TWEED SHIRE COUNCIL

Environmental assessment of an unnamed creek adjacent Harrys Road, Crystal Creek

July 2013

TWEED SHIRE COUNCIL | TOGETHER FORWARD

REV	Description	Author	Approval	Date
A	Final report issued for August meeting of the Tweed Shire Council	Design Unit, Engineering and Operations Division	David Hannah	31/7/2013

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EXECUTIVE SUMMARY

This report has been prepared in response to a notice of motion of council at its meeting of 18 April 2013, to bring forward a report on the state of the unnamed creek at Harrys Road, Crystal Creek including recommendations for remediation as soon as possible.

The current assessment aimed to collect a snapshot of data on sediments, water quality and aquatic biota in relation to the subject creek supplemented by any existing background information. Although there is substantial background water quality monitoring data associated with an adjacent Council Quarry (Kinnears Quarry), there is however no information on sediments and aquatic biodiversity related to the subject creek. Consequently, sampling was required to inform the current assessment.

The assessment found that the water quality within the subject creek has greatly improved since late 2011 although ongoing management is warranted to limit the source of iron to the subject creek. Similarly, sediment quality levels were generally within guidelines although elevated levels of some metals are present. The improved quality of the creek is supported by the presence of fish and macroinvertebrates (including crustaceans) detected during the assessment - the composition of which was found to be not too dissimilar to an adjacent reference creek unaffected by past quarry operations.

An assessment of the creek geomorphic features and processes, and analysis of sediments at various locations in the subject creek, did not support a sediment slug event resulting in infilling of the pond area downstream of the quarries. Rather, deposition of organic matter and sediments is likely to have occurred over a long period (at least 10 to 20 years). Recommendations are provided to manage a small bank scour on adjacent private land.

Although acid soils are present in the pond area above Harrys road culvert, leaving the pond area undisturbed shouldn't lead to any further issues. As a precaution, in the event that water levels recede and soils in the pond are exposed, then recommendations to remove and treat soils should be enacted.

1.0 INTRODUCTION

1.1 Purpose (aims and objectives)

This report has been prepared in response to a notice of motion of council at its meeting of 18 April 2013, to bring forward a report on the state of the unnamed creek at Harrys Road, Crystal Creek including recommendations for remediation as soon as possible. The unnamed creek, (referred to from here on as 'the subject creek') is located adjacent to two hard rock quarries known as Kinnears Quarry and Sandercocks Quarry. At these quarries, localised naturally occurring pyritic (pyrite-rich) rock has been exposed by past quarry operations resulting in production of low pH and iron concentrated water which has impacted on the adjacent subject creek. Within the creek iron staining is prevalent and iron precipitate (also referred to as iron floc) is covering most in-stream substrates between the quarries and the downstream culverts at Harrys Road adjacent Numinbah Road.

To address the notice of motion, a number of assessments have been conducted including review of existing water quality data dating back to 2006 associated with Council's Quarry, analysis of sediments and current water quality within the creek, and preliminary surveys of aquatic biota. Comparisons of the aquatic biota are made to a reference creek in an adjacent catchment not affected by past quarry operations. In addition, a number of specialists working in the fields of acid sulfate soils remediation and wetland rehabilitation were engaged to provide further comment and advice on the status of the subject creek. Following this, and in accordance with the notion of motion, options and recommendations for remediation are proposed.

1.2 The Study Area

The subject creek is located adjacent Harrys Road and flows in a northerly direction crossing under North Arm Rd and flowing ultimately into the Rous River. Harrys Road is located approximately 6km west of Murwillumbah (refer Figures 1 and 2 for location details).

The soil landscape within the study area is mapped predominantly as Burringbar (Bu) and characterised as high rolling hills on metamorphics of the Neranleigh – Fernvale Group (discussed further below) (Morand, 1996). Topography in the vicinity of the subject creek ranges between about 10 and 90 m AHD, with the highest point occurring east of the quarries on a north-south ridgeline and the lowest point associated with the subject creek.

The vegetation community occurring adjacent the subject creek on the western side of Harrys Road is described as Camphor Laurel dominant open forest. It is analogous with the Tweed Vegetation Management Strategy vegetation community 1004. Kingston *et al* (2009) describes this vegetation community type as: dominated by exotic Camphor Laurel, often occurring as pure even-aged stands or where extensive disturbance has occurred within other vegetation types some emergent or remnant species from the original community may be present. Field validation of this vegetation in the past has noted the potential for this community to regenerate to Lowland Rainforest Endangered Ecological Community with appropriate restoration works (namely weed control).

1.3 Background to past quarry operations

Adjacent to the subject creek are two hard rock quarries; Kinnears Quarry and Sandercocks Quarry, established in the western flank of a steep, heavily wooded ridge, formed in deeply incised terrain of hard, resistant rocks of the Neranleigh Fernvale Geological Group. A third Quarry, Singh's Quarry, is located on the eastern side of the ridge and drains to another sub catchment.

A review of historical aerial photography shows that Quarries were operational prior to 1970 (refer Figure 3). Tweed Shire Council (TSC) purchased the land (now Lot 1 DP 1004207) that contains Kinnears Quarry in 1991 and continued extraction until 2006 and has not been operational since that time. Little is known about the operation of the Quarry prior to this time except that in terms of past management, the quarry commenced operation sometime in the 1960's, apparently extended down towards subject creek, and the southern extent of Harrys Road adjacent the toe of the quarries is probably built on backfill material presumably sourced from quarry.

Sandercocks Quarry has operated under an existing use right although production is now ceased. Both quarries have been worked as typical hillside quarries commencing from Harrys Road and gradually working back (east) into the slope and upwards.

Naturally occurring beds or lenses of pyrite-rich, graphitic shale have been exposed from past quarry operations and generates low pH surface and groundwater. This acid rock drainage (ARD) occurs when sulphide minerals such as pyrite oxidise in the presence of oxygen and water. The reaction is: sulphide mineral + oxygen + water = sulphate + acidity + metals. Ecorock (2009) who investigated the management of ARD at Kinnears Quarry, note that the occurrence of potentially acid forming rocks in Kinnears Quarry is typical of similar quarry sites within the similar units of the Neranleigh Fernvale beds and is presenting the attendant problem of very low pH and iron concentrated water releasing from the quarry to the natural drainage system. Also, a small isolated and structurally unrelated deposit of carbonaceous shale was observed in the adjoining and upstream Sandercocks Quarry and this presents the same water quality risks as those being addressed in Kinnears Quarry (Ecorock 2009).

During and after rainfall events, low pH and iron concentrated water, if untreated or managed, eventually flows into the adjacent subject creek located along the site's western boundary. As a consequence, in March 2009 the Office of Environment and Heritage (OEH) (formerly Department of Environment and Climate Change) issued a Prevention Notice to TSC requiring investigation of the ARD at Kinnears Quarry. In response to this Prevention Notice, TSC engaged Ecoroc Pty Ltd to undertake an initial appraisal of the likely cause of the ARD condition and provide advice on what investigations and remedial treatment options are available to address the problem at the site (Ecoroc, 2009). In September 2009 the OEH issued a Prevention Notice to TSC requiring the construction of some of the ARD controls recommended in the Ecoroc (2009) report, and the investigation of groundwater at the site. Consequently, Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) were commissioned to undertake a hydro-geological investigation of the groundwater regime within the site including installation of a groundwater borehole network and monitoring of groundwater chemistry (AGE 2010).

In February 2011, OEH issued a Prevention Notice to TSC requiring Council to develop an Acid Rock Drainage (ARD) Management Plan for Kinnear's Quarry. A management plan was subsequently developed and approved by OEH. Kinnears Quarry is now managed in accordance with this plan and involves the containment of ARD water, treatment and subsequent release of this treated water. The treated water is tested to ensure compliance with licence conditions before discharge into the subject creek. The accumulated solids are dried on site before testing and transport to landfill for disposal. The areas of the site not occupied by water treatment and access facilities are being revegetated.

Sandercocks Quarry, as noted, operates under existing use rights and is reported as having a limited life span. The quarry is also affected by ARD and is required to manage ARD water under a TSC approved Environmental Management Plan. Measures have been implemented by the Quarry owners to minimise ARD from the quarry and include construction of pits to capture and treat water prior to discharge. The effectiveness of this treatment process is unclear as no specific water quality discharge data could be obtained as part of this review.

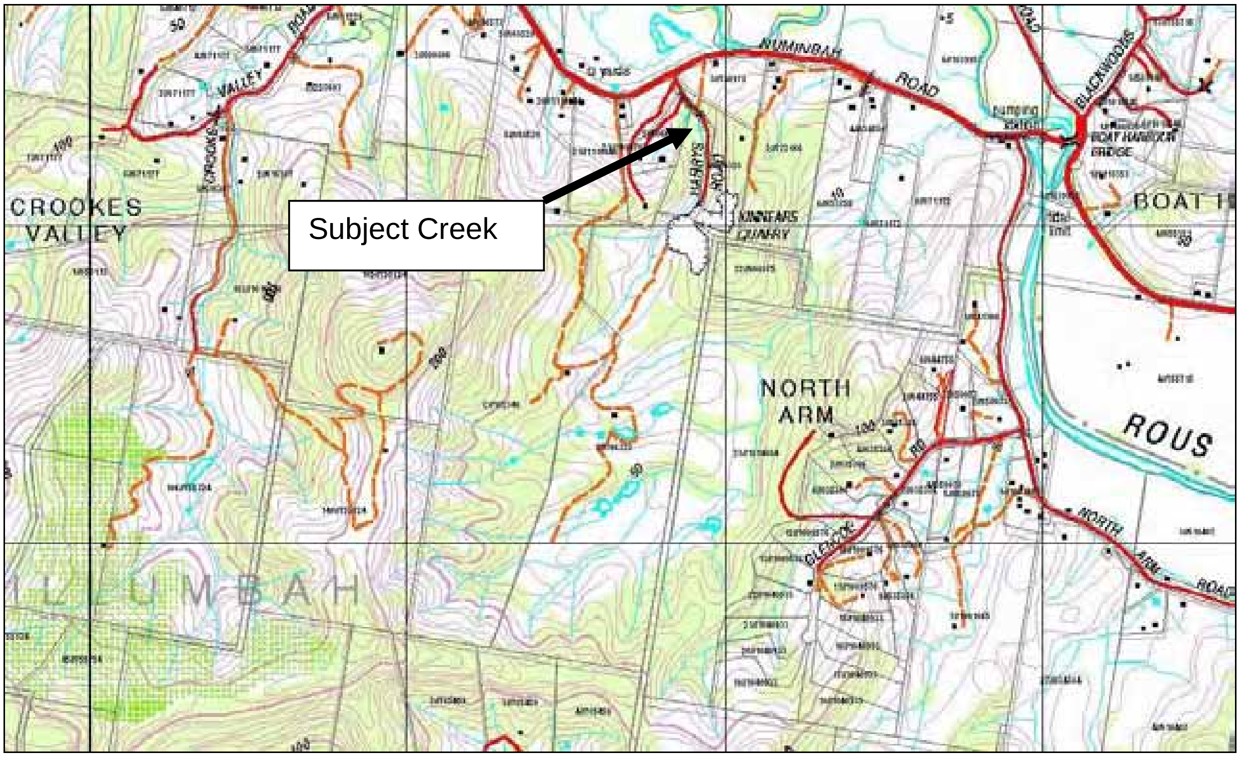

Figure 1: Subject creek locality plan (1:25000 Topographic)

Figure 2: Aerial photograph (2012) of the subject creek and adjacent lands

Figure 3: 1970 aerial photograph noting commencement of quarry operations at Harrys Road (note that the Harrys Road entrance was moved further west along north arm road by 1991)

2.0 METHODOLOGY

2.1 Review of background information

The following reports and studies were reviewed to inform the assessment of the subject creek and assist in identifying options for management:

- ECOROC (2009). Report on Acid Rock Drainage (ARD) Investigations and Remedial Solutions – ECOROC Pty Ltd July 2009.
- AGE (2010). Kinnears Quarry Acid Rock Drainage – Groundwater Assessment – Australasian Groundwater & Environmental Consultants Pty Ltd – October 2010
- TSC (2011). Acid Rock Drainage Management Plan, Kinnears Quarry.
- McCallum v Sandercock (2011). NSW Land and Environment Court 175.
- Tweed Shire Council Water Quality Monitoring Data for Kinnears Quarry (2006 to present)
- Tweed Shire Council Enlighten GIS mapping resources including aerial photography, soils and geology, waterway, vegetation and other biodiversity mapping layers.

2.2 Consultation

As part of collating background information for the status assessment, discussions were had with relevant Council staff in relation to Kinnears Quarry site management, and Council's Environmental Health Unit staff in relation to environmental management of Sandercocks Quarry.

A discussion was also had with the adjacent land owner of Lot 5 DP606655 on the 28 May 2013 who noted the following: That there had been a significant slug of sediment come down the creek filling the dam area on the upstream side of the culverts at Harry's Road. This in turn was considered to be causing bank erosion adjacent the driveway access to Lot 5 DP606655 and potentially undermining of the driveway. It was also noted by the landowner that the subject creek was unlikely that any aquatic species (such as fish and yabbies) would inhabit the stream given the high acidity levels that he had experienced within the creek.

On the 12 June 2013, staff from the University of NSW (UNSW) were invited to inspect the subject creek and to provide feedback on the state of degradation of the creek compared to acid sulphate soil effected drains and creeks. The UNSW team are involved in the research into, and remediation of, floodplain watercourses as a result of acid sulphate soils in the Tweed Shire.

In addition, on the 24 July 2013, Australian Wetlands were also asked to provide advice on the ecological health of the creek and provide recommendations for remediation where required.

2.3 TSC existing water quality data

2.3.1 Kinnears Quarry water quality sampling program

Tweed Shire Council has been conducting water quality testing within the subject creek and at Kinnears Quarry for many years. This testing was conducted under various regimes and included ground water, surface water, and discharge water monitoring. A plan showing water quality monitoring locations is provided in Figure 4.

The water quality data for Kinnears Quarry was summarised for the three sites associated with the subject creek. The KIN1 monitoring site is located above inputs from Sandercocks and Kinnears Quarry's and is representative of background water quality for the sub catchment. The subject creek then passes under the floor of Sandercocks Quarry via a pipe before discharging back into the natural creek line. The KIN2 monitoring site is located at the outlet of this pipe and also receives surface water flows across the floor of Sandercocks Quarry. KIN3 is located at the culverts at Harrys Road. Water quality monitoring commenced at KIN1 on the 14/11/2007 and the 18/9/2006 for KIN2 and KIN3. All data reviewed as part of this assessment was up until 30/5/2013.

