on the eastern pool edges. There were two pools separated by a riffle section, with the lower pool widening and the bank becoming steep along the western side. There were three ponds (ponds 28 to 30) in this creek section overlying MW9 in March 2006 (ERM 2006a).

Zone 4

The southernmost limit of MW9 underlying Bowmans Creek is located around 400m upstream from the Hunter River confluence. The creek channel throughout the impact area is uniform, consisting of a deeply incised channel 10-15m below the surrounding floodplain. The channel basin is relatively flat averaging 0.8 to 1m deep throughout the section, with an exposed cobble bar on the inside corner of the creek bend. Riparian banks are steep (~45°) and vegetated by grasses and weeds, with scattered riparian Casuarinas, Eucalypts and Willows. Bank undercutting is present along the outside edge.

3.2.5 Groundwater Dependent Ecosystems

Both the flora and fauna report (ERM 2008) and this aquatic report considered the occurrence of Groundwater Dependent Ecosystems (GDEs) in the study area. Potential GDEs of the study area were identified using the eight-step rapid assessment (DLWC 2002) and it was concluded that there are no known or likely wetland, terrestrial or aquifer/cave ecosystem GDEs in the study area. Assessment of riparian vegetation did not indicate any specific riparian plant communities, which could be considered groundwater dependent.

Aquaterra (2008) report that there is a small saline baseflow component from the saturated alluvials of Bowmans Creek to the creek, thus it is assumed that there is a hyporheic zone between the saturated alluvials and the creek bed. Given the lateral extent of saturated alluvials (as indicted on Aquaterra 2008, Fig 19), it is also concluded that there are probably some parafluvial zones in the creek.

With regard to the degree of dependency of possible aquatic or hyporheic GDEs to baseflow in the Bowmans Creek study area the following factors are relevant:

- The creek is perennial with sub-surface creek sediment saturation controlled for the majority of the time by surface water rather than upwelling groundwater.
- Due to there being some surface flow most of the time, riparian and edge emergent vegetation plus riffle zone fauna are more dependent on fluctuating surface water levels than on groundwater upwelling, and there is insufficient groundwater upwelling to make any significant impact on surface water levels except under prolonged drought periods.
- When there is no surface water during prolonged drought conditions such that the baseflow may start to become significant, there are no riffles, there are only small disconnected pools remaining and the pool edge vegetation will have died off. At that time salinity of the baseflow also becomes significant, thus limiting the remaining aquatic macroinvertebrate assemblages that could reside in the pools and limiting the microinvertebrate fauna that could reside in the hyporheic zone.

It is concluded that possible aquatic and hyporheic GDEs in Bowmans Creek within the study area would not be considered significantly dependent on baseflow groundwater.

3.2.6 Sub-catchment Tributaries

There are four main sub-catchments draining across the mining lease to Bowmans Creek from the east (Figure 1). Sub-catchment tributaries within the mine lease may generally be characterised as shallow, grassed drainage depressions, with some being subject to gully erosion, particularly as they near Bowmans Creek. All of the tributaries would have intermittent surface flow for short periods after rainfall (i.e., they are ephemeral), with some volume of runoff being retained in in-line stock watering dams.

Most of the site dams (in-line and elsewhere) allow direct stock access and appear to have high suspended sediments. It is assumed that dam water may also have high nutrient concentrations. Very few dams had riparian cover or contained aquatic vegetation, and off-line dams generally collected drainage from extensive areas of open pasture. It is concluded that these semi-permanent to permanent standing water bodies overlying the ACOL underground mine offer little in the way aquatic habitat or favourable water quality for aquatic ecosystems.

The only tributary with any defined channel structure was a small tributary located on the western bank above proposed MW7 and 8 (adjacent Zone 1 as described in Section 3.2.4). Even then, this tributary consisted mostly of a shallow drainage line with intermittently occurring ponds, containing a combination of macrophytes (Cumbungi, Water Ribbons (*Triglochin sp.*) and Common Reed (*Phragmites australis*); suggesting at least a semi-permanent (and probably shallow submerged) water supply.

The presence of submerged terrestrial vegetation in inundated shallow depressions and in holes within the tributary creek lines observed during the July 2008 field inspection indicates that these ponds most probably dry out rapidly following rainfall.

3.3 Seasonal Water Quality

The ecological value of the Bowmans Creek study area aquatic habitats is linked to both habitat availability and condition (summarised in Sections 3.1 and 3.2 above) and to the water quality attributes of the ponded waters. In this section, available water quality data is reviewed. Section 3.3.1 considers the 'whole of mine' monthly water quality collected by ACOL over the mining period and Section 3.3.2 considers the water quality data collected by the aquatic ecology teams over the period of aquatic ecology sampling (2005 onwards). TEL and MPR sampled water quality in spring 2005, autumn 2006, and autumn 2007 to autumn 2008 at four sites in the study area.

3.3.1 ACOL Water Quality Data

With regard to understanding the various contributions of natural and human contributions to water quality in Bowmans Creek, ACOL have established a network of water quality monitoring stations (see Figure 1) most of which have been sampled since September 2004. In terms of Bowmans Creek inputs and outputs the following monitoring sites are relevant:

- Water quality monitoring sites above New England Highway are located on Bettys Creek (SM1 above all Ashton mining activities and SM2 above the confluence with Bowmans Creek) and in Bowmans Creek (SM3 upstream and SM4A downstream of the Bettys Creek Confluence).
- There are three sites in Bowmans Creek below the New England Highway (SM4 to SM6). SM4 and SM6 are located upstream and downstream of the proposed underground mining footprint and SM5 is located about mid way at the weir pool.
- There are two sites in the Hunter River, SM9 upstream and SM10 downstream of the Bowmans Creek confluence.

Full results of this water quality monitoring are provided in the ACOL Annual Environmental Monitoring Reports (AEMRs) and are not reproduced for this report. However, summary statistical results relevant to an understanding of aquatic ecology are provided in Table 2 below with graphed results contained in Appendix A.

Table 2 provides summary statistics for five of the six ACOL water quality parameters from all the relevant Bowmans/Bettys Creek/Hunter River sites. The sixth parameter (oil and grease) was excluded as all data were reported as "less than detection limit".

Over the 42 months of sampling, the two up-stream Bettys Creek sites SM1 and SM2 were predominantly dry and only showed sufficient water levels for sampling following the June 2007 flood. Since then they have only been sampled three times, also when there was sufficient water for sampling. The additional Bowmans Creek site SM4A was established in March 2007 to aid in determining the cause/source of the water quality anomalies at Site SM4 (see below). The upstream Bowmans Creek site SM3 was sampled over the complete sampling period, but was dry over the period 13 March to 7 June 2007. Whilst all summary results are shown in Table 2, the results from Bowmans Creek sites SM1 and SM2 (with only three sample results each) were excluded from this analysis.

Table 2
ACOL Life of Mine Monthly Water Quality Data
Summary Statistics Sept 04 to Feb/Mar 08

Statistic	BCk Up	BCk Conf	Bow Up	BowB Conf	Rock Pool	Weir Pool	Bow Conf	Hunt Up	Hunt Dwn
Site	SM1	SM2	SM 3	SM4A	SM 4	SM 5	SM 6	SM 9	SM 10
Alkalinity (mg/L CaCO3)									
N	3	3	38	12	42	42	42	42	42
Min	39	71	102	106	97	105	107	131	112
Max	283	303	383	344	1590	363	371	358	356
Mean	147	159	301	251	683	291	241	218	221
SE of Mean	72	72	10	22	64	8	10	8	9
Total Suspended Solids (TSS mg/L)									
N	3	3	38	12	42	42	42	42	42
Min	8	18	2	2	2	2	2	1	2
Max	504	98	160	103	278	31	36	204	160
Mean	175	48	23	24	49	11	15	26	26
SE of Mean	165	25	5	9	8	1	1	5	4
Acidity (pH)									
N	3	3	39	13	43	43	43	42	42
Min	7.2	6.6	6.9	7.5	7.4	6.9	6.9	7.8	7.9
Max	7.9	7.6	7.9	7.9	9.1	8.1	8.3	8.5	8.5
Mean	7.6	7.1	7.5	7.7	8.0	7.7	8.0	8.1	8.2
SE of Mean	0.20	0.29	0.04	0.04	0.06	0.03	0.04	0.02	0.02
Conductivity (μS/cm)									
N	3	4	39	12	43	43	42	42	42
Min	277	574	421	434	428	432	453	304	319
Max	1800	1950	1750	1980	14400	2040	1850	1270	1290
Mean	951	1032	1375	1263	4574	1486	1001	740	767
SE of Mean	448	313	46	139	590	48	53	32	33
Total Dissolved Solids (TDS mg/L)									
N	3	3	38	12	42	42	42	42	42
Min	578	586	294	300	286	296	308	236	255
Max	1190	1120	976	1130	8820	1160	1080	658	672
Mean	919	791	818	734	2833	870	539	385	401
SE of Mean	180	166	25	76	364	27	31	18	18

Inspection of the tabulated and graphical statistical summary results (Table 2 and Appendix Figures A-1 to A-5) indicate that variations in mean electrical conductivity (EC), Total Dissolved Solids (TDS), alkalinity, and pH between sites were similar, with the exception of Site SM4. SM4 has had significantly higher mean values recorded for all parameters than all other sites.

Appendix Figures A6 to A10 compare the variations over time for each of the water quality parameters for the four Bowmans Creek sites (SM3, SM4, SM5 and SM6) for which complete data sets exist. The individual site variations over time for EC, TDS and alkalinity are reflected across all four sites. The pattern for Site SM4 indicates:

- A moderate increase in values up to June 2005 with two intervening decreases back to 'other site' readings in February 2005 and July 2005.

- From July 2005 on there is a continuous increase in the values of the three parameters through to March 2007, with some variation around this maximum through to the June 2007 survey.
- After the flood event in the week following the June 2007 monitoring survey, subsequent values for the three parameters are similar to the values at the other three sites (through to the current available sampling data in March 2008).

Variation over time for pH is shown in Figure A9. Generally pH values were in the range 7 to 9 pH units. Over the sampling period there were three distinct patterns:

- September 2004 to December 2006: pH values ranged from 7.25 to 8.5 pH units.
- January 2007 to June 2007: pH at the SM5 and SM6 ranged from 7.6 to 8.4 pH units whilst pH readings at SM4 site values were elevated (8 to 9 pH units) and the upstream site SM3 values were depressed (7 to 7.25 pH units).
- Post June 2007 flood: pH values for all sites were similar, varying between 7 and 8.25 pH units.

TSS concentrations showed similar variations, but there were overall larger spatial and temporal variations which masked some of the pattern. Nevertheless TSS at site SM4 showed a similar net increase over time up to the June 2007 flood event and a similar decrease in July 2007. Temporal variation at the upstream site SM3 was high but there was a similar pattern to the SM4 rise, from May 2006 to June 2007.

ACOL collect rainfall data for the locality and provided monthly summary data for the duration of the study period. Figure A11 shows the monthly rainfall data superimposed over the monthly variation in EC, TDS, alkalinity and TSS for Site SM4 over the total sample period. Whilst it is clear from the figure that the variations in water quality parameters can be correlated in some way with rainfall there is insufficient correlation to show why the values of most parameters continued to rise between July 2005 and June 2007.

Daily mean flow data for the Bowmans Creek Flow Gauging station (Foy Brook 210130) was accessed from the NSW Government Water Information Internet site: (http://waterinfo.nsw.gov.au/river-provisional-sites.shtml), and data for the period January 2004 to August 2008 downloaded for analysis.