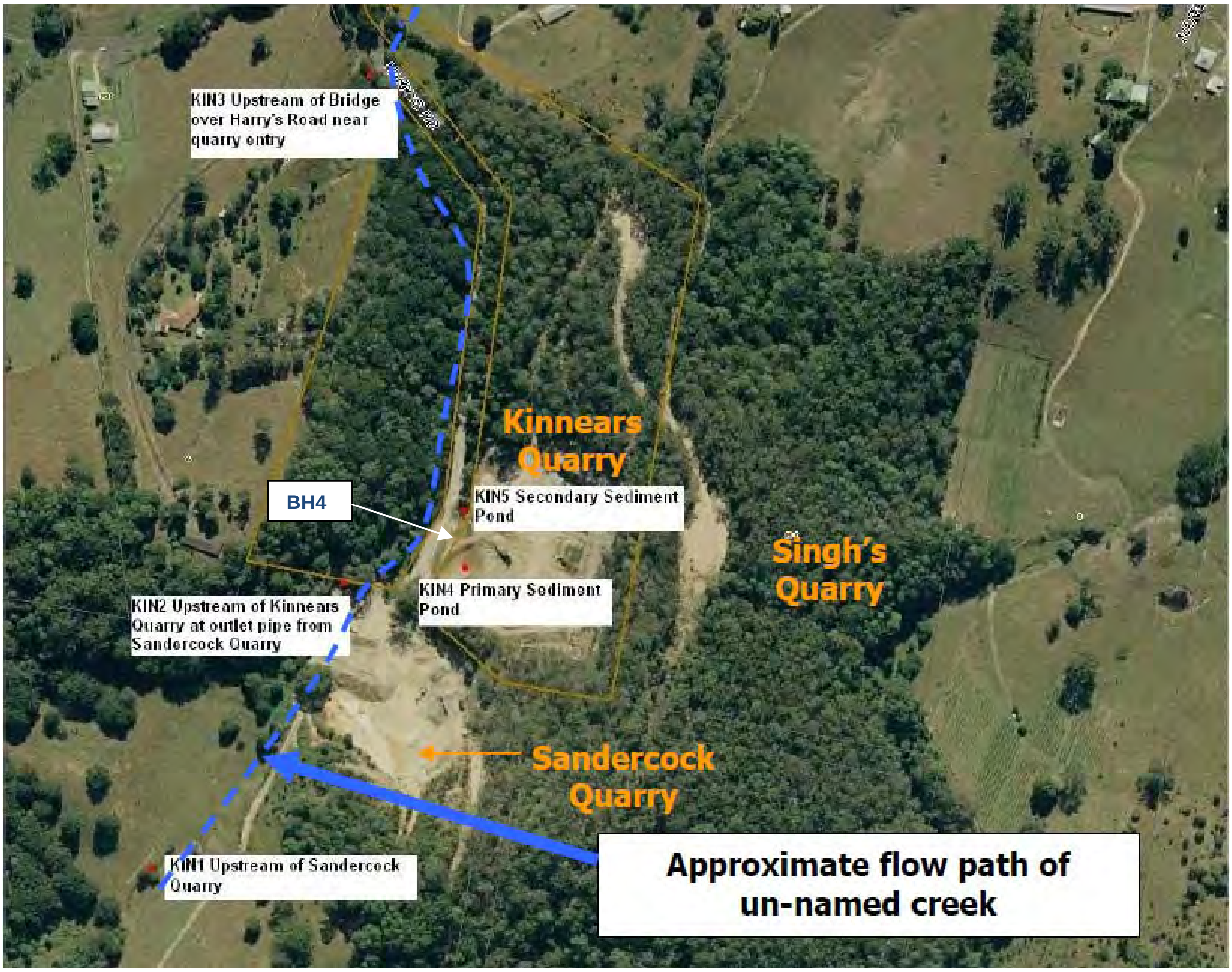

Figure 4: Water quality monitoring locations (*extract from Ecoroc Pty Ltd 2009*)

Groundwater Borehole Monitoring

Groundwater samples are collected from BH4 coinciding with discharging of water from the treatment pond (pond 2) at Kinnears Quarry. Seven (7) samples have been logged between 28 November 2012 and 9 April 2013. Prior to this, periodic sampling of four boreholes was undertaken between 10 February 2010 and 31 August 2010 and consisted of six sampling events.

Surface Water Monitoring

Prior to initiation of dedicated ARD treatment (commencing around the 23 August 2011), surface water sampling had been undertaken within the Subject Site Creek and within the basin within Kinnears Quarry since September 2006. Note that no sampling was being undertaken between September 2006 and November 2007 upstream of Sandercocks Quarry. In general, sampling was carried out monthly and after each significant rainfall event.

Discharge monitoring

In addition to upstream and downstream water quality testing within the Subject Creek, Clause 1(c) of the OEH Prevention Notice requires an ongoing water quality testing program for treated ARD water discharged from the treatment ponds within Kinnears Quarry to the Subject Creek. Samples are taken from monitoring point KIN6. Samples are also collected in the event of overtopping of the ponds due to rainfall events that exceed the treatment basins capacity to contain all runoff – although given the dams are actively managed to allow maximum freeboard, only significant rainfall events would trigger this requirement.

Consequently, once pH and dissolved oxygen is within the OEH nominated range, water is discharged to the subject creek and a water sample taken and analysed for additional parameters including metals. In total, 40 samples have been analysed coinciding with discharge events between 22 December 2011 and the 14 June 2013.

Water quality target values for Kinnears Quarry are nominated within the OEH Final Prevention Notice and included within Environmental Protection Licence (EPL) 20014.

All testing results are posted in the TSC website as required under licence for Kinnears Quarry.

2.3.2 Rous River sampling

A review of Tweed Shire Councils Shire Wide water quality monitoring data layer found one water quality monitoring site located within the Rous River approximately 10km downstream of the subject creek (reference TWE13). A range of data parameters at different depth profiles has been collected since November 2008. The water quality program is decribed below in Table 9 from Aber (2012).

Table 9: Tweed Shire Council long-term water quality sampling program details

Methods	Discrete water quality samples, in-situ sampling with multi-parameter sensor
Parameters	Chloride (mg/L), Chlorophyll 'a' (µg/L), Dissolved Oxygen (mg/L),Iron Total (mg/L), pH (pH units), Salinity (psu), Sulfate(mg/L), Suspended Solids (mg/L), Temperature (C), Total Aluminium (mg/L), Total Nitrogen, (mg/L) Total Phosphorus (mg/L), Turbidity (NTU), Thermo-tolerant Coliforms (cfu/100ml)
Sites	CGN1,CGN2,CGN3,CGR1,CGR2,CGR3,CGR4,CGR6,MBL1,MBL2,MBL3,MBL4
Duration	1999-present (on-going)

2.4 Site selection for rapid assessments

Sediment and water sampling

The current assessment aimed to collect a snapshot of data on sediments, water quality and aquatic biota in relation to the subject creek supplemented by any existing background information. As noted above, there is substantial background water quality monitoring data primarily associated with Kinnears Quarry. However, there is no information on sediments and aquatic biodiversity related to the subject creek. Consequently, sampling was required to inform the current assessment.

Communication with an adjacent landholder had suggested that a large rainfall event had resulted in sediments being deposited in the small in stream dam on the upstream side of Harrys Road referred in later discussions as the "culver pond". Consequently, sediment samples were taken from the leading edge of this dam, above a weir between the small dam and the Quarries, and a composite of samples from within the riffle sections of the stream.

At the time of sediment sampling, water quality samples were also collected including a sample of the iron floc observed within the stream.

Aquatic biota sampling

Given that no background aquatic biota assessments have been undertaken in association with the subject creek, the assessment aimed to identify adjacent reference streams that could provide an indication of typical aquatic species richness and diversity in streams unaffected by quarrying activities. Selection of reference sites had to consider the following factors:

- No quarrying activities draining the stream
- Same geology as the subject creek
- Stream is located within the Rous River catchment.

A review of the Morand (1996) Soil Landscapes of the Murwillumbah-Tweed Heads Sheet soils indicates the regional geology being dominated by the Neranleigh Fernvale Group. A reference site was located off Glencoe Road with head waters originating from vegetated ridgeline approximately 1.3km due south of Kinnears Quarry. Aquatic biodiversity sampling was undertaken within the reference site on the same evening as sampling within the subject site (discussed further below). Refer to Figure 5 below for location details.

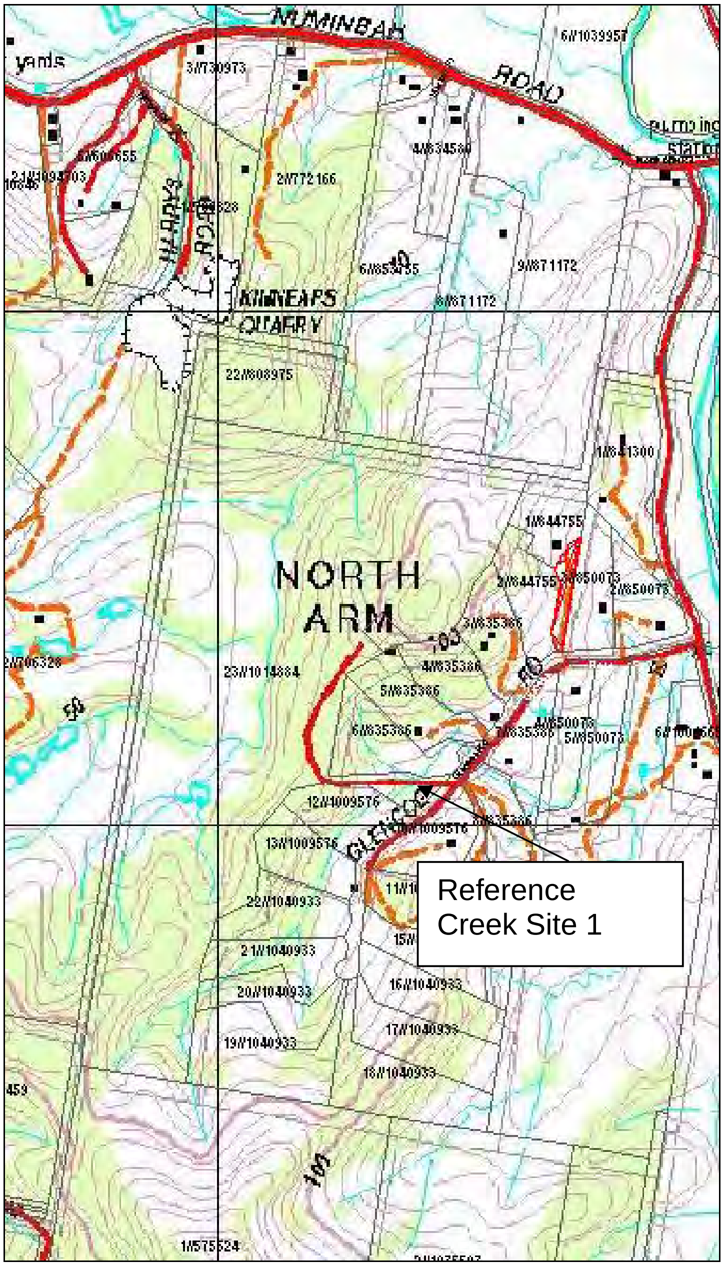

Figure 5: Glencoe Road reference stream location

(Extract 1:25000 Murwillumbah Topographic map 9541-N 2012, Land & Property Information)

Stream Geomorphology

A rapid geomorphological assessment of the subject creek and reference creek consisted of both desktop and field assessment methodologies. The following descriptive variables (adapted from Hydrosphere 2012) were considered when characterising the stream sections and included:

- Channel form (e.g. pool, run, riffle, backwater)
- Bank stability (e.g. eroding, stable, depositing)

- Factors affecting stability (e.g. stock access, clearing vegetation, bridge/ford etc.)
- Artificial bank protection measures (e.g. fencing, levee banks, rock or wall layer, vegetation planting, fenced stock watering points etc.)
- Type and extent of any bars present (e.g. vegetated/vegetated side, mid channel, braided, in filled channel, bars absent etc.)
- Substrate composition (% composition bedrock, boulder, pebble, sand, fines etc.)
- Presence of artificial features or in-stream barriers (e.g. culverts, erosion control, weirs) and
- Presence of in-stream habitat features such as woody debris, diversity of hydraulic environments and substrate types.

2.5 In-stream sediment and water quality sampling

In-stream sediment sampling was carried out on 31 May and 14 June 2013 at the Subject Creek. Two in-stream sediment samples were taken: one from within a deposition zone immediately upstream of a constructed weir; and another sample from the head of the pond adjacent the culverts at Harrys Road. The sites are described in more detail in Table 1 below.

Weather conditions leading up to sampling was fine on the day of sampling, however, rainfall recorded for the month leading up to the sampling date was 30.0mm for May (31 days) and 76.0mm for June (BOM Station 058158, Bray Park, Murwillumbah). The long-term cumulative mean from January to June was 1058.2mm (1972 - 2013) with rainfall to date for 2013 (January to June) being 1387.9mm - an increase of approximately 330mm above mean.

Table 1: Field Sample composition and location

Sample Type	Sample description	Sample location	Assessment type
In-stream Sediment	Composite Sample	Culvert Pond	Field description, Metals suite, Chromium reducible suite
In-stream Sediment	Discrete Sample	Weir	Field description
In-stream Iron precipitate (floc)	Iron floc from within low flow area/fringe of creek	Approximately 20m upstream of the head of the pond.	Bacteria, metals suite
Water Sample	Surface Water	Approximately 20m upstream of the head of the pond.	Metals suite

Representative Instream sediment samples were collected via a combination of equipment that included:

- Stainless steel trowel for sediment within small riffle sections (to depth of ~100mm)

- Handheld steel auger 75mm Ø for weir sample (to depth of ~ 1.3m)
- Handheld vacuum pump for collection of sediment within culvert pond (to depth of ~ 1.0m) (*Note: Due to high density of leaf litter within pond conventional samplers were unable to extract a sample).*
- Samples were placed in airtight (clip lock) plastic bags and labelled accordingly.

A water sample and iron floc sample was collected from the reach located between the weir and the culvert pond. Collection details are as follows:

- Water sample was collected by hand in a 1litre high density polyethylene (HDPE) container.
- Floc sample was collected by hand in a 250ml polystyrene jar

Samples for laboratory analysis were placed within a chilled esky and transported to the NATA accredited Tweed Laboratory (Banora Point) for analysis.

Samples collected for descriptive purposes only were stored within a sealed air proof bag within a fridge at TSC offices.

2.6 Aquatic biodiversity rapid assessment

A rapid assessment of fish and macroinvertebrate activity was undertaken within the subject creek and an adjacent reference creek (Glencoe) in order to better understand the impacts that contaminants such as iron may be having on the health of the subject creek. Aquatic surveys of the two streams were undertaken on one evening only on the 28 May 2013. An evening sample was undertaken to record active fish and crustaceans given that electro fishing was not utilised for the survey.

It is recognised that the survey provides a snap shot assessment of active species at the time of the assessment. Further, the survey does not account for seasonal variation in aquatic fauna or variation in hydrological conditions. Rather, the aquatic assessment was employed to provide a preliminary indication of aquatic health to supplement water quality and sediment data and it is recognised that this assessment would not comply with aquatic biodiversity survey guidelines generally employed for impact assessment studies – primarily due to the limited time provided to undertake the assessment.

The approach for fish and macroinvertebrate sampling within the subject creek involved surveying three 30m sections of the creek. Sites were situated as follows:

- Downstream site - commencing at the upstream edge of the pool at Harrys Road culverts
- Midstream site – located directly upstream of the weir
- Upstream site – located between the outlet at Kinnears Quarry and Sandercocks Quarry.

Site locations aimed to survey the representative geomorphology of the subject creek whilst also considering likely pollutant point sources from the adjacent quarrying activities. Within each 30m sampling reach, five plots measuring 2m in reach length and spaced 5 metres apart was sampled for fish and macroinvertebrates.

Only one 30m reach section was sampled within the Glencoe reference stream. The restricted sampling effort was an artefact of the limited establishment time for the study, in turn limiting access to private land. Nonetheless, the site and sample location was considered suitable as a reference site given the geological location, and the similar geomorphology of the stream compared to the subject creek.

The following parameters were measured at the time of sampling:

- Date and location details
- Prevailing weather conditions
- Characterisation (fresh, tidal, perennial, intermittent)
- Waterway classification (as per NSW Fisheries 1999)
- Riparian vegetation description
- Surrounding landuse
- Evidence of disturbance (pollution, erosion etc)
- In-stream features (such as reach dimensions, morphology, substrate, aquatic vegetation)
- Water quality at time of sampling (including conductivity, pH, dissolved oxygen, and Temperature using a YSI meter)
- Relative abundance scores (0-5 rank) for periphyton, filamentous algae, macroinvertebrates, macrophytes, and fish

Fish were sampled using a combination of sweep netting and observation of free swimming species. Information was collected on fish presence/absence only and an estimate of relative abundance. Macroinvertebrates were sampled at the same time as fish sampling. Macroinvertebrate samples were collected using a triangular dip hoop with dimensions 35 x 30 x 30cm and bag with mesh size 0.9 x 0.3mm and bag depth of 59cm to sample riffle, pool edge and macrophyte habitats (where present) at the sample sites. Identification of macroinvertebrate species was undertaken using available keys and guides for the Northern Rivers region. Macroinvertebrates were also assigned SIGNAL scores (Chessman, 2003).

3.0 RESULTS

3.1 Summary of water Quality Objectives

In regards to categorising the subject creek in this location from a water quality perspective, it is more typical of an upland river (e.g. with bedrock steps and small cascades) rather than a slow flowing sinuous lowland river such as the Rous River or Tweed River.

In establishing a suitable ANZECC guideline (2000) criteria, the subject creek falls somewhere in between an upland river and lowland river based on the relatively short reach of creek (~350m) under assessment, that discharges to the downstream floodplains of the Rous River. The default trigger values for rivers in south east Australia (including Tasmania) are classified into two categories, based on altitude: lowland rivers (below 150m) and upland rivers (above 150m). The criteria, although indicative, does not consider local variability, habitat or geomorphology in assessing trigger values.

Tailoring Water Quality Objectives to local conditions

Local water quality varies naturally because of various factors, including the type of land the waters are draining (e.g. soils, slope), or rainfall and runoff patterns (e.g. ephemeral or permanent streams). Different land use and land management practices also affect water quality. Local water quality objectives (WQO's) must take account of these variations, particularly for the environmental value of aquatic ecosystems (ANZECC 2000).

The ANZECC Guidelines (2000) establish default trigger values that are set conservatively and can be used as a benchmark for assessing water quality. Further refinement of the trigger values may be needed to take account of local conditions, especially for aquatic ecosystems and particularly in places, or for issues, requiring priority action. This should be consistent with the approach advocated by the ANZECC 2000 Guidelines of focusing on the actual issue (or threatening process) that is a risk or potential risk to the environmental value(s). The selection of the indicator and derivation of the trigger value should trigger action or investigation before the environmental value is compromised. Trigger levels that have been locally refined must still protect the environmental value and drive local protection or improvement of water quality (ANZECC 2000).

Proposed Water Quality Indicator Values (trigger values) for the subject creek are listed below in Table 2 and utilise the adopted Tweed River WQO's in line with the ANZECC (2000) guidelines for the protection of aquatic ecosystems, to assess water quality in this report.

Table 2: Summary of water quality indicators (trigger values) for aquatic ecosystems to assess subject creek

Parameter	Tweed River WQO's (values are trigger levels)	See notes below	Comment
pH (pH Units)	6.5 – 8.0	2,4	Upland river context, however native geology is associated with lower pH values for local conditions
Conductivity (μScm^{-1})	125 – 2,200	2,4	Based on naturally lower levels of pH and therefore typically higher valves of EC
Dissolved Oxygen (% saturation)	80-110%	2,4	Upland river context
TSS (mg/L)	50	1	Not listed in ANZECC
Turbidity (NTU)	6-50	2,4	Based on surrounding disturbed land eg landuse of farming, quarrying, rural residential
TN (ug/L)	<250	2,4	
TP (ug/L)	< 20	2,4	
Oil & Grease (mg/L)	< 10	1	
Metals (stated as µg/L)			
Iron	ID	2,3	Insufficient Data - see comments below.
Aluminium >pH 6.5 <pH 6.5	ID	2,3 2	Insufficient Data - see comments below.
Arsenic	13	2	
Boron	370	2	
Cadmium	0.2	2	
Chromium	1.0	2	
Copper	1.4	2	
Lead	3.4	2	
Mercury	0.6	2	
Nickel	11	2	
Zinc	8	2	
Manganese	1900	2	

[1] Tweed Shire Council Development Design Specification D7 – Stormwater Quality

[2]Aquatic ecosystem criteria from Australian and New Zealand Environment and Conservation Council (ANZECC)(2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000* (Table 3.3.2, 3.3.3 – Lowland rivers, and Table 3.4.1 – Freshwater criteria)

[3] Freshwater criteria from Table 1-C of National Environment Protection (Assessment of Site Contamination) Measure 1999. Schedule B(1) Guideline on the Investigation Levels for Soil and Groundwater.

[4] Water Quality Objectives for the Tweed River and Catchment

ID - **Aluminium** at pH <6.5 for freshwater a low reliability trigger of 0.8ug/L is derived for aluminium, however this trigger value is species dependant, localised background levels may provide indicative working levels for aquatic habitat assessment (refer sect 8.3.7.1 from ANZECC guidelines 2000). **Iron**, insufficient data available for reliable trigger values, localised background levels may provide indicative working levels for aquatic habitat assessment (refer sect 8.3.7.1 from ANZECC guidelines 2000).

3.2 Kinnears Quarry water quality monitoring results

Surface Water

A summary of water quality monitoring results since commencement of the Kinnears Quarry monitoring program is summarised in Table 3 below. The results show a trend in decreasing water quality compared to background levels. When looking at the entuire data set since 2006, the average upstream pH of 6.09 is lowered to pH 4.89 after passage flow through Sandercocks quarry, and then further lowered to an average of pH 3.96 after receiving runoff from Kinnears quarry. Similarly, the salinity of the water and presence of iron (total) also increased from background.

Table 3: Summary of results for the Kinnears Quarry water quality monitoring program

		KIN1			KIN2			KIN3			
Test	**Units**	**Samples**	**Mean**	**Std. Dev.**	**Samples**	**Mean**	**Std. Dev.**	**Samples**	**Mean**	**Std. Dev.**	**WQO's**
pH	pH units	79	6.09	0.55	89	4.89	1.25	99	3.96	1.50	6.5-8.0
Ec @ 25 C	Us/cm	79	129.62	105.32	89	325.66	335.11	99	704.61	647.07	125-2200
DO	mg/l	21	7.30	0.58	21	8.267	0.78	20	7.16	1.21	85-110%
Total Suspended Solids	mg/l	55	11.75	21.89	67	566.71	1912.60	69	15.30	32.49	Turbidity 6-50 NTU; 50mg/l
Calcium	mg/l	21	2.95	0.49	21	5.32	2.84	20	16.64	31.56	n/a
Magnesium	mg/l	21	1.83	0.21	21	2.84	1.39	20	4.33	2.10	n/a
Sodium	mg/l	21	13.29	1.52	21	13.11	3.39	20	12.06	2.42	n/a
Sulphur (Soluble)	mg/l	20	3.07	1.95	20	14.83	15.49	19	31.67	34.06	n/a
Aluminium (Total)	mg/l	21	0.24	0.17	21	0.93	1.06	20	0.35	0.34	ID[1]
Sulphur as Sulphate	mg/l	79	5.61	3.14	89	115.60	187.01	99	329.69	626.55	n/a
Iron (Total)	mg/l	79	0.77	3.70	89	13.63	29.20	99	12.67	24.76	ID[2]
Chloride	mg/l	35	17.42	6.01	47	19.93	12.91	56	19.43	15.35	n/a

Data from 14/11/2007 to 30/5/2013 for KIN1 and from 18/9/2006 to 30/5/2013 for KIN2 and KIN3.

[1] - at pH <6.5 for freshwater a low reliability trigger of 0.8ug/L is derived for aluminium, however this trigger value is species dependant, localised background levels may provide indicative working levels for aquatic habitat assessment (refer sect 8.3.7.1 from ANZECC guidelines 2000).

[2] - insufficient data available for reliable trigger values, localised background levels may provide indicative working levels for aquatic habitat assessment (refer sect 8.3.7.1 from ANZECC guidelines 2000).

In contrast, since construction of the dedicated ARD treatment basins on the Kinnears Quarry site in 2011, downstream water quality has improved considerably (refer Table 4). This is clearly shown in Figures 6a-d where data is presented for pH Levels, dissolved oxygen, aluminium and iron post treatment pond construction and commissioning (February 2012).

Table 4: Summary of the Kinnears Quarry water monitoring program since establishment of EPA licensed treatment basins 9/2/2012 to 30/5/2013

		KIN1			KIN2			KIN3			
Test	Units	Samples	Mean	Std. Dev.	Samples	Mean	Std. Dev.	Samples	Mean	Std. Dev.	WQO's
pH	pH	17	6.21	0.38	17	5.95	0.83	16	6.14	0.38	6.5-8.0
Conductivity @ 25 C	Us/cm	17	106.88	12.23	17	148.24	67.63	16	177.13	59.90	125-2200
DO	mg/l	17	7.37	0.59	17	8.30	0.86	16	7.20	1.33	85-110%
Total Suspended Solids	mg/l	17	2.98	2.17	17	16.35	18.33	16	7.07	7.06	Turbidity 6-50 NTU; 50mg/l
Calcium	mg/l	17	2.92	0.54	17	4.98	3.05	16	8.43	4.32	n/a
Magnesium	mg/l	17	1.81	0.23	17	2.72	1.52	16	3.88	1.40	n/a
Sodium	mg/l	17	13.12	1.36	17	12.96	3.61	16	12.15	1.66	n/a
Sulphur (Soluble)	mg/l	17	2.41	1.22	17	9.56	8.41	16	18.79	13.04	n/a
Aluminium (Total)	mg/l	17	0.18	0.08	17	0.81	1.14	16	0.24	0.18	ID[1]
Sulphur as Sulphate	mg/l	17	2.41	1.22	17	9.56	8.41	16	19.06	12.89	n/a
Iron (Total)	mg/l	17	0.26	0.16	17	2.88	3.60	16	3.10	2.60	ID[2]

[1] - at pH <6.5 for freshwater a low reliability trigger of 0.8ug/L is derived for aluminium, however this trigger value is species dependant, localised background levels may provide indicative working levels (refer sect 8.3.7.1 from ANZECC guidelines 2000).

[2] - insufficient data available for reliable trigger values, localised background levels may provide indicative working levels (refer sect 8.3.7.1 from ANZECC guidelines 2000).

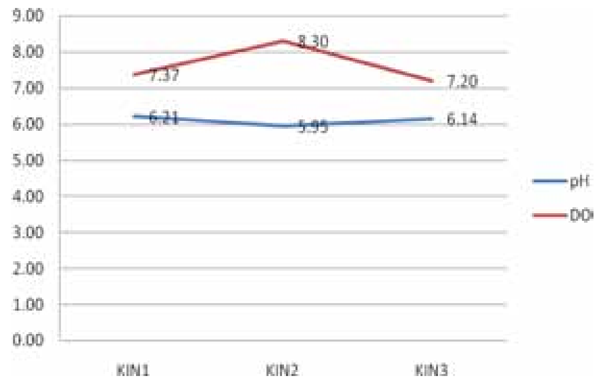

Figure 6a. Results for pH and Dissolved Oxygen since treatment ponds established at Kinnears Quarry

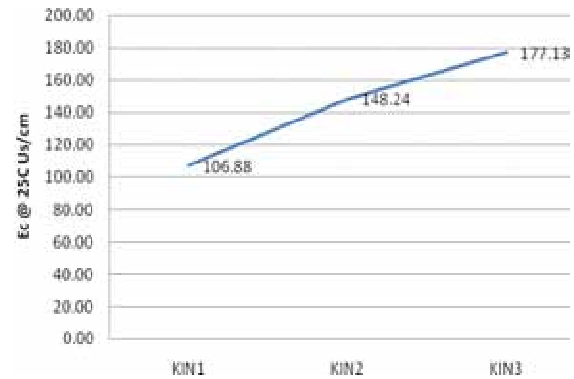

Figure 6b: Results for Conductivity since treatment ponds established at Kinnears Quarry

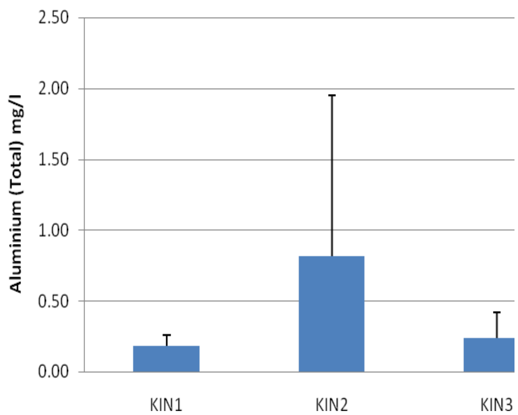

Figure 6c: Aluminium levels post establishment of treatment ponds at Kinnears Quarry

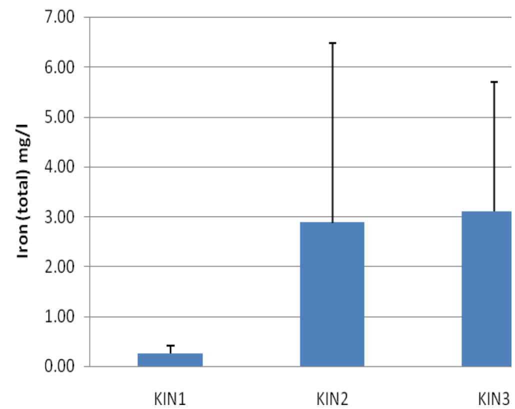

Figure 6d: Iron (Total) levels post establishment of treatment ponds at Kinnears Quarry

Figure 6a-6d: Results for water quality parameters at upstream and downstream sampling locations (KIN1,2,3) since construction of ARD treatment basins at Kinnears Quarry

As required under licence, the ARD contaminated water produced on the Kinnears Quarry site is contained within ponds and corrected for pH (6-8), Dissolved Oxygen (>5 mg/L) and Total Suspended Solids (TSS <20 mg/L) prior to discharge to the adjacent subject creek. A water sample is collected at the time of discharge and tested for a range of parameters and is summarised in Table 5. Results show that water quality discharged from the Kinnears site is within EPA licence requirements for pH, DO and Turbidity. These results have remained within licence conditions since December 2011.