Figure A12 shows a graph of the mean daily flow at the weir in ML/day. The range for this graph is set at 0 to 1800 ML/day to show all storm events other than the major storm events of 9 to 11 June 2007 (off the scale with mean daily flows of 8992, 17826 and 5498 ML/day respectively). Figure A13 shows the same data but with a more restricted range (0 to 15 ML/day) to highlight the variation in low flow events over the study period. The figure also shows the ACOL SM4 site monthly conductivity data.

From the combined graphs, it appears that the water quality at Site SM4 is directly related to creek flow rate. When flows are low, EC, alkalinity and TDS values at SM4 increase and when flow is very low or stopped, values peak. This correlation is demonstrated in the following discussion where changes in conductivity values at site SM4 are related to changes in mean daily flow conditions (see also Figure A13):

- Following small February and March 2004 storms and associated flow peaks there was an overall decrease in mean daily flow from around 2.5 ML/day to around 0.5 ML/day on 2 February 2005 (mean flow over this dry period was 1.8 ML/day for 313 days. This low flow period coincides with elevated conductivity of up to 4510 μS/cm) at Site SM4 between September 2004 and January 2005.
- The fall in conductivity for the 23 February and 30 March sampling events follow a 323 ML/day flow event on 3 February 2005 and this storm is followed by a period of relatively elevated daily flows (mean 10 ML/day) until the next storm on 19-29 March 2005 (137 ML total).
- From March to May 2005 there is another increase in EC as mean daily flow decreases to 3.1 ML/day over 102 days. EC peaked at 2520 μS/cm.
- Another fall in EC occurred on 12 July 2005 following a flow peak of 132 ML/day on 1 to 2 July 2005.
- There was no significant rainfall for the period 3 July 2005 to 8 June 2007 (706 days) and the mean daily flow for the period was only 1.1 ML/day, including a period of 74 days leading up to 7 June 2007 where the mean daily flow was generally zero or a trickle (mean 0.003ML/day). This period coincides with a dramatic increase in EC from around 1400 to a peak of 14,400 μS/cm (in March 2007). EC remained elevated above 11,000 μS/cm for the monthly water quality surveys in April to June 2007 with the June sample taken before the flood event (which started on 9 June 2007).

- Mean daily flow over the June 2007 flood period ranged from 17,826 ML/day on 10 June to 1561 ML/day on 20 June (mean of 3137 ML/day for 12 days).
- For the remainder of the (currently available) monthly conductivity sampling periods (July 2007 to March 2008) the SM4 EC values remained similar to those measured at the other Bowmans Creek sites, with one exception (in November 2007), when SM4 conductivity increased to 2220 μS/cm (approximately double the recorded values at the other sites). This rise followed a dry period of some 95 days from 25 August 2007 to the sampling date of 22 November 2007 over which time daily flow decayed from 233 ML/day to 1.3 ML/day.

One further analysis was made of the SM4 water quality data. A simple linear correlation analysis was made of the four analytes (see matrix of r^2 values below):

	Cond	TDS	Alk	TSS
TDS	0.98			
Alk	0.87	0.86		
TSS	0.65	0.71	0.45	
pH	0.60	0.66	0.51	0.58

Salinity, TDS and alkalinity were all highly correlated (as expected). There was some correlation between TDS and TSS (r^2 value of 0.71) and the remaining correlations were generally weak (r^2 values less than 0.65).

Aquaterra (2008) found that salinity in the upper Permian coal measures ranged from 1100 to 9390 μS/cm EC and that some Bowmans Creek baseflow is derived locally from the Permian at site SM4. Thus, the increase in salinity within the SM4 pool would be expected to be inversely related to overall flow in Bowmans Creek (as was the case).

That is, when upstream surface contributed inflow rates are low, the contribution of Permian derived baseflow to the SM4 pool becomes more significant and conductivity in pool SM4 rises, with the rate of rise dependent on the preceding flow history. Further, when there is a long dry period with little to no surface water in-flow, conductivity in pool SM4 can be expected to become highly elevated (as observed).

The monthly ACOL EC data for sites downstream from the SM4 pool and the daily EC data from the weir pool do not show any significant increases over the periods when the SM4 pool salinity is elevated and it is concluded that the elevated EC in pool SM4 is generally confined to that pool by virtue of the correlation with low to no flow periods.

3.3.2 Aquatic Survey Water Quality Data

Field water quality measurements were made at all aquatic ecology sites in Bowmans Creek sites during each of the five aquatic ecology sampling programs (spring 2005 to autumn 2008) and results are provided in the various monitoring reports). Water quality results obtained during these studies may be summarised as follows:

- For All Bowmans Creek monitoring sites, salinity and pH values were within the range set for Lowland Rivers by ANZECC (2000) guidelines.
- On three of the five surveys, mean dissolved oxygen (DO) values (measured as % saturation) were below the range set by ANZECC Guidelines for Lowland Rivers of 85 to 110% saturation; TEL recorded mean DO values of 68.3 and 74.4% saturation in the low flow and drought periods (spring 2005 and autumn 2006 respectively). During high flow conditions (autumn 2007), MPR recorded a mean DO value of 59 %. Higher values were encountered in spring 2007 and autumn 2008 by MPR (mean DO % saturation values of 91.4 % and 91 % respectively).

From the consideration of the combined ACOL water quality monitoring program and the aquatic ecology field water quality measurements it is concluded that for all the sites where measurements were made (with the exception of site SM4), water quality was generally reasonable and acceptable for the maintenance of aquatic ecological function. Water quality and thus aquatic ecology, deteriorated during low flow and flood flow periods with the main aquatic stress arising from low dissolved oxygen concentrations. Site SM4 is highly stressed by elevated conductivity during low to no flow periods and this is likely to have had a significant (i.e. measurable) impact on the biotic assemblages of this pool.

3.4 Macroinvertebrate and Fish Communities

To date there have been eight aquatic ecology surveys in Bowmans Creek that have incorporated sampling for macroinvertebrates and fish, including two that used electro-fishing techniques. Surface stream flow conditions varied between surveys, and even between sites within surveys. For references to flow condition in the following paragraphs the following flow descriptors have been adopted:

- ‘dry’ represents no surface flows during time of sampling in the majority of site pools,

- ‘low flow’ represents surface flow conditions encountered at all sites, with generally only trickle flow through riffle zones in the shallow cobble and boulder beds in between pools.
- ‘Normal flow’ conditions are more representative of mean flow rates for Bowmans Creek, and
- ‘Wet flow’ includes periods with higher than mean flows following rainfall through to floodwaters (i.e., where normally exposed banks are submerged).

3.4.1 Macroinvertebrates

A total of 28 edge and 2 riffle habitat sites have been sampled over 8 surveys between spring 2001 and autumn 2008. Seasonal summary statistics for the edge habitats sampled between 2001 and 2008 are presented in Table 3 below. Unless otherwise stated, the following summary applies to edge habitat data only.

To date, a total of 70 aquatic macroinvertebrate taxa (taken to AusRivAS required family level) have been identified from the combined studies. Four of the taxa were recorded from riffle habitats only; riffle beetles (family Elmidae), water pennies (family Psephenidae), fly larvae (family Dolichopodidae) and dobsonflies (family Cordyalidae). The majority of the taxa are insects (67%), with the remainder being molluscs (12%), crustaceans (9%). Arachnids, flatworms, annelid worms, leeches, roundworms and springtails were all <3%.

Table 3
Macroinvertebrate Summary Statistics for Bowmans Creek

Flow Condition	Dry	Dry	Dry	Low flow	Low flow	Normal Flow	Wet	Wet
Flow rate (ML/D)	N/A	0.4	0.4	0.7-0.8	1.7	27.7-24.8	123-129	840-158
Sampler	MPR	TEL	MPR	TEL	MPR	MPR	MPR	MPR
No of Sites	N=2	N=4	N=2	N=4	N=3	N=4	N=4	N=4
Season and Year	Sp01	Au06	Au06*	Sp05	Sp05*	Au08	Au07	Sp07
Total number of invertebrate taxa:	8	31	31	33	33	32	25	30
Mean number of taxa per site:	5.0	15.5	16.3	20.5	23.0	18.8	14.0	17.0
Standard Error:	0.0	1.8	4.7	1.9	3.0	1.1	2.5	1.9
Creek SIGNAL scores:	3.88	3.83	4.59	4.06	4.43	4.97	3.80	4.43
Site SIGNAL Min	3.00	3.22	4.33	3.00	3.67	4.79	3.00	4.33
Site SIGNAL Max	4.80	3.50	4.80	3.41	4.86	5.19	4.00	5.25
Mean of All sites	3.90	3.41	4.49	3.14	4.34	5.00	3.67	4.59
Standard Error:	0.90	0.06	0.16	0.09	0.35	0.09	0.23	0.22

*Represents aquatic ecology surveys undertaken from upstream Bowmans Creek locations

There were thirteen taxa which were found in Bowmans Creek on six or more of the eight surveys, and six of those taxa were also common throughout the creek (i.e. occurring at over 75% of total sites sampled); midge fly larvae (sub-family Chironominae), freshwater shrimp (family Atyidae), damselflies (family Coenagrionidae), mayflies (family Caenidae), water boatmen (family Corixidae) and caddis flies (family Leptoceridae).

Individual site diversity ranged between 5 taxa (spring 2001 drought) to 26 taxa (spring 2005 dry with some flow). Comparisons of the seasonal mean number of taxa per site show reduced taxa diversity during wet and dry periods when compared to low flow and normal flow conditions. Despite this, seasonal total number of creek taxa figures during wet and dry flow periods are almost as high as those in periods of low flow to normal flow. That is, even though individual sites may not support as diverse an assemblage of aquatic macroinvertebrates under drought or flood conditions, the aquatic drought and flood refuges in the creek as a whole continue to support similar taxa diversities.

In terms of SIGNAL grades, the study area pools support diverse fauna with a full range of pollution tolerances, from the most sensitive taxa, Mayfly family Leptophlebiidae (grade 10) to the pollution tolerant snail family Physidae, Dragonfly family Lestidae and Springtails (grade 1). In general, the Bowmans Creek monitoring sites support a pollution tolerant macroinvertebrate fauna, as indicated by the AusRivAS model and validated by the SIGNAL index scores over consecutive surveys. From analysis of taxa present in Bowmans Creek on a seasonal basis, SIGNAL values all indicate a range of severe to moderate impairment under drought and flood conditions, and moderate impairment during normal flow conditions. There were no real trends in overall creek SIGNAL scores relating to different flow conditions. Individual site SIGNAL values range between 3.00 and 5.25 for wet conditions, between 3.00 and 4.80 for dry conditions, and between 3.09 and 5.19 for low flow to normal flow conditions.

3.4.2 Fish and Other Fauna

To date there have been 14 fish species recorded from the Bowmans Creek catchment, 2 of which are introduced species (see Table 4 below). MPR (2001) listed two species recorded in Glennies Creek that could also be expected to occur within Bowmans Creek, they are bullrout (*Notesthes robusta*) and the introduced goldfish (*Carassius auratus*). Although Australian smelt are listed above as potadromous, recent studies of populations in coastal drainages of south-eastern Australia showed that a majority of the fish analysed inhabited the sea or estuaries during early life stages (Crook *et al* 2008).