Table 5 Kinnears Quarry Release data – since 22/12/2011

EPA6 - Discharge parameters	Units	No. Samples	Mean	Std. Dev.
pH	mg/L	40	6.73	0.85
Conductivity	Us/cm	40	990.40	338.44
Dissolved Oxygen	mg/L	40	7.90	0.77

EPA6 - Discharge parameters	Units	No. Samples	Mean	Std. Dev.
Total Suspended Solids	mg/L	40	9.06	11.02
Calcium	mg/L	40	168.10	66.10
Magnesium	mg/L	40	24.73	12.40
Sodium	mg/L	40	7.41	2.65
Sulfur (soluble)	mg/L	40	187.93	99.00
Aluminium (total)	mg/L	40	0.53	0.80
Iron (total)	mg/L	40	4.23	14.09

Groundwater

AGE (2010) investigated hydrographs of groundwater level measurements and daily rainfall totals recorded over a six month monitoring period between February and August 2010. These show groundwater levels responding to rainfall events, particularly within the quarried areas where enhanced seepage of surface water runoff occurs via exposed fractured rock surfaces within the quarry catchment area. Given the interaction with groundwater, monitoring has been ongoing for one downstream groundwater well (MB4) which tends to reflect water quality in the upstream treatment ponds. A summary of samples from MB4 are presented in Table 6. In general, results are typical of water within the 2nd stage sediment basin – that is, water that has been treated prior to discharge.

Table 6: Groundwater well MB4 results

MB4	Units	No. Samples	Mean	Std. Dev.
pH	mg/L	7	7.03	0.42
Conductivity	Us/cm	6	1332.83	498.97
DO (membrane electrode)	mg/L	7	4.90	1.65
Suspended Solids	mg/L	5	21.40	9.52
Calcium	mg/L	5	174.00	64.26
Magnesium	mg/L	5	70.80	25.00
Sodium	mg/L	5	27.00	8.99
Aluminium (Total)	mg/L	5	0.38	1.75
Iron (Total)	mg/L	5	3.44	1.44
Manganese	mg/L	1	1.70	0.40

Water quality response to rainfall

Water quality data collected since the installation of the treatment ponds at Kinnears quarry was also investigated in response to rainfall events (refer Table 7 and Figure 7a and 7b). In the week preceding the 27 February 2013, 160mm of rain had been recorded at the BOM station at Murwillumbah (BOM 058158 station Bray Park). Within the subject creek, the pH was found to drop markedly at KIN2 although was similar to background levels at KIN3. Similarly, aluminium and iron levels had also risen at KIN2 before approaching background levels at KIN3. Consequently, in large rainfall events, untreated ARD water is being recorded within the subject creek with the increased potential of iron precipitate/floc being deposited within the subject creek. It is noted that rainfall levels of this magnitude are difficult to manage (and accordingly, are not conditioned under licence or within Environmental Management Plans).

Table 7: Mean values for pH, Aluminium (Total) and Iron recorded at WQ monitoring stations post installation of treatment ponds at Kinnears Quarry

Sample date	Rain previous day	Rain previous week	pH KIN1	pH KIN2	pH KIN3	DO KIN1	DO KIN2	DO KIN3	Al KIN1	Al KIN2	Al KIN3	Iron KIN1	Iron KIN2	Iron KIN3
30/05/2013	2	15	6.2	6.7	6.4	7.4	8.8	7.9	0.23	0.54	0.13	0.2	1.47	0.69
29/04/2013	0	0	5.9	5.8	6.8	7.4	8.5	7.6	0.21	0.47	0.09	0.24	1.7	1.14
28/03/2013	2	17	6.2	6.2	6.8	6.8	8	7.4	0.26	0.33	0.09	0.24	0.85	1.05
27/02/2013	7	248	6	3.3	6	7.4	7.3	6.9	0.27	4.72	0.3	0.28	1.88	0.92
05/02/2013	0	96	6.6	5.9	5.8	6.8	7.8	7.2	0.15	0.62	0.22	0.2	1.24	1.27
24/12/2012	1	28	7.5	4.5	5.3	7.4	7.5	5.3	0.11	1.94	0.38	0.69	6.33	1.07
30/11/2012	0	2	6.3	6.6		5.9	7.7		0.2	0.28		0.38	2.81	
24/10/2012	0	0	6.3	6.6	6.4	7.5	8.9	4.4	0.19	0.18	0.36	0.3	1.29	3.85
26/09/2012	2	2	6.2	6.3	6.3	7.7	9.1	4.9	0.06	0.11	0.04	0.11	1.24	0.28
29/08/2012	0	5	5.9	6.1	5.9	8.7	9.4	8.2	0.11	1.86	0.11	0.1	16	0.88
19/07/2012	1	35	6	6.1	6	7.7	9.1	9	0.12	0.45	0.12	0.09	2.19	1.36
22/06/2012	0	0	6	6.2	6.1	7.6	9.2	8.6	0.11	0.19	0.74	0.12	3.02	2.28
31/05/2012	1	21	6	6.2	6	7.8	9.2	8	0.36	0.28	0.33	0.4	1.68	4.25
26/04/2012	0	22	6.1	6.1	6.5	7.2	8.4	8.2	0.27	0.42	0.17	0.46	2.16	1.36
29/03/2012	5	45	6.1	6.3	6.2	7.1	8	6.5	0.2	0.39	0.14	0.23	1.63	5.24
08/03/2012	0	32.5	6	6.2	5.9	7	6.2	7	0.16	0.38	0.16	0.26	1.56	1.58

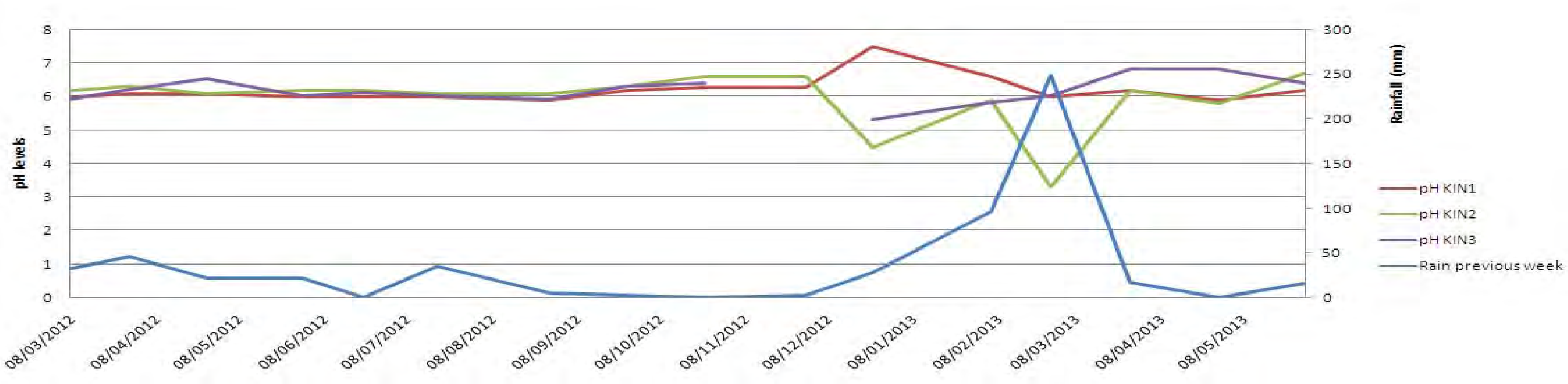

Figure 7a: pH levels within the subject creek plotted against previous week's rainfall

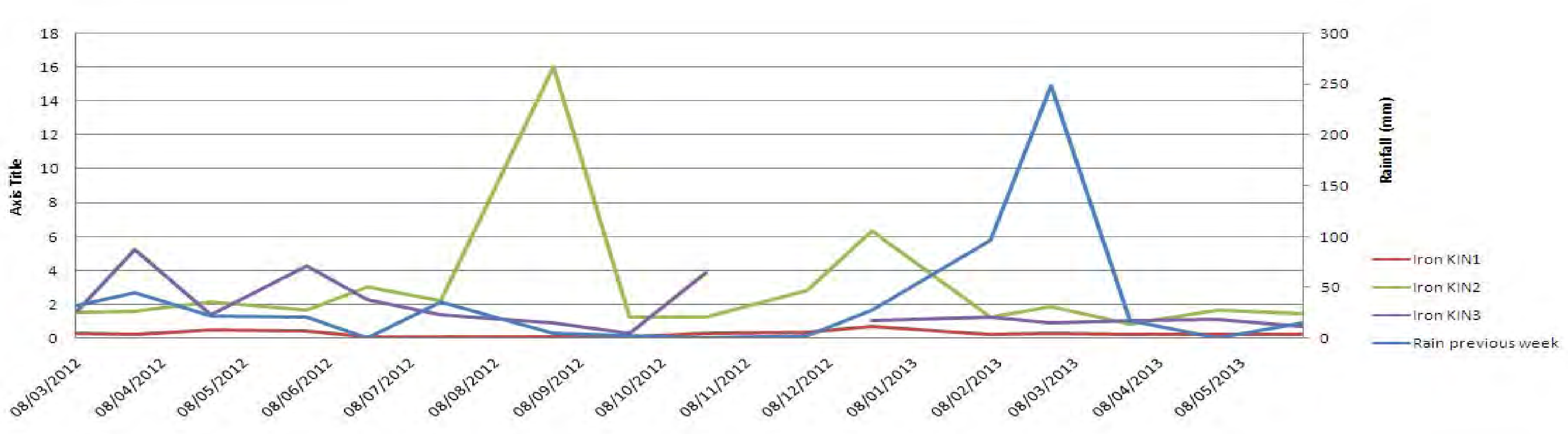

Figure 7b: Iron levels within the subject creek plotted against previous week's rainfall

3.3 Rous River monitoring location

ABER (2012) undertook a comprehensive review of the water quality data collected within the Tweed Estuary between 2007 and 2011. This includes data collected from the TWE13 sample station located approximately 10km downstream of the junction of the subject creek and Rous River.

ABER (2012) used the Tweed WQO adopted in 2012 and compared these with ANZECC (2000) guidelines for the protection of aquatic ecosystems, to assess water quality in this report. It is noted that until late December 2007, all effluent from the Murwillumbah WWTP was released to the Rous River estuary just upstream of site TWE13. After this date, the treatment train was upgraded and a portion of effluent (~40%) was routed to the Condong sugar mill for use as cooling water, after which it was discharged to the Tweed estuary just upstream of site 8. The remainder of the effluent (~60%) was discharged to the Rous estuary.

For the Rous River, ABER (2012) noted the following water quality conditions:

- Consistently lower pH measurements in the Rous estuary indicate a relatively greater influence of acid sulfate soil runoff in this tributary.
- In regards to estuary concentrations, Total nitrogen concentrations exceeded the guideline thresholds for greater than 75% of the time during high flow conditions throughout the transition, middle and upper estuary sites. Compliance was better during low to median flow conditions, with the Rous estuary sites exceeding thresholds for greater than 50% of the time.
- Total Phosphorous concentrations in the Rous estuary were consistently high throughout the study. There was a trend of increasing concentrations with flow, with high flow conditions having significantly higher concentrations than both median and low flow conditions.
- For Ammonium and NOx, the Rous estuary sites generally exceeded thresholds for greater than 25% of the time during high flow conditions.
- Oxidised nitrogen was generally highest in the Rous estuary during all flow conditions.
- DIN:DIP ratios were consistently higher in the Rous estuary, most likely reflecting high DIN concentrations in STP effluent.
- Similarly, Chlorophyll-a was consistently highest in the Rous estuary.

In regards to Ecological Implications, ABER (2012) note that:

- Chlorophyll-a concentration in the Rous (and Tweed) estuaries are consistently higher than ANZECC (2000) guidelines for the maintenance of aquatic ecosystems.
- TSS in the Rous estuary was generally high relative to the main Tweed estuary. TSS is a critical ecological indicator due to the importance of good water clarity in maintaining ecosystem processes in both the Tweed and Rous estuaries.

In summary, the ABER (2012) review found that there was elevated nutrient concentrations in runoff during and post high flow, and that the WWTP was dominating the nutrient loadings during low and median flow. Consequently, it was suggested that there was a need to reduce catchment TSS exports during median and high flows, reduce phytoplankton blooms during low to median flows through STP management (ABER, 2012). A number of specific recommendations were identified in regards to the ongoing management of water quality and discharge regimes for the WWTP.

Summary data for TWE13 between 2008 and 2013 is presented in Table 8 and in Figure 8a to 8d for selected variables.