Table 4
Fish Species Recorded from Bowmans Creek

Family	Species	Common name/s	Life cycle*	Recorded	Native/ Introduced
Anguillidae	*Anguilla australis*	Short-finned Eel	C	X	N
Anguillidae	*Anguilla reinhardtii*	Long-finned Eel	C	X	N
Atherinidae	*Craterocephalus amniculus*	Darling Hardyhead	U	X	N (species of concern)
Cyprinidae	*Cyprinus carpio*	Common Carp	L	X	I
Eleotridae	*Gobiomorphus australis*	Striped Gudgeon	A	X	N
Eleotridae	*Gobiomorphus coxii*	Cox's Gudgeon	P	X	N
Eleotridae	*Hypseleotris compressa*	Empire Gudgeon	U	X	N
Eleotridae	*Philypnodon grandiceps*	Flathead Gudgeon	U	X	N
Eleotridae	*Philypnodon macrostomus*	Dwarf Flathead Gudgeon	U	X	N
Mugilidae	*Mugil cephalus*	Sea Mullet	A	X	N
Percichthyidae	*Macquaria novemaculeata*	Australian Bass	C	X	N stocked
Plotosidae	*Tandanus tandanus*	Freshwater Catfish	L	X	N (species of concern)
Poeciliidae	*Gambusia holbrooki*	Plague Minnow	L	X	I
Retropinnidae	*Retropinna semoni*	Australian Smelt	P	X	N

Key:
A- Amphidromous (fish that migrate between the estuary and the sea, but not for breeding purposes).
C- Catadromous (fish that spend most of their lives in freshwater but migrate to the sea to breed).
P- Potadromous (fish that migrate wholly within freshwater).
L- Local (species that require fish passage only in their immediate environment).
U- Unknown
Note*: Life cycle characteristics referenced from Thorncraft & Harris 2000.

No species of fish or aquatic invertebrates, as currently listed under the NSW Fisheries Management Act 1994 (FMA), or under the Commonwealth Environment Protection & Biodiversity Conservation Act 1999 (EPBC Act), were recorded or expected in any of the monitoring conducted to date, and no protected fish, as listed under the FMA, have been found or observed in Bowmans Creek.

Two species are listed a species of concern in Morris *et al* 2001; The Darling hardyhead and the Freshwater catfish.

- The Darling hardyhead (*Craterocephalus amniculus*) is listed due to its taxonomic uncertainty. It is endemic to streams in the upper Darling River system. Specimens tentatively identified as *Craterocephalus amniculus* were collected from upper Bowmans Creek in 1976 and 1980, though no further individuals have since been collected (cited in Morris *et al* 2001). This species has not been observed or caught in any

of the ACOL surveys (from 2005 onwards) and was not caught during the TEL electro-fishing survey of the creek in (2005-2006).
- Morris *et al* 2001 note that whilst the freshwater catfish (*Tandanus tandanus*) is not currently listed as threatened in NSW, its distribution and abundance has been significantly reduced throughout the southern parts of its known range. Freshwater catfish are generally found close to sand or gravel bottoms in slow moving streams, lakes and ponds with fringing vegetation (Allen *et al* 2002), habitat features consistent with that encountered in Bowmans Creek. This species has been recorded from refuge pools in the study area during the autumn 2006 drought.

The introduced pest species, plague minnow (*Gambusia holbrooki*), has been the most commonly encountered fish during all aquatic ecology monitoring surveys. They have been recorded at every monitoring site sampled in Bowmans Creek between spring 2005 and autumn 2008, with the exception two sites in post flood conditions during autumn 2007. carp have also been commonly observed over all surveys, with the exception of high flow periods encountered during autumn and spring 2007.

With regard to other possible fauna associated with the Bowmans Creek aquatic habitats, the various studies have reported amphibians (tadpoles and frogs), ducks and other water birds, long-necked turtles, water dragons and water skinks. Whilst platypus are known from the locality (in Glennies Creek) there have been no records or sightings in the Bowmans Creek study area. Also, although possible feeding stations for Australian native water rat have been observed previously, no animals have been observed or recorded.

4 IMPACT ASSESSMENT

4.1 Potential Impacts

The main potential impacts which can arise from long-wall mining below a creek are related to subsidence, with the following potential results:

- Lowering of sections of creek resulting in deeper pools or new pools or steeper riffle sections between pools depending on the location of longwalls with respect to overlaying pool morphology.
- Destabilisation of steep unconsolidated banks with resultant accelerated bank erosion and increased sedimentation within the creek bed.

- Cracking of rock bar or rock bank constrained pools with possible draining or leakage of pools.
- Fracturing of aquclades below the creek alluvium resulting in increased leakage from the creek pools to the fractured rock and possibly leakage to the mine itself.
- Altered water quality arising from increased leakage water percolating laterally through fractured rock or alluvium and re-emerging further downstream.

With regard to aquatic ecology impacts arising from these subsidence related effects, the main consequences are potential increased isolation of pools, increases in barriers to fish passage, a reduced availability of drought refuge pools and changes to water quality, particularly during low flow events.

Barriers to fish passage can cause local extinctions or greatly reduce fish abundance and diversity (Thorncraft & Harris 2000), and, if there are longer prolonged periods of no or intermittent surface flow in Bowmans Creek over the proposed mining area, the resultant increased barrier to fish migration between the Hunter River and upstream Bowmans Creek pool sites could affect the five diadromous species that have been previously recorded in Bowmans Creek (short and long-finned eel, striped gudgeon, sea mullet and Australian Bass).

Isolation of pools can also favour introduced species like Plague Minnow, which are capable of rapid reproduction, spawn many times within a year and can tolerate a wide range of environmental conditions. These factors, combined with a well documented aggression towards native species, can then impact upon native fish and amphibian populations in refuge pool environments.

Both MPR (2007) and TEL (2006b) documented the isolation of in-stream macrophyte beds from reduced-size Bowmans Creek pool sites during the autumn 2006 drought period. More generally, aquatic habitats become impacted by exposure of physical structures such as logs, undercut banks, boulders, bank vegetation, and tree roots that would otherwise serve as habitats for fish and macroinvertebrates.

Aquatic biota can also be impacted by the decline in water quality due to the reduction in pool water volume and the lack of pool water replenishment when flow ceases. For example, there can be increases in the amount of filamentous green algae, there can be high turbidity caused by Carp disturbing the reduced pool bottom sediments and there can be decreased oxygen concentrations in the water due to the oxygen demand from the concentrated populations of aquatic biota.

4.2 Predicted Impacts

From the combined longwall mining impacts studies undertaken to date (SCT 2008, Aquaterra 2008, ACOL 2008 and ACOL *pers. comm.*) the main predicted impacts can be summarised as follows;

- Mining induced subsidence of between 200 and 350mm is expected to occur in Bowmans Creek sections overlying miniwalls. Whilst there is therefore some potential for localised ponding within the creek channel, the level of ponding is considered unlikely to be outside the variability that is currently evident within the channel or that occurs naturally during flood scouring.
- Local tilting of the surface may cause the stream channel to move sideways within the creek bed, but for the low tilt levels expected and the short distances over which tilting would be occurring, the changes are expected to be within the natural variation that is evident in the creek.
- There could be minor changes to creek channel morphology (e.g., redistribution of sediments within pools, changes to pool riffle sequences), but it is considered unlikely that the overall channel shape will change as a result of subsidence.
- Mining will reduce the base-flow contribution from Permian (saline) aquifers to Bowmans Creek surface flows with a maximum predicted decrease of 1.2 L/sec (about 0.104 ML/day) at the end of extraction from the Pikes Gully Seam.
- An average drawdown of approximately 0.8 m in the alluvium within the floodplain above the mine is predicted, and this equates to a predicted reduction of 12% in the volume of groundwater storage in the Bowmans Creek alluvium between the New England Highway and the Hunter River. However, In the central parts of the floodplain, close to Bowmans Creek itself, drawdowns of less that 0.1m are predicted.
- Subsidence over full width longwall panels is expected to reach a maximum of 1.6m however these areas do not underlie the channel of Bowmans Creek.
- Surface cracking is expected to develop over the goaf edges of Longwalls 5, 6 and 9 as a result of mining subsidence and is likely to require remediation to prevent ingress of surface water, injury to livestock, or entrapment of small animals. This process has been successfully undertaken over Longwalls 1 and 2 and there does not

appear to be any impediment to similar treatment within the Application Area.

- It is unlikely that subsided surface areas will intercept saline groundwater in the sub-catchments draining into Bowmans Creek within the study area.
- Long term post mining groundwater quality, and contribution to stream flows is expected to be similar to pre-mining conditions.

Currently, baseflow from the Permian is a source of elevated salinity waters in Bowmans Creek at the SM4 water quality point, located just below the New England Highway. Seepage rates are considered to be relatively low as salinity increases only become significant in this pool when there is no (or very little) contributing surface flows (see Section 3.3.1). For the other water quality sampling sites within the proposed mining area, conductivity is similar to that of Bowman Creek waters upstream of the New England Highway, indicating little baseflow contribution to Bowmans Creek from either the alluvials or Permian measures groundwater in the area. This is confirmed by the Aquaterra (2008) groundwater study; "Bowmans Creek alluvium contributes some baseflow to Bowmans Creek although the contribution from the planned mining area is very small".

It is also predicted (Aquaterra 2008) that baseflow contribution from saline groundwaters to Bowmans Creek will be reduced during mining and for a period after the completion of mining until groundwater aquifers recover. Loss from alluvium would be in the order of 1.2L/s. Accordingly, there would be negligible lowering of the alluvial water table in the vicinity if the actual creek (less than 0.1 m) and it is expected that water quality in Bowmans Creek would not be adversely impacted by mining and could even improve during low and no flow conditions.

Assessment of possible Groundwater Dependent Ecosystems (GDEs) in the study area (Section 3.2.5 above) concluded that possible aquatic and hyporheic GDEs in Bowmans Creek within the study area would not be considered significantly dependent on baseflow groundwater. Notwithstanding this conclusion, the assessment by Aquaterra (2008) of the possible impacts on groundwater quality and quantity arising from the proposed mining under Bowmans Creek indicates that there would be an insignificant lowering of baseflow to the creek (in the order of 1.2L/sec) over the duration of the mining period with recovery occurring over time following cessation of mining. This is expected to have no significant impact on water availability or water quality for creek biota for most of the time. During prolonged droughts with low to no surface flow conditions, whilst there would be less baseflow water to offset evaporation losses in isolated pools overall water quality could show an incremental improvement due to the lower salt load being introduced to the creek from baseflow,.

As noted in Section 3.3.4, and as is typical for a meandering stream, a significant proportion of the creek sections overlying the designated miniwall areas are subject to non-mining related bank erosion with consequent increased sedimentation, alteration of stream bed character from cobble/sand to sediment plus shallowing of pools, all of which affect the aquatic ecology of the stream. Whilst subsidence could be expected to exacerbate this instability on a local scale in the vicinity of the miniwalls, the net effect is not expected to be significant, particularly given the scale of present impact. In any case, the riparian stabilisation works currently being instigated on Bowmans Creek are designed to minimise non-mining related bank instability and would consequently ensure that there are no significant impacts of subsidence on bank stability.

As noted in Section 3.2.5, most of the tributaries and impoundments within the study area have been heavily impacted by agricultural practices and currently offer very little in the way of aquatic habitat diversity or drought refuge. Subsidence induced interception of groundwaters are not predicted to occur. Consequently, the potential effects of subsidence and related impacts on the present aquatic ecology of the tributaries and their sub-catchments are considered minor.

In the sub-catchment areas where predicted subsidence is in the order of 1.6m, localised ponding of the drainage swales may occur. Measures to address surface ponding have been developed and included in the ACOL Land Management Plan (ACOL *pers com* 2008). Typically, remediation measures to drain ponded areas will be employed. However, where this is not achievable, the ponded areas could be used to provide additional aquatic habitat areas, especially if it is determined as part of the ongoing monitoring program that active works are required to enhance aquatic habitat.

4.3 Aquatic Ecology Impact Conclusions

Based on the assessment of predicted subsidence induced changes to creek morphology plus to water quantity and quality provided above, the impacts of proposed mining on aquatic biota and habitats in Bowmans Creek plus its tributaries are expected to be negligible and there is not expected to be any significant impact on the availability of drought refuge pools within the section of Bowmans Creek in the proposed mining area. It is also concluded that there would be no significant impact on fish passage through the section of Bowmans Creek in the proposed mining area and no significant impact on fish passage between the Hunter River and Bowmans Creek above the proposed mining area.

5 MITIGATION AND MONITORING OF POSSIBLE IMPACTS

5.1 Mitigation Measures

In relation to the aquatic ecological function of Bowmans Creek, the two main possible impacts of mining assessed above include contribution to instability of the creek banks and stream bed and the possible alterations to water quality and/or quantity. Based on the assessment of predicted subsidence induced changes to creek morphology plus to water quantity and quality provided in other specialist reports, the impacts of proposed mining on the aquatic ecology of Bowmans Creek was assessed to be insignificant or negligible.

Notwithstanding this conclusion, protection of the aquatic ecology of Bowmans Creek within the mining area is likely to be enhanced pre-mining by the riparian management works currently being instigated. Further, these works are likely to make the creek more robust to possible mining induced changes.

The riparian management program will provide for the exclusion of cattle from the riparian and creek areas along the entire creek length on both sides of the creek (with provision for on-demand stock watering facilities away from the riparian zone where required), revegetation of the riparian corridors and establishment of understorey layers which can stabilise the broader channel areas and minimise the impacts of flood events. The rehabilitation will increase overall creek and riparian ecological function by:

- minimising the development of erosion and bank slumping caused by stock access,
- stabilising instream banks and minimising the extent of bank collapse or slumping when riparian trees fall,
- providing habitat corridors for terrestrial species and providing increased localised biodiversity.

Where subsidence induced pond formation in the off-stream sub-catchments and drainages cannot be otherwise remediated to drain naturally, riparian revegetation techniques (stock exclusion and provision of edge and emergent vegetation) should also be considered. Decisions regarding whether this should be done would need to be made on a site by site basis as mining progresses. Accordingly, it is recommended that, following individual longwall completion, field assessments be made in the areas overlying longwalls and miniwalls, to ascertain the extent of subsidence impacts on creek and tributary channel ecosystems so that targeted riparian or habitat enhancement/protection measures can be recommended.

5.2 Suggested Monitoring Program

Continued monitoring of stream-health plus of water quality and availability in Bowmans Creek is recommended to detect any possible mining impact and to determine the need for any specific mitigation measures as a consequence. For example, monitoring could determine if there is a noticeable increase in saline water contribution to Bowmans Creek stream flows at any location within the study area, or if there is a detectable decrease in stream flows that could be linked to mine workings.

Monitoring would require a guiding set of criteria or protocols developed to establish the circumstances under which mitigation measures would be required. These would be specified in Site Management Plans and Trigger Action Response Plans (TARP). As a general guide, where perceptible impacts are noted through site monitoring activities, the following general procedure would be applied:

- Undertake additional investigations to ascertain the actual cause (mine-related or other cause) of deteriorating aquatic conditions;
- If mining related, notify relevant government authorities;
- Develop and implement a specific response plan to prevent further impacts, and
- Undertake remediation as required.

The response plan would need to be prepared on a case by case basis, with suggested short-term mitigation measures such as minor physical repair works and possible intermittent environment flow supplements as required, which could be implemented until such time that necessary long-term remediation works have been completed.

5.2.1 Water quality and quantity monitoring

With regard to water quality monitoring, recommended groundwater monitoring is described in the specialist groundwater report (Aquaterra 2008). With regard to surface water quality it is recommended that the existing water quality monitoring programs plus some additional site specific monitoring be undertaken:

- The combined monthly water quality monitoring program at the present 'whole of mine' ACOL Bowmans Creek, Bettys Creek and Hunter River sites should be continued.
- Field water quality monitoring during the biannual aquatic ecology monitoring program should be continued and extended to include depth

profile monitoring of field water quality parameters where possible or practicable.

- Additional periodic field monitoring of the water quality in those subsidence-induced ponded areas within sub-catchment drainages which are identified as potentially suitable for rehabilitation as aquatic habitat.

It is further recommended that additional field conductivity monitoring be undertaken between sites SM4 and SM5, when SM4 conductivity starts to deviate significantly upwards from conductivity at SM4A (as described to occur naturally during low to no-flow events). This will allow an estimation of the degree of contribution of elevated saline water from the SM4 pool to the pools immediately downstream.

With regard to creek surface water quantity monitoring for stream health purposes, it is considered that the present weir gauge monitoring data are important (and sufficient) for enabling the interpretation of Bowmans Creek water quantity change. STC (2008) conclude that subsidence at the location of the weir is expected to reach a maximum of 200mm at the western end and 140mm at the eastern end. The section of the channel where the weir is located will also subside by a similar amount, so there is not expected to be more than a few centimetres of relative movement once mining has finished, but there will be a transient effect when mining is proceeding directly under the site. Accordingly it is recommended that this gauging station (or a replacement gauging station, if required) be maintained and re-calibrated as necessary, at least over the period of the proposed mining.

5.2.2 Aquatic Ecology Monitoring

With regard to aquatic ecology monitoring, there are currently four aquatic ecology monitoring sites sampled bi-annually in Bowmans Creek (see Figure 1 in Section 1 above). The selection of these sites was based on the layout of the original mine plan, which included eight longwall panels of (approximately) equal width.

Long-term monitoring for the impacts of the adopted mine plan require moving one of the original sites and introducing several additional sites, for a net long-term monitoring set of six sites (see Figure 2 below). The following modifications to the existing long term aquatic ecology monitoring program are recommended:

- The upstream and downstream reference sites (BCUp and BCDown) remain as designated reference sites above and below the mining impact area.

- The long term reference site BCLW7 be re-named BCMW8, as this site is located over the western edge of MW8.
- A new site BCMW5 will replace site BCLW5. The new site would be moved immediately downstream to the southern ox-bow bend overlying MW5.
- Establish a new long term aquatic ecology monitoring site (BC1) at the ACOL water quality monitoring site SM4, as pre-mining monitoring of this site will provide a measure of the impacts of naturally elevated conductivity on macroinvertebrate and fish communities during low to no flow periods.
- Establish a new reference site (BCMW7) to be located in Zone 1 above MW7 (site BCMW7). This pool is shallow, located in one of the broad, flat creek sections in the study area and is also one of two areas of maximum predicted (miniwall) subsidence in Bowmans Creek. Monitoring of this site would also provide a measure of the influence of low flow on shallow pool habitat complexity and aquatic assemblages.

As shown in Figure 2, a number of proposed short-term miniwall monitoring sites have been incorporated into sections of Bowmans Creek overlying specific miniwalls. In addition to the six long-term monitoring sites, these sites would be introduced into the aquatic ecology monitoring program on a staged basis, that is, relative to the progression of the respective miniwall mining. It is recommended that sampling of each of these sites would be scheduled into the regular bi-annual sampling program to incorporate a before, and at least two after samples from each site according to the scheduled mining program. This will enable the direct assessment of mining impacts on individual pools as mining proceeds and will also facilitate the interpretation of long-term monitoring results. For each of the short-term sites any decision to continue monitoring beyond the two post-mining studies would be made on a site by site basis, and only if there was evidence of localised mining impact arising from the before/after comparisons.

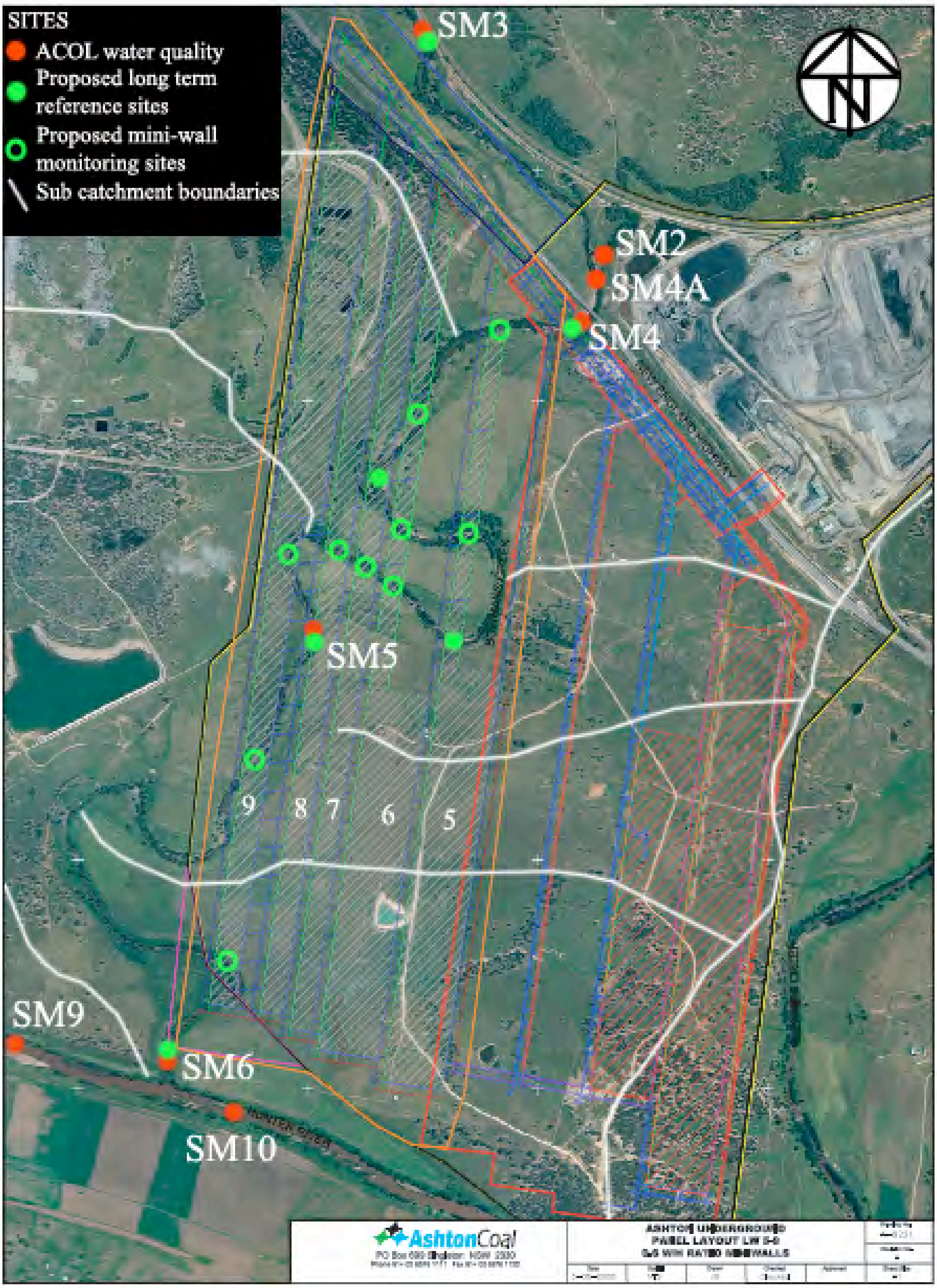

Fig 2 Proposed Stream Health Monitoring Sites

6 SUMMARY

This assessment of the present aquatic ecology of Bowmans Creek and its sub-catchments within the study area (i.e., downstream of New England Highway) indicates that Bowmans Creek provides valuable fish passage conditions linking the Hunter River to upstream Bowmans Creek fish habitats. Bowmans Creek provides valuable localised fish and aquatic habitat within the study area. Whilst Bowmans Creek is perennial, there can be long periods of limited fish passage due to the disconnection of pools during periods of low flow, when the flow is confined to sub-surface sediments. The sub-catchment drainages flowing through the study area and draining to Bowmans Creek have been altered by agricultural practices to the extent that they do not supply any significant aquatic ecological habitat (with the exception of limited habitat provisions via in-line and other farm dams).