Table 8:TWE13 data summary from 2008-2013

Site	Biochemical Oxygen Demand (mg/L)	pH (pH units)	Salinity (ppk)	Suspended Solids (mg/L)
Median	1.7	7.1	0.1	8.7
Average	1.79	7.08	0.76	12.76
Min	1	5.4	0.1	3.5
Max	4.4	8.4	8.7	185
Count Numbers	47	199	84	71
Count Readings	71	199	199	71

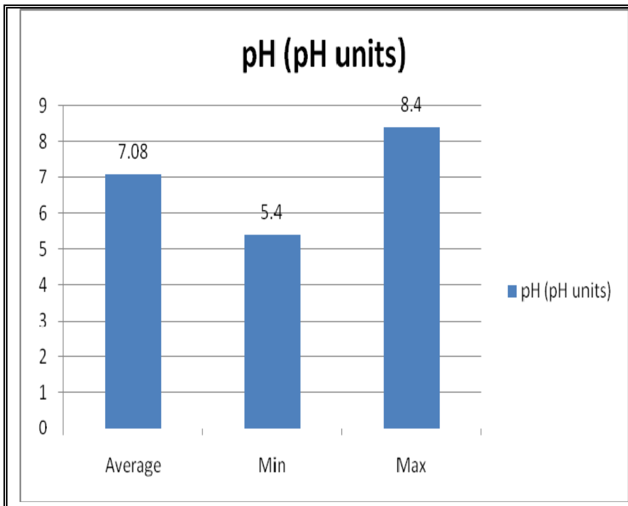

Figure 8a: pH data for TWE13 between 2008 and 2013 (n=199)

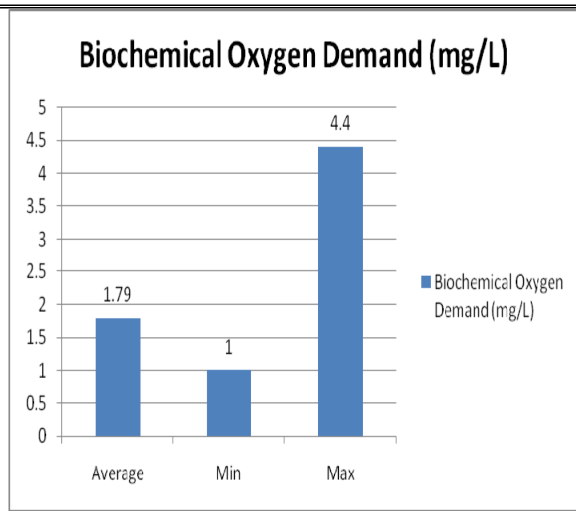

Figure 8b: BOD data for TWE13 between 2008 and 2013 (n=47)

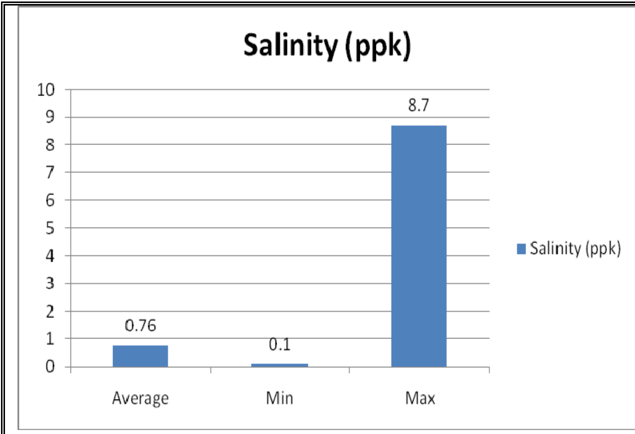

Figure 8c: Salinity data for TWE13 between 2008 and 2013 (n=84)

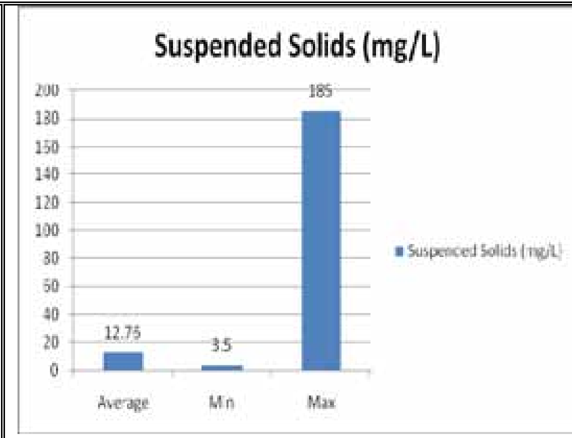

Figure 8d: Suspended solids (mg/l) data for TWE13 between 2008 and 2013 (n=71)

Figure 8a-8d: Water quality parameters for Rous River monitoring location TWE13 between 2008 and 2013.

3.4 Subject stream geomorphic features and processes

An independent assessment of the geomorphic features of the stream and subsequent processes in relation to sediment transport was provided by Australian Wetlands (refer Appendix A). In summary, AW (2013) found:

- the section of the subject creek below Kinnears Quarry is a gully less than 50m wide with a sinuous channel comprising cobble, gravel and fine sediments and occasional bedrock features.
- The bed also includes in stream and bank attached compound bars and small pools with well vegetated banks comprised predominantly of Camphor Laurel and native rainforest species with little evidence of bank scour or instability.
- A weir positioned about 100m downstream of the quarry is now full of sediment,
- The section of creek downstream of the quarries with its confined valley setting and steeper grade would have been a transport rather than accretion zone, however depending on when the weir was built sediment lost from upper valley slopes would have been intercepted.
- The presence of in stream geomorphic features such as pools, riffles, vegetated bars and very high water clarity, demonstrates that there are not large volumes of sediment moving through this section of creek.
- Previous Council surveys have confirmed the presence of macroinvertebrates, native fish and yabbies which supports this view.
- Further the presence of up to 1m of organic matter within the dam upstream of the causeway on Harry's Road (the culvert pond) suggest that this has been the case for at least 10 to 20 years (assuming that organic matter accretes in the dam at a rate of 5cm to 10cm per year).
- Within this dam there is some evidence of minor and very localised bank scour (<5m^2) beneath the driveway of the adjoining property and this could possibly be the result of

lost storage capacity through build-up of organic matter (and sediment) over time (refer Section 4 and 5 for further discussion).

A summary of the AW (2013) assessment is provided below. Further discussion on sediment composition is provided in Section 3.5.

Table 1: Summary of Geomorphic Features and Processes

AWC

Riverstyle	As a whole, the creek is a laterally unconfined, single thread, meandering channel. Locally the channel is laterally confined with a narrow valley margin. Banks are generally stable and the channel comprises sand, gravel and cobble, pools and riffles with bank attached and instream compound bars.
Valley Setting	Laterally unconfined but confined within the reach of interest.
Channel Planform	Low to moderate sinuosity, laterally stable in the reach of interest, but highly unstable on the floodplain.
Bed material	Continuous sand, gravel, cobble, well mixed, gravel (20mm to 50mm) dominant. No sediment slugs observed.
Geomorphic units	In focus reach – pools, riffles, bank and instream bars. No flood plain present in this section.
Channel geometry	Symmetrical, trench like in the reach of interest. Steep banks, no flood benches, terraces or ledges in this reach.
Vegetation Type	Regenerating Lowland rainforest with a high proportion of Camphor Laurel.
Creek Behaviour	
Low Flow Stage	The low flow stream is a meandering sand gravel bed system with in-stream and bank attached compound bars, pools and riffles. There is some colonisation of bars by vegetation.
Bankfull stage	Steep valley margins create a fixed boundary condition and no connection to adjoining floodplains. This creates a high energy flow environment in which sands, gravel and cobble are re-worked locally. There is no evidence of bank failure in the creek section downstream of Kinnears Quarry.
Overbank Stage	Steep valley margins means there is no bank overtopping in high flows.
Upstream Catchment Area	<3km^2
Process Zone	Sediment transport zone, naturally a steep valley with limited opportunity for sediment accretion – ignoring sediment capture that occurred historically behind the weir. No large deposits of fine sediment typical of high rates of erosion were observed.
Valley slope	15-20% on upper slopes, 2-4% downstream of Kinnears Quarry to Harry's Road, 0.5% to 1% downstream of Harry's Road.

3.5 In-Stream Sediment and Water Quality Sampling

3.5.1 Sediment sampling results

Sampling results indicate well sorted (homogenous) deposition at the weir. The deposition timeline at the weir is unknown, however sediment described as firm gleyed clay/silt, would indicate that the majority of deposited sediment has been there for some time to evolve to that level of leaching and compaction (bulk density). Additionally as the sediment is homogenous with few gravels it indicates that mobilised material is generally comprised of silt and clay rather than a mixed load (including unsorted gravels). Fines are more associated with turbid stormwater runoff rather than the mobilisation of quarry spoil. However it could also be attributed to the cumulative erosion of fine quarry material such as overlying soils rather than specifically quarry rock and crushed gravels.

From the limited investigations of the culvert pond, it also contained fines, however the bulk of the pond volume in recent times seems to be more attributed to organic matter (leaf litter) rather than mobilised sediment. This is supported by the Australian Wetlands review (Appendix A).

A brief description of instream sediment is listed below in Table 9. Due to time constraints no additional sediment analysis was undertaken that would include particle size analysis and statistical analysis.

Table 9: In-stream sediment description

Depth	Texture	Comment
Culvert Pond 0 - ~ 1000mm	Instream material extracted appeared as homogenous soft wet (loose) fine clay/silt, grey/brown in colour. Zone of deposition expected potential MBO's which are traditionally black in colour and gel like in texture. While the texture was not black it was soft in texture, however not gel like.	Refer to discussion of laboratory results
Weir 0 - ~ 1200mm (refusal due to bedrock)	Heavy Clay/Silt (wet) Abrupt boundaries. Colours reducing in chroma at depth (thin orange surface layer to gleyed colours at depth). Typical of reducing environment (anerobic) due to deposition within water body of weir.	Visual Only
Instream	Instream material extracted appeared generally as soft wet (loose) small gravels, sands and clay/silt, brown in colour.	Visual Only

Sediment Laboratory Results

The National Water Quality Management Strategy (NWQMS) has identified interim sediment quality guidelines (ISQG) for heavy metals, based on a literature review of sediment toxicity testing. The guidelines define ISQG-high and ISQG-low values which represent the lower 10th percentile and 50th percentile of chemical concentrations associated with adverse biological effects.

The guideline levels were obtained from studies undertaken in North America with some minor alterations for Australian applications. An evaluation of the ISQG applicability to Australian biota undertaken in New South Wales estuaries concluded that the ISQG-low guidelines are appropriate for compliance and protection.

Results from culvert pond sediment were compared to ANZECC/ARMCANZ interim sediment quality guidelines (2000). All results were below the ISQG-low trigger value except for copper and mercury which returned results between the low and high trigger value.

Results for both iron and aluminium are elevated, however results are expected based on potential source material. No trigger values are listed for both Iron and Aluminium. Parameters of copper and mercury were slightly above the ISQG-low trigger values.

Results obtained from sediment analysis are indicative only as more intensive sampling would be required to determine mean representative values across the culvert pond to determine if sediment quality is affecting habitat diversity.

Table 10: Comparison of sediment results to Interim Sediment Quality Guidelines (2000)

Sample **Mg/kg dry wt**	**ISQG-low**	**ISQG-high**	**Results** **(See Appendix B for full results)**
Copper	65	270	134*
Aluminium	NL	NL	3982
Arsenic	20	70	<5
Chromium	80	370	<6
Iron	NL	NL	25850
Manganese	NL	NL	245
Nickel	21	52	16
Zinc	200	410	34
Cadmium	1.5	10	<1
Lead	50	220	10
Mercury	0.15	5	1*
Cobalt	NL	NL	7

* Elevated as compared to ISOG-low trigger value

3.5.2 Acid Sulfate Soils Investigations

Regional Geology

Based on the 1:100 000 Murwillumbah Geological Sheet the site lies within Palaeozoic Neranleigh Fernvale Beds. The ridges are comprised of high rolling to steep hills which are predominantly phyllitic siltstones, shale, quartzite, greywacke and argillite. The adjacent downstream landscape is an alluvial plain, comprising deep Quaternary alluvium comprising soils of clay, silt, sand and gravel derived from the surrounding metamorphic hills of the adjacent Neranleigh Fernvale Beds.

Geomorphically acid sulfate soils (ASS's) have mostly developed during the Holocene (last 10 000yrs) when sea levels were higher than present. As a consequence of these Holocene conditions, many of our low-lying coastal plains now form tracts of ASS typically at elevations typically less an RL 5.0m eg ASS's are typically found in lowland areas such as estuaries and floodplains, tidal mangrove flats, lakes and wetlands, and swamps.

Due to the siliceous nature of the soils parent material (eg phyllitic siltstones and shale) combined with the long-term leaching of bases (cations) typical soils of the landscape are naturally to strongly acidic eg pH < 5.0_{water}.

The elevation of the existing ground at the culvert pond is approximately 10m AHD therefore considered above the 5.0m AHD demarcation and potential Holocene deposited sediment.

<u>ASS Risk Mapping</u>

According to NSW ASS Planning Maps (Department of Infrastructure, Planning and Natural Resources, 2004) the proposed works are located on land identified as Class 5 land with management described as:

Class 5 Land - works within 500 metres of adjacent Class 1 2 3 or 4 land which are likely to lower the water table below 1.0m AHD on adjacent Class 1 2 3 or 4 land.

Although the culvert pond site is mapped as Class 5, sediment recovered is not natural ground and therefore not considered and part of Class 5 landscape. Reasoning for carrying out ASS analysis is due to the presence of exposed sulfidic pyrite upstream within quarries and its associated acid mine drainage. This may have the potential to form monosulfidic black ooze's (MBO's) contained within downstream culvert pond. The formation of MBO's requires a combination of acid sulfate runoff, carbon (eg from vegetation) and a low flow environment which the pond displays.

<u>ASS Testing Results</u>

Due to wet sample potentially containing MBO, the sample was analysed for acid volatile sulphur (S_{AV} %).

- pH field was measured as 6.4 and dropping to pH 2.6 as field oxidation. Net acidity was calculated based on S_{AV} % of 0.21 at 62.3% moisture.

According to the ASSMAC assessment guidelines (Stone et. al. 1998), the action criteria level for light clays is 0.03 % S for < 1000t disturbed, therefore as listed in Table 11, the action criteria is exceeded and treatment of material would be required.

Neutralisation with agricultural lime is a widely accepted method to minimise the generation of acid and acid products associated with the disturbance of ASS. Agricultural lime is readily available, relatively easy to handle and less hazardous than some other agents such as hydrated lime. It is extensively used in both the agricultural and construction industries.

Table 11: Action Criteria based on ASS soil analysis for three broad texture categories (Source: ASSMAC Manual)

Type of Material	Action Criterion 1-1000 tonnes disturbed		Action Criterion More than 1000 disturbed	
Texture Range	**Sulfur Trail % S oxidisable**	**Acid Trail Mol H+/tonne**	**Sulfur Trail % S oxidisable**	**Acid Trail Mol H+/tonne**
Coarse Texture Sands to loamy sands	0.03	18	**0.03**	**18**
Medium Texture Sandy loams to light clays	0.06	36	0.03	18
Fine Texture Medium to heavy clays and silty clays	0.1	62	0.03	18

Fine grade agricultural lime is recommended for treatment of ASS as it has a relatively high neutralising value (NV) of 85 to 95 % as well as its occupational health and safety merits.