With regard to possible Groundwater Dependent Ecosystems (GDEs), the report concludes that as there is a small saline baseflow component from the saturated alluvials of Bowmans Creek to the creek, there is a hyporheic zone between the saturated alluvials and the creek bed plus some parafluvial zones in the creek. With regard to the degree of dependency of possible aquatic or hyporheic ecosystems to baseflow in the Bowmans Creek study area, it is concluded that these ecosystems would not be considered significantly dependent on baseflow groundwater. That is, there are no significant GDEs in the Bowmans Creek study area.

The Bowmans Creek aquatic habitats (and fish passage potential) have been compromised by the combined effects of historical regional plus local riparian vegetation clearing, continued stock access to the riparian habitats (for the creek and dams), and the consequential destabilising of riparian banks, the deposition of mobile sediments into the creek, the shallowing of ponds and the alteration of pool water quality, particularly during low to no flow periods.

In relation to the provision of aquatic ecological function, the two main possible impacts of mining under Bowmans Creek relate to the contribution of potential collapse of existing steep riparian banks, movement of the creek bed within the existing channel (i.e., migration of sand bars and sediments), and the minor possibility of alterations to creek (or sub-catchment drainage) water quality and/or quantity.

ACOL are presently instigating riparian rehabilitation measures to address and reverse this deterioration within their lease area and, whilst mining contributions to geomorphic instability is predicted to be insignificant, it is considered that the riparian rehabilitation works being undertaken pre-mining, will provide an additional buffer against potential mining impacts, mainly by stabilising riparian banks.

With regard to possible water quality and quantity alterations arising from mining it is concluded that whilst these impacts are predicted to be insignificant, if deterioration is identified by monitoring and it is determined that remediation is required, it would be possible to make provision for a supply of good quality water which could be used to off-set mining related deterioration in creek water quality/quantity, should this arise.

With regard to subsidence induced ponding within sub-catchment drainages leading to Bowmans Creek, the general objective of remediation for these areas will be to maintain the current agricultural land capability of the site and accordingly, where possible, earthworks and drainage measures would be implemented to allow these areas to drain to Bowmans Creek and avoid ponding. It is recommended that the potential ponding effects of longwall mining within sub-catchment drainages be assessed on a site by site basis with regard to the possible inclusion of formed ponds to the overall aquatic habitat resource of the site (by active remediation measures such as stock exclusion and riparian and emergent planting).

Long-term stream health monitoring currently utilises a network of water quality monitoring sites sampled monthly and four Bowmans Creek aquatic ecology sites, sampled twice a year in spring and autumn. In order to monitor for the possible impacts of mining from the proposed mine plan it is recommended that:

- The same water quality monitoring program be continued with provision for additional field (i.e., metered) conductivity monitoring in the section of creek between sites SM4 and SM5 when there is elevated conductivity found at site SM4 (i.e., under low or no flow conditions).
- An additional two aquatic ecology monitoring sites be introduced with one of the existing sites re-located over a miniwall.

It is recommended that these changes be made immediately to the pre-mining monitoring program so that the current impacts of the localised elevated conductivity at site SM4 and possible impacts of pool shallowing during low flow/drought can be determined prior to the commencement of mining.

In addition to the six long-term monitoring sites, an additional eight short-term 'during mining' aquatic ecology monitoring sites are recommended, with each of these sites to be brought on-line in the seasonal (i.e., autumn or spring) survey prior to mining under each site. It is recommended that each of these short term sites would be monitored seasonally once before mining proceeds under the site and at least twice after mining has passed under the site.

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APPENDIX A

ACOL 'WHOLE OF MINE''

WATER QUALITY DATA

SUMMARY ANALYSIS

SEPT 2004 TO MARCH 2008

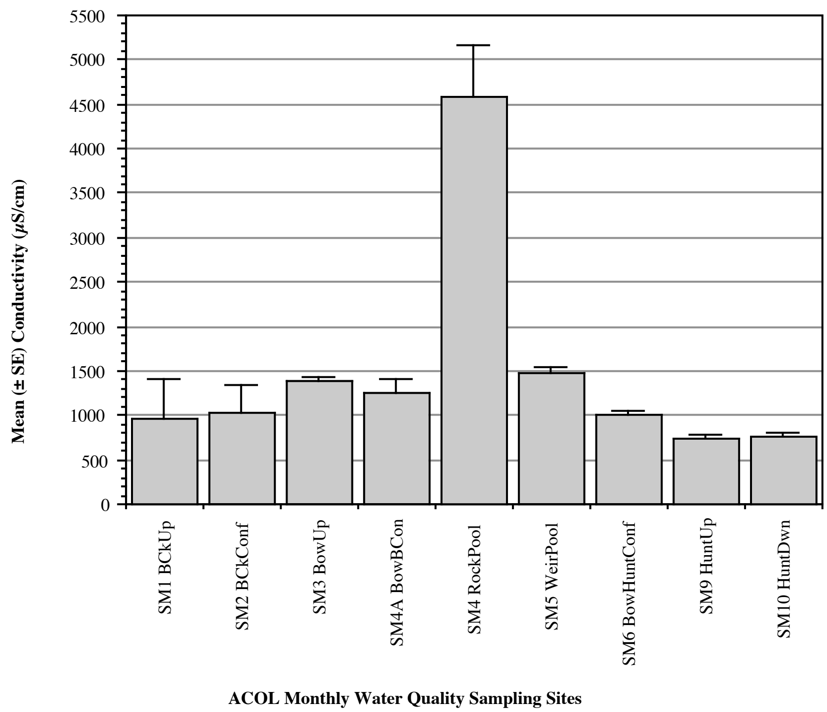

Fig A-1 ACOL Site Mean Conductivity Results

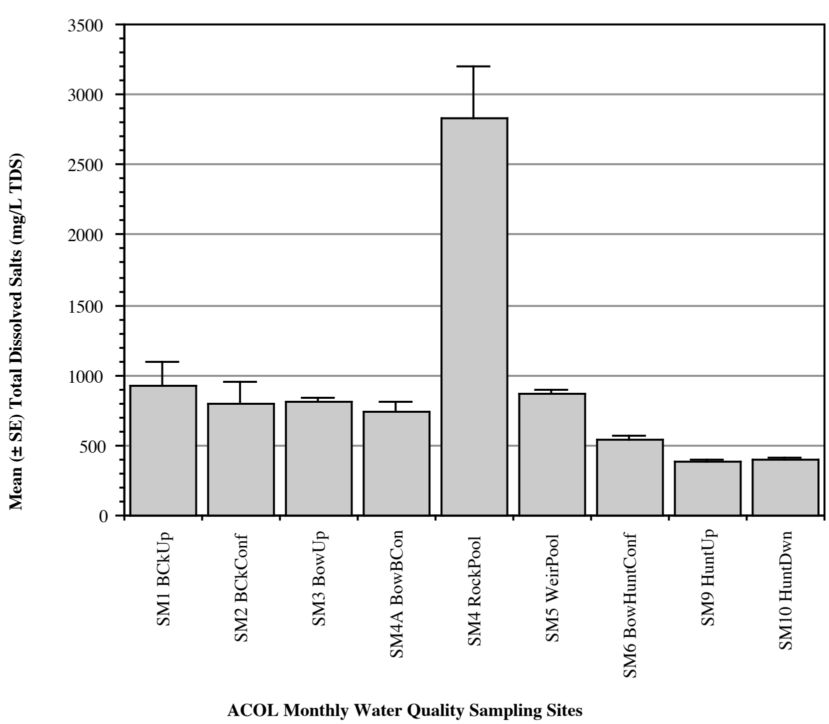

Fig A-2 ACOL Site Mean TDS Results

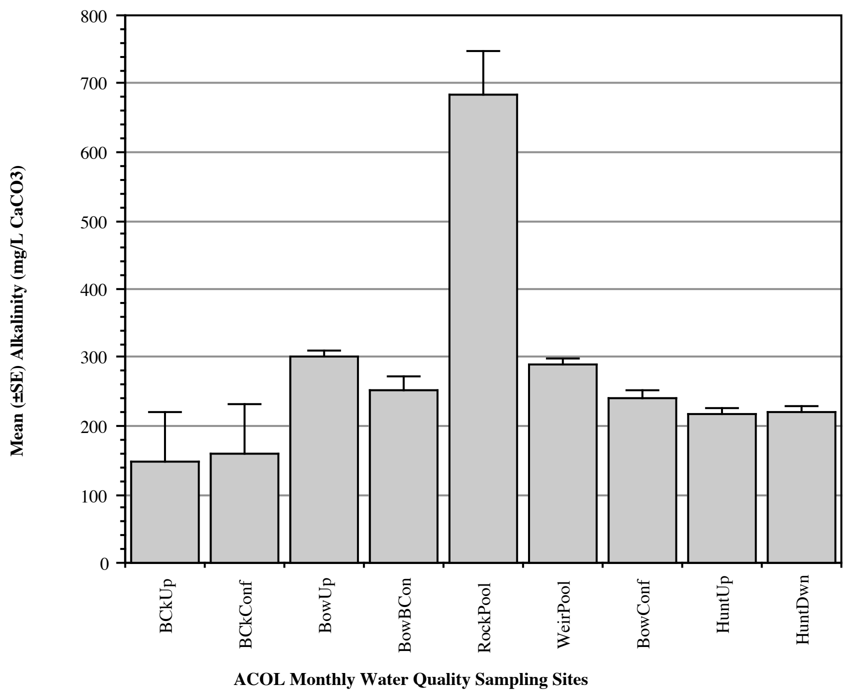

Fig A-3 ACOL Site Mean Alkalinity Results

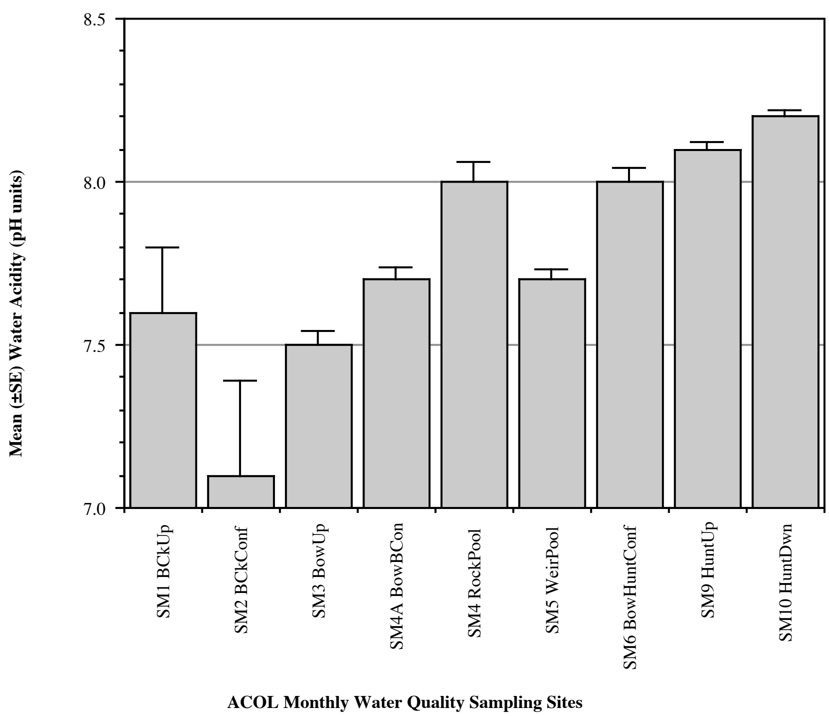

Fig A-4 ACOL Site Mean pH Results

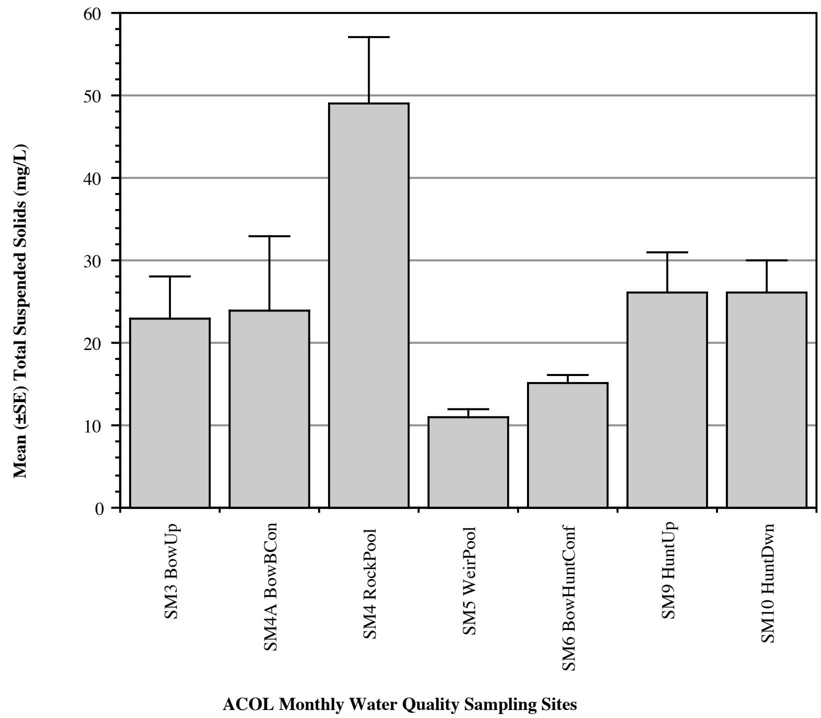

Fig A-5 ACOL Site Mean TSS Results

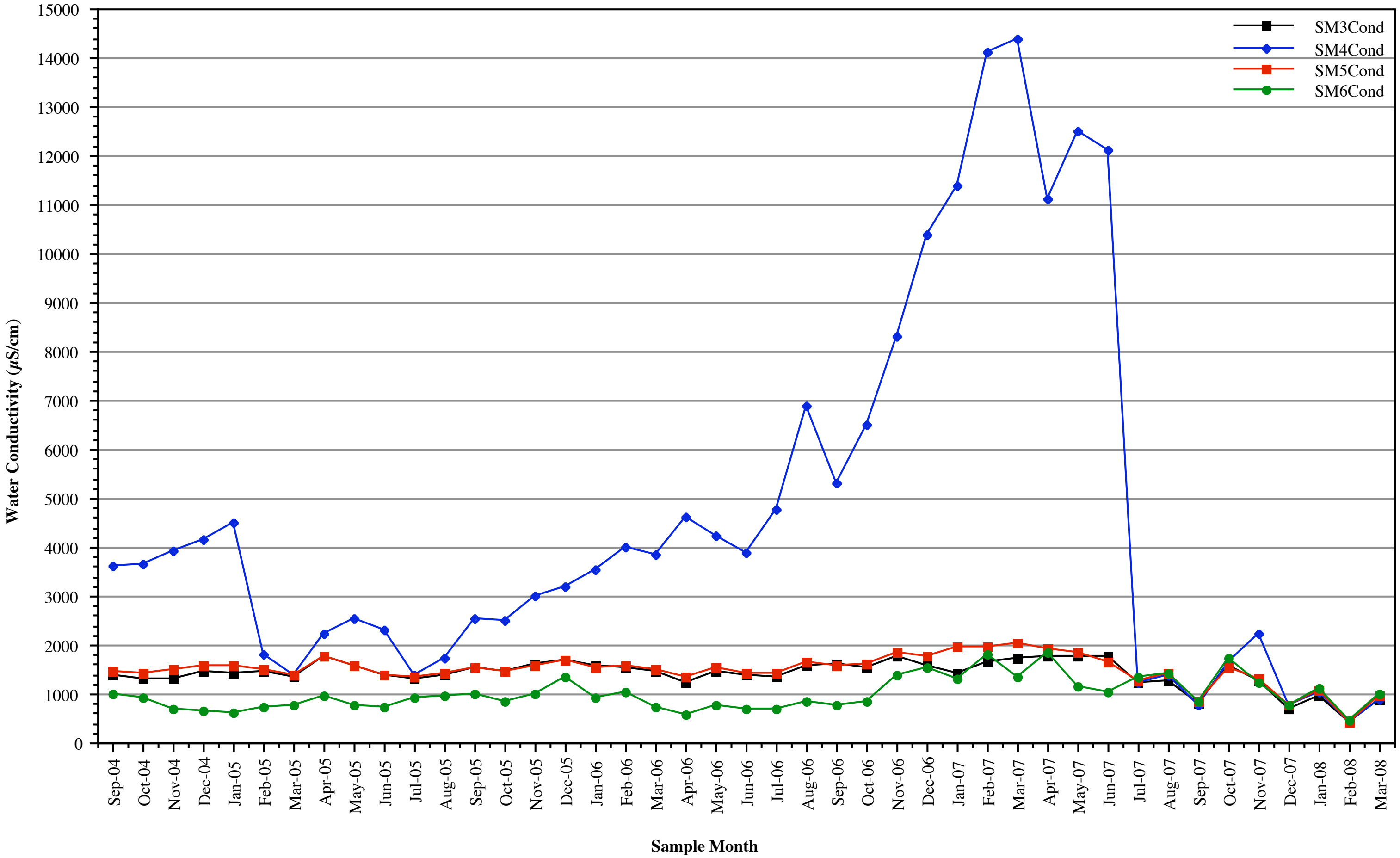

Fig A6 Monthly Water Conductivity (Sites SM3, SM4, SM5 and SM6

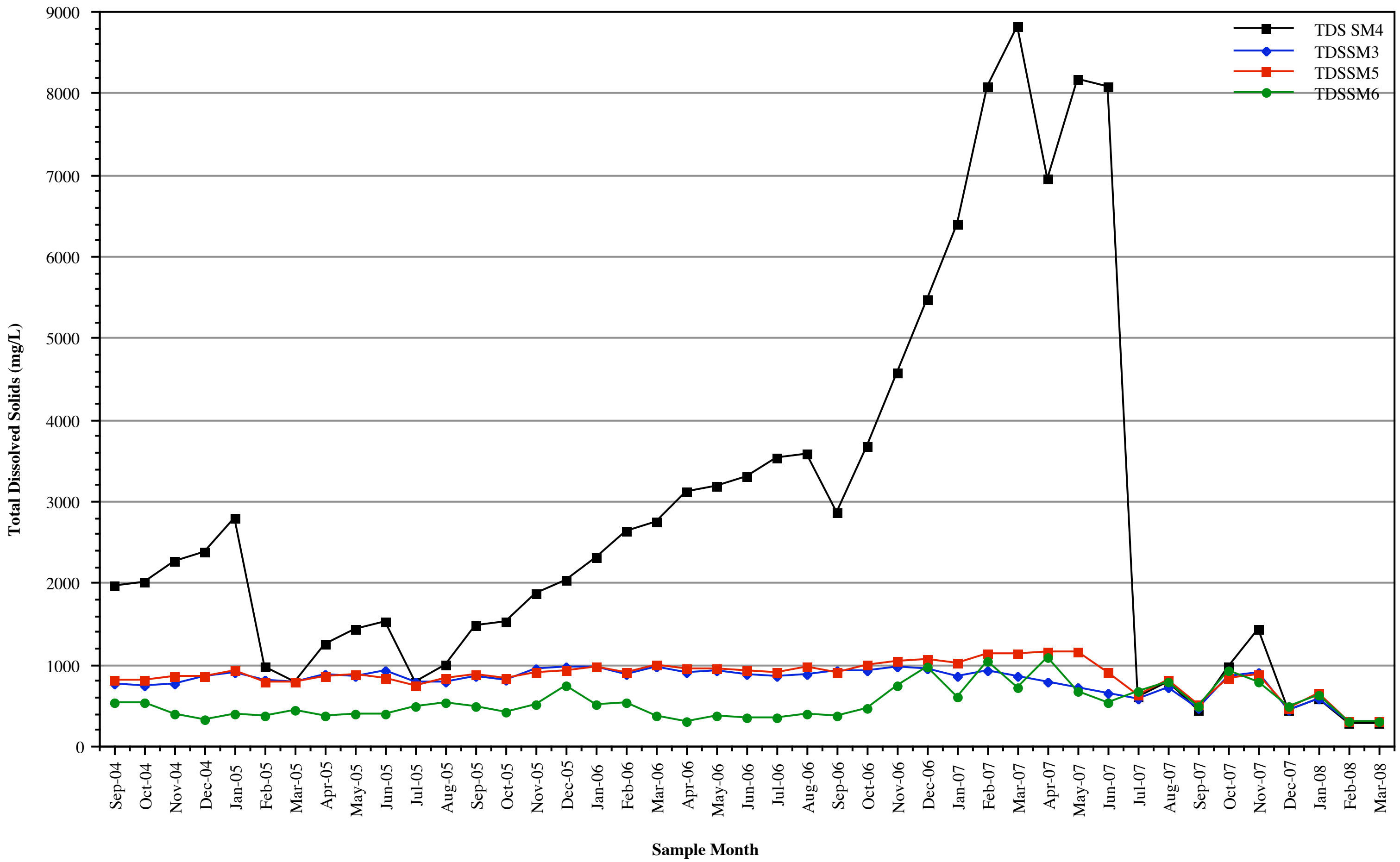

Fig A7 Monthly Total Dissolved Solids (Sites SM3, SM4, SM5 and SM6)