If the material from the culvert dam was excavated the resultant material would require treatment/neutralisation with agricultural lime at the rate of 14 kg/m3 based on an approximate bulk density of 1.4, and a recommended safety factor of 1.5.

Due to high volume of leaf litter within culvert pond an estimation of sediment within pond is not possible without more comprehensive surveying and representative sampling within confines of the culvert pond.

3.5.3 In-Stream Water Quality

The results for in-stream water sampling (containing iron floc) was compared to proposed water quality trigger values as listed previously in Table 2. Results of sampling are compared below in Table 12. Time of sampling was during natural flows on 31 May 2013 at approximately 10.05am.

Based on comparison of water quality indicators at time of sampling, all parameters were below trigger values based on WQO's of Tweed River and ANZECC guidelines (2000).

Table 12: Comparison of water sample and floc sample results 31 May 2013

Sample parameters	Units	Water Sample	Floc	Indicator Value (see Table 2)
pH*	mg/L	7.5	-	6.5-8.0
Conductivity (EC)*	µs/cm	1700** (by calculation)	-	125 – 2,200
Dissolved Oxygen*	67%	67%	-	80-110%
Aluminium (total)	mg/L	0.26	6.91	ID
Arsenic	mg/L	<0.005	<0.005	13
Boron	mg/L	0.06	-	370
Chromium	mg/L	<0.01	<0.01	1.0
Copper	mg/L	0.03	0.03	1.4
Iron (total)	mg/L	1.57	48.0	ID
Manganese	mg/L	1.53	2.01	1900
Molybdenum	mg/L	<0.01	-	ID
Nickel	mg/L	0.02	0.04	11
Zinc	mg/L	0.06	0.11	8.0
Cadmium	mg/L	-	0.001	.2
Lead	mg/L	-	0.01	3.4
Mercury	mg/L	-	<0.10	0.6
Cobalt	mg/L	-	0.02	ID

*samples taken with handheld YSI meter

** Based on temperature of 16.7^{o}C and salinity of 0.08ppt

ID - **Aluminium** at pH <6.5 for freshwater a low reliability trigger of 0.8ug/L is derived for aluminium, however this trigger value is species dependant, localised background levels may provide indicative working levels for aquatic habitat assessment (refer sect 8.3.7.1 from ANZECC guidelines 2000). **Iron, Cobalt and Molybdenum**, insufficient data available for reliable trigger values, localised background levels may provide indicative working levels for aquatic habitat assessment (refer sect 8.3.7.1 from ANZECC guidelines 2000).

3.6 Aquatic biota

3.6.1 In-stream habitats

Significant manmade features observed within the subject creek included a piped section across the floor of Sandercocks Quarry (PLATE 1), a weir located midway between the Kinnears Quarry outlet and the culverts at Harrys Road (PLATE 2) and large pools directly upstream and downstream of the Harrys Road crossing (PLATE 3).

The subject creek in the location of aquatic sampling sites was characterised by numerous shallow pools and riffle sections. The downstream sampling site consisted only of riffle sections, whilst the midstream plots were characterised by small pools – associated with a flatter topography above the weir. The upstream sampling site was a combination of pools and riffles. Maximum stream depth recorded during plot sampling was about 0.6m although on average, stream depth was about 0.4m. Average stream width was 2m. All three sampling sites showed visible evidence of iron hydroxide precipitate with the prevalence of iron staining increasing from the upstream site to the downstream site.

In-stream habitat was limited within the subject creek with little to no periphyton and macrophytes. Overhanging vegetation was similarly limited – particularly within the downstream and midstream sampling sites. Some bank vegetation and tree roots were evident within the upstream site where the stream was more incised.

In contrast, there were no signs of iron hydroxide precipitate within the reference creek. Overhanging vegetation and periphyton was common. Both the reference creek and subject creek were bordered by rainforest vegetation resulting in shading of the waterway.

Plate 1: Outlet of piped section of the subject creek.

Plate 2: Constructed weir located midway between the culverts at Harrys Road and Kinnears Quarry (note iron staining on concrete surfaces; Fish and crustaceans were observed in the pools directly below the weir)

Plate 3: Pond located above culverts at Harrys Road – view looking downstream towards culverts (note dominance of the aquatic weed Parrots Feather *Myriophyllum aquaticum*)

3.6.2 Fish sampling results

One fish species was observed during sampling within the Subject Creek, the Striped Gudgeon (*Gobiomorphus australis*) (refer PLATE 4). The striped Gudgeon occurs in coastal streams of southern Queensland, New South Wales and eastern Victoria (Australian Museum website http://australianmuseum.net.au/Striped-Gudgeon-Gobiomorphus-australis-Krefft-1864/). The Striped Gudgeon is an inhabitant of fresh water streams with adults recorded to feed on Eastern Gambusia and aquatic insects. Within the Subject Creek, ten individuals were recorded in a 30m section below the weir. In this section of the stream, numerous small pools had formed in the slower flatter gradient areas below the weir. Pools averaged about 2m wide and 0.5m deep. No fish were observed above the weir confirming the significant obstruction of the weir to fish passage.

Plate: 4 Striped Gudgeon (*Gobiomorphus australis*) from the subject creek adjacent Harrys Road, Chillingham (photographed within a temporary holding tank).

The striped Gudgeon and a Longfin Eel (*Anguilla reinhardtii*) was recorded from the reference Creek. No Eastern Gambusia were recorded in either creeks in the areas sampled.

Hydrosphere (2012) explain that as a general rule, the species diversity, relative abundance and hardiness of fish species encountered within the freshwater reaches of a catchment will increase closer to the estuary because:

- Many Australian native fish are diadromous and therefore undertake migrations between estuarine (or some cases oceanic) environments and freshwater habitats as an obligatory part of their natural life cycle. Such fish therefore need unimpeded access along the river system to the estuary. The lower gradient reaches at the end of streams are less likely to present natural barriers (e.g. high water velocities, waterfalls and cascades) and are less likely to be developed and present man-made obstructions such as floodgates, road crossings and weirs;
- Headwater streams have less discharge, are smaller and consequently offer less potential overall habitat area compared to downstream sites that receive greater runoff and are naturally less confined;
- Fish species inhabiting upstream reaches are often less tolerant of poor water quality and habitat change, whereas fish surviving in downstream locations are more likely to be subjected to runoff from agricultural or urban areas, may be affected by natural factors such as acid sulfate soils.

Although little can be deduced on the status of fish within the subject creek given the rapid nature of the current assessment, it is clear that suitable habitat and water quality currently persists within the subject creek to support reasonable numbers of at least one species of fish.

Table 13: List of aquatic biota recorded from the Subject Creek and Reference Creek

Common Name	Scientific description	Subject Creek	Reference Creek	SIGNAL 2 – Score[1]
Macro-invertebrates				
Freshwater Mussel	Class: Bivalvia		+	3
Water strider	Oder: Hemiptera		+	4
Dragon fly nymph	Oder: Odonata	+		4
Nematode	Order: Nematoda	+		3
Water boatman	Oder: Hemiptera	+		2
Whirligig beetle	Order: Coleoptera	+		4
Crustaceans				
Long-armed prawn	Macrobrachium spp		+	4
Riffle shrimp	Australtya striolata		+	4
Yabby	Cherax spp	+	+	4
Fish				
Striped Gudgeon	Gobiomorphus australis	+	+	
Longfin eel	Anguilla reinhardtii		+	
Amphibians				
Tadpole	Unidentified	+		
Tadpole	Mixophyes spp	+		
	Species Diversity	**8**	**7**	

1 - SIGNAL 2 scores are 4,3=Tolerant Bugs, 2=Very Tolerant Bugs

3.6.3 Macroinvertebrates

Total numbers for macroinvertebrates recorded from sampling plots and average numbers among plots are presented in Table 14. Diversity of macroinvertebrate species was similar between the subject creek and the reference creek. Overall total abundance was much greater although this is considered to be an artefact of the disparity in sampling effort only. Once density was averaged based on sampling effort, the average macroinvertebrate diversity was found to be similar among creeks.

When comparing species recorded, on average more yabbies were recorded in the subject creek compared to the reference creek. In contrast, species such as the riffle shrimp was only recorded in the reference creek likely due to the presence of macrophytes providing suitable habitat for this species. As noted by Hydrosphere (2012), trailing vegetation at the water's edge forms an important habitat for macroinvertebrates (and fish) and also protects banks from erosion. Freshwater mussels and Long-armed prawns were also only recorded in the reference creek suggesting a greater diversity of habitat (and likely habitat condition) compared to the subject creek.

The subject creek was found to have higher average densities of some water bugs. In general, a healthy waterway tends to have high species richness and diversity with no one particular species dominating the system. In contrast, polluted waterways will have only a few different types of macroinvertebrates present, often in large numbers. Although diversity was similar between the two creeks, there was a tendency for some water bugs to dominate in the subject creek.

Table 14: Total and average numbers of macroinvertebrates recorded from the Subject Creek and Reference Creek sampling plots

Macroinvertebrate species	Total numbers recorded	Mean No. Individuals	SIGNAL 2 – Score[1]
Reference Creek			
Long-armed prawn	18	3.6	4
Freshwater Mussel	2	0.4	3
Riffle shrimp	2	0.4	4
Water strider	4	0.8	4
Yabby	1	0.2	4
	27	**5.4**	
Subject Creek			
Dragon fly nymph	1	0.07	4
Nematode	1	0.07	3
Water boatman	44	2.93	2
Water strider	21	1.4	4
Whirligig beetle	9	0.6	4
Yabby	21	1.4	4
	97	**6.47**	

Summary of signal scores

Low Signal scores reflect a general dominance of pollution tolerant species, whereas high signal scores indicate the presence of sensitive species which would not occur if the waterway was polluted. A preliminary investigation of the subject creek found that pollution tolerant species (signal scores between 3 and 5) were most common from sample plots. No pollution sensitive species (signal scores 6 – 8) or very sensitive species (9-10) were recorded from samples in either creeks. High numbers of one very tolerant species, the Water Boatman, was recorded from the subject creek; none were recorded form the reference creek sample.

Given that the macroinvertebrate community was restricted to pollution tolerant species, with some taxa dominant in terms of numbers of individual species (e.g. Water Boatman) the aquatic assessment indicates that the subject creek (between the quarrys and the culvert pond) is characteristic of a degraded waterway. However, this level of degradation is not considered to be significantly different to the reference stream assessed. Standardised sampling of aquatic biota is required to confirm this significance statistically.

Incidental aquatic species recorded

In-stream sampling also recorded a number of tadpoles from the subject creek (refer Table 15). All tadpoles recorded from standard monitoring plots were observed from small pools within the midstream sampling site. One of the tadpole species was from the genus *Mixophyes* spp and is likely either *M. iteratus* or *M. fasciolatus*; the former species is listed as Endangered in NSW and nationally. Targeted surveys using a combination of active searches and call broadcast in spring/summer would likely confirm the presence of *M. iteratus* within the subject creek. No tadpoles were observed within plots in the reference creek.

Table 15: Summary of amphibian metamorphs recorded and location details

Sample location	Reach type	Maximum plot width (m)	Maximum plot depth (mm)	Species	Number observed
Midstream Plot 1	Pool	2	500	Unidentified tadpole	1
Midstream Plot 3	Pool	2.5	300	Unidentified tadpole	4
Midstream Plot 4	Pool	2.5	300	Mixophyes tadpole	1
Midstream Plot 5	Pool	2	600	Unidentified tadpole	2
Incidental site	Recorded in a pool at base of weir	2	400	Mixophyes tadpole	1

4.0 ENVIRONMENTAL STATUS OF THE SUBJECT CREEK

A 350m section of creek adjacent two hard rock quarries at Harrys Road, Crystal Creek was assessed in terms of past and current water quality, geomorphic features and processes, sediment composition and toxicity, and aquatic biota. The adjacent quarries are known to have naturally occurring beds or lenses of pyrite-rich, graphitic shale that have been exposed from past quarry operations. During and after rainfall events, low pH and iron concentrated water, when left untreated or managed, eventually flow into the adjacent subject creek. As a consequence, the subject creek has been known to have very low pH water and has visible iron floc covering most aquatic substrates from the quarries to at least the dams at Harrys Road culverts.

Since late 2011, water captured within the Kinnears Quarry site is treated and discharged under licence conditions. Consequently, the average pH, dissolved oxygen, and to a lesser extent turbidity, of the subject creek downstream of the Quarry is comparable to upstream background levels.

A snapshot assessment of the water quality within the stream as part of this assessment found that all parameters tested during low flow conditions (i.e. no quarry discharge to the subject creek) were below water quality indicator values / trigger values for aquatic ecosystem protection with the exception of dissolved oxygen which was listed as 67% (indicator value/trigger value 80-100%). Dissolved oxygen is expected to increase associated with flow events.

In stream sediment sampling results were below the ISQG-low trigger values except for copper and mercury which were slightly above the ISQG-low trigger values. Clearly evident from the instream sediment data are the elevated values of both iron and aluminium. However, when comparing background levels since 2011, downstream aluminium and iron concentrations are not considered to be significantly greater than background. This was not the case prior to 2011. Nonetheless, iron floc remains clearly visible within the stream despite the greatly improved water quality reporting from Kinnears Quarry. Consequently, although Council's Quarry has undergone significant remediation works to limit discharge of acid rock drainage water, it is likely that other point and non-point sources are still contributing low pH water and an iron source to the subject creek; some of which can be managed and some of which is due to the prevailing geology. Ecorock (2009) noted that disseminated pyrites can and often does occur throughout the general rock masses of the Neranleigh Fernvale Beds particularly the quartzites and cherts and generally not as visibly obvious as the distinct black carbonaceous shale occurrences. Weathering processes of the rock mass as a whole can also therefore lead to lower than normal pH water. This could explain the higher acid environment (lower pH) present just as background ambient conditions (Ecorock, 2009)

A rapid assessment of the aquatic biota within a 350m section of the subject creek found the presence of at least one species of native freshwater fish and a community of macroinvertebrates including crustaceans. When compared to an adjacent reference stream unaffected by acid rock drainage, the aquatic biota was not too dissimilar in terms of species diversity and richness, and their tolerance to pollution (based on SIGNAL scores).