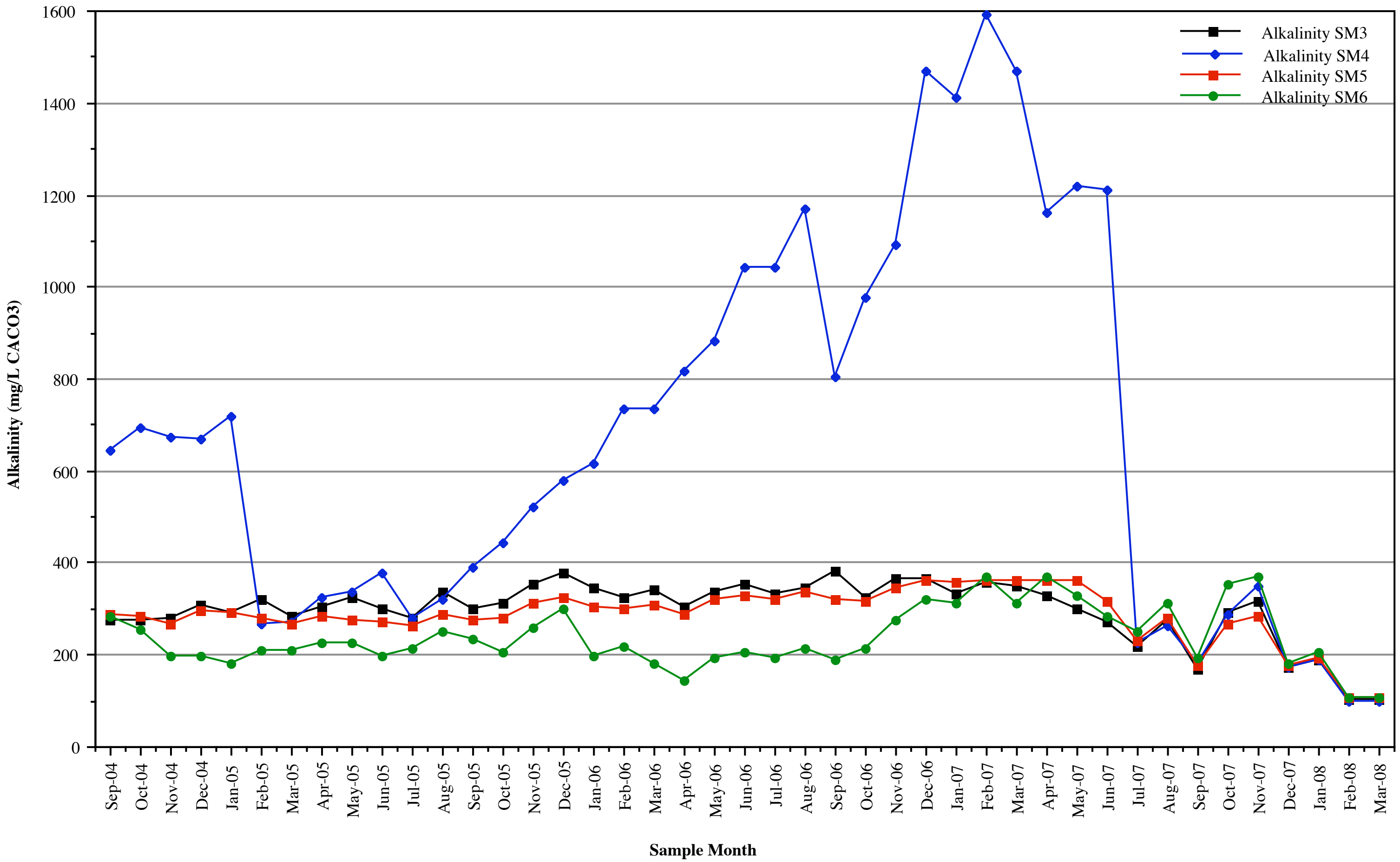

Fig A8 Monthly Water Alkalinity (Sites SM3, SM4, SM5 and SM6

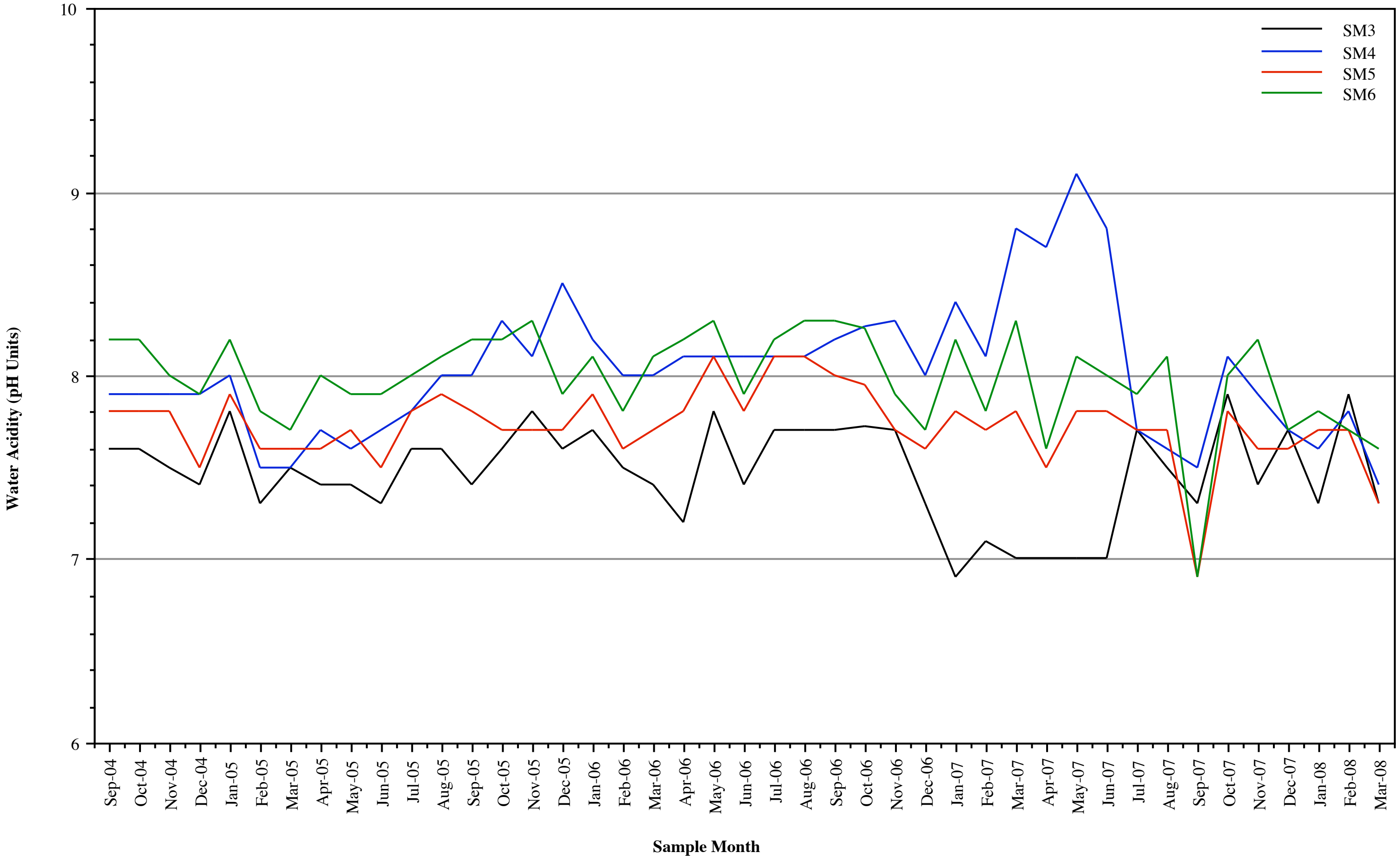

Fig A9 Monthly Water Acidity (Sites SM3, SM4, SM5 and SM6

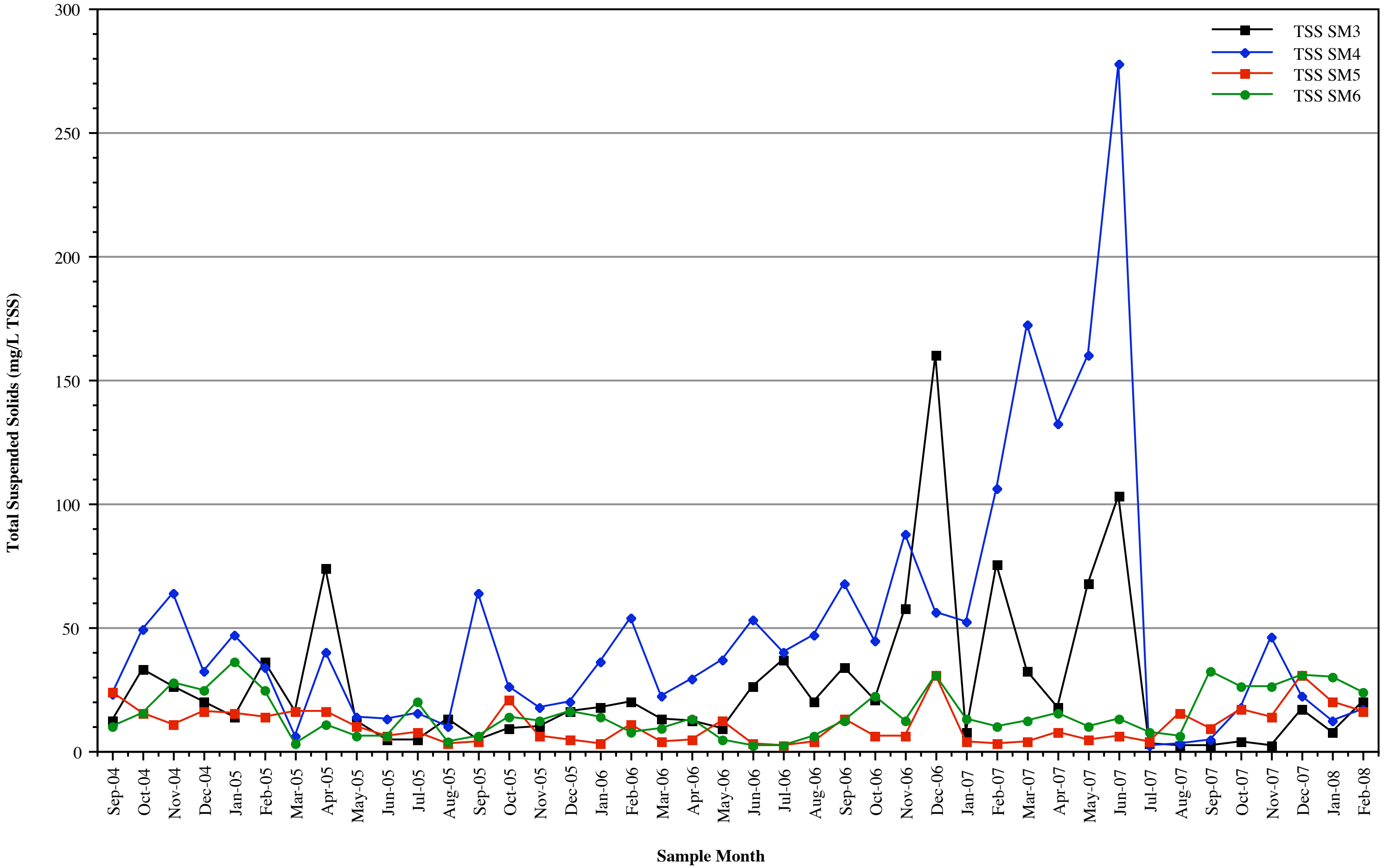

Fig A10 Monthly Total Suspended Solids Concentrations (Sites SM3, SM4, SM5 and SM6)

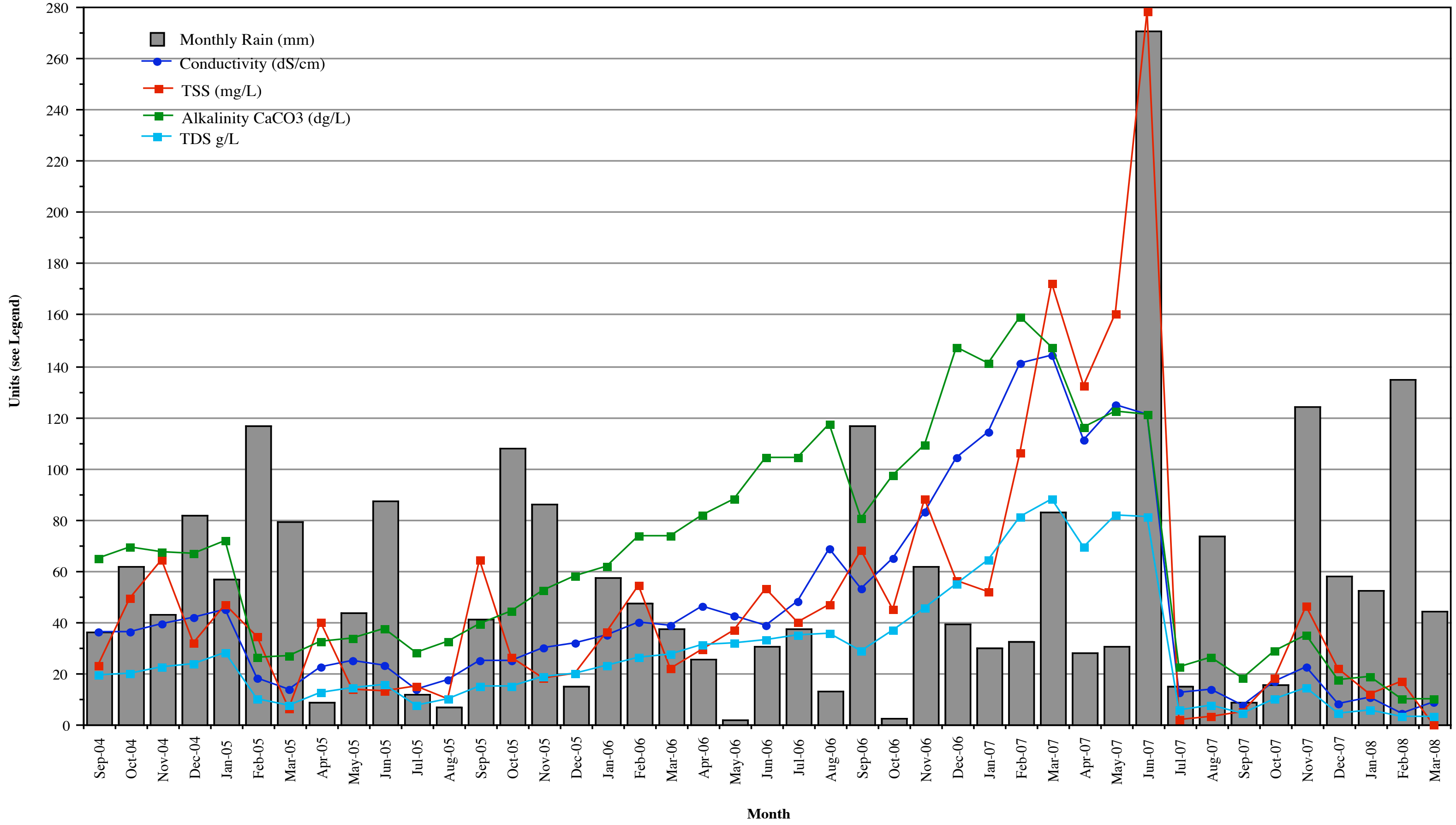

Fig A-11 ACOL Monthly Rainfall & Water Quality at Site SM4 September 2004 to March 2008

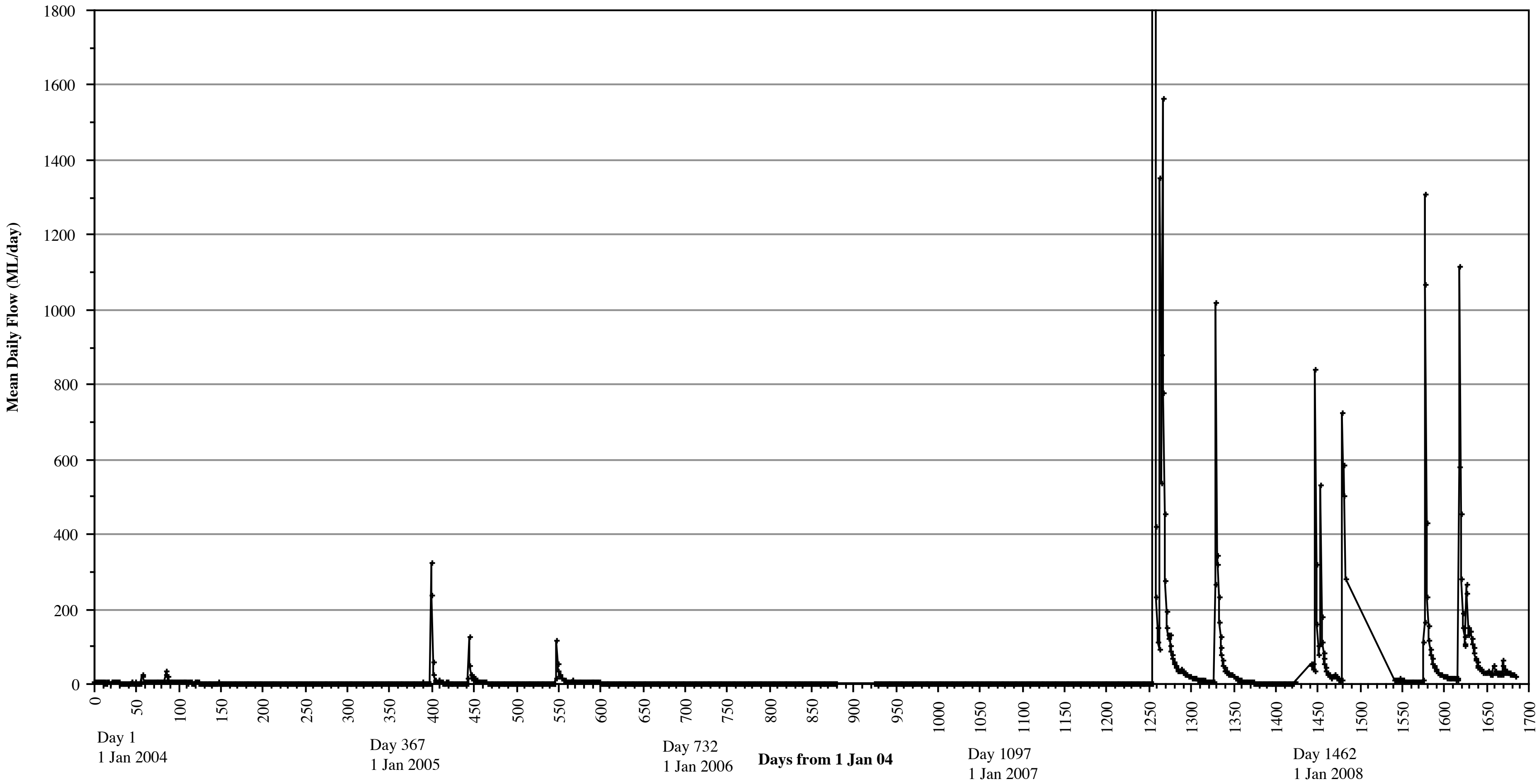

Fig A-12 Daily Flow (ML/day) at Bowmans Creek Gauging Station (showing Storm events)

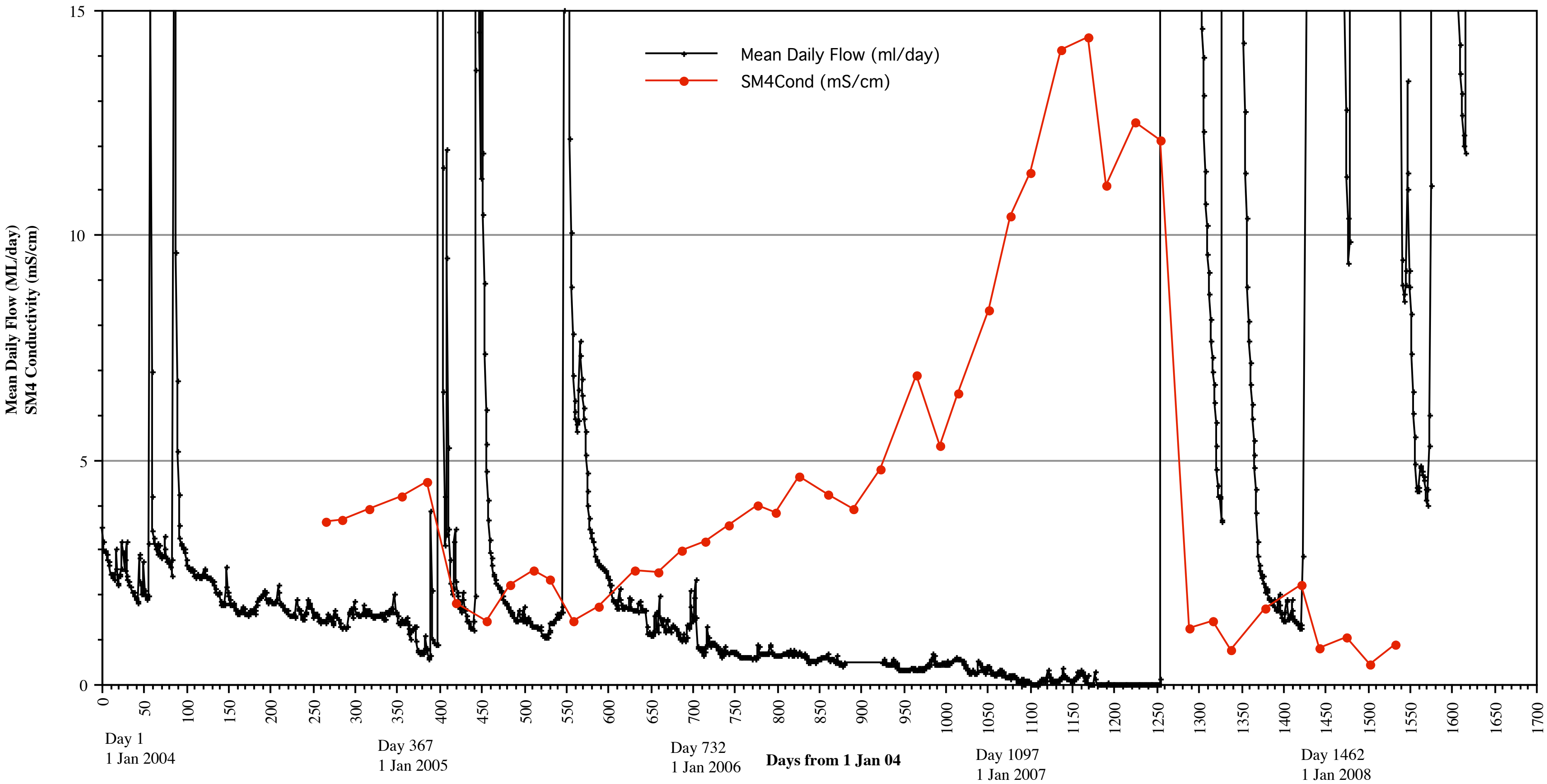

Fig A 13 Daily Flow (ML/day) at Bowmans Creek Gauging Station and site SM4 Conductivity (in mS/cm)