Due to the potential for the sediments within the culvert pond resembling acid sulfate soils (and specifically, MBOs or mono sulphidic black oozes), a sample was analysed for acid volatile sulphur. According to the ASSMAC assessment guidelines, the action criteria level was exceeded and treatment of material would be required if removed from the pond and exposed to oxygen.

Given the similarities in site issues in regards to acid sulfate soils, and subsequent cost benefits for managing these soils, scientist from the University of New South Wales (UNSW) were asked to undertake a preliminary site inspection of the subject creek adjacent Harrys Road to:

- provide comment on the status of the creek in terms of degradation from acidity and metals as a result of acid rock drainage; and
- compare this to creeks and drains effected by acid sulfate soils that the UNSW team are currently remediating within the Tweed Shire.

Following an on-site meeting and preliminary review of soil and water results, the UNSW team discussed that the site doesn't seem as degraded compared to some of the acid sulfate soil drains that they deal with and the metal concentrations aren't that high in the water sample and imagined these to be below water quality guidelines (for environmental purposes). After reviewing results for metals and ASS results from the sediment sample taken at the Harrys Road pond, the UNSW team noted that the pond has accumulated with MBO’s and any excavation of this is likely to lead to acidification/deoxygenation during the excavation process. Consequently, it was suggested that leaving the pond area undisturbed shouldn't lead to any issues (unless it dried out and oxidised) (UNSW email correspondence dated 25/6/13).

Australian Wetlands were engaged to provide an independent assessment of the geomorphic features of the subject creek in relation to sediment transportation and deposition as a result of quarry activities and the subsequent impacts on the pond adjacent the culverts at Harrys Creek. Their assessment found that the presence of in stream geomorphic features such as pools, riffles, vegetated bars and very high water clarity, demonstrates that there are not large volumes of sediment moving through this section of the creek. This is supported by the fish and macroinvertebrate results. In regards to the culvert pond, the presence of up to 1m of organic matter within the dam upstream of the causeway on Harry’s Road suggest that this has been the case for at least 10 to 20 years (assuming that organic matter accretes in the dam at a rate of 5cm to 10cm per year). The Australian Wetlands assessment noted that within the dam there is some evidence of minor and very localised bank scour (<$5m^2$) beneath the driveway of the adjoining property (refer Figure 9) and this could possibly be the result of lost storage capacity through build-up of organic matter (and sediment) over time.

Based on the assessment by Australian Wetlands, and the result of sediment sampling and in stream aquatic assessment, the likelihood of the scouring being associated with a large sediment slug type event is not supported. This small scour area could be addressed using standard bank revetment measures rather than excavation of potential large volumes of organic matter and fine sediments in the dam which has the potential to likely to lead to acidification/deoxygenation during the excavation process as noted above.

5.0 RECOMMENDATIONS

Controlling the source of iron in the creek

A review of the water quality results for water released under licence from Kinnears Quarry found that the site complies with EPA licence criteria. Similarly, groundwater monitoring down gradient of the treatment dams at Kinnears Quarry reflects the quality of the discharge water.

A review of upstream and downstream water quality results in relation to previous week's total rainfall levels recorded elevated pH and iron levels following large rainfall events (possibly over 100mm events) at a monitoring point within the subject creek adjacent to Sandercocks Quarry. These types of rainfall events are difficult to manage and accordingly, are not licensed or conditioned to this level of control. Nonetheless, an audit of existing measures for the diversion of clean water away from the Quarry sites is warranted in order to assess the efficiency of such controls.

Limited information was obtained regarding the water quality management of Sandercocks Quarry. Sandercocks Quarry is known to experience acid rock drainage similar to Kinnears Quarry. Consequently, ongoing assessment of the management of acid rock drainage from Sandercocks Quarry by Council's Environmental Health Unit (who regulate the environmental management of the site) is supported to limit any future source of iron to the creek.

Fine sediment transportation

Although Kinnears Quarry and Sandercocks Quarry are non-operational, it is feasible that there is continued mobilisation of fine sediments to the creek following rainfall events. It is also feasible that these sediments may contain elevated concentrations of metals given the prevailing geology and acid rock drainage conditions. An audit of on-site erosion and sediment controls for both quarry sites is recommended including maintenance of controls where relevant.

Management actions associated with the culvert ponds

Council is involved in the remediation of acid sulphate soil hotspots at a number of locations within the Tweed. To provide context to the current situation at Harrys Road, at Reserve Creek and associated Cudgen Lake, downstream impacts from acid sulphate soils have included repeated black water events and subsequent fish kills, and the exporting of some 36 tonnes of Aluminium and over 100 tonnes of total iron associated with one rainfall event in January/February 2013.

In its present state (under water), the potential acid sulphate soils contained within the pond do not pose a pollution risk. It is if these soils are exposed to air and oxidise, that the pH decreases rapidly resulting in acidification and mobilisation of metals. Removal of sediments from the waterway (whilst under flow conditions) would require significant environmental controls to mitigate any downstream impacts as well as controls associated with the transportation and treatment of wet soils.

As a precautionary measure only, in the event that there is a decline in water levels during an extended period of dry weather resulting in exposure of sediments within the pond, then removal and management of the acidic soils (MBOs) is recommended to prevent a flush of low pH water following a rain event. The material in the pond would need to be treated in accordance with a site specific acid sulphate soil management plan.

As discussed in the Australian Wetlands report, the localised scour within the pond could be addressed through reinforcement of the batter locally, possibly with timber, coir logs or (less desirably) boulders 450mm to 650mm in diameter. Placement of rock would need to ensure that the scour is not inadvertently caused in another location.

To facilitate efficient creek flows through the pond area, regular maintenance of culverts to remove obstructions and allow full discharge capacity of pipes is required. At the time of this assessment, the pipes were partially blocked with flood debri.

It is noted that the removal of the weir located midway between the ponds at Harrys Road and the quarries is not supported given the significant disturbance required to facilitate the removal including clearing potential lowland rainforest Endangered Ecological Community for access, and mobilisation of in stream sediments.

Aquatic biodiversity monitoring

Macroinvertebrate monitoring provides readily obtainable, repeatable and quantitative data that allows for on-going condition assessment of waterways. It is suggested that repeat surveys over time would provide cost-effective on-going assessment of the health of the subject creek and is recommended to be conducted on an annual basis to track the health of the subject creek.

A summary of recommendations, triggers for action and responsibilities is presented in Table 16 below.

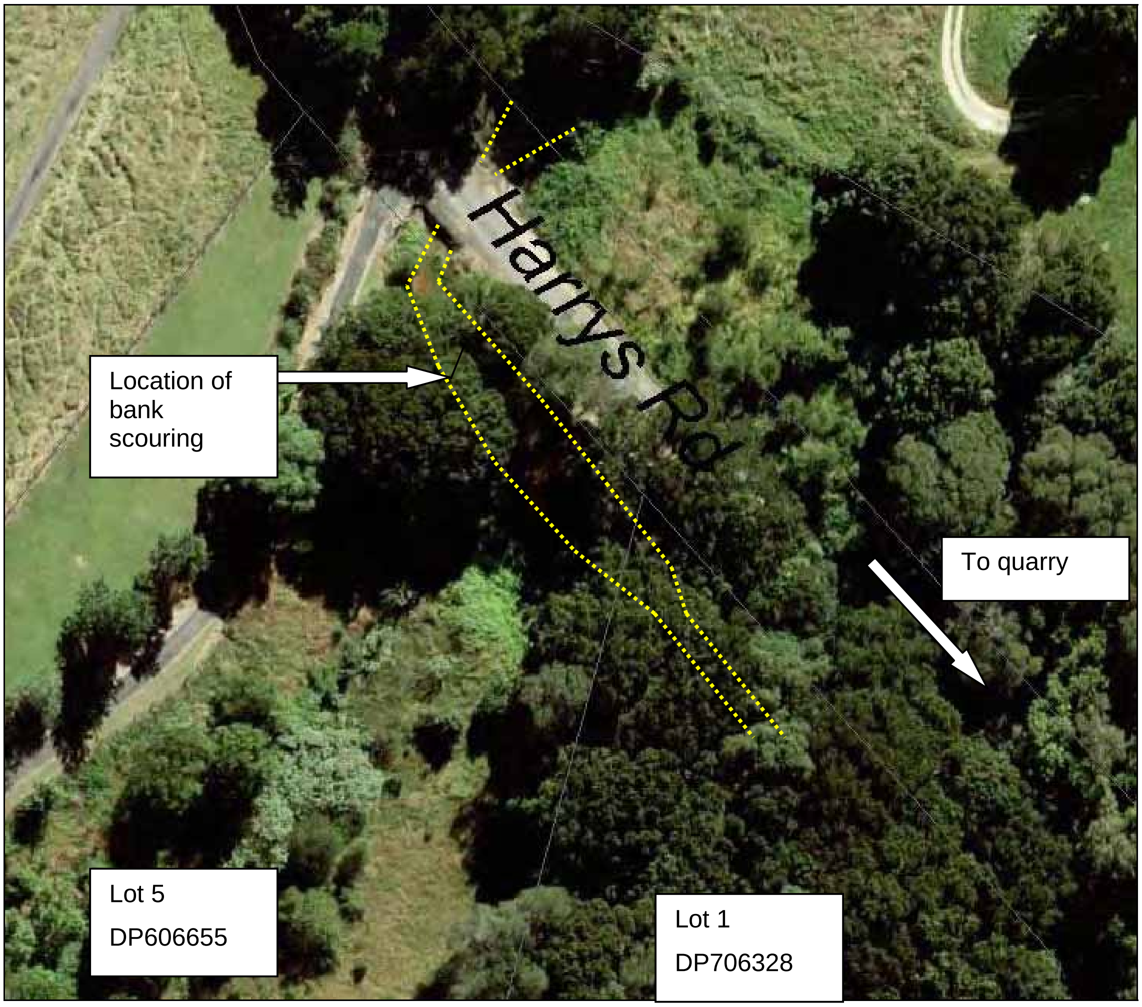

Figure 9: Aerial view of culvert pond location. Location of localised scour on the north western bank immediately below driveway of Lot 5 DP606655. (dashed yellow line indicates approximate culvert pond). Source: TSC Enlighten 2012 aerial photo.

Summary of recommendations and responsibilities

Table 16: Summary of recommendations including action triggers and associated responsibilities

Recommendation type	Trigger for action	Responsibility	Comments
Quarry environmental management			
Audit of clean water diversion controls	25mm in 24 hours	Kinnears Quarry – Technical Officer Quarry Management Sandercocks Quarry – Quarry manager/TSC Environmental Health Officer	
Audit of Erosion and sediment controls	In accordance with Environmental Management Plan	Kinnears Quarry – Technical Officer Quarry Management Sandercocks Quarry – Quarry manager/TSC Environmental	

Recommendation type	Trigger for action	Responsibility	Comments
		Health Officer	
Pond management actions			
Removal of sediments within pond in the event of drying out due to low water levels	Water levels decline following extended dry weather and sediments are exposed.	Kinnears Quarry – Technical Officer Quarry Management to: 1. Visibly monitor water levels at the pond; 2. Review monthly monitoring data for KIN3 (EPA3) for low pH levels.	Works would require: 1. Confirmation of planning approval requirements 2. Preparation of an ASSMP 3. Development of work method – likely to involve vegetation clearing to access the pond with a long reach excavator, establishment of downstream environmental controls, removal of material into a truck and transport to sludge drying area of Kinnears Quarry, treatment in accordance with ASSMP and removal to landfill. Costs are estimated at approx. $15,000 to $20,000
Localised bank scour remediation and protection on Lot 5 DP606655. Options could include: reinforcement of the batter with timber, coir logs or (less desirably) boulders 450mm to 650mm in diameter	To be determined by land owner	Land owner	
Culvert maintenance	Regular inspections by TSC Technical Officer Quarry Management	TSC maintenance staff	In the event of that debri is blocking culvert, TSC Quarry staff to notify Maintenance Engineers to action removal
Macroinvertebrate monitoring			
Annual macroinvertebrate monitoring within subject creek and reference creek	Annual summer monitoring with adaptive management to refine or cease monitoring	TSC Engineering and Operations Division	Annual monitoring including reporting is estimated at approx. $5,000/annum.

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APPENDIX A: Australian Wetlands Report

AWC

David Hannah

Tweed Shire Council

PO Box 816

Murwillumbah, NSW, 2484

25th July, 2013

AWC Reference: 1-13319

Water | Ecology | Management

PO Box 2605
Byron Bay NSW 2481

70 Butler Street
Byron Bay NSW

p. (02) 6685 5466
f. (02) 6680 9406

e. info@awconsult.com.au
w. awconsult.com.au

Dear David,

RE: Preliminary Creek Assessment, Quarry, Chillingham

Following a site inspection yesterday, we have compiled a preliminary appraisal of an un-named creek line into which adjacent hardrock quarry's discharge. The purpose of the assessment was to determine what impact discharges from the quarry may be having on the creek line and adjoining driveways. Within this short report we will characterise the creek from a geomorphic perspective, and provide feedback on our impression of creek health and trajectory. Recommendations are made for the management of potential erosion issues. We have also reviewed documents provided by Council including:

- Aerial photography from 1962, 1970 and 1991,
- The Kinnears Quarry Acid Rock Drainage Management Plan (TSC ARDMP), 2011,
- Report on Acid Rock Drainage Investigations and Remedial Solutions (2009).

Site Context

The quarry's sit at the lower end of short valley, 400m to 500m upstream of the Rous River, parallel to the creek in a partly confined valley setting, but upstream widens into an upland valley. The downstream section connects with the Rous River floodplain.

Australian Wetlands Consulting Pty Ltd
ABN 81 140 533 919

The creek section below Kinnears Quarry sits in a gully less than 50m wide with a sinuous channel comprising cobble, gravel and fine sediments and occasional bedrock features. The bed also includes instream and bank attached compound bars and small pools. Adjoining banks are well vegetated (mixture of predominantly Camphor Laurel and native rainforest species – refer to the TSC ARDMP for a flora list), with little evidence of bank scour or instability.

There is a weir about 100m downstream of the quarry, the age of which is uncertain. Interrogation of aerial photography from 1962 and 1970 show the section of creek partly obscured by vegetation, making it difficult to determine if the weir was constructed prior to the quarry being built. The weir has been positioned to take advantage of the confined valley setting and steeper creek grade (2%-3%) and probably created a dam reaching at least 50m back up the creekline. The weir is now full of sediment and provides no water storage. The weir has however still reduced the grade of the creek section alongside the quarry.

Initially the weir would have intercepted sediment, while also creating a hydraulic step of 1.5m to 2m which would have scoured the downstream side of the weir and mobilised sediments. Now that the weir is full to capacity with sediment, movement of material downstream will be continuing, however the hydraulic step still remains and continues to create some degree of localised scour.

Interrogation of historical photographs (1962, 1970) suggests a sediment plug on the upstream side of Sandercock Quarry, and would have been the result of extensive vegetation clearing on the upper valley slopes. These slopes have now largely regenerated with a mixture of Camphor and Eucalypt species. The section of creek downstream of the quarry's with its confined valley setting and steeper grade would have been a transport rather than accretion zone, however depending on when the weir was built sediment lost from upper valley slopes would have been intercepted. If the weir was constructed prior to land clearing occurring in the upper valley, its capacity would have been quickly lost as erosion increased exponentially.

The presence of instream geomorphic features such as pools, riffles, vegetated bars and very high water clarity, demonstrates that there are not large volumes of sediment moving through this section of creek. Previous Council surveys have confirmed the presence of macroinvertebrates, native fish and yabbies which supports this view. Further the presence of up to 1m of organic matter within the dam upstream of the causeway on Harry's Road suggest that this has been the case for at least 10 to 20 years (assuming that organic matter accretes in the dam at a rate of 5cm to 10cm per year).

Within this dam there is some evidence of minor and very localised bank scour (<5m^2) beneath the driveway of the adjoining property and this could possibly be the result of lost storage capacity through build-up of organic matter (and sediment) over time.

Recommendations

The following options for remediation could be considered:

- Scour within the dam could be addressed through removal of organic matter and reinforcement of the batter locally, possibly with timber, coir logs or (less desirably) boulders 450m to 650mm in diameter. Placement of rock would need to ensure that scour is not inadvertently caused in another location. It should be noted that the culverts beneath Harry's Road were partly blocked with timber and debris at the time of inspection, which could contribute to localised scour.
- The process of removal of organic matter (and sediment) from the dam should include the removal of the aquatic weed Parrots Feather (*Myriophyllum aquaticum*).
- The weir could be removed and the original creek line and grade could be reinstated, however this would come at considerable expense and disturbance to the creek and adjacent lowland rainforest vegetation, so the benefits of this action would need careful consideration.
- Rehabilitation of riparian and aquatic vegetation along the creek line would assist in enhancing this lowland rainforest remnant. Planting of macrophytes within the channel for enhancement of aquatic habitats is unlikely to be successful due to heavy shade, acidic soil conditions and inappropriate creek bed material.

Table 1 provides an overview of the geomorphic character and condition.

I trust this summary is satisfactory, however please call with any questions.

Sincerely

Damian McCann
Director

Table 1: Summary of Geomorphic Features and Processes

Riverstyle	As a whole, the creek is a laterally unconfined, single thread, meandering channel. Locally the channel is laterally confined with a narrow valley margin. Banks are generally stable and the channel comprises sand, gravel and cobble, pools and riffles with bank attached and instream compound bars.
Valley Setting	Laterally unconfined but confined within the reach of interest.
Channel Planform	Low to moderate sinuosity, laterally stable in the reach of interest, but highly unstable on the floodplain.
Bed material	Continuous sand, gravel, cobble, well mixed, gravel (20mm to 50mm) dominant. No sediment slugs observed.
Geomorphic units	In focus reach – pools, riffles, bank and instream bars. No flood plain present in this section.
Channel geometry	Symmetrical, trench like in the reach of interest. Steep banks, no flood benches, terraces or ledges in this reach.
Vegetation Type	Regenerating Lowland rainforest with a high proportion of Camphor Laurel.
Creek Behaviour	
Low Flow Stage	The low flow stream is a meandering sand gravel bed system with in-stream and bank attached compound bars, pools and riffles. There is some colonisation of bars by vegetation.
Bankfull stage	Steep valley margins create a fixed boundary condition and no connection to adjoining floodplains. This creates a high energy flow environment in which sands, gravel and cobble are re-worked locally. There is no evidence of bank failure in the creek section downstream of Kinnears Quarry.
Overbank Stage	Steep valley margins means there is no bank overtopping in high flows.
Upstream Catchment Area	<3km^2
Process Zone	Sediment transport zone, naturally a steep valley with limited opportunity for sediment accretion – ignoring sediment capture that occurred historically behind the weir. No large deposits of fine sediment typical of high rates of erosion were observed.
Valley slope	15-20% on upper slopes, 2-4% downstream of Kinnears Quarry to Harry's Road, 0.5% to 1% downstream of Harry's Road.

Rehabilitation Options	Remove weir and reinstate original creek grade Provide scour protection for localised erosion within dam upstream of Harry's Road Rehabilitate regenerating lowland rainforest, targeting Camphor and Lantana as a priority Establishing macrophytes within the creek line is not likely to be successful due to heavy shade, acidic soil conditions and coarse bed material Remove accumulated organic matter (and sediment) from the dam to reinstate the storage capacity. Additionally the weed species Parrots Feather (*Myriophyllum aquaticum*) could be removed in the process.
Typical creek character	
	

APPENDIX B: In-stream sediment and water quality sampling results

Tweed Laboratory Centre

TWEED SHIRE COUNCIL

Tweed Laboratory Centre, 46 Enterprise Avenue, Tweed Heads South NSW 2486 Australia
Phone: 07 5569 3103 Fax: 07 5524 2676 Email: samplereception@tweed.nsw.gov.au ABN: 90 178 732 496
(All correspondence: Tweed Shire Council PO Box 816 Murwillumbah NSW 2484)
www.tweed.nsw.gov.au/tweedlab/

FINAL CERTIFICATE OF ANALYSIS

Client: Design Unit
Address: Tweed Shire Council
PO Box 816
MURWILLUMBAH
NSW 2484

		Lims1 Report No:	13/1455-C
Attention:	David Hannah	**Client Reference:**	A4930.7049
Copy To:	Greg Jones	**Date of Report:**	18/06/2013

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Taken By:	Client	**No of Samples:**	2
Date Taken:	31/05/2013	**Date Testing Commenced:**	31/05/2013
Date Received:	31/05/2013	**Date Testing Completed:**	18/06/2013

Sample Description: Kinnears Creek Soil Sample - Chemical

Sample/Site No	Sample/Site Description
1	Kinnears Sediment
2	Kinnears Sediment (as received result)

COMMENTS:

Results refer to samples as received at the Laboratory.
* Tests not covered by NATA accreditation.

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accredited for compliance with ISO/IEC 17025

Accreditation No: 12754 & 13538

Dr Paul J Wright
(Laboratory Coordinator)
paulw@tweed.nsw.gov.au

TWEED SHIRE COUNCIL

Tweed Laboratory Centre

Client: Design Unit

Lims1 Report No: 13/1455-C
Date Testing Completed: 18/06/2013
Date of Report: 18/06/2013

Address: Tweed Shire Council
PO Box 816
MURWILLUMBAH
NSW 2484

Attention: David Hannah

Sample Description: Kinnears Creek Soil Sample - Chemical

Sample Identification:			Kinnears Sediment	Kinnears Sediment (as received result)
Date Taken:			31/05/2013	31/05/2013
Date Received:			31/05/2013	31/05/2013
Date Testing Commenced:			31/05/2013	31/05/2013
Test	Method	Units	13/1455-C-1	13/1455-C-2
Aluminium in Soil	M8	mg/Kg	3,982	11,217
Arsenic in Soil	M8	mg/Kg	<5	<14
Chromium in Soil	M8	mg/Kg	6	17
Copper in Soil	M8	mg/Kg	134	377
Iron in Soil	M8	mg/Kg	25,850	72,817
Manganese in Soil	M8	mg/Kg	245	690
Nickel in Soil	M8	mg/Kg	16	45
Zinc in Soil	M8	mg/Kg	34	96
Cadmium in Soil	M8	mg/Kg	<1	<3
Lead in Soil	M8	mg/Kg	10	28
Mercury in Soil	M5	mg/Kg	1	<3
Cobalt in Soil	M8	mg/Kg	7	20
Moisture Content	ORG03	%	64.5	--

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NSW 2484

		Lims1 Report No:	13/1455-S
Attention:	David Hannah	**Client Reference:**	A4930.7049
Copy To:	Greg Jones	**Date of Report:**	11/06/2013

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Taken By:	Client	**No of Samples:**	1
Date Taken:	31/05/2013	**Date Testing Commenced:**	31/05/2013
Date Received:	31/05/2013	**Date Testing Completed:**	11/06/2013

Sample Description: Kinnears Creek Soil Sample - ASS Chromium

Sample/Site No	Sample/Site Description
1	Kinnear Sediment

COMMENTS:

Results refer to samples as received at the Laboratory.
* Tests not covered by NATA accreditation.

As a suspected MBO, sample was frozen until tested and analysis was done on a wet basis (see % mositure result).
SCR% done under conditions to minimise oxidation during preparation.
phKCL and TAA not performed due to nature of the sample.

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(Laboratory Coordinator)
paulw@tweed.nsw.gov.au

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MURWILLUMBAH
NSW 2484

Attention: David Hannah

Lims1 Report No: 13/1455-S
Date Testing Completed: 11/06/2013
Date of Report: 11/06/2013

Sample Description: Kinnears Creek Soil Sample - ASS Chromium

Sample Identification:			Kinnear Sediment
Date Taken:			31/05/2013
Date Received:			31/05/2013
Date Testing Commenced:			31/05/2013
Test	Method	Units	13/1455-S-1
*pH field		pH units	6.4
*pH field oxidised		pH Units	2.6
S_{CR}	ASS7	%	0.21
Moisture Content	ORG03	%	62.3

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Client: Design Unit
Address: Tweed Shire Council
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NSW 2484

		Lims1 Report No:	13/1456-A
Attention:	David Hannah	**Client Reference:**	A4930.7049
Copy To:	Greg Jones	**Date of Report:**	04/06/2013

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Taken By:	Client	**No of Samples:**	1
Date Taken:	31/05/2013	**Date Testing Commenced:**	31/05/2013
Date Received:	31/05/2013	**Date Testing Completed:**	04/06/2013

Sample Description: Kinnears Creek Water Sample - Algae

LIMS NO.	Sample/Site No	Sample/Site Description
13/1456-A/1	1	Kinnears Floc

COMMENTS:

Samples have been received in correct containers and in good condition.

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Dr Paul J Wright
(Laboratory Coordinator)
paulw@tweed.nsw.gov.au

TWEED SHIRE COUNCIL

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Client: Design Unit

Address:
Tweed Shire Council
PO Box 816
MURWILLUMBAH

Attention: David Hannah

Lims1 Report No: 13/1456-A
Date Testing Completed: 04/06/2013
Date of Report: 04/06/2013

Sample Description: Kinnears Creek Water Sample - Algae

		Algal Identification	Method Code	Units	Count
LIMS NO.	**13/1456-A/1**				
		Algae ID only	B9		Iron bacteria predominant in organic and inorganic floc.

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NSW 2484

		Lims1 Report No:	13/1456-C
Attention:	David Hannah	**Client Reference:**	A4930.7049
Copy To:	Greg Jones	**Date of Report:**	14/06/2013

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Taken By:	Client	**No of Samples:**	1
Date Taken:	31/05/2013	**Date Testing Commenced:**	31/05/2013
Date Received:	31/05/2013	**Date Testing Completed:**	14/06/2013

Sample Description: KInnears Creek Water Sample - Chemical

Sample/Site No	**Sample/Site Description**
1	Kinnears Floc

COMMENTS:

Results refer to samples as received at the Laboratory.
* Tests not covered by NATA accreditation.

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(Laboratory Coordinator)
paulw@tweed.nsw.gov.au

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Client: Design Unit

Address: Tweed Shire Council
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MURWILLUMBAH
NSW 2484

Attention: David Hannah

Lims1 Report No: 13/1456-C
Date Testing Completed: 14/06/2013
Date of Report: 14/06/2013

Sample Description: KInnears Creek Water Sample - Chemical

Sample Identification:			Kinnears Floc
Date Taken:			31/05/2013
Date Received:			31/05/2013
Date Testing Commenced:			31/05/2013
Test	Method	Units	13/1456-C-1
Aluminium (Total)	M8	mg/L	6.91
Arsenic (Total)	M7	mg/L	<0.005
Chromium (Total)	M8	mg/L	<0.01
Copper (Total)	M8	mg/L	0.41
Iron (Total)	M8	mg/L	48.0
Manganese (Total)	M8	mg/L	2.01
Nickel (Total)	M8	mg/L	0.04
Silicon	M8	mg/L	14.0
Zinc (Total)	M8	mg/L	0.11
Cadmium (Total)	M7	mg/L	0.001
Lead (Total)	M7	mg/L	0.01
Mercury (Total)	M5	µg/L	<0.10
Cobalt (Total)	M8	mg/L	0.02

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NSW 2484

		Lims1 Report No:	13/1457-C
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Taken By:	Client	**No of Samples:**	1
Date Taken:	31/05/2013	**Date Testing Commenced:**	31/05/2013
Date Received:	31/05/2013	**Date Testing Completed:**	13/06/2013

Sample Description: Kinnears Creek Water Sample - Chemical

Sample/Site No	Sample/Site Description
1	Kinnears Creek

COMMENTS:

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NSW 2484

Attention: David Hannah

Lims1 Report No: 13/1457-C
Date Testing Completed: 13/06/2013
Date of Report: 13/06/2013

Sample Description: Kinnears Creek Water Sample - Chemical

Sample Identification: Date Taken: Date Received: Date Testing Commenced: Test	Method	Units	Kinnears Creek 31/05/2013 31/05/2013 31/05/2013 13/1457-C-1
Alkalinity as $CaCO_3$	C10	mg/L	5
*Total Acidity	APHA 2310	mg/L $CaCO_3$	6
Calcium	M8	mg/L	8.8
Magnesium	M8	mg/L	4.0
Sodium	M8	mg/L	12.0
Potassium M8	M8	mg/L	<5.0
Sulphur as Sulphate	M8	mg/L	40.0
Aluminium (Total)	M8	mg/L	0.26
Arsenic (Total)	M7	mg/L	<0.005
Boron (Total)	M8	mg/L	0.06
Chromium (Total)	M8	mg/L	<0.01
Copper (Total)	M8	mg/L	0.03
Iron (Total)	M8	mg/L	1.57
Manganese (Total)	M8	mg/L	1.53
Molybdenum (Total)	M8	mg/L	<0.01
Nickel (Total)	M8	mg/L	0.02
Silicon	M8	mg/L	7.7
Zinc (Total)	M8	mg/L	0.06

TWEED
SHIRE COUNCIL

Customer Service | 1300 292 872 | (02) 6670 2400

tsc@tweed.nsw.gov.au
www.tweed.nsw.gov.au

Fax (02) 6670 2429
PO Box 816
Murwillumbah NSW 2